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Review

Systematic literature review of eco-innovation models: Opportunities and recommendations for future research

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ABSTRACT

The literature on eco-innovation provides extensive contributions for the achievement of the long-term sustainability, which implies an urgent need for holistic changes around business processes. In this sense, several models have been proposed in order to help companies achieve greater understanding of the dynamics of eco-innovation or even structure and facilitate the integration of sustainable processes within them. These eco-innovation models may be classified into different ways, because they not always have the same approach or common language, in terms of applicability and purpose. Classification is an essential tool to facilitate the diffusion of this field of knowledge and to achieve a higher maturity level on the concept of eco-innovation. Through a systematic literature review on eco-innovation models, this study aims to present gaps and opportunities for the advancement of the field, outlining promising directions regarding potential research areas, contents and predominant characteristics for new eco-innovation models. This paper has been developed upon an analytical framework in order to explore the diversity of eco-innovations models and to present suggestions according to several classification criteria (research area, model approach, model characterization, application sectors, generalization level, among others). In general, the models that have been analysed reveal a predominance of generic and descriptive characteristics. Moreover, there is a gap of eco-innovation models related to organizational structural factors and to social aspects of sustainability. Opportunities for normative models can be highlighted, such as methods, tools and models can be adapted to systems and industrial segments. Therefore, this field of knowledge still offers broad possibilities for new research and new eco-innovation models.

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1. Introduction

The term eco-innovation (environmental innovation, green innovation or sustainable innovation) has been used to identify the innovations that contribute to a sustainable environment through the development of ecological improvements (Kemp and Foxon, 2007; Carrillo-Hermosilla et al., 2009; Halila and Rundquist, 2011). Due to increased mass production and improved technology efficiency, eco-innovations need to implement economical, ecological and social aspects in order to impose limitations towards the present state of technology on environmental resources (Karakaya et al., 2014; Brundtland, 1987). Despite the importance of such concept, eco-efficiency and corporate social responsibility practices define much of the current industrial sustainability agenda. However, they are insufficient in themselves to deliver the holistic changes necessary to achieve the long-term social and environmental sustainability. It is necessary to understand how we can encourage corporate eco-innovation, so that it significantly changes the way companies operate to ensure greater sustainability (Bocken et al., 2014).

In practice, organizations need guidance on how to apply their efforts in a systematic manner in order to achieve environmental goals and maintain continual improvements in the environmental performance of products and processes (ISO, 2011). This is because all companies need methods and tools that support the management of innovation due to the high volume and complexity of knowledge generated in the process (Restrepo et al., 2005). Therefore, the innovation process involves a managerial issue. The innovation comes to be seen as the central process of business, and companies seek to find a way to organize and manage the innovation process in order to guarantee their survival and growth. The management of a company includes the formulation of strategies and the use of the organizational structure as a way of grouping and coordinating the resources in order to reach its objectives (Tidd and Bessant, 2008).

The fact remains that the successful implementation of sustainable innovation is quite elusive for most companies (Kuratko et al., 2014). There is a general lack of internal consensus on what business innovation means and a lack of clarity about the roles of management and responsibilities towards innovation (Brousell, 2008). This becomes even more challenging when the strategic focus is on the sustainability of environmental, social and economic factors. Several companies have difficulty in associating their speeches and management practices to a complete definition of sustainability. Some concentrate on social issues; others, on environmental issues; many, exclusively, on economic issues (Claro et al., 2008). Consequently, the integration of information to decision-making management are not sufficiently embedded and integrated to change the corporate culture (Epstein, 2004).

To help companies integrate sustainability aspects in their business processes, many eco-design methods have been developed to support the design engineers reducing the environmental impact of the product throughout its life cycle (Fiksel, 1996; Chen and Yen, 1999). Recent literature surveys show that there are over 100 techniques, methods and tools to integrate ecodesign in Product Development Project (PDP), especially in the technical sphere (Pigosso et al., 2013). However, despite the wide availability of research available in the literature, the integration of environmental issues remains a challenge for companies (Fiksel, 1996; Verhulst and Boks, 2011). This is because the use of eco-design methods, tools and metrics, merely, does not seem enough to achieve environmental sustainability (Alblas et al., 2014). To fill such gaps, it is necessary to develop methods with broad strategic vision for the management of innovation and of environmental sustainability (Jönbrink et al., 2013; Alblas et al., 2014). When economic, environmental and social aspects of innovation are processed and integrated into the company's strategy, its innovative potential is maximized. This proactive posture systemically modifies the organization on their goals, values, culture, leveraging innovative, economic and sustainable results (Xavier et al., 2015). Thus, eco-innovation is a challenge once it is necessary to integrate the environmental dimension throughout the whole innovation process, not only on the eco-design phase (Blaise, 2014; Zhang et al., 2013).

Therefore, the understanding of the characteristics and particularities of the eco-innovation process is crucial to manage it more efficiently, since more sustainable markets are increasingly imminent (Xavier et al., 2015). Several models have been proposed in order to achieve greater understanding of the dynamics (or even the structure) of eco-innovation, and facilitate the integration and implementation of eco-innovation processes in the company. In this paper, the term 'model' refers to the idea of "structures with described or normative features", according to the definition proposed by Bell et al. (1988). This way, it is assumed that an eco-innovation model covers a description, illustration or orientation of a process, system or practices of eco-innovation. These eco-innovation 'models' can be classified in different ways, because they not always have the same approach or common language, in terms of applicability and purpose. Classification is an essential tool to facilitate the diffusion of this field of knowledge and the achievement of a higher level of maturity on the concept. Besides, classification could help better frame the research problem around particular areas and highlight the frame of eco-innovation from a strategic management perspective.

In this sense, several literature reviews have been conducted with the aim of mapping and/or classifying existing models, methods and techniques in different fields of knowledge. In their research, Silva et al. (2014) and Cagnazzo et al. (2008) centered their review on innovation management models. The former conducts a survey and comparative critical analysis of classic models for innovation management in order to understand the modeling, phases and organizational factors of the innovation process. The latter aims to investigate the main evolutions of innovation management models and proposes a discussion of the forms and structures of these models over the years, through a strength-weakness analysis. Still in the field of innovation management, the research of Hidalgo and Albors (2008) present a similar literature review, but its focus is on innovation management techniques (not models), providing a comprehensive review of the scope, trends and major actors of their development and use.

Other research that analyze models, methods, techniques in other fields of knowledge rather than innovation may be mentioned: Ruy and Alliprandini (2010) raise and classify the main methods of environmental assessment for use in conceptual design phase; Rossi et al. (2016) perform a review of ecodesign methods and tools in order to understand the barriers for their implementation in industrial companies; Reim et al. (2015) provide a systematic literature review to understand the implementation of (Product-Service System (PSS) business models and tactical practices; Puglieri (2010) conducts a review and an analysis of ecodesign methods based on Quality Function Development (QFD) and Failure Modes and Effects Analysis (FMEA); Salgado et al. (2010) classify and analyze reference models for the product development process in order to identify gaps for future research; Schneider and Spieth (2013) provide a systematic review of the existing academic literature on business model innovation; Krassmann et al. (2014) present a systematic mapping in order to identify methods, models, frameworks and existing techniques for evaluating the deployment of cloud computing in the education sector; and Mahdavi et al. (2013), who conduct a systematic review of generic operating models in health services, with the main objective of raising the models which are used and how they are developed. In the context of sustainable innovation, O'Hare and McAloone (2014) provide a review and reflection upon the current status of eco-innovation research and suggest areas where the design community can contribute to develop the maturity of this approach. In the conclusions, the authors suggest 10 potential areas for the engineering design research community to contribute to the advancement of eco-innovation.

Notwithstanding the extensive research on revision and analysis of models, both in innovation and in different areas, it was not identified any study that maps the state of the art on "eco-innovation models", or any classification to organize and disseminate such knowledge.

In order to fill this gap in the literature, this study aims to present gaps and opportunities for the advancement of the field, outlining promising directions regarding potential research areas, contents and predominant characteristics for new eco-innovation models. An analytical framework is developed in order to explore the diversity of eco-innovations models and to present suggestions according to several classification criteria (research area, model approach, model characterization, application sectors and generalization level, as well as gaps and opportunities for future research). Through the classification and critical analysis of the models, this research presents trends, recommendations and issues for further studies, approaching the proposal of the articles mentioned in the paragraph above. Thus, it is intended to answer the main research question: *what research gaps currently exist and what research directions may be promising in the field of eco-innovation models*? To answer this question, the following secondary issues are proposed:

- *Which approaches and research methods have been used to develop eco-innovation models?*
- *What is the development and detailing level of the published eco-innovation models?*
- *Which research fields or disciplines are publishing eco-innovation models?*
- *Which sectors or market segments have been studied and used as application unit of eco-innovation models?*
- *What is the difference in content and predominant characteristics of these eco-innovation models?*

This study may be characterized as theoretical and conceptual, and comprises two main contributions: 1) it offers a literature review based on studies published between 1995 and 2015 in major databases, including a mapping and a classification of selected studies that develop eco-innovation models; 2) it offers a qualitative analysis of models, which contains an identification of gaps and suggestions for future research in this field of knowledge. The results summarize the main areas of research and application sectors of eco-innovation models. Furthermore, the present paper outlines entry points for new researchers, by submitting suggestions based on the results of the classification of models in relation to: the approach and method of research; characterization of the models; level of development, detail and generalization; content and predominant characteristics.

This paper is divided into six sections, the first section being devoted to introduction. In the next sections, the following topics are addressed: Section 2 discusses the background theory; Section 3 presents the research method used in this research; Section 4 presents the classification of the selected studies/models and a descriptive analysis of the models; Section 5 presents the findings and discussion; and Section 6 presents the conclusions and suggestions for future research. Lastly, the references and appendices are listed.

2. Background theory

This session will discuss the concepts and applications of eco-innovation, its differences from the traditional process of innovation and the interrelations with other concepts, highlighting the main areas of research that will be addressed in the systematic review; and a discussion of similar terminology to 'model' used for different modeling approaches. This discussion aims to analyze the definitions, purposes and limits of each term (*model, framework, method, tool*) used in the literature in order to facilitate understanding and enhance research and publication.

2.1. Eco innovation: concept and application

The concept of sustainable development and the general understanding that the environment and the economy are interdependent have aroused increasing interest in recent years amongst political powers and society. Since the end-of-pipe approach (in which pollution concerns are addressed at the point of discharge) is often costly and ineffective, industry has increasingly adopted cleaner production, considering the environmental impact throughout the product's lifecycle and integrating environmental strategies into their own management systems (Machiba, 2010). Such evolution of sustainable manufacturing initiatives and the urgency for change have led to increasing application of the term 'innovation' in environmental management and policy (Carrillo-Hermosilla et al., 2009). This way, environmental sustainability challenges, plus the increasing range of environmental constraints faced by industry, conveys that there is an urgent need for approaches that can deliver step change improvements in the environmental performance of products. Eco-innovation is an approach that has the potential to meet this need (O'Hare and McAloone, 2014).

The term eco-innovation (environmental innovation, green innovation and sustainable innovation) has been used to identify innovations that contribute to a sustainable environment through the development of ecological improvements (Kemp and Foxon, 2007; Carrillo-Hermosilla et al., 2009; Halila and Rundquist, 2011). Since sustainable concepts focus on different themes, they are affiliated to different communities (Franceschini et al., 2016). Consequently, the eco-innovations may be grouped into some categories, as well as their determining factors. They may comprise not only eco-friendly products, processes and services, but also organizational management systems that are sensitive to environmental concerns and systems innovations (Porter and Van Der Linde, 1995; Belin et al., 2009). Due to these heterogeneity of definitions, the term *eco-innovation* is used with different connotations and is often classified similarly to the term *eco-design* – essentially defined as a sum of actions guided by the perspective of environmental impacts reductions (O'Hare, 2010; ISO 14006, 2011; Deutz et al., 2013). This is because, despite the innovation comes from a systemic and interactive process, as highlighted by Chesbrough (2006), there are few theories about internal factors or intra-organizational processes for eco-innovation. Thus, the size of the design is strongly linked to the innovation process (Arnold and Hockerts, 2011; Carrillo-Hermosilla et al., 2009). However, the research focused on eco-innovation propose a more global vision of sustainability, which includes a change of the functionalities required in new products and a change of its business model (Carrillo-Hermosilla et al., 2010). This way, not only environmental impacts but also social impacts are reduced. Similarly, OECD (2009) underlines a more holistic approach of eco-innovation, stressing it is an organizational practice that integrates an array of characteristics ranging from changes to innovation across products, processes, organizations and institutions. In this approach, eco-innovation seems to be situated at a higher level as compared to eco-design, once eco-design is associated to incremental improvement, whereas eco-innovation is linked to radical changes (Charter and Chick, 1997). This research uses this approach to differentiate the terms eco-innovation and eco-design, assuming eco-design as part of eco-innovation.

From this holistic approach, an important option for companies is to choose between different ways to operationalize strategies that allow them to benefit from more open and sustainable approaches (Chesbrough, 2006) and different ways of opening their innovative process (Dahlander and Gann, 2010). Therefore, in addition to the design context and development of new products, eco-innovation is also studied in the field of management and innovation strategy, as well as in management, strategy and environmental policy. This is because sustainability is seen not only as an operational excellence exercise, but as an innovation that requires different organizational dynamics (Van Oppen and Brugman, 2011). Besides, in order to reach the sustainable goals, innovation is an important mechanism driven by the continuous need for quality improvement and by policy measures and regulation (Hallenga-Brink and Brezet, 2005).

For this reason, the literature in the field of eco-innovation has been abundant in different research perspectives, arousing interest among scholars of different disciplines. Other fields that support interdisciplinary research of eco-innovation are ecological economics and industrial ecology. Ecological economics addresses the relationships between ecosystems and economic systems (Costanza et al., 1992), by integrating ecological, social and economic aspects of sustainable development (Rennings (2000)). This is supported by the concept of industrial ecology that advocates increased efficiency of material and energy flows within a regional industrial system (Burstrom and Korhonen, 2001). And in this regional perspective, the development of systems and supply chains that take into account the aspects of sustainability (EURADA, 2012) also appears as a research field to the study of eco-innovation. These two research areas, ecological economics and industrial ecology, present eco-innovation models applied in different contexts (Chen and Chen, 2007; Yang and Chen, 2012), bringing new approaches to the field of knowledge.

Considering the whole context, and according to the definition of Tyl (2011), the eco-innovation can be either the result of a process or the process itself. This definition is supported by Cluzel et al. (2013), which adds it is an innovation that significantly improves the overall sustainability performance of a product during its life cycle and high systemic level. Therefore, it is extremely important to understand how sustainability is integrated in the process of innovation management (Boks and Stevels, 2003). Despite the processes follow the same steps in the process of eco-innovation, unlike conventional, sustainability is an integrated objective in corporate policy and therefore the process success factor, having different methods and success indicators (Siebenhüner and Arnold, 2007; Jones, 2003). However, it is not always clear how a sustainable process is organized within the company. Despite many authors see innovation as a key factor in sustainability, little attention is paid to how firms might find and develop eco-innovations (Roscoe et al., 2016). Roscoe et al. (2016) argue that sustainability should be taken as part of the way an organization conducts its business, rather than something "beyond" its general business practices and procedures. In this sense, innovative management stimulates companies to continually develop and test new models and methods of management, in order to manage the innovation processes effectively, as well as to motivate and stimulate their personnel towards creativity and innovation, strategic agility, and the ability to grasp the possibilities offered by the environmental action quickly (Hautamäki, 2010).

Many eco-innovation models have been proposed, what increases the heterogeneity in terms of approaches and terms used. Therefore, they can be classified in different ways. This could be explained through two perspectives: first, these models not always have the same approach or common language, in terms of applicability and purpose; second, there is no better way to manage innovation, since firms differ in technology and have specificities concerning their strategies, organizational structures and management (Tidd and Bessant, 2008). Unlike eco-innovation, eco-design has a well-defined framework since 2003, developed by ISO TR 14062. This standard gives elements and directives that enable the integration of environmental aspects within design. However, there is no norm for eco-innovation because it is still an undefined notion, permeated with different definitions (Blaise, 2014). For this reason, the classification is an essential tool to facilitate the understanding of the wide range of existing models, to identify the characteristics that differentiate the models from common standards, and to understand what the knowledge field challenges and opportunities are.

In spite of this, no study that could classify these models - so to facilitate further research and propose new models (generic or adapted) to market segments still unexplored, or even to consolidate and validate the existing ones - was identified. The research of Díaz-García et al. (2015) provides an overview of the existing body of literature on eco-innovations, and identifies the most relevant publications in the field and the topics of interest. From their analysis, it can be observed that there is a clear increase in the relevance of this issue within academia and several thematic trends arise in eco-innovation research, with drivers of eco-innovation being the most popular. Other literature reviews have been proposed in order to provide an overview of the emerging literature and a synthesis around several issues related to eco-innovation. Hojnik and Ruzzier (2016) and Bossle et al. (2016) conducted literature reviews focused at eco-innovation concepts and the drivers for its adoption. Del Río González (2009) and Franceschini et al. (2016) provide bibliometric analysis on eco-innovation – the former research focuses on sustainable terms and technological change; the latter regards the terms and meanings that associate with innovation and sustainability. This research is similar to the literature reviews mentioned in the survey objective and analysis of emerging literature in order to propose new lines for future research on eco-innovation field. However, it differs by conducting a classification and qualitative analysis of models, methods and other approaches on eco-innovation applied in various areas of knowledge and in different segments. Scientific knowledge is based on the classification activity. Therefore, the importance of classificatory research is clear to the processes of organization and dissemination of knowledge (Godinho Filho and Fernandes, 2004).

2.2. Models and terminologies

The use of the word 'model' is broad and has different connotations. Likewise, other terms (*framework*, *method*, *tool*) are used to designate different approaches and models are also used in ambiguous and diverse forms from their theoretical purpose. This lack of clarity as for terminology leads to a huge extent of the use of these terms, reflected in the confusion and difficulty when researching and publishing. Therefore, it should be relevant analyze their definitions, purposes and limits.

As proposed by Abbagnano (1970), model is one of the fundamental scientific concepts. A model represents a selective abstraction of reality, representations of real objects and situations (Eppen et al., 1987; Anderson et al., 1991; Pidd, 1998), and it aims to clarify the relationship between different elements, indicating effective causalities and interactions (Harding and Long, 1998). Models are relevant because they allow a better understanding of something that will be built. According to Zilbovicius (1997), models have a key role in the dissemination of practices due to the fact that they set way of thinking, approaching and articulating the organizational problems. Also, they are reference points, in the sense they operate as prescription for agents who make decision about practices to be employed in operations and organizational processes. Thus, a model is an abstract, conceptual construct that represents processes, variables and relationships without necessarily providing specific guidance or practices for implementation (Tomhave, 2005). The term framework can be defined as the set of components and independent structures that have a predefined relationship (Pree et al., 2001). It is used as a way of transforming complex issues in structures that can be studied and analysed (Shehabuddeen et al., 2000). The role of frameworks is to facilitate the understanding and communication among participants that may have different perspectives in a specific situation (Odeh and Kamm, 2003). The term method, on the other hand, is adopted in any regular and explicit procedure that can be repeated to achieve something, either material or conceptual (Bunge, 1974). That is, methods are the various existing forms of developing a process. As proposed by Tomhave (2005), a methodology is a targeted construct that defines specific practices, procedures and rules for implementation or execution of a specific task or function. Finally, the tools is used to refer to something unitary and specific, such as a device or a mechanism (Bates, 2005), everything that will be used by methods in the development of a process or task. They are vital to support and develop the quality improvement process (Bunney and Dale, 1997).

From the understanding of the terms highlighted above, it is possible to establish the scopes and limitations of each one. Models are conceptual constructs that represent processes, variables and relationships without, necessarily, providing specific guidelines or practices for implementation (Tomhave, 2005); that is what determines their described or normative character (Ghauri et al., 1995). A framework is a construct that defines concepts, values and practices to facilitate understanding, reporting and analysis of a given situation, theory or complex issues (Tomhave, 2005; Jabareen, 2009). The characteristics of the model are part of the frameworks' characteristics (Harding and Long, 1998). However, while models can be considered types of framework, not every framework is a model. This is because the purpose of the framework is to facilitate the understanding, and not necessarily to indicate causality or interactions between the elements. A method, on the contrary, has a more formal character than the framework (Tomhave, 2005), being a set of procedures to develop a process. Finally, the tools are everything that will be used by methods in the development of a process. To exemplify these different concepts, we can use the field of ecodesign, which addresses numerous proposals for approaches. These examples are available on Table 1.

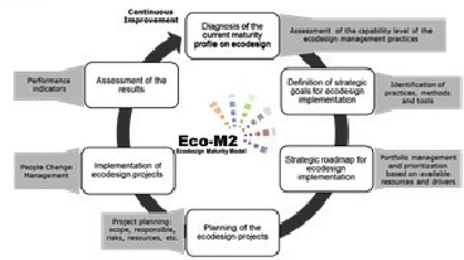
In this paper, the term 'model' is used as “structures with descriptive or normative features”, following the definition proposed by Bell et al. (1988). In common language use, an abstract system that proposes to describe behaviour is called *descriptive model*; on the other hand, an abstract system that attempts to capture how ideal people might behave is called a normative model (Bell et al., 1988). According to Chorley and Haggett (1975), descriptive models deal with certain stylistic description of reality, organization of empirical information, whereas regulatory models deal with what is expected to occur under the conditions established. Thus, the descriptive analyses seek to identify and understand the characteristics of each unit. As for the normative analysis, they set standards of behaviour in order to identify performance standards of the units (Ghauri et al., 1995; Bell et al., 1988). Therefore, in this research, eco-innovation model is assumed as a description, illustration (descriptive feature) or orientation (normative feature) of a process, system or activity of eco-innovation.

3. Research method

This is a theoretical-conceptual research, and it provides a systematic review of the literature in order to map the eco-innovation models' state of art. According to Denyer and Tranfield (2009), systematic review is a specific methodology that locates existing studies, selects and evaluates contributions, analyses and synthesizes data, and reports the evidence in such a way that allows reasonably clear conclusions to be reached about what is and is not known. This method will be used to map and synthesize a specific theme, providing a rigorous and reliable basis of literature review (Biolchini et al., 2005; Brereton et al., 2007). Thereby, the development of a systematic review of this study followed the 5 steps proposed by Denyer and Tranfield (2009):

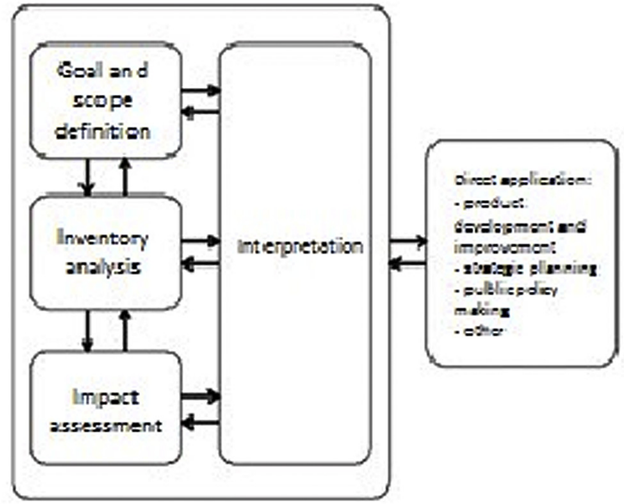
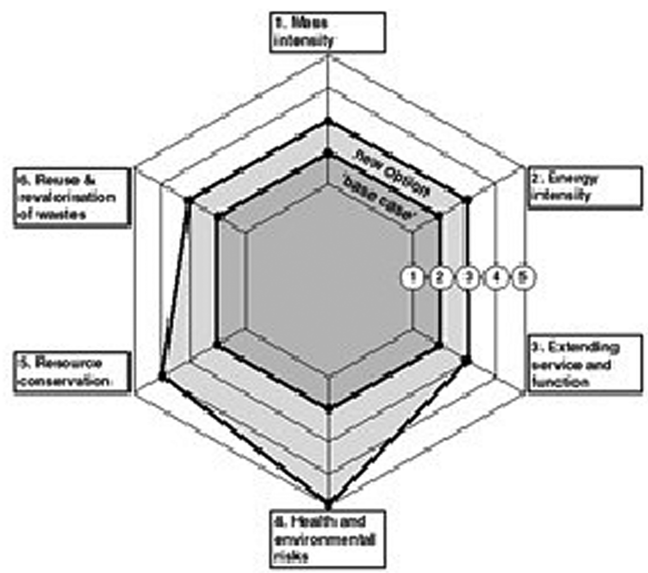
- *step 1: formulation of the research question;*
- *step 2: location of studies;*
- *step 3: selection and evaluation of studies;*
- *step 4: analysis and synthesis; and*
- *step 5: reporting and use of research results.*

Table 1
Definitions and examples of approaches.

Approach	Definition		Example
Model	A conceptual constructs that represent processes, variables and relationships without, necessarily, providing specific guidelines or practices for implementation (Tomhave, 2005); that is what determines their described or normative character (Ghauri et al., 1995).	**EcoM2- Ecodesign Maturity Model**: The EcoM2 is a maturity model of ecodesign, which aims to assist the improve environmental performance in product lifecycle management. It encompasses ecodesign practices, maturity levels and a method of application (Pigosso et al., 2013).	 Figure: EcoM2. Source: Pigoso et al. (2013)
Framework	A construct that defines concepts, values and practices to facilitate understanding, reporting and analysis of a given situation, theory or complex issues (Tomhave, 2005; Jabareen, 2009), but not necessarily indicating causality or interactions between the elements.	**Remanufacturing Guidelines:** A recognized ecodesign framework, which presents guidelines that should be considered for the development of a product aimed at remanufacturing (Ijomah et al., 2007).	• ease of disassembly: Where disassembly cannot be bypassed, by making it easier, less time can be spent during this non-value-added phase. Permanent fastening such as welding or crimping should not be used if the product is intended for remanufacture. Also, it is important that no part be damaged by the removal of another. • ease of cleaning: Parts which have seen use inevitably need to be cleaned. In order to design parts such that they may easily be cleaned, the designer must know what cleaning methods may be used, and design the parts such that the surfaces to be cleaned are accessible, and will not collect residue from cleaning (detergents, abrasives, ash, etc...). • ease of inspection: As with disassembly, inspection is an important, yet a non-value-added phase. The time which must be spent on this phase should be minimized. • ease of part replacement: It is important that parts that wear are capable of being replaced easily, not just to minimize the time required to reassemble the product, but to prevent damage during part insertion. • ease of reassembly: As with the previous criteria, time spent on reassembly should be minimized using Design For Assembly guidelines (Boothroyd & Dewhurst 1991). Where remanufactured product is assembled more than once, this is very important. Tolerances also relate to reassembly issues • reusable components: As more parts in a product can be reused, it becomes more cost effective to remanufacture the product (especially if these parts are costly to replace). • Standardization: - modular components: By making designs modular, the assembly and disassembly times can be reduced which enhances remanufacturing. - fasteners: By standardizing the fasteners to be used in parts, the number of different fasteners can be reduced, thus reducing the complexity of assembly and disassembly, as well as the material handling processes. - interfaces: By standardizing the interfaces of components, a fewer of parts are needed to produce a large variety of similar products. This helps to build economies of scale which also improve remanufacturability. Figure: Design for Remanufacturing Guidelines. Source: Amezquita et al., 1995

(*continued on next page*)

Table 1 (*continued*)

Approach	Definition	Example	
Method/Methodology	A method is a set of procedures to develop a process. A methodology is a targeted construct that defines specific practices, procedures and rules for implementation or execution of a specific task or function (Tomhave, 2005).	**LCA - Life cycle Assessment:** One of the most famous and complete methods for environmental impact assessment associated with all the stages of a product's life (Andersson et al., 1998).	 Figure: Methodological Framework of an LCA. Source: ISO 14040, 1997
Tool	A tools is used to refer to something unitary and specific, such as a device or a mechanism (Bates, 2005), everything that will be used by methods in the development of a process or task (Bunney and Dale, 1997).	**Eco-compass:** A tool that assists in life cycle analysis. This tool allows to position and evaluate product design options and solutions in more than six design criteria in five scales (Fussler and James, 1996).	 Figure: The Eco-compass. Source: Fussler & James (1996)

3.1. Step 1: formulation of the research question

A good systematic review is based on a well-formulated, answerable question. The question guides the review by defining which studies will be included, what the search strategy to identify the relevant primary studies should be, and which data need to be extracted from each study (Counsell, 1997). Therefore, the main research question and the secondary issues were formulated and presented in the first section of this study.

3.2. Step 2: location of studies

A comprehensive, unbiased search is one of the fundamental differences between a traditional narrative review and a systematic review (Mulrow, 1994). A systematic search begins with the identification of keywords and search terms, which are built from the scoping study (Tranfield et al., 2003). Before conducting the review and start searching for relevant studies, a protocol based on and incorporating the review questions should be developed (Petticrew and Roberts, 2006). A protocol ensures that the review is systematic, transparent and replicable, which are the key features of a systematic review (Briner and Denyer, 2012). The reviewer should decide, then, on the most appropriate search strings for the study. The output of the information search should be a complete list of articles and papers (core contributions) on which the review will be based (Tranfield et al., 2003).

For the systematic review of this study, the main scientific databases were selected and the keywords and research strings were defined. Research strings are the logical expressions that combine keywords with their synonyms in order to cover the largest number of studies for a research. In the present review, articles, publications, dissertations, theses and chapters of books on the subject of eco-innovation models were consulted. For reasons of transparency, it should be precisely explained how the systematic review process was designed, for example, in terms of selection of the literature, or of the choices made regarding search terms and databases used (Saunders et al., 2012). Therefore, sources selection criteria were defined by the use of international databases, exclusively, since they have a higher impact factor. Thus, the first parameters established for the review was the English language, the most internationally accepted in scientific studies. However, databases in other languages were also used seeking a greater scope for the research. The study period was from 1995 to 2015.

The databases consulted were: *Scielo; Science Direct; Springer; Wiley; Web of Science; Scopus; JSTOR*; and *Scholar Google*. The second parameter was the selection of terms or keywords and search strings. First, there were selected equivalent terms for eco-innovation used by the main authors of the field of knowledge. There are four different notions/terms used in the literature to describe innovations that have a reduced negative impact on the environment: "green", "eco", "environmental" and "sustainable". Some researches analyze the different notions for these terms (Kemp and Pearson, 2007; Reid and Miedzinski, 2008; Schiederig et al., 2012; Xavier et al., 2015; Díaz-García et al., 2015), concluding that the core aspects these notions/terms represent apply to nearly all of these innovation definitions, with some exceptions. However, most researchers use the terms interchangeably. Therefore, this paper will consider the four terms as interchangeable and identical.

Then, the terms "model" and "modeling" were chosen, because of their generic and comprehensive character, which encompass descriptive and prescriptive approaches of the studied research field. The term "process" was also selected as a way of expanding the search and, thus, of finding research that had structured eco-innovation processes, even when a terminology rather than "model" is used. The main terms that outline the research question are: *eco-innovation; green innovation; sustainable innovation; environmental innovation; model; modeling; process.* The logical expressions that combine keywords and their synonyms were obtained by the combination of the terms, which were used to obtain the greatest amount of relevant studies, as shown on Table 2. Through the selection of keywords and research strings, the review protocol was completed for the selection and evaluation of the studies, as shown in the next item.

3.3. Step 3: selection and evaluation of studies

Following the requirement for transparency of process, systematic reviews use a set of explicit selection criteria to assess the relevance of each study found to see if it actually address the review question. Detailed decisions are recorded specifying, precisely, the basis on which information sources have been included and excluded (Denyer and Tranfield, 2009). Following this logic, the main criteria used in this paper to select and evaluate the studies were:

- *Inclusion criteria:* There were selected studies that present and describe models of eco-innovation. Due to the range of contexts and ambiguities in the use of some terms, other eco-innovation structures not entitled 'model' were also analysed, such as *method, methodology, tool, framework, systematic* and *approach*. In this sense, it was used as inclusion metric the methodological basis of modeling proposed by Bell et al. (1988), selecting studies that present in their 'models' descriptive or normative/prescriptive characteristics and contain at least one of the three features below:
  1. a description of the eco-innovation process management;
  2. an illustration of the eco-innovation system behaviour;
  3. a guidance to eco-innovation practices.
- *Exclusion criteria*: there were excluded studies that did not present a description, illustration or orientation of a process, system or practices of eco-innovation.

According to Briner and Denyer (2012), the evaluation of studies is a key part of the systematic review. Each study is critically appraised in relation to the quality criteria devised as part of the systematic review protocol. In this sense, many checklists and tools have been conceived in order to help with critical appraisal of many different study types, including qualitative studies of various kinds, observational studies, interrupted time series studies and questionnaire surveys (Briner and Denyer, 2012). With the systematic

Table 2
Research strings.

Research strings	
Eco-innovation	Eco-innovation model
	Eco-innovation modeling
	Model of eco-innovation
	Eco-innovation process
Green innovation	Green innovation model
	Green innovation modeling
	Model of green innovation
	Green innovation process
Sustainable innovation	Sustainable innovation model
	Sustainable innovation modeling
	Model of sustainable innovation
	Sustainable innovation process
Environmental innovation	Environmental innovation model
	Environmental innovation modeling
	Model of environmental innovation
	Environmental innovation process

review, there were obtained about 1800 studies, including articles, theses, book chapters and other publications. During the reading process and evaluation of these studies, there were excluded those that did not have any structure/model of eco-innovation, even if they would contain some of the keywords or search strings. This was the first filter, through which 125 studies were selected. The review was conducted in January 2015. Each of the 125 studies were analysed through a second filter, considering the inclusion and exclusion criteria. Table 3 shows the number of studies found and selected in each database. However, since some studies have been raised in more than one database, the results of the second filter were crossed, as shown in Table 4. After this second filter and thorough analysis, there were selected 45 studies that present and describe an eco-innovation model. Topic 4 of this research presents the studies that were selected and the result of classification and analysis. For unification and consolidation of the selected information on this research, the registration of the studies was done by *Mendeley* software, which manages bibliographic database. In addition, *Microsoft Excel* was used for developing the review protocol, as well as a classification framework of the proposed studies and models. This will be presented in the next section.

3.4. Step 4: analysis and synthesis

After the collection and evaluation of the selected studies, the next stage was dedicated to a systematic review, which concerns analysis and synthesis (Briner and Denyer, 2012). The aim of the analysis is to break down individual studies into constituent parts, and describe how each relates to the other. On the other hand, the aim of synthesis is to make associations among the parts identified in individual studies. A synthesis needs to go beyond mere description by recasting the information into a new or different arrangement, and by developing knowledge that is not apparent from the reading of individual studies, in isolation (Denyer and Tranfield, 2009). Thus, after applying the selection and evaluation criteria, each of the selected studies was analysed in order to reach some conclusions about the quality of each study included in the review. For the development of this activity, it was built an analytical framework based on understanding of the objectives defined by the research questions and on some pre-established criteria for classification proposed in the research of Martín et al. (1999), Carnevalli and Miguel (2007) and Salgado et al. (2010). All the following criteria for classification and analysis of the selected studies and models proposed are briefly described in Table 5. This classification made it possible to synthesize, integrate and accumulate information and the results of different studies on the research topic, in accordance with the objectives and initial questions posed.

Table 3
Search results.

Databases	Total	1st Filter	2nd Filter
Science Direct	114	35	15
Web of Science	235	16	23
Scielo	166	13	2
Springer	165	17	8
Wiley	877	19	5
Google Scholar	127	22	17
Scopus	83	3	2
JSTOR	1	0	0
RESULTS	**1768**	**125**	

Table 4
Search results.

Databases	2nd Filter
Scopus Web of Science Science Direct Google Scholar	1
Scopus Web of Science Wiley Google Scholar	1
Wiley Google Scholar	2
Web of Science Science Direct	13
Web of Science Wiley	2
Springer Web of Science	4
Springer	4
Web of Science	2
Science Direct	1
Scielo	2
Google Scholar	13
RESULTS	**45**

3.5. Step 5: reporting and use of research results

In terms of research, systematic reviews can provide researchers with a solid understanding of the current state of knowledge in their field. The findings set out what is known and unknown about the review question (Briner and Denyer, 2012). In addition, as noted by Higgins and Green (2008), the primary purpose of a review should be to present information, rather than to offer advice. Thus, the discussion and conclusions should help people to understand the implications of the evidences presented in relation to practical decisions. In this sense, the topic 5 of this paper discusses the main results of the classification and analysis of the proposed studies and models in order to provide a mapping of the state of the art and to identify gaps for future research in this field of knowledge.

Although there were used authority databases to collect scientific papers as well as theses and dissertations, a great number of universities limits the access of their publications. However, despite of such limitation for the research, it is important to note that many of the dissertations and theses are also published in paper format. Another limiting factor of the research concerns the number of citations of each model that were analysed. Different types of studies - not only journal articles - were selected, but several of them have no published information regarding the respective number of citations, such as books, reports and theses. Because of this, the number of citations could not be used, in qualifying terms, for comparison. Therefore, this parameter was dismissed as analysis criteria.

4. Classification and analysis

4.1. Classification of selected studies

There were identified 45 models of eco-innovation. The allocation of the publications in the researched period (1995–2015) is shown in Fig. 1. Although the research period starts in 1995, the first publication of eco-innovation model found was from 1999. It can be seen an exponential increase in publications, highlighting the highest incidence of publications in the last five years (2010–2015).

There could be highlighted six major research areas (see Fig. 2): (1) environmental management, strategy and policy; (2) product design and innovation; (3) innovation process, management and strategy; (4) business strategy and organizational management; (5) supply chain management and sustainability; (6) industrial ecology and ecological economics. Of the 45 selected studies, the majority

Table 5
Criteria for classification and analysis of the studies and models proposed.

Analysis of the selected studies	
Year	year publication of the study
Reference	bibliographic reference of the study
Name	the name given by the author to the model
Brief description	brief explanation of the model
Research area	main field, discipline or research area of the study (product design, eco-design, innovation management, business strategy, environmental management, etc.)
Research application country/location	location/country in which the model was applied and/or tested
Application sector/segment	sector/segment in which the model was applied and/or tested
Approach	approach of the research, which can be classified as "quantitative" and "qualitative"
Research method	type of study (modeling, theoretical and conceptual literature review, simulation, survey, case study, action research and experimentation)
Analysis unit	unit of analysis or object of study in which the model is applied and/or tested (individuals or groups, group of companies, innovation systems, organizational unit)
Geographic coverage	geographic scope of application and/or test of the model (regional, national or international)
Document type	type of study and publication (journal paper, congress article, dissertation, thesis, book, other)
Database	database used to find the study (see Table 3)
Publishing house	organization/company that published the study
Journal's name	name of the journal that published the study
Terminology	terminology used by the author(s) (model, framework, flowchart, method, etc.)
Analysis of the proposed models	
Model characterization	methodological basis of modeling (descriptive or normative)
Model presentation	format in which the model is presented (conceptual and/or illustrative)
Development level	development level of the model (theoretical, experimental, consolidated)
Level of detail	level of detail of the model (superficial, succinct, complete)
Level of generalization	level of generalization of the model (generic or adapted - to a sector, industry, company, product or system)
Type of approach	approach that is appropriate, considering the possible elements and characteristics (model, framework, flowchart, method, etc)
Predominant content and characteristics	the main elements and characteristics of the model

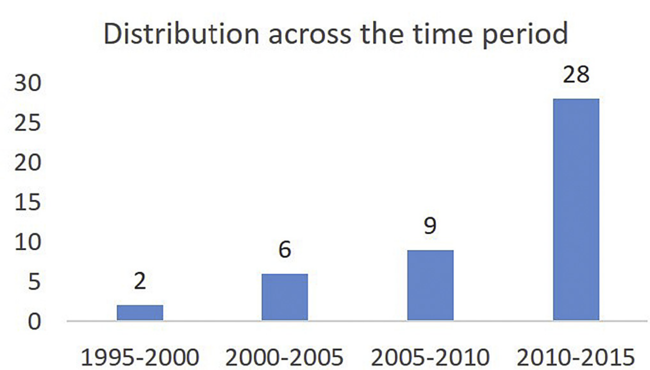


Fig. 1. Distribution across the time period.

belongs to the areas: *product design and innovation* (14) and *environmental management, strategy and policy* (13). It is also important to highlight that about 38% of the studies regard the themes of *ecodesign*, *environmental policy* and *environmental strategy*.

Among the databases that were used, *Web of Science* showed the greatest number of studies with models of eco-innovation, which represents 50% of them; Google Scholar appears afterwards, responsible for 38% of the studies. Regarding the type of the published document, it is possible to perceive that 60% of the publications are journal papers. Among the journal papers, 20% are from the *Journal of Cleaner Production.* Reviewing the terminology used for the proposed models, more than a half of the studies mention their approaches as *model* (26). This evidence highlights the generalizing character assigned to the term *model*, often used in names of the approaches, even when the description refers to it as a *framework*. This information is available on Fig. 3.

Regarding the methodological approach, the vast majority of studies are qualitative (about 78%), 60% use the case study method, with about 60% of single case study and 40% multiple case studies (see Fig. 4).

Among the 28 studies that have practical applications (case and survey), 50% had as unit of analysis a group of companies. Fig. 5 illustrates the studies distribution by the types of analysis unit. These 28 models of eco-innovation have been applied/tested in different sectors and segments of the economy. Many of the models have been applied in manufacturing companies, but they were not limited to a particular segment. This is because the method used in such cases was the multiple case studies, involving a group of manufacturing companies of different segments in a particular region. Similarly, it was the delimitation of certain research not an industry sector, but to the Small and Medium-sized Enterprises (SMEs) segment, or companies focused on the Product-Service System. Analysing in a macro way, it can be highlighted the electronics segment, with 4 applied studies of eco-innovation. Is possible to check the other sectors studied on Fig. 5.

In addition, with respect to applied studies, about 55% have a regional coverage, that is, they are applied in companies of a city or cluster. The distribution is similar between studies with national and international coverage. The country where there has been the highest incidence of applied studies was Taiwan (4), followed by the Netherlands (3). It is worth noting the large concentration of applied studies in Europe (14). The territorial distribution is portrayed on Fig. 6.

4.2. Classification of eco-innovation models

After analysing the characteristics of each of the selected studies, it was performed a second analysis on the proposed models, related to their: characterization, presentation, level of development, detail and generalization, content and predominant characteristics. As for their characteristics, 60% of the models present descriptive characteristics (see Fig. 7). This analysis is not exhaustive, since the modeling process is flexible and depends on the competence of the modeler. Thus, to categorize models as strongly descriptive or normative is not simple, once normative

Fig. 2. Distribution by research area.

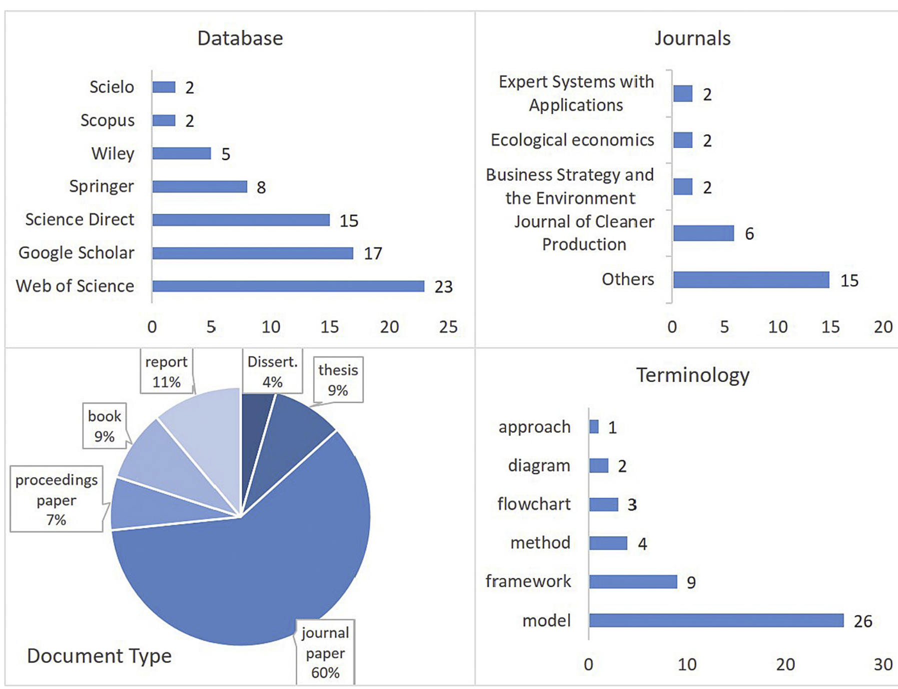


Fig. 3. Distribution by database, journals, document type and terminology.

APPROACH	
qualitative	35
quantitative	5
quali-quanti	5

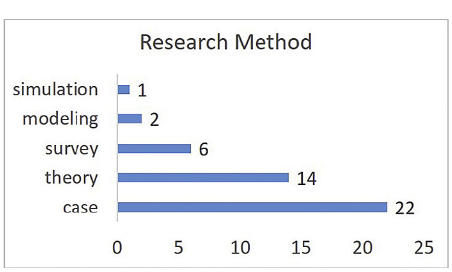
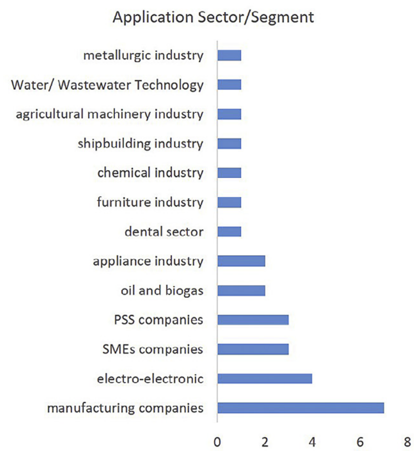
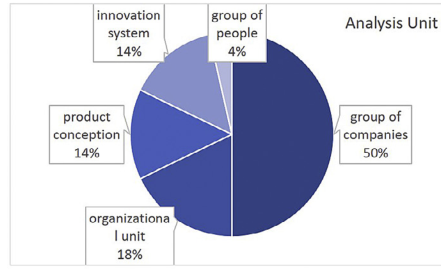


Fig. 4. Distribution by research method.

models are sometimes used for descriptive purposes; and other descriptive models are modified to be applied as standards at an appropriate organizational behaviour (Bell et al., 1988). Therefore, the descriptive/normative characterization will strongly depend on the individual understanding, and in this case, on the analyst perspective. Therefore, this research used certain references of the modeling field of knowledge to justify the classification choices (as shown on topic 2.2). The models were classified into conceptual (through a theoretical description) and illustrative (through a structured visual representation, such as drawing and diagram). Except for two models presented in a purely conceptual way, the other ones are presented in both conceptual and illustrative





MODEL PRESENTATION	group of companies	organizational unit	product conception	innovation system	group of people
Multiple cases	9 studies (100%)				
Single case		5 studies (38%)	4 studies (31%)	4 studies (31%)	
Survey	5 studies (83%)				1 study (17%)

Fig. 5. Distribution by application sector/segment and analysis unit.

GEOGRAPHIC COVERAGE	
Regional	15
National	7
International	6

Fig. 6. Distribution by geographic coverage and research application country/location.

MODEL CARACTERIZATION	
Descriptive	27
Normative	18

MODEL PRESENTATION	
Conceptual	2
Conceptual and Illustrative	43

Fig. 7. Distribution by model characterization and presentation.

perspective.

Regarding the level of development, this research found that the models are theoretical (no application) or experimental (applied studies). It also examined whether the models are 'consolidated', that is, validated by a series of experimental research and wide application in the field of knowledge or business environment. As result of the analysis, about 60% of the models can be considered experimental; and 37% theoretical. Only 2 models can be considered consolidated. In addition, about 80% of eco-innovation models are generic; it means they do not belong to any specific system, segment/industry or company. On the other hand, all adapted models are experimental or consolidated, which demonstrates methodological rigor.

Less than 10% of the models present a complete theoretical level of detail. For this analysis, three categories were established: *superficial* (low level of theoretical detail, that is, very little reasoning on each of the elements and their relationships – usually inherent to papers that have a severe page limitation), *succinct* (mid-level of theoretical detail, in which the elements and relationships are founded, but without much detail – usually inherent to papers that have moderate page limitation) and *complete* (high level of theoretical detail, with all the elements and relationships well-founded – usually inherent to theses and books). Thus, about 90% of the eco-innovation models are considered *succinct*. Since most of the models is paper publications (genre with limited number of pages), it is natural that their level of detail is reduced. Therefore, the theoretical foundation is limited, especially in cases with applied studies, in which much of the study is focused on the analysis of results. Thus, studies with complete level of detail are, mostly, of extensive publications, such as theses and books. The only complete model published as an article is a theoretical publication, offers no application throughout it (see Fig. 8).

4.3. Descriptive analysis of eco-innovation models

The models of eco-innovation were analysed individually, according to their elements and characteristics. After detailed analysis, it was possible to separate and classify the 45 models into seven types of approach: diagram, framework, flowchart, process model, systemic model, conceptual model and method. This classification facilitates the description of the analysis and understanding of the essence of each model. The description of the approaches and the references to each of them can be viewed in Table 6, and the distribution of the models by type of approach can be viewed in Table 7.

About 25% of the models can be understood as diagrams, and these schemes show: flows of information from the eco-innovation process; flow of knowledge and resource between eco-innovation groups; elements related to social aspects; the strategies of eco-innovation in supply chains; the differences between incremental and radical eco-innovations; the structural dimensions of eco-innovation in biodiesel chain; and drivers of eco-innovation (theme divided into 5 models). The diagram proposed by Del Río et al. (2011) illustrates this approach. It incorporates the impact of firms' internal factors and their interactions with external drivers on the development of eco-innovations. It is shown that, while all capabilities are relevant for the development of eco-innovations,

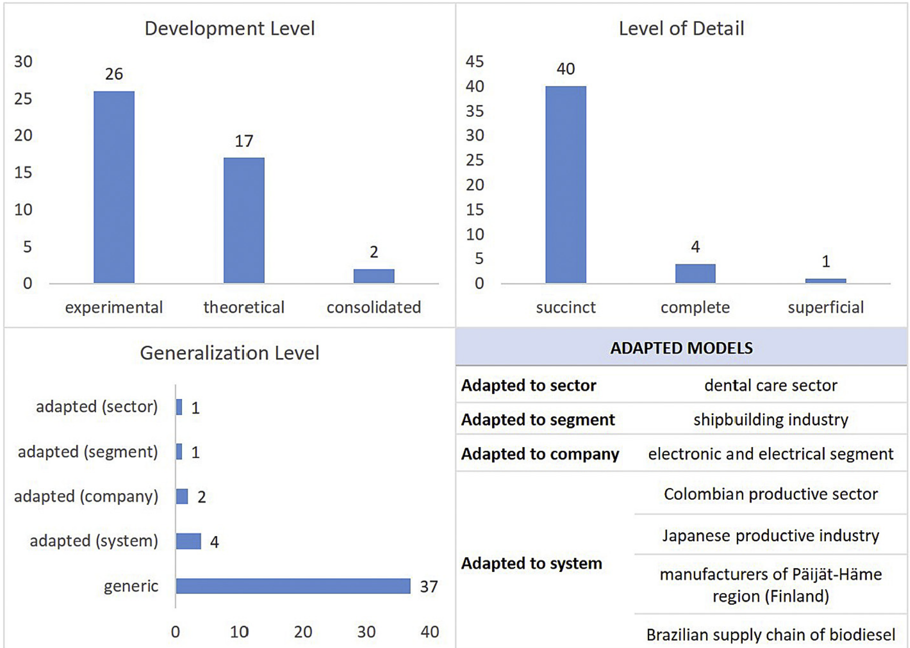


Fig. 8. Distribution of studies by level of development, detail and generalization.

Table 6
Description and distribution by models approaches.

Approach	Description	References	Models
Diagram	scheme that shows the flow of elements, relationships, information, knowledge, resources, determinants	Wong (2004); Diezmann and English (2001)	11 models
Framework	descriptive frame with actions, good practices, elements, steps, determinants	Pree et al. (2001); Shehabuddeen et al. (2000)	9 models
Flowchart	flow of a specific process, of some stage (ideation, problem solving) or type of eco-innovation	Schmenner (1999); Barnes (1977)	6 models
Process Model	macro model of eco-innovation process (illustrating steps for implementation, for the whole life cycle, or for a specific phase)	Tidd and Bessant. (2008); Burgelman (1983)	6 models
Systemic Model	model that illustrates the whole system (the internal, external aspects and their relationships)	Johannessen (2009); Rothwell (1992)	6 models
Conceptual Model	conceptual model to investigate the relationship and influence between elements of eco-innovation (for hypothesis testing)	Moody (2005); Hitchman (2004)	5 models
Method	structured procedure for implementation or stage of eco-innovation and support tools	Tomhave (2005); Bunge (1974)	2 models

their relative relevance differs between different dimensions of eco-innovation. The relevance of these factors regarding several dimensions of eco-innovation is illustrated with case studies. The model intended to assist organizations in building innovative qualities and knowledge management practices.

About 20% present characteristics of a framework, by the description of: actions for eco-innovation through five technological levers; steps to sustainable manufacturing; steps to eco-innovation; eco-innovation activities classified in design, innovation and green technology; capabilities needed for sustainability innovation; characteristics of different levels of eco-innovation; the nine key elements for environmental innovation process; the archetypes of sustainable business model; and a model that describes the procedure of a specific process of eco-innovation – through the use of ARIZ (the central analytical tool of TRIZ – Theory of Inventive Problem Solving) and biomimetic concept - for eco-product design. The framework proposed by Bocken et al. (2014) presents a categorization of eight business model archetypes, classified into three categories: technological, social and organizational. The technological archetypes: 1) maximize material and energy efficiency; 2) create value from waste; 3) substitute with renewables and natural process. The social archetypes: 4) deliver functionality rather than ownership; 5) adopt a stewardship role; 6) encourage sufficiency. Finally, the organizational archetypes: 7) repurpose for society/environment; and 8) develop scale-up solutions. The purpose of the model is to link the theoretical concept of business model innovation to the practical transformation mechanisms emerging for delivering industrial sustainability.

In relation to ‘flowcharts’,’process models’ and ‘systemic models’ approaches, they represent 18 models, 6 models each. In other words, each approach is equivalent to about 13% of the total models. The models of flowcharts showed: the process flow of the early stages of eco-innovation (ideation process); the flow of eco-innovative design process for problem solving; the flow of the method of eco-innovative design by TRIZ; the eco-innovation process flow of a PSS; a flowchart for eco-product design; and the flow of a process of eco-innovation design. Chen and Huang (2011) proposed a flowchart of the design process for PSS eco-innovation

Table 7
Distribution by approach and research area.

Approach/Research area	Product design and innovation	Environmental management, strategy and policy	Innovation process, management and strategy	Business strategy and organizational management	Industrial ecology and ecological economics	Supply chain management and sustainability
Method				Samet (2010); Buttol et al. (2012)		
Framework	Demirel and Kesidou (2011); Bocken et al. (2014)	Noci and Verganti (1999); OECD (2009, p.13); OECD (2009, p.15); Arnold and Hockerts (2011)	Van Oppen and Brugman (2011)		Chen and Chen (2014)	Takhtay (2011)
Diagram	Foster and Green (2000); Hautamäki (2010); Potts (2010); Del Río et al. (2011)	Verloop and Wissema (2004); Santos et al. (2014)	Rennings (2000); Albers and Brewer (2003); Van Bommel (2011)	Rashid et al. (2014); Triguero et al. (2014)		
Flowchart	Chen and Huang (2011); Chakroun et al. (2014)	Jones (2003); Chang and Chen (2004)			Chen and Chen (2007); Yang and Chen (2012)	
Conceptual Model	Eiadat et al. (2008); Kaenzig and Wüstenhagen (2010)	Dupuy (1999)	Li (2014); Chen et al. (2014)			
Process Model	Simpson (2011); Aguado et al. (2013)	Hallenga-Brink and Brezet (2005); Blaise (2014)		Cluzel (2012)		Comas (2012)
Systemic Model	Herrmann et al. (2007); METI (2007)	Van Hoof and Herrera (2007); Kanerva et al. (2009)	Dangelico and Pujari (2010); Peralta et al. (2012)			

divided into three stages process. The first and the major process focuses on function analysis and substance-field analysis for PSS eco-innovation. The second part is the process of searching the most similar PSS cases, in which the designer can find suitable service types for his problem and process into the next step. The third part is to find eco-innovation ideas through the analysis of eco-efficiency versus service effectiveness, by comparing similar cases. This flowchart supports designers in developing PSS by using functional analysis and the TRIZ substance-field model.

The models characterized as 'process models' present the process of eco-innovation in a macro form. Even when is oriented to a specific stage, there is no much concern about the flow, but about the steps. Among the six models, there exists: process of eco-innovation to PSS; sustainable innovation implementation process of oral health promotion interventions; process focused on the ideation stage of eco-innovation; process of a naval sector through six work packages; a process for the improvement of a lean production system through environmental innovation; 6-steps process for eco-innovation. The process model proposed by Simpson (2011) is based on the stages of innovation implementation and the factors affecting sustainability for interventions of oral health promotion. The main stages are: training, adoption, implementation and practice improvement. The model is a designation of key factors that sequentially influence sustainability of an innovation. More specifically, it highlights readiness of organizations and the infrastructure their services to embrace a specific intervention. Furthermore, the model denotes that the sustainability of innovations over time will be dictated in large part by resource allocations and organizational climate factors.

The systemic models, in turn, characterized by comprehensively illustrate a particular system of eco-innovation, are presented as: systemic model of the Colombian productive sector with environmental variables; systemic model of the life cycle of the innovation process with environmental aspects; systemic model of eco-innovation in Japanese industry; systemic model of eco-innovation processes (bioethanol); systemic model of the dimensions of green product innovation; systemic model for the industrial sector, based on eco-design techniques. Peralta et al. (2012) proposed a systemic model (MGE2) based on environmental management standards for designing and developing products and manufacturing systems with an approach from the Cradle to Cradle (C2C), which links the dimensions of sustainability. This model illustrates the environment, tools and techniques for eco-innovation, and functions as a framework for designing bio-inspired products and industrial systems. It consists of the basic techniques of ecodesign, which are oriented to eco-effectiveness and are support with biomimetic design strategies within the areas of eco-industry and industrial ecology. Therefore, MGE2 is compatible with any industrial sector and adaptable to the objectives and strategies proposed in projects.

Other 5 models were characterized as 'conceptual models', since their purpose was to analyze the hypotheses in the context of eco-innovation. Thus, the models at issue analysed: the relationship between environmental policies and the process of eco-innovation; the argument that environmental innovation strategy influences business performance; the relationship among institutional pressure, eco-innovative practices and commitment of resources and performance; the determinants of radical and incremental innovation performance; and the influence of the information of life cycle cost (LCC) in the eco-innovation investment decisions. Li (2014) proposed a conceptual model for the relationships among institutional pressures, eco-innovation practices, resource commitment and performance. It investigates the antecedents and outcomes of eco-innovation practices through a large-scale study, and provides a more comprehensive understanding on the consequences of such eco-innovative practices.

Finally, between the two models that present method features, that is, structured procedure to eco-innovation, the first is a five-step method for analysing problems and searching for innovative solutions, while the second is a method to support SMEs on eco-innovation products. The innovative method (Ecosmes.net) proposed by Buttol et al. (2012) provides a comprehensive and integrated offer of information, training and tools for supporting SMEs through all of the phases of the process (awareness and training; analysis; product (re)design; communication/certification) and a user-friendly system of services to lower the main existing barriers to product eco-innovation. Almost all the enterprises involved in a structured use of Ecosmes.net have given positive feedback and shown interest in using the platform and its tools beyond the end of the project.

The following table (Table 7) presents the eco-innovation models distributed by type of approach and the six major research areas that fit each model.

5. Findings and discussion

After classifying the selected studies and their proposed models, the results were analysed together in order to answer the research questions. Then some gaps and opportunities for future research could be proposed.

5.1. Answers to the research questions

5.1.1. Which research fields or disciplines are publishing eco-innovation models?

Six major research areas could be highlighted: (1) product design and innovation; (2) environmental management, strategy and policy; (3) innovation process, management and strategy; (4) business strategy and organizational management; (5) supply chain management and sustainability; (6) industrial ecology and ecological economics. The main research themes were ecodesign, environmental policy and environmental strategy. On the one hand, it is clear that eco-innovations are still strongly linked to product and therefore to design for sustainability. On the other, there is an urge for models that consider the strategic issues, what leads to the assumption that the external aspects are determinant to eco-innovation. This second aspect is essential to the search field, in view of the challenge of developing tools with broad strategic vision of eco-innovation, which integrates the environmental dimension throughout the whole process in order to maximize the innovation potential (Jönbrink et al., 2013; Alblas et al., 2014; Blaise, 2014; Xavier et al., 2015). In addition, it is possible to note the increasing number of publications on the theme, highlighting the year 2014, during which the highest number of works were published. This result indicates a strong trend in this area of research and evidences that there we will probably have an increase in the number of studies on eco-innovation and on the new proposed models.

This study's analytical framework, presented in Appendix A, was developed in order to explore the diversity of eco-innovations models and to present suggestions according to some of the several classification criteria (research area, model approach, model characterization, application sectors and generalization level). The complete analytical framework, with all the classification criteria presented in the above topics, can be requested by e-mail to the authors. Therefore, some considerations could be made for each of the six major research areas of eco-innovation models:

Product design and innovation (14 models): Great emphasis on eco-design theme; the models were presented in various types of approaches, with the exception of method; most of the models are experimental and qualitative, especially when it comes to the case study method; despite being applied studies, only two models are adapted to a system (systemic model of eco-innovation in the Japanese industry) and to a segment (sustainable innovation implementation process of oral health promotion interventions); most have descriptive and succinct level of detail; just one model focused on the social aspect (diagram of the different forms of capital, and having the well-being and sustainability as core values), and one model that incorporates service (flowchart of the design process of an eco-innovative product-service system).

Environmental management, strategy and policy (13 models): emphasis should be given to the theme of environmental policy; no approach stands over the other, and there was no method among the models. Most of the models are experimental and almost all are qualitative, especially the case study and theoretical-conceptual models. However, only two models are adapted to a system (model of the Colombian productive sector with environmental variables and model of eco-innovation bioethanol process) and business (framework of the key elements to the process of eco-innovation in an electronics company). Most have descriptive characteristics and are succinct. No model with international application. No model focusing on any social aspect.

Innovation process, management and strategy (8 models): diagrams, systemic models, conceptual models and framework approaches. No methods, flowcharts or process models. Emphasis on experimental and qualitative models, with a predominance of theoretical and conceptual models. Therefore, there were no suitable models. Most had descriptive character. Only two systemic models for innovation management and sustainability, focused on product eco-design. Two models that addressed structural factors of the company (knowledge flow diagram and resource for eco-innovation and framework capabilities needed for eco-innovation), and only a model that includes the strategic perspective of innovation (diagram of sustainable strategies in supply chain).

Business strategy and organizational management (5 models): diagrams, process model and method approaches. Only one theoretical model. This is the only area that presented models already consolidated. Most of the application was through case study, but only one model is adapted to a company. Although one of the models can be considered with complete level of detail, most are succinct. Absence of systemic model and framework that addresses all managerial process of eco-innovation, including external and internal aspects of the organization and their interactions.

Industrial ecology and ecological economics (3 models): among the three models, two were presented in experimental flowcharts with a qualitative approach, through case study and normative characteristics. One qualitative and quantitative framework with modeling method and descriptive characteristics. All models have focused on the use of problem-solving method (two flowcharts for eco-product design by TRIZ and one descriptive model of eco-innovation procedure by ARIZ), and they are of regional application, generic and succinct. No model with systemic approach or method, or that addresses the pillars of sustainability.

Supply chain Management and sustainability (2 models): one of the models is a descriptive framework of a value chain in a region of Finland, and the other a policy development process model, specific to the naval industry. Both models are experimental with application through case study. Furthermore, these models are adapted to a system and to a sector with succinct details. There are no systemic models of the value chain area, nor diagrams and flowcharts for process steps, or even conceptual models for hypothesis testing.

5.1.2. Which approaches and research methods have been used to develop eco-innovation models?

Most studies have qualitative approach, being more than half with case study method and regional coverage. Regarding the location of the studies application, it is possible to highlight Taiwan and the Netherlands. Furthermore, there was a high concentration of applied studies in Europe. This aspect can be compared to the fact that Europe is the continent with the highest environmental performance (measured by the Environmental Performance Index -

EPI, 2014), being a good setting for applied studies. The most commonly used term for approaches was 'model', what highlights the general character of the terminology. However, it is possible to note the confusion between the terminology used, evidencing the need for research to clarify the purposes and limits of each term.

5.1.3. What is the development and detailing level of the published eco-innovation models?

The two main databases that provided the highest number of eco-innovation models were the *Web of Science* and *Google Scholar*. The main form of publication of the models is through scientific journals, with great emphasis on the *Journal of Cleaner Production*. This aspect may be related to the fact that most of the models have succinct level of detail, in view of the limited number of pages of the papers. Therefore, dissertations and theses in this field of research, and greater access to theses' database, are necessary to have more detailed models.

The majority of models indicated descriptive characteristics, as opposed to normative, and had their presentation was conceptual and illustrative (through a visual representation). More than a half are experimental models and only two models can be considered consolidated, what highlights the need for greater application of eco-innovation models to check their strength and subsequent validation in new research. Thus, the use of quantitative methods, such as survey, will allow a higher level of development and an expansion of geographical coverage, increasing the field of analysis models.

However, although more than half of the models are experimental, most of them have high level of generalization, with few adapted models. That is, few models are specific to some system, segment/industry or company. According to Tyl et al. (2015), practical cases based on eco-innovation tools are poorly documented. Bujis (2003) states that depending on the objectives and goals of the company, it is necessary to choose a specific model, a specific version of the model or a specific level of detail. Thus, while generic models are essential for the field of knowledge and wider scope of application, the content and form of the models should also be defined by the characteristics of each company and sector (Pavitt, 1998; Tidd and Bessant, 2008; Restrepo et al., 2005; Longanezi et al., 2008). This is because firms differ in technology, market and specific as strategy, structure and management. Therefore, it is important that adapted models are developed, tested and validated.

5.1.4. Which sectors or market segments have been studied and used as application unit of eco-innovation model?

Most models were applied in manufacturing companies, but a lot of research covered a group of different companies of different segments in a particular region. Among the segments that had the highest number of applied studies, we highlight the electronics segment, the SMEs segment and PSS companies, the oil and biofuel industry segment and the home appliance products segment.

5.1.5. What is the difference in content and predominant characteristics of these eco-innovation models?

After detailed analysis, it was possible to separate and classify the models in seven types of approach. Most of the eco-innovation models could be characterized as diagrams, showing the flow of information between elements. Another widely used approach was the framework, with tables describing eco-innovation. Other approaches that characterized the models were: flowcharts; process model; systemic model; conceptual model and method. Through the analysis of the diagram models, we realize the interaction and differentiation of the aspects, dimensions and drivers of eco-innovation, and this allows us to expand knowledge on themes and specific segments. According to the research of Rennings (2000), which proposed a diagram of the determinants of eco-innovation, the consideration of the peculiarities may help to overcome market failure by establishing a specific eco-innovation policy, and to avoid a 'technology bias' through a broader understanding of innovation.

The flowchart models take into consideration environmental aspects, prioritizing and solving engineering problems. These approaches can assist designers and engineers to construct eco-innovative products and provide a synergy between the ecodesign tools and the inventive principles, as proposed by the PSS eco-innovative design methodology (Chen and Huang, 2011). Finally, these approaches enable a clear understanding of the eco-innovation process, which facilitates the identification of elements that could be improved and allows for the generation of new ideas.

The frameworks present an overview of eco-innovation and its characteristics, in terms of typology, mechanism, impact, capabilities, activities and other key elements. These frameworks can be used as an organizational analysis model, a design model or a practical guide to support eco-innovation. Therefore, through the combination of a wider range of innovation mechanisms, it is possible to yield higher environmental improvements in the medium to long term (Van Oppen and Brugman, 2011; OECD, 2009).

The method approach, in turn, provides a comprehensive and integrated offer of information, through the structured approach and easy understanding and utilization. The formalization of the problem can be guided by recommendations related to each action. Thus, it is possible to solve a problem quickly, through a full-oriented analysis. This type of approach allows for the integration of information, training and tools for supporting organizations throughout all the phases of the eco-innovation process (Samet, 2010; Buttol et al., 2012).

The process model presents the stages of eco-innovation process and outlines the flow of work packages or factors affecting sustainability. Through the systematization of various factors of eco-innovation, as strategy, ecodesign, environment, among others, it is possible to understand the flow of the steps and the interactions of the process, even if it is a specific stage of eco-innovation. The process models can provide new vision of product life cycle, package processes linked to specific tools and a focus on processes and products improvement. Moreover, it can serve as a basis for the development of new tools and methods of eco-innovation (Comas, 2012; Blaise, 2014).

The systemic models advance our understanding on innovativeness of green products and life cycle analysis. The approach allows for the classification and description of failures and serves as the framework for environmental driven innovations. A complete system model can encompass environmental management standards and illustrate the environment, tools and techniques for eco-innovation, as the MGE2 model (Peralta et al., 2012) proposes. Therefore, eco-innovation can be seen as an overarching concept, which provides direction and vision for pursuing the overall societal changes needed to achieve sustainable development, supporting process of environmental policies (METI, 2007; Dangelico and Pujari, 2010).

Finally, the conceptual models can represent a key argument or a relationship between elements, such as environmental policies and eco-innovation process (Eiadat et al., 2008; Dupuy, 1999). Through this approach, it is possible to test hypotheses and investigate cause-and-effect relationships between different theories and factors. It provides a more comprehensive understanding of the antecedents and the consequences of environmental innovation practices and illustrates ways in which an eco-innovation strategy is influenced by environmental pressures (Li, 2014;

Eiadat et al., 2008).

The results show a trend in models dedicated to the process of eco-innovative product design, diagrams illustrating the flow of the determinants of eco-innovation, and models focused on problem solving approach. Thus, it is evident the strong focus on technological innovations towards sustainability, and the models tend to outline their design and deterministic flows. Moreover, there is a trend in the use of methodologies for the early stages (ideation), as TRIZ. However, there are few models that face the social aspects of sustainability or the organizational management system with exclusive focus on service.

5.2. Gaps and opportunities for future research

Regarding the research area, content and predominant characteristics: The results show a trend in the modeling of eco-innovative design process, in diagrams of the determinants of eco-innovation and in models focusing on problem-solving approach. However, the organizational models that conduct eco-innovation to the strategic level of the company were not given a central place. Although eco-innovation occurs not only in products and processes, but also in organizational models and systems (Porter and Van Der Linde, 1995; Belin et al., 2009), there is a lack of models related to structural factors of the company (specific skills, environmental capacity, culture, leadership). Two models can be highlighted as examples: the “Ecosmes” method (Buttol et al., 2012) provides a comprehensive and integrated offering of information, training and tools for supporting SMEs through all of the phases of the eco-innovation process; and the “Green flagging” framework (Arnold and Hockerts, 2011) describes a new corporate sustainability innovation strategy with nine key elements in the innovation process. Besides, neither models focused on the social aspects of sustainability, education, inclusion and community appreciation, as well as models specifically focused on service, have ample prominence. The diagram “IRW-formula” (Hautamäki, 2010) illustrates a model of eco-innovation proposal based on the reproduction of capital and on improvement of the well-being. Although research has raised some models that deal with incremental and radical eco-innovations, it is possible to see a gap for approaches that have a broad strategic focus, unlike the models that only aim at the characterization and differentiation of these types of innovation. The framework proposed by Van Oppen and Brugman (2011) is an organizational design model for eco-innovation that can be used as an organizational analysis model. In this sense, there can be highlighted opportunities for models that reflect the sustainable-innovation potential of the organization. Therefore, the dealings will be in strategic, structural and management factors, in order to develop radical and disruptive eco-innovations.

Regarding the level of generalization: It is worth mentioning the large number of generic models, despite their different approaches. This feature shows great coverage of knowledge of the field, providing vast departure platforms for various types of applications and the development of new methods and tools to support planning, implementation or evaluation of eco-innovation. Furthermore, the present research found few models adapted to either segments, systems or brands. This way, there were few systemic and value chain models that encompass all elements and relations between internal and external context of eco-innovation. The MGE2 - Genomic Model of Eco-innovation and Eco-design (Peralta et al., 2012) is an example of a systemic model based on environmental management standards, and it comprehensively illustrates the environment, tools and techniques for eco-innovation.

Regarding the modeling type: The analysis highlights the predominance of interactive models (through diagrams and conceptual models, mainly) with a strong focus on the relational dynamics of the eco-innovation elements. Furthermore, the review highlighted several frameworks describing in details the best practices for sustainable innovation. On the other hand, there is a gap of models that present method features. It highlights opportunities for the development of new structured procedures for the implementation of eco-innovation and new support tools. A suitable example of a complete method to support eco-innovation is “Ecosmes.net” (Buttol et al., 2012), which provides a comprehensive and integrated offer of information, training and tools for supporting SMEs through all of the phases of the eco-innovation process.

Regarding the level of detail: Another gap regards the models with in-depth level of detail. The majority of the analysed models has succinct level, with no conclusive grounds. This way, it highlights opportunities for doctoral and master’s research. In Cluzel’s thesis (2012) it is possible to see the high level of detail of the model, focused on ideation stage of eco-innovation process at Alstom company. It is noteworthy that, in the event of final publication in an article, it is important to refer to the original research thesis in order to allow the reader to research it if it deems appropriate.

Regarding the characterization of the models: A significant gap stands regarding the normative characterization of the models. This characterization is reflected into guidance to organizational behaviour. The process model proposed by Aguado et al. (2013) illustrates this normative character, guiding efficient and sustainable improvements in the lean production system through environmental innovation processes. Therefore, despite the descriptive models are essential for illustration of a reality or scenario, it is through the normative models that improvements emerge and an ideal performance standard is possible to be applied.

Regarding the development level: One opportunity verified is the application of the non-experimental models, first as a way to evaluate the theoretical proposition and then for a methodological verification and validation of the model. The generic method Ecosmes.net (Buttol et al., 2012), tested on European SMEs, and the process model proposed by Cluzel (2012), adapted to Alstom, illustrate two approaches that have been consolidated through experimentation. Thus, it is possible to note opportunities for new models to be tested and adapted to segments not yet studied, such as: information technology; biotechnology; mechatronics; food; pharmaceutical; automotive; construction; military; naval.

6. Conclusions

The aim of this study was to present gaps and opportunities for the advancement of the field, outlining promising directions regarding potential research areas, contents and predominant characteristics for new eco-innovation models. Thus, it is intended to answer the main research question: *which research gaps currently exist and what research directions may be promising in the field of eco-innovation models?*

To answer the research question, the models were analysed with respect to their research areas, predominant characteristics, research methods, level of detail and development, application sectors, among other factors. Consequently, it is possible to highlight as gaps and promising opportunities for future research in the field of eco-innovation models:

- a gap of models that present characteristics of method, through structured procedure for implementation of eco-innovation or for a stage of eco-innovation as well as its supporting tools;
- a lack of models related to structural factors of the company (specific skills, environmental capacity, culture, leadership), of models related to social aspects of sustainability, of models focusing on service, and also of models that reflect the high sustainable-innovation potential of the organization;

- there are few adapted models to segments, systems or companies. Thus, there are opportunities for systemic models and value chain, which encompass all elements and relations between internal and external context of eco-innovation;
- a significant gap in the normative characterization of the model. It is through the normative models that applications and standard of a ideal performance for future research opportunities are developed;
- few are the models with in-depth level of detail, what increases the possibility for new dissertations, theses and books;
- application opportunity of the non-experimental models in segments not yet studied, such as: information technology, biotechnology, mechatronics, food, pharmaceutical, automotive, construction, military, naval;
- despite some research focus on PSS companies, no model of eco-innovation was proposed specifically to a service industry. Similarly, some studies have had their studies applied to SMEs, but no model direct at small TBCs (technology-based companies). Therefore, this field of knowledge is still ample for new researchers.

Among the challenges for the development of this research, it is worth highlighting the lack of consensus regarding terminology and vocabulary in the field of knowledge of eco-innovation, the impossibility to analyze the number of citation of the models (due to the lack of data for certain types of publication), and the fact that some studies may not have been identified in the search process. In addition, this research does not exhaust all the methodological possibilities, classification and analysis. Other methods may be used for exploratory analysis of the literature, as well as new criteria for classification and investigate its results.

Nevertheless, the objectives were achieved, enabling promising directions for further research in the area and helping to consolidate knowledge in eco-innovation. Finally, there are considered contributions of this research: the mapping and classification of studies that develop models of eco-innovation, the promotion of opportunities for researchers develop new research on the subject, and the identification numerous gaps in the development of new models of eco-innovation.

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Appendix A

An analytical framework was developed to explore the diversity of eco-innovation models and to present suggestions according to the various classification criteria presented in topic 4. One summarized framework is presented below for each of the six major research areas: innovation process, management and strategy; product design and innovation; environmental management, strategy and policy; business strategy and organizational management; supply chain management and sustainability; industrial ecology and ecological economics. These frameworks include the sub-areas of research, the model approach, the model characterization, the application sectors, and the level of generalization of the eco-innovation models, as well as the gaps and research opportunities. The complete analytical framework, with all classification criteria, can be requested by e-mail to the authors.

Innovation process, management and strategy

Reference	Name	Brief Description	Research Area	Model Approach	Model Characterization	Application Area	Generalization Level
Rennings (2000)	Determinants of eco-innovation	a conceptual framework that considers three peculiarities of eco-innovation: technology push; regulatory push; market pull	innovation management	diagram	descriptive	NA	generic
Albers and Brewer (2003)	Eco-innovation Model	a model to assist organizations in building innovative qualities and knowledge management practices	innovation strategy	diagram	descriptive	NA	generic
Dangelico and Pujari (2010)	A conceptual framework for green product innovation	a conceptual framework that presents three key environmental dimensions of green product innovation identified in the life cycle phases of products	innovation strategy	systemic model	descriptive	SMEs manufacturing companies in Italy and Canada	generic
Van Oppen and Brugman (2011)	Sustainable Innovation Model	a framework for conducting business to the maximum level of eco-innovation	innovation process	framework	normative	NA	generic
Van Bommel (2011)	A conceptual framework for analyzing sustainability strategies in industrial supply networks from an innovation perspective	a conceptual framework that analyzes and understands the implementation process of sustainability in industrial supply networks	lean manufacturing	diagram	descriptive	NA	generic

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Reference	Name	Brief Description	Research Area	Model Approach	Model Characterization	Application Area	Generalization Level
Peralta et al. (2012)	MGE2-Genomic Model of Eco-innovation and Eco- design	a model based on environmental management standards and that illustrates the environment, tools and techniques for eco-innovation	technology innovation	systemic model	normative	furniture manufacturers products (office chair design)	generic
Chen and Chen (2014)	Conceptual model for environmental innovation practices and performance	a conceptual model for the relationships among institutional pressures, environmental innovation practices, resource commitment and performance	innovation management	conceptual model	descriptive	manufacturers in Pearl River Delta	generic
Chen et al. (2014)	The Determinants of Green Radical and Incremental Innovation Performance	a research framework about Green Shared Vision, Green Absorptive Capacity and Green Organizational Ambidexterity	innovation management	conceptual model	descriptive	Taiwan's electronics industry	generic

Gaps and opportunities for future research

There are diagrams, systemic models, conceptual models and framework approaches. No methods, flowcharts or process models. Emphasis on experimental and qualitative models, with a predominance of theoretical and conceptual models. Therefore, there were no suitable models. Most had descriptive character. Only two systemic models for innovation management and sustainability, focused on product eco-design. Two models that addressed structural factors of the company and only a model that includes the strategic

Product design and innovation

Reference	Name	Brief Description	Research Area	Model Approach	Model Characterization	Application Area	Generalization Level
Foster and Green (2000)	'Network' links and information flows for greening the innovation process	flows of signals relating to product and environmental performance for an idealized business	product design	diagram	descriptive	UK manufacturing companies	generic
Herrmann et al. (2007)	Life Cycle Innovation model	a descriptive framework that is explicitly applicable for environmental driven innovations	product innovation	systemic model	descriptive	NA	generic
METI (2007)	The scope of Japan's eco-innovation concept	a integrated application of sustainable manufacturing that focuses less on products' functions and more on the environment and people	green product innovation	systemic model	descriptive	Japonese productive sector	adapted (system)
Eiadat et al. (2008)	Conceptual model of environmental innovation strategy	a theoretical model that represents the key argument that environmental innovation strategy influences firms' business performance	product design	conceptual model	descriptive	chemical industry in Jordan	generic
Hautamäki (2010)	IRW-formula	a model of eco-innovation based on the reproduction of capital and improvement the well-being	green product innovation	diagram	descriptive	NA	generic
Potts (2010)	The natural advantage model	the model identifies drivers, transformative measures and outcomes as phases through which a region will move to build natural advantage	product/service systems	diagram	normative	manufacturers in New South Wales	generic
			product design	framework	descriptive	NA	generic

(*continued*)

Reference	Name	Brief Description	Research Area	Model Approach	Model Characterization	Application Area	Generalization Level
Demirel and Kesidou (2011)	General model of eco-innovation	a model of the characteristics specific to each type of eco-innovation, in line with the OECD framework (2009)					
Chen and Huang (2011)	Flowchart of the PSS eco-innovation process	a PSS eco-innovative design methodology, with a flowchart of the design process for PSS eco-innovation divided into three-stage process	eco-design	flowchart	normative	European PSS companies	generic
Simpson (2011)	A Framework for Implementing Sustainable Oral Health Promotion Interventions	a model related to the stages of innovation implementation and factors that affect sustainability	eco-design	process model	normative	US addiction treatment programs	adapted (segment)
Del Río et al. (2011)	Integrated framework of the impact of external and internal drivers on eco-innovations	a framework that shows the interactions between internal and external factors of eco-innovation	eco-design	diagram	descriptive	eco- innovative products and services	generic
Aguado et al. (2013)	Model of efficient and sustainable improvements in a lean production system	a model for improvement in a lean production system through environmental innovation processes	eco-design	process model	normative	metallurgical products (forming tube)	generic
Bocken et al. (2014)	Sustainable business model archetypes	a categorization model of eight sustainable business model archetypes	eco-design	framework	normative	NA	generic
Chakroun et al. (2014)	Flowchart of eco-innovative design process	an eco-innovative design process that takes into consideration quality and environmental aspects when prioritizing and solving technical engineering problems	eco-design	flowchart	normative	centrifugal spreader product	generic
Kaenzig and Wüstenhagen (2010)	Conceptual Model: LCC of Eco-Innovations and Cost Cognition	a conceptual model of the influence of life cycle cost (LCC) information on consumer investment decisions regarding eco-innovation	eco-design	conceptual model	descriptive	NA	generic

Gaps and opportunities for future research

Great emphasis on eco-design theme; the models were presented in various types of approaches, with the exception of method; most of the models are experimental and qualitative, especially when it comes to the case study method; despite being applied studies, only two models are adapted to a system and to a segment; most have descriptive and succinct level of detail; just one model focused on the social aspect, and one model that incorporates service.

Environmental management, strategy and policy

Reference	Name	Brief Description	Research Area	Model Approach	Model Characterization	Application Area	Generalization Level
Dupuy (1999)	Environmental-innovation model	a framework that shows the relationship between environmental policies and eco-innovation process	environmental policy	conceptual model	descriptive	water and wastewater Technology Sub-Sector	generic
Noci and Verganti (1999)	Framework with the actions necessary to implementation of green innovation strategies	a framework that illustrates the implementation of green innovation strategies through actions on the levers of the technology strategy	environmental management	framework	normative	SMEs in Lombardy (Italy)	generic

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Reference	Name	Brief Description	Research Area	Model Approach	Model Characterization	Application Area	Generalization Level
Jones (2003)	Recommended process for eco-innovation	a model of eco-innovation process focused on the early stages of idea generation and tools	environmental policy	flowchart	normative	NA	generic
Chang and Chen (2004)	Flowchart of eco-innovative design process	it presents an effort in developing eco-innovative design process and multi-contradiction problem solving approach	environmental policy	flowchart	normative	NA	generic
Verloop and Wissema (2004)	The value-driven model for sustainable innovation	a model that reflects the required interaction among its three drivers: business, society and technology	environmental policy	diagram	descriptive	(Shell) Oil Company	generic
Hallenga-Brink and Brezet (2005)	The sustainable innovation design diamond model	a process model of sustainable innovation in product-service combination development (based on Roozenburg and Eekels, 1991)	environmental policy	process model	descriptive	micro-sized enterprises in the tourism industry	generic
Van Hoof and Herrera (2007)	Environmental Developments effects over the Colombian productive sector (2007−2010)	it presents the developments related to the integration of the environmental variable in the center of Colombia's competitiveness	sustainable innovation policy	systemic model	descriptive	Colombian productive sector	adapted (system)
Kanerva et al. (2009)	Qualitative model for environmental innovation	a qualitative model that presents the eco-innovation chain	environmental policy	systemic model	normative	NA	generic
OECD (2009, p.13)	Conceptual relationships between sustainable manufacturing and eco-innovation	an illustration of the general conceptual relations between sustainable manufacturing and eco-innovation	environmental strategy	framework	descriptive	NA	generic
OECD (2009, p.15)	A proposed framework of eco- innovation	an overview of eco-innovation and its typology (in terms of target), mechanism and impact	environmental management	framework	descriptive	NA	generic
Arnold and Hockerts (2011)	Green flagging in the innovation process	it describes the concept 'green flagging' as a new corporate ssustainability innovation strategy with nine keyelements in the innovation process	environmental strategy	framework	descriptive	electronic company (Philips)	adapted (company)
Blaise (2014)	Eco-innovation process	a model of 6 stages of the eco-innovation process	environmental strategy	process model	descriptive	NA	generic
Santos et al. (2014)	Sustainable competitiveness of the Brazilian biodiesel chain	a conceptual model based on five structural dimensions that influences the Brazilian biodiesel supply chain	environmental strategy	diagram	descriptive	Brazilian biodiesel supply chain	adapted (system)

Gaps and opportunities for future research

Emphasis should be given to the theme of environmental policy; no approach stands over the other, and there was no method among the models. Most of the models are experimental and almost all are qualitative, especially the case study and theoretical-conceptual models. However, only two models are adapted to a system and business. Most have descriptive characteristics and are succinct. No model with international application. No model focusing on any social aspect.

Business strategy and organizational management

Reference	Name	Brief Description	Research Area	Model Approach	Model Characterization	Application Area	Generalization Level
Samet (2010)	Eco-MAL'IN - Méthodes d'Aide à L'Innovation	a method of 5 steps to problem analysis and searching of eco-innovative solution	behavioral research	method	normative	appliance products	generic

(*continued*)

Reference	Name	Brief Description	Research Area	Model Approach	Model Characterization	Application Area	Generalization Level
Buttol et al. (2012)	Ecosmes.net	an innovative approach to support product eco-innovation in SMEs	business strategy	method	normative	European SMEs	generic
Cluzel (2012)	Time line of the eco-innovation process at Alstorn Grid PEM	a model focused on the ideation stage of eco-innovation process	business strategy	process model	normative	electrical networks	adapted (company)
Rashid et al. (2014)	Conceptual diagram of eco-innovation towards sustainability development	a conceptual diagram that differentiates radical and incremental eco-innovations	institutional theory	diagram	descriptive	NA	generic
Triguero et al. (2014)	Framework of eco-innovations adoption	a framework that distinguishes external and internal (firm-level) factors that may influence eco-innovators' strategies	knowledge management	diagram	descriptive	European SMEs	generic

Gaps and opportunities for future research

There are diagrams, process model and method approaches. Only one theoretical model. This is the only area that presented models already consolidated. Most of the application was through case study, but only one model is adapted to a company. Although one of the models can be considered with complete level of detail, most are succinct. Absence of systemic model and frame work that addresses all managerial process of eco-innovation, including external and internal aspects of the organization and their interactions.

Supply chain management and sustainability

Reference	Name	Brief Description	Research Area	Model Approach	Model Characterization	Application Area	Generalization Level
Takhtay (2011)	SAMPO model of eco- innovation	a model developed by Lahti School of Innovation (2011), based on innovation activities, design, and clean technology of Päijät-Häme region	supply chain and sustainability	framework	descriptive	Päijät-Häme region, Finland	adapted (system)
Comas (2012)	Eco-REFITEC Methodology	a model that outlines the flow of 6 work packages of the naval sector	supply chain and sustainability	process model	normative	shipbuilding industry	adapted (sector)

Gaps and opportunities for future research

One of the models is a descriptive framework of a value chain in a region of Finland, and the other a policy development process model, specific to the naval industry. Both models are experimental with application through case study. Furthermore, these models are adapted to a system and to a sector with succinct details. There are no systemic models of the value chain area, nor diagrams and flowcharts for process steps, or even conceptual models for hypothesis testing.

Industrial ecology and ecological economics

Reference	Name	Brief Description	Research Area	Model Approach	Model Characterization	Application Area	Generalization Level
Chen and Chen (2007)	Flowcharts of eco-innovation method by TRIZ contradiction matrix	an eco-innovative design methodology based on the use of TRIZ method to innovate the new concepts of smart active fasteners for active disassembly at the end-of-life stage of products	regional development	flowchart	normative	appliance products	generic
Yang and Chen (2012)	The flowchart for designing a new eco-product	a design flowchart that describes the main approaches for designing a new eco-product with the TRIZ, LCA and CBR methods	ecological economics	flowchart	normative	new mobile phone displays	generic
Chen and Chen (2014)	The procedures of eco innovation by integrating ARIZ and biomimetics concepts	it presents an integration of biomimetic concept and ARIZ eco-innovation process for eco-product design	industrial ecology	framework	descriptive	NA	generic

Gaps and opportunities for future research

Among the three models, two were presented in experimental flowcharts with a qualitative approach, through case study and normative characteristics. One qualitative and quantitative framework with modeling method and descriptive characteristics. All models have focused on the use of problem-solving method and they are of regional application, generic and succinct. No model with systemic approach or method, or that addresses the pillars of sustainability.

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