Original Article

Dynamic capabilities and the ecosystem context of the Scientific and Technological Park at PUCRS

As capacidades dinâmicas e o contexto ecossistêmico do Parque Científico e Tecnológico da PUCRS

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ABSTRACT

Purpose: To understand how the development of dynamic capabilities in a science and technology park influenced the trajectory of the smart city movement in an innovation ecosystem from 2002 to 2022.

Design/Methodology/Approach: A single case study was used, with a qualitative, exploratory, and descriptive approach, to analyze a science and technology park based on interviews with its coordinators.

Findings: The research revealed that the dynamic capabilities of the science and technology park were driven by initiatives for change, innovation, technology acquisition, and process reorganization. These capabilities, in turn, are related to the dimensions of smart cities, manifesting themselves in transformation, multifunctionality, autonomy, management, and processes.

Research limitations/Implications: Given the complexity of regional development processes, which involve a series of interconnected variables, the analyses in this study present limitations inherent to this multifaceted nature.

Practical implications: The development of dynamic capabilities in the technology park has led to innovative initiatives, contributing to the advancement of the city as a smart model.

Social implications: The collaboration between the university, technology park, and city has strengthened the innovation ecosystem, boosting regional development.

Originality value: This research presents an original contribution by relating dynamic capabilities to smart cities, opening new perspectives for future investigations and filling a gap in the literature.

Keywords: Dynamic capabilities; Science and technology parks; Smart cities; Innovation ecosystems; Regional development

RESUMO

Finalidade: Compreender como o desenvolvimento das capacidades dinâmicas em um parque científico e tecnológico influenciou a trajetória do movimento de cidade inteligente em um ecossistema de inovação no período de 2002 a 2022.

Design/Metodologia/Abordagem: Utilizou-se um estudo de caso único, com abordagem qualitativa, exploratória e descritiva, para analisar um parque científico e tecnológico, com base em entrevistas com seus coordenadores.

Constatações: A pesquisa revelou que as capacidades dinâmicas do parque científico e tecnológico foram impulsionadas por iniciativas de mudança, inovação, aquisição de tecnologias e reorganização de processos. Essas capacidades, por sua vez, relacionam-se às dimensões das cidades inteligentes, manifestando-se em transformação, multifuncionalidade, autonomia, gestão e processos.

Limitações/Implicações da pesquisa: Diante da complexidade dos processos de desenvolvimento regional, que envolvem uma série de variáveis interconectadas, as análises deste estudo apresentam limitações inerentes a essa natureza multifacetada.

Implicações práticas: O desenvolvimento de capacidades dinâmicas no parque tecnológico impulsionou iniciativas inovadoras, contribuindo para o avanço da cidade como um modelo inteligente.

Implicações sociais: A colaboração entre universidade, parque tecnológico e cidade fortaleceu o ecossistema de inovação, impulsionando o desenvolvimento regional.

Originalidade valor: Esta pesquisa apresenta uma contribuição original ao relacionar capacidades dinâmicas com as cidades inteligentes, abrindo novas perspectivas para futuras investigações e preenchendo uma lacuna na literatura.

Palavras-chave: Capacidades dinâmicas; Parques científicos e tecnológicos; Cidades inteligentes; Ecossistemas de inovação; Desenvolvimento regional

INTRODUCTION

Given a new strategic scenario, increasingly grounded in the organizational environment, this study adopts the dynamic capabilities model as its theoretical basis. Dynamic capabilities are fundamental in environments characterized by rapid and constant change (Teece et al., 1997). In this context, considering environmental dynamism, this study addresses an organizational performance model composed of three interrelated dynamic capabilities: absorptive capacity, adaptive capacity, and innovative capacity (Wang and Ahmed, 2007).

Absorptive capacity, as conceptualized by Cohen and Levinthal (1990), is fundamental for organizational innovation and competitiveness. By enabling firms to recognize the value of information and integrating it into their processes, this capacity

drives the creation of new knowledge and solutions. Studies such as Tutida et al. (2023) highlight that fostering a collaborative organizational culture and developing individual competencies are crucial elements for optimizing this capacity and ensuring the spillover of knowledge to other levels.

Adaptive capacity involves the dynamic process of incorporating acquired knowledge into organizational processes, considering the environmental context (Hörisch et al., 2014). This capacity is multifaceted, encompassing external factors that influence it and the interactions between individuals, communities, and authorities. Bossio et al. (2019) highlight the importance of adaptive capacity as a strategic resource for governance systems, enabling organizations and communities to respond effectively to environmental changes and challenges.

Teece (2007) defines innovative capacity as an organization's ability to adapt to dynamic and competitive technological environments through research and development (R&D) investments and the capacity to learn from other firms. Research indicates that fostering knowledge sharing among organizational members is crucial for promoting innovation, and that absorptive capacity, the ability to recognize and utilize external knowledge, are directly linked to innovative capacity, driving organizational performance (Kang and Lee, 2018).

Given the development of dynamic capabilities and the increasingly complex organizational environment, organizational structures have been undergoing constant transformation, culminating in agglomerations of organizations known as innovation ecosystems. These ecosystems, characterized by their intangible organizational peculiarities, are often "the result of policies that foster synergy between higher education institutions and businesses" (Spinosa et al., 2018). In this context, the importance of strategic alliances among local actors, with an emphasis on universities, stands out.

Innovation ecosystems, therefore, often emerge from a central institution, such as universities, academic medical centers, and technology parks (Heaton et al., 2019). While technology parks exhibit diversity in their models, they share the characteristic of fostering

the orchestration of human capital, promoting knowledge dissemination and interactions among local entities. This complexity and the diversity of involved actors make these ecosystems conducive environments for innovation, particularly in urban development.

When considering urban development, a new paradigm emerges: smart cities. Unlike traditional approaches, smart cities leverage technology and innovation to improve citizens' quality of life, the efficiency of urban services, and the city's competitiveness, seeking a balance between economic, social, and environmental aspects.

Through these theoretical interactions, this paper seeks to answer the following question: how has the development of dynamic capabilities in a science and technology park influenced the trajectory of smart cities within the context of an innovation ecosystem? In order to understand this relationship, a specific case was analyzed, investigating how the development of dynamic capabilities in a technology park contributed to the construction of the smart city movement in a specific region, between 2002 and 2022.

The specific objectives of this study are: (a) to present the co-evolutionary stages of a science and technology park within the context of the innovation ecosystem that enabled the smart city movement; (b) to identify the mechanisms of dynamic capabilities development that influenced the smart city movement; and (c) to establish the existing relationships between the development of dynamic capabilities in the science and technology park over time and the smart city movement, within the context of the innovation ecosystem.

Previous studies (Lavandoski et al., 2016; Garcia, 2017; Migliavacca, 2017) indicate that dynamic capabilities, derived from broader theories, drive organizations to seek continuous change to ensure sustainable competitive advantages. Although these studies highlight the positive impacts of dynamic capabilities on firms, they present a gap by not exploring the role of these capabilities in urban and regional development strategies, such as in the case of smart cities. Therefore, understanding the relationship between the development of dynamic capabilities in science and technology parks and the smart city movement is fundamental for the development of more flexible and comprehensive strategic models for regional development.

THEORETICAL FRAMEWORK

Dynamic Capabilities and Organizational Strategic Adaptation

Barney's (1991) seminal resource-based view theory has been instrumental in advancing the study of dynamic capabilities. By highlighting the significance of organizational resources in crafting effective strategies, this theory has paved the way for a deeper understanding of how firms can develop and refine their capabilities over time to adapt to an increasingly dynamic business environment. Research advancements in this field demonstrate that both leadership style and organizational tacit knowledge exert a significant influence on the formation of dynamic capabilities and, consequently, on achieving sustainable competitive advantages (Liu et al., 2019).

Although the seminal work of Teece et al. (1997) has propelled research on dynamic capabilities, the authors did not fully clarify the concept, leaving gaps regarding the attributes, identification, and origin of these capabilities within organizations. To fill this gap, Meirelles and Camargo (2014) proposed a more detailed framework, establishing constituent elements, indicators, and mechanisms of change for dynamic capabilities, significantly contributing to the development and operationalization of this construct in empirical research.

Meirelles and Camargo (2014) propose a model for dynamic capabilities that is based on three interconnected elements: behaviors and skills for change and innovation, search or innovation processes and routines, and knowledge management and governance mechanisms. The first element emphasizes the role of organizational members' commitment to change. The second element highlights the importance of work routines and processes in generating innovations. Finally, the third element underlines the need for a continuous cycle of learning and knowledge creation for the development of dynamic capabilities.

The understanding of dynamic capabilities has evolved significantly since the pioneering work of Teece et al. (1997). Meirelles and Camargo (2014) contributed to

this evolution by proposing a more operational model, which considers organizations as active agents in building their capabilities. This perspective converges with the studies of Wang and Ahmed (2007), who identify three essential capabilities: absorption, adaptation, and innovation.

Zahra and George (2002) posit a correlation between organizational resources and absorptive capacity, contending that resources underpin the development of dynamic capabilities. The authors advance a model that bifurcates absorptive capacity into two dimensions: potential absorptive capacity, linked to knowledge acquisition and assimilation; and realized absorptive capacity, tied to knowledge transformation and application. By highlighting the significance of organizational resources and routines, Zahra and George (2002) offer a more nuanced comprehension of how firms can leverage knowledge to gain a competitive edge.

The capacity for adaptation has been the subject of extensive scholarly inquiry, with various authors contributing to its conceptualization. Staber and Sydow (2002) characterize it as an iterative learning process that equips organizations to navigate complex environments. Birkinshaw and Gibson (2004) delve into how adaptive capacity unfolds within business units, emphasizing the significance of an organizational context that fosters a blend of flexibility, discipline, support, and trust. These scholars converge in underscoring the pivotal role of organizational resources and routines in the development of dynamic capabilities.

Complementing the previous perspectives, Akgun et al. (2007) propose that organizational adaptability is intrinsically linked to the interaction between individuals and infrastructures. According to these authors, organizations are complex systems composed of people who interact, learn, and build cultures, and of infrastructures that process information and shape behaviors. It is precisely at this interface between the human and the technological that the capacity for adaptation resides, transforming organizations into intelligent systems capable of responding effectively to environmental changes.

The capacity for innovation is fundamental for the competitiveness of organizations. Wang and Ahmed (2004) delve deeper into this discussion by identifying five dimensions of innovation: product, market, behavioral, process, and strategic. By relating these dimensions to organizational characteristics, the authors demonstrate that innovation is a complex process involving both the generation of new ideas and their implementation. The main contribution of this study lies in highlighting the importance of innovation as a core capability of organizations, which can be developed and enhanced through strategic actions.

Dynamic capabilities are essential for organizations to adapt to the constant changes in the environment and promote innovation. Ambrosini et al. (2009) demonstrate how dynamic capabilities allow companies to identify and exploit new business opportunities. In the context of science and technology parks, dynamic capabilities play an even more strategic role. Parks act as catalysts for innovation, absorbing knowledge, adapting it, and applying it to promote sustainable development. By strengthening dynamic capabilities, parks contribute to the creation of an innovative and competitive ecosystem.

Innovation Ecosystems and Science and Technology Parks

Clustered industrial transformation found an emblematic example in the creation of Stanford Industrial Park in the United States in 1951, now known worldwide as Silicon Valley. Since then, the conception of these collaborative spaces has sought theoretical grounding in the analogy of biological systems proposed by Moore (1993). According to this perspective, every organization is defined by its internal and external interactions, with customers, competitors, and a broader ecosystem. In this context, technology parks emerge as true complex networks where companies, consumers, governments, and other entities coexist, developing their capabilities and promoting the exchange of knowledge, technology, and information.

Zahra and Nambisan (2011) define innovation ecosystems as complex and dynamic networks where organizations collaborate and compete to generate new solutions.

Namba (2006), in turn, describes them as intangible structures that connect suppliers and customers, forming a strategic public. This constant interaction among the involved actors not only consumes innovations but also co-creates them, highlighting the importance of people as agents of transformation in these environments. However, recent research, such as that of Fialho et al. (2022), points to the need to strengthen cultural incentives and public policies to stimulate the dissemination of innovations in ecosystems.

In this context, universities, clusters, and science and technology parks emerge as central business models of innovation ecosystems. When analyzing the organizational models that sustain these ecosystems, a constant search for adaptation and evolution is observed. However, the fundamental characteristic of innovation ecosystems lies in their clustered nature, composed of a diversity of actors, companies, technologies, and skilled labor that interact in the same territory, both in cooperation and competition.

With the consolidation of the first innovation ecosystems and advances in studies on the role of clusters in innovative processes, there has been a growing interest at the political level in fostering collaboration among companies from various sectors. With the aim of stimulating industrial development and research through the adoption of new technologies and the updating of traditional industries, governments have started to invest in initiatives such as science and technology parks.

Science and technology parks are industrial areas dedicated to the generation, adaptation, and dissemination of new technologies. With different management models, parks aim to concentrate innovative and entrepreneurial activities in various sectors, often incubating early-stage companies (Benko, 1991). This concentration of knowledge and resources favors the creation of an environment conducive to innovation and technological development.

Science and technology parks are immersed in a continuous evolutionary process, seeking to ensure their relevance in the management of intangible assets (Ondátegui, 2001). The concentration of human capital and research laboratories in science and technology parks drives the creation of new generations of parks,

increasingly focused on the industrialization of innovations. This organizational co-evolution, as highlighted by Heaton et al. (2019), goes through different stages. In the initial stage, innovation ecosystems have low density, poorly defined identity, and few links between companies. However, in parks, there is a gradual strengthening of cooperation among companies around key activities, building a critical mass that drives the development of the ecosystem.

As it evolves from its initial phase to a more advanced stage of development, the innovation ecosystem adopts a holistic approach, seeking to develop "dynamic capabilities and robust productive systems" (Teece, 2018). In this context, a common language and culture emerge, interorganizational cooperation networks, and a social environment conducive to the generation of new knowledge. Upon reaching the consolidation stage, the innovation ecosystem demonstrates consistent performance over time, requiring, however, constant adaptation to markets and new technologies. Science and technology parks inserted in these ecosystems must, therefore, continuously renew their resources and capabilities to ensure their longevity. The literature, such as the work of Heaton et al. (2019), points out that many science and technology parks fail to overcome this transition phase, while others transform and contribute to the generation of new waves of innovation.

Thus, this study deepens the analysis of the co-evolution process of an innovation ecosystem from its core business, such as a science and technology park. Following the proposal of Heaton et al. (2019), the research investigates how the development of each stage of the ecosystem influences the configuration of a smart city, analyzing the role of the park in this process. The objective is to understand how the actions of the science and technology park shape the design and implementation of innovative solutions in the studied city.

The Smart Cities Movement

The advancement of information and communication technologies, driven by the internet and artificial intelligence, has transformed cities into complex informational

systems. The massive production of data and its strategic use have given rise to a new urban model: the smart city. Aiming to optimize public services, stimulate economic development, and promote sustainability, smart cities employ technologies to enhance citizens' quality of life in various aspects, such as energy, transportation, and health (Lai et al., 2020). In Brazil, this movement has gained momentum, with over 673 municipalities adopting such initiatives, and São Paulo leading the way in national rankings.

Given the proliferation of smart city initiatives around the world, Giffinger and Gudrun (2007) proposed a comprehensive classification of these cities, identifying six main dimensions: quality of life, competitiveness, human and social capital, citizen participation in public services, information and communication technology (ICT) infrastructure, and natural resources. Table 1 presents in detail the dimensions and indicators proposed by the authors to assess the degree of intelligence of cities.

Table 1 – Dimensions and Evidence of a Smart City

Dimensions	Evidence
Quality of life	Culture; Health; Security; Quality of housing; Education; Tourism; Social cohesion; Acting; Business verticalization.
Competitiveness	Innovation; Entrepreneurship; Marketing; Productivity; Work flexibility; Internationalization; Transformation capacity.
Human and social capital	Qualification; Continuous learning; Social plurality; Flexible population; Creativity; Cosmopolitanism; Participation in political life.
Public services	Popular participation; Public and social services; Accountability; Strategy exchanges.
ICT infrastructure	Accessibility; ICT infrastructure; Data use; Transport systems.
Natural resources	Attractiveness; Pollution; Preservation; Sustainable resources.

Source: Prepared by the authors based on Giffinger and Gudrun (2007)

Other authors, such as Desdemoustier et al. (2019), have delved deeper into the analysis of smart cities, "investigating the role of political actors in the appropriation of innovations and the promotion of urban development." In this sense, smart cities act as a catalyst for innovation, driving actors such as science and technology parks and companies to develop more creative and adapted solutions to local challenges.

By adopting a pragmatic approach, public policies for smart cities encourage experimentation and collaboration among different actors, promoting a dynamic and constantly evolving environment. The successful implementation of a smart city requires a solid governance structure, capable of coordinating the various initiatives and adapting to the changes of the urban context.

METHODOLOGY

Classified as descriptive research, this study qualitatively analyzed the collected data, seeking to understand the history of the science and technology park and the innovation ecosystem, and how this trajectory impacted the innovative development of the smart city. According to Richardson (1999), the qualitative approach allowed for a deeper understanding of the meanings and nuances of the interviewees' statements. By accurately describing the facts and phenomena, as proposed by Triviños (1987), the study contributed to the characterization of the investigated context, revealing its most relevant aspects.

With an exploratory character, the research contributes to expanding the knowledge about the object of study, since there are few previous studies on the subject (Collis and Hussey, 2005). The choice of the case study as a methodological strategy made possible an in-depth analysis of the research problem, allowing the identification of relevant aspects and gaps in the literature.

Given the above, it was decided to investigate Tecnopuc, the Science and Technology Park of the Pontifical Catholic University of Rio Grande do Sul, located in Porto Alegre. This choice is justified by the constitution of the internal elements that make up the trajectory of Tecnopuc, such as: companies of various sizes; Technology Management Agency; Tecnopuc Startups Incubator and Accelerator, which is composed of the innovation hubs: Garage, Road, Orbit and Track; Technology Transfer Office; Specialized Laboratory Complex in Electroelectronics, Calibration and Testing (Labelo); InovaPUCRS; Entrepreneurial Nucleus; Ideia Institute; Creativity Laboratory; Venture Management Agency; Tecnopuc Viamão; Innovation Management Support

Nucleus; Tecna Audiovisual Production Center; São Lucas Hospital and the city of Porto Alegre through the Pacto Alegre Project and the Innovation Cabinet.

In order to deepen the understanding of the study object, six in-depth interviews were carried out with managers and coordinators of the departments. The interviews, fully transcribed, constituted the main source of primary data for this study. The interviews are synthesized in Table 2.

Table 2 – Interviews with Tecnopuc members

Interview	Main functions at Tecnopuc and/or university	Year of entry	Duration time
E1	Advisor to the Superintendent of Innovation and Development at PUCRS – Director of Fundraising at the Association Brother Norberto Rausch – Professor at the PUCRS Business School – Founder of Crialab	2008	53:59
E2	Coordinator of Tecnopuc Startups – Coordinator of the Enterprise Management Agency – Professor at the PUCRS Computer Science course	2002	54:53
E3	Tecnopuc Infrastructure Coordinator	2007	1:04:00
E4	Coordinator of the Tecnopuc Creativity Laboratory – Designer in Social Innovation at Tecnopuc.	2016	1:05:00
E5	Professor at the PUCRS Polytechnic School and PPGCC at PUCRS – Superintendent of Innovation and Development at PUCRS and Tecnopuc	1985	54:04
E6	Professor at the PUCRS Polytechnic School and PPGCC at PUCRS – Executive Director of Tecnopuc – Coordinator of the MuNDDoS Research Group	2008	45:34

Source: Prepared by the authors (2023)

To collect data, semi-structured interviews were employed, guided by a structured script developed based on the theoretical categories established for the study and previously defined analytical evidence. Furthermore, a documentary research was conducted, involving an analysis of the bibliography and documents from the science and technology park, thereby complementing the analysis of the primary data. Table 3 provides a synthesis of the theoretical framework and analytical categories employed in the research.

The data analysis was framed within a historical perspective, seeking to situate Tecnopuc's evolution from 2002 to 2022 within its broader context. To achieve this,

we employed the methodological framework outlined by Pettigrew et al. (1992), which posits three interrelated dimensions: context, content, and process. This analytical lens facilitated a comprehensive exploration of the multifaceted factors that have shaped the development of the science and technology park.

Table 3 – Analysis categories, evidence and theoretical basis of analysis

Analysis categories	Evidence of analysis	Theoretical basis
Creation	Talent attraction; Collaborative initiatives; Identification.	Moore (1993); Heaton et al. (2019)
Development	Communication channels; Informal systems; Crossing of knowledge.	
Consolidation	Periods of stagnation; New projects; Patenting of technologies.	
Behaviors and skills	Commitment to change; Change initiatives; Strong competitive behavior; Key behaviors and skills; Stimulating skills.	Meirelles and Camargo (2014)
Processes and routines	Search for innovation; Technological imitation barriers; Adaptation to the local market; Generation of ideas; Globalization and life cycles.	
Learning mechanisms	Identification of external technologies; Adaptation of resources; Reorganization of processes; Improvement of actions and decisions; Obsolete technological outputs.	
Absorption	Acquisition; Assimilation; Transformation; Application.	Zahra and George (2002)
Adaptation	Decision-making autonomy and management style; Information and decision support systems; Plurality; Team multifunctionality.	Staber and Sydow (2002) Birkinshaw and Gibson (2004) Akgun et al. (2007)
Innovation	Products; Markets; Processes; Behavioral; Strategic.	Wang and Ahmed (2004)
Quality of life	Acting; Business verticalization.	Giffinger and Gudrun (2007)
	Work flexibility; Internationalization.	
Human and social capital	Cosmopolitanism; Participation in political life.	
Public services	Accountability; Exchange of strategies.	
ICT Infrastructure	ICT generation; Data usage.	
Natural resources	Preservation of the city; Natural conditions.	

Source: Prepared by the authors (2023)

To analyze the collected data, content analysis, as outlined by Bardin (2006), was employed. This methodological approach facilitated an in-depth interpretation of the data, with a particular focus on the interview transcripts. Using the MAXQDA® 2020 software, we were able to systematically identify and categorize salient information, which was then subjected to a rigorous reflexive and critical analysis, following Flick's (2009) recommendations.

PRESENTATION OF RESULTS

Tecnopuc and the City of Porto Alegre

Tecnopuc, a science and technology park located in Porto Alegre, Brazil, originated from joint initiatives between Pontifical Catholic University of Rio Grande do Sul (PUCRS) and the Federal Government. Founded in the 1990s, the park has established itself as a hub for innovation and entrepreneurship. In 1999, a partnership with Dell Inc. marked the establishment of a software development center at PUCRS, demonstrating the university's ability to attract multinational companies. The creation of the Technology Management Agency in the same year was fundamental for the structuring and development of Tecnopuc, with the mission of managing innovation processes and promoting research and development (R&D).

With the creation of the Technology Management Agency, the science and technology park project began to take shape. In 2001, the acquisition of the former 18th Motorized Infantry Battalion headquarters by PUCRS initiated the construction of the park's infrastructure. From 2003 onwards, Tecnopuc underwent a period of significant expansion, marked by the founding of the Raiar Multisectoral Incubator and the establishment of the Microsoft Innovation Center. These initiatives solidified Tecnopuc's position as a leading innovation hub in the region, attracting technology companies and fostering technology-based entrepreneurship.

In 2005, with the renovation of the former barracks completed, Tecnopuc inaugurated its Technology Transfer Office, responsible for fostering innovation

and protecting intellectual property. In the same year, the Labelo complex, focused on conformity assessment and energy efficiency, was inaugurated, expanding the park's service offerings. The growing dynamism of Tecnopuc's innovation ecosystem culminated, in 2006, in the creation of InovaPUCRS, a platform for connecting academia, the private sector, and government. Simultaneously, the Entrepreneurial Nucleus was founded, a space dedicated to the development of new ideas and supporting entrepreneurs in the early stages of their businesses.

In 2007, the university's Engineering Nucleus underwent a restructuring and was transformed into the Ideia Institute, solidifying its presence at Tecnopuc. In 2011, a strategic partnership with resident companies DBServer, D.School, and HP resulted in the creation of Crialab, a space dedicated to innovation and the development of new products and services. In parallel, the Brain Institute, inaugurated in 2012 in partnership with São Lucas Hospital, consolidated Tecnopuc as a center of excellence in neuroscience research and development, with a focus on technology transfer in imaging.

Tecnopuc's rapid growth, driven by business expansion and the creation of new structures, necessitated increasingly complex management. To optimize the management of enterprises and ensure the park's sustainability, the Enterprise Management Agency was established in 2013. In the same year, Tecnopuc expanded its operations to the city of Viamão, inaugurating a new unit. In 2014, given the need to coordinate the activities of both units, the Innovation Management Support Nucleus was created. In 2017, Tecnopuc Viamão inaugurated Tecna, consolidating its presence in the metropolitan region of Porto Alegre.

By 2019, Tecnopuc had already consolidated an average of four innovative products and services created and patented annually by its productive arrangements. Given the exponential growth and the need to optimize the management of various projects, the Raiar Incubator underwent restructuring. The creation of the Garage, a space dedicated to generating and developing new ideas, marked the beginning of this process. In the Garage, entrepreneurs are encouraged to develop value propositions

and business models. After initial validation of the idea, projects are transferred to the Road, the next phase of incubation, where prototypes and minimum viable products are developed over a 12-month period.

After validating the business model in the Road phase, entrepreneurs enter the Orbit, the final incubation stage, lasting 30 months. In this phase, the focus is on business scalability, investment attraction, and market consolidation of the product or service. The creation of Orbit in 2020, along with the Garage and the Road, resulted in the restructuring of the Raiar Incubator, which was renamed Tecnopuc Startups. To strengthen the connection between academia and the market, Track, a platform facilitating knowledge transfer and the generation of new startups, was created in 2021. Figure 1 summarizes these findings, illustrating the years and departments created at Tecnopuc.

The process of structuring the science and technology park was not static but rather marked by constant change and adaptation. This co-evolution involved the city of Porto Alegre and all partner institutions. Over the years, the park and the city grew interdependently, with the technology park playing a fundamental role in the economic and social development of the city. It is impossible to tell the story of Tecnopuc without considering its impact on the city and the importance of Porto Alegre for the success of the park's ventures.

Located in the Metropolitan Region, which encompasses 103 municipalities, Porto Alegre has an estimated population of 4.3 million inhabitants. The city presents a diversified economic scenario, with a highlight on the services and commerce sectors, which historically concentrate a large number of companies, including multinationals. Although present, industrialization plays a secondary role in the local economy. Since the 1990s, Porto Alegre has shown notable social development, with the Human Development Index (HDI) constantly rising. This progress is the result of investments in areas such as education, health, and income.

Figure 1 – Years of creation and departments of Tecnopuc
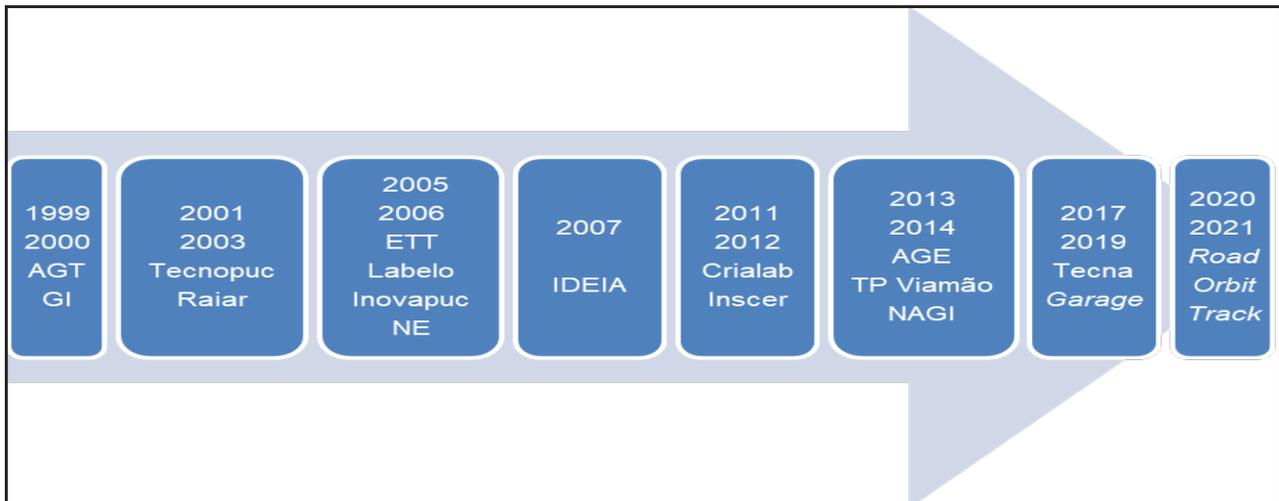
Source: Prepared by the authors based on research data (2023)

PUCRS' tradition in technology and its partnerships with companies have set it apart in the local scene, making it a natural partner for the Municipal Government. In 1995, this partnership resulted in the creation of the Porto Alegre Tecnópole Program, aimed at stimulating innovation in the city. In 2018, the three largest universities in Porto Alegre (PUCRS, UFRGS, and Unisinos) joined forces with the city government, giving rise to Pacto Alegre, an initiative that reinforced the city's commitment to innovation.

Since then, these projects have driven the city's technological development. One example, among many, is 'Wi-Fi Porto Alegre Livre', which offers free internet in public spaces such as Redenção Park and the Public Market. Thanks to initiatives like this, Porto Alegre has consolidated itself as the smartest city in the state and, together with PUCRS, other universities, companies, the city hall, and neighboring municipalities, forms a highly relevant innovation ecosystem.

The Coevolutionary Stages and the Main Events that occurred at Tecnopuc

The creation phase of Tecnopuc, between 2002 and 2006, was marked by the organization of the park's productive arrangement by anchor companies, in partnership with the PUC's Physics R&D center and the Labelo laboratories. This

initial complexity, with diversified actions, demonstrated the strong link with the university's expertise. Talent attraction and opportunity identification were based on this expertise, strengthening collaboration among the various stakeholders involved. The development of Tecnopuc was driven by public and private incentives, which were renewed over time, keeping pace with the park's evolution.

The period between 2007 and 2017 was marked by the development of Tecnopuc. During this period, the park established strategic partnerships with companies and research institutions, strengthening collaboration networks. A new methodology was implemented to stimulate creativity and innovation, and relationships with the market intensified with the emergence of investment funds and venture capital, which provided financial support for incubated and accelerated companies. In 2008, the InovaPUC Network was created with the aim of strengthening the articulation between academic units and research institutes, promoting the cross-fertilization of knowledge and the generation of new ideas. The InovaPUC Network formalized communication channels, complementing existing informal partnerships and aiming to maximize the application of research results in innovative solutions for the market and society.

Throughout its three development stages, Tecnopuc has played a fundamental role in Porto Alegre's innovation ecosystem, co-evolving with the city. Each phase has been associated with a specific set of functions and capabilities of PUCRS. Since 2018, with the restructuring of the Raiar Incubator into a coworking model and the creation of Tecnopuc Startups, the park has rapidly adapted to new market demands, driven by the presence of a specialized workforce. This dematerialization has accelerated the generation of new projects and the patenting of technologies, consolidating Tecnopuc as an innovation platform in the regional scenario.

In order to organize and optimize project management, Tecnopuc implemented a strategic plan that divided projects into specific thematic areas. This subdivision was essential to meet the growing demand and to adapt to the new coworking

model, which required a more flexible and collaborative organization among partner companies, startups, and park departments. Table 4 presents a summary of the periods, co-evolutionary stages, and main events that marked Tecnopuc's transformation trajectory during the analyzed period.

Table 4 – Periods and co-evolutionary stages of Tecnopuc and main events

Periods	Internships	Main Events that occurred in the park
2002 to 2006	Creation	- Financial incentives from the Federal Government; - Occupation of the space by PUC's Physics R&D center; - Business promotion in partnership with anchor companies; - Occupation of space by Labelo and its laboratories.
2007 to 2017	Development	- Articulation of inter-organizational networks; - Creation of prototyping laboratories; - Formalization of communication channels by Inovapuc.
2018 to 2022	Consolidation	- Reformulation of the Raiar Incubator, and creation of Tecnopuc Startups.

Source: Prepared by the authors based on research data (2023)

By recognizing the entrepreneurial potential of new technologies, Tecnopuc actively engaged in their development, as highlighted by Heaton et al. (2019). The presence of visionary leaders was fundamental in promoting a gradual and comprehensive change in the innovation ecosystem (Pettigrew et al., 1992). The city of Porto Alegre and neighboring cities played a crucial role in this process, highlighting the importance of the local context for the development of Tecnopuc. Table 5 presents a summary of the evidence that supports this claim.

The evolution of Tecnopuc was not a spontaneous process. The transition involved significant changes in areas such as technology, customers, and internal processes, as well as a substantial investment of financial resources and a strong commitment from leadership. The success of Tecnopuc demonstrates the importance of "dynamic and long-term strategies, such as the ability to adapt business models," as proposed by Teece (2018).

Table 5 – Contexts, contents and processes that co-evolved Tecnopuc

Periods	Context	Content	Process
2002/2006	- Partnerships with local companies; - Installation of anchor companies; - Licensed products; - Coordination mechanism between universities, companies and government.	- Creation of key departments, such as: AGT, GI, Raiar Incubator, ETT and NE.	- Management of R&D processes and projects; - Attraction of companies; - Business promotion; - Proofs of concepts; - Internal production arrangement; - Business plan competitions.
2007/2017	- Interdisciplinary spaces; - Evolution of structures; - Expansion of niches; - Incubation of audiovisual, games and cinema companies.	- Creation of key departments, such as: Instituto Ideia, Crialab, Inscer, AGE, NAGI and Tecna; - Reformulation of Crialab.	- Transfer of technology to society; - Relationship with the market; - Investors; - Economic sustainability; - Reduction of local taxes.
2018/2022	- Business support; - Attraction and development of ideas.	- Reformulation of Raiar; - Creation of Garage, Road, Orbit, and Track Startups; - Creation of coworking spaces.	- Orchestration of companies, departments, research and production; - Support to the entrepreneur in setting up the business and preparing for scale.

Source: Prepared by the authors based on research data (2023)

The development of Dynamic Capabilities in the Stages analyzed

When analyzing the development of dynamic capabilities at Tecnopuc, we observe that its evolution was guided by a set of strategic decisions and organizational capabilities. The interactions of dynamic capabilities with the innovation ecosystem focused on the detection and exploitation of new technologies, as well as the building of partnerships with industry companies. The identification of new business opportunities always resulted in the creation of new products, processes, or services, demanding continuous investment in R&D. Table 6 presents the key elements that composed the process of developing dynamic capabilities, highlighting the main characteristics and results observed in the investigated period.

The analysis of Tecnopuc's three co-evolutionary stages reveals a trajectory marked by a continuous pursuit of innovation and change initiatives. This combination of elements is consistent with dynamic capabilities theory, which suggests that the need to innovate is driven by market dynamism. As Wang and Ahmed (2007) point out, the more dynamic the business environment, the greater the pressure on firms to develop new capabilities and adapt their business models. The case of Tecnopuc exemplifies this relationship, demonstrating how the dynamism of the local market has driven the pursuit of innovation and the development of new capabilities over the years.

Table 6 – Component elements of dynamic capabilities in Tecnopuc

Component Elements	Creation/Development/Consolidation Stages
Behaviors and skills	- Commitment to change;
	- Change initiatives;
	- Strong competitive behavior;
	- Key behaviors and skills;
	- Stimulation of skills.
Processes and routines	- Search for innovation
	- Barriers to technological imitation;
	- Adaptation to the local market;
	- Generation of ideas;
	- Globalization and life cycles.
Learning and knowledge governance	- Identification of technologies;
	- Adaptation of resources;
	- Reorganization of processes;
	- Improvement of actions and decisions;
	- Obsolete technological outputs.

Source: Prepared by the authors based on research data (2023)

Throughout the park's three development stages, the ability to assimilate, transform, and apply knowledge in various partnerships was observed, highlighting the importance of absorptive capacity in all phases of the process. The analysis also revealed a strong adaptive capacity, present in all stages. This capacity manifested itself through "autonomy in decision-making, efficient information systems, multifunctional

teams, and a dynamic organizational system". These elements, according to Staber and Sydow (2002), allowed the park to adapt to environmental changes and learn from its experiences. Finally, the analysis demonstrates that the capacity for innovation was a central element in all phases of Tecnopuc's development, with the creation of new products, the exploration of new markets, and the optimization of processes. Table 7 summarizes these capabilities.

Table 7 – Dynamic capabilities observed in co-evolutionary periods

Capabilities	Creation/Development/Consolidation
Absorption	- Assimilation;
	- Transformation;
	- Application.
Adaptation	- Decision-making autonomy and management style;
	- Information and decision support system;
	- Multifunctionality of the team.
Innovation	- Products;
	- Markets;
	- Processes;
	- Behavioral;
	- Strategic.

Source: Prepared by the authors based on research data (2023)

When analyzing Tecnopuc's absorptive, adaptive, and innovative capacities, a co-evolutionary process characterized by a certain degree of homogeneity and complementarity among its components was observed, which contributed to the configuration of the park's structure.

Dynamic Factors that Influenced the Porto Alegre Smart City

Porto Alegre had already demonstrated a significant interest in technologies even before entering the ranking of smart cities, strengthening public-private partnerships with higher education institutions. The inauguration of Tecnopuc, coinciding with a substantial increase in federal resources allocated to the city's technological development, deepened this relationship, highlighting the institution's central role in this process.

Since 2015, Porto Alegre has consistently ranked among the best-evaluated Brazilian cities in the Connected Smart Cities Ranking, always leading the state ranking. The research, based on the Giffinger and Gudrun model (2007), analyzed how Tecnopuc contributed to the city's development as an innovation hub. The results, presented in Table 8, highlight the various dimensions of urban intelligence that have strengthened over the years, intersecting with the technological park's activities.

Table 8 – Smart city dimensions present in Porto Alegre in the analyzed period

Creation	Development	Consolidation
- Quality of life - Public services - Competitiveness - Human and social capital - ICT infrastructure - Natural resources	- Competitiveness - Quality of life - Public services - Human and social capital - Natural resources - ICT infrastructure	- Natural resources - Competitiveness - Public services - ICT infrastructure - Human and social capital - Quality of life

Source: Prepared by the authors based on research data (2023)

Tecnopuc played a pivotal role in each of Porto Alegre's smart city development stages. In the initial phase, the technology park contributed significantly to the movement, focusing on quality of life, public services, and competitiveness. As the city evolved, priorities adjusted, with competitiveness gaining prominence, followed by quality of life and public services. In the consolidation stage, natural resources emerged as a central axis of Tecnopuc's activities, alongside competitiveness and public services.

A crucial factor in Tecnopuc's co-evolution was the definition of a central objective that aligned the park's activities with the city's needs. Although competitiveness was a constant in all three analyzed stages, the combination of various dimensions – quality of life, public services, natural resources – was decisive in achieving it. The table, created using MaxQDA's color coding, demonstrates how these dimensions manifested in each stage, highlighting the complexity and interdependence of the factors that contributed to Porto Alegre's smart city status.

The MaxQDA color coding establishes a visual scale for the frequency of interactions between the evidence. The color red indicates a low level of interaction, signaling that certain evidence was mentioned infrequently by the interlocutors. The yellow hue represents a moderate level of interaction, with evidence being mentioned between five and eight times. The color green, in turn, highlights the most frequent evidence, that is, those widely discussed by the participants. Finally, the color blue signals the most prominent and relevant evidence in the analyzed period.

Table 9 – Evidence of smart city dimensions

Evidence	Creation	Development	Consolidation
Performance	🟥	🟩	🟦
Business verticalization	🟦	🟥	🟥
Work flexibility	🟦	🟦	🟩
Internationalization	🟥	🟥	🟥
Cosmopolitanism	🟥	🟥	🟥
Participation in political life	🟦	🟦	🟦
Accountability	🟦	🟥	🟥
Exchange of strategies	🟩	🟦	🟦
ICT generation	🟦	🟦	🟩
Data usage	🟥	🟩	🟥
City preservation	🟦	🟥	🟦
Natural conditions	🟦	🟥	🟨

Source: Prepared by the authors based on research data (2023)

The co-evolution of Tecnopuc and the Metropolitan Region resulted in an innovation ecosystem that propelled regional development. The technological park's influence transcended the boundaries of Porto Alegre, extending to other cities in the region, which also began to appear in the Connected Smart Cities ranking. This synergy between Tecnopuc and other cities demonstrates the importance of a regional approach to promoting innovation.

CONCLUSIONS

Research on dynamic capabilities has intensified, but there are still gaps in understanding how these capabilities manifest in specific contexts, such as science and

technology parks. This study aims to fill this gap by analyzing the case of Tecnopuc and its influence on the smart city movement. The analysis period was set between 2002 and 2022, and the study investigated how the development of dynamic capabilities within the park contributed to the transformation of Porto Alegre into a smarter city, highlighting the importance of a systemic approach to urban innovation.
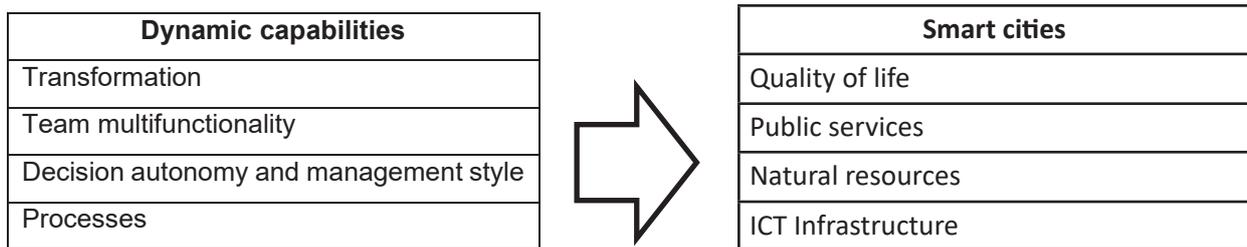
By historically contextualizing the development of the science and technology park, analyzing its partnerships and strategic events, it was possible to identify the dynamic capabilities that emerged at each stage of its co-evolution. This analysis allowed us to understand how these capabilities contributed to the development of the dimensions of a smart city, within the context of the innovation ecosystem investigated.

The analysis identified three co-evolutionary stages: creation (2002-2006), development (2007-2017), and consolidation (2018-2022). The initial stage was marked by the attraction of talent, while the development stage was characterized by the integration of knowledge, and the consolidation stage, in turn, by the generation of new projects and patents.

The park's dynamic capabilities evolved throughout the stages. Initially, the emphasis was on identifying external opportunities and seeking innovation. As the park progressed to the development and consolidation stages, the reorganization of internal processes became a fundamental element, complementing the initiatives for change and the pursuit of innovation.

The capacity for transformation, characterized by the team's initial multifunctionality and the increasing autonomy and process refinement, was a constant throughout all stages. This evolution demonstrates the importance of continuous adaptation and strategic management for the park's success. Corroborating this analysis, the investigation of all constructs, focusing on science and technology parks, allowed the identification of theoretical convergences that culminated in Figure 2. This figure visualizes the relationship between dynamic capabilities and smart cities.

Figure 2 – Theoretical convergence of dynamic capabilities and smart cities

Dynamic capabilities	Smart cities
Transformation	Quality of life
Team multifunctionality	Public services
Decision autonomy and management style	Natural resources
Processes	ICT Infrastructure

Source: Prepared by the authors (2023)

The relationship between the science and technology park and the city of Porto Alegre has evolved over the years. In the initial stages, the park contributed to the improvement of the quality of life of the population. Over time, the focus shifted to economic development, through stimulating competitiveness and technology transfer. In the consolidation phase, the park directed its efforts towards the exploration of natural resources, always with a focus on flexible work as a key element for adapting to the city's demands.

The results of this research evidence that science and technology parks, by developing dynamic capabilities in a cyclical manner, act as agents of social and economic transformation. By connecting universities, companies, and the market, these parks promote innovation, knowledge generation, and talent development, contributing to the construction of smarter and more competitive cities. Thus, it is perceived that regional design demands a systemic vision that transcends business and institutional relationships. By analyzing the territory holistically, it is possible to develop more effective competitive strategies, capable of promoting innovation and long-term sustainability.

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2. Development of hypotheses or research questions (empirical studies)	√	√	
3. Development of theoretical propositions (theoretical work)			
4. Theoretical foundation / Literature review	√	√	√
5. Definition of methodological procedures	√	√	√
6. Data collection	√		
7. Statistical analysis			
8. Analysis and interpretation of data	√	√	√
9. Critical revision of the manuscript	√	√	√
10. Manuscript writing	√	√	√
11. Other (please specify)			

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