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The assessment of ecodesign applications using the Analytic Hierarchy Process: a case study in three furniture companies

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This paper presents a triple case study in which the assessment of ecodesign concepts application was performed based on a multicriteria decision support method, the Analytic Hierarchy Process (AHP). The assessment took place in three furniture companies, which have established design procedures and methodologies. A research methodology was developed considering that the application in other industries is available. A theoretical framework about ecodesign concepts and practices were made. Then, a focus group with a multidisciplinary team of experts in eco-conception and furniture manufacturing established constructs able to represent the top term ecodesign. The constructs were: materials, components, products and process characteristics, use of energy, products distribution and stocks, packaging and scraps. Each construct was deployed in items. Using the AHP with a multidisciplinary team from each company, the ecodesign constructs were weighed and the relative importance for each company was defined. At the end, a questionnaire was answered by the team from each company in order to check the performance of each item. By comparing the assessed performance with the relative importance of each ecodesign constructs, it was possible to prioritize strategies for environmental improvement related from eco-conception.

1. Introduction

Concepts such as ecodesign and life-cycle analysis promote a re-design of techniques of design and production of goods (Byggeth, Broman and Robert, 2007) and offer the theoretical basis for implementing new policies on design of product. After Fiksel (1996), ecodesign is a technique of product design in which the usual goals of the project, such as performance, reliability and cost of manufacturing, appear together with environmental objectives, such as reduction of environmental hazards, reducing the use of natural resources, increase of energy efficiency and recycling. It allows linking the functions of the product or service with sustainability aspects relating to environment, and so reducing the environmental impact and increasing the presence of eco-efficient products (Karlsson and Luttropp, 2006; Manzini and Vezzoli, 2005). After Vercarlsteren (2001), companies consider the ecodesign as means to preserve not only the environment, but also competitiveness and public image related to the business.

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A lot of different requirements for ecodesign are proposed in literature. The main of them regards materials, components, processes and products characteristics, use of energy, storage and distribution, packaging and waste (Wimmer et al., 2005; Luttropp and Lagersted, 2006; Fiksel, 1996).

In this study, it is meant to prioritize resources and actions of ecodesign. Supported by Hermann, Kroeze and Jawjit (2007), which speak on measurement of performance on environmental aspects, the authors consider relevant to identify the degree of importance of each ecodesign construct for companies in a particular industry and the extent to which each company meets every requirement on each construct. This paper sets out to provide a method for assessing the performance of ecodesign, applied in a particular industry, the furniture manufacturing. The method was developed assuming that the application in other industries is feasible. For thus, the objectives are: (i) to propose a tree-like structure able to represent the top end expression "ecodesign" and its constructs and items of application, (ii) to present the method, supported by the Analytic Hierarchy Process (AHP), to evaluate the tree-like structure, and (iii) to test and to refine the method by applying it to multiple case studies.

The research method is the case study. The stages of development of this research were: (i) the construction of a tree-like structure able of representing the top end ecodesign and its constructs, (ii) the weighing of the structure using the AHP method, suitable for furniture manufacturers, (iii) the split of the ecodesign constructs into items of application, and the preparation of a questionnaire to identify the degree in which every item is reached, (iv) the comparison of the performance obtained for each item of a particular construct with the degree of importance assigned for that construct, (v) the test of the method developed in two more companies of the furniture industry.

The AHP method is cited, among others, by Chen and Tong (2008) and by Berander (2007) as the method of decision support most applied to problems of priority in development of products. The theoretical foundation of the AHP is found, among others, in Forman and Selly (2001) and Saaty (1980). In this research, the criterion for the acceptance of an assessment was adopted from Saaty (1980): the existence of a consistency ratio of less than 0.10 ($CR < 0.10$).

2. Literature review: Ecodesign Practices and Tools

Regarding the potential of a company for the application of ecodesign and, consequently, the insertion of the same in routines for product development, the organization must assess factors regarding: the company (internal), the environment (external) and the product (Vercalsteren, 2001). As internal factors are: (i) motivation of the company and, in particular, of the senior management, (ii) innovation, considering the company's ability to influence the specifications of the product, (iii) competitiveness, since the leader in the market for a specific sector is more likely to redesign its products; on the other hand, a company that produces only for a small part of the market may consider the ecodesign as an opportunity to increase market share, and (iv) the sector in which the company is, whereas, if there are already equivalent initiatives in the sector, the company can learn from these experiences.

Regarding to external factors, the items that stand out are: (i) regulation, which may be an important stimulus for the company start the deployment of ecodesign, (ii) customers

and market, where it is necessary to assess whether the market will accept or not green products, and (iii) suppliers, since it is essential their will to cooperate. Additionally, the product must have potential to be redesigned, based on environmental considerations.

Identified the potential of a company for the application of ecodesign, it is necessary to understand the constructs bound to it. In this sense, Fiksel (1996) proposed a set of practices related to ecodesign, summarized in the sequence: (i) to choose low impact materials in all phases of the product life cycle, preventing materials that can not be recycled or reused; (ii) to have projects focused on simplicity, using simpler forms that have a lower cost of production and use less quantity of material; create products whose parts can be replaced in case of defect, without the need to exchange the whole product, look for an easy access to components, (iii) to incinerate waste, ensuring acceptable limits of hazardous substances, (iv) to reduce the use of energy in production, distribution and use of the product, (v) to use renewable forms of energy (solar, wind and hydroelectric), (vi) to develop multifunctional products with parallel functions (the same product simultaneously serve more than one purpose) and sequential functions (when a product has a primary use, and after it passes to a secondary use); (vii) to plan products with greater durability, extending the lifetime of the product, (viii) to recover packaging; to develop packaging material made of recyclable, reusable or returnable-to-manufacturer materials, to provide for the recycling of packaging material, and if so, use refill, and (ix) do not use hazardous substances, eliminating of the production process all substances that can damage the health of employees and consumers, and the human element that does the product disassembly for recycling; preferring the use of water-based products (solvents, adhesives and paints).

More recently, Wimmer *et al*. (2005) proposed, for manufactured products, six essential requirements to be met by an organization that develop products in ecodesign basis. These requirements are observed in Fiksel's (1996) list, however there is a greater emphasis on eliminating losses in production processes. Luttropp and Lagersted (2006) also suggest a set of requirements for ecodesign. There are two requirements presented by Luttropp and Lagersted (2006) and not detailed in Fiksel (1996): (i) the finishing of products, in which is recommended to invest in materials with surface treatment against dust and corrosion, aiming to reduce the maintenance and increase the lifetime of the product, and (ii) the assembly of products, which takes into account the use of the elements for fixation defined in accordance with the expected life cycle.

3. Three Case Studies

The tree-like structure for the ecodesign, able of deploy it in constructs and items, presented in Table 1, was built in focus group meetings with experts and researchers. Four researchers that work in areas related to ecodesign and two managers, one of a furniture company and the other of a footwear company, participated in the focus group. The requirements proposed by Fiksel (1996), Luttropp and Lagersted (2006) and Wimmer et al. (2005) and the experience of the group members served as the basis for the development of this phase of the research.

The next step was the consideration of the structure of the ecodesign, using the AHP. This weighing was done in a furniture company (Company A) in order to test the applicability of the same. The authors mediate the sections.

Table 1 – Tree-like structure for ecodesign (first and second levels)

First level (constructs)	Second level (items)
Materials: choice and use	(i) ability to use raw material closer to their natural state, (ii) ability to avoid mixtures of non-compatible materials, (iii) ability to eliminate the use of toxic, hazardous and carcinogenic substances, (iv) ability to not use raw materials that generate hazardous waste (Class I); (v) ability to use recycled and / or renewable materials, and (vi) ability to reduce atmospheric emissions caused by the use of volatile organic compounds.
Product components: selection and choice	(i) ability to recover components or to use components recovered, (ii) ability to facilitate access to components, (iii) ability to identify materials and components, and (iv) ability to determine the degree of recycling of each material and component.
Product/Process characteristics	(i) ability to develop products with simpler forms and that reduce the use or consumption of raw materials, (ii) the ability to design products with longer lifetime (iii) capacity to design multifunctional products, (iv) capacity to perform upgrades to the product, and (v) ability to develop a product with a "design" that complies with the world trends
Use of energy	(i) ability to use energy from renewable resources, (ii) ability to use devices for reduction of power consumption during use of the product, (iii) ability to reduce power consumption during the production of the product, and (iv) ability to reduce power consumption during product storage.
Products distribution	(i) ability to plan the logistics of distribution, (ii) ability to favor suppliers / distributors located closer, (iii) ability to minimize inventory in all the stages of the product lifetime, and (iv) ability to use modes of transport more energy efficient.
Packaging and documentation	(i) ability to reduce weight and complexity of packaging, (ii) ability to use electronic documentation, (iii) ability to use packaging that can be reused, (iv) ability to use packages produced from reused materials, and (v) ability to use refillable products.
Waste	(i) ability to minimize waste generated in the production process, (ii) ability to minimize waste generated during the use of the product, (iii) ability to reuse the waste generated, (iv) ability to ensure acceptable limits of emissions, and (v) ability to eliminate the presence of hazardous waste (Class I).

In sequence, the constructs were split into implementation items of ecodesign, developing a questionnaire to identify the degree of performance of each item. The questionnaire had 32 questions and was tested and adjusted based on the analysis of the group of researchers and managers that participated in the first stage of the research. For the answers, it was used a Likert scale from 1 to 5, where 1 represents the case where the item is not present or is never reached, and 5 is equivalent to the case where the item is completely met. To compare the performance obtained for each application item of a particular construct, given the degree of importance assigned to construct, the method was applied to other two furniture companies (Company B and Company C).

All three companies are located in southern Brazil, considered the largest furniture manufacturers center of the country. The potential and the conditions proposed by Vercalsteren (2001) for the implementation of ecodesign in this industry were identified considering the initiatives and projects focused on environmental issues, pointed out by the entities that represent the furniture sector in this region, and considering the experience of the group of researchers and managers who participated in this research.

The Company A is a manufacturer of modular furniture. The main raw materials and inputs it uses are MDF (Medium Density Fiberboard), MDP (Medium Density Particleboard), thermoplastics, water based adhesives, EVA (ethylene-vinyl acetate)

resins, glass, aluminum and steel. The production is in bulk, but customised. The company has 498 employees. The application of AHP in that company occured in meetings with five managers of the following areas: product development, production management and environmental management. The same group of managers answered the questionnaire on the implementation of each requirement of ecodesign. Company B has 155 employees and produces furniture, walls and doors to order. The main raw materials and inputs are glass, aluminum, steel and MDF. The participants were the manager of product engineering, the designer and the manager of production and logistics. The company C produces chairs, armchairs, tables and shelves predominantly in methacrylate. It has 33 employees. In C, the application of AHP and the questionnaire responses were made by the company's owner and the director of operations.

Table 2 shows the relative importance (in percentage) of each construct given by the application of AHP in each company. In the three companies to construct “Product / process characteristics" returned the highest relative importance and the construct “ Use of energy” returned the lowest relative importance. With regard to the construct "materials", the managers highlighted how little is the flexibility to change or propose use of new materials because of the technologies required and the lines of products with a consolidated market. The construct "packaging / documentation" had a significant importance due to the vast amount of cardboard and wrapping plastic used, most of them without a plan for recycling or provision for return to the company for reuse.

Table 2 - The relative importance of each construct and degree of implementation

Construct	Company A		Company B		Company C	
	Weight of the construct	Degree of implementation	Weight of the construct	Degree of implementation	Weight of the construct	Degree of implementation
Materials	17%	8.49 pp	13%	8.31 pp	25%	20.84 pp
Product components	6%	2.21 pp	4%	2.12 pp	6%	3.11 pp
Product/Process Characteristics	39%	22.18 pp	26%	15.34 pp	40%	28.24 pp
Use of energy	3%	1.64 pp	2%	0.99 pp	4%	1.64 pp
Products distribution	10%	5.57 pp	26%	15.97 pp	6%	3.71 pp
Packaging / documentation	22%	14.22 pp	20%	11.80 pp	14%	6.95 pp
Waste	3%	1.80 pp	9%	5.26 pp	5%	4.43 pp
total	**100%**	56.11%	**100%**	59.79%	**100%**	68.92%
CR	**9%**		**7%**		**4.6%**	

In company A, the construct “Materials” reached at 17% of importance and is implemented in only 8.49 percentual points (pp), which represents about half of the maximum value it could reach (17 pp). Summing all constructs, the company reached 56,11% of the maximum it could reach, according to the items checked by the questionnaire. Companies B and C reached respectively 59.79% and 68.92% of the maximum performance. This means that the companies must focus not in the questions that they have appropriately answered, but in the questions in which low score had produced the gaps of performance regarding 100%.

4. Final remarks

The objective of this research was to build a structure for measuring the ecodeisgn performance that could be, at the same time, capable of giving feedback for future actions on the aplication of ecodesign, and flexible enough to be modified whenever the context requires. The flexibility was achieved by the methodology adopted, which can be replicated whenever the underlying theory or the context change, in order to adapt the structure. The proposed procedure was tested by constructing a structure to assess the presence of ecodesign in furniture manufacturers. The method also allows the prioritization of actions based on by the impact of them on each construct of ecodesign and the relative importance of these constructs for the formation of ecodesign.

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