XVII SemeAD
Seminários em Administração

outubro de 2014
ISSN 2177-3866

Effects of the advanced systems of additive technologies in the performance of companies: An investigation in the front end fuzzy of the PDP

JORGE LINO ALVES
Universidade do Porto
falves@fe.up.pt

SELMA REGINA MARTINS OLIVEIRA
Universidade Federal do Tocantins - UFT
selmaregina@webmail.uft.edu.br

Área temática: Gestão da Inovação

Título do trabalho: Effects of the advanced systems of additive technologies in the performance of companies: An investigation in the front end fuzzy of the PDP

Resumo: Este artigo tem por objetivo apresentar o efeito da incorporação de inovações tecnológicas baseada em modelação 3D e manufatura aditiva na performance da firma, na perspective do front end fuzzy do processo de desenvolvimento de produto (PDP), sistematizada em duas fases: elaboração e verificação do modelo conceitual. Para confirmar o modelo, um estudo de múltiplos casos foi aplicado em um segmento de estanho em Portugal. A pesquisa contou com a intervenção de especialistas. Diversos métodos de supporte foram usados para reduzir a subjetividade nos resultados alcançados: escalagem psicométrica Lei dos Julgamentos Categóricos de Thurstone de 1927, Análise Multicriterial: Compromise Programming, Electre III e Promethee II, Redes Neurais Artificiais e Tecnologia Neurofuzzy. Os resultados mostraram-se satisfatórios, validando a proposta apresentada para incorporação de inovações tecnológicas baseadas em modelação 3D e manufatura aditiva. Isto possibilita a criação de valor para o negócio.

Palavras-chave: Efeitos dos sistemas de tecnologias aditivas; Performance da firma; Front end fuzzy do PDP.

Abstract: This article aims to show the effects of the incorporation of technological innovations based on 3D modeling and additive manufacturing in the performance of companies, in the *front end fuzzy* of the product development process (PDP), systematized in two phases: elaboration and verification of a conceptual model. To confirm the conceptual model, a case study of multiple products was elaborated in a traditional segment of pewter in Portugal. The research involved the intervention of experts. Several support tools will be used to formulate the modeling to reduce subjectivity in the results: psychometric scaling – Thurstone's Law of Categorical Judgments (LCJ), Multicriteria Analysis-Compromise Programming, Electre III and Promethee II, Artificial Neural Networks (ANN) and Neurofuzzy Technology. The results were satisfactory, validating the submitted proposal, allowing to show that it is possible to combine additive manufacturing techniques and traditional processes of production of components in pewter and the incorporation of other components in composite materials and other metallic alloys, allowing to develop innovative products in very short time frames, with market acceptance and creating business value.

Keywords: Effects of the advanced systems of additive technologies; Performance of companies; Front end fuzzy of the PDP

1. Introduction

Recently, relevant changes have made organizational boundaries more fluid and dynamic in response to the rapid pace of knowledge diffusion (Abrahamson, 1991; Griliches, 1990; Teece, 1986), and innovation and international competition (Chesbrough and Rosenbloom, 2002; Christensen, 2003; Damanpour, 1996). This helps to reconsider how to succeed with innovation (Teece et. al., 1997; Tidd et.al., 1997; Teece, 1986; Martin, Horne, Schultz, 1999; Wheelwright and Clark, 1992). Thus, innovative companies make use of their capabilities to appropriate the economic value generated from their innovations (Griliches, 1990; Teece, 1986). Therefore, the supply of innovative products is presented as a quality standard in the race for pressing demands.

Developing products is not a recent phenomenon, but reconstruction presents successful and unsuccessful experiences. In any case, product development is a complex chain of events and decisions, which can break at any of the weakest link: some projects lost due to unrealistic predictions or the absence of its real role in the agenda, or other motivations that somehow followed ideas that had many missteps or a detail error. The integration and the speed between the various stages of product development are essential elements in the competitiveness of companies. The quick transition from the concept of the product to its production is in fact an instrument of competitiveness in which the additive manufacturing is an innovative mechanism for the PDP, which enables time reduction between the conception and the placement of this product on the market, translating into reduction in investment costs and improvement in the quality of the final product.

In this sense, the incorporation of 3D modeling and additive manufacturing technologies, when used in an appropriate way and based on projective methodology, enables innovation, regardless of the complexity of the object intended to be designed. The introduction of new technologies is clearly evident in innovative products and it is considered one of the most remarkable ways of promoting new functionalities and improving the performance of existing products (Niosi, Hanel e Fiset, 1995; Sehror e Arteaga, 2000; Madu, 1989), in addition to being one of the inducers to create competitive advantages in the global market (Baranson, 1970; Caves, 1974; Contractor, 1980; Dunning, 1979; Kojima, 1975; Lai e Streeten, 1977; Mason, 1981; Morley e Smith, 1977; Negandhi, 1975; Prasad, 1983b; Wells, 1973). Thus, this article aims to show the effects of the incorporation of technological innovations based on 3D modeling and additive manufacturing in the performance of companies, in the *front end fuzzy* of the product development process (PDP). The article is divided according to the following sections: Framework of conceptual model and hiphotesis; Verification of the conceptual model and subjacent analyzes subjacent; conclusions and implications.

2. Methodology

2.1. Framework of Conceptual Model: Constructs and hypotheses

This section examines the conceptual model (Figure.1) and presents the hypotheses to be tested throughout this work.

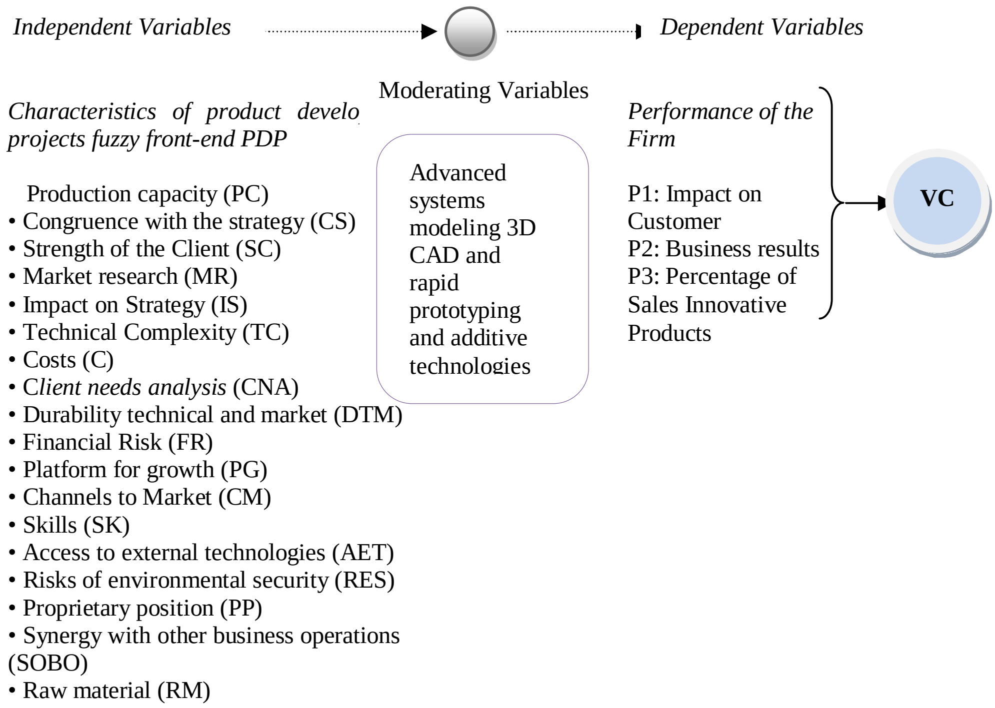

Figure 1: Framework of Conceptual Model

The creation of value in the long run has been widely discussed in both academic environnment as well as in companies. In this perspective, technologies emerges as one of the most important strategic resources for the companies in PDP. The use of additive manufacturing techniques has been effective in the reduction of time of product development, helping identify flaws and improving the final quality of the product, since it is possible to perform repetitive tests, such as building a prototype, testing it, re-designing it, building it and testing it again. As such, it enables to create business value.It is true that the volume of investments in a product design is always less in the early stages of development (BAXTER, 1998). It is believed that identifying a problem yet in the design and development stage of this product can significantly reduce the risks of this one. In this spectrum, investment in prototypes is a viable question, especially before the decision taking on the amount of resources to be invested in the production of the product (DALAKAKIS, EKC and ROLLER, 2004). From the theoretical excerpts, the following variables and hypotheses of this study were raised:

Independent Variables: from the findings in the literature the following Characteristics of product development projects fuzzy front-end PDP were identified: Production capacity (PC); Congruence with the strategy (CS) ; Strength of the Client (SC); Market research (MR); Impact on Strategy (IS) ; Technical Complexity (TC) ; Costs (C) ; C*lient needs analysis* (CNA) ; Durability technical and market (DTM) ; Financial Risk (FR); Platform for growth (PG) ; Channels to Market (CM); Skills (SK); Access to external technologies (AET); Risks of environmental security (RES); Proprietary position (PP); Synergy with other business operations (SOBO); and Raw material (RM).

Moderating variables: from the findings in the literature were identified: Advanced systems modeling 3D CAD and rapid prototyping and additive technology.

Dependent Variables: the following dependent variables were selected for this research: *Performance of the Firm:* P1: Impact on Customer; P2: Business results; and P3: Percentage of Sales Innovative Products.

Hypothesis: H1: The modeling 3D CAD and rapid prototyping and additive technology influence to a greater or lesser degree the performance of firm in the front end fuzzy of PDP. In this perspective, value create for the business. Next, these procedures were detailed, which contributed significantly to the analysis of the results achieved in each phase and step of the modeling. *H2:* Optimal Efficiency Rate of effects of the incorporation of technological innovations based on 3D modeling and additive manufacturing in the performance of company, in the front end fuzzy of the product development process depends on the combination and interaction of the projects characteristics of the companies.

3. Conceptual Model Verification and Underlying Analyses

This section presents the verification procedures for the conceptual model. This article aims to show the effects of the incorporation of technological innovations based on 3D modeling and additive manufacturing in the performance of companies, in the front end fuzzy of the product development process (PDP). This section is structured in three phases: Phase 1: Determination of Critical Success Factors (CSF) of firm. Phase 2: Identification and evaluation of characteristics of product development projects fuzzy front-end PDP in Relation to CSFs. Phase 3: Evaluation of characteristics of product development projects fuzzy front-end PDP in relation to performance of firm, under modeling and additive manufacturing, using Spearman. And Phase 4: Determination of effects of additive technologies and 3D on performance of firm in light of characteristics of projects. Next, these procedures were detailed.

Phase 1: Determination of Critical Success Factors (CSF) of firm

This phase is focused on determining the CSF, and is itself structured in two stages: (A) identification of CSF and (B) evaluation of CSF. (A) *Identification:* The identification of CSF is based on the combination of various methods (Liedecker and Bruno,1984): (a) environmental analysis (external variable: political, economical, legislation, technology, among others.); (b) analysis of the industry structure (users' needs, the evolution of the demand, users' satisfaction level, their preferences and needs; technological innovations); (c) meeting with specialists and decision makers; and (d) the study of literature. The experts' intervention is crucial to evaluate the CSFs. Once the CSFs are identified, the next step is to group them for a better understanding, using the "cluster" technique, according to the tree structure principle, which distributes the CSFs in different processes or areas involved, but always observing the relevant relationship. The CSFs are evaluated in order to establish a ranking by relevance. Here the scale model of categorical judgments designed by Thurstone in 1927 has been adopted. As a result, a hierarchical structure of CSFs is obtained.

Phase 2: Identification and evaluation of characteristics of product development projects fuzzy front-end PDP in Relation to CSFs

In this phase are evaluated the characteristics of product development projects fuzzy front-end PDP in relation to CSFs, in light of literature and the Method of Categorical Judgments of Thurstone (1927). Thus, the research is based on the literature and confirmed by the assessment of experts. In other words, prioritize the "characteristics of product development projects" according to their classification using the method Categorical Judgments. After this procedure, the following characteristics are evaluated using the multicriteria methods in the light of the data obtained by the experts. The methods used were *Compromise Programming, Electre III and Promethee II*. The *Compromise Programming* due to its wide diffusion and application simplicity and understanding renders it an alternative to evaluate problems as referenced in this application. Within this perspective, the multicriteria methods are viable instruments to measure the performance of the *characteristics of product development projects fuzzy front-end PDP in Relation to CSFs.*

Phase 3: Evaluation of characteristics of product development projects fuzzy front-end PDP in relation to performance of firm, under modeling 3D CAD and additive technology using Spearman

In this section the evaluation of characteristics of product development projects fuzzy and performance of firm are determined using Spearman's correlation. The method is often used to describe the relationship between two ordinal characteristics. The data are extracted by the experts from a judgment matrix.

Phase 4: Determination of the effects of the incorporation of technological innovations based on 3D modeling and additive manufacturing in the performance of company using Neurofuzzy Technology

This phase focuses on determining the optimal efficiency rate (OERP) of the effects of the incorporation of technological innovations based on 3D modeling and additive manufacturing in the performance of company using Neurofuzzy Technology (Figure 2). It is a process whose attributes usually possess high subjectivity characteristics, in which the experience of the decision maker is very significant. Thus within this spectrum there is the need for a tool that allows adding quantitative and qualitative variables that converge towards a single evaluation parameter (Cury and Oliveira; 1999; von Altrock, 1997). This model combines the Neural Networks and Logic Fuzzy technology (neurofuzzy technology). Here this model supports the planning of technological innovation in companies, as it allows to evaluate the desirable rate toward the acceptable of the effects of the incorporation of technological innovations based on 3D modeling and additive manufacturing in the performance of company. The model shown here uses the model of Cury and Oliveira (1999). Based on the Neurofuzzy technology, the qualitative input data are grouped to determine the comparison parameters between the alternatives. The technique is structured by combining all attributes (qualitative and quantitative variables) in inference blocks (IB) that use fuzzy-based rules and linguistic expressions, so that the preference for each alternative priority decision of the optimal rate of the effects of the additives technologies and modeling 3D on the performance determinants, in terms of benefits to the company, can be expressed by a range varying from 0 to 10. The model consists of qualitative and quantitative variables, based on information from the experts. The neurofuzzy model is described below.

Determination of Input Variables (IV): This section focuses on determining the qualitative and quantitative input variables (IV). These variables were extracted from the independent variables (dimensions of Characteristics of product development projects fuzzy front-end. The linguistic terms assigned to each IV are: High, Medium and Low. Accordingly, Table 1 shows the IVs in the model, which are transformed into linguistic variables with their respective Degrees of Conviction or Certainty (DoC), with the assistance of twenty judges opining in the process.

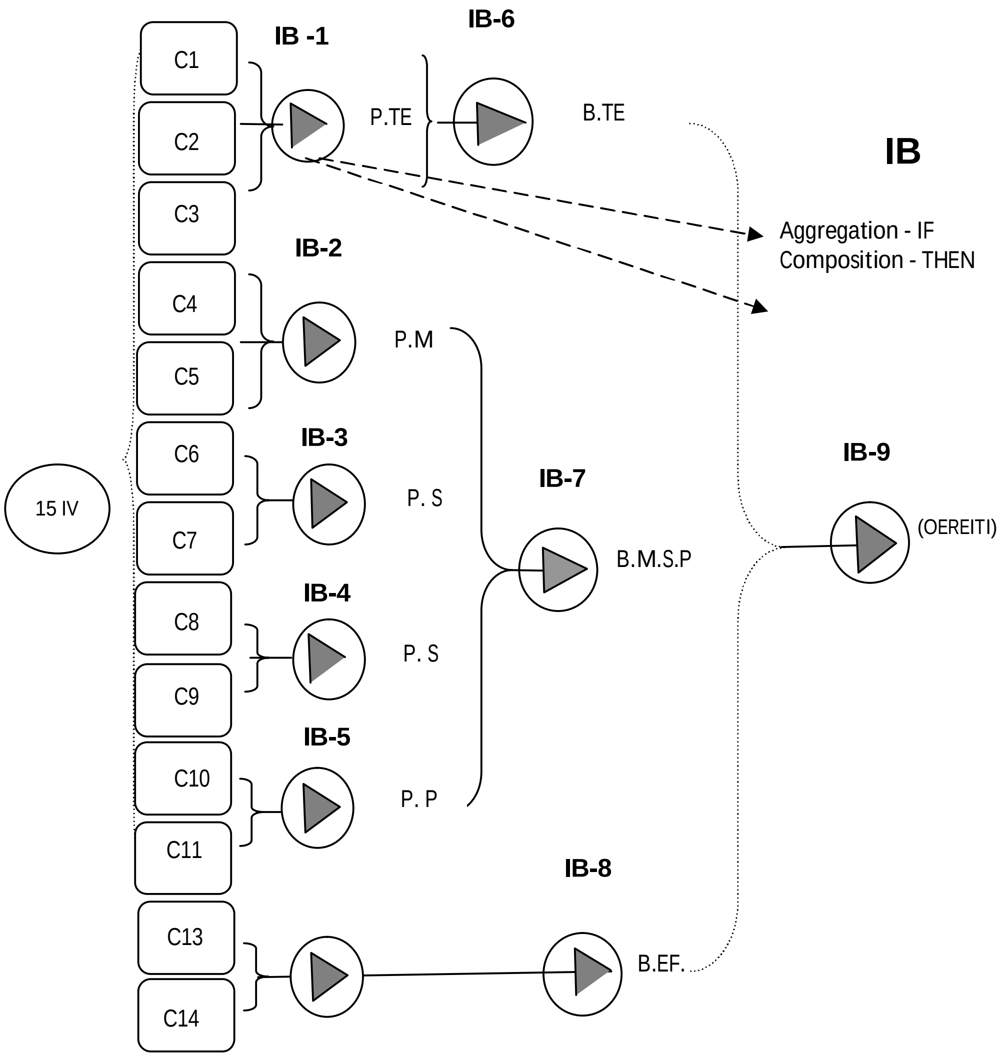

Figure 2: Model Neurofuzzy

Determination of Intermediate Variables and Linguistic Terms: The qualitative input variables go through the inference fuzzy process, resulting in linguistic terms of intermediate variables (IVar). Thus, the linguistic terms assigned to IVar are: Low, Medium and High. The intermediate variables were obtained from: Performance of the input variables. The results confirm the *H2: o*ptimal efficiency rate of effects of the incorporation of technological innovations based on 3D modeling and additive manufacturing in the performance of company, in the front end fuzzy of the product development process depends on the combination and interaction of the projects characteristics of the companies.

Determination of Output Variable – Optimal efficiency rate of effects of the Incorporation of technological innovations based on 3D modeling and additive manufacturing in the performance of company

The output variable (OV) of the neurofuzzy model proposed was called Optimal Efficiency Rate of optimal efficiency rate of effects of the incorporation of technological innovations based on 3D modeling and additive manufacturing in the performance of company. The fuzzification process determines the pertinence functions for each input variable. If the input data values are accurate, results from measurements or observations, it is necessary to structure the fuzzy sets for the input variables, which is the fuzzification process. If the input variables are obtained in linguistic values, the fuzzification process is not necessary.

4. Sample and Data Collection

The case study of multiple products was elaborated in a traditional segment of pewter in Portugal. The objective of this study is to present the effects of the advanced systems of additive technologies in the performance of company. The study was designed, based on the literature and confirmed by the assessment of experts. The data collection was performed using a scale/matrix assessment questionnaire. Next, a survey was conducted with experts, selected according to their technical-scientific criteria. The researcher regarded the new product project managers, experienced product planning personnel, innovation managers, engineers, designers, organizational managers, R&D managers, technology manegers, planning, technological innovation and modeling managers. Next, these procedures were detailed.

The Case Study of Multiple Products: Implementation and Results

In this section, a case study is developed in the light of an innovative experience in product and process, It was performed by a multidisciplinary team consisting of designers, engineers and production technicians who have worked together to develop new products that were intended to be introduced into the national and international market through a partnership between two institutions of higher education and a pewter product company in, Portugal, whose traditional products developed by this company were in discontinuity of the innovation process. This project allowed to combine additive manufacturing techniques and traditional processes of production of pewter components and the incorporation of other components in composite materials and other metallic alloys, allowing to develop innovative products in very short time frames and contributing to an increase in the creation of business value. The multiple products investigated (Parts “Synesthesia”, Effect in Candlestick - wax, M. Packaging, Identification L. Products, Cover Catalog, Candlesticks "Cube", Candlesticks "Lágrimas", Fruit Bowl Symbiosis and Gutta, Parts “Unda”, Fruit Bowl "Nirvana", Solitary Spiral and Bellevalia, Parts Cube and Bateau, and Parts Spiral and Synesthesia, others) in this research are innovative for the company and for the market. From the first initial sketches to the introduction of products in the market, it took little more than five months. The company introduced a whole new line of products on the market, more innovative, within a short period of time, through the adoption of new methods and new product development technologies, such as 3D CAD modeling, use of virtual "prototypes", additive manufacturing technologies to obtain prototypes for viewing, conversion technologies and rapid manufacturing of tools for production of functional prototypes and final pieces. The innovation and introduction of design and new projective methodologies in this type of enterprise of traditional nature allow a more efficient return of funds, definition of more innovative, more aggressive and of higher quality strategies of product and market in order to increase business value and gain sustainable competitive advantage in the global market. The study presents the PDP, the manufacture and placement on the market of pewter products aimed at innovating developed products and, simultaneously, it introduces new methods and product development technologies in the referred company. Thus, it was possible to know the details of the PDP of this company.

Product Development

The 3D CAD Modeling: All of the objects made were modeled in SolidWorks 2007 software. The use of this tool allowed to build virtual simulations of the objects, their adjustment and correction whenever necessary. From the 3D modeling it was possible to create the technical drawings of all the parts to create a technical file to be consulted by the employees of the company during the manufacturing process. The files of some of the pieces developed were converted to the format *.stl to make prototyping in the stereolithography possible (additive manufacturing).

Prototypes in Stereolithography: Stereolithography is a process that provides for the production of three-dimensional prototypes by photopolymerization, layer by layer, of a liquid resin (epoxy, polyester or vinylester) through the incidence of a laser beam of ultraviolet rays. The Cube, Bateau and Stroke pieces were selected to be manufactured by this process.

Developed products

The Figure 3 shows a piece obtained by plastic deformation where the spiral shape functions as an extension of a flower (Solitary).

Figure 3: Solitary Spiral and Bellevalia

The other single one involved casting/foundry and welding process. In both cases, glass test tubes are used to count the flower and the water. Although the company does sand casting, due to its slowness and cost involved, this process is only used in the manufacture of parts that cannot be obtained by other more cost effective processes.

Fruit Bowls: In this product segment, the piece is made of pewter with two elements in epoxy resin or polyurethane, which can be varied from object to object to the formal and the material level, with the possibility of mixing it with pewter powder, sand, mica, coconut fiber or other materials.

Figure. 4: Casting resin in silicon mold obtained from a model of PR
Figure 5: Fruit Bowl "Nirvana"

Candlesticks: This project was conceived with the intention to use a base in carbon fiber, where the pieces of pewter supporting the candles are glued. The parts of pewter were obtained by spinning pewter plates, using a mold obtained from the additive manufacture model.

Figure 6: *Candlesticks:*"Lágrima", based in carbon fiber in the company's stand in Ceranor 2008
Figure 7: Effect in candle holder

In summary, the process of product development was backed by the theoretical clippings: development of the concept of product, development of project scope, production preparation, launch and post-launch of product.

Underlying Analises

This section is structured in three phases: Phase 1: Determination of Critical Success Factors (CSF) of firm. Phase 2: Identification and evaluation of characteristics of product development projects fuzzy front-end PDP in Relation to CSFs. Phase 3: Evaluation of characteristics of product development projects fuzzy front-end PDP in relation to performance of firm, under modeling and additive manufacturing, using Spearman. And Phase 4: Determination of effects of additive Technologies and 3D on *performance* of firm in light of characteristics of projects. Next, these procedures were detailed using the "Synesthesia" product.

Phase 1: Determination of Critical Success Factors (CSF) of firm

The section present the results of c*ritical success factors (CSF) of firm (Table).*

Table 1: Classification of CSF

Stimulation	**C1**	**C2**	**C3**	**C4**	$(\mu i = -\sum_{j=1}^{4} \boldsymbol{Zij}/4)$,	CLASSIFICATION
Market	-1,22	-1,22	-0,76	-0,13	-3,34	**1º**
Economical and Financial	-0,76	-0,13	0,13	0,76	0	**3º**
Environmental	-0,13	0,43	0,76	3,86	4,92	**5º**
Political	-1,22	-0,76	-0,43	1,22	-1,19	**2º**
Technical	-0,76	0,13	0,76	1,22	1,36	**4º**

Phase 2: Identification and evaluation of characteristics of product development projects fuzzy front-end PDP in Relation to CSFs

This section evaluates the characteristics of product development projects fuzzy front-end PDP in Relation to CSFs. This procedure was developed using the multicriteria analysis, with the methods Compromise Programinng, Electre III e Promethee II. The methods used were Compromise Programming, Electre III and Promethee II. The results achieved confirm the modeling 3D CAD and rapid prototyping and additive technology influence to a greater or lesser degree the performance of firm in the front end fuzzy of PDP, and assigning values to each criterion, we arrive at a matrix of Criteria x Alternatives that together with the vector weights provides the necessary support to apply the multicriteria methods. The structure of this prioritization (classification by hierarchical analysis) is proposed at three planning levels in a judgment matrix, in which at the first hierarchical structure level it defines the goal, which is to achieve the value creation for companies that will feed the system; the criteria are in the second level, which are the performances of the companies: Performance of the Firm: P1: Impact on Customer; P2: Business results ; and P3: Percentage of Sales Innovative Products. The characteristics of product development projects fuzzy front-end PDP are: Production capacity (PC) ; Congruence with the strategy (CS); Strength of the Client (SC); Costs (C); Market research (MR); Impact on Strategy (IS); Technical Complexity (TC); C*lient needs analysis* (CNA); Durability technical and market (DTM); Financial Risk (FR); Platform for growth (PG); Channels to Market (CM); Skills (SK); Access to external technologies (AET); Risks of environmental security (RES); Proprietary position (PP); Synergy with other business operations (SOBO); Raw material (RM). The prioritization process obeys the judgment of the evaluators (experts). With the results of the judgment matrix, the methods were applied: Promethee II, Electre III and Compromise Programming to evaluate the innovation capacities in relation to the performance of the companies. Table 2 shows the results produced.

Table 2: Assessment of preferences – evaluation of characteristics of product development projects fuzzy front-end PDP in Relation to CSFs

	CLASSIFICATION		
Characteristics of product development projects	PROMETHEE II	COMPROMISE PROGRAMMING	ELECTRE III
Congruence with the strategy (CS)/ Impact on Strategy (IS)	1ª	1ª	1ª
Strength of the Client (SC);/ Client needs analysis (CNA)/ Market research (MR)/ Channels to Market (CM)	2ª	2ª	3ª
Costs (C)/ Financial Risk (FR)/	3ª	3ª	2ª
Production capacity (PC)/Technical Complexity (TC)/Durability technical and market (DTM)/ Access to external technologies (AET)	4ª	4ª	2ª
Platform for growth (PG)/Skills (SK)/ Synergy with other business operations (SOBO)/ Risks of environmental security (RES)/ Proprietary position (PP);; Raw material (RM).	4ª	4ª	3ª

Assembling here the many dimensions of the of projects characteristics in relation to CSFs, the results show (Table 2) that Congruence with the strategy, Impact on Strategy, Channels to Market and Needs Client are predominant to sustain the CSFs, especially the market factor. This is seen when taking into account the relevancy of Strength of the Client and market for the firms in the new products development. With this scenario, having defined the market factor and its components, it is possible to understand the information that is included in the macro guidelines defined by market policies; the strategic decisions. To sum it up, by developing this factor, it is possible to understand information referring to: the guidelines for strategic planning of new products, development, supporting the proposals; the strategic objectives to be reached by innovations projects; assurances of effective cost and risk advantages of innovation; partnerships with clients, suppliers and competitors and all innovation value chain in PDP; efficiency in decisions; innovation capacity; adequate management of environmental impacts and new technologies, others. Thus, new strategies for definition of new technologies are fundamental, especially in the PDP. Businesses are adopting a global strategy and taking a whole-world view of their operations (Ming and Xing, 1999). The advanced systems of additive technologies have emerged in recent years with mechanism to: product development speed, product cost reduce, product performance improve, value creation to product, others (Bernard and Fischer, 2002). Next, the degree of correlation between the dimensions of projects characteristics and performance of the firm, under modeling 3D CAD and additive technologies was determined. For this Spearman's multivariate statistical technique was used. The technique adapts to the case in question.

Phase3: Determination of the effect of additive technologies in the Company performance in the light of the characteristics of the projects

In this section the evaluation of characteristics of product development projects fuzzy and performance of firm under modeling 3D CAD and additive technologies are determined using Spearman's correlation. Table 3 shows the results.

Table 3: Effects of the incorporation of technological innovations based on 3D modeling and additive manufacturing in the performance of companies in the light of the characteristics of the projects - Spearman

Effects of the incorporation of technological innovations based on 3D modeling and additive manufacturing in the performance of companies in the light of the characteristics of the projects – SPEARMAN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
- Production capacity (PC) / Access to external technologies (AET)	1,0															
. Congruence with the strategy (CS)	**0,8**	1,0														
. Strength of the Client (SC)	0,5	0,5	1,0													
. Market research (MR) / Raw material (RM)	0,1	0,4	0,5	1,0												
. Impact on Strategy (IS)	0,2	0,4	0,7	0,6	1,0											
Technical Complexity (TC)/ Proprietary position (PP)	0,6	0,5	0,3	-0,2	0,1	1,0										
Costs (C)	0,6	0,5	0,4	0,2	0,5	0,5	1,0									
Client needs analysis *(CNA)*	0,4	0,1	0,2	0,1	-0,3	0,2	0,1	1,0								
Durability technical and market (DTM)	0,4	**0,8**	0,4	**0,8**	0,5	0,2	0,3	0,0	1,0							
Financial Risk (FR)	0,3	0,6	0,5	0,7	0,5	0,2	0,3	-0,1	0,8	1,0						
Platform for growth (PG) / Risks of environmental security (RES)	0,7	0,7	0,6	0,3	0,6	0,5	0,9	0,0	0,5	0,4	1,0					
Channels to Market (CM)/ Synergy with other business operations (SOBO)	0,3	0,6	0,5	0,7	0,5	0,2	0,3	**-0,1**	**0,8**	**1,0**	0,4	1,0				
Skills (SK)	0,7	0,7	0,6	0,3	0,6	0,5	**0,9**	0,0	0,5	0,4	**1,0**	0,4	1,0			
Percentage of Sales Innovative Products	0,3	0,6	0,5	0,7	0,5	0,2	0,3	**-0,1**	**0,8**	**1,0**	0,4	**1,0**	0,4	1,0		
ROI – Business results	0,7	0,7	0,6	0,3	0,6	0,5	**0,9**	0,0	0,5	0,4	**1,0**	0,4	**1,0**	0,4	1,0	
Additive Technologies and Modeling 3D	**0,9**	**0,8**	**0,8**	0,3	**0,6**	0,5	**0,9**	0,0	0,5	0,4	**1,0**	0,4	**1,0**	0,4	**1,0**	1,0

The variables produced by ROI – Business results and Additive Technologies and Modeling 3D are strongly correlated. It is believed that this partnership is not a recent event in company. From a business perspective, this can be explained by the need to conduct new technologies for development of new products and processes; in addition to product quality improvement. Innovation. The Congruence with the strategy (CS), Market, Strength of the Client (SC), Production capacity (PC) / Access to external technologies (AET) and Additive Technologies and Modeling 3D are strongly correlated and together have a strong influence on the business return dimension. From a global industry perspective, a country's competitive position is dependent on the relative strength and weakness of other companies. In fact, the modeling 3D CAD and rapid prototyping and additive technology influence to a greater or lesser degree the performance of firm in the front end fuzzy of PDP. In this perspective, value create for the business. Creating value involves innovation that creates or increases valuation of the benefits from consumption. Value creation implies increasing the size of the pie itself, not just a cut of the pie. .In fact, the creation of value in the long run has been widely discussed in both academic environnment as well as in companies. Creating value involves innovation that creates or increases valuation of the benefits from consumption. In this perspective, technology emerges as one of the most important strategic resources for the companies (Ding et.al., 2004).

Phase 4: Determination of effects of the incorporation of technological innovations based on 3D modeling and additive manufacturing in the performance of companies, in light of characteristics of projects using Neurofuzzy Technology

This phase focuses on determining the optimal efficiency rate of the effects of the incorporation (OEREI) of technological innovations based on 3D modeling and additive manufacturing in the performance of companies, in light of characteristics of projects using Neurofuzzy Technology. It is a process whose attributes usually possess high subjectivity characteristics, in which the experience of the decision maker is very significant. Thus within this spectrum there is the need for a tool that allows adding quantitative and qualitative variables that converge towards a single evaluation parameter (Cury and Oliveira; 1999; von Altrock, 1997). The results is described below.

Determination of Input Variables (IV): This section focuses on determining the qualitative and quantitative input variables (IV). These variables were extracted (15 variables) from the independent variables (dimensions of *characteristics of projects* of the company). The linguistic terms assigned to each IV are: High, Medium and Low. Accordingly, Table 1 shows the IVs in the model, which are transformed into linguistic variables with their respective Degrees of Conviction or Certainty (DoC), with the assistance of twenty judges opining in the process. The degrees attributed by the judges are converted into linguistic expressions with their respective DoCs, based on fuzzy sets (Table 4) and IT rules (aggregation rules), next (composition rules).

Table 4: Linguistic terms of Input Variables

Input Variables	Type	Linguistic terms		
Production capacity (PC)	Qualitative	Low	MEDIUM	High
Congruence with the strategy (CS)	Qualitative	Low	MEDIUM	High
Strength of the Client (SC)	Qualitative	Low	MEDIUM	High
Market research (MR)	Qualitative	Low	MEDIUM	High
Impact on Strategy (IS)	Qualitative	Low	MEDIUM	High
Others…				

In summary, based on data collected, to achieve this step, the top 15 projects characteristics (Production capacity (PC); Congruence with the strategy (CS); Strength of the Client (SC); Market research (MR); Impact on Strategy (IS) ; Technical Complexity (TC); Costs (C); C*lient needs analysis* (CNA); Durability technical and market (DTM); Financial Risk (FR); Platform for growth (PG); Channels to Market (CM); Skills (SK); Access to external technologies (AET); Risks of environmental security (RES); Proprietary position (PP); Synergy with other business operations (SOBO); and Raw material (RM)) classifications were selected (Table 1) to feed the input variables in this Phase and Step. For example (hypothetical), when the expert's opinion was solicited about which desired degree of projects characteristics the product development manager should have, the answer was 7.0. Next, the fuzzification process (simulation) took place, assigning the linguistic terms: LOW, MEDIUM and HIGH levels of evaluation on a 1 to 10 scale. For score 7, considered LOW by 0% of the specialists, MEDIUM by 55% and HIGH by 45%. The fuzzy inference takes place from the base of rules, generating the VS linguistic vector obtained through the steps of aggregation and composition. Figure 26 illustrates the simulated weighting of the experts assigning the following linguistic terms: LOW, MEDIUM and HIGH, evaluated on a scale from 1 to 10. With the specialists' responses the degree of certainty of linguistic terms in each of the input variables was determined using the "fuzzy" sets. The generic "fuzzy" sets were defined for all the qualitative IVs, which always have three levels of linguistic terms: a lower, middle and higher level.

Determination of Intermediate Variables and Linguistic Terms: The qualitative input variables go through the inference fuzzy process, resulting in linguistic terms of intermediate variables (IVar). Thus, the linguistic terms assigned to IVar are: Low, Medium and High. The intermediate variables were obtained from: A - Market Performance: Channels to Market (CM), Strength of the Client (SC), Market research (MR), C*lient needs analysis* (CNA), Access to external technologies (AET); B - Economic and Financial Performance: Costs, Financial Risk (FR); C-Technical Performance: Production capacity (PC), Technical Complexity (TC), Durability technical and market (DTM), Platform for growth (PG), Skills (SK), Proprietary position (PP), Synergy with other business operations (SOBO), Raw material (RM); D - Environmental Performance: Risks of environmental security (RES); and E - Strategic Performance: Congruence with the strategy (CS), Impact on Strategy (IS).

The architecture proposed is composed of nine expert fuzzy system configurations, qualitative input variables that go through the *fuzzy* process and through the inference block, thus producing an output variable (OV), called intermediate variable (IVar). Then, the IVars, which join the other IVar variables form a set of new IVars, thereby configuring a sequence until the last layer in the network. In the last layer of the network the output variable (OV) of the *neurofuzzy* Network is defined. This OV is then subjected to a defuzzification process to achieve the final result: Optimal Efficiency Rate. In summary, the fuzzy inference occurs from the base-rules, generating the linguistic vector of the OV, obtained through the aggregation and composition steps.

For example, when the experts' opinion was requested on the optimal efficiency rate for the *effects of the incorporation of technological innovations based on 3D modeling and additive manufacturing in the performance of company,* the response was 8.0. Then the fuzzification (simulation) process was carried out, assigning LOW, MEDIUM and HIGH linguistic terms to the assessment degrees at a 1 to 10 scale. Degree 8, considered LOW by 10% of the experts, MEDIUM by 45% and HIGH by 45% of the experts. In summary, the expert's response enabled to determine the degree of certainty of the linguistic terms of each of the input variables using the fuzzy sets. The results confirm the *Hiphotese: Optimal efficiency rate of effects of the incorporation of technological innovations based on 3D modeling and additive manufacturing in the performance of company, in the front end fuzzy of the product development process depends on the combination and interaction of the projects characteristics of the company.*

Determination of Output Variable – Optimal efficiency rate of effects of the incorporation of technological innovations based on 3D modeling and additive manufacturing in the performance of company

The output variable (OV) of the neurofuzzy model proposed was called optimal efficiency rate of effects of the incorporation of technological innovations based on 3D modeling and additive manufacturing in the performance of company (by type of product). By way of demonstration, using assigned IT (average) hypothetical Parts “Synesthesia”, Effect in Candlestick - wax, M. Packaging, Identification L. Products, Cover Catalog, Candlesticks "Cube", Candlesticks "Lágrimas", Fruit Bowl Symbiosis and Gutta, Parts “Unda”, Fruit Bowl "Nirvana", Solitary Spiral and Bellevalia, Parts Cube and Bateau, and Parts Spiral and Synesthesia. The numerical value scale corresponds to value for optimal efficiency rate (0,8936 – corresponds all the products).

With this result (optimal efficiency rate) produced for a better combination and interaction of strategic innovation projects of products multiples of the Company that converged toward a single parameter, To illustrate this, assuming that the study-object company demonstrate the following optimal efficiency rate of effects of the incorporation of technological innovations based on 3D modeling and additive manufacturing in the performance of company by type of product (Figure 8).

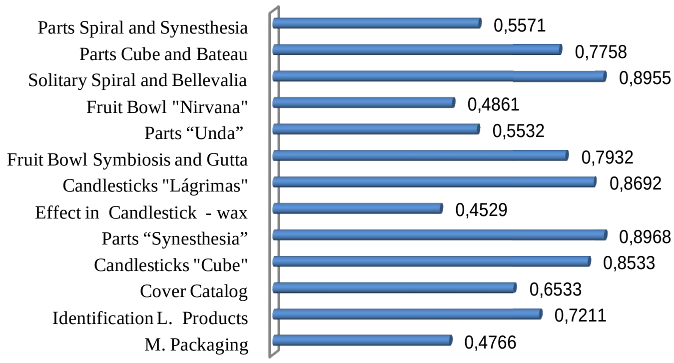

Figure 8: Optimal efficiency rate of effects of the incorporation of technological innovations based on 3D modeling and additive manufacturing in the performance of company for each product

The expected reference performance for all products is 0.7756 (hypothetical). It is concluded that: Candlesticks "Cube", Parts “Synesthesia”, Candlesticks "Lágrimas", Fruit Bowl Symbiosis and Gutta, and Solitary Spiral and Bellevalia products, show efficiency in the combination of their innovation activity strategies and value creation, based on the performance expectations (P1: Impact on the Customer; P2: Business results, P3. Percentage Sales of Innovative Products). The priorities of innovation activities are dynamic and dependent on constraints and uncertainties that come from the environment at any given time. The environmental contingencies are crucial and essential to adapt the strategies. The modeling approach presented here enables this sophistication refinement for every contingency presented.

5. Conclusions and Implications for Practice Management

In fact, the company object of this research introduced a whole new and more contemporary line of products on the market in a short period of time. This was due to the adoption of new methods and new product development technologies, such as 3D CAD modeling, the use of virtual "prototypes" in the perspective of meeting customer expectations, the use of additive manufacturing technologies to obtain prototypes for visualization and conversion technologies and rapid manufacturing of tools for producing functional prototypes and final pieces. From different dimensions, the results refer to the additive technologies as a mechanism that leads to increasing business value from the perspective of the project, consistency with the strategy, production capacity, strength of the client/market need, technical competence and cost. It is also evident that the technological innovation is a dynamic list of priorities, depending on the essential and desired existing capacities that emerge over practice time, always bringing new concepts and demanding new behaviors, new content and technical implementations, thus fundamentally requiring to permanently reconfigure the new capacities for the new innovation performances. Regarding this effort, the research on such priorities should be applied permanently and periodically.

Of the findings of the state of the art and state of practice, it is reasonable to state that this research is vulnerable to criticism. This study includes several limitations as specified below, which also helps to identify potential areas for future studies. In the research, cross-sectional data used in this study may not be appropriate to establish fundamental relationships between variables, but as referenced by Kenny (1979), the relationships that use cross sections are satisfactory and popularly accepted in relationship tests. Furthermore, a survey was developed for company in Portugal in a static context, which may represent a limiting factor. Therefore, it is recommended to reproduce and replicate the model in companies from other countries in order to confirm the results. It is also recommended that the innovation capacity dimensions should be extracted from the state of the art, but strongly confirmed by the state of practice, by the judgment of other experts (from other countries), taking into account that values, beliefs, cultures and experiences are determinants in the assessment, which can overturn the effects on the results. Of the research findings, the innovative companies undertake the ever-fast changes, intense competition and a highly uncertain and risky environment. The effect produced by technology on the development of new products is equally intensive. Nevertheless, the capacity to innovate companies will have to be anchored in efficient planning policies.

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