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Ecodesign field of research throughout the world: mapping the territory by using an evolutionary lens

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Abstract The development of environmentally friendly products is one of the key contemporary trends in the environmental management and planning field of knowledge. Ecodesign is considered a practical mechanism for integrating environmental considerations throughout the life cycle of the product. Within this scope, the aim of this paper is to systematize the publications on ecodesign and to propose the historical evolutionary phases of this area, considering important characteristics such as geographical distribution. To this end, a bibliometric analysis was performed by identifying key papers, authors, and journals that deal with the theme and the history of the number of papers published. Among the results, a recent growth in publications was found, with a wide range of authors conducting research and publishing papers on the subject. The majority of research is conducted in European countries, especially France and Nordic region. Most journals that publish papers on ecodesign are from the environmental field as opposed to those that deal with new product development and innovation and project management. This work also identifies historical research phases; among the most recent, it is possible to notice efforts to link

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ecodesign with other areas of management, such as the fuzzy method, lean product development, and project management.

Keywords Bibliometric analysis · Sustainability · Ecodesign · Green products · Sustainable development · Historical research phases

Introduction

The theme of environmental sustainability has implications for various areas of management such as innovation, product development (Pujari 2006; Brones et al. 2014) and consumption choices (Barr et al. 2011). In addition to generating benefits for different stakeholders (Sarkis et al. 2010), it is widely reported (Fiksel 1996; Brones and Carvalho 2015) that the environmental dimension, when properly integrated into new product development (NPD), provides such benefits as increased resource efficiency (Sanyé-Mengual et al. 2014), improved corporate image (Chen et al. 2012), increased sales and market share, and greater qualification in new technologies (Dangelico et al. 2013). Over the years, research, such as that conducted by Porter and Van der Linde (1995) and Dangelico (2015), has indicated that the development of environmentally sustainable products can offer advantages to companies, positively influencing operational performance (Jabbour et al. 2015), innovation (Hellström 2007), and market performance (González-Benito and González-Benito 2005; Pujari 2006).

It has also been observed that there is a growing amount of research calling attention to the need for companies to incorporate environmental sustainability into their activities regarding NPD (Eppinger 2011; Pigosso et al. 2013; Brones et al. 2014) in an effort to develop environmentally sustainable products. These kinds of products are designed to reduce environmental impact throughout their life cycle (Collado-Ruiz and Ostad-Ahmad-Ghorabi 2012), from the extraction and acquisition of raw materials, reduced consumption of energy and materials, manufacture and use to the final disposal or return of the product to the production company. Jabbour et al. (2015) emphasized that starting from the design phase, the development of these products should consider elements such as the substitution of pollutant materials and components, a reduction in consumption of resources and waste generation during production, use and distribution of the product, as well as aspects such as dismantling, reuse, and recycling.

Based on the theory of NPD (Brones et al. 2014; Dangelico 2015), several studies have highlighted the application of ecodesign as a practical mechanism for integrating environmental considerations during the project with the aim of optimizing the life cycle of the product (Byggeth and Hochschorner 2006; Knight and Jenkins 2009; Bovea and Pérez-Belis 2012; Brones and Carvalho 2015). Despite the importance of ecodesign for good environmental performance and NPD, Poulikidou et al. (2014) noted that its practical implementation is still not widespread among businesses, which suggests the importance of expanding research on ecodesign in order to identify problems and alternatives for researchers and professionals involved in this field.

In the context of environmental management, research into ecodesign intensified in the late 1990s, with the emergence of concepts such as product life-cycle management and life-cycle assessment (Hertwich et al. 1997; Hendrickson et al. 1998 Joshi 1999). Also known as design for environment (Fiksel 1996; Knight and Jenkins 2009), life-cycle design, design for eco-efficiency, green product development, and sustainable design

(Fiksel 1996), ecodesign focuses on the integration of environmental considerations into product development (Karlsson and Luttropp 2006; Poulikidou et al. 2014). Since environmental impacts are a consequence of decisions taken primarily during the design stages in the development of new products, it is seen as important to integrate environmental considerations from the very start of these development projects (Sroufe et al. 2000).

Although there are some theoretical studies on ecodesign (Brones and Carvalho 2015) and systematic reviews on the theme (e.g., Baumann et al. 2002; Diwekar and Shastri 2011; Karlsson and Luttropp 2006; Dangelico 2015), no studies have yet presented a historical evolution of the subject. The precise objective of this paper is to systematize the publications on ecodesign and to trace the evolutionary stages of the area. To achieve this objective, a bibliometric analysis was performed on studies published in scientific, peer-reviewed journals, identifying the papers with the most citations and key authors and journals, as well as the historical number of papers published on the area per year. Bibliometric methods are firmly established as scientific specialties, and the number of publications using the bibliometric analysis as a tool for science studies has been increasing gradually during recent years (Ellegaard and Wallin 2015).

Initially, this study presents the research method employed and the procedures and techniques adopted in the survey of the papers considered in this paper. Subsequently, the results are presented and analyzed, and the historical evolution of ecodesign is proposed. Finally, the conclusions, limitations, and proposals for future research are presented.

Research method

The studies included in this paper were obtained from the Scopus database, which presents rigorous indexing and higher citation counts (Bergman 2012). Scopus was also selected because it is more extensive than others such as the Thomson Reuters ISI Web of Science, which only includes journals indexed in the Journal Citation Reports (JCR). Besides, some recent studies in environmental management and sustainability utilize Scopus as data source (Ferenhof et al. 2014; Goodall et al. 2014; Restall and Conrad 2015). Data were collected throughout the month of May 2015.

Keywords were used as search terms in the database. The following search terms were used: "ecodesign" or "eco-design" or "design for environment" or "sustainable product development" or "green product development" or "green innovation" or "design for sustainability" or "green design." This search was conducted in the "*Article Title, Abstract, Keywords*" search field. After the results, a filter was applied so as to only include papers published in journals and in English. Later, exclusion criteria were defined in order to only include publications aligned to the objective of the research in the final result. The papers were filtered through the reading of the titles and abstracts. In this way, studies with no relation to the research subject were excluded (e.g., studies on the green supply chain or sustainable manufacturing that did not refer directly to the development of new products). An example of an excluded study is that of Murugesan (2008); although this publication is widely cited in Scopus, it does not refer directly to the NPD but rather to the use of environmental practices focused on information technology. Another example of an excluded study is the publication of Zhu and Sarkis (2007), which is relevant in the area of the green supply chain but does not directly address aspects of NPD. Other excluded articles refer to specific technological solutions, such as studies on chemical toxicity in product development (e.g., Stalmans et al. 2002). Duplicate studies and publications with no abstract and/or no indication of the authors were also excluded from this survey.

A statistical analysis of the data followed, which aimed to find: (a) the number of papers on ecodesign by year of publication, (b) the journals with the most papers published on the subject, (c) the authors with the most studies published on the subject, and (d) the most cited papers. To systematize the publications, an analysis of the citation network within the field of ecodesign was also carried out. This type of analysis has been applied successfully in bibliometric studies in other research areas related to sustainability, such as industrial symbiosis (Yu et al. 2013) and nanobiotechnology (Takeda et al. 2009). Based on the cocitations and keyword co-occurrence, we analyzed the core literature as well the main issues in the research field (Nakamura et al. 2011; Iwami et al. 2014). The analysis of the citation network was completed with the support of VOS Viewer software, which is capable of generating cocitation maps, an analysis of keywords based on bibliographic data, and a map co-occurrence of terms based on content titles and abstracts. These phases, conducted for the bibliometric research, are illustrated in Fig. 1.

After the bibliometric analysis of the papers, a historical and conceptual overview of the development of ecodesign was established through qualitative interpretation. By observing and categorizing the most cited and most recent publications obtained from the set of valid papers, the observations related to the integration of environmental aspects into NPD were systematized. Thus, it was possible to explain the state of the art in the field, the latest

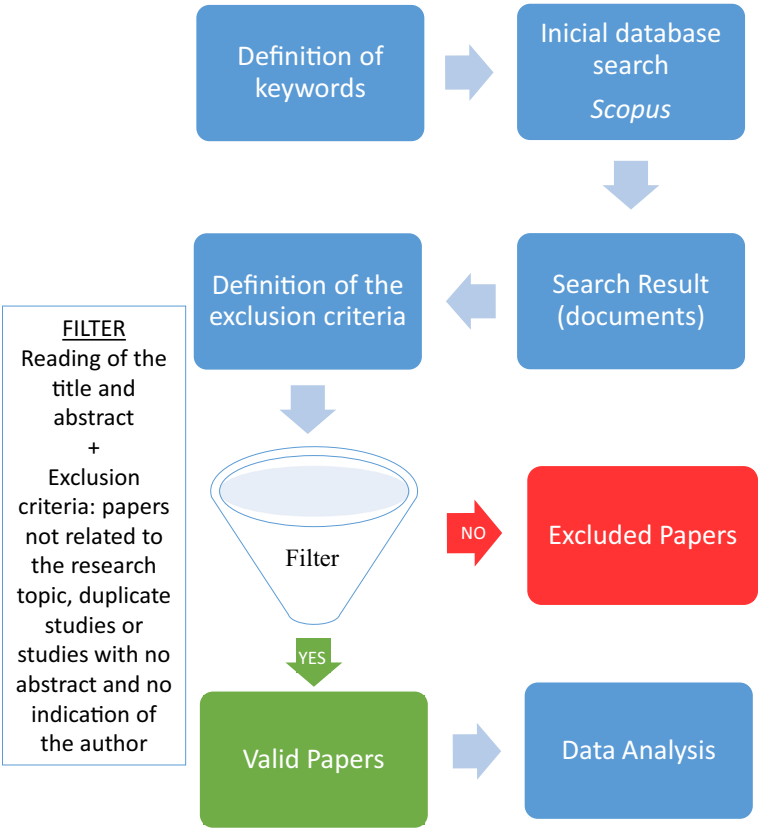

Fig. 1 Bibliometric research phases

themes, and the possible gaps to be filled by future studies. The next section presents the results of this research.

Findings

The initial search of the database, described in the "Research Method" section, resulted in 3315 papers from journals, congress, and other publications (such as book summaries and journals that were not peer reviewed, among others), which was reduced to 1576 papers due to the criterion of analyzing only English-language journals. After applying the other exclusion criteria presented in the previous section, 375 papers were identified as valid for this study.

Considering these 375 identified papers, Fig. 2 shows the number of papers on ecodesign in the Scopus database per year of publication. The average number of papers published until 2009 was 7.8 papers per year, with the number of publications remaining stable. A sharp increase in the number of papers was observed from 2010 onward, with an average number of papers of 38.5 per year. This growth peaked in 2013, which was the year with the most publications (55), followed by 53 in the next year. It is noteworthy that just over a third of the papers were published in the last 3 years (2013–2015), which shows the relevance of current research and increased knowledge on the subject.

From this sample, the authors with the most published papers on ecodesign were identified. The result indicated that about 81 % of the authors published only one paper. Of the 147 identified authors with more than one publication, 11 had five or more papers. These authors and their number of publications are shown in Fig. 3. The author with the most publications in the field was the Chinese author Chan Hing Kai, of the Nottingham University Business School, who has published seven papers.

A list that contains at least 20 of the main authors was drawn up. In addition to the 11 authors present in Fig. 3, the 11 authors with the highest h-index among the four publications were selected, resulting in 22 authors.

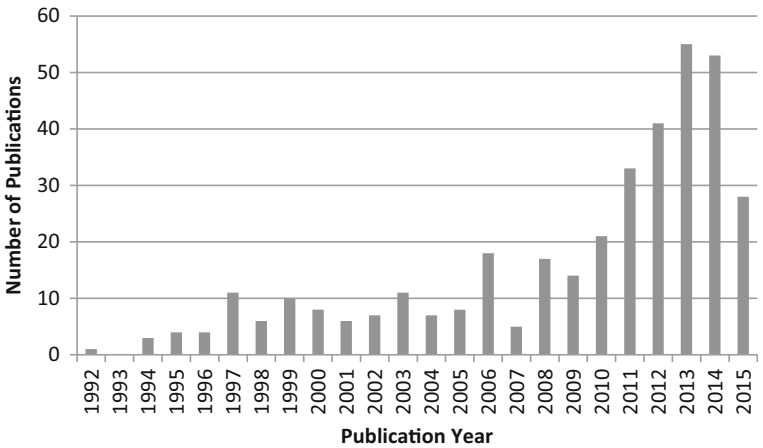

Fig. 2 Number of publications on ecodesign per year

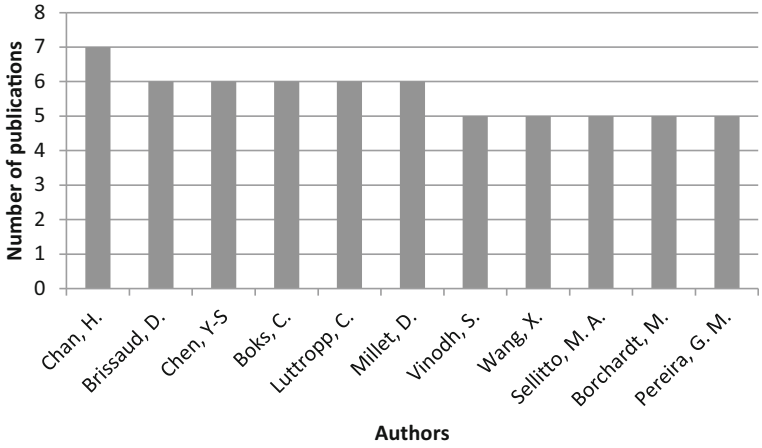

Fig. 3 Authors with the most publications on ecodesign

Figure 4 presents the geographic distribution of research in the field, illustrating the number of publications by the country of origin of the institution. Figure 4 shows that research has been done on all continents, with a concentration of publications in Europe, especially France, the United Kingdom, Italy, and Germany. Outside of Europe, research from the United States, China, Japan, and Brazil are highlighted.

The information regarding number of publications, *h-index*, and institution of the 20 main authors identified are shown in Table 1.

Table 1 shows that most of the authors were concentrated in European countries. France, in particular, stood out with four authors, as well as some Nordic countries, such as Sweden, Norway, and Denmark, which together also had four. In South America, Brazil had three authors on the list.

Regarding the main journals with publications in the field, 155 journals were identified with papers related to the subject. Of these, 52 journals (33.5 %) appeared with more than one published document. These journals contained approximately 72.5 % (272 of 375) of the papers studied. Table 2 shows all the journals with more than three papers published on

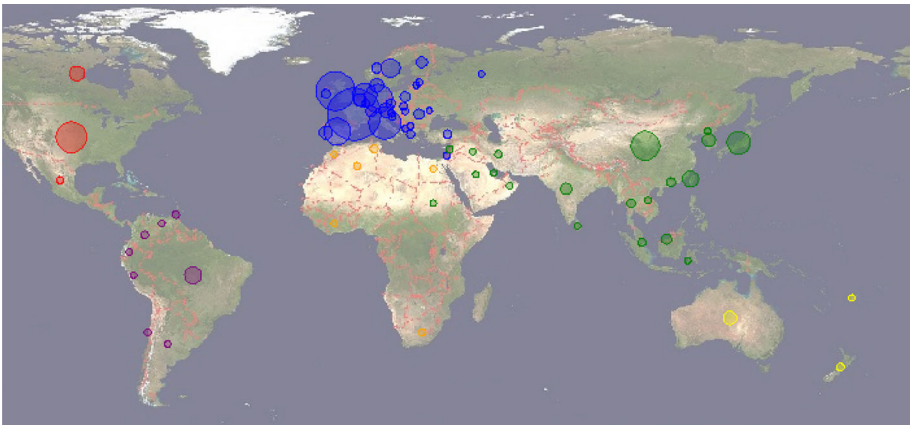

Fig. 4 Geographical distribution of the publications

Table 1 Number of publications, *h-index*, and institution of the main authors

Author	No. of publications	h-index	Institution	Country
Hingkai Chan	7	23	Nottingham University Business School China	China
Casper Boks	6	12	Norges Teknisk-Naturvitenskapelige Universitet	Norway
Daniel Brissaud	6	14	Universite Grenoble Alpes	France
Yu-Shan Chen	6	13	National Taipei University	Taiwan
Conrad Luttropp	6	6	The Royal Institute of Technology	Sweden
Dominique Millet	6	6	Lismma	France
Miriam Borchardt	5	4	Universidade do Vale do Rio dos Sinos	Brazil
Giancarlo Medeiros Pereira	5	4	Universidade do Vale do Rio dos Sinos	Brazil
Miguel Afonso Sellitto	5	5	Universidade do Vale do Rio dos Sinos	Brazil
Sekar Vinodh	5	14	National Institute of Technology Tiruchirappalli	India
Xiaojun Wang	5	8	University of Bristol	England
Joan Rieradevall	4	21	Universitat Autònoma de Barcelona	Spain
Tracy Bhamra	4	8	Loughborough Design School	England
Peggy Zwolinski	4	8	Universite Grenoble Alpes	France
Ching-Hsun Chang	4	7	Tamkang University	Taiwan
Tim McAloone	4	7	Danmarks Tekniske Universitet	Denmark
Glenn Johansson	4	6	Hogskolan i Jonkoping	Sweden
Hideki Kobayashi	4	4	Osaka University	Japan
Carman Lee	4	4	Hong Kong Polytechnic University	China
German Arana-Landin	4	2	Universidad del Pais Vasco	Spain
Lucie Domingo	4	2	Universite Grenoble Alpes	France
Gopinath Rathod	4	2	Basaveshwar Engineering College	India

Table 2 Journals with publications on ecodesign

Source	Number of published articles
Journal of Cleaner Production	71
Journal of Industrial Ecology	15
Int. Journal of Life Cycle Assessment	11
Business Strategy and the Environment	5
Design Studies	5
Clean Technologies and Environmental Policy	4
Industry and Environment	4
Int. Journal of Product Development	4
Int. Journal of Sustainable Engineering	4
Journal of Business Ethics	4
Journal of Engineering Design	4
Proceedings of the IME, Part B: Journal of Engineering Manufacture	4

the subject. The *Journal of Cleaner Production*, *Journal of Industrial Ecology*, and *International Journal of Life Cycle Assessment* appeared significantly more often than the others, with 16 papers on the list (approximately 31 %).

The analysis of the studies by their academic impact, measured by the number of citations, follows. Of the 375 valid papers, 267 documents were cited in at least one publication. Table 3 shows the 40 most cited papers. This set of papers accounts for about 63 % of the total citations (3623 of 5763).

Of these publications listed in Table 3, 18 (45 %) refer to theoretical studies. The large number of theoretical studies among the most cited papers was the expected result, since these papers are based on various later studies of empirical nature, whether qualitative or quantitative. Twelve papers with a quantitative approach were identified, among surveys and studies with mathematical modeling. The 10 remaining papers were qualitative in nature, involving case studies or action research.

To verify the core articles, an analysis of the cocitations was performed. Figure 5 shows the map of cocitations for the set of identified items.

The articles shown in more than one cluster in Fig. 5 (Baumann et al. 2002; Byggeth and Hochschorner 2006; Knight and Jenkins 2009) are the most frequently cited and present different themes in ecodesign (for example: theoretical review and ecodesign tools in the same article). Therefore, the presence of these publications is central in the cocitation map. Figure 6 shows the results of keyword co-occurrence.

Figure 6 shows that terms including product, recycling, and energy are relevant in the context of research in ecodesign. Figure 7 presents the occurrence of similar terms in the titles and abstracts of the articles identified. Figure 7 shows that terms such as life cycle assessment, energy, recycling, and regulation are highlighted in publications about ecodesign.

Analysis of the results

Figure 2 shows an upward trend in publications on ecodesign, with particular concentration in the last 3 years. The analysis also demonstrates that research on ecodesign is quite decentralized in terms of authors. For example, the main author identified had only seven papers, and 81 % of the authors identified had only one publication on the subject.

The analysis of the journals highlighted a predominance of publications in journals from environmental fields such as *Journal of Cleaner Production*, *Journal of Industrial Ecology*, *International Journal of Life Cycle Assessment*, and *Business Strategy and the Environment*. At the same time, it was found that there is little research on ecodesign published in journals from the fields of innovation and new product development.

The analysis of articles from each cluster presented in the analysis of keyword co-occurrence (Fig. 6) resulted in the identification of the main issues related to the research about ecodesign. In addition to issues directly related to ecodesign, such as product design and product development, other terms related to the NPD with environmental concerns also proved to be important, such as: sustainable development and environmental issues, environmental regulation and industry regulations, and construction and architecture. In analyzing Fig. 7, it is possible to note the occurrence of terms with a management focus and those that relate to technical aspects (especially related to construction) and environmental aspects (energy, resource use, emissions) of the NPD. It was also observed that an important research relationship exists between ecodesign with the life cycle assessment method, and the themes of environmental legislation and industry regulation.

Table 3 Most cited papers on ecodesign

References	No. of citations	Approach
Hendrickson et al. (1998)	328	Quantitative
Joshi (1999)	208	Theoretical
Baumann et al. (2002)	173	Theoretical/Bibliometric
Luttropp and Lagerstedt (2006)	154	Theoretical
Maxwell and Van der Vorst (2003)	150	Theoretical
Manzini and Vezzoli (2003)	145	Qualitative
Chen et al. (2006)	142	Quantitative
Chen (2001)	126	Quantitative
Van Hemel and Cramer (2002)	118	Quantitative
Ljungberg (2007)	99	Theoretical
Pujari (2006)	97	Quantitative
Handfield et al. (2001)	96	Qualitative
Knight and Jenkins (2009)	91	Qualitative (case study)
Chen (2008)	91	Quantitative (survey)
Byggeth and Hochschorner (2006)	90	Theoretical
Kaebernick et al. (2003)	90	Theoretical
Hertwich et al. (1997)	89	Theoretical (comparison of methods)
Karlsson and Luttropp (2006)	86	Theoretical
Nielsen and Wenzel (2002)	80	Theoretical
Lofthouse (2006)	73	Qualitative
Albino et al. (2009)	72	Quantitative
Boks (2006)	71	Qualitative (interview)
Klöpffer (2003)	71	Theoretical
Sroufe et al. (2000)	70	Qualitative (case studies)
Gottberg et al. (2006)	60	Qualitative (case studies)
Hur et al. (2005)	60	Theoretical (comparison of methods/quantitative)
Calcott and Walls (2000)	58	Quantitative (mathematical modeling)
Pujari et al. (2004)	57	Quantitative (survey)
Lindahl (2006)	55	Qualitative (interview)
Hauschild et al. (2004)	55	Theoretical
Kobayashi (2006)	51	Theoretical
Ammenberg and Sundin (2005)	50	Theoretical
Pigosso et al. (2010)	49	Theoretical (systematic review)
Bovea and Pérez-Belis (2012)	47	Theoretical (review of tools)
Le Pochat et al. (2007)	47	Qualitative
Calcott and Walls (2005)	46	Quantitative (modeling)
Chiou et al. (2011)	45	Quantitative (survey)
Donnelly et al. (2006)	45	Qualitative (case study)
Zhu and Deshmukh (2003)	44	Quantitative
Brezet (1997)	44	Theoretical

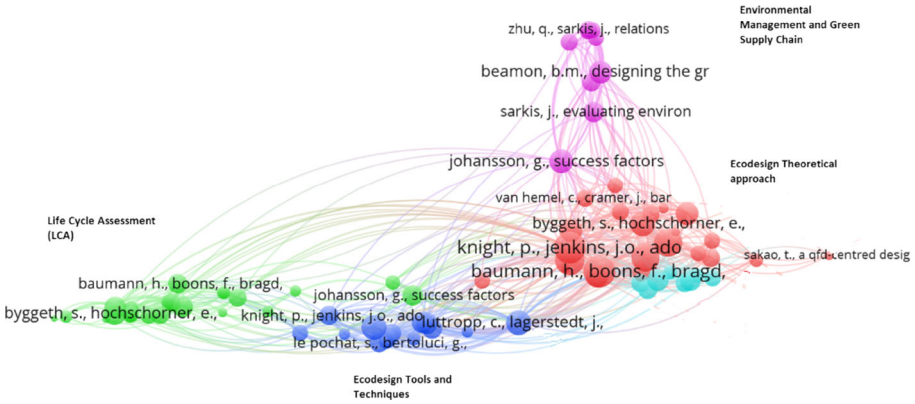

Fig. 5 Network of core literature in ecodesign by cocitation analysis

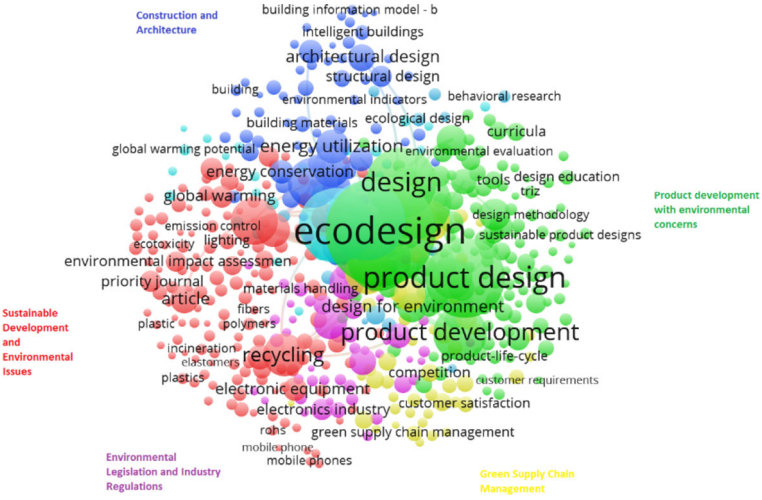

Fig. 6 Keywords co-occurence map with clusterization

It was observed that studies on ecodesign intensified in the late 1990s, with the life-cycle management of products, the introduction of life-cycle assessment expertise, and with analyses on the environmental impact of the product at each stage of the cycle (Hendrickson et al. 1998; Hertwich et al. 1997; Joshi 1999). At the same time, knowledge on ecodesign became more widely shared, with greater intensity, in order to explore environmental issues in NPD (Brezet 1997; Sroufe et al. 2000). During this period, the volume of ecodesign studies also intensified, leading to green product development being considered an important research topic in the environmental field (Boks and Mcaloone 2009).

From the 2000s onward, the delineation of ecodesign as a field of study and organizational practice began (Baumann et al. 2002; Diwekar and Shastri 2011; Karlsson and Luttropp 2006). At the same time, the political and strategic issues related to green product development (Chen 2001; Manzini and Vezzoli 2003) and product management in the context of environmental management systems—ISO 14000 (Ammenberg and Sundin

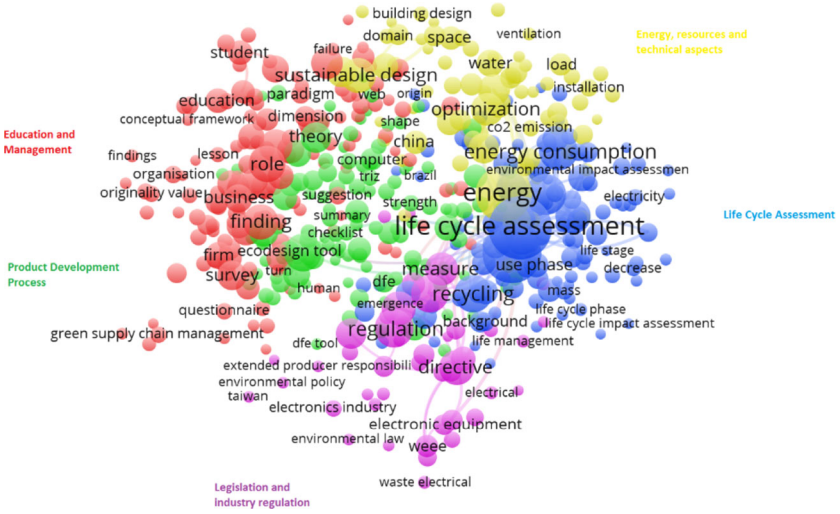

Fig. 7 Map of co-ocurrence of terms in title or abstract

2005; Lewandowska and Matuszak-Flejszman 2014) also began to show greater relevance in scientific studies.

Alongside the development of ecodesign as a field of study were efforts to integrate it with the theory of NPD (Handfield et al. 2001; Luttropp and Lagerstedt 2006; Maxwell and Van der Vorst 2003; Nielsen and Wenzel 2002; Poulikidou et al. 2014; Dangelico 2015). From the NPD standpoint, in addition to traditional environmental considerations in the selection of materials (Angel and Rock 2005) and resource consumption throughout the product life cycle, such as reuse, remanufacturing, and recycling Ljungberg 2007; Lu et al. 2011), the research has advanced toward studying and proposing the adoption of specific ecodesign methods and tools (Byggeth and Hochschorner 2006; Knight and Jenkins 2009) as a means to overcome the tradeoffs that many companies face between the development of environmentally sustainable products, their production costs, final prices, features that the product can perform, and their environmental impact (Luchs et al. 2012). Among these methods and tools can be cited the environmental-quality function deployment (EQFD), analysis of the product life cycle, environmental failure mode effects analysis (E-FMEA), ecodesign checklist, and eco-ideas mapping, among others (Byggeth and Hochschorner 2006; Knight and Jenkins 2009; Puglieria et al. 2011; Bovea and Pérez-Belis 2012; Pigosso et al. 2013).

The main barriers and incentives to ecodesign have also been the subject of studies (Poulikidou et al. 2014). Among the incentives presented, the positive impact of the adoption of environmental strategies, such as eco-efficiency and environmental management systems (e.g., ISO14001), is noteworthy. Other studies also highlighted the opportunities for innovation and potential market opportunities (Van Hemel and Cramer 2002) and the increased product quality (Van Hemel and Cramer 2002; Dangelico 2015) that the ecodesign can provide. Among its barriers to implementation include the greater complexity associated with these product designs, which may require more development time, the greater need for information in the project planning stage, and the greater uncertainty of results (Collado-Ruiz and Ostad-Ahmad-Ghorabi 2012).

In recent years, the propositions of maturity models specific to ecodesign have stood out (Pigosso et al. 2013), as has the expansion of environmental considerations to include the whole process of innovation rather than only specific steps of NPD, known as *green innovation* (Chang 2011; Chen et al. 2012; Chen 2012; Chiou et al. 2011; Cuerva et al. 2014; Pujari 2006). Dangelico and Pujari (2010) also proposed guidelines for ecodesign such as a tool related to design in the context of green product innovation.

The ecodesign maturity model proposed by Pigosso et al. (2013) aims to assist in the process of implementation and continuous improvement of ecodesign through three dimensions: (1) eco-design practices (a set of practices related to ecodesign management, technical aspects of product design, and associated techniques and tools), (2) maturity levels (a set of successive stages for the incorporation of environmental issues into NPD), and (3) application method (a continuous improvement approach to support the implementation and management of ecodesign). In this model, the practices were classified in levels of evolution and capability (how well the practice is applied). Thus, the maturity levels are seen as a combination of the levels of evolution and of capability.

Regarding the latest research on ecodesign, a concern with integrating environmental sustainability into project management can also be observed (Silvius and Schipper 2014; Sánchez 2015; Marcelino-Sábada et al. 2015). In this sense, Sánchez (2015) proposed a framework for integrating environmental issues into project management. Marcelino-Sábada et al. (2015) emphasized that despite not being included in the three main dimensions of project management (cost, scope, and schedule), the ethical aspect has grown in importance among organizations and stakeholders, which tends to lead to the inclusion of ecodesign in project management. Another factor that reinforces this trend is the fifth edition of the Project Management Body of Knowledge (PMBOK), which included stakeholder management as one of its areas of expertise (PMI 2012), which can create more pressure for the inclusion of environmental aspects in project development.

It was observed that most current studies also draw attention to the contribution methods of project management for integration of environmental sustainability into NPD (Brones et al. 2014), the design of sustainable product-service systems (Armstrong et al. 2014; Manzini and Vezzoli 2003; Vezzoli et al. 2015), the fuzzy methodology applied to ecodesign (Alblas et al. 2014; Chan et al. 2013; Herva et al. 2012; Kai et al. 2014; Vinodh and Rathod 2012; Wang et al. 2015), the integration of axiomatic design theory into ecodesign (Beng and Omar 2014; Kim et al. 2014), and the relationship between "lean" product development and "green" product development (Johansson and Sundin 2014). Similarly, other studies highlighted the scarcity of studies that examine the relationship between the use of practices aimed at ecodesign and product portfolio performance (Brones and Carvalho 2015; Brook and Pagnanelli 2014; Dangelico and Pujari 2010; Pigosso et al. 2013). Based on the results presented in this topic, Fig. 8 aims to illustrate the synthesis of the evolution of knowledge in ecodesign.

In recent years, discussion has also been raised on the potential synergies between the approaches of lean production and ecodesign. The premise is that the lean approach is aimed at reducing waste, which would lead to a better performance both environmentally and regarding NPD (Johansson and Sundin 2014; Fahimnia et al. 2015). In this sense, Johansson and Sundin (2014) recommended the extension of studies that address lean concepts in an integrated manner with those present in areas of environmental management such as ecodesign.

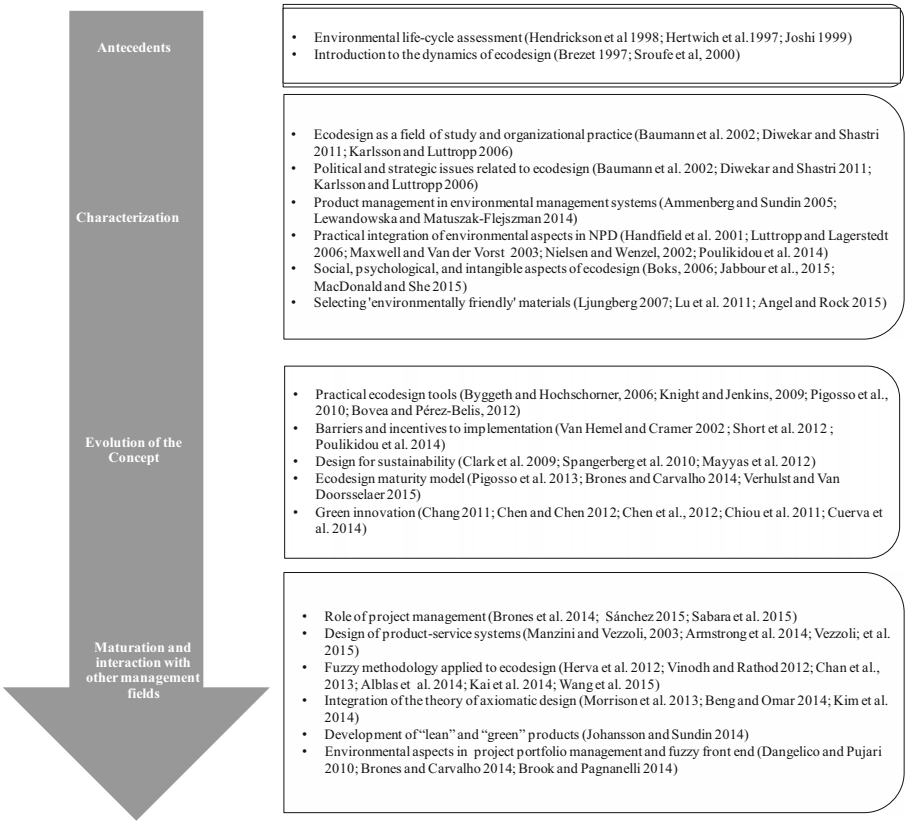

Fig. 8 Ecodesign evolution phases

Conclusions

The objective of this study was to present the evolution of research into ecodesign in order to explore the key studies of the last 20 years. The mapping of these publications, by creating a database and performing a statistical analysis, enabled the identification of the main authors and journals on the subject in addition to the delineation of the trend toward growth of such publications. The papers from the bibliometric research were systematized in order to propose a state-of-the-art history of knowledge.

Regarding the bibliometric research, the main results were an indication of the trend toward ecodesign growth in terms of the number of studies and the difficulty of listing the main authors, since literature on the subject is dispersed among many researchers. Among the major journals, those in the environmental field were highlighted, especially the *Journal of Cleaner Production*, the *Journal of Industrial Ecology*, and the *International Journal of Life Cycle Assessment*. On the other hand, there are few publications about ecodesign in journals in the areas of new product development and innovation and project management. The majority of research is conducted in European countries, especially France and Nordic region.

From the reading and interpretation of the papers identified in this study, phases of research on ecodesign can be highlighted (i.e., a proposal of an evolutionary itinerary). The

first, until the beginning of the 2000s, established the main concepts of ecodesign and the application of life-cycle assessment as a method of ecodesign support. From 2001 to 2010, environmental product development and ecodesign were established as a field of study and practice, and research turned to studies on strategic and organizational implications. The third phase, from 2010 to 2013, was marked by the expansion of the concept of ecodesign, with the inclusion of the social dimension resulting in the design for sustainability and with extrapolation out of NPD introducing concepts of green innovation and maturity models. This phase also covered studies on the tools and practices applied in ecodesign and the identification of the main barriers and incentives for their adoption. The last phase extended from 2013 to the present.

Ecodesign is currently a mature area of research. At the same time that its concepts and tools are being established, there is a trend of growth in research aimed at quantitative approaches, like the fuzzy method, and joint exploration with other areas such as lean product development, project management, and the relationship with the issue of project and product portfolios. Future studies could rely on quantitative methods and focus on ecodesign's interaction with portfolio management, product-portfolio management performance, and NPD performance.

The findings of this study must be understood in accordance with the limitations of its method. The search for papers was limited to the Scopus database, which does not contain many papers that are indexed in other databases. The Google Scholar database, for example, is more extensive (with more sources indexed) than Scopus. The use of the search terms chosen also restricted the resulting papers. The study was limited to papers from journals with a greater academic impact. The subjectivity in the filter of the valid papers must also be taken into account, even if establishing clear criteria for exclusion. Another limitation of this study is the categorization and delineation of a historical evolution of the subject based on the interpretation of the authors. Because it is a set of overlapping knowledge, its phases intersect with each other and are not restricted to the period considered. Despite starting or focusing on a specific period, many ecodesign concepts continued to be studied in later phases. It is recommended that future studies replicate the bibliometric research in other, more extensive databases such as Google scholar.

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References

Albino, V., Balice, A., & Dangelico, R. M. (2009). Environmental strategies and green product development: An overview on sustainability-driven companies. *Business Strategy and the Environment, 18*(2), 83–96. doi:10.1002/bse.638.

Alblas, A. A., Peters, K., & Wortmann, J. C. H. (2014). Fuzzy sustainability incentives in new product development: An empirical exploration of sustainability challenges in manufacturing companies. *International Journal of Operations & Production Management, 34*(4), 513–545. doi:10.1108/IJOPM-10-2012-0461.

Ammenberg, J., & Sundin, E. (2005). Products in environmental management systems: Drivers, barriers and experiences. *Journal of Cleaner Production, 1*(4), 405–415. doi:10.1016/j.jclepro.2003.12.005.

Angel, D. P., & Rock, M. T. (2005). Global standards and the environmental performance of industry. *Environment and Planning A., 37*(11), 1903–1918. doi:10.1068/a3788.

Armstrong, C. M., Niinimäki, K., Kujala, S., Karell, E., & Lang, C. (2014). Sustainable product-service systems for clothing: Exploring consumer perceptions of consumption alternatives in Finland. *Journal of Cleaner Production, 97*(15), 30–39. doi:10.1016/j.jclepro.2014.01.046.

Barr, S., Shaw, G., & Coles, T. (2011). Sustainable lifestyles: Sites, practices, and policy. *Environment and Planning A, 43*(12), 3011–3029. doi:10.1068/a43529.

Baumann, H., Boons, F., & Bragd, A. (2002). Mapping the green product development field: Engineering, policy and business perspectives. *Journal of Cleaner Production, 10*(5), 409–425. doi:10.1016/S0959-6526(02)00015-X.

Beng, L. G., & Omar, B. (2014). Integrating axiomatic design principles into sustainable product development. *International Journal of Precision Engineering and Manufacturing-Green Technology, 1*(2), 107–117. doi:10.1007/s40684-014-0015-2.

Bergman, L. E. M. (2012). Finding citations to social work literature: The relative benefits of using Web of Science, Scopus, or Google Scholar. *Journal of Academic Librarianship, 38*(6), 370–379.

Boks, C. (2006). The soft side of ecodesign. *Journal of Cleaner Production, 14*(15–16), 1346–1356. doi:10.1016/j.jclepro.2005.11.015.

Boks, C., & McAloone, T. C. (2009). Transitions in sustainable product design research. *International Journal of Product Development, 9*(4), 429–449. doi:10.1504/IJPD.2009.027475.

Bovea, M. D., & Pérez-Belis, V. (2012). A taxonomy of ecodesign tools for integrating environmental requirements into the product design process. *Journal of Cleaner Production, 20*(1), 61–71. doi:10.1016/j.jclepro.2011.07.012.

Brezet, H. (1997). Dynamics in ecodesign practice. *Industry and Environment, 20*(1–2), 21–24.

Brones, F., & Carvalho, M. M. (2015). From 50 to 1: Integrating literature toward a systemic ecodesign model. *Journal of Cleaner Production, 96*(1), 44–57. doi:10.1016/j.jclepro.2014.07.036.

Brones, F., Carvalho, M. M., & Zancul, E. S. (2014). Ecodesign in project management: A missing link for the integration of sustainability in product development? *Journal of Cleaner Production, 80*(October), 106–118. doi:10.1016/j.jclepro.2014.05.088.

Brook, J. W., & Pagnanelli, F. (2014). Integrating sustainability into innovation project portfolio management—A strategic perspective. *Journal of Engineering and Technology Management, 34*, 46–62. doi:10.1016/j.jengtecman.2013.11.004.

Byggeth, S., & Hochschorner, E. (2006). Handling trade-offs in ecodesign tools for sustainable product development and procurement. *Journal of Cleaner Production, 14*(15–16), 1420–1430. doi:10.1016/j.jclepro.2005.03.024.

Calcott, P., & Walls, M. (2000). Can downstream waste disposal policies encourage upstream "design for environment "? *American Economic Review, 90*(2), 233–237. doi:10.1257/aer.90.2.233.

Calcott, P., & Walls, M. (2005). Waste, recycling, and design for environment: Roles for markets and policy instruments. *Resource and Energy Economics, 27*(December), 287–305. doi:10.1016/j.reseneeco.2005.02.001.

Chan, H. K., Wang, X., White, G. R. T., & Yip, N. (2013). An extended fuzzy-AHP approach for the evaluation of green product designs. *IEEE Transactions on Engineering Management, 60*(2), 327–339. doi:10.1109/TEM.2012.2196704.

Chang, C. H. (2011). The influence of corporate environmental ethics on competitive advantage: The mediation role of green innovation. *Journal of Business Ethics, 104*(3), 361–370. doi:10.1007/s10551-011-0914-x.

Chen, C. (2001). Design for the environment: A quality-based model for green product development. *Management Science, 47*(2), 250–263. doi:10.1287/mnsc.47.2.250.9841.

Chen, Y. S. (2008). The driver of green innovation and green image–green core competence. *Journal of Business Ethics, 81*(3), 531–543.

Chen, Y. (2012). The driver and green competence innovation of green green core image. *Journal of Business Ethics, 81*(3), 531–543. doi:10.1007/s10551-007-9522-1.

Chen, Y. S., Lai, S. B., & Wen, C. T. (2006). The influence of green innovation performance on corporate advantage in Taiwan. *Journal of Business Ethics, 67*(4), 331–339. doi:10.1007/s10551-006-9025-5.

Chen, A. Y., Lai, S., Wen, C., Journal, S., Sep, N., & Chen, Y. (2012). The influence of green innovation performance on corporate advantage in Taiwan the influence of green on corporate innovation advantage wen performance in Taiwan. *Journal of Business, 67*(4), 331–339. doi:10.1007/s10551-006-9025-5.

Chiou, T. Y., Chan, H. K., Lettice, F., & Chung, S. H. (2011). The influence of greening the suppliers and green innovation on environmental performance and competitive advantage in Taiwan. *Transportation Research Part E: Logistics and Transportation Review, 47*(6), 822–836. doi:10.1016/j.tre.2011.05.016.

Collado-Ruiz, D., & Ostad-Ahmad-Ghorabi, H. (2012). Estimating environmental behavior without performing a life cycle assessment. *Journal of Industrial Ecology, 17*(1), 31–42. doi:10.1111/j.1530-9290.2012.00510.x.

Cuerva, M. C., Triguero-Cano, Á., & Córcoles, D. (2014). Drivers of green and non-green innovation: Empirical evidence in low-tech SMEs. *Journal of Cleaner Production, 68*(1), 104–113. doi:10.1016/j.jclepro.2013.10.049.

Dangelico, R. M. (2015). Green product innovation: Where we are and where we are going. *Business Strategy and the Environment*. doi:10.1002/bse.1886.

Dangelico, R. M., Pontrandolfo, P., & Pujari, D. (2013). Developing sustainable new products in the textile and upholstered furniture industries: Role of external integrative capabilities. *Journal of Product Innovation Management, 30*(4), 642–658. doi:10.1111/jpim.12013.

Dangelico, R. M., & Pujari, D. (2010). Mainstreaming green product innovation: Why and how companies integrate environmental sustainability. *Journal of Business Ethics, 95*(3), 471–486. doi:10.1007/s10551-010-0434-0.

Diwekar, U., & Shastri, Y. (2011). Design for environment: A state-of-the-art review. *Clean Technologies and Environmental Policy, 13*(2), 227–240. doi:10.1007/s10098-010-0320-6.

Donnelly, K., Beckett-Furnell, Z., Traeger, S., Okrasinski, T., & Holman, S. (2006). Eco-design implemented through a product-based environmental management system. *Journal of Cleaner Production, 14*(15–16), 1357–1367. doi:10.1016/j.jclepro.2005.11.029.

Ellegaard, O., & Wallin, J. A. (2015). The bibliometric analysis of scholarly production: How great is the impact? *Scientometrics, 105*(3), 1809–1831. doi:10.1007/s11192-015-1645-z.

Eppinger, S. (2011). The fundamental challenge of product design. *Journal of Product Innovation Management, 28*(3), 399–400. doi:10.1111/j.1540-5885.2011.00810.x.

Fahimnia, B., Sarkis, J., & Davarzani, H. (2015). Green supply chain management: A review and bibliometric analysis. *International Journal of Production Economics, 162*, 101–114. doi:10.1016/j.ijpe.2015.01.003.

Ferenhof, H. A., Vignochi, L., Selig, P. M., Lezana, Á. G. R., & Campos, L. M. S. (2014). Environmental management systems in small and medium-sized enterprises: An analysis and systematic review. *Journal of Cleaner Production, 74*(1), 44–53. doi:10.1016/j.jclepro.2014.03.027.

Fiksel, J. (1996). *Design for environment: A guide to sustainable product development*. New York: McGraw Hill.

Goodall, P., Rosamond, E., & Harding, J. (2014). A review of the state of the art in tools and techniques used to evaluate remanufacturing feasibility. *Journal of Cleaner Production, 81*(15), 1–15. doi:10.1016/j.jclepro.2014.06.014.

González-Benito, J., & González-Benito, O. (2005). Environmental proactivity and business performance: An empirical analysis. *Omega, 33*(1), 1–15. doi:10.1016/j.omega.2004.03.002.

Gottberg, A., Morris, J., Pollard, S., Mark-Herbert, C., & Cook, M. (2006). Producer responsibility, waste minimisation and the WEEE Directive: Case studies in eco-design from the European lighting sector. *Science of the Total Environment, 359*(1–3), 38–56. doi:10.1016/j.scitotenv.2005.07.001.

Handfield, R. B., Calantone, R. J., & Melnyk, S. A. (2001). Integrating environmental concerns into the design process: The gap between theory and practice. *IEEE Transactions on Engineering Management, 48*(2), 189–208. doi:10.1109/17.922478.

Hauschild, M. Z., Jeswiet, J., & Alting, L. (2004). Design for environment–Do we get the focus right? *CIRP Annals—Manufacturing Technology, 53*(1), 1–4. doi:10.1016/S0007-8506(07)60631-3.

Hellström, T. (2007). Dimensions of environmentally sustainable innovation: The structure of eco-innovation concepts. *Sustainable Development, 15*(3), 148–159. doi:10.1002/sd.309.

Hendrickson, C., Horvath, A., Joshi, S., & Lave, L. (1998). Economic input-output models for environmental life-cycle assessment. *Environmental Science and Technology, 32*(7), 184–191. doi:10.1021/es983471i.

Hertwich, E. G., Pease, W. S., & Koshland, C. P. (1997). Evaluating the environmental impact of products and production processes: A comparison of six methods. *Science of the Total Environment, 196*(1), 13–29. doi:10.1016/S0048-9697(96)05344-2.

Herva, M., Franco-Uría, A., Carrasco, E. F., & Roca, E. (2012). Application of fuzzy logic for the integration of environmental criteria in ecodesign. *Expert Systems with Applications, 39*(4), 4427–4431. doi:10.1016/j.eswa.2011.09.148.

Hur, T., Lee, J., Ryu, J., & Kwon, E. (2005). Simplified LCA and matrix methods in identifying the environmental aspects of a product system. *Journal of Environmental Management, 75*(3), 229–237. doi:10.1016/j.jenvman.2004.11.014.

Iwami, S., Mori, J., Sakata, I., & Kajikawa, Y. (2014). Detection method of emerging leading papers using time transition. *Scientometrics, 101*(2), 1515–1533. doi:10.1007/s11192-014-1380-x.

Jabbour, C. J. C., Jugend, D., Jabbour, A. B. L. S., Gunasekaran, A., & Latan, H. (2015). Green product development and performance of Brazilian firms: Measuring the role of human and technical aspects. *Journal of Cleaner Production, 87*(15), 442–451. doi:10.1016/j.jclepro.2014.09.036.

Johansson, G., & Sundin, E. (2014). Lean and green product development: Two sides of the same coin? *Journal of Cleaner Production, 85*(December), 104–121. doi:10.1016/j.jclepro.2014.04.005.

Joshi, S. (1999). Product environmental life-cycle assessment using input-output techniques. *Journal of Industrial Ecology, 3*(2), 95–120. doi:10.1162/108819899569449.

Kaebernick, H., Kara, S., & Sun, M. (2003). Sustainable product development and manufacturing by considering environmental requirements. *Robotics and Computer-Integrated Manufacturing, 19*(6), 461–468. doi:10.1016/S0736-5845(03)00056-5.

Kai, H., Wang, X., & Raffoni, A. (2014). An integrated approach for green design: Life-cycle, fuzzy AHP and environmental management accounting. *The British Accounting Review, 46*(4), 344–360. doi:10.1016/j.bar.2014.10.004.

Karlsson, R., & Luttropp, C. (2006). EcoDesign: What's happening? An overview of the subject area of EcoDesign and of the papers in this special issue. *Journal of Cleaner Production, 14*(15–16), 1291–1298. doi:10.1016/j.jclepro.2005.11.010.

Kim, S. J., Kara, S., & Kayis, B. (2014). Economic and environmental assessment of product life cycle design: Volume and technology perspective. *Journal of Cleaner Production, 75*, 75–85. doi:10.1016/j.jclepro.2014.03.094.

Klöpffer, W. (2003). Life-cycle based methods for sustainable product development. *The International Journal of Life Cycle Assessment, 8*(3), 157–159. doi:10.1007/BF02978462.

Knight, P., & Jenkins, J. O. (2009). Adopting and applying eco-design techniques: A practitioners perspective. *Journal of Cleaner Production, 17*(5), 549–558. doi:10.1016/j.jclepro.2008.10.002.

Kobayashi, H. (2006). A systematic approach to eco-inoovative product design based on life cycle planning. *Advanced Engineering Informatics, 20*(2), 113–125. doi:10.1016/j.aei.2005.11.002.

Le Pochat, S., Bertoluci, G., & Froelich, D. (2007). Integrating ecodesign by conducting changes in SMEs. *Journal of Cleaner Production, 15*(7), 671–680. doi:10.1016/j.jclepro.2006.01.004.

Lewandowska, A., & Matuszak-Flejszman, A. (2014). Eco-design as a normative element of environmental management systems-the context of the revised ISO 14001:2015. *The International Journal of Life Cycle Assessment, 19*(11), 1794–1798. doi:10.1007/s11367-014-0787-1.

Lindahl, M. (2006). Engineering designers' experience of design for environment methods and tools—Requirement definitions from an interview study. *Journal of Cleaner Production, 14*(5), 487–496. doi:10.1016/j.jclepro.2005.02.003.

Ljungberg, L. Y. (2007). Materials selection and design for development of sustainable products. *Materials and Design, 28*(2), 466–479. doi:10.1016/j.matdes.2005.09.006.

Lofthouse, V. (2006). Ecodesign tools for designers: Defining the requirements. *Journal of Cleaner Production, 14*(15–16), 1386–1395. doi:10.1016/j.jclepro.2005.11.013.

Lu, B., Zhang, J., Xue, D., & Gu, P. (2011). Systematic lifecycle design for sustainable product development. *Concurrent Engineering: Research and Applications, 19*(4), 307–324. doi:10.1177/1063293X11424513.

Luchs, M. G., Brower, J., & Chitturi, R. (2012). Product choice and the importance of aesthetic design given the emotion-laden trade-off between sustainability and functional performance. *Journal of Product Innovation Management, 29*(6), 903–916. doi:10.1111/j.1540-5885.2012.00970.x.

Luttropp, C., & Lagerstedt, J. (2006). EcoDesign and The ten golden rules: Generic advice for merging environmental aspects into product development. *Journal of Cleaner Production, 14*(15–16), 1396–1408. doi:10.1016/j.jclepro.2005.11.022.

Manzini, E., & Vezzoli, C. (2003). A strategic design approach to develop sustainable product service systems: Examples taken from the "environmentally friendly innovation" Italian prize. *Journal of Cleaner Production, 11*(8 SPEC), 851–857. doi:10.1016/S0959-6526(02)00153-1.

Marcelino-Sábada, S., González-Jaen, L. F., & Pérez-Ezcurdia, A. (2015). Using project management as a way to sustainability. From a comprehensive review to a framework definition. *Journal of Cleaner Production, 99*(15), 1–16. doi:10.1016/j.jclepro.2015.03.020.

Maxwell, D., & Van der Vorst, R. (2003). Developing sustainable products and services. *Journal of Cleaner Production, 11*(8 SPEC), 883–895. doi:10.1016/S0959-6526(02)00164-6.

Murugesan, S. (2008). Harnessing green IT: Principles and practices. *IT Professional, 10*(1), 24–33. doi:10.1109/MITP.2008.10.

Nakamura, H., Suzuki, S., Hironori, T., Kajikawa, Y., & Sakata, I. (2011). Citation lag analysis in supply chain research. *Scientometrics, 87*(2), 221–232. doi:10.1007/s11192-011-0341-x.

Nielsen, P., & Wenzel, H. (2002). Integration of environmental aspects in product development: A stepwise procedure based on quantitative life cycle assessment. *Journal of Cleaner Production, 10*(3), 247–257. doi:10.1016/S0959-6526(01)00038-5.

Pigosso, D. C. A., Rozenfeld, H., & McAloone, T. C. (2013). Ecodesign maturity model: A management framework to support ecodesign implementation into manufacturing companies. *Journal of Cleaner Production, 59*(15), 160–173. doi:10.1016/j.jclepro.2013.06.040.

Pigosso, D. C. A., Zanette, E. T., Filho, A. G., Ometto, A. R., & Rozenfeld, H. (2010). Ecodesign methods focused on remanufacturing. *Journal of Cleaner Production, 18*(1), 21–31. doi:10.1016/j.jclepro.2009.09.005.

Porter, M. E., & Van der Linde, C. (1995). Toward a new conception of the environment–competitiveness relationship. *Journal of Economic Perspectives, 9*(4), 97–118. doi:10.1257/jep.9.4.97.

Poulikidou, S., Björklund, A., & Tyskeng, S. (2014). Empirical study on integration of environmental aspects into product development: Processes, requirements and the use of tools in vehicle manufacturing companies in Sweden. *Journal of Cleaner Production, 8*(1), 34–45. doi:10.1016/j.jclepro.2014.06.001.

Pujari, D. (2006). Eco-innovation and new product development: Understanding the influences on market performance. *Technovation, 26*(1), 76–85. doi:10.1016/j.technovation.2004.07.006.

Pujari, D., Peattie, K., & Wright, G. (2004). Organizational antecedents of environmental responsiveness in industrial new product development. *Industrial Marketing Management, 33*(5), 381–391. doi:10.1016/j.indmarman.2003.09.001.

Puglieria, F. N., Ometto, A., & Miguel, P. A. C. (2011). Eco-design methods for developing new products based on QFD: A literature analysis. *Product: Management and Development, 9*(1), 23–29. doi:10.4322/pmd.2011.003.

Restall, B., & Conrad, E. (2015). A literature review of connectedness to nature and its potential for environmental management. *Journal of Environmental Management, 159*, 264–278. doi:10.1016/j.jenvman.2015.05.022.

Sánchez, M. A. (2015). Integrating sustainability issues into project management. *Journal of Cleaner Production, 96*(1), 319–330. doi:10.1016/j.jclepro.2013.12.087.

Sanyé-Mengual, E., Pérez-López, P., González-García, S., Lozano, R. G., Feijoo, G., Moreira, M. T., et al. (2014). Eco-designing the use phase of products in sustainable manufacturing. *Journal of Industrial Ecology, 18*(4), 545–557. doi:10.1111/jiec.12161.

Sarkis, J., Gonzalez-Torre, P., & Adenso-Diaz, B. (2010). Stakeholder pressure and the adoption of environmental practices: The mediating effect of training. *Journal of Operations Management, 28*(2), 163–176. doi:10.1016/j.jom.2009.10.001.

Silvius, A. J. G., & Schipper, R. (2014). Sustainability in project management: A literature review and impact analysis. *Social Business, 4*(1), 63–96. doi:10.1362/204440814X13948909253866.

Sroufe, R., Curkovic, S., Montabon, F., & Melnyk, S. A. (2000). The new product design process and design for environment: "Crossing the chasm". *International Journal of Operations & Production Management, 20*(2), 267–291. doi:10.1108/01443570010304297.

Stalmans, P. Van, Aken, E. H., Feron, E. J., & Stalmans, I. (2002). Toxic effect of indocyanine green on retinal pigment epithelium related to osmotic effects of the solvent. *American Journal of Ophthalmology, 134*(2), 282–285.

Takeda, Y., Mae, S., Kajikawa, Y., & Matsushima, K. (2009). Nanobiotechnology as an emerging research domain from nanotechnology: A bibliometric approach. *Scientometrics, 80*(1), 23–38. doi:10.1007/s11192-007-1897-3.

Van Hemel, C., & Cramer, J. (2002). Barriers and stimuli for ecodesign in SMEs. *Journal of Cleaner Production, 10*(5), 439–453. doi:10.1016/S0959-6526(02)00013-6.

Vezzoli, C., Ceschin, F., & Diehl, J. C. (2015). Sustainable product-service system design applied to distributed renewable energy fostering the goal of sustainable energy for all. *Journal of Cleaner Production, 97*(15), 134–136. doi:10.1016/j.jclepro.2015.02.069.

Vinodh, S., & Rathod, G. (2012). Application of fuzzy logic-based environmental conscious QFD to rotary switch: A case study. *Clean Technologies and Environmental Policy, 14*(2), 319–332. doi:10.1007/s10098-011-0404-y.

Wang, X., Chan, H. K., & Li, D. (2015). A case study of an integrated fuzzy methodology for green product development. *European Journal of Operational Research, 241*(1), 212–223. doi:10.1016/j.ejor.2014.08.007.

Yu, C., Davis, C., & Dijkema, G. P. J. (2013). Understanding the evolution of industrial symbiosis research: A bibliometric and network analysis (1997–2012). *Journal of Industrial Ecology, 18*(2), 280–293. doi:10.1111/jiec.12073.

Zhu, J. Y., & Deshmukh, A. (2003). Application of Bayesian decision networks to life cycle engineering in green design and manufacturing. *Engineering Applications of Artificial Intelligence, 16*(2), 91–103. doi:10.1016/S0952-1976(03)00057-5.

Zhu, Q., & Sarkis, J. (2007). The moderating effects of institutional pressures on emergent green supply chain practices and performance. *International Journal of Production Research, 45*(18–19), 4333–4335. doi:10.1080/00207540701440345.