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The next frontier: Open innovation and prospecting of knowledge for value co-creation in complex environments based on new business models by 3D modeling and additive manufacturing

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This article aims to contribute to a policy of innovation management. To do so, it presents the influence of practices of open innovation in the prospecting of knowledge for value creation in highly complex environments under 3D modeling and additive manufacturing. The research was conducted in the light of theoretical excerpts and application of a survey to specialists, with knowledge about the investigated object, selected by scientific and technical criteria. A case study of multiple products was elaborated in a traditional segment of pewter in Portugal. The data were extracted by means of a matrix of judgment in which experts made their judgments about the variables investigated. In order to reduce subjectivity in the results achieved, the following methods were used: multicriterial analysis, artificial neural networks and neurofuzzy technology. The produced results were satisfactory, validating the presented proposal.

Key words: Open innovation practices, prospecting of knowledge, value co-creation, complex environments, and 3D modeling and additive manufacturing.

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; Teece et al., 1997), and innovation and international competition (Chesbrough and Rosenbloom, 2002; Christensen, 2003; Damanpour, 1996). This helps to reconsider how to succeed with innovation (Teece, 1986; Teece et al., 1997; Wheelwright and Clark, 1992). Innovation events, such as the introduction of a new product or process, represent the end of a series of knowledge and the beginning of a value creation process that can result in improvement in business performance marked by the ability to counteract the vulnerability of the globalization of business. However, the ability to design and provide innovative products with great incremental value to customers in a

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specific issue requires technical expertise of different knowledge derived from internal and external sources of knowledge (Chesbrough, 2003). But it is also true that organizations need to properly use the knowledge derived from different sources and check the business status of their activities and therefore, innovations should be used as increments of the process of interaction of knowledge. Different innovations depend on different types and sources of knowledge. This way, it is believed that assessing the relative importance of the different sources of knowledge for the performance of innovation is relevant because it informs the companies in their strategic decisions about the development of different channels for knowledge acquisition (Frenz and Ietto--Gillies, 2009).

The sources of knowledge (P&D, Universities and research Centers among others) have multifaceted nature (Kline and Rosenberg, 1986; Von Hippel, 1988) and show different impacts on a company's business, since the innovation performance is strongly dependent on and boosted by knowledge and its respective sources (Frenz and Ietto--Gillies, 2009). With the widespread diffusion of knowledge, all the knowledge necessary for creating innovations is no longer present within the firm's boundaries. They need to acquire knowledge from other sources. In fact, knowledge expands the potential for creating business value (Roper et al., 2008). However, the capacity of prospecting of knowledge is a complex challenge. Several studies have referenced the importance of the collaboration from knowledge and innovation generation (Chesbrough, 2003). This takes to evaluate the influence of innovation practices, in particular open innovation in the prospecting of knowledge. Open innovation is a new way of thinking of innovation for firms, where firms explicitly cooperate with others to create new innovations (Chesbrough, 2003). Open innovation is a model that assumes that firms can and should use external as well as internal ideas and internal and external paths to market, as they look to advance their technology (Chesbrough, 2006). Open innovation can be thought of as systematically exploring a wide range of internal and external sources for innovation opportunities, consciously integrating that exploration with the firm's capabilities and resources, and broadly exploiting those opportunities through multiple channels (West and Gallagher, 2006; Grotnes, 2009).

In this dichotomy, technical efficiency is a parameter of the developing capacity of innovative products, which translates into one of the most remarkable logical arguments to potentialize and encourage competitive advantage (Wheelwright and Clark, 1992). Companies make use of its innovative capacities to achieve sustainable competitive advantage and value co-creation. 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 et al., 1995; Sehror and 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 and Streeten, 1977; Mason, 1981; Morley and Smith, 1977; Negandhi, 1975; Prasad, 1983; Wells, 1973).

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 (Zhang et al., 2014; Zhang et al., 2013a, b). In this perspective, new technologies emerge as one of the most important strategic resources for the companies in product development product and value co-creation for the business. The use of additive manufacturing techniques has been effective in the reduction of time of product development. 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. As such, it enables to create business value.

Thus, this article aims to contribute to a policy of innovation management. To do so, it presents the influence of practices of open innovation in the prospecting of knowledge for value creation in highly complex environments under 3D modeling and additive manufacturing. The case study of multiple products was elaborated in a traditional segment of pewter in Portugal. The article is divided according to the following sections: Methodology, verification of the conceptual model and subjacent analyzes, and conclusions and implications.

DESIGNER OF RESEARCH

Conceptual Model framework: Constructs and hypotheses

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

The open innovation paradigm (Chesbrough, 2003) can be characterized by its porous innovation process, and the strong interaction of the company with its environment. By integrating a large number of individuals into the innovation process, new creativity and know-how are brought into the organization (inbound open innovation). Von Hippel (1988) suggested using lead users and other stakeholders as external sources of innovation (Schroll and Mild, 2011). Not only can this attract more talent, it can also transfer idle innovative ideas and R&D technology externally to other companies. Enterprises use the concept of open innovation, in which

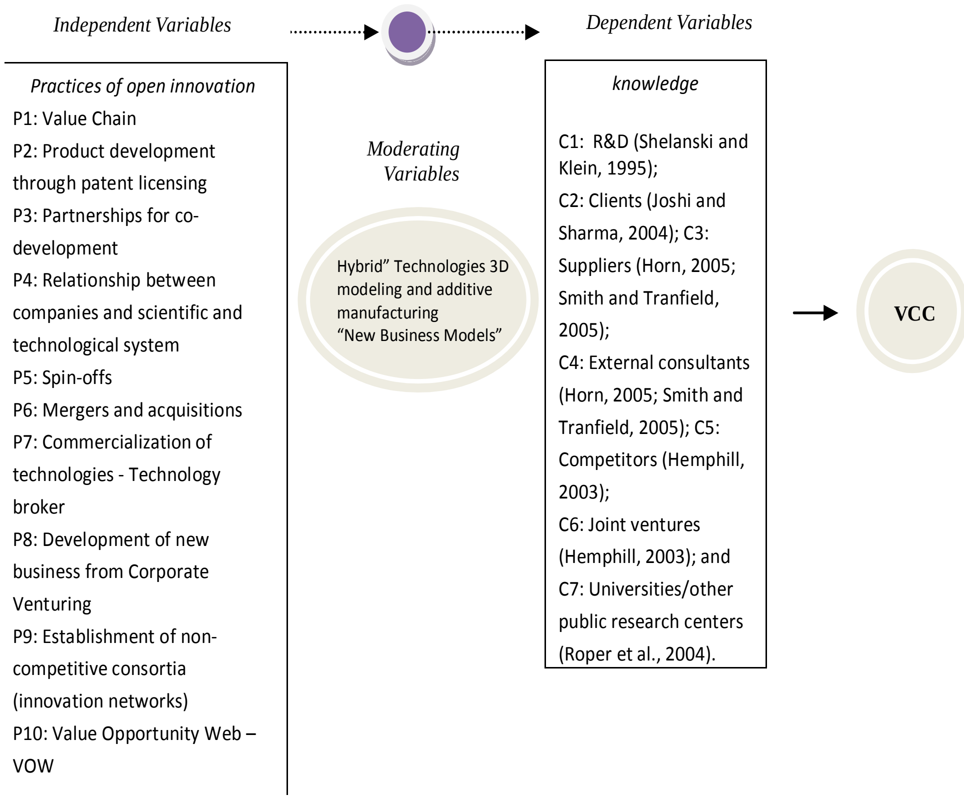

Figure 1. Conceptual model.

internal innovative ideas can flow outward and external ideas and technologies can flow inward within an enterprise. Chesbrough (2003) proposed the concept of open innovation which indicated that businesses should become more open to innovation processes and value creation. Value is generated by nurturing informal relations and encouraging a free, horizontal flow of knowledge across organizational boundaries by opening new channels of communication and sustaining propagation of new ideas (Grimaldi and Cricelli, 2012). In this perspective the knowledge has forced firms to ground their value creation. The open innovation approach explores knowledge acquired from external sources (competitors, universities, partners) (Grimaldi and Cricelli, 2012). Business exposure to internal and external knowledge promotes the generating value (St-Jean and Audet, 2012; Fosfuri and Tribo, 2008; Norman, 2004). In contexts where knowledge is a crucial asset, companies increase their dependency on external sources to improve firm performance (Morgan and Berthon, 2008). Knowledge emerges as one of the most important strategic resources for the companies. One of the basic premises of dominant logic is that knowledge is a fundamental source of competitive advantage. To raise the capacity of value and innovation creation, the organizations must be able to create this value. Kotler and Keller (2006) use the term "customer perceived value" and define it as "the difference between the prospective customer's evaluation of all the benefits and all the costs of an offering and the perceived alternatives". Value can be examined from two perspectives: customers and firms. It is important to recognize that value resides with customers. In addition, customers use products or services in a wide range of activities. Thus, value needs to be examined from a customer's perspective (Kim and Mauborgne, 2000; MacMillan and McGrath, 1997) and, more specifically, from their experience with the products or services.

Co-creation is advocated as a means to expand the innovation and value creation capability of the firm […] (Sawhney et al., 2005; Prandelli et al., 2006; von Stamm, 2004). Creation refers to the process of integrating different resources from different actors in order to actualize their value potential. It captures the activity or way; the mechanism through which the resources provided by different actors are integrated into value creation processes and then developed into value-in-use. Mechanisms are firm, customer, or even community led activities through which additional resources are offered for the use of other actors. In relationships between firms and customers, co-production, co-design, and co-development (Sheth and Uslay, 2007) are examples of mechanisms through which customer resources are engaged in the value creation for a firm. Here, that value creation is supported by the customer. However, mechanisms can also be designed through which additional firm resources are provided for the support of the customer and the firm (B2B and B2C). Technology is often seen as facilitating the emergence of different types of mechanisms by enabling the transfer of new resources effectively and efficiently for the use of other actors. In this perspective, new technologies emerge as one of the most important strategic resources for the companies in product development product and value co-creation for the new business. In this context, the use of 3D modelling and additive manufacturing techniques has been effective in the reduction of time of product development. The 3D modeling and additive manufacturing is an innovative mechanism for the PDP and a new business model. In recent years, the business model concept has been used as a general construct explaining how a firm is interacting with suppliers, customers, and partners (Zott and Amit, 2007). Business model includes customer value creation as one of the core elements. Business model should explain how the firm creates value for its customers, with terms such as “profit potential,” “revenue model,” “revenue logic,” “capture value,” “profit formula,” or “returns for stakeholders”. Thus, it can be concluded that the business model should also explain how the firm yields a profit from its operations. The business model construct should be also externally oriented and illuminate the relationships that the firm has with the various actors in its value network. Business model is an underlying economic logic that explains how we can deliver value to customers at an appropriate cost” (Nenonen and Storbacka, 2010; Magretta, 2002).

Rapid prototyping systems offer the opportunities to make products faster and usually at lower costs than using conventional methods. Since rapid prototyping and manufacture can substantially reduce the product development cycle time, more and more businesses are taking advantage of the speed at which product design generated by computers can be converted into accurate models that can be held, viewed, studied, tested, and compared (Yan and Gu, 1996). Rapid prototyping generally refers to techniques that produce shaped parts by gradual creation or addition of solid material, therein differing fundamentally from forming and material removal manufacturing techniques (Kruth et al., 1998). Prototyping and modeling remain the main forms of investment and growth for 3D printing, although this is changing with investors and technologists growing increasingly excited about the wider possibilities of 3D technologies (Birtchnell and Urry, 2012). Capacities and the potential of rapid prototyping technologies have attracted a wide range of industries to invest in these technologies and value create to industries (Yan and Gu, 1996). Thus, from the theoretical excerpts, the following variables and hypotheses of this study were raised.

Independent Variables: from the findings in the literature (Lopes and Teixeira, 2009; Moreira et al., 2008) the following open innovation practices were identified (Trentini et.al., 2012):

Value Chain: the value chain of innovation is one of the most popular practices, because it increases significantly the incremental value of business. Chesbrough (2006) shows that open innovation assumes that useful knowledge is widely distributed and that even more capable of organizations of R&D should identify, connect and boost external sources of knowledge as an elementary process for innovation.

Product development through patent licensing. It is a very common practice. The occurrence of technology licensing has been mainly concentrated in the chemical industry - pharmaceutical, electrical and electronic equipment, computers and industrial machinery.

Partnerships for co-development. It is a practice that has become business model that enables increasing innovation reducing P&D costs and facilitates the expansion and dissemination of innovation.

Relationship between companies and scientific and technological system. It is a practice that enables the research developed at universities and research centers supports the industrial requirements, allowing the specialization of each entity with return for both parties. Moreira et al. (2008) report some of the challenges to be overcome, such as: relationship difficulties, lack of communication, divergent goals and visions, deadline mismatches, the distribution model of knowledge in universities that hinders the identification of researchers and research made, and the steps of assessment and valuation of technologies.

Spin-offs are companies created to develop opportunities generated by the parent company. They aim to explore new business conditions in order to minimize negative impacts on the parent company. In this kind of practice, projects that do not have any internal interest may generate new business.

Mergers and acquisitions. Mergers and acquisitions are aimed at absorbing knowledge and external technology, allowing a faster establishment in new markets and impeding the entry of new competitors, as well as reducing costs and increasing the possibility of releases.

Commercialization of technologies via Technology broker. It is a practice of open innovation in which a professional assists in finding, rating, marketing and managing the transfer of certain technology / knowledge through a network of contacts.

Development of new business from Corporate Venturing. It is a form of investment in which companies invest capital in new-born businesses with innovations that may or may not be related to the business and have a high level of risk, but with great potential for growth.

Establishment of non-competitive consortia (innovation networks). It is a collaborative practice in which P&D companies associate with universities, research centers or competing companies with the goal of generating knowledge and products that would hardly be possible in an individual way.

V*alue Opportunity Web – VOW,* is a practice of capturing and analyzing potentially valuable data on the external environment and transforming that information into winning products for consumers. The goal of a VOW is to analyze the data obtained taking into account new needs, new ways of doing things, new product features and new models the company may deliver value to the customer.

Moderating Variables: The moderating variables were extracted from the specialized literature and assessed by experts for confirmation. The following moderating variables were identified: Hybrid" Technologies 3D modeling and additive manufacturing.

Dependent Variables: The independent variables were extracted from the specialized literature and assessed by experts for confirmation. The following independent variables were identified: Stakeholders' knowledge: C1: R&D (Shelanski and Klein, 1995); C2: Customers (Joshi and Sharma, 2004); C3: Suppliers (Horn, 2005; Smith and Tranfield, 2005); C4: External consultants (Horn, 2005; Smith and Tranfield, 2005); C5: Competitors (Hemphill, 2003); C6: Joint ventures (Hemphill, 2003); and C7: universities/other public research centers (Ropper et al., 2004). For the Customer dimension, the construction used is based on Joshi and Silva (2004). For the suppliers variable (Horn, 2005; Smith and Tranfield, 2005), the content was derived from the construction used by Dow et al. (1999) and Forza and Filippini (1998). For the R&D variable, the construct was mainly derived from Shelanski and Klein (1995); Gupta, Wilemon, and Atuahene-Gima (2000) and Chiesa et al. (1996), which capture two important R&D aspects: capabilities and connections. As for the variable External Consultants, the construct is based on Horn (2005); Smith and Ranfield (2005). The variable Competitors is based on Hemphill (2003). Finally, the variable Joint Ventures is based on Hemphill (2003).

From the conceptual model, the following hypotheses were made:

Hypothesis - *H1*: The practices of open innovation influence to a greater or lesser degree the prospecting of knowledge for value creation in highly complex environments under 3D modeling and additive manufacturing.

***H2*:** The optimal rate of value creation depends on the combination and interaction of the influence of the practices of open innovation in the prospecting of knowledge in highly complex environments under 3D modeling and additive manufacturing.

RESEARCH METHODOLOGY

Background to the case study 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. The technique used was the stated preference, taking into account that these methods work with the preferences of the decision makers, revealed by the choice made among the alternatives selected from a set of real alternatives, or not. In this classification framework, the research interviews and consultations with the experts are highlighted. The experts issued their judgments through a scale questionnaire for the first external validation. Before applying the final collection instrument, a pretest was conducted with experts to clarify whether the instructions were clear and objective; to verify that the questions were objective and without interpretation ambiguity; and to investigate possible comprehension problems by the experts on the expected responses. There were few adjustment suggestions. 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 managers, planning, technological innovation and modeling managers. The phases and steps of the model were based on the following methods: (i) Thurstone's Law of Categorical Judgment psychometric scaling; (ii) multivariate analysis; and (iii) multicriteria: Compromise Programming, Promethee II, and Electre III, and neurofuzzy technology. 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

Figure 2. Silicon Mold - Centrifugation Process.

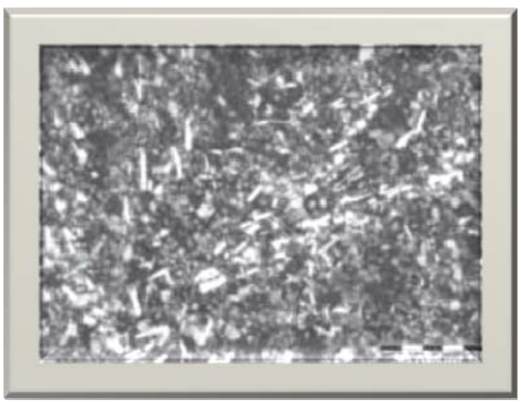

Figure 3. Microstructure of tin alloy used by the company.

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.

RESULT

Product development

Centrifugal Casting

This is one of the most used processes in the company, as it allows large production output. In the centrifugation casting, the silicon mold is placed in a centrifuge where the centrifugal force generated by the rotation of the dish of the machine allows the liquid metal poured into the center of the mold to completely fill the most intricate cavities. Figure 2 shows a mold used in the process.

Figure 4. Part of mechanical lathe.

The pewter alloy, often the type Sn-4.5Cu-4.5Sb, is poured at temperatures between 300 and 380° C, depending on the type of part being produced. Centrifugation facilitates the flow of heat flow, reducing the time of solidification, thereby increasing productivity. Figure 3 shows the microstructure of this alloy after polishing and metallographic etching (2ml HCl, 5ml HNO3 and 93ml H_2O).

This structure is composed of a tin-rich solid solution containing needles of small particles of Cu6Sn5 (white color). The tightness in mechanical lathe (Figure 4) uses wood or bakelite molds that are more durable and long lasting. A pewter plate is fixed on the lathe and spun by the operator to acquire the forms of the mold.

The purpose of this section is to present the u*nderlying analyses* of the results of the study.

Manufacture of pewter tube: The company has equipment for metal spinning. Through this equipment, pewter is conducted in a sequence to get to a tube shape.

The 3D CAD Modeling: All of the objects made were modeled in Solid Works 2007 software. The use of this tool allowed to build virtual simulations of the objects, their adjustment and correction whenever necessary. Once the phase 3D CAD modeling was completed, the files were converted in the format *.vrml to make its reading in Cinema 4D software possible. This program achieved more realistic renders of the developed parts (Figure 5).

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

Figure 5. Simulation of object Estamine by software CAD 3D.

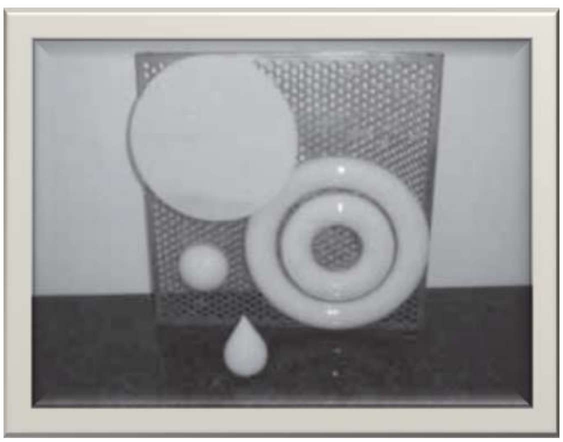

Figure 6. Prototypes in Stereolithography in building platform.

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.

The *.stlfiles, created from SolidWorks 2007 software, were introduced into the equipment software and then the process was started. The photopolymerization lasted for about ten hours. Once this period was finished, the prototypes were introduced into a solvent bath for construction waste disposal and cleaning of adhesive resin (Figure 6), being later removed from the building platform and having their supports removed.

Figure 7. Prototypes in Stereolithography:-Cube and Bateau.

Figure 8. Prototypes in Stereolithography, a final product in pewter.

The models were placed in an oven for a post curing of the resin by ultraviolet rays and increase its mechanical resistance (Figure 7).

Finally, the pieces were polished and painted in order to simulate the superficial aspect of pewter (Figure 8). Some of the prototypes were used to produce silicone and resin molds to cast away resins loaded with different types of particles. The pieces obtained through this process were applied in some of the pewter pieces. In other cases, the prototypes were used in the company for display and the manufacture of molds for different production processes that involve casting/foundry (by gravity and by centrifugation) and the formation of pewter plates.

Developed products

Figure 9 shows a piece obtained by plastic deformation where the spiral shape functions as an extension of a

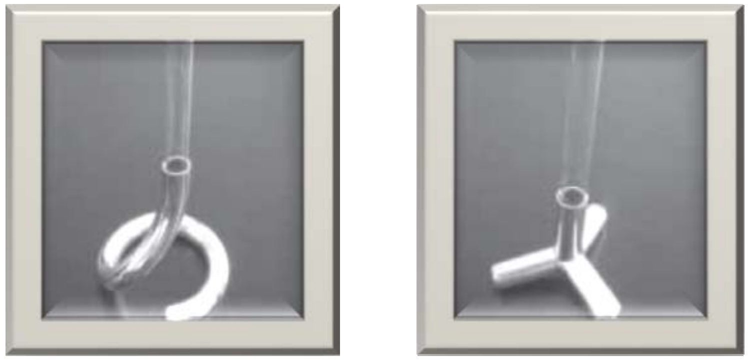

Figure 9. Solitary Spiral and Bellevalia.

Figure 10. Casting resin in silicon mold obtained from a model of PR

Figure 11. Fruit Bowl "Nirvana".

flower (Solitary).

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 (Figures 10 and 11).

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 (Figures 12 and 13).

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.

Conceptual model verification and underlying analyses

To solve the research problem and achieve the desired

Figure 12. *Candlesticks:*"Lágrima", based on carbon fiber in the company's stand in Ceranor 2008.

Figure 13. Effect in candle holder.

goal, the practices of open innovation of the traditional segment of pewter were identified and then evaluated according to their influence on the prospecting of knowledge according to the respective sources of knowledge. Finally, the optimal rate of value is modeled from the interaction between all dependent variables.

Phase 1: Modeling of the influence of the Open Innovation practices in the prospecting of knowledge of the actors (sources)

This phase is systematized in the following steps:

Step 1) identification of the practices of open innovation. Thus, the following practices of open innovation from the specialized literature were identified and confirmed by experts: Value Chain; Product development through patent licensing; Partnerships for co-development; Relationship between companies and scientific and technological system; Spin-offs; Mergers and acquisitions; Commercialization of technologies via Technology broker; Development of new business from Corporate Venturing; Establishment of non-competitive consortia (innovation networks); and Value Opportunity Web – VOW.

Step 2) identification of the sources of knowledge and their respective knowledge: The identification is systematized in the following: C1: R&D (Shelanski and Klein, 1995); C2: Clients (Joshi and Sharma, 2004); C3: Suppliers (Horn, 2005; Smith and Tranfield, 2005); C4: External consultants (Horn, 2005; Smith and Tranfield, 2005); C5: Competitors (Hemphill, 2003); C6: Joint ventures (Hemphill, 2003); and C7: universities/other public research centers (Roper et al., 2004).

Step 3) Evaluation of the influence of practices of open innovation in the prospecting of knowledge in high tech industries. This procedure was developed using the multi-criteria analysis Electre III, Promethee II e Compromise Programming and Artificial Neural Network (ANN). Next, these procedures were detailed. The methods used were Compromise Programming, Electre III and Promethee II. The results achieved confirm *Hypothesis 1:* The practices of open innovation influence to a greater or lesser degree the prospecting of knowledge of the actors, 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. In other words, one applies the selection and classification methodology of alternatives, using the Compromise Programming, Promethee II and Electre III methods. 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. The problem solution compromise is the one that comes closest to the alternative. This method was designed to identify the closest solution to an ideal one; therefore it is not feasible, using a predetermined pattern of distances. In Promethee II there is a function of preferences for each criterion among the alternatives which must be maximized, indicating the intensity of an alternative to the other one, with the value ranging from 0 to 1. Of the Electre family (I,II,III,IV and V), Electre III is the one considered for the cases of uncertainty and inaccuracy to evaluate the alternatives in the decision problem. All these methods enable one to analyze the discrete solution alternatives, and taking into consideration subjective evaluations represented by numerical scores and weights. As these are problems involving subjective aspects, the methods that best fit the situation of this research are the methods of the family Electre and Promethee. It should be mentioned that although the Compromise Programming method is not part of this classification, it has similar characteristics, showing much

Table 1. Assessment of preferences – Influence of practices of open innovation in the prospecting of knowledge for value creation in highly complex environments.

	Multicriteria analysis		
	Promethee II	**Compromise programinng**	**Electre III**
Value Chain / Partnerships for co-development	1ª	1ª	1ª
Relationship between companies and scientific and technological system	1ª	2ª	2ª
Product development through patent licensing	3ª	2ª	2ª
Value Opportunity Web – VOW / Spin-offs Commercialization of technologies via Technology broker	4ª	4ª	3ª
Development of new business from Corporate Venturing	4ª	4ª	3ª
Mergers and acquisitions / Establishment of non-competitive consortia (innovation networks)	3º	3º	4º

simplicity in order to understand its operation, which makes it feasible for this application.

Within this perspective, the multicriteria methods are viable instruments to measure the performance of the practices of open innovation in the prospecting of knowledge for value creation in the high tech enterprises. The results produced by this prioritization enable managers to better focus their efforts and resources on managing the practices of open innovation that perform best, which results in achieving the goals sought by the companies. 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 of the companies that will feed the system; the criteria are in the second level, which are the knowledge (prospecting) of actors: K1: R&D (Shelanski and Klein, 1995); K2: Clients (Joshi and Sharma, 2004); K3: Suppliers (Horn, 2005; Smith and Tranfield, 2005); K4: External consultants (Horn, 2005; Smith and Tranfield, 2005); K5: Competitors (Hemphill, 2003); K6: Joint ventures (Hemphill, 2003); and K7: universities/other public research centers (Roper et al., 2004). The practices of open innovation of the companies are in the third level, the alternatives, which are: P1: Value Chain; P2 Product development through patent licensing; P3: Partnerships for co-development; P4: Relationship between companies and scientific and technological system; P5: Spin-offs; P6: Mergers and acquisitions; P7: Commercialization of technologies via Technology broker; P8: Development of new business from Corporate Venturing; P9: Establishment of non-competitive consortia (innovation networks); and P10: Value Opportunity Web – VOW. 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 1 shows the results produced.

Open innovation networks introduce highly complex and multifaceted inter-organizational relationships (Jarvenpaa and Wernik, 2011). The results produced by the methods demonstrate the value chain and partnerships practices of open innovation as the most significant ones to ensure the knowledge prospecting and value creation for the companies. In today's competitive global market, enterprises must possess the capability to design and deliver innovative products with great value to customers in a timely matter. Each organization must focus on its own strong area where it will be uniquely competitive. Hence, all partners should ruminate about where and how values are created, and what contribution they can make based on their core competencies.

In addition, interorganizational relationships must be rapidly built up or dismantled among dynamically networked organizations. Once value chains are composed, all partners hold a definite vision of the coherence within the industry value system to become a collaborative value chain. All members of a given value chain must work together to respond to the changes of market demands rapidly (Chiang and Trappey, 2006). In this kind of environment, enterprises not only must reach out and enhance their relationships with each others, but also need to integrate their business processes (Chiang and Trappey, 2006). In fact, value chain provides enterprises with the opportunity to identify their core competencies and position themselves in the marketplace according to their competitive abilities (Al-Mudimigh et al., 2004; Chiang and Trappey, 2006). Firms benefit from engaging in a range of co-creation activities across the value chain, involving various touch-points and domains, rather than just one way of co-creating value with a particular type of co-creator (Ramaswamy, 2009). This paper presents value co-creation specifically business-to-consumer (B2C). B2C co-creation is rooted in relational marketing theory (Maklan et al., 2008). Atividades de co-criação de B2C são mais propensos a enfatizar formas de mercado como governança co-criação, porque esses empreendimentos estão criando um mercado para soluções aos desafios co-criação específicas. Perspective on co-creation in management is the study of open innovation (Chesbrough, 2003). Open innovation is characterised by the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively. Open innovation assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology (Chesbrough et al., 2006; Roser et al., 2013).

Once value chains are composed, all partners hold a definite vision of the coherence within the industry value system to become a collaborative value chain. Many business model definitions discuss the value network of the firm with terms such as "structure of value chain," "partner network," "value network," "links to external stakeholders," or "transactional links to exchange partners" (Nenonen and Storbacka, 2010). "Business is fundamentally concerned with creating value and capturing returns from that value, and a model is simply a representation of reality. We define a business model as a representation of a firm's underlying core logic and strategic choices for creating and capturing value within a value network" (Shafer et al., 2005). "We offer an interpretation of the business model as a construct that mediates the value creation process" (Chesbrough and Rosenbloom, 2002).

All members of a given value chain must work together to respond to the changes of market demands rapidly (Chiang and Trappey, 2006). Organizations create values for themselves and their customers via executing primary and supporting tasks. In the 1980s, value creation mainly depended on cost reduction and industry automation, but modern companies focus on value chain integration to achieve time-to-market and to enhance customer satisfaction (Garetti et al., 2005; Chiang and Trappey, 2006). Thus, the value chain concept offers management a means by which they can evaluate both existing and new strategic opportunities to create customer and partner value (Walters and Rainbird, 2007). Essentially the value creation system is an analytical tool; it facilitates the identification and evaluation of strategic alternatives (Walters and Rainbird, 2007). Value chain analysis identifies the flow of added value through the value creation processes within both the industry and the firm. In the business model of the future, value chains compete rather than individual companies, and the connectivity and process excellence are key challenges (AeIGT: 2003 cited in Johns et al., 2005). In addition, the cooperation in the value chain requires a complex repertoire of behaviors in that members organizations need to learn to mitigate the risks stemming from the other's opportunism and also to avoid lapses in their respective knowledge-sharing (Jarvenpaa and Wernik, 2011). Increasingly, it has been argued, innovative capacity is dependent upon building linkages through collaborative relationships (Coombs et al., 1996) […] this enables learning which adds to an organization's existing knowledge base and the creation of completely new knowledge (Inkpen, 1996) and also contributes to "novelty and variety in the economic system" by creating "new economic resources which otherwise simply would not exist" (Coombs et al., 1996). Such collaboration might involve sub-contracting, strategic alliances or joint ventures […] (McLoughlin, 1999; Walters and Rainbird, 2007). Partnership/co-operative innovation combines elements of process innovation management and product innovation management within a network structure that neither partner can create using its own resources to meet customer/market determined expectations for product and/or service performance at an economic (viable) cost. Thus, the value chain concept offers management a means by which they can evaluate both existing and new strategic opportunities to create customer and partner value. Essentially the value creation system is an analytical tool; it facilitates the identification and evaluation of strategic alternatives (Walters and Rainbird, 2007).

When comparing the results in terms of performance, the Compromise Programming and Promethee II methods did not differ in their classifications. For Electre III, the results were incompatible. And this is because the p, q and v veto thresholds, respectively, of indifference, strong preference and veto or incomparability have a discrepancy in the structure of their results (classification). Electre III presents a set of solutions with a more flexible hierarchical structure. This is due to the conception of the method, as well as the quite explicit consideration of the indifference and incomparability aspect between the alternatives. The results referenced by the Promethee II and Compromise Programming methods reflect the preference, according to the experts, for value chain and partnerships. The essence of the practices of open innovation is the accumulation of knowledge over time. Next is the influence of the practices of open innovation in the knowledge prospecting. For this ANN was used. The technique adapts to the case in question.

Prospecting of knowledge using the artificial neural networks – ANN

The artificial neural networks - ANN is understood to simulate the behavior of the human brain through a number of interconnected neurons. A neuron executes weighed additions for the activations of the neurons representing nonlinear relations. The ANN has the capacity to recognize and to classify standards by means of processes of learning and training. The training of the net is the phase most important for the success of the applications in neural network. The topology of the net can better be determined of subjective form, from a principle that consists of adopting the lesser intermediate number of possible layer and neurons, without

Table 2. Classification of practices of open innovation using artificial neural networks and multicriteria analysis methods.

	Multicriteria analysis			
	Promethee II	**Compromise programinng**	**ELECTRE III**	**ANN**
Value Chain / Partnerships for co-development	1ª	1ª	1ª	1ª
Relationship between companies and scientific and technological system	2ª	2ª	3ª	2ª
Product development through patent licensing	3ª	3ª	2ª	2ª
Value Opportunity Web – VOW / Spin-offs Commercialization of technologies via Technology broker	4ª	4ª	2ª	3ª
Development of new business from Corporate Venturing	4ª	4ª	3ª	4ª
Mergers and acquisitions / Establishment of non-competitive consortia (innovation networks)	3º	3º	4º	3ª

compromising the precision. Thus, in this application, the layer of the entrance data possess 10 neurons corresponding to the 10 variable referring to practices of open innovation. The intermediate layer possesses 8 neurons, and the exit layer possesses 1 corresponding neuron in a scale value determined for the ANN. The process of learning supervised based in the Back propagation algorithm applying software Easy NN determines the weights between the layers of entrance and intermediate, and between the intermediate and exit automatically. The training process was finished when the weights between the connections had allowed minimizing the error of learning. For this, it was necessary to identify which configuration that would present the best resulted varying the taxes of learning and moment. After diverse configurations to have been tested, the net of that presented better resulted with tax of an equal learning of 0.45 and equal moment 0.92. The data had been divided into two groups, where to each period of training one third of the data is used for training of net and the remaining is applied for verification of the results. The net was trained for attainment of two results' group for comparison of the best-determined scale for the networks. In the first test the total of the judgment of the agents was adopted; however, only in as test was gotten better scales, next of represented for method of the multi-criteria analysis. With this, the last stage of the modeling in ANN consisted of testing the data of sequential entrance or random form, this process presented resulted more satisfactory. The reached results were satisfactory, emphasizing the subjective importance of scale's methods to treat questions that involve high degree of subjectivity and complexity. How much topologies are used in the networks; the results showed some confi-gurations of the ANN and compared to the multicriteria analysis, it was observed that ANN 1 is better if approached with the classification obtained from the multi-criteria analysis. Thus, even other topologies do not Tenaha been the best ones, it had been come however close in some practices of open innovation of the multi-criteria analysis. The results can be observed in Table 2 that follows.

In fact, the goal of knowledge is to create value from organizational and individual knowledge. The benefits derived from good knowledge are multiple, and include: reduced duplication of effort, creation of new knowledge, and increased efficiency and productivity. Knowledge and innovation are the building blocks of sustainable competitive advantage (Porter, 1985), and therefore are a source for sustainable development and growth for enterprises. Co-creating means extending the value chain (Helm and Jones, 2010). Hence, involving co-creators leads to an expansion of organizational boundaries and management of new and different relationships (Sawhney and Prandelli, 2000). In addition, firms require a flexible yet systematic integration and alignment of processes and stakeholder activities across business processes, particularly where customer encounters take place (Payne et al., 2008, 2009; Clarke and Nilsson, 2008). Indeed, the challenge in building a more service oriented and customer centred business model relates to the type of relationships and interactions to be utilized in co-creating value (Roser et al., 2013).

Thus, an innovation is the use of innovative knowledge so as to create effective value for the stakeholders in the value chain. From the perception of the innovation, the innovation value chain may be represented differently. Indeed, innovation starts from an idea that is often embedded with an innovative knowledge, to become somehow a prototypical invention, to finally become an innovative product or piece of technology that is industrially exploited or even commercialized. Porter (1985) argues that firms that optimize their value chain activities vis-a-vis competition stand a better chance of leveraging valuable capabilities into sustainable competitive advantage (Prajogo et al., 2008). Clearly any partnership innovation must be beneficial to all parties (Walters and Rainbird, 2007). The results produced in the light of artificial neural networks confirm value chain and partnerships as the practice of open innovation that shows the most (in greatest degree) influence in the prospecting of knowledge. The value chain is supported by a particular value that creates a logic and its application results in particular strategic postures. Adopting a network perspective, a new economic value is configured to the organizations. Traditionally, value chain has been used as a concept and a tool to understand the analysis of industries and proved to be a useful mechanism for portraying the threaded engagement of traditional activities in industries (Porter, 1980). Moreover, it also shaped the thinking about value and value creation.

The value chain of a company relates to other chains and knowledge coming from different sources (suppliers, competitors, channels and customers, among others), which then become a value chain of the industry. At the same time, a company can make analyses of the links in the value chain between its suppliers, manufacturers and customers' chain in order to find ways to increase the competition. For the concept of value network, value is co-created by a combination of actors in the network. Business networks are independent. After all, how is value created? A traditional answer to this question is simply the value chain. In this perspective, the knowledge is certainly one of the best resources and the only sustainable competitive advantage. In this context, Additive Manufacturing technologies create parts layer by layer. Thereby, lots of benefits are offered. Especially extended design freedoms provide new potentials for the design of technical parts. To make these benefits accessible to different user groups (Adam and Zimmer, 2014). Recently, important technological and material developments increasingly enable Additive Manufacturing's applicability for the creation of end-use parts (Hague et al., 2004).

Thus, Additive Manufacturing more and more turns to a production capable technology (Kruth et al., 1998). Using Additive Manufacturing in terms of Direct Manufacturing – to manufacture end-use parts – new benefits can be gained due to the layer by layer manufacturing (Adam and Zimmer, 2014). Thereby the extension of design freedoms is one of Additive Manufacturing's most noteworthy potentials (Levy et al., 2003). It enables the manufacturability of highly complex parts which cannot be produced with conventional technologies like milling or casting. Additionally, Additive Manufacturing decouples parts manufacturing costs from its complexities (Adam and Zimmer, 2014). This increases the industrial relevance of Additive Manufacturing significantly, too (Hague et al., 2003). Here, Additive Manufacturing provides lots of potentials and benefits (Adam and Zimmer, 2014). Thus, in order to be able to enhance both value creation (the consumer's valuation of the benefit of consumption) and innovation, organizations must be able to create such value. We believe that the enabling factors are these three: individualized immediate feedback, a new organizational logic, and new cooperation structures (Johannessen and Olsen, 2010). Currently, the global products industry finds itself faced with many challenges. These challenges are multifaceted and complex, and the need for the application of innovative ideas and solutions is obvious (Van Horne et al., 2006). Hence, new technology facilitates network logic in the global. Thus, the innovation and economic growth are created. And the innovation of products and processes is seen as a promising answer to many of the challenges faced by the products industry.

Phase 2: Modeling of the optimal effectiveness rate of value creation in the light of the influence of the practices of open innovation in the prospecting of knowledge of the actors under 3D modeling and additive manufacturing

This phase focuses on determining the optimal efficiency rate (OERVC) for value creation in the company using Neurofuzzy modeling. 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 the practices of open innovation on the knowledge and value creation of high-tech companies, as it allows one to evaluate the desirable rate toward the acceptable performance of high-tech companies. 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 value creation 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 (10 variables: Value Chain; Product development through patent licensing; Partnerships for co-development; Relationship between companies and scientific and technological system; Spin-offs; Mergers and acquisitions; Commercialization of technologies via Technology broker; Development of new business from Corporate Venturing; Establishment of non-competitive consortia (innovation networks); and Value Opportunity Web – VOW) from the independent variables (dimensions of results Influence of practices of open innovation in the prospecting of knowledge for value creation in highly

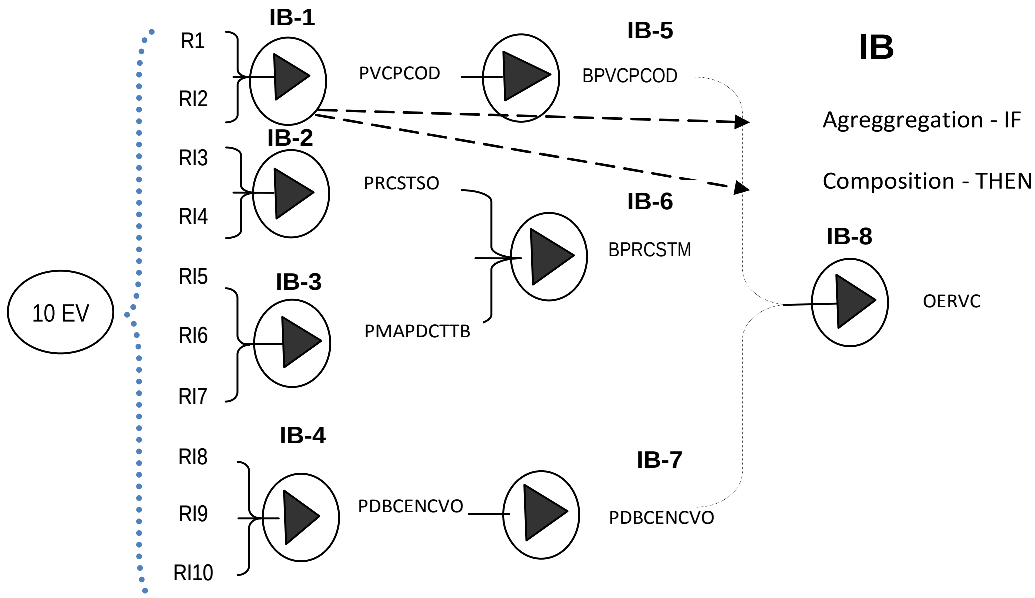

Figure 14. Neurofuzzy model.

complex environments. 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 and IT rules (aggregation rules), next (composition rules) (Figure 14).

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 value chain and partnerships for co-development: PVCPCOD; Performance of relationship between companies and scientific and technological system and Spin-offs: PRCSTSO: Performance of mergers and acquisitions, product development through patent licensing and commercialization of technologies via Technology broker: PMAPDCTTB; Performance of development of new business from corporate venturing, establishment of non-competitive: DNBENC consortia (innovation networks); and Performance of Value Opportunity Web – VOW): PDBCENCVO. The architecture proposed is composed of eight expert fuzzy system configurations, four quailtative 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 of Value Creation of High-Tech Companies. 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 technological innovation capacity performance of company A, 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 0% of the experts, MEDIUM by 55% and HIGH by 45% of the experts. In summary, the expert's response enabled one to determine the degree of certainty of the linguistic terms of each of the input variables using the fuzzy sets. The results confirm the *H2:* The optimal efficiency rate depends on the combination and interaction of the innovation capacities of the high-tech companies. The generic fuzzy sets were defined for all qualitative IVars, which always one to exhibit three levels of linguistic terms: a lower, a medium and a higher one. After converting all IVars into its corresponding linguistic variables with their respective DoC, the fuzzy inference blocks (IB), composed of IF-THEN rules, are operated based on the MAX-MIN operators, obtaining a linguistic value for each intermediate variable and output variable of the model, with the linguistic terms previously defined by the judges. With the input variables (features extracted from product development projects), the rules are generated. Every rule has an individual weighting factor, called Certainty Factor (CF), between 0 and 1, which indicates the degree of importance of each rule in the fuzzy rule-base. And the fuzzy inference occurs from the rule-base, generating the linguistic vector of OV, obtained through the aggregation and composition steps.

Determination of Output Variable – Optimal Efficiency Rate of Value Creation

The output variable (OV) of the neurofuzzy model proposed was called Optimal Efficiency Rate of Value Creation in high-tech companies. 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. A fuzzy set A in a universe X, is a set of ordered pairs represented by Equation 1.

$$A=\{(\mu_A(x),x)|x \in X\} \quad (1)$$

Where *(x)* is the pertinence function (or degree of pertinence) of x in *A* and is defined as the mapping of *X* in the closed interval [0.1], according to Equation 2 (Pedrycz and Gomide, 1998).

$$\mu_A(x):X\rightarrow [0.1] \quad (2)$$

Fuzzy Inference: The fuzzy inference rule-base consists of IF-THEN rules, which are responsible for aggregating the input variables and generating the output variables in linguistic terms, with their respective pertinence functions. According to Von Altrock (1997), a weighting factor is assigned to each rule that reflects their importance in the rule-base. This coefficient is called Certainty Factor (CF), and can vary in range [0,1] and is multiplied by the result of the aggregation (IT part of inference). The fuzzy inference is structured by two components: (i) aggregation, that is, computing the IF rules part; and (ii) composition, the THEN part of the rules. The Degree of Certainty (DoC) that determines the vectors resulting from the linguistic processes of aggregation and composition are defined with Equation 3.

$$DoC;:max[FC_1 \ . \ min\{GdC_{A11},GdC_{A12},...,GdC_{1n}\},...,FCn \ . \ min\{GdC_{An1},GdC_{An2},...,GdC_{Amn}\}| \quad (3)$$

Defuzzification: For the applications involving qualitative variables, as is the case in question, a numerical value is required as a result of the system, called defuzzification. Thus, after the fuzzy inference, fuzzification is necessary, that is, transform linguistic values into numerical values, from their pertinence functions (Von Altrock, 1997). The IT Maximum Center method was popularized to determine an accurate value for the linguistic vector of OV. Based on this method, the degree of certainty of linguistic terms is defined as "weights" associated with each of these values. The exact value of commitment (VC) is determined by considering the weights with respect to the typical values (maximum values of the pertinence functions), according to Equation 4 presented below (Von Altrock, 1997; Cury and Oliveira, 1999).

$$OV=\frac{\sum_{i=1}^{n} DoC_i \ . \ X_i}{\sum_{i=1}^{n} DoC_i \ . \ X_i} \quad (3)$$

Where i DoC represents the degrees of certainty of the linguistic terms of the final output variable and i X indicates the end of the typical values for the linguistic terms, which correspond to the maxima of fuzzy sets that define the final output variable. By way of demonstration, using assigned IT (average) hypothetical (Company A) enters-IT into the calculation expression of TPCITj with GdCi of the following linguistic vector of the output variable, also hypothetical: LOW=0.20, MIDDLE=0.53, HIGH=0.17. The numerical value of OERVC at a 0 to 1 scale corresponds to 0.9417, resulting from the arithmetic mean of the values resulting from the defuzzification of each of the simulated twenty judges. This value corresponds to an average value for OERP. With this result (optimal efficiency rate: 0.9417) produced for a better combination and interaction of strategic practices of open innovation that converged toward a single parameter, it is feasible to assert that this combination of technological innovation activities of the firm at this time, can at least ensure the performance desired by the firm at that time. It is plausible that the company maintains at least this value (0.9417), which ensures the desired performance. It is also plausible to state that, to some degree, there is efficiency in the management of those planning innovation in this category of companies. To illustrate this, assuming that the study-object companies demonstrate the following optimal effectiveness rate of value creation in the light of the influence of the practices of open innovation in the prospecting of knowledge of the actors under 3D modeling and additive manufacturing, in the perspective of multiple products of company (Figure 15):

The expected reference for value creation for firm (mean) is 0.6596 (Figure 3). It is concluded that: "Synesthesia" Product (0.8442) shows efficiency in the combination of their practices of open innovation in prospecting of knowledge and value co-creation for firm based on the 3D modeling and additive manufacturing. The priorities of practices of open innovation for value creation are dynamic and dependent on constraints and uncertainties that come from the environment at any

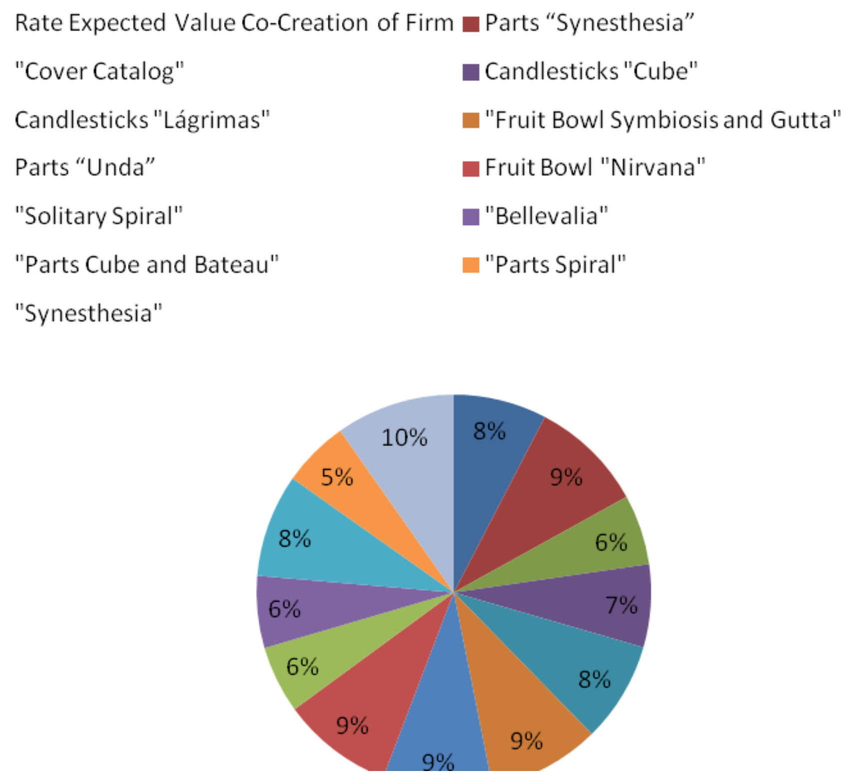

Figure 15. Optimal efficiency rate of value creation

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. Thus, it is important to look at the practices of open innovation in the prospecting of knowledge and value creation. Value capture implies focusing on getting the biggest possible cut of the pie, whereas value creation involves innovation that establishes or increases the consumer's valuation of the benefit of consumption (Priem, 2007). This research investigated the influence of practices of open innovation in the prospecting of value and value creation enhancing innovation and value creation. The knowledge is the recipient for success of open innovation. We have also seen a change in focus on how value is created. This leads us toward a long-ignored knowledge (and sources of knowledge) lens on both innovation and value creation in company.

CONCLUSIONS, IMPLICATIONS, AND LIMITATIONS

This article aims to contribute to a policy of innovation management. To do so, it presents the influence of practices of open innovation on the prospecting of knowledge for value creation in highly complex environments, based on the 3D modeling and additive manufacturing. The study attempted to cover an existing space in the literature about innovation management based on the practice of open innovation in the prospecting of knowledge and value creation for highly complex environments based on the 3D modeling and additive manufacturing, which is the case of multiple products in a traditional segment of pewter in Portugal. Product features, quality, cost and time to market are important factors for a manufacturer to remain competitive (Yan and Gu, 1996). 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.

There are a couple of interesting managerial conclusions that can be drawn based on the present research. Firms can radically improve value co-creation, and thus increase their share of the co-created value, by designing business models that have a high degree of internal and external configurational fit. Here, a new business model connotes the compatibility of the firm's business model with its customers, suppliers and other business partners. Higher degree of external configurational fit can be achieved both by modifying the firm's own business model and by altering the firm's customer, supplier, and partner portfolios. In addition, the business model framework can be used as a tool in strategy work. Such detailed understanding of the business model is especially valuable when the firm seeks to alter its strategic position in the value network (e.g. moving from product business to solution business) or attempts to enter new geographical markets (Nenonen and Storbacka, 2010).

Thus, open innovation has been defined as ''both a set of practices for profiting from innovation and also a cognitive mode, for creating, interpreting and researching those practices'' (Chesbrough, 2006), ''the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively'' (Chesbrough et al., 2006) and ''systematically performing knowledge exploration, retention, and exploitation inside and outside an organization's boundaries throughout the innovation process'' (Lichtenthaler, 2011). Open innovation practices, in general, provide greater opportunities for firms to advance and commercialize their technologies and, hence, enhance their innovation capability and international competitiveness (Chesbrough, 2003; Laursen and Salter, 2006; Clausen and Pohjola, 2009; Gassmann et al., 2010; Wynarczyk et al., 2013). In addition, open innovation allows for internal ideas to be taken to market through external channels, outside the firm's internal mechanisms, in order to generate additional value (Wynarczyk et al., 2013).

Thus, according to Huizingh (2010), open innovation practices are the processes that managers start when deciding ''when, how, with whom, with what purpose, and in what way should they cooperate with external partners''. Here, the practices of open innovation support the external knowledge prospecting and value creation in high tech industries. In fact, the benefits derived from good knowledge management are multiple, and include: reduced duplication of effort, creation of new knowledge, and increased efficiency and productivity. Knowledge and innovation are the building blocks of sustainable competitive advantage (Porter, 1980), and therefore are a source for sustainable development and growth for enterprises. The innovation is the use of innovative knowledge so as to create effective value for the stakeholders of the industry (Van Horne et al., 2006). Here, the best practices of open innovation have been the value chain and partnerships and collaborations. In fact, all value chain activities are equally important as firms strive toward specific strategic goals. Porter (1980) suggests that achieving competitive advantage begins with an effort to develop deeper organizational expertise in performing certain competitively critical value chain activities (Prajogo et al., 2008).

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 case of multiple products was developed in a traditional segment of pewter 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 practices of open innovation 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. It is also underscored that the methodologies and technical basis of this modeling should undergo evaluation by a multidisciplinary team of specialists permanently and periodically, hence proposing possible additions or adjustments to these methodologies. And also replace some of the technical implementations used herein by others, in order to provide a similar role to verify the robustness of the model. Of the research findings, the industries 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. Prospecting of knowledge of R&D is crucial for practices of open innovation. It confirms the state of the art. Shanklin and Ryans (1984) suggest that high-tech companies anticipate potential technical and scientific capabilities that provide quick responses to the existing techniques, enabling to meet the market demands to be constructed or altered. It is reasonable to focus efforts on knowledge of R&D, thereby creating an internal stock of scientific knowledge (Feinberg and Majumdar, 2001; Griliches, 1979; Hall and Mairesse, 1995), which enables one to develop and introduce new products, lower production costs, more competitive prices and greater financial return (Kafouros, 2008a, 2008b). Knowledge of R&D has indirect effects on increasing the organizational learning, enables one to understand external ideas and technologies and apply them to the ultimate business outcome (Cohen and Levinthal, 1989) and also contributes to identifying areas that are still technologically unexplored (Miller et al., 2007). This logic will be maintained, however only through opening spaces for the various strata: partners, suppliers and customers. Nevertheless, the practices of open innovation in the prospecting of knowledge of companies will have to be anchored in efficient planning policies.

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