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Comparative Analysis of Brazilian Smart Cities[ξ]

Análise Comparativa das Cidades Inteligentes Brasileiras

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Resumen

El objetivo general de este artículo fue identificar las configuraciones de las ciudades brasileras seleccionadas que las llevaron a ser consideradas inteligentes y, más específicamente, analizar el papel de la gobernanza pública en el desarrollo de las ciudades inteligentes en Brasil. A través del análisis cualitativo comparativo (QCA), se aplicaron cinco categorías de políticas en las ciudades inteligentes brasileñas: políticas sociales, políticas educativas, políticas de ciencia y tecnología, políticas de planificación urbana y políticas de salud. Los resultados muestran que las inversiones en ciencia y tecnología tuvieron una buena participación en el desarrollo de las ciudades inteligentes brasileras, y que las políticas educativas resultaron ser significativas en comparación con las demás políticas analizadas. Además, la aplicación conjunta de políticas públicas para el desarrollo de tecnologías inteligentes demostró ser eficaz, destacando su papel en el desarrollo y ayudando a reducir las desigualdades económicas en el país.

Palabras clave: Ciudades Inteligentes; Políticas Públicas; Desarrollo Regional; Gestión Municipal; Análisis Cualitativo Comparativo

Resumo

O objetivo geral deste artigo foi identificar as configurações de cidades brasileiras selecionadas que as levaram a serem consideradas inteligentes e, mais especificamente, analisar o papel da governança pública no desenvolvimento de cidades inteligentes no Brasil. Por meio de análise qualitativa comparativa (QCA), cinco categorias de políticas foram aplicadas nas cidades inteligentes brasileiras: políticas sociais, políticas educacionais, políticas de ciência e tecnologia, políticas de planejamento urbano e políticas de saúde. Os resultados mostram que os investimentos em ciência e tecnologia alcançaram boa participação no desenvolvimento das cidades inteligentes brasileiras, e as

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políticas educacionais mostraram-se significativas em comparação com as demais políticas analisadas. Além disso, a aplicação conjunta de políticas públicas para o desenvolvimento de tecnologias inteligentes mostrou-se eficaz, destacando o seu papel no desenvolvimento e ajudando na redução das desigualdades económicas no país.

Palavras-chave: Cidades Inteligentes; Políticas públicas; Desenvolvimento Regional; Gestão Municipal; Análise Qualitativa Comparativa.

Abstract

The general objective of this paper was to identify the configurations of selected Brazilian cities that led them to be considered smart and, more specifically, to analyze the role of public governance in the development of smart cities in Brazil. Through comparative qualitative analysis (QCA), five categories of policies were applied in Brazilian smart cities: social policies, educational policies, science and technology policies, urban planning policies and health policies. The results show that investments in science and technology achieved good participation in developing Brazilian smart cities, and educational policies proved to be significant compared to the other policies analyzed. Furthermore, jointly applying public policies for the development of smart was found to be effective, detaching their role in the development and helping in reducing economic inequalities in the country.

Keywords: Smart Cities; Public Policy; Regional Development; City Management; Comparative Qualitative Analysis.

JEL code: C38, O10, R10.

1. Introduction

Throughout the 21st century, there have been many transformations in the social, economic and technological spheres, while large cities have grown exponentially. With the growth and development of cities, including large metropolises, several problems have arisen in the urban context related to urban mobility, sustainability and inclusive growth. Much of the literature on the subject claims that urban density has created its own alternative residential arrangements. Furthermore, when one understands the positive and negative effects of the transformation of urban areas, it is possible to understand the dynamics of cities and their development trajectories, even with the proliferation of suburbs and peripheral areas (Glaeser et al., 2000).

However, when analyzing the role of urban spaces in developing countries, it is observed that most cities have an urban structure linked to the issue of innovation. In Brazil, for example, the use of smart technologies in large cities, such as São Paulo and Curitiba, is part of everyday urban life. In this context, the concept of a smart city emerges, which goes back to the reference of a city that overcomes the challenges of the past and moves toward the future. With technologies capable of delivering urban services as efficiently as possible, the city is able to achieve a positive transformation in the urban population's quality of life (Cunha et al., 2016).

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The concept of smart cities has several approaches. For Alves et al., (2019), there are three approaches: the first is technocentric, consisting of an emphasis on ICT hardware, use and infrastructure. The second consists of people, with an emphasis on social innovation and human capital. The third approach is integrated; that is, the integration of the two previous points is promoted at the strategic level of cities.

Furthermore, Brazil is selected because its cities are recognized as pioneers in the implementation of projects associated with the concept of smart cities, despite the organizational and social problems arising from the rapid and intense urbanization of Brazilian cities (Weiss et al., 2015). Thus, the justification for carrying out this article is to complement the existing literature with applied research on cities with distinct economic configurations in different regions of Brazil.

Thus, the objective of this study is to identify the configurations of the selected Brazilian cities for which they are considered smart cities. Specifically, the article seeks to i) analyze the influence and factors relevant to the development of smart cities in Brazil through a theoretical and empirical review; ii) evaluate the selected cities within the scope of the characteristics of cities; and iii) identify and define public policies to enhance smart cities. The hypothesis is that smart cities represent a configuration based on more integrated cities, with government policy investments in strategic and sustainable areas (Cortese et al., (2019), Trindade et al. (2017) and Basiri et al. (2017)).

Furthermore, future trends aim to create more livable cities by reducing the number of cars on the streets and developing public spaces for children, adults, and the elderly. It is important to note that smart cities should not be equated with sustainable cities. Achieving sustainability in smart cities involves a comprehensive and multidisciplinary approach to urbanization. In other words, the development of sustainable and smart cities requires integration across various fields of study. This includes strengthening the Information and Communication Technology (ICT) sector, enhancing the quality of natural resources, and improving urban ecosystems and sustainable development practices to ensure a higher quality of life for residents (Abdala et al., 2014; Botton et al., 2021; Carli & Ribas, 2021; Santos et al., 2022). In this way, the database will include a set of policy analyses (budgetary actions and programs) from the Transparency Portal (CGU)[1]. Furthermore, the ranking of Brazilian smart cities was supported by the connectedness smart city ranking prepared by Urban Systems.

The article is organized into five sections, including the introduction. The second section will address the theoretical and empirical framework. The third section will present the methodological approach and database. The fourth section will present the results. Finally, in the fifth section, the conclusions are discussed. The research intends to contribute to the literature on the construction of a public policy agenda with the objective of assisting in the identification of configurations that enhance the creation and maintenance of smart cities.

2- The smart city: theoretical and empirical review

[1] For more informations about the database, access at: https://portaldatransparencia.gov.br/

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Regarding the dimension of urban spaces, Henderson (1974) stated that the sizes of cities vary due to the efficiency offered by the city's organization, the provision of public goods and differentiated access to exports and input markets. Even without differences in the mentioned factors, the size of cities would still be different. In this way, preliminary studies by Henderson (1974) helped in the definition and analysis of small, medium and large cities, as well as in the explanations of why there are cities that have greater prominence and development.

Additionally, large cities tend to grow at approximately the same rate as small towns, and large local governments that have income redistribution policies that benefit the neediest tend to reduce local growth. Glaeser (2000) shows that these points are useful, but they do not fully answer the questions inherent to the theory of economic growth. Studies presented in the most recent literature on the role of urban spaces relate to the literature widely used in urban economics. Glaeser et al., (1992) state that the most recent theories of economic growth, such as those of Romer (1986) and Jacobs (1969), emphasized the role of technological spillovers in generating growth. Indeed, knowledge spillovers are particularly effective in cities, as communication between individuals is more robust. The authors conclude that local competition and urban variety encourage employment growth in industries. Thus, the literature suggests that important knowledge spillovers occur between firms, which shows a relationship with technology located in some urban centers.

Studies on the concept of the smart city model began in the 1990s. For Rizzon et al., (2017), the focus on the meaning of this model was the search for the fundamentals regarding the application, use and development of information and communication technologies (ICTs). Over time, the strong relationship between smart cities and technology was evident; thus far, several studies have emerged with the objective of developing the concept of the model.

The denomination of smart cities comes from several definitions, such as intelligent cities (Komninos, 2009), knowledge cities (Yigitcanlar et al., 2008) and u-cities (Shin, 2009). These different terminologies have points in common, despite having individual elements and different scopes and contexts. However, the aforementioned definitions focus on the use of technology in urban areas.

In more recent studies, especially those of the current decade, such as Alves et al., (2019), there is no clear definition of the concept. The study reveals that there are three approaches in the literature: the first is technocentric, which emphasizes the importance of using ICT hardware and infrastructure; the second focuses on people, emphasizing social innovation and human capital; and the third approach focuses on the integration of the two previous points, which is the most integrated and strategic method at the city level.

In this sense, Cunha et al., (2016) associate the concept of smart cities with the opportunities provided by the digital revolution. Such opportunities are related to the growing diffusion and computing capacity of new technologies, social innovation and the integration of mechanisms and actions for planning and managing urban spaces. The authors emphasize the double challenge that cities have in the social dimension, mainly in the aspect of absorbing citizens from different origins, as well as taking advantage of

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the diversity provided with the objective of promoting culture and innovation. Regarding the concept, Song et al., (2017) argue that a smart city is characterized by the strategic, systematic and coordinated implementation of the most modern ICT applications in various urban sectors. In this way, smart cities aim to comprehensively meet the needs of individuals with regard to economic and social sustainability, happiness and well-being.

In the sense of sustainability, the study of smart cities is directly related. Basiri et al., (2017) emphasize in their study the importance of the sustainable urban planning development approach and its role in urban management. In this case, according to the diffusion of technology in the urban environment, there is a kind of pressure for sustainable development in cities. Therefore, the smart city concept itself has great potential for addressing aspects of sustainability, such as promoting citizen participation, developing innovative, intelligent and sustainable solutions, and increasing the efficiency of urban systems by adopting measures of transparent and inclusive governance.

Thus, a city considered smart has the potential to maximize smart and sustainable solutions in an increasingly urbanized environment. Furthermore, in creative cities, a creative environment is developed, with green areas, cultural enjoyment and respect for cultural, social and economic differences (Messias et al., 2020). Therefore, creativity is the main variable of human capital with regard to creative cities, and this variable plays a very innovative role in smart cities to promote a better quality of life for their citizens through technology.

The study by Gascó-Hernandez (2018) demonstrated the issue of innovative planning for the city of Barcelona, Spain, and its evolution toward become a smart city. The study emphasized the importance of partnering with citizens when designing, implementing and evaluating potential smart city-related projects. In parallel, Rana et al., (2018) examined the obstacles that affect the development of smart cities in Indian cities. Their research concluded that governance is the most significant barrier and recommended that policy-makers promote e-governance services to improve accountability of the decision-making process in the development of smart cities.

The work of Barrionuevo et al., (2012) used examples of smart technologies in the most diverse cities of the world. The Singapore experience revealed that bureaucracies in smart cities should be reduced as most procedures can be performed automatically. It is noteworthy that since the 1980s, Singapore has supported numerous initiatives to facilitate communication and collaboration between government, civic and business institutions. The city's e-government system is among the most advanced in the world, and city residents have access to more than 1,600 online services via mobile devices.

In the context of smart cities in developing countries, particularly in Latin America, Corrales et al. (2019), Arce et al. (2020), and Trindade et al. (2017) highlight Medellín, Colombia, as an innovative city with notable characteristics. These include environment and land use, culture and quality of life, economic and investment conditions, progress and potential, centers of power, education and human capital, technology and research, and mobility and infrastructure. These factors contribute to its recognition as a smart city.

Medellín's transformation is particularly remarkable given its history of peak urban violence, primarily due to drug trafficking. The city began its turnaround when educators

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arrived with the goal of promoting technological, pedagogical, and cultural projects that fostered an entrepreneurial spirit. Additionally, social transformation was spurred by government programs focused on education, entrepreneurship, and innovation. These programs supported the enhancement of public schools and the development of educational institutions, libraries, museums, parks, and transportation infrastructure in areas previously considered highly dangerous (Trindade et al., 2017).

Studies on smart cities in Brazil have become an interesting context to be analyzed due to their social, urban and security problems. In the country, discussions are taking place on how smart city modeling can be beneficial in various urban sectors, both for the population residing in the cities and for their public managers. Viale Pereira et al., (2017) analyzed Rio de Janeiro in the context of municipal management; however, Porto Alegre with the Integrated Command Center (CEIC) and Belo Horizonte with the Operations Center (COP-BH) were added as a case study. These cities have been recognized as smart cities and represent the three most relevant municipal operation centers in the country. The authors state that the cities vary greatly in terms of population, demography, economy and location, which allows an interesting comparative analysis of these characteristics.

Regarding the role of small and medium-sized enterprises (SMEs) in the development of smart cities in Brazil, Carli and Ribas (2021) emphasize that these companies contribute significantly to economic and social development, particularly when supported by reduced tax burdens. SMEs are crucial for the success of smart cities. Specifically, urban policies and strategies that involve three key components—companies, universities, and the city itself—lead to an evaluation of the social, cultural, and urban impacts of the adopted planning processes. The synergy among these components fosters the development of an innovative smart city, driven by both technological advancements and urban resilience (Santos & Souza, 2020; Duarte, 2005).

In an analysis of the southern region of Brazil, Macke et al., (2018) stated that the city of Curitiba is considered one of the ten smartest cities in the world in terms of transport models, urbanization and respect for the environment. The city has introduced an intelligent and integrated transport system to improve urban mobility. The main city centers have high-capacity, high-speed and high-frequency bus services, known as “Ligeirinhos” and “Expresso Ligeirão”, complemented by other conventional lines. The city also has 120 kilometers of bicycle paths.

The reflections raised in this section help in the development of smart cities, especially in models of cities in peripheral countries such as Brazil (Storper & Venables (2005), Glaeser (2000); Duranton & Puga (2001)). Studies on innovation in cities are largely beneficial for improving the quality of life and urban infrastructure and become a driving force of the role of public policies in promoting innovation processes at regional and local scales, as shown by Crocco & Diniz (2006). In this way, the literature addressed in this work generates significant insights for the formulation of models of cities based on smart cities, especially for application in Brazilian cities.

Many of the examples listed in this work present smart city models that have been applied in developed countries whose economic disparities are not as alarming as they are in the Brazilian case, requiring a project that makes sense with the economic reality of Brazilian municipalities. However, using these models of smart cities as examples is an interesting point to think about their implementation in Brazilian cities. This is because

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the use of technological modeling in the urban environment could be a tool in the search for more integrated Brazilian cities, as well as transforming Brazilian municipalities into places of greater accessibility and with greater equality of opportunities.

3- Methodological approach and database

The objective of this section is to present the methodological procedures and the database used for the methodological application. Next, the budget actions and programs selected as variables (conditions) for the QCA methodology will be briefly described.

3.1- Methodology

The methodology that will be used in the research is Comparative Qualitative Analysis (QCA), which represents a methodological tool directly associated with the Theory of Sets. QCA was initially discussed by Ragin (1987), an American social scientist who represents an analytical approach to multivariate data (Betarelli Junior & Ferreira, 2018). Methods based on QCA lie between quantitative and qualitative research, as they balance the breadth of analysis derived from quantitative data with the depth of knowledge of case studies provided by qualitative analysis (Hudson & Kuehner, 2013).

In summary, the great advantage of the fuzzy set would be to scale different association scores = and, thus, allow partial or complete associations. Thus, the fuzzy sets encompass qualitative and quantitative analysis (Dias, 2011). Furthermore, from the application of Boolean algebra, fsQCA identifies which combinations of attributes are relevant for the possible conditions and discriminates the cases of the analysis set (Gonçalves Montenegro et al,. 2021). Within the scope of this research, there will be a breakdown of cases of sets of cities considered smart in view of the analysis variables for classification as such.

Thus, there are two calibration methods: direct and indirect. Both forms allow accurate calibration of association scores based on qualitative anchors (direct method) or qualitative groupings (indirect method). Additionally, with the fsQCA, it is possible to assess whether there is a certain degree of consistency in the relation of the determined subset of the analysis using Equation (1)

$$\text{Consistency} \qquad (X_i \leq Y_i) = \frac{\sum \min (X_i,\ Y_i)}{\sum (X_i)} \qquad (1)$$

where is the degree of association in the set X; Y_i is the degree of association in the set Y; and ($X_i \leq Y_i$) is the ratio of the analysis subset - min orders the selection of the two lowest scores.

Briefly, consistency shows the degree to which the relationship between causal conditions is close to the result sought. In addition, the concept of coverage is distinct from consistency. This is because coverage calculates the extent to which the causal combination is responsible for the occurrences of the outcome and measures how much the outcome is explained by the causal condition.

The coverage calculation can be applied to the analysis of the necessary conditions. For this, the measure of the importance of X_i as a necessary condition of Y_i is given by

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the degree of coverage of X_i by Y_i, as seen in Equation 2:

$$\text{Coverage } (X_i \geq Y_i) = \frac{\sum \min (X_i, Y_i)}{\sum (X_i)} \quad (2)$$

The interpretation for coverage analysis can be explained when the coverage of X by Y is low, meaning the effect of X on Y is negligible. This result means that low coverage has an irrelevant effect or that the condition is not needed. It is also observed that the calculation of consistency for the sufficiency relationship (Equation 1) is similar to the calculation for coverage, which is relevant for a necessary relationship (Equation 2).

QCA also has its own terminology, with differences from traditional statistical techniques (Schneider & Wagemann, 2012). Explanatory variables are referred to in QCA as conditions, the dependent variable is called outcome, observations are defined as cases, and equations are labeled solutions. The combination of individual sets or causal conditions is listed as a specific configuration. Finally, in a solution formula, the result and the causally relevant conditions are demonstrated by letters related to Boolean operations (Betarelli Junior & Ferreira, 2018). The table below presents the main differences between the QCA and quantitative techniques.

3.2 - Database

The data will be extracted from the 2020 Transparency Portal, belonging to the Comptroller General of the Union (CGU). Considered an important instrument of social control, the data published on the Portal are from different sources of information, such as the Integrated System of Financial Administration of the Federal Government (SIAFI) and the Integrated System of Human Resources Administration (SIAPE).

The analysis aims to observe the action of public power on the development of cities, which is also useful for the effects of policies based on budget programs. The programs are divided into three types: thematic, management, maintenance and State services, and special ones. Thematic programs are those that portray the broader objectives of public policies. Management programs represent the expenses necessary for the functioning of the State. Finally, special operation programs depict Brazilian debt expenditures (Portal of Transparency, 2021). In this context, to achieve the objectives of the programs, the budget defines the budgetary actions (policies). The policies represent a detailing of the programs, and through the actions, the government executes the programs and advances in the objectives for each of the areas (Portal of Transparency, 2021). Thus, the use of the actions and budget programs selected for the article will help in the composition of the conditions that promote smart cities in Brazil, as shown in Table 1.

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Table 1- Description of Policies (Budgetary Action and Budget Program)

Policy	Goal
Social inclusion through Bolsa Família and the articulation of Public Policies (Budget Program)	The objective of the program is to alleviate poverty by guaranteeing income and promoting access to education, health and social assistance services.
Science, Technology and Innovation (Budget Program)	The program's strategic guideline is the promotion of science, technology, innovation and stimulus to productive development, with the amplification of competitiveness, productivity and sustainability of the economy.
Fund for Maintenance and Development of Basic Education and Valuing Education Professionals - FUNDEB (Budgetary Action)	It covers all basic education, from kindergarten to high school. Substitute for the Fund for Maintenance and Development of Elementary Education and for the Valorisation of Teaching (FUNDEF), which was in force from 1997 to 2006, FUNDEB has been in force since January 2007 and will extend until 2020.
Urban Planning (Budget Program)	The strategic guideline is based on the promotion of integrated and sustainable urban development, with the aim of improving housing, sanitation, accessibility, urban mobility and traffic conditions, with a focus on environmental quality.
Implementation of health care policies (Budget Action)	The purpose of the action is to monitor the National Registry of Health Establishments – CNES – of health units, services and teams; the transfer of cost and capital incentives for these services to the structuring of the units.

Source: Own elaboration based on the Transparency Portal and website of the Ministry of Citizenship.

The choice of policies is linked to the analysis of Brazilian smart cities in the social, science and technology development, educational, urban planning and public health spheres. This is because, starting from the concept of a smart city, it must translate urban planning efforts that promote the participation of citizens and local institutions to stimulate sustainable economic development, reinforce social cohesion and guarantee the education of the population. Thus, public participation leads to better planning and development of public policies (Guimarães & Xavier, 2016).

In this way, the role of public authorities in the construction of Brazilian cities becomes a key factor. Certainly, investments in the social, educational and health guarantee spheres promote more participatory individuals and, consequently, stimulate the development of cities. Furthermore, in the field of technological development, policies related to science and technology promote a stimulus to productive progress, which, together with urban planning policies, evaluate Brazilian cities in the context of urban development, according to their regional particularities.

Public investment by the federal government plays a crucial role in the development of smart cities in Brazil. However, some policies fail to achieve their goals because they do not account for the specific characteristics of the locations they aim to develop. Factors contributing to these shortcomings include information asymmetry, induction rules, and program operating rules within a federal context (Oliveira & Grin, 2023). Grin and Abrucio (2021) argue that efforts to advance smart cities and digital inclusion do not

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always yield satisfactory results. The challenge lies in effectively leveraging digital technologies to drive social and economic growth. The core of digital inclusion programs is addressing these challenges and ensuring that individuals can effectively use digital tools. Additionally, both the industrial and service sectors must adapt to this evolving market by integrating skilled labor, especially individuals with the knowledge and capabilities needed to thrive in the digital economy.

Additionally, the indicator that is composed of the Connected Smart Cities ranking will be used, which consists of the understanding and definition of variables that point to the development of Brazilian cities for their intelligent, sustainable and human development (Urban Systems, 2021). The ranking is composed of 11 thematic axes and 70 indicators that connect to each other. The thematic axes represent the following areas: mobility, urbanism, environment, energy, technology and innovation, economy, education, health, security, entrepreneurship and governance. The cities selected will be those that obtained the top fifty positions in the Connected Smart Cities ranking for the year 2020, as shown in Table 2.

Table 2 –Brazilian Smart Cities Ranking – 2020

Ranking	Cities	State
1º	São Paulo	SP
2º	Florianópolis	SC
3º	Curitiba	PR
4º	Campinas	SP
5º	Vitória	ES
6º	São Caetano do Sul	SP
7º	Santos	SP
8º	Brasília	DF
9º	Porto Alegre	RS
10º	Belo Horizonte	MG
11º	Niterói	RJ
12º	Rio de Janeiro	RJ
13º	Barueri	SP
14º	Campo Grande	MS
15º	Recife	PE
16º	Balneário Camboriú	SC
17º	Jaguariúna	SP
18º	Itajaí	SC
19º	Blumenau	SC
20º	São José dos Campos	SP
21º	Vinhedo	SP
22º	Jundiaí	SP
23º	Joinville	SC
24º	Maringá	PR

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25º	Londrina	PR
26º	Praia Grande	SP
27º	Salvador	BA
28º	São Bernardo do Campo	SP
29º	Fortaleza	CE
30º	Sorocaba	SP
31º	Ribeirão Preto	SP
32º	Palmas	TO
33º	Santo André	SP
34º	Viçosa	MG
35º	Juiz de Fora	MG
36º	Goiânia	GO
37º	Paulínia	SP
38º	Teresina	PI
39º	Santana de Parnaíba	SP
40º	Limeira	SP
41º	São José do Rio Preto	SP
42º	Santa Maria	RS
43º	Indaiatuba	SP
44º	Piracicaba	SP
45º	Nova Lima	MG
46º	Linhares	ES
47º	Americana	SP
48º	Presidente Prudente	SP
49º	Pato Branco	PR
50º	Resende	RJ

Source: Own elaboration based on Urban Systems (2020).

Therefore, due to its specific and comparative nature, the QCA methodology is suitable for characterizing the link, if any, between the Connected Smart Cities Ranking, which represents the development of Brazilian smart cities (cases), and the solutions, which are the policies (budgetary actions and programs). In this research, the use of the QCA is appropriate because it addresses a small number of cases (50 Brazilian cities)[2]. The use of the QCA makes it possible to define which are the interactions of the conditions that influence the result of the development of Brazilian smart cities in each city; in other words, it allows us to identify which are the policies that present high and low scores for the development of the cities in the sample.

Thus, as pointed out by Rizzon et al. (2017), the implementation of technologies is

[2] When analyzing a small number of cases using Qualitative Comparative Analysis (QCA), we typically employ strategies common in qualitative research. For example, with a dataset of 50 cities, we use analytical techniques that are straightforward to implement with a smaller number of cases. However, these strategies become less practical with larger populations due to increased analytical complexity.

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insufficient for a city to become a smart city. This is because the adoption of smart city initiatives is to meet the demands of the population at the local level. Empirical literature on smart cities from the perspectives of governance and innovation learning reveals several key insights. Lazzaretti et al. (2019) argue that smart cities integrate aspects of Information and Communication Technology (ICT) with improvements in people's quality of life. This integration connects and empowers individuals, fostering ongoing interactions within cities and enhancing public governance. Similarly, Rampazzo et al. (2019) emphasize that technologies associated with the ICT sector must address contemporary urban challenges related to social needs and demands. Only by aligning technological advancements with these social challenges can cities truly become "smart." However, the progress of governance and technological innovations often lags in supporting organizational and administrative processes and improving citizens' lives. The goal is to overcome existing challenges and enhance living conditions for residents (Machado, 2023; Fariniuk, 2020).

Smart technologies have become tools for solving urban developments, such as the increase in population density, public safety problems, the need for the management and planning of urban spaces, and access to health care and universal education (Rodrigues & Franco, 2020). However, in the Brazilian case, there is a need to assess the role of the State in the relevance of these smart technologies in the construction of more innovative and integrated cities. In this way, the evaluation of the policies contained in this work seeks to analyze the role of public governance in the evolution of Brazilian smart cities.

4- Results

In this section, the results of the application of the comparative qualitative analysis (fsQCA) methodology will be presented. The purpose of the methodology will be to analyze and explore the characteristics of the 50 cities that make up the sample of the Connected Smart Cities ranking, within the scope of social, educational, technological, health and urban planning policies. It will be possible to evaluate the differences between the application of policies in the analyzed cities, as well as analyze the conditions that influenced the development of Brazilian smart cities, according to their economic and regional characteristics.

4.1- Specific settings for cities in 2020

Table 3 presents the configurations that enabled public investment in the development of smart cities in the Brazilian cities in the ranking. Analyzing and interpreting the settings is useful for understanding the intensity of the conditions presented. Capital letters represent high-intensity (magnitude) conditions, while lowercase letters represent low intensity. From the analysis of Table 3, in 2020, only the cities of Barueri and Palmas, located in different Brazilian regions, southeast and north, respectively, obtained a combination of causal conditions with above-average scores (SCEPH).

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Table 3 - Result of specific configuration sets

Configurations	Number of cases
SCEPH	(2) Barueri (SP), Palmas (TO)
SCEPh	(3) Vitória (ES), Viçosa (MG), Santa Maria (RS)
SCEph	(1) Belo Horizonte (MG)
SCePH	(1) Limeira (SP), Resende (RJ)
SCePh	(1) São Bernardo do Campo (SP)
SCepH	(2) Campinas (SP), Rio de Janeiro (RJ)
SCeph	(1) Piracicaba (SP)
ScEPH	(2) Recife (PE), Teresina (PI)
ScEPh	(2) Campo Grande (MS), Pato Branco (RS)
ScEpH	(1) Linhares (ES)
ScEph	(2) Fortaleza (CE), Juiz de Fora (MG)
ScePH	(1) Niterói (RJ)
ScePh	(2) São José dos Campos (SP), São José do Rio Preto (SP)
ScepH	(2) Sorocaba (SP), Presidente Prudente (SP)
Sceph	(1) São Paulo (SP)
sCEPH	(2) Itajaí (SC), Santana de Parnaíba (SP)
sCEPh	(3) Blumenau (SC), Maringá (PR), Praia Grande (SP)
sCEph	(1) Balneário Camboriú (SC)
sCePH	(1) Jundiaí (SP)
sCePh	(1) Paulínia (SP)
sCepH	(3) Brasília (DF), Porto Alegre (RS), Americana (SP)
sCeph	(2) Florianópolis (SC), São Caetano do Sul (SP)
scEPH	(1) Salvador (BA)
scEpH	(2) Londrina (PR), Nova Lima (MG)
scEph	(3) Curitiba (PR), Joinville (SC), Goiânia (GO)
scePH	(1) Jaguariúna (SP)
scePh	(1) Ribeirão Preto (SP)
scepH	(3) Santos (SP), Vinhedo (SP), Indaiatuba (SP)
sceph	(1) Santo André (SP)

Source: Own elaboration.

In the cities highlighted and represented as cases, the specific configuration found (SCEPH) shows that there is a need for high levels of investment in social, science and technology, educational, urban planning and health public policies for the intelligent development of these cities. It is important to point out that there are several other factors, in addition to those presented in this analysis, that can influence the development of these cities, such as the economic situation, private incentives, social programs, among other factors. However, it was possible to observe that public policies have a leading role in the success and development of smart cities. Thus, a smart city project represents the city and public policies aimed at building a more efficient city (Mullick & Patnaik, 2022).

Furthermore, it is to be noted that not all smart cities in the sample follow the same

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pattern due to their heterogeneity. The different degrees of magnitude found in the configurations show the inequalities between public policies and their effects on the performance of smart cities in Brazil. The city of São Paulo, for example, presented only social policies with high intensity (Sceph), as did the cities of Florianópolis and São Caetano do Sul (sCeph) with high intensity in science and technology policies and Ribeirão Preto (scePh) with high intensity in urban planning policies. In these cases, the different configurations highlight the regional disparities found, since the central-southern region is known for high public and private investments in its regional development, further enhancing already developed cities, as is the case of 22 cities in the State of Sao Paulo alone. In this regard, Penna & Ferreira (2014) state that the lack of access to resources, such as information, knowledge and technology, hinders the ability to face situations related to the development of cities. Furthermore, long-term planning for the development of smart cities in Brazil must consider local, regional, metropolitan, and national levels of city development, such as education and sustainable growth.

To analyze the relationship between the conditions and the result, as well as predict the sets of conditions that most made the development of smart cities viable, Table 4 shows the matrix of sufficiency and need. The matrix shows the proportion of the total cities that are in each of the five conditions that are related to the development of smart cities (I), as well as each of the conditions presented. In general, it can be seen that the results of the matrices for 2020 presented similar results. The highest score was approximately 72%, indicating that high investments in science and technology policies (C) would be enough to leverage the development of a smart city (I). This result is seen by Pires (2021), who highlights that cities present complex problems, in which technology and innovation are factors inherent in the daily life of contemporary society and should be used as strategies for mapping public policies and regulatory activities in city environments.

Table 4. Matrix of the sufficiency and necessity

Variables	I	S	C	E	P	H
I	1					
S	0.633	1				
C	0.721	0.655	1			
E	0.663	0.686	0.624	1		
P	0.612	0.688	0.705	0.682	1	
H	0.646	0.661	0.638	0.651	0.646	1

Source: Own elaboration.

Another similar aspect was achieved with educational policies (E), with a score of 66%. Thus, investments in educational policies represent continued success for the satisfactory performance of Brazilian smart cities (I). The teaching-learning processes must seek synergy between the reality of the population and focus on the development of skills that allow the building of intelligent solutions for individuals, providing a better quality of life. In the same sense, urban (P) and social (S) planning policies showed slightly lower scores of approximately 61% and 63%, respectively, corroborating the importance of the set of government policies in different areas for the development of smart cities. Regarding the relationship between conditions, science and technology

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policies (C) and urban planning policies (P) reached a score of approximately 71%. Social policies (S) related to urban planning policies (P) also obtained impressive results, with a score of 69%.

Despite the sets presenting very significant and close results, the matrix (Table 4) does not present the consistency and coverage rate, which shows the sufficiency and need relationships. Thus, it is necessary to evaluate the sufficiency relationships to discover the logical combinations that favor the development of Brazilian smart cities with the application of public transfers, as shown in Table 5.

Table 5 presents the tests for the sufficiency of the condition settings (S, C, E, P and H) in relation to the result (I). According to Gonçalves Montenegro (2021), this prior analysis is important because, as the relationships between the conditions are analyzed, they are reduced to a minimum number of sets that synthesize and translate the configurations of the conditions according to the profile and frequency of the sample that reaches the result. A positive point in the analysis is that all settings showed consistency above 0.80. This result indicates that the closer to 1, the greater the consistency of the configuration (Ragin, 2006). In the analysis of conditions, all solutions were significant at 5% by p value analysis.

Table 5. Test-based consistent settings

Configurations	Consistency	F-test	P-value	Number of cases
sceph	0.85	11.19	0.00	1
scepH	0.84	5.11	0.03	3
scePh	0.82	5.93	0.02	1
scePH	0.87	14.52	0.00	1
scEph	0.88	15.34	0.00	3
scEPH	0.85	7.95	0.01	1
sCeph	0.93	34.94	0.00	2
sCepH	0.89	8.78	0.01	3
sCePh	0.84	6.98	0.01	1
sCePH	0.88	10.25	0.00	1
sCEph	0.96	140.54	0.00	1
sCEPh	0.91	26.61	0.00	3
sCEPH	0.87	6.78	0.01	2
Sceph	0.85	8.82	0.01	1
ScepH	0.83	4.63	0.04	2
ScePH	0.83	4.77	0.03	1
ScEph	0.86	13.72	0.00	2
SCeph	0.87	7.48	0.01	1
SCepH	0.92	33.6	0.00	2
SCEph	0.96	116.98	0.00	1
SCEPh	0.86	7.68	0.01	3
SCEPH	0.88	9.6	0.00	2

Source: Own elaboration.

In addition, by analyzing the configurations in Table 5, a total of twenty-two (22) configurations with the participation of thirty-eight (38) cities are observed., which is a

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reduced participation compared with the fifty (50) cities presented in the sample. This result can be explained by the multidisciplinary development focus of smart cities, that is, the interaction of several strategic areas is necessary according to the transfer of budget actions and programs and the degree of absorption capacity of these investments. The more developed the city is, the more easily it will distribute and transfer investments to its strategic areas (health, education, transport, infrastructure, etc.).

For example, the configuration (ScEph) was found in the cities of Fortaleza - CE and Juiz de Fora - MG, which have a high score in social and educational policies. This configuration is interesting in the aforementioned locations, such as the Federal University of Ceará (UFC) and the State University of Ceará (UECE), both in Fortaleza, and the Federal University of Juiz de Fora (UFJF), in the city of Minas Gerais, are located there, highlighting the educational dynamics in both cities. Another interesting point can be highlighted according to data from the United Nations Development Program (UNDP), in which the Human Development Index (HDI) of the two cities is considered high compared with the Brazilian average (0.724), with 0.754 for Fortaleza and 0.778 for Juiz de Fora in 2010. This aspect is interesting when analyzing the high score in the transfer of social inclusion policies through Bolsa Família and the articulation of public policies, a budget program of the federal government used as a measure of the social policy in this study.

From the decrease in configurations and the reduction in the participation of cities (Table 6), it was observed that there were no major changes in the interaction process; that is, the cities fit into the same configurations as before the tests applied. This relationship reveals that the development of Brazilian smart cities has a hardened configuration with different scores; that is, they do not have the same pattern of development, application of actions, or budgetary policies. De Macedo & Porto (2018) argue that investment is not carried out in all cities homogeneously; in contrast, they are concentrated in the regions with the greatest endowment of economic and social infrastructure and with greater positive externalities.

Table 6- Minimization of condition sets

Configurations	Raw coverage	Unique and total Coverage	Solution consistency
s*C*p*h	0.386	0.386	0.933

Source: Own elaboration.

To exemplify, cities that achieved only one policy or none with a high score—with the need for high investments in this sphere—are concentrated in the central-southern region of Brazil, with emphasis on cities in the State of São Paulo. The cities are Santo André (SP) with a low score in all policies (sceph); Santos (SP), Vinhedo (SP) and Indaiatuba (SP) with high scores in health policy (scepH); Ribeirão Preto (SP) with a high score in urban planning policy (scePh); Curitiba (PR), Joinville (SC) and Goiânia (GO) with the need for a high level of investment in educational policy (scEph); and Florianópolis (SC) and São Caetano do Sul (SP) with high scores in science and technology policy (sCeph) and São Paulo (SP) with the need for a high level of investment in social policy (Sceph).

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The condition sets in Table 6 represent the reduced configuration equations for a minimum number of sets. Moreover, gross coverage is related to the relative empirical importance per term in explaining the solution, while single coverage reveals this empirical importance; that is, it explains each term of the solution separately, disregarding the present conditions that are covered by other solutions. Thus, both coverages are significant, as they reveal their relative empirical weight. The results showed a significant consistency solution for 2020, with a value of 93%. For the same year, the partial solutions revealed that high levels of investment in science and technology policies (C) are preponderant factors in the development of smart cities in Brazil. It is important to note that in this test stage, it is only possible to visualize the combination of expressive configurations for the period of analysis, meaning it is not feasible to determine which cities fit the configuration found.

In summary, the results presented showed that for the period of analysis, the budget policies passed by the federal government (public investment) have significant importance in the development of Brazilian smart cities. This result confirm that smart cities in general, not just in Brazil, need major investments and infrastructure modernization, to make them safer, more reliable, resilient and globally competitive.

Finally, the challenges encountered in the development of cities are many, especially in regard to regional disparities, which were identified by the different scores found in the policy configurations, as well as in the level of development of these cities. However, policies related to science and technology proved to be more representative of the development of smart cities in the country, as shown in the empirical review of international examples by Ismagilova et al., (2019); Barrionuevo et al., (2012); Praharaj et al., (2018) and the OECD (2018). This result highlights the importance of educational and technological policies in the medium and long term, with the aim of expanding people's quality of life and providing greater innovation for cities, which represents the key point for the creation and strengthening of smart cities in Brazil.

5- Conclusions

This article aimed to identify the configurations of fifty (50) selected cities that are considered Brazilian smart cities based on public policies in strategic areas, namely, social, educational, scientific-technological, urban planning and health. The methodology used was qualitative comparative analysis, as it is an appropriate method for a small sample and to analyze cities according to their specificities.

Furthermore, the choice of policies (budgetary actions and programs) occurred with the aim of encompassing social, science and technology, educational, urban planning and health policies. The actions and budget programs chosen aimed to reduce missing data, following the thematic axes mentioned above. For the improvement and treatment of each action/program used, the variable estimates of the population residing in Brazilian municipalities were inserted to evaluate policies at the population level and their effects on smart cities.

According to the results, a strong concentration of smart cities was observed in the center-south region, to the detriment of the north and northeast regions. The results also

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indicate that not all smart cities have the same effects when submitted to public policies. It is worth mentioning that investments in the areas of science and technology obtained significant results in the development of Brazilian smart cities, especially in cities that are not considered metropolises and/or capitals. In addition, educational policies also proved to be relevant to smart cities in a comparative sense to other applied policies. Finally, urban and social planning policies showed similar results, highlighting the importance of the joint application of regional public policies for the success of smart cities.

Additionally, in terms of conditions, the results showed that science and technology policies applied together with urban planning policies achieved a significant score, as did social policies related to urban planning. In this way, public policies play a major role in the growth and development of Brazilian smart cities. However, the different degrees of magnitude identified in the specific configurations revealed the inequalities and asymmetries in relation to the public policies applied in the cities.

It is worth noting that cities such as Fortaleza (CE) and Juiz de Fora (MG) obtained high scores in their configurations in social and educational policies for 2020. However, these cities have higher education centers of reference and high development rates, which contrasts with the configurations found. Thus, one of the explanations could be that, in the development of cities, the participation of municipal and State powers, in addition to the private sector and the federal public sphere, the latter being outside the scope of this work.

Therefore, the results discussed in this work contribute to the empirical literature in the areas of urban and regional economics and the economics of technology in the case of Brazil. The theoretical review presented addressed discussions on international examples of empirical research related to the theme and for the Brazilian case. However, the article's differential contribution consists of the analysis of public policies in the constitution and development of Brazilian smart cities.

To make future contributions to the literature in the area of urban economics, it is recommended that the analysis be expanded to include more Brazilian cities that are considered smart, as well as to carry out comparisons at an international level, to identify which technologies and policies could be applied and used at the national level. Additionally, a more in-depth study involving the north and northeast regions of Brazil (which obtained a small number of cases in the sample of this work) in parallel with the use of other methodologies in the area in different periods would require a more detailed investigation, evaluating in greater detail the sources of regional inequality, potential and vulnerability in relation to other smart cities.

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