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New product development: examining its evolution and the introduction of environmental issues

Angelo Varandas Júnior, Eduardo de Senzi Zancul, Paulo A. Cauchick Miguel
Programa de Pós-graduação em Engenharia de Produção, Escola Politécnica, Universidade de São Paulo – USP
e-mails: angelo.varandas@usiminas.com; ezancul@usp.br; cauchick@usp.br

Abstract: Environmental impacts have required a greater commitment of the companies in the search for sustainable solutions for the improvement of the process of new product development (NPD). In this context, the objective of this work is to examine 50 NPD structures, to identify if those structures have considered environmental issues. The publications were located in different databases were accessed to retrieved the publications and a systematic literature review was conducted. The results indicate that there are few NPD structures that take into account environmental issues in order to reduce impact of their product and process. In addition, there are differences in the scope of these structures according to the area of knowledge that proposes them as well as differences in the distribution of the phases in the NPD process according to the characteristics of the developed product. Conclusively, the NPD structures have been constantly developed in the literature. Nevertheless, the integration of environmental issues into NPD structures can be seen in more recent publications, in which such structures seem to minimize the environmental impacts during the product life cycle.

Keywords: product development process, NPD structures, ecodesign, environmental aspects.

1. Introduction

The current competitive market has required more quality and speed when launching new products and, consequently, increased to the complexity of the process of new product development (NPD), generating a concern with the effectiveness of this process (LIN et al., 2006; CROSS; SIVALOGANATHAN, 2007; DUYSTERS et al., 2008). Companies that aim to enhance the development of new products usually adopt organizational structures by process, typically divided into phases combined by a managerial decision points (called gates), whose objective is to assess the progress of projects with regard to various performance aspects involved in project continuity (COOPER, 2008, 2014). These processes may vary in the number of stages and level of detail, depending on the type of product, degree of technology innovation, product and organizational complexity, etc. (CLARK; FUJIMOTO, 1991; CLARK; WHEELWRIGHT, 1993; GARCIA; CALANTONE, 2002).

In addition to the importance of using a NPD structure as a reference model, there are some actions that should be in place to better management (COOPER, 2008, 2014): the product should be differentiated in the market, provide benefits to users, and target an attractive market; the process should spend more time to the pre-development phase, integrate the functional areas involved with NPD, and align the development with the company's strategies, among other issues. Moreover, there is a need to improve NPD management by focusing on the use of support methods and tools, project management practices, team communication support, and senior management involvement (BARCZAK et al., 2009; BARCZAK; KAHN, 2012). However, to effectively structure and manage NPD to achieve positive results is not a simple task, because the NPD is interdisciplinary and multifunctional and, therefore, should be conducted in an integrated manner. For this reason, the NPD is constantly an object of investigation of several disciplines with different perspectives, which usually generate conflicts of interest among various areas such as sales and marketing, engineering, production, and others (MALTZ et al., 2001; HAQUE et al., 2003; KRISHNAN; LOCH, 2005; BRETTEL et al., 2011).

Monitoring the NPD through financial or operational performance measures has a positive impact on its results, as identified earlier (e.g. GRIFFIN; PAGE, 1993; HULTINK; ROBBEN, 1995; DRIVA, H. et al., 2000). Other needs for NPD improvement involve the necessity to integrate the process through multidisciplinary teams and use of technical and managerial support tools to carry out NPD activities, aiming at having a common language among the teams involved in the NPD process (NOBELIUS, 2004; FREDERICKS, 2005; SONG; NOH, 2006; JUGEND et al., 2013).

In addition to the needs for constantly improvement of NPD performance, other issues related to this process are addressed in the literature like the relation of NPD to the life cycle of the product as well as the need to emphasize the environmental issues since the early stages when developing new products. In this context, this work aims to analyze the evolution of NPD structures available in the literature considering their structural and organizational differences. In addition, due to increased environmental requirements by the market, legislation, and society in reducing the environmental impacts of the product during its life cycle, the paper also aims to identify the environmental importance that is given by the analyzed NPD structures.

2. Research methods and procedures

This is characterized as theoretical work, more specifically aimed at the mapping and analyzing NPD structures in the literature. A literature review process was adopted to find out different structures of NPD. This process allows to comprehensively identify and synthesize research results of a particular subject, through procedures to collect and analyze the literature, in a replicable way (LITTELL et al., 2008). Table 1 shows the data bases, strings, and terms used for searching in title, abstract, and full text.

The search generated 677 publications about NPD processes. Some criteria were adopted for filtering the publications. Firstly, only those that meet the purpose of this work were selected. It is important to define the concepts to standardize the understanding (WACKER, 2004) so a definition of NPD structure was chosen to assist in the identification of NPD structures. The following definition was established: "all structured and systematized representations that facilitate the understanding, managing, and control of NPD in an integrated way in order to aid in the decision making". Another term for this definition currently used in the literature is 'NPD reference model'.

In addition, considering the NPD analysis, only structures that represented their phases were selected or those that had textual description good enough for a full interpretation of the NPD structure.

Based on these criteria, 50 NPD structures were select and analyzed to better understand the evolutionary process of these reference models, application areas, and the contents of their phases. The work by Rozenfeld et al. (2006) was chosen as a reference model to represent the phases of the 50 NPD structures found in the literature. This choice is justified by the fact that this NPD structure takes into account an extensive life cycle, which integrates pre-development, development, and post-development macro phases. By this reference model, an analysis was conducted, by breaking up analysis into three periods (60-70; 80-90; and 2000-2013). Moreover, for main concepts and theoretical discussion of these NPD structures, other NPD classic references were used (e.g. PAHL; BEITZ, 1977; CLARK; FUJIMOTO, 1991; WHEELWRIGHT; CLARK, 1992; COOPER, 1993; ROOZENBURG; EEKELS, 1995; ULRICH; EPPINGER, 2012).

3. Evolution of NPD structures

It is important to emphasize that the literature presents several ways to structure the NPD such as quantity of phases, different tasks/activities, use of support tools, according to the contingency of each organization. However, the objective of these NPD structures are virtually the same: they seek to improve resource allocation, enhance information flow, reduce development time and costs, minimize risk and failure, and achieve success after product development (JOHANSSON, 2002; TZOKAS et al., 2004). In addition, NPD structures should clearly represent the NPD operational schema in order to provide a macro view of the process steps and facilitate the understanding of all involved as well as to support decision making (KRISHNAN; ULRICH, 2001).

Moreover, the NPD structure may be specific to a company or generic and applicable to any type of NPD, regardless of the quantity of phases, types of activities, and forms of control (SCHMIDT et al., 2009). On the other hand, it is necessary to consider that the NPD structures are interpreted by different perspectives (people from various functional areas), that focus on specific characteristics of these structures when applied by the companies (RUDDER et al., 2001). Therefore, one should understand that these NPD structures are generic and need to be adapted, according to the characteristics of the project to be developed. As mentioned before, the NPD structures were divided into three distinct periods: from 1960 to 1970, from 1980 to 1990, and from 2000 to 2013. Table 2 illustrates the phases of the NPD structures, according to Rozenfeld et al. (2006) in the first period (1960 to 1970).

During the 60-70 decades, the first NPD structures were divided into phases related to the project development itself in addition to the definition of responsibilities of the areas

Table 1. Search of NPD structures in the literature.

Databases	Strings	Terms of cross search
Compendex; EBSCO/ Emerald; IEEE Xplore/ISI Web of Science; ProQuest; SciELO; Science Direct; Scirus; Scopus; SIbiNet USP	Design; design of product; development of product; innovation; innovation of product; new product; new product development; new product development process; NPD; NPD process; PD; PD process; Product design; product development; product development process; product innovation	Proposed method; proposed methodology; proposed model; reference method; reference methodology; reference model

involved in NPD, also due to a concern with reworking costs and economic viability. Moreover, those NPD structures considered the NPD as a linear system with discrete stages arranged sequentially similar to the tradition project design methodology, with practically no integration of the stages and functional areas.

The central feature of the NPD structures in Table 2 is in collecting and analyzing information to understand the problem, develop the product, test, and implement alternative concepts. Moreover, the NPD structures of this period were developed with the vision of one specific functional area (product engineering) and, consequently, the stages adopted in structuring NPD were towards the interest this area. The analysis also shows that there was no concern with post-development stages in these NPD structures, with function of monitoring product performance and environmental impacts related to the discontinuity and disposal of the product and packaging.

Table 3 presents the NPD structures for the period from 1980 to 1999.

During this intermediate period (80's-90's) there was a significant increase in quantity of NPD proposals.

Table 2. NPD structures in the literature (decades 60-70).

Ref.	NPD stages								
	Pre-development		Development					Pos-development	
	1	2	3	4	5	6	7	8	9
Asimov (1962)	X			X	X	X			
Archer (1971)	X		X	X	X	X	X		
Kotler (1974)	X			X	X		X		
Pahl and Beitz (1977)			X	X	X				
Bonsiepe (1978)	X	X	X	X	X	X			

Note: - stages according to Rozenfeld et al. (2006): (1) Strategic plan; (2) Project management plan; (3) Informational stage; (4) Conceptual stage; (5) Detailed project stage; (6) Production preparation; (7) Launching stage; (8) Product and process monitoring; (9) Discontinuing the product from the market. Source: Literature search and analysis.

Table 3. NPD structures in the literature (decades 80-90).

Ref.	**NPD stages**								
	Pre-development		Development					Pos-development	
	1	2	3	4	5	6	7	8	9
Booz (1982)	X			X		X	X		
Saren (1984)	X		X	X	X	X	X		
Verein Deutscher Ingenieure (1985)			X	X	X	X			
Andreasen and Hein (1987)	X			X		X	X		
Park and Zaltman (1987)	X			X			X		
Suh (1988)	X		X	X	X	X			
Clark and Fujimoto (1991)				X	X	X			
Graf and Saguy (1991)			X	X	X	X	X	X	
Rosenthal (1992)	X			X	X	X			
Wheelwright and Clark (1992)	X	X	X	X	X	X	X		
Cooper (1993)	X	X	X	X	X	X	X		
Urban and Hauser (1993)	X			X	X		X	X	
Automotive Industry Action Group (1994)	X			X	X	X	X		
Fuller (1994)	X			X	X	X	X		
Ingle (1994)	X		X	X	X				
MacFie (1994)				X	X	X	X		
Nijssen and Lieshout (1995)	X			X	X		X		
Rudolph (1995)		X			X		X	X	
Roozenburg and Eekels (1995)	X			X	X	X	X		
McGrath (1996)	X	X	X	X	X	X	X		
Ertas and Jones (1996)	X			X	X	X			
Dickson (1997)	X			X	X		X		
Earle (1997)	X			X		X	X		
Prasad (1997)	X			X	X	X		X	
British Standards Institution (1997)	X	X		X	X	X	X		X
Fleischer and Liker (1997)	X			X	X	X	X		
Peters et al. (1999)	X			X	X	X	X	X	

Note: - stages according to Rozenfeld et al. (2006): (1) Strategic plan; (2) Project management plan; (3) Informational stage; (4) Conceptual stage; (5) Detailed project stage; (6) Production preparation; (7) Launching stage; (8) Product and process monitoring; (9) Discontinuing the product from the market. Source: literature search and analysis.

The improvements have been done due to a number of issues, such as: to reduce the uncertainties and risks of NPD, increase the speed and flexibility for developing new products, organize the information, integrate the activities and functional areas involved in the process, facilitate decision making, improve performance and product quality, meet customer needs, manage the phases of the NPD and, in particular, minimize the differences from the point of view of the various functional areas that started to participate in the decision-making process.

As another contribution from this period, some researchers went beyond their traditional knowledge and origin in order to analyze NPD without a specific vision of a functional area and domains. Those works surely contributed to the NPD theory (e.g. CLARK; FUJIMOTO, 1991; COOPER, 1993; PRASAD, 1997). They focused on consolidating managerial control and NPD integration, which resulted in new approaches such as Integrated Product Development and Concurrent Engineering.

Some NPD structures (e.g. ANDREASEN; HEIN, 1987; ROSENTHAL, 1992; WHEELWRIGHT; CLARK, 1992; PRASAD, 1997) began to partition the process in overlapping stages to increase speed of activities execution and parallel tasks of the process as well as to use managerial and data feedback and loops in the information flow of the different stages to support the decision making process. In general, these NPD proposals developed in those decades used the previous NPD structures as a basis, and added relevant issues in order to have a more comprehensive view of NPD and its complexity.

Moreover, the NPD structures in this period incorporated new methods and tools to support product development, integrated the entire supply chain, and shifted the NPD vision to a company business process focused on fulfilling customer needs. Some quality and product design guides emerged as standards (e.g. VEREIN.., 1985; AUTOMOTIVE..., 1994; BRITISH..., 1997) along with the NPD structures and provided another level of detail and integration of the stages and their interfaces, process documentation, decision making, input and output information, and also indicators to assess NPD performance.

Other NPD structures started to pay more attention to process management (e.g. WHEELWRIGHT; CLARK, 1992; COOPER, 1993), by representing the stages and gates to highlight the need for assessment and control during the progress of the new product development. It is important to note that although those NPD structures encompass a graphic representation of linear stages, most of them are cyclical with loops and feedback in the information flow.

Up to the end of 90s, NPD structures had three key approaches (ROOZENBURG; EEKELS, 1995): (i) A focus on the engineering design phase, which was intended to solve problems and to structure a logical reasoning called the basic design cycle (i.e. analysis, synthesis, simulation, evaluation, and decision); (ii) Focus on segmenting the engineering design, by dividing it into four phases (project specification, conceptual design, final design, and detailed design); and (iii) Concentrate in a NPD phased structure, which consisted of the product design stages, part of the production preparation, and marketing plan. This helped to change NPD vision by seeing it as part of the business.

It is also observed that the NPD structures from this period give low attention to the performance monitoring of the product as well as measures to reduce its environmental impacts, such as use of strategies of recycling, remanufacturing, and disposal of products and packaging. Finally, the project planning stage is not well-highlighted, although it is a relevant theme considered by the authors. Little is demonstrated in the stages of the analyzed NPD structures.

Table 4 shows the NPD structures for a most recent period from 2000 to 2013.

Most recent NPD structures in Table 4 continue to seek to improve the management and integration of NPD. All development stages are used, thus, complementing the NPD structures developed previously. The NPD structures in this period address other NPD-related concerns such as: enhance management practices, consider the entire product life cycle, introduce other support tools, align the organization's strategy with NPD, integrate the supply chain and customers in the NPD process, analyze the implications of knowledge management, improve information flow, and define more evident responsibilities and provide support for decision making. Moreover, some researchers seek to adapt generic NPD structures to particular industrial sectors or for a specific type of product.

Environmental issues became important for companies to remain competitive in the market. Examples are the introduction of ecodesign strategies and other best practices to integrate environmental concerns into the NPD. Environmental indicators show that previous NPD structures do not fulfill environmental requirements (BAKSHI; FIKSEL, 2003; LINDAHL et al., 2003). From this scenario, recent NPD structures that emerged are now interested in environmental impact of products in the final stages of the process (end of pipe), e.g. the destination of products and packaging at the end of their useful life, less consumption of materials, reuse of materials through remanufacturing, recycling and reuse strategies.

In order to include environmental aspects in the NPD structures, Tischner and Charter (2001), for instance, emphasized the use of eco design-specific tools in conjunction with other product development concepts. In parallel, ISO/TR 14062 (INTERNATIONAL..., 2002)

Table 4. NPD structures in the literature (2000-2013).

Ref.	NPD stages								
	Pre-development		Development					Pos-development	
	1	2	3	4	5	6	7	8	9
Crawford and Benedetto (2000)	X			X	X	X	X		
Nwabueze and Law (2001)	X			X	X		X	X	X
Kalpic and Bernus (2002)	X			X	X	X	X		
Tischner and Charter (2001)	X		X	X	X	X	X		
International Organization for Standardization (2002)	X			X	X	X	X	X	
Unger (2003)				X	X	X	X		
Buijs (2003)	X			X	X	X	X		
Pahl et al. (2005)		X		X	X	X			
Ford and Coulston (2005)	X			X	X	X		X	
Sun and Wing (2005)	X		X	X	X	X	X	X	
Prašnikar and Skerlj (2006)	X			X	X		X		
Crul and Diehl (2006)	X	X	X	X	X			X	
MacGregor et al. (2006)	X				X				
Rozenfeld et al. (2006)	X	X	X	X	X	X	X	X	X
Thomke and Nimgade (2007)	X			X	X	X	X		
Ulrich and Eppinger (2007)	X	X	X	X	X	X			
Yeh et al. (2010)	X	X		X	X	X			
Bigliard, Bottani and Rinaldi (2013)	X			X	X	X	X		

Note: - stages according to Rozenfeld et al. (2006): (1) Strategic plan; (2) - Project management plan; (3) Informational stage; (4) Conceptual stage; (5) Detailed project stage; (6) Production preparation; (7) Launching stage; (8) Product and process monitoring; (9) Discontinuing the product from the market. Source: literature search and analysis.

was also developed to guide companies in integrating environmental aspects into NPD.

In general, by analyzing the 50 NPD structures found out in the literature, divergences of focus can be observed due to the perspective of each area of knowledge. In NPD structures developed with marketing vision emphasized the macro phases of 'pre-development' and 'post-development' as well as customer-suport after launching the product in the market (e.g. CRAWFORD; BENEDETTO, 2000). In contrast, the NPD structures that focus on the engineering side (e.g. PAHL; BEITZ, 1977) are more concerned to the macro phase of 'development' and deepen into details of product design and engineering activities.

Finally, the NPD structure focused on sequential activities and with more attention to the macro phase of 'development' adopted the vision of the process of NPD as a business process, aligning the process with the company' strategic plan and integrating the internal and external areas involved as well as the environment. Nevertheless, the integration of environmental aspects into NPD structures is still under developed. Only few NPD structures superficially state the importance of this integration and they do not make clear how to tackle that. Such publications do not mention in which phases of the NPD should be integrated ecodesign practices, for instance, nor explain how to operationalize this integration.

4. Most adopted stages and identification of environmental concerns

Table 5 presents most common stages with NPD structures obtained in the literature. Considering the NPD 'pre-development' macro phase, the project management plan is less cited stage. Most authors gives greater importance to the alignment of the strategic planning phase of the product, which relates the portfolio of existing products with the identification of new product opportunities to build the portfolio of products to be developed.

In the 'development' macro phase the informational design stage is also the least explored when comparing it to the other stages. This stage covers the activities of product design, product specification definition, prototype development, process and product certification, pilot production, finishing with launching the product in the market.

The NPD 'post-development' macro phase is the least addressed in the NPD structures, consisting of the following stages: product and process monitoring (24%) and discontinuing the product (6%). This may be happen because the classical structures do not address the concepts of remanufacturing strategies, recycling, product collection and disposal, i.e. they do not yet have a view of all phases of the product life cycle that is currently relevant to minimizing the environmental impact of the product.

Table 5. Most common phases in NPD structures.

NPD stages	# citations (%)	References that cite the stage of NPD	Environmental issues
(1)	45 (90%)	Asimov (1962), Archer (1971), Kotler (1974), Bonsiepe (1978), Booz (1982), Saren (1984), Andreasen and Hein (1987), Park and Zaltman (1987), Suh (1988), Graf and Saguy (1991), Rosenthal (1992), Wheelwright and Clark (1992), Cooper (1993), Urban and Hauser (1993), Automotive Industry Action Group (1994), Fuller (1994), Ingle (1994), Nijssen and Lieshout (1995), Rudolph (1995), Roozenburg and Eekels (1995), McGrath (1996), Ertas and Jones (1996), Dickson (1997), Earle (1997), Prasad (1997), British Standards Institution (1997), Fleischer and Liker (1997), Peters et al. (1999), Crawford and Benedetto (2000), Nwabueze and Law (2001), Kalpic and Bernus (2002), Tischner and Charter (2001), International Organization for Standardization (2002), Buijs (2003), Pahl et al. (2005), Ford and Coulston (2005), Sun and Wing (2005), Prašnikar and Skerlj (2006), Crul and Diehl (2006), MacGregor et al. (2006), Rozenfeld et al. (2006), Thomke and Nimgade (2007), Ulrich and Eppinger (2007), Yeh et al. (2010), Bigliard, Bottani and Rinaldi (2013)	Social, economic, political, technological, environmental, and legal analysis
(2)	10 (20%)	Bonsiepe (1978), Graf and Saguy (1991), Rudolph (1995), McGrath (1996), British Standards Institution (1997), Pahl et al. (2005), Crul and Diehl (2006), Rozenfeld et al. (2006), Ulrich and Eppinger (2007), Yeh et al. (2010)	Define who is involved in each stage of the product life cycle. Develop the product scope that should describe the characteristics, functionalities, and the desired product environmental performance
(3)	22 (44%)	Archer (1971), Pahl and Beitz (1977), Bonsiepe (1978), Booz (1982), Saren (1984), Verein Deutscher Ingenieure (1985), Andreasen and Hein (1987), Suh (1988), Graf and Saguy (1991), Wheelwright and Clark (1992), Cooper (1993), Ingle (1994), Rudolph (1995), McGrath (1996), Earle (1997), Tischner and Charter (2001), Pahl et al. (2005), Sun and Wing (2005), Crul and Diehl (2006), MacGregor et al. (2006), Rozenfeld et al. (2006), Ulrich and Eppinger (2007)	Detail the life cycle of the product and define customers niche. Identify the environmental requirements of the customer
(4)	50 (100%)	Asimov (1962), Archer (1971), Kotler (1974), Pahl and Beitz (1977), Bonsiepe (1978), Booz (1982), Saren (1984), Verein Deutscher Ingenieure (1985), Andreasen and Hein (1987), Park and Zaltman (1987), Suh (1988), Clark and Fujimoto (1991), Graf and Saguy (1991), Rosenthal (1992), Wheelwright and Clark (1992), Cooper (1993), Urban and Hauser (1993), Automotive Industry Action Group (1994), Fuller (1994), Ingle (1994), MacFie (1994), Nijssen and Lieshout (1995), Rudolph (1995), Roozenburg and Eekels (1995), McGrath (1996), Ertas and Jones (1996), Dickson (1997), Earle (1997), Prasad (1997), British Standards Institution (1997), Fleischer and Liker (1997), Peters et al. (1999), Crawford and Benedetto (2000), Nwabueze and Law (2001), Kalpic and Bernus (2002), Tischner and Charter (2001), International Organization for Standardization (2002), Unger (2003), Buijs (2003), Pahl et al. (2005), Ford and Coulston (2005), Sun and Wing (2005), Prašnikar and Skerlj (2006), Crul and Diehl (2006), MacGregor et al. (2006), Rozenfeld et al. (2006), Thomke and Nimgade (2007), Ulrich and Eppinger (2007), Yeh et al. (2010), Bigliard, Bottani and Rinaldi (2013)	Develop alternative environmental solution for the product conception in terms of systems, sub systems and components

Note: - stages according to Rozenfeld et al. (2006): (1) Strategic plan; (2) Project management plan; (3) Informational stage; (4) Conceptual stage; (5) Detailed project stage; (6) Production preparation; (7) Launching stage; (8) Product and process monitoring; 9 - Discontinuing the product from the market. Source: literature search and analysis.

Table 5. Continued...

NPD stages	# citations (%)	References that cite the stage of NPD	Environmental issues
(5)	49 (98%)	Asimov (1962), Archer (1971), Kotler (1974), Pahl and Beitz (1977), Bonsiepe (1978), Booz (1982), Saren (1984), Verein Deutscher Ingenieure (1985), Andreasen and Hein (1987), Suh (1988), Clark and Fujimoto (1991), Graf and Saguy (1991), Rosenthal (1992), Wheelwright and Clark (1992), Cooper (1993), Urban and Hauser (1993), Automotive Industry Action Group (1994), Fuller (1994), Ingle (1994), MacFie (1994), Nijssen and Lieshout (1995), Rudolph (1995), Roozenburg and Eekels (1995), McGrath (1996), Ertas and Jones (1996), Dickson (1997), Earle (1997), Prasad (1997), British Standards Institution (1997), Fleischer and Liker (1997), Peters et al. (1999), Crawford and Benedetto (2000), Nwabueze and Law (2001), Kalpic and Bernus (2002), Tischner and Charter (2001), International Organization for Standardization (2002), Unger (2003), Buijs (2003), Pahl et al. (2005), Ford and Coulston (2005), Sun and Wing (2005), Prašnikar and Skerlj (2006), Crul and Diehl (2006), MacGregor et al. (2006), Rozenfeld et al. (2006), Thomke and Nimgade (2007), Ulrich and Eppinger (2007), Yeh et al. (2010), Bigliard, Bottani and Rinaldi (2013)	Define final specifications of the product, by integrating and analyzing its components and production process. Consider a plan for product end of life, assembly, disassembly packaging, recycling, reuse, and disposal
(6)	40 (80%)	Asimov (1962), Archer (1971), Bonsiepe (1978), Booz (1982), Saren (1984), Verein Deutscher Ingenieure (1985), Andreasen and Hein (1987), Suh (1988), Clark and Fujimoto (1991), Graf and Saguy (1991), Rosenthal (1992), Wheelwright and Clark (1992), Cooper (1993), Automotive Industry Action Group (1994), Fuller (1994), MacFie (1994), Rudolph (1995), Roozenburg and Eekels (1995), McGrath (1996), Ertas and Jones (1996), Earle (1997), Prasad (1997), British Standards Institution (1997), Fleischer and Liker (1997), Peters et al. (1999), Crawford and Benedetto (2000), Kalpic and Bernus (2002), Tischner and Charter (2001), International Organization for Standardization (2002), Unger (2003), Buijs (2003), Pahl et al. (2005), Ford and Coulston (2005), Sun and Wing (2005), MacGregor et al. (2006), Rozenfeld et al. (2006), Thomke and Nimgade (2007), Ulrich and Eppinger (2007), Yeh et al. (2010), Bigliard, Bottani and Rinaldi (2013)	Test and define the environmental control and product parameters and certify the process. Assess the product processes, suppliers, logistics, and maintenance processes
(7)	35 (70%)	Archer (1971), Kotler (1974), Booz (1982), Saren (1984), Andreasen and Hein (1987), Park and Zaltman (1987), Graf and Saguy (1991), Wheelwright and Clark (1992), Cooper (1993), Urban and Hauser (1993), Automotive Industry Action Group (1994), Fuller (1994), MacFie (1994), Nijssen and Lieshout (1995), Rudolph (1995), Roozenburg and Eekels (1995), McGrath (1996), Dickson (1997), Earle (1997), British Standards Institution (1997), Fleischer and Liker (1997), Peters et al. (1999), Crawford and Benedetto (2000), Nwabueze and Law (2001), Kalpic and Bernus (2002), Tischner and Charter (2001), International Organization for Standardization (2002), Unger (2003), Buijs (2003), Sun and Wing (2005), Prašnikar and Skerlj (2006), MacGregor et al. (2006), Rozenfeld et al. (2006), Thomke and Nimgade (2007), Bigliard, Bottani and Rinaldi (2013)	Iniciate the production for comercialization, update the end-of-life plan, document of launching; Define sales, distribution, customer support and marketing campaign

Note: - stages according to Rozenfeld et al. (2006): (1) Strategic plan; (2) Project management plan; (3) Informational stage; (4) Conceptual stage; (5) Detailed project stage; (6) Production preparation; (7) Launching stage; (8) Product and process monitoring; 9 - Discontinuing the product from the market. Source: literature search and analysis.

Table 5. Continued...

NPD stages	# citations (%)	References that cite the stage of NPD	Environmental issues
(8)	12 (24%)	Graf and Saguy (1991), Urban and Hauser (1993), Rudolph (1995), Earle (1997), Prasad (1997), Peters et al. (1999), Nwabueze and Law (2001), International Organization for Standardization (2002), Ford and Coulston (2005), Sun and Wing (2005), Crul and Diehl (2006), Rozenfeld et al. (2006)	Improvement opportunities for environmental adequacy of the product and services. and register of lessons learned
(9)	12 (24%)	British Standards Institution (1997), Nwabueze and Law (2001), Rozenfeld et al. (2006)	Receive the product back, use the concepts of recycling, remanufacturing, reuse, and discharge

Note: - stages according to Rozenfeld et al. (2006): (1) Strategic plan; (2) Project management plan; (3) Informational stage; (4) Conceptual stage; (5) Detailed project stage; (6) Production preparation; (7) Launching stage; (8) Product and process monitoring; 9 - Discontinuing the product from the market. Source: literature search and analysis.

Although there is a possibility of minimizing environmental impacts in all phases of the NPD, most authors only emphasize that it is important to integrate the environmental issues in the initial phases of the NPD (e.g. SHERWIN; BHAMRA, 1999; LOFTHOUSE; BHAMRA, 2001; BOKS, 2006; DEVANATHAN et al., 2010; KENGPOL; BOONKANIT, 2011). In this sense, the later the project decisions are made during the NPD the fewer will have opportunities to reduce the environmental impact of the product throughout its life cycle (REBITZER et al., 2004).

To contribute to the adoption of ecodesign practices in the NPD, Pigosso et al. (2013) developed a 'NPD environmental maturity framework' that aims to assist companies in the management of this integration and to incorporate ecodesign management practices in NPD. The previous authors use as all the stages of NPD, starting from strategic planning to the stage of product monitoring. In this same line of thought, Platcheck et al. (2008) aimed at improving the sustainability of the electronics products developed by placing ecodesign variables in the initial stages of conceptual design and product development.

Although the concern with environmental aspects was raised in the 1970s – until the end of this study – there was no detailed NPD structure that explicitly prescribes in which stages and what kind of practices should be adopted to mitigate the environmental impacts. Of course, this may have contingencies to the type of product but a more extensive and detailed evidence still required. Moreover, most of the 50 NPD structures do not consider the incorporation of environmental issues into the NPD process. This is reflected in the low utilization of the 'pre-development' and 'post-development' macro phases of NPD. It is also relevant to remember that in the initial phases of new product development, important decisions should be taken into account to improve the product's environmental performance in terms of definition of concept and design alternatives. In the 'post-development' macro phase is where product data for subsequent product development and improvement are obtained so adjustments should to be made to reduce the environmental impact of the product during its life cycle.

5. Conclusions

When analyzing the NPD structures, it was noted that there are divergences of focus in the those structures according to the area of knowledge that proposes them (marketing or engineering, for instance) and, consequently, differences in the stages occur. Conclusively, only few NPD structures in the literature fully integrate environmental issues into the stages. Unfortunately, when this occurs, the description is usually superficial. In this sense, by analyzing the stages that compose NPD structures, 'pre-development', and 'post-development' macro phases are less addressed. Nevertheless, decisions of paramount importance for the environmental perspective are made in the stages of those macro phases for a more effective product life cycle. As a research gap, future research will concentrate in understanding how to incorporate environmental issues in new product development process. This may consider how to consider aspects of environmental criteria in portfolio management in the pre-development phase.

Finally, on positive side of the existing NPD structures, they are in constant development by researchers and practitioners, considering the theoretical and organizational needs. Although there is no comprehensive incorporation of environmental issues in NPD structures, most recent studies have been working in this direction.

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