Regional Development in Brazil and the Challenges Facing Technology-Intensive Cities: A Proposal for a Framework of a Municipal Innovation System

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Abstract--**There are Brazilian cities that have evolved from a low-tech status to become relevant players in the high-tech arena, as it is the case of São José dos Campos, in the State of São Paulo. It is at the center of the Brazilian aerospace and defense industries, and it displays companies such as Embraer, Avibrás, Petrobrás, Visiona, Johnson & Johnson, National Panasonic, Monsanto, and General Motors, as well as important R&D institutions, namely the Department of Aerospace Science and Technology, the National Institute of Space Research, the R&D laboratories of Boeing and the Airbus Group, and universities, such as the Federal and The State Universities of São Paulo, and the University of the Paraiba Valley. Stakeholders have been addressing the strategic challenges facing the city, and their impacts on the sustainability of its competitive position. Initiatives were implemented, including the creation of a competitiveness center and technological parks, reinforcing the existing innovation system. The paper will discuss current and future competitive issues and challenges, such as the development and production of a new fighter jet for the Brazilian Air Force, and it will propose a framework for an innovation system, supporting the political decision making process regarding strategic initiatives.**

I. INTRODUCTION

The current global economy presents characteristics that are contradictory at a first glance. Innovative activities are not uniformly or randomly distributed; actually, the more knowledge intensive economic activities are, the greater is their geographical concentration, especially in sectors such as aerospace, defense, information and communication technologies, biotechnology and financial services. Additionally, the concentration tendency has been increasing, according to Asheim & Gertler [1], [2].

The importance of such trend has contributed to stimulating the Research Group in Technology Management and Economics (NPG) at the Institute of Aeronautical Technology (ITA) to study innovation systems and innovation clusters, and the roles they play in promoting scientific, technological, economic, and social development in Brazil, both at the regional and the national level.

The Council of Competitiveness of the United States of America has pointed out that the country's competence in producing high value added goods and services depends on creating and strengthening innovation clusters and innovation systems, the interconnections of the former leading to innovation networks, an important component of innovation systems. The Silicon Valley and Route 128 in Massachusetts are good examples of such networks [4].

The Institute of Aeronautical Technology (ITA), a DCTA´s[1] organization, in conjunction with other institutions of the region, has been studying the local innovation system, with the objective of subsidizing actions promoting its continuous development. A particular action led to the creation of Cecompi – the Center for Innovation, Entrepreneurship and Competitiveness in the Eastern Cone (Region) of The State of São Paulo -, in November 2003, whose mission is similar to that of the U.S. Council on Competitiveness, at the regional level.

The establishment of Cecompi was supported by the Secretary of Economic Development, Science, Technology and Innovation of the State of São Paulo, who took into consideration the existence, in the region, of large technology intensive companies, such as Embraer, Petrobrás, Avibrás[2], General Motors, Delphi, Volkswagen, Ford, Chery/Brazil[3], Monsanto, National Panasonic, and LG, as well as a significant number of small and medium technology-based enterprises, and several educational, scientific and technological institutions. The Secretary concluded that there was a favorable environment to implementing structured initiatives for stimulating technology innovation and the ensuing contributions to economic development.

One of such initiatives was the was the inauguration, in 2006, of the Technological Park of São José dos Campos, which is part of the State of Sao Paulo's System of Technological Parks. The Technology Park of Sao José dos Campos is currently managed by the Municipality and it is an important component of the city's innovation system.

The NPG, considering the context just described, decided to concentrate its effort in analyzing the aeronautical cluster, due to its natural alignment with ITA's mission and its relevance to the region and to the country. There was the need for researching the interconnections of this cluster with the regional economy and its innovation system, and the production of suggestions for planning regional development and defining measures to stimulate the different sectors of its economy. Additional issues referred to sustaining the aeronautical cluster's competitive advantages, and identifying opportunities and threats that might affect its evolution, such as new entrants in the regional aircraft market.

[1] The Institute of Aeronautical Technology (ITA) is an Engineering Faculty subordinated to the DCTA, which stands for the Department of Aerospace Science and Technology, an organization of the Brazilian Air Command (COMAER), subordinated to the Ministry of Defense (MD).

[2] Avibrás is an important Brazilian Defense company, established, as Embraer, by engineers graduated at ITA.

[3] Chery is a Chinese automotive manufacturer, which recently established a plant at the nearby city of Jacarei.

These very considerations apply to the other existing clusters, including those in the space, automotive, petrochemical, chemical, biotechnology and electronic sectors. It should be added that, in recent years, important companies, such as Solectron, Kodak, and Philips, ceased their operations in São José dos Campos. The alleged reasons were corporate restructuring in the former case, and technological disruptive changes and the production of digital cameras and TV sets elsewhere, in the latter. Innovation and competitive issues, however, were common to both cases.

The conceptual model that was chosen to analyze the aeronautical cluster very closely resembles the one developed by the Council on Competitiveness, in order that the results of the analysis could be compared to similar studies, undertaken for clusters such as the ones established in Wichita, Kansas, Montreal, in Canada, and Toulouse, France.

It was also taken into consideration the model developed by the Washington Technology Center, from the State of Washington, which is expressed by the Index of Innovation and Technology. It should be noted that the conceptual model was developed considering clusters in general and not only aeronautical clusters [14].

These models are oriented towards understanding the contributions that R&D programs, projects and activities and clusters bring to increasing the innovative capacity, the productivity, and the economic development of a region.

The analytical model that apprehends and organizes the conceptual elements and attributes of clusters, and its relationships with regional economic development, is structured according to the following elements:

- interconnection of factors related to technological innovation, competitiveness and prosperity
- performance of the regional economy
- evaluation of clusters´ competitiveness
- evaluation of international references, such as in the USA, France and Canada, in the case of the aeronautical cluster
- analysis of the results associated with technological innovation, competitiveness and economic performance
- the development of a regional agenda and initiatives that will sustain current competitive advantages, generate new competences and skills, and deal with competitive challenges

Technology and innovation represent essential elements for the strength and economic vitality of technology-intensive regions such as the one centered in São José dos Campos. It is not, however, an easy task to identify the relationships between economic development and the drivers of a technology-based economy. Cluster analysis models, on their turn, with their components and associated performance variables, may very well provide the basis for the framework of an innovation system, that will be developed in order to support the political decision making process regarding the economic development of the region.

That framework will include information categories that should be maintained and provided by the innovation system, which will subsidize stakeholders in their actions to addressing competitive issues and promoting municipal development and prosperity.

The rational decision making model proposed by Herbert Simon, described in Laudon & Laudon [5], will be used as a reference for the political decision making process. According to this model, an individual identifies objectives, classifies alternative actions according to their contributions for achieving such goals, and then chooses the alternative with the best anticipated behavior and return, economic or otherwise. It is also considered an extension of such process, also described by the authors, in order to support group decision making, which is comprised by the following activities: idea generation, organization, prioritizing, and policy development. It should be noted that the latter model holds a closer resemblance with the political decision making process, albeit too linear.

The cluster analysis model will provide subsidies for the development of the framework of the innovation system that has been under development in São Jose dos Campos, beginning with the implementation of the Department of Aerospace Science and Technology (DCTA), in the late forties and early fifties of the last century, with the support of MIT. Since then, several organizations of higher education, research and development, innovation promotion and industry, such as Embraer and Avibrás, have been established in the city, constituting a *de facto* innovation system, the framework of which this paper will propose.

The systems concept that will be used is that of a set of institutional actors that, together, plays the major role in influencing innovative performance, according to Nelson & Rosenberg [9].

The next topic will present the conceptual relationships among innovation, competitiveness, and prosperity, which are necessary to provide a reference for understanding the roles performed by innovation systems in general, and clusters, in particular, in promoting such relationships. It will also enable the proposal of the framework for the innovation system that will support decision makers at the municipal level.

II. INNOVATION, PRODUCTIVITY, COMPETITIVENESS AND PROSPERITY

The technology innovation process encompasses, in general, the production of new knowledge and the invention of new technologies, their deployment into new processes, products, services, and business models, and their introduction and operation in the market and society, at large.

The Council on Competitiveness, in its National Innovation Summit, defined innovation as *the intersection of invention and insight that leads to the creation of economic and social value* [4]. The latter definition is broader than the former and is very appropriate to the objectives of this paper.

Porter's diamond [11] organizes the determinants of regional productivity in four main areas, that are composed by:

- factor conditions
- demand condition
- the context for firm strategy and competition
- the presence of related and supporting companies, industries and institution[4]

Porter emphasizes that these areas act as a system, enabling synergistic effects.

Factor conditions refer to their availability, cost, quality and specialization.

Demand conditions influence the process of creating and improving products and services. The presence of sophisticated clients in the region puts pressure on the technology innovation process, and leads to new perceptions of current and future needs.

That has been the case of the Brazilian Air Force and the programs it has been contracting with Embraer, such as the Bandeirante aircraft, that was developed at DCTA in the mid-sixties and was the company's first product, and recent programs, such as a the KC-390 new cargo airplane to substitute and compete with the Hercules aircraft, and the Gripen Next Generation fighter, contracted with SAAB[5], with Embraer participating in its integration and production.

The context for firm strategy and competition is composed by rules, incentives and pressures that influence the type and the intensity of local competition. Examples are provided by policies that promote investments, protect intellectual property, as well as the presence of local competition and regulation institutions. Examples of the latter institutions are the Brazilian National Civil Aviation Agency and the Industrial Promotion and Certification Institute[6] (respectively, ANAC and IFI, in Portuguese).

Related and supporting firms, industries and institutions for collaboration may constitute a cluster if they belong to the same sectors and are installed in a particular geographical region, and if they are interconnected by common and complementary aspects. They integrate and are essential components of a local innovation system.

Porter identifies the several contributions of clusters to increasing a region's productivity, being among them:

- better access to specialized factors
- the creation and promotion of a more favorable business environment to innovation
- the facilitation of the commercialization of innovations, reducing entry barriers to new firms, by means of start-ups and spin-offs
- the attraction of new companies
- the promotion of entrepreneurial spirit and attitudes

Such contributions reinforce productivity and innovation, thus enabling a virtuous cycle to be established, as it was the case of the city of São José dos Campos, which was able to accumulate an expressive trade surplus of US$ 30 billion dollars, since the year 2000 to the present date, according to the City Hall´s statistics.

Porter understands that the appearance of the diamond's elements and their inter-relations occurs spontaneously or by means of the actions of firms and organizations such as governmental agencies, research centers, universities and infrastructure providers.

The historical development of the region will provide indications about this process, and that is exactly the case of São José dos Campos, where the establishment of the Aeronautical Technical Center, in the early fifties, created the human resources, the intellectual capital and the technical facilities that were the main foundations for the establishment of the Brazilian aeronautical industry.

The development and the improvement of the diamond's components are also promoted by governmental or institutional initiatives aiming at increasing the collaboration among them, and that was fostered by the Brazilian Air Force, promoting the improvement of the Brazilian companies participating of the aeronautical industry, by means of training and certification programs.

Institutions for collaboration, on their turn, create and amplify the inter-relations among the areas of Porter's diamond. Such institutions, of which Cecompi and the Technology Parks of São José dos Campos are examples, facilitate information and technology interchange, as well as promote several forms of coordination and collaboration, which contribute to improving the business environment of clusters and the regional economy.

Innovation and competitiveness are also influenced by economic attitudes and values. They affect the behavior of individuals and organizations of a region and its social capital. Their presence in the region of São José dos Campos can be represented by entrepreneurs such as Ozires Silva, one of the founders of Embraer[7], and the late João Verdi de Carvalho Leite, the founder of Avibrás.

All the diamond's elements influence the productivity and competitiveness of a region, including a common innovation infrastructure – mainly provided by the Department of Aerospace Science and Technology (DCTA) and the National Institute of Space Research (INPE[8]) -, as well as specific characteristics of clusters, and the quality of the interconnections among the diamond's components.

[4] CECOMPI and both the Technology Parks of São José dos Campos are examples of supporting institutions operating in the county of São José dos Campos.

[5] SAAB has a local partner, Akaer, an engineering firm specialized in providing engineering services to the Brazilian aeronautical industry.

[6] IFI, as ITA, are DCTA´s organizations, thus belonging to the Brazilian Air Command and to the Brazilian Ministry of Defense.

[7] Embraer which was founded in 1969, stands for Brazilian Aeronautics Enterprise, and Avibrás for Brazilian Aircrafts; Avibrás is, nowadays, an important Brazilian Defense company. Both Ozires Silva and João Verdi are both ITA's alumni.

[8] The National Institute of Space Research (INPE) is linked to the Brazilian Ministry of Science, Technology and Innovation.

Oakley and Pearson [10], in Lefebvre and Lefebvre [10], describe the relationships among innovation, technology, and regional development, with special focus on the historical evolution of regional development agencies in Great Britain. There is such an agency in the Paraiba Valley, the Integrated Committee for the Development of the Paraiba Valley (CODIVAP, in Portuguese). The Committee has exercised its activities by providing a forum whereby the region's mayors and staff can discuss their political agendas and common interests. It lacks, however, a formal framework for supporting the political decision making process regarding the development of the region, as well as an innovation system to support the implementation of resulting policies regarding science, technology and innovation.

It is also important to consider the integration of academia, government and industry in the context of an innovation system. Such integration favors the establishment and the development of the so-called Golden Triangle, or the Triple Helix model, and the virtuous circle it enables, by means of which investments are transformed into new knowledge basis, that are incorporated into innovations and new business models, thus contributing to generating revenues and new investments, and the circle works, virtuously.

The conceptual relationships among innovation, productivity, competitiveness, and prosperity were presented, and they allowed the establishment of the proposed framework for the innovation system of the city of São José dos Campos, which will encompass the following main dimensions, that will be addressed in this paper:

- Evaluation of the municipal economy
- Evaluation of cluster´s competitiveness
- Innovation and competitiveness challenges

It is adequate to highlight that the first two dimensions will support the third dimension, regarding the main output of the proposed framework, that is, the identification of innovation and competitive challenges, to be addressed by local authorities and stakeholders, in order to promote the development of the municipal economy.

III. EVALUATION OF THE MUNICIPAL ECONOMY

The evaluation of the municipal economy is the first dimension addressed by the proposed framework for the innovation system. This system will be coordinated by a central organization, such as a secretary of the municipal administration, and it will require a set of data and information, that is, intelligence, to subsidize the decision process of public administrators, regarding the planning and the execution of actions to promote local economic development.

This topic presents information categories, which might be provided by a local or regional information system, operated by organizations such as the aforementioned CODIVAP, or SEADE – The São Paulo´s Foundation for the State System of Data Analysis –, or a particular secretary of the municipal administration of São José dos Campos[9].

The first dimension of the proposed framework for the municipal innovation system will encompass the following elements:

- historical evolution of the municipal economy
- economic development
- composition and evolution of the economy
- innovation capacity
- subsidies for promoting municipal development

In the development of an innovation system, having a historical perspective is very important, especially concerning the main aspects and variables to be considered and monitored by an innovation system, and it will be addressed in the next topic.

A. Historical Evolution Of The Municipal Economy

The description of the historical evolution of Sao José dos Campos has the purpose of establishing an evolutionary perspective for the development of the proposed innovation system framework. It will identify the events that are considered important, highlighting the progressive constitution of the areas of scientific and technological expertise and the institutions that integrate the Porter's diamond, and the innovation system itself.

It will take into consideration relevant planning actions regarding national and municipal development, undertaken by governmental institutions at different levels and diverse administrations and administrative periods. It will also include the initiatives taken by private entrepreneurs.

It also takes into consideration the technology trajectory of the main systems that are developed by organizations integrating the local clusters.

The description of the historical evolution can be facilitated when different phases the municipal development are considered. They range from the foundation of Sao José dos Campos until its transformation into an important scientific, technological and economic city, either from the regional or national standpoint. The following phases are initially suggested to describe the historical evolution of the city:

- First phase: from the foundation of Sao José dos Campos until the creation of the Aeronautical Technology Center (CTA), in the early fifties
- Second phase: from the establishment of CTA until the constitution of Embraer (Brazilian Aeronautical Enterprise), in the late sixties
- Third phase: from the creation of Embraer until its privatization, in 1994

[9] In fact, the Secretary of Economic Development and Science and Technology is responsible for the coordination of the *de facto* Innovation System of São José dos Campos, with the Cecompi and the Technology Park of São José dos Campos, both social organizations linked to the Secretary, operating to implement the municipal policy for economic development, and science and technology.

- Fourth phase: from the privatization of Embraer until the implementation of the of Cecompi and the Technological Park of Sao José dos Campos, in the mid 2000´s
- Fifth phase: from the implementation of Cecompi and the Technological Park of Sao José dos Campos up to the current days

The historical evolution of the city and its neighboring region will be best developed and maintained by the municipality of São José dos Campos, with the participation of local universities and its specialists, as well as by representatives of the private sector, including commercial and industrial associations, and the community at large.

It will provide the historical perspective that is important and necessary to properly formulate the decision making framework and special issues that public and private stakeholders will have to tackle, regarding the development of an innovation system and the city's economic development. This perspective is particularly relevant in the city, due to the presence of industries that are subjected to cyclical economic fluctuations, such the aeronautical and automotive. It is important to note that these industries are responsible for a sizeable part of the level of formal employment in the city.

The next topic will address the component of the cluster analysis model regarding the performance of a municipal economy and the variables that will describe it. These variables should be integrated in the innovation system, and their behavior should be closely monitored, in order to evaluate the performance of the system itself and the local economy.

B. Municipal Economic Performance

The component of the cluster analysis model regarding the economic performance of a municipality will be provided by a municipal information system, or by the innovation system itself, and it will keep track of the behavior over time of set of variables of economic nature. Another set of variables is oriented toward technological innovation results or products.

The set of economic variables will provide performance indicators of economic vitality and it is composed by:

- Employment level
- Unemployment level
- Average wages
- Productivity
- Exports
- Quality of life

Technological innovation outcomes, incorporated in new product and services, will provide performance indicators with the purpose of evaluating the future potential of the city's competitiveness, and they are expressed by the following variables:

- Patents registered by organizations of the region
- Risk investments
- Creation of new firms
- Entrepreneurship promotion[10]

The innovation system will gather data and produce information that will allow local stakeholders to analyze the behavior of the suggested indicators, and to detect trends regarding the economic performance of the city of Sao José dos Campos.

The system will also enable comparisons and benchmarking to be made with other technology-intensive cities, as well as to the national economy, thus eliciting competitive issues that will deserve attention and action of concerned stakeholders. The position of the city's exports, vis-à-vis the exports of other cities and national exports, might be one example of such comparisons.

The next topic will disaggregate the economic performance of a city according to the main sectors that contributes to its development. The variables presented thus far provide a general view of the economic behavior of the region, enabling political decision makers to visualize and understand the trends indicated by the variables that are monitored by the innovation system. A deeper understanding of the underlying causes of favorable or unfavorable trends, however, will require the analysis of the contributions of specific sectors to such observables trends, such as the participation of the aeronautical cluster in the city's or national exports and trade balance.

C. Composition and Evolution of the Municipal Economy

A regional or municipal economy, according to the Council of Competitiveness [4], is composed by a first class of firms, designated by traded clusters, which is responsible for products and services that compete in national and international markets. Embraer, Avibrás, General Motors[11] and Johnson & Johnson are examples of such firms.

Firms whose products are directed to local markets integrate a second category: they are the local clusters. The dairy sector, for example, is still thriving in the Paraiba Valley.

A third category is made by resource-oriented clusters, usually in regions where natural resources are abundant. This is not the case of the region of São José dos Campos.

[10] It is important to highlight, from the social standpoint, that the municipality also supports the development of low-tech companies, through its Bank for the Entrepreneurs (BEJ), providing low-cost loans – up to a US$ 1000 - to enterprising people at the base of the social pyramid (BoP). The BEJ is managed by the Secretary of Economy Development, and Science and Technology. The BEJ has the support of the National Service for the Assistance of Small and Medium Size Companies (SEBRAE). It is interesting to know that the Bank has presented a very high rate of loans payment.

[11] Press reports indicate that the Brazilian GM branch is a healthy one, and that is has not been affected by the difficulties the corporation is suffering in the US. In the first quarter of 2016, sales of the Brazilian automotive industry have diminished by a sizeable facto of thirty percent, but GM is currently a sales leader, ahead of VW, FCA, FORD, and other manufacturers such as the PSA Group, Citroen, and Hyundai.

A last category involves the local operations of clusters established elsewhere, represented by firms that integrate the automotive cluster.

The innovation system considers that the economy of the city of São José dos Campos can be described using these concepts, and the historical behavior of its different sectors and clusters, by means of associated economic variables, and those referring to technological innovation products, such as the following:

- Employment distribution by clusters or sectors
- Employment level by clusters or sectors
- Composition of average wages
- Registered patents by clusters or sectors[12]
- Productivity indicators by clusters or sectors

The innovation system will support the analyses of the behavior over time of such variables by local stakeholders, enabling them, among other possibilities, to understand the relative importance of the different sectors or clusters, therefore subsidizing the identification of those whose performance is key to regional prosperity, and those that require attention and actions to bring them to the desired level of performance. Among such measures there will be the variables referring to the region's innovation capacity.

The analysis of such capacity is treated in the following component of the innovation system that will be presented next, as part of framework for supporting political decision-making.

D. Municipal Innovation Capacity

The innovation capacity of the city of Sao José dos Campos is analyzed taking into consideration the general business and innovation environment, including attributes that affect the regional economy and specific clusters.

Such characteristics are associated with Porter's diamond, including the role of government, and the performance of institutions for collaboration. They are now presented, along with indicators that describe their performance according to the following categories:

- **Basic and specialized factors**
  - Physical infra-structure, including components such:
    - Information and communication infra-structure
    - Transportation and logistics infra-structure[13]
    - Energy supply, water supply and sewage treatment
  - Specialized workforce
  - Quality of general education, including
    - Investments in education at all levels
  - Availability of risk capital
  - Research and development institutions and investments[14]
- **Context for firm strategy and competition**
  - Economic competition legislation
  - Regulation
  - Tax policy (e.g.: investment and fiscal incentives)
  - Local presence of rivals[15]
- **Related and supporting organizations**
  - Concentration of main companies in different economic sectors and their industrial value chains
  - Local position in sectors such as
    - Support services to businesses, such as legal and logistical services
- **Demand sophistication**
  - Local levels of per capita income and education
- **The role of federal, state, and municipal government[16], including**
  - Actions regarding the diamond elements, as well as
    - Zoning legislation
    - Agency coordination
    - Research, development and innovation investments
- **Institutions for collaboration**
  - Existence, role performed and governance[17]
- **Attitudes toward business**
  - Local attitudes regarding the sources of economic prosperity[18]

The municipal innovation capacity is, off course, a fundamental dimension of the proposed framework of the innovation system, although a very demanding one, in terms of the data base that will have to be built and maintained.

Nevertheless, it will provide the subsidies that will enable local stakeholders to verify the region's capacity to sustain the evolution of its economic prosperity, and, therefore, its quality of life, in the medium and the long range.

The main dimensions of the performance of the municipal economy were addressed, referring to its historical evolution, economic performance, composition and evolution, and innovation capacity.

[12] It is important to note that Embraer has been progressively emphasizing the protection of the intellectual property it produces by means of patents whereas, in the past, the policy was to protect them by means of trade secrets.

[13] The city of São José dos Campos has inaugurated, in 2015, an expansion of its airport, named after Professor Urbano Ernesto Stumpf, a Brazilian Air Force officer, an ITA´s alumnus, and the father of the Brazilian Ethanol Program.

[14] It is important to note that the Municipality has been promoting international cooperation with foreign scientific, technological and educational institutions, in order to promote the interchange of knowledge and specialists. Cooperation agreements have involved institutions from the Netherlands, Canada and Japan.

[15] Bombardier does not have a local presence in the region of São José dos Campos; the press, however, has registered actions of the company in recruiting Embraer´s engineers.

[16] The role of the various level of government, supporting the municipal innovation system, is described in the report *The City of São José dos Campos and its Innovation System*, prepared by the author of the present paper to the Secretary of Economic Development and Science and Technology.

[17] The governance aspect of the functioning of institutions for collaboration has been gaining importance, due to the diversity of interests of local actors as well as to the need of addressing investment and strategic alignment issues.

[18] The city of São José dos Campos has a very much pro-business policy that has to be reassured and disseminated among local stakeholders.

The innovation system, which keeps track of the variables that describe the behavior of the economy, will provide several and important subsidies to decision makers regarding the development of the city, and they will be discussed in the next topic.

E. Information Subsidies for Promoting Municipal Economic Development

The analysis of the information produced by the innovation system will support the development of diagnosis, prognosis and conclusions about the region's economic performance, especially in respect to the systemic areas of Porter's diamond – factor conditions, demand conditions, context for firm strategy and competition, and related and supporting industries - .

It will support specific analysis referring to:

- Municipal competitiveness
- Innovation capacity
- Achievements and local successes
- Strengths
- Challenges, including the need for new directions

The subsidies provided by the innovation system and their analysis will support the development of actions regarding bottlenecks, threats and opportunities that will be undertaken by local leaders.

Such actions will involve different stakeholders, organizations in the private and governmental sectors, as well as universities, research and development centers, and business and industrial associations.

They will be oriented toward the municipal economy as whole, supporting the development of policies and actions plans and programs regarding economic, scientific and technological and social development.

The provision of subsidies regarding the municipal economy is oriented toward the strategic level of the political decision making framework, and it is supported by the innovation system first dimension. The implementation of such framework should be given a high implementation priority, since local decision makers do not usually have a formal framework to support the decisions they currently take.

The needs, however, remain for devising plans and programs that will address the challenges affecting specific clusters, as the analysis about the composition and evolution of the municipal economy, and the analysis of its innovation capacity, might have elicited.

To summarize, the first dimension of the proposed framework for a municipal innovation system was addressed, and it encompasses the following elements regarding the evaluation of the municipal economy:

- Historical evolution
- Municipal economic performance
- Composition and evolution of the municipal economy
- Municipal innovation capacity
- Subsidies for promoting municipal development
  - which is the main result of the first dimension that will be treated by the innovation system

The second dimension of the proposed framework for the innovation system, the one that addresses the performance of municipal innovation clusters, will be presented in the next topic.

IV. THE EVALUATION OF CLUSTERS´ COMPETITIVENESS

The components of the Porter´s Diamond, namely factor conditions, the sophistication of demand, the context for competition, and related and support institutions and companies, are normally more relevant to the understanding of cluster performance than that of the region or city where they belong.

Cecompi, for instance, monitors the issues and demands that might affect the export potential of the aeronautical, space and defense cluster, as far as meeting the requirements of companies such as the Airbus Group, which has recently expressed its intentions of increasing the volume of orders to South America, and the aeronautical cluster[19] of São José dos Campos, in particular.

Factor conditions, for instance, are relevant at cluster level, but they should emphasize specialized inputs, as the availability of research centers related to their specific area of concentration, instead of general-purpose inputs, such as general education.

Such is the case of DCTA (The Department of Aerospace Science and Technology) and its institutes, in regard to the aeronautical cluster. INPE (The National Institute of Space Research) performs a similar role for the space cluster.

It is also important to analyze governmental institutions and policies that are oriented toward promoting collaboration in specific clusters. Cecompi and both the Technology Parks of São José dos Campos - the Technology Park, supported by the municipality, and the Technology Park of the University of the Paraiba Valley - are examples of such institutions, as it was previously mentioned,

Cluster performance in a given region will be analyzed according to dimensions that are similar to those which were employed to understanding municipal economic performance.

The following dimensions will then be employed:

- Historical development of clusters
- Economic development of clusters
- Cluster´s structure
- Cluster´s innovation capacity
- Conclusions about cluster´s performance

[19] Cecompi manages the local aerospace and information and telecommunication clusters, which are composed, respectively, by over a hundred companies and over sixty companies, mostly locally established.

The paper will present next each of the elements that the innovation system will incorporate, in order to provide to local stakeholders adequate and consistent information and subsidies that will support the development of common agendas and initiatives, oriented toward promoting the sustainable development of the city's clusters.

It should be observed that the innovation system should be designed and implemented considering that the data and information about specific clusters will be gathered and produced in a progressive way, since addressing all the existing clusters simultaneously will imply an expressive and probably prohibitive level of resources. The priority for addressing a particular cluster will most likely result from the analysis of the composition and evolution of the regional economic, and the conclusions about pressing issues for regional development.

The analysis of the aeronautical cluster of the region of São José dos Campos, for instance, is of the utmost priority, due to its contribution for the economic development of the region.

Embraer, for instance, was Brazil's largest exporter from 1999 to 2001 and the second largest in 2002, 2003 and 2004. It currently employs more than 17.389 people, 88% based in the country[20]. It is also relevant to mention that the city of São José dos Campos has been able to produce a consolidated trade surplus in excess of thirty billion dollars since 2.000, according to the City Hall's data, mainly due to the export of aeronautical products by Embraer and the city's aeronautical cluster.

São José dos Campos is currently the leading export city in the State of São Paulo, second only to São Paulo, the capital of the State. Data produced by the Federal Government show that the city has exported, between January and September, 2015, US$ 3.136 billion, compared to US$ 3 billion in the same period, in 2014; aeronautical exports were responsible for US$ 2.4 billion, and the U.S. market for 68% of the exports total, indicating the vitality and the competitiveness of the city's innovation system and its economy, that the system supports.[21]

A. Historical Development of Clusters

The perspective provided by the historical evolution of the clusters established in Sao José dos Campos is required in order to highlight important events regarding the progressive constitution of the areas that integrate Porter's diamond. These are the same approach and justification that were used to describe the historical development of that region.

In the same vain, it will also take into consideration the relevant planning actions regarding national and regional development that were undertook by different governmental levels in distinct administrations.

The description of the city's historical evolution can be made more relevant to the purposes of the innovation system if important phases of its development are considered.

They will be the same that were chosen to depict the historical development of the city of São José dos Campos, although they will highlight more specific events that are relevant to the particular cluster being monitored, such as the privatization of Embraer, in 1994.

B. Economic Development of Clusters

The recent economic development of specific clusters will be monitored by the innovation system by gathering data and producing information about economic and technology innovation results and product indicators.

Economic indicators are the same that were proposed to monitor municipal economic performance, and they include, at cluster level:

- Employment level
- Unemployment level
- Average wages
- Productivity
- Exports
- Quality of life

Technology innovation indicators are the same that were devised to monitor regional innovation performance and they include, at cluster level:

- Patents registered by firms and organizations of the cluster
- Risk investments
- Creation of new firms
- Entrepreneurship promotion[22]

Those indicators will support analytic studies addressing issues deemed to be relevant to establishing the cluster current economic and innovation status and future productivity and competitiveness issues.

The aggregation of the analysis of the region's clusters will provide subsidies for developing general policies and

[20] The information is available in the company's web site, www.embraer.com, accessed in April 20th, 2009. Embraer inaugurated, in 2014, a major facility in Melbourne, in the State of Florida, to better support its North-American operations, including the maintenance services to executive jets sold in the US market and military airplanes provided to the US Air Force. The facility, installed in Melbourne, is also a major engineering center, and more than 300 engineers will be hired, as part of a requirement of the Government of the State of Florida. It is important to note that Embraer´s central research, development and engineering sector is established in São José dos Campos.

[21] Source: http://redevida.com.br/programa/jornal-da-vida/sao-jose-lidera-ranking-de-exportacao.html, accessed in April 15, 2016.

[22] The city of São José dos Campos sponsors four incubators for technology-intensive new businesses, and they are located at both the technology parks, at ITA, and the local oil refinery of Petrobrás. This network of incubators is coordinated by Cecompi, which invests roughly US$ 300.000 annually for that purpose. More than100 businesses were developed by these incubators since the establishment of these incubators; 30 companies are currently being incubated, employing 80 entrepreneurs in total. A new company named Altave was recently chosen by the Federal Government to supply a surveillance airship to the Olympics Games of Rio de Janeiro. Altave was incubated at Incubaero, which is the business incubator of the Institute of Aeronautical Technology (ITA), and it was established by ITA´s alumni.

plans regarding its development, with the benefit of exploring the potential of likely commonalities, complementarities and synergies.

C. Cluster's Structure

The structures of existing clusters in the city of São José dos Campos will be described by the innovation system according to the model proposed by Michael Porter, and adopted by the US Competitiveness Council. Such model is integrated by the following elements:

- Large firms or concentration of similar companies, such as Embraer in the aeronautical cluster
- Vertical industrial chains, upstream and downstream, such as Embraer´s suppliers and distributors
- Horizontal industrial chains, that produce complementary goods, or that use similar inputs or technologies, such as the automotive sector
- Institutions that provide specialized resources, such as skills and knowledge, technologies, information, capital and infra-structure, such as Department of Aerospace Science and Technology (DCTA) and its Institute of Aeronautical Technology (ITA)
- Regulatory and governmental organizations, such as the Brazilian National Civil Aviation Agency (ANAC), the equivalent to the Federal Aviation Administration
- Cooperation-oriented organizations, such as Cecompi and the Technological Parks of São José dos Campos

It was noted earlier that the innovation system should be designed and implemented considering that data and information about specific clusters will be gathered and produced in a progressive way, since addressing all the existing cluster's elements simultaneously will imply an expressive and probably unavailable level of resources. The same observation applies to the structure of a cluster.

The successive implementation of versions of the innovation system will contribute to providing the basis for a future and desirable real time monitoring of such a structure, thus contributing to expedite the political decision making process regarding its needs and opportunities.

The priority for addressing a particular cluster will most likely result, as it has been said before, from the analysis of the composition and evolution of the regional economy, and the conclusions about important issues for regional development. Furthermore, the mapping should include, at first, the description of the main components that were mentioned – i.e., Embraer and its main suppliers and distributors, thus mapping the firm's value chain. Later versions will progressively include further details about these components. Another example could illustrate these considerations. It has been a recurring local and national issue the expanding and the deepening of the industrial value chains of the aeronautical cluster, as it is the case of the Canadian aeronautical cluster of Montreal.

Therefore, its mapping should identify the existing firms of different industrial chains and the main links among them, as far as commercial and technological relationships are concerned, in order to subsidize decisions regarding the companies that should be included in industrial promotion programs, as the ones supported by the BNDES (National Bank for Economic and Social Development), and other federal organizations, as the National Financing of Studies and Projects (FINEP), the latter linked to the Ministry of Science, Technology and Innovation.

The following data of 2014 provide an overview of the dimension of the aeronautical industrial value chain of São José dos Campos, which is managed by Cecompi, noting that data referring to Embraer is not included[23]:

- Associated companies: 106
- Workforce: 5.565 workers
- Annual revenue: approximately US$ 300.000 million
- Exporting companies: 30
- Annual value of exports: US$ 30 million
- Certified companies: 63

D. Cluster's Innovation Capacity

According to Porter (1998), clusters influence regional and firm innovation capacity essentially by means of:

- Increasing innovation capacity
- Increasing the productivity of firms and industries
- Promotion of new businesses

The improvement of innovation capacity is due to promoting factors, especially those resulting from cluster characteristics associated to productivity, such as:

- Physical proximity of its components
- Face-to-face contacts
- Continuous interactions
- Easier and improved access to information

These same characteristics are explored and promoted in science and technology parks, thus facilitating the creation of new business and the attraction of investors and companies located elsewhere.

In São José dos Campos, for instance, the Vale do Rio Doce Company decide to explore the local innovation capacity through an associated firm, the Vale Solutions in Energy (VSE), established in the technological park of the city. Entry barriers for VSE were lowered through the availability of specialized resources in the region, especially at DCTA, as result of the pioneering efforts undertaken by the General Command during the development of the National Alcohol Program.[24].

[23] The data is collected by Cecompi, that manages the local aeronautical value chain, and it is provided by associated companies.

[24] An overview of the programs developed by CTA is presented by Damiani (2008) in the proceedings of PICMET´08: *The Technological Innovation Process and the Main Institutions and Actors Involved in the Development of an Ethanol-fueled Airplane: The Case of Ipanema*.

It is important to highlight that the Vale Company decided to change its strategic innovation portfolio, and its facilities at the Technology Park of Sao José dos Campos were sold to a local company, Akaer, which is associated with SAAB in the development of the Gripen Next Generation Fighter for the Brazilian Air Force.

The increase of innovation capacity also occurs as a result of:

- Faster detection of client needs
- Identification of new opportunities regarding to
  - technology
  - operations
  - logistics
- Experimentation facilitate by less resource consumption
- Flexibility and greater capacity for action, via:
  - Improved access to inputs and complementary assets
- Pressures resulting from peers, benchmarking, and the competitive context

Those elements are associated to the interactions among the main areas of Porter's diamond which, in their turn, interface with the local and national innovation systems.

Once the contribution of clusters to the municipal innovation capacity is understood, one can devise a way of assessing the innovation capacity of a particular cluster, so that the innovation system can gather data about it and produce relevant information for local stakeholders.

Cluster's innovation capacity is analyzed by means of the characteristics associated with Porter's diamond, as well as with the role of government, the performance of collaboration institutions, and the attitudes toward businesses. They were discussed in the topic that dealt with the relationships amongst innovation, productivity, competitiveness, and prosperity.

Cluster's characteristics related to innovation capacity are now presented, and they are organized according the same categories that were employed to analyze the municipal innovation capacity:

- Basic and specialized factors
  - Specialized research centers[25]
  - Specialized talent base[26]
  - Teaching and training specialized institutions[27]
- Context for competition and firm strategy
  - Intensity of competition amongst the firms of the cluster
  - Cooperation amongst the firms of the cluster
- Related and supporting organizations
  - Extension of related industries within and external to the cluster
- Sophistication of the demand
  - Sophistication of the demand for the cluster's products and services
- Government
  - Specific policies to the cluster
- Institutions for collaboration
  - Existence of cluster specific organizations, such as the coordination of the local aeronautical cluster, conducted by Cecompi
- Attitudes toward business
  - Attitude prevailing in clusters regarding the sources of economic prosperity

The basic purpose of that component of the innovation system framework – cluster innovation capacity – is to verify the cluster capacity to contribute to sustaining the evolution of economic prosperity at the local level.

A similar observation regarding the mapping of cluster structure deserves to be made at this point. The priority for addressing the innovation capacity of a particular cluster will most likely result from the analysis of the composition and evolution of the regional economy, and the conclusions derived about critical issues for regional development.

Furthermore, the measurement of innovation capacity should include, at first, a general but consistent description of the components mentioned above. Later versions will progressively include the remaining details about these components.

An example could illustrate these considerations. It has been a frequent issue which should be the adequate level of R&D investments in the aeronautical cluster. Therefore, its measurement should identify the investment made by existing firms from different industrial chains and governmental institution, as far as strategic technologies and complementary assets, such as wind tunnels and testing facilities are concerned[28]; the resulting investment level would then be compared to corresponding expenditures in competing clusters.

As Embraer and Bombardier are involved in a fierce competition for the global regional aircraft market, with

[25] The Department of Aerospace Science and Technology is a specialized research center of the Brazilian Air Command (COMAER), established in 1950 by the Brazilian Air Force hero Marshal Casimiro Montenegro Filho, with the support of Professor Richard Harbert Smith, from MIT,

[26] It should be note that ITA has been graduating engineers for the Brazilian Aeronautical industry since its establishment, in the early fifties. Most of Embraer´s technological leadership, for instance, is provide by ITA alumni. New engineers are mostly recruited by Embraer after they finish a Professional Master Engineering Program (PEE), organized as a joint effort between ITA and Embraer; more than 1.500 professional masters have already been graduated since the establishment of this program. ITA is currently engaged in a program to double the number of engineers it graduates – from 120 to up to 300 engineers, yearly -, in order to meet the demand of the aerospace and defense, as well as the national demand for engineers.

[27] The city of São José dos Campos has an important number of public and private faculties and universities, including: the Federal University of the State of São Paulo (Unifesp), the State University of São Paulo (Unesp), the Technical University of the State of São Paulo (Fatec), the University of the Paraiba Valley, among others.

[28] Embraer, for instance, has been doing some of the aerodynamics testing of its new airplanes in the NLR/NDW wind tunnels. From a competitive standpoint, it might be considered advisable to consider the building of such or similar tunnels in Brazil.

Embraer being currently the world leader in this category, information regarding competitive issues and the development of new and improved technologies will prove to be invaluable.

The market segment of the worldwide executive aviation market also presents a similar and though competition. Embraer holds an important market-share of twenty percent, albeit being a latecomer. The recent entrance of Honda, with its recent light jet, will only add to that strong competition, thus highlighting the importance of competitive benchmarks, which are the object of the coming topic.

E. Conclusions about Cluster's Performance

The following components of the architecture of the innovation system regarding the measurement cluster's performance were described:

- historical evolution
- recent economic development
- cluster structure
- innovation capacity, including strengths, weaknesses and challenges

The innovation system will then be capable of supporting the production of scenarios and reports emphasizing topics that refer to the performance of the areas integrating Porter's diamond, as well as about lessons learned.

They might prove to be invaluable to local stakeholders and from other regions that are trying to promote the development of their own clusters.

The importance of governmental and entrepreneurial actions will also be addressed, as well as competitive benchmarking, as it was mentioned.

Porter has observed that, once the expansion of a particular cluster has begun, it behaves like a chain reaction. It depends, however, on the efficacy of the diamond's interconnections in regard to cluster's needs, as far as, for example, educational, R&D&I, regulatory and supply matters are concerned.

Cluster development may become particularly dynamic at cluster's interconnections, a situation that is particularly present in the region of Sao José dos Campos. Embedded electronics and software, and new materials, for example, are essential technologies for space vehicles, aircrafts, and automobiles.

The region of Sao José dos Campos has scientific and technological organizations and firms in all these areas. Promoting their integration might result in cross-fertilization and valuable business opportunities.

A good example in this regard is the use of the Integration and Testing Laboratory, of the Institute of Space Research, originally designed to support the design and testing of satellites, by the Brazilian automotive industry.

Another example is the Light Structure Laboratory (LEL), installed at the Technology Park of São José dos Campos. It is managed by the Institute of Technology Research of the State of São Paulo (IPT), and it is considered to be the largest facility of its kind in the Southern Hemisphere, with a 1,500 square meters clean room. The laboratory is oriented toward the needs of the aerospace and defense industries, and it can also support the needs for new and lighter materials in the automotive, civil construction and energy industries.

The development of autonomous automobiles also might be a good opportunity, since they required technologies that are currently used in the aeronautical sector.

The following dimensions of the proposed framework for the innovation system of the city of São José dos Campos were presented:

- Evaluation of the municipal economy
- Evaluation of cluster´s competitiveness

The last dimension and the main product of the proposed framework will now be presented, regarding the innovation and competitiveness challenges that will be addressed by the municipality and local stakeholders.

V. INNOVATION AND COMPETITIVENESS CHALLENGES

The political decision making framework and its associated innovation system will also address chosen regions and clusters that represent competitive challenges to the city of Sao José dos Campos. The relevant information will be organized according the proposed framework. The information categories are similar, by construction, to the studies that analyzed clusters, especially aeronautical clusters located in Wichita, Kansas, Seattle, Washington, Montreal, Canada, and Toulouse, France, and, more recently, in China, Russia and Japan, as firms in these countries are engaging in the production of airplanes that compete with Embraer´s best selling products. As a result, comparative and benchmarking analyses will be facilitated, minimizing the needs for additional local studies.

Such comparative analysis will enable the development a wide range of initiatives, including the development of policies, strategies, plans and programs, in order to meet the identified challenges, and the conception, promotion and support of new programs and projects, specially those at clusters´ convergence, that will further regional economic development.

The establishment of Cecompi, the Technological Park of São José dos Campos, and the Technology Park of the University of the Paraiba Valley (UNIVAP), resulted mainly from the tacit knowledge accumulated by local stakeholders and political decision makers.

Future actions regarding the scientific and technological advancement of the region, competitive challenges, and the resulting economic development, will be better supported by a formal framework such as the one described in this paper.

Laudon & Laudon (2002) describe the benefits of a group decision-support system, which can be associated to the proposed framework for the innovation system. Among them,

the authors mention improved planning, increased participation, a collaborative atmosphere, evaluation objectivity, setting priorities, and the preservation of organizational memory, all of them of great value and of the utmost importance to improve the quality of the prevailing political decision making framework.

VI. CONCLUSIONS AND RECOMMENDATIONS

In a context where the corporate headquarters of the Boeing Corporation left a city like Seattle, and there is a possible move of Embraer´s management facilities to the nearby city of São Paulo, in spite its efforts developed by Seattle and São José dos Campos for positioning themselves as attractive locations to high-tech companies, it seems reasonable to conclude that the city of Sao José dos Campos should dedicate its best efforts in improving its business environment, in deepening and strengthening its clusters, improving its innovation capacity, and, therefore, its competitiveness, in order to maintaining and even improving the prosperity levels already reached.

The examples of important companies that closed their facilities in Sao José dos Campos emphasize the need for such actions.

It has been emphasized by Porter that adequate macroeconomic policies are necessary to promoting competitiveness, but are not enough. More relevant and probably more effective governmental influences will be exercised at the microeconomic level. Obstacles removal and bottleneck elimination are deemed of utmost importance for cluster improvement and development, even more than providing subsidies to attract new companies and convincing established companies to stay in the city. In his opinion, this approach is self-defeating, in the long term.

The proposed framework for a innovation system for supporting the political decision making process at the local will provide information subsidies for local stakeholders for developing relevant and timely initiatives with emphasis on the microeconomic level.

It will also highlight lesson learned, challenges, new directions and opportunities, regarding other important areas, besides aerospace and defense, such as energy, sustainability, biotechnology, and cybernetic security, autonomous vehicles, among others.

It is understood then that it is reasonable to assume that the proposed framework fulfills the innovation systems concept proposed by Nelson & Rosenberg (1993), i.e., that of a set of institutional actors that, together, plays the major role in influencing innovative performance of a city´s economy, as it is the case of the present paper.

It seems also reasonable to conclude that the improvement of such an innovation system, and its establishment, as a *de juris* system, should be considered a priority project for organizations that will benefit from its products and services, such as the Municipality of Sao José dos Campos, administrators of educational and R&D institutions, business executives, local entrepreneurs, and other stakeholders and the society at large.

It is important to take into consideration that the current economic slowdown indicates the increased need for conducting business and technology intelligence activities, such as the proposed framework will require and support.

It is suggested that the implementation of the proposed framework for the innovation system should be initiated by its first and more aggregate dimension, which is oriented to the economic performance of city. The results of such implementation will contribute to motivating local stakeholders to promote the development and deployment of the second dimension, which is cluster specific.

It should be added that such a system is not currently formally defined – it is a *de facto* system, as it was mentioned -, and that relevant decisions about the future of the city strongly depend on tacit information and unstructured sources of information.

Cecompi, an organization subordinated to the Secretary of Economic Development and Science and Technology of the City of São José dos Campos, with the support of ITA´s NPG, might be the natural candidate for leading the efforts of deploying the proposed framework, since it is totally coherent with its mission, of supporting the municipality in the all important matters of economic and science and technology development.

It will be desirable that this system, inasmuch as possible, uses data and information produced by organizations that traditionally monitor the status of the technological, social, and economic development of the whole country and its regions, in order that their efforts will not be unnecessarily duplicated.

Another reason should be added, and that is to expedite the formalization, the development, and the implementation of the innovation system, in order to meet the pressing needs of local decision makers and stakeholders, who are faced with though issues regarding the development and the assurance of the prosperity of the São José dos Campos, especially in a period of an important national economic downturn.

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