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**EVALUATION OF THE INNOVATION CAPABILITY OF CLUSTER-BASED FIRMS:
a graph-theoretic approach**

João Pessoa
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RESUMO

Inovação é um elemento distintivo para a competitividade e o desenvolvimento econômico. A literatura indica que redes de negócios como os *clusters* industriais trazem melhorias às economias regionais e são ambientes propícios para inovar, pois possibilitam a competição e a cooperação. Nesse sentido, essa dissertação busca desenvolver um *framework* para avaliar a capacidade de inovação (CI) de empresas inseridas no contexto de *clusters*. O *framework* proposto é baseado no *Graph-Theoretic Approach* (GTA), um método multicritério, e é capaz de quantificar aspectos qualitativos, gerando um Índice de Capacidade de Inovação (ICI) para cada empresa analisada. O ICI mede a influência de fatores e subfatores (mapeados na literatura por meio de uma revisão sistemática) na capacidade de inovação das empresas inseridas em *clusters*. Cinco fatores de CI foram identificados: colaboração em rede, criação e transferência de conhecimento, desenvolvimento de tecnologia, influência de mercado, e proximidade. Para determinar as interdependências entre esses fatores e seus subfatores, o método Delphi foi usado. Em seguida, para testar o *framework* proposto, estudos de caso múltiplos foram desenvolvidos em um *cluster* de Tecnologia da Informação e Comunicação (TIC) e Economia Criativa (EC) localizado em Recife, Brasil. A identificação dos fatores e subfatores permite um maior entendimento da capacidade de inovação de empresas inseridas em *clusters*, além de contribuir para a tomada de decisão estratégica em relação às características e capacidades organizacionais (o que melhorar, onde investir, etc.). O *framework* pode ser considerado genérico e ser aplicado em empresas inseridas em clusters de diversos setores econômicos.

Palavras-chave: Capacidade de inovação. *Clusters* industriais. *Graph-Theoretic Approach*.

ABSTRACT

Innovation is a distinctive element for competitiveness and economic development. Literature indicates that business networks such as industrial clusters enhance regional economies and are a propitious environment to innovate, since it enables competition and cooperation. In this sense, this dissertation aims to develop a framework to evaluate the innovation capability (IC) of cluster-based firms. The proposed framework is based on Graph-Theoretic Approach (GTA), a multicriteria method, and is able to quantify qualitative aspects, generating an innovation capability index (ICI) for each firm. It measures the influence of factors and sub-factors (mapped in the literature through a systematic review) on the IC of firms in the context of clusters. Five IC factors were identified: network collaboration, knowledge creation and transfer, technology development, market influence, and proximity. To determine the interdependencies among these factors and their sub-factors, the Delphi method was used. Then, to test the proposed framework, multiple case studies were developed in an Information and Communications Technology (ICT) and Creative Economy (CE) cluster located in Recife, Brazil. The identification of factors and sub-factors allows a greater understanding on the innovation capability of cluster-based firms, besides contributing to strategic decision-making regarding the organizational characteristics and capabilities (what to improve, where to invest, etc.). The framework can be considered generic and can be applied in firms based on clusters of diverse industries.

Keywords: Innovation capability. Industrial clusters. Graph-Theoretic Approach.

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LIST OF ACRONYMS

AHP	Analytic Hierarchy Process
CE	Creative Economy
CMC	Cluster's Management Center
ELECTRE	ELimination Et Choix Traduisant la REalité
GTA	Graph-Theoretic Approach
IC	Innovation Capability
ICI	Innovation Capability Index
ICT	Information and Communications Technology
IT	Information Technology
OECD	Organisation for Economic Co-operation and Development
SLR	Systematic Literature Review
WOS	Web of Science

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1. INTRODUCTION

1.1. RESEARCH TOPIC AND PROBLEM

National and international market oscillations, faster technological progress and changing customer requirements have created a situation in which individual businesses barely have the skills and competencies required to meet a market of needs and desires that change constantly, in addition to subjecting companies to immense pressure to innovate (Atalay, Dirlik, & Sarvan, 2017; Chandrashekar & Hillemane, 2018; Pechlaner & Bachinger, 2010).

Taking into account the current scenario of high competition, Cavalheiro and Brandão (2017) emphasize that, increasingly, the value of companies is determined by their ability to innovate, since innovation generates competitiveness and, consequently, increase productivity and economic growth (Cappellin, 2003), becoming fundamental specially in technological environments (Álvarez, Marin, & Fonfría, 2009).

Ter Wal and Boschma (2011) argue that for a company to be innovative, location matters. At the same time, the literature points out that organizations tend to have better performance and opportunities when they are embedded in the context of collaboration (Moreno & Miguélez, 2012; Whittington, Owen-Smith, & Powell, 2009). On the other hand, its competitiveness is based on the development of commercial networks (Pechlaner & Bachinger, 2010) and resources sharing through participation in interorganizational networks, such as clusters (Ucler, 2017).

Industrial clusters are geographic concentrations of firms in the same industry or related industries, interconnected with supporting institutions (such as government, universities, associations, etc.) that collaborate and compete with each other for strategic and operational reasons, having a unique set of resources and capabilities that influence their performance (Hervás-Oliver & Albors-Garrigós, 2007; O'Dwyer, O'Malley, Murphy, & McNally, 2015; Porter, 1998, 2003; Schmitz, 1992).

According to Cavalheiro and Brandão (2017), industrial clusters are environments where opportunities for improving competitiveness are sought constantly. The agglomerations of companies, including clusters, have been studied for more than 100 years (Britton, 2004) and yet they remain a frequent topic in current literature.

The strategy to form agglomerations such as industrial clusters is often adopted by companies, particularly small and medium-sized enterprises, in both developed and

developing countries, even though they present differences in their technological capabilities (Cavalheiro & Brandão, 2017).

Considering that industrial clusters promote cooperation and competition, their companies end up acting more productively, increasing access to technology and information exchange, making it possible to motivate the development and the innovation capability of cluster-based companies (Antolin-Lopez, Martinez-del-Rio, Cespedes-Lorente, & Perez-Valls, 2015; Porter, 2003; Strand, Wiig, Torheim, Solli-Sæther, & Nettet, 2017; Wonglimpiyarat, 2006).

Aside from innovation, Strand et al. (2017) argue that high levels of integration and competition between firms stimulate cost reduction. Thus, among other aspects, companies can take the decision to collaborate in order to reduce the costs and risks of innovation, to acquire (formal or informal) knowledge and skills of partner companies, etc. (Samarra & Biggiero, 2008), given that performance in innovation is significant for company performance (Strand et al., 2017).

Besides, because of geographic proximity and business interconnections, an industrial cluster can bring together firms that once operated in isolation, and increase collaboration between them and other industries in the region (Yström & Aspenberg, 2017). From the effective collaboration between firms, the agglomeration can achieve success, since innovation is an active social process and cooperation speeds innovation by promoting collective learning (Dalcin, Balestrin, & Teixeira, 2017).

Regarding other aspects of cooperation, Antolin-Lopez et al. (2015) describe firms as a heterogeneous grouping of resources and capabilities and consider that the development of organizational capabilities is a condition for interorganizational collaboration and for innovation. Thus, the competitive advantage of a company depends not only on its internal resources but also on the potential to access strategic resources or develop critical capabilities through cooperation (Antolin-Lopez et al., 2015). Therefore, when a company intends to promote innovation, such resources and capabilities must be accessed and developed.

For this research, the term “capabilities” will be considered as the abilities of an organization to perform a set of tasks using organizational resources, in an effort to make feasible the process of decision making, and with the purpose of achieving a particular result (Helfat & Peteraf, 2003; Winter, 2003). In turn, dynamic capabilities will be treated as those responsible for integrating, building and reconfiguring internal and external competencies to respond to rapidly changing environments that must be

incorporated into the company's routines (Helfat & Peteraf, 2003; Teece, Pisano, & Shuen, 1997; Ter Wal & Boschma, 2011). Meanwhile, innovation capability will be treated as the multiple skills and competencies needed to absorb, dominate, and enhance or create new existing products, services or processes to meet market needs and profit (Quintana-García & Benavides-Velasco, 2005; Romijn & Albaladejo, 2002; Szeto, 2000).

According to Novelli, Schmitz, and Spencer (2006), there is a correlation between the ability of cluster members to improve their products through inter-firm relationships and innovative business approaches, as well as the agglomeration competitiveness. Dagnino, Levanti, Minà, and Picone (2015) also state that interorganizational networks contribute to innovative performance by increasing their opportunities and innovation capabilities. However, Yström & Aspenberg (2017) point out that little is known about how clusters can assist their members in the pursuit of innovation.

This can be explained, since most of the studies focus on innovation in a collaborative context approaches of networks, strategic alliances, innovation regions, technological and scientific parks, among others (Álvarez et al., 2009; Atalay et al., 2017; Britton, 2004; Dangelico, Garavelli, & Petruzzelli, 2010; De Marchi & Grandinetti, 2017; Grillitsch, Tödtling, & Höglinger, 2015; Koçak & Can, 2014; Montoro-Sánchez, Ortiz-de-Urbina-Criado, & Mora-Valentín, 2011; Sammarra & Biggiero, 2008; Spigel, 2017). Thus, little research has been focused on innovation in the specific context of clusters.

In addition, when considering innovation research in companies operating in the context of business networks (generally speaking), many have focused on the importance of knowledge as a resource or capability that leads to the development of innovations (Britton, 2004; Cantner, Meder, & Ter Wal, 2010; Cappellin, 2003; Díez-Vial & Fernández-Olmos, 2015; Ganesan, Malter, & Rindfleisch, 2005; Larty, Jack, & Lockett, 2017; Lawson & Lorenz, 1999; Maskell & Malmberg, 1999; Pechlaner & Bachinger, 2010; Presutti, Boari, & Majocchi, 2011).

Other authors have verified that the geographical proximity is an important characteristic that can lead to the innovation in cluster-based companies (Dagnino et al., 2015; O'Dwyer et al., 2015; Presutti et al., 2011; Romijn & Albu, 2002; Silvestre & Dalcol, 2009). In particular, Yström and Aspenberg (2017) demonstrated how to

promote collaboration among cluster members in the search of collaborative innovation.

Regarding innovation capability and, in particular, the evaluation of this capability, research is still scarce. Among the few studies found, Boly et al. (2014) proposed a model for the evaluation of innovation capability which is activity- and process-oriented and based on 15 best practices of innovation management. Rejeb et al. (2008) also proposed a method for assessing innovation capability using 13 best practices as innovation process attributes. These authors attempt to assess innovation capability according to the level of application of such practices, also from the perspective of innovation management.

Nevertheless, both Rejeb et al. (2008) and Boly et al. (2014) evaluated these capabilities in the context of individual firms. Allen et al. (2016), in turn, studied innovation capabilities in biotech start-ups in relation to geographic proximity and interaction for knowledge exchange in the R&D network of a high technology cluster. They concluded that innovation is a function of the company's position in the collaborative network, and the measure of innovation used by the authors were patent applications.

Considering that the work found in the present literature is limited to evaluating innovation capability at the firm level, or focus on knowledge, or, in the context of clusters, use patents as a measure of innovation, this dissertation will try to answer the following question: **How to evaluate the innovation capability of companies in the context of clusters?**

1.2. PURPOSES

General:

- To develop a framework to measure the influence of factors and sub-factors raised in the literature on the innovation capability (IC) of cluster-based firms, providing an overview of which of these factors affect to a greater or lesser extent the capability to innovate.

Specific:

1. To define factors and sub-factors presented in the literature that influence the IC of cluster-based firms.

2. To identify hierarchical relationships and interdependence among the factors of IC in clusters-based firms through experts.
3. To apply the proposed framework in cluster based-firms that operate in an Information and Communications Technology (ICT) and Creative Economy (CE) cluster.

1.3. JUSTIFICATION

Due to geographic proximity, collective learning, exchange, combination and knowledge creation are stronger in industrial clusters than in companies that do not participate in any type of interorganizational network (Cantner et al., 2010; Sammarra & Biggiero, 2008). Lei and Huang (2014) reinforced this argument by stating that companies are more likely to establish a high level of networking when they are embedded in an industrial cluster. In addition, geographic proximity facilitates face-to-face contact and a sense of community, which encourages people to share ideas (Romijn & Albu, 2002). All these aspects would be enablers for innovation.

Managing innovation-related cooperation is a complex process (Antolin-Lopez et al., 2015), thus, it is important to know in depth the capabilities related to innovation in clusters-based firms. Yström and Aspenberg (2017) also address the role of industrial clusters in stimulating innovation, noting that this occurs both within individual firms and in collaborative relationships.

Since the research on innovation in industrial clusters focuses on knowledge as a resource or capability, the intention of this dissertation is to focus on the factors that lead to innovation capability. For this, a literature review was carried out to raise these factors in the context of interorganizational networks.

Treating the agglomeration as a technologically homogeneous object of study would be a crucial mistake, since generalizations made to the entire cluster would bring inconsistent and distorted results (Silvestre & Dalcol, 2009). Therefore, this dissertation will be conducted in a subgroup of companies that operate in the cluster.

As pointed out previously, none of the researches that studied innovation capability in the cluster context focused on the quantitative evaluation of this capability, except Allen et al. (2016), which analyzed this capability from the perspective of patent submissions. On the other hand, Boly et al. (2014) and Rejeb et al. (2008) proposed models to evaluate the innovation capability based on company's best practice. The

two papers present an index called “potential innovation index” (PII), which represents the global innovation performance of the firm. However, their studies were performed outside the context of business networks.

In its turn, this dissertation proposes the development of a framework that can measure the influence of factors and sub-factors raised in the literature on the innovation capability of cluster-based firms, providing an overview of which of these factors affect to a greater or lesser extent the capability to innovate.

A multicriteria tool was used for the development of the framework, since it is able to establish relations and quantitative measures for the evaluation criteria (Anbanandam et al., 2011) (often qualitative), such as learning (Capello, 1999; Lawson & Lorenz, 1999), cooperation (Christopherson & Clark, 2007), relationships (Altenburg, Schmitz, & Stamm, 2008), etc., outstanding characteristics in the context of cluster-based companies. Considering the nature of the research problem involves the evaluation of cluster-based firms, the use of a multicriteria tool helped answering the research question and in the formulation of the proposed framework. Besides, after a thorough bibliographic research, no papers were found using GTA in the context of IC evaluation of cluster-based firms.

Thus, the *Graph Theoretic Approach* (GTA) was chosen, since it is a multicriteria evaluation method that is capable of converting qualitative in quantitative factors and modeling the interdependencies of these factors, and can be applied in case studies to approach the reality of companies. Using GTA, an index is generated for the evaluated system. In this research, an innovation capability index (ICI) will represent the level of innovation capability of the firm in the context in which it is inserted (the cluster).

The proposed framework contributes to the literature since it aims to evaluate the impact or influence of factors (capabilities and characteristics on the innovation capability of cluster-based companies), allowing a greater understanding on the theme. To verify the applicability of the framework, it was tested in companies that operate in a high technology cluster in the state of Pernambuco that constantly deal with the need to innovate to maintain a position of competitive advantage.

Thus, the identification and evaluation of the factors influencing on the innovation capability of these companies can contribute to the strategic decision making regarding the organizational characteristics and capabilities (what to improve, where to invest, etc.), since it will enable the identification of how these factors

influence the ability to develop innovative solutions. In addition, this research contributes to regional development, since the evolution of the cluster and its innovation process implies in development and growth of the region in which it is inserted (Novelli et al., 2006; Porter, 2003; Wonglimpiyarat, 2006).

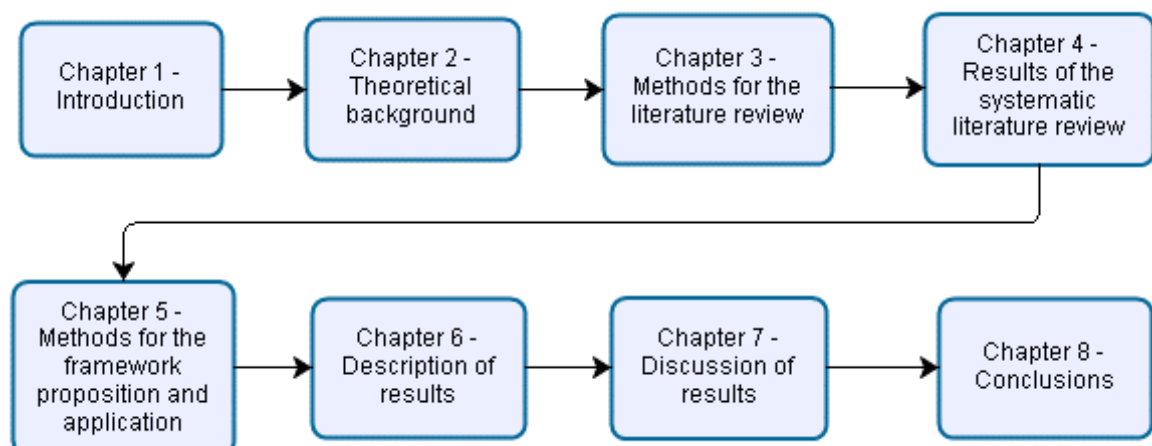
1.4. RESEARCH DELIMITATION

- The companies studied should be part of a cluster that promotes innovation in the Northeast region of Brazil (such as companies in a high technology cluster or information technology);
- The capabilities were mapped in the literature available in online databases;
- The evaluation of the innovation capabilities was performed through multicriteria analysis, using the Graph Theoretic Approach (GTA);
- The proposed framework evaluates how the factors related to the innovation capability of the cluster-based firms influence the innovation capability of each company, and not of the cluster as a whole.

1.5. DOCUMENT STRUCTURE

The presente document is structures in eight chapters, as depicted in Figure 1. Chapter 1 addresses the introduction to the studied subject, as well as the definition of the research problem, the general and specific purposes, and the justification. The research delimitation and the document structure conclude this chapter.

Figure 1: Structure of the dissertation



In Chapter 2, the main concepts for the development of this work are presented: industrial clusters, innovation in industrial clusters and innovation capabilities in industrial clusters. Chapter 3 describes the procedures for the systematic literature review (SLR): its concept, the definition of its step-by-step and the criteria used for the selection of the article sample.

In Chapter 4, the SLR results are presented, beginning with the analysis of the preliminary exploratory sample. Next, the analyses of research on innovation capability in the context of business networks are presented, as well as a critical synthesis of these results, which indicates which factors and sub-factors will be used as input data for the proposed framework.

Next, Chapter 5 presents the framework based on GTA, as well as the procedures for the application and validation of this model in clusters-based firms, including the procedures for the Delphi technique and for the application of case studies.

Chapter 6 describes the results according to the procedures for the development and validation of the evaluation framework. In Chapter 7, the results are discussed in light of the literature consulted. Finally, in Chapter 8 the conclusions of the study are presented, recalling its purposes, highlighting the contributions of the work, the limitations and the suggestions for future research.

2. THEORETICAL BACKGROUND

In this chapter, the main theoretical concepts that served as bases for the present study are presented. Section 2.1 introduces a theoretical background of industrial clusters and interorganizational networks in general, while section 2.2 presents innovation and contextualizes this topic from the perspective of clusters. Lastly, section 2.3 brings together the notions of capabilities, innovation and clusters.

2.1. INDUSTRIAL CLUSTERS

National and international market oscillations lead companies to develop alternative forms of competition, based on the notion that, more and more, the skills and resources required for sustainable performance are beyond the limits of the firm (Atalay et al., 2017). Industrial clusters can be considered one of these alternative forms, because they are environments driven by competition and cooperation (Strand et al., 2017).

The pioneering studies on agglomerations of companies date back to the late 19th and early 20th centuries, with Marshall (1920) as one of the most notable authors of the time and who introduced the concept of industrial districts. Porter (1998, 2003), another prominent author in this field of study, played a role in the popularization of the term industrial clusters. Table 1 shows some concepts about the theme.

From the definitions presented in Table 1, all have in common the aspect of geographical proximity. From the perspectives of Porter (1998, 2003) and O'Dwyer et al. (2015), the cluster companies are from the same industry or segment. While the other authors (see Table 1) define clusters as agglomerations of companies, Porter (1998, 2003) and Molina-Morales, Martínez-Fernández, and Coll-Serrano (2012) include other institutions (government, support) as active entities.

The terms industrial clusters and industrial districts are treated interchangeably by Molina-Morales, Martínez-Fernández, and Coll-Serrano (2012). From the authors mentioned in the table, only Crespo, Suire, and Vicente (2014) explicitly cover the network aspect of clusters in their definition, although others address exchanges and collaboration.

Based on these arguments and the definitions presented in Table 1, in this study, industrial clusters will be treated as a group of companies and institutions geographically agglomerated, whose relationships have as main characteristics the

collaboration and the exchange of resources, making it necessary that there is a high cognitive proximity between its actors (Molina-Morales et al., 2012; Porter, 1998, 2003; Yström & Aspenberg, 2017).

Table 1: Concepts of industrial districts and clusters

Authors	Concepts
Marshall (1920)	Industrial districts are agglomerations of companies that can benefit by increasing access to resources such as labor, suppliers and customers, as well as by more efficient transmission of knowledge among firms.
Porter (1998, 2003)	Industrial clusters are geographic concentrations of interconnected enterprises and institutions that are part of the same industry, including government institutions and others such as universities, associations, regulatory agencies, etc.
Altenburg and Meyer-Stamer (1999)	Industrial cluster is an agglomeration of firms of considerable size in a spatially delimited area, which has a specialized profile and in which exchanges between firms are essential.
Molina-Morales, Martínez-Fernández, and Coll-Serrano (2012)	Industrial clusters [or industrial districts] are territorial agglomerations of companies and institutions with a high degree of physical and cognitive proximity.
Crespo, Suire, and Vicente (2014)	Industrial cluster is a local structure of relationships that can be represented in the form of a network.
O'Dwyer et al. (2015)	Industrial clusters are networks of individual companies that share the same geographic location and market segment.
Yström and Aspenberg (2017)	Industrial clusters are considered a way to bring businesses closer together in a given region, and have the potential to increase collaboration between companies within and between businesses and industries in that region. In addition, clusters function as an ecosystem in which collaboration among members is stimulated, since everyone benefits from peer success, thus strengthening the cluster as a whole.

Companies operate in the context of networks to exploit resources and capabilities disseminated and that circulate through this network, with each company being endowed with a set of distinct and specialized resources, knowledge and capabilities (Dagnino et al., 2015).

Literature indicates that companies in industrial clusters have greater incentives to exchange information than individual companies (Lei & Huang, 2014), and clusters are considered as a pioneering concept for regional competitiveness and growth policies (Crespo et al., 2014). Thus, in the modern scenario, clusters can be a great opportunity for collaboration and business success. (Novelli et al., 2006).

Therefore, collaboration between companies allows access to new or complementary resources and capabilities, which can lead to competitive advantage (Atalay et al., 2017; Kalsaas, 2013; Ucler, 2017). Hence companies collaborate for a

number of strategic and operational reasons, including innovation (O'Dwyer et al., 2015).

Schmitz (1992) emphasizes the importance of the collective actions of the companies inserted in industrial clusters and the consequent possibility of innovation. Strand et al. (2017) are aligned with Schmitz (1992) and O'Dwyer et al. (2015), since they affirm that the relations and the geographical proximity of the cluster firms make possible rich exchanges of information that, in turn, stimulate the innovation.

Yström and Aspenberg (2017) also deal with the role of industrial clusters in stimulating innovation, emphasizing that this occurs both within individual companies and in collaborative relationships. However, there is evidence that companies participating in consolidated clusters have better opportunities than individual firms (Strand et al., 2017).

Although it is the main and perhaps most important feature of clusters, geographic proximity alone does not strengthen the competitive advantages of a firm (Allen et al., 2016; Lei & Huang, 2014). Companies ought to develop a collaborative relationship, through which competitive advantage will be increased (Lei & Huang, 2014).

A collaborative relationship is achieved through communication and cooperation that are stimulated by geographical proximity, and enables the transmission of information in the business network (Schilling & Phelps, 2007). From the managerial point of view, geographic concentrations of companies belonging to related sectors provide opportunities to access new local technologies (Britton, 2004).

Access to new technologies can be obtained through the exchange of technical know-how between the companies of the cluster, obtained through collaboration due to an atmosphere of trust (Atalay et al., 2017; Fleming, King, & Juda, 2007). According to Ter Wal and Boschma (2011), clusters are characterized by high levels of integration, expressed through a cohesive social environment. In this sense, close and intense relationships in clusters are responsible for the existence of trust (Fleming et al., 2007; Lei & Huang, 2014; Schilling & Phelps, 2007).

As pointed out by Porter (2000), cluster-based firms have better access to employees and suppliers, specialized information and complementary experience with other cluster members. Moreover, these companies enjoy institutional and public support, and a highly demanding customer base, driving the productivity of cluster-based firms to higher levels (De Bruijn, 2004).

Such aspects trigger interactions and direct contact between companies and those entities and, consequently, companies in cluster contexts apprehend new technological opportunities when compared to firms that act alone (Porter, 2000). Successful technological innovation requires complex forms of business organization, thus, innovative organizations must form links for advanced technological systems cannot be created in isolation (Teece, 1992).

In this sense, Feldman (2014) argues that innovative activities tend to cluster in regions where resources relevant to performance and survival are more abundant. The author also points out that because entrepreneurial firms define the behavior of the industry in a specific location, local resources, taken together, are larger than the sum of the parts.

Given that the geographical proximity allows for high levels of trust and greater interaction, as well as increased communication, it is possible that relations between companies are strengthened and the emergence of innovations is fostered (Feldman, 2014; Ganesan et al., 2005).

2.2. INNOVATION IN INDUSTRIAL CLUSTERS

At present days, the great complexity of technology makes innovation a differential element for competitiveness and for the performance of companies (Álvarez et al., 2009; Saunila, 2017), and can be an agent of increasing productivity, economic growth and development (Cavalheiro & Brandão, 2017; Zukauskaitė, 2012).

Schumpeter (1947) defines innovation as doing new things, or doing things in a new way, pointing out that this "new thing" does not need to be spectacular or to have historical relevance. The Organisation for Economic Co-operation and Development (OECD, 2005) follows the same line of reasoning and exposes that the minimum requirement for an innovation is that the product, process, marketing method or organizational method must be new or significantly improved for the company. Kalsaas (2013) adds the idea that innovation must generate value creation.

It is important to note that the innovation process comprises the technological development of an invention combined with its introduction into the market, since innovation differs from invention insofar as it provides economic value and is widespread for end users (Garcia & Calantone, 2002). In this sense, the creation of innovation must take into account the perspectives of a community and external agents

(Wannenmacher & Antoine, 2016), for if there is no demand, it will not reach the desired diffusion or market.

In this dissertation, innovation is defined as a new or significantly improved product, service, process, marketing method or organizational method that creates value as it corresponds to and responds to a market demand (Garcia & Calantone, 2002; Kalsaas, 2013; OECD, 2005; Wannenmacher & Antoine, 2016).

Regarding the typology of innovation, Garcia and Calantone (2002) carried out an extensive literature review on the subject. According to the authors, innovation can be of three types: radical, really new, or incremental. Radical innovations are innovations that cause marketing and technological discontinuities at the macro and micro levels. Incremental innovations occur only at the micro level and cause a commercial or technological discontinuity, but not both. Really new innovations cover the combinations between these two extremes.

It is considered that innovation reaches the macro level when it is new to the world, the market or an industry, whereas at the micro level, innovation is identified as new to the company or the customer (Garcia & Calantone, 2002). The authors also point out that the typology of innovation varies from firm to firm; a radical innovation for one company can be considered incremental in another business context. Besides, Garcia and Calantone (2002) argue that most innovations are incremental or really new, and the emergence of radical innovation is rare.

OECD (2005) proposes a classification that separates innovation into four types: product, process, organizational, and marketing innovation. On the other hand, Mattos and Guimarães (2012) argue that the classification of innovation depends on the perspective of analysis adopted. Thus, the authors present two classifications – the first divides the innovations into incremental, radical and fundamental; the second, in product, process and service innovation.

Table 2 shows a summary of the definitions presented by Garcia and Calantone (2002), OECD (2005) and Mattos and Guimarães (2012). Intersecting the classifications of OECD (2005), Garcia and Calantone (2002) and Mattos and Guimarães (2012), a product innovation can be radical, really new, or incremental. The same can occur for process, marketing, or organizational innovations.

Table 2: Types of innovation

Type of innovation	Definition	Authors
Radical	Innovations that incorporate new technology that results in a new market infrastructure. They cause marketing and technological discontinuities at macro and micro level. An innovation that causes discontinuity on a global, industrial, or market level will automatically cause discontinuities at the company and customer level, rendering obsolete what was previously employed. Radical innovations often create a demand previously unrecognized by the consumer and require the development of new marketing channels.	Garcia and Calantone (2002); Mattos and Guimarães (2012)
Really new	At a macro level, a really new product will result in a market discontinuity or technological discontinuity. If both occur, it should be classified as a radical innovation; if no discontinuity occurs at the macro level, it should be classified as an incremental innovation.	Garcia and Calantone (2002)
Incremental	Products that offer new features, benefits or enhancements to existing technology in the marketplace. In general, these changes improve functional performance, reduce costs, or increase the efficiency and quality of production processes. It occurs only at the micro level and cause a commercial or technological discontinuity, but not both.	Garcia and Calantone (2002); Mattos and Guimarães (2012)
Fundamental	When the impact of innovation is such that it enables the development of many other innovations.	Mattos and Guimarães (2012)
Product	The introduction of a new or significantly improved good in relation to its intended characteristics or uses. This includes significant improvements in technical specifications, components and materials, software or other functional features. The development of a new use for a product with only minor changes in its technical specifications is a product innovation.	Mattos and Guimarães (2012); OECD (2005)
Process	The implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software. Process innovations may aim to lower unit costs of production or delivery, or increase quality.	Mattos and Guimarães (2012); OECD (2005)
Marketing	The implementation of a new marketing method involving significant changes in product design or packaging, product positioning, product promotion or pricing. Marketing innovations seek to meet the needs of customers, open new markets or position a company's product in the market, with the aim of increasing the company's sales. The innovation should be part of a new concept or marketing strategy that has a significant distance from the company's existing marketing methods.	OECD (2005)
Service	Happens when new ways of providing services are developed.	Mattos and Guimarães (2012)
Organizational	The implementation of a new organizational method in the company's business practices, organization in the workplace or in external relations. Organizational innovations can aim to increase a company's performance by reducing administrative or transaction costs, improving workplace satisfaction, gaining access to assets such as uncoded external knowledge, or reducing costs of supplies.	OECD (2005)

Mattos and Guimarães (2012) still argue that the distinction between process, product and service innovations is not always clear and depends on the perspective, for example: an innovation in a bank ATM represents (1) for the customer, an innovation in service, (2) for the bank, in process, and (3) for the equipment manufacturer, in product.

Be they of any kind, innovation activities depend greatly on the cultural proximity with the workforce (Capello, 1999), which brings innovation closer to the context of agglomerations of companies such as clusters.

Literature points out that innovation is an active social process (Dalcin et al., 2017), a result of networking relationships (Pechlaner & Bachinger, 2010), therefore interactive and spatially integrated, and cannot be understood independently of the specific institutional and cultural context of the region (Altenburg et al., 2008). Consequently, innovation rarely happens in an independent manner (Petruzzelli, Albino, & Carbonara, 2009).

This idea is reiterated by Dagnino et al. (2015), when they point out that the innovation process is the result of interactions and exchanges between suppliers, customers, partners, universities, research organizations, government and financial institutions. Cappellin (2003) also mentions the relationships between these entities, noting that innovation is based on the ability to combine cumulated competences within companies, in various technological and organizational aspects, with customer needs, networks of specialized suppliers, other complementary companies and several others institutions and organizations.

These relationships with external agents generate an interactive learning process in the sense of providing information and consequent renewal of firms' know-how, allowing the resolution of new problems, which may result in the development of innovative activities (Cappellin, 2003; Ganesan et al., 2005).

Besides cooperation, another engine for the innovation process is interorganizational competition, which also drives economic development (Antolin-Lopez et al., 2015; Teece, 1992). Within industrial clusters there is a high level of competition and cooperation, generating, therefore, a strong motivation for innovation (Atalay et al., 2017).

Several authors point out the importance of the role of geographical proximity, while others focus on the interaction with other companies and external agents as mediators for the innovation process. Tables 3 and 4 summarize these aspects.

Table 3: Innovation and geographical proximity

Authors	Arguments
Brown and Duguid (2002)	The local character is important for innovation due to the development of social networks, highlighting the case of Silicon Valley.
De Bruijn (2004)	Emphasizes the role of regional factors and geographical proximity, arguing that the latter is a catalyst for innovation.
Díez-Vial and Fernández-Olmos (2015)	Points out that proximity allows companies access to services and support to market their products, thus obtaining better performance than companies that work in isolation.
Giuliani (2013)	Companies that operate with geographical proximity achieve better performance in innovation.
Ganesan, Malter, and Rindfleisch (2005)	Emphasizes the importance of informal and face-to-face communication, and suggests that almost all the benefits of geographic proximity depend on relationships with strong ties.
Grillitsch, Tödtling, and Höglinger (2015)	Brings the concepts of cognitive, technological, organizational, social, cultural and institutional proximity. According to the authors, the geographical proximity allows these other types of proximity and this context leads to innovation.
Larty, Jack, and Lockett (2017)	The geographical agglomeration of firms offers greater opportunity for knowledge exchange, leading to an increase in innovation in the region.
Silvestre and Dalcol (2009)	At least three elements determine the relationship between geographic proximity and innovation: industry patterns in which the agglomeration is embedded, local dynamics (involving support institutions and policies), and the role of the firm in the value chain [of the cluster].

Table 4: Innovation and interaction with other companies and external agents

Authors	Arguments
Antolin-Lopez et al. (2015)	Interorganizational cooperation can improve the innovation performance of cooperating companies.
Cantner, Meder, and Ter Wal (2010)	Interorganizational collaboration is a mechanism for knowledge exchange among firms. Knowledge gained through other organizations can be used for the company's innovative activities.
Huggins et al. (2012)	Companies do not innovate in isolation, but through a set of interactions with external agents.
Jang, Kim, and Von Zedtwitz (2017)	In addition to the internal factors of the company, the external environment and the collaboration network influence innovation.
Petruzzelli, Albino, and Carbonara (2009)	Individual agents are rarely able to innovate independently. Innovation is linked to the creation of new technological knowledge, which, in turn, demands the combination of internal and external learning processes, through interaction, for example.

Industrial clusters provide both geographical proximity and interaction, and stimulate not only the individual innovation of firms but also foster collaborative innovation, bringing new possibilities for companies, whether related to technological

aspects, operations or logistics, making them more propitious to new technologies and services (Yström & Aspenberg, 2017).

The logic of collaborative innovation is determined by the resources and capabilities that companies need to access or develop through collaboration, in addition to their own organizational characteristics (Antolin-Lopez et al., 2015). In this sense, Grillitsch and Nilsson (2015) point out that the innovation process relies on the internal capabilities and competences of companies and access to external elements, which is precisely the situation provided by the industrial clusters.

Literature indicates that the collaborative environment distinctive of clusters increases access to technology, making it possible to motivate the innovation capability of the participating companies (Antolin-Lopez et al., 2015; Porter, 2003; Strand et al., 2017; Wonglimpiyarat, 2006). Hence, the following section addresses innovation capabilities in the context of industrial clusters.

2.3. INNOVATION CAPABILITY IN INDUSTRIAL CLUSTERS

Sections 2.1 and 2.2 reinforce the strategic relevance of innovation for organizations located in the context of industrial clusters. However, to achieve these strategic benefits, it is necessary for clusters to develop and strengthen their innovation-driven capabilities as a means of obtaining quick and flexible responses to the change and expansion of global markets (Christopherson & Clark, 2007).

Innovative industrial clusters are inserted in this context as important drivers for productivity growth and wealth creation (Brown & Duguid, 2002). Therefore, they can be considered as a means to increase the innovation capability.

Capabilities are important determinants of innovation activity (O’Gorman & Kautonen, 2004). Therefore, for understanding the concept of innovation capability, first, it is necessary to understand capabilities in the context of the organizational environment, Table 5 presents some concepts of capability.

The definitions given by Amit and Schoemaker (1993) and Helfat and Peteraf (2003) are aligned and rather similar, focusing on capabilities as a means to achieve results. Winter (2003) also addresses the results, but introduces the issue that capabilities act to make decision making viable.

Amit and Schoemaker (1993) also point out that capabilities can be tangible or intangible, company specific, and developed over time through complex interactions

between company resources. According to them, capabilities can be thought of as “intermediate goods” generated by the company to provide greater productivity of its resources, as well as strategic flexibility and protection for its final product or service.

Table 5: Definitions of capabilities

	Authors	Concepts
Capabilities	Amit and Schoemaker (1993)	Processes of a company that use resources, through organizational processes, to reach a desired end. The capabilities are based on the development, transport and exchange of information through the human capital of the company.
	Helfat and Peteraf (2003)	The ability of an organization to perform a set of tasks or routines, using organizational resources, for the purpose of achieving a particular result.
	Winter (2003)	A routine or collection of high-level routines that gives the management of the organization a set of decision-making options to produce meaningful results of a specific type.
	Peltoniemi (2013)	A collection of organizational routines and know-how that, together, enable companies to function, learn, and adopt new capabilities to adapt to the ever-changing business environment.
Dynamic capabilities	Teece, Pisano, and Shuen (1997)	The firm's ability to integrate, build and reconfigure internal and external skills to respond to rapidly changing environments; such capabilities thus reflect the organizational ability to achieve new and innovative forms of competitive advantage.
	Helfat and Peteraf (2003)	Dynamic capabilities involve adaptation and change because they build, integrate, or reconfigure other resources and capabilities.
	Quintana-García and Benavides-Velasco (2005)	Dynamic capabilities refer to the ability to renew competences in order to achieve congruence with the changing business environment.
	Ter Wal and Boschma (2011)	A structural feature of the firm that hides a company's ability to introduce innovations relatively steadily over time. In other words, dynamic capabilities give way to replicable change processes that are encapsulated in a company's routines.

The concept of capability as a set of routines, proposed by Helfat and Peteraf (2003), implies that, for the performance of an activity to constitute a capability, the capability must have attained some level of practiced or routine activity. That is, for something to qualify as a capability, it must at least function reliably (Helfat & Peteraf, 2003).

On the other hand, capabilities as described by Peltoniemi (2013) approach the concept of dynamic capabilities of Teece, Pisano, and Shuen (1997). According to the latter, the term “capability” emphasizes the central role of strategic management in adapting, integrating and reconfiguring organizational skills, resources and competencies, whether internal or external, to match the requirements of the ever-

changing environment. The term “dynamic”, in turn, refers to the ability to renew competences in order to meet the demands of the business environment, since innovative responses are needed when the pace of technological change is rapid, and the nature of competing firms and the market is difficult to identify (Teece et al., 1997).

Following the same reasoning, Helfat and Peteraf (2003) also claim that capabilities can evolve and change over time. Ter Wal and Boschma (2011) relate dynamic capabilities to the introduction of innovations in the marketplace as change processes encapsulated in a company's routines. Thus, the innovation capability can be considered a dynamic capability. Table 6 presents some definitions of innovation capability.

Table 6: Definitions of innovation capability

Authors	Concepts
Akman and Yilmaz (2008)	An important factor that facilitates an innovative organizational culture, internal activities of promotion features and capabilities to understand and respond appropriately to the external environment.
Altenburg, Schmitz, and Stamm (2008)	The creation of new knowledge put into productive use.
Martínez-Román, Gamero, and Tamayo (2011)	It can be considered an instrument to achieve success in the market. The effort of adaptation to the environment would be one of the fundamental objectives to justify the existence of innovation capability in the organizations.
Quintana-García and Benavides-Velasco (2005)	The ability to shape and manage multiple competences, such as technology skills, production management and marketing. It can be defined as a dynamic capability as it integrates, adapts and reconfigures capabilities and competences to create profitable products and services.
Romijn and Albaladejo (2002)	The skills and knowledge required to effectively absorb, master and improve existing technologies, and to create new ones.
Szeto (2000)	It refers to a continuous improvement of the global capability of companies to generate innovation for the development of new products to meet the needs of the market.
Wonglimpiyarat (2010)	Ability to make major improvements and modifications to existing technologies, and create new ones.

In this research, the capabilities will be considered the abilities of an organization to perform a set of tasks using organizational resources, in an effort to make feasible the process of decision making, and with the purpose of achieving a particular result (Helfat & Peteraf, 2003; Winter, 2003). The dynamic capabilities will be treated as those responsible for integrating, building and reconfiguring internal and external competencies to respond to rapidly changing environments that must be

incorporated into the company's routines (Helfat & Peteraf, 2003; Teece et al., 1997; Ter Wal & Boschma, 2011).

On the other hand, innovation capability will be treated as the multiple skills and competences needed to absorb, dominate, and enhance or create new existing products, services or processes to meet market needs and profit (Quintana-García & Benavides-Velasco, 2005; Romijn & Albaladejo, 2002; Szeto, 2000).

In the business environment, where competitive advantage is always sought, it is necessary to explore both the internal capabilities of the company as well as the external ones (Teece et al., 1997). This context is made possible by the distinctive collaborative environment of industrial clusters, since the differences among the participants are exploited to produce innovative solutions and balance the different needs of stakeholders (O'Dwyer et al., 2015).

Combining the concepts of industrial clusters and dynamic capabilities, Lawson and Lorenz (1999) point out that the capabilities of geographically grouped firms are understood in terms of the existence of shared knowledge, common local routines and the capability of companies to combine and recombine diverse knowledge.

Adding the idea of innovation capability, Quintana-García and Benavides-Velasco (2005) propose that the capability clusters possess to improve their innovation capability can be defined as a dynamic capability as they integrate, adapt and reconfigure the resources and skills to create profitable products and services. Thus, it can be assumed that geographic proximity helps companies to access distributed resources and improve their dynamic capabilities (Quintana-García & Benavides-Velasco, 2005).

Companies with superior capabilities to create new technologies, products and processes and to commercialize them successfully are attractive partners for other companies (Ter Wal & Boschma, 2011), as a consequence, the environment of innovative clusters becomes attractive as their innovation capability is enhanced. In this context, arises the motivation to study the factors that influence the innovation capability of cluster-based firms.

3. METHODS FOR THE LITERATURE REVIEW

In the present chapter, the methodological procedures of the literature review are presented. The first section approaches the exploratory search led in the beginning of the study, while the second section describes the systematic literature review (SLR), its parameters and results.

3.1. PRELIMINARY EXPLORATORY SEARCH

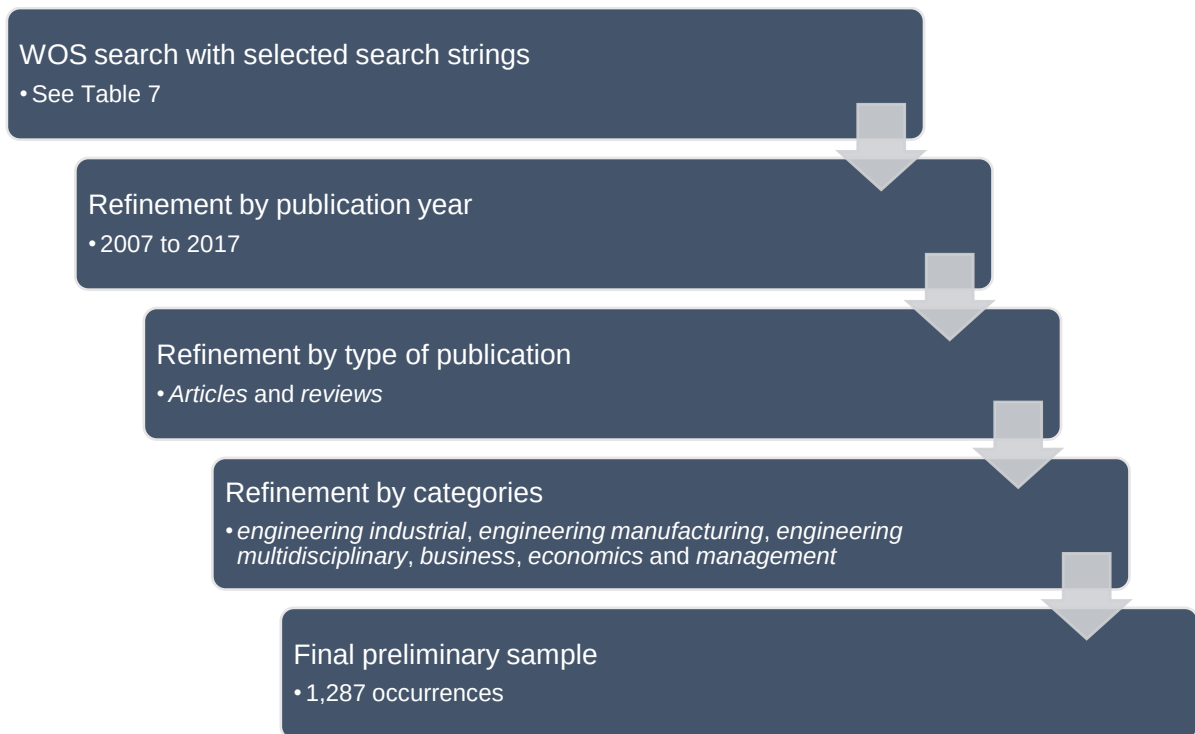
To determine the most appropriate terms for the search to define the paper sample for the SLR, an exploratory preliminary search was conducted in July 2017 to evaluate the state of the art of the intended field of research. The search strings presented in Table 7 were submitted to Web of Science (WOS) database.

Because it is an exploratory research whose purpose was to perform a network analysis to obtain an overview of the current research on the subject, the method proposed by Lacerda, Ensslin, and Ensslin (2012) was simplified. The procedures are detailed in Figure 2.

Table 7: Exploratory research parameters

Connective	Search strings	Topic or title
-	<i>capabilit* or competenc* or resource* or capacity or capacities</i>	Topic
AND	<i>cluster* or "industrial district*"</i>	Topic
NOT	<i>"cluster analysis"</i>	Topic

With this sample of 1,287 articles (sample 1), a network analysis was performed (see Chapter 4, section 4.1) through which it was realized that, although it was not used in the search, the keyword “innovation” had a significant presence in the network. Since it is in a central position and next to the word “cluster”, the network analysis served as an indication that it is a term of relevance within the sample.

Figure 2: Exploratory research procedures

3.2. SYSTEMATIC LITERATURE REVIEW

To achieve the first specific purpose of this research, “to identify and define the factors and sub-factors present in the literature that influence the innovation capability of cluster-based firms”, a systematic literature review (SLR) was used. The SLR is a tool to identify, assess and interpret available and relevant research for a specific research question, area of study or phenomena of interest (Kitchenham, 2004).

The systematization of the literature review provides an overview of the primary studies that contain explicit objectives, materials and methods, and were conducted according to an explicit and replicable methodology (Greenhalgh, 1997). Systematic reviews are carried out from these primary studies and are therefore considered secondary studies. The SLR methodology used in the present research, depicted in Figure 3, is based on the methodology proposed by Lacerda, Ensslin, and Ensslin (2012).

Figure 3: The applied step-by-step for the systematic literature review

Source: Based on Lacerda, Ensslin, and Ensslin (2012)

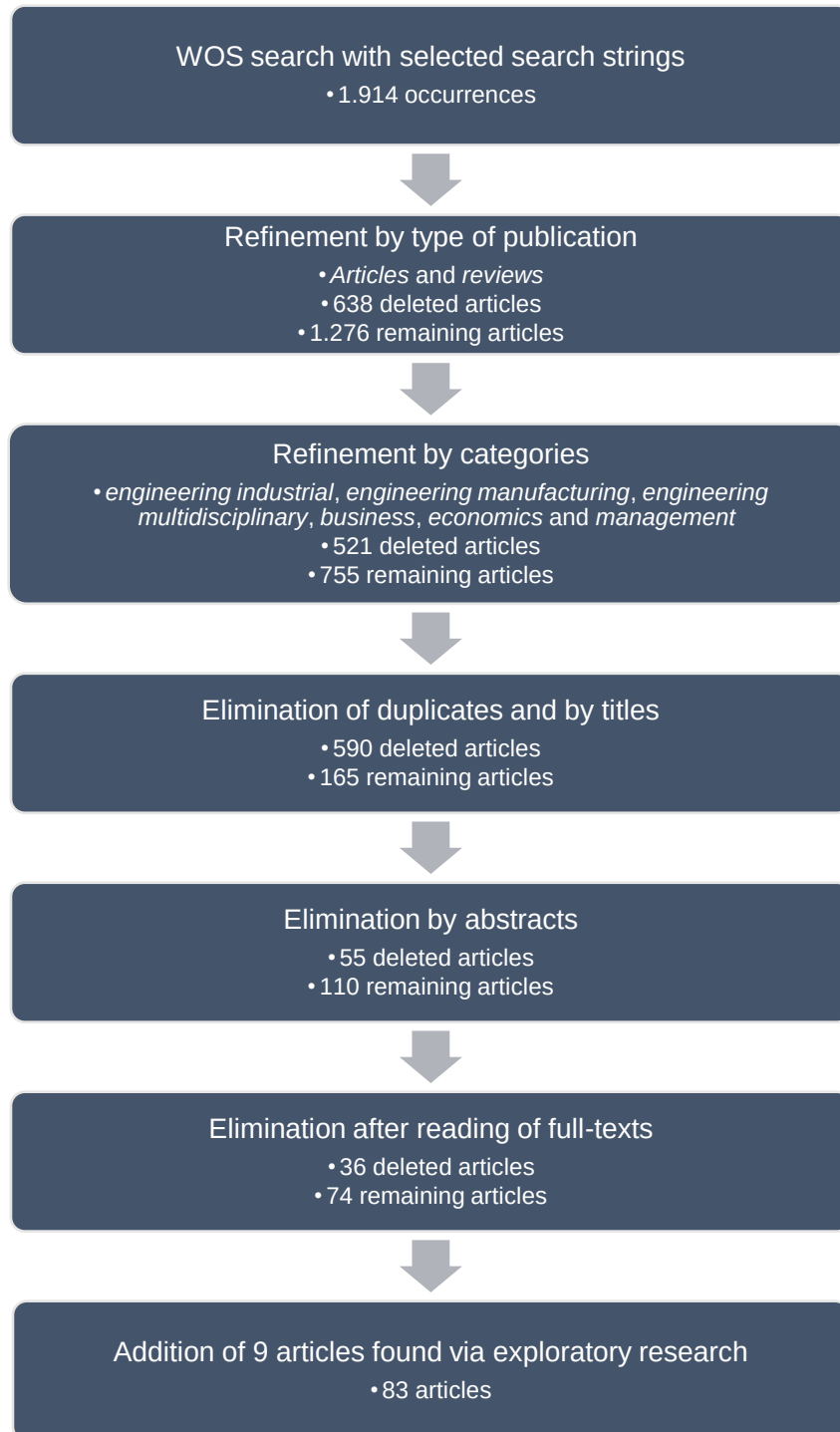
Following the exploratory search described in section 3.1, innovation became a focus theme of the present research. In this sense, a new search was made in WOS, in June 2019, using the terms presented in Table 8. The WOS categories used for refinement are the same as those used in the preliminary search. The new sample (sample 2) resulted in 755 occurrences.

Table 8: Parameters of the second search

Connective	Search strings	Topic or title
-	<i>resourc* or capabilit* or competenc*</i>	Tópico
AND	<i>cluster* or "industrial district"</i>	Tópico
AND	<i>innovation or "new product development"</i>	Tópico

The step-by-step procedure of the second search is shown in Figure 4, also derived from the method of Lacerda, Ensslin, and Ensslin (2012).

Figure 4: Procedures of the second search



In order to help the refinement of sample 2, two bibliographic management tools were used: EndNote Web and Mendeley. Thus, the articles were first exported from

the Web of Science to EndNote Web, where the duplicates were eliminated and then the elimination was carried out by reading titles, with 165 articles remaining. Also in the EndNote Web platform, the elimination was done by reading the abstracts, which resulted in 110 articles.

Then, the 110 articles were downloaded using the Brazilian database *Portal de Periódicos Capes*, for the reading of the full-texts. After this step, 36 articles were excluded, thus remaining 74 in the final sample.

The criteria for elimination, both in the stage of reading abstracts and full-texts, were: only the pre-print version was found in the consulted database; the article did not deal with clusters or industrial districts, developed firm-level study and did not contribute to the study of innovation capabilities; the article focused on spinoff of companies participating in clusters; the article specifically dealt with the social aspects of relationships and networks between companies; the article addressed the benefits of infrastructure investments in agglomerations.

In addition to the articles from the systematic review, other 09 relevant publications were found in an exploratory manner. As these articles were not present in sample 2, they were added to the final sample, therefore totaling 83 articles.

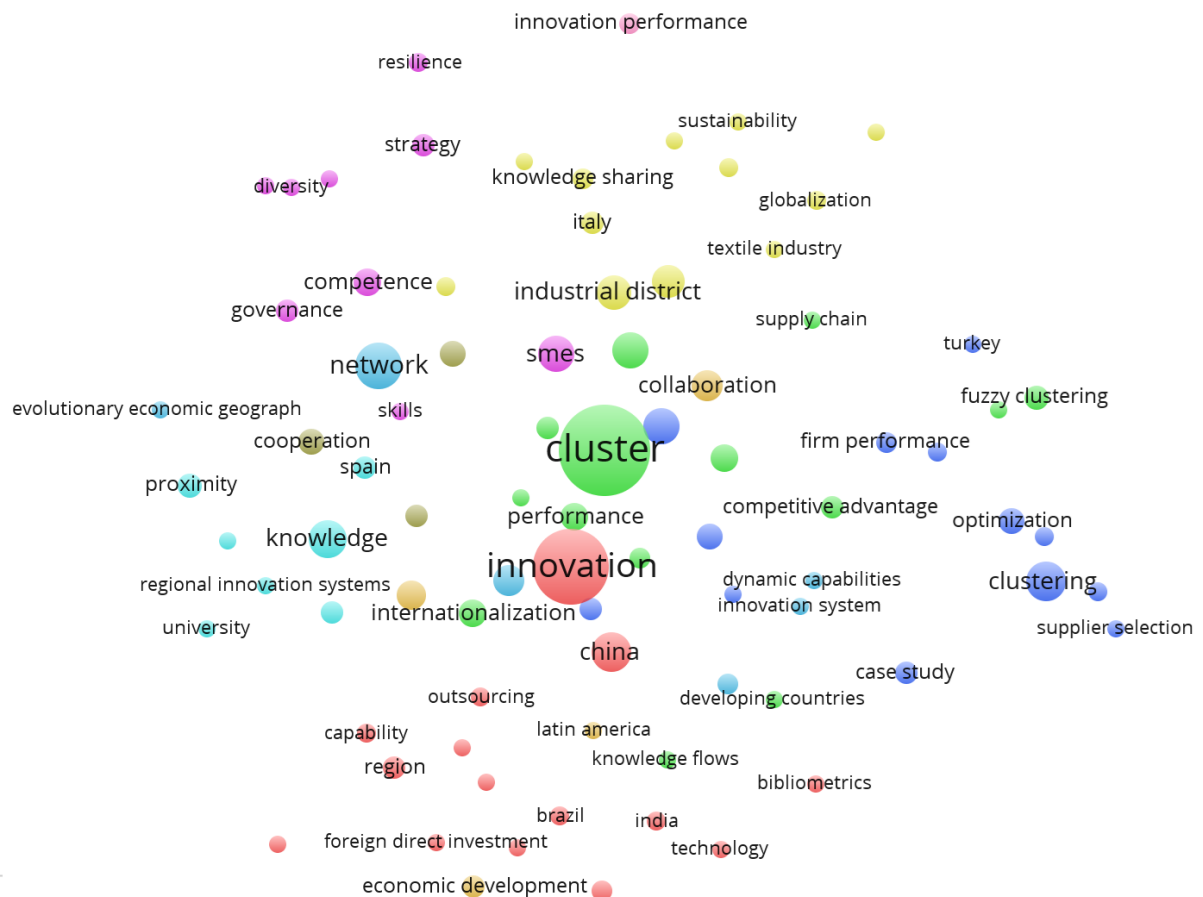
From the final sample, a content analysis was performed in two phases: (1) quantitative analysis: Microsoft Excel was used to generate descriptive statistics charts, which helps in understanding the state of the art, as presented in chapter 4, section 4.2; (2) qualitative analysis: the 83 full-texts were read with the purpose of better understanding the innovation capability in the context of clusters. Furthermore, the factors that influence the innovation capability of cluster-based firms, identified in the literature, were presented (section 4.3).

4. RESULTS OF THE SYSTEMATIC LITERATURE REVIEW

4.1. PRELIMINARY EXPLORATORY ANALYSIS

From the results of the preliminary exploratory research, the VOSviewer software was used to carry out a network analysis of the sample of 1,287 articles, the result of which is shown in Figure 5. The analysis was made using authors' keywords with at least 5 occurrences using the following criteria: *co-occurrence, author keywords, at least 5 times*.

Figure 5: Network analysis



The search strings used for this sample were shown in Table 7. Although it was not used as a search criterion, the keyword “innovation” had a significant presence in the network, being in a central position and close to the word “cluster”, an indication that it is a term of relevance within the sample. In addition to the proximity, the sizes of the spheres indicate that these two terms are those of greater relevance in the exploratory sample.

Other types of agglomerations have appeared appear in the network: *industrial district*, *network*, *innovation system* and *regional innovation systems*. The occurrence of the latter two reinforces the relevance of the term “innovation” and its relationship with business agglomerations.

It can also be observed in Figure 10 that the terms *innovation* and *capability* are in the same grouping of the network, both in red color, which means that they are keywords that are often used together in that group of authors/articles. Thus, it was possible to identify that the terms *innovation*, *cluster* and *capability* are related in the network resulting from the exploratory research, which aroused the interest for the development of the present work.

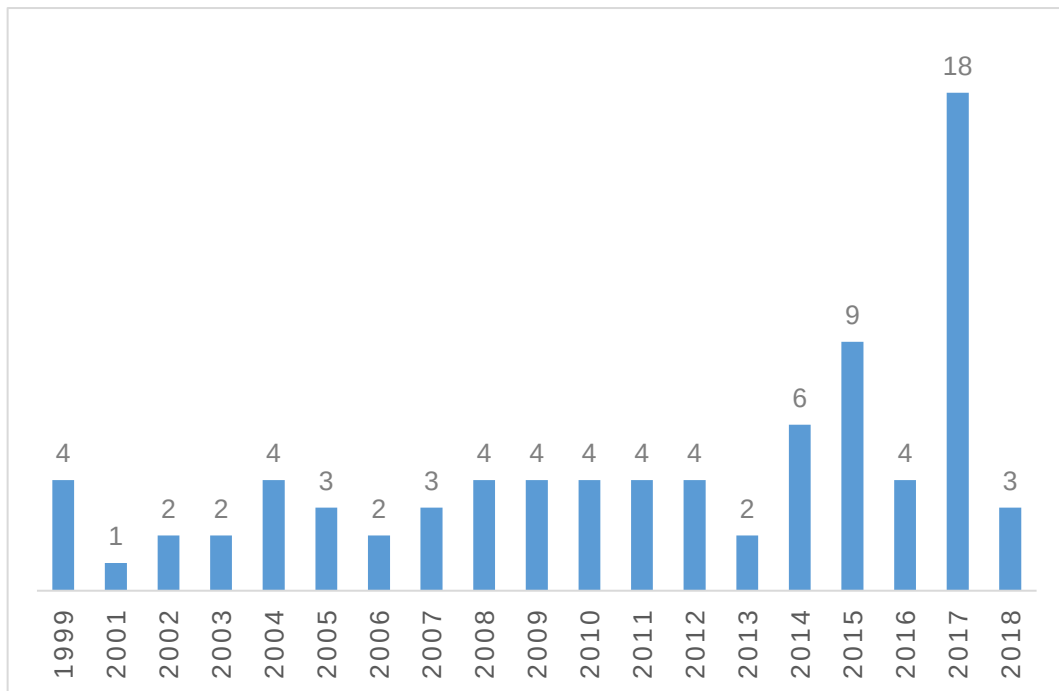
4.2. INNOVATION CAPABILITY IN THE CONTEXT OF BUSINESS NETWORKS

In this section, an overview of the main sample of articles will be presented, through quantitative and qualitative analyzes. Sample 2, derived from RSL and the exploratory search, is composed of 83 articles, the information of which is presented in Appendix A.

In order to propose an overview of this sample, an analysis through descriptive statistics was made. Figure 6 shows the evolution of publications over the years. It can be observed that, until the year 2016, there is an oscillation in the number of publications, without a definite trend. However, in 2017 there was a significant increase, which indicates that the topic under study is current and pertinent.

There was no temporal constraints in the systematic search, however, the first relevant publications to the present research were published in 1999, being: Capello (1999), Lawson and Lorenz (1999), Maskell and Malmberg (1999), and Nooteboom (1999). Maskell and Malmberg (1999) is the most cited article of the sample, with 727 citations according to Web of Science. The other three have, respectively, 237, 286 and 125 citations, and can therefore be considered relevant publications.

These four articles have in common the theme of learning, relating it to technological environments, technological regions or geographical proximity. Amongst them, Lawson and Lorenz (1999) are the only authors that deal specifically with industrial clusters, establishing a relationship between clusters and the concept of collective learning.

Figure 6: Evolution of publications over the years

In Figure 7 are presented the journals that had at least two occurrences in the sample. The two most recurring journals, *Regional Studies* e *Technovation*, have an impact factor 3.074 and 5.622, respectively, indicating the high quality of both and, consequently, of the publications used in the SLR.

Figure 7: Main journals of the sample

Table 9 presents the impact factors of the journals shown in Figure 7, except for International Journal of Innovation Management and Competitiveness Review, which were not found. The data was collected from the official website of each journal. It can be observed that, in general, the journals of the sample have high impact factor.

Table 9: Impact factors of main journals

Journal	2018 impact factor
Regional Studies	3.074
Technovation	5.622
Entrepreneurship and Regional Development	2.928
Research Policy	7.352
Cambridge Journal of Economics	2.063
Journal of Business Research	4.747
Tijdschrift Voor Economische En Sociale Geografie	0.856
World Development	3.905
Technology Analysis & Strategic Management	1.739
Journal of Knowledge Management	4.604
Journal of Manufacturing Technology Management	2.642

Table 10 summarizes the methods used in sample 2 and Figure 10 shows the methods used over the years. The predominance of the survey can be noticed, which indicates a tendency of quantitative studies in the subject. Following, there are the case studies. In total, there are 31 qualitative articles, 46 quantitative articles, and 6 quali-quant, which shows that the quantitative approach is predominant for the studied subject. Of the four papers that use mathematical modeling, three use multicriteria decision models: Ucler (2017) integrates *fuzzy e Analytic Hierarchy Process* (AHP) methods, Boly et al. (2014) uses *fuzzy*, and Rejeb et al. (2008) uses AHP and ELECTRE, a method that emerged in Europe and whose name comes from the French expression “*ELimination Et Choix Traduisant la REalité*”.

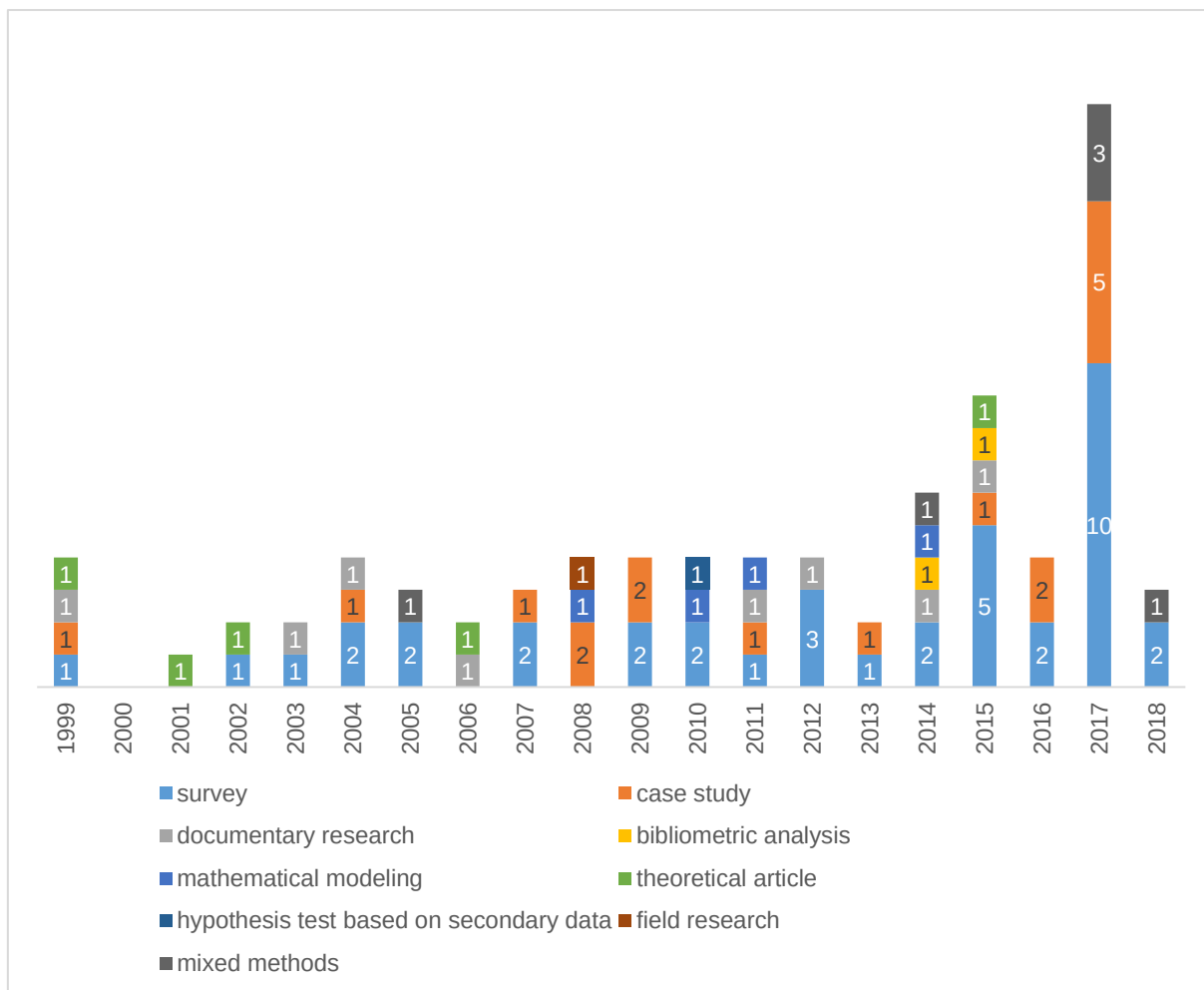
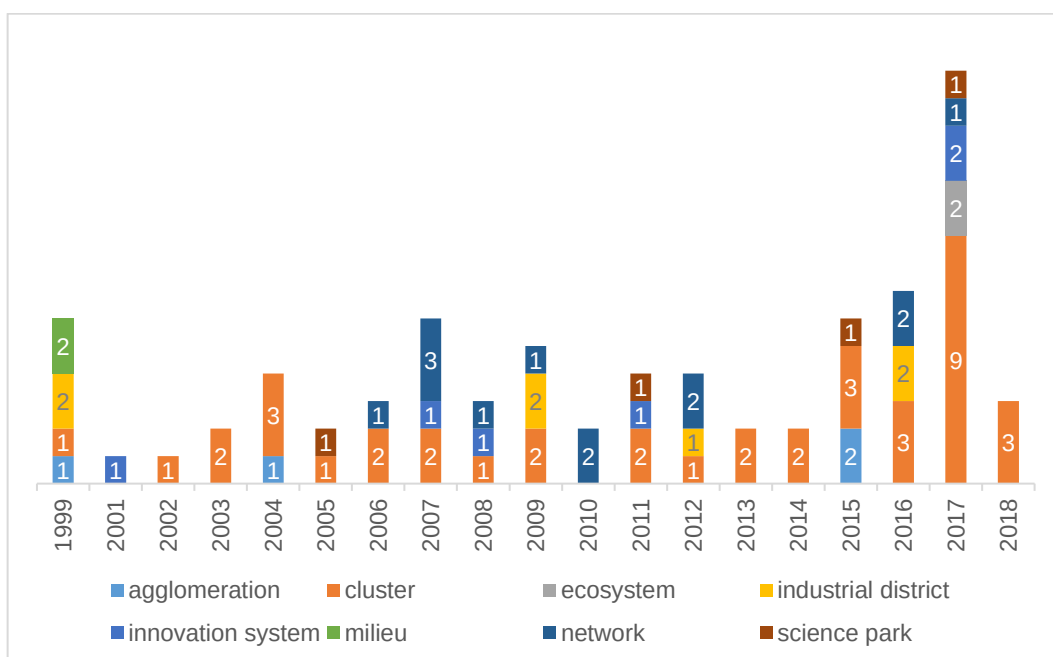
Table 10: Summary of the used methods in article sample

Method	Nature	Absolute frequency	Relative frequency
Survey	Quanti	39	46,99%
Case study	Quali	17	20,48%

Method	Nature	Absolute frequency	Relative frequency
Documentary research	Quali	8	9,64%
Mixed methods	Quali-quantitative	6	7,23%
Theoretical article	Quali	5	6,02%
Mathematical modeling	Quantitative	4	4,82%
Bibliometric analysis	Quantitative	2	2,41%
Field research	Quali	1	1,20%
Hypothesis test based on secondary data	Quantitative	1	1,20%
Total	-	83	100,00%

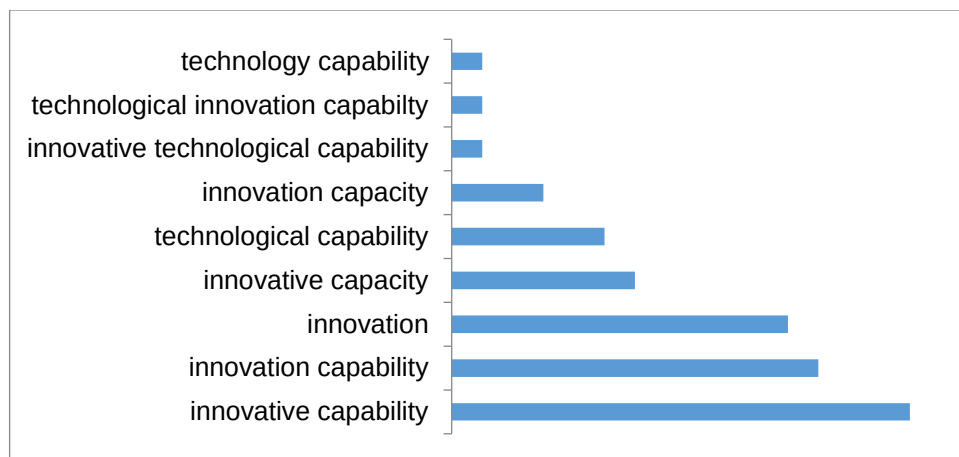
Figure 8 shows that the use of survey method has kept approximately stable between 1999 and 2014, showing an increase in 2015, a decrease in 2016 and another increase in 2017. Thus, there is not a very clear trend of using this method within the sample, but in 2015 and 2017 it was predominant. Documentary research, the third most common method in the sample, presented a stable frequency over the years, with one or two papers present each year.

In relation to the types of interorganizational networks within the sample, the most recurrent is, in fact, cluster, followed by network, industrial district and innovation system, according to Figure 9. The terms “cluster” and “industrial district” were used as search strings and therefore their frequency is justified. The term “network” has shown relevance even though it was not a search string; this happens because it is a generic term that can encompass all types of agglomerations. This scenario is consistent with the results of the network analysis presented in Figure 5, section 4.1.

Figure 8: Methods over the years**Figure 9: Interorganizational network types present in the sample**

In relation to the terms referring to innovation capability, the two most used are “innovative capability”, followed by “innovation capability” itself (Figure 10). The term “innovation” was also included in the count, as many articles deal with capabilities and factors that lead to innovation. Besides, terms that involved technological capabilities when they referred to innovation were also considered: technological capability, technological innovation capability, innovative technological capability, and technological capability.

Figure 10: Innovation capability terms



Amongst the articles in the sample, four stand out regarding the method, objective, or application of the research when compared to what is proposed in the present study: Allen et al. (2016), Boly et al. (2014), Rejeb et al. (2008) e Wonglimpiyarat (2010).

Allen et al. (2016) conducted their study in a biotech industrial cluster located in Boston, United States, and their goal was to examine the innovation capabilities of biotech startups in relation to geographic proximity and knowledge sharing interactions in the cluster R&D network.

Over a year, R&D employees from more than 70 companies were consulted and, through weekly surveys, information on communication and social links with other researchers, universities and pharmaceutical companies were collected, as well as the geographic locations of each one of them. The authors used patents as a measure of innovation, on the grounds that they are one of the only collectable and analyzable measures for firm performance.

By comparing the information collected with the amount of patent applications over the years, Allen et al. (2016) have come to the conclusion that innovation is a function of the company's positioning in the collaborative network, strengthening the idea that communication would be more relevant than geographical proximity. According to them, the closer the company is to the “heart of communication”, the more innovative it is, regardless of its location.

Therefore, the research of Allen et al. (2016) has the following implication: the location matters, but only if company employees do not communicate with the social network. Although these authors performed the analysis in the context of clusters, it is limited to assessing innovation capability using only one measure (patents).

The study of Boly et al. (2014), in its turn, had the objective of proposing a model for the evaluation of innovation capability based on 15 best practices of innovation management. Each practice was subdivided into multiple criteria that are directly observable phenomena or facts, such as: presence of a research department, presence of a human resources manager, existence of training focused on innovation, existence of a well defined marketing service, among others.

The authors propose a potential innovation index (PII) to represent the global innovation performance of the company. To do so, they adopted a multicriteria methodology and statistical tests to recommend a classification in four types of innovative firms: proactive, preactive, reactive and passive. The characteristics of each of these groups allow the determination of the firms' innovation capability.

The sample data were collected from a group of 39 small and medium-sized manufacturing companies located in France through a survey, and then used to test the model to determine the firms' innovation capability. However, what is observed in the model proposed by Boly et al. (2014) is that it is activity and process-oriented and the index is related to innovation performance, while the present study takes into consideration the firm's organizational capabilities and proposes an index related to innovation capability.

As well as Boly et al. (2014), Rejeb et al. (2008) also focused on the industrial sector and proposed a method for evaluating innovation capability. The authors sought to integrate the evaluation and comparison of the innovation capability of companies. According to them, this capability is correlated to a set of competences, knowledge, tools and financial resources. The authors carried out a survey with definition of criteria, collection of data and methods of treatment and elaboration of mathematical models.

Rejeb et al. (2008) focused on analyzing the integration of strategic tasks, organizing new projects and improving innovation management practices. They used 13 best practices as attributes of the innovation process; however, these authors have undertaken to evaluate innovation capability according to the level of application of such practices, from the perspective of innovation management. Analogous to Boly et al. (2014), Rejeb et al. (2008) also proposed the PII as the evaluation index of innovation performance.

To compose an index for each of the 13 practices, Rejeb et al. (2008) defined sub-practices (directly observable and measurable phenomena, similar to Boly et al. (2014)). In total, 45 sub-practices were used. To validate these indexes, they carried out an experiment with a panel of 20 companies, whose data were provided by the executives involved in the innovation process of each one of them. Then, to calculate the innovation capability score of each company, the authors used three methods: a multicriteria analysis, an algorithmic method based on multicriteria analysis, the development of a mathematical model, and data mining.

As a result, Rejeb et al. (2008) say that to be innovative, a company can choose between two strategies: to reach a higher level in practices that focus on short-term growth of the company and the construction of internal knowledge, or to be more or less effective (approximately 75%) in practices aiming at future growth and collection of external knowledge.

Lastly, Wonglimpiyarat (2010) developed an index to assess the efficiency of innovation in a Thai national industrial innovation system. The author analyzes five dimensions of innovation capability: organizational, process, service, product and marketing, with the intention of providing general information on the national innovation capability index. According to the author, one of the functions of this index is to help assess what the country must do to drive innovation, resulting in the construction of economic growth and jobs.

The index proposed by Wonglimpiyarat (2010) is based on the frameworks of competitiveness factors from the International Institute for Management Development (IMD) and the World Economic Forum (WEF). To build its own theoretical framework, the author used a questionnaire to collect information on the general characteristics of Thailand's innovation capabilities.

The questionnaire was sent to Thai companies and addressed the five dimensions of innovation capability mentioned above, evaluated on a four-point scale.

Scores for each dimension were then aggregated for the calculation of the overall innovation capability index. An examination of secondary data was performed to provide a cross-check of the internal validity of the results.

At the end of the survey, the Thai national innovation capacity index was 2.30/4.00, or 57.50%, and the analysis of Wonglimpiyarat (2010) revealed that the main obstacles in the development of the national innovation system are the lack of effective links between public and private organizations.

Both Rejeb et al. (2008) and Boly et al. (2014) papers evaluate innovation capability in the context of individual firms, while Wonglimpiyarat (2010) applies the questionnaires at an organizational level, but with the purpose of evaluating a country's innovation capability. Only Allen et al. (2016) performed the analysis in the context of clusters but limited itself to assessing innovation capability using only one measure (patents).

Considering the papers' sample, although the majority focuses on innovation capability, only these four papers do some sort of evaluation of that capability, in different levels of complexity. However, through the content analysis of the sample articles, it was possible to identify several factors that lead or influence the innovation capability, which are shown in Table 11. This table also presents the innovation term used in each article.

The terms with the greatest corroboration in the literature are geographical proximity, absorptive capacity and knowledge exchange, with five, three and three occurrences, respectively. This does not mean that within the entire sample, these and the other terms were not used in other articles. This concerns the factors considered necessary for the innovation capability, in the context of these papers.

Section 4.3 presents the factors and sub-factors used in this research, that influence or impact on the firms' innovation capability. They were grouped according to similarity and will be considered for the development of the evaluation framework.

Table 11: Factors and sub-factors that lead to innovation capability, and the related innovation term

Factors	Sub-factors	Related to	Authors
collective learning	trust / organizational proximity	innovative capability	Capello (1999)
collective learning		innovative capability	Lawson and Lorenz (1999)
collective learning processes		innovation	Quintana-Garcia and Benavides-Velasco (2005)
learning capabilities		technological innovation capability	Strand et al. (2017)
density and quality of relationships among enterprises		innovative capability	Altenburg, Schmitz, and Stamm (2008)
high density and strength of ties between partners		innovation	Elche, García-Villaverde, and Martínez-Pérez (2018)
integrative capabilities	widely diversified knowledge of technologies	innovation	Cappellin (2003)
integrative capabilities	firm-specific knowledge development and exploitation	innovative capability	Herstad and Ebersberger (2014)
interaction with suppliers, customers, public agencies, industry associations, foundations and the like		innovation capability	Romijn and Albu (2002)
network cooperation		capacity for innovation	Christopherson and Clark (2007)
relationships between enterprises and support institutions		innovative capability	Altenburg, Schmitz, and Stamm (2008)
technological collaboration	learning routines and incentives to reveal their own tacit knowledge	innovation	Cappellin (2003)
combinative capability	mobility of skilled personnel on the local labour market	innovative capability	Lawson and Lorenz (1999)
combinative capability	co-operation among independent producers	innovative capability	Lawson and Lorenz (1999)
combinatory capabilities	widely diversified knowledge of technologies	innovation	Cappellin (2003)

Factors	Sub-factors	Related to	Authors
absorptive capacity		innovation capability	Altenburg, Schmitz, and Stamm (2008)
absorptive capacity		innovation capacity	Diez-Vial and Fernandez-Olmos (2015)
absorptive capacity	knowledge acquisition	innovation	Van Geenhuizen (2008)
in-house knowledge capability	the knowledge of each individual working for the firm	innovation	Grillitsch, Todtling, and Hoglinger (2015)
in-house knowledge capability	the homogeneity/diversity of experience and knowledge of staff	innovation	Grillitsch, Todtling, and Hoglinger (2015)
in-house knowledge capability	the communication processes within the firm	innovation	Grillitsch, Todtling, and Hoglinger (2015)
in-house knowledge capability	the role of gatekeepers	innovation	Grillitsch, Todtling, and Hoglinger (2015)
in-house knowledge capability	the expectations and ambitions of the firm	innovation	Grillitsch, Todtling, and Hoglinger (2015)
knowledge exchange		innovation capability	Molina-Morales, Martinez-Fernandez, and Coll-Serrano (2012)
knowledge exchange	trust	innovation	Nooteboom (1999)
knowledge exchange	cultural proximity	innovation	Nooteboom (1999)
knowledge sharing		innovation	Larty, Jack, and Lockett (2017)
managerial knowledge exchange		innovative capability	Sammarra and Biggiero (2008)
market knowledge exchange		innovative capability	Sammarra and Biggiero (2008)
spillovers		innovation	Diez-Vial and Fernandez-Olmos (2015)

Factors	Sub-factors	Related to	Authors
spillovers		innovation	Quintana-Garcia and Benavides-Velasco (2005)
technological knowledge exchange		innovative capability	Sammarra and Biggiero (2008)
market capability	To transform new technological knowledge into marketable products and/or services, firms need to combine and mutually adapt technological knowledge	innovative capability	Sammarra and Biggiero (2008)
marketing capabilities		technological innovation capability	Strand et al. (2017)
marketing capability		technological innovation capability	Yam et al. (2004)
cognitive proximity		innovation	Boschma (2005)
cognitive proximity		innovative capability	Dangelico, Garavelli, and Petruzzelli (2010)
cultural proximity		innovative capability	Capello (1999)
geographic proximity	collective learning processes	innovative capability	Dalcin, Balestrin, and Teixeira (2017)
geographical proximity		innovation	Boschma (2005)
geographical proximity		innovation	Larty, Jack, and Lockett (2017)
geographical proximity	trust and cognitive identification	innovation	Presutti, Boari, and Majocchi (2011)
geographical proximity		innovation capability	Silvestre and Dalcol (2009)
geographical proximity	competitiveness, information exchange, collaboration	innovation	Ucler (2017)
institutional proximity		innovation	Boschma (2005)
organizational proximity		innovation	Boschma (2005)
organizational proximity		innovative capability	Dangelico, Garavelli, and Petruzzelli (2010)

Factors	Sub-factors	Related to	Authors
physical proximity	local transfer of information	Innovation	Atalay, Dirlik, and Sarvan (2017)
physical proximity		Innovation	Cappellin (2003)
social proximity		Innovation	Boschma (2005)
capacities in emerging technologies		capability for innovation	Toivanen (2014)
new technology opportunities		innovative capability	Alvarez, Marin, and Fonfria (2009)
R&D capabilities		technological innovation capability	Strand et al. (2017)
technology capability		innovation capability	Cavalheiro and Brandão (2017)
technological competences		innovativeness	Grillitsch, Todtling, and Hoglinger (2015)
manufacturing capabilities		technological innovation capability	Strand et al. (2017)
organisational capabilities		technological innovation capability	Strand et al. (2017)
resource capabilities		technological innovation capability	Strand et al. (2017)
skilled labour force		innovative capacity	Christopherson and Clark (2007)
strategic capability		technological innovation capability	Strand et al. (2017)

4.3. FACTORS AND SUB-FACTORS FOR INNOVATION CAPABILITY IN INDUSTRIAL CLUSTERS

The factors selected to evaluate the impact (or influence) of the innovation factors on the innovation capability of cluster-based firms, drawn from the SLR and extracted from Table 11, were grouped into five categories, according to theme similarity: network collaboration, knowledge creation and transfer, technology development, market influence, and proximity, according to Table 12. Next, a more detailed explanation is presented.

a) Network collaboration

Firms collaborate to obtain technological and market information, and such interactions with suppliers, customers and public agents can provide important resources for the accumulation of innovation capability (Romijn & Albu, 2002). Innovation processes are strongly linked to the various forms of collaboration between companies, networks and other actors (Cappellin, 2003). Thus, interactions with these different actors were identified as a relevant factor for innovation capability.

It can be observed that collaboration has a strong social character, since it is realized through social relations. In addition, it produces information sharing and knowledge spillovers (which are critical factors for sustainable innovation) so network collaboration promotes a rapid and flexible response to changing and expanding markets, and thus promotes innovation capability (Christopherson & Clark, 2007).

Going beyond what was approached by Romijn and Albu (2002) and Cappellin (2003), Altenburg, Schmitz, and Stamm (2008) point out that the innovation capability also depends on the density and quality of these collaborative relationships, either between companies or between companies and support institutions, an argument corroborated by Elche et al. (2018).

Innovation is based on the ability to establish relationships between internal competences and the needs of customers, supplier networks, other companies and various other intermediary institutions and organizations (Cappellin, 2003), that is, the company must be able to adapt, if necessary, its resources and capabilities in order to establish good collaborative relationships.

Table 12: Factors and sub-factors related to innovation capability

Factors	Synthesis	Sub-factors	Authors
Network collaboration	Collaboration with various actors can provide important resources for building innovation capability.	Relationships between companies Integrative capability Interaction with other entities Technological collaboration Combinative capability	Altenburg, Schmitz, and Stamm (2008); Cappellin (2003); Christopherson and Clark (2007); Elche et al. (2018); Herstad and Ebersberger (2014); Lawson and Lorenz (1999); Romijn and Albu (2002)
Knowledge creation and transfer	The knowledge transit among cluster actors is directly influenced by the capability to share, absorb and pass it on.	Absorptive capacity Knowledge sharing Knowledge spillovers Collective learning Learning capability	Capello (1999); Diez-Vial and Fernandez-Olmos (2015); Grillitsch, Todtling, and Hoglinger (2015); Larty, Jack, and Lockett (2017); Lawson and Lorenz (1999); Molina-Morales, Martinez-Fernandez, and Coll-Serrano (2012); Nooteboom (1999); Quintana-Garcia and Benavides-Velasco (2005); Sammarra and Biggiero (2008); Strand et al. (2017); Van Geenhuizen (2008)
Technology development	Technologies are important sources of innovation and increase the innovation capability of companies.	New technological opportunities Technological capability R&D capability	Alvarez, Marin, and Fonfria (2009); Cavaleiro and Brandão (2017); Strand et al. (2017); Toivanen (2014)
Market influence	The existence of innovations depends on the demand and acceptance of the innovative product, service or process in the market.	Capability to adapt innovation to demand Capability to advertise and sell new products	Sammarra and Biggiero (2008); Strand et al. (2017); Yam et al. (2004)
Proximity	Determining characteristic for the formation of innovative collaborative networks. It includes geographical, cognitive, organizational, social and institutional proximity.	Geographical proximity Cognitive proximity Organizational proximity Social proximity Institutional proximity	Atalay, Dirlik, and Sarvan (2017); Alvarez, Marin, and Fonfria (2009); Boschma (2005); Cappellin (2003); De Bruijn (2004); Fontes and Sousa (2016); Grillitsch, Todtling, and Hoglinger (2015); Quintana-Garcia and Benavides-Velasco (2005); Nooteboom (1999); Petruzzelli, Albino, and Carbonara (2009); Pietrobelli and Rabellotti (2011); Presutti, Boari, and Majocchi (2011); Silvestre and Dalcol (2009)

In relation to the integrative capability, identified in the work of Herstad and Ebersberger (2014), the authors argue that innovative activities are systematic and integrated and therefore companies rely on the integrative capability to develop and exploit their resources. This argument is in line with the concept of collaboration and cooperation.

For technological collaboration, firms need learning routines to reveal their own tacit knowledge (Christopherson & Clark, 2007); thus, in addition to technological collaboration, the company would be able to integrate external knowledge into the company's knowledge base.

Combinative capability is the ability to combine and recombine resources flexibly, and can be achieved through mobility of personnel through the local market, or by establishing formal or informal relations of cooperation (Lawson & Lorenz, 1999). Cappellin (2003) adds that, for innovation, combinative capability assumes a vast and diverse knowledge in technology. In all cases, the ability to combine and adapt resources will depend on a language shared between the actors that make part of the cluster.

b) Knowledge creation and transfer

The way knowledge transits among industrial cluster actors is directly influenced by the ability to share, absorb, and pass on knowledge, which can occur in a formal or informal way.

The absorptive capacity is the ability of the company to identify, seek, acquire and use knowledge (Cohen & Levinthal, 1990) and concerns the effective absorption and application of knowledge in general (Ter Wal & Boschma, 2011). It can be considered a dynamic capability that drives the interactions between the companies in a cluster, whose main source is the level of similar or related competences of the companies (Chandrashekar & Hillemane, 2018; Grillitsch & Nilsson, 2015). According to Nooteboom (1999), a necessary condition for the geographic distance to become irrelevant is the existence of sufficient absorptive capacity.

In order for knowledge to be shared, a common understanding must be developed among the agents (in the case of industrial clusters, between companies) that, to a greater or lesser degree, constitute an investment in the relation (Nooteboom, 1999) and therefore demands firms' resources.

Larty, Jack, and Lockett (2017) suggest that the sharing of knowledge depends on the existence of social networks between companies. In their study, the authors also point out the existence of knowledge sharing intermediaries, such as universities and government agencies, whose role would be to encourage the creation of new networking opportunities between firms, with the objective of facilitating new collaborations and knowledge exchange.

Knowledge spillovers can be considered one of the main reasons behind the formation of clusters, especially high technology ones, and are considered important elements for innovation performance (Quintana-García & Benavides-Velasco, 2005). In general, spillovers are a consequence of easier access to research, ideas, and experiences from universities or research centers, as well as from socially related suppliers, customers, or companies, acquired informally, due to social interactions and geographical proximity (Díez-Vial & Fernández-Olmos, 2015; Quintana-García & Benavides-Velasco, 2005).

The position of a company within an industrial cluster and its access to local spillovers increases the attractiveness of the company to potential partners (Quintana-García & Benavides-Velasco, 2005), since the firm expands its portfolio of knowledge by having access to those of the partner companies.

Also related to the knowledge creation and transfer, organizational learning is an organization's ability to process knowledge - in other words, to create, acquire, transfer and integrate knowledge, aiming at improving performance (Jerez-Gómez, Céspedes-Lorente, & Valle-Cabrera, 2005). While these authors speak of "processing" knowledge, Lawson and Lorenz (1999) argue that organizational learning can be understood as the process of "generation" of knowledge, be it technical, organizational, or related to marketing and sales.

In its turn, learning capability, as defined by Yam et al. (2004), presents a temporal character because it is linked to the organization's ability to identify, assimilate and explore knowledge of the environment, learn from its experiences and pass on this knowledge over time.

Besides learning capability, the literature review identified collective learning as a factor for innovation capability. Capello (1999) points out that the main difference between learning and collective learning lies in the social nature of the latter. In this sense, collective learning can be defined as a cumulative social process of knowledge based on a set of shared rules and procedures that allow individuals to coordinate their

actions in the search for problem solving (Capello, 1999). The author also highlights that, for both types of learning, the transmission of knowledge over time is ensured by the continuous interaction between the agents.

Following the same reasoning, Quintana-García and Benavides-Velasco (2005) argue that the collective learning process is motivated by networks of specialized partners who share complementary resources and competences. Another aspect pointed out by Capello (1999) is that collective learning is intrinsic to the innovative environment. In this way, clusters become environments that are more conducive to collective learning.

c) Technology development

The arrival of new technological opportunities justify the contribution of the networks to the innovative capabilities of firms (Álvarez et al., 2009). The combination of technologies are important sources of innovation (Nooteboom, 1999) and technological competences increase the innovation capability of companies (Grillitsch et al., 2015).

The technological capability is the stock of resources, skills, knowledge and experiences incorporated in the workers and in the organizational system (Cavalheiro, Brandão, & Brandao, 2017). As suggested by Silvestre and Dalcol (2009), the accumulation of technological capability is facilitated by participation in agglomerations, due to the sharing of information and knowledge.

R&D capabilities are defined by Strand et al. (2017) according to the following aspects: the need for sufficient investment in the development of new products and/or services; efficient communication of R&D activities in the various departments or sectors of the company; application of customer feedback in the development of technology, to ensure end-user satisfaction; specification of clear purposes and plans for research projects.

d) Market influence

According to Sammarra and Biggiero (2008), market capability relates to the transformation of new technological know-how into salable products and/or services and that companies need to combine and adapt technological know-how to this end. In the proposed framework, this is called “capability to adapt innovation to demand”.

The “capability to advertise and sell new products” is based on the definition of Yam et al. (2004) of marketing capability. According to the authors, this concerns the ability of a company to advertise and sell products based on an understanding of consumer needs, the competitive environment, costs and benefits and acceptance of innovation.

Strand et al. (2017) define the marketing capability based on four aspects: establishing a good relationship with customers; maintaining a positive reputation; obtaining information from different market segments; customer after-sales service needs. Thus, the market is a determinant of innovation capability because the existence of innovations depends on the demand and acceptance of the innovative product, service or process in the market.

e) Proximity

Proximity is a determining characteristic for the formation of collaborative networks, and there is evidence that networks can increase business competitiveness (Álvarez et al., 2009). However, although the term “proximity” initially seems to refer only to geographic distance, it has other meanings.

According to Boschma (2005), the French School of Proximity Dynamics made a contribution to the literature on innovation when he proposed that proximity encompasses a number of different dimensions: geographical, organizational, and institutional. Boschma (2005) himself added two dimensions to the argument of the French School: social and cognitive proximity.

Some authors suggest another kind, the relational proximity, and argue that it originates from social, organizational and institutional proximities (Fontes & Sousa, 2016; Grillitsch et al., 2015). However, the present study treats these three types of proximity separately.

Geographical proximity can be defined as the spatial distance between the actors (Boschma, 2005). Companies that are geographically close and often are from the same or related sectors are motivated to establish external relationships to access new information and create knowledge (Álvarez et al., 2009; Silvestre & Dalcol, 2009), thus making geographical proximity an important factor of innovation capability.

This happens because a configuration in which the companies are geographically concentrated facilitates a greater exchange of information, through formal and informal communication processes, since, even with advanced

technological tools, certain information is tacit in nature and better transmitted when agents are close (Grillitsch et al., 2015; Quintana-García & Benavides-Velasco, 2005).

Geographical proximity also brings benefits such as reduced transportation costs, ease of access to firms and individuals, sharing of cultural characteristics, in addition to norms, routines, similar customs (Silvestre & Dalcol, 2009).

Organizational proximity, in turn, is defined as the extent to which actors share the same space of relationships in an organizational system, whether within or between organizations (Boschma, 2005). It facilitates interaction since it allows an understanding of the rules, hierarchies and codes of behavior of a given organization (Fontes & Sousa, 2016). Boschma (2005) argues that too much organizational proximity provides a lack of flexibility, while little organizational closeness brings lack of control, increasing the danger of opportunism.

Social proximity is defined in terms of social relations between agents at the micro level, involving trust based on friendship, affinity and experience, since relationships of trust facilitate the exchange of tacit knowledge and decrease the risk of opportunistic behavior (Boschma, 2005). However, Boschma (2005) argues that much social proximity can cause excessive loyalty and lead to the underestimation of situations of opportunism, and can make the members of a network have a determined way of acting to the detriment of their learning and innovation capability.

In its turn, cognitive proximity can be perceived as the existence of understanding, and of a common knowledge base and expertise among the agents (Nooteboom, 1999; Petruzzelli et al., 2009). Nooteboom (1999) argues that there must be, however, a sufficient “cognitive distance”, for otherwise knowledge becomes redundant: nothing new is learned.

Sufficient and mutual cognitive proximity, and trust (which implies dispensing complex, detailed, costly, restrictive contracts and containing spillover risks) are achieved on the basis of shared norms and values, family bond or friendship, or shared routines (Nooteboom, 1999).

Regarding to institutional proximity, it is related to the institutional structure at the macro level and includes both the idea of actors who share the same institutional rules as a set of cultural habits and values (Boschma, 2005). The author cites as examples a common language, shared habits, a system of law that guarantees property and intellectual property rights, etc., which provide a basis for collective learning.

Excessive institutional proximity is unfavorable to new ideas and innovations due to “institutional imprisonment” (obstruction of the awareness of new possibilities) and inertia (barrier to institutional adjustments needed); on the other hand, the lack of institutional proximity is detrimental to collective action and innovation due to weak formal institutions and lack of social cohesion and common values (Boschma, 2005).

It is perceived that proximity in any of its dimensions is not conducive to innovation if it occurs in excess or in scarcity. Thus, the ideal would be an intermediary proximity, which Boschma (2005) denominates “loose coupling”, aiming to protect organizational, social and institutional autonomy within and between organizations, maintain flexibility and satisfactory control.

5. METHODS FOR THE FRAMEWORK PROPOSITION AND APPLICATION

In Chapter 3, the methods for the SLR were described, while its results were reported in Chapter 4. In particular, section 4.3 describes the factors and sub-factors used as input for the framework. In the present chapter, the methodological procedures for the development of this framework and its empirical application are presented. Using a multi-criteria decision method, an evaluation framework was proposed, and then applied in cluster-based companies through multiple case studies.

Most of the papers that study cluster innovation focus on knowledge as a resource or capability. In order to develop the second specific research purpose, “To identify hierarchical relationships and interdependence among the factors of IC in clusters through expert research”, an analysis of the literature was conducted regarding the capabilities required for innovation in cluster-based firms, by defining factors and sub-factors (specific purpose 1).

The study of the capabilities and characteristics that contribute to the firms’ innovation capability, as well as the cluster as a whole, leads to a greater understanding on the subject. At the same time, the framework can be used by companies and cluster managers for decision-making when it comes to organizational capabilities (what to improve, on what to invest, etc.), enabling a better performance of both companies and cluster, and the increase of the competitive advantage.

After defining factors and sub-factors of innovation capability, the evaluation framework can be developed based on the GTA logic, which is presented below.

5.1. GRAPH-THEORETIC APPROACH

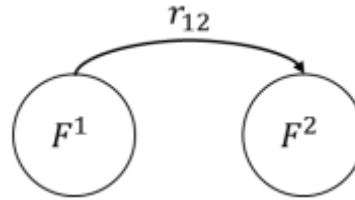
The GTA provides an index to the system, with the aim of evaluating its performance as a whole (Rajesh, Nikhil, & Vivek, 2013). In the present case, it means measuring the innovation capability of the firms, besides providing indexes to the five evaluation factors.

Amongst the many multi-criteria decision methods, GTA remains popular due to its versatility and the possibility to represent qualitative factors graphically and mathematically, with a clear identification of the system, subsystem and its components (Anand & Bahinipati, 2012; Anbanandam et al., 2011). As a result, the decision problem can be easily analyzed (Anbanandam et al., 2011).

Besides the contribution of the factor itself on the system index, GTA considers also the dependence among the other factors (Anand & Bahinipati, 2012). This means the relationship between the factors that lead to IC is considered in the index calculation.

According to Rajesh, Nikhil, and Vivek (2013), GTA “[...] consists of three steps namely – digraph representation, matrix representation and permanent function representation”. To facilitate the comprehension of the system and the method, it will be represented in the images below.

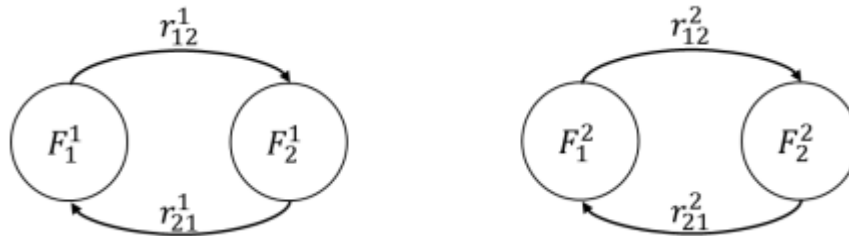
Figure 11: Digraph of a system



The nodes of the digraph represent the measure of the factors that characterize the system, namely F^1 and F^2 . The influence or dependence of F^1 over F^2 is represented by an edge, r_{12} . If the influence happens in also in the opposite direction, another edge (r_{21}) must be drawn.

The same graphic representation can be used for the sub-factors, as shown in Figure 12 for F^1 and F^2 and the sub-factors F_1^1, F_2^1 and F_1^2, F_2^2 . Similarly, the influence or dependence of one sub-factor over another is represented by an edge. For instance, the influence of F_1^1 over F_2^1 is represented by r_{12}^1 .

Figure 12: Digraph representation for F^1 and F^2 sub-factors



When the system has many factors and sub-factors, the analysis can become difficult. So, despite being suitable for visual analysis, for some systems the digraphs are not the most appropriate option for they cannot be computer processed. In this

regard, a matrix can be used as a one to one representation of the digraph, as well as being suitable for computer processing (Rajesh et al., 2013).

Considering that the main problem is F , the square matrix used to represent it is shown in Equation 1. The factors F^1 and F^2 are placed at the main diagonal, and off the main diagonal are the interactions between them. In the example given, F^1 influences F^2 but the opposite does not happen, thus the zero. Comparatively, the sub-factors and their interaction have a matrix representation as shown in Equations 2 and 3.

$$F = \begin{pmatrix} F^1 & r_{12} \\ 0 & F^2 \end{pmatrix}$$

Equation 1

$$F^1 = \begin{pmatrix} F_1^1 & r_{12}^1 \\ r_{21}^1 & F_2^1 \end{pmatrix}$$

Equation 2

$$F^2 = \begin{pmatrix} F_1^2 & r_{12}^2 \\ r_{21}^2 & F_2^2 \end{pmatrix}$$

Equation 3

To know the value of F , the permanent of the matrixes must be calculated. As stated by Rajesh, Nikhil, and Vivek (2013), the permanent representation is the mathematical expression of characteristics (in this case, the factors and sub-factors) and their interdependence. The generic expression for the permanent is presented in Equation 4 (Baykasoglu, 2012). Each element has its value determined by the permanent of its own matrix. Table 13 synthetizes the elements of the permanent.

$$\begin{aligned} per(F) = & \prod_{i=N}^N F_i + \sum_{i,j,...,N} (r_{ij}r_{ji})F_k F_l \dots F_N + \sum_{i,j,...,N} (r_{ij}r_{jk}r_{ki} + r_{ik}r_{kj}r_{ij})F_l F_n \dots F_N \\ & + \left\{ \sum_{i,j,...,N} (r_{ij}r_{ji})(r_{kl}r_{lk})F_n F_m \dots F_N \right. \\ & + \sum_{i,j,...,N} (r_{ij}r_{jk}r_{kl}r_{li} + r_{il}r_{lk}r_{kj}r_{ji})F_n F_m \dots F_N \left. \right\} \\ & + \left[\sum_{i,j,...,N} (r_{ij}r_{ji})(r_{kl}r_{ln}r_{nk} + r_{kn}r_{nl}r_{lk})F_m F_o \dots F_N \right. \\ & + \sum_{i,j,...,N} (r_{ij}r_{jk}r_{kl}r_{ln}r_{ni} + r_{in}r_{nl}r_{lk}r_{kj}r_{ji})F_m F_o \dots F_N \left. \right] + \dots \end{aligned}$$

Equation 4

Table 13: Elements of the permanent

Element	Description
F	Index of the object of study
F^I	Evaluation factor
F_i^I	Evaluation sub-factor
r_{ij}	Influence of factor i over j
r_{ij}^I	Influence of sub-factor i over sub-factor j

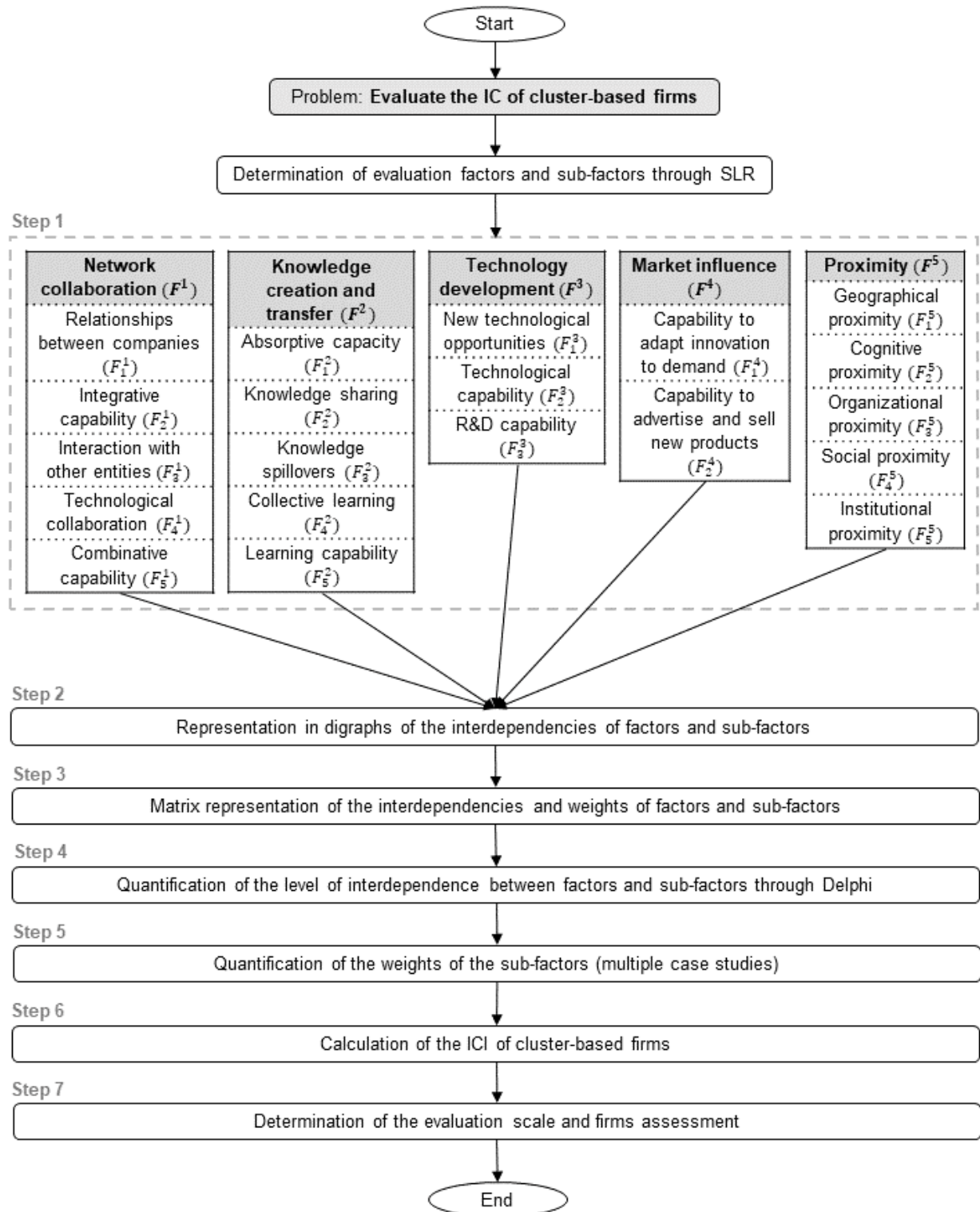
5.2. FRAMEWORK DEVELOPMENT

With the factors and sub-factors at hand, the framework can be developed based on the GTA logic, according to the seven steps described in Table 14 and shown in Figure 13.

Table 14: Methods for the framework proposition and application

Step	Description
1	Determination of evaluation factors and sub-factors
2	Digraph representation of factors, sub-factors, and their interdependencies
3	Matrix representation of interdependencies and weights of factors and sub-factors
4	Quantification of the level of interdependence between factors and sub-factors through Delphi
5	Quantification of weights of the sub-factors through multiple case studies
6	Calculation of the ICI of cluster-based firms
7	Determination of the evaluation scale and firms assessment

Figure 13: Evaluation framework of innovation capability of cluster-based firms



5.2.1. Step 1: Determination of the evaluation factors and sub-factors

This is the first step of the methodology and it was achieved through the SRL, described in section 3.2 and whose result was shown in chapter 4. The selected factors are presented in Table 15, now using a GTA-appropriate nomenclature.

Table 15: Factors and sub-factors for the evaluation of IC of cluster-based firms

Factors (F^I)	Sub-factors (F_i^I)
Network collaboration (F^1)	Relationships between companies (F_1^1)
	Integrative capability (F_2^1)
	Interaction with other entities (F_3^1)
	Technological collaboration (F_4^1)
	Combinative capability (F_5^1)
Knowledge creation and transfer (F^2)	Absorptive capacity (F_1^2)
	Knowledge sharing (F_2^2)
	Knowledge spillovers (F_3^2)
	Collective learning (F_4^2)
	Learning capability (F_5^2)
Technology development (F^3)	New technological opportunities (F_1^3)
	Technological capability (F_2^3)
	R&D capability (F_3^3)
Market influence (F^4)	Capability to adapt innovation to demand (F_1^4)
	Capability to advertise and sell new products (F_2^4)
Proximity (F^5)	Geographical proximity (F_1^5)
	Cognitive proximity (F_2^5)
	Organizational proximity (F_3^5)
	Social proximity (F_4^5)
	Institutional proximity (F_5^5)

5.2.2. Step 2: Digraph representation of factors, sub-factors, and their interdependencies

In step 2, the factors and sub-factors are represented by digraphs. Figure 14 represents the evaluation factors, while Figures 15 to 19 show the digraphs of the sub-factors. Initially, it is considered that all factors and sub-factors have influence on one another.

Figure 14: Digraph of evaluation factors

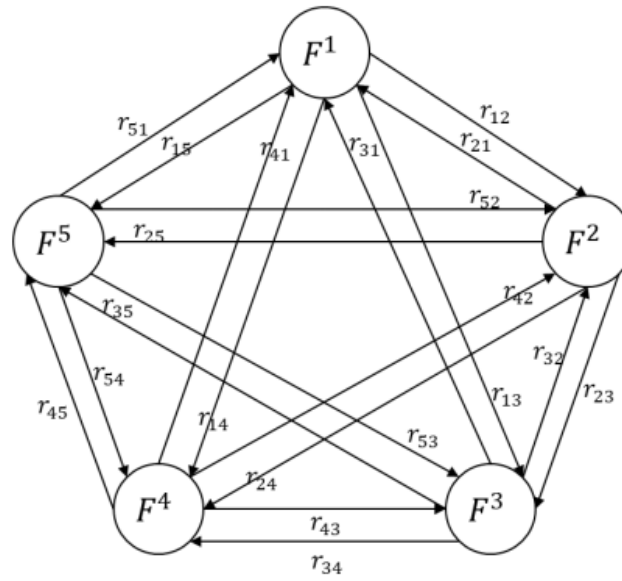
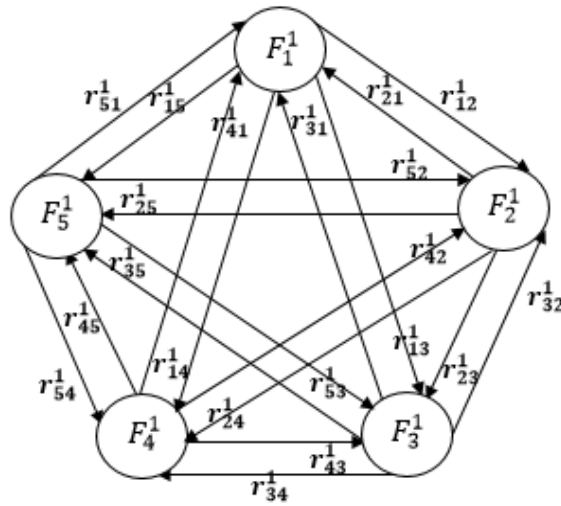
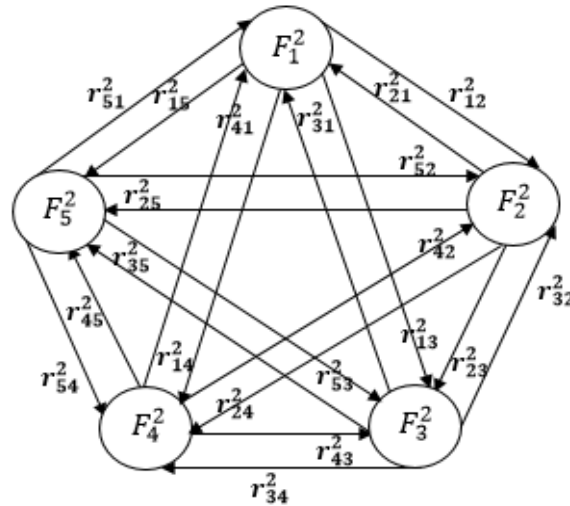
Figure 15: Digraph of the sub-factor F^1 Figure 16: Digraph of the sub-factor F^2 

Figure 17: Digraph of the sub-factor F^3

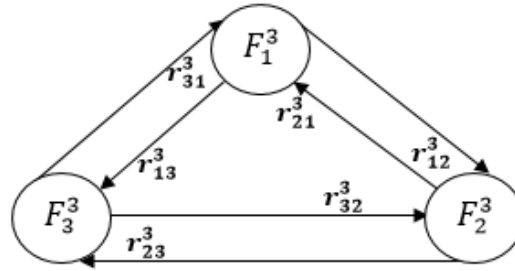


Figure 18: Digraph of the sub-factor F^4

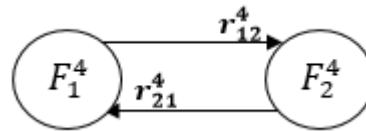
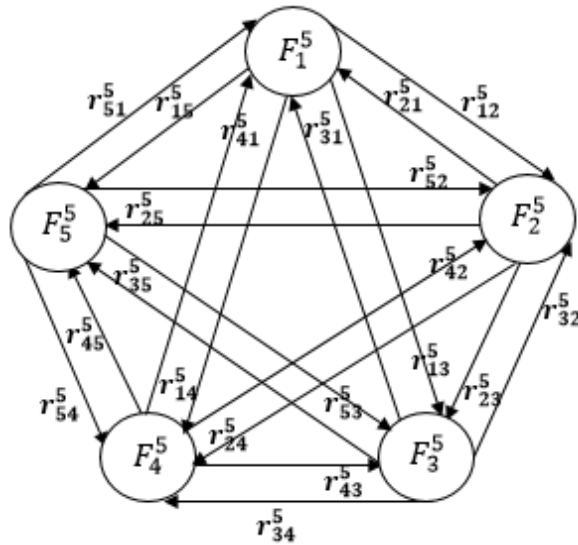


Figure 19: Digraph of the sub-factor F^5



5.2.3. Step 3: Matrix representation of interdependencies and weights of factors and sub-factors

In Step 3, the digraphs are represented as matrixes, as shown in Equations 5 to 10.

$$ICI = per \begin{pmatrix} F^1 & r_{12} & r_{13} & r_{14} & r_{15} \\ r_{21} & F^2 & r_{23} & r_{24} & r_{25} \\ r_{31} & r_{32} & F^3 & r_{34} & r_{35} \\ r_{41} & r_{42} & r_{43} & F^4 & r_{45} \\ r_{51} & r_{52} & r_{53} & r_{54} & F^5 \end{pmatrix}$$

Equation 5

$$F^1 = per \begin{pmatrix} F_1^1 & r_{12}^1 & r_{13}^1 & r_{14}^1 & r_{15}^1 \\ r_{21}^1 & F_2^1 & r_{23}^1 & r_{24}^1 & r_{25}^1 \\ r_{31}^1 & r_{32}^1 & F_3^1 & r_{34}^1 & r_{35}^1 \\ r_{41}^1 & r_{42}^1 & r_{43}^1 & F_4^1 & r_{45}^1 \\ r_{51}^1 & r_{52}^1 & r_{53}^1 & r_{54}^1 & F_5^1 \end{pmatrix}$$

Equation 6

$$F^2 = per \begin{pmatrix} F_1^2 & r_{12}^2 & r_{13}^2 & r_{14}^2 & r_{15}^2 \\ r_{21}^2 & F_2^2 & r_{23}^2 & r_{24}^2 & r_{25}^2 \\ r_{31}^2 & r_{32}^2 & F_3^2 & r_{34}^2 & r_{35}^2 \\ r_{41}^2 & r_{42}^2 & r_{43}^2 & F_4^2 & r_{45}^2 \\ r_{51}^2 & r_{52}^2 & r_{53}^2 & r_{54}^2 & F_5^2 \end{pmatrix}$$

Equation 7

$$F^3 = per \begin{pmatrix} F_1^3 & r_{12}^3 & r_{13}^3 \\ r_{21}^3 & F_2^3 & r_{23}^3 \\ r_{31}^3 & r_{32}^3 & F_3^3 \end{pmatrix}$$

Equation 8

$$F^4 = per \begin{pmatrix} F_1^4 & r_{12}^4 \\ r_{21}^4 & F_2^4 \end{pmatrix}$$

Equation 9

$$F^5 = per \begin{pmatrix} F_1^5 & r_{12}^5 & r_{13}^5 & r_{14}^5 & r_{15}^5 \\ r_{21}^5 & F_2^5 & r_{23}^5 & r_{24}^5 & r_{25}^5 \\ r_{31}^5 & r_{32}^5 & F_3^5 & r_{34}^5 & r_{35}^5 \\ r_{41}^5 & r_{42}^5 & r_{43}^5 & F_4^5 & r_{45}^5 \\ r_{51}^5 & r_{52}^5 & r_{53}^5 & r_{54}^5 & F_5^5 \end{pmatrix}$$

Equation 10

5.2.4. Step 4: Quantification of the level of interdependence between factors and sub-factors through Delphi

As part of the evaluation framework, the Delphi method was used as a tool for the quantification of the level of influence or interdependence between factors and sub-factors, represented by r_{ij} and r_{ij}^I , respectively.

The Delphi consists of a technique to obtain a collective view of a subject by soliciting the opinion of experts, generally when there is no or little evidence (Okoli & Pawlowski, 2004; Thangaratinam & Redman, 2005). The anonymity of the respondents is guaranteed, and according to Okoli and Pawlowski (2004), the absence of direct confrontation among panelists is one of the biggest advantages of the Delphi

approach. The author also points out that Delphi is a popular tool for prioritizing issues for managerial decision-making. Thus, it fits well the purposes of the present research.

As stated by Thangaratinam and Redman (2005), it is “[...] an iterative questionnaire exercise with controlled feedback to a group of panellists who are anonymous”. The iterative nature is necessary to reach the consensus, so, Delphi usually requires a minimum of two rounds, and most studies use up to three rounds (Thangaratinam and Redman, 2005). However, there is no strict definition of the number of needed rounds in the scientific literature.

Okoli and Pawlowski (2004) compare Delphi to traditional surveys and suggest that the first provides richer data due to the multiple iterations and the possibility of revision of responses. In this sense, from the second round on, the researcher designs the questionnaires in a manner the experts will be able to reconsider their opinion based on the group responses, until a satisfactory degree of consensus is reached (Okoli & Pawlowski, 2004).

Regarding the panelists, Okoli and Pawlowski (2004) indicate the necessity of choosing appropriate experts who are qualified to answer the questions. Scientific literature also does not have a consensus about the “appropriate” number of participants, however, Rowe and Wright (1999) indicate the groups can have from 3 to 98 experts, whilst Thangaratinam and Redman (2005) mention that panel sizes can range from 4 to 3000.

The questionnaires usually ask the experts to assign a level of importance to a list of items, generally using a linear numerical scale. In the present case, the experts were asked to judge the relationships between factors and sub-factors and to assign the level of importance for each of these relations, besides open questions and suggestions boxes for commentaries.

It is important to note that, up until this point, the proposed framework is in its generic form. Now, it will be explained how the Delphi technique was put into practice in the present study and then joined with GTA to calculate the index of IC.

The Delphi technique was applied in step 4 of the proposed framework, which regards the interactions between the factors and those between the sub-factors. The weights of these interactions were determined using the Delphi method, which collected the opinion of experts in the area of study.

In this research, the experts were selected within the main article sample (sample 2) and in consultation to Lattes Platform (database of Brazilian researchers’

résumés). The selection criteria were (1) to have publications and/or (2) research projects related to the topic of study.

To analyze the level of influence of these relationships, we adopted a Likert scale, as suggested by Anand and Bahinipati (2012) and Thangaratinam and Redman (2005). Besides the 5-point Likert scale, the experts could also attribute 0 (zero) when they judged there was no influence among those factors or sub-factors (Table 16).

Table 16: Evaluation scale between factors and sub-factors

Value	Level of influence
0	No influence
1	Very weak
2	Weak
3	Average
4	Strong
5	Very strong

The questionnaires were elaborated (Appendix B) and sent via e-mail to 101 experts. From the 101 e-mails sent in the first round, 18 experts replied declining the invitation claiming they were not able to participate for various reasons (being busy, on sick leave, on vacation, etc.). Other 76 e-mails were not replied, which then leads to 7 valid responses. In this research, there were 3 rounds of Delphi. The period between the first and the last round was 3 months.

In the second round, the questionnaire was adapted to show the following information: lowest value, highest value, and most frequent value for each of the relationships r_{ij}^I . When the weight given in the first round was not convergent to the most frequent value, the expert then was asked to consider, upon reflection, if he/she would maintain or change the given weight. From the 7 e-mails sent, 6 experts answered.

For the third round, the questionnaire was again modified, this time with a panorama of the second round, containing the most frequent value and the weight given by the expert. Analogously to the second round, the weights that converged with the most frequent value did not need to be reconsidered. Table 17 shows a summary of the three rounds.

Table 17: Delphi rounds

Round	Length	Number of invited experts	Number of replies	Percentage of replies
1	2 months	101	7	6,93%
2	9 days	7	6	85,71%
3	19 days	6	4	66,67%

For each round, the weights given by the experts were submitted to a statistical test of agreement, Kendall's coefficient of concordance (W), in order to measure the convergence of the rounds. According to Legendre (2010), Kendall's coefficient is "a measure of the agreement among several (m) quantitative or semiquantitative variables that are assessing a set of n objects of interest".

In this dissertation, m is the number of experts and n is the influence among factors and sub-factors. The coefficient varies between 0 (no agreement between experts) and 1 (complete agreement among experts) (Azevedo et al., 2012).

The methodology suggested by Azevedo et al. (2012) was replicated. The application MegaStat for Microsoft Excel was used to calculate the coefficient for the sets of responses for the factors and sub-factors. To corroborate the results of W , another statistical measure was applied: p-value. It indicates the level of statistical significance of W and should be below 5% (0,05).

The detailed results are shown in chapter 6, section 6.1.

5.2.5. Step 5: Quantification of weights of the sub-factors through multiple case studies

For the application of the proposed framework, this step was carried out through multiple case studies in a group of companies that are part of an ICT and CE cluster in Recife, capital of the state of Pernambuco, located in the northeast region of Brazil.

According to Miguel (2007, p. 4), the case study "is a study of an empirical nature that investigates a certain phenomenon, usually contemporary, within a real context of life, [...] to stimulate understanding, to suggest hypotheses and questions or to develop the theory".

Thus, the application of the framework through multiple case studies will contribute to demonstrating its applicability by showing it is useful, easy to use, and allows the firms to know their ICI, thus promoting a better understanding of the processes and the innovation capabilities of the companies involved.

The multiple case studies contribute to a greater degree of generalization of the proposed framework and enable an in-depth study of the participating companies (Yin, 2015), allowing a better understanding of the influence of the innovation factors on the IC of these companies. The case study was carried out according to the following steps: (1) definition of the theoretical conceptual structure; (2) case planning; (3) data collection; (4) data analysis and (5) generation of the final report (Miguel, 2007; Yin, 2015), further explained in Table 18.

Table 18: General procedures for the development of the case studies

Step	Description
1 Definition of the theoretical conceptual structure	The first step of a case study is the definition of a theoretical and conceptual background, presented in Chapter 2. The definition of the research questions is also part of the initial stage.
2 Case planning	In this step, the analysis units (single or multiple case), the sector, the time (retrospective or longitudinal), and the contacts are selected. The planning phase also involves the development of the collection protocol, which deals with the context and the part investigated.
3 Data collection	For the data collection, a questionnaire and a semi-structured interview script was used (Appendix C). In each company, the interview was applied with a person responsible for the innovation processes and/or decision makers in the strategic area.
4 Data analysis	For the analysis of the data from the questionnaires, the data obtained was transferred to a spreadsheet using Microsoft Excel, from which it was possible to generate the necessary matrices from the GTA, as explained in section 5.1 and shown in section 6.4. Regarding the data obtained through the interviews, the information was submitted to a content analysis, in order to justify the answers obtained through the questionnaires. The information was analyzed and presented within-cases and cross-cases, as suggested by Yin (2015).
5 Generation of the final report	After the data triangulation, the empirical research report was generated, and is presented in chapter 5.

Since the framework proposes the evaluation of the IC of cluster-based firms, the companies chosen to participate are inserted in the context of a cluster. Another important aspect is the innovative character of the companies. Whereas the cluster itself has innovation as its main axis, all the selected firms develop innovative activities in ICT and CE industries.

The data collection (step 3) through questionnaires has the objective of evaluating the influence of the innovation factors on the IC of the firms. The semi-structured interviews (with open questions), in their turn, have the purpose of

contextualizing and justifying the information that was obtained through the questionnaires.

To schedule the interviews, the firms were contacted by phone and e-mail. In total, 67 calls were made and 12 e-mails were sent. At the end, 5 interviews were scheduled and applied *in loco* in March 2019.

The interviews were made with one person per company, except for company B (see Table 23, section 6.3). All the interviewees participate actively in the innovation process inside the companies, either as a strategic/business manager or as a project manager. Since the companies are small-sized, interviewing one person per firm – if that individual is responsible or directly involved in the decision-making regarding innovation –, was sufficient for the expected results.

The data collection protocol (interview script) is presented in Appendix C. It contains open questions in the format of a semi-structured interview, in which the interviewee is free to make comments, contextualize and exemplify, describing their impressions on the sub-factors of innovation capability.

After each section (which corresponds to one sub-factor), there is a questionnaire in which the interviewee is asked to impute a numeric grade for the sub-factor. The 9-point Likert scale used for this evaluation is shown in Table 19, as recommended by Anand and Bahinipati (2012).

Table 19: Scale used for the degree of importance of the evaluation sub-factors

Value	Importance scale
1	Extremely low
2	Vary low
3	Low
4	Marginally low
5	Average
6	Marginally high
7	High
8	Very high
9	Extremely high

Since the open questions are based on the literature and directly related to the sub-factors mapped in step 1 (section 5.1), the interviewee was led to reflect on that theme before being asked to grade each sub-factor. The interviews lasted an average of 75 minutes, were recorded and transcribed, totaling 90 pages.

In order to develop step 5 of the proposed framework, as the case studies were used to apply and validate the evaluation framework, the information was analyzed and presented within-cases and cross-cases, as suggested by Yin (2015), thus becoming possible to perform the triangulation of data from the identification of the convergences and divergences of the sources of evidence.

At the within-case analyses, the answers from the interviews were submitted to content analysis, in which the results of the framework were contextualized. The cross-case analysis confronted the results of each case amongst them and with the theoretical background presented in this study.

5.2.6. Step 6: Calculation of the ICI

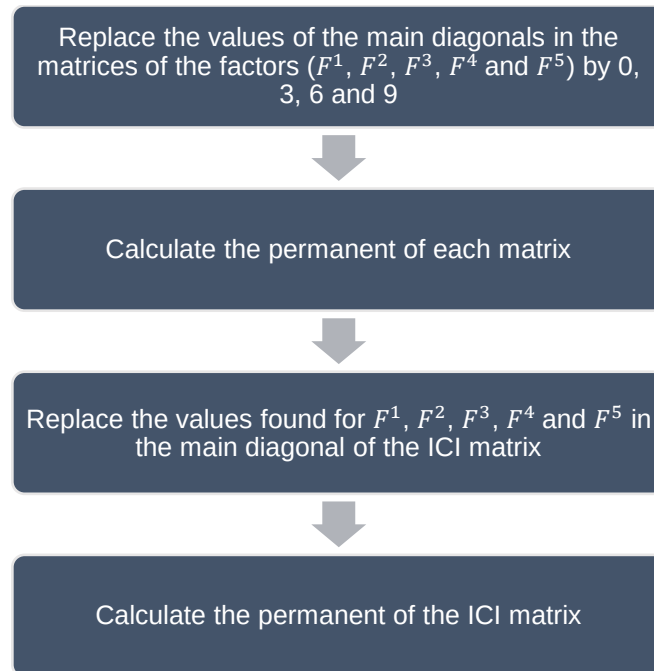
After the experts panel and the multiple case studies, all the factors (F^I), sub-factors (F_i^I) and their relationships/interdependencies (r_{ij} and r_{ij}^I) are mapped. Thus, it is possible to proceed to the next phase of the framework: the calculation of the ICI of the cluster-based firms.

First, the permanent of the matrixes regarding each factor F^I is calculated, which results in the firm's result for that specific factor. With these five permanents at hand, the permanent of the ICI matrix is calculated, as explained in section 5.2.1.

The software MATLAB was used in this step. The detailed calculation is shown in chapter 6.

5.2.7. Step 7: Determination of the evaluation scale

After the determination of the ICI, it is necessary to determine an evaluation scale in which each firm's index can be inserted and then compared to, that is, construction of the scenario analysis. In that sense, the values of the main diagonal of the matrixes are replaced by the worst and best case scenario, that is, when the sub-factors have extremely low or extremely high influence. This way, it was possible to assess whether the IC index is satisfactory or not, namely, if it approaches the best practical index. The procedure is detailed in Figure 20.

Figure 20: Procedures to determine the evaluation scale

Lastly, it was possible to compare the ICI of each firm, as described in the next chapter. A logarithmic scale was used in the construction of the classification scale, to simplify the understanding and interpretation of the values, as well as the comparison among firms. With this step, the development and application of the framework is concluded.

6. DESCRIPTION OF RESULTS

This chapter presents the results of GTA application through the panel of experts and the case studies. All the calculation explained in chapter 5 is shown and detailed the following in sections, until the ICI is calculated, following the steps described in Table 14. Table 20 below recalls the factors, sub-factors, their symbols and descriptions.

Table 20: Factors, sub-factors, their symbols and descriptions

Element	Symbol	Description
Factors (F^I)	F^1	Network collaboration
	F^2	Knowledge creation and transfer
	F^3	Technology development
	F^4	Market influence
	F^5	Proximity
Sub-factors (F_i^I)	F_1^1	Density and quality of relationships between companies
	F_2^1	Integrative capability
	F_3^1	Interaction with other entities
	F_4^1	Technological collaboration
	F_5^1	Combinative capability
	F_1^2	Absorptive capacity
	F_2^2	Knowledge sharing
	F_3^2	Knowledge spillovers
	F_4^2	Collective learning
	F_5^2	Learning capability
	F_1^3	New technological opportunities
	F_2^3	Technological capability
	F_3^3	R&D capability
	F_1^4	Capability to adapt innovation to demand
	F_2^4	Capability to advertise and sell new products
	F_1^5	Geographical proximity
	F_2^5	Cognitive proximity
	F_3^5	Organizational proximity
	F_4^5	Social proximity
	F_5^5	Institutional proximity

6.1. STEPS 1-3: DETERMINATION OF EVALUATION FACTORS AND SUB-FACTORS, DIGRAPH AND MATRIX REPRESENTATIONS

Steps 1, 2 and 3 were described in chapter 5, sections 5.2.1, 5.2.2 and 5.2.3, respectively. Step 1 corresponds to the results of the SLR, while steps 2 and 3 regard the digraph and matrix representation of factors and sub-factors. Sections 6.2 to 6.5 show the results of steps 4 to 7.

6.2. STEP 4: QUANTIFICATION OF THE LEVEL OF INTERDEPENDENCE BETWEEN FACTORS AND SUB-FACTORS: DELPHI RESULTS

As explained in section 5.2.4, Delphi was used to quantify the influences or interdependencies between the factors and sub-factors. At the first round questionnaires sent via e-mail, each expert attributed weights, varying from 1 to 5 (or 0, if there was no influence). The answers were classified using the following criteria: lowest value, highest value, and most frequent value for each of the relationships r_{ij}^l . The results are shown in Appendix D.

At the second round, each expert received a questionnaire in which he/she had a panorama of the first round. When the weight given in the first round was not convergent to the most frequent value, the expert then was asked to consider, upon reflection, if he/she would maintain or change the given weight. The second round result are also shown in Appendix D.

In the third round, another version of the questionnaire was sent, this time with a panorama of the second round, containing the most frequent value and the weight given by the expert. Analogously to the second round, the weights that converged with the most frequent value did not need to be reconsidered. The tables containing the results for the third round are shown in Appendix D.

With these results, Kendall's coefficient of concordance (W) was used to measure the convergence of the rounds, as indicated in section 5.2.4. Besides W , another statistical measure was used for analysis: p-value.

The coefficient of concordance shows that there was an improvement between rounds and the level of significance at the third round was below 0,05 for all sets of data, except for F^4 (see Table 21). The infinitesimal values were rounded to zero.

Table 21: Convergence of rounds – Kendall's coefficient and level of significance

Data		Round 1		Round 2		Round 3	
		W	p-value	W	p-value	W	p-value
Factors		0.420	0.0000	0.657	0.0000	0.685	0.0001
Sub-factors	F^1	0.233	0.0408	0.598	0.0000	0.816	0.0000
	F^2	0.215	0.0731	0.526	0.0000	0.685	0.0001
	F^3	0.223	0.1680	0.409	0.0314	0.787	0.0076
	F^4	0.257	0.1797	0.500	0.0833	0.750	0.0833
	F^5	0.348	0.0004	0.637	0.0000	0.668	0.0001

Factor F^4 (market influence) has only two sub-factors and, hence, only two interactions. Besides, the number of experts decreased from round two to three, lowering the amount of data. These two facts can explain the p-value of 0,0833.

However, although the p-value of F^4 is not inside the expected range (0,05 or less), it is very close, and it can be assumed that the level of agreement is satisfactory in the third round, specially due to the values of W .

Whereas the results shown in Table 21 and the necessity to consider all the experts' opinions in the matrices of factors and sub-factors, the average of the third round weights was calculated for each relation. The average weights are shown in Table 22, as well as the matrices containing these values are presented below (Equations 11 to 16).

Table 22: Average weights of the relations between factors and sub-factors

Relation	Avg	Relation	Avg	Relation	Avg	Relation	Avg	Relation	Avg
r_{12}	4.75	r_{12}^1	4	r_{12}^2	2.5	r_{12}^3	3.25	r_{12}^5	3.5
r_{13}	4.25	r_{13}^1	4.75	r_{13}^2	1.5	r_{13}^3	3.25	r_{13}^5	2.75
r_{14}	3	r_{14}^1	4	r_{14}^2	3.5	r_{21}^3	4.75	r_{14}^5	4.5
r_{15}	3.75	r_{15}^1	4.75	r_{15}^2	4.5	r_{23}^3	4.75	r_{15}^5	3.25
r_{21}	3.25	r_{21}^1	2.25	r_{21}^2	2.75	r_{31}^3	3.75	r_{21}^5	1.25
r_{23}	4.75	r_{23}^1	2.5	r_{23}^2	4.75	r_{32}^3	4.75	r_{23}^5	2.25
r_{24}	1.75	r_{24}^1	3.25	r_{24}^2	5	r_{12}^4	4.75	r_{24}^5	4.5
r_{25}	3	r_{25}^1	4	r_{25}^2	4	r_{21}^4	3.75	r_{25}^5	4
r_{31}	3.25	r_{31}^1	4	r_{31}^2	3	-	-	r_{31}^5	1.75
r_{32}	4	r_{32}^1	4	r_{32}^2	3.5	-	-	r_{32}^5	3
r_{34}	3.25	r_{34}^1	3.75	r_{34}^2	4	-	-	r_{34}^5	2.5
r_{35}	1.5	r_{35}^1	3.25	r_{35}^2	3.5	-	-	r_{35}^5	3
r_{41}	3	r_{41}^1	4	r_{41}^2	5	-	-	r_{41}^5	1.5
r_{42}	3.25	r_{42}^1	3.25	r_{42}^2	4.5	-	-	r_{42}^5	4.25
r_{43}	3.5	r_{43}^1	1.75	r_{43}^2	3.25	-	-	r_{43}^5	2.75
r_{45}	3	r_{45}^1	3.75	r_{45}^2	4.25	-	-	r_{45}^5	3.5
r_{51}	4.5	r_{51}^1	3	r_{51}^2	5	-	-	r_{51}^5	2
r_{52}	4	r_{52}^1	4.5	r_{52}^2	3.25	-	-	r_{52}^5	2.5
r_{53}	3.75	r_{53}^1	3	r_{53}^2	3	-	-	r_{53}^5	2.25
r_{54}	3	r_{54}^1	3.75	r_{54}^2	4.25	-	-	r_{54}^5	3

$$ICI = per \begin{pmatrix} F^1 & 4.75 & 4.25 & 3 & 3.75 \\ 3.25 & F^2 & 4.75 & 1.75 & 3 \\ 3.25 & 4 & F^3 & 3.25 & 1.5 \\ 3 & 3.25 & 3.5 & F^4 & 3 \\ 4.5 & 4 & 3.75 & 3 & F^5 \end{pmatrix}$$

Equation 11

$$F^1 = per \begin{pmatrix} F_1^1 & 4 & 4.75 & 4 & 4.75 \\ 2.25 & F_2^1 & 2.5 & 3.25 & 4 \\ 4 & 4 & F_3^1 & 3.75 & 3.25 \\ 4 & 3.25 & 1.75 & F_4^1 & 3.75 \\ 3 & 4.5 & 3 & 3.75 & F_5^1 \end{pmatrix}$$

Equation 12

$$F^2 = per \begin{pmatrix} F_1^2 & 2.5 & 1.5 & 3.5 & 4.5 \\ 2.75 & F_2^2 & 4.75 & 5 & 4 \\ 3 & 3.5 & F_3^2 & 4 & 3.5 \\ 5 & 4.5 & 3.25 & F_4^2 & 4.25 \\ 5 & 3.25 & 3 & 4.25 & F_5^2 \end{pmatrix}$$

Equation 13

$$F^3 = per \begin{pmatrix} F_1^3 & 3.25 & 3.25 \\ 4.75 & F_2^3 & 4.75 \\ 3.75 & 4.75 & F_3^3 \end{pmatrix}$$

Equation 14

$$F^4 = per \begin{pmatrix} F_1^4 & 4.75 \\ 3.75 & F_2^4 \end{pmatrix}$$

Equation 15

$$F^5 = per \begin{pmatrix} F_1^5 & 3.5 & 2.75 & 4.5 & 3.25 \\ 1.25 & F_2^5 & 2.25 & 4.5 & 4 \\ 1.75 & 3 & F_3^5 & 2.5 & 3 \\ 1.5 & 4.25 & 2.75 & F_4^5 & 3.5 \\ 2 & 2.5 & 2.25 & 3 & F_5^5 \end{pmatrix}$$

Equation 16

At this point, by quantifying the relationships between the factors and sub-factors, the IC evaluation framework can be applied in any cluster-based firm, which makes it generic. However, in order to meet the last specific objective of this dissertation, the framework was applied in five firms that follow the determined criteria, in order to validate the IC evaluation framework, as presented in section 6.4.

Sections 6.2 and 6.3 present, respectively, the characterization of the cluster and the firms where the case studies were performed.

6.3. STEP 5: QUANTIFICATION OF WEIGHTS OF THE SUB-FACTORS THROUGH MULTIPLE CASE STUDIES

6.3.1. Characterization of the cluster

Since the present dissertation focuses on the evaluation of the innovation capability, the choice of the interorganizational network had to be coherent with that

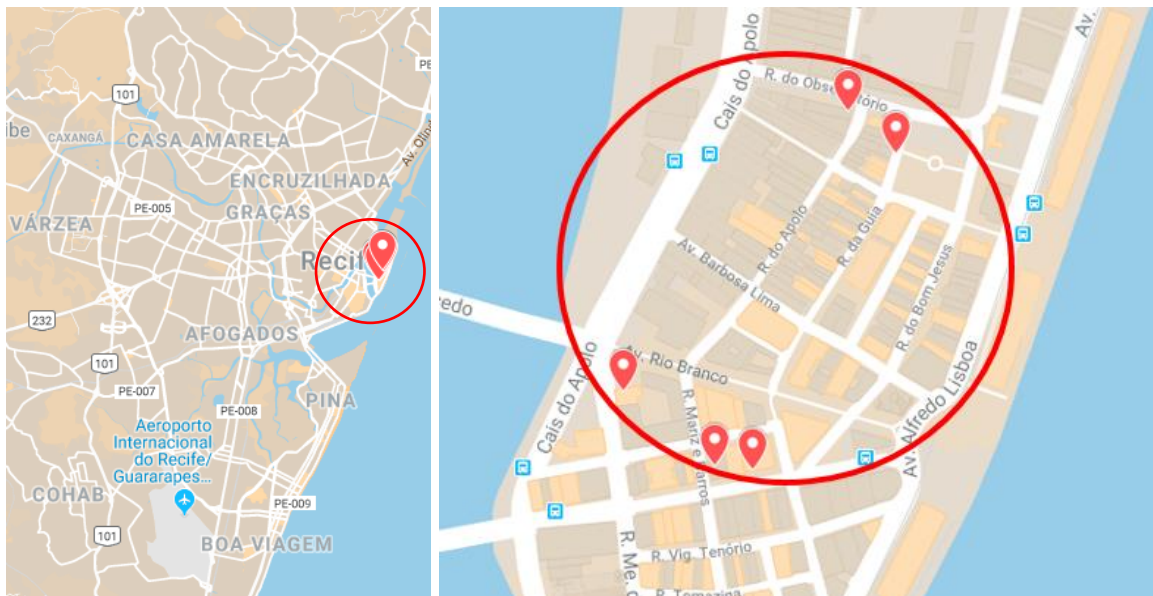
context. In this sense, the cluster chosen to develop the study is a renowned innovation environment in Brazil, with approximately 300 companies and support institutions, and 9,000 workers. It is located in the city of Recife, capital of the state of Pernambuco, one of the biggest cities of the northeast region of Brazil.

The cluster operates in two big areas: Information and Communications Technology (ICT) and Creative Economy (CE), and its companies produces both goods and services in the segments of software development, communications, games, design, music, cinema, among others.

6.3.2. Characterization of the firms

The five firms that agreed to participate in the case studies are located in the downtown of Recife, in a radius of approximately 320 meters (Figure 21). Their main aspects are presented in Table 23, as well as a summarized description of the interviewees.

Figure 21: Location of cluster and firms



Hereafter, a description of the firms is made, detailing the information presented in Table 23 and other aspects considered relevant to the discussion of results presented in Chapter 7 – such as relationships with competition, government, associations, universities and research centers. It is important to point out that all the firms involved in the study use computers and softwares as the means to develop their

end goods and services. Thus, the suppliers are the same for the five firms: computer and software companies.

Table 23: Brief description of participant firms and interviewees

Firm	Main area of activity	Founded	Number of employees	Position of the interviewees	Time in the company
A	Development of IT solutions for schools and universities	2007	20	CEO	12 years
B	Support and commercialization of IT solutions for drugstores	2001	9	Co-founder, commercial director	17 years
				Support analyst, management	1 year, 5 months
C	Future forecasting	2017	4	Founder, senior futurist	2 years
D	Development of IT and design solutions	2017	6	Co-founder, CEO	2 years
E	Game development	2013	10 (+7 freelancers)	Producer, project manager	1 year, 4 months

Firm A

Since its opening in 2007, this company's focus is the development of information technology (IT) solutions in the education area, which interviewee A calls "educational technology", both for schools and universities. Their clients range from private school and universities, to a few Brazilian state governments and institutions such as SENAC. In the past few years, firm A also began to develop corporate solutions outside the educational field, mainly in artificial intelligence and automation.

According to interviewee A, there are no competitors in the educational segment, once firm A was a pioneer in the northeast region of Brazil and has a solid position in the market. Regarding government support, the respondent said he saw no influence and stated their company was "100% private".

In respect to associations, the respondent talked about the importance of an association of technology in the state of Pernambuco, Sucesu-PE, in which he has a position as president of innovation projects. This organization promotes events for its associated members with renowned professionals in the innovation area, with the aim of bringing enlightenment about new technology uses and developments.

When it comes to universities and research centers, the interviewee pointed out their relationships were directly with students, meaning there are no formal projects and relationships between the company and the universities itself. They independently select and hire the students for internships. The company has a coworking space near the biggest public university of Recife, where the students hired as interns have facilitated access to a working space in a convenient location.

Firm B

In the market since 2001, firm B has two main areas of activity: (1) commercialization of IT solutions for drugstores, as well as after-sales technical support, which represents 70% of the activity of the company; and (2) development of servers, safety methods and systems for data backup.

This interview had two participants, one being its co-founder and commercial director (interviewee B1), and the other works as a support analyst and acts in managerial areas, giving support to the board of directors (interviewee B2).

In what concerns the competition, interviewee B1 pointed out that the growing number of drugstores in Brazil entailed the expansion of the competing firms, both in and outside of the northeast region. On the topic of government support, both respondents allege the influence is indirect; for instance, when the federal government fomented the creation of “popular drugstores”, the market grew and, thereafter, the company was positively affected.

The relationships with associations of drugstores is considered solid by interviewee B1, while B2 pointed out the associations act as bridges since the company is able to establish partnerships with clients through this linkage. Firm B does not invest in relationships with universities and research centers.

Firm C

The company opened formally at the year of 2017 and works with strategic consulting in the area of future studies/forecasting and strategic foresights, using design tools to create prototypes of alternative visions of long-term future (15 to 50 years). Interviewee C affirms that their work is still not widely understood amongst the potential clientele, since it exceeds the frontiers of the customary strategic consulting. However, firm’s clients include, for instance, the Cluster’s Management Center (CMC) and a large Brazilian retail company with on and offline presence.

Regarding the competitive scenario, the respondent points out that there are no other companies that do exactly what they do, neither in Brazil or abroad. There are giant and renowned companies that develop strategic consulting, but do not involve the design features, and companies that focus on innovative design, which is also not the focus of firm C.

As for government support, the interviewee claimed their firm does not exactly fit the public calls for innovation, because they usually request a good or service such as a software, and firm C creates products (which can vary from short movies, to a role-playing or a simulation) as a mean to prototype the future for a specific client request.

On the question of universities and research centers, interviewee C mentioned he and another member of the company are teachers at a private university located inside the cluster. So, both of them have close relations in this environment but not as a company. However, since they are involved in innovation labs and projects, this ends up somehow influencing their acting in the company context.

Besides, interviewee C is also filiated to international organizations and associations as an individual, which affects the firm nonetheless. The respondent also stated they intend to associate themselves as a firm in a near future. Regarding the relationship with the cluster itself, interviewee C said there is a close link between firm C and the management center, which is also their client.

Firm D

Active since 2017, interviewee D defines firm D as a software studio that makes IT and design solutions from the very beginning, meaning they design specific solutions with no particular precedent or common application.

About the competitive scenario, the interviewee highlighted the fact that they have a close and friendly relationship with the great majority of the competing firms. According to him, this subgroup of companies promotes meetings and talks from which the ecosystem could grow and evolve.

In respect to government aspects, the respondent talked about matters of public security and urban planning in the area of the cluster. He stated that, despite having several firms, commercial buildings, restaurants and being a touristic area, it is still dangerous. Besides, because of the lack of urban planning, there is no sufficient

parking for the demand, which hampers the access for clients and the workers themselves.

Firm D participates in an association of ICT called Softex Recife, also based in the premises of the cluster. The association promotes biweekly events and has a discussion forum online for members. When it comes to universities and research centers, firm D does not have any relations or partnerships.

Firm E

This game development studio was opened in 2013 and their products range from 2D and 3D art, full development (from the conception of the storytelling of the game, to the design and programming), for both mobile and web platforms. The firm has 17 employees, being 10 of those formal and the other 7 freelance workers.

Regarding the competing firms, interviewee E pointed out four other firms but, according to him, despite their service being similar, their focus is different. One of these firms acts also as a partner of firm E, working together in the capturing, planning and execution of projects.

As for government, associations and universities, the interviewee highlighted the CMC itself, specifically through its creative economy branch, which promoted workshops, talks and events with CE associations that brought new knowledge and perspectives to the firm. Apart from that, firm E is also a member of the Brazilian Association of Electronic Game Developers (Abragames).

6.3.3. Case studies results

As explained in section 5.3, during the interviews, the firms were asked to give grades (from 1 to 9, as described in Table 19) to each sub-factor mapped in the SLR. The results are shown in Table 24.

Table 24: Results from the case studies

Factor	Sub-factor	Grade per firm				
		A	B	C	D	E
Network collaboration F^1	F_1^1	3	8	9	9	9
	F_2^1	9	6	9	9	8
	F_3^1	8	9	9	9	3
	F_4^1	9	9	9	9	9
	F_5^1	8	9	9	9	6
Knowledge creation and transfer F^2	F_1^2	9	9	9	9	9
	F_2^2	5	7	5	9	2
	F_3^2	2	4	7	8	8
	F_4^2	8	6	9	9	7
	F_5^2	9	7	9	2	7
Technology development F^3	F_1^3	9	8	9	9	6
	F_2^3	5	7	9	9	1
	F_3^3	9	4	9	9	6
Market influence F^4	F_1^4	8	9	9	6	9
	F_2^4	7	9	6	9	5
Proximity F^5	F_1^5	1	9	9	9	8
	F_2^5	5	7	6	4	8
	F_3^5	5	7	4	9	1
	F_4^5	8	7	9	9	6
	F_5^5	5	5	9	9	3

6.4. STEP 6: CALCULATION OF THE ICI

The grades from Table 24 were submitted to the generic framework presented in section 6.1. The final matrices are shown in Table 25 and their permanents are presented in Table 26.

Table 25: Final matrices with all elements

Table 26: Permanents of the matrices of factors

Factor	Firm				
	A	B	C	D	E
F^1	163579.76	245229.50	311981.19	311981.19	163851.79
F^2	164634.75	180940.34	251175.12	220820.5	181698.86
F^3	939.16	682.78	1311.91	1311.91	407.41
F^4	73.81	98.81	71.81	71.81	62.81
F^5	34374.96	94825.90	98793.68	129986.98	41077.38

With these data at hand, it is possible to calculate the ICI for each firm. Table 27 shows the ICI matrix and its permanent for the five firms.

Table 27: ICI calculation

Firm	Matrix	Permanent
A	$\begin{pmatrix} 163579.76 & 4.75 & 4.25 & 3 & 3.75 \\ 3.25 & 164634.75 & 4.75 & 1.75 & 3 \\ 3.25 & 4 & 939.16 & 3.25 & 1.5 \\ 3 & 3.25 & 3.5 & 73.81 & 3 \\ 4.5 & 4 & 3.75 & 3 & 34374.96 \end{pmatrix}$	6.4183×10^{19}
B	$\begin{pmatrix} 245229.50 & 4.75 & 4.25 & 3 & 3.75 \\ 3.25 & 180940.34 & 4.75 & 1.75 & 3 \\ 3.25 & 4 & 682.78 & 3.25 & 1.5 \\ 3 & 3.25 & 3.5 & 98.81 & 3 \\ 4.5 & 4 & 3.75 & 3 & 94825.90 \end{pmatrix}$	2.8392×10^{20}
C	$\begin{pmatrix} 311981.19 & 4.75 & 4.25 & 3 & 3.75 \\ 3.25 & 251175.12 & 4.75 & 1.75 & 3 \\ 3.25 & 4 & 1311.91 & 3.25 & 1.5 \\ 3 & 3.25 & 3.5 & 71.81 & 3 \\ 4.5 & 4 & 3.75 & 3 & 98793.68 \end{pmatrix}$	7.2942×10^{20}
D	$\begin{pmatrix} 311981.19 & 4.75 & 4.25 & 3 & 3.75 \\ 3.25 & 220820.5 & 4.75 & 1.75 & 3 \\ 3.25 & 4 & 1311.91 & 3.25 & 1.5 \\ 3 & 3.25 & 3.5 & 71.81 & 3 \\ 4.5 & 4 & 3.75 & 3 & 129986.98 \end{pmatrix}$	8.4374×10^{20}
E	$\begin{pmatrix} 163851.79 & 4.75 & 4.25 & 3 & 3.75 \\ 3.25 & 181698.86 & 4.75 & 1.75 & 3 \\ 3.25 & 4 & 407.41 & 3.25 & 1.5 \\ 3 & 3.25 & 3.5 & 62.81 & 3 \\ 4.5 & 4 & 3.75 & 3 & 41077.38 \end{pmatrix}$	3.1308×10^{19}

Since the order of magnitude of the ICI permanents varies between 10^{19} and 10^{20} , these values were transformed into logarithmic scale, in order to facilitate the construction and comprehension of the evaluation scale. The values after the application of the logarithmic function are shown in Table 28.

Table 28: Logarithmic value of permanents

Factor	Firm				
	A	B	C	D	E
$\log(F^1)$	5.21	5.39	5.49	5.49	5.21
$\log(F^2)$	5.22	5.26	5.40	5.34	5.26
$\log(F^3)$	2.97	2.83	3.12	3.12	2.61
$\log(F^4)$	1.87	1.99	1.86	1.86	1.80
$\log(F^5)$	4.54	4.98	4.99	5.11	4.61
$\log(ICI)$	19.81	20.45	20.86	20.84	19.50

6.5. STEP 7: DETERMINATION OF THE EVALUATION SCALE

As described in section 5.5, the indexes presented in Table 28 need to be inserted in an evaluation scale that considers different scenarios. To do so, it was necessary to determine a scale in which the firms are classified according a low, moderate or high level of IC, by replacing the main diagonal of the matrices of factors with 0, 3, 6 and 9, thus creating the three desired intervals (low, moderate, high). The matrices generated for the scale are shown in Table 29.

The results of the permanents are presented in Table 30, while Table 31 shows the ICI matrices and permanents. Table 32 presents the values after the application of logarithmic function, which were used the classification scale. The scale is depicted in Figure 22 and the values found in the case studies were inserted in this scale, according to the results discussed in chapter 7, sections 7.1 and 7.2.

Table 29: Matrices for the classification scale

Factor	Value																			
	0					3					6					9				
F^1	$\begin{pmatrix} 0 & 4 & 4.75 & 4 & 4.75 \\ 2.25 & 0 & 2.5 & 3.25 & 4 \\ 4 & 4 & 0 & 3.75 & 3.25 \\ 4 & 3.25 & 1.75 & 0 & 3.75 \\ 3 & 4.5 & 3 & 3.75 & 0 \end{pmatrix}$					$\begin{pmatrix} 3 & 4 & 4.75 & 4 & 4.75 \\ 2.25 & 3 & 2.5 & 3.25 & 4 \\ 4 & 4 & 3 & 3.75 & 3.25 \\ 4 & 3.25 & 1.75 & 3 & 3.75 \\ 3 & 4.5 & 3 & 3.75 & 3 \end{pmatrix}$					$\begin{pmatrix} 6 & 4 & 4.75 & 4 & 4.75 \\ 2.25 & 6 & 2.5 & 3.25 & 4 \\ 4 & 4 & 6 & 3.75 & 3.25 \\ 4 & 3.25 & 1.75 & 6 & 3.75 \\ 3 & 4.5 & 3 & 3.75 & 6 \end{pmatrix}$					$\begin{pmatrix} 9 & 4 & 4.75 & 4 & 4.75 \\ 2.25 & 9 & 2.5 & 3.25 & 4 \\ 4 & 4 & 9 & 3.75 & 3.25 \\ 4 & 3.25 & 1.75 & 9 & 3.75 \\ 3 & 4.5 & 3 & 3.75 & 9 \end{pmatrix}$				
F^2	$\begin{pmatrix} 0 & 2.5 & 1.5 & 3.5 & 4.5 \\ 2.75 & 0 & 4.75 & 5 & 4 \\ 3 & 3.5 & 0 & 4 & 3.5 \\ 5 & 4.5 & 3.25 & 0 & 4.25 \\ 5 & 3.25 & 3 & 4.25 & 0 \end{pmatrix}$					$\begin{pmatrix} 3 & 2.5 & 1.5 & 3.5 & 4.5 \\ 2.75 & 3 & 4.75 & 5 & 4 \\ 3 & 3.5 & 3 & 4 & 3.5 \\ 5 & 4.5 & 3.25 & 3 & 4.25 \\ 5 & 3.25 & 3 & 4.25 & 3 \end{pmatrix}$					$\begin{pmatrix} 6 & 2.5 & 1.5 & 3.5 & 4.5 \\ 2.75 & 6 & 4.75 & 5 & 4 \\ 3 & 3.5 & 6 & 4 & 3.5 \\ 5 & 4.5 & 3.25 & 6 & 4.25 \\ 5 & 3.25 & 3 & 4.25 & 6 \end{pmatrix}$					$\begin{pmatrix} 9 & 2.5 & 1.5 & 3.5 & 4.5 \\ 2.75 & 9 & 4.75 & 5 & 4 \\ 3 & 3.5 & 9 & 4 & 3.5 \\ 5 & 4.5 & 3.25 & 9 & 4.25 \\ 5 & 3.25 & 3 & 4.25 & 9 \end{pmatrix}$				
F^3	$\begin{pmatrix} 0 & 3.25 & 3.25 \\ 4.75 & 0 & 4.75 \\ 3.75 & 4.75 & 0 \end{pmatrix}$					$\begin{pmatrix} 3 & 3.25 & 3.25 \\ 4.75 & 3 & 4.75 \\ 3.75 & 4.75 & 3 \end{pmatrix}$					$\begin{pmatrix} 6 & 3.25 & 3.25 \\ 4.75 & 6 & 4.75 \\ 3.75 & 4.75 & 6 \end{pmatrix}$					$\begin{pmatrix} 9 & 3.25 & 3.25 \\ 4.75 & 9 & 4.75 \\ 3.75 & 4.75 & 9 \end{pmatrix}$				
F^4	$\begin{pmatrix} 0 & 4.75 \\ 3.75 & 0 \end{pmatrix}$					$\begin{pmatrix} 3 & 4.75 \\ 3.75 & 3 \end{pmatrix}$					$\begin{pmatrix} 6 & 4.75 \\ 3.75 & 6 \end{pmatrix}$					$\begin{pmatrix} 9 & 4.75 \\ 3.75 & 9 \end{pmatrix}$				
F^5	$\begin{pmatrix} 0 & 3.5 & 2.75 & 4.5 & 3.25 \\ 1.25 & 0 & 2.25 & 4.5 & 4 \\ 1.75 & 3 & 0 & 2.5 & 3 \\ 1.5 & 4.25 & 2.75 & 0 & 3.5 \\ 2 & 2.5 & 2.25 & 3 & 0 \end{pmatrix}$					$\begin{pmatrix} 3 & 3.5 & 2.75 & 4.5 & 3.25 \\ 1.25 & 3 & 2.25 & 4.5 & 4 \\ 1.75 & 3 & 3 & 2.5 & 3 \\ 1.5 & 4.25 & 2.75 & 3 & 3.5 \\ 2 & 2.5 & 2.25 & 3 & 3 \end{pmatrix}$					$\begin{pmatrix} 6 & 3.5 & 2.75 & 4.5 & 3.25 \\ 1.25 & 6 & 2.25 & 4.5 & 4 \\ 1.75 & 3 & 6 & 2.5 & 3 \\ 1.5 & 4.25 & 2.75 & 6 & 3.5 \\ 2 & 2.5 & 2.25 & 3 & 6 \end{pmatrix}$					$\begin{pmatrix} 9 & 3.5 & 2.75 & 4.5 & 3.25 \\ 1.25 & 9 & 2.25 & 4.5 & 4 \\ 1.75 & 3 & 9 & 2.5 & 3 \\ 1.5 & 4.25 & 2.75 & 9 & 3.5 \\ 2 & 2.5 & 2.25 & 3 & 9 \end{pmatrix}$				

Table 30: Permanent of the matrices for the classification scale

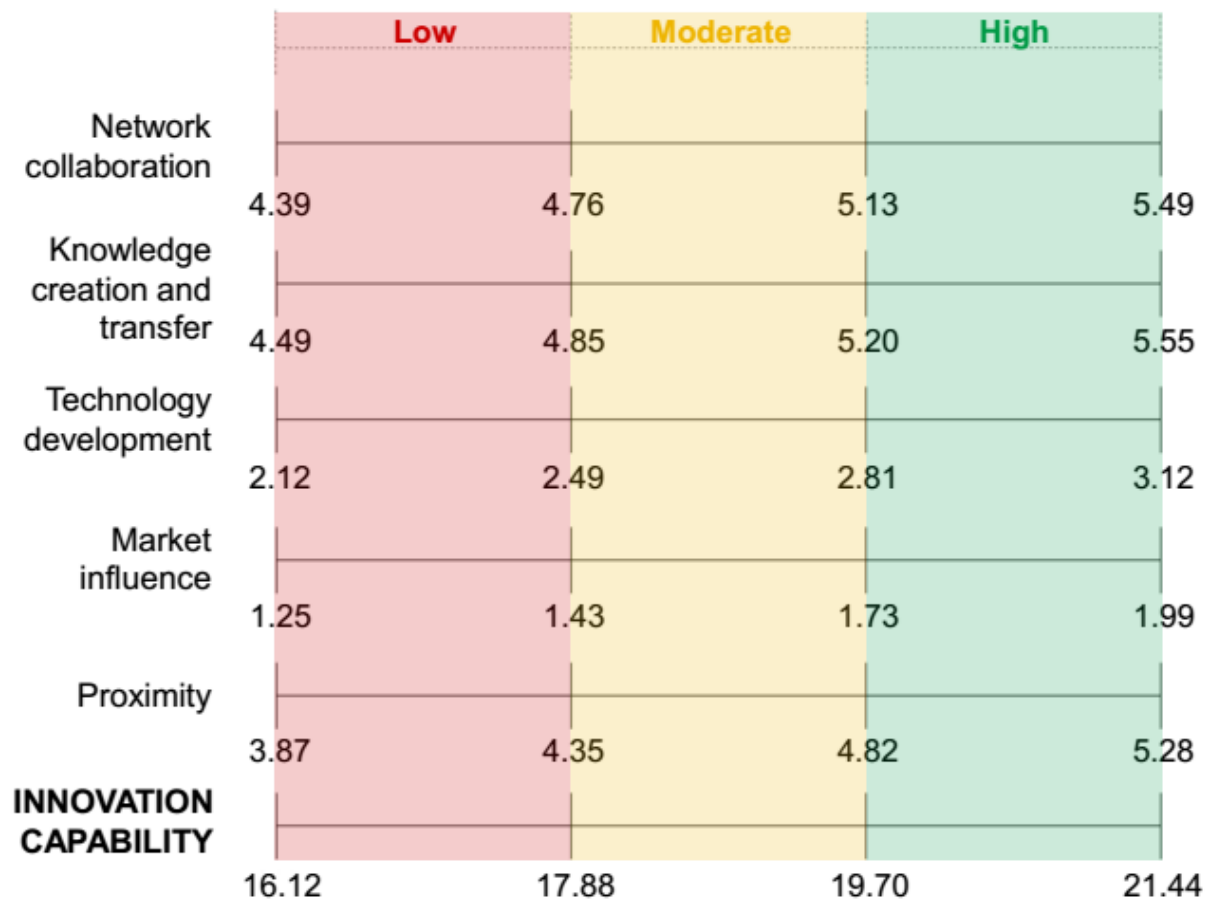
Factor	Value			
	0	3	6	9
F^1	24532.58	57527.94	134326.02	311981.19
F^2	31065.74	70744.23	159757.91	358056.91
F^3	131.22	308.78	648.34	1311.91
F^4	17.81	26.81	53.81	98.81
F^5	7392.78	22422.45	66321.03	188893.39

Table 31: ICI matrices for classification scale

Value	Matrix	Permanent
0	$\begin{pmatrix} 24532.58 & 4.75 & 4.25 & 3 & 3.75 \\ 3.25 & 31065.74 & 4.75 & 1.75 & 3 \\ 3.25 & 4 & 131.22 & 3.25 & 1.5 \\ 3 & 3.25 & 3.5 & 17.81 & 3 \\ 4.5 & 4 & 3.75 & 3 & 7392.78 \end{pmatrix}$	1.3233×10^{16}
3	$\begin{pmatrix} 57527.94 & 4.75 & 4.25 & 3 & 3.75 \\ 3.25 & 70744.23 & 4.75 & 1.75 & 3 \\ 3.25 & 4 & 308.78 & 3.25 & 1.5 \\ 3 & 3.25 & 3.5 & 26.81 & 3 \\ 4.5 & 4 & 3.75 & 3 & 22422.45 \end{pmatrix}$	7.5650×10^{17}
6	$\begin{pmatrix} 134326.02 & 4.75 & 4.25 & 3 & 3.75 \\ 3.25 & 159757.91 & 4.75 & 1.75 & 3 \\ 3.25 & 4 & 648.34 & 3.25 & 1.5 \\ 3 & 3.25 & 3.5 & 53.81 & 3 \\ 4.5 & 4 & 3.75 & 3 & 66321.03 \end{pmatrix}$	4.9669×10^{19}
9	$\begin{pmatrix} 311981.19 & 4.75 & 4.25 & 3 & 3.75 \\ 3.25 & 358056.91 & 4.75 & 1.75 & 3 \\ 3.25 & 4 & 1311.91 & 3.25 & 1.5 \\ 3 & 3.25 & 3.5 & 98.81 & 3 \\ 4.5 & 4 & 3.75 & 3 & 188893.39 \end{pmatrix}$	2.7355×10^{21}

Table 32: Logarithmic value of permanents for classification scale

Factor	Value			
	0	3	6	9
$\log(F^1)$	4.39	4.76	5.13	5.49
$\log(F^2)$	4.49	4.85	5.20	5.55
$\log(F^3)$	2.12	2.49	2.81	3.12
$\log(F^4)$	1.25	1.43	1.73	1.99
$\log(F^5)$	3.87	4.35	4.82	5.28
$\log(ICI)$	16.12	17.88	19.70	21.44

Figure 22: Classification scale

The contextualization and discussion of the numeric results presented along this chapter are presented in Chapter 7.

7. DISCUSSION OF RESULTS

This chapter presents a discussion of the results obtained through the application of the IC evaluation framework. Section 7.1 approaches the individual results for each firm (within-case analyses), while section 7.2 presents a comparison between them (cross-case analysis). Section 7.3 discusses the applicability of the proposed framework using the criteria suggested by Platts (1993).

7.1. WITHIN-CASE ANALYSES

In this section, the evaluation scale for each firm is presented, as well as the numerical results presented in chapter 6 are contextualized with the qualitative content of the interviews.

Firm A

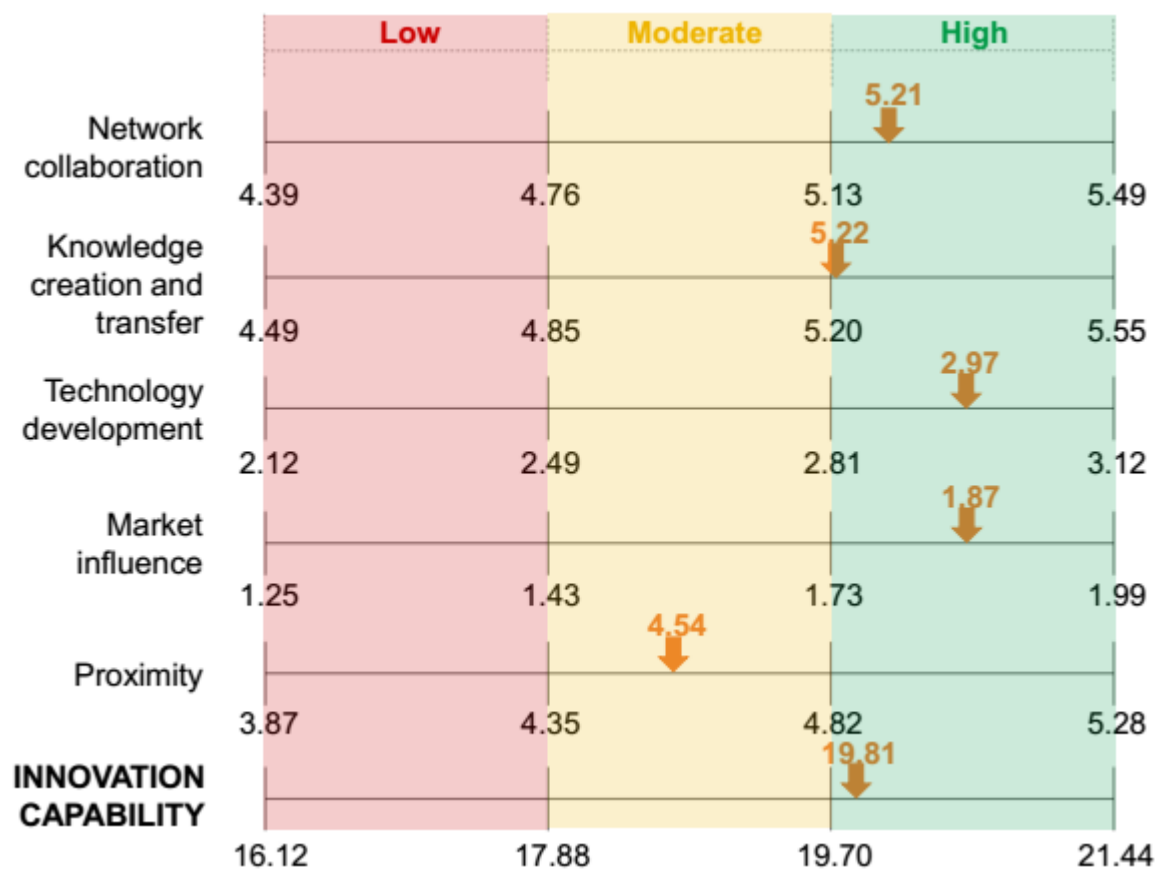
The ICI obtained for Firm A (19.81) indicates a high level of innovation capability, as illustrated in Figure 23. According to the evaluation framework, Firm A has a high level of network collaboration (5.21). The firm presented substantial evidence of collaboration with other organizations and good use of resources in such processes. Also, the educational nature of the firm's activities contributes to the collaborative relationships and thus to the innovation capability of the company. See Table 33 for more details.

Table 33: Aspects of network collaboration – Firm A

Sub-factor	Grade	Empirical results
Relationships between companies	3	Firm A establishes partnerships in specific projects, usually among technical teams, whether with other IT companies or firms from other segments. As an example, the firm has a partnership with a law firm to develop a virtual lawyer for petition creation/writing. For these relationships to succeed, the firms must have similar purposes, ethical and service standards. Another aspect pointed out was the possibility of improvement due to these interactions. Although the interviewee perceives the importance of this sub-factor, Firm A has difficulties in implementing these relationships since the nature of their products is usually different from potential partners.
Integrative capability	9	A distinctive characteristic of Firm A is the capability to integrate its innovative activities and exploit its resources in this process.
Interaction with other entities	8	The interactions with other entities (such as the CMC and the state technology agency) to develop IT solutions and also participate in training actions, occasionally through public calls.

Sub-factor	Grade	Empirical results
Technological collaboration	9	Since technological collaboration is linked to learning practices and routines, Firm A has solid methodologies to teach individuals how to use technological tools, which is applied whether inside the firm itself or in inter-firm relationships.
Combinative capability	8	Regarding the flexibility to combine and obtain resources, Firm A focuses its actions mostly on human resources and the majority of collaborations happen formally. In addition, by offering a coworking space, the firm can gather quality work force in one place, which leads to recruitment of interns and employees. This environment also encourages human interactions and thus an improvement of human capabilities.

Figure 23: Firm A results



Firm A obtained an index of 5.22 regarding knowledge creation and transfer. An important observation made by interviewee A regarding this factor is that “high levels of knowledge leads to much better solutions” in the context of Firm A, which corroborates its high level regarding this evaluation factor. Table 34 presents the comments for each sub-factor.

Table 34: Aspects of knowledge creation and transfer – Firm A

Sub-factor	Grade	Empirical results
Absorptive capacity	9	For Firm A, partnerships are a great source for acquisition of external knowledge, especially from firms of different segments (non-ICT).
Knowledge sharing	5	There are no investments in relationships with other cluster-based firms. In particular, Firm A seeks to exchange knowledge with state educational institutions to improve the development of innovation capability.
Knowledge spillovers	2	The interviewee does not consider that Firm A has easy access to knowledge acquired informally in the environment. In this sense, the influence of spillovers in the firm's reality was evaluated as very low. However, he sees the importance and notes that its existence would be positive for the firm.
Collective learning	8	The team of developers is encouraged to participate in trainings and certifications. The social aspect comes in sequence, as they share the acquired knowledge among themselves, engendering collective learning. the collective aspect of the learning process is extremely helpful for problem solving and in the development of IC.
Learning capability	9	In Firm A, knowledge is not concentrated in individuals. Knowledge is passed over time so that at least two employees have experience and expertise in a particular competence (technology, programming language, etc.). The learning capability potentializes the quality of the IT solutions and, thus, the development of IC.

Regarding to technology development, Firm A obtained a level of 2.97. According to Interviewee A, the firm rapidly seeks to insert new technologies in its projects and invests in developing new and improved solutions based on these new and combined technologies. More information considering the sub-factors related to technology development are presented in Table 35.

Table 35: Aspects of technology development – Firm A

Sub-factor	Grade	Empirical results
New technological opportunities	9	The emergence of a new technology, specially regarding artificial intelligence, immediately triggers Firm A to dedicate its resources into studying it and, posteriorly, evaluating if it fits in any of its ongoing projects. Besides, they seek to combine different technologies to have the ability to choose the best solution and also accelerate the creation process.
Technological capability	5	The employees have technological skills and knowledge that contribute to the IC of the firm. However, as stated before, Firm A does not interact with other cluster-based companies to exchange technological information and knowledge.
R&D capability	9	Firm A invests in the development of unprecedented products in a daily basis, according to market demand. The company also focuses on developing improvements for existing solutions, based on newly launched technologies. The R&D activities, however, are made on demand by the developer, not by a specific R&D branch. Customer feedback is considered in the decision making regarding technology development. Another important aspect of R&D capability is having clear goals in projects, which happens through investments in human resources, innovations and equipments.

Regarding market influence, Firm A presented an index of 1.87, which is also high according to the evaluation framework. Interviewee A argued that the firm has competencies in identifying market demands and customer needs, which corroborates the results for this factor. The comments about the sub-factor related to market influence are described in Table 36.

Table 36: Aspects of market influence – Firm A

Sub-factor	Grade	Empirical results
Capability to adapt innovation to demand	8	The firm has the capability of transforming its technological knowledge into salable products, considering market demand and firm's sale projections. As an example, he cited a software that corrects essays designed in partnership with a renowned local Portuguese teacher, an existing demand due the Brazilian unified public standardized test for school graduate students (ENEM).
Capability to advertise and sell new products	7	To Firm A, a competitive environment influences the IC positively, because it can create a capability of constant improvement. When it comes to customers, Interviewee A understands that maintaining good relationships and reputation guarantee customer loyalty. These aspects are determinant to the capability to advertise and sell new products and thus influence the firm's IC.

For proximity, Firm A obtained an index of 4.54, which indicates a moderate level in the evaluation scale. Overall, social proximity was evaluated as valuable sub-factor for the firm's innovation capability, while the other sub-factors have a moderate to low level of importance. The details are shown in Table 37.

Table 37: Aspects of proximity – Firm A

Sub-factor	Grade	Empirical results
Geographical proximity	1	The influence of geographical proximity in the establishment of inter-firm relationships is recognized, however currently this sub-factor does not have a high influence in the IC of Firm A.
Cognitive proximity	5	Firm A employees have a common knowledge base and expertise and, when the staff is competent and coactive, it has insights and perceptions that are able to enhance the development of solutions. However, in present days the influence of cognitive proximity in the firm's IC is not recognized, indicating this sub-factor is subject to improvement in the company's context.
Organizational proximity	5	Organizational rules and hierarchies are important for the fulfilment of firm's goals and purposes, which is directly connected to the development of IC. However, the influence of organizational proximity regarding other cluster-based firms was not recognized for Firm A, thus the moderate influence.
Social proximity	8	The social relationships are based on trust, affinity and experience, which facilitates the exchange of knowledge among the employees. As an

Sub-factor	Grade	Empirical results
		example, the interviewee cited trainings and refreshments that are always shared and socialized, generating debates and discussions that are only possible because of social proximity.
Institutional proximity	5	The institutional proximity is not very relevant in Firm A's circumstances, and there are only two aspects regarding this sub-factor: common language and shared habits. Still, for this company, this sub-factor only has a moderate influence in the IC of the firm.

In order to increase Firm A's ICI, the main factor that needs improvement is Proximity, which presented the lowest level among all five factors. Four out of five sub-factors of Proximity received a low evaluation: geographical proximity, cognitive proximity, organizational proximity and institutional proximity. Regarding the geographical aspect, although interviewee A recognizes its importance, Firm A still does not benefits from it, especially when it comes to relationships with other cluster-based firms. The interviewee also perceived a lack organizational proximity from Firm A in respect to other cluster-based firms, possibly another indicator that Firm A could improve its relationships with these firms.

Other sub-factors that presented a low evaluation (and thus are subject to improvement) were: relationships between companies, knowledge sharing, knowledge spillovers and technological capability. As stated previously, Firm A has difficulties in implementing relationships with other firms (especially cluster-based) since the nature of their products is different from potential partners. Then, to improve the performance of this sub-factor, the Firm could seek to strengthen the relations with companies of complementary sectors. This would also impact in technological capability, knowledge sharing and spillovers, which are also related to the aforementioned relationships.

Firm B

The ICI obtained for Firm B (20.45) indicates a high level of innovation capability, as illustrated in Figure 24. Firm B practices network collaboration at a level of 5.39, considered high. The comments that corroborate the given grades are presented in Table 38. Interviewee B2 highlighted that quality network relationships facilitate mobilization and flexibility, enabling partnerships that can reach a common good by saving resources and eliminating difficulties. He also stated that the existence of relationships enables the exchange of information and thus is a driver for innovation capability.

Figure 24: Firm B results

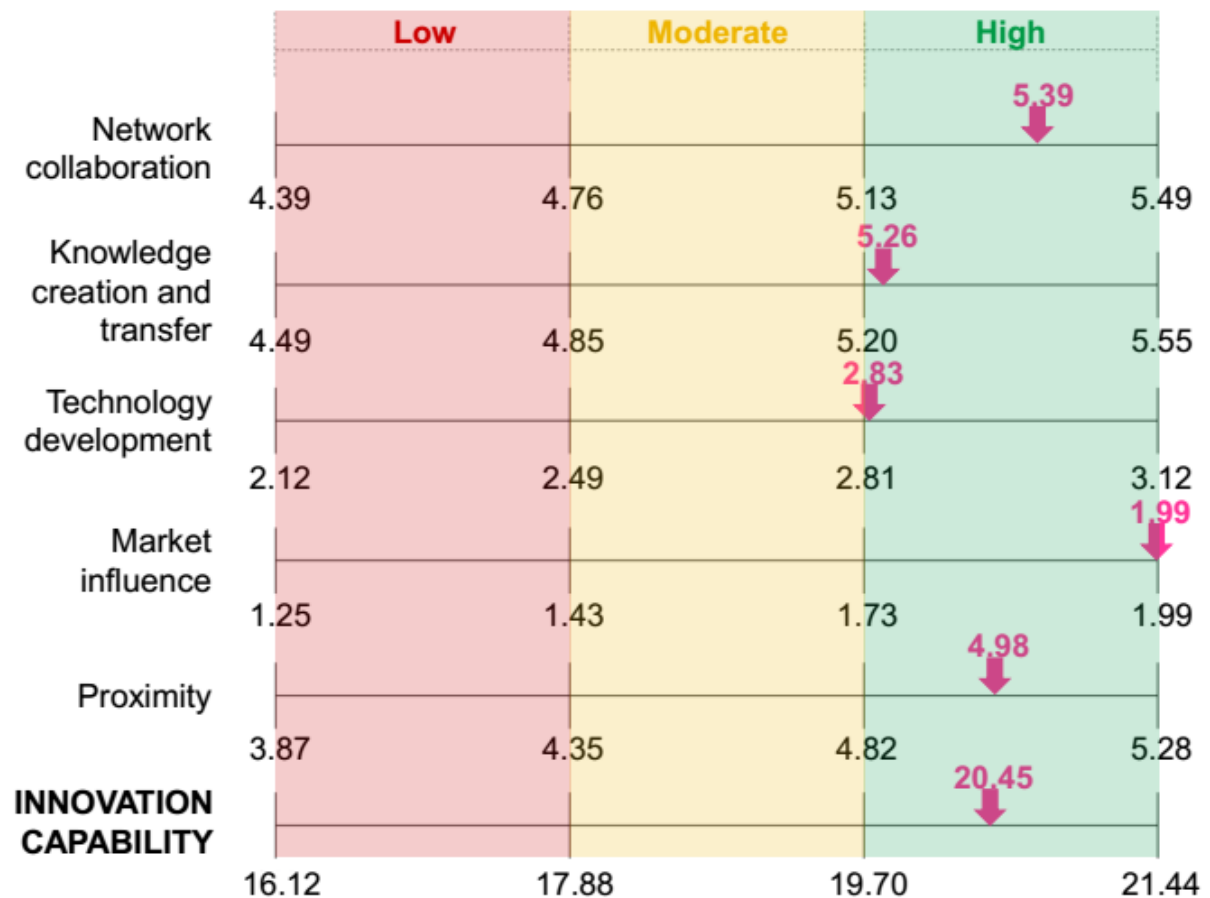


Table 38: Aspects of network collaboration – Firm B

Sub-factor	Grade	Empirical results
Relationships between companies	8	As examples of good relationships with other firms, interviewee B1 cited a partner firm that possesses expertise in database that combined with Firm B's expertise in data security, results in a service that Firm B alone could not provide. Interviewee B2 also noted the firm has quality relationships with other firms that supply hardware, in case a client demands a solution that requires a specific equipment. To maintain good relationships with partner companies, Firm B has periodic reviews of work procedures and business models, establishes frequent contact, and practices good communication and policy sharing.
Integrative capability	6	The innovative activities are not systematic and integrated according to the parameters delineated by Firm B. However, the importance of integrative capability is recognized and improvements are necessary regarding this sub-factor. According to interviewee B2, in some cases the lack of defined procedures can even deviate the objective of the project.
Interaction with other entities	9	Firm B interacts with other entities to generate innovation, specially the CMC and the drugstore association. From the interaction with the latter, Firm B is able to observe and respond to market demand, besides acquiring new clients by indication. E.g., in a certain occasion, a law was modified and changes were necessary in a system developed by the firm – in this case, the employees eventually have to acquire new knowledge and interact among themselves, developing the IC of Firm B.

Sub-factor	Grade	Empirical results
Technological collaboration	9	The existence of learning routines and practices help Firm B to access market trends more easily, besides facilitating the recycling/refreshing of competences, thus influencing the development of IC.
Combinative capability	9	The firm has the ability to combine and obtain resources, mainly by having open and flexible relationships with other firms. The fact of having a network already boosts the development of innovation capability. For example, Firm B provided training for another firm of the same franchise that did not possess the technical knowledge to develop a certain solution already worked by Firm B. In addition, in Firm B's experience, the cluster actors have a good communication, specially from the CMC towards the cluster-based firms.

Firm B obtained an index of 5.26 for knowledge creation and transfer, indicating a high performance regarding this index. Overall, the interviewees' comments emphasize the knowledge creation and transfer outside the frontiers of the firm happens mostly with entities and institutions than with other cluster-based firms. Table 39 presents in details for each sub-factor.

Table 39: Aspects of knowledge creation and transfer – Firm B

Sub-factor	Grade	Interviewees comments
Absorptive capacity	9	Trainings and courses offered by the CMC favor the acquirement of knowledge from external actors. Interviewee B2 mentioned the external knowledge is acquired, learned, implemented when appropriate, and transmitted among employees. These actions stimulate the relationships among cluster-based firms and promote exchange of experience, creation of study groups, knowledge sharing, thus developing the IC. For Firm B, knowledge exchange happens both with companies that have similar and distinct competences.
Knowledge sharing	7	Firm B does not invest thoroughly in knowledge sharing with other cluster-based firms. However, the firm invests in relationships with support institutions, mainly when it comes to conferences participation (either in the area of IT or drugstores conventions), and both interviewees emphasized the importance of these relationships to the IC development. The CMC promotes training actions to foment the IC of the cluster-based companies and, consequently, the cluster as a whole. For example: (1) an unpaid foreign language course, aiming at internationalizing the agglomeration, whose consequence was that the employees who took part in it became more engaged in the firm context; (2) a project management training, offered when this subject became relevant and present in market demand.
Knowledge spillovers	4	Firm B does not have access to knowledge in an informal manner in a scale it would impact the innovation capability of the firm.
Collective learning	6	Within the context of Firm B, learning happens cumulatively and socially. The social character occurs within projects, in a demand that is not met by one employee but by another, and the latter is able to pass on the knowledge. However, there are no rules and procedures in this sense.
Learning capability	7	The company identifies, assimilates and explores knowledge from the environment. To transmit knowledge over time within the firm, there are weekly meetings. However, the knowledge flow (and thus the learning capability) are being restructured in the last two years since, primarily, the firm had a director focused on IT that centralized part of the technological

Sub-factor	Grade	Interviewees comments
		knowledge. To solve this issue, the firm is making adjustments and trainings in which the IT director is sharing his expertise with other employees.

When it comes to technology development, Firm B obtained an index of 2.83, indicating a high level regarding this factor, which is corroborated by the interviewees' descriptions. The details are presented in Table 40.

Table 40: Aspects of technology development – Firm B

Sub-factor	Grade	Empirical results
New technological opportunities	8	The emergence of new technological opportunities promotes innovation in Firm B. It occurs specially inside the firm's segment, particularly regarding IT security. The firm usually combines different technologies, using the best part available of each seeking to improve the innovation capability.
Technological capability	7	The resources, abilities, knowledge, and experience of the employees, in its totality, do not influence the IC at a very high level, since they are distinct for each person. However, the heterogeneity of these characteristics foments the gathering of technological knowledge, which promotes growth, reaching a consensus for both interviewees the technological capability influences the IC for Firm B.
R&D capability	4	The firm invests in the development of new IT services, however it does not possess a sector dedicated to R&D. The R&D activities occur in the middle of projects, when an innovative idea or improvement arises in the middle of the process of resolution, as "a healthy improvisation". In addition, customer feedback is considered for decision-making regarding technology development, but sometimes the same IT solution generates different feedback from customers, according to their own experience and background. Within the context of Firm B, projects with well-defined goals and plans limit the openness for innovation, thus having a low influence in the IC of the firm.

Regarding market influence, Firm B presented an index of 1.99, which is the maximum level according to the evaluation framework. The interviewees remarked the importance of the competitive environment as an influencer of IC. The comments are described in Table 41.

Table 41: Aspects of market influence – Firm B

Sub-factor	Grade	Empirical results
Capability to adapt innovation to demand	9	The technological knowledge of the firm is transformed in marketable products and services. For example, a project of database security the firm is developing due to data vulnerability in digital medias, a frequent topic in current days.
Capability to advertise and sell new products	9	For Firm B, customer needs have a great influence on IC, since customers trigger the demands. Customer behavior was highlighted as an influencer of IC. Regarding the competitive environment, it not only contributes to the innovation capability of the firm, but it can also be a “checkmate”, leaving the firm with no option but to adapt to the environment. Regarding the the maintenance of a positive reputation, Firm B considers it has influence over its IC since innovation is fundamental for creating market share and building a business over time, especially in an everchanging industry such as ICT.

As to proximity, Firm B obtained an index of 5.07, considered high, especially as to the geographical, cognitive and social aspects. The detailed information regarding these sub-factors is shown in Table 42.

Table 42: Aspects of proximity – Firm B

Sub-factor	Grade	Empirical results
Geographical proximity	9	For Firm B, the geographical location is important in the stablishment of relationships and participation in events promoted by CMC, which are often exclusive for cluster-based firms. As an example, interviewee B1 cited a visit from Microsoft that resulted in the acquisition of discounted software licenses, which in its turn boosted firm’s sales and innovation capability.
Cognitive proximity	7	The employees have distinctive expertises: one part of the team is specialized in server infrastructure, while the other part focuses on database systems and implantation, creating two synergistic environments in the firm. According to the interviewees, this influences the firm’s IC in the means that there is exchange of ideas and information.
Organizational proximity	7	Currently in the middle of restructuring its organizational aspects, Firm B does not have clear rules and hierarchies. Matters such as work scope and clear definition of assignments are being adjusted. Interviewee B2, however, recognizes the importance of organization proximity for the firm’s IC, which corroborates their actions aiming at its improvement.
Social proximity	7	According to interviewee B2, the employees of Firm B have trust relationships based in friendship, affinity and experience, which facilitates the interaction of peers and experience sharing, generating knowledge exchange and thus influencing innovation capability. Regarding other cluster firms, both interviewees noted the social proximity is subject to improvement and they do not see its influence in Firm B’s IC.
Institutional proximity	5	Although interviewee B1 considers the institutional proximity very important, Firm B is still developing its shared set of habits and cultural values, which is why its influence on the firm’s IC is not high.

The main factors that could be improved in order to increase the ICI of Firm B are Knowledge creation and transfer (specially the sub-factor knowledge spillovers)

and Technology development (mainly regarding R&D capability). Other sub-factor that received a low evaluation was institutional proximity, although Proximity presented a high evaluation level as a whole.

To improve access to knowledge spillovers, Firm B must invest in establishing relationships with entities, clients and cluster-based firms, to acquire knowledge informally due to these social interactions. When it comes to R&D capability, Firm B has a limiting character regarding the nature of its work. The main products they offer (IT solutions for drugstores and database security) do not presuppose creativity, thus, innovation happens mostly due to a market demand or a new law.

In its turn, institutional proximity is still under construction for Firm B, being referred to as “an ongoing challenge” by interviewee B1. So, although the employees have a satisfactory social and cognitive proximity, the firm still has to strengthen its cultural values to improve the institutional aspect.

Firm C

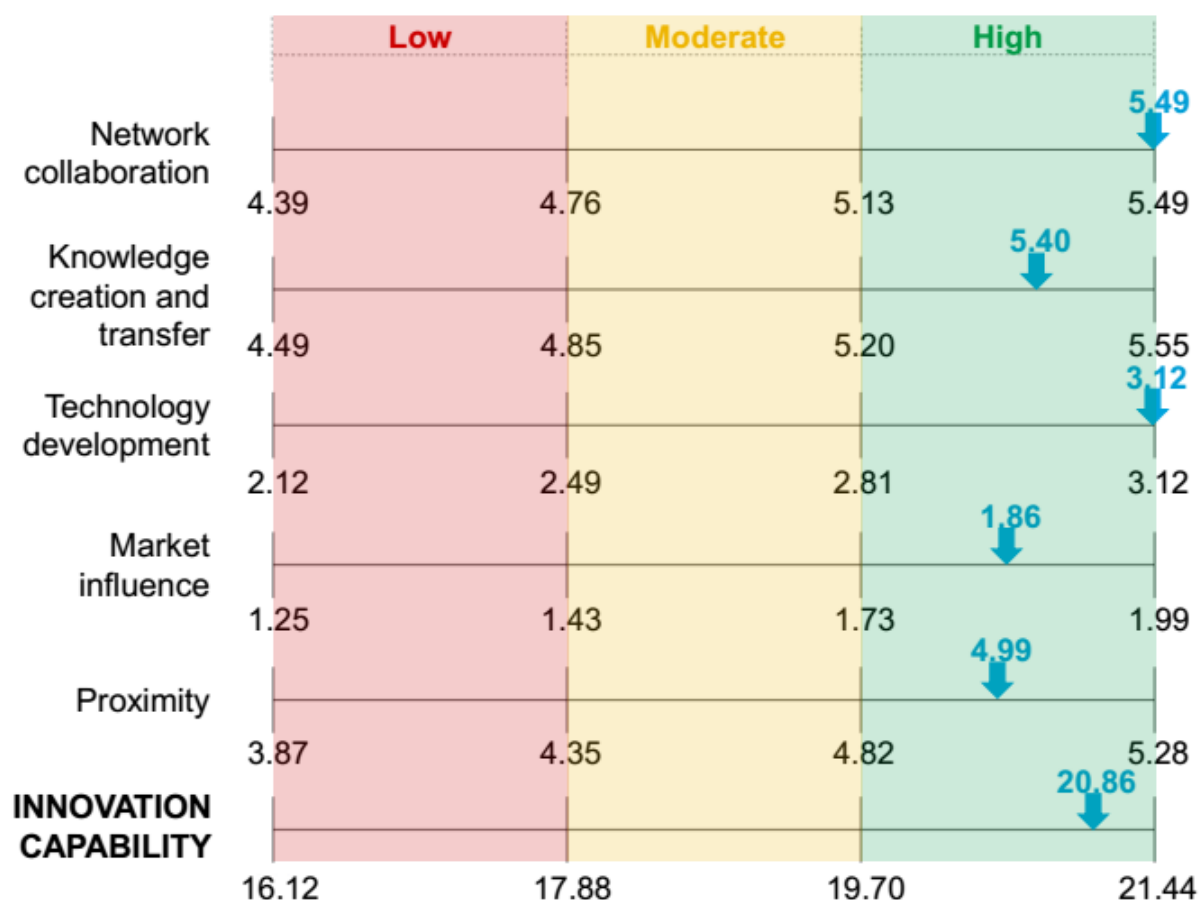
The ICI attained for Firm C (20.86) indicates a high level of innovation capability, as illustrated in Figure 25. Firm C practices Network collaboration at a level of 5.49, the maximum level according to the evaluation framework. Interviewee C considers networks the bridges for organizations that are interested in developing innovation. In addition, he remarked that even if it does not happen in a daily basis, the collaborative relationship allows accessing to a required knowledge Firm C does not possess, which is fundamental to the company's end activity. The comments that corroborate the given grades are presented in Table 43.

Table 43: Aspects of network collaboration – Firm C

Sub-factor	Grade	Empirical results
Relationships between companies	9	Firm C is composed by professionals of design and business, so when the prototypes demand, e.g., a software solution, a third party must be involved. Thus, the firm invests on the maintenance of good relationships with other companies through strategic partnerships, when there is need for complementary resources and capabilities. The most important element for a quality relationship among firms is trust, particularly with a fairly intangible product such as Firm C's. Trust in the firm's capability and authority on future forecasting is achieved through peer recognition. Besides, from trust relationships, new networks can be accessed, generating a capillarity and enlarging the firm's network.
Integrative capability	9	The innovative activities of the firm are systematic and integrated, and each case demands specific, tailor-made and methodologies, developed

Sub-factor	Grade	Empirical results
		inside the client firm's environment and in which it becomes part of the team.
Interaction with other entities	9	Besides other companies, Firm C also interacts with local universities for complementary resources and capabilities (e.g., for the development of a design tool in which the employees are not skilled). Furthermore, the firm has strategic insertion and partnership talks with national and international organizations such as Institute for the Future, School of International Futurists, Softex Recife (a non-profit association for ICT companies), as well as the CMC itself. Softex also makes connections with Firm C and potential clients, besides resources exchange.
Technological collaboration	9	Firm C has learning routines that facilitate the transmission of knowledge with other firms. Since their methodologies are inclusive, some level of literacy on future thinking is required, so there is technological collaboration in the firm's innovation process.
Combinative capability	9	The methodologies developed by Firm C are essentially combinative: different resources and loose narratives are combined in an innovative manner to generate the future forecast. The combinative capability is the core of the firm's methodology. Regarding the collaborative relationships, they happen both formal and informally and the interviewee considers it influences the IC as the company's visibility is increased.

Figure 25: Firm C results



For knowledge creation and transfer, Firm C obtained an index of 5.40, indicating a high performance regarding this factor. In general terms, the knowledge creation and transfer happen in a social manner within Firm C. Table 44 presents the comments for each sub-factor.

Table 44: Aspects of knowledge creation and transfer – Firm C

Sub-factor	Grade	Empirical results
Absorptive capacity	9	As stated previously, knowledge acquired from external actors is in the core of the firm's activities and, in the case of Firm C, knowledge is acquired from firms with distinctive competencies. Regarding the influence of knowledge transmission in the relationships of cluster-based firms, in Firm C it still occurs prematurely and in a non-systematic way. Nevertheless, the evaluation received a maximum grade since Firm C's nature resided in the consumption of information and generation of knowledge, especially in the field of innovation.
Knowledge sharing	5	Firm C usually invests more in the relationships with other cluster-based firms, but eventually realized their customer base is outside the cluster. In general, the companies that hire Firm C are seeking transformation instead of generating transformation (in the sense of problem resolution, which is the nature of most cluster-based firms). In general, aside from the CMC, knowledge sharing with support institutions currently does not have a great influence on the development of IC.
Knowledge spillovers	7	Firm C has access to spillovers when the CMC promotes events or by relevant information publicized by the press. However, the access to ideas and experiences occurs mostly from the initiative of the firm than in an informal and social manner.
Collective learning	9	When the firm is actively operating inside a client company, there are clear methodologies for implementation that generate a collective learning process. When the firm is not working for a client, learning occurs in semi-structured means – researches and firm meetings, which support problem resolution and the development of IC.
Learning capability	9	The knowledge is constantly acquired from the environment by all members of Firm C, and is socialized through the firm's social media groups or in meetings. This transmission happens almost automatically and the knowledge generated is tacit and often unstructured. However, when the firm is in activity within another organization, the learning is systematized and documented.

When it comes to technology development, Firm C obtained an index of 3.12, which is the maximum level regarding this factor, which is substantiated by the comments given by the interviewee and the dynamic nature of the firm's services. The details are presented in Table 45.

Table 45: Aspects of technology development – Firm C

Sub-factor	Grade	Empirical results
New technological opportunities	9	The emergence of new technologies strengthens the innovation capability of the firm, since Firm C is constantly seeking and researching new technologies. Additionally, the combination of concepts and technologies is a fundamental part of the firm's activities, e.g., if technology X combined with technology Y and social change Z, what are the implications for the future market? Which problems will emerge? Which opportunities will arise? Thus, these results explain the extremely high level of influence of this sub-factor on the company's IC.
Technological capability	9	The firm members have resources, skills, knowledge and experience that lead to IC, but focused on user experience. None of them is a programmer, for instance, but the majority can design artefacts for the prototypes. Thus, even if the firm may lack technical skills, the social technology and problem solving capabilities is a strong feature of Firm C.
R&D capability	9	The company does research and prototypes of alternatives (which would correspond to the <i>development</i>). The diffusion of the R&D activities among employees, which stimulates IC, happens through social media groups or meetings. Customer feedback occurs both formal and informally, using a questionnaire, a form or a simple e-mail, to assess the process, the tools, the methodology itself, and even the emerging opportunities. For each project, Firm C has well established goals and plans, which, according to the interviewee, brings attention to the whys of each project, influencing directly on the innovation capability. The circulation of technological information is also essential for the nature of the firm's end activity, which intends to "do things differently" and avoid "more of the same".

Regarding market influence, Firm C presented an index of 1.86, which is considered high according to the evaluation framework. The comments of the interviewee are described in Table 46.

Table 46: Aspects of market influence – Firm C

Sub-factor	Grade	Empirical results
Capability to adapt innovation to demand	9	Firm C attends to a client demand, but does not sell the product itself, i.e., what is sold is not the prototype of the future scenario, but the process of discovery and innovation. The capability to adapt innovation to demand as extremely fundamental; however, at the same time, it is extremely difficult to adapt the firm's innovation process to the reality of each client firm.
Capability to advertise and sell new products	6	The best client for Firm C is a company that is bothered by a present situation or future projection. Besides, client's literacy is fundamental in the acquisition process. Thus, the needs of the clients are a fundamental influence on the firm's IC. The firm maintains good relationships with the customers and has a good return rate. Since Firm C does not fit neither as a design nor as a consulting firm, the lack of a competitive environment is considered prejudicial by the interviewee. Finally, for Firm C, reputation is pivotal, because of its direct relation to authority, fundamental to the firm's end activity. In general, interviewee C assesses the capability to advertise and sell new products is still under development in the firm, and is even part of its strategic planning.

As to proximity, Firm C obtained an index of 4.99, considered high. Overall, interviewee C reinforced the importance of the social character of the firm, and emphasized the relevance of cultural values for all members. The detailed information about the each sub-factor is shown in Table 47.

Table 47: Aspects of proximity – Firm C

Sub-factor	Grade	Empirical results
Geographical proximity	9	The geographical proximity has a strong influence on the establishment of inter-firm relationships and Firm C is motivated to initiate and maintain such relationships. Being a part of a wordly renowned ecosystem enables instant contact with notorious figures of innovation, important companies of the field, which is fundamental for the development of IC.
Cognitive proximity	6	Although the members of Firm C comprehend each other in order to encourage the development of innovation, they have different academic backgrounds, so their knowledge is diverse and unstructured (except when it concerns the projects, since each one has its own repository). The interviewee considers cognitive proximity as extremely important, but recognizes Firm C still lapses much.
Organizational proximity	4	Firm C does not have a formal hierarchy. As a matter of fact, all members consider themselves at the same hierarchical level. When compared to the agents of the cluster, interviewee C does not consider the firm members have similar behavior. Thus, organizational proximity has a low influence on the firm's IC.
Social proximity	9	The members of Firm C have trust relationships, besides affinity and friendship, and for this Firm these aspects facilitate the exchange of knowledge by enabling constant conversations among them. This social proximity is also as a characteristic of the local citizens. Regarding the cluster context, the local mobility among cluster companies is considered an enabler of social connexions between firms.
Institutional proximity	9	The collaborators have common habits and cultural values and this is elementary for Firm C. The promotion of a better, more inclusive future is a shared goal/value of all firm members. In 10 years, e.g., they wish to have influenced public inclusion policies, and the promotion of a better future is a core value of the company.

Two sub-factors received a low evaluation for Firm C: knowledge sharing and organizational proximity. Currently, Firm C does not invest in relationships aiming specifically at knowledge sharing, although it maintains social relationships with other entities and cluster-based firms. Therefore, investing in the obtainment of knowledge specifically with other cluster-based firms and entities could boost the firm's IC.

Regarding organizational proximity, interviewee C highlighted that due to the size and configuration of the firm, the four collaborators are on the same hierarchical level, also due to the seniority acquired in the context of the cluster. However, Firm C

should consider strengthening its organizational rules, hierarchy and codes of behavior, since they facilitate interactions and thus influence on firm's IC.

Overall, Firm C obtained a high evaluation for all five factors; nevertheless, the ICI is subject to improvement, particularly regarding the aforementioned sub-factors.

Firm D

The ICI obtained for Firm D (20.84) indicates a high level of innovation capability, as illustrated in Figure 26. According to the evaluation framework, Firm D practices network collaboration at a maximum level (5.49). The qualitative content of the interview that corroborates the given grades are presented in Table 48. Interviewee D highlighted that interaction, and thus collaboration are always essential, since the good or service required by the customer can only be understood when there is human interaction.

Figure 26: Firm D results

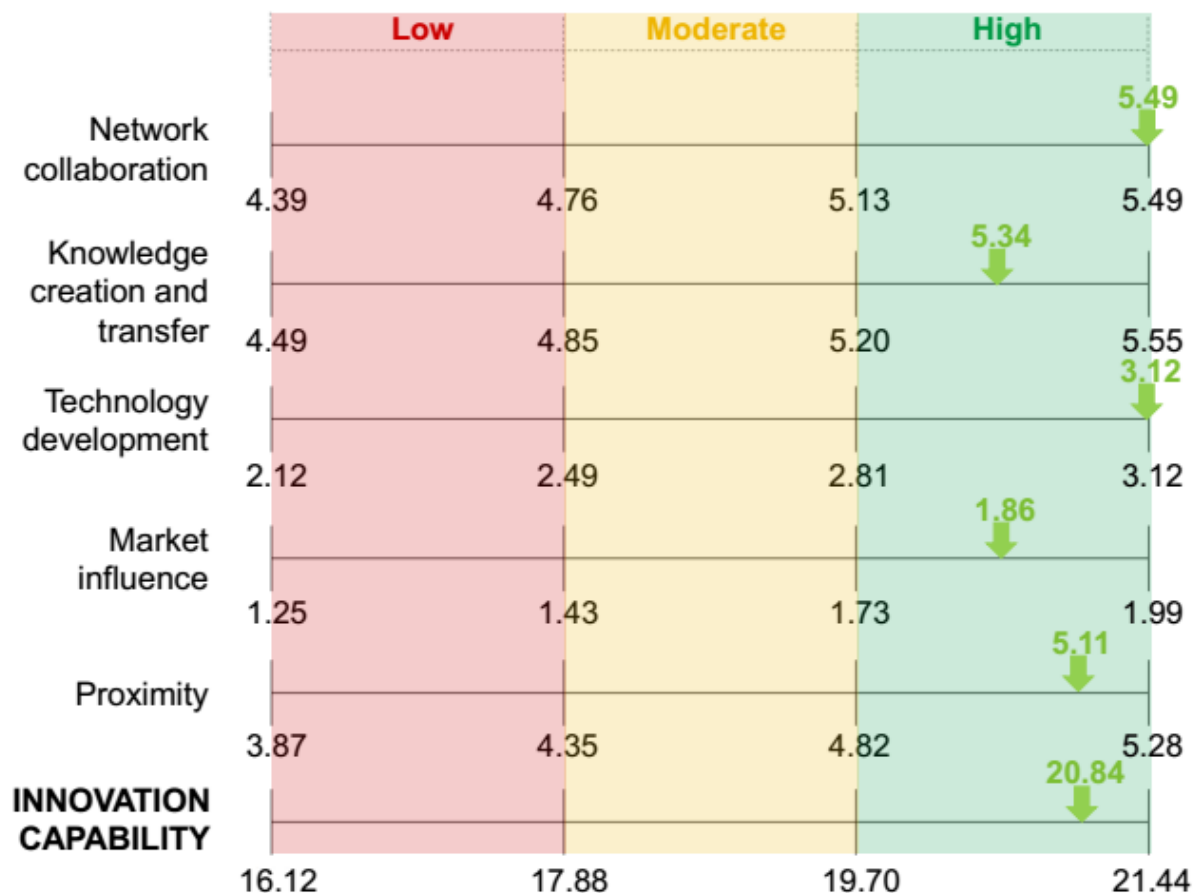


Table 48: Aspects of network collaboration – Firm D

Sub-factor	Grade	Empirical results
Relationships between companies	9	Quality relationships among firms induce learning, knowledge exchange and validation of business ideas. These interactions are essential for the understanding and meeting of customer needs.
Integrative capability	9	Integrated innovation activities enable the exchanging of information and knowledge acquired in courses, lectures or in contact with customers.
Interaction with other entities	9	Firm D is a part of Softex Recife, an association that promotes events and meetings that allow the exchange of information. Besides Softex, interviewee D indicated the CMC as a support institution, given its actions, programs and events promote exchanges among companies and external actors, besides bringing the cluster into prominence in the national and international market.
Technological collaboration	9	Besides participating in events, Firm D also has study groups with other firms, with “open source” initiatives, and interfirm groups in social media apps, which enable the development of technological collaboration.
Combinative capability	9	When it comes to the combination and obtainment of resources, two aspects were pointed out: knowledge and human resources. Firm D establishes mostly informal relationships, which has already facilitated the mobility of employees from other companies, aside from knowledge exchange and good communication with other cluster members.

Firm D obtained an index of 5.34 regarding knowledge creation and transfer. This indicates a high capability to share and absorb knowledge, which, according to interviewee D, is greatly valuable in the technological industry. Table 49 presents the comments for each sub-factor.

Table 49: Aspects of knowledge creation and transfer – Firm D

Sub-factor	Grade	Empirical results
Absorptive capacity	9	Firm D identifies, seeks and acquires knowledge from external stakeholders of the same industry, using them in the company in the implementation of policies, best practices and strategies for software development. According to the interviewee's experience, this practice is most common among technology firms.
Knowledge sharing	9	Firm B invests in the relationships with other cluster-based firms and support institutions, especially in the on-site coworking office. Such relationships drive the development of IC by creating an environment of mutual exchange of information and knowledge.
Knowledge spillovers	8	In the beginning of its operation, Firm D worked in a coworking environment and had more access to knowledge spillovers than nowadays. However, as stated previously, the firm establishes good relationships with other cluster-based companies and the spillovers happen in the meetings, events and even in social media groups.
Collective learning	9	Learning occurs socially, usually during the resolution of a client's problem, and in study group meetings, when firm members identify there is a weakness in a specific knowledge or technology.
Learning capability	2	Although big and complex projects bring more skills and knowledge to the firm, the acquired knowledge is not passed on efficiently over time when employees are working on separate projects.

When it comes to technology development, Firm D obtained the maximum level (3.12). This indicates that Firm D acts strongly in terms of technological resources and developing new techniques, practices and combinations. Interviewee D noted that not always the best technological solution is the most efficient, so the employees must be able to identify this trade-off and choose the most appropriate path. The details are presented in Table 50.

Table 50: Aspects of technology development – Firm D

Sub-factor	Grade	Empirical results
New technological opportunities	9	The emergence of new technological opportunities encourages the company to innovate and combine different technologies to design new and more efficient products in its field of activity (especially artificial intelligence).
Technological capability	9	Employees have technological skills that lead to IC and there is information sharing with other cluster-based firms, as stated previously, which enables the technological capability.
R&D capability	9	A few weekly hours are invested in the development of new products, as well as refresher courses and new courses/trainings. In the development process, all sectors of the company are involved, including legal; another factor taken into consideration during this step is customer feedback, which is often received during informal conversations as the customer tests the product.

Regarding market influence, Firm D presented an index of 1.86, which is also high according to the evaluation framework. In general terms, interviewee D remarked the obstacles encountered in the acceptance of high-level and complex IT solutions. Despite this scenario, Firm D manages to transform its technological knowledges into marketable products. The comments of the interviewee are described in Table 51.

Table 51: Aspects of market influence – Firm D

Sub-factor	Grade	Empirical results
Capability to adapt innovation to demand	6	The company has difficulties transforming its technological know-how into marketable products. The interviewee attributed this to two main reasons: the Brazilian context, in which customers are not willing to pay a higher value for a higher quality good or service; and the high competitiveness of the international market, in which the company must compete with several other companies to gain market share.
Capability to advertise and sell new products	9	The firm is focused on providing solutions to problems presented by customers (products on demand), using combinations of different technologies for this purpose. The multidisciplinary nature is an important factor and, when allied to the combination of different technologies, potentializes ideas and leads to innovation.

As to proximity, Firm D obtained an index of 5.11, considered of high level. Overall, interviewee D emphasized the importance of geographical, organizational, social and institutional proximity for Firm D. According to the respondent, the cognitive dimension is not a condition to the development of IC. The detailed information is shown in Table 52.

Table 52: Aspects of proximity – Firm D

Sub-factor	Grade	Empirical results
Geographical proximity	9	Due to the geographical proximity, there is a greater and faster exchange of information and resources between cluster-based firms. Besides, the agglomeration gives a greater visibility for its companies.
Cognitive proximity	4	There is cognitive proximity among the company founders. However, for the selection of employees, the academic training is not a determinant aspect. According to the interviewee, the human aspects are more important and the expertise can be built after the hiring. This generates different knowledge bases and hinders a greater cognitive proximity.
Organizational proximity	9	The hierarchy of the firm is horizontal and the employees are free to make decisions and test new possibilities, contributing to an organizational proximity. In relation to the cluster, other companies are considered for benchmarking purposes, observing the results of new processes, policies and behaviors implemented by them.
Social proximity	9	There is a good relationship of trust between the firm's employees, which lead to knowledge exchange inside the firm and contributes to IC. Between cluster-based firms it happens analogously, although there are customers' confidential information that cannot be shared.
Institutional proximity	9	The firm seeks to maintain collaborators and contact with institutions that have common values, habits and behavior/conduct, aiming at good results and increasing innovation, besides preventing the firm from opportunistic behavior.

To increase its ICI, Firm D could focus on two sub-factors: learning capability and cognitive proximity, since both received the lowest evaluation. When it comes to learning capability, Firm D has to improve its methodologies to transmit knowledge over time. As to cognitive proximity, the firm considers human and social aspects more important than the academic training and cognitive aspects. However, having a common comprehension and a common knowledge base among collaborators influences the IC and, thus, is subject to improvement in the context of Firm D.

Firm E

The ICI obtained for Firm E (19.69) indicates a moderate level of innovation capability, as depicted in Figure 27. Firm E practices network collaboration at a level of 5.21, considered high according to the evaluation framework. The comments that

corroborate the given grades are presented in Table 53. The interviewee remarked Firm C has a close relationship with another game studio, also located on the cluster, which was mentioned throughout the interview.

Figure 27: Firm E results

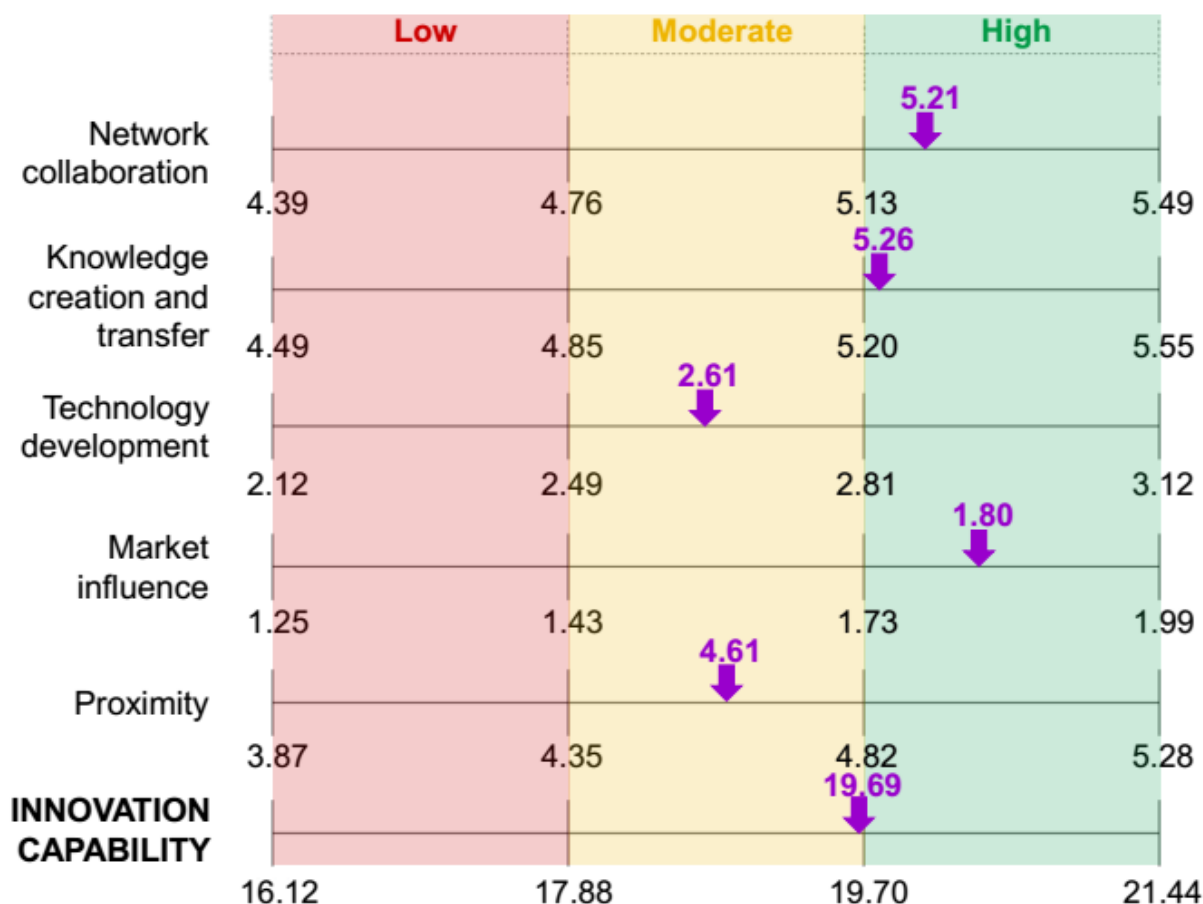


Table 53: Aspects of network collaboration – Firm E

Sub-factor	Grade	Empirical results
Relationships between companies	9	Firm E seeks to maintain good relationships with other firms. There is a particular company (once was a client and eventually became a partner) with which Firm E collaborates in various ways (project execution, attracting new projects/clients, project planning etc.). These relationships contribute to IC to the extent that it enables connecting with external agents and knowing the right people. In the company's context, a lasting quality relationship became possible when it began to solve problems before they appeared or even when the firm was not hired to do so (in other words, proactive problem solving and qualified services).
Integrative capability	8	The innovative activities of the firm happen systematically and the exploitation of resources is less important than the integration of activities and routines.
Interaction with other entities	3	The firm participates in workshops and events promoted by the CMC. This interaction happens sporadically and influences the IC by opening doors and opportunities to the firm, rather than supporting the end

Sub-factor	Grade	Empirical results
		activity. In current the context of Firm E, the interaction with other entities has a low relevance to the development of IC.
Technological collaboration	9	The firm has well defined learning routines and practices when it comes to technological collaboration, and these aspects are crucial in the development of the firm's innovation capability. The technological collaboration process is also one of the most important elements for the game developing industry.
Combinative capability	6	The employees easily exchange resources (specially knowledge) and the (re)combination of resources generates more knowledge to the firm, thus influencing the IC. Regarding the collaborative relationships, the firm has both formal and informal links, from which information is collected with the aim of creating a panorama of the innovative activities of the environment.

Firm E obtained an index of 5.26 regarding knowledge creation and transfer. Table 54 presents the comments for each sub-factor. An interesting aspect mentioned by the interviewee was that he considers informal knowledge facilitates the understanding of the environment and thus the negotiations with potential partners, which could put the firm in a position of competitive advantage.

Table 54: Aspects of knowledge creation and transfer – Firm E

Sub-factor	Grade	Empirical results
Absorptive capacity	9	The knowledge acquired from the interaction with external actors is relevant since it is applied in different areas of the company: from production/development, to executive/strategic. It happens mainly inside the same industry (technology and games) and especially with the main partner firm, stimulating this collaborative relationship.
Knowledge sharing	2	Despite having a close relationship with a specific partner firm, the interviewee does not consider Firm E invests thoroughly in knowledge sharing relationships with other cluster-based firms, support institutions or the CMC.
Knowledge spillovers	8	A great part of the acquired knowledge in Firm E's context is due to spillovers. Through this informal knowledge, it is easier to understand the environment and thus to negotiate with potential partners.
Collective learning	7	Although the learning does not happen in a systematic manner, in Firm E it has a social, cumulative and intuitive nature. Knowledge is shared in informal conversations among the employees.
Learning capability	7	Knowledge is assimilated and exploited from the environment, and Firm E possesses documentation (usually for each project) to which every involved employee has access. This procedure facilitates problem resolution, especially if it is a recurrent issue, and guarantees knowledge is passed over time, which influences in the development of IC.

Regarding technology development, Firm E obtained an index of 2.61, indicating a moderate level for this factor. Some of the main aspects pointed out by interviewee E were that Firm E has well-established technological processes and clear goals for

each project, but, when possible, seeks to adopt new technologies that could generate better solutions. The details are presented in Table 55.

Table 55: Aspects of technology development – Firm E

Sub-factor	Grade	Empirical results
New technological opportunities	6	The combination of different technologies is a common practice in the tech industry. An advantage for this Firm is that the integration of two or more technologies means the firm/the employees have a reasonable competence regarding their behavior/functions. A new technology is explored if Firm E reckons a running project will be benefited from its adoption. However, the adoption of technological tools happens mostly on customer demand. This scenario influences positively the IC of the firm; however, a great number of processes are pre-determined and thus not subject to the emergence of new technologies.
Technological capability	1	The employees have technological resources, capabilities, knowledge and experience that influence the development of IC. However, interviewee E does not recognize the sharing of information with other cluster-based firms besides the aforementioned partner company.
R&D capability	6	As soon as a product or service is demanded, the developing team starts to study the possible solutions, which requires a deep knowledge of diverse technologies. The R&D activities are not difused amongst all the areas of the firm; instead, it is focused on the competent sector. In some cases, a specific employee is signed to work on R&D. They also involve the customers in this process, by evidencing all the information they might need in case of future issues (a kind of documentation), but do not consider customer feedback for decision making in terms of technology, only for procedures, order of activities and such.

Regarding market influence, Firm E presented an index of 1.80, which is high according to the evaluation framework. Interviewee E remarked they do not have clear metrics related to customer relationships and innovation. However, the capability to adapt innovation to demand put the firm in a high level regarding the factor of market influence. The results from the empirical research regarding the sub-factors are described in Table 56.

Table 56: Aspects of market influence – Firm E

Sub-factor	Grade	Empirical results
Capability to adapt innovation to demand	9	The analysis of market demand propels the internal R&D activities, which transforms the technological knowledge of the firm in salable products.
Capability to advertise and sell new products	5	Regarding this sub-factor, the firm maintains good relationships with customers due to good quality products and after sales assessment. Besides, benchmarking is essential for the development of IC. When it comes to the influence of reputation on the firm's IC, he does not see a strong or direct influence.

As to proximity, Firm E obtained an index of 4.61, considered moderate. Overall, interviewee E gave prominence to the social aspect of proximity. The detailed information regarding the sub-factors is shown in Table 57.

Table 57: Aspects of proximity – Firm E

Sub-factor	Grade	Empirical results
Geographical proximity	8	Geographical proximity helps in the development of relationships among firms, and Firm E feels motivated to establish relationships to access new information and knowledge.
Cognitive proximity	8	A common comprehension, knowledge base and expertise of the employees facilitates innovation. These shared aspects bring a bigger alignment among employees, besides making the communication easier.
Organizational proximity	1	Firm E has a more horizontal and non-complex hierarchy, and the employees have whom to report to, but they do not have similar behaviors to the extent that the organizational dimension influence the development of the firm's IC.
Social proximity	6	There are relationships based on trust, friendship and affinity among the employees and that this facilitates the exchange of knowledge in the firm. There is also a certain lightness in the relationships (horizontal or vertical), and this ambience makes it easier to be more open with the professional opinions. This happens analogously with partner firms.
Institutional proximity	3	Although the interviewee sees the institutional proximity influences on the IC because of the common habits and cultural values of the firm, he thinks the social aspect is more relevant.

To improve its ICI, Firm E must focus on the following sub-factors: interaction with other entities, knowledge sharing, technological capability, capability to advertise and sell new products, organizational proximity and institutional proximity.

Although interviewee E stated Firm E establishes contacts with entities and institutions only sporadically, he recognized the influence of these interactions on the firm's innovation capability; therefore, the firm should invest on improving this sub-factor in a thorough manner.

As to knowledge sharing, Firm E must invest in exchanging knowledge with other firms and entities apart from the main partner firm mentioned by the interviewee. This is also related to another sub-factor: technological capability. Its medium evaluation is due to the lack of technological knowledge exchange among Firm E and other cluster-based firms (again, apart from the aforementioned partnership).

Regarding the capability to advertise and sell new products, it is subject to improvement due to the aspect of reputation, which received a low evaluation.

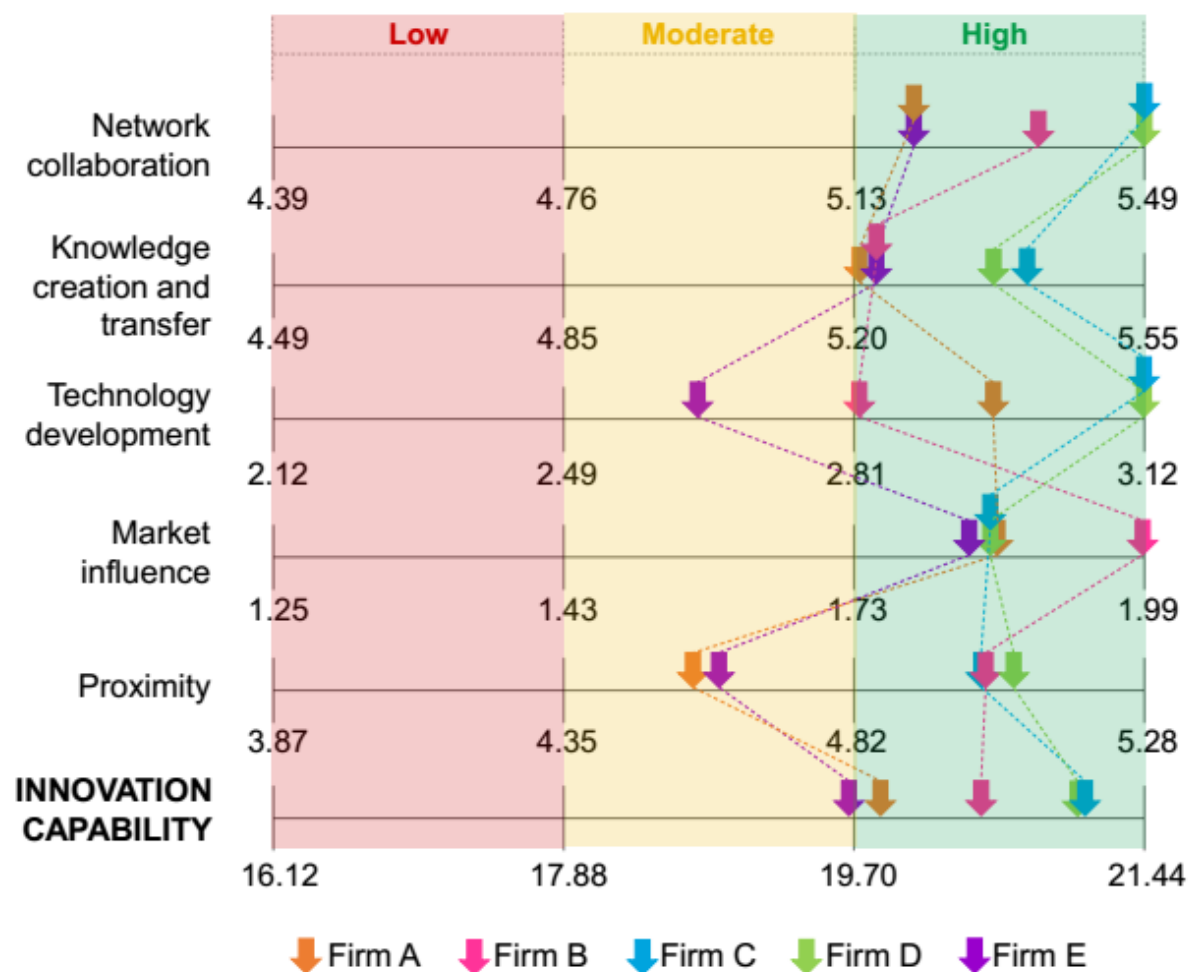
Regarding to organizational proximity, the same argument used for Firm C can be applied to Firm E: the latter should also consider strengthening its organizational

rules, hierarchy and codes of behavior, to improve its ICI. As to institutional proximity, it seems the interviewee did not fully understand its concept, making a comparison to the social aspect of proximity. Nevertheless, to improve its performance, Firm E should consider defining clear cultural values and a set of common habits to bolster its institutional proximity and thus its ICI.

7.2. CROSS-CASE ANALYSIS

After the within-case analyses, it is relevant to assess and compare the indexes obtained for the evaluation factors and for the IC, through a cross-case analysis. The indexes for the five firms are depicted in Figure 28.

Figure 28: Comparison between case studies



Firm C possesses the highest ICI (20.86), followed closely by Firm D (20.84). In its turn, Firm E obtained the lowest global index (19.50). The following discussion brings to attention the main aspects of the empirical studies that may explain these results.

Firms C and D attained the maximum index of **Network collaboration** (5.49), indicating they invest in the social aspect enabled by their presence in the cluster, which corroborates the argument of Romijn and Albu (2002) that relationships with other firms and support institutions stimulate innovation capability. The empirical evidences from the interviews substantiate this finding, since Firms C and D presented broader indication of social networking amongst the environment of the cluster, when compared to the other three companies.

However, Firms A, B and E also obtained a high evaluation for this factor (5.21, 5.39 and 5.21, respectively). Firms B and E presented stronger indications of literature findings regarding quality network relationships and partnerships that lead to saving of resources, besides the exchange of information that promotes IC (Altenburg et al., 2008; Romijn & Albu, 2002). In particular, Firm E maintains a close and trustworthy relationship with another game studio, with which the collaboration occurs in various ways (project execution, attracting new projects/clients, project planning, etc.).

One of the main aspects that enhance Firm A's performance in Network collaboration is the sub-factor of technological collaboration, which is linked to learning practices and routines (Christopherson & Clark, 2007), reinforced by the firm's solid experience in teaching individuals how to use technological tools, which is applied whether inside the firm itself or in inter-firm relationships. Firm E also presented a good performance in technological collaboration, by having well-defined learning routines and practices, besides flexible integration of resources that lead to combinative capability (Lawson & Lorenz, 1999).

For **Knowledge creation and transfer**, Firms C and D achieved the higher indexes (5.40 and 5.34, respectively). Their main advantage towards the other three companies lies, once again, in the social network they have established within the cluster. In accordance with literature, Firms C, D and E recognize the relevance of spillovers, linked to extra-firm social interactions (Díez-Vial & Fernández-Olmos, 2015; Quintana-García & Benavides-Velasco, 2005). The scenario is the exact opposite for Firms A (5.22) and B (5.26), which currently do not recognize the existence of spillovers.

It is important to note that Firms A, B and E had similar indexes for Knowledge creation and transfer, adjacent to the inferior limit of the “high level” in the evaluation scale, indicating these three firms should be more invested in the creation and transfer of knowledge.

Firms C and D also attained the maximum level for the factor **Technology development** (3.12). According to the empirical results, Firm C is constantly seeking and researching about new technologies. Besides, the firm’s core activities are linked to the combination of technologies, as suggested by Nooteboom (1999), and R&D activities are continually diffused among the firm members (Strand et al., 2017).

In its turn, Firm D works with artificial intelligence, implying in the use of cutting-edge technology, and invests a few weekly hours in the development of new products. Thus, empirical evidence suggests both Firms C and D are in line with literature, since they make effective use of its accumulated technological resources and capabilities (Cavalheiro & Brandão, 2017), which is facilitated by participation in agglomerations (Silvestre & Dalcol, 2009).

In general, Firms A (2.97) and E (2.61) do not interact with other cluster-based companies to exchange technological information and knowledge. The exception for Firm E is the partner game studio, which is also located in the same cluster. Thus, these firms should enhance their technological capability as suggested by Cavalheiro and Brandão (2017) and Silvestre and Dalcol (2009), specially Firm E, that attained only a moderate level in Technology development.

Although none of the firms have a dedicated team or sector for R&D, Firm B – whose index regarding Technology development is 2.83 – was the only firm to describe its R&D activities occurred as an “improvisation”. The context of Firm B does not presuppose creativity, thus, the company is not motivated to innovate if it is not due to a market demand or a new legal regulation.

Regarding **Market influence**, Firm B attained the maximum index (1.99). The periodical contact with drugstores association, combined with the development of services demanded by the current market (e.g., data vulnerability) and the relevant assessment of the competitive environment validate the literature findings of Sammarra and Biggiero (2008) and Yam et al. (2004).

Firms A (1.87), C and D (both 1.86) achieved similar levels of Market influence. Despite having a high performance in the market, Firm A faces a challenge: convincing

the heads of educational institutions to adopt the firm's project – thus, related to the sale and advertising aspect advocated by Yam et al. (2004).

For Firms A and C, maintaining a good reputation is fundamental, in line with Strand et al. (2017). For Firm A, it means customer loyalty, while for Firm C it is related to authority in a certain area, fundamental to the firm's end activity. On the other hand, Firm E does not invest thoroughly in the development of reputation since they do not see a strong or direct influence on the firm's IC.

In addition, Firm D was the only company to express the difficulties of transforming its technological know-how into marketable products (Samarra & Biggiero, 2008). In Firm E, there are not clear metrics in regard to customer relationships and innovation, going against the findings of Yam et al. (2004). However, the firm considers benchmarking essential for the development of IC.

Firm D reached the higher level of **Proximity** (5.11), emphasizing the importance of geographical, organizational, social and institutional proximity. The cognitive dimension was the only one that received a low evaluation, approaching the argument of Nooteboom (1999) that there must be a sufficient "cognitive distance", for otherwise knowledge becomes redundant.

Three aspects of Proximity are very strong for Firm C (4.99): geographical, social and institutional. The empirical evidence reinforced the importance of the social character of the firm, and emphasized the relevance of cultural values for all members, in terms with Boschma (2005). Regarding the geographical dimension, the importance of the industrial cluster and the CMC was emphasized. Furthermore, its creation was only possible due to a public policy in the beginning of the 2000s, and the CMC, regardless of all criticism, plays the role of projecting the cluster in the worldwide ICT and CE market.

For Firm A, which obtained a moderate level of Proximity (4.54), the only dimension that is truly relevant is the social proximity. Being located in the cluster is not considered relevant to the development of Firm A's IC, since, supposedly, the CMC does not act to promote inter-firm interactions. This argument goes against the empirical evidence of Firms B, C and D.

In turn, Firms B and E, whose Proximity indexes are, respectively, 4.98 (high) and 4.61 (moderate), presented positive evaluations regarding geographical, cognitive and social aspects. For Firm B, the organizational and institutional proximities are currently under development and structuring. Instead, for Firm E, there is not a

definition of organizational codes or rules, neither strong institutional values nor culture. Boschma (2005) argues that too much organizational proximity provides a lack of flexibility, while little organizational closeness brings lack of control, increasing the danger of opportunism. Thus, Firms B and E must invest in defining a trade-off point for their organizational proximity.

7.3. APPLICABILITY OF THE PROPOSED FRAMEWORK

The construction of the evaluation framework was based on the GTA logic, which presupposes the definition of relationships, influences or interactions among evaluation factors and sub-factors. To measure the weight of these interactions, the Delphi technique was the chosen tool, seeking an impartial opinion from specialists who had no access whatsoever to the context in which the case studies would be developed. Therefore, the Delphi technique provided the framework a level of credibility (due to the selected specialists) and generality (since it can be applied within any innovative cluster, regardless of its industry).

The framework was applied in five firms based in an ICT cluster and its results provide information regarding the innovation capability of each firm, in relation to the factors and sub-factors considered in its development. In this way, each firm is able to identify what can be improved individually and take actions that promote and enhance the innovation capability.

According to Platts (1993), the development of methods and strategies with practical applications leads to the fulfillment of real needs and knowledge creation. The author proposed three criteria for the evaluation of a model (in this case, a framework): feasibility (if the model can be developed); usability (if the model is easy to use); and utility (if the model is useful and has relevant results).

Regarding feasibility, as described above, the framework is generic and can be applied by firms based on innovative clusters, with the purpose of evaluating the innovation capability at a firm-level. Once the ICI is calculated, it enables strategic decision-making in order to increase firm's performance at each evaluation factor and sub-factor and, consequently, the IC level.

With relation to usability, since its methodology was thoroughly described in Chapter 5, the framework is also replicable, requiring only the understanding of the GTA tool and the mathematical operations involved. Also, evaluation factors and sub-

factors can be modified, removed or added, according to the reality of the firm(s) and the cluster.

Moreover, the framework can also be considered useful, since it enables the firms a better management of the factors that lead to IC, by pointing to what can be improved to develop this capability. Thus, the use of the framework can bring a greater level of awareness regarding the firm's capabilities and what leads to innovation, a self-reflection that brings benefits within the context of the firm and in the relationships with other firms. In addition to benefits inside the boundaries of each company, the use of the framework can also bring awareness to the CMC about the importance and influence of each factor and sub-factor on innovation capability, which can lead to improvements in the administration of the business network as a whole.

Therefore, once innovation capability is strengthened, the competitive advantage of each firm can increase, contributing to the cluster globally and thus generating regional development.

8. CONCLUSION

In this chapter, the conclusions of the research are presented by the verification of the achievement of the purposes, as well as the theoretical and empirical contributions. Finally, the limitations and opportunities for future research are described.

8.1. ACHIEVEMENT OF PURPOSES

In order to achieve the general purpose of this research, “to develop a framework to evaluate the innovation capability (IC) of cluster-based firms”, three specific purposes were defined. These purposes, as well as the actions developed to meet them, are described below.

Specific purpose 1: To identify and define the factors and sub-factors present in the literature that influence the IC of cluster-based firms.

To achieve this purpose, a systematic literature review was performed, to identify scientific researches that approached innovation capability of cluster-based firms as an object of study. The Web of Science database was used and, from article sample 2, the factors of IC (network collaboration, knowledge creation and transfer, technology development, market influence, and proximity) and their sub-factors in cluster-based firms were defined, as presented in Table 12, section 4.3.

Specific purpose 2: To identify hierarchical relationships and interdependence among the factors of IC in clusters-based firms through expert research.

To define the hierarchy and interdependence of IC factors and sub-factors, a multicriteria tool was used. Given that the factors have relations amongst themselves, the GTA was chosen, since it considers these influences. For the definition of the weights of the interrelations, we conducted a panel of experts using the Delphi technique (step 4 of the framework). Until this step, the framework can be considered generic and can thus be applied in any cluster-based firm that wishes to evaluate its innovation capability.

Specific purpose 3: To apply the proposed framework in cluster based-firms that operate in an information and communications technology (ICT) and creative economy (CE) cluster.

With the purpose of applying the framework, five case studies were developed in firms based in an ICT and CE cluster in Recife, a city in the northeast of Brazil, in order to calculate the ICI of each of them and demonstrate the applicability of the framework.

To carry out the case studies, interviews were conducted with managers who had sufficient knowledge to answer the questions in the interview script. The interviewees assigned notes for each IC sub-factor of the framework, justifying the notes through open questions. The grades attributed by the companies were inserted in the matrixes proposed by GTA, allowing the generation of an IC index for each analyzed firm. Together with the qualitative data extracted in the open questions made during the interviews, it was possible to analyze and discuss the results, as well as verify the applicability of the framework by analyzing its feasibility, usability and utility, according to Platts (1993).

According to the aforementioned, we can conclude the specific purposes of this dissertation were fulfilled, thus, the general purpose was achieved. Next section approaches the contributions of this research in theoretical, empirical and managerial aspects.

8.2. RESEARCH CONTRIBUTIONS

The study of sub-factors that influence the development of IC in the context of companies operating in industrial clusters is still scarce in the literature. Thus, regarding the **theoretical** contributions:

- (i) The present research allows a greater understanding on the innovation capability of cluster-based firms, due to the identification of factors and sub-factors that influence the IC of such firms. These factors and sub-factors are the result of a systematic literature review and a content analysis thoroughly performed in a sample of 74 articles (of a total of 83, considering the exploratory search);

- (ii) To evaluate the IC of firms in the context of clusters-based firms, a quantitative analysis was proposed: the evaluation framework, which is the main contribution of this dissertation, especially due to its generic aspect which enables its application in cluster-based firms of diverse industries;
- (iii) The framework can be considered robust, since it was based on GTA, a quantitative tool, and used the Delphi technique to establish the weights of the inter-relationships among factors and sub-factors, then submitted to a statistical test (using Kendall's coefficient of concordance) to verify the significance of the data. With this set of tools, the framework became generic and can be applied in any cluster-based firm;
- (iv) Besides, according to the analysis of previous researches, no papers using GTA to evaluate the IC of cluster-based firms were found.

As to **practical and managerial** aspects, the framework application allows:

- (i) The identification and evaluation of the factors and sub-factors of IC, providing an overview of which of these factors affect to a greater or lesser extent the capability to innovate. Thus, it can contribute to strategic decision-making regarding the organizational characteristics and capabilities (what to improve, where to invest, etc.), since it will enable the identification of how these factors influence the ability to develop innovative solutions in cluster-based firms;
- (ii) Since the framework is generic and can be applied in firms with different contexts and from different industry sectors, and its methodology is described throughout this document, it can be adapted by researchers (regarding the choice of factors submitted to specialists evaluation) and by managers (regarding the choice of evaluation factors for the firm).

In addition, this research contributes to regional development, since the evolution of the cluster and its innovation process implies in development and growth of the region in which it is inserted (Novelli et al., 2006; Porter, 2003; Wonglimpiyarat, 2006), particularly because it is a representative cluster for the State of Pernambuco and for the Northeast region as a whole. Therefore, improving the innovation capability of companies within this cluster can help reduce regional asymmetries.

8.3. LIMITATIONS AND OPPORTUNITIES FOR FUTURE RESEARCH

The development of this research presented a few limitations. The first one is related to the SLR developed to identify the factors and sub-factors of IC, especially regarding the creation of the articles sample, whose methods were described in Chapter 3 and the results shown in Chapter 4. For example, some of the articles were not available for download, a search string may have been left out, as well as a relevant database. Further research could use other database and different search strings.

Regarding the framework, it evaluates the innovation capability of each cluster-based firm, not providing an index for the whole industrial cluster. In addition, it does not consider the relationships among sub-factors of different factors (e.g., the influence of geographical proximity on knowledge spillovers, present in the literature, was not quantified). As opportunities for future research, a comparative study between cluster-based and non-cluster-based firms could be made, as well as an index for the IC of the cluster could be proposed. Besides, to consider the interdependence of non-hierarchical sub-factors, another multicriteria tool could be chosen.

As to the Delphi technique, after three rounds and almost three months, the consensus was not reached, which is why a statistical test was used to evaluate the significance of the attributed weights. However, even the statistical test faced a limitation: a subset of data (Market influence) presented a significance level slightly higher than expected, due to the small size of the set. An alternative would be using focal groups instead of Delphi.

For four firms, the case studies interviews were applied to only one person. Future research could consider focal groups. Also, the study was not longitudinal and thus corresponds only to the present time. Thus, an opportunity for further research is making a longitudinal case study. Besides, the longitudinal studies could consider the influence of business lifecycle's phases on the development of innovation capabilities.

The use of GTA implies in a series of mathematical calculations (permanents, logarithms). So, another opportunity for future research is the development of a software that automatizes the framework, in which only the firms' grades are inserted. The companies would have access to a powerful tool for strategic decision-making regarding innovation.

REFERENCES

- Akman, G., & Yilmaz, C. (2008). Innovative Capability, Innovation Strategy and Market Orientation: an Empirical Analysis in Turkish Software Industry. *International Journal of Innovation Management*, 12(01), 69–111. <https://doi.org/10.1142/S1363919608001923>
- Allen, T. J., Gloor, P. A., Fronzetti Colladon, A., Woerner, S. L., & Raz, O. (2016). The power of reciprocal knowledge sharing relationships for startup success. *Journal of Small Business and Enterprise Development*, 23(3), 636–651. <https://doi.org/10.1108/JSBED-08-2015-0110>
- Altenburg, T., & Meyer-Stamer, J. (1999). How to Promote Clusters: Policy Experiences from Latin America. *World Development*, 27(9), 1693–1713. [https://doi.org/http://dx.doi.org/10.1016/S0305-750X\(99\)00081-9](https://doi.org/http://dx.doi.org/10.1016/S0305-750X(99)00081-9)
- Altenburg, T., Schmitz, H., & Stamm, A. (2008). Breakthrough? China's and India's Transition from Production to Innovation. *World Development*, 36(2), 325–344. <https://doi.org/10.1016/j.worlddev.2007.06.011>
- Álvarez, I., Marin, R., & Fonfría, A. (2009). The role of networking in the competitiveness of firms. *Technological Forecasting and Social Change*, 76(3), 410–421. <https://doi.org/10.1016/j.techfore.2008.10.002>
- Amit, R., & Schoemaker, P. J. H. (1993). Strategic Assets and Organizational Rent. *Strategic Management Journal*, 14(1), 33–46. Retrieved from <http://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=12493458&site=ehost-live>
- Anand, G., & Bahinipati, B. K. (2012). Measuring horizontal collaboration intensity in supply chain: a graph-theoretic approach. *Production Planning & Control*, 23(November), 801–816. <https://doi.org/10.1080/09537287.2011.642164>
- Anbanandam, R., Banwet, D. K., Shankar, R., Anbanandam, R., Banwet, D. K., & Shankar, R. (2011). Evaluation of supply chain collaboration: a case of apparel retail industry in India. <https://doi.org/10.1108/17410401111101449>
- Antolin-Lopez, R., Martinez-del-Rio, J., Cespedes-Lorente, J. J., & Perez-Valls, M. (2015). The choice of suitable cooperation partners for product innovation: Differences between new ventures and established companies. *European Management Journal*, 33(6), 472–484. <https://doi.org/10.1016/j.emj.2015.09.002>
- Atalay, M., Dirlik, O., & Sarvan, F. (2017). Impact of multilevel strategic alliances on innovation and firm performance. *International Journal of Innovation Science*, 9(1), 53–80. <https://doi.org/10.1108/IJIS-06-2016-0012>
- Azevedo, S. G., Govindan, K., Carvalho, H., & Cruz-Machado, V. (2012). An integrated model to assess the leanness and agility of the automotive industry. *Resources, Conservation and Recycling*, 66, 85–94. <https://doi.org/10.1016/j.resconrec.2011.12.013>
- Baykasoglu, A. (2012). A review and analysis of “graph theoretical-matrix permanent”

- approach to decision making with example applications. *Artificial Intelligence Review*, 7(1), 10–18. <https://doi.org/10.1007/s10462-012-9354-y>
- Boly, V., Morel, L., Assielou, N. G., & Camargo, M. (2014). Evaluating innovative processes in french firms: Methodological proposition for firm innovation capacity evaluation. *Research Policy*, 43(3), 608–622. <https://doi.org/10.1016/j.respol.2013.09.005>
- Boschma, R. A. (2005). Proximity and innovation: A critical assessment. *Regional Studies*, 39(1), 61–74. <https://doi.org/10.1080/0034340052000320887>
- Britton, J. N. H. (2004). High technology localization and extra-regional networks. *Entrepreneurship and Regional Development*, 16(5), 369–390. <https://doi.org/10.1080/08985620410001674351>
- Brown, J. S., & Duguid, P. (2002). Local knowledge: innovation in the networked age. *Management Learning*, 33(4), 427–427.
- Cantner, U., Meder, A., & Ter Wal, A. L. J. (2010). Innovator networks and regional knowledge base. *Technovation*, 30(9–10), 496–507. <https://doi.org/10.1016/j.technovation.2010.04.002>
- Capello, R. (1999). Spatial transfer of knowledge in high technology milieux: Learning versus collective learning processes. *Regional Studies*, 33(4), 353–365. <https://doi.org/10.1080/00343409950081211>
- Cappellin, R. (2003). Territorial knowledge management: towards a metrics of the cognitive dimension of agglomeration economies. *International Journal of Technology Management*, 26(2/3/4), 303. <https://doi.org/10.1504/IJTM.2003.003384>
- Cavalheiro, G. M. do C., & Brandão, M. (2017). Assessing the IP portfolio of industrial clusters: the case of the Brazilian footwear industry. *Journal of Manufacturing Technology Management*, 28(8), 994–1010. <https://doi.org/10.1108/JMTM-10-2016-0137>
- Cavalheiro, G. M. do C., Brandão, M., & Brandao, M. (2017). Assessing the IP portfolio of industrial clusters: the case of the Brazilian footwear industry. *Journal of Manufacturing Technology Management*, 28(8), 994–1010. <https://doi.org/10.1108/JMTM-10-2016-0137>
- Chandrashekar, D., & Hillemane, B. S. M. (2018). Absorptive capacity, cluster linkages, and innovation. *Journal of Manufacturing Technology Management*, 29(1), 121–148. <https://doi.org/10.1108/JMTM-05-2017-0087>
- Christopherson, S., & Clark, J. (2007). Power in firm networks: What it means for regional innovation systems. *Regional Studies*, 41(9), 1223–1236. <https://doi.org/10.1080/00343400701543330>
- Cohen, W. M., & Levinthal, D. A. (1990). Absorptive Capacity : A New Perspective on and Innovation Learning. *Administrative Science Quarterly*, 35(1), 128–152.

- Crespo, J., Suire, R., & Vicente, J. (2014). Lock-in or lock-out? How structural properties of knowledge networks affect regional resilience. *Journal of Economic Geography*, 14(1), 199–219. <https://doi.org/10.1093/jeg/lbt006>
- Dagnino, G. B., Levanti, G., Minà, A., & Picone, P. M. (2015). Interorganizational network and innovation: a bibliometric study and proposed research agenda. *Journal of Business & Industrial Marketing*, 30(3/4), 354–377. <https://doi.org/10.1108/JBIM-02-2013-0032>
- Dalcin, T., Balestrin, A., & Teixeira, E. K. (2017). Start-Up Cluster Development: A Multi-Case Analysis in the Brazilian Context. *International Journal of Innovation and Technology Management*, 14(06), 1750035. <https://doi.org/10.1142/S0219877017500353>
- Dangelico, R. M., Garavelli, A. C., & Petruzzelli, A. M. (2010). A system dynamics model to analyze technology districts' evolution in a knowledge-based perspective. *Technovation*, 30(2), 142–153. <https://doi.org/10.1016/j.technovation.2009.09.006>
- De Bruijn, P. J. M. (2004). Mapping innovation: Regional dimensions of innovation and networking in the Netherlands. *Tijdschrift Voor Economische En Sociale Geografie*, 95(4), 433–440. <https://doi.org/10.1111/j.0040-747X.2004.00329.x>
- De Marchi, V., & Grandinetti, R. (2017). Regional Innovation Systems or Innovative Regions? Evidence from Italy. *Tijdschrift Voor Economische En Sociale Geografie*, 108(2), 234–249. <https://doi.org/10.1111/tesg.12217>
- Díez-Vial, I., & Fernández-Olmos, M. (2015). Knowledge spillovers in science and technology parks: how can firms benefit most? *Journal of Technology Transfer*, 40(1), 70–84. <https://doi.org/10.1007/s10961-013-9329-4>
- Elche, D., García-Villaverde, P. M., & Martínez-Pérez, Á. (2018). Inter-organizational relationships with core and peripheral partners in heritage tourism clusters: divergent effects on innovation. *International Journal of Contemporary Hospitality Management*, 30(6), 2438–2457. <https://doi.org/10.1108/IJCHM-11-2016-0611>
- Feldman, M. P. (2014). The character of innovative places: Entrepreneurial strategy, economic development, and prosperity. *Small Business Economics*, 43(1), 9–20. <https://doi.org/10.1007/s11187-014-9574-4>
- Fleming, L., King, C., & Juda, A. I. (2007). Small Worlds and Regional Innovation. *Organization Science*, 18(6), 938–954. <https://doi.org/10.1287/orsc.1070.0289>
- Fontes, M., & Sousa, C. (2016). Types of proximity in knowledge access by science-based start-ups. *European Journal of Innovation Management*, 19(3), 298–316. <https://doi.org/10.1108/EJIM-10-2014-0104>
- Ganesan, S., Malter, A. J., & Rindfleisch, A. (2005). Does Distance Still Matter? Geographic Proximity and New Product Development. *Journal of Marketing*, 69(4), 44–60. <https://doi.org/10.1509/jmkg.2005.69.4.44>

- Garcia, R., & Calantone, R. (2002). A critical look at technological innovation typology and innovativeness: a literature review. *The Journal of Product Innovation Management*, 19(2), 110–132. [https://doi.org/10.1016/S0737-6782\(01\)00132-1](https://doi.org/10.1016/S0737-6782(01)00132-1)
- Giuliani, E. (2013). Network dynamics in regional clusters: Evidence from Chile. *Research Policy*, 42(8), 1406–1419. <https://doi.org/10.1016/j.respol.2013.04.002>
- Greenhalgh, T. (1997). How to read a paper: Papers that summarise other papers (systematic reviews and meta-analyses). *Bmj*, 315(7109), 672–675. <https://doi.org/10.1136/bmj.315.7109.672>
- Grillitsch, M., & Nilsson, M. (2015). Innovation in peripheral regions: Do collaborations compensate for a lack of local knowledge spillovers? *Annals of Regional Science*, 54(1), 299–321. <https://doi.org/10.1007/s00168-014-0655-8>
- Grillitsch, M., Tödtling, F., & Höglinger, C. (2015). Variety in knowledge sourcing, geography and innovation: Evidence from the ICT sector in Austria. *Papers in Regional Science*, 94(1), 25–43. <https://doi.org/10.1111/pirs.12050>
- Helfat, C. E., & Peteraf, M. A. (2003). The dynamic resource-based view: Capability lifecycles. *Strategic Management Journal*, 24(10 SPEC ISS.), 997–1010. <https://doi.org/10.1002/smj.332>
- Herstad, S. J., & Ebersberger, B. (2014). Urban agglomerations, knowledge-intensive services and innovation: Establishing the core connections. *Entrepreneurship and Regional Development*, 26(3–4), 211–233. <https://doi.org/10.1080/08985626.2014.888098>
- Hervás-Oliver, J. L., & Albors-Garrigós, J. (2007). Do clusters capabilities matter? An empirical application of the resource-based view in clusters. *Entrepreneurship and Regional Development*, 19(2), 113–136. <https://doi.org/10.1080/08985620601137554>
- Huggins, R., Johnston, A., & Thompson, P. (2012). Network Capital, Social Capital and Knowledge Flow: How the Nature of Inter-organizational Networks Impacts on Innovation. *Industry and Innovation*, 19(3), 203–232. <https://doi.org/10.1080/13662716.2012.669615>
- Jang, S., Kim, J., & von Zedtwitz, M. (2017). The importance of spatial agglomeration in product innovation: A microgeography perspective. *Journal of Business Research*, 78(December 2016), 143–154. <https://doi.org/10.1016/j.jbusres.2017.05.017>
- Jerez-Gómez, P., Céspedes-Lorente, J., & Valle-Cabrera, R. (2005). Organizational learning capability: A proposal of measurement. *Journal of Business Research*, 58(6), 715–725. <https://doi.org/10.1016/j.jbusres.2003.11.002>
- Kalsaas, B. T. (2013). Collaborative innovation: The decade that radically changed drilling performance. *Production Planning and Control*, 24(2–3), 265–275. <https://doi.org/10.1080/09537287.2011.647881>

- Kitchenham, B. (2004). Procedures for performing systematic reviews. *Keele, UK, Keele University*, 33(TR/SE-0401), 28. <https://doi.org/10.1.1.122.3308>
- Koçak, Ö., & Can, Ö. (2014). Determinants of inter-firm networks among tenants of science technology parks. *Industrial and Corporate Change*, 23(2), 467–492. <https://doi.org/10.1093/icc/dtt015>
- Lacerda, R. T. de O., Ensslin, L., & Ensslin, S. R. (2012). Uma análise bibliométrica da literatura sobre estratégia e avaliação de desempenho. *Gestão & Produção*, 19(1), 59–78. <https://doi.org/10.1590/S0104-530X2012000100005>
- Larty, J., Jack, S., & Lockett, N. (2017). Building regions: a resource-based view of a policy-led knowledge exchange network. *Regional Studies*, 51(7), 994–1007. <https://doi.org/10.1080/00343404.2016.1143093>
- Lawson, C., & Lorenz, E. (1999). Collective Learning, Tacit Knowledge and Regional Innovative Capacity. *Regional Studies*, 33(4), 305–317. <https://doi.org/10.1080/713693555>
- Legendre, P. (2010). Coefficient of concordance. In N. J. Salkind (Ed.), *Encyclopedia of Research Design* (pp. 164–169). SAGE Publications.
- Lei, H.-S., & Huang, C.-H. (2014). Geographic clustering, network relationships and competitive advantage: Two industrial clusters in Taiwan. *Management Decision*, 52(5), 852–871. <https://doi.org/10.1108/JBIM-06-2016-0127>
- Marshall, A. (1890). *Principles of Economics* (8th ed.). London: Macmillan.
- Martínez-Román, J. A., Gamero, J., & Tamayo, J. A. (2011). Analysis of innovation in SMEs using an innovative capability-based non-linear model: A study in the province of Seville (Spain). *Technovation*, 31(9), 459–475. <https://doi.org/10.1016/j.technovation.2011.05.005>
- Maskell, P., & Malmberg, A. (1999). Localised learning and industrial competitiveness. *Cambridge Journal of Economics*, 23(2), 167–185. <https://doi.org/10.1093/cje/23.2.167>
- Mattos, J. R. L. de, & Guimarães, L. dos S. (2012). *Gestão da Tecnologia e Inovação* (2ª). São Paulo: Saraiva.
- Miguel, P. A. C. (2007). Estudo de caso na engenharia de produção: estruturação e recomendações para sua condução. *Produção*, 17(1), 216–229. <https://doi.org/10.1590/S0103-65132007000100015>
- Molina-Morales, F. X., Martínez-Fernández, M. T., & Coll-Serrano, V. (2012). La eficiencia y la innovación en las subredes de empresas. Un estudio del distrito cerámico español. *Innovar*, 22(46), 111–127. Retrieved from http://zv4fy5pr5l.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info:ofi/enc:UTF-8&rft_id=info:sid/ProQ%253Apqrl&rft_val_fmt=info:ofi/fmt:kev:mtx:journal&rft.genre=article&rft.jtitle=Innovar&rft.atitle=La+eficiencia+y+la+innovacion+en+las+subre

- Montoro-Sánchez, A., Ortiz-de-Urbina-Criado, M., & Mora-Valentín, E. M. (2011). Effects of knowledge spillovers on innovation and collaboration in science and technology parks. *Journal of Knowledge Management*, 15(6), 948–970. <https://doi.org/10.1108/13673271111179307>
- Moreno, R., & Miguélez, E. (2012). A relational approach to the geography of innovation: A typology of regions. *Journal of Economic Surveys*, 26(3), 492–516. <https://doi.org/10.1111/j.1467-6419.2012.00727.x>
- Nooteboom, B. (1999). Innovation, organisation learning and industrial. *Cambridge Journal of Economics*, 23(2), 127–150.
- Novelli, M., Schmitz, B., & Spencer, T. (2006). Networks, clusters and innovation in tourism: A UK experience. *Tourism Management*, 27(6), 1141–1152. <https://doi.org/10.1016/j.tourman.2005.11.011>
- O'Dwyer, M., O'Malley, L., Murphy, S., & McNally, R. C. (2015). Insights into the creation of a successful MNE innovation cluster. *Competitiveness Review*, 25(3), 288–309. <https://doi.org/10.1108/CR-08-2014-0026>
- O'Gorman, C., & Kautonen, M. (2004). Policies to promote new knowledge-intensive industrial agglomerations. *Entrepreneurship and Regional Development*, 16(6), 459–479. <https://doi.org/10.1080/0898562042000224369>
- OECD. (2005). *Oslo Manual: Guidelines for collecting and interpreting innovation data*. Communities (3rd ed., Vol. Third edit). Paris: OECD Publishing. <https://doi.org/10.1787/9789264013100-en>
- Okoli, C., & Pawlowski, S. D. (2004). The Delphi method as a research tool: An example, design considerations and applications. *Information and Management*, 42(1), 15–29. <https://doi.org/10.1016/j.im.2003.11.002>
- Pechlaner, H., & Bachinger, M. (2010). Knowledge networks of innovative businesses: An explorative study in the region of Ingolstadt. *Service Industries Journal*, 30(10), 1737–1756. <https://doi.org/10.1080/02642060903580722>
- Peltoniemi, M. (2013). Mechanisms of capability evolution in the Finnish forest industry cluster. *Journal of Forest Economics*, 19(2), 190–205. <https://doi.org/10.1016/j.jfe.2013.02.001>
- Petruzzelli, A. M., Albino, V., & Carbonara, N. (2009). External knowledge sources and proximity. *Journal of Knowledge Management*, 13(5), 301–318. <https://doi.org/10.1108/13673270910988123>
- Platts, K. W. (1993). A Process Approach to Researching Manufacturing Strategy. *International Journal of Operations & Production Management*, 13(8), 4–17. <https://doi.org/https://doi.org/10.1108/01443579310039533>
- Porter, M. E. (1998). Clusters and the New Economics of Competition. *Harvard Business Review*, (November), 77–90.
- Porter, M. E. (2000). Economic Development: Local Clusters in a Global Economy.

- Economic Development Quarterly*, 14(1), 15–34.
<https://doi.org/10.1177/089124240001400105>
- Porter, M. E. (2003). The economic performance of regions. *Regional Studies*, 37(6–7), 549–578. <https://doi.org/10.1080/0034340032000108697>
- Presutti, M., Boari, C., & Majocchi, A. (2011). The Importance of Proximity for the Start-Ups' Knowledge Acquisition and Exploitation. *Journal of Small Business Management*, 49(3), 361–389. <https://doi.org/10.1111/j.1540-627X.2011.00331.x>
- Quintana-García, C., & Benavides-Velasco, C. A. (2005). Agglomeration economies and vertical alliances: The route to product innovation in biotechnology firms. *International Journal of Production Research*, 43(22), 4853–4873.
<https://doi.org/10.1080/00207540500161753>
- Rajesh, A., Nikhil, D., & Vivek, S. (2013). Graph theoretic approach (GTA) – A Multi-Attribute Decision Making (MADM) Technique. *Research Journal of Engineering Sciences*, 2(1), 50–53. Retrieved from <http://www.isca.in/IJES/Archive/v2i1/10.ISCA-RJEngS-2012-118.pdf>
- Rejeb, H. Ben, Morel-Guimarães, L., Boly, V., & Assiélou, N. G. (2008). Measuring innovation best practices: Improvement of an innovation index integrating threshold and synergy effects. *Technovation*, 28(12), 838–854.
<https://doi.org/10.1016/j.technovation.2008.08.005>
- Romijn, H., & Albaladejo, M. (2002). Determinants of innovation capability in small electronics and software firms in southeast England. *Research Policy*, 31(7), 1053–1067. Retrieved from <http://core.ac.uk/download/pdf/7074474.pdf>
- Romijn, H., & Albu, M. (2002). Innovation, networking and proximity: Lessons from small high technology firms in the UK. *Regional Studies*, 36(1), 81–86.
<https://doi.org/10.1080/00343400120099889>
- Rowe, G., & Wright, G. (1999). The Delphi technique as a forecasting tool: Issues and analysis. *International Journal of Forecasting*, 15(4), 353–375.
[https://doi.org/10.1016/S0169-2070\(99\)00018-7](https://doi.org/10.1016/S0169-2070(99)00018-7)
- Sammarra, A., & Biggiero, L. (2008). Heterogeneity and Specicity of Inter-Firm Knowledge Flows in Innovation Networks. *Journal of Management Studies*, 45(4), 800–829. <https://doi.org/10.1111/j.1467-6486.2008.00770.x>
- Saunila, M. (2017). Managing continuous innovation through performance measurement. *Competitiveness Review*, 27(2), 179–190.
<https://doi.org/10.1108/CR-03-2015-0014>
- Schilling, M. A., & Phelps, C. C. (2007). Interfirm Collaboration Networks: The Impact of Large-Scale Network Structure on Firm Innovation. *Management Science*, 53(7), 1113–1126. <https://doi.org/10.1287/mnsc.1060.0624>
- Schmitz, H. (1992). On the Clustering of Small Firms. *IDS Bulletin*, 23(3), 64–69.
<https://doi.org/10.1111/j.1759-5436.1992.mp23003012.x>

- Schumpeter, J. A. (1947). The Creative Response in Economic History. *The Journal of Economic History*, 7(2), 149–159.
<https://doi.org/10.1017/S0022050700054279>
- Silvestre, B. dos S., & Dalcol, P. R. T. (2009). Geographical proximity and innovation: Evidences from the Campos Basin oil & gas industrial agglomeration-Brazil. *Technovation*, 29(8), 546–561.
<https://doi.org/10.1016/j.technovation.2009.01.003>
- Spigel, B. (2017). The Relational Organization of Entrepreneurial Ecosystems. *Entrepreneurship: Theory and Practice*, 41(1), 49–72.
<https://doi.org/10.1111/etap.12167>
- Strand, Ø., Wiig, M., Torheim, T., Solli-Sæther, H., & Nettet, E. (2017). Technological Innovation Capability and Interaction Effect in a Scandinavian Industry Cluster. *International Journal of Innovation Management*, 21(05), 1740007. <https://doi.org/10.1142/S1363919617400072>
- Szeto, E. (2000). Innovation capacity: working towards a mechanism for improving innovation within an inter-organizational network. *The TQM Magazine*, 12(2), 149–158. <https://doi.org/10.1108/09544780010318415>
- Teece, D. J. (1992). Competition, cooperation, and innovation. Organizational arrangements for regimes of rapid technological progress. *Journal of Economic Behavior and Organization*, 18(1), 1–25. [https://doi.org/10.1016/0167-2681\(92\)90050-L](https://doi.org/10.1016/0167-2681(92)90050-L)
- Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, 18(7), 509–533.
- Ter Wal, A. L. J., & Boschma, R. (2011). Co-evolution of firms, industries and networks in space. *Regional Studies*, 45(7), 919–933.
<https://doi.org/10.1080/00343400802662658>
- Thangaratinam, S., & Redman, C. W. (2005). The Delphi technique. *The Obstetrician & Gynaecologist*, 7(2), 120–125. <https://doi.org/10.1576/toag.7.2.120.27071>
- Toivanen, H. (2014). The shift from theory to innovation: the evolution of Brazilian research frontiers 2005-2011. *Technology Analysis and Strategic Management*, 26(1), 105–119. <https://doi.org/10.1080/09537325.2013.850160>
- Ucler, C. (2017). Intelligent assignment in clusters to enhance collaboration and innovation. *Journal of Manufacturing Technology Management*, 28(5), 554–576.
<https://doi.org/10.1108/JHOM-09-2016-0165>
- Wannenmacher, D., & Antoine, A. (2016). Management of innovative collaborative projects: Moments of tension and the Peer-Mediation Process—a case-study approach. *Knowledge Management Research & Practice*, 14(1), 35–45.
<https://doi.org/10.1057/kmrp.2014.34>
- Whittington, K. B., Owen-Smith, J., & Powell, W. W. (2009). Kjersten Bunker Whittington. *Administrative Science Quarterly*, 54(1), 90–122.

- Winter, S. G. (2003). Understanding dynamic capabilities. *Strategic Management Journal*, 24(10 SPEC ISS.), 991–995. <https://doi.org/10.1002/smj.318>
- Wonglimpiyarat, J. (2006). The dynamic economic engine at Silicon Valley and US Government programmes in financing innovations. *Technovation*, 26(9), 1081–1089. <https://doi.org/10.1016/j.technovation.2005.09.005>
- Wonglimpiyarat, J. (2010). Innovation index and the innovative capacity of nations. *Futures*, 42(3), 247–253. <https://doi.org/10.1016/j.futures.2009.11.010>
- Yam, R. C. M., Guan, J. C., Pun, K. F., & Tang, E. P. Y. (2004). An audit of technological innovation capabilities in Chinese firms: Some empirical findings in Beijing, China. *Research Policy*, 33(8), 1123–1140. <https://doi.org/10.1016/j.respol.2004.05.004>
- Yin, R. K. (2015). *Estudo de caso: Planejamento e métodos* (5th ed.). Porto Alegre: Bookman.
- Yström, A., & Aspenberg, H. (2017). Open for Innovation? Practices Supporting Collaboration in Swedish Regional Clusters. *International Journal of Innovation Management*, 21(05), 1740008. <https://doi.org/10.1142/S1363919617400084>
- Zukauskaitė, E. (2012). Innovation in cultural industries: The role of University links. *Innovation: Management, Policy and Practice*, 14(3), 404–415. <https://doi.org/10.5172/impp.2012.14.3.404>

APPENDIX A – Articles from the main sample

Nº	AUTHORS	TITLE	JOURNAL
1	Allen et al. (2016)	The power of reciprocal knowledge sharing relationships for startup success	Journal of Small Business and Enterprise Development
2	Altenburg, Schmitz, and Stamm (2008)	Breakthrough? China's and India's transition from production to innovation	World Development
3	Alvarez, Marin, and Fonfria (2009)	The role of networking in the competitiveness of firms	Technological Forecasting and Social Change
4	Antolin-Lopez et al. (2015)	The choice of suitable cooperation partners for product innovation: Differences between new ventures and established companies	European Management Journal
5	Atalay, Dirlik, and Sarvan (2017)	Impact of multilevel strategic alliances on innovation and firm performance: Evidence from the yacht-building industry in Turkey	International Journal of Innovation Science
6	Best (2015)	Greater Boston's industrial ecosystem: a manufactory of sectors	Technovation
7	Boly et al. (2014)	Evaluating innovative processes in french firms: Methodological proposition for firm innovation capacity evaluation	Research Policy
8	Britton (2004)	High technology localization and extra-regional networks	Entrepreneurship and Regional Development
9	Brown e Duguid (2002)	Local knowledge - Innovation in the networked age	Management Learning
10	Cantner, Meder and Ter Wal (2010)	Innovator networks and regional knowledge base	Technovation
11	Capello (1999)	Spatial transfer of knowledge in high technology milieux: Learning versus collective learning processes	Regional Studies
12	Cappellin (2003)	Territorial knowledge management: towards a metrics of the cognitive dimension of agglomeration economies	International Journal of Technology Management
13	Cavalheiro and Brandão (2017)	Assessing the IP portfolio of industrial clusters: the case of the Brazilian footwear industry	Journal of Manufacturing Technology Management
14	Chandrashekar and Subrahmanya (2017)	Absorptive capacity as a determinant of innovation in SMEs: A study of Bengaluru high-tech manufacturing cluster	Small Enterprise Research
15	Chandrashekar and Hillemane (2018)	Absorptive capacity, cluster linkages, and innovation: An evidence from Bengaluru high-tech manufacturing cluster	Journal of Manufacturing Technology Management
16	Christopherson and Clark (2007)	Power in firm networks: what it means for regional innovation systems	Regional Studies
17	Claver-Cortés et al. (2017)	Location in scientific-technological parks, dynamic capabilities, and innovation	Technology Analysis & Strategic Management
18	Cooke (2001)	Regional Innovation Systems, Clusters, and the Knowledge Economy	Industrial and Corporate Change
19	Crespo, Suire, and Vicente (2014)	Lock-in or lock-out? How structural properties of knowledge networks affect regional resilience	Journal of Economic Geography
20	Dagnino et al. (2015)	Interorganizational network and innovation: a bibliometric study and proposed research agenda	Journal of Business & Industrial Marketing
21	Dalcin, Balestrin, and Teixeira (2017)	Start-up Cluster Development: a multi-case analysis in the Brazilian context	International Journal of Innovation and

			Technology Management
22	Dangelico, Garavelli, and Petruzzelli (2010)	A system dynamics model to analyze technology districts' evolution in a knowledge-based perspective	Technovation
23	De Bruijn (2004)	Mapping innovation: Regional dimensions of innovation and networking in The Netherlands	Tijdschrift Voor Economische En Sociale Geografie
24	De Marchi and Grandinetti (2017)	Regional Innovation Systems or Innovative Regions? Evidence from Italy	Tijdschrift Voor Economische En Sociale Geografie
25	Díez-Vial and Fernandez-Olmos (2015)	Knowledge spillovers in science and technology parks: how can firms benefit most?	Journal of Technology Transfer
26	Elche, García-Villaverde and Martínez-Pérez (2018)	Inter-organizational relationships with core and peripheral partners in heritage tourism clusters: Divergent effects on innovation	International Journal of Contemporary Hospitality Management
27	Expósito-Langa et al. (2018)	Embeddedness in cluster knowledge networks, the moderating role of network competence. The case study of the Romanian wine cluster of Muntenia-Oltenia	Romanian Journal of Economic Forecasting
28	Feldman (2014)	The character of innovative places: entrepreneurial strategy, economic development, and prosperity	Small Business Economics
29	Fleming, King, and Juda (2007)	Small worlds and regional innovation	Organization Science
30	Fontes and Sousa (2016)	Types of proximity in knowledge access by science-based start-ups	European Journal of Innovation Management
31	Ganesan, Malter, and Rindfleisch (2005)	Does distance still matter? Geographic proximity and new product development	Journal of Marketing
32	Giuliani (2013)	Network dynamics in regional clusters: Evidence from Chile	Research Policy
33	Grillitsch and Nilsson (2015)	Innovation in peripheral regions: do collaborations compensate for a lack of local knowledge spillovers?	Annals of Regional Science
34	Grillitsch, Todtling, and Hoglinger (2015)	Variety in knowledge sourcing, geography and innovation: Evidence from the ICT sector in Austria	Papers in Regional Science
35	Herstad and Ebersberger (2014)	Urban agglomerations, knowledge-intensive services and innovation: establishing the core connections	Entrepreneurship and Regional Development
36	Huggins, Johnston, and Thompson (2012)	Network Capital, Social Capital and Knowledge Flow: How the Nature of Inter-organizational Networks Impacts on Innovation	Industry and Innovation
37	Jang, Kim, and von Zedtwitz (2017)	The importance of spatial agglomeration in product innovation: A microgeography perspective	Journal of Business Research
38	Kalsaas (2013)	Collaborative innovation: the decade that radically changed drilling performance	Production Planning & Control
39	Lai and Shyu (2005)	A comparisson of innovation capacity at science parks across the Taiwan strait: the case of Zhangjiang High-Tech Park and Hsinchu Science-based Industrial Park	Technovation
40	Larty, Jack, and Lockett (2017)	Building Regions: A Resource-Based View of a Policy-Led Knowledge Exchange Network	Regional Studies

41	Lawson and Lorenz (1999)	Collective learning, tacit knowledge and regional innovative capacity	Regional Studies
42	Lei and Huang (2014)	Geographic clustering, network relationships and competitive advantage: Two industrial clusters in Taiwan	Management Decision
43	Liu, Ying, and Wu (2017)	Catch-up through Collaborative Innovation: Evidence from China	Thunderbird International Business Review
44	Marco-Lajara et al. (2016)	Knowledge sources, agglomeration, and hotel performance	Journal of Business Research
45	Martínez-Pérez and Beauchesne (2017)	Overcoming the Dark Side of Closed Networks in Cultural Tourism Clusters: The Importance of Diverse Networks	Cornell Hospitality Quarterly
46	Maskell and Malmberg (1999)	Localised learning and industrial competitiveness	Cambridge Journal of Economics
47	Molina-Morales, Martínez-Fernandez, and Coll-Serrano (2012)	Efficiency and innovation in sub-networks of companies. A study of the Spanish ceramic district	Innovar-Revista De Ciencias Administrativas Y Sociales
48	Montoro-Sánchez, Ortiz-de-Urbina-Criado, and Mora-Valentín (2011)	Effects of knowledge spillovers on innovation and collaboration in science and technology parks	Journal of Knowledge Management
49	Moreno and Miguelez (2012)	A relational approach to the geography of innovation: a typology of regions	Journal of Economic Surveys
50	Nooteboom (1999)	Innovation, learning and industrial organisation	Cambridge Journal of Economics
51	Novelli, Schmitz, and Spencer (2006)	Networks, clusters and innovation in tourism: A UK experience	Tourism Management
52	O'Gorman and Kautonen (2004)	Policies to promote new knowledge-intensive industrial agglomerations	Entrepreneurship and Regional Development
53	O'Dwyer et al. (2015)	Insights into the creation of a successful MNE innovation cluster	Competitiveness Review
54	Ozer and Zhang (2015)	The effects of geographic and network ties on exploitative and exploratory product innovation	Strategic Management Journal
55	Pechlaner and Bachinger (2010)	Knowledge networks of innovative businesses: an explorative study in the region of Ingolstadt	Service Industries Journal
56	Petrizzelli, Albino, and Carbonara (2009)	External knowledge sources and proximity	Journal of Knowledge Management
57	Pietrobelli and Rabellotti (2011)	Global Value Chains Meet Innovation Systems: Are There Learning Opportunities for Developing Countries?	World Development
58	Porter (2003)	The economic performance of regions	Regional Studies
59	Presutti, Boari, and Majocchi (2011)	The Importance of Proximity for the Start-Ups' Knowledge Acquisition and Exploitation	Journal of Small Business Management
60	Quintana-Garcia and Benavides-Velasco (2005)	Agglomeration economies and vertical alliances: the route to product innovation in biotechnology firms	International Journal of Production Research
61	Rejeb et al. (2008)	Measuring innovation best practices: Improvement of an innovation index integrating threshold and synergy effects	Technovation
62	Romijn and Albu (2002)	Innovation, networking and proximity: Lessons from small high technology firms in the UK	Regional Studies
63	Sammarra and Biggiero (2008)	Heterogeneity and specificity of inter-firm knowledge flows in innovation networks	Journal of Management Studies
64	Saunila (2017)	Managing continuous innovation through performance measurement	Competitiveness Review

65	Schilling and Phelps (2007)	Interfirm collaboration networks: The impact of large-scale network structure on firm innovation	Management Science
66	Schütz (2017)	Australia's regional innovation systems: inter-industry interaction in innovative activities in three Australian territories	Economic Systems Research
67	Silvestre and Dalcol (2009)	Geographical proximity and innovation: evidences from the Campos Basin oil & gas industrial agglomeration-Brazil	Technovation
68	Spigel (2017)	The Relational Organization of Entrepreneurial Ecosystems	Entrepreneurship Theory and Practice
69	Strand et al. (2017)	Technological Innovation Capability and Interaction Effect in a Scandinavian Industry Cluster	International Journal of Innovation Management
70	Ter Wal and Boschma (2011)	Co-evolution of Firms, Industries and Networks in Space	Regional Studies
71	Toivanen (2014)	The shift from theory to innovation: the evolution of Brazilian research frontiers 2005-2011	Technology Analysis & Strategic Management
72	Ucler (2017)	Intelligent assignment in clusters to enhance collaboration and innovation	Journal of Manufacturing Technology Management
73	Valkokari et al. (2017)	Orchestrating Innovation Ecosystems: A Qualitative Analysis of Ecosystem Positioning Strategies	Technology Innovation Management Review
74	Van Geenhuizen (2008)	Knowledge networks of young innovators in the urban economy: biotechnology as a case study	Entrepreneurship and Regional Development
75	Wannenmacher and Antoine (2016)	Management of innovative collaborative projects: Moments of tension and the Peer-Mediation Process-a case-study approach	Knowledge Management Research & Practice
76	Whittington, Owen-Smith, and Powell (2009)	Networks, Propinquity, and Innovation in Knowledge-intensive Industries	Administrative Science Quarterly
77	Wonglimpiyarat (2006)	The dynamic economic engine at Silicon Valley and US Government programmes in financing innovations	Technovation
78	Wonglimpiyarat (2010)	Innovation index and the innovative capacity of nations	Futures
79	Xue (2017)	Understanding knowledge networks and knowledge flows in high technology clusters: the role of heterogeneity of knowledge contents	Innovation: Organization & Management
80	Yam et al. (2004)	An audit of technological innovation capabilities in chinese firms: some empirical findings in Beijing, China	Research Policy
81	Yoon (2015)	Development of International Cooperation Maps for R&D Policy: Exploring National Factors in South Korea	Science Technology and Society
82	Yström and Aspenberg (2017)	Open for Innovation? Practices Supporting Collaboration in Swedish Regional Clusters	International Journal of Innovation Management
83	Zukauskaitė (2012)	Innovation in cultural industries: The role of university links	Innovation-Management Policy & Practice

APPENDIX B – Experts questionnaire

Figure 29: Experts questionnaire (first round)

Table 2 - Evaluation scale
between factors and subfactors

Evaluation Scale
0 - No influence
1 - Very weak
2 - Weak
3 - Average
4 - Strong
5 - Very strong

Figure 1 - Filling example

INFLUENCES \ IN	Factor A	Factor B
Factor A	0	4 - Strong
Factor B	2 - Weak	0

Factors	Description
Network collaboration	Collaboration with various actors can provide important resources for building innovation capability.
Creation and transmission of knowledge	The knowledge transit among cluster actors is directly influenced by the capability to share, absorb and pass it on.
Technology development	Technologies are important sources of innovation and increase the innovation capability of companies.
Adequacy between innovation and market	The existence of innovations depends on the demand and acceptance of the innovative product, service or process in the market.
Proximity	Determining characteristic for the formation of innovative collaborative networks. It includes geographical, cognitive, organizational, social and institutional proximity.

Interaction between factors					
ON \ INFLUENCES	Network collaboration	Creation and transmission of knowledge	Technology development	Adequacy between innovation and market	Proximity
Network collaboration	0				
Creation and transmission of knowledge		0			
Technology development			0		
Adequacy between innovation and market				0	
Proximity					0

Figure 30: Experts questionnaire (second round)

Table 1 - Evaluation scale between factors and		Figure 1 - Filling example													
Evaluation Scale															
0 - No influence															
1 - Very weak															
2 - Weak															
3 - Average															
4 - Strong															
5 - Very strong															

INFLUENCES \ ON	Factor A						Factor B					
	Lowest value	Highest value	Most frequent value	Weight given in 1st round	Weight given in 2nd round	Obs (optional)	Lowest value	Highest value	Most frequent value	Weight given in 1st round	Weight given in 2nd round	Obs (optional)
Factor A	-	-	-	-	-	-	3	5	5	3	4	

According to the assessment of the first round, Factor A had an "average influence" on Factor B. From the second round, the specialist evaluated the influence of Factor A on Factor B as a "strong influence".

Interaction among factors																		
INFLUENCES \ ON	Network collaboration						Creation and transmission of knowledge						Technology development					
	Lowest value	Highest value	Most frequent value	Weight given in 1st round	Weight given in 2nd round	Obs (optional)	Lowest value	Highest value	Most frequent value	Weight given in 1st round	Weight given in 2nd round	Obs (optional)	Lowest value	Highest value	Most frequent value	Weight given in 1st round	Weight given in 2nd round	Obs (optional)
Network collaboration							4	5	5				2	5	4			
Creation and transmission of knowledge	0	5	3				-						4	5	5			
Technology development	1	4	3				2	5	4				-					
Adequacy between innovation and market	0	3	3				0	5	2				0	5	3			
Proximity	3	5	5				3	5	4				3	5	4			

INFLUENCES \ ON	Adequacy between innovation and market						Proximity					
	Lowest value	Highest value	Most frequent value	Weight given in 1st round	Weight given in 2nd round	Obs (optional)	Lowest value	Highest value	Most frequent value	Weight given in 1st round	Weight given in 2nd round	Obs (optional)

Figure 31: Experts questionnaire (third round)

Table 1 - Evaluation scale between factors and subfactors													
Evaluation Scale													
0 - No influence													
1 - Very weak													
2 - Weak													
3 - Average													
4 - Strong													
5 - Very strong													
Interaction among factors													
ON		Network collaboration				Creation and transmission of knowledge				Technology development			
INFLUENCES		Most frequent value	Conver- gence rate	Weight given in 2nd round	Weight given in 3rd round	Most frequent value	Conver- gence rate	Weight given in 2nd round	Weight given in 3rd round	Most frequent value	Conver- gence rate	Weight given in 2nd round	Weight given in 3rd round
Network collaboration		-				5	67%			4	83%		
Creation and transmission of knowledge		3	67%			-				5	67%		
Technology development		3	50%			4	67%			-			
Adequacy between innovation and market		3	100%			2	50%			3	50%		
Proximity		5	67%			4	33%			4	67%		
ON		Adequacy between innovation and market				Proximity							
INFLUENCES		Most frequent value	Conver- gence rate	Weight given in 2nd round	Weight given in 3rd round	Most frequent value	Conver- gence rate	Weight given in 2nd round	Weight given in 3rd round				
Network collaboration		3	83%			4	67%						
Creation and transmission of knowledge		1	50%			3	67%						
Technology development		3	50%			1	67%						
Adequacy between innovation and market		-				3	50%						
Proximity		3	83%			-							

APPENDIX C – Interview scriptInformações sobre a empresa

Nome: _____

Ano de fundação: _____

Localização: _____

Número de funcionários: _____

Informações sobre o entrevistado

Nome: _____

Cargo na empresa: _____

Área em que atua: _____

Formação profissional: _____

Tempo de atuação na empresa: _____

Informações sobre a entrevista

Data: _____

Início: _____

Término: _____

Informações sobre os relacionamentos da empresa no contexto do cluster:

- Concorrentes
- Fornecedores
- Governo
- Associações
- Universidades e centros de pesquisa

Fatores e subfatores de avaliação

Para responder às questões, será utilizada a seguinte escala:

Valor	Grau de Importância
1	Extremamente baixo
2	Muito baixo
3	Baixo
4	Marginalmente baixo
5	Médio
6	Marginalmente alto
7	Alto
8	Muito alto
9	Extremamente alto

1. COLABORAÇÃO EM REDE

1.1. Densidade e qualidade dos relacionamentos entre empresas

- 1.1.1. A empresa busca valorizar os relacionamentos com outras empresas? De que forma?
- 1.1.2. Esses relacionamentos contribuem para o desenvolvimento da CI?
- 1.1.3. Quais seriam as características de um relacionamento de qualidade? Essas características contribuem para a CI?
- 1.1.4. Qual o grau de importância da “densidade e qualidade dos relacionamentos entre empresas” para o desenvolvimento da capacidade de inovação?

Ext. baixo ()	Muito baixo ()	Baixo ()	Marg. baixo ()	Médio ()	Marg. alto ()	Alto ()	Muito alto ()	Ext. alto ()
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1.2. Capacidade de integração

- 1.2.1. As atividades inovadoras da empresa ocorrem de maneira sistemática e integrada?
- 1.2.2. As atividades inovadoras desenvolvem e exploram os recursos da empresa?
- 1.2.3. Qual o grau de importância da “capacidade de integração” para o desenvolvimento da capacidade de inovação?

Ext. baixo ()	Muito baixo ()	Baixo ()	Marg. baixo ()	Médio ()	Marg. alto ()	Alto ()	Muito alto ()	Ext. alto ()
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1.3. Interação com outras entidades

- 1.3.1. A empresa interage com outras entidades para gerar inovação? Se sim, quais? Se não, por quê?

1.3.2. Se sim, de que forma tais entidades contribuem para a CI?

1.3.3. Qual o grau de importância da “interação com outras entidades” para o desenvolvimento da capacidade de inovação?

Ext. baixo ()	Muito baixo ()	Baixo ()	Marg. baixo ()	Médio ()	Marg. alto ()	Alto ()	Muito alto ()	Ext. alto ()
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1.4. Colaboração tecnológica

1.4.1. A empresa possui rotinas ou práticas de aprendizagem que visem ajudar na transmissão do conhecimento tecnológico com outras empresas?

1.4.2. Caso afirmativo, como essas rotinas ou práticas influenciam no desenvolvimento da CI?

1.4.3. Qual o grau de importância da “colaboração tecnológica” para o desenvolvimento da capacidade de inovação?

Ext. baixo ()	Muito baixo ()	Baixo ()	Marg. baixo ()	Médio ()	Marg. alto ()	Alto ()	Muito alto ()	Ext. alto ()
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1.5. Capacidade combinatória

1.5.1. A empresa possui flexibilidade para combinar, recombina, obter recursos? Como isso acontece?

1.5.2. Essa flexibilidade contribui para o desenvolvimento da CI?

1.5.3. Há grande mobilidade de pessoal no mercado local? Essa mobilidade traz CI?

1.5.4. As relações de colaboração são majoritariamente formais ou informais? Como essas relações contribuem para a CI?

1.5.5. Os atores do *cluster* têm boa comunicação e uma linguagem compartilhada? Em caso afirmativo, tais aspectos trazem o desenvolvimento da CI?

1.5.6. Qual o grau de importância da “capacidade combinatória” para o desenvolvimento da capacidade de inovação?

Ext. baixo ()	Muito baixo ()	Baixo ()	Marg. baixo ()	Médio ()	Marg. alto ()	Alto ()	Muito alto ()	Ext. alto ()
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2. CRIAÇÃO E TRANSMISSÃO DE CONHECIMENTO

2.1. Capacidade absorativa

2.1.1. A empresa identifica, busca, adquire conhecimento proveniente de atores externos?

2.1.2. Se sim, utiliza esse conhecimento de que maneira?

2.1.3. Essas ações impulsionam ainda mais as relações entre as empresas do *cluster*?

2.1.4. As empresas que costumam adquirir e utilizar conhecimento de outras têm competências similares ou distintas?

2.1.5. Qual o grau de importância da “capacidade absorptiva” para o desenvolvimento da capacidade de inovação?

Ext. baixo ()	Muito baixo ()	Baixo ()	Marg. baixo ()	Médio ()	Marg. alto ()	Alto ()	Muito alto ()	Ext. alto ()
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2.2. Compartilhamento de conhecimento

2.2.1. A empresa investe nos relacionamentos com as outras empresas do *cluster*? Em caso afirmativo, de que forma?

2.2.2. A empresa investe nos relacionamentos com as instituições de apoio? Se sim, de que forma?

2.2.3. Esses relacionamentos impulsionam no desenvolvimento de CI?

2.2.4. Em geral, há um entendimento comum (linguagem, ações) entre os agentes do *cluster*? Se sim, de que maneira esse entendimento influencia na CI?

2.2.5. Qual o grau de importância do “compartilhamento de conhecimento” para o desenvolvimento da capacidade de inovação?

Ext. baixo ()	Muito baixo ()	Baixo ()	Marg. baixo ()	Médio ()	Marg. alto ()	Alto ()	Muito alto ()	Ext. alto ()
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2.3. Spillovers de conhecimento

2.3.1. A empresa tem fácil acesso a pesquisas, ideias e experiências provenientes de universidades, centros de pesquisa, fornecedores, clientes ou empresas socialmente relacionadas? Caso positivo, esse acesso se dá de maneira formal ou informal?

2.3.2. A empresa tem mais oportunidades de parceria devido ao acesso a esses conhecimentos adquiridos?

2.3.3. Qual o grau de importância dos “*spillovers* de conhecimento” para o desenvolvimento da capacidade de inovação?

Ext. baixo ()	Muito baixo ()	Baixo ()	Marg. baixo ()	Médio ()	Marg. alto ()	Alto ()	Muito alto ()	Ext. alto ()
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2.4. Aprendizagem coletiva

- 2.4.1. A aprendizagem ocorre na empresa segundo regras e procedimentos definidos?
- 2.4.2. A aprendizagem ocorre de maneira social e cumulativa?
- 2.4.3. O conhecimento adquirido coletivamente auxilia na solução de problemas e no desenvolvimento de CI?
- 2.4.4. Qual o grau de importância da “aprendizagem coletiva” para o desenvolvimento da capacidade de inovação?

Ext. baixo ()	Muito baixo ()	Baixo ()	Marg. baixo ()	Médio ()	Marg. alto ()	Alto ()	Muito alto ()	Ext. alto ()
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2.5. Capacidade de aprendizagem

- 2.5.1. A empresa identifica, assimila e explora o conhecimento do meio ambiente (empresas parceiras, concorrentes, instituições de apoio)?
- 2.5.2. De que maneira o conhecimento adquirido é repassado ao longo do tempo?
- 2.5.3. Esse conhecimento influencia no desenvolvimento de CI? De que forma?
- 2.5.4. Qual o grau de importância da “capacidade de aprendizagem” para o desenvolvimento da capacidade de inovação?

Ext. baixo ()	Muito baixo ()	Baixo ()	Marg. baixo ()	Médio ()	Marg. alto ()	Alto ()	Muito alto ()	Ext. alto ()
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3. DESENVOLVIMENTO DE TECNOLOGIA

3.1. Novas oportunidades tecnológicas

- 3.1.1. O surgimento de novas oportunidades tecnológicas incentiva a empresa a inovar? Em caso afirmativo, dê exemplos dessas inovações.
- 3.1.2. A empresa costuma fazer combinação de diferentes tecnologias? Caso positivo, de que maneira isso influencia na CI?
- 3.1.3. Qual o grau de importância de “novas oportunidades tecnológicas” para o desenvolvimento da capacidade de inovação?

Ext. baixo ()	Muito baixo ()	Baixo ()	Marg. baixo ()	Médio ()	Marg. alto ()	Alto ()	Muito alto ()	Ext. alto ()
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3.2. Capacidade tecnológica

- 3.2.1. Os colaboradores da empresa possuem recursos, habilidades, conhecimento e experiência que levem à CI?

3.2.2. A empresa compartilha informações e conhecimento com as outras empresas do *cluster*, de modo a incentivar o desenvolvimento da CI?

3.2.3. Qual o grau de importância da “capacidade tecnológica” para o desenvolvimento da capacidade de inovação?

Ext. baixo ()	Muito baixo ()	Baixo ()	Marg. baixo ()	Médio ()	Marg. alto ()	Alto ()	Muito alto ()	Ext. alto ()
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3.3. Capacidades de P&D

3.3.1. A empresa investe no desenvolvimento de novos produtos e/ou serviços? Se sim, de que maneira?

3.3.2. A empresa difunde as atividades de P&D nos diversos setores da empresa? Caso positivo, de que modo?

3.3.3. Essa difusão influencia o desenvolvimento de CI? De que forma?

3.3.4. A empresa procura o *feedback* dos clientes para a tomada de decisão referente ao desenvolvimento de tecnologia? Caso sim, como?

3.3.5. A empresa possui metas e planos claros para seus projetos? Se afirmativo, como isso influencia na CI?

3.3.6. Qual o grau de importância das “capacidades de P&D” para o desenvolvimento da capacidade de inovação?

Ext. baixo ()	Muito baixo ()	Baixo ()	Marg. baixo ()	Médio ()	Marg. alto ()	Alto ()	Muito alto ()	Ext. alto ()
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4. INFLUÊNCIA DO MERCADO

4.1. Capacidade de adaptar inovação à demanda

4.1.1. Os conhecimentos tecnológicos da empresa são transformados em produtos ou serviços vendáveis? Poderia citar alguns exemplos de como isso ocorre?

4.1.2. Qual o grau de importância da “capacidade de adaptar inovação à demanda” para o desenvolvimento da capacidade de inovação?

Ext. baixo ()	Muito baixo ()	Baixo ()	Marg. baixo ()	Médio ()	Marg. alto ()	Alto ()	Muito alto ()	Ext. alto ()
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4.2. Capacidade de divulgar e vender novos produtos

4.2.1. Como as necessidades do consumidor influenciam na CI? A empresa mantém bom relacionamento com os clientes?

4.2.2. Como o ambiente competitivo contribui para a CI?

4.2.3. A manutenção de uma reputação positiva interfere na CI?

4.2.4. A obtenção de informação de diferentes segmentos de mercado contribui para o desenvolvimento de CI? De que forma?

4.2.5. Qual o grau de importância da “capacidade de divulgar e vender novos produtos” para o desenvolvimento da capacidade de inovação?

Ext. baixo ()	Muito baixo ()	Baixo ()	Marg. baixo ()	Médio ()	Marg. alto ()	Alto ()	Muito alto ()	Ext. alto ()
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5. PROXIMIDADE

5.1. Proximidade geográfica

5.1.1. A localização geográfica influencia no estabelecimento de relacionamentos? Se sim, como?

5.1.2. A empresa é motivada a estabelecer relacionamentos com empresas geograficamente próximas para ter acesso a novas informações e conhecimentos?

5.1.3. Como isso influencia na CI?

5.1.4. Qual o grau de importância da “proximidade geográfica” para o desenvolvimento da capacidade de inovação?

Ext. baixo ()	Muito baixo ()	Baixo ()	Marg. baixo ()	Médio ()	Marg. alto ()	Alto ()	Muito alto ()	Ext. alto ()
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5.2. Proximidade cognitiva

5.2.1. Os colaboradores se compreendem de modo a incentivar o desenvolvimento de inovação?

5.2.2. A empresa possui uma base comum de conhecimento e *expertise*?

5.2.3. Caso positivo, como isso influencia na CI?

5.2.4. Qual o grau de importância da “proximidade cognitiva” para o desenvolvimento da capacidade de inovação?

Ext. baixo ()	Muito baixo ()	Baixo ()	Marg. baixo ()	Médio ()	Marg. alto ()	Alto ()	Muito alto ()	Ext. alto ()
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5.3. Proximidade organizacional

5.3.1. Os colaboradores da empresa têm comportamentos similares? Eles seguem as regras e hierarquias? Caso positivo, de que maneira isso contribui para o desenvolvimento da CI?

5.3.2. E em relação aos outros entes do *cluster*?

5.3.3. Qual o grau de importância da “proximidade organizacional” para o desenvolvimento da capacidade de inovação?

Ext. baixo ()	Muito baixo ()	Baixo ()	Marg. baixo ()	Médio ()	Marg. alto ()	Alto ()	Muito alto ()	Ext. alto ()
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5.4. Proximidade social

5.4.1. Os colaboradores da empresa possuem relações de confiança baseadas em amizade, afinidade e experiência? Caso positivo, isso facilita o intercâmbio de conhecimento na empresa? De que forma?

5.4.2. E no contexto do *cluster*?

5.4.3. Qual o grau de importância da “proximidade social” para o desenvolvimento da capacidade de inovação?

Ext. baixo ()	Muito baixo ()	Baixo ()	Marg. baixo ()	Médio ()	Marg. alto ()	Alto ()	Muito alto ()	Ext. alto ()
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5.5. Proximidade institucional

5.5.1. A empresa e seus colaboradores tem um conjunto de hábitos e valores culturais comuns? Exemplos: linguagem comum, hábitos compartilhados, direitos de propriedade intelectual.

5.5.2. Caso positivo, de que maneira isso contribui para a CI?

5.5.3. Qual o grau de importância da “proximidade institucional” para o desenvolvimento da capacidade de inovação?

Ext. baixo ()	Muito baixo ()	Baixo ()	Marg. baixo ()	Médio ()	Marg. alto ()	Alto ()	Muito alto ()	Ext. alto ()
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APPENDIX D – Delphi results

Table 58: Results from the first round of Delphi

	Influence	Expert							Lowest value	Highest value	Most frequent value
		A	B	C	D	E	F	G			
Factors	r_{12}	5	4	5	4	5	5	4	4	5	5
	r_{13}	4	4	5	3	4	2	4	2	5	4
	r_{14}	3	3	4	2	4	1	3	1	4	3
	r_{15}	4	3	4	4	4	5	0	0	5	4
	r_{21}	1	4	0	3	5	3	3	0	5	3
	r_{23}	5	4	5	4	4	5	5	4	5	5
	r_{24}	3	4	1	1	4	1	4	1	4	1
	r_{25}	1	3	1	4	3	4	0	0	4	3 or 4
	r_{31}	1	4	3	3	4	2	3	1	4	3
	r_{32}	4	4	3	4	3	5	2	2	5	4
	r_{34}	0	4	5	3	3	2	1	0	5	3
	r_{35}	1	3	1	0	3	5	1	0	5	1
	r_{41}	0	3	3	3	3	0	0	0	3	3
	r_{42}	2	4	5	4	4	0	0	0	5	4
	r_{43}	2	4	5	4	4	3	0	0	5	4
	r_{45}	0	3	3	1	3	1	0	0	3	3
	r_{51}	4	3	5	4	5	5	3	3	5	5
	r_{52}	4	3	5	4	5	4	3	3	5	4
	r_{53}	4	3	5	4	4	3	3	3	5	3 or 4
	r_{54}	2	3	5	3	3	1	2	1	5	3
Sub-factors of Network collaboration	r_{12}^1	5	5	3	4	3	4	4	3	5	4
	r_{13}^1	0	4	3	4	5	5	5	0	5	5
	r_{14}^1	4	4	5	4	4	5	4	4	5	4
	r_{15}^1	5	4	5	4	2	5	3	2	5	5
	r_{21}^1	2	4	1	4	3	2	2	1	4	2
	r_{23}^1	2	4	0	4	3	2	2	0	4	2
	r_{24}^1	3	4	2	4	3	4	3	2	4	3 or 4
	r_{25}^1	3	4	2	4	5	5	4	2	5	4
	r_{31}^1	1	4	2	4	5	5	4	1	5	4
	r_{32}^1	0	4	4	4	3	5	4	0	5	4
	r_{34}^1	1	3	4	4	5	5	2	1	5	4 or 5
	r_{35}^1	2	3	4	4	2	4	1	1	4	4
	r_{41}^1	1	4	5	4	4	3	2	1	5	4
	r_{42}^1	2	4	5	3	3	5	3	2	5	3
	r_{43}^1	1	3	1	4	5	5	1	1	5	1
	r_{45}^1	4	3	3	4	4	5	4	3	5	4
	r_{51}^1	1	3	1	3	3	2	2	1	3	3
	r_{52}^1	4	3	5	3	5	5	2	2	5	5
	r_{53}^1	2	3	5	4	3	3	1	1	5	3
	r_{54}^1	4	3	5	3	4	4	4	3	5	4
Sub-factors of Knowledge	r_{12}^2	2	5	1	5	2	3	2	1	5	2
	r_{13}^2	1	4	1	5	2	5	1	1	5	1
	r_{14}^2	3	4	1	5	2	4	2	1	5	2 or 4
	r_{15}^2	5	4	5	5	4	5	0	0	5	5

	Influence	Expert							Lowest value	Highest value	Most frequent value
		A	B	C	D	E	F	G			
Sub-factors of Technology development	r_{21}^2	2	4	5	1	2	5	2	1	5	2
	r_{23}^2	1	4	5	3	5	5	5	1	5	5
	r_{24}^2	5	5	5	3	5	5	4	3	5	5
	r_{25}^2	4	4	5	4	5	5	2	2	5	4 or 5
	r_{31}^2	2	3	5	3	2	2	2	2	5	2
	r_{32}^2	3	3	5	4	3	5	4	3	5	3
	r_{34}^2	1	3	5	3	5	2	3	1	5	3
	r_{35}^2	1	3	5	3	5	1	3	1	5	3
	r_{41}^2	4	5	5	2	3	5	3	2	5	5
	r_{42}^2	4	4	5	4	5	2	2	2	5	4
	r_{43}^2	3	3	5	3	5	5	4	3	5	3 or 5
	r_{45}^2	4	4	5	3	5	5	4	3	5	4 or 5
	r_{51}^2	5	5	5	0	5	5	5	0	5	5
	r_{52}^2	3	4	1	3	3	5	3	1	5	3
	r_{53}^2	2	3	1	3	3	5	4	1	5	3
	r_{54}^2	4	4	1	3	5	5	4	1	5	4
	r_{12}^3	3	5	5	3	2	4	1	1	5	3 or 5
	r_{13}^3	3	3	5	5	3	4	3	3	5	3
	r_{21}^3	5	4	5	3	5	5	5	3	5	5
	r_{23}^3	4	4	5	3	5	5	5	3	5	5
	r_{31}^3	5	3	5	4	3	5	4	3	5	5
	r_{32}^3	3	3	5	3	5	5	5	3	5	5
Sub-factors of Market influence	r_{12}^4	2	5	5	4	3	5	4	2	5	5
	r_{21}^4	3	4	1	4	2	2	4	1	4	4
Sub-factors of Proximity	r_{12}^5	3	3	5	3	5	4	4	3	5	3
	r_{13}^5	2	3	3	3	1	3	5	1	5	3
	r_{14}^5	2	3	5	3	4	5	5	2	5	5
	r_{15}^5	3	3	5	3	4	3	5	3	5	3
	r_{21}^5	0	3	5	0	2	2	0	0	5	0
	r_{23}^5	2	2	5	3	2	5	1	1	5	2
	r_{24}^5	2	3	5	3	5	5	4	2	5	5
	r_{25}^5	1	2	5	3	4	5	0	0	5	5
	r_{31}^5	0	2	1	3	4	2	0	0	4	0 or 2
	r_{32}^5	3	2	5	3	4	3	1	1	5	3
	r_{34}^5	3	3	5	3	1	4	2	1	5	3
	r_{35}^5	3	3	5	2	3	4	0	0	5	3
	r_{41}^5	0	3	5	0	5	4	0	0	5	0
	r_{42}^5	4	3	5	4	5	5	4	3	5	4 or 5
	r_{43}^5	3	3	3	3	2	3	0	0	3	3
	r_{45}^5	3	3	4	3	5	3	0	0	5	3
	r_{51}^5	0	2	2	2	3	3	0	0	3	2

Influence	Expert							Lowest value	Highest value	Most frequent value
	A	B	C	D	E	F	G			
r_{52}^5	2	2	2	3	4	4	1	1	4	2
r_{53}^5	2	3	2	3	1	5	2	1	5	2 or 3
r_{54}^5	3	2	5	3	5	4	3	2	5	3

Table 59: Results from the second round of Delphi

	Influence	Expert							Lowest value	Highest value	Most frequent value
		A	B	C	D	E	F	G			
Factors	r_{12}	5	4	5	4	5	5	4	4	5	5
	r_{13}	4	4	5	4	4	4	4	4	5	4
	r_{14}	3	3	4	3	3	3	3	3	4	3
	r_{15}	4	3	4	4	4	2	2	2	4	4
	r_{21}	3	4	3	3	4	3	3	3	4	3
	r_{23}	5	4	5	4	5	5	4	4	5	5
	r_{24}	2	3	1	1	3	1	1	1	3	1
	r_{25}	2	3	1	3	3	3	1	1	3	3
	r_{31}	2	4	3	3	4	3	2	2	4	3
	r_{32}	4	4	3	4	4	2	2	2	4	4
	r_{34}	2	4	3	3	3	1	1	1	4	3
	r_{35}	1	3	1	1	2	1	1	1	3	1
	r_{41}	3	3	3	3	3	3	3	3	3	3
	r_{42}	2	4	3	2	4	2	2	2	4	2
	r_{43}	3	4	5	3	4	3	3	3	5	3
	r_{45}	2	3	3	2	3	0	0	0	3	3
	r_{51}	5	3	5	5	5	3	3	3	5	5
	r_{52}	4	3	5	4	5	3	3	3	5	4
	r_{53}	4	3	4	4	4	3	3	3	4	4
	r_{54}	3	3	3	3	3	2	2	2	3	3
Sub-factors of Network collaboration	r_{12}^1	4	4	4	4	4	4	4	4	4	4
	r_{13}^1	4	4	5	5	5	5	4	4	5	5
	r_{14}^1	4	4	5	4	4	4	4	4	5	4
	r_{15}^1	5	4	5	5	5	5	4	4	5	5
	r_{21}^1	2	4	1	3	3	2	1	1	4	2 or 3
	r_{23}^1	2	4	2	3	3	2	2	2	4	2
	r_{24}^1	3	4	3	4	3	3	3	3	4	3
	r_{25}^1	4	4	4	4	4	4	4	4	4	4
	r_{31}^1	3	4	4	4	5	4	3	3	5	4
	r_{32}^1	3	4	4	4	4	4	3	3	4	4
	r_{34}^1	4	3	4	4	5	4	3	3	5	4
	r_{35}^1	3	3	4	4	3	4	3	3	4	3 or 4
	r_{41}^1	3	4	5	4	4	3	3	3	5	4
	r_{42}^1	3	4	5	3	3	3	3	3	5	3
	r_{43}^1	1	3	1	3	4	1	1	1	4	1
	r_{45}^1	4	3	4	4	4	4	3	3	4	4
	r_{51}^1	2	3	3	3	3	3	2	2	3	3
	r_{52}^1	4	4	5	4	5	5	4	4	5	4 or 5

	Influence	Expert						Lowest value	Highest value	Most frequent value
		A	B	C	D	E	G			
Sub-factors of Knowledge creation and transfer	r_{53}^1	3	3	5	3	3	3	3	5	3
	r_{54}^1	4	3	5	4	4	4	3	5	4
	r_{12}^2	2	5	1	3	2	2	1	5	2
	r_{13}^2	1	4	1	3	2	1	1	4	1
	r_{14}^2	4	4	4	4	2	2	2	4	4
	r_{15}^2	5	4	5	5	4	5	4	5	4 or 5
	r_{21}^2	2	4	5	3	2	2	2	5	2
	r_{23}^2	3	4	5	4	5	5	3	5	5
	r_{24}^2	5	5	5	4	5	5	4	5	5
	r_{25}^2	4	4	5	4	5	2	2	5	4
	r_{31}^2	2	3	5	2	2	2	2	5	2
	r_{32}^2	3	3	3	4	3	3	3	4	3
	r_{34}^2	3	3	5	3	5	3	3	5	3 or 5
	r_{35}^2	3	3	5	3	4	3	3	5	3
	r_{41}^2	5	5	5	4	4	3	3	5	5
	r_{42}^2	4	4	5	4	5	2	2	5	4
	r_{43}^2	3	3	5	3	5	3	3	5	3
	r_{45}^2	4	4	5	4	5	4	4	5	4
	r_{51}^2	5	5	5	4	5	5	4	5	5
	r_{52}^2	3	4	3	3	3	3	3	4	3
	r_{53}^2	3	3	3	3	3	3	3	3	3
Sub-factors of Technology development	r_{54}^2	4	4	4	4	5	4	4	5	4
	r_{12}^3	3	5	5	3	2	3	2	5	3
	r_{13}^3	3	3	5	4	3	3	3	5	3
	r_{21}^3	5	4	5	4	5	5	4	5	5
	r_{23}^3	5	4	5	4	5	5	4	5	5
	r_{31}^3	5	4	5	4	3	4	3	5	4
	r_{32}^3	5	4	5	4	5	5	4	5	5
Sub-factors of Market influence	r_{12}^4	4	5	5	4	5	4	4	5	4 or 5
	r_{21}^4	4	4	3	4	3	4	3	4	4
Sub-factors of Proximity	r_{12}^5	3	3	5	3	5	3	3	5	3
	r_{13}^5	3	3	3	3	1	3	1	3	3
	r_{14}^5	5	3	5	4	5	5	3	5	5
	r_{15}^5	3	3	3	3	4	3	3	4	3
	r_{21}^5	0	3	0	0	2	0	0	3	0
	r_{23}^5	2	2	4	2	2	2	2	4	2
	r_{24}^5	5	3	5	4	5	4	3	5	5
	r_{25}^5	3	3	5	4	5	0	0	5	3 or 5
	r_{31}^5	0	2	1	2	4	0	0	4	0 or 2
	r_{32}^5	3	2	3	3	4	2	2	4	3
	r_{34}^5	3	3	5	3	1	3	1	5	3
	r_{35}^5	3	3	5	3	3	3	3	5	3
	r_{41}^5	0	3	3	0	4	0	0	4	0

Influence	Expert						Lowest value	Highest value	Most frequent value
	A	B	C	D	E	G			
r_{42}^5	4	3	5	4	5	4	3	5	4
r_{43}^5	3	3	3	3	2	2	2	3	3
r_{45}^5	3	3	4	3	5	3	3	5	3
r_{51}^5	1	2	2	2	3	0	0	3	2
r_{52}^5	2	2	2	2	4	2	2	4	2
r_{53}^5	2	3	2	3	1	2	1	3	2
r_{54}^5	3	3	3	3	4	3	3	4	3

Table 60: Results from the third round of Delphi

Influence	Expert				Lowest value	Highest value	Most frequent value
	A	B	C	E			
Factors	r_{12}	5	4	5	5	4	5
	r_{13}	4	4	5	4	4	5
	r_{14}	3	3	3	3	3	3
	r_{15}	4	3	4	4	3	4
	r_{21}	3	4	3	3	3	4
	r_{23}	5	4	5	5	4	5
	r_{24}	1	3	1	2	1	3
	r_{25}	3	3	3	3	3	3
	r_{31}	3	4	3	3	3	4
	r_{32}	4	4	4	4	4	4
	r_{34}	3	4	3	3	3	4
	r_{35}	1	3	1	1	1	3
	r_{41}	3	3	3	3	3	3
	r_{42}	2	4	3	4	2	4
	r_{43}	3	4	4	3	3	4
	r_{45}	3	3	3	3	3	3
	r_{51}	5	3	5	5	3	5
	r_{52}	4	3	4	5	3	5
	r_{53}	4	3	4	4	3	4
	r_{54}	3	3	3	3	3	3
Sub-factors of Network collaboration	r_{12}^1	4	4	4	4	4	4
	r_{13}^1	5	4	5	5	4	5
	r_{14}^1	4	4	4	4	4	4
	r_{15}^1	5	4	5	5	4	5
	r_{21}^1	2	3	1	3	1	3
	r_{23}^1	2	3	2	3	2	3
	r_{24}^1	3	4	3	3	3	4
	r_{25}^1	4	4	4	4	4	4
	r_{31}^1	4	4	4	4	4	4
	r_{32}^1	4	4	4	4	4	4
	r_{34}^1	4	3	4	4	3	4
	r_{35}^1	3	3	4	3	3	4
	r_{41}^1	4	4	4	4	4	4
	r_{42}^1	3	4	3	3	3	4

	Influence	Expert				Lowest value	Highest value	Most frequent value
		A	B	C	E			
	r_{43}^1	1	2	1	3	1	3	1
	r_{45}^1	4	3	4	4	3	4	4
	r_{51}^1	3	3	3	3	3	3	3
	r_{52}^1	4	4	5	5	4	5	4 or 5
	r_{53}^1	3	3	3	3	3	3	3
	r_{54}^1	4	3	4	4	3	4	4
Sub-factors of Knowledge creation and transfer	r_{12}^2	2	4	2	2	2	4	2
	r_{13}^2	1	3	1	1	1	3	1
	r_{14}^2	4	4	4	2	2	4	4
	r_{15}^2	5	4	5	4	4	5	4 or 5
	r_{21}^2	2	4	3	2	2	4	2
	r_{23}^2	5	4	5	5	4	5	5
	r_{24}^2	5	5	5	5	5	5	5
	r_{25}^2	4	4	4	4	4	4	4
	r_{31}^2	2	3	5	2	2	5	2
	r_{32}^2	3	3	5	3	3	5	3
	r_{34}^2	3	3	5	5	3	5	3 or 5
	r_{35}^2	3	3	4	4	3	4	3 or 4
	r_{41}^2	5	5	5	5	5	5	5
	r_{42}^2	4	4	5	5	4	5	4 or 5
	r_{43}^2	3	3	3	4	3	4	3
	r_{45}^2	4	4	4	5	4	5	4
	r_{51}^2	5	5	5	5	5	5	5
	r_{52}^2	3	4	3	3	3	4	3
	r_{53}^2	3	3	3	3	3	3	3
	r_{54}^2	4	4	4	5	4	5	4
Sub-factors of Technology development	r_{12}^3	3	4	4	2	2	4	4
	r_{13}^3	3	3	4	3	3	4	3
	r_{21}^3	5	4	5	5	4	5	5
	r_{23}^3	5	4	5	5	4	5	5
	r_{31}^3	4	4	4	3	3	4	4
	r_{32}^3	5	4	5	5	4	5	5
Sub-factors of Market influence	r_{12}^4	4	5	5	5	4	5	5
	r_{21}^4	4	4	4	3	3	4	4
Sub-factors of Proximity	r_{12}^5	3	3	3	5	3	5	3
	r_{13}^5	3	3	3	2	2	3	3
	r_{14}^5	5	3	5	5	3	5	5
	r_{15}^5	3	3	3	4	3	4	3
	r_{21}^5	0	3	0	2	0	3	0
	r_{23}^5	2	2	3	2	2	3	2
	r_{24}^5	5	3	5	5	3	5	5
	r_{25}^5	3	3	5	5	3	5	3 or 5
	r_{31}^5	0	2	2	3	0	3	2

Influence	Expert				Lowest value	Highest value	Most frequent value
	A	B	C	E			
r_{32}^5	3	2	3	4	2	4	3
r_{34}^5	3	3	3	1	1	3	3
r_{35}^5	3	3	3	3	3	3	3
r_{41}^5	0	2	1	3	0	3	-
r_{42}^5	4	3	5	5	3	5	5
r_{43}^5	3	3	3	2	2	3	3
r_{45}^5	3	3	3	5	3	5	3
r_{51}^5	2	2	2	2	2	2	2
r_{52}^5	2	2	2	4	2	4	2
r_{53}^5	2	3	2	2	2	3	2
r_{54}^5	3	3	3	3	3	3	3