



# Network analysis as a management tool for inter-organizational projects

## *Análise de redes como ferramenta de gestão para empreendimentos interorganizacionais*

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**Abstract:** The social and economic progress of a nation depends on the development of its scientific, technological and innovation systems. The cooperation capacity of the innovation agents involved is recognized as an essential element for the maturity of the system. The consolidation of cooperative action mechanisms depends on the design and implementation of an inclusive management system accepted by the entities. The creation of the Arrangement for Innovation Promotion in the area of nanotechnology in Florianópolis technological complex is a milestone for the scientific and technological development of this area in Brazil. This paper aims to present how the analysis of the network composed by potential participants of this cooperation assisted in the design and establishment of the management model. The research was able to provide information to determine the maturity of the organizations and the network resilience which are main factors for the strategically understand of inter-organizational relationship dynamics.

**Keywords:** Cooperation network; Network analysis; Management model; Resilience.

**Resumo:** *O progresso social e econômico de uma nação depende do seu desenvolvimento científico, tecnológico e de seus sistemas de inovação. A capacidade de cooperação dos agentes de inovação envolvidos é reconhecida como um elemento essencial de maturidade de um sistema. A consolidação dos mecanismos de ação cooperativa depende da concepção de um sistema onde o modelo de gestão seja inclusivo e aceito por todas as entidades envolvidas. A criação do Arranjo Promotor de Inovação de Nanotecnologia no complexo tecnológico de Florianópolis é um marco do desenvolvimento científico e tecnológico nessa área no Brasil. Este artigo tem por objetivo apresentar como a análise de uma rede composta por agentes com potencial de cooperação pode auxiliar na concepção e estabelecimento de seu modelo de gestão. A pesquisa apresentou informações que permitiram determinar a maturidade organizacional e a resiliência da rede, considerados como principais fatores estratégicos para entendimento das dinâmicas das relações interorganizacionais.*

**Palavras-chave:** *Redes de cooperação; Análise de redes; Modelo de gestão; Resiliência.*

## 1 Introduction

The formation and action in inter-organizational networks are, increasingly, incorporated in companies' corporative strategies and reveals one strategic positioning alternative to generate competitive advantage (Powell & Grodal, 2005; Verschoore & Balestrin, 2008; Porter, 2009).

The partnership among companies, universities, research groups and laboratories and government entities are determinants for the technological development (Powell & Grodal, 2005). Innovation, science and economic development are results of new ideas and

knowledge generation that are strengthened by the network action (Tapscott & Williams, 2007).

The knowledge about the participants' competences, resources, knowledge and especially their connections is fundamental in the cooperation network formation and development process. As important as the participants' experience, are the connections they have in the process of network analysis (Hansen et al., 2011).

This work aims to analyze the activities of organizations in cooperative networks, specifically in innovative ventures in order to identifying the

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organizational maturity and resilience of the network, allowing the design of a management model. It is understood that such analysis can provide higher assertiveness in the manager's decision making process and greater effectiveness to the planning, forming and management process of cooperation. The analysis will also minimize risks related to intensive research and development innovation projects, which by nature involves a high degree of subjectivity.

A survey of theories was developed to guide the methodological approach for the analysis of a cooperative network. In order to apply this methodology, a case was selected that allowed for better understanding of the functioning of relations between staff of different organizations in a cooperative network.

The study case selected was the Arrangement for Innovation Promotion in Florianópolis technological complex in the area of nanotechnology, called API. nano. The Arrangement is a multi-organizational network involving companies, government agencies, laboratories and research groups, all facing the development of innovation projects, research and development of nanotechnology products. The project for forming the production arrangement aims to establish management processes that will provide the sufficient maturity level for the network to establish itself as an innovation cluster.

The choice of this case as an object of study for the application of the technical analysis of the innovation cluster, was due to the perception of an opportunity for observation. This type of environment is conducive to the formation of a network between companies, university and government, like the incubators and technology parks already widespread in Brazil.

The application of network analysis tools is a facilitator in the managerial challenge. The managerial challenge is maximized by the complexity inherent to the nature of relationships between organizations, where the conflict of interest generated by the market competitiveness and management of cooperative innovation actions are substantially greater, given the dynamism of the network and the large number of agents and existing connections.

## 2 Inter-organizational networks conceptual analysis

A cooperation network is characterized by a measurable pattern of relationships between organizations in a social environment, whose collective actions are usually fostered by strong socio-economic or technological change (Powell et al., 2005). Although there are several studies on the subject since the nineteenth century, with the work from Marshall in 1890, the idea of forming cooperative networks is in a consolidation process in contemporary society. This was a paradigm shift in the orientation of business due to the need

of organizations to conform to the interconnected and interdependent market model (Verschoore & Balestrin, 2008). It consists of multiple entities that are organized in a nonhierarchical manner, ensuring the autonomy of each agent network, which are interconnected by different linking forms, usually formally, to the achievement of common objectives (Provan et al., 2007).

An inter-organizational network is a form of organization where functions such as product development, technology, communication and decision-making processes are part of the organizational characteristics that has its management effort maximized by challenges related to subjective issues like credibility among the agents involved, negotiation, trust relationships and competitiveness (Flecha et al., 2012). Acting in a network necessarily implies in the collective enterprise of new businesses and projects that, through collective action, can be met the goals of each individual agent that forms the network (Lucanera, 2010).

Castells (2000) states that, in the past decade, we are living in a new economy based on three pillars: information, globalization and networks. The networks emphasized by the author are those formed by companies that develop specific projects and, at its conclusion, connect with other network partners to carry out new projects. This dynamic network structure is characterized by a set of interactions focused on the relationship between production and consumption, experience, relationships and power relations.

The reality imposed by the market determines a differentiated business structure, where the main difference is found in the contrast to the traditional bureaucratic structure of the companies, which resulted in the obligation of the predisposition to act in a cooperative manner and its consolidation became competitive advantage.

In this context, the central argument for the formation of cooperative networks is the possibility of competitive gains by bringing together attributes among stakeholders arranged in a single structure, with uniform action in order to enable adaptation to the competitive environment (Verschoore & Balestrin, 2008). Thus, the results are measured by the competitiveness of the community and not the individual competitiveness of each network component (Lucanera, 2010).

The network action seeks for the synergy of actions in the market, keeping the focus on creating competitive advantages and use of knowledge that individually components of the network organizations would not be able to accomplish. Thus, innovation projects and the generation of competitive advantages can be achieved through the analysis and identification of complementary skills of agents that form the network.

There are challenges that require high degree of organizational maturity in a networked enterprise, such

as the adoption of new contractual practices, interest conflicts management between those involved in the project, the initial costs for network establishment and implementation of management model process that could delimitate the participation of each agent in the network (Lucanera, 2010). The acting in network, since these challenges are overcome, can serve as a sustainable competitive advantage, since it makes possible to combine the skills of actors and, from this combination, generate competitive advantages making the product proposed by the cooperative action relatively irreplaceable.

The network formation is justified as an access to key resources such as: products, services, information, goods and potential to maintain or enhance competitive advantage, being those in the production of differentiated products and services and also by reducing organizational costs (Gulati et al., 2000; Lucanera, 2010).

Studies from Powell & Grodal (2005) revealed that inter-organizational relationships and forms of partnerships are important components of corporate strategy and that complex networks of companies, universities and government laboratories are crucial to the development of business, especially when it comes to technological progress, such as the production of computers, semiconductors, pharmaceuticals and biotech products.

The authors also argue that organizations, through networks, may provide or trade his resources and new ideas, as well as providing the exchange of experiences, access to a larger and more diversified set of activities, employees and abilities. Networks can provide the complementary expertise that a single organization would not reach, and considering that the creation of knowledge is crucial to innovation, networks can become the ideal mechanism to foster innovation and competitive positioning.

Another major factor is the knowledge commercialization, which has assumed an important role in the new economy, a role that can be maximized through collaboration and therefore has been fostering and turning collaborative projects common practice.

However, it is important to note that despite the outcome of the network to be collective, organizations remain autonomous and measuring their results individually, while for the network usually there are no results measurement mechanisms, including financial (Castro et al., 2011).

In this respect, the analysis of relational return, which aims to determine whether the link between the network of agents provides greater return than an individual action, and cooperation, that is the alignment between cooperation and competition policies, make two important points for managerial decision analysis to the managers of each organization about the formation or inclusion in a network level.

Political skills are as important as technical skills in the survival of an organization (Wegner & Padula, 2012).

Since the concepts of networks are presented, it is necessary to discuss concepts related to two main analysis topics proposed in this study: organizational maturity and network resiliency.

The network has processes and management structure capable of ensuring the sustainability of the forming community. In this context the analysis of organizational maturity prioritized the identification of the conscious management of the network. The governance and management model presents key dimensions of analysis of network maturity.

In spite of the facts that many authors agree that there is still a gap to be filled by studies about governance and management models within networks, there is agreement that those aspects that can generate definitive impact on the results of the cooperative actions. Governance in the networks determines how the relationships between the organizations occur, the rules of reciprocity, forms of contracting and delimitation of the powers of network managers. Although a cooperative action can generate strategic advantages, the network may also fail and so in order to mitigate the risks of failure, it is necessary to design governance policy that ensures the internal and external legitimacy of the network since its formation (Provan et al., 2007).

Networks can present various characteristics regarding the temporal dimension, graduating from a specific project to a long-term relationship. It is crucial to the adoption of the management model and network governance that can be hierarchical, with a central authority or organized with distributed authority. These characteristics, then determine the network's governance policies, which may be analyzed under the bias of the governance of economic activities proposed by the network and also as a way of proposing an organizational structure and a management model for the network as a whole (Provan et al., 2007; Roth et al., 2012).

It is noteworthy that the application of governance policies and adoption of a management model presupposes awareness about the strategic potential of the network by those involved in it and the collective proactivity as the adoption of a management model which practically determines the organizational maturity of network. Williams & Karahanna (2013) states that the coordination of a cooperative action should be treated more as a management practice of social dynamics between those involved than a standardization of rules and administrative procedures.

The concept of resilience when applied to organizations is related to the capacity that they have to adapt to the changing environment and evolving trends, and overcome adversities and crises. Resilience

is the sum of organizational capabilities that allow organizations to resist and adapt to external stimuli without collapsing (Reinmoeller & Van Baardwijk, 2005; Santos, 2009; Sabbag, 2012). When applying the concept in the context of analysis of inter-organizational networks, the term resilience is applied to the network as a whole or in their communities trying to identify what is the impact that one organization leaving or alteration of any agent of the network can have in the degree of connections of each agent. It is a measure of how much you can modify the network of agents with no damage to its synergy (Newman, 2003; Hansen et al., 2011).

Based on the concepts discussed, it is explicit the managerial challenge of operations in cooperative networks with respect to the importance of forming and maintenance of organizational networks for the strategic positioning of companies and their implications for organizational maturity. Such challenge starts with the definition of the criteria and responsibilities related to the decision making and the autonomy of organizations involved in the network with respect to managing conflicts of interest and constant changes in individual organizational goals with impact on collective strategies.

### 3 Technical analysis of inter-organizational networks

The network analysis is characterized by the set of techniques that aims to provide the manager or analyst information about each set of relationships and connection patterns between the agents that make up the network. The focus of the network analysis is not the agents individually, but the connections, the number of nodes and the location of each individual in the network giving priority to “know who” instead of “know how” (Hansen et al., 2011). Such analysis is a tool that will guide the decisions of network managers.

The primary need for network managers is to understand how it develops, operates and adapts to environment. In order to further evaluate a cooperative network and facilitate the decision on the governance and management model to be defined, managers need management tools to efficiently support decision-making process.

The challenge in network analysis is to explain the forming, catalyzing and duration of a network, as well as the various forms it can take with organizations being placed on the best locations. It is possible to have some groups more isolated than others, formal organizations with informal connections and communities with more associations than others (Powell & Doerr, 2005).

Understanding how the cooperative network is formed, how relations between their forming agents

occur is essential since the network success is directly dependent on the maturity of the interacting agents regarding the involvement and knowledge exchanges (Provan et al., 2007). This approach defines the flow of knowledge between the network agents as a major factor in network sustainability by allowing the constant evolution of innovation processes. It is an approach that contrasts or even evolves the approach that inter-organizational networks are mainly characterized by being local productive clusters, where geographic location is an important factor for maintenance of competitive, as established by the first studies on networks due to Marshall (1890) and also supported by the strategic perspective of Porter (2009).

Bramwell et al. (2008), presented a case analysis of the technological cluster of Waterloo, confirming that sustainability and resilience of a cluster is based on the knowledge flow that occurs on the network, as the learning processes between a network of agents and even the dynamics between different networks form important innovation development factors.

Network analysis comes from scientific studies about the impact and working relationships between people, organizations and technologies. In this analysis the focus is given on the actors of the network, and carried out from these interactions or relationships within the network (Argawall, 2011).

The cooperative network formation mechanism begins with the identification of the connection between the network agents or network nodes, and the network growth process is performed by adding new nodes to the group of pre-existing organizations. In this context the network develops based on the connectivity and dynamics of its nodes, important factors for the potential success of inter-organizational relationships. This development can be observed from the self-regulation network capacity, expansion of actions taken within the network, the dynamic of horizontal relationships or absence of subordination, and interdisciplinary skills (Flecha et al., 2012).

The network analysis can be performed from the graphic visualization that enables the understanding of working mechanisms of these networks. The visual approach, inherent to graphical tools, has been used for a long time by managers, researchers and other professionals in understanding large amounts of data. In respect to a network, the visualization of relationships between various actors and their proximity, whether geographical or related to intense interaction between these actors, has been of great value to professionals who use these tools (Moody et al., 2005).

Usually in this analysis, the use of graphs shows the nodes or vertices of the network, representing actors of the network, and their connections, representing the relationships and interactions between each of

the components actors of the network (Argawall, 2011; Newman, 2003).

Powell et al. (2005) corroborates this method by arguing that a social network analysis disregards the individual attributes and demonstrations related to individuality and turn exclusively to the understanding of the relationships, cooperation and improvement possibilities and benefits generated by the strengthening of the network.

The network analysis allows the identification and characterization of temporal relationships inherent to social networking. The characterization of the networks can be analyzed based on the inter-organizational network map, which identifies the vertices of the network (nodes) - individuals and organizations - and their connections. Hansen et al. (2011) present the types of networks as follows:

1. **Complete, partial and egocentric networks** - the egocentric networks are those focused on an individual and the people connected to it. The complete network covers all persons or institutions linked to central individual and their connections, while the partial network selects a sample or piece of the whole network.
2. **Unimodal, multimodal and affiliation networks** - unimodal network refers to network that connects nodes of the same type, whether individuals or institutions or documents; however, networks can include different kinds of vertices creating a multimodal network. Affiliation networks comprises a combination of two vertices affiliates, for example, a network of people and their online posts, in which case no user will be directly connected to each other.
3. **Multiplex networks** - networks formed by a combination of more than one type of connection (people, institutions and media for example).

In respect to the analysis of the relations dimension in a social network, there is no widely accepted methodology, given the subjectivity of this analysis. However, based on the concept of relations in triads (Newman, 2003) it is possible to classify two important analysis focuses, the degree of cooperation and confidence in the network relations. The first concerns the coordination of cooperative activities so that the complementary skills can generate competitive advantages. The measurement of the degree of confidence aims to measure the intensity of relations, and consequently, the identification of the strongest and weakest vertices that comprise the network (Freitag, 2011).

The third dimension concerns the temporality, given that a network of organizations is not a static

network, but characterized by dynamics of their relationship. This dimension is essential in the real world where relationships are formed by constant changes of interest and other irregularities. In this way, the identification of relationship changes rate benefits managers, providing information about endurance, speed and intensity of change of a collaborative network (Moody et al., 2005).

Once typified and having the dimensions characterized, the network can be analyzed based on more specific metrics as (i) degree centrality - the number of network members at which each member of the network (node) is connected, namely determines the number of agents that each agent is relating. It is one alternative to assess the level of involvement or participation in the network; (ii) betweenness centrality - the bridging function between different nodes of the network. It allows to identify when a member of the network has a key role in mediating the flow of information; (iii) closeness centrality - is a measure of the extent to which a node is connected to other nodes that are not connected to each other. It's a measure of the degree to which a node serves as a bridge. A member of the network is so much more central the shorter the path he needs to go to reach the other members of the network; (iv) eigenvector centrality - it is an effort to find the most central actors (i.e. those with the smallest farness from others) in terms of the global structure of the network, and to pay less attention to patterns that are more local; and (v) clustering coefficient - indicates how concentrated the neighborhood of that vertex is, allowing to identify subnets or communities (Hansen et al., 2011).

These metrics allow the network manager or analyst to understand how this network is formed and identify the key players and communities on the network, so that their understanding of the complexity of the network as a whole will allow more assertive decision making.

#### 4 Network formation environment and the Florianópolis nanotechnology API

The development of a network is influenced by the development policies found in regions of operation. While geographic location is no longer considered an obstacle to participation in the network, the external environment of operation will invariably impact on management. Tigre et al. (2011) in his study on software clusters, and Bramwell et al. (2008), present public policy actions to regional development as important impacting factor in the success of a network.

In this research, we studied the API.nano - Nanotechnology Arrangement for Innovation Promotion of Florianópolis, a network formed by agents, who work directly in the development of nanotechnologies

in the governmental, academic and business levels in Florianópolis area.

The city of Florianópolis has in fostering innovation one of its economic pillars, given that in recent years has been made efforts to develop knowledge-based services. Sectors ranging from information technology to automation, biotechnology to media production, software, nanotechnology, games and animation films are present in the region (ACATE, 2009, p. 3). The option to base the economic development in knowledge, according to data provided by the Florianópolis City Hall in the Innovation Municipal Law Project, is based on the city structure that consists of about 600 technology-based companies, 15 universities, 4 venture capital funds, 10 research centers and institutes. It is noteworthy that in 2012, was established the Municipal System of Innovation through the Innovation Municipal Law - Law No. 432/2012 - in which the access to the various support mechanisms will be allowed through organization of entrepreneurs from Innovation Arrangements - API's (Florianópolis, 2012).

In this context, the project to develop the Nanotechnology Arrangement in Florianópolis aims to develop this area, taking advantage of the mechanisms and funding sources for innovation in local, state and federal level, considering projections of nanotechnology market. A market, which according to the Brazilian Agency for Industrial Development (ABDI, 2010) reached US \$ 135 billion in 2007 and has great growth forecast with estimates to reach \$ 2.95 trillion in 2015.

The Second Technical-Business Nanotechnology Symposium (held in Florianópolis on 21 and 22 March 2013), organized by CERTI Foundation and the Santa Catarina Federal University – UFSC had the participation of several research laboratories from different universities, so as manufacturing companies that uses nanotechnology. On that occasion it was established that the use of nanotechnology in various products provides potential to generate competitive advantage, even able to provide, in the medium and long term, disruptive innovations with major impacts on the world economy (Fundação CERTI, 2013).

The nanotechnology potential in the world market and the undeniable importance of cooperation networks in competitive scenarios of innovation increases the importance of management skills. The joint efforts of different actors with very different profiles, interests and skills enhance the challenge for forming and managing cooperative actions. This study aims to minimize the risk of failure by management problems resulting from the lack of existing formal and informal relationships.

The city of Florianópolis, known as Innovation Capital is seeking to promote the organization of cooperative networks as a way to leverage and maximize

the results of their innovation agents focusing on the triple helix as support, where government, universities and private companies are involved in promoting innovation (Kormives, 2013). This effort is based on an Innovation Municipal Act that provides incentives for the formation of API's, which constitute networks focused on developing technologies, innovative products and services.

The study of this network is important in the planning, design and building of the management model for the cooperation, whose application identifies the main actors and their degree of ability to influence others in the nanotechnology API development project as well as identify the influences of an environment as the city of Florianópolis in the formation of the network. As stated by Engel & Del-Palacio (2009) the formation of the network can include universities, small, medium and large enterprises, service providers and other institutions organized towards common goals.

The API's forming and development allows participants to a more competitive market positioning with complementary skills between organizations, which contributes mainly to accelerate the production of innovative products and services as well allowing greater dynamics of processes and cost reduction.

## 5 Methodology and procedures

To achieve the objectives proposed in this research, we adopted an exploratory and descriptive approach characterizing the research as qualitative and quantitative, as it seeks to analyze, understand and classify the actors involved in nanotechnology cooperation network in Florianópolis region (Denzin & Lincoln, 2006; Silva et al., 2006; Richardson et al., 1999).

The studies were developed in order to observe and contribute to the formation of a network management model, featuring the research strategy as a case study. This is the description of a specific context in which the study took place and led to the interpretation of relationships in a real environment (Yin, 2005).

Data collection was divided into four stages: documentary research, census research, semi-structured interviews and questionnaires administration (Lakatos & Marconi, 2005; Alves-Mazzotti & Gewandszajder, 1999; Creswell, 2007; Silva et al., 2006).

The documentary research allowed researchers to understand the state of the art regarding the issues related to management models and network governance, providing information that supported the network organizational maturity analysis for cooperative actions, and network analysis techniques, which based the analysis focused on understanding the network resiliency.

The research units of analysis were potential agents involved in the nanotechnology network development. In this work we identified the competence cells formed

by laboratories and research groups in nanotechnology, and nanotechnology companies. In each unit it was analyzed the inter-relationships and the cooperative network formation potential.

The census was conducted in order to create a database with nanotechnology innovators in Florianópolis area. The census information was used to identify the relationships that form the Florianópolis API.nano network.

Based on the data provided by the census, semi structured interviews were applied with agents identified whose objectives were: (i) confirmation of nanotechnology nature of the actions developed by the agents; (ii) identification of major innovative projects developed and which are the partners involved in each project; (iii) identification of the nature of relationships and the formalization of partnerships between agents; (iv) the organizational structure of each agent; (v) the management tools applied to the management of partnerships formed; (vi) and the impact that innovation environment provides the developed projects.

Finally, there was a collection of data through the application of objective questionnaires during the event II Technical and Business Nanotechnology Symposium, held on 21 and 22 March in Florianópolis, whose focus was the identification and measurement of intentions from several companies to use nanotechnology in their products and processes as well as if there is interest in co-participation in the development of nanotechnological innovative solutions.

The data collected allowed the analysis of API.nano network in relation to its formation, organizational maturity and resilience. The data analysis was made from the management perspective of challenges that the management of a network presents and how data analysis can facilitate the decision making of managers in building robust and sustainable cooperative actions. The purpose of these analyzes is to create metrics that identify the nature of the network and quantify the resilience of social relationships involved based on the measurement of the connections, communities, position and importance of each agent in the network. It was used the software Node XL in this analysis.

It was performed a condensed analysis based on metrics degree, centrality intermediation, central proximity, centrality of eigenvector and clustering coefficient (Hansen et al., 2011), which allowed to determine the weaknesses and network strength as a whole. It was given more importance for identifying and analyzing network communities. In this approach, the network as a whole is analyzed, substructures formed by the groups are identified, allowing the identification of relationships that most share interests and knowledge, as well as the agents that more intensely develop joint actions in order to meet common goals (Newman, 2003; Nicosia, 2008). The adoption of this

approach in this paper allows the manager to easily understand how the relationships between network members produce benefits and mainly supply the network manager visualization of how the network itself organizes and adapts to the changes.

The order to detect communities in the network it was used the quantitative measure called modularity. Specifically, in this study, it is used the algorithm proposed by Blondel et al. (2008) to quantify the division of the network into communities. The aim is to check in a clipping of the network the existence of a community, or a fraction of the network, which, from its modularity, is characterized by a more intense relationship with the members of this community than with the rest of the network members (Nicosia, 2008).

## 6 Nanotechnology API network analysis

The first finding of research through the formed network study is the classification of potential participants of cooperation in three categories, namely: scientific cell with expertise in nanotechnology, producers of nanotechnology products and services and companies demanding these products / services. Major attention from the formation and maintenance process manager will be will be given to these categories. The network management model in this paper was focused on competence cells and the production companies for their direct involvement in the formation and development of the network. At first it was observed that although the network is located in Florianópolis, where most part of the agents are located, there is the presence of several agents directly involved in the network that do not share the same geographical location. This information shows that the networks or innovation clusters do not have the geographical location as a major factor for the development of their cooperative projects.

It was found that the network already exists independently of its formalization. However, from the moment that the identity was created for the network and that this was mapped, it allowed to identify that a management model could optimize the network resources use as a whole and facilitate the flow of knowledge between the agents.

Information gathering held at the research identified key partners of each of the organizations / companies mapped (competence cells and nanotechnology companies), ranking each of its partners by level of importance. The objective was to identify the intensity of each partnership or network vertices, so it was possible to draw a parallel about the trust relationship between nodes (businesses and competent cells) with each other. In Figure 1 it is shown a large network from the relationships reported by participants during interviews. There were pre-existing relationships

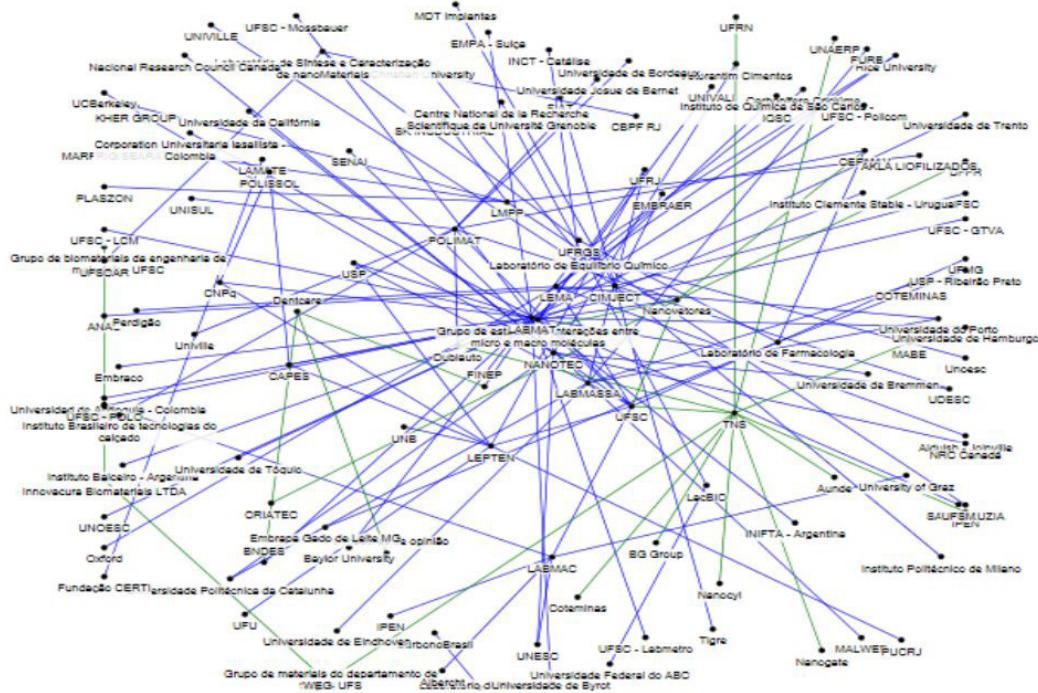


Figure 1. Network graph model - Network nanotechnology companies and research laboratories in Florianopolis.

between agents of the potential API.nano, which may be indicative to formalization feasibility of cooperation with a management model adopted collectively.

The focus of the analysis led to building a unimodal network, since it adopts as vertices / network nodes only the agents, characterizing it as a social network of organizations.

It was found out that the competence cells, research laboratories in nanotechnology are mostly from UFSC, which is characterized as the main network nodes. Among the nine companies mapped in the network, two of them have greater intensity in relation to the competence cells located at UFSC. It also found that the presence of the federal government development agencies such as the CNPq and FINEP show that the participants in the network already have the practice to look for resources and incentives available in these agencies.

Another element observed is the presence of several client companies in specific connections with certain laboratories, leading to infer that they already have partnership relations with these.

In addition, one can find the presence of the development banks (BNDES) and venture capital agencies such as CRIATEC, as well as research centers, foreign and national universities and other of technical education institutions.

Figure 2 shows a unimodal-egocentric network that highlights the central role played by the Santa Catarina Federal University (UFSC) where are situated

22 competence cells mapped in the study. This alert to the need to develop strategies for the inclusion of other research institutions from Santa Catarina who are developing skills in the sector.

In Figure 3 we can identify the communities generated from the relationship of each cell of competence and companies. In this graph it can be seen the size of each subnet formed. Identifying these relationships becomes important to share and leverage the contacts and relations opened by participants of the API. It can be observed that some organizations have a greater amount of relationship, being potential agents with active participation and influence on the environment.

The communities were identified using as a metric the modularity from the algorithm proposed by Blondel et al. (2008), where the final computation of modularity refers to an index that presents results in the range -1 (negative) to 1 (a positive). A higher index, with greater proximity to 1, presents the stronger relations in the analyzed community. Analyzing the average result from the modularity metric it is obtained an index of 0.757. The modularity index shows that formed communities have robust relations and of great significance for those involved in the community, but there is a high degree of independence and low relationship between communities, indicating that the network manager needs to promote greater integration between communities.

The results of metric analysis, degree, centrality of proximity and centrality of eigenvector shows a



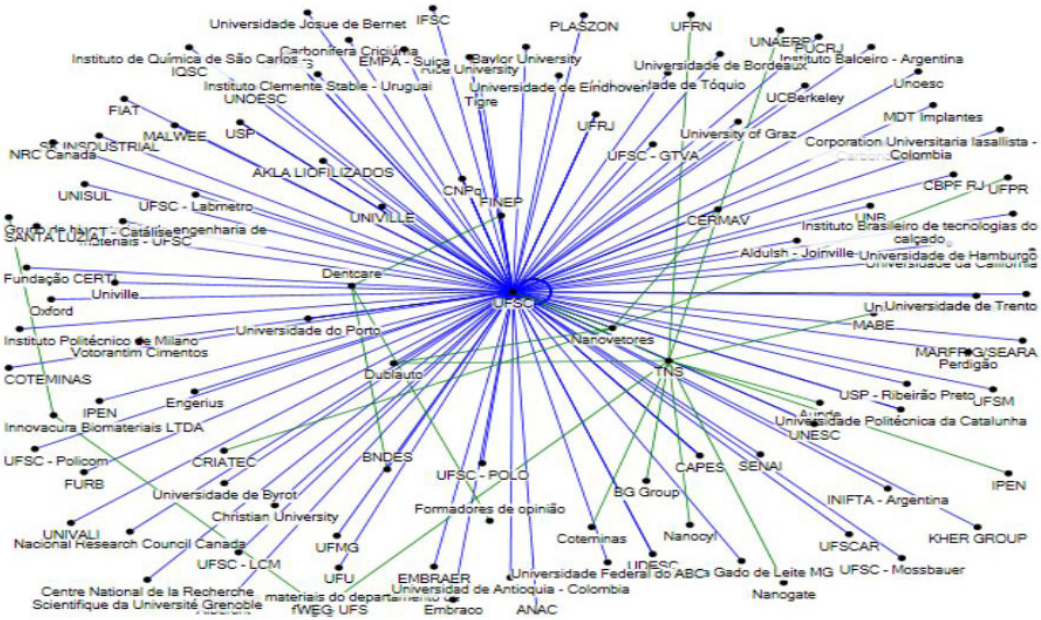


Figure 2. Network graph showing relationship between UFSC and companies.

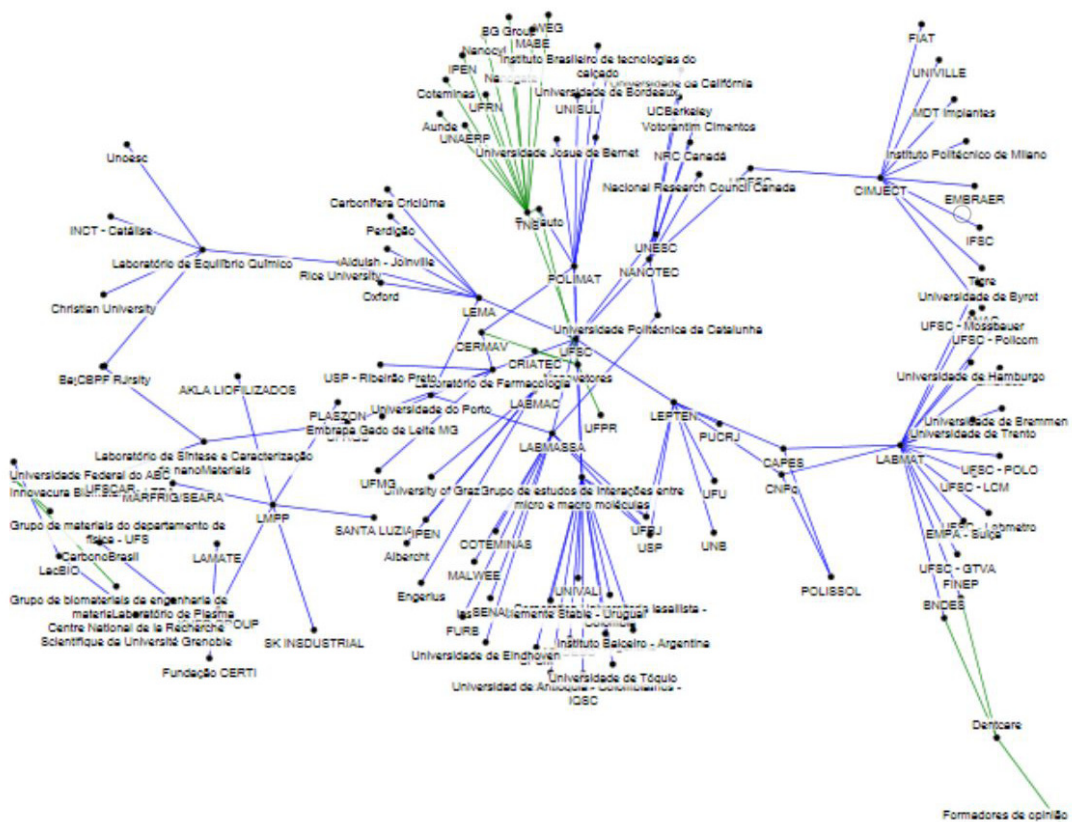


Figure 3. Non centralized network graph.

great variation. It reveals that there are most active and most popular actors, with higher number of connections than others. Fact observed by the action of the UFSC competence cells that have highlighted and greater centralization in their communities.

Most part of network members presents a degree 1 or 2 (103 from the 129 nodes in the network). This demonstrates that there is still a predominance of local relationships between UFSC laboratories with other public institutions (universities, development

agencies) and private (nanotechnology firms or companies using this technology).

The network members clustering coefficient is low. This coefficient, which expresses an indication of the integration of an agent to a network, can assume values between 0 and 1. In the case of the network being analyzed it was found a maximum value of 0.333 and an average value of 0.008 indicating a weak relationship between agents with the network still in its early stages of formation.

The network depends on the UFSC, a fact proved by the centrality of intermediation with the value 4248. Universities such as UDESC with the value 891 and UFRGS with the value 315 do not play essential role in maintaining the network. Two companies with centrality of intermediation 1048 and 327 respectively are relevant to a specific group, for developing technology in partnership with laboratories of universities and provide solutions to companies using these technologies.

Thirteen communities were identified in the Florianópolis nanotechnology network. These have a direct relationship with the network resiliency potential, since it can be said that this indicator shows the impact on the network when one agent leaves

the network. For example, if a research laboratory in nanotechnology for some reason leaves or is disconnected from the network this metric answers the question about how many other agents will also be automatically disconnected because they have only this node as a way to connecting to the others. When we analyzed the network as a whole based on this aspect, it became clear the high degree of centralization of the communities in skills cells, which are organized within the network from common interests related to their areas of research. This finding confirms the low resilience of communities since nanotechnology companies are highly dependent of specific competence cells.

Based on Figure 4, it can be said that the vast majority of organizations involved in the mapped network has strong cooperation relations, since the partnerships considered important and formalized by contracts or agreements stand out in the chart. It is important to note the high degree of relations formalization and allows inferring certain degree of structuring organizational management processes. For the graphical representation of cooperation and trust of relations it was used five variations in size of the lines, and the thicker represent the most important

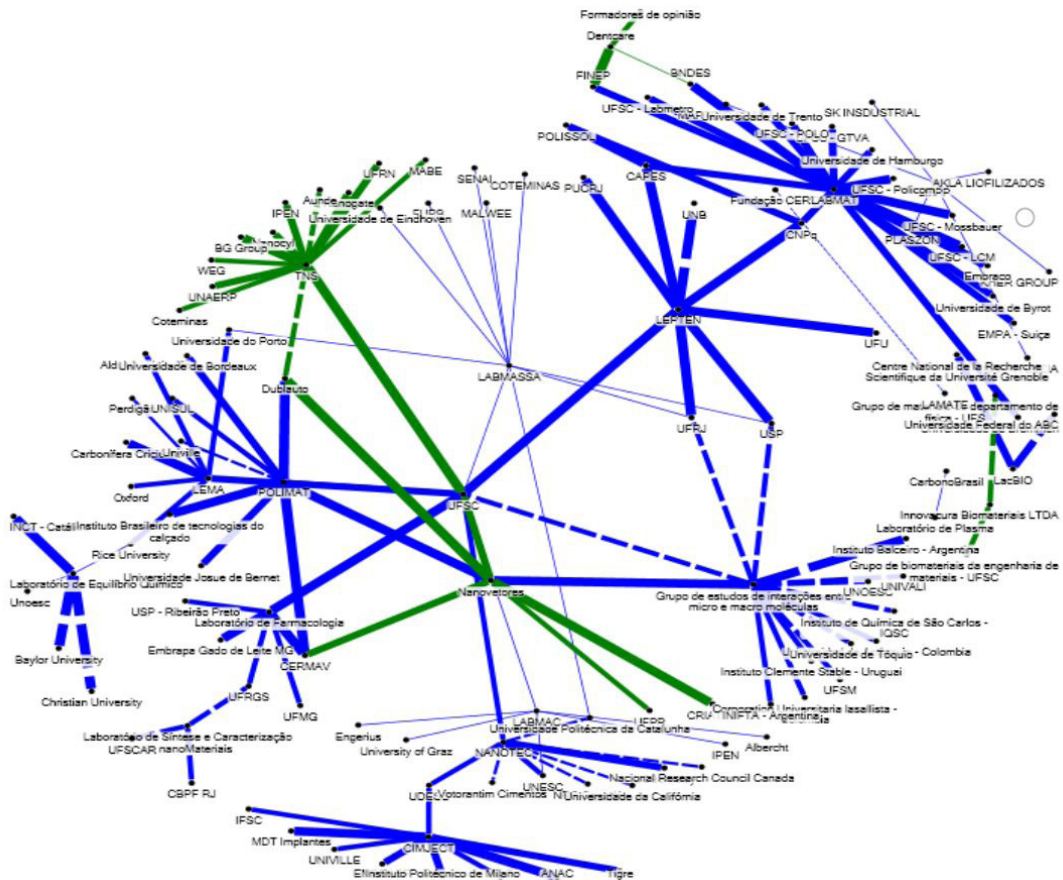


Figure 4. Network graph considering relationship classification.

relationships and also a variation between dotted and solid lines, where the solid lines represents formalized relations by contracts or agreements and the dotted lines represents informal relationships.

Although there is no integrated management of nanotechnology network as a whole, the cells of competence and nanotechnology companies already have a cooperative work culture, which facilitates the creation of a Innovation Arrangement. This culture is fostered also by the nature of Nanoscience and Nanotechnology, since this kind of knowledge is characterized by its transversality between the areas of research. This area requires an integration of skills in different areas of research to become possible the development of projects.

## 7 Final considerations

Qualitative and quantitative analyzes allow a network manager to visualize situations and understand scenarios that would not be possible without this approach. The overall objective of this research was to analyze the network as a whole and not the participant's individual actions and it was based in two parts: the network organizational maturity analysis and network resilience analysis

It was found based on the research that the organizational maturity level of a cooperative network is crucial to its continuity. This includes impacts on its resilience, as a well-managed network is able to better adapt to contingencies. Maturity can also be observed from some subjective points: network existence awareness, adoption of a management and governance model to enable integration, establishment of roles and fostering cooperation.

The maturity of the network was determined based on degree, centrality of intermediation, eigenvector centrality and clustering coefficient metrics. The API.nano network presents low resilience and is vulnerable at this point. We have a network in formation still very dependent on specific institutions, in this case the Santa Catarina Federal University and its research laboratories.

It was observed that there is an API.nano network, but it is still not recognized by involved participants. The network existence is observed through the existing relationships and connections between the agents; however, there is no formal management and governance policies implemented. It should be noted that the deployment of API.nano in 2012, has precisely this objective (see [www.apinano.org.br](http://www.apinano.org.br)).

The graphs generated by the research allowed a quantitative analysis for easy identification of factors; otherwise, the network manager could not identify them. From this analysis it is clear that there is a cooperative network of nanotechnology agents formed. There is interest among agents for working cooperatively, considering the collaborative work

already developed. However, the empirical nature in which it is sustained generated a network where their resilience is quite low. Since the research laboratories are all linked to UFSC, which is dangerously positioned in the center, when research laboratories presents problems or are disconnected to the network many other agents will be affected.

Another finding of this study was to identify the communities that make up the network and the factors that divide it this way such as the nature of the research projects at a research laboratory. It was clear that the independence of actions between communities can be a strength of the network allowing contingencies that are affecting a community not to impact others. However, this same identification showed that such independence creates a distance between communities hampering the flow of knowledge in the network as a whole. In the case of API.nano, this is probably the biggest management challenge for the management model and project governance.

It is emphasized that under the bias of the innovation environment where the API.nano is being formed there is a culture of partnerships formation and optimization of organizational efforts from the knowledge and skills sharing. This environment is promoted by the multidisciplinary nature of nanotechnology and nanoscience.

It also identified in the census that organizations initially not considered as potential members in the formation of nanotechnology API proved to be connected to the network. The identification of previously disregarded agents impels the network manager to promote greater involvement in order to strengthen the network.

The contribution of this work to the academic literature is based on the practical application of the network analysis theory. This theory supports real-time modeling process of a management system of a cooperation that aims for the scientific and technological development in an area where the need for innovation is strategic for Brazil.

The success of cooperation depends on the acceptance by potential participants in the proposed management model that should be properly legitimate and inclusive. The manager in charge of promoting the dissemination of the proposed cooperation will better understand the network. In this way, the manager will have a strategic vision of the importance of agents to be entered, thus reducing the risk of rejection.

The network analysis was used in the project of the gradual implementation of a management system that will be hosted regularly in the various actors already structured. The continuation of this research is related to the business process modeling of the management model of the innovation system which considers the skills acquired and the recurrent use of the techniques applied.

## References

- Agência Brasileira de Desenvolvimento Industrial – ABDI. (2010). *Panorama nanotecnologia*. Brasília.
- Alves-Mazzotti, A. J., & Gewandsznajder, F. (1999). *O método das ciências naturais e sociais: pesquisa quantitativa e qualitativa*. São Paulo: Pioneira. 203 p.
- Argawal, C. C. (2011). *Social network data analytics*. New York: Springer.
- Associação Catarinense de Empresas de Tecnologia – ACATE. (2009). *Projeto setorial em tecnologia da informação e comunicação de Florianópolis: mapeamento da demanda por recursos humanos: informação e documentação: referência – elaboração*. Florianópolis.
- Blondel, V. D., Guillaume, J.-L., Lambiotte, R., & Lefebvre, E. (2008). Fast unfolding of communities in large networks. *Journal of Statistical Mechanics*, 2008(10), P10008. <http://dx.doi.org/10.1088/1742-5468/2008/10/P10008>.
- Bramwell, A., Nelles, J., & Wolfe, D. A. (2008). Knowledge, innovation and institutions: global and local dimensions of the ICT Cluster in Waterloo, Canada. *Regional Studies*, 42(1), 101-116. <http://dx.doi.org/10.1080/00343400701543231>.
- Castells, M. (2000). Materials for an exploratory theory of the network society. *The British Journal of Sociology*, 51(1), 5-24. <http://dx.doi.org/10.1080/000713100358408>.
- Castro, M., Bulgacov, S., & Hoffmann, V. E. (2011). Relacionamentos Interorganizacionais e Resultados: Estudo em uma Rede de Cooperação Horizontal da Região Central do Paraná. *RAC: Revista de Administração Contemporânea*, 15, 25-46. Recuperado em 12 de agosto de 2013, de <http://www.anpad.org.br/rac>
- Creswell, J. W. (2007). *Projeto de pesquisa: métodos qualitativo, quantitativo e misto* (2. ed.). Porto Alegre: Artmed
- Denzin, N. K., & Lincoln, Y. S. (2006). *O planejamento da pesquisa qualitativa: teorias e abordagens* (2. ed.). Porto Alegre: Artmed.
- Engel, J., & Del-Palacio, I. (2009). Global Networks of Clusters of Innovation: Accelerating the Innovation Process. *Business Horizons*, 52(5), 493-503. <http://dx.doi.org/10.1016/j.bushor.2009.06.001>.
- Flecha, A. C., Silva, A. V. C., Fusco, J. P. A., & Bernardes, A. T. (2012). Redes de empresas e seus efeitos sobre o turismo. *Revista de Administração de Empresas*, 52(4), 386-406. <http://dx.doi.org/10.1590/S0034-75902012000400003>.
- Florianópolis. (2012, 7 de maio). *Lei complementar nº 432, de 7 de maio de 2012. Dispõe sobre sistemas, mecanismos e incentivos à atividade tecnológica e inovativa, visando o desenvolvimento sustentável do município de Florianópolis*. Florianópolis: Diário Oficial.
- Freitag, A. R. (2011). *Utilização do censo de tríades na análise de confiança e cooperação em aglomerações produtivas* (Dissertação de mestrado). Universidade Federal de Santa Catarina, Florianópolis.
- Fundação CERTI. (2013). *2º Simpósio Técnico-empresarial de Nanotecnologia*. Florianópolis. Trabalhos apresentados.
- Gulati, R., Nohria, N., & Zaheer, A. (2000). Strategic networks. *Strategic Management Journal*, 21(3), 203-215. [http://dx.doi.org/10.1002/\(SICI\)1097-0266\(200003\)21:3<203::AID-SMJ102>3.0.CO;2-K](http://dx.doi.org/10.1002/(SICI)1097-0266(200003)21:3<203::AID-SMJ102>3.0.CO;2-K).
- Hansen, D. L., Shneiderman, B., & Smith, M. A. (2011). *Analysing social media networks with NodeXL: insights from a connected world*. Burlington: Morgan Kaufmann.
- Kormives, E. (2013). Redesenhando a cidade. *LOCUS: Ambiente da Inovação Brasileira*, 19(73), 1-100. Recuperado em 12 de agosto de 2013, de [http://issuu.com/portomediterraneo/docs/locus\\_73\\_issuu](http://issuu.com/portomediterraneo/docs/locus_73_issuu)
- Lakatos, E. M., & Marconi, M. A. (2005). *Fundamentos de metodologia científica* (6. ed.). São Paulo: Atlas.
- Lucanera, R. A. (2010). Red de empresas: empresas virtuales. *Panorama Socioeconomico*, 28(41), 190-199.
- Marshall, A. (1890). *Principles of economics*. London: Macmillan.
- Moody, J., McFarland, D., & Bender-deMoll, S. (2005). Dynamic network visualization. *American Journal of Sociology*, 110(4), 1206-1240. <http://dx.doi.org/10.1086/421509>.
- Newman, M. E. J. (2003). The structure and function of complex network. *Society for Industrial and Applied Mathematics*, 45(2), 167-256.
- Nicosia, V. (2008). Modularity for community detection: history, perspectives and open issues. In *Workshop at the University of Catania*. Catania. Recuperado em 12 de agosto de 2013, de <http://supernet.isenberg.umass.edu/fulbright-catania/workshop-talks/nicosia-nagurney-daniele-workshop.pdf>
- Porter, M. E. (2009). *Competição: on competition*. Rio de Janeiro: Elsevier. 546 p.
- Powell, W. W., & Doerr, L. S. (2005). Networks and economic life. *The Handbook of Economic Sociology*, 2, 379-402.
- Powell, W. W., & Grodal, S. (2005). Networks of innovators. In J. Fagerberg, D. C. Mowery & R. R. Nelson (Eds.), *The Oxford Handbook of Innovation* (p. 56-85). Oxford: Oxford University Press.
- Powell, W. W., White, D. R., Koput, K. W., & Owen-Smith, J. (2005). Network dynamics and field evolution: the growth of interorganizational collaboration in the life sciences. *American Journal of Sociology*, 110(4), 1132-1205. <http://dx.doi.org/10.1086/421508>.
- Provan, K. G., Fish, A., & Sydow, J. (2007). Interorganizational networks at the network level: A review of the empirical literature on whole networks. *Journal of Management*, 33(3), 479-516. <http://dx.doi.org/10.1177/0149206307302554>.

- Reinmoeller, P., & Van Baardwijk, N. (2005). The link between diversity and resilience. *MIT Sloan Management Review*, 46, 61-65.
- Richardson, R. J., Peres, J. A. S., Wanderley, J. C. V., Correia, L. M., & Peres, M. H. M. (1999). *Pesquisa social: métodos e técnicas* (3. ed.). São Paulo: Atlas.
- Roth, A. L., Wegner, D., Antunes, J. A. V., Jr., & Padula, A. D. (2012). Diferenças e inter-relações dos conceitos de governança e gestão de redes horizontais de empresas: contribuições para o campo de estudo. *Revista de Administração da Universidade de São Paulo*, 47(1), 112-123.
- Sabbag, P. Y. (2012). *Resiliência: Competência para enfrentar situações extraordinárias na sua vida profissional*. São Paulo: Elsevier Brasil.
- Santos, F. T. (2009). Resiliência estratégica para um desenvolvimento regional sustentável. *Revista Portuguesa de Estudos Regionais*, 20, 29-40.
- Silva, A. B., Godoi, C. K., & Bandeira-De-Mello, R. (2006). *Pesquisa qualitativa em estudos Organizacionais: paradigmas, estratégias e métodos*. São Paulo: Saraiva.
- Tapscott, D., & Williams, A. D. (2007). *Wikinomics: como a colaboração em massa pode mudar o seu negócio*. Rio de Janeiro: Nova Fronteira.
- Tigre, P. B., La Rovere, R. L., Teixeira, F. L., López, A., Ramos, D., Bercovich, N., Pinheiro, A. O. M., Araújo, S., & Rodrigues, R. F. (2011). Knowledge cities: a taxonomy for analyzing software and information service clusters. *RAE: Revista de Administração de Empresas*, 51(1), 15-26.
- Verschoore, J. R., & Balestrin, A. (2008). Fatores Relevantes para o Estabelecimento de Redes de Cooperação entre Empresas do Rio Grande do Sul. *Revista de Administração Contemporânea*, 12(4), 1043-1069. <http://dx.doi.org/10.1590/S1415-65552008000400008>.
- Wegner, D., & Padula, A. D. (2012). Quando a cooperação falha: um estudo de caso sobre o fracasso de uma rede interorganizacional. *Revista de Administração Mackenzie*, 13(1), 145-171. <http://dx.doi.org/10.1590/S1678-69712012000100007>.
- Williams, C. K., & Karahanna, E. (2013). Causal explanation in the coordinating process: a critical realist case study of federated IT governance structures. *Management Information Systems Quarterly*, 37(3), 933-964.
- Yin, R. K. (2005). *Estudo de caso: planejamento e métodos* (3. ed.). Porto Alegre: The Bookman.