ECOM2 WEB PORTAL: COLLECTING EMPIRICAL DATA AND SUPPORTING COMPANIES' ECODESIGN IMPLEMENTATION AND MANAGEMENT

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ABSTRACT
Despite the recognition of the potential benefits of ecodesign, a promising approach to integrate environmental concerns into the product development process, its application has failed to reach large numbers of companies and sectors worldwide due to managerial difficulties. In response to that a comprehensive framework has been developed, with the aim of ensuring systematic management, implementation and continuous improvement of the ecodesign process. The framework, called Ecodesign Maturity Model (EcoM2), enables the diagnosis of the company's ecodesign maturity profile; the identification of strengths and limitations; and the establishment of strategic roadmaps for improved ecodesign implementation. This paper describes the development of the EcoM2 web portal, which will allow for the framework to be tested on greater numbers of companies and at the same time to provide a quick diagnosis of their current ecodesign maturity profile. Analyses of the collected data will allow the establishment of patterns on ecodesign implementation in regards to criteria such as sector and size of companies and the improvement of empirical knowledge on ecodesign implementation and best practices.

Keywords: ecodesign management, sustainability, new product development, ecodesign implementation, maturity model

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1   INTRODUCTION

Ecodesign is a promising proactive environmental management approach that aims to integrate environmental concerns into the product development and related processes (such as production, purchasing and marketing), in order to improve the environmental performance of products throughout their entire material life cycle (i.e. from material extraction and manufacturing to use and end-of-life), without compromising other essential requirements for a product such as performance, functionality, quality and cost (Weenen, 1995; Johansson, 2002).

Despite the recognition of the potential benefits of ecodesign, its application has failed to reach large numbers of companies and sectors worldwide over the last decades (Pascual et al., 2003; Boks, 2006; Johansson, 2006), mainly due to difficulties in ecodesign implementation and management, such as:

- Lack of systematisation of existing ecodesign practices;
- Intense development of new tools in detriment to the study and improvement of the existing ones (Brezet and Rocha, 2001; Baumann et al., 2002; Dewulf and Duflou, 2004);
- Limited integration of ecodesign into management and corporate strategy (Bhamra et al., 1999; Brezet and Rocha, 2001; Charter, 2001; Baumann et al., 2002; ISO, 2002; Pascual and Stevels, 2004);
- Lack of roadmaps for continuous improvement of ecodesign implementation (Brezet and Rocha, 2001; Boks and Stevels, 2007); and
- Difficulties in selecting the most suitable ecodesign practices to be implemented according to the companies' needs (Boks and Stevels, 2007).

In order to support ecodesign application into companies, an Ecodesign Maturity Model (EcoM2) was developed and subsequently tested following a hypothetic-deductive approach. The EcoM2 is a framework with an evolutionary (step-by-step) approach which aims to support companies[1] in carrying out ecodesign implementation and management (Pigosso and Rozenfeld, 2011a, 2011b; Pigosso et al., 2011). The EcoM2 enables companies to assess their maturity profile in ecodesign over time, to understand their strengths and limitations, and to establish roadmaps for ecodesign implementation based on the most suitable ecodesign practices, according to their maturity level and strategic objectives and drivers (Pigosso et al., 2012). It is composed of three main elements:

- Ecodesign practices: correspond to a collection of ecodesign best practices related to ecodesign management, technical issues of product design and associated techniques and tools;
- Maturity levels: represent a company's level of evolution in incorporating environmental issues into the product development and related business processes; and
- Application method: presents a PDCA (plan, do, check and act) approach for process improvement in regards to ecodesign implementation and management.

The EcoM2 application method establishes a framework for continuous improvement through the incorporation of ecodesign practices into the product development and related processes and is composed of six steps (figure 1):

1.   Diagnosis of the current maturity profile in ecodesign;

Proposition of practices and improvement projects for ecodesign implementation;

Portfolio management of improvement projects for ecodesign implementation;

Planning of the improvement projects for ecodesign implementation;

Implementation of the improvement projects;

Assessment of the results.

At the end of each improvement cycle, the company can begin the next improvement cycle, reassessing the current maturity profile in ecodesign, in order to define new ecodesign projects to be implemented.

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[1] The domain in which the EcoM2 is applicable is composed by companies that present a structured product development process (PDP) and are classified in the category C-Manufacturing by ISIC (International Standard Industrial Classification of All Economic Activities) (United Nations, 2008).
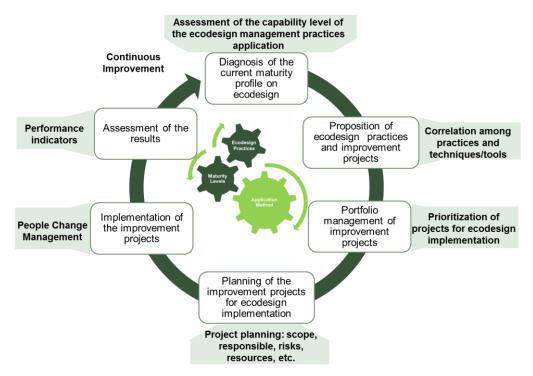
Figure 1. EcoM2 application method for ecodesign implementation and management

Under the current methodology applied for the EcoM2 framework, the application of the first two steps of the improvement cycle (I. diagnosis of the current maturity profile on ecodesign; and II. proposition of ecodesign practices and improvement projects) typically take around one month to be performed. The subsequent steps are carried out internally by the company and their duration depends on the employed resources, the number and complexity of the improvement projects, the organisational change speed of each company, etc.

In this context, the most critical step in terms of time for the initial application of the EcoM2 is the diagnosis of the current maturity profile, which on average takes fifteen working days to be finalised. It is performed in three stages:

1.   Documental analysis of the existing product development and related processes of the company;

Face-to-face interviews with employees of different hierarchical levels, areas and facilities involved in the product development (ideally 10 – 20 people) following a structured questionnaire for maturity assessment;

Consolidation of the results and elaboration of the company's ecodesign maturity profile, represented graphically as a radar-plot that enables the identification of strengths and opportunities for improvement.

In order to enable large scale application (and therefore empirical testing) of the EcoM2, this paper describes the development of a web portal, designed to perform a quick and automated diagnosis of a company's ecodesign maturity profile and at the same time gather large amounts of empirical data from the users of the portal. Two key requirements of the web portal, as opposed to the original research framework are that (i) the diagnosis should be able to be performed at vastly reduced time-scales (from fifteen days to a matter of hours); and (ii) the diagnosis should be able to be performed by the companies themselves and not by a researcher.

The methodology employed is presented in section 2 and is followed by a description of the portal's content and of the diagnosis module (section 3). Section 4 presents the final remarks and future researches. Finally, the references and acknowledgements are presented.

2   METHODOLOGY

This section presents the methodology employed to develop both the EcoM2 and the EcoM2 web portal.

The EcoM2 was developed following a hypothetic-deductive (Lancaster, 2005) and iterative approach. Initially, the model was theoretically developed by means of a systematic literature review (Biolchini et al., 2005) on ecodesign best practices and maturity levels. Afterwards, it was evaluated by a set of

fourteen well-known experts on ecodesign, who pointed out the strengths of the model and opportunities for improvement. Subsequently, the EcoM2 was further improved via action research (Coughlan and Coghlan, 2009) carried out in a large multinational manufacturing company, which brought a practical perspective to the application of the model and valuable inputs for the development of the application method. Finally, the EcoM2 was successfully applied into two other manufacturing companies (one in Brazil and one in Europe) for theory-testing (Dul and Hak, 2008). Since the application of the EcoM2 in these case companies, all three companies have been working to improve their ecodesign approaches systematically according to the model's recommendations; the first results are currently emerging from the ecodesign improvement projects proposed by the EcoM2 diagnosis and proposition.

In order to develop the EcoM2 web portal, the first step was to evaluate which adaptations were required from the current diagnosis methodology (which comprises face-to-face interviews with a set of employees, as described in the previous section). In this step, several alternative methodologies for diagnosis were analysed and assessed, in order to select the most suitable one for a quick diagnosis via the web, which could also provide meaningful results to the companies and enable empirical data collection on ecodesign implementation and management. Once the preferred methodology was selected, the requirements for the development of the diagnoses module and the database scheme were refined. It also included the definition of the data flow logic for carrying out the diagnosis, consolidating the results and representing the current maturity profile of the company in a graphical and easy to understand way. An additional requirement to the portal development was the easy exportation of the empirical data, in order to enable future analyses on ecodesign implementation and management. The content of the website and the layout were defined in accordance to user-friendly requirements. A prototype of the portal based on the EcoM2 elements and on the aforementioned requirements was developed, tested internally by the researcher and further improved in order to build up the final and current version of the EcoM2 web portal, presented in the next section.

3   ECOM2 WEB PORTAL

This section presents the EcoM2 web portal and its main characteristics. It is subdivided into four sub-sections:

- Sub-section 3.1 describes general information about the EcoM2 web portal and highlights the content of the pages and sub-pages;
- Sub-section 3.2 presents the module for the diagnosis of the current maturity profile on ecodesign implementation;
- Sub-section 3.3 presents the EcoM2 portal data flow for performing the diagnosis and getting the results of the current maturity profile,
- Sub-section 3.4 describes the current status of the portal development and next steps planned to be carried out.

3.1   General information

The EcoM2 web portal (freely available at http://www.eco-m2.com) is currently provided as a Wordpress®-based platform that provides information and support to manufacturing companies aiming to implement and manage ecodesign, based on the concepts and practices of the Ecodesign Maturity Model.

Currently, the EcoM2 web portal is available in two languages: Portuguese and English. Careful consideration has been given to the language, layout and style of the portal in order to maximize companies' comprehension of ecodesign, their current maturity profile and the opportunities that lay ahead for improvement. The portal was intentionally designed to feel like a tool for the company, not as an academic research model.

The EcoM2 web portal contains five pages, subsequently subdivided into nine sub-pages, as described in the following:

- Home: initial page, contains general information about the model, the content of the portal, the developers and supporters;
- Ecodesign: provides information about ecodesign, the drivers and benefits for its application and the barriers that companies usually face for ecodesign implementation and management;

- EcoM2: contains general information about the model, its main elements (ecodesign practices, maturity levels and application method) and benefits of application;
- Diagnosis: provides access to the module that allows companies to perform the diagnosis of their ecodesign current maturity profile by answering a structured and intelligent questionnaire;
- Contact: form for contacting the administrator of the portal, clarifying questions, etc.

In the next section, the module for the diagnosis of the current maturity profile on ecodesign is presented.

3.2 Module for the diagnosis of the current maturity profile

The module for performing the diagnosis of the current maturity profile of companies on ecodesign implementation can be divided into three main parts (figure 2):

1. Questionnaire for maturity assessment (section 3.2.1);

EcoM2 maturity radar (section 3.2.2); and

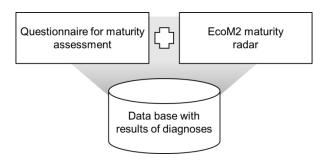Database with the results of the diagnoses (section 3.2.3).

Figure 2. Components of the diagnosis module of the EcoM2 web portal

All of these diagnosis and information elements provided to the user of the portal are of direct interest to the researcher, as they provide live empirical data from the companies utilising the portal.

3.2.1 Questionnaire for maturity assessment

The questionnaire for maturity assessment was developed using the LimeSurvey® plugin, an open source survey application. It contains a total of 62 questions, corresponding to the ecodesign management practices of the original EcoM2 (Pigosso and Rozenfeld, 2011a) (figure 3).

For each question the users are required to answer the capability level of the application of the ecodesign practice at the company, according to their perception. There are five different capability levels (adapted from (SEI, 2006)), which qualitatively measure how well a practice is currently being applied by the company (Pigosso and Rozenfeld, 2011b)[2]. In addition to the capability level, the user must also provide a rationale/commentary on the assigned capability levels. Furthermore, the user is encouraged to upload evidences (such as reports, procedures, databases, etc.) that corroborate their answers.

In order to ensure data reliability and consistence, the capability levels assigned are analysed against the provided rationale and evidences, and subsequently validated by the researcher. Whenever necessary, the capability level can be adjusted to the commentaries and evidences of the documental analysis.

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[2] The capability levels are defined as:
- Capability level 1 – Incomplete: the ecodesign management practice is not applied or is applied incompletely by the company;
- Capability level 2 – Ad hoc: the ecodesign management practice is applied in an ad hoc way, i.e., to correct a problem or to accomplish a specific task by some individuals in the company, but not yet in a formalized and systematised way;
- Capability level 3 – Formalised: the application of the ecodesign management practice is formalised in documented processes and the infrastructure to support the process is well established. The process is planned and implemented in accordance with company policy and the responsibilities and resources required to produce the desired outputs are allocated;
- Capability level 4 – Controlled: the application of the ecodesign management practice is formalised and controlled, and its performance is measured and monitored. The process serves as a reference for all the company's projects;
- Capability level 5 – Improved: the performance of the application of the ecodesign management practices is improved based on the results of the measurements and monitoring performed in the previous capability level. The goal is to ensure a continuous improvement of the application of those ecodesign practices into the product development and related processes.
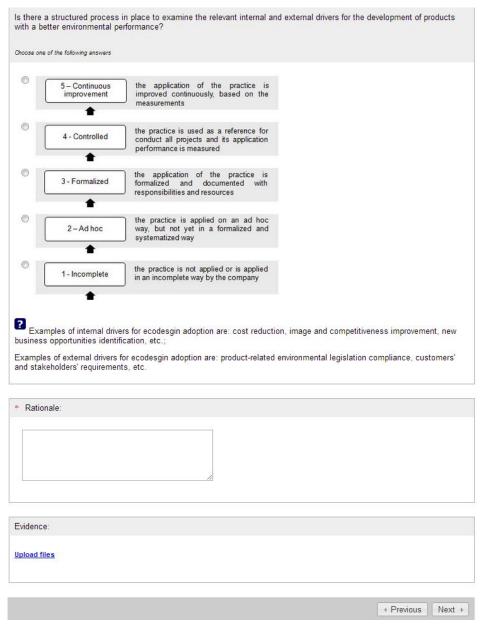
Figure 3. Example of each question structure in the EcoM2 web portal

In order to make the diagnosis faster, a customisation of the questionnaires according to the area of expertise of the employee was carried out. There are therefore seven different questionnaires, relating to the main knowledge areas of product development and related processes: marketing; manufacturing; supply chain and logistics; product design and packaging; strategic planning; environment; and research and development. Furthermore, an optimisation of the answering time is achieved via an intelligent questionnaire that considers the interdependence among the questions.

The quality of the diagnosis increases as more employees from different areas and hierarchical levels answer the questionnaire, providing a broader and more comprehensive overview of the ecodesign practices currently applied at the company. In this sense, the users are motivated to invite other colleagues from the same company to answer the questionnaire, in order to improve the quality of the diagnosis. There is no limit to the number of people from the same organisation that can participate in the diagnosis. A good diagnosis can be expected with around three users of different hierarchical levels from each area (Pigosso et al., 2012), which equals approx. 20 users in total. A user is only allowed to perform the diagnosis once.

3.2.2 EcoM2 maturity radar

Once the answers had been validated by the researcher, the EcoM2 web portal automatically consolidates the results of the diagnosis and generates the EcoM2 maturity radar of the company (Pigosso and Rozenfeld, 2011b), using Highcharts®, a JavaScript charting library.

The consolidated radar represents the average capability level of each ecodesign management practice, according to the validated responses of the employees of a same company. Figure 4 presents an example of the EcoM2 maturity radar, which graphically represents the maturity profile of a company on ecodesign implementation.
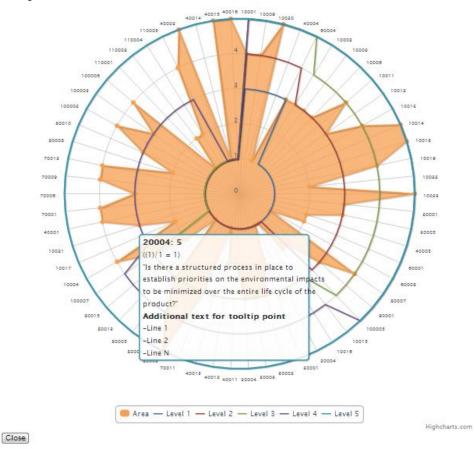

Figure 4. EcoM2 maturity radar of a fictional company

The ecodesign management practices are represented in the radar by their codes and organised according to their evolution levels, following a clockwise direction from the first to the fifth evolution level. The capability levels (1 to 5) correspond to the axis of the radar and the coloured lines inside the radar represent the standard maturity levels defined by the EcoM2.

The orange area represents the current profile of the company on ecodesign implementation, showing which ecodesign management practices are currently being applied and with which capability. This representation also allows for the easy identification of gaps for further improvements.

The EcoM2 maturity radar is interactive and also contains comments of the researcher, which can improve companies' understanding about the current maturity profile. The results of the diagnosis and the EcoM2 maturity radar of the company are automatically updated after each new user's answers are validated.

3.2.3 Diagnoses database

The EcoM2 web portal contains a database to store the data inserted by users during the diagnosis and the results generated by the portal. It comprises the registration data of each user, the responses of each question (capability level, rationale and evidences (when applicable)), the data of the companies, the maturity profile, etc.

All the data inserted by the users are confidential and cannot be accessed individually via the EcoM2 portal. Additionally, all the data concerning a company and its corresponding maturity radar can only be viewed by employees of the same company, allowing for complete privacy of the results.

Furthermore, confidentiality is guaranteed with respect to the comments and provided evidence from each employee, in relation to their colleagues from the same company.

The information collected in the diagnosis database can only be used by the EcoM2 portal in the form of generic representations regarding ecodesign implementation, which can be related, for example, to the identification of patterns for ecodesign implementation in different sectors and kinds of organisations (in regards to size, country, type, etc.) and to the development of specific reports that can support companies on ecodesign implementation.

These generalisations have a potential, from an academic perspective, to bring great understanding of the current application of ecodesign in companies worldwide, increasing the knowledge on that area and supporting the continuous improvement of the EcoM2 itself, with the identification of new trends for ecodesign management and best practices.

3.3 EcoM2 web portal data flow

The data flow of the EcoM2 web portal module for performing the diagnosis of the current maturity profile of a company on ecodesign implementation is composed of seven steps, as presented in figure 5 and detailed below:
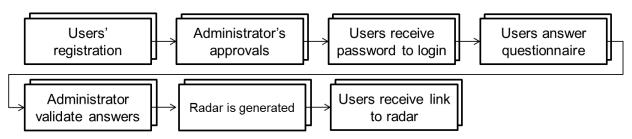

Figure 5. Scheme of the EcoM2 web portal data flow

1. Users' registration: in order to be able to perform the diagnosis, the user must be registered in the EcoM2 web portal. In the registration form, it is required information about users' occupation and area of expertise, data about the company under assessment, corporate e-mail (for information security reasons), etc. After finalising the registration, the user is informed that the password will be send by e-mail after administrator's approval;
2. Administrator's approvals: the EcoM2 administrator receives an automatic e-mail from the system warning that a new user has registered and is pending approval. The registration data by the administrator are checked and the user the approved;
3. Users receive password to login: as soon as the administrator approves the registration, the user receives an e-mail informing its username and password to login into the diagnosis module;
4. Users answer the questionnaire: once logged in into the EcoM2 web portal, the user has access to answer the questionnaire related to its area of expertise, as informed in the registration form. The user can only answer the questionnaire once, but it is possible to stop and continue filling it later on from the last answered question.
5. Administrator validates the answers: once the user has completed the questionnaire, the administrator receives an automatic e-mail to evaluate each answer against the commentaries and evidences of the user (see section 3.2.1) and subsequently validate them.
6. Radar is generated: once the answers had been validated by the administrator, the system automatically generates the EcoM2 maturity radar of the company considering all of the previous answers from other employees (if that's the case).
7. Users receive a link to radar: finally, the users receive an e-mail with the link to the radar, which is only available in his private area in the EcoM2 web portal.

As previously mentioned, the users are motivated to invite other colleagues from different areas and hierarchical levels to perform the diagnosis, in order to improve the quality of the maturity profile on ecodesign implementation of the company. The EcoM2 maturity radar is updated for each new answer.

3.4 Current status and next steps

The EcoM2 portal is currently in the final development stage and tests are planned for the next months. The testing phase is planned to occur in three stages:
*   Preliminary test with the existing data from the three aforementioned case studies, in order to

test the consistency of the ecodesign maturity profile generated by the portal;

- Supervised application into new companies, in order to evaluate the usability of the portal and identify improvement opportunities;
- Pilot application into companies without supervision, in order to verify how well the companies can answer the questionnaire by themselves and understand the results of the ecodesign maturity profile.

The current version of the EcoM2 portal will be further improved based on the conclusions drawn from the performed tests. Subsequently, an official launch of the EcoM2 portal will be carried out, which will enable the collection of a large amount of data in regards to ecodesign implementation and management in several companies.

Additionally, the development of a new module in the EcoM2 web portal is planned, in order to enable companies to identify which are the best practices and improvement projects to be implemented based on their current maturity profile (second step of the application method – figure 1).

4   FINAL REMARKS

This paper has presented the development of the EcoM2 web portal, a platform that concurrently enables to: collect empirical data from product development companies regarding their ecodesign implementation maturity and best practices, and provide information and support to companies regarding ecodesign implementation and management.

The data collected to perform the diagnosis of the current maturity profile and the data generated by the EcoM2 web portal (especially the ecodesign maturity profile of the company) are of direct interest to the researcher, as they provide live empirical data from the companies utilising the portal. Several analyses in regards to ecodesign implementation and management will be derived from that data. It includes, for example, the establishment of maturity patterns according to company size, product complexity, sector and region. It will also be possible to identify which ecodesign practices are often applied by companies, the practices that are still not applied, the barriers faced by companies, success factors for ecodesign implementation and management, new ecodesign practices, etc. As companies reuse the EcoM2 web portal in further improvement cycles, it will be also possible to measure and understand how ecodesign implementation and management has evolved in those companies. Correlations among the maturity profile of companies on ecodesign and the environmental impact of the products developed by these companies will also be performed in order to identify to what extend one interferes to the other.

Moreover, the use of the EcoM2 web portal will support companies to perform a quick diagnosis of their current maturity profile on ecodesign implementation and management, to identify strengths and limitations in ecodesign application, to select the most suitable ecodesign practices to be applied, to establish a strategic roadmap for ecodesign implementation and, finally, to have a common and shared language inside the organization for ecodesign implementation and management.

As a result of the EcoM2 application in companies worldwide, enabled by the EcoM2 web portal, a growth in ecodesign maturity is expected in a long term perspective both from applied and theoretical perspectives.

REFERENCES

Baumann, H., Boons, F., Bragd, A. (2002) Mapping the green product development field: engineering, policy and business perspectives, *Journal of Cleaner Production*, vol.10, No.5, pp.409–425.

Bhamra, T., Evans, S., McAloone, T. (1999) Integrating Environmental Decisions into the Product Development Process: Part 2 The Later Stages, *Proceedings EcoDesign'99: First International Symposium On Environmentally Conscious Design and Inverse Manufacturing*, IEEE, pp. 334-337.

Biolchini, J., Mian, P.G., Natali, A.C.C., Travassos, G.H. (2005) *Systematic review in software engineering*. Rio de Janeiro.

Boks, C. (2006) The soft side of ecodesign, *Journal of Cleaner Production,* vol. 14, No. 15-16, pp.1346–1356.

Boks, C., Stevels, A. (2007) Essential perspectives for design for environment, Experiences from the electronics industry*, International Journal of Production Research*, vol. 45, No. 18, pp. 4021–4039.

Brezet, H., Rocha, C. (2001) Towards a model for product-oriented environmental management systems. In Charter, M., Tischner, U. (eds), *Sustainable Solutions: developing products and services for the future*, Sheffield: Greenleaf Publishing, pp. 469.

Charter, M. (2001) Managing ecodesign. In Charter, M., Tischner, U. (eds), *Sustainable Solutions: developing products and services for the future*, Sheffield: Greenleaf Publishing, pp. 221–241.

Coughlan, P., Coghlan, D. (2009) Action Research. In Karlsson, C. (ed), *Researching Operations Management*. Routledge, pp. 322.

Dewulf, W., Duflou, J.R. (2004) Integrating Eco-Design into Business Environments: A multi-level approach. In Talaba, D., Roche, T. (eds), *Product Engineering: Eco-Design, Technologies and Green Energy Sources*. Springer, pp. 539.

Dul, J., Hak, T. (2008) *Case Study Methodology in Business Research*, Burlington: Elsevier, pp. 302.

ISO (2002) *ISO 14.062 - Environmental Management: Integrating environmental aspects into product design and development*, ISO Bulletin.

Johansson, G. (2002) Success factors for integration of ecodesign in product development: a review of state of the art, *Environmental Management and Health*, vol. 13, No.1, 98–107.

Johansson, G. (2006) Incorporating environmental concern in product development: A study of project characteristics, *Management of environmental Quality: an international Journal,* vol. 17, No. 4, 421–436.

Lancaster, G. (2005) *Research methods in management: a concise introduction to research in management and business consultancy*, Oxford: Elsevier Butterworth-Heinemann, pp. 258.

Pascual, O., Stevels, A. (2004) Ecodesign in industry is not an environmental issue, *Proceedings of Electronic Goes Green,* Berlin, pp. 855–859.

Pascual, O., Stevels, A., Boks, C. (2003) Measuring implementation and performance of ecodesign in the electronics sector, *Proceedings of EcoDesign 2003: Third International Symposium on Environmentally Conscious Design and Inverse Manufacturing*. Tokyo, pp. 192–197.

Pigosso, D., Rozenfeld, H. (2011a) Ecodesign Maturity Model: the ecodesign practices, *Design for Innovative Value Towards a Sustainable Society: Proceedings of EcoDesign2011 International Symposium on Environmentally Conscious Design and Inverse Manufacturing*. Kyoto, Springer, pp. 423–428.

Pigosso, D., Rozenfeld, H. (2011b) Proposal of an Ecodesign Maturity Model: supporting companies to improve environmental sustainability. In Hesselbach, J., Herrmann, C. (eds), *Glocalized Solutions for Sustainability in Manufacturitng*. Braunschweig: Springer-Verlag, pp. 136–141.

Pigosso, D., Rozenfeld, H., Seliger, G. (2012) Ecodesign Maturity Model (EcoM2): the application method, *10th Global Conference on Sustainable Manufacturing - Towards Sustainable Manufacturing*. Istambul.

Pigosso, D., Rozenfeld, H., Seligerl, G. (2011) Ecodesign Maturity Model: criteria for methods and tools classification, *Advances in Sustainable Manufacturing*. Berlin, Springer-Verlag, pp. 239–243.

SEI (2006) *CMMI® for Development: improving processes for better products*. SEI.

United Nations (2008). *International Standard Industrial Classification of All Economic Activities* (ISIC), Rev. 4. New York.

Weenen, J.V. (1995) Towards sustainable product development, *Journal of Cleaner Production,* vol. 3, No. 1-2, pp. 95–100.