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Proposal of a conceptual framework based on the triple helix of innovation for smart cities: a study in southern Brazil

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Summary

Objective: To present a framework with the elements to guide a smart city from the Triple Helix of innovation.
Methodology: this is a generic qualitative study, applying a semi-structured questionnaire with 12 interviewees in four project initiatives that use ICTs in Porto Alegre and Caxias do Sul RS.
Originality/Relevance: the article discusses the important interaction of project initiatives that apply information and communication technology within cities and how the interaction of these projects with the Triple Helix of innovation "University – Company – Government" impact the citizen and the urban environment.
Results: The government of a city lacks to indicate visions for the city and to solve real problems, as well as to develop public politics to encompass these visions. Companies producing services and technologies for a smart city emphasize the capitalization of knowledge for a smart economy, high-tech industry, and a supportive business and enterprise environment. Universities have contributed to smart city projects through their knowledge of making cities clean and green through skilled human resources.
Social / Management Contributions: In the model proposed in this research, it becomes the central element of the concept of smart cities and the Triple Helix of innovation because, according to the combination of smart governance and smart people, these two assumptions develop, apply knowledge through from universities and companies and receive resources and can feed back the innovation ecosystem, contributing to the social, economic and sustainable well-being of the whole community.

Keywords: Smart city. Triple helix. Innovation. Generic qualitative. ICTs.

Proposta de um *framework* conceitual baseado na hélice tripla de inovação para cidades inteligentes: um estudo no sul do Brasil

Resumo

Objetivo: Apresentar um *framework* com os elementos para nortear uma cidade inteligente a partir da Hélice Tripla de inovação.
Metodologia: é um estudo qualitativo genérico, aplicando um questionário semiestruturado com 12 entrevistados em quatro iniciativas de projetos que utilizam TICs, nas cidades de Porto Alegre e Caxias do Sul. RS.
Originalidade/Relevância: artigo discute a importante interação de iniciativas projetos que aplicam tecnologia de informação e comunicação no âmbito das cidades e como a interação

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destes projetos com a Hélice Tripla de inovação “Universidade – Empresa – Governo” impactam o cidadão e o ambiente urbano.
Resultados: O governo de uma cidade carece de indicar visões para a cidade e resolver problemas reais, bem como desenvolver políticas públicas para abranger essas visões. As empresas produzem serviços e tecnologias para uma cidade inteligente enfatizam a capitalização do conhecimento para uma economia inteligente, a indústria de alta tecnologia e um ambiente adepto às empresas e negócios. As universidades vêm contribuindo para projetos em cidades inteligentes por meio do conhecimento em tornar as cidades limpas e verdes através de recursos humanos capacitados.
Contribuições sociais / para a gestão: No modelo proposto nesta pesquisa se torna o elemento central do conceito de cidades inteligentes e Hélice Tripla de inovação, pois, de acordo com a combinação de governança inteligente e pessoas inteligentes estes dois pressupostos se desenvolvem, aplicam conhecimento através de universidades e empresas e recebem recursos e são capazes de retroalimentar o ecossistema de inovação, contribuindo para o bem-estar social, econômico e sustentável de toda a coletividade.

Palavras-chave: Cidade inteligente. Hélice tripla. Inovação. Qualitativo genérico. TICs.

Propuesta de un marco conceptual basado en la triple hélice de innovación para ciudades inteligentes: un estudio en el sur de Brasil

Resumen

Objetivo: Presentar un marco con los elementos para orientar una ciudad inteligente desde la Triple Hélice de la innovación.
Metodología: se trata de un estudio cualitativo genérico, aplicando un cuestionario semiestructurado con 12 entrevistados en cuatro iniciativas de proyectos que utilizan TIC, en las ciudades de Porto Alegre y Caxias do Sul.RS.
Originalidad/Relevancia: el artículo discute la importante interacción de iniciativas de proyectos que aplican tecnologías de información y comunicación dentro de las ciudades y cómo la interacción de estos proyectos con la Triple Hélice de innovación “Universidad – Empresa – Gobierno” impacta al ciudadano y al entorno urbano.
Resultados: Al gobierno de una ciudad le falta señalar visiones para la ciudad y resolver problemas reales, así como desarrollar políticas públicas para abarcar estas visiones. Las empresas que producen servicios y tecnologías para una ciudad inteligente enfatizan la capitalización del conocimiento para una economía inteligente, una industria de alta tecnología y un entorno comercial y empresarial de apoyo. Las universidades han estado contribuyendo a los proyectos de ciudades inteligentes a través de su conocimiento de hacer que las ciudades sean limpias y verdes a través de recursos humanos calificados.
Aportes Sociales/Gestión: En el modelo propuesto en esta investigación, se convierte en el elemento central del concepto de ciudades inteligentes y Triple Hélice de la innovación, pues, de acuerdo a la combinación de gobierno inteligente y personas inteligentes, estos dos supuestos se desarrollan, aplican conocimientos. a través de universidades y empresas y reciben recursos y son capaces de retroalimentar el ecosistema de innovación, contribuyendo al bienestar social, económico y sostenible de toda la comunidad.

Palabras clave: ciudad inteligente. Triple hélice. Innovación. Cualitativo genérico. TIC.

Introduction

For Weiss et al. (2015), the Smart Cities proposal emerges as an alternative solution to the problems arising from urban development consented to by Information and Communication Technology (ICT) and social engagement. This new paradigm addresses the

importance of supporting popular participation in urban innovation and more effective governance that benefits this potential use of human capital (Macke et al. 2019). As benefits, advances in the quality of life and the design of a sustainable city for its population are expected (Giffinger & Gudrun, 2010).

For Etzkowitz and Leydesdorff (2000), innovation, economic development, and knowledge production happen from the collaboration between the private field and the university. Oliveira et al. (2018) highlight the implication of a third party: the government, perfecting the model known as the Triple Helix. In this model, in which each agent has a distinct role, there must be a collaborative process that tolerates the definition of a common goal of making a smart city (Rucinska & Knezova, 2014).

Rucinska and Knezova (2014) developed in their research a proposal for a framework that integrates the smart city and the Triple Helix of innovation that addresses some factors such as: institutional, technological, and human. The Brazilian Institute of Human, Intelligent, Creative and Sustainable Cities - IBRACHICS (2021) also reports these three key factors, also solidifies four indicators that allow classifying Brazilian Smart Cities based on governance, architecture and urbanism, technology and security.

A smart city is a city that aims to link physical, IT, social, and business infrastructures to leverage the collective intelligence of the city (Giffinger & Gudrun, 2010). This growing phenomenon was born from the generic use of Information and Communication Technologies (ICTs) in urban space. In this context, the performance of the various actors (companies, public governments, universities) in the city's ecosystem is categorical in increasing new services and products to satisfy people's needs.

While the Triple Helix and subsequent patterns of innovation in ecosystems over the last decade (Etzkowitz & Leydesdorff, 2000; Rucinska & Knezova, 2014) have addressed the role of key actors in the development of innovation, few studies have analyzed their role in the smart city ecosystem. In this sense, the research question is: Are there more elements within the human, technological and institutional factors to be considered for a smart city from the point of view of innovation? In this way, the study's objective is to present a conceptual framework with the elements to guide a smart city from the Triple Helix of innovation. The article is divided into an introduction, theoretical framework, research method, analysis and discussion of results, and final considerations.

Theoretical background

Smart and technological city

The concept of a smart city is related to a new conjecture for solving the issues caused by rapid urbanization, making use of the intense use of information and communication

technologies (ICT), is born as a means to make the cities of the future viable (Boioni, 2021; Weiss et al. 2015). Giffinger and Gudrun (2010) point out that it is those cities that achieve the vision of the future in several aspects – economy, people, governance, mobility, environment, and quality of life – and are designed on the intelligent combination of several urban elements (Macke et al. al., 2019).

The Smart City concept goes beyond the focus on ICTs, as it considers central aspects of a city's urban, social, and economic development, such as human capital (Neiroti et al., 2014). Information and communication technologies (ICTs) provide the smart infrastructure that is the basis for all key themes of a smart city, such as smart economy, smart governance, smart mobility, smart health, and smart buildings. Therefore, a smart city comprises several infrastructure artifacts that form a complex system, effectively collaborating with its ecosystem (Tsoutsa et al., 2021).

These ideas in the literature indicate that the smart city concept still lacks consensus, largely because it is a relatively new phenomenon. In this way, multiple concepts go beyond the role of new technologies as influencers in the dynamics of the smart city (Macke et al., 2018). The commitment of researchers to understand how to enable the development of smart cities and their innovations effectively have been growing over the years, as has the number of cities that have sought to become smart, taking advantage of the opportunities that technological solutions offer to face challenges. urban challenges (Giffinger, & Kramar, 2021; Boioni, 2021; Hutchinson, 2021).

To Komninos (2009), smart cities are born from the composition of local innovation systems that work in the center of cities as technological surroundings, technology parks, innovation poles, “clusters”, equipped with digital networks and uses of the information society. According to Camboim (2018), designing an “innovation district” should be an important step for a city that wants to become smart. The innovation district can be where startups, creative and high-tech companies, universities, and research and technology centers need to situate their activities to expand solutions to the needs of the actors who will consume such innovation (Komninos et al., 2021).

The study of innovation encompasses diverse theoretical models of different natures and contexts, whether social, economic, marketing, or business. Since Schumpeter's studies (1985), it has been known that the development process of a nation is rooted in local potential and agents' ability to articulate, interact, collaborate, and study to create something, that is, developing innovation.

Governance is defined as the mechanism by which the conditions for collective action are created (Schumpeter, 1961). Based on this premise, smart governance can be perceived as a process in which various stakeholders interact, or “stakeholders” (Beck & Conti, 2021), contribute, and get involved in decision-making (Macke et al., 2019).

Cities that promote innovative business, especially those that rely on joint efforts by governments, academia, and entities from the economic sectors, are born from the need to bridge the gap between society and innovation-producing environments, characterized by an effective push towards local networked development (Giffinger, & Kramar, 2021; Castells, 2011).

According to Oliveira and Carvalho (2017), for Brazil to develop its Smart Cities on a desirable scale and not exclusively in certain parts of the country, it is necessary to structure a stable innovation dynamic. The challenge of transforming cities into smart ones does not depend solely on the will and action of Brazilian municipalities, and it is a value that involves multiple actors "government, private initiative, citizens, universities and other institutions" (ABDI, 2018).

Triple helix for smart city innovation

The Triple Helix was born through the union of two streams of thought that gained strong representation in the 1990s (Etzkowitz & Leydesdorff, 2000). Its design was based on debates involving the affinity between university and business. Thus, the term Triple Helix was originally schematized by Henry Etzkowitz and Loet Leydesdorff, outlining the government-university-company relationship (Etzkowitz & Zhou, 2017).

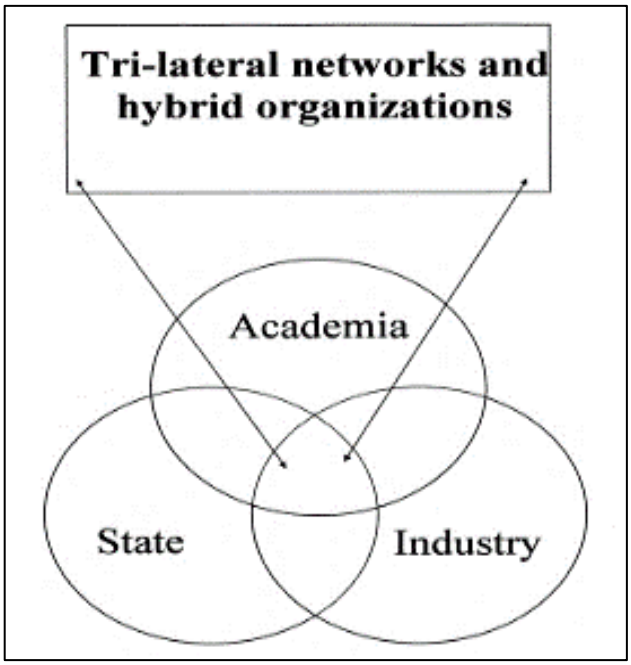
According to Etzkowitz and Zhou (2017), the interaction between government-university-company was responsible for stimulating the development process in Silicon Valley, boosting the emergence of innovative companies, guided by contributions from universities in partnerships with government institutions, responsible for the funding of research and assistance with technology companies (Komninos et al., 2021).

According to Oliveira and Ranault (2020), the university is a basic institution for generating and transferring knowledge and operates with the government and companies. The panorama of post-industrial and technological society has promoted strategies that leverage contributions from the relationship between universities, companies, and governments (Gomes et al., 2015; Etzkowitz & Leydesdorff, 2000).

The Triple Helix model is understood as a set of initiatives, commitments, and concrete actions requested by teams conceiving "[...] communities, organizations, educational institutions, and government, aligned with socioeconomic development, progress and continued existence of communities where they are established" (Oliveira, Marins & Delamaro, 2018; Etzkowitz & Leydesdorff, 2000).

Figure 1

Triple Helix Model and its relationships



Source: Etzkowitz e Leydesdorff (2000).

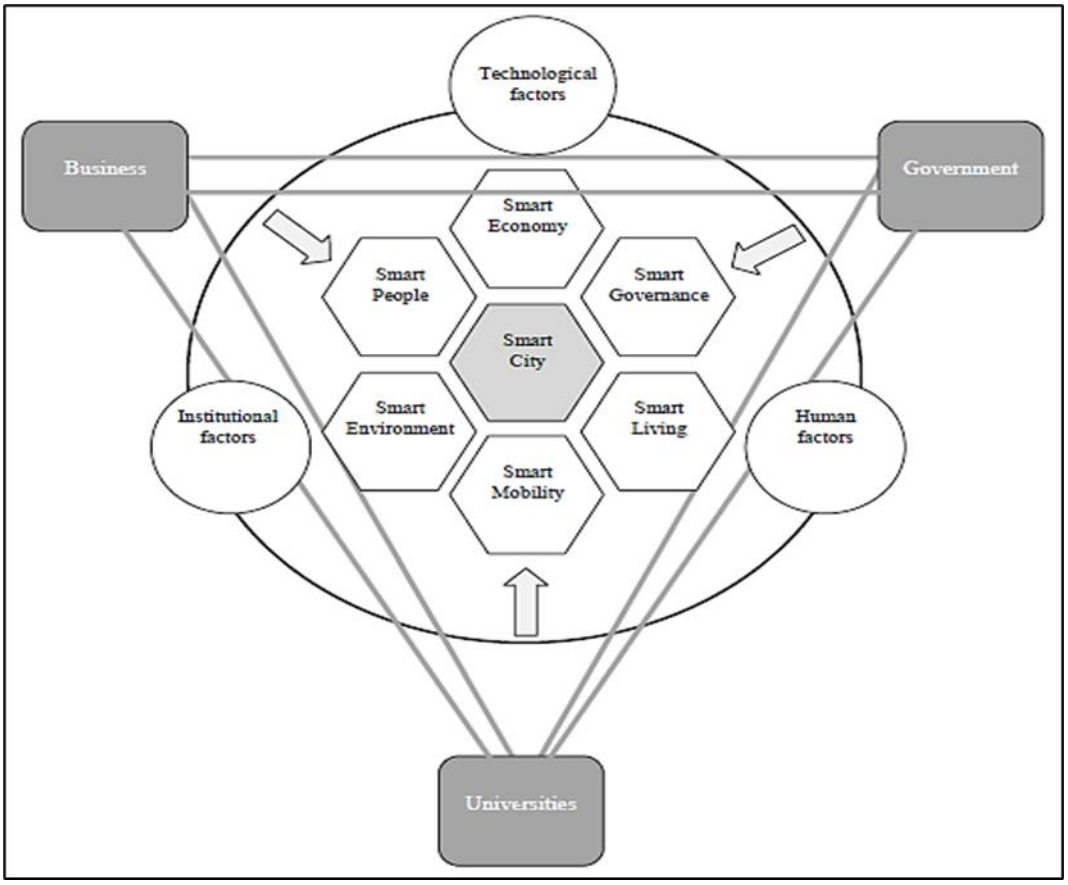
The form originally proposed by Etzkowitz and Leydesdorff (2000) in the 1990s pondered the essence of an area of interconnection between the three agents of Government – University – Business in a values assessment to request modifications in the prominent interfaces of science-technology-industry. Since its creation, the unprecedented model has inspired academics and researchers to investigate how to strengthen and sustain ties between academia, industry, and government (Selznick, 1996).

Therefore, the Triple Helix model, in which the cultivation of new ideas and the implementation of projects are carried out based on exchanges between universities, companies, and public administration, can generate new adaptations of knowledge, benefiting theoretical and practical innovations in a way especially at city level (Ranga & Etzkowitz, 2013).

Rucinska and Knezova (2014) reinforce the link between the theme of smart cities and the Triple Helix. For the authors, the constitution of a smart city has different dimensions (economic, governance, habitability, mobility, environment, and human capital) interconnected to the actors considered in the helix. Rucinska and Knezova (2014) developed a Triple Helix model for smart cities where the meaning of the best probabilities of using the development plan as a policy tool for designing a city in the context of new convergences and customs of the main development actors who systematically cooperate in this intelligent method.

Figure 2

Connection of Smart Cities components and Triple Helix model



Source: Rucinska e Knezova (2014).

Among the different experiments to conceptualize and categorize these interactions between the actors of a smart city, Deakin and Leydesdorff (2013) determined the concept of Triple Helix of a smart city and its use (Selznick, 1996). Universities combine the helix, companies, and democratic governments, and their exchanges produce the knowledge that supports the city's evolution. Lombardi et al. (2012) used this method to measure the performance of smart cities spanning the Triple Helix. Kourtit et al. (2013) describe the relationship between Smart Cities (inter) Regional Academic Network (SCRAN) and the Triple Helix model of knowledge production in cities (Oliveira & Ranault, 2020; Ranga & Etzkowitz, 2013).

Research method

The research developed is exploratory. This type of research is appropriate when the researcher has a problem or a research question that provides few previous studies, and the researcher aims to obtain insights for a more rigorous verification (Cooper & Schindler, 2016). The objective of exploratory studies is to look for ideas, patterns, or test hypotheses, aiming to

collaborate with the field of study (Rodrigo-Pedrosa & Fontanella, 2021; Creswell, 2014).

Marshall and Rossman (2006) indicate that qualitative research suggests immersion in everyday life of the meaning chosen for the study. The researcher transversally enters the world of ongoing interaction, searching for informants, perspectives, and meanings (Creswell, 2014). The methodological assumption brings an inductive characteristic, studies the theme within its context, and uses an emergent design (Sampieri, Callado & Lucio, 2013)

Research tends to apply itself to one or a small number of cases, to use active interviews or in-depth analysis of historical materials, to be discursive in method, and to be concerned with accounting for the overarching design of an event or unit. Even if they contain a low number of cases, qualitative researchers, as a rule, find enormous amounts of information from their studies (Rodrigo-Pedrosa & Fontanella, 2021). This type of work in the social sciences is related to case studies, which focus on a particular event, decision, institution, location, problem, or a part of an event (Creswell, 2014).

The generic qualitative strategy differs from other qualitative studies, as it seeks to encompass the phenomena or processes from the worldview and perspectives of the interviewed subjects. Furthermore, this type of research focuses on how individuals interpret and construct meaning from their experiences (Merriam, 2009). To this end, the study is based on three central attributes: focus on the interpretation of experiences, the constitution of each subject's world, and the meaning they attribute to their experiences (Merriam, 2009). Percy, Kostere, and Kostere (2015), on the other hand, ensure that generic qualitative research should be adopted as a research strategy when one assumes the particular aspects that qualitative research has and, based on that, the report of experience and interpretation world underpins the researcher's analysis (Rodrigo-Pedrosa & Fontanella, 2021; Merriam, 2009). In the present study, in-depth interviews, secondary research, and non-participant observation were conducted to optimize data analysis using the NVivo® 12 software.

Loci of study

There are already, in Brazil, cities that apply projects in smart cities in practice, according to the Brazilian Institute of Human, Smart, Creative and Sustainable Cities - IBRACHICS (2021) has been working with the Federal Government in national policies for the development of human, intelligent, creative and sustainable cities, there are more than 600 affiliates throughout Brazil.

The Brazilian Network of Human, Intelligent, Creative and Sustainable Cities (REDE CHICS) was created in 2013, in the domain of the National Front of Mayors – which groups the 420 largest Brazilian cities – and at that time only grouped secretaries and municipal science leaders, technology and innovation, as well as municipal secretaries of economic development (IBRACHICS, 2021).

In Rio Grande do Sul, three cities are part of the Brazilian Network of Human, Smart, Creative, and Sustainable Cities: Caxias do Sul, Porto Alegre, and Estância Velha. The two largest cities in Rio Grande do Sul were selected as a criterion for choosing the cases, Porto Alegre and Caxias do Sul. In these two cities, we sought to investigate project initiatives that included the Triple Helix model for Smart Cities by Rucinska and Knezova (2014).

According to the IBGE (2021), Porto Alegre has 1,483,771 inhabitants. In the area of work and income, the average salary of employed workers was 4.1 minimum wage in 2017, with employed persons 795,011 in 2017. In education, the schooling rate from 6 to 14 years was 96.6 % in 2010; in the economic area, it has a GDP per capita of R$ 49,577.53 human development index - HDI in 2010 is 0.805 (IBGE, 2021).

Caxias do Sul has 510,906 inhabitants (IBGE, 2021). In the area of work and income, the average salary of employed workers is 3.2 minimum wage and, in 2017, the proportion of employed persons similar to the total population was 40.3%; in the area of education, the enrollment rate for 6 to 14-year-olds in 2010 is 96.3%; in the economic area, it has a GDP per capita in 2016 of R$ 44,007.35; the municipal human development index (IDHM) in 2010 was 0.782 (IBGE, 2021).

Mapping of projects in the cities of Porto Alegre and Caxias do Sul

In order to map the projects, a search was carried out on the universities' websites to seek understanding and adherence to this research purpose. Secondary data are available, such as newspapers, periodicals, and books. Table 1 brings the mapping of projects.

Table 1

Mapping of projects through the Triple Helix

Project	University	Enterprises	Government
CIPIG - DAI CNPQ – Smart cities: an integrated platform for managing Smart Cities	University of Caxias do Sul - UCS	Quadros & Zanchin Ltda	Caxias do Sul City Hall
Database Implementation, Information System project for Environmental Monitoring Programs - Taquari-Antas Hydroelectric Basin - SIA AMBIENTAL.		Energética Campos de Cima da Serra Ltda. (PCHs Passo do Meio e Pezzi), Linha Emília Energética S/A (PCH Linha Emília), Caçador Energética S/A (PCH Caçador), Cotiporã Energética S/A (PCH Cotiporã), CERAN: UHE Monte Claro, UHE 14 de Julho, UHE Castro Alves, Companhia Energética Rio das Antas, HIDROTÉRMICA S.A.: Vêneto Energética S.A (PCH Jararaca), Da Ilha Energética S.A. (PCH da Ilha), Boa Fé Energética S.A. (PCH Boa Fé), São Paulo Energética S.A. (PCH São Paulo), Autódromo Energética S.A. (PCH Autódromo), Criúva Energética S.A. (PCH Criúva), Serrana Energética S.A. (PCH Palanquinho), Hidrotérmica S.A., PCH Quebrada Funda, Cooperativa Regional de Desenvolvimento Teutônia - CERTEL, (PCH Salto Forqueta e CGH Boa Vista), CERTEL Rastro de Auto Geração de Energia SA (PCH Rastro de Auto) e Cooperativa Regional de Desenvolvimento Teutônia - CERTEL	118 municipalities covering the Taquari - Antas watershed
Digital Health Implement electronic medical records in POA. Advance in digital health management processes. Allow portability, integration and quick access to the histories of care and exams of each citizen.	c Federal University of Rio Grande do Sul – UFRGS University of Vale do Rio dos Sinos - UNISINOS	Grupo Hospitalar Conceição	Porto Alegre City Hall
CAP4CITY – PUC. Strengthening Governance Capacity for Smart and Sustainable Cities	Strengthening Governance Capacity for Smart and Sustainable Cities	Procempa is the Information and Communication Technology Company of Porto Alegre City Hall	Porto Alegre City Hall

Source: present study (2022)

Field research and data collection techniques

In order to assess the credibility of the data obtained through the interviews, it was essential to obtain validation of the semi-structured interview script by specialists in the researched area. Mishler (1990) recalls that validation is the social construction of knowledge, allows to measure the veracity, interpretation, and generalizations that can be applied by the researcher in the object of his research (Flick, 2015).

Non-participant observation was used, which according to Flick (2015), can be carried out during the interviews themselves, in scheduling meetings, in institutional visits, or at any other time when the researcher remains present in the environment to be researched. The interview is named according to the degree of effectiveness, and the immediacy and depth of the verbal narrative received (Rodrigo-Pedrosa & Fontanella, 2021). There was theoretical data saturation with twelve interviews (Pandit, 1996). The documentary research resulted in 83 digitized pages of documents and one hour and thirty minutes of videos collected from the project sites. The total number of recorded hours of the interviews was five hours and thirty-three minutes, with 45 transcribed pages and 13 observation pages.

The technique used was Bardin's (2016) content analysis. The analysis was carried out in three stages: pre-analysis of the collected material, exploration of the material or codification, and treatment of data through narratives, schemes, and figures. For applied ontology, the nature of reality is evident, characterizing the subjective and multiple realities the participants see and the practical implication and citations that participants provide from different perspectives (Merriam, 2009).

In this sense, the rigor of qualitative research was also established through the research protocol, observation protocol, cover letter, and consent term, which refers to the quality of Flick (2015) grounded in this study. Triangulation utilizes a data source, using different data sources (Creswell, 2014). The generic qualitative study can have other data sources besides the narrative, starting by accepting many different ways of understanding and making sense of the world (Rodrigo-Pedrosa & Fontanella, 2021; Flick, 2015; Merriam, 2009). After content analysis and coding, categories of analysis were defined a posteriori, based on the model by Rucinska and Knezova (2014), to assess institutional, technological, and human factors and the interaction between companies, government, and universities within the smart city model.

Results and discussion

Conceptual framework proposition

Rucinska and Knezova (2014) presented the framework (Figure 3), which contains the dimensions and their main elements, the relationship between them, and the main components

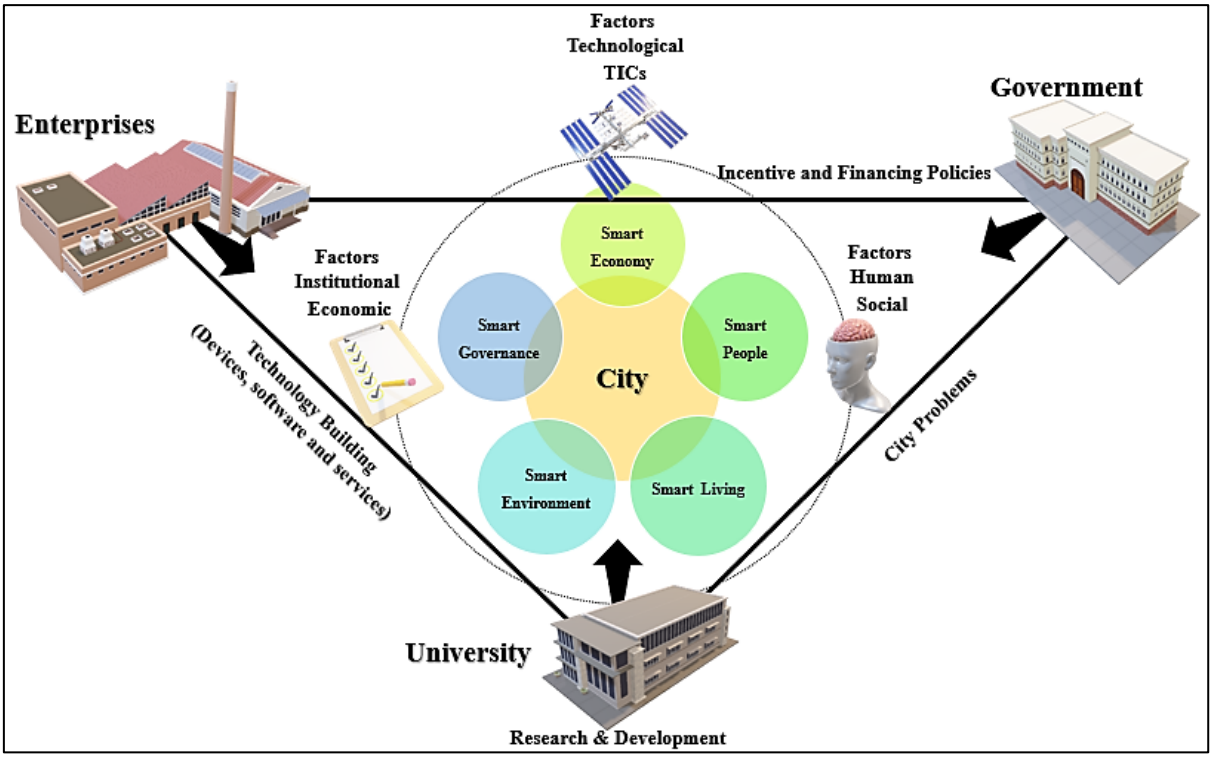
that can be respected in each dimension. The dimensions, as seen in Figure 3, are Companies, Government, and Universities, which according to Etzkowitz and Leydesdorff (2000) for the Triple Helix model considered the essence of an interconnection area between the three agents Government – University – Company in an evaluative perspective of values to solicit changes at relevant science-technology-industry interfaces.

At the ends of the circle of these elements, we present the factors in the form of categories with the addition of more terms such as technological and ICT factors, institutional and economic factors, and human and social factors. It is important to note that the dimensions at the center are presented in the study by Giffinger and Gudrun (2010): smart economy, smart governance, smart life, smart mobility, smart environment, and smart people.

Figure 3 presents our proposed framework based on Etzkowitz and Leydesdorff (2000), Giffinger and Gudrun (2010) and Rucinska and Knezova (2014), and other authors mentioned in this study.

Figure 3

Conceptual Framework proposed



Source: present study (2022).

The government of a city needs to indicate visions for the city and solve real problems, as well as develop public policies to encompass these visions, contemplating institutional and economic factors in the form of incentive laws, regulations, norms, and others, enthuse the way people acts in matters of territorial and organizational development. Innovation districts

are extraordinary in government affairs by opting for, accepting, designing, and practicing ICTs (Komninos et al., 2021). Thus, innovative districts need to be considered as key components of any municipal government project or program initiative to understand the values of a smart city.

The companies produce services and technologies for a smart city and emphasize the capitalization of knowledge for a smart economy, high-tech industry, and a business-friendly environment. A smart economy supported by smart governance involves research and development, technology transfer, and technological innovation as innovative companies. In addition to an orientation toward high technology and industrial innovation, Porto Alegre and Caxias do Sul promote government–university–business integration (Oliveira & Ranault, 2020; Etzkowitz & Zhou, 2017; Etzkowitz & Leydesdorff, 2000). The smart and sustainable business climate provides a more open focus by linking innovation-driven urban development rather than just focusing on the economy.

Universities have contributed to smart city projects through knowledge of making cities clean and green through trained human resources. One of the main concepts behind this desire is the smart environment (Giffinger & Gudrun, 2010; Macke et al., 2019). The environment is one of the main strategic elements of a smart city. In a world where resources are insufficient and where cities are increasingly resting their growth and fortune on natural tourism, cities need to support the safe and renewable use of their eco-heritage. A smart city must have a large-scale environmental monitoring system, considering, for example, internal and external monitoring of air quality and measurement and telemetry of noise and pollution, as presented in the SAI Ambiental and CIPIG project initiatives - DAI CNPQ – Cities smart: an integrated platform for managing Smart Cities.

In addition, some of the elements identified, such as technological factors and ICTs, can be estimated as central to a spirit of a smart city (Kourtit et al., 2013). In addition, broadband and wireless internet are key elements of the city's infrastructure, pointing to smart governance.

Human and social factors category

Regarding the motivation of employees, we sought to understand why the interviewees were acting as direct actors in the projects. According to Giffinger and Gudrun (2010), one of the dimensions referred to by the authors as 'smart people' is linked to human development capital (Rucinska & Knezova, 2014), which is an important precondition of the interaction of regional partners, learning process, ability to create knowledge and be a source of innovations (Giffinger & Kramar, 2021). In this category, two specific motivators were highlighted for human factors: the personal and the professional. The professional motivator is evident in the interviewees' speeches E2, E3, and E5, participants of the Digital Health project.

> Eu já tenho por perfil um trabalho inovador na minha área na oncologia por estar trabalhando com o cuidado centrado no paciente e já trabalho nisto já faz uns 12 anos que é interdisciplinaridade do atendimento médico multidisciplinar e se chama de medicina integrativa[...] (E2)
> [...] é mais a minha experiência na área e por que eu gosto de pesquisa e porque eu acredito muito neste projeto e por ser professora da UNISINOS e as reuniões acontecem lá acho que tem que ter pessoas da saúde envolvidas (E3).
> [...] eu atuo como pesquisador através em parceria com a FURG onde me reporto a coordenadora do projeto que tem mais experiencia. No caso fui convidado pela coordenadora sou o único colaborador externo fora da PUC a trabalhar no projeto (E5).

Corroborating E2, E3, and E5's statements, we have the issue of E11's motivation to work on the SIA project. Environmental:

> I like working in the environment because I think that all areas that care for the well-being of people and the planet are quite noble [...] I think that is what motivates me the most (E11).

As for the citizen, one can assess the importance of projects for people. Concerning the opportunities, it should be noted how relevant the projects for the Intelligent Life of a city and the potentially affected areas are, as demonstrated in the area of public health with a humane and fair service, referencing the quality of life (Boioni, 2021; Macke. et al., 2018; Weiss, Bernardes & Consoni, 2015). Agreeing with this statement, we have the speech of Interviewee E10, about Digital Health:

> [...] that his health information is with him is already a step taken and that the information is with the health agent and qualifies the patient's care, reduces procedures, repetition of exams, accelerates the diagnostic process, increases the patient safety, and increases health efficiency (E10).

In the speech of E10, it can also be noted that the qualification of patient care refers to ethical behavior and human rights (ABDI, 2018; Castells, 2011). The educational level talks about intellectual development (Macke et al., 2019), and their level of qualification and continuing education proves this statement (Giffinger & Gudrum, 2010), there is the speech of respondents E9, E5, and E7 about the project CAP4CITY – PUC:

> After implementing the project, it could be people's educational level (E9).
> [...] number of people impacted by the courses that will be measured from the accesses of those enrolled in the classes (E5).
> [...] social indicator may be in the future after implementing the MOOCS. How many MOOCS are reaching the population (E7).

Categoria fatores institucionais e econômicos

Institutional factors compose the effect of the convergence of influence of theoretical bodies originating especially from political science, sociology, and economics, which seek to group in their propositions the idea of institutions and patterns of behavior, norms, and values, of beliefs and of hypotheses, in which individuals, groups, and organizations are immersed

(Selznick, 1996).

As for the norms and management of these projects, there are some formally documented protocols, but no project management is applied as a standard methodology. Management takes place through meetings and project documents. Regarding meetings, corroborating this statement, there are the statements of respondents E2, E3, and E8:

> [...] there are weekly meetings where brainstorms are held to present what was done until November 2019 (E2).
> We have weekly meetings and documents shared on google drive, so we divide into teams by specialty and make spontaneous contributions (E3).
> All project management is done very simply with periodic meetings[...] (E8).

Project management documents are followed and standardized according to the specific application, which was addressed by respondents E5 and E7.

> There is a manual by Erasmus himself, a hybrid of PMI and adaptations of previous projects, so there is an instrument for sharing information about defined roles, defined actors, and a formal project practice[...] (E5).
> [...] in terms of management, I've been using it since March 2018, and until now, I've been organizing a series of documents, but it's based on deliverables and tasks, and it's done within an Excel spreadsheet which is a formal schedule and has In Word, the detailed project has an opening of all the tasks, who does what, how it is done, delivery dates, predecessor task, all this is in these spreadsheets and documents (E7).

Following the ABDI (2018), there are opportunities for government administrations to adopt different actions to encourage innovation, including research carried out at universities. Bilateral agreements with the public sector, fiscal incentives, opportunities for support and mentoring, and promotion of an entrepreneurial and innovative culture among government, business, and university actors can be worked out (Etzkowitz & Leydesdorff, 2000). Cooperation was mentioned by interviewee E1 from the SAI project. Environmental:

> [...] the relationship today is through a technical cooperation agreement that evolved with additive terms as we evolved with the system[...] (E1).

Collaboration is one of the key factors for the success of projects. Other partnerships models were highlighted, such as the cooperation of the municipal government, as elucidated by respondents E2 and E3:

> The project's closest partners are the employees and the city hall (E2).
> They are people from the city hall who work actively in the city hall's digitalization systems and manage health data[...] (E3).

Cooperation between companies and universities through applied research is demonstrated in the statements of respondents E4 and E5:

> [...] we met with some partners from the hydroelectric plants to discuss what is being done, what could be improved, and their demands (E4).
> The partners are the Universidad Nacional del Sur, the Brazilian Union of Education and Assistance, the Universidad Externado de Colombia, the Universidad Nacional de La Plata, etc. [...] We have a chatting point where we share information and documents are posted where everyone has access (E5).

Actions to encourage partnerships cited by Oliveira and Ranault (2020), Oliveira and Carvalho (2017), and Kourtit et al. (2013) to develop innovation ecosystems in a city through the cooperation of government and universities tend to be a door to success in smart city project initiatives, and the involvement of private organizations can complement this triple helix of innovation in cities.

Smart governance was evidenced in the previous speeches of E2 and E3, where it was identified that the governance models used in the initiatives in Porto Alegre and Caxias do Sul are intelligent, follow the same principles of governance in the area of e-government (electronic government), which are: open, sustainable, collaborative and participatory government (Tsoutsa et al., 2021; IBRACHICS, 2021; Rucinska & Knezova, 2014).

As for the smart economy of a city with the support of well-being and quality of life, and also distinguishing the city as an environment in which economic relations are expanded, with the production and movement of wealth, it must be understood that the city's economic consignment represents a paradigm shift (Giffinger & Kramar, 2021). In one of the interview reports, respondent E9 commented on who works with information and communication technology and what this relationship brings to the city.

> [...] Porto Alegre, in terms of technology, master's and doctoral students who work with information technology leave here already employed and start working before graduating and with good wages, so graduates who work with programming earn more than the CNPQ scholarship is 2200.00 reais the organizations here absorb this professional SAP has 1000 jobs here in the region and is going to open another 700, and this type of skilled labor is needed and the university influences this relationship to seek these projects with information and communication technology there is an exchange, and this increases the salary and economic power in the city[...] (E9)

Economic investments were also reported between governments and companies in the speeches of E5 and E12:

> The project revolves around 1 million euros distributed among these institutions [...] the major investments are in the construction of the course, because it will be developed in three languages: English, Spanish and Portuguese and in the necessary skills to develop a city smart and sustainable [...] and also from local development studios to transfer technology knowledge (E5).
> [...] the larger project of the knowledge-based development observatory that houses the Smart Cities project was funded by CNPQ from 2014 to 2018, and from 2018 we are looking for partnerships [...] we had research support number of DAI grants from CNPQ (E12).

Technological factors and ICT category

ICTs represent the central nervous system of an interconnected city, which allows the acquisition of data from different "sensor" sources (Hutchinson, 2021). The information collected by the devices can be correlated, analyzed, and then used to create plan and control processes, improving public managers' productivity and assertiveness in decision-making (ABDI, 2018; Castells, 2011).

In these technological factors, the intelligent environment was emphasized clearly and objectively, always seeking improvement for the citizen, one of the actors impacted by the projects. Examples in the environmental dimension serve as encouragement for other projects as a gain in the quality of life for the citizens. It is necessary to re-educate, abandon old customs and follow new ones concerning the citizen and his relationship with existence on the planet (Macke et al., 2019).

Interviewee E1 corroborates with the issue of doing something new for the environmental dimension and making a relevant contribution to the application of the SAI project. Environmental: "The project permanently challenges me in the sense of developing new applications, new functionalities, as I told you, it started with a need for a database [...]" E1. Furthermore, it is important to be competent to act in search of options for their environmental problems to improve their quality of life in the city. The issue of environmental education was evidenced in the speech of E12: "If we can integrate these data and environmental practices, we will be able to work on the issue of recycling culture and environmental education".

As seen previously, smart cities and ICTs can enhance interactions between city elements and design new interventions by interpreting, structuring, and classifying large amounts of urban data that city citizens and their database. Weiss et al. (2015) point out that ICT is an area that employs technological instruments intending to promote communication and the acquisition of something trivial to real and safe information for the technology used. To corroborate this statement, the statement from E11: "[...] The system is a research tool that allows the development of technical-scientific work, as it contains historical data on the monitored variables, establishing correlations between them, scenario generation, land, and water use planning, among others".

The information was treated as educational in the context of training better city managers, as well as their citizens, which is clear in E5's speech:

> [...] let us take our best case, which is the city of Curitiba in Paraná, which is an urban mobility system with minimal ICT that is, in fact, smart, but it is limited and does not work on other dimensions; it does not work on citizen participation. Citizens, the use of renewable energies. So the real impact of our project is on the training and development of public managers to develop smart and sustainable city projects in real practice (E5).

> The data must be simple in observations about the state of the information phenomenon, easily structured, easily obtained by machines or devices, frequently quantified and evaluated, easily transmitted, and must be correctly translated. To corroborate this statement, we have the speech of E6: "[...] these data have to be treated, and decisions of situations have to be investigated, there has to be a person monitoring [...].

The projects analyzed in this study have R&D in their development, being carried out in partnership with universities, private organizations, and the government offers goals and attributes of formal and informal management since, in most cases, they are managed by the researchers. The projects presented in this study have this characteristic. Researchers are responsible both for the research itself and for all research processes. However, with high knowledge in management and knowledge characteristic of their areas of research. To corroborate, we have the speeches of E12 and E1:

> So this research will happen as an action research project, at least that is what we are designing today […] we designed this project as an action research project because there will be an application, an intervention. It will have time to observe the results more globally, in terms of research and development that will entail the tool itself, an artifact that will follow the development path that the software industry suggests (E12).

> As soon as R&D was established through the university-company relationship and because it became an information management tool, it ended up also becoming a service and that, over time and continues to allow the development of new applications and new tools[...] (E1)

R&D involves training human capital in generating new knowledge and developing new technologies (Giffinger & Gudrun, 2010), as well as infrastructure for the city. Another clear issue affecting the technological and economic factors evident is the opening of startups to generate new business. As stated by interviewee E12:

> [...] a colleague from Spain at the congress in Florianópolis, where we presented the project, asked us why the project could not become a startup so that this could be replicated in the form of a business to generate more business.

Final remarks

This study provides an integration model between the Triple Helix applied across smart city design initiatives. It is useful for policymakers, municipal managers, and other stakeholders, as it offers a guide that can assist in tactics and design of actions related to structuring the concepts in smart cities. This guide was summarized in the framework based on the factors studied by Rucinska and Knezova (2014), Etzkowitz and Leydesdorff (2000),

and the smart elements for a city cited by Giffinger and Gudrun (2010).

Concerning multiple pieces of evidence, it is plausible to infer the complexity of structuring a smart city, which begins with the process of meditation on the aptitude of the city, arising from the knowledge of the problems and the definition of the priority needs, that is, a vision situated in real problems.

In the case of the proposed framework, we included elements presented in Figure 3 that, during the analysis of the narratives, came to stand out, such as the social, economic, and ICTs. In this sense, we can say that we complement the factors mentioned by Rucinska and Knezova (2014), and we present how the relations between the university that develops research and development, the government that brings the real demand of the city's problems and has to develop fiscal and financing channels for universities and companies, through the production of technologies and services provided to the city.

Practical and theoretical contributions to the cities

In the proposed model, the concept of smart cities and Triple Helix of innovation are central because, according to the combination of smart governance and smart people, these two assumptions develop, apply knowledge through universities and companies and receive resources, and can feed back the innovation ecosystem, contributing to the social, economic and sustainable well-being of the entire community.

Local governments are responsible for the governance of the ecosystem that contains the survey of ecosystem needs, innovation design (involving government and companies), the materialization of information, maintenance of a database focused on real problems, preparation and measurement of indicators, and provides guidelines for companies and entrepreneurs. The four projects analyzed in the cities of Caxias do Sul and Porto Alegre work with the application of ICTs at their base. The consolidated database in the case of SIA Ambiental, where 21 companies in 118 municipalities contribute to the project in partnership with the University of Caxias do Sul. The other three projects are in the execution phase and have a high application potential for both cities.

The practical development of research at universities makes up the R&D element of the proposal, as they gather information about the knowledge required for the idealization of innovation and develop research and technological projects, in addition to training the workforce to work in the ecosystem. In addition, it maintains a database of knowledge and information on skilled labor available to work on ongoing or planned projects and actions.

Regarding the theoretical contribution, the framework includes important elements, such as information and communication technology, economics that addresses sustainable investments and business, and the social environment where everyone is inserted in this living ecosystem of smart cities. It should be noted, in this sense, the probability of replicating this

model, with due openness to the range of characteristics, in any city. It is understood that the framework model is integrative and simulates a possible by-product of this academic contribution in increments, but whose minimum prerequisites for its constitution are found in this research.

The connection of multiple actors to increase skills in favor of the genesis of solutions and acceptance of particular collective interests composes a dynamic method in which those involved engage in negotiations, experiences, competition, and practice. The generation of solutions in an intelligent innovation district is an artifice through which existing institutions are altered and adjusted to the ecosystems of the cities of Caxias do Sul and Porto Alegre through developed capacities and cooperation, operating in open systems that excite and are enthusiastic about the actors who bring about innovation changes in a city.

Research limitations and future studies

Theoretical limitations can be pointed out since the references to the topics, and researched approaches were not exhausted. Despite having read articles, dissertations, and theses, there is no way to guarantee that the perspectives of theoretical understanding on the subject have been exhausted. Considering only the non-academic means, there is a faithful dissemination of information about actions and undertakings relevant to the various subsystems of cities, so it becomes impractical to provide a final vision on the subject of smart cities, the Triple Helix of innovation.

The methodology is also limited, as only project managers and collaborators were interviewed. So, if we had interviewed other people who work with the collaborating companies and managers of the cities where the research was applied, we would have other perspectives and knowledge about integrating the Triple Helix of innovation and smart cities.

Regarding future research, new studies, multidisciplinary or specific, can be carried out on the issues and dimensions presented in Figure 3. These studies need to contain several areas of scientific knowledge, such as themes related to Brazilian laws, bilateral agreements, and new business models, for the design of new digital management practices, themes related to engineering to improve or adapt technological solutions in order to subjugate digital technical provocations, and themes related to teaching, mainly regarding the training of public servants and the smart citizen, in addition to studies to promote the green and environmental economy.

Can we add studies on smart cities and collaborative networks carried out in Brazil (Przeybilovicz & Pereira, 2022; Castells, 2011); smart cities and social capital (Sarate, Macke & Pecqueur, 2020), as well as smart cities and value creation for stakeholders (Beck & Ferasso, 2023; Axelsson & Granath, 2018).

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