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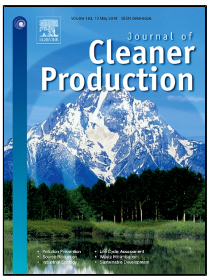

Proposal of a Novel Reference System for the Green Product Development Process (GPDP)

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Proposal of a Novel Reference System for the Green Product Development Process (GPDP)

Abstract

This study aimed to investigate the alignment between environmental sustainability and the product development process of Small and Medium-sized Enterprises that operate in Southern Brazil, as well as to propose a system to assist the execution of a green product development process. To that end, an exploratory research was carried out in two steps: (i) narrative bibliographic review and (ii) a field research. The (i) bibliographic review was conducted in the "Web of Science" and "Scopus" databases. The (ii) field research was executed with managers of 18 industries of different segments. Regarding the theoretical research, results show the state-of-the-art in academic research on product development process and sustainability practices, which provided support for the design of the data collection instrument and for the reference system suggested at the end of the work. As to the field research, results show that the sampled organizations understand the need for product and process environmental sustainability and they define internal drivers for the adoption of adequate practices, adapting such practices to the regulatory pressures and to market demands. Nevertheless, environmental matters do not comprise a dominant topic on product development. In this sense, we propose a reference model that aims to support companies to strategically align environmental aspects to the product development process. Although literature describes specific reference models, the need for a new system is justified since previous models presented specificities, lacked both post development assessment phases and introductory phases of product planning before the conceptual design. Therefore, the reference system proposed present phases that precede the development process (Sustainability-Oriented Organizational Strategic Planning; Portfolio Strategic Planning; and Project Strategic Planning), followed by the development phases (Operational Planning of the Product; Production Preparation; and Product's Launch Plan), and one post-development phase (Market Follow-Up of the Product). Future studies can apply the model in real cases through the action research method.

Keywords: Green Product; Process Innovation; System Efficiency; Sustainable Practice.

1. Introduction

In recent years, innovation related to environmental sustainability has occupied a central place in the scientific debate and in policy makers agenda (Williams et al., 2017). Theoretically, environmental innovation, also named green innovation or ecoinnovation, comprises new or modified products, processes, techniques and/or systems, developed with the aim to avoid or reduce environmental damage (Marchi, 2012). Its practice enables the development of a greater capacity of anticipating market, governmental and societal demands (Lacasa et al., 2016), generating competitive advantage (Dangelico, 2016).

The focus on the development of green innovations causes companies to employ new techniques and technologies, supplying the market with more efficient products and provoking changes in their business models and in their supporting systems (Rajala et al., 2016). Besides, green innovation actions can generate cost management efficiency, once they lead to resource optimization, reduce or eliminate spending associated to environmental legislation and diminish raw material use (Horbach, 2008; Markusson, 2011; Levidow et al., 2016).

In this scenario, for successful green innovation performance, it is mandatory that new product development processes be sustainable (Maxwell and van der Vorst, 2003; Moreira et al., 2015; Lacasa et al., 2016). Conceptually, product development process (PDP) comprises a sequence of activities executed by a company to generate, design and market a product (Pujari et al., 2003). Nevertheless, on the environmental dimension, there is still a lot of potential for the inclusion of ecological aspects in several development phases (Sihvonen and Partanen, 2016; Govidan and Hasanagic, 2018), especially in small and medium-sized enterprises (SMEs) (Chang and Chen, 2013; Klewitz and Hansen, 2014).

Regarding innovation strategy for the promotion of competitive advantage, big corporations are similar to SMEs, since both lack culture and formalized processes oriented toward innovative practices (Terziovski, 2010). Additionally, limited financial resources, human resources with poor qualification to manage environmental issues, and the status received by sustainability inside the organization can compromise the ecological approach of the development processes (del Brío and Junquera, 2003; Chang and Chen, 2013). These characteristics tend to hamper the implementation of the necessary transformations to comprehend and implement circular economy-related concepts and tools, such as the cradle-to-cradle approach (McDonough and Braungart, 2002; Jacques and Guimarães, 2012) and the life cycle assessment (Hertwich, 2005; Gmelin and Seuring, 2014a and 2014b, 2018).

In face of the exposed, this study aims to investigate the alignment between environmental sustainability and product development process in SMEs that operate in Southern Brazil, as well as to propose a system that helps on the execution of a green product development process. Small and medium-sized enterprises correspond to 48% of the Gross National Product (GNP) of Brazilian industry (IPEA, 2016). However, reports disclosed by the Brazilian Business Council for Sustainable Development

(CEBDS) highlights that many organizations focus their practices on reactive rather than proactive models of environmentally sustainable management (CEBDS, 2015). In addition, just over a third of Brazilian industrial companies are innovative (IBGE, 2016b) and the country ranks 69th (out of 128 countries) in the Global Innovation Index (GII, 2017). In this sense, the National Confederation of Industry (CNI) has institutionalized a business movement for innovation, which aims to stimulate Brazilian companies' innovation strategy and to broaden the effectiveness of innovation support policies through constructive and long-lasting interactions between institutions, companies, universities, and the public sector (CNI, 2018).

In addition to the exposed in the previous paragraphs, this study is justified on the lack of studies that address green innovation in middle income and developing countries, specially, research related to green product development practices (del Río et al., 2016; Jugend et al., 2017). Additionally, studies reported on the literature indicate the need for the promotion of mechanisms that can assist with the systemic integration between environmental aspects and the product development process (Poulikidou et al., 2014; Sihvonen and Partanen, 2016). Furthermore, reference models that help to insert and to control sustainable practices throughout product innovation management should be created (Gaziulusoy, 2015).

Structurally, this article is divided into six sessions: (i) introduction; (ii) methods; (iii) theoretical background; (iv) results of the field research; (v) discussion and (vi) final considerations.

2. Methods

Considering the objective of the present study, we carried out a two-step exploratory research. Thus, initially, aiming to investigate the theory of green product development process, a bibliographic review was conducted. Afterwards, data was collected with managers that work on companies from different sectors aiming to identify how these companies develop their products, as well as whether environmentally sustainable issues are inserted in the development processes.

For the bibliographic review, we decided to use the narrative method. Narrative reviews are employed to describe the state-of-the-art of a specific subject, both on the theoretical and on the contextual point of view (Schrank et al., 2012). Nevertheless, although this type of review does not provide a methodology for the search of

bibliographical references, we decided to follow a structured roadmap according to the steps described in Figure 1.

Steps for the Narrative Bibliographic Review	Description
Search for sources of information	The authors restricted the search to journals indexed in the "Web of Science" and "Scopus" databases.
Search operationalization	The search was performed through the use of the same keywords in both databases, without time interval restriction and filtering for keyword presence in the article's title and/or abstract and/or keywords. "sustainable product development process"; "green product development process"; "environmental innovation"; "green innovation"; and "eco-innovation".
Selection of articles to be read and systematized	After the exclusion of the duplicates, the selection occurred through the reading of the abstracts and the analysis of fitness between the articles read and the objectives of this study.
Analysis of the selected articles	The selected articles were grouped according to the objectives. Afterwards, we read and selected the relevant contributions, always focusing on the research objectives of this paper. Since we decided to use a narrative review, the authors' personal critical analysis and interpretation is justified.

Figure 1 - Description of the stages of the Narrative Bibliographic Review

For the field research, we used a non-probabilistic sample selected by convenience. In this sampling type, the elements are defined based on the personal judgement of the researchers (Malhotra, 2003). Firstly, based on the assumption that smaller organizations present yet incipient environmental management practices in their product development processes when compared to larger organizations (Deutz et al., 2013), we defined the universe of interest to be consisted of small and medium-sized enterprises of Southern Brazil.

Thus, 18 cases were selected based on the analysis of the criteria of (i) ease of access to the companies, (ii) the participants' comprehension on the theme investigated and, also, (iii) the economic importance of such organizations for the region (the summed gross industrial production of the sectors under research corresponds to 35,98% of the region's total production, also, the sectors under study employ more than 41% of the manufacturing industry jobs, according to data from IBGE, 2016a). Table 1 presents a characterization of the researched sample.

Table 1 - Sample characterization

Sector	Total of Organizations Researched	Number of employees
Metal-Mechanic	7	70
Textile	5	110
Food	2	46
Furniture	2	21
Printing	2	31
TOTAL	18	278

The research instrument used for data collection was a questionnaire which encompassed both open and closed questions. Open questions aimed to provide researchers with a better understanding of the companies' PDP, analyze whether sustainable practices were aligned to the organization's strategic planning, and understand how sustainability was inserted in the product development process, that is, the actions, methods and/or tools used. Closed dichotomic questions (yes or no) were designed to verify how the formal PDP steps are conducted, as well as the possibility of inserting sustainable practices in the PDP. Closed questions of the "item ranking scale" type aimed to assess managers' perception of importance of variables associated to the structure of the PDP and to the execution of sustainability-related activities throughout the process.

Before its application, the questionnaire underwent the validation of three experts (one from the Marketing field, one from the Environmental Engineering field, and one from the Industrial Engineering field). Additionally, still regarding collection procedures, the instrument was personally applied by the researchers in previously scheduled meetings.

Regarding the data analysis procedure, we employed frequency analysis and univariate statistics (involving the calculation of the average and the standard deviation). Finally, based on both the bibliographic review and the data derived from the field research, we propose a reference system for the management of the green product development process.

3. Theoretical Background

The term "product development process" (PDP) encompasses a set of activities which, based on market needs and on the technological restrictions and possibilities, aims to meet project specifications of a product and its production process to enable its manufacturing (Brown and Eisenhardt, 1995). PDP can also be defined as the

implementation of steps that move the product from the concept to its launch (Cooper, 2008; Kahn et al., 2012). Therefore, PDP involves a sequence of practices in which information is processed through the decomposition of project steps into smaller subtasks (Ahmad et al., 2013; Holahan et al., 2014).

PDP main characteristics are the use of multifunctional teams, a formal and structured process, and market planning (Pujari, 2006; Genç and Di Benedetto, 2015). There is not one single development practice that suits all projects, therefore, the choice of the process to be followed must be determined by the project's characteristics (van Hemel and Cramer, 2002; Choi et al., 2008; Brones et al., 2014). Nevertheless, currently, in face of the need for sustainable managerial and operational practices, environmental issues must be encompassed within product development practices, regardless of the reference model used to orient the process (Baumann et al., 2002; Albino et al., 2009; Sihvonen and Partanen, 2016). Additionally, as Jacques and Guimarães (2012) described, the addition of environmentally responsible activities throughout the product development stages encompasses an important change toward the "cradle-to-cradle" approach.

In this scenario, a great body of research has been carried out to diagnose practices and to propose suggestions of green aspects to the PDP of organizations of different sectors, sizes and geographical locations. Based on the theoretical review developed for this research, we decided to group the analyzed research into three dimensions: (i) studies that focus on the integration of sustainable practices into product development process models that already exist; (ii) studies that propose specific models for green PDP; and (iii) studies that present and test tools to be used in sustainable development processes (see Figure 2).

Although some of the studies do not specifically address small and medium-sized enterprises (which are the object of this study), we considered all the selected contributions to be relevant, mainly to orient the design of a reference system for green product development. As described by Klewitz and Hansen (2014), small and medium-sized enterprises (SMEs) present product, process and management innovation practices that are, frequently, inspired on the actions of large organizations. Also, as verified by the authors, SMEs that present environmentally-related proactive behaviors have greater capabilities of generating radical innovations and stablishing cooperative networks with their stakeholders.

Synthesis of the Papers Analyzed	
Proposition of sustainable practices to be integrated into the PDP	Cooper (1994); van Weenen (1995); Brezet (1997); Polonsky and Ottman (1998); Simon et al. (2000); Baumann et al. (2002); van Hemel and Cramer (2002); Pujari et al. (2003); Bhamra (2004); Petrick and Echols (2004); Pujari et al. (2004); Johansson and Magnusson (2006); Luttropp and Lagersfedt (2006); Pujari (2006); Choi et al. (2008); Luh et al. (2010); Hallstedt et al. (2010); Tsai (2012); Deutz et al. (2013); Hallstedt et al. (2013); Brones et al. (2014); Gmelin and Seuring (2014a, 2014b and 2018); Johansson and Sundin (2014); Garza-Reyes (2015); Genç and Di Benedetto (2015); Marcelino-Sádaba et al (2015); Alänge et al. (2016); Saravia-Pinilla et al., (2016); Costantini et al. (2017); Depping et al., (2017); De los Rios and Charnley (2017); Hallstedt and Isaksson (2017); Zimmerling et al. (2017).
Proposition of specific reference models for Green PDP	Nissen (1995); Hanssen (1999); Nielsen and Wenzel (2002); Maxwell and van der Vorst (2003); Maxwell et al. (2006); Tingström et al. (2006); Byggeth et al. (2007); Fargnoli et al. (2014); Brones and de Carvalho (2015); Moreira et al., (2015); Pacelli et al. (2015); Lacasa et al. (2016).
Tools to be used in the Green PDP	Bras (1997); Knight and Jenkins (2009); Dangelico and Pantradolfo (2010); Vinodh and Rathod (2010); Askham et al. (2012); Bovea and Pérez-Belis (2012), Bereketli and Genovois, (2013); Hede et al. (2013); Chan et al. (2014); Vinodh et al. (2014); Wang et al. (2015); de Souza and Borsato (2016); Buchert et al. (2017); Rodrigues et al. (2017); Schöggl et al., (2017).

Figure 2 – Synthesis of the analyzed papers

Regarding the **(i) proposition of sustainable practices to be integrated into the PDP**, Cooper (1994), in the last century, suggested a hierarchical system for waste management, which significantly contributed to the creation and application of the 3R principles (resource reduction, reuse, and recycling) in the development processes. Yet, van Weenen (1995) addressed the importance of designing products for a long service life, which afterwards based such approaches as the green design and design for efficient longevity. Brezet (1997) defined four steps for the promotion of innovation through eco-design (product improvement; product reproject; innovation through functionalities; and innovation through systems).

Johansson and Magnusson (2006), Pujari (2006) and Genç and Di Benedetto (2015) highlight the importance of integrating environment specialists in new projects of product development. Simon et al. (2000), van Hemel and Cramer (2002), Bhamra (2004), Luttropp and Lagersfedt (2006), and Hallstedt and Isaksson (2017) present a set of justifications for sustainable design to be integrated in the initial phases of the PDP (before the conceptual project). In this sense, Baumann et al. (2002), Pujari et al. (2003 and 2004) e Alänge et al. (2016) emphasize the importance of an organizational strategic orientation towards the inclusion of environmental aspects in the PDP.

Still et al. (2004) and Costantini et al. (2017) describe the need for a heuristic approach, by prioritizing technological trajectories and supply chain management for decision making in green product development. Choi et al. (2008) and Luh et al. (2010)

stablish methodologies to enable the integration of environmental and business issues for decision making throughout the project of new products. Hallstedt et al. (2010) emphasize the need for adequate practices of organizational communication for the successful integration of sustainable elements in the PDP, while Tsai (2012) and Brones et al. (2014) highlight the importance of mapping the environmental requirements to be considered throughout the project.

Deutz et al. (2013) state that good practices of environmental design must be defined so companies can qualify their development processes. Hallstedt et al. (2013) mapped key elements for the successful development of sustainability strategies in the initial steps of the PDP. According to the authors, an adequate product development process depends on the existence of a corporate strategic plan that encompasses sustainability. Furthermore, the involvement of stakeholders in the initial phases of the process is also necessary, as well as, the use of tools that enable performance assessment, and consequently, learning and repeating actions that lead to successful innovations.

Gmelin and Seuring (2014a, 2014b and 2018) reinforce the importance of the adherence of product life cycle assessment to the PDP management, which is a widely known tool that assists the green product design based on a "cradle-to-cradle" approach. Johansson and Sundin (2014) and Garza-Reyes (2015) compared the concepts of lean product development (LPD) and green product development (GDP), verifying the similarities between the concepts, as well as the important differences (such as the objective and focus, value creation, process structure, performance metrics and the tools/techniques used). Yet, Marclino-Sádaba et al. (2015) developed a framework based on the assumption that the use of project sustainability criteria in project processes, organization's strategy, and in project managers' training are necessary elements to successfully integrate environmental sustainability to the PDP.

According to Saravia-Pinilla et al. (2016), it is necessary to apply designing methods in the PDP that are compatible with ergoecology (human + environmental aspects). By means of an empirical study, Depping et al. (2017) demonstrate the value of the environmental assessment application to the product development and to the selection of processing technologies. De los Rios and Charnley (2017) highlight that the insertion of sustainability issues in the PDP demands the development of specific competences and abilities, which vary from technical matters, such as a more profound

knowledge regarding material composition, to broader issues, such as the comprehension of social behaviors. Finally, Zimmerling et al. (2017) evidence the benefits of user integration in all stages of the innovation process to develop new green products and services.

In sum, research grouped in dimension (i) comprehend both operational actions, to be conducted in the different steps of the product development process, as well as strategic and governance actions. Studies with an operational focus present a description of ways to environmentally qualify the project and production planning steps (Cooper 1994; Yet and van Weenen, 1995; Brezet, 1997; Johansson and Sundin, 2014; Garza-Reyes, 2015; Saravia-Pinilla et al., 2016; Depping et al., 2017), the need for ways to identify environmental requirements that will be considered during the project with the stakeholders (Tsai, 2012; Brones et al., 2014), life cycle assessment (Gmelin and Seuring, 2014a, 2014b and 2018), and user integration for cocreation practices (Zimmerling et al., 2017). Articles focused on organizational strategy as driver for green activities in the PDP highlight the need to integrate environmental issues in the initial phases of the development process (Simon et al., 2000; van Hemel and Cramer, 2002; Bhamra, 2004; Luttropp and Lagersfedt, 2006; Hallstedt and Isaksson, 2017), the need for an environmentally proactive organizational culture (Baumann et al., 2002; Pujari et al., 2003 e 2004; Deutz et al., 2013; Hallstedt et al., 2013; Alänge et al., 2016), and the need to develop green competencies (Marclino-Sádaba et al., 2015; De los Rios e Charnley, 2017). Finally, governance-related research stresses the importance of an adequate supply chain management (Still et al., 2004; Costantini et al., 2017), the importance of methods and tools to integrate sustainability in the organization and, specifically, in the PDP (Choi et al., 2008; Luh et al., 2010), and the consolidation of organizational communication actions (Hallstedt et al., 2010).

Concerning the **(ii) proposition of specific reference models,** Nissen (1995) suggested a six-step sequence for the development of complex green products (as washing machines, computers and cars), which correlates the definitions and the implementation of functionalities to the environmental impact that methodological product development possibilities can cause. Hanssen (1999) presented a summary of the results derived from the case studies that used the method developed by the Nordic Project for Environmentally Sound Product Development (NEP project), where results indicated that a successful green PDP requires important changes in the infrastructure of

the production, distribution and consumption of energy, in the transport infrastructure systems and in the material cycle management.

Nielsen and Wenzell (2002) described a series of environmental steps for the development of green products to be inserted within the steps of analysis, concept development and detailed development. In parallel, Maxwell and van der Vorst (2003) and Maxwell et al. (2006) present and test a model composed of four macro stages, spanning the development of the concept, the determination of life cycle stages, the determination of the sustainability dynamics for the supply chain management and the optimization of the sustainable impacts. Through a case study, Tingströmet al. (2006) integrated a series of environmental activities in a gate-type model. Byggethet al. (2007) establish a modular, and flexible structure, compatible with the organizational distinct necessities, without restricting the areas involved and emphasizing the relevance of the insertion of tools for green product development.

Fargnoli et al. (2014) propose a more user-centered development approach. The approach named Design Management for Sustainability (DMS) was designed and tested through the application for the redesign of a motorized lawnmower. Brones and de Carvalho (2015) established a conceptual structure that combines scientific constructions to the best practices with five integration principles. Thus, green PDP must contemplate a three-level systemic approach (macro, meso and micro scales), integrating top-down and bottom-up initiatives. According to the authors, the macrolevel encompasses innovation and environmentally sustainable strategies and targets. In the mesolevel, there is the formal incorporation of environmental requisites and, at the microlevel, ecological and personalized tools are implemented, and environmental aspects are integrated into the project management.

Moreira et al. (2015) suggest a new conceptual and integrative design structure in the Green Aircraft Completion. The model proposed by these authors contemplates the involvement of the final consumer, of the suppliers and of the local communities. Pacelli et al. (2015) formulated a design method focused on the minimization of industrial waste. Finally, Lacasa et al. (2016) described a method for product development that gathers traditional design criteria, such as operational principles or use mode and the sustainability requirements, by means of a three-step proposition: production inventory; sustainability assessment; and product redesign.

The analysis of dimension (ii) shows that several green PDP reference models have been proposed. Nevertheless, linking the reference models to the studies from dimension (i), fragilities can be found. The models of Hanssen (1999) and Lacasa et al., (2016) do not present introductory phases for product planning before concept generation, which is a relevant strategic matter highlighted in previous studies. The models of Nielsen and Wenzel (2002), Maxwell and van der Vorst (2003), Maxwell et al. (2006), Byggeth et al. (2007) and Brones and de Carvalho (2015) do not list steps to assess post-development steps, a very important practice to complement life cycle assessment. Yet, some of the analyzed models lack generalization properties due to their specificities (Nissen, 1995; Tingström et al., 2006; Fargnoli et al., 2014; Moreira et al. 2015, Pacelli et al., 2015).

Concerning the **(iii) tools to be used in the green PDP**, Bras (1997) designed a matrix to assess the reduction of the environmental impact in the development process, described in X-Y axis, which relates life cycle periods to the eco-design practices. More recently, Knight and Jenkins (2009) suggest the use of the MET Matrix which can be used to systematize the environmental impact of each product life cycle phase. Dangelico and Pontrandolfo (2010) developed the Green Option Matrix, which uses three dimensions to describe the environmental contributions of a green product (focus on materials, energy or pollution; stage of the life cycle when the benefit occurs and; comparison to traditional products). Vinodh and Rathod (2010) and Bereketli and Genevois (2013) propose green QFD tools and the life cycle assessment for PDP control.

Askham et al. (2012) design a tool to assist in the product development strategic decisions, combining environmental and economic indicators to information from the REACH (European Union's regulation adopted to promote the protection of human health and the environment in face of the risks of the chemical industry). Bovea and Pérez-Beliz (2012) systematize a set of eco-design tools for the product project (tools based on the Design Matrix, on the QFD, on the Value Analysis – VA, on the FMEA, and others, such as life cycle planning and TRIZ).

Hede et al. (2013) establish a framework that encompasses the critical role played by a Muticriteria Hyerarchical Model (MCHM), which must mainly work from the idea screening to the business viability analysis. Chan et al. (2014) and Wang et al. (2015) adopt the concept of LCA as an environmental tool to measure the impact of

new products and add a broader method that integrates Fuzzy Extent Analysis and Fuzzy TOPSIS to assess the environmental performance of different product projects.

Vinodh et al. (2014) describe a model that integrates environmentally conscious quality function deployment, the theory of inventive problem solving (TRIZ) and, the Analytic Hierarchy Process (AHP) into the product development process of innovative and sustainable automobile products. Yet, de Souza and Borsato (2016) developed an assessment tool based on the Stage-Gate model, based on Toyota's set-based approach and on the Management Sustainability Principles of end of life products.

Buchert et al. (2017) developed the Design Decision Support Assistant (DDSA) – an IT-based assistance system – to provide support for product development teams in the selection, scheduling and application of design methods for environmentally sustainable products in the product development process. Rodrigues et al. (2017) generated a set of process-oriented indicators to support and improve the implementation and the management of ecological designs. Finally, Schöggl et al. (2017) suggest a new checklist for sustainable product development.

In a general analysis of the contributions from the studies described in dimension (iii), we found that organizations have a broad set of possibilities to assess and ecologically improve their development processes. When a relationship is established between the tools listed and the models presented in dimension (ii), another gap can be found, since most of the reference models cited do not clearly stress the tools and in which gates such tools must be used.

Finally, although some characteristics of SME environmentally sustainable innovation management differ from those of large companies (del Brío and Junquera, 2003; Chang and Chen, 2013), it is a consensus that environmentally sustainable product development practices must not be considered marginal issues to SMEs (Noci and Verganti, 1999). Organizing the product development process is an important internal competence to enable smaller companies to develop environmentally sustainable innovations competitively (van Hemel and Cramer, 2002; Darnall et al., 2010). Such managerial action can be oriented towards the inclusion of ecologically adequate steps and/or activities to the processes (Ferenhof et al., 2014; Caldera et al., 2018), as well as to the implementation of specific tools (Maxwell and van der Vorst, 2003; Dangelico and Pujari, 2010; Cuerva et al., 2014) or, to the adoption of a new product development process and/or structure (Noci and Verganti, 1999).

4. Results of the field research

The data collection instrument was divided into two major blocks: the first block (i) comprises questions to diagnose how product development processes are structured in the SMEs investigated (tables 2, 3, and 4); the second one comprehends (ii) questions that aimed to verify the sustainable practices in the PDP (tables 5, 6, 7, and 8).

Generally, SMEs do not use structured strategies for innovation (Terziovski, 2010). Nevertheless, SMEs can present characteristics in their PDP that attempt to facilitate the process's organization (Nicholas et al., 2011). Table 2 summarizes the PDP-related practices of the companies sampled.

Table 2 - Practices related to the PDP supporting structure

Variables	Yes	No
There is a reference model for PDP in the organization	10	8
The organization conducts strategic planning	12	6
The project planning is linked to the strategic planning	9	9
The company carries out market researches to assess market-valued attributes	14	4
Other sectors of the company take part in the product development	11	7
Investment in experimentation practices are made	10	8
Investments in new technologies to facilitate the PDP are made	15	3
New product planning is aligned with the production planning	11	7
There is sales planning for the launch of a new product	6	12
There is customer service planning for the launch of a new product	4	14
There is technical assistance planning for the launch of a new product	4	14
There is a communication planning for the launch of a new product	9	9
There is a selling/distribution planning for product launch	9	9
There is a customer satisfaction monitoring after the introduction of a product	10	8

Analyzing the data, the practices related to a higher frequency PDP reference model refer to the technological and market knowledge domain. Comparing this diagnosis to the studies of de Medeiros et al. (2015) and Jabbour et al. (2015), we found that these practices are relevant to insert environmentally sustainable matters within the PDP. At the same time, since reference models describe good practices for process management, by presenting and linking phases and activities to several techniques and methods available (Cooper, 2008; Kahn et al., 2012; Holahan et al., 2014), the finding that 8 organizations do not present a formalized PDP structure is a worrying fact. Organizations that do not have a structured PDP tend to find the addition of environmentally sustainable actions to be more difficult (del Brío and Junquera, 2003; Chang and Chen, 2013).

Aiming to further comprehend the structured models used by the companies, an open question requested managers from companies that use a PDP reference model to describe the structured models. Table 3 lists the most used steps.

Table 3 - PDP steps from organizations that use reference models

Steps	Frequency
Production planning and preparation	10 citations
Concept development based on market specifications	7 citations
Prototyping	7 citations
Concept development from the R&D team	3 citations
Market follow-up after product launch	1 citation

The variables described in Table 3 provide evidence that the PDP analyzed focus on the development stages. Only one company performs post development activities through a market research that aims to assess satisfaction and gather suggestions for possible improvements, as well as product maintenance. Furthermore, none of the organizations that claim to use a reference model to guide development practices considers stages prior to concept development as PDP steps. These characteristics require improvements to enable companies to develop environmentally sustainable innovations competitively (Darnall et al., 2010). As described in the studies of Simon et al., (2000), van Hemel and Cramer (2002), Bhamra (2004), Luttropp and Lagersfedt (2006) and Hallstedt and Isaksson (2017), the environmental dimension must be inserted before the "conceptual project" step. Additionally, to effectively consider the "cradle-to-cradle" approach (McDonough and Braungart, 2002), it is mandatory that companies address product life cycle management after market launch (Jacques and Guimarães, 2012; Gmelin and Seuring, 2014a, 2014b and 2018).

Finally, Table 4 presents the perception of importance of the practices related to the new product development process. In this set of questions, the data collection instrument presents item ranking statements, through which the participants evaluated the described variables indicating a degree of importance from 1 to 10 (1 meaning unimportant and 10 meaning very important).

Table 4 - Managers' perception of importance towards PDP practices

PDP Practices	N	Minimum	Maximum	Average	Standard Deviation
Systematization of a reference model for the product development process	18	4	10	7,94	1,662
Organization's execution of strategic planning	18	5	10	9,00	1,237
Project planning aligned to the strategic planning	18	5	10	8,39	1,539
Conduction of market researches to understand target customers' valued attributes	18	3	10	8,33	1,847
Interfunctional collaboration for product development	18	3	10	7,94	1,798
Investments in experimentation practices	18	3	10	7,61	1,883
Investments in new technologies	18	5	10	8,50	1,618
Product planning is aligned with production planning	18	5	10	9,00	1,455
Sales planning for a new product launch	18	1	10	7,39	3,256
Customer service planning for the launch of a new product	18	1	10	7,22	3,300
Technical assistance planning for the launch of a new product	18	1	10	6,78	3,173
Promotion planning for the launch of a new product	18	1	10	7,50	3,034
Selling/distribution planning for the launch of a new product	18	1	10	7,72	3,340
Customer satisfaction monitoring after the introduction of a new product	18	1	10	8,39	2,355

As shown in table 4, the practices related to organizational management, to project and to product development present high averages. On the other hand, the practices with the lowest importance on manager's perception are the ones related to product launch and its market follow-up. However, since "experimentation" and "interfunctional collaboration" are key factors for the success of green product innovations (de Medeiros et al., 2014; Genç and Di Benedetto, 2015), it is a worrying fact that some managers have assigned a 3 degree of importance to such variables (minimum).

Table 5 summarizes the sustainable practices that SMEs integrate in their PDP. It is important to highlight that the variables listed in the questionnaire considered the contributions from the studies described in section 3, specifically: (i) operational actions, related to the integration of ecological activities in the project planning and production planning steps (Cooper 1994; Yet and van Weenen, 1995; Brezet, 1997; Johansson and Sundin, 2014; Garza-Reyes, 2015; Saravia-Pinilla et al., 2016; Depping

et al., 2017), as well as life cycle assessment (Gmelin and Seuring, 2014a, 2014b and 2018); and (ii) strategic actions (Baumann et al., 2002; Pujari et al., 2003 and 2004; Deutz et alk., 2013; Hallstedt et al., 2013; Alänge et al., 2016).

Table 5 - Sustainable practices approached in the PDP

Variables	Yes	No
The organization's strategic planning comprehends sustainability	12	6
The PDP is sustainable	13	5
The company seeks to develop products with greater environmental performance	16	2
The company seeks to reduce the use of natural resources during manufacturing	11	7
The company develops products with reduced consumption of natural resources during the use phase	10	8
The company develops products with higher probability of recycling	9	9
The company develops products with an extended life cycle	14	4
The company develops products with recycled materials as raw material	9	9
The company develops products that use raw materials with lower environmental impact	9	9
The company transforms waste into new products	14	4
The company focuses in materials savings	18	0
The company uses end-of-pipe technologies throughout the PDP	11	7

Based on the results presented, we identified some relevant practices for the addition of environmental sustainability in the PDP. However, analyzing these results through the proactive optics, we cannot affirm that organizations are either reactive or proactive (Alrazi et al., 2015). Still, it can be stated that the contingencies in which the companies are inserted tend to directly influence the number and the type of sustainable practices adopted (Maletič et al., 2018).

Table 6 presents the most cited variables on the question about how sustainability was addressed in the company's strategic planning. Only respondents who stated that the strategic planning indeed encompassed sustainability issues answered this question. According to the studies reviewed in section 3, this relationship plays an important role since environmentally sustainable PDPs require organizational strategic orientation (Baumann et al., 2002; Pujari et al., 2003 and 2004; Marclino-Sádaba et al., 2015; Alänge et al., 2016; De los Rios and Charnley, 2017).

Table 6 - Means to incorporate sustainability in the Organizational Strategic Planning

Means	Frequency
Organizational culture focused on waste reduction and material reuse	8 citations
Organizational communication actions to communicate company's employees about cleaner production practices adopted by the company	3 citations
Mapping of opportunities and threats in environmentally-related issues	3 citations
Actions for the proper disposal of the company's waste	1 citation
Life cycle extension of the company's product portfolio	1 citation

When addressing organizational culture, managers mentioned that sustainable practices demand proactive leaders and employees, as well as behavioral change. Theoretically, the studies of Chen (2010) and Chen and Chang (2013), among others, highlight that the elimination of cultural barriers and proactivity are important issues to guide green innovations. Regarding the organizational communication actions, managers highlight that communication enables them to improve predisposition to collaborate. In this sense, Hallstedt et al. (2010) and Albino et al. (2012) stress that the predisposition of different areas to collaborate is determinant to reach sustainability targets. Finally, regarding mapping threats and opportunities in environmentally-related issues, another manager commented that stakeholder integration encompasses an opportunity to reach organizational sustainability. In this line, De Marchi (2012), among other researchers, have identified that establishing partnerships with different stakeholders positively influences companies' green practices and policies.

Table 7 presents the most cited variables regarding the environmental sustainability aspects inserted in the PDP. Based on the theoretical contributions from section 3, we aimed to understand and analyze the operational, strategic, and governance activities and tools used by companies, which were not embraced by the list of variables described in Table 5.

Table 7 - Means to integrate environmental sustainability in the PDP

Means	Frequency
Waste reduction	3 citations
Proper waste disposal	3 citations
Green supply chain	2 citations
Development of byproducts	2 citations
Avoidance of production waste	2 citations
Production leftover reuse	2 citations
Recycling	2 citations
Investment in the development of products with higher yield	1 citation
Investment in the development of products with reduced environmental impact during use	1 citation

According to data, it is evident that most of the means refer to operational aspects, which are closely related to the 3R principles (resource reduction, reuse and recycling) (Cooper, 1994). Nevertheless, it is important to highlight that some managers highlighted the adequate management of the supply chain (a governance-related variable) for the development of green innovations (Still et al., 2004; Costantini et al., 2017). Additionally, although strategy-related variables were not cited in this question,

some of these variables have already been contemplated in the previously analyzed questions. Finally, managers' lack of knowledge about tools was evident. In fact, although some respondents listed actions related to life cycle assessment, it is inferred that there is lack of expertise regarding the procedures to operationalize LCA, as well as to other methods and tools designed and tested by academia.

To conclude the description of the results, Table 8 summarizes the degree of importance assigned by the managers to the addition of sustainable practices throughout the PDP.

Table 8 - Perception of importance towards sustainable practices in the PDP

Sustainable Practices in the PDP	N	Minimum	Maximum	Average	Standard Deviation
Strategic planning addresses sustainability	18	5	10	8,78	1,478
Investments in the development of products with higher performance	18	5	10	8,94	1,552
Investments in the reduction of natural resource usage during the production process	18	5	10	8,78	1,478
Investments in the development of products that demand less natural resource usage during the use phase	18	1	10	7,67	2,951
Investments in the development of products with higher recycling probability	18	1	10	7,61	2,993
Investments in the development of products with an extended life cycle	18	4	10	8,44	1,723
Investments in the development of products with recycled materials as raw material	18	1	10	8,11	2,447
Investments in the development of products with raw material of lower environmental impact	18	1	10	8,28	2,421
Transformation of waste into new products	18	1	10	8,61	2,253
The company focuses on material savings	18	5	10	9,33	1,188
End-of-pipe technologies throughout the PDP	18	1	10	8,44	2,640

Analyzing table 8, we observed that, in general, all practices show relatively high averages, varying from 7,61 to 9,33, with a low standard deviation, in most cases (values below 2,0). Thus, we observed that managers do realize the importance of adding environmentally sustainable aspects in the PDP, an important fact for the adoption of a green PDP.

Finally, regarding the sectors studied, it is worth mentioning, according to Maletič et al. (2018), that organizations with similar characteristics (capabilities, performance and activities) can develop different and personalized approaches to manage the business and environmental sustainability interface. In this way, we reiterate

the importance of seeking a proactive posture for the adoption of environmentally sustainable practices (Annunziata et al., 2017), aligned with the application of maturity models (Sihvonen and Partanen, 2016; Brones et al., 2017).

5. Discussion

Transformation towards a more environmentally sustainable society demands greater sophistication in production process management, in addition to important environmental changes, mainly those related to consumption and the view of a linear economy (Seadon, 2010; Ghisellini et al., 2016). In this context, Johnson (2017) points out that sustainable development must be pursued by all companies, be they large, medium or small.

It is known that in many cases, environmental issues are applied in SME as a reactive posture instead of proactive environmental management. Although these companies are skeptical regarding the benefits achieved from environmental actions, sustainability orientation can be incorporated by SMEs through the environmental knowledge associated to the level of experience and capability, in both strategical and operational aspects (Johnson, 2017).

In light of the exposed and based on the inferences from the results of the bibliographic and the field researches, this section describes the proposition of a reference model of green PDP (figure 3).

Initially, we suggest phases before the development process: (i) Organization strategic planning oriented towards sustainability, (ii) strategic planning of the portfolio and (iii) strategic planning of the project. The elaboration of an organization strategic planning oriented towards sustainability leads to the creation of projects and the management of products and services within this green scope. Such concept was presented by Baumann et al. (2002), Pujari et al. (2003 and 2004), Maxwell and van der Vorst (2003), Maxwell et al. (2006), Hallstedt et al. (2013) and Alänge et al. (2016), being a key element for the implementation of a sustainability perspective in the product innovation process.

Afterwards, aligned with the strategic planning focused on sustainability, it is necessary to design the strategic planning of the portfolio, evaluating the life cycle of the existing products (Hertwich, 2005; Gmelin and Seuring, 2014a, 2014b and 2018), proposing the generation of green innovations, and conducting a market research in

order to identify environmental requirements valued by customers (Foster and Green, 2000; Tsai, 2012; Brones et al., 2014). Concepts related to circular economy, such as Solid Waste Hierarchy and Zero Waste can assist managers during this stage.

This is because the Solid Waste Hierarchy stimulates the development of management focused on the reduction of resource usage, reuse and recycle (van Ewijk and Stegemann, 2016). Additionally, the Zero Waste (ZW) approach prioritizes a vision that wastes must be converted into resources, comprehending their holistic management and recognizing that they are important assets to be reused (Zaman, 2014a and 2014b, Hottle et al., 2015; Silva et al., 2017).

The strategic planning of the portfolio must be aligned with the strategic planning of the project. In this stage the priority must be to integrate experts of the environmental field (Polonsky and Ottman, 1998; Johansson and Magnusson, 2006; Pujari, 2006; Genç and Di Benedetto, 2015), to identify the necessary investments in technology seeking the process ecoefficiency (Ageron et al., 2012), to study the economic viability, to clearly list the environmental requirements and to choose the follow-up indicators (Tingström et al, 2006; Byggeth et al., 2007; Depping et al., 2017). Approaches such as eco-design and design for sustainable behavior (DfSB) may serve as alternatives to qualify the project plan and further stages.

In a general way, ecodesign takes into consideration the different aspects of the process and product that may exert a negative environmental impact (Bonou et al., 2016). These aspects include material selection (usage of non-toxic substances, recycled materials), decisions regarding production processes (waste and emissions reduction), products' energy consumption during use, and destination stages at the end of its service life, also taking into consideration such matters as repair and recycling (Kiurski et al., 2017). Yet, the DfSB seeks to control the way that users use the product, ensuring that the use will be environmentally friendly and that it will contemplate the user's behavior comprehension (Lilley, 2009; Tang e Bhamra, 2012). The DfSB contemplates the comprehension of user behavior and the establishment of a desired behavior through the application of strategies leading to such attitudes (Boks, 2012; Lockton et al., 2013). In fact, the DfSB theoretical framework presents, explains and structures possible strategies, proposing design solutions based on these strategies and using case studies to evaluate the acceptance and efficacy of such solutions (Boks, 2012).

As for the development stage, the phases to be followed are: (iv) Operational Planning of the Product, (v) Production Preparation and (vi) Product's Launch Plan. Considering that the environmental impacts appear as the details of the product are defined (Nissen, 1995; Nielsen and Wenzel, 2002), we suggest the development of the Operational Planning of the Product, in which conceptual and detailing issues will be delineated (Maxwell and van der Vorst, 2003; Maxwell et al., 2006).

Subsequently, within the Production Preparation phase, end-of-pipe technologies need to be contemplated. However, besides this reactive action, we suggest that organizations address other practices such as, for example, practices that increase process performance, materials, energy and water savings, shorter idle time in the production line and use of renewable energy sources (Crabbé et al., 2013; Alkaya e Demirer, 2015; Costantini et al., 2017). To conclude the development stage, there is the Product Launch Plan phase. This stage is relevant for the organization to find distribution and commercialization partners engaged in environmental sustainability (Foster and Green, 2000; Brones et al., 2017).

After the development, the next stage is the (vii) Market Follow-up of the products. The possibility presented by this stage is to, primarily, assess the performance according to the Strategic Management of the Portfolio, emphasizing the maintenance of the product in the market. One possible alternative to address this issue would be focusing on the Product Service System concept (PSS), both product-oriented PSS (addition of services of maintenance, repair, training, and consulting), or user-oriented PSS (by not transferring the property to the customer, which favors use maximization, increasing product life cycle to meet the demand) (Tukker, 2004; Morelli, 2006; Annarelli et al., 2016). Reverse logistics and product remanufacturing are also possible alternatives for this step (Pigosso et al., 2010; Pacelli et al., 2015). This stage's implementation is important since the development process' logic should not be linear, instead, it should be systemic. Systemic references comprise an inter-related whole, its characteristics and properties. Also, systemic references are iterative and based on innovation-oriented learning (de Medeiros et al., 2015).

Finally, according to Hallstedt et al. (2013) and Brones and de Carvalho (2015), for a successful integration between PDP and an environmentally sustainable approach, tools of ecologic conception must be associated to the project development. In this sense, analyzing the studies that investigated and/or proposed methodological

alternatives to monitor and facilitate the operationalization of a green product development process, this study suggests, as a priority, but not exclusively, the use of the Green Option Matrix (Dangelico and Pantradolfo, 2010), green QFD (Vinodh and Rathod, 2010; Bereketli and Genevois, 2013) and FMEA (Bovea and Pérez-Beliz, 2012). Such position is justified on the tools' didactic, generalization and ease of comprehension/use capabilities.

Insert figure 3

Figure 3 - Reference system for the green PDP

It is important to highlight that the reference system for the green PDP proposed in this study was conceived with the intention of orienting the development process of small and medium-sized industries in an easy and logic way, seeking to discipline the process and improve PDP's efficiency. The authors understand that such activity is relevant since the internal resources act as drivers for the success of environmentally sustainable innovations according to the strategic view of the dynamic capabilities (Cainelli et al., 2015; Dangelico et al., 2017). However, observing its linearity, one cannot neglect the importance of creative and experimental thinking (Shapira et al., 2017), and of the establishment of open innovation practices (Behnam et al., 2017), mainly on what regards user integration throughout the process (Zimmerling et al., 2017).

6. Final Considerations

After a bibliographic and a field research with SMEs, we found that environmental issues are still not a dominant topic in product development practices, and there is great potential for the inclusion of these practices in distinct phases of the PDP, mainly in the phases before concept generation and in the post-launch phases. Nevertheless, we highlight that operational and strategic matters previously highlighted by academic research on environmentally sustainable product development process are already considered by SME. Among these activities, we highlight the ecologic integration in the project planning and production planning steps, and a strategic planning that contemplates sustainability. Yet, another relevant finding lies on the fact that SMEs are not aware of most of the methods and tools to adapt and assess the PDP's ecological qualification.

Finally, a reference model was proposed, taking into consideration that, although some characteristics of SME's environmental innovation management differ from the characteristics of large organizations, environmentally sustainable product development practices need to be operationalized. It is necessary to highlight that the name "reference model" is used to serve as basis and provide subsidies for companies, so that, these companies can develop specific models for their realities. Thus, despite the study providing reference system proposition, it is important to mention that organizations should customize the reference system according to their needs, objectives, and available resources. Still, observing the inherent complexity regarding current competitive contexts, the linearity serves to guide thinking and communication among stakeholders, but it also needs to be aligned to the flexibility inherent to the competency called "organizational learning".

As for the limitations of the study it is to be noticed that, initially, the proposed system was not applied through action research studies, a fact that could enable its visualization in the practical context of product development management, generating information for the improvement of the reference model. Still, the sample of 18 cases could be enlarged, so that the specificities of other market contexts could be analyzed and contemplated. Therefore, such aspects should be approached in future researches.

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