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Models of innovation development in small and median-sized enterprises of the aeronautical sector in Brazil and in Canada

Modelos de desenvolvimento da inovação em pequenas e médias empresas do setor aeronáutico no Brasil e no Canadá

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Abstract: This paper presents the results of an investigation that aimed to generate detailed knowledge on the process of innovation development in small and medium-sized enterprises (SMEs) of the aeronautical sector. As a theoretical foundation, five models of technological innovation were took: linear, reverse linear, coupling, interaction chain and systemic. Data were collected in two large Brazilian enterprises subcontracted by a larger Brazilian enterprise of the same sector, and two Canadian enterprises also subcontracted of a larger Canadian enterprise. The methodological approach was qualitative research of multiple cases. Data collected by semi-structured interviews were analyzed with Atlas-ti software in quantitative analysis of within case and cross case that focused the comparison of data in the search for similarities and differences which reveal valid results for the set of cases. These results are synthetized in an integrator model of the innovation that explains the process of the cases. This model has five phases that consider the client´s needs and the cooperation of sources of information associated to universities and other enterprises of the productive chain of the aeronautical sector.

Keywords: Innovation; Technology; Model; Small and Medium-sized Enterprises (SMEs); Aeronautical sector.

Resumo: *O presente trabalho apresenta os resultados de uma pesquisa cujo objetivo foi gerar conhecimentos mais detalhados sobre como ocorre o processo de desenvolvimento da inovação em pequenas e médias empresas (PME) do setor aeronáutico. Utilizam-se como base conceitual cinco modelos de inovação tecnológica oferecidos pela literatura: linear, linear reverso, coupling, de interações em cadeia e sistêmico. Os dados foram coletados em duas empresas brasileiras, subcontratadas de uma grande empresa brasileira do mesmo setor, e duas empresas canadenses, também subcontratadas de uma empresa de grande porte do setor, mas do Canadá. A abordagem metodológica utilizada foi a do estudo qualitativo de casos múltiplos. Os dados foram coletados com entrevistas semiestruturadas em profundidade e analisados com auxílio do software Atlas-ti em análises qualitativas dos tipos intracaso e intercaso. Elas focaram a comparação dos dados na busca de similaridades e diferenças reveladoras dos resultados válidos para o conjunto dos casos. Tais resultados são sintetizados em um modelo integrador explicativo do processo de inovação dos casos. O modelo compõe-se de cinco fases que consideram as necessidades dos clientes e a colaboração de fontes de informação vinculadas a universidades e a outras empresas da cadeia produtiva do setor aeronáutico.*

Palavras-chave: *Inovação; Tecnologia; Modelo; Pequenas e Médias Empresas (PME); Setor aeronáutico.*

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1 Introdution

Innovation processes are fundamental in order to provide competitive force to enterprises. Innovations frequently are moved by entrepreneurial intentions that aim to provide new market demands, aggregate value to goods and services already offered to the market or offer new goods and services. So these processes reflect organization competencies that renew the competitive force and contribute for the enterprise longevity (Freeman & Soete, 1997; Leiponen & Helfat, 2010).

In order to generate innovation and its results in an optimized way in an enterprise, it is necessary to develop management systems and ways of exploring the knowledge of the personal who generate the innovation. This knowledge will be applied in the use of the entrepreneurial resources and will make possible the improvement of products and processes already offered to the market or the appearance of new products (Leiponen & Helfat, 2010; Musiolik et al., 2012). To explain the occurrence of innovation, some authors have developed models made of different phases of knowledge management (Barbieri, 2003; Kline, 1978; Viotti & Macedo, 2003). One of the advantages of working with models is the possibility of a detailed understanding of the sources of the knowledge used as a base for innovation, as applied research, scientific research and the market needs (Viotti & Macedo, 2003; Lobosco et al., 2011).

The processes of innovation development can vary from one enterprise to another and be influenced by the sector of activity and by the enterprise size (Conde & Araújo-Jorge, 2003). The focus of this research is related to these factors, which consist in the particularities of the innovation process in SMEs of the aeronautical sector. The SMEs have a simple and more adaptable structure when compared to large enterprises, so they can be considered more organic than mechanic as for their structure (Mintzberg, 1989).

Among the various classifications of SMEs available, there are the ones called small and medium-sized enterprises of technological basis that employ high qualified labor and have low hierarchy levels, few departments (when some exist) and are close to their clients. It means that concerning the process of innovation development and in comparison with larger enterprises, they present a potential for a more quick management of the knowledge to create new products and productive processes.

In addition, the aeronautical sector, focus of this research, counts on particularities as more frequent inter-entrepreneurial nets of cooperation, intense use of the knowledge developed at universities, intense provision of incentive for technology development by government agencies and physical closeness with most of the enterprises that are part of the same productive chain. Besides, in economic terms it is an important sector for wealth generation in its countryside.

The theoretical foundation for this paper did not allow us to identify researches that specifically explain the process of innovation development in the SMEs of the aeronautical section. Due to the importance of the subject and the apparent absence of writings about it, this paper is justified for generating new important knowledge, as we search answers for the research question: How does the process of innovation development in SMEs of aeronautical sector occur? Five innovation models available were explored to answer this question. They are described below.

2 Theoretical foundation

2.1 Theories and models on the process of innovation development

The competitive environment that characterizes the business management forces the enterprises of large, medium and small sizes to compete based on the innovative processes (Rodrigues et al., 2011).

It also forces the high education institutions to improve tuition favorable to innovation, as the one related to entrepreneurship and small enterprise management improvement, which faces serious challenges in Brazil (Lima et al., 2015). In all Economics sectors the innovation principle guides the efforts of the strategies for domination of its innovation models (Anderson & Tushman, 1990). So the awareness that innovation is essential for any modern organization appears not to be new to most of the managers of large, medium and small enterprises. However the best way to acquire and to associate the innovation to the business management model and make it more profitable is still not a consensus among them.

In this context Longanezi et al. (2008) present three aspects that should be taken in account when implementing a process of innovation development: (i) to adopt a referential model that represents the process in its best comprehensiveness; (ii) to use processes management techniques that integrate the different areas and stages necessary to the process; and (iii) to develop specific tools to support the managers decisions.

Moreira & Queiroz (2007) and Rodrigues et al. (2011) enhance the difficult of organizing the process of innovation development. These authors explain that this difficult occurs because there is no classifying scheme that embraces all the types of innovation with their varieties, their nature and the innovative processes. They also enhance that it is difficult to perform a mental map of the process, as for the lack of consensus on the most important variables that can be related to innovation, as for the inconsistence of the innovation research strategies that can be anyway applied to the subject of investigation that is the innovation.

Many theories were developed to analyze and understand the nature of innovation and how it occurs in order to avoid these difficulties. Generally, each one is associated to the prevailing line of thought when it was developed (Galanakis, 2006; Ortt & Van Der Duin, 2008).

Rothwell (1994) resumed the chains in five models about how the process of innovation development occurs:

1. **Linear model** (also called *technology push* and *science push* – **first generation**): predominates in the 1950's and in the first half of the 1960's. Considers the innovation as a simple linear process in which the scientific and technologic advances push a new product to the market. This theory concentrates itself in scientific findings. According to Viotti & Macedo (2003) and Nobelius (2004), this model reveals that there is an investment in science that generates a stock of scientific knowledge in the country and this stock is used for the enterprises in producing innovation, which leads to the economic and social development as presented in Figure 1;

2. **Reverse linear model** (also known as *market pull* or *demand pull* – **second generation**): dominates the second half of the 1960's and the early 1970's. Also represents a linear model in which innovation is stimulated by the market needs or by the enterprises' operational problems (Rothwell, 1994; Barbieri, 2003) and demonstrates that the search for necessary knowledge to the innovation process is not mandatorily generated by the interest in scientific research and not only by interest in intern processes of the enterprises that perform this research, as demonstrated in Figure 2;

3. **Coupling model of innovation (third generation):** dominated the scenario from the 1970's to the early 1980's and recognized that the push and pull models combined have a better approach of reality (Cooper, 1994; Rothwell, 1994). This new model is a result of combining the two previous, showing the strong link between the marketing and the research and development areas, as presented in Figure 3. The innovation process is presented as a sequential one, but not necessarily continuous. It can be divided into interdependent stages and returns for the previous phase. The intra-organizational links and the external influences create a complex net, connecting the different functions of the enterprise, the scientific and technological community and the market;

4. **Model of chain interactions (fourth generation):** Developed by Kline (1978), predominates in the early 1980's and middle 1990's. Stal (2007) argues that the previous models failed for their linear conception so they are insufficient to explain what effectively occurs inside the organizations. The fail was supplied by this chain interaction model in which the interactions of different phases of the process are emphasized specially in the central innovation chain. As presented in Figure 4, the arrows inside the central chain illustrated the typical trajectory of the linear model; but in this model, arrows are added to indicate that the stages do not have strict limits, existing permeability among them;

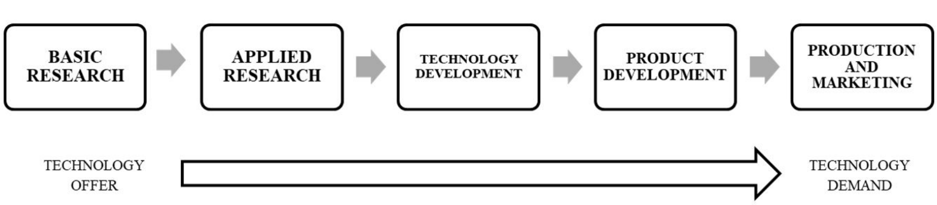

Figure 1. Linear Model of Innovation (*Technology Push* or *Science Push*). Source: Adapted form de Rothwell (1994) and Viotti & Macedo (2003).

Figure 2. Linear Reverse Model (*Market Pull* or *Demand Pull*). Source: Adapted from Rothwell (1994) and Barbieri (2003).

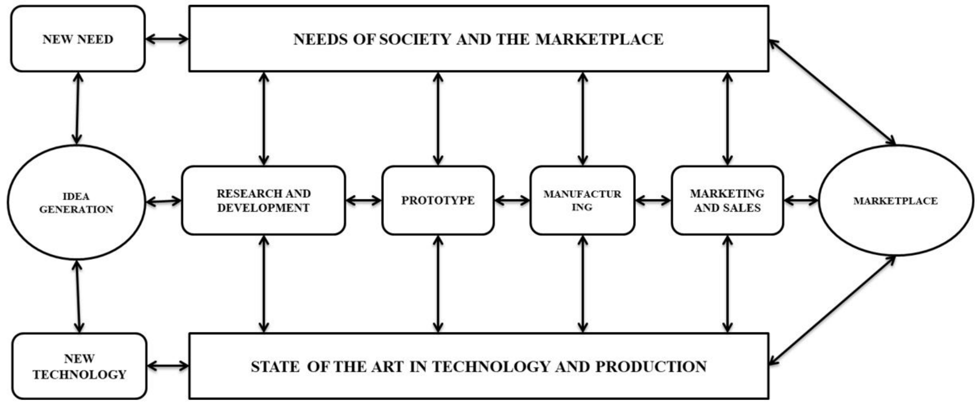

Figure 3. *Coupling* Model of the Innovation Process. Source: Adapted from Rothwell (1994).

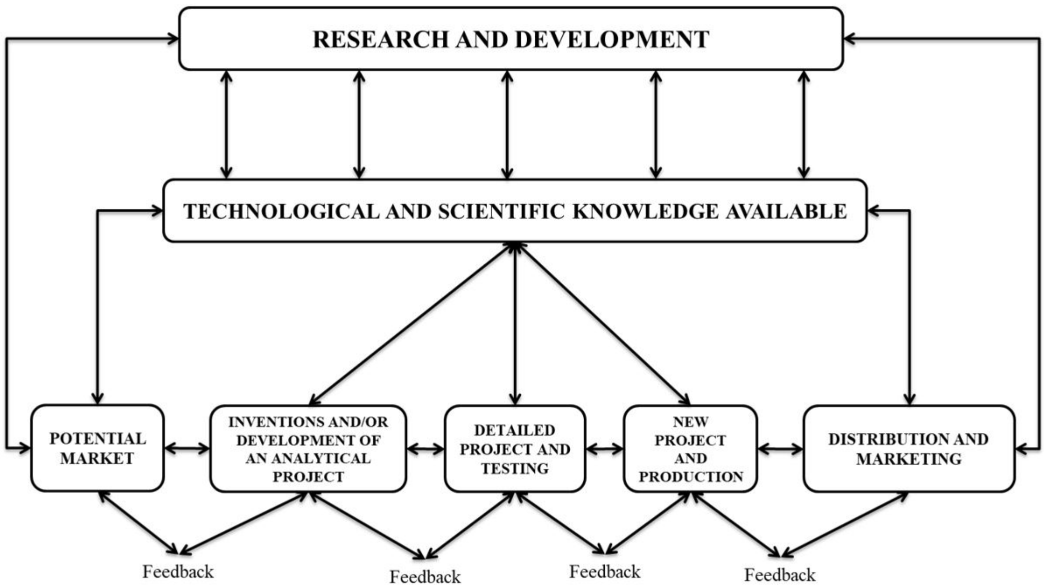

Figure 4. Model of Chain Interactions. Source: Adapted from Kline (1978).

5. **Systemic Model of Innovation (fifth generation):** also known as model of the integration process of the systems. Developed by *Organization for Economic Co-operation and Development* (OECD, 1999) in the middle 1990's, predominates until today. It is based on the fourth generation process but enhances the need of a continuous change. It demonstrates that enterprises do not innovate themselves alone (OECD, 1999) but generally in a net system of relationship with other enterprises by means of the public and private infrastructures of research (universities and institutes) under influence of national and international economies and the normative system (Viotti & Macedo, 2003). These interrelationships are present in Figure 5.

According the system model above described, the universities are considered as a pillar of the innovative process, which corroborates the triple propeller concept. As knowledge is even more a very important input for social and economic development, it is acceptable that universities, as institutional spaces for generation and transmission of knowledge, be recognized as important social agents (Lobosco et al., 2011).

The five generations that represent the innovation process indicate that the innovative perspective linked to research and development is changing and adapting itself to the context of the great organizational changes (Nobelius, 2004).

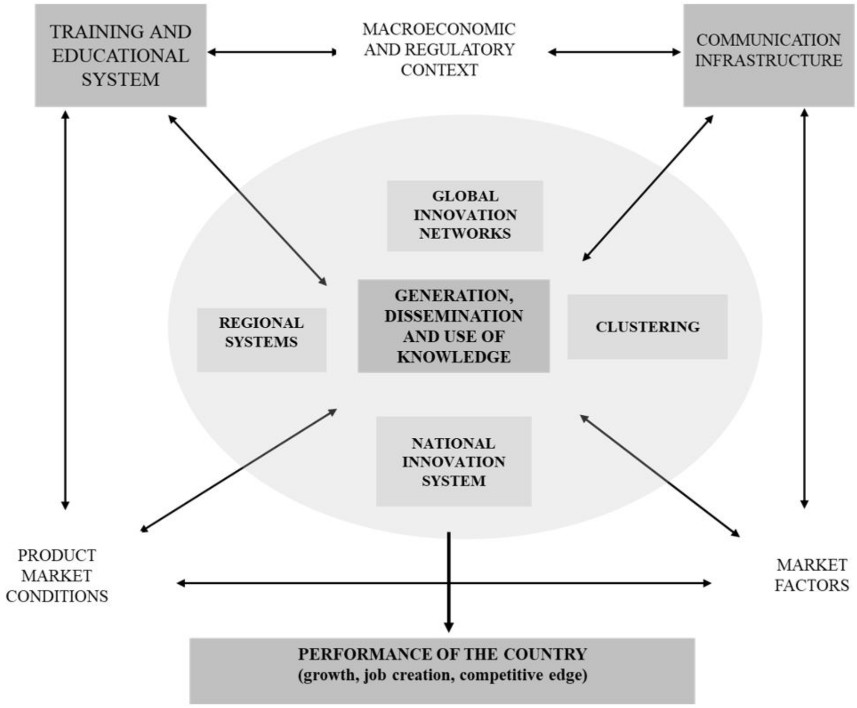

Figure 5. Systemic Model of Innovation. Source: adapted from OECD (1999) and Viotti & Macedo (2003).

2.2 Small and medium-sized enterprises of Brazilian and Canadian aeronautical sectors

Nowadays aeronautical sector is one of the greatest an innovative sectors of the São Paulo Metropolitan Region (Paraíba River Valley and North Coast) in Brazil, and Montreal Metropolitan Region in Canada. These are worldwide important regions in the aeronautical area as well as Wichita, in the United States, and Tolouse, in France.

The SMEs concentrated in the same area contribute for empowering the aeronautical sector playing an important role in the economic and social development of the region and the country, generating innovation in high added valued products besides generating qualified jobs and stimulating the process of developing science and technology. One important feature of the SMEs of the aeronautical sector is that they are very sensitive to the macroeconomic environment and to the commercial performance of the anchor-company as EMBRAER (Brazilian Aeronautical Company), in Brazil, and Bombardier, in Canada.

The annual reports delivered by the Brazilian Association of Aeronautical Industries (*Associação das Indústrias Aeroespaciais do Brasil* – AIAB, 2013) and by the Canadian Association of Aeronautical Industries (*Association des Industries Aérospatiales du Canadá* – AIAC, 2013) demonstrate that the development of the SMEs are directly related to the economic infrastructure of the region, to the easier access to private and public venture capital and to governmental support in the three spheres of the public power. Nowadays in Brazil, especially in São José dos Campos, Taubaté and Caçapava, all located in the State of São Paulo, there are 330 SMEs on the aeronautical sector and approximately 75 outsourced to EMBRAER. In Canada there are near 400 SMEs and about 250 outsourced to Bombardier, mainly located in Montreal, Mirabel, Laval and Longueil (AIAB, 2013; AIAC, 2013).

These SMEs present a monthly individual income varying from US$ 500 thousand to 3 million and employ an average of 13.800 to 23.650 professionals in Brazil and Canada, respectively. Their contribution to the Gross Domestic Product in their regions in both countries is very representative as they respond to 35% and 47% of it, respectively (AIAB, 2013; AIAC, 2013).

The outsourced SMEs in each country are organized in three levels: a) intelligence b) expertise c) capacity. The intelligence outsourced SMEs are organizations in which activities are complex, products have a high benefit, resources are focused in strategic activities and they are directly connected to the hiring company.

It's important to enhance that SMEs are considered as strategic partners of their main client and the services them offer (as R&D, design and manufacturing) are integrated to the subcontractor, what suggests that the intelligence outsourced SMEs present a high dependence level to its main client. This dependence level restricts its strategic and entrepreneurial activities.

The outsourced expertise SMEs are companies that provide support to the productive system of the contracting company. They have a high level of expertise, their products have high added value and they are considered as technical partners of the main contracting company.

The capacity outsourced SMEs are companies not directly related to the productive system of the contracting company. Their products have a low added value and its relationship to the main client is for a short period.

To better understanding one can say that the outsourcing relationship is like an industrial client / provider relationship in which the client is the main contractor that establishes the technical specifications and the procedures of reception for the provided product (Billaudot & Julien, 2003).

The great value of these companies' segment is not only related to the establishments they embrace. The aeronautical sector also offers another contribution as it performs an important socioeconomic function, employing qualified labor, generating jobs and profit and pushing up the development and the learning of advanced technology in education institutions. It also develops technologies and innovation to attend important market needs, creates sites or productive local arrangements to improve the regional economy, helps to create a regional category of entrepreneurs and establishes closer relationships between companies, their owners-managers and their employers. The physical closeness, besides reducing the coordination costs, makes easier the actors integration and allows the learning and sharing of knowledge and values that assure the excellence of the activities. One can easily note it in regional conglomerates of technological companies as the software producers in Blumenau region – SC, Brazil (Lima, 2005).

3 Methods

The theoretical base for this research was the multiple case study according Eisenhardt (1989). We approached four SMEs of the aeronautical sector in their day by day reality, two Brazilian and two Canadian and described the models of the process of innovation development they employ. The cases election is important because it defines the research design: an appropriate random that allows to control the external varieties and to establish limits for the results considerations applied to other contexts (Eisenhardt, 1989).

The SMEs sample approached is present in Chart 1. Cases were intentionally elected based on the contribution they could bring to this research. The sample was classified as theoretical and intentional. To select the sample we considered from each company the following features:

Chart 1. Sample of the SMEs.

SMES of aeronautical sector (Age and Location)	Employees	Activities and Products
Aeronautical Business (fictitious name) 1998 – São José dos Campos – Brazil (inside Technological Field - Univap)	128	A medium company specialized in developing solutions for landing gear. It also projects and manufactures civil and military aircrafts.
Aero Brasil (fictitious name) 2005 – São José dos Campos – Brazil (graduate company of Incubaero)	31	Small company specialized in developing multifunction displays for air navigation in special appliances. Also specialized in developing command, control and intelligence solutions based on Unmanned Aerial Vehicles (UAV).
Altitude Aerospace 2005 – Montreal – Canada	70	Small company specialized in conception, structural analysis and certification as for developing new aircrafts as for fleet maintenance.
Mechtronix 1987 – Saint-Laurent – Canada	200	Medium-sized company with multidisciplinary specialization in design, engineering and manufacturing intelligent machines for a large client company of Canadian aeronautical sector.

Source: Elaborated by the authors.

- **Nature:** technology-based company, outsourced of a large company that develops design of regional aircrafts;
- **Size:** small (20 to 99 employees) and medium (100 to 499);
- **Location:** metropolitan region of Paraíba River Valley in Brazil, and Montreal metropolitan region;
- **Business field:** aeronautical sector;
- **Age:** more than 5 years of existing.

Data collect for this research was based on semi-structured interviews with the managers-owners and CEOs of the SMEs of the aeronautical sector. The interviews lasted about 2h40' and were recorded to avoid loss of information. This qualitative technique helps to deeply obtain and explore data and to take in account the interviewed perceptions and experiences. Data collected from the interviews were compared to secondary data from the investigated companies and from AIAB and AIAC and were analyzed in two steps: within-case and cross-case analysis.

Within-case analysis consists in describing, understanding and explaining what happens in a single and limited context, i. e., in a single case (Miles & Huberman, 1994). Lima (2010) explains that this kind of analysis aims to enhance the most important conceptual contents to describe and explain a phenomenon by taking each case of the sample separately.

On the other hand the cross-case analysis aims to describe, understand, explain and cross the conceptual contents, the processes and results of a single phenomenon in a context of a multiple cases and based on them to develop a more detailed understanding of all the cases of the sample (Miles & Huberman, 1994).

Data obtained by the interviews were analyzed by using the Atlas-ti software. This tool facilitates the organization, codification and classification of the qualitative data (Bandeira-de-Mello, 2006; Lima, 2010; Mühr, 1995). Atlas-ti is used in qualitative researches to analyze data by attributing codices to data fragments in order to perform comparisons to understand and explain a phenomenon (Bandeira-de-Mello, 2006; Lima, 2010; Mühr, 1995).

In the present research to complete the data codification for identifying similarities and differences within and inter-case of the approached phenomenon, we used cluster meta-matrixes as a way of organizing the partial results (Miles & Huberman, 1994). This procedure consisted in a determinant phase of the analysis once it allowed a simple and effective data visualization, helped to plan another phases of the analysis and facilitated the direct use of the collected information increasing the consistence of the final results of this investigation.

Cluster meta-matrixes are frames that organize a series of concrete happenings or events chronologically ordered and classified in categories or dimensions (Miles & Huberman, 1994). They aim to make intelligible in a same space of visualization a set of information that in other way would not easily be detached.

4 Whithin-case data analysis

Here we present the within-case analysis of the four analyzed companies. The main data that helped to respond the research question, that aims to generate new knowledge on the process of innovation development in SMEs of the aeronautical sector.

4.1 Aeronautical business company

Focused in providing advanced design and engineering solutions for aeronautical sector, was founded in 1998 in São José dos Campos, SP – Brazil. It was the result of its founder desire to create a business to execute engineering projects and manufacture aeronautical products. For this he concentrated efforts in developing and producing landing gears, a high added value item for aircrafts.

As a landing gear solutions provider, this SME is the most important intelligence outsourced for the T-25 Tucano aircraft landing gear. The company has a large tradition in the innovation field and continues to expand its line of products and services to meet the creation of new aeronautical sector solutions that embraces the most advanced technologies and materials. Both its managing and technical staffs are very experienced. Some of them had more than 25 years working in the aeronautical sector, especially in EMBRAER and were involved in the development of various and important aeronautical projects.

Based on the data collected by the interviews, Figure 6 presents the model for innovation development from Aeronautical Business Company.

In Figure 6 we found two sources of information that feed the process of innovation development in the R&D department. They are: a) client demand: the client request for the development of a new product in order to increase productivity and competition; b) applied research: includes research projects that represent the investigation focused to find new knowledge and have specific business concerns related to some products and processes.

The fragment of an interview below brings a short explanation of the first part of the innovation model of Aeronautical Business Company presented in Figure 6:

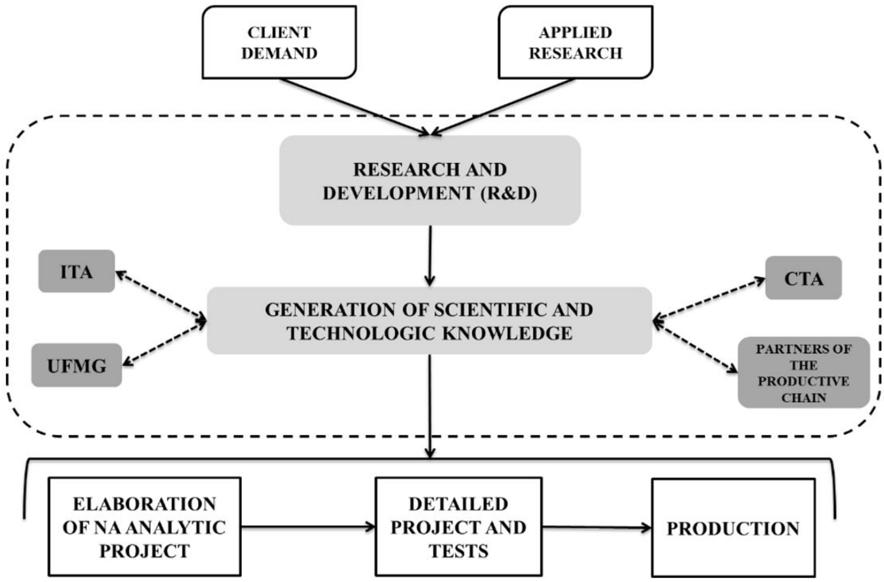

Figure 6. Model for Innovation Development of Aeronautical Business Company. Source: Elaborated by the authors.

> *As 70% of our gross income come from a single client, many times our process of developing an innovation starts with his request. But this is not our only way of innovating. As we have a team of very creative aeronautical engineers, the creation of a new product can also results from their researches. It is by the means of the applied research that the engineers contribute for solving problems or concrete and immediate needs of our sector.*

In the second part of the innovation model one can notice that the new scientific and technological knowledge originated in the R&D department comes from the dynamic and coordinated relationship between the analyzed company and companies of the aeronautical productive chain and of research, development and innovation agencies (R,D&I).

The company holds R&D agreements with the Technological Aeronautical Agency - *Instituto Tecnológico de Aeronáutica* (ITA), the Federal University of Minas Gerais (UFMG) and research agencies of the Aerospace Technical Center (CTA).

New knowledge becomes an analytic project that embraces all the stages of the process of innovation development. After that more detailed projects that embrace the experimental development of the product are elaborated and the prototypes tests begin. If approved, the new product starts being manufactured.

Interviewed enhanced that innovation plays a central role in the company and technology is one of the basis for strategic management, riding the fundamental issue on how to obtain competitive advantage and how to assure the company survival.

4.2 Aero Brazil Company

A company founded in 2005 by two former ITA students using full Brazilian capital. Focused on developing aeronautical systems, it was the first company supported by the Business Incubator of the Aeronautical Technology Institute (INCUBAERO).

Since its foundation, it supports the development of robotic systems in projects for EMBRAER and Brazilian Defense Ministry. It also participates of the Unmanned Aerial Vehicles Project (UAVP) under the supervision of the General Command of Aerospace Technology. Nowadays it is a small sized expertise company subcontracted of the aeronautical sector with as main goal the innovation development and its process. Based on the interviewed reports we elaborated Figure 7 that presents the model for the company innovation development.

As showed in Figure 7, the model for innovation of Aero Brazil is linear. According to Viotti & Macedo (2003), this is the ancient kind among the innovation models. In the linear conception, technical change is as a sequence of stages in which new knowledge originated from scientific research lead to invention processes followed by applied research and technological development that result in the generation of new products and marketing processes (Conde & Araújo-Jorge, 2003).

As informed by the interviewed the information source for the process of innovation development in Aero Brazil Company is applied research. In this stage of production the R&D department carries out a high intellectual and financial investment in generating new

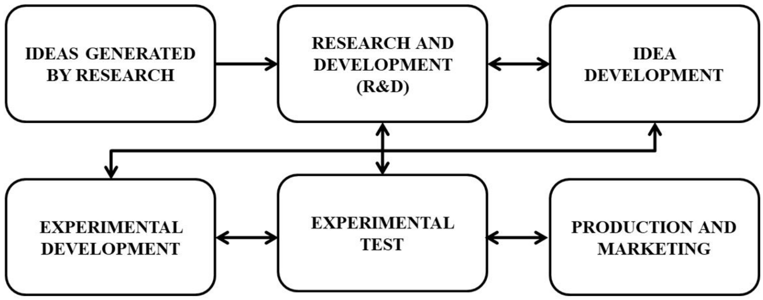

Figure 7. Model for Developing Innovation by Aero Brazil Company. Source: Elaborated by the authors.

ideas that can lead the company to ask for financial help from other sources, as public financial agencies or an angel investor (Moraes et al., 2013). The following exert of the interview describes this stage:

> *The main cooperation source that feeds our process of innovation development is the participation in ITA research groups, where we can identify the most recent researches in our sector.*

According the interviewed, after the development of the ideas generated by the research, more complex phases of the process of innovation development start and then the experimental development and the prototypes tests are performed. In these two stages the company presents a high dependence of financial resources and many times these resources come by FINEP (Brazilian public agency for financing innovation). As presented in Figure 7, the R&D stages, ideas development, experimental development and tests are connected and interact all the time with the prototype approval.

After the prototype approval, it comes to the production and marketing phase. At least there is the participation in the aeronautical fair, that takes place all the years in France, and in the Expo Aero Brazil, that takes place in São José dos Campos, SP, Brazil. The owners-managers consider these fairs the best ways to attract new customers in the aeronautical sector.

According the interviewed, innovation represents the support, the continuous development and the continuity of Aero Brazil. Innovation is what keeps the company alive and is the base for its strategic vision.

4.3 Altitude Aerospace

Altitude Aerospace is a Canadian company located in Montreal, founded in 2005 and moved by the will of its founders to establish a business that could meet the demand for regional aircrafts engineering services.

Nowadays it is a leader company in space engineering, specialized in conception, structural analysis and certification as for developing new aircrafts, as for fleet maintenance. It has a solid partnership with Bombardier, a regional aircraft manufacturer, and cooperates in developing important subsets as fuselage, wing boxes, divisions, structural doors and cockpits.

It is a small sized expertise company subcontracted of Bombardier. Its mission is to provide qualified engineering services to the clients, to help them to develop new products with the participation of a local engineering staff and to develop new products with a quick return on investment. Innovation and its development process are the main supports of the company business model. According to data collected, Figure 8 presents the linear innovation model of Altitude Aerospace.

Reports indicate that innovation projects mean commitment to an unknown and full of risks future. To reduce uncertainties, the company performs innovation development in four interacted phases, as we describe next.

(1) **Idealization of the innovation:** it is the most creative phase of the innovation model. The interviewed argues that innovative ideas do not come out from the blue. The idealization can occur by two ways: by the client's solicitation for developing a new product and by directed research for new knowledge with business goals;

(2) **Ideas generation:** it is a phase of refining ideas. Collected data reveal it as an important phase, because there are interaction among the employees and exchange of information for generating ideas. Business opportunities can appear in this phase;

(3) **Developing and testing**: it is a phase for high investments in R&D, creation and testing of pilot-projects. Reports indicate that development and testing reduce uncertainty and accelerate the generation of a strategic management focused on the developed technology. The interviewed adds

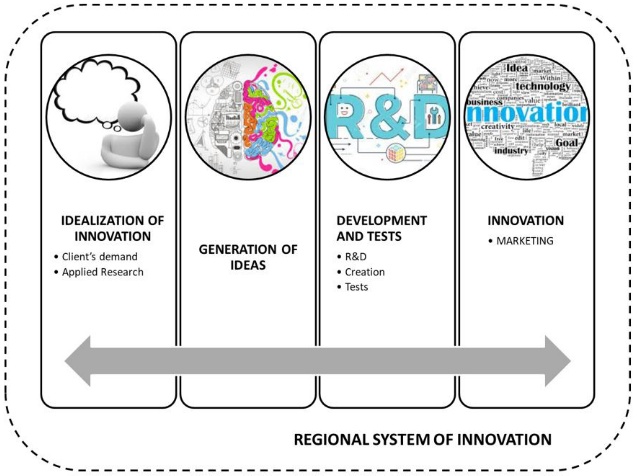

Figure 8. Model of Innovation Development of Altitude Aerospace. Source: Elaborated by the authors.

that the earlier innovation emerges, the more quickly the company will achieve competitive advantage. The company performs pilot-projects, simulations and tests for verifying the grip solution before placing it on the market;

(4) **Business:** it is last phase of the innovation development model of Altitude Aerospace. After approving the pilot projects, the sale of the new products and the delivery of new services start.

The process of the innovation development in the company is integrated to the regional innovation system in Montreal metropolitan region and contributes to spread the innovation culture as a competitive differential for aerospace companies. The innovation system intends to generate knowledge and competence on the process of how technologic innovation appears and supports the generation of new products and production processes (Sáenz & García Capote, 2002).

Also according the interviewed, in Altitude Aerospace Company the innovation is a practical appliance of creativity, so creativity plays an important role to increase the company results. She also considered the importance of focusing and prioritizing crucial issues and to perform the projects of innovation search in an objective way.

4.4 Mechtronix

In the middle of the microprocessors revolution in the 1980's, the *National Research Council* (NRC) challenged the students of the Canadian engineering universities to build a flight simulator using the microprocessor technology. For this challenge, the Concordia University, located in Montreal, selected five students that had participated in R&D projects. Fernando Petruzzielo, Joaquim Frazão, Marco Petruzziello, Thomas Allen e Xavier Henri Hervé have successfully completed the Project and founded Mechtronix, in 1987.

It is a company specialized in design, engineering and production of smart machines; a medium-sized specialized company subcontracted of Bombardier Aerospace and Bombardier Transportation. Based on the managers' reports, Mechtronix has 72% of its gross revenue linked to these two companies.

Based on the interviews, Figure 9 presents the model for innovation development of Mechtronix. For the interviewed, the process of innovation development consists in the cooperation between the company and its strategic partners, specially the universities and training centers. They consider the innovation development as a process that changes opportunity in product.

Figure 9 reports that the innovation development starts with the generation of ideas, that emerges from to the scientific knowledge generated for the partner universities (as Concordia University, Toronto University and China University) and the technological knowledge generated in partner companies as Bombardier Aerospace, Bombardier Transportation and Tecnam. The following excerpt of an interview brings a brief explanation of the ideas generation phase for innovation:

> *Innovation comes from a new idea. So we have periodical meetings with our partners. In these meetings, we generate an average of 100 new ideas. Then these ideas go through a refinement till they generate innovation.*

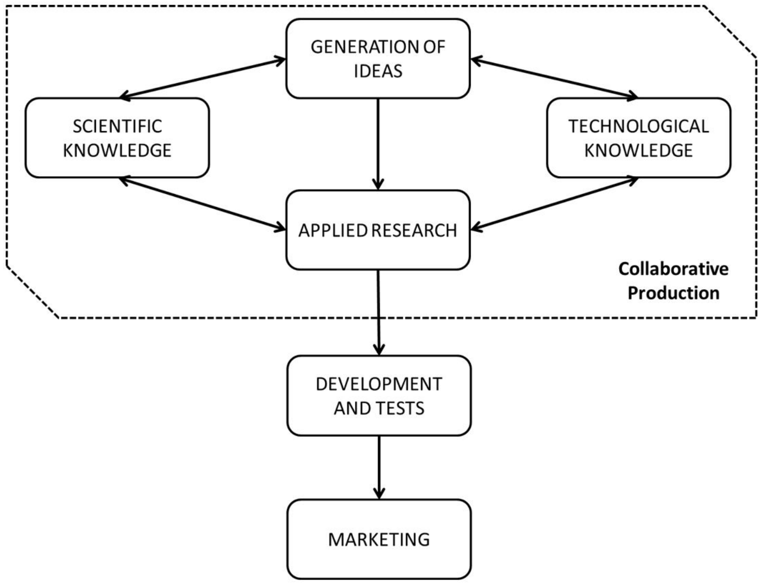

Figure 9. Innovation Development Model of Mechtronix. Source: Elaborated by the authors.

After the ideas refinement, the process of innovation development goes to applied research. This phase includes the research projects performed with the universities and companies partners. For the company, applied research corresponds to find out new scientific and technological knowledge with a specific marketing goal.

The research projects go to the development and test phase. Reports reveal that it is a very important innovation phase because it includes the rationalization of the innovation project in order to change the idea into product. This stage encompasses based planning, founded tests and the adaptation of the production processes.

After the approval in the test phase, the product is ready to the market phase. The interviewed revealed that in this stage there is integration between the departments of production and marketing. They explain that the innovation model helps to share efforts and contributes to strategic actions planning. In order to collaborate, exchange and build new knowledge, Mechtronix associates strategic partners and the innovation development with collaborative production.

For the interviewed, the cooperative production plays an important role in generating new products because the information are transferred from agent to agent, i.e., from the company to its partners and vice versa. The cooperation among companies brings an important change to the competitive paradigm as one considers that the competition in the market occurs at the productive chains level and not only in the isolated business unities (Canongia et al., 2001).

5 Cross case analysis

In this section we present the main similarities and differences in the process of the innovation development by comparing the approached cases and enhancing the most relevant data to answer the research question. They are displayed in the meta-matrix on Chart 2, according Miles & Huberman (1994).

Chart 2 indicates that Aero Brazil and Altitude Aerospace, both small-sized companies, work with a linear model of the process of innovation development. The model for both companies reveals a sequential and hierarchical process. On the other hand, Business Aeronautical and Mechtronix, both medium-sized companies, work with a model of chain interaction in the process of innovation development. For the interviewed of both companies, innovation is a complex process of interaction among its agents, which includes universities, research centers and the market.

In the first stage of the process of innovation development we found that Aeronautical Business and Altitude Aerospace are similar, because both have information sources that feed the process: client's demand and applied research. Aero Brazil and Mechtronix achieve innovation by generating ideas that lead to applied research.

Also in the first stage we found that only Aeronautical Business and Mechtronix generate new scientific and technological knowledge. In the Brazilian company the new knowledge emerges from a dynamic and coordinate relationship with companies of the aerospace productive chain and organizations of RD&I as ITA, UFMG and CTA. For the Canadian company, new scientific knowledge are generated by partners as Concordia University, Toronto University and China University, and the technological knowledge is developed by partner companies as Bombardier Aerospace, Bombardier Transportation and Tecnam.

A difference found in the first stage is only Mechtronix associates the generation of ideas and new scientific and technological knowledge to a cooperative production. They consider that cooperative production plays a most important role when creating new products, as the information is transferred from the company to its partners and vice versa.

The analysis of stages 2 and 3 revealed that all the researched companies elaborate detailed projects that include the experimental development of the product. In stage 2, that supposes high investments in R&D, the prototypes are tested and if approved, in stage 3 the production and marketing of the product takes place.

A last difference was found in Altitude Aerospace, where the process of innovation development is part of a regional system of innovation.

5.1 Innovation model for the aeronautical sector

The model for innovation development of the aeronautical sector presented in Figure 10 shows that the Technology-based SMEs do not achieve innovation alone. They generally innovate through their net of relationship with universities, research centers and different companies of large, small and medium size, parts of the aeronautical and aerospace productive chain.

Chart 2. Comparison of the Process of Innovation Development in the approached cases.

Company	Type of Model	1st Stage		2nd Stage	3rd Stage
Aeronautical Business Company	Model of Chain Interactions	Client's Demand Applied Research	Scientific and Technological Knowledge	Experimental Development	Production and Marketing
Aero Brasil	Linear Model	Generation of ideas Applied Research	-	Experimental Development	Production and Marketing
Altitude Aerospace	Linear Model	Client's Demand Applied Research	-	Experimental Development	Production and Marketing
		Regional System of Innovation			
Mechtronix	Model of Chain Interactions	Generation of ideas Applied Research	Scientific and Technological Knowledge	Experimental Development	Production and Marketing
		Collaborative Production			

Source: Elaborated by the authors.

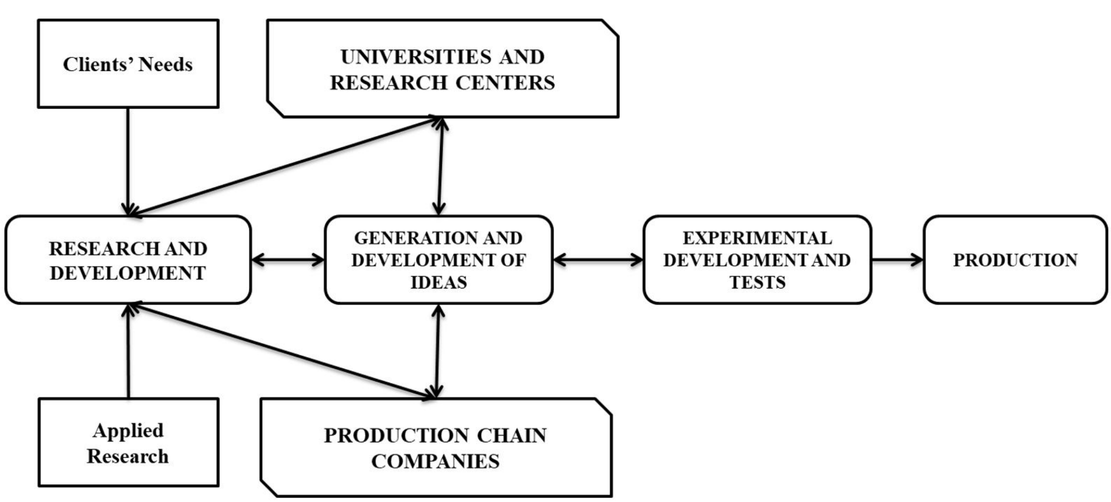

Figure 10. Model of Innovation Development of SMEs of the Aeronautical Sector. Source: Elaborated by the authors.

Figure 10 shows that the innovation process does not occur in a linear way. It comes and goes in interactive relations that include science, technology, learning, production, politics and market demand. This approach overcomes the cause and effect chain that starts with R&D and ends with production and market changes brought by innovation. According to the data, the innovation development in SMEs of the aeronautical sector approached here is stimulated by the clients' needs and applied research. Considering both the SMEs managers gather data on productive, economic and human viabilities for developing a new product, and the generation and development of ideas is a central activity in the innovation processes.

As the ideas are consolidated, the SMEs develop prototypes and after that experimental tests and prototypes tests. New ideas can appear during these processes. According to the Frascati Manual (OECD, 2002), the experimental development is a systematic work that emerges from a pre-existing knowledge achieved by research and / or practical experience, and applied in the production of new material, products and sets; in providing new processes, systems and services and also in the significant improvement of the pre-existing ones.

After the approval of the prototype the production and marketing of the new product starts. Due to the high added value of the products developed in the aeronautical sector, activities in this new phase significantly contribute for the regional development, because these activities employ high qualified labor substantively well paid.

6 Final considerations

According to Conde & Araújo-Jorge (2003), the emergence of a knowledge-based Economics brought activities related to Science, Technology and Innovation (S,T&I) to the core of public debate and governments political priorities. In the last years the efficacy of the models of technological innovation on innovation systems have become the focus of concerning and research, in order to achieve a greater understanding of its dynamic for building indicators of a current state of the art of S,T&I, to anticipate the consequences of scientific advances and technological changes and to evaluate the demands and results of innovation activities.

However the high complexity of the processes of these activities and the intense and multiple connections among its parts make difficult the construction of synthetic models that provide an overview of the S,T&I state of art or to identify the casual connections among technology, Economics and society.

This paper contributes, anyway, to overcome the difficulties above mentioned because it aims to generate new knowledge on the process of innovation development in SMEs of the aeronautical sector. Based on the results we can say that Technology-based SMEs of the aeronautical sector do not innovate alone, but through their net of interaction with universities, research centers and different companies of large, small and medium size, parts of the aeronautical and aerospace productive chain. So the technological innovation is a continuous and cooperative process that involves management, coordination, business, research on the client's needs, competences and the management of the development of new products.

One can say that the model of innovation development in SMEs of the aeronautical sector is an interactive model that combines interactions in the exterior environment of each company and interacts with institutions of the regional system of innovation, as universities, research centers and companies.

Finally, the contribution of this paper is for the academic environment, i. e., the research contributes for other Brazilian researches in the management of innovation. It also contributes by relating the innovation process to the particularities of the small and medium-sized companies of the aeronautical sector, presenting a model of analysis that contributes for a better understanding on how the process of innovation development in Brazilian and Canadian companies of the aeronautical sector occur.

References

Anderson, P., & Tushman, M. L. (1990). Technological descontinuities and dominant designs: a cyclical model of technological design. *Administrative Science Quarterly*, 35(4), 604-633. http://dx.doi.org/10.2307/2393511.

Associação das Indústrias Aeroespaciais do Brasil – AIAB. (2013). *Números da Associação das Indústrias Aeroespaciais do Brasil*. São José dos Campos: AIAB. Recuperado em 29 de julho de 2013, de http://www.aiab.org.br/portugues/index.php?option=com_content&task=view&id=13&Itemid=26

Association des Industries Aérospatiales du Canadá – AIAC. (2013). *Le Rapport: l'état de l'industrie aérospatiale canadienne*. Canada: AIAC. Recuperado em 29 de julho de 2013, de http://www.aiac.ca/uploadedFiles/Canadas_Aerospace_Industry/Industry_Statistics/StateOfCdnAeroIndustry2013_FINAL_FR.pdf

Bandeira-de-Mello, R. (2006). Softwares em pesquisa qualitativa. In C. K. Godoi, R. Bandeira-De-Mello & A. B. Silva (Eds.). *Pesquisa qualitativa em estudos organizacionais: paradigmas, estratégias e métodos* (pp. 429-460). São Paulo: Saraiva.

Barbieri, J. C. (2003). *Organizações inovadoras: estudos e casos brasileiros*. Rio de Janeiro: Editora FGV.

Billaudot, B., & Julien, P. A. (2003). Organisation Industrielle et sous-traitance: du fordisme à l'entreprise-réseau. In P. A. Julien, L. Raymond, R. Jacob & G. Abdul-Nour (Eds.), *L'entreprise-réseau: dix ans d'expérience de la Chaire Bombardier Produits Récrèatifs* (pp. 47-95). Québec: Presses de l'Université du Québec.

Canongia, C., Lamb, C. M. S. R., Carvalho, C. S. D. P., & Silva, V. S. (2001). Convergência da inteligência competitiva com construção de visão de futuro: proposta metodológica de sistema de informação estratégica (SIE). *Revista de Ciência da Informação*, 2(3), 1-15.

Conde, M. V. F., & Araújo-Jorge, T. C. (2003). Modelos e concepções de inovação: a transição de paradigmas, a reforma da C&T brasileira e as concepções de gestores de uma instituição pública de pesquisa em saúde. *Ciência & Saúde Coletiva*, 8(3), 727-741. http://dx.doi.org/10.1590/S1413-81232003000300007.

Cooper, R. G. (1994). Perspective third-generation new product processes. *Journal of Product Innovation Management*, 11(1), 3-14. http://dx.doi.org/10.1016/0737-6782(94)90115-5.

Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review*, 14(4), 532-550. http://dx.doi.org/10.5465/amr.1989.4308385.

Freeman, C., & Soete, L. (1997). *The economics of industrial innovation* (3rd ed.). Cambridge: The MIT Press.

Galanakis, K. (2006). Innovation process: make sense using systems thinking. *Technovation*, 26(11), 1222-1232. http://dx.doi.org/10.1016/j.technovation.2005.07.002.

Kline, S. J. (1978). Innovation is not a linear process. *Research Management*, 4(28), 36-45.

Leiponen, A., & Helfat, C. E. (2010). Innovation, objectives, knowledge sources and benefits of breadth. *Strategic Management Journal*, 31(2), 224-236. http://dx.doi.org/10.1002/smj.807.

Lima, E. (2005). Microdinâmicas da difusão de inovações entre micro, pequenas e médias empresas. In P. P. H. Wilhelm & M. Amal (Eds.), *Arranjos produtivos locais: estratégias de cooperação e desenvolvimento* (pp. 83-120). Blumenau: Nova Letra. Recuperado em 2 de maio de 2017, de https://www.researchgate.net/profile/Edmilson_Lima2/publications

Lima, E. (2010). Teorizando a partir de dados qualitativos em Administração. *Pretexto*, 1(11), 73-93.

Lima, E., Lopes, R. M., Nassif, V., & Silva, D. (2015). Opportunities to improve entrepreneurship education: contributions considering brazilian challenges. *Journal of Small Business Management*, 53(4), 1033-1051. http://dx.doi.org/10.1111/jsbm.12110.

Lobosco, A., Moraes, M. B., & Maccari, E. A. (2011). Inovação: uma análise do papel da Agência USP de Inovação na geração de propriedade intelectual e nos depósitos de patentes da Universidade de São Paulo. *Revista de Administração da UFSM*, 3(4), 406-424.

Longanezi, T., Coutinho, P., & Bomtempo, J. V. M. (2008). Um modelo referencial para a prática da inovação. *Journal of Technology Management & Innovation*, 3(1), 74-83.

Miles, B. M., & Huberman, A. M. (1994). *Qualitative data analysis: an expanded sourcebook* (2nd ed.). Thousand Oaks: Sage.

Mintzberg, H. (1989). *Mintzberg on management: inside our strange world of organizations*. New York: The Free Press.

Moraes, M., Lobosco, A., & Lima, E. (2013). Expectations of FINEP and São Paulo Anjos Agents concerning the use of venture capital in technology-based small and medium enterprises. *Journal of Technology Management & Innovation*, 8, 92-104.

Moreira, D. A., & Queiroz, A. C. S. (Eds.). (2007). *Inovação organizacional e tecnológica*. São Paulo: Thomson Learning.

Mühr, T. (1995). Atlas/ti, release 1.1 E. In E. A. Weitzman & M. B. Miles (Eds.), *Computer programs for qualitative data analysis* (pp. 217-229). Thousand Oaks: Sage.

Musiolik, J., Markard, J., & Hekkert, M. (2012). Networks and Network Resources in Technological Innovation Systems: towards a conceptual framework for system building. *Technological Forecasting and Social Change*, 79(6), 1032-1048. http://dx.doi.org/10.1016/j.techfore.2012.01.003.

Nobelius, D. (2004). Towards the sixth generation of R&D management. *International Journal of Project Management*, 22(5), 369-375. http://dx.doi.org/10.1016/j.ijproman.2003.10.002.

Organisation for Economic Co-operation and Development – OECD. (1999). *Managing national innovation systems*. Paris: OCDE.

Organisation for Economic Co-operation and Development – OECD. (2002). *Manual Frascati: propuesta de norma práctica para encuestas de investigación y desarrollo experimental* (Fundación Española para la Ciência y Tecnologia, Trad.). Paris: OCDE.

Ortt, J. R., & Van Der Duin, P. A. (2008). The evolution of innovation management towards contextual innovation. *European Journal of Innovation Management*, 11(4), 522-538. http://dx.doi.org/10.1108/14601060810911147.

Rodrigues, L. C., Heringer, B. H. F., & França, A. L. (2011). Padrões de inovação em multinacional de base tecnológica. *Revista Inteligência Competitiva*, 1(2), 198-204.

Rothwell, R. (1994). Towards the fifth-generation innovation process. *International Marketing Review*, 11(1), 7-31. http://dx.doi.org/10.1108/02651339410057491.

Sáenz, T. W., & García Capote, E. (2002). *Ciência, inovação e gestão tecnológica*. Brasília: CNI/IEL/SENAI, ABIPTI.

Stal, E. (2007). Inovação tecnológica, sistemas nacionais de inovação e estímulos governamentais à inovação. In D. A. Moreira & A. C. S. Queiroz (Eds.), *Inovação organizacional e tecnológica*. São Paulo: Thomson Learning.

Viotti, E., & Macedo, M. (2003). *Indicadores de ciência, tecnologia e inovação no Brasil*. Campinas: Editora Unicamp.