Ecodesign Maturity Model (EcoM2)

1 INTRODUCTION

Ecodesign can be defined as a proactive approach to environmental management that involves the consideration of environmental issues in the product life cycle management (PLM) in order to minimize the environmental impacts throughout the product’s life cycle (from material extraction to end-of-life), without compromising other essential criteria such as performance, functionality, aesthetics, quality and cost [1] [2].

The application of Ecodesign practices is essential to companies that have recognized that environmental responsibility is vital to long term success since it promotes reputation improvement, cost and risks reduction, product innovation and attracts new consumers [3]. Although, it is still not clear to companies which strategies, guidelines and methods/tools should be selected and how to manage the process of integration into the product development process and continuous improvement.

In this sense, it can be argued that the application of ecodesign has not reached companies worldwide over the last decade mainly due to:

1. There are no systematization of the existing ecodesign practices;
2. There is an intense development of new ecodesign methods and tools in detriment of the study and improvement of the existing ones [4];
3. There is a lack of integration between ecodesign and the broad context of the product development process and product life cycle management [5][6][7][8];
4. Ecodesign is poorly integrated into corporate strategy and management [4];
5. There is not a roadmap for continuous improvement that can be followed by companies in implementing ecodesign;
6. Companies usually fail in adopting ecodesign due to the selection of practices that is not in accordance with their current maturity level.

Consequently there is a need to propose models that help companies to implement ecodesign in their product development processes in an effective way. Such a model should be based on a systematization of existing ecodesign practices, linking them to the development process and company strategy and showing how to implement them in accordance with the company’s maturity level.

In this sense, the main goal of this paper is to present the development of an Ecodesign Maturity Model, which aims to guide companies into the effective implementation of ecodesign practices into the product life cycle management in accordance with their strategic objectives and drivers.

The next section presents the methodology that was used to the development of the Ecodesign Maturity Model. The model is detailed in Section 3, which presents the goal and the elements of the Ecodesign Maturity Model: Ecodesign Practices, Ecodesign Maturity Levels and Application Method. The Summary and Outlook, Acknowledgments and References are presented in sections 4, 5 and 6, respectively.

2 METHODOLOGY

In order to develop the Ecodesign Maturity Model, the following activities were performed:

2.1 Systematization of Ecodesign Practices

The ecodesign practices were obtained and classified by means of a systematic literature review, the way by which the researcher can map the existing and previous developed knowledge and initiatives in a specific research area. Besides the analysis of previous discovery, techniques, ideas and ways to explore topics, the systematic review also allows the evaluation of information relevance to the issue, its synthesis and summarization [9] [10].

The ecodesign practices identified during the systematic literature review were sorted out into three groups: Ecodesign Management Practices, Ecodesign Operational Practices and Ecodesign Methods and Tools. The description of these practices is presented in the section 3.2: Ecodesign Practices.

2.2 Establishment of Ecodesign Maturity Levels

In order to define the maturity levels on ecodesign, it was performed a review to understand how is the evolution faced by companies in adopting Ecodesign. It was also studied the dimensions that influences this evolution. For each maturity level, the most appropriated practices were properly addressed. The correlation and dependencies between practices was also determined. The maturity levels defined in the Ecodesign Maturity Model is presented in section 3.3.

2.3 Development of the Application Method

In order to define the way a company can apply the Ecodesign Maturity Model, it was developed an Application Method, following the literature of business process management (BPM), which provides guidelines to process improvement. The Application Method is presented in section 3.1.

3 ECODESIGN MATURITY MODEL

The Ecodesign Maturity Model is a concept framework composed by a structured collection of ecodesign practices that can be used to develop and improve an organization’s product life cycle management (PLM) concerning environmental issues. It provides:

- a benchmarking of ecodesign best practices;
- an assessment of strengths and weaknesses concerning the application of ecodesign practices;
- a common language and a shared vision across the organization;
- a guide for integrating ecodesign practices into PLM;
- a roadmap for PLM improvement towards environmental sustainability.

The goal of the Ecodesign Maturity Model (EcoM2) is to guide companies in the effective implementation of ecodesign practices into product life cycle management (PLM) and related process in accordance with their strategic objectives and drivers.

The Ecodesign Maturity Model is composed by three main elements (Figure 1): 

- Application method: presents the way in which companies can use the model for process improvement. It contains a scheme of continuous improvement (like PDCA – plan, cycle) based on Business Process Management (BPM) approach;
- Ecodesign practices: corresponds to the best practices currently adopted by companies and developed by universities for the integration of environmental concerns into the product development process – It is composed by management
practices (those that deal with the management of ecodesign), operational practices (related to technical design issues) and ecodesign methods and tools that support the application of management and operational practices;

- Maturity levels: represents the company evolution level in applying the environmental issues into their business processes;

The elements of the Ecodesign Maturity Model are detailed in the following sections: 3.1, 3.2 and 3.3.

3.1 Ecodesign Application Method

The Ecodesign Maturity Model Application Method (Figure 2) was developed following the BPM (Business Process Management) approach for process improvement and aims to guide the application of the Ecodesign Maturity Model. It is composed by six steps:

- Diagnosis of the current Maturity Level: the first step in the method is to assess the current situation of an organization concerning the consideration of environmental issues. It is done by performing a diagnosis of the current maturity level of the company by assessing which Ecodesign Management Practices are applied and with which capability level (see section 3.3);
- Proposition of Ecodesign Management Practices to be implemented: once the current Maturity Level is obtained, it is proposed which practices are more suitable for company application considering its maturity level (first filter of the practices) and also the strategic drivers for the adoption of ecodesign (that includes environmental laws and regulations, costs reduction, environmental customer awareness, new business opportunities, value creation and also innovation opportunities);
- Selection of practices to be implemented: the Ecodesign Management Practices are then selected by the company according to the ponderation method for ecodesign practices developed by Charter and Tischner [13] that classifies the practices in the following groups:
  - Rejected
    0: the option had been rejected; moreover, it was of no future interest to the company;
  - Of interest
    1: the option had been studied in more depth; realization had still been rejected.
    2: the option has not yet been studied; it was assured of the company’s future interest;
    3: the option was still being studied, realization was still not certain.
  - Prioritized
    4: the option was being implemented; realization was expected within three years;
    5: the option was being implemented; realization was expected within one year;
    6: the option had already been implemented or would be implemented very soon (the option realized)
  - Not considered

Figure 1: Elements of the Ecodesign Maturity Model
The information about the classification of the practices by the company will be reused in the following cycles of process improvement. For example, if one practice is rejected in one given cycle, it will not be proposed for application in the following ones.

- Definition of the improvement projects: once it is defined the prioritized Ecodesign Management Practices to be applied by the company, it is then analyzed the correlation between the selected Ecodesign Management Practices within the Ecodesign Operational Practices and the Ecodesign Methods and Tools (see section 3.2). The improvement projects should contain a set of Ecodesign Management Practices, Operational Practices and also Ecodesign Methods and Tools, which supports the application of the Ecodesign Management Practices. It needs to be performed the portfolio management of these improvement projects and also the project planning with the definition of schedule, responsibilities, resources, etc.

- Implementation of the improvement projects: during the implementation of the ecodesign practices considered by the improvement projects, it needs to be taken a special care on the People Change Management, since people has a strong importance on the process;

- Assessment of the results: it needs to be defined performance indicators according to the practices in order to assess the results of the improvement projects.

The improvement cycle can be repeated as many times as the company needs for maintain its continuous improvement towards higher maturity levels on Ecodesign.

3.2 Ecodesign Practices

Ecodesign practice is the general name attributed to ecodesign activities, strategies, methods and tools, etc. that aims at integrating the environmental issues into product development process. In the Ecodesign Maturity Model, the ecodesign practices were classified into three groups:

- Ecodesign Management Practices: related to the management activities and tasks of product development process that addresses the environmental issues. These practices are used to assess the maturity levels of companies in applying ecodesign. The 75 Ecodesign Management Practices identified are classified according to the maturity levels (see section 3.3) and also to the phases of the reference model for product development [11] (product strategic planning, project planning, informational design, conceptual design, detailed design, production preparation, product launch, product monitoring and take back of products). The application of the ecodesign management practices can be supported by the Operational Practices and/or by Ecodesign Methods and Tools.

- Ecodesign Operational Practices: It is a summary of ecodesign guidelines for product design with more than 480 practices identified and systematized. It is divided in three levels of detail: ecodesign strategies (minimize energy consumption, minimize material consumption, extend material life time, optimize product life time, select low impact resources and processes, and facilitate disassembly -- adapted from [12]), ecodesign guidelines (which provides a detail of the ecodesign strategies) and design options (to support the idea generation of solutions to achieve the guidelines). The Ecodesign Operational Practices deal with the technical issues of product design and are associated to the Ecodesign Management Practices. The application of the guidelines can also be supported by the Ecodesign Methods and Tools;

- Ecodesign Methods and Tools: systematic means for the application of ecodesign that can support the application of both Ecodesign Management and Operational Practices. By means of a systematic literature review, it was identified more than 100 ecodesign methods and tools. They were classified in 6 criteria to support the selection of the most suitable ones for companies according to their needs and current maturity level: (1) Nature of the main goal of the method/tool (Prescriptive/Comparative/Analytic); (2) Type of the tool used (Checklist/ Guideline/Matrix/Software); (3) Nature of input and output data (Qualitative/Quantitative); (4) Considered Product Life Cycle Phases (Raw material extraction, manufacturing, use, end-of-life), (5) Application evolution (Theory/Experimental/ Consolidated); (6) Evaluation of Environmental Impacts (Yes/No). The classification criteria used in the Ecodesign Maturity Model is presented in detail in the paper [13]. The ecodesign methods and tools can support the application of ecodesign management and operational practices.

The practices are organized in a spreadsheet where all the information are displayed together and in an interrelated way. In order to have a broader view of the inter-relationship among Ecodesign Management Practices, Ecodesign Operational Practices and Ecodesign Methods and Tools, it is presented an example in Figure 3.

One of the Ecodesign Management Practices is “20001: Assess the environmental impact of products”. In order to support the application of this management practice, there are a lot of ecodesign methods and tools that can be used, such as Life Cycle Assessment (LCA) [14][15][16][17], MET (Material, Energy and Toxics Matrix) [18][19], MECO (Material, Energy, Chemicals and Others Matrix) [20][21], etc. The most suitable ecodesign method/tool to be used can be obtained by the selection according to the company needs, current maturity level and the criteria used to classify the methods [11]. The practice 20001 is also a pre-requirement for the application of the practice “80001: Analyze and select the suitable ecodesign strategies according to the environmental goals and phases/environmental aspects of the product life cycle in which the environmental improvement opportunities are higher”, since it supports the identification of the environmental hot spots of the product under analysis. In order to select the most suitable ecodesign strategies, the ecodesign operational practices need to be analyzed. For example, if the hot spot is at the end-of-life of products, concerning to solid waste, the strategies “Facilitating Disassembly” and “Products Life Time Optimization” should be more adequate. Focusing on “Products Life Time Optimization” and assessing its guidelines, it can be concluded that “Facilitating Remanufacturing” is of higher importance. To support the application of this guideline, there are also a set of ecodesign methods and tools such as EDIT (Environmental Industrial Template) [22], ELDA (End-of-Life Advisor) [23] and LCP (Life Cycle Planning) [24].

3.3 Ecodesign Maturity Levels

The Ecodesign Maturity Model is composed by five maturity levels, which represents the evolution from the lack of knowledge and no consideration of environmental issues to the integration of environmental concern into the company strategic planning and
decision making process. It shows the path that a company should follow in order to improve the environmental performance of their processes and products.

The maturity levels were developed by the combination of two dimensions: knowledge level on ecodesign (adapted from [25][26]) and innovation level on ecodesign (adapted from [12][26][27][28]). The ecodesign maturity levels defined in the Ecodesign Maturity Model are:

- Level 1: Company has no experience on ecodesign and does not yet apply practices to improve the environmental performance of the developed products. The environmental issues and products of the benefits of ecodesign adoption are not exploited yet. In this level, the company needs to understand the ecodesign concept, define the internal and external drivers to ecodesign adoption, do a benchmarking to understand what competitors are doing in this area and collect all the legal issues and standards related to the environmental performance of products.

- Level 2: The company does the first moves in the application of Ecodesign, is already familiar with some practices and with the potential benefits. It is performed pilot and punctual projects focusing on the incremental improvement of the environmental performance of existing products, with focus on specific phases of product life cycle. It is observed punctual and not consolidated approaches for the use of ecodesign practices, with emphasis in the application of the practices related to product design (operational practices). In this level, company strives to create awareness and motivation on ecodesign and starts a formalized Ecodesign Program.

- Level 3: In this level, the company recognizes the importance and benefits of Ecodesign by the application results. It is performed projects to improve the environmental performance of products (e.g. materials and energy intensity) considering all the life cycle phases, from raw material extraction to end-of-life. It is observed the technical integration into Detailed Design phase with the first insertions of ecodesign practices into the processes and first steps to structure the environmental approach and common patterns. On this level, the ecodesign projects starts to focus on the redesign of existing products.

- Level 4: The ecodesign practices are systematically incorporated into the product development process, since the initial phases (e.g. idea generation and portfolio management). Functionality analysis is now applied to conduct ecodesign. New concepts (products, services or PSS) are developed in order to satisfy the customer needs with better environmental performance.

- Level 5: There are the incorporation of environmental issues into company’s corporate, business and product strategies. Environmental issues are considered jointly with technical and economic issues to support the decision making process. Company aims the system innovation, with the development of new products and services that requires changes in the infrastructure related to product.

Additionally to the Maturity Levels, the Ecodesign Maturity Model also considers the Capability Level in applying a specific management practice. The capability levels (adapted from [29]) are:

1. do not apply;
2. apply ad hoc;
3. apply in a formal way;
4. apply in a controlled way;
5. performs a continuous improvement of the application.

Figure 4 presents a graphical representation of the maturity levels considering the Ecodesign Management Practices that is applied (represented in the figure with a code) and the Capability Level of the application of each practice. For example, to be classified as Maturity Level 1, the company needs to apply the Ecodesign Management Practices of Level 1 with Capability Level 3 (apply formally). A company will be classified as Maturity Level 2 if it applies the Ecodesign Management Practices of Level 1 with a Capability 4 and the practices of Level 2 with a Capability 3. The next maturity levels follow the same logic. A company will be classified with the Maturity Level 5 if all the Ecodesign Management Practices is applied with a Capability Level 5.

4 SUMMARY AND OUTLOOK

This paper presented the general concept of the Ecodesign Maturity Model and its constituent elements: Application Method, Ecodesign Practices and Ecodesign Maturity Levels.

The Ecodesign Maturity Model is inedited and aims to guide companies in the continuous improvements of their PLM process with the incorporation of the environmental dimension striving for sustainability in their business. It considers the individual needs, drivers, characteristics, maturity levels and strategies of companies to support the decision making process.

Besides the contribution to companies, the Ecodesign Maturity Model should also contribute to the organization of the knowledge

![Figure 4: Graphical Representation of the Ecodesign Maturity Levels](image-url)
in the ecodesign and PLM research areas, structuring the practices and establishing interrelationships among them.

The theoretical concept of the Ecodesign Maturity Model was validated by 15 experts on Ecodesign from Europe, United States of America and Brazil from March to August 2010. It is currently being applied in companies with different maturity levels. Results of the validation and application will be presented in future papers.