Journal of Cleaner Production 96 (2015) 44–57

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

From 50 to 1: integrating literature toward a systemic ecodesign model

Fabien Brones*, Marly Monteiro de Carvalho

Production Engineering Department, Polytechnic School of the University of São Paulo – USP, Av. Prof Almeida Prado – Trav 2, n° 128, 05508-900 São Paulo, SP, Brazil

ARTICLE INFO

Article history:
Received 9 October 2013
Received in revised form
11 July 2014
Accepted 15 July 2014
Available online 8 August 2014

Keywords:
Ecodesign
Integration
Model
Product development process
Systemic

ABSTRACT

Integration plays a key role in ecodesign, with its concept defined as incorporating environmental aspects into projects and product development process of businesses with a life cycle perspective. Assuming the lack of a comprehensive integration framework in accordance with the principles of innovation management, this study aims to fill this research gap. The research method, based on a review of the worldwide literature, used two databases and other sources, classifying and prioritising publications from primary sources. The result was a set of 52 models which was then analysed by encoding the information content according to key variables. Accordingly, a conceptual framework that combines scientific constructs and best practices with five integration principles was created. 1: a three level systemic approach (macro, meso and micro scales), integrating "top-down" and "bottom up" initiatives. 2: at macro level, strategy and goals for innovation and environmental sustainability. 3: at "meso" level, formal incorporation of environmental requirements in the product development process and portfolio management. 4: at "micro" level, implementation of customised ecodesign tools and integration of environmental aspects into project management. 5: in addition to the three levels, a transversal approach focused on change management and the "soft side" of ecodesign, emphasising the company's culture and human factors in a multifunctional vision. The conceptual model is proposed as a synthesis of main theoretical contributions found in the surveyed literature, in a systemic perspective. It is a path towards more effective ecodesign integration, building on fundamental principles of innovation management coupled with environmental sustainability knowledge.

1. Introduction

Interest in environmental sustainability and its relationship with product innovation is not new, however this concern has grown and is increasingly acknowledged as essential for organisations, as stated in an article in the Harvard Business Review (Nidumolu et al., 2009), which explains "Why sustainability is now the key driver of innovation". According to Hart and Dowell (2010) "15 years after the publication of "A Natural-Resource-Based View of the Firm" (Hart, 1995), the argument contained in that original piece has only become stronger and more relevant." However, "leading researchers have lamented that the 'revolution' has taken decades" (Goffin, 2012, p. 105). This evolution refers to ecodesign, which emerged in the 1990s as a promising approach to sustainable production and consumption (Brezet and Van Hemel, 1997).

The concept of "integration" (from the Latin "integrare", to make whole) plays a key role in the literature of ecodesign. The term appears with two perspectives: as the definition of what ecodesign is and as organisational challenges. Thus, the recent ISO 14006 standard (International Standard, 2011) determines ecodesign as "The integration of environmental aspects in product design and development, aiming to reduce adverse environmental impacts throughout the product's life cycle", whose document title is: "Environmental management systems - Guidelines for incorporating ecodesign", where the words "integrate" and "incorporate" are synonymously used. This dual use can be viewed as a consistency/alignment advantage, or as a possible confusion. Nevertheless, it explains the substantial use of the term in the literature.

However two decades after the publication of the first ISO 14000 standards, notwithstanding that environmental dimension in product innovation of companies is seen as an increasingly relevant guideline for sustainability strategies and policies, most publications still report modest results in terms of application effectiveness and scope, and also in terms of the limited effective

* Corresponding author.
E-mail address: fabienbrones@usp.br (F. Brones).

http://dx.doi.org/10.1016/j.jclepro.2014.07.036
0959-6526/

integration of ecodesign and product innovation (Baumann et al., 2002; Deutz et al., 2013; Guelere, 2009; Hart and Dowell, 2010; Pigosso et al., 2013; Verhulst and Boks, 2012; etc.)

A key issue with regards to ecodesign research, whether academic or applied, remains "how to make it happen?", according to a widely cited article by Karlsson and Luttropp (2006), in the introduction of a special edition of the Journal of Cleaner Production, which included 15 articles on ecodesign.

Deutz et al. (2013) pointed to the "significant implementation gap between the theory and practice of eco-design". Since the beginning the literature has focused on ecodesign tools (Arana-Landin and Heras-Saizarbitoria, 2011; Baumann et al., 2002; Stevels, 2007), and such publications continue to increase (Rio et al., 2013). Although the theory and methods are available, in practice it appears that implementing sustainable design is not an easy task, possibly due to the lack of a holistic approach to the implementation process, from a theoretical and empirical point of view (Verhulst and Boks, 2012). Other studies corroborate this perspective, declaring that the reason ecodesign has not been consolidated in businesses around the world is mainly due to difficulties in the ecodesign management (Pigosso, 2012; Pigosso et al., 2013).

Part of the integration problem may be related to the gap between the abundant literature on new product development (NPD) and the literature on ecodesign. Goffin (2012, p. 106) warned that "Organisations need to make significant modifications to NPD processes to achieve sustainable innovation". "So adding a sustainability perspective to NPD complicates an already complex process"; and further: "Research has shown that there is a gap in many organisations between the proponents of sustainability and those who develop the products and so are responsible for implementation" (p. 110). Spangenberg et al. (2010) also highlighted the gap between sustainability and design, and regretted that "sustainability plays a minor role in design education and practice, and design is not recognised as a relevant factor in the sustainability discourse." (p. 1485).

Consequently, there is still little recognition of systemic perspectives in ecodesign research (Baumann et al., 2002). Also, insufficient attention was paid to change processes and management, which could take into account the different dimensions of the company's Product Development Process (PDP) (Goffin and Mitchell, 2010; Rozenfeld et al., 2006).

As a starting point this article assumes there are still gaps in ecodesign literature about implementing a systemic change management approach, which considers the interaction of environmental issues with the various dimensions of the PDP. To deal with this research gap this article tried to address the following questions:

Q1: What is the scientific state of the art for the integration of ecodesign and PDP in companies?
Q2: Are there available and complete models to direct such integration? How are these models characterised? What are their main variables and relationships?
Q3: How do the existing models converse with the most accepted PDP models in companies?
Q4: What requirements and propositions can be prepared in terms of scientific concepts (Questions 1–3) to guide the development of a conceptual model in order to leverage the integration of ecodesign in companies?

These issues were addressed using the methodological approach of a systematic literature review.

This article is structured in five sections. Section 2 presents the methodology that was followed, detailing the protocol for the literature review. Section 3 contains the results of the bibliographic review. The following sections show the discussion of the models found (4) and propositions for building a more complete model (5) and the conclusions and limitations (6) of this broad study on best practices in the literature directed to the business context.

2. Research methods

The chosen methodological approach is a systematic literature review, striving for an overview of the state of the scientific art of ecodesign integration, focussing on previously published models.

The systematic review followed the three steps of the process suggested by Tranfield et al. (2003): data collection, data analysis and synthesis. Synthesis is the step that most adds value to a review as it generates new knowledge based on complete data collection and meticulous analysis (Crossan and Apaydin, 2010, p. 4). Several qualitative and quantitative methods can be used to help review the literature, such as the bibliometric approach, meta-analysis and content analysis (Carvalho et al., 2013); the latter was chosen for this work.

This work focuses on analysing the literature on the subject of ecodesign integration. Due to the scope of the subject, such review entails several challenges, which were categorised into three topics: aligning the vocabulary, dispersed literature and organisational aspects and macro processes taken into account. These challenges, which are discussed at the beginning of this section, justify our methodological choices.

- Aligning the vocabulary

In the sphere of environmental sustainability, though the term ecodesign is widespread and substantiated by ISO 14006-2011 (International Standard, 2011), similar terms are still used. For example, in the United States the term "design for environment" (DFE) is preferred and ecodesign is less used as it has a restrictive connotation associated with aesthetic design. The multiplicity of terms used for the concept and its expansion create search difficulties in the databases and compromises the quantitative research assessments. However within a comprehensive interpretation, several expressions have equivalent meanings, with the possibility of being interpreted differently depending on the authors.

- Dispersed literature

There are still few publications on ecodesign specifically targeting innovation management (Stevels, 2007). Yet, there is a scientific work on ecodesign that addresses "Environmental Management", as for instance through the concept of POEMS: Product Oriented Management System (Donnelly et al., 2006). There is also a series of publications dedicated to eco-innovation, a term which can lead to multiple interpretations.

- Organisational aspects and macro processes

According to the introduction, this work follows a proposal directed to a systemic approach to sustainable innovation, with the life cycle perspective (extended supply chain). This outlook leads to strongly consider other business processes interacting with PDP, such as sustainability management and supply chain management. Therefore, the search for information and publications should exceed the boundaries of the product innovation management area (search scope, keywords, etc.), aimed at careful consideration to elaborate an ecodesign integration model in the future.

2.1. Literature review approach

Due to the research scope focused on a concept intrinsically linked to ecodesign definition, a complete literature review might require a review of all literature on ecodesign. Unfortunately such a task would hardly be feasible today, in light of the multiplication of scientific productions observed. For example, Baumann et al., in a classic article in 2002, mapped 650 publications on ecodesign and environmental product development, showing a rapid growth in the number of publications. This trend was confirmed by Rio et al. (2013) with regards to the growing number of papers published on ecodesign methods (437 publications).

Considering this quantitative challenge, the methodology prepared for this study included three complementary assessment approaches of the publications (Fig.1), to combine the scope of the subject and the depth and completeness sought in the main theme.

Approach 1. Analysis of basic concepts and identification of relevant subtopics associated with classic or emerging ecodesign.

With the in-depth essential normative documents and some key material from the literature, we sought to identify a set of reference publications, as well as relevant subtopics that favoured a literature analysis of ecodesign integration.

Besides the topic "integration models", the main subject of the search and of the research, four subthemes were regarded as useful to complement the assessment: "Methods and tools", "Project management", "Portfolio management" and "Soft side" (relating to socio psychological or organisational practice and ecodesign integration).

Approach 2. Models and frameworks for the integration of ecodesign, key theme of the research.

At the forefront of the main work, a literature review was conducted in the scientific literature (especially focussing on publications in the English language), for a period of twenty years. To search for articles in the databases ISI Web of Science, Scopus, multiple key words were used due to the varying vocabulary used in this theme in different parts of the world: *eco-design*, *ecodesign*; "*design for environment*"; "*sustainable product development*"; "*sustainable product design*"; "*life-cycle design*"; "*life cycle design*"; "*green design*"; "*sustainable design*"; "*life cycle engineering*"; "*design for sustainability*"; "*environmentally conscious design*" (Baumann et al., 2002; International Standard, 2011; Pigosso, 2012). As this research focuses on the product development business process, life cycle design and life cycle engineering were considered, more than wider life cycle management principles, which apply to other business processes as stated by Jensen and Remmen (2006): "Life cycle management has been defined as the application of life cycle thinking in modern business practice".

This step confirmed the increasing publication trend. Table 1 shows the updated results until May 2013.

Moreover, as seen in the initial searches carried out, additional keywords were included in order to identify publications focussing on the more strategic dimension of ecodesign and innovation

Sub themes related to ecodesign	Search and exploration method of the literature
Approach 1: General concepts	- Normative and related documents - In-depth study of some key materials in the literature, identification of reference publications - Identification of relevant sub-topics
Approach 2: Models and frameworks for the integration of ecodesign = main research theme	1. Systematic search conducted in ISI Web of Science and Scopus database, publications since 2002 2. Selection by relevance from abstracts 3. Systematic content analysis 4. In-depth study of other key publications cited in recent articles 5. Identification and selection of models
Approach 3: Specific or emerging sub-topics	Directed qualitative or quantitative search: basis for content analysis and relevance of articles and propositions
Methods and tools	The most classic theme in ecodesign. Search of reference or recent articles, with a focus on literature synthesis or survey on the topic.
Project management	Systematic search in ISI Web of Science and Scopus database conducted in previous research, personal summary available
Portfolio management	Systematic search in ISI Web of Science and Scopus database, conducted in previous research, personal summary available
"Soft side of ecodesign" (socio-psychological factors)	Related theme identified as relevant in the analysis of general literature; Expression created by Boks (2006) and addressed by Stevels (2007). Additional search in databases and qualitative analysis.

Fig. 1. Ecodesign literature review approaches.

Table 1
Main search strings and results (March/2013).

Search strings	ISI/Web of science	Scopus
Eco-design; ecodesign; "design for environment"; "sustainable product development"; "sustainable product design"; "life-cycle design"; "life cycle design"; "green design"; "sustainable design"; "life cycle engineering"; "design for sustainability"; "environmentally conscious design"	1206	2054

management, such as "*sustainable innovation*", "*sustainable* R&D", as well as "*ecoinnovation*".

As the literature review focused on identifying integrative models and frameworks in the NPD and PDP literature, complementary keywords aimed at "models" were used as, namely: "*model*", "*framework*", "*development process*", "*new product development*".

The abstracts were used to analyse and select the publications according to their relevance. Next, a content analysis was performed, with which other key and older publications cited in the previous ten years were identified. This iterative process sought to identify the models published under various perspectives in the ecodesign literature. The selection criterion was articles' alignment with the research topic, i.e., consistently including ecodesign (or equivalent concept) models or framework.

Approach 3. Directed qualitative searches on specific or emerging subtopics.

Complementing previous studies, searches, analyses and additional classifications of publications related to four ecodesign themes were performed. Moreover, the snowball sampling method was applied (Fink, 1995), thus, the sample was expanded by incorporating other publications that had been cited in the initial sample. In this activity, additional publications with different functions were identified, helping to interpret the main set and as a basis for analysing the content relevance of articles and propositions. The arrows in Fig. 1 show the dynamic interconnections between the three approaches and the sets of publications analysed.

2.2. Content analysis

Next, focussing on the set of publications identified comprehending integration models, a content analysis of publications and models was carried out. The characteristics of publications and models were encoded in order to analyse their distribution and evolution (Carnevalli and Cauchick, 2008; Prasad and Tata, 2005). This set of models, considered relevant, was studied in depth taking into consideration the full contents of the articles, in order to systematise and synthesise the contributions to the research topic and to enable discussing the key constructs found.

The coding included two blocks of parameters in order to facilitate the representation and analysis. The first block comprised the following characterisation parameters: year of publication, authors, geographical origin (first author's country) and type of publication (J = scientific journals; C = conference proceedings; B = books or brochures; T = doctoral thesis and S = standards). The content analysis block displays the following information about the main contents of the integration models: summary of the models' main focus; systemic levels addressed in the models (micro, meso and macro), and type of PDP considered in the models (see Appendix 1).

As pointed out in the introduction, the work is developed in a systemic approach in order to analyse the innovation processes, in particular PDP, NPD and ecodesign as integrated systems with multiple levels of analysis. This assumption was also proposed in previous studies on portfolio management as an intermediate level system ("meso") between the corporate or strategic level (here termed as "macro") and the operational level to run projects and associated decision making ("micro" level). Such classification is consistent with business experience in innovation and also with recognised publications on the subject (Goffin and Mitchell, 2010; Larsson, 2007). Similar systemic approaches were found as the main or underlying propositions in several publications of the set.

The encoding of the models' type of PDP, according to the information in the publications, was based on several reference models in the field of innovation management. In the literature of innovation management, two classical models are particularly found, the "development funnel" (Clark and Wheelwright, 1993) and the "stage-sates" model of Cooper et al. (2002), emphasising the decision points between phases along the design of new products. In summary, the concepts and types of PDP found in the publications were classified as: Stage-gate, Multiphase, Multiphase Funnel, Specific, PDCA (common cyclic process in quality management, Plan, Do, Check, Act), or ND if undefined.

3. Results

The search results of publications in the literature were recorded in Table 2, which shows the main articles or theses found and considered in the subsequent analyses. The main assessment focus is highlighted in the last line that shows the publications found and selection flow performed to identify the associated integration models. This set was obtained by an iterative process that included "recycling" of publications from or to other topics, and search for primary sources of the models cited in the selected publications. From this analysis, the most relevant articles were chosen according to the selection criterion. 35 articles were selected from the search in the databases, checking that they really addressed the studied subject and contained ecodesign integration models. Another 45 publications were identified indirectly, through the snowball sampling from the references cited in the initial set of 35 articles or appearing in the other publications identified on the other topics related to ecodesign (general concepts, methods and tools, project management, portfolio management and "soft side"), resulting in 80 publications. From this pool a final sample of 52 publications and models was constituted by selecting the relevant publications and eliminating duplicated models, representing 65% of the initial sample of 80 publications.

Although several literature reviews on ecodesign methods and tools were performed and reported in the literature (Baumann et al., 2002; Bovea and Pérez-Belis, 2012; Guelere et al., 2007; Guelere, 2009; Pigosso et al., 2013), no previous review on integration models was found.

3.1. Set of publications obtained

The collection of 52 selected publications that show integration models contains a rich set of scientific and historical information about the evolution of the subject in the last twenty years worldwide. It was organised in a complete Excel file which was used for all the encoding tasks and content analysis. To answer the research questions outlined above a synthetic representation was organised and is available in Appendix 1a-c (the full Excel file contains more than a hundred A4 pages). The appendix summarises the content analysis by model presented in chronological order and coded by geographic origin, type of publication, type of PDP, and systemic level of analysis. Moreover, each model is accompanied by a brief description of the goals.

Table 2
Overview of the inquiry results in the literature on ecodesign.

Related topics	Publications considered and main concepts	Key references	# Ref.
General concepts of ecodesign	Two main normative documents	ISO/TR 14062: ABNT, 2004 ISO 14006: International Standard, 2011	2
	Focus in 10 publications between recent and classic works on the subject in the literature	Baumann et al., 2002, Bhamra and Lofthouse, 2007, Brezet and Van Hemel., 1997, Deutz et al., 2013, Hübner, 2012, Johansson, 2002, Karlsson and Luttropp, 2006, Kurk and Eagan, 2008, Luttropp and Lagerstedt, 2006, Stevels, 2007	10
Main sub–themes related to ecodesign			
Methods & tools (M&T)	Among the subtopics, the highest concentration of publications in ecodesign was in M&F	Baumann et al., 2002, Bovea and Pérez-Belis, 2012, Byggeth and Hochschorner, 2006, Guelere, 2009, Guelere et al., 2007, Lofthouse, 2006, Lofthouse and Bhamra, 2001, Luttropp and Lagerstedt, 2006, O'Hare, 2010, Pigosso and Rozenfeld, 2013, Ritzen and Lindahl, 2001	11
Project management	Incipient theme approached in specialised ecodesign articles	Brones et al., 2014, Johansson and Magnusson, 2006, Knight and Jenkins, 2009, Ny et al., 2008, Tingström and Karlsson, 2006, Tingström et al., 2006, Vezzoli and Sciama, 2006	6
Portfolio management	Theme rarely addressed in ecodesign: only in Ölundh and Ritzén (2004) with initial propositions, focussing on project selection.	Arnold and Hockert, 2011, Bhamra et al., 1999,Boks and Mcaloone, 2009, De Caluwe, 2004, Donnelly et al., 2006, Ölundh, 2006, Ölundh and Ritzén, 2004, Simon et al., 2000, Stevels, 2007, Vandaele and Decouttere, 2013	10
"*Soft side*" of ecodesign	Theme under development	Boks, 2006, Hassi et al., 2009, Lofthouse 2003, Lofthouse 2004, Petala et al., 2010, Stevels, 2007, Verhulst and Boks 2012, Verhulst et al., 2007	8
Models and frameworks for ecodesign integration	80 publications found in databases (mostly at conferences) → 35 articles deemed relevant → +45 other publications identified by citations (theses, books or articles) → Content analysis and selection of articles with relevant models (priority of primary sources)	Creation of a body of 52 classified publications: Excel file with models and comments to content analysis	

3.2. Distribution of publications: type, journals, time and geography

Fig. 2 shows the distribution of the 52 publications analysed by type of document, highlighting the articles published in scientific journals (48%), accounting for almost half of the sample, followed by conference proceedings (29%), books or brochures (10%), doctoral dissertations (10%) and standards (4%), in decreasing order of participation.

Table 3 shows the distribution of the 25 articles (48%) regarded according to the journals. This calculation clearly indicates the predominance of the Journal of Cleaner Production as the main knowledge dissemination platform for the subject of ecodesign management. But it also indicates that, occasionally, the topic was addressed in several journals of other areas such as engineering, business and design.

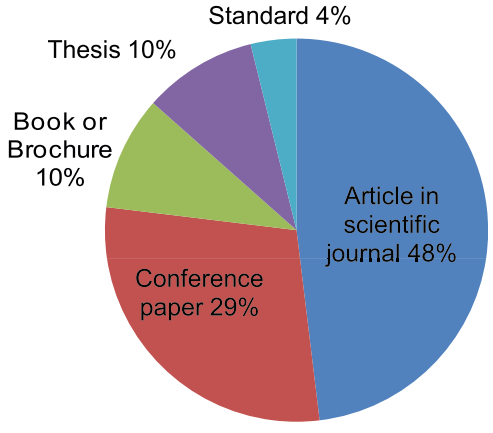

Fig. 2. Distribution in types of publications.

Fig. 3 shows the evolution of publications over the sample period analysed. A higher rate of publications is observed since 2001; however, there is no logical explanation for the absence of publication in 2003.

According to Fig. 4 the geographical origin of publications shows a wide range of distribution worldwide. The classification by continent points to a greater representation of Europe (73% in 11 countries), followed by North America (12%), Asia (8%), South America (6%) and Oceania (2%). Three European countries stand out for their longer tradition in publishing this subject: UK, Sweden and the Netherlands, known for their universities which are active in ecodesign research. Surprisingly, there is no publication coming from Japan in this set – a country recognised for its activity in ecodesign particularly through the technical conferences held on the subject since the late 1990s. This gap just means that no Japanese publication on the research subject was found in the searches in the database or in the models cited in other studied references.

Table 3
Distribution of articles in periodicals.

Journal	#	%
Journal of Cleaner Production	14	56%
Business Strategy and the Environment	2	8%
Computers & Chemical Engineering	1	4%
International Journal of Production Economics	1	4%
Journal of Achievements in Materials and Manufacturing Engineering	1	4%
Journal of Mechanical Design	1	4%
Journal of Systems Science and Systems Engineering	1	4%
Materials and Design	1	4%
The International Journal of Life Cycle Assessment	1	4%
The Journal of Design Research	1	4%
The Journal of Sustainable Product Design	1	4%
Total	25	100%

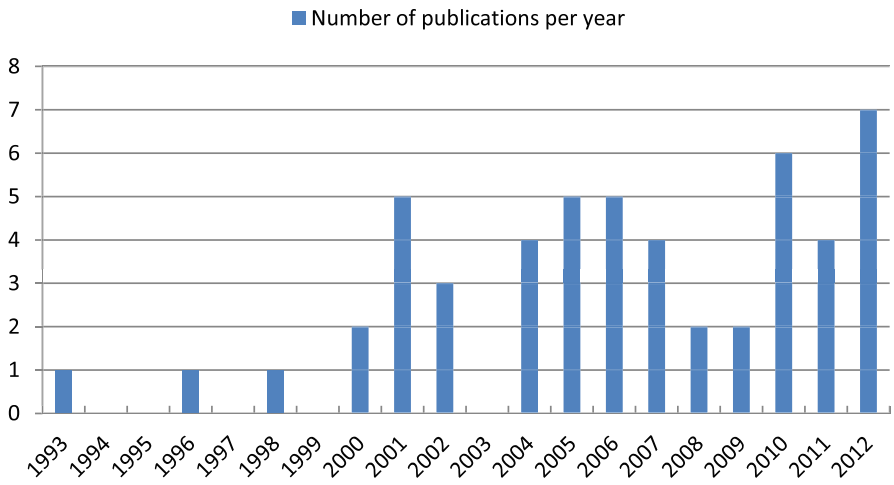

Fig. 3. Distribution of publications per year.

3.3. Systemic levels and types of PDP

Table 4 outlines the distribution of the systemic levels regarded in the models. The micro or operational level predominance (73% of the models) is observed, however there is a significant presence, over 50%, of other levels in the set. The distribution of the number of levels in the model shows a higher occurrence of one or two levels (around 40% for each modality), with only 20% of the sample addressing the three levels.

Fig. 5 shows the evolution of the number of levels regarded in the 52 models of the sample over time (classification used in 3 levels). This distribution of levels suggests that there was no clear evolution over time, as there was no growth of multilevel systemic approaches, particularly with the three levels.

With regards to the types of PDP in the 52 models, Table 5 shows that 50% of the publications do not determine a specific type of PDP reference model. The multiphase type models are considered in one fourth of the publications, followed by stage-gate type models.

4. Discussion of results

4.1. Systemic perspective of integration levels

The systemic perspective of integration, explored in this work, was confirmed as an interesting filter to analyse and compare the models. Observably, there is no unanimity in the number and boundaries of the levels under consideration as there are several publications and models with three levels of distribution (Dewulf and Duflou, 2004; Kara et al., 2005; Stevels, 2001; Van Hemel, 1998), with four (Baumann et al., 2002) or up to five levels (Robèrt et al., 2002). An additional level refers to the company's relationship with external systems (e.g., groups of companies, public policies …). It was decided to not emphasise this level in the assessment because the objective is focused on the internal management of environmental sustainability and innovation.

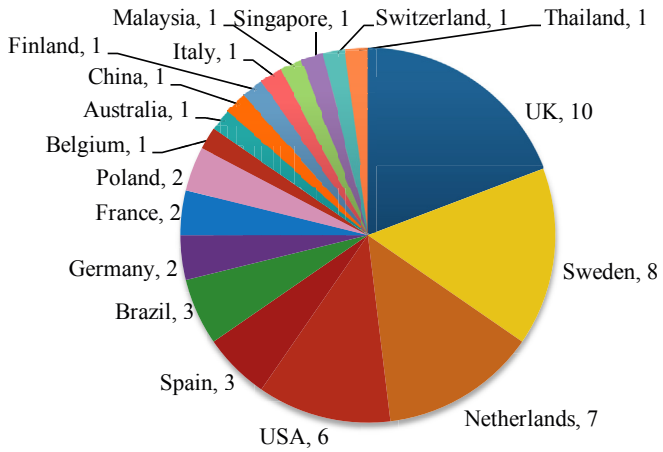

Fig. 4. Distribution of publications by country (first author's affiliation).

The segmentation used in our analysis can be considered as the most common and in line with recognised principles of innovation management, very similar to the model proposed by Kara et al. (2005), which describes the three levels as strategic, tactical and operational.

Looking at the evolution of the levels considered in the models (cf. Fig. 5), somehow there is a trend toward greater or more in-depth detail of the subject in the publications, for example the number of references cited and the number of ecodesign tools considered in the articles (e.g., Bovea and Pérez-Belis, 2012; or Ramani et al., 2010; with 218 references analysed).

However, such approaches bring limited progress on the issue of ecodesign integration, as Baumann et al. observed in 2002, who already pointed out an excess of tool development, but little connection between strategic intent and content; little about the broader context of product development and limited recognition of systemic perspectives in policy formulations.

Returning to the initial definition of ecodesign integration concept, it can be observed that the “micro” level corresponds to the first definition of ecodesign integration (integration of environmental aspects in product design and development, commonly focussing on the technical, practical and tools aspects); the other definition that addresses the organisational dimension relates to “meso” and “macro” levels in PDP and other related business processes, including strategic planning.

4.2. Reference PDP

With regard to the PDP in the integration models, the data in Table 5 point out that most of the articles do not specify a reference PDP. Publications considering a PDP with various steps are the minority and only 17% consider a predefined process with formal steps and approval requirements at gates such as stage-gate model (Cooper et al., 2002).

Table 4
Distribution of models in the systemic levels.

Level	# Models	%	References
Micro level	39	75%	ABNT, 2004, Ammenberg and Sundin, 2005, Baumann et al., 2002, Bhamra, 2004, Bovea and Pérez-Belis, 2012, Bucci et al., 2012, Crul and Diehl, 2009, Dewulf and Duflou, 2004, Donnelly et al., 2006, Ferrer et al., 2012, Fiksel, 1993, Ghazilla et al., 2008, Goffin, 2012, Hallstedt et al., 2010, Handfield et al., 2001, Hassi et al., 2009, Howarth and Hadfield, 2006, International standard, 2011, Jeganova, 2005, Jones et al., 2001, Kara et al., 2005, Kengpol and Boonkanit, 2011,Le Pochat et al., 2007, Lewandowska and Kurczew, 2010, Lofthouse, 2006, Neal and Heintz, 2001, Nowosielski et al., 2007, Pigosso, 2012, Poyner and Simon, 1996, Ramani et al., 2010, Ritzén, 2000, Robèrt et al., 2002, Simon et al., 2000, Stevels, 2001, Trappey et al., 2011, Van Hemel, 1998, Vezzoli and Manzini, 2008, Waage, 2007, Yang and Song, 2006
Meso level	29	56%	ABNT, 2004, Alakeson and Sherwin, 2004, Ammenberg and Sundin, 2005, Arana-Landin and Heras-Saizarbit, 2011, Baumann et al., 2002, Berchicci and Bodewes, 2005, Bhamra, 2004, Bucci et al., 2012, Dewulf and Duflou, 2004, Donnelly et al., 2006, Fiksel, 1993, Goffin, 2012, Handfield et al., 2001, Hermenau et al., 2005, International standard, 2011, Jeganova, 2005, Kara et al., 2005, Keskin et al., 2013, Le Pochat et al., 2007, Ölundh, 2006, Pigosso, 2012, Poyner and Simon, 1996, Ritzén, 2000, Robèrt et al., 2002, Sherwin and Bhamra, 2001, Stevels, 2001, Tingström, 2007, Van Hemel, 1998, Vezzoli and Manzini, 2008
Macro level	27	52%	Alakeson and Sherwin, 2004, Baumann et al., 2002, Carrillo-Hermosilla et al., 2010, Crul and Diehl, 2009, Dewulf and Duflou, 2004, Donnelly et al., 2006, Dusch et al., 2010, Hallstedt et al., 2010, Handfield et al., 2001, Hassi et al., 2009, Hermenau et al., 2005, Howarth and Hadfield, 2006, International standard, 2011, Kara et al., 2005, Ölundh, 2006, Pigosso, 2012, Ramani et al., 2010, Ritzén, 2000, Robèrt et al., 2002,Simon et al., 2000, Spangenberg et al., 2010, Stevels, 2001, Tingström, 2007, Van Hemel, 1998, Van Hemel and Cramer, 2002, Verhulst and Boks, 2012, Waage, 2007
Models with 1 level	20	38%	Arana-Landin and Heras-Saizarbit, 2011, Berchicci and Bodewes, 2005, Bovea and Pérez-Belis, 2012, Carrillo-Hermosilla et al., 2010, Ferrer et al., 2012, Ghazilla et al., 2008, Jones et al., 2001, Kengpol and Boonkanit, 2011, Keskin et al., 2013, Lewandowska and Kurczew, 2010, Lofthouse, 2006, Neal and Heintz, 2001, Nowosielski et al., 2007, Sherwin and Bhamra, 2001, Spangenberg et al., 2010, Trappey et al., 2011, Dusch et al., 2010, Van Hemel and Cramer, 2002, Verhulst and Boks, 2012, Yang and Song, 2006
Models with 2 levels	21	40%	ABNT, 2004, Alakeson and Sherwin, 2004, Ammenberg and Sundin, 2005, Bhamra, 2004, Bucci et al., 2012, Crul and Diehl, 2009, Fiksel, 1993, Goffin, 2012, Hallstedt et al., 2010, Hassi et al., 2009, Hermenau et al., 2005, Howarth and Hadfield, 2006, Jeganova, 2005, Le Pochat et al., 2007, Ölundh, 2006, Poyner and Simon, 1996, Ramani et al., 2010, Simon et al., 2000, Tingström, 2007, Vezzoli and Manzini, 2008, Waage, 2007
Models with 3 levels	11	21%	Baumann et al., 2002, Dewulf and Duflou, 2004, Donnelly et al., 2006, Handfield et al., 2001, International standard, 2011, Kara et al., 2005, Pigosso, 2012, Ritzén, 2000, Robèrt et al., 2002, Stevels, 2001, Van Hemel, 1998

In some cases, the explanation for this lack of formal PDP can be related to the business context: for example, in SMEs (Small and Medium Enterprises), such informal situation is relatively common, as argued in the TR 14062: “In large companies the product design and development process may be a formalised approach with fixed milestones and gateway management, whereas in small companies one or several people, working in an informal and more intuitive manner can carry out product development.” (International Standard, 2002, p.14). However, such formalisation is possible and even recommended, as reported by Le Pochat in SMEs (2007).

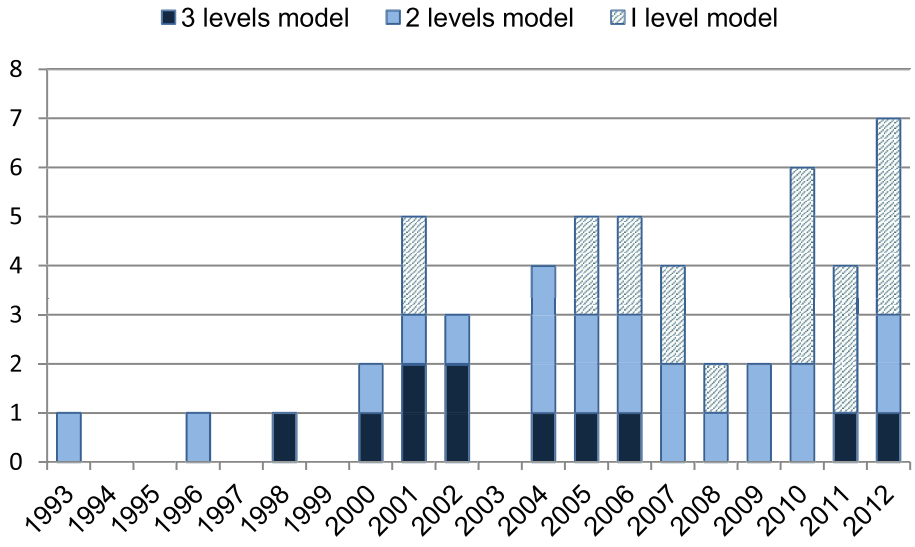

Fig. 5. Number of levels in the models by year of publication.

Table 5
Types of PDP in the models.

Type of PDP	#	%	References
Not defined	26	50%	Alakeson and Sherwin, 2004, Ammenberg and Sundin, 2005, Arana-Landin and Heras-Saizarbit, 2011, Berchicci and Bodewes, 2005, Bovea and Pérez-Belis, 2012, Carrillo-Hermosilla et al., 2010,Dusch et al., 2010, Ferrer et al., 2012, Fiksel, 1993, Hallstedt et al., 2010, Hermenau et al., 2005, Howarth and Hadfield, 2006, Kara et al., 2005, Kengpol and Boonkanit, 2011, Lofthouse, 2006, Neal and Heintz, 2001, Ramani et al., 2010, Robèrt et al., 2002, Simon et al., 2000, Spangenberg et al., 2010, Stevels, 2001, Trappey et al., 2011, Van Hemel and Cramer, 2002, Van Hemel, 1998, Verhulst and Boks, 2012, Yang and Song, 2006
Multiphase	13	25%	ABNT, 2004, Baumann et al., 2002, Dewulf and Duflou, 2004, Donnelly et al., 2006, Ghazilla et al., 2008, Handfield et al., 2001, Jones et al., 2001, Le Pochat et al., 2007, Lewandowska and Kurczew, 2010, Nowosielski et al., 2007, Sherwin and Bhamra, 2001, Vezzoli and Manzini, 2008, Waage, 2007
Stage-gate	9	17%	Bucci et al., 2012, Crul and Diehl, 2009, Goffin, 2012, Jeganova, 2005, Ölundh, 2006, Pigosso, 2012, Poyner and Simon, 1996, Ritzén, 2000, Tingström, 2007
Multiphase funnel	2	4%	Bhamra, 2004, Hassi et al., 2009,
PDCA	1	2%	International Standard, 2011
Specific	1	2%	Keskin et al., 2013
Total	52	100%	

Another explanation for the low definition of PDP is a tendency by the authors to focus on propositions aimed at environmental approach and management, without necessarily considering the basic principles in the area of innovation management.

Goffin (2012), a renowned English expert in this specific area, recently addressed the question of "Sustainability and new product development", and argues: "proposing a new process ignores the comprehensive body of knowledge of NPD that has been developed from practice and research over several decades" (p. 112). Berchicci and Bodewes (2005) already had a similar observation. Goffin (2012) concludes with the recommendation that the stage-gate process can be expanded to include sustainability issues.

4.3. Integration and change management

Since the publications of the 1990s, experts have debated that incorporating ecodesign requires not only a set of tools and techniques, but also that its implementation takes place within a system integrated to the product development cycle (Fiksel, 1993) and to the company's operations, in three levels (Dewulf and Duflou, 2004).

One of the lines developed to lead to change management in the integration models follows the principles of quality management extended to environmental management (Ammenberg and Sundin, 2005; Arana-Landin and Heras-Saizarbitoria, 2011; Dewulf and Duflou, 2004; Donnelly et al., 2006; International Standard, 2011; Simon et al., 2000). Initiated in Europe in the 1990s, these models have used the acronym POEMS (Product Oriented Environmental Management System) with its pillars based on the PDCA improvement cycle (Plan-Do-Check-Act) or Deming cycle, which is also the basis for ISO 14001 and ISO 9001 (Ammenberg and Sundin, 2005).

With the maturing of the systemic view, it became clear that the implications and changes needed surpass the technical dimension and the PDP frontiers to effectively implement ecodesign. However, this formal normative approach, suitable for system quality or site oriented environmental management systems, does not appear to have conquered the PDP universe.

One explanation is that the innovation process and its instrument (PDP) do not follow a PDCA like formal repetitive logic given its unique project oriented nature, which includes a number of sub processes with their own cycles of evolution and feedback (strategic planning, funnel and pipeline management, portfolio management, project management). In this context it leans more to a contingency approach (Shenhar, 2001), in a more customised approach. Thus, another line proposed in the direction of promoting changes in business gave more emphasis to socio-organisational and human issues.

The views and concerns of all stakeholders should be part of the designer's concern towards sustainability (Howarth and Hadfield, 2006). According to Tingström (2007), there is a multifaceted interest in integration that must have the ability to accommodate a diverse range of activities and individuals in order to build a view of how environmental considerations should be integrated into a company's work and product development. To Sherwin and Bhamra (2001) the concept of integration refers to the principles of concurrent engineering, which promotes dialogue and communication at the early stages and throughout the development process in order to improve the quality, cost and development time reduction, and more recently, extending to environmental issues.

As shown in Section 3, a strand of publications has extended this socio-psycho-organisational integration of ecodesign, or "soft side" (Boks, 2006). Hassi et al. (2009) insisted on people and behaviour (attitudes, motivation) to develop a set of techniques that are suitable for the transformational change required for sustainability concerns. Some authors suggested an "integrated and holistic view" (Spangenberg et al., 2010; Verhulst and Boks, 2012). Spangenberg et al. (2010) focused on skills, roles and learning, implemented through an interdisciplinary, integrative methodology and transdisciplinary project.

This line usually follows a change management approach in search of a process to implement life cycle and sustainable product development adapted to the company's culture, considering a number of human factors, including employee participation, training, resistance to changes and so forth.

5. Proposed integrative conceptual model

The systematic literature review pointed out several literature gaps, as well as potential synergies and complementarities. Insights emerging from the content analysis brought the material necessary to build an integrative conceptual model aligned to the goal of the work, through an inductive process.

Within the scope of enterprise innovation and sustainability management studied in this work, a variety of qualitative and intuitive models and frameworks were found. Bhamra (2004) explains that "models are often understood as simplistic ways of representing and/or understanding the world, usually having the purposes of being descriptive or prescriptive. They have the potential to summarise complex information in a manageable and understandable manner and for ecodesign represent a range of its characteristics, fields and practices" (p. 559).

The pioneering view of the protagonists of ecodesign in the 1990s should be remembered, such as Fiksel (1993) who stated:

> "The emergence of the DFE is a convergence of two pervasive thrusts that are transforming the nature of manufacturing businesses throughout the world: *enterprise integration and sustainable development.* Enterprise integration is re-engineering business processes and information systems to improve teamwork and coordination across organisational boundaries, thereby increasing the effectiveness of the enterprise as a whole" (p. 126).

Corroborating with these statements and taking into consideration the best practices in innovation management can be an effective basis for developing a broader ecodesign integration model, following Goffin (2012), but adding other dimensions and considerations.

The proposed model comprehends five integration lines. The first is a systemic approach with three levels (macro, meso and micro). The second one, "macro" level, is the incorporation of the strategy and goals for innovation and environmental sustainability. The "meso" level is the third integration line, which introduces the formal environmental requirements to PDP and portfolio management. The "micro" level, the fourth integration line, proposes the implementation of customised ecodesign tools and integration of environmental aspects in project management, a missing link pointed out by Brones et al. (2014). The fifth and last line brings a complementary transversal approach to the three levels aimed at the soft side of ecodesign and change management, with an emphasis on company culture and human factors within a multifunctional view (Fig. 6).

The analysis and discussion of the proposed integration ecodesign model follows these five lines.

1. **Construction of a systemic approach with three levels (macro, meso and micro)**, for coherent articulation between initiatives and principles at the different levels, which Ölundh (2006) called "vertical integration of ecodesign". The expected inter-level requires combined integrative forces in two convergent movements:
   - "Top down" deployment and alignment between strategy and corporate objectives, from the stimulus of the company's executive management, as recommended in ISO 14006 (International Standard, 2011).
   - "Bottom up" knowledge building associated with pilot projects and team empowering (Kara et al., 2005).
2. **Macro level:** strategy and corporate objectives in innovation and environmental sustainability, based on life cycle thinking principles (Jensen and Remmen, 2006), promoting internal direction, including any existing business units, with ecodesign and/or environmental, global and deployed goals (Ölundh, 2006). This line, besides strategic planning and sustainability strategy, may also include internal and external communication strategy and initiatives in ecodesign.
3. **Meso level**: aimed at PDP and portfolio management.
   - Alignment and insertion of formal environmental requirements in PDP throughout the key stages and gates for decision making, from the early and particularly decisive stages (Goffin, 2012).
   - Integration of ecodesign in portfolio management, including decision/trade-offs criteria associated with the environmental dimension; quantitative environmental life cycle indicators (Pigosso et al., 2013), relationship between units within the company.
4. **Micro level** includes ecodesign tools and project management.
   - The broad theme of ecodesign tools has not been explored in detail in this review, given that it is the most discussed aspect in the literature, but we pointed out some key publications. The Ecodesign Maturity Model (Pigosso, 2012; Pigosso et al., 2013) can be a highly interesting tool to diagnose the company's need, in terms of practices and ecodesign tools and associated management practices. To cite a few references classical tools include ecodesign guidelines (Brezet and Van Hemel, 1997; Fiksel, 1993), environmental assessment tools, based on life cycle assessment, (Donnelly et al., 2006; Kara et al., 2005) and verification tools (Fiksel, 1993). Ecodesign tools customisation, however, should be emphasised in this model proposal, taking into consideration the specificities of PDP and the company's culture. The principle of customisation appeared as a recommended best practice in a number of publications (i.e.: Knight and Jenkins, 2009; Luttropp and Lagerstedt, 2006; O'Hare, 2010; Ritzen and Lindahl, 2001), but is still a challenging task for effective integration.
   - The integration of ecodesign in project management, complementing more global portfolio guidelines (meso level), calls for new approaches such as project success factors and "trade-off" solutions between the various dimensions (quality, cost, time and environmental sustainability), the multifunctional teamwork, covering the perspectives of life cycle of products and the various stakeholders of the value chain (as we explore in a separate publication).
5. **Change management and "soft side" of ecodesign**, considering the company's culture through human factors, including and promoting the participation of employees and areas, training and knowledge management, overcoming resistance to change (Boks, 2006; Verhulst and Boks, 2012). This transversal approach has to go through the three aforementioned levels of integration, seeking to ensure the progress of processes and practices.

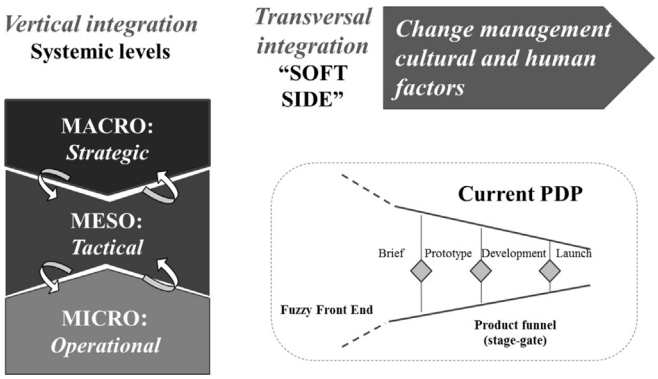

Fig. 6. Ecodesign integration model: combining vertical and transversal integration axes into the existing PDP.

Finally, these five integration lines of the ecodesign integration model will have to take into account several requirements induced from the set of models studied:

- Applicable to various types of companies/versatile.
- Easy to understand visual representation, easy to remember and communicate to different potential users of the model, incorporating already established elements such as the funnel or stage-gate PDP.
- Vocabulary/keywords to assist memorisation.
- Trade-offs between level of detail and completeness of the model and clarity.

6. Conclusion

The objective of this study was to map the state of the scientific art on ecodesign integration from a comprehensive review of international publications. The main studies in this area were classified and coded in terms of the level of analysis, publication type, PDP type, research country, and the temporal evolution of the studies.

Next, 52 integration models were identified and analysed in depth. These models feature a wide variety of approaches and representations. However they are usually the result of relatively specific works, supported by case studies, and take into consideration the extensive fields of knowledge from innovation and sustainability management in a limited way, and only a few previous models. It is observed that they rarely refer directly to the most accepted models of innovation management in companies, such as stage-gate, although this is quite recommended by some experts in the topics.

As a result of the systematic literature review, relevant gaps were found that may explain why ecodesign integration still remains a challenge, particularly in the innovation management processes and generally in operations management. The literature analysis enables to merge some of the best theoretical constructs and practices in a systemic and integrative perspective, as a promising approach towards more effective ecodesign integration. Thus, a new ecodesign integration model was presented as a synthesis of these analyses. The proposed conceptual framework connects three systemic levels (macro, meso and micro), with top-down and bottom-up flows that promote vertical integration, while the transversal integration axis occurs through change and people management within a perspective of the organisation's culture. Both axes are based on established innovation management practices, including the development pipeline and stage-gate process, and are consistent with product oriented life cycle management practices.

As implied in the challenges of undertaking a literature review on this topic, such as the lack of vocabulary alignment, dispersed literature and organisational aspects and complexity, the main limitations of this review regard the fact that some studies may not have been identified in the search processes.

The models and framework are widely dispersed in the literature, and some interesting publications were indirectly found. Therefore, not all possibilities were covered, and our survey is not expected to have a quantitative representativeness, but can be considered as an in-depth exploratory study.

Another potential limitation was the subjectivity in the analysis of the models, regarding the levels and types of PDP. The presented evaluation (systemic levels and PDP) does not intend to cover all of the depth and richness of approaches used in the publications, and a more detailed content analysis is underway.

However, the study objectives were achieved and opened a promising path to consolidate ecodesign knowledge. The synthesis based on scientific constructs associated with the success factors of innovation management coupled with the dissemination of environmental sustainability principles can be a significant contribution to the body of ecodesign and product oriented life cycle management themes.

Besides the formalisation and more detailed representation of the model in a future work, these propositions should be further developed and tested in subsequent field studies through Action-Research, a path suggested by Ritzén (2000), deemed as necessary yet little practiced in ecodesign, which was only found in the O'Hare (2010) work on the narrower scope of simple tools development for SMEs.

Acknowledgements

The authors thank the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and the Coordenação de Aperfeiçoamento de Pessoal De Nível Superior (CAPES) for supporting this research. The authors express their gratitude to the reviewers who contributed to the improvement of this article.

Appendix 1a. Summary content of the publications and models identified (from 2009 to 2013).

Year	Reference	Country	Pub	Main focus	Levels			PDP
					Micro	Meso	Macro	
2013	Keskin et al.	Holland	J	Sustainable innovation process in new business ventures; Internal and external factors		X		Specific (3 phases)
2012	Bucci et al.	Brazil	C	PDP, reference model. Focus on packaging and product development	X	X		Stage-gate
	Goffin	UK	B	Sustainability issues and requirements in phases, and potential conflicts. Role of executive management	X	X		Stage-gate
	Verhulst and Boks	Belgium	C	Change management, human factors and business culture			X	ND
	Ferrer et al.	France	J	Problem solving; process and tools	X			ND
	Bovea and Perez-Belis	Spain	J	Choosing environmental evaluation and integration tools with other requirements	X			ND
	Pigosso	Brazil	T	Maturity assessment in ecodesign with 61 indicators: PDP practices/management, operational practices and methods and tools; improvement tool (roadmap)	X	X	X	Stage-gate
2011	International standard	Switzerland	S	ISO 14006: guidelines to incorporate and implement a systematic and structured ecodesign process in an Environmental Management System	X	X	X	PDCA
	Arana-Landin and Heras-Saizarbit.	Spain	J	PDCA implementation approach for ecodesign		X		ND
	Kengpol and Boonkanit	Thailand	J	Applied ecodesign process, detailing tools and methods	X			ND

(*continued on next page*)

(*continued*)

Year	Reference	Country	Pub	Main focus	Levels			PDP
					Micro	Meso	Macro	
	Trappey et al.	China	J	Applied ecoinnovation process using various methods and tools	**X**			ND
2010	Dusch et al.	UK	C	Relationship between innovation and sustainability			**X**	ND
	Spangenberg et al.	Germany	J	Global/holistic approach; skills, roles and learning			**X**	ND
	Ramani et al.	USA	J	Overview of sustainability issues related to product development systems in the U.S.	**X**		**X**	ND
	Carrillo-Hermosilla et al.	Spain	J	8 key dimensions to characterise ecoinnovation: design, user, services/products and governance.			**X**	ND
	Lewandowska and Kurczewi.	Poland	J	Ecodesign procedure based on ISO 14062, focussing on applications and tools in the early stages of the project	**X**			Multiphase
	Hallstedt et al.	Switzerland	J	Top-down systemic view with development of incentives and systematic control and tools for decision making at all levels	**X**		**X**	ND
2009	Crul et al.	Holland	B	10 steps for integrating sustainability into standard PDP in pilot projects with classic tools	**X**		**X**	Stage-gate
	Hassi et al.	Finland	C	"who" and "what": people and behaviors, to develop a set of techniques suitable for transformational change for sustainability.	**X**		**X**	Multiphase funnel

Appendix 1b. Summary content of the publications and models identified (from 2005 to 2008).

Year	Reference	Country	Pub	Main focus	Levels			PDP
					Micro	Meso	Macro	
2008	Ghazilla et al.	Malaysia	C	Incorporate modified versions of various tools to improve the integration and implementation of ecodesign	**X**			Multiphase
	Vezzoli and Manzini	Italy	B	Information technology to deal with the complexity and amount of data	**X**	**X**		Multiphase
2007	Le Pochat et al.	France	J	Demonstrative methodology for SMEs with support from external experts, bringing expertise	**X**	**X**		Multiphase
	Nowosielski et al.	Poland	J	Generic method of ecodesign in 6 steps, indicating the essential activities and tools for each step	**X**			Multiphase
	Waage	USA	J	Approach for "developing sustainable strategy" to ensure consistency between view, strategies and appropriate tools, and between short and long-term	**X**		**X**	Multiphase
	Tingström	Sweden	T	4 main integration factors: Leadership Team; DfE mindset, DfE tools, PDP.		**X**	**X**	Stage-Gate
2006	Yang and Song	Singapore	C	Integration of methods and lifecycle tools in PDP, focus on flow and data management	**X**			ND
	Ölundh	Sweden	T	Modernising ecodesign with more strategic approach, deployed in the organisation (vertical integration), depending on the existing PDP.		**X**	**X**	Stage-gate
	Donnelly et al.	USA	J	Product based environmental management system with PDCA principle, integration in business and PDP processes through checklist and LCA	**X**	**X**	**X**	Multiphase
	Lofthouse	UK	J	Requirements to develop appropriate tools for industrial designers: guidance, education and information, appropriate content and presentation, easy access	**X**			ND
	Howarth and Hadfield	UK	J	To assess product sustainability aspects, along with manufacturing aspects, considers 13 types of interested stakeholders interacting with the designer	**X**		**X**	ND
2005	Berchicci and Bodewes	Holland	J	3 factors to integrate the environmental dimension in PDP: product design specifications and trade off; coordinating multi-functional teams, management support		**X**		ND
	Jeganova	Sweden	C	Systemic integration approaches at each PDP stage, with high or low priority level; adaptive feedback; everyone's skills and engagement.	**X**	**X**		Stage-gate
	Hermenau et al.	Germany	C	Strategic planning; PDP (requirements and flows); dedicated people; adaptation of tools, creation of information base, supply chain integration		**X**	**X**	ND
	Kara et al.	Australia	C	3 levels: strategy; tactic; operations. 5 key points: environmental goals and top-down approach, performance based on LCA; early stages; simple bottom up practical application	**X**	**X**	**X**	ND
	Ammenberg and Sundinb	Sweden	J	Product-oriented Environmental Management System (POEMS), type of PDCA cycle; connects environmental considerations in PDP and in business management system	**X**	**X**		ND

Appendix 1c. Summary content of the publications and models identified (from 1993 to 2004).

Year	Reference	Country	Pub	Main focus	Levels			PDP
					Micro	Meso	Macro	
2004	Bhamra	UK	C	5 main factors: initial and maintained motivation; communication and information flow; holistic thinking; practical ecodesign, global positioning	X	X		Multiphase funnel
2004	Alakeson and Sherwin	UK	B	8 recommendations to create a sustainable innovation system considering broader external interactions, and internal culture (leadership, values, people). 4 integration stages		X	X	ND
2004	Dewulf and Duflou	Belgium	B	Integration in 3 levels (project, company, industry); PDCA approach at each level	X	X	X	Multiphase
2004	ABNT (ISO TR 14062)	Brazil	S	Indicators for ecodesign integration in PDP and design (2 levels assimilated) in a progressive way, top down or bottom up	X	X		Multiphase
2002	Baumann et al.	Sweden	J	4 levels: PDP; company; supply chain; society. Promotes systemic perspective, multilevel and less focus on tools	X	X	X	Multiphase
2002	Van Hemel and Cramer	Holland	J	Importance of social and economic factors to integrate in SMEs (barriers and stimuli) and internal motivation			X	ND
2002	Robert et al.	Sweden	J	Systemic and strategic approach to sustainable development in organisations, split into 5 levels	X	X	X	ND
2001	Handfield et al.	USA	C	Roadmap with 7 steps linking global corporate strategy with goals, PDP tools and monitoring	X	X	X	Multiphase
2001	Stevels	Holland	C	An integration process with 3 levels (strategy, development and tools), evolving to internal and external multistakeholder approach		X	X	ND
2001	Neal and Heintz	USA	C	Business model based on expert system and internal knowledge	X			ND
2001	Sherwin and Bhamra	UK	J	Integration in PDP in the early stages, with “Top down” approach and not “bottom up” as previously recommended (PROMISE)		X		Multiphase
2001	Jones et al.	UK	J	2 ecoinnovation tools for generating ideas at the beginning of PDP	X			Multiphase
2000	Simon et al.	UK	J	“ARPI framework”: 4 steps (Analyse, Report, Prioritise, Improve), similar to PDCA, for ecodesign practice at strategic and operational level.	X		X	ND
2000	Ritzén	Sweden	T	Cyclical implementation: set goals, develop knowledge, adapt resources, tying at all levels, focussing on individuals	X	X	X	Stage-Gate
1998	Van Hemel	Holland	T	In SMEs, identified factors related to DFE performance: B to B, owner's support, external support, innovation capacity and internal organisation	X	X	X	ND
1996	Poyner and Simon	UK	C	DFE tools integrated into PDP, with guidelines for each project stage and gate	X	X		Stage-Gate
1993	Fiksel	USA	C	DFE as a convergence of integration processes in the company (simultaneous engineering) and sustainability. Requires: metrics, guidelines and verification methods, with system-oriented development.	X	X		ND

References

ABNT – Associação Brasileira de Normas Técnicas – ISO/TR 14062, 2004. Gestão Ambiental – Integração de Aspectos Ambientais no Projeto e Desenvolvimento do Produto (Environmental Management- Integration of Environmental Aspects into Product Project and Development) (Brasília).

Alakeson, V., Sherwin, C., 2004. Innovation for Sustainable Development (A Forum of the Future report, London).

Ammenberg, J., Sundin, E., 2005. Products in environmental management systems: drivers, barriers and experiences. J. Clean. Prod. 13 (4), 405–415.

Arana-Landin, G., Heras-Saizarbitoria, I., 2011. Paving the way for the ISO 14006 ecodesign standard: an exploratory study in Spanish companies. J. Clean. Prod. 19 (9–10), 1007–1015.

Arnold, M.G., Hockert, K., 2011. The greening Dutchman: Philips' process of green flagging to drive sustainable innovations. Bus. Strategy Environ. 20 (6), 394–407.

Baumann, H., Boons, F., Bragd, A., 2002. Mapping the green product development field: engineering, policy and business perspectives. J. Clean. Prod. 10 (5), 409–425.

Berchicci, L., Bodewes, W., 2005. Bridging environmental issues with new product development. Bus. Strategy Environ. 14 (5), 272–285.

Bhamra, T., Evans, S., Mcaloone, T., Simon, M., Poole, S., Sweatman, A., 1999. Integrating Environmental Decisions into the Product Development Process. Part I the Early Stages. Presented at Ecodesign '99.

Bhamra, T., Lofthouse, V., 2007. Design for Sustainability: a Practical Approach. Design for Social Responsibility Series, Gower, UK.

Bhamra, T.A., 2004. Ecodesign: the search for new strategies in product development. Proceedings of the institution of mechanical engineers, part B: engineering manufacture. J. Eng. Manuf. 218 (5), 557–569.

Boks, C., 2006. The soft side of ecodesign. J. Clean. Prod. 14 (15–16), 1346–1356.

Boks, C., Mcaloone, T., 2009. Transitions in sustainable product design research. Int. J. Prod. Dev. 9 (4), 429–448.

Bovea, M.D., Pérez-Belis, V., 2012. A taxonomy of ecodesign tools for integrating environmental requirements into the product design process. J. Clean. Prod. 20 (1), 61–71.

Brezet, H., Van Hemel, C., 1997. United Nations Environment Programme. Industry and Environment (Paris), Rathenau Instituut (The Hague), Delft University of Technology (Delft). Ecodesign: a Promising Approach to Sustainable Production and Consumption. UNEP.

Brones, F.A., Carvalho, M.M., Zancul, E.S., 2014. Ecodesign in project management: a missing link for the integration of sustainability in product development? J. Clean. Prod. 80, 106–118. http://dx.doi.org/10.1016/j.jclepro.2014.05.088.

Bucci, Z.D., Ta, L., Forcellini, F., 2012. Product – packaging development process: a proposal oriented to sustainability. Sustainable Innovation Conference, Bonn.

Byggeth, S., Hochschorner, E., 2006. Handling trade-offs in ecodesign tools for sustainable product development and procurement.gue process in product development. J. Clean. Prod. 14 (15–16), 1420–1430.

Carnevalli, J., Cauchick, P., 2008. Review, analysis and classification of the literature on QFD—types of research, difficulties and benefits. Int. J. Prod. Econ. 114 (2), 737–754.

Carrillo-Hermosilla, J., Del Río, P., Könnölä, T., 2010. Diversity of eco-innovations: reflections from selected case studies. J. Clean. Prod. 18 (10–11), 1073–1083.

Carvalho, M.M., Fleury, A., Lopes, A.P., 2013. An overview of the literature on technology road mapping (TRM): contributions and trends. Technol. Forecast. Soc. Change 80 (7), 1418–1437.

Clark, K.B., Wheelwright, S.C., 1993. Managing New Product and Process Development: Text and Cases. The Free Press, New York.

Cooper, R.G., Edgett, S.J., Kleinschmidt, E.J., 2002. Optimizing the stage-gate process: what best practice companies do. Res. Technol. Manag. 45 (5), 21–27.

Crossan, M.M., Apaydin, M., 2010. A multi-dimensional framework of organizational innovation: a systematic review of the literature. J. Manag. Stud. 47 (6), 1154–1191.
Crul, M.R.M., Diehl, J.C., Ryan, C. (Eds.), 2009. Design for Sustainability – a Step-by-step Approach. UNEP, Paris.
De Caluwe, N., 2004. Business benefits from applied ecodesign. IEEE Trans. Electron. Packag. Manuf. 27 (4), 215–220.
Deutz, P., Mcguire, M., Neighbour, G., 2013. Eco-design practice in the context of a structured design process: an interdisciplinary empirical study of UK manufacturers. J. Clean. Prod. 39 (1), 117–128.
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. Elsevier Science BV, Netherlands, pp. 55–76.
Donnelly, K., Beckett-Furnell, Z., Siegfried Traeger, S., Okrasinski, T., Holman, S., 2006. Eco-design implemented through a product-based environmental management system. J. Clean. Prod. 14 (15–16), 1357–1367.
Dusch, B., Crilly, N., Moultrie, J., 2010. Developing a framework for mapping sustainable design activities. Design & Complexity. DRS 2010. Design Research Society International Conference. Montreal, Canada, pp. 7–9.
Ferrer, J., Negnya, S., Roblesb, G., Le Lanna, J.M., 2012. Eco-innovative design method for process engineering. Comput. Chem. Eng. 45, 137–151.
Fiksel, J., 1993. Design for environment: an integrated systems approach. Proceedings of the 1993 IEEE International Symposium on Electronics and the Environment.
Fink, A., 1995. How to Sample in Surveys. Sage Publications, London.
Ghazilla, R., Taha, Z., Sakundarini, N., 2008. Eco design tools in product development: review and direction. Proceedings of the 9th Asia Pasific Industrial Engineering & Management Systems Conference, APIEMS.
Goffin, K., 2012. Sustainability and new product development. In: Cranfield on Corporate Sustainability, pp. 105–118. Chapter 6.
Goffin, R., Mitchell, R., 2010. Innovation Management. Strategy and Implementation Using the Pentathlon Framework. Palgraave Macmillan, Basingstoke.
Guelere Filho, A., 2009. Integração do Ecodesign ao Modelo Unificado para a Gestão do Processo de Desenvolvimento de Produtos: estudo de caso em uma grande empresa de linha branca (Ecodesign Integration to the Unified Model for Product Development Process Management: a Case Study in a Large Company of White Line Appliances). Universidade de São Paulo, São Carlos. PhD thesis.
Guelere Filho, A., Rozenfeld, H., Pigosso, D.C.A., Ometto, A.R., 2007. Improving environmental performance of products by integrating ecodesign methods and tools into a reference model for new product development. In: Concurrent Engineering 2007, São José Dos Campos.
Hallstedt, S., Ny, H., Robert, K.-H., Broman, G., 2010. An approach to assessing sustainability integration in strategic decision systems for product development. J. Clean. Prod. 18 (8), 703–712.
Handfield, R., Melnyk, S., Calantone, R., Curkovic, S., 2001. Integrating environmental concerns into the design process: the gap between theory and practice. IEEE Trans. Eng. Manag. 48 (2), 189–208.
Hart, S., 1995. A natural-resource-based view of the firm. Acad. Manag. Rev. 20 (4), 986–1014.
Hart, S., Dowell, G., 2010. A natural-resource-based view of the firm: fifteen years after. J. Manag. 37 (6), 1464–1479.
Hassi, L., Peck, D., Dewulf, K., Wever, R., 2009. Sustainable innovation – organization and goal finding. R. Conference Proceedings Joint Actions on Climate Change.
Hermenau, U., Hansen, S., Abele, E., 2005. Integration of Life Cycle Design in Industrial Practice: Problems and Solutions. IEEE.
Howarth, G., Hadfield, M., 2006. A sustainable product design model. Mater. Des. 27 (10), 1128–1133.
Hübner, R., 2012. Ecodesign: reach, limits and challenges 20 years of ecodesign – time for a critical reflection. Forum Ware Int. 1, 25.
International Standard, 2002. ISO TR 14062:2002, Environmental Management – Integrating Environmental Aspects into Product Design and Development. ISO, Geneva. Technical Report.
ISO 14006 International Standard, 2011. Environmental Management Systems – Guidelines for Incorporating Ecodesign (Geneva).
Jeganova, J., 2005. Product Life Cycle Design – a Model of Integrating Environmental Aspects into Product Design and Development Process at a Swedish Industry: Adaptive Feedback Approach. IEEE.
Jensen, A., Remmen, A., 2006. Life Cycle Management – a Bridge to More Sustainable Products. UNEP (in Collaboration with the Society for the Environmental Sustainability (SETAC)), Paris.
Johansson, G., 2002. Success factors for integration of ecodesign in product development e a review of state-of-the-art. Environ. Manag. Health 13 (1), 98–107.
Johansson, G., Magnusson, T., 2006. Organising for environmental considerations in complex product development projects: implications from introducing a "green" sub-project. J. Clean. Prod. 14 (15–16), 1368–1376.
Jones, E., Harrison, D., Mclaren, J., 2001. Managing creative eco-innovation: structuring outputs from eco-innovation projects. J. Sustain. Prod. Des. 1 (1), 27–39.
Kara, S., Honke, I., Kaebernick, H., 2005. An integrated framework for implementing sustainable product. Fourth International Symposium on Environmentally Conscious Design and Inverse Manufacturing, Eco Design 2005. IEEE.
Karlsson, R., Luttropp, C., 2006. Ecodesign: what's happening? J. Clean. Prod. 14 (15–16), 1291–1298.
Kengpol, A., Boonkanit, P., 2011. The decision support framework for developing ecodesign at conceptual phase based upon ISO/TR 14062. Int. J. Prod. Econ. 131 (1), 4–14.
Keskin, D., Diehl, J.C., Molenaar, N., 2013. Innovation process of new ventures driven by sustainability. J. Clean. Prod. 45 (4), 50–60.
Knight, P., Jenkins, J.O., 2009. Adopting and applying eco-design techniques: a practitioners perspective. J. Clean. Prod. 17 (5), 549–558.
Kurk, F., Eagan, P., 2008. The value of adding design-for-the-environment to pollution prevention assistance options. J. Clean. Prod. 15 (6), 722–726.
Larsson, F., 2007. Managing the New Product Portfolio. Towards an End-to-end Approach. Technical University of Denmark, Copenhagen. Doctoral thesis.
Le Pochat, S., Bertoluci, G., Froelich, D., 2007. Integrating ecodesign by conducting changes in SMEs. J. Clean. Prod. 15 (7), 671–680.
Lewandowska, A., Kurczewski, P., 2010. ISO 14062 in theory and practice – eco-design procedure. Part 1: structure and theory. Int. J. Life Cycle Assess. 15 (8), 769–776.
Lofthouse, V., 2003. Designing for designers-ecodesign tools to inform and inspire. Electronics and the Environment, IEEE International Symposium, pp. 377–382.
Lofthouse, V., 2006. Ecodesign tools for designers: defining the requirements. J. Clean. Prod. 14 (15–16), 1386–1395.
Lofthouse, V., 2004. Investigation into the role of core industrial designers in eco-design projects. Des. Stud. 25 (2), 215–227.
Lofthouse, V.A., Bhamra, T.A., 2001. Making things better – an industrial designer's approach to ecodesign. In: Proceedings of D3 Desire, Designum, Design: 4th European Academy of Design Conference, Aveiro, Portugal, pp. 10–12.
Luttropp, C., Lagerstedt, J., 2006. Ecodesign and the ten golden rules: generic advice for merging environmental aspects into product development. J. Clean. Prod. 14 (15–16), 1396–1408.
Neal, T.L., Heintz, M., 2001. A system for integrating design for environment (DFE) criteria into the new product introduction process. Proceedings of the 2001 International Symposium on Electronics and the Environment.
Nidumolu, R., Prahalad, C.K., Rangaswami, M.R., 2009. Why sustainability is now the key driver of innovation. Harv. Bus. Rev. 87 (9), 56–64.
Nowosielski, R., Spilka, M., Kania, A., 2007. Methodology and tools of ecodesign. J. Achiev. Mater. Manuf. Eng. 23 (1), 91–94.
Ny, H., Hallstedt, S., Robèrt, K.-H., Broman, G., 2008. Introducing templates for sustainable product development: a case study of televisions at the Matsushita Electric Group. J. Ind. Ecol. 12 (4), 600–623+8.
O'Hare, J.A., 2010. Eco-innovation Tools for the Early Stages: an Industry-based Investigation of Tool Customisation and Introduction. University of Bath (PhD thesis).
Ölundh, G., 2006. Modernising Ecodesign – Ecodesign for Innovative Solutions. Royal Institute of Technology, Stockholm. Doctoral thesis.
Ölundh, G., Ritzén, S., 2004. Making an ecodesign choice in project portfolio management. The 2004 IEEE EMS International Engineering. Management Conference. Singapore.
Petala, E., Wever, R., Dutilh, C., Brezet, H., 2010. The role of new product development briefs in implementing sustainability: a case study. J. Eng. Technol. Manag. 27 (3–4), 172–182.
Pigosso, D.C.A., 2012. Ecodesign Maturity Model: a Framework to Support Companies in the Selection and Implementation of Ecodesign Practices. Doctoral thesis. EESC USP, São Carlos.
Pigosso, D.C.A., Rozenfeld, H., McAloone, T.C., 2013. Ecodesign maturity model: a management framework to support ecodesign implementation into manufacturing companies. J. Clean. Prod. 59, 160–173.
Poyner, J.R., Simon, M., 1996. The continuing integration of the ecodesign tool with product development. Proceedings of the 1996 IEEE International Symposium on Electronics and the Environment.
Prasad, S., Tata, J., 2005. Publications patterns concerning the role of teams/groups in the information systems literature from 1990 to 1999. Inf. Manag. 42 (8), 1137–1148.
Ramani, K., Ramanujan, D., Bernstein, W.Z., Zhao, F., Sutherland, J., Handwerker, C., Choi, J.-K., Kim, H., Thurston, D., 2010. Integrated sustainable life cycle design: a review. J. Mech. Des. 132.
Rio, M., Reyes, T., Roucoules, L., 2013. Toward proactive (eco) design process: modeling information transformations among designers activities. J. Clean. Prod. 39 (1), 105–116.
Ritzén, S., 2000. Integrating Environmental Aspects into Product Development: Proactive Measures. Doctoral thesis. Department of Machine Design, Royal Institute of Technology, Stockholm.
Ritzen, S., Lindahl, M., 2001. Selection and implementation – key activities to successful use of ecodesign tools. In: International Symposium on Environmentally Conscious Design and Inverse Manufacturing, vol. 2. IEEE, Tokyo, Japan.
Robèrt, K.H., Schmidt-Bleek, B., Aloisi De Larderel, J., Basile, G., Jansen, J.L., Kuehr, R., Price Thomas, P., Suzuki, M., Wackernagel, M., 2002. Strategic sustainable development – selection, design and synergies of applied tools. J. Clean. Prod. 10 (3), 197–214.
Rozenfeld, H., et al., 2006. Gestão de Desenvolvimento de Produtos: Uma Referência para a Melhoria do Processo. São Paulo, Saraiva.
Shenhar, A.J., 2001. One size does not fit all projects: exploring classical contingency domains. J. Manag. Sci. 47 (3), 394–414.
Sherwin, C., Bhamra, T., 2001. Early ecodesign integration: experiences from a single case. J. Des. Res. 1 (2), 40–48.

Simon, M., Poole, S., Sweatman, Andrew, Evans, S., Bhamra, T., Mcaloone, T., 2000. Environmental priorities in strategic product development. Bus. Strategy Environ. 9 (6), 367–377.
Spangenberg, J.H., Fuad-Luke, A., Blincoe, K., 2010. Design for sustainability (DfS): the interface of sustainable production and consumption. J. Clean. Prod. 18 (15), 1485–1493.
Stevels, A.L.N., 2007. Adventures in Ecodesign of Electronic Products – 1993–2007. Delft University of Technology, The Netherlands.
Stevels, A.L.N., 2001. Application of ecodesign: ten years of dynamic development. 2nd International Symposium on Environmentally Conscious Design and Inverse Manufacturing (EcoDesign'01). IEEE, p. 905.
Tingström, J., 2007. Product Development with a Focus on Integration of Environmental Aspects (Doctoral thesis).
Tingström, J., Karlsson, R., 2006. The relationship between environmental analyses and the dialogue process in product development. J. Clean. Prod. 14 (15–16), 1409–1419.
Tingström, J., Swanström, L., Karlsson, R., 2006. Sustainability management in product development projects – the ABB experience. J. Clean. Prod. 14 (15–16), 1377–1385.
Tranfield, D., Denyer, D., Smart, P., 2003. Towards a methodology for developing evidence informed management knowledge by means of systematic review. Br. J. Manag. 14 (3), 207–222.
Trappey, A., Ou, J., Lin, G., Chen, M., 2011. An eco- and inno-product design system applying integrated and intelligent QFDE and TRIZ methodology. J. Syst. Sci. Syst. Eng. 20 (4), 443–459.
Van Hemel, C.G., 1998. Ecodesign Empirically Explored. In: Design for Environment in Dutch Small and Medium Sized Enterprises, Design for Sustainability Research Programme. Delft University of Technology, Delft, the Netherlands.
Van Hemel, C., Cramer, J., 2002. Barriers and stimuli for ecodesign in SMEs. J. Clean. Prod. 10 (5), 439–453.
Vandaele, N.J., Decouttere, C.J., 2013. Sustainable R&D portfolio assessment. Decis. Support Syst. 54 (4), 1521–1532.
Verhulst, E., Boks, C., 2012. Bringing about sustainable change in product development: theory versus practice. In: Advances in Production Management Systems. Value Networks: Innovation, Technologies, and Management, vol. 384. IFIP Advances in Information and Communication Technology, pp. 448–457.
Verhulst, E., Boks, C., Masson, H., 2007. The human side of ecodesign from the perspective of change management. Proceedings of the 14th CIRP International Conference on Life Cycle Engineering, Tokyo, Japan, pp. 107–112.
Vezzoli, C., Manzini, E., 2008. Design for Environmental Sustainability. Springer, London.
Vezzoli, C., Sciama, D., 2006. Life cycle design: from general methods to product type specific guidelines and checklists: a method adopted to develop a set of guidelines/checklist handbook for the eco-efficient design of NECTA vending machines. J. Clean. Prod. 14 (15–16), 1319–1325.
Waage, S.A., 2007. Re-considering product design: a practical "road-map" for integration of sustainability issues. J. Clean. Prod. 15 (7), 638–649.
Yang, Q., Song, B., 2006. Eco-design for product lifecycle sustainability. Industrial Informatics, 2006 IEEE International Conference, pp. 548–553.