

## Proposal of a Conceptual/Functional Model to Support New Product Development Design

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### Abstract

Innovation and creativity are fundamental for new product development (NPD). NPD processes are a key factor for the survival of firms, in a market that nowadays is very competitive, instable and aggressive. Thus, life cycle of products it is becoming shorter, and that also due to the markets globalization. So, the development of models that can support NPD processes became a real and needed challenge. This paper aims to propose a comprehensive model of functional nature, which integrates the strategic, organizational and procedural levels, as well as the set of factors to take into account in NPD projects. Based on literature review, a comprehensive and integrated conceptual model is obtained through a deductive-inductive pathway. The conceptual model is validated in the industrial environment through four explanatory case studies, regarding the implementation of new products and services, both incremental and disruptive. After validation the conceptual framework becomes functional. And it was referred as "Systemic and Integrated Model of NPD" - SIMNPD. As a result, it is a tool to measure and evaluate processes, projects and products, dedicated to companies that innovate, design and develop new products.

### Keywords

Innovation, New product development, Functional model, NPD tools, SIMNPD, Case studies

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## 1. Introduction

The processes of conception and development of new products are crucial for the existence of competitive businesses and products, which means that innovation has become, not only, one of the key factors of business survival but also of its success. The first goal of this work is the generation of a systemic, integrated and holistic conceptual model, which after its validation becomes a true functional model, lacking in prior state of the art, knowledge or existing practices. The second goal is intended to ensure that the specific utilities of the model are viable, especially the ones concerning the business field. The theoretical investigation and review of the literature carried out were conducted in an exploratory manner, through a deductive strategy in the wake of a previously established set of constructs, which allowed the construction of the referred conceptual model in an inductive way. In this paper is proposed a Systemic and Integrated Model of NPD (SIMNPD). Four cases of study were performed that, not only tested the model and its usefulness, but also conducted to model adjustments, which guaranteed final functional form (external validation). This was, therefore, a theoretical and empirical inductive-deductive research of a qualitative nature. As a final result of the investigation a functional model was obtained, which has two different uses: the first, of a purely scientific nature allows the model to be used as an organized solution menu to solve problems concerning NPD, using the known methodological and instrumental tools; the second, of an operational and applied nature (a byproduct of the above), where the model works as a diagnostic tool (or script roadmap benchmark) of processes, projects and products, dedicated to companies that innovate, design and develop new products.

## 2. Research Methodology

It was decided from the beginning on a deductive-inductive structure research, through literature review, in order to build SIMNPD, and there was the need for its empirical validation. So, the option for the use of case studies seemed to be adequate, since most issues to validate are questions of "how" and "why" type, in their qualitative and explanatory variant, as recommended by [1]. 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 [1][2]. About this feature, [3] 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. The actual purpose of the case studies - defining what the "case" is [4] 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) it we used: recorded or not recorded interviews; 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. Proposal of a conceptual/Functional Model for NPD Design

Bringing together the various parts of the framework developed during the literature review carried out, a conceptual model was achieved. However after being tested on products and services in four cases studies, based on the protocol (as explained in the next chapter), it was possible to propose the functional systemic and integrated model to support NPD processes - SIMNPD, more complete that the conceptual one. Functional SIMNPD aims to solve real problems occurring at NPD design processes, using the NPD tools that are mentioned in literature review. Figure 1 shows the final functional model proposed in this paper, obtained after the four case studies that were carried out, and that are explained in the next chapter.

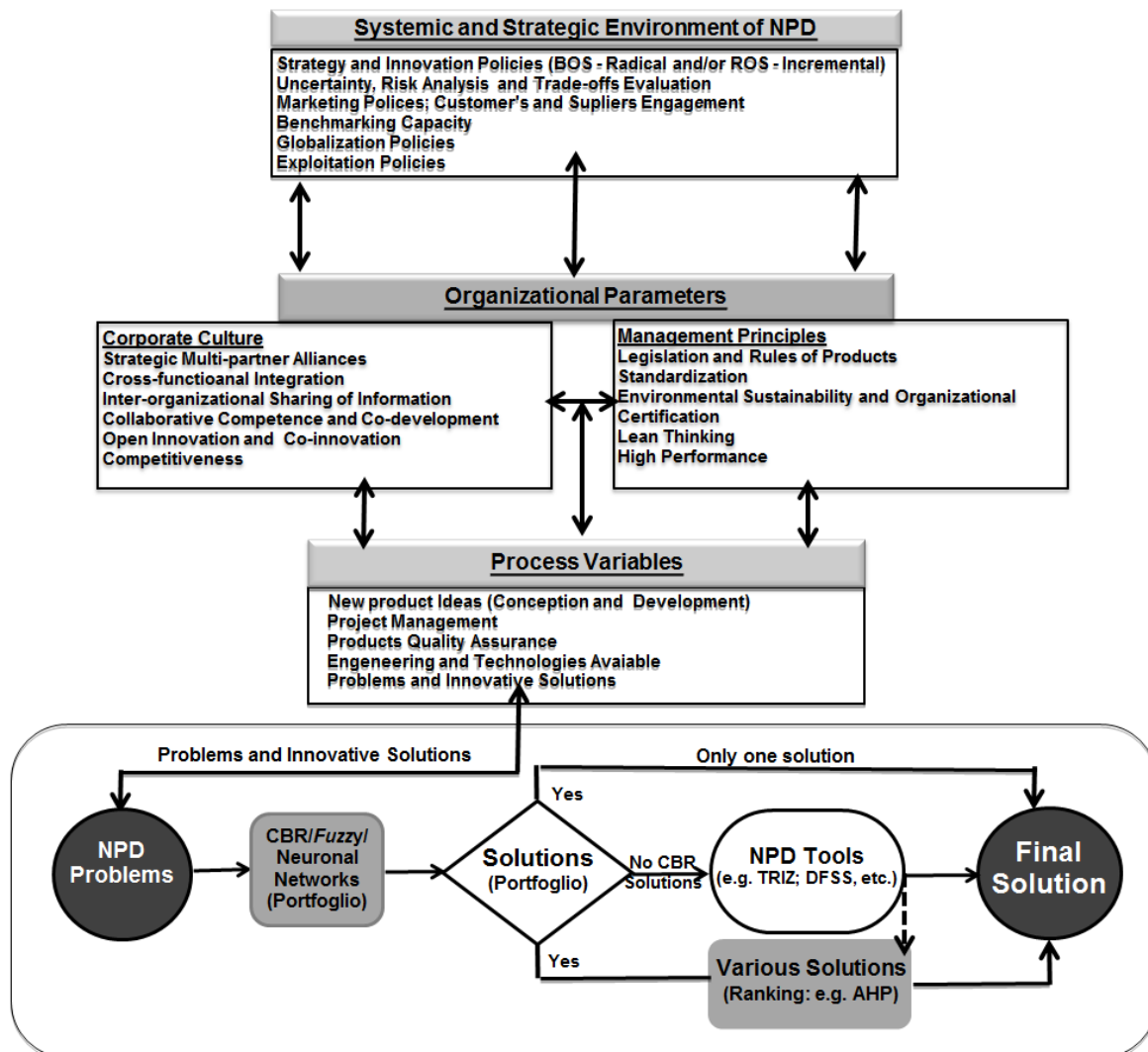


Figure 1 - SIMNPD Functional model

As can be seen from figure 1 and regarding both the investigation developed during the literature review and the case study results, the item "export policy" in "systemic and strategic environment" level of NPD was added, which was found essential in this first level decision. It was introduced in the elaborate case studies (the case "HaturalHy", as explained later). Figure 1 also shows that: SIMNPD is an integrated model, since it embraces all the levels that surround a NPD process; SIMNPD is also a systemic model, since all parts that integrate the model interact in a totally dynamic way, and not only in a up/down way, since parts have an hierarchical component (from the most comprehensive first level to the most processual/particular third level). It is also shown that only after NPD process surroundings being checked is possible to identify the existing problem, and use the NPD tools in order to achieve the innovative solution, independently if a similar problem has ever occurred or not, and if there are one solution or more. So, all the possibilities of solving a NPD process problem are contemplated in the model.

## 4. Case Studies

According to [3] replicable "cases" were chosen. Four case studies were carried out for products/services 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 SIMNPD 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. We developed the protocol of each case, pointing out the various business aspects for products under review, ranking factors according to documented evidence. We 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. A cared-completing the script in the presence of their respective directors were performed, 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 we 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, were presented the SIMNPD items.

### 4.1 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, i.e. for delivery and use in the work. This case was concluded by validating SIMNPD, well as its usefulness as the theoretical items are suited to the reality analyzed.

#### 4.2 Case “WJ-LASER”

The second case called “WJ-LASER” was a service, regarding 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 SIMNPD 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.

#### 4.3 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 SIMNPD, 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 SIMNPD actually functional model with consideration of the relevance of export policy as a determining factor, both from economic and strategic point of view.

#### 4.4 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 Grummam; 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 SIMNPD, 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.

## 5. Discussion of Results

SIMNPD provided by the measurement for each case studied found the following results. In the "HVAC" case and in general terms we 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", we 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 SIMNPD from the panel of tools available, the use of some tools (modular and tolerance design) was the maximum possible i.e. 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 we 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 SIMNPD stood always in 4 i.e. "accomplishes all that it takes." By measuring the level "process variables", we found that the classification factors stood at 4, i.e. "carries everything that is need" and only one at 0, i.e. "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 SIMNPD we can conclude that the firm knows very well the range of tools available. In this service, we detected that some tools are used more than others and, regarding its crossing, we found that this is commonly done. In this case we 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 we 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 we detected a significant gap in SIMNPD. Indeed, consideration of the effect of NPD in exports of the country is a gap that we did not find during the literature review, and we corrected for converting the conceptual SIMNPD to a functional model. In fact, the literature review we only found a paper on this subject [5], relevant at empirical and business perspectives. The same we found at the level of "organizational parameters" and their sublevels where the classification of factors stood at 4. There 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 so only the observation of what have already been mentioned in the description of the case presented above, and that it was possible to conclude 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 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", we found that the classification of factors was also almost always punctuated with 4. Finally, and on the use of methodologies and tools provided by SIMNPD, 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 was detected specific application of DFSS as a key tool of providing the service, but still, with the support of many other tools. The scores obtained by each SIMNPD member item applied to the 4 case study analyzed are presented in Table 1.

Table 1- Summary score of the factors measured by SIMNPD

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

## 6. Conclusions

The research on literature review followed a deductive-inductive pathway, in order to achieve a comprehensive and integrated conceptual model (SIMNPD) to support NPD design processes. The model was validated in the industrial environment through four explanatory and explanatory case studies, referring to the implementation of new products and services, both incremental and disruptive. From the literature review it was not detect 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 conclude that this objective was achieved. The SIMNPD 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 SIMNPD 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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