

## PROPOSTA DE UM MODELO ABRANGENTE E INTEGRADO DE APOIO AO DESENVOLVIMENTO DE NOVOS PRODUTOS

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Artigo submetido em 12/12/2017 e aceito em 15/01/2018

### RESUMO

O desenvolvimento de novos produtos (DNP) é crucial para a existência das empresas, fonte de vantagem competitiva e factor determinante do seu êxito empresarial. Diversos factores, tanto operacionais como organizacionais ou até estratégicos, contribuem para o processo de inovação que suporta o DNP. A avaliação holística de todos estes factores, no seu conjunto, não tem sido objecto de investigação conducente à proposta de um modelo integrado e sistémico. Desta forma, este artigo tem como objectivo a proposta de um modelo abrangente

de natureza conceptual, que integre os níveis estratégico, organizacional e processual, bem como o conjunto de factores a ter em conta nos projectos DNP. Com base na revisão de literatura, chega-se por via dedutiva-indutiva a um modelo conceptual abrangente e integrado de apoio ao DNP (MAIDNP). Este modelo pode constituir-se, portanto, como uma ferramenta aferidora de processos, projectos e produtos, dedicado às empresas que inovam, concebem e desenvolvem novos produtos.

**PALAVRAS-CHAVE:** inovação, desenvolvimento de novos produtos, ferramentas de apoio ao DNP, modelo funcional.

## PROPOSAL FOR A COMPREHENSIVE AND INTEGRATED MODEL OF SUPPORT FOR THE DEVELOPMENT OF NEW PRODUCTS

### ABSTRACT

The development of new products (NPD) is crucial for the existence of companies, source of competitive advantage and determinant of their business success. Several factors, both operational and organizational or even strategic, contribute to the innovation process that supports NPD. The holistic assessment of all these factors as a whole has not been the subject of research leading to the proposal for an integrated and systemic model. In this way, this article aims to propose a comprehensive conceptual model that integrates the

strategic, organizational and procedural levels, as well as the set of factors to be taken into account in NPD projects. Based on the literature review, a comprehensive and integrated conceptual model of NPD support (MAIDNP) is deductive-inductive. This model can therefore be a tool for evaluating processes, projects and products, dedicated to companies that innovate, design and develop new products.

**KEYWORDS:** innovation, new product development, NPD support tools, functional model.

## 1 INTRODUCTION

New products are the result of innovation processes that companies approach in a systematically way, or in some cases, through creative improvisation fueled by the turmoil surrounding the organization (Akgün et al., 2007). According to Karniel and Reich (2009), NPD processes are crucial for the existence of competitive business and firms, being one of the determinant factors of business success (Kim et al., 2008). Furthermore, the ideas about innovative products must be implemented by firms and brought to market as quickly as possible, in order to gain competitiveness in the global market (Raehse 2012; Urze and Abreu, 2016). But the innovation that supports NPD is not a path free of difficulties, and the failure of an idea or a project that initially seems destined for success, can be one of the possible destinations. Therefore, the NPD involves not inconsiderable risks associated to the uncertainty in the markets, as evidenced by Mu et al. (2009). Thus, the risk is the barrier to transpose in a market mined of uncertainty, turbulence and complexity, as recognized by Karniel and Reich (2009) or also Liu (2013). As a result of these difficulties, the time available to manage efficiently and effectively the simplest projects is becoming shorter, especially those relating to NPD (Heising, 2011). According to (Liu, 2013), under these conditions, for a proactive and structured management of their projects and to ensure competitiveness, the firms, even in complex environments for knowledge sharing in innovation networks (Karlsson and Warda 2014) require to have a holistic view (Patanakul and Milosevic, 2009), in particular concerning the set of parameters and variables to take into account in strategic, organizational and procedural various levels. This finding is very relevant in NPD projects and their implementation, which requires an increasingly rational and comprehensive approach (Bonabeau et al., 2008). Consulting the existing literature, it was found a lack of a systemic conceptual and functional framework encompassing the various conceptual levels: strategic, organizational and procedural / operational, to take into account in NPD projects. To serve these needs is proposed in this paper one Systemic and Integrated Framework of NPD (SIFNPD).

## 2 MATERIALS AND METHODES

It was decided from the beginning on a deductive-inductive structure research, through literature review, it was possible to achieve SIFNPD, and there was the need for its empirical validation. So, it was decided for the use of case studies, since most issues to validate are questions of "how" and "why" type, in their qualitative and explanatory variant, as recommended by Yin (2009). In accordance with its goals, the research was generally regarded as descriptive as it aims to accurately describe the phenomena of reality studied and hence not require the use of techniques and statistical methods because the model and their meanings are the main focus of the approach.

In the domain of exact sciences, methodologies often use quantitative methods, while in social sciences are often used qualitative methods, given its high scope and flexibility (Stuart et al., 2002 and Yin, 2009). About this feature, Eisenhardt (1989) emphasizes that flexibility or freedom in research does not constitute authorization for it is not rigorous or systematic. This appetite for qualitative methods has extended to many works of engineering and industrial management, especially when concerning models of conceptual and strategic nature. Just in NPD domain are referred as examples: Campbell et al. (2007); Yeh et al. (2010); Gnyawali and Park (2011) and Petty et al. (2012).

The actual purpose of the case studies - defining what the "case" is, Yin (2011) has called the "unit of analysis", which is to be studied. In this investigation, the units of analysis are

composed of innovative products, goods and services, whose development plans to test the proposed conceptual model. To this purpose, and as the basis of a previous script (protocol) recorded or not recorded interviews were performed; site visits as deemed necessary; telephone conversations; mail contacts; documents and collection of various types of written or computer data, both to those in charge of organizations under study, as related organizations, where crossed or triangulated the information collected, whenever raised any questions as well as the use of "key informants" (only one or a panel) that are trustworthy people with technical knowledge and scientific, with ability to build bridges in the organization. Where it was specifically requested, the confidentiality of data or information collected remained anonymous, without this did not stop despite everything, to amplify the perspective on the issue under consideration. Besides the above, was also obtained formal authorization from the organization boards and provide to their representatives, as well as the "key informants", to review the material provided.

### 3 LITERATURE REVIEW

To design a theoretical framework, systemic and member of several factors that determine the NPD, it was assumed at the outset of an arrangement of the parameters and variables that comprise NPD in three levels interacting with each other. A first strategic level, then a second organizational level that decomposes into two sub-levels of equal importance: the corporate culture of a structural nature; and the management principles, responding to market situations, and finally, a third operational or procedural level and its process variables. Based on these assumptions the literature review was organized as shown in Figure 1. Arrows between levels and sublevels show the relationship they have and establish among themselves.

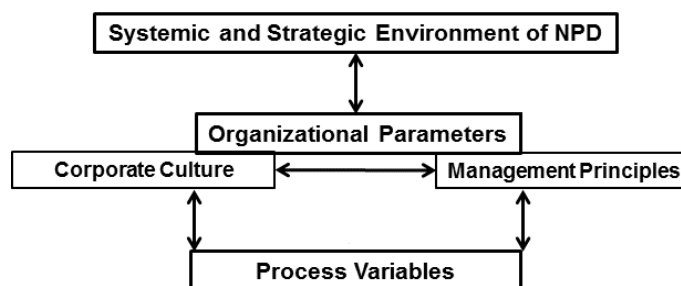


Figure 1 – General Framework Approach.

#### 3.1 Systemic and strategic environment

At a systemic and strategic level of NPD is fundamental the intimate relationship between innovation, source of NPD, and the strategy itself (Acur et al., 2012). Strategic innovation embodiments in a highly competitive environment (Markides, 1997) although Kim and Mauborgne (2004 and 2005) or Kim et al. (2008), having detected the existence of industries based on products usually of disruptive nature that develop in an environment without competitors they called "blue ocean strategy" (BOS) as opposed to the conventional market of high level of competition that they designated by "red ocean strategy" (ROS).

According to the same authors, these new product BOS were not developed on the basis of the strategic choice of differentiation and low cost, but rather on aggregate, given the absence of competitors. Indeed, according to Kim and Mauborgne (2004), red oceans represent all industries that currently exist - the known market space; blue oceans demarcate all industries that do not yet exist - an unknown space. About these two opposing strategies, Kim and Mauborgne (2004), reported that at ROS, the boundaries of industries are defined and accepted, and the rules of the

game are known to all competitors. Here, firms try to overcome their rivals in order to gain more and more market share they are competing in. In recent decades the strategic focus of enterprises, according to the authors, has been based in painful and difficult survival in these oceans "red blood spilled in fights and deaths" (bankruptcies).

According to Lindic et al. (2012), BOS policy is especially relevant for faster growth of companies and businesses creating unique offerings for new markets rather than compete with existing rivals. Nowadays even innovative leadership can itself be assumed from the strategic standpoint as being a "blue ocean leadership" (Kim and Mauborgne, 2014). But there are hybrid strategies in which firms develop new products that emanate from both radical and gradual forms of innovation. Based on experiments conducted in a sample of Italian small and medium enterprises (SMEs), Gandellini and Venanzi (2011), devoted a mixed policy they called "purple ocean strategy" (POS). It is a strategy in which industries develop disruptive products that will not have competitors in the market for some time while the remaining products of incremental innovation face the tough competition existing. In addition to these strategic policy options, firms have to make other decisions involving more factors of systemic and strategic nature and should be considered together thus requiring rigorous evaluations of the trade-offs involved (Pollack and Liberatore, 2006), namely those that study the various risks and their committed relationship. In a competitive environment of greater complexity in production processes there are risks that must be evaluated in a systematic way. This implies an ongoing evaluation of trade-offs combining the various risk factors of NPD and their respective projects, especially those involving quality, time and costs (Kim et al., 2012).

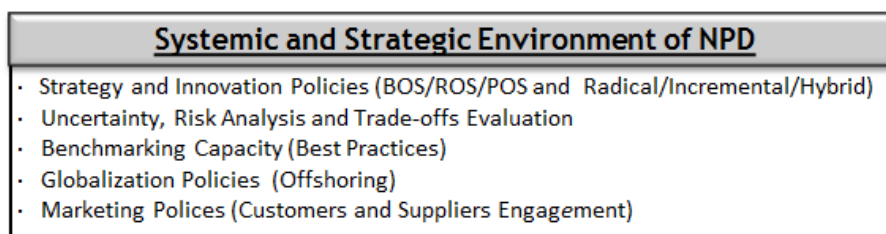
Whether NPD policies are based on radical, incremental or mixed innovation strategies, these firms can not overlook the risks they expose themselves and also need to be attentive to the dynamics of competition by implementing systematic benchmarking practices (Barczak and Kahn, 2012). In order to achieve the most interesting performances of NPD business, Cooper et al. (2004) carried out the benchmarking of best practices concerning the seventeen topics of the highest performing companies in this field, and concluded the importance of factors that relate to the teams that develop new projects, their multidisciplinary and collaborative attitude, which should integrate the corporate culture. The globalization of markets and business operations is a trend that will remain strong in the coming decades, according to the opinion of Roy and Sivakumar (2011). Also according to these authors, an unavoidable aspect of the process of globalization has been the global trend of outsourcing, especially the knowledge-based services, such as NPD.

Due to the compulsive need for companies to reduce costs in the developed world, the question is not whether a particular company will outsource or work abroad, but when it will outsource and how it will leverage outsourcing for greater competitive advantage (Roy and Sivakumar, 2011). One of the problems that arise in the process of outsourcing, offshoring in particular, is the "intellectual property" (IP) jointly developed. The referred work of Roy and Sivakumar (2011) also examines the effect of the access, exploitation and defense of IP when generating innovation, both incremental (Parast, 2011) as radical (Verganti and Öberg, 2013), carried out by firms outsourced and concludes that, in political terms this situation is nonetheless have implications for the strategic management of the focal company.

Globalization and internationalization of business involving NPD projects correspond to engineering and management complex systems (Voegtlin and Scherer, 2017) both in the integration of the project as the product itself, which often involve research and subjects highly reserved. According to Harmancioglu (2009), these strategic options contain risks of opportunistic expropriation of knowledge and related monitoring costs of the subcontracted partners, which

sometimes are not only distant in geography but also in culture. This author proposes the modularity of the project, as a technique, which constitutes as a good chance to moderate the relationships complex model, because it can serve as a substitute for other less effective formal or informal controls in a "portfolio controls" (Harmancioglu, 2009). Still on the internationalization and globalization of NPD projects, Tripathy and Eppinger (2011) present several case studies, diverse and enlightening facing the strategic options for offshoring and/or onshoring product design for the following phases: development of system architecture; of the tasks and components and the integration of the overall system. Tripathy and Eppinger (2011) concluded that the exclusive skills and responsibilities of the focal firm must ensure control over content, design and interface processes, decisions onshore/offshore, third-party option (third-party logistics 3pl) and above all, ensuring the integrity of the final product. The development of these systems in a network of relationships, involve increased complexity and the concomitant risk that deserve evaluation of their trade-offs (Choi et al., 2001). From the point of view of corporate strategy and business in industries NPD, is also considered crucial the ongoing and systematic relationship with the market, meeting and even anticipating, if possible, the needs of customers (Wang and Chen, 2012). Therefore, the marketing performs this important function which is to establish a permanent communication between the company and the market making heard within the organization which is known as the "voice of the customer" (Fain, 2010 a).

There are different proposals presented by some authors refer to cases that show the intense customer involvement throughout the NPD process (Li et al., 2012). The main features that should be noted, since the recognition of the needs of the market through production and final product delivery (areas beyond the domain of NPD), through the design specifications of the product, as well as the various phases of the project, according to Campbell et al. (2007), are presented next. Firstly the permanent interaction with the customer, providing important suggestions, as well as a validation built step by step with the designer, resulting in the evolution of the product in the form of intermediate functional prototypes. Despite the difficulties, such interaction could prove critical to the success of certain new products for the right kind of customers (Schaarschmidt, 2014). Secondly, the consideration that the solution resulted in a relevant experimentation and application to concrete cases of new customized products (Campbell et al., 2007). Thirdly, the strategy of intimate relationship with the market and customers, in a firm that develops new products, often follows along with fellow close relationship with many suppliers involved in the new projects (Jayaram, 2008). According to Kim and Kim (2009), it must also be considered that in strategic terms, if innovation in NPD requires the marketing function, the role played by it in the development of the project also depends on the level of product innovation in question as well as their design and the positive trade-off marketing/quality cost/time (Kang et al., 2007). From a general perspective, obtained from the literature on the most relevant factors that comprise a systemic and strategic vision in NPD environment described above, is presented in Figure 2 with a thereof summary.



**Figure 2 - Systemic and strategic environment. Framework approach.**

## **3.2 Organizational parameters**

It was assumed that: parameters influencing in a structural way firms that develop new products, report to corporate culture; and the ones of a conjunctural order derivate from management and their managerial principles. Each one has specific factors, as evidenced by the existing literature.

### **3.2.1 Corporate culture**

Organizational parameters that can be considered part of a corporate culture, one of the most relevant is the ability to function in the development of projects with cross-functional teams perfectly interlocked in a natural and systematic way. Virtually all authors advise multidisciplinary, multifunctional and/or cross-functional organization type, are cited: Rihar et al. (2010), Kahn et al. (2012), Akgün et al. (2007) e Brettel et al. (2011). Other authors in specific circumstances, propose the formation of collaborative teams (e.g. Sharma, 2005), which may include employees of the organization, suppliers and customers. Therefore, it is crucial reliable information flow (Brentani and Reid, 2012), which ensure visibility and transparency in connecting people, processes and technologies. Through information obtained from the presented quotes it's realized that the organizational strategy of working in multidisciplinary integrated teams (cross-functional) is not an isolated reality but who live together in partnerships and collaborative alliances with inter-organizational information sharing, skills and innovation (Athaíde and Zhang, 2011). That is, a joint innovation capacity and development of products and projects in organizations that work on network (Krause et al., 2000) and that encompass collaboration with customers and suppliers (Al-Zu`bi and Tsinopoulos, 2012).

Another way to characterize the innovative processes is what concerns to open innovation and, in contrast to that of the stems, fewer recurrent insulation business. Are commonly known as open innovation phenomena of knowledge transfer (Fain, 2010 b), in which resources move easily at the border or interface company/market (Robertson et al., 2012). When open innovation is necessarily shared in the form of partnership or strategic alliance assumes the designation of co-innovation (Traitler et al., 2011). These authors also found that through this shared innovation, can benefit the value chain to the customer, this sorting model of win-win, thus enhancing the new product from the market. About this theme Lee et al. (2012), argue that the co-innovation represents a new paradigm of innovation where new ideas and approaches from different internal and external sources are integrated into a platform in order to generate new organizational and values shared network (Urze and Abreu, 2016). Yet according to the authors, the core of co-innovation includes engagement, co-creation and the great experience of value creation (Camarinha-Matos et al., 2008; Abreu and Camarinha-Matos, 2011). Regarding the benefits of sharing innovation and on the collaborative and cooperative processes operating on the network come to similar conclusions (Galati and Bigliardi, 2017).

It was concluded that the set sharing various factors such as: ability to network with collaborative alliances and processes of open innovation; co-innovation; co-design and joint development, should work seamlessly to achieve a better performance in NPD (Durugbo, 2013). It follows that the corporate culture should incorporate another common inter-organizational factor (Ahn et al., 2010.): the competitiveness (Shih, 2014). It regarding to install in the institution, in a lasting way, a competitive spirit associated with the effectiveness and success of new products available to the market (Danilevicz and Ribeiro, 2013).

### 3.2.2 Management principles

On the principles of management, organizational parameters as response to the market situation, are considered the following relevant factors: compliance with legislation of the product (López-Mielgo et al., 2009) inherent to each of the specific markets in which each product or all of them are developed, produced and consumed; product standardization (Wang, 2012) that permits conform with international rules and internal flexibility, facilitating the process of modularization (Salvador and Villena, 2013); certification; and the association and the agility and performance (Javier et al., 2014), which also connects to philosophy or lean thinking (Narasimham, et al., 2006 and Chen et al., 2010) in the search for maximum efficiency and productivity (Yang et al., 2013). In order to embody the paradigm of optimal organizational and process productivity there is need to combine lean practices with flexibility and quick response, the manufacture of various types of products and agility to mass production (Chang et al., 2013).

Since long ago that Nailor et al. (1999) understood the need to associate lean and agile concepts and even proposed the term "leagility" to integrate them in the paradigm of Supply Chain Management (SCM) in response to markets. Likewise, flexibility combined with the concept of proactive flexibility was transformed into "adaptability" according to Sawhney (2006). Considering the relevant factors NPD integrated at the organizational level and based on the literature review is presented a summary thereof in Figure 3.

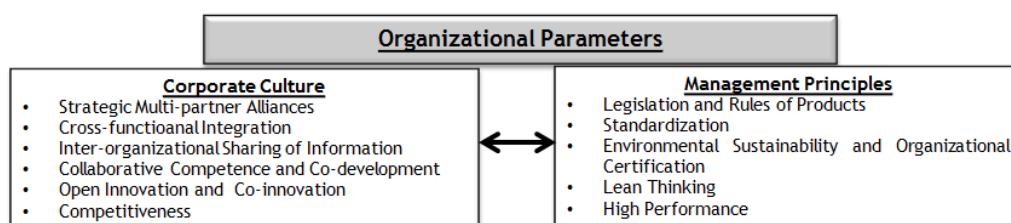


Figure 3 – Organizational parameters. Framework Approach.

### 3.3 Process variables

Upon approach to the relevant factors and parameters that integrate the strategic and organizational levels that influence organizations to develop new products with the support of the literature, it is now a third operational level with the procedural variables. There are considered as relevant process variables: the materialization of the idea of the product through a process of innovation management; (Júnior et al, 2014.) the organization and management of the project (Tripathy and Eppinger, 2011); the quality of the project, the product and its control (Li et al, 2012.); the engineering capabilities (Pei et al., 2011); as well as the technological (Wang and Li-Ying, 2014).

Add up tools and methodologies for problem solving NPD, namely innovative problems. It can be said that innovation management is a structured process of getting new ideas, which enables an organization to realize new ways to create value and anticipate technological and market demands (Júnior et al., 2014). There are different perspectives of innovation, product, process, etc. So, each innovation process is unique. From product point of view, innovation is therefore a process of creation and introduction of something new (different characteristics or features) not yet known by the market or put into practice and that is related to many factors such as research, technology, creativity and invention (He and Luo, 2017). Therefore, it is not a one-off measure, but an overall process extending over time. Shéu and Lee (2011) describe innovation as a process of generating ideas that can be convergent or not convergent. Convergent when the idea is the result of a

systematic collective process based on trial and error; not convergent when a "flash of genius" of some bright and creative collaborator occurs.

For Hansen and Birkinshaw (2007) there is a value chain of innovation that consists of three main phases: generation of ideas; conversion which decomposes in the selection of ideas and their development; and finally, its dissemination by the organization and the market. If the decision of the materialization of the innovative idea into a new product is the first step towards its implementation and development, the next step corresponds to the project management of NPD.

There are proposals for generic project management that can be considered classic as is the case of the sequential model of Ulrich and Eppinger (2000, p.9). Beyond the architecture of the product, when it takes place on a global scale, Tripathy and Eppinger (2011) assume the existence of two types of architecture in the administration of NPD projects. So, they refer to "organizational architecture" that groups, composes and arranges the sub-teams, their inter-relationships and hierarchies, in terms of information flows and the "architecture of processes", which organizes the set of tasks and activities, as well and the respective flow-related information between this set and the sum of which will produce in terms of the final product.

Tripathy e Eppinger (2011) also present a model of iterative project management, or other designating the spiral model. In the proposed spiral flexible specifications are possible, thus avoiding the need for resumption of work whenever the complexity oblige. The spiral repeats regular steps, including concept development, level design, details, integration and testing. Either way should be considered variants of the sequential model. But there are other interesting proposals for managing NPD projects more agile and flexible, sufficiently tested in industry and widely disseminated in the scientific world. It's the case of concurrent or simultaneous engineering, referred by Lin et al. (2012); Bullinger et al. (2000); Yang e Yang (2011) ; Ko et al. (2011) and Yang et al. (2014) and also the Stage–Gate® as referred by Cooper (2008); Yang and El-Haik (2009; pp.70-79) and Lenfle (2014). The guarantee of the quality levels of the project and the new product is also a relevant variable in the process, as many authors consider, including Thia et al. (2005), Lee et al. (2010) and Yang (2012). It is also the current application of Taguchi (1986) method and its specific tools in order to obtain sufficiently robust products and high quality, under fluctuations, which may influence both the environment of the NPD project, as the production process itself (Kang et al., 2007).

The implementation of NPD also implies control of varying capacities, which stand out as the most relevant: the engineering capabilities (Pei et al., 2011) and the technological ones (Wang and Li-Ying, 2014). Failing to master all these skills, many firms integrated in open innovation networks, find in technology licensing a cheap and effective way to access external knowledge for NPD (Wang and Li-Ying, 2014). Also in the case of many engineering processes and their installed capacities, the authors point to the participation in collaborative networks as a way to solve many of the needs not met by existing capacity.

Bogers and Horst (2013) arrive at the same conclusion for the need for prototyping, where collaboration is established across functional, hierarchical and organizational boundaries. Considering the most relevant variables integrated into the NPD process level, and based on the literature, presents a summary thereof in Figure 4.



<b>Process Variables</b>
<ul style="list-style-type: none"> <li>. Innovation Management (New Product Ideas)</li> <li>. Project Management</li> <li>. Products Quality Assurance</li> <li>. Engeneering and Technologies Available</li> <li>. Problems and Innovative Solutions</li> </ul>

**Figure 4 – Process Variables. Framework Approach.**

### 3.4 Problem and innovative solutions

The tools and methodologies available for innovative problem solving and other NPD problems are one of the most important variables of the respective process. Yang et al. (2006) and Yeh et al. (2010) conducted a survey of about three dozen tools and techniques obtained and listed after the literature review and interviews with managers and administrators in a sample based on Taiwanese companies, as well as discussions with experts. Based on this sample presented in Table 1 more than two dozen tools that are commonly found in literature on NPD.

**Table 1 – NPD Tools and Methodologies.**

Survey of Tools to Support NPD	
Grouping	Tools and Methodologies
Creative and Innovative Solutions	TRIZ; DOE; DFX; Pugh analysis; Creative Design; Axiomatic Design
Focus on Quality Function	QFD (e.g.: Kano Model; Ishikawa diagram; DFMEA; Pareto law)
Focus on Precision Manufacturing	DFSS (DMAIC cycle and it's variants)
Focus on Involvement of Suppliers	SDI
Design Support	Robust Design; Modular Design; CE
Decision Support	AHP; CBR; DEA; Delphi Panel; Fuzzy logics; Neuronal Networks
Acronyms: TRIZ ( <i>Theory of Inventive Problem Solving</i> ); DOE ( <i>Design of Experiments</i> ); DFX ( <i>Design for Excellence</i> ); QFD ( <i>Quality Function Development</i> ); DFMEA ( <i>Design Failure Model and Effect Analysis</i> ); DFSS ( <i>Design for Six Sigma</i> ); DMAIC ( <i>Define-Measure-Analyse-Improve-Control</i> ); CE ( <i>Concurrent Engineering</i> ); AHP ( <i>Analytical Hierarchy Process</i> ); CBR ( <i>Case Based Reasoning</i> ); DEA ( <i>Data Envelopment Analysis</i> )	

As a matter of ease of grading, tools or methodologies, as they are treated in the literature, were grouped by putting its focus on use in: “Creative and Innovative Solutions”; “Focus on Quality Function”; “Focus on Precision Manufacturing”; “Focus on Involvement of Suppliers”; “Design Support” and “Decision Support”.

As for the specific model of using tools to solve problems of NPD, it is necessary to know beforehand if similar problems have had or not too similar solutions (Dias et al., 2014; Navas, 2015). This is likely to be achieved by an adequate portfolio of problems and their solutions, as the methodology called "case-based reasoning" (CBR). Other tools are often used for this task, in particular based on fuzzy logic or neural networks (Lin and Lee, 2011). When there is not any solution previously found is necessary to use any of the available tools and methodologies in accordance with Table 1. If there are several solutions available via portfolio or via panoply of existing tools, it is necessary to determine a ranking in order to adopt the more convenient solution. One of the methods most commonly used for this task is the Analytical Hierarchy Process (AHP), a tool for decision support within the NPD project. It is very useful in screening

and ranking of possible alternatives for the decision to be made. This conceptual possibility is represented as shown in Figure 5.

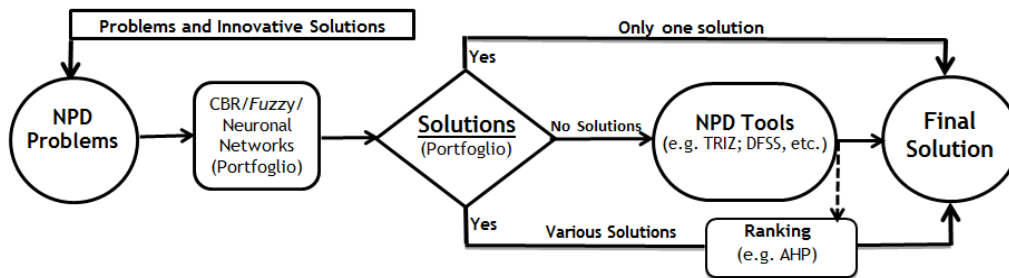


Figure 5 – NPD Problems and Innovative Solutions. Framework Approach.

### 3.5 Proposal of a conceptual/functional model

Bringing together the various parts of the model developed during the literature review, however tested on products and services in the cases studied, based on the protocol, it was in a position to promote the integration of the various parts and propose the final SIFNPD - the functional one (Figure 6).

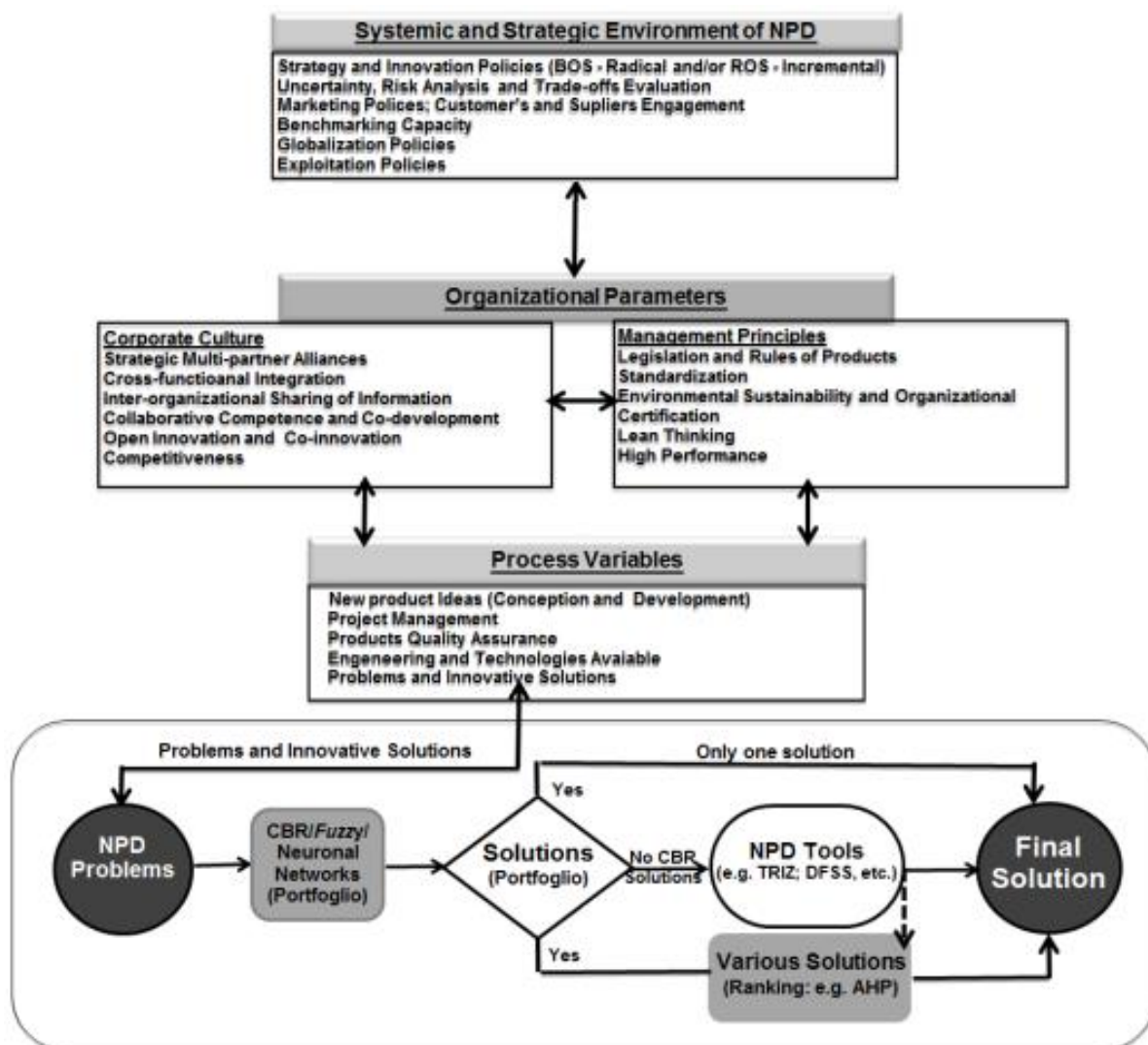


Figure 6 – SIFNPD.

As can be seen from Figure 6 and regarding the investigation developed during the literature review, the item "export policy" was added in "systemic and strategic environment" level of NPD, which was found in one of the cases studied level, be essential in this first level decision.

### 3.6 Case studies

According to Eisenhardt (1989) replicable "cases" were chosen. Four cases of products/services are presented identified by names, which proved sufficient to validate the various parts of the model developed based on literature review, and according to a specific protocol adopted. Firstly it was validated in the business field the proposed SIFNPD and, secondly, its usefulness was evidenced by demonstrating that it can successfully applied in the assessment of companies that design and develop new products, allowing to punctuate the evolutionary state of all their strategic, organizational and operational aspects and also its range of innovative products to market.

The protocol was developed of each case, pointing out the various business aspects for products under review, ranking factors according to documented evidence. It was used the following "scale of achievement" of five levels that count: "0" - carries very little or nothing; "1" - accomplishes little; "2" - realizes something; "3" - carries a lot; "4" - carries everything that is need.

The scripts were filled in the presence of their respective directors, getting up in the final common with the diagnosis of the functioning of the organization and innovative products and services, highlighting the factors according to the model. In each script was still considered a final space where the respondents could write down "other areas and domains relevant to mention" that would allow the addition of items not included in the model, and also more detailed explanations of the questions, which lacked them.

Of the four cases studied, two related to products and the other two to services. The first ones are called "HVAC" and "WJ-LASER" and the others called "NaturalHy" and "Brazing". After describing cases, a summary table of the scores according to the following criterion of measurement, presented the SIFNPD items.

#### 3.6.1 Case "HVAC"

In the "HVAC" (Heating, Ventilating and Air Conditioning) case there were a range of innovative products for a small/medium company (SME) in the metal industry, dedicated to the production and marketing in HVAC equipment, which requires a relatively high capacity for innovation relating to the manufacture processes of various products. It refers to these: rectangular ducts; circular ducts; SPIRO®system; oval ducts with EPDM sealing gasket; silencers; air handling units (AHUs); fan units; storage heat and chilled water tanks; heat exchangers; grilles and diffusers; chilled beams and CADvent – calculation and dimensioning software for air duct installations. Regarding the NPD, the company primarily performs actions for continuous improvement of existing products, but how many of them contain a significant number of components (namely AHUs) that is where the company applies in developing something innovative. The company does not disruptive innovation because it provides timely through specific orders from its customers, which means, for delivery and use in the work. This case was concluded by validating SIFNPD, well as its usefulness as the theoretical items are suited to the reality analyzed.

### **3.6.2 Case “WJ-LASER”**

The second case called "WJ-LASER", was a service, regards the use of cutting technology water jet (WJ) and (light amplification by stimulated emission of radiation (LASER)). When applying these technologies to NPD the firm preferably used the "creative design tool. The use of water jet and laser has as main target customers those associated to the fields of arts, advertising and rehabilitation of old objects of all kinds of materials (e.g. papyri, painted oil paintings, artefacts of pottery, etc.). These technologies are not only applied to cutting materials, but also in the removal of waste with very high precision, without damaging the base material. In cutting sector innovative products obtained are characterized by a high complexity of the forms and the need for a very high level of dimensional accuracy. Are automated, fast, flexible processes, almost no waste, ideal for small series manufacturing or obtaining single parts (NPD). In this case it was evident the successful use of SIFNPD as well as its usefulness as sealer grid of a service provided by a business group of top innovation of new products for industrial and technological nature in Portugal, since the theoretical items are suited to the reality measured.

### **3.6.3 Case “NATURALHY”**

It is a service provided by a company that focuses intensively on R&D, both nationally and internationally, which may be developed only by the firm with partnerships. NaturalHy project was recently completed and in which the firm participated as executive/steering committee. This case relates to the use and distribution of natural gas to hydrogen addition for the mixture to be used and transported efficiently and safely across Europe, through distribution networks developed for this purpose. This new service involves several areas of engineering. Thus, in addition to having set the conditions under which hydrogen can be added to the natural gas result of combustion so that the minimum possible amount of carbon dioxide, also involved the construction of distribution and storage of this type of gas. This distribution covered a wide range of use (ranging from domestic to industrial) as well as the development of methods for monitoring and performing various actions permanently (tests, adjustments, adaptations, validations, etc.). NaturalHy project was developed between 2004 and 2009, together with over 38 business partners, having a very high dimension and investment. The financing was EUR 11 million (granted by the European Commission), having surpassed the profit of EUR 17 million. Following the project, the activity of the firm has expanded in the Middle East, currently participating in the construction and operation of the Research Centre of the Petroleum Institute in Abu Dhabi laboratories. The analysis of this case, it was found to be in the presence of a firm that values entrepreneurship and technological innovation, especially disruptive or radical type. In this case it was possible to validate the use and usefulness of SIFNPD, at an organization of top in innovation, design and development of new products of technological nature. Apart from validating the model and its usefulness in gauging a new business service, it was able to harvest relevant data for the transformation of a conceptual SIFNPD actually functional model with consideration of the relevance of export policy as a determining factor, both from economic and strategic point of view.

### **3.6.4 Case “BRAZING”**

This case concerns an NPD based brazing technology in polymers with lead-free alloys, recent worldwide service, although its use in alloys with lead has started in the nineties of the twentieth century. The firm conducts tests integrating international projects for manufacturing new electrical and electronic components for various types of industries (e.g. appliances, audio visual,

aerospace, etc.), in partnership with: airlines; armed forces; government agencies; R&D and/or manufacturing of electrical and electronic components companies. From these entities stand out: *Boeing, American Air Force; NASA; BAESystems; Crane-NSWC; Northrop Grumman; ITB, Inc.; Texas Instruments; APIEE* (Portuguese association of electrical and electronics industries), etc. The main advantage of soldering with lead-free alloys is to be able to work with other elements that do not have the same drawbacks for health. However the non-use of lead involves technological risks arising from the need to use elements with higher melting points, such as tin. This implies difficulties in welding with polymeric materials which are the support of printed circuit boards. The risk of using this type of circuits obtained with unleaded soldering depends on the intended purpose. In the case of a television set failure, the risk to human life is very low, but in the case of an aircraft or a missile misses such risk is already very high. For these reasons, it is essential to conduct millions of tests, to decide in what situations should be used alloys of tin or lead. Such tests are one of the phases of the project circuit which uses the DFSS in this type of NPD. This case also validated the SIFNPD, as well as its inherent usefulness this time at a service - brazing new polymer products with lead-free alloys provided by a top firm in the innovation, design and development of new products for industrial and technological nature in Portugal since what theoretical items are suited to the reality analyzed.

#### **4 RESULTS AND DISCUSSION**

SIFNPD provided by the measurement for each case studied found the following results. In the "HVAC" case and in general terms it was detected that regarding the "systemic and strategic environment" classification of the factors was situated between 1 and 2. This is perfectly acceptable, given the degree of autonomy regarding the products and markets in which it operates and it's not disruptive innovative level. Regarding the level "organizational parameters" both sublevel "culture" as in "organizational principles", the majority incidence occurred between 1 and 3. In fact, in the case of matters requiring compliance with the rules and obligations to the market, would not expect another classification of related factors score. For the level of "process variables", it was found that the score was between 1 and 2. It is only as the observation, measurement, because the company devotes to a product group of restricted range and this is part of its strategy to not spread beyond the capabilities of technology and engineering that has. Finally, of the measurement performed by SIFNPD from the panel of tools available, the use of some tools (modular and tolerance design) was the maximum possible with score 4. This would be expected by not using various tools (TRIZ; DFSS, etc.). Also the fact of not cross the use of multiple tools has led to the same classification. Expectable results for a firm that focuses on innovation of the gradual type.

In the "WJ-LASER", and in general was found that for the "systemic and strategic environment" level rating for the achievement of the respective factors stood almost always in 4, except with regard to political red ocean vs. blue ocean where "accomplishes something" (the bare minimum) with score 2. Another exception for this service is to not resort to outsourcing. The same was obtained for "organizational parameters" regarding the sub-level "organizational culture", where the classification of the factors is almost always situated on 4. Refer to as exceptions factors relating to partnerships with suppliers and customers where the measurement was only 2 or 3, which is appropriate to the service in question. In the sublevel "management principles" the measurement performed with SIFNPD stood always in 4 - "accomplishes all that it takes." By measuring the level "process variables", it was found that the classification factors stood at 4 - "carries everything that is need" and only one at 0 - "almost performs nothing that necessary" in relation to a driving of stage-gate® projects, not applicable in the WJ-LASER

service. Regarding the level "process variables", the solutions using methodologies and tools provided in SIFNPD it can be concluded that the firm knows very well the range of tools available. In this service, it was detected that some tools are used more than others and, regarding its crossing, it was found that this is commonly done. In this case was detected specific application of creative project associated with the modular design, and others. Refers to non-use of TRIZ tool, as there are no techniques to solve contradictions and still DFSS, which is not applied to the production of individual units.

In the "NaturalHy" case and in general it was found that relating to the "systemic and strategic environment" level classification of factors was always situated in 4 (except that concerns the political red ocean where "only accomplishes something"). In this area a significant gap was detected in SIFNPD. Indeed, consideration of the effect of NPD in exports of the country is a gap that was not found during the literature review, and the conceptual SIFNPD was converted into a functional model. In fact, in the literature review was only found a paper on this subject (Erat and Kavadias, 2008), relevant at empirical and business perspectives. The same was found at the level of "organizational parameters" and their sublevels where the classification of factors stood at 4. Were detected two or three exceptions: outsourcing, offshoring, and the demand for cheap solutions or even the case of not giving priority to efficiency at the expense of other factors. In the level measurement "process variables", it was found that the factor score was between 1 and 4. This is only the observation of what have already been said in the description of the case presented above, and that it can be concluded that the firm knows very well the panoply of tools available and some are used more than others, and as the intersection of the tools, it was found that this is currently done. Understandably, such a finding regards to the type of products and services made, particularly in this case, the "NaturalHy" (e.g. not using DFSS is not applied to the production of gases).

In the "Brazing" "and in general it was found that relative to the "systemic and strategic environment" level the scores of the various factors was almost always 4. For the level "organizational parameters" in both sub-levels, the scores of the factors stood almost always in 4. Regarding the level "process variables", it was found that the classification of factors was also almost always punctuated with 4. Regarding the level "process variables", it was found that the classification of factors was also almost always punctuated with 4. Finally, and on the use of methodologies and tools provided by SIFNPD, it was found that the firm knows, uses and preforms their cross-service at welding of polymers with lead-free alloys whenever justified. In this case specific application of DFSS as a key tool of providing the service were detected, but still, with the support of many other tools. The scores obtained by each SIFNPD member item applied to the 4 case study analyzed are presented in Table 2.

**Table 2 – Summary Score of the Factors Measured by SIFNPD.**

Levels	Parameters and Variables	Cases			
		HVAC	WJ-LASER	NaturalHy	Brazing
Systemic and Strategic Environment	Strategy and innovation policies	2	2	2	4
	Risk analysis and trade-offs evaluation	1	4	4	4
	Marketing policies; customer's and suppliers engagement	1	2	4	4
	Benchmarking capacity	1	4	4	4
	Globalization policies	2	4	4	4
	Exploitation policies	-----	-----	4	-----
	Strategic multi-partner alliances	3	4	4	4

<b>Organizational</b> (Culture)	<b>Cross-functional Integration</b>	2	4	4	4
	<b>Inter-organizational sharing of information</b>	2	3	4	4
	<b>Collaborative competence and co-development</b>	3	4	4	4
	<b>Open innovation and co-innovation</b>	2	4	4	4
	<b>Competitiveness</b>	2	4	4	4
<b>Organizational</b> (Management Principles)	<b>Legislation and rules of product</b>	3	4	4	4
	<b>Standardization</b>	3	4	4	4
	<b>Environmental sustainability</b>	3	4	4	4
	<b>Organizational certification</b>	3	4	4	4
	<b>Lean thinking</b>	1	4	4	4
	<b>High performance</b>	2	4	4	4
<b>Process Variables</b>	<b>New product ideas</b> (conception and development)	2	4	4	4
	<b>Project management</b>	2	3	3	4
	<b>Products quality assurance</b>	3	4	4	4
	<b>Engineering and technologies available</b>	2	4	4	4
	<b>Problems and innovative solutions</b>	1	4	4	4
<b>Problems and Innovative Solutions</b> (Methodologies and Tools)	<b>TRIZ; DOE; DFX; QFD; DFMEA; DFSS; DMAIC; CE; AHP; CBR; DEA; etc.</b>	1	3	3	3

Four cases study of new products or services developed by companies mentioned it was considered enough to be seen by measuring levels, sublevels and their parameters and variables contained in SIFNPD, this fits easily to the analyzed reality. The SIFNPD was obtained based on an extensive literature review, having begun as a conceptual model. After empirical validation the conceptual model was considered as a functional model because it is in line with the business operation in NPD.

## 5 CONCLUSION

Based the research on literature review reached by deductive-inductive pathway, a comprehensive and integrated (SIFNPD) conceptual model was built. The conceptual model was validated, in the industrial environment through four explanatory and explanatory cases study, referring to the implementation of new products and services, both incremental and disruptive. From the literature review there were not detected until now any holistic models of NPD regarding the NPD phenomenon, but only partial or appropriate for cases of enterprises or industries models. This justified the completion of this investigation, and for all the foregoing, it can be concluded that this objective was achieved. The SIFNPD initially theoretical and conceptual, became functional because after the empirical validation is found that works at the industrial level. A complementary goal of operational nature, which was also considered to have been reached, was the successful use of SIFNPD in applying the products tested in empirical cases, which may become a diagnostic tool or an evaluation grid roadmap for measurement of processes, projects and products, applicable to companies that innovate, design and develop new products.

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