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CHARACTERIZATION OF SMART CITIES DIMENSIONS IN THE METROPOLITAN REGION OF VALE DO PARAÍBA AND NORTH COAST - BRAZIL

CARACTERIZAÇÃO DAS DIMENSÕES DE SMART CITIES NA REGIÃO METROPOLITANA DO VALE DO PARAÍBA E COSTA NORTE - BRASIL

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Abstract

Disorderly population growth in urban areas without proper planning causes economic and social problems. There is evidence that public management does not provide quality care, cannot meet the population's demand, in addition to the challenge of promoting social equality. Recent studies demonstrate the application of smart cities to help public management to minimize these problems. The general objective of this article is to diagnose the dimensions of smart cities through the perception of the inhabitants of the municipalities of São José dos Campos, Taubaté, Pindamonhangaba and Ilhabela located in the Metropolitan Region of Vale do Paraíba and North Coast. Therefore, a quantitative descriptive research was used as a methodological approach, obtained through the application of a structured questionnaire with closed questions to the inhabitants. We opted for probabilistic sampling, the survey type research (questionnaire). The data analysis process took place in four phases: characterization of the respondents' profile, data validation, descriptive statistics of the dimensions of smart cities and factor analysis. It can be concluded that to improve the provision of services to the population, in addition to changing the view of the inhabitants of São José dos Campos, Taubaté, Pindamonhangaba and Ilhabela, it is important to create new public policies for government interaction with the population with projects use of technology in services provided to society, such as health, education, transport and security, among others.

Keywords: Management. Regional Development. Smart City. Dimensions.

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Resumo

O crescimento desordenado da população em áreas urbanas sem um planejamento adequado causa problemas econômicos e sociais. Há evidências de que a gestão pública não oferece assistência de qualidade, não consegue atender à demanda da população, além do desafio de promover a igualdade social. Estudos recentes demonstram a aplicação de cidades inteligentes para auxiliar a gestão pública a minimizar esses problemas. O objetivo geral deste artigo é diagnosticar as dimensões das cidades inteligentes por meio da percepção dos moradores dos municípios de São José dos Campos, Taubaté, Pindamonhangaba e Ilhabela localizados na Região Metropolitana do Vale do Paraíba e Litoral Norte. Para tanto, utilizou-se como abordagem metodológica uma pesquisa descritiva quantitativa, obtida por meio da aplicação de um questionário estruturado com perguntas fechadas aos moradores. Optou-se pela amostragem probabilística, do tipo survey (questionário). O processo de análise dos dados ocorreu em quatro fases: caracterização do perfil dos respondentes, validação dos dados, estatística descritiva das dimensões das cidades inteligentes e análise fatorial. Pode-se concluir que para melhorar a prestação de serviços à população, além de mudar a visão dos moradores de São José dos Campos, Taubaté, Pindamonhangaba e Ilhabela, é importante criar novas políticas públicas de interação governamental com a população. com projetos de uso de tecnologia em serviços prestados à sociedade, como saúde, educação, transporte e segurança, entre outros.

Palavras-chave: Gestão. Desenvolvimento Regional. Cidade inteligente. Dimensões.

Introduction

A study by the United Nations Population Fund (2019) shows that the world is facing the biggest wave of urban growth in history. The study shows that, in 2015, approximately 3.6 billion people lived in the urban area, and that by 2030 that number will increase to 5 billion people.

In the Brazilian reality, this growth is even greater. According to the 2010 census (IBGE, 2010), the Brazilian population living in the urban area represents 84.35% and that in 2030 this index will reach 91.1%.

The increase in population growth, particularly in the urban area, causes many challenges for urban sustainability (RANA, 2011; ROSENZWEIG *et al.*, 2010; ABDULLAH; RAHIM, 2020; KOCA; EGILMEZ; AKCAKAYA, 2021), such as: difficulty in management of urban solid waste, resources scarcity, air and water pollution, human health problems, traffic congestion, inadequate, deteriorated, and old infrastructures and among others (CHORABI *et al.*, 2012; SILVA; KHAN; HAN, 2018).

But how to improve the functioning of cities? The great challenge for technicians and scholars of urban planning and public managers is to promote an orderly urban development together with the objective of improving the quality of life of citizens. To face these challenges, managers of Brazilian cities need to define city strategies related to urban planning. Currently, a city strategy that is being discussed is to transform city management into a smart and sustainable city.

However, cities need to design an individual strategy on how to become smart and sustainable, that is, adapt to their urban context, as noted by Angelidou (2016). The author explains that a city that aspires to become smart and sustainable must have an integrated strategic plan. Angelidou (2016) adds that this plan must define a vision and a methodology based on the use of digital technologies and city management to improve urban functions.

In this context, this article seeks to contribute to the discussions on the management of smart cities and urban development, mainly in the municipalities located in the Metropolitan Region of Vale do Paraíba and North Coast. So, the question was formulated to guide this research: What are the characteristics of the dimensions of Smart Cities perceived by the inhabitants of São José dos Campos, Taubaté, Pindamonhangaba and Ilhabela, through the public services provided?

Theoretical Perspectives of Smart Cities and their Dimensions

Academically, the term 'smart cities' had emerged since 1994, but in the urban planning field the term spread after the adoption of the concept by the European Union in 2010 (AHVENNIEMI *et al.*, 2017; LUCAS; MORAES, 2019).

Two main approaches to the concept of smart cities derive from the literature, one highlighting the dependence on technologies as a source of efficiency for infrastructures and resource optimization, centered on the informational / technological function, and the other based on people, dependent on human capital, social and quality of life to then be considered intelligent, such as security, participation, knowledge, equity, and others) (ANGELIDOU, 2014).

At first, it is worth highlighting the approach taken by Angelidou (2015) regarding the focus of technology from the Industrial Revolution and World War II, when the search for shelter and better living conditions generated the need for the development of planned cities and suburbs, which little by little they evolved in materials and methods of construction, while research and development aimed at war was developed in other isolated locations.

The new technologies of the 1960s also awakened scholars about the use of technology in the built environment and even fully mechanized cities (ANGELIDOU, 2015). In the 1960s and 1980s, many publications were related to information systems linked to the city under the terms cybercities, information cities, smart cities, digital cities, and virtual cities, adapted to the reality of that moment and in the future conceptions of cities.

The peak was the popularization of information and communication technologies (ICTs) in the mid-1990s, with studies of their use as a facilitator of democracy and city management (ANGELIDOU, 2015; BATTY *et al.*, 2012).

Regarding the dissemination of the Internet, the International Telecommunication Union (ITU, 2018) states that 51.2% of the world population in 2018 was connected, equivalent to 3.9 billion individuals.

The growing number of people with access to technology allows greater participation in the creation of urban policies, collaborating in the generation of data in real time, the monitoring of urban phenomena, facilitating the resolution of problems and giving greater efficiency in spatial planning and urban management (MURGANTE; BORRUSO, 2013).

For Castells (2012), ICTs determine the creation of the informational city through the virtual world, which enabled the structuring of a networked society in which economic and social phenomena happen almost instantly. Information technology favors access and the exchange of knowledge between people (SILVA, 2004), with knowledge management strongly linked to urban development (ANGELIDOU, 2015).

As for the definition of smart city, there is still no unanimously accepted literature or criteria for its evaluation (ANGELIDOU, 2015; MARSAL-LLACUNA; COLOMER-LLINÀS; MELÉNDEZ-FRIGOLA, 2015; PRADO *et al.*, 2016; THOMAS *et al.*, 2016).

Several other terminologies are found in the literature, such as smart and sustainable cities (AHVENNIEMI *et al.*, 2017); smart and creative cities (CARTA, 2014); smart and inclusive cities (REBERNIK *et al.*, 2017); smart and innovative cities (VLACHOSTERGIOU *et al.*, 2015); smart and resilient cities (PAPA, 2015) and among other terms.

Despite the different terms, the common characteristic of the concept of smart cities in the literature is to improve the quality of life in cities as a model that tries to mitigate current urban problems (CARAGLIU *et al.*, 2009; NAM; PARDO, 2011; BATTY *et al.*, 2012; LAZAROIU, 2012; PIRO *et al.*, 2014; PRADO *et al.*, 2016; YIGITCANLAR; KANKAMANGE; VELLA, 2021).

By highlighting the evolution of the concept of smart cities in the world, authors such as Albino, Berardi and Dangelico (2015), Dameri and Cocchia (2013), Cocchia (2014), Gil-Garcia, Pardo and Nam (2015) and Weiss (2016, 2019) identify the main boundary existing within the evolutionary process of this concept, ranging from the most technological issues to the most human issues.

For Hall *et al.* (2000), smart cities are those that monitor and integrate the conditions of their urban infrastructures, define the best use and optimization of resources, acting preventively for the continuity of the fundamental activities of the city. It is a vision of efficiency in the infrastructure.

Giffinger *et al.* (2007) conceptualize smart cities as those that realize the vision of the future in several aspects: economy, people, governance, mobility, environment, and quality of life. In addition, they are built under the smart combination of decisive, independent, and conscious attitudes of the actors who act in them. It is a concept related to the efficiency of the city in a context of quality in the provision of the service offered by the cities, and the role of citizens in societies is

much more relevant than the role of innovations and technological resources, that is, they demonstrate the centrality of the citizen in the urban ecosystem.

In 2010, the term smart is associated with the instrumented, digitized, and interconnected concept. From that year, the concept of smart city extends to several areas of the city. The interconnection between physical (infrastructure), social (inhabitants) and economic (business) guides the city, highlighting the interconnectivity between these areas.

Still in 2010, another relevant point is smart computing, a time when technology becomes fundamental in the management of critical points in the city: management, education, health, security, public services, and transport, all of which are interconnected (JORDÃO, 2016).

For Nam and Pardo (2011), a smart city disseminates information in its physical infrastructure to improve conveniences; facilitate mobility; add efficiency; save energy; improve air and water quality; identify problems, acting on them with agility; recover quickly from disasters, collect data to improve decision-making; deploy resources effectively; and share data to enable collaboration between entities and domains.

Another definition, by Bakici, Almiral and Wareham (2012), sees in the smart city an advanced and intensive high-tech dynamic to connect people, information, and elements, to create a sustainable city. In other words, it uses new technologies to have a more sustainable, green, innovative, and competitive trade, with increasing quality of life.

Barrionuevo, Berrone and Ricart (2012) reinforce that being a smart city means using all available technologies and resources in an intelligent and coordinated way, to develop centers that are at the same time integrated, livable, and sustainable.

Kourtit, Nijkamp and Arribas (2012) define smart cities as the result of intensive and creative knowledge strategies, which aim to improve the socioeconomic, ecological, logistical, and competitive performance of cities. A combination of human capital, infrastructure capital, social capital, and entrepreneurial capital. According to the authors, smart cities have high productivity, since they have a relatively high proportion of highly educated people, knowledge-intensive jobs, results-oriented planning systems, creative activities, and sustainability-oriented initiatives.

According to Zygiaris (2013), a smart city develops intellectual skills that address various innovative socio-economic and technological aspects of growth. About innovation, it is characterized by knowledge based on experienced and creative human capital. These aspects refer to the smart city, conceived as:

- green: referring to urban infrastructure for protecting the environment and reducing CO2 emissions;
- interconnected: referring to the revolution in the broadband economy; and
- intelligent: producing value-added information, in real time, from sensors.

For Angelidou (2014), smart cities are a conceptual model of urban development embodied in the use of human, collective and technological capital aimed at the development of urban agglomerations.

Marsal-Llacuna, Colomer-Llinàs and Meléndez-Frigola (2015) mention that the smart city has the initiative to seek to improve urban performance using data, information, and ICT, aiming at providing more efficient services to citizens, monitoring, and optimizing the existing infrastructure, encourage collaboration between economic agents and encourage innovative business models for both public and private sectors.

The authors add that the use of information and communication technology serves as an instrument of improvement and political-economic efficiency, in addition to enabling social, cultural, and urban development, such as the creation of urban spaces oriented to business, the social inclusion of citizens with the use of information and communication technologies applied to public services, and the encouragement of long-term urban growth from creative and technology companies.

Bouskela *et al.* (2016) portray that a smart city is one based on the development of people as the main objective. In this way, it incorporates information and communication technologies in urban management, using them as tools in the formation of an efficient government that encompasses collaborative planning and citizen participation. Based on this definition, integrated and sustainable development should be favored, becoming more innovative, competitive, attractive, and resilient.

The term smart is not limited to the incorporation of technology in the urban space, but also involves participatory management. Technology is the means and not the end goal.

Weiss (2016) defines a smart city as one that implements information and communication technologies as a means of transforming patterns of organization, learning, infrastructure management and the provision of public services, promoting more efficient urban management practices for the benefit of social actors, leading always considering historical vocations and cultural characteristics.

The union between technology and knowledge is characteristic of a smart city, making strategic and political plans feasible, and achieving observable results, which can be enjoyed for a long time instead of statistical abstractions.

There are several approaches and concepts about the smart city, from a more technological approach to a more humanized one. However, Giffinger *et al.* (2007) stand out from the other authors previously mentioned. This is because in addition to defining the concepts, these authors create tools to identify and classify a city as smart and its degree of intelligence, making it possible to identify problems and from a diagnosis seek smart solutions, which result in improving the quality of the services offered the population.

For this reason, this study is based on Giffinger *et al.* (2007). The authors classify smart cities into six distinct dimensions: smart economy, smart people, smart governance, smart mobility, smart environment, and smart living. As shown in Table 1.

Table 1: Dimensions and Characteristics of Smart City

SMART ECONOMY (Competitiveness)	SMART PEOPLE (Social and Human Capital)
Innovative spirit **Entrepreneurship** **Economic image and trademarks** **Productivity** **Flexibility of labor Market** **International embeddedness** **Ability to transform**	Level of qualification Affinity to lifelong learning Social and ethnic plurality Flexibility Creativity Cosmopolitanism/Open-mindedness Participation in Public Life
SMART GOVERNANCE (Participation)	SMART MOBILITY (Transport and ICT)
Participation in decision-making **Public and social services** **Transparent governance** **Political strategies and perspectives**	Local accessibility (Inter-)national accessibility Sustainable, innovative and safe transport systems
SMART ENVIRONMENT (Natural resources)	SMART LIVING (Quality of life)
Lack of pollution of natural conditions **Pollution** **Environmental protection** **Sustainable resource management**	Cultural facilities Health Conditions Individual Safety Housing quality Education facilities Touristic Social Cohesion

Source: Giffinger *et al.* (2007).

The dimensions presented have their own characteristics (GIFFINGER *et al.*, 2007). The smart economy includes elements such as economic competitiveness, innovation, entrepreneurship, trademarks and patents, productivity, flexibility of the labor market and integration with the international market. In the dimension of smart people, the level of qualification and education of citizens is assessed by the quality of social interactions related to integration, public life, and openness to the outside world.

The smart governance dimension encompasses political participation, services for the population and the functioning of public management. About the analysis of smart mobility, it addresses issues of international and local accessibility, modern and sustainable transport systems and the availability of resources provided by information and communication technology.

The smart environment dimension includes natural conditions, pollution, resource management and efforts to protect the environment. Finally, the smart living dimension specifies the various characteristics of quality of life, such as culture, health, safety, housing, entertainment, and others.

The dimensions presented encompass social, cultural, economic, structural, and administrative aspects that will be detailed in the development of the research. This method, adopted in the present research, it was adapted with respect to factors and indicators for application in the cities of São José dos Campos, Taubaté, Pindamonhangaba and Ilhabela.

Methodological Procedures

This research has a quantitative and descriptive character. It aims to know the perception of the inhabitants of the municipalities located in the Metropolitan Region of Vale do Paraíba and North Coast (RMVALE) using resources and statistical techniques. Quantitative research is characterized by logical thinking, with a mathematical focus. It elaborates the logical rule and measurable attributes, but it does not emphasize the holistic visions to learn what is experiencing the phenomenon (POLIT; BECK; HUNGLER, 2004, p. 201).

According to Selltiz *et al.* (1965), descriptive research seeks to describe in detail a phenomenon or situation, allowing it to accurately cover the characteristics of an individual, a situation, or a group and to discover the relationship between the events.

In view of this choice of methodological approach, it was decided to conduct the research in the Metropolitan Region of Vale do Paraíba and Litoral Norte (RMVPLN) because it is located between the two most important regions of the country: São Paulo and Rio de Janeiro. It stands out nationally for its intense and diversified economic activity.

Industrial production is highly developed, with a predominance of the automobile, aeronautical, aerospace, and warlike sectors in the municipalities located on the axis of the Presidente Dutra Highway. Also noteworthy are the port and oil activities in the North Coast and tourism in the Serra da Mantiqueira, Litoral and historic cities. The region is also characterized by housing important environmental heritage sites of national relevance, such as the Mantiqueira, Bocaina and Mar Mountains, and by farms of historical and architectural value (EMPLASA, 2019).

It is worth mentioning that the RMVPLN was created in 2012 through State Complementary Law 1166, of January 9, 2012 (ASSEMBLEIA LEGISLATIVA DO ESTADO DE SÃO PAULO, 2012). According to this Law 1166, article 3 and 4, the region is made up of 39 municipalities, divided into five sub-regions.

After choosing the municipalities, the research sample was described. For this study, the sample consisted of a probabilistic sample with the inhabitants of the cities studied. Therefore, a sample calculation was performed to define this sample, with the objective of making a diagnosis of the reality of that population. So, the suggested sample calculation had as parameters, the 95% confidence level index and 5% sampling error.

Table 2 shows the research sample and the number of valid questionnaires applied. Data were collected between August 2018 and March 2020, after approval by the Research Ethics Committee of the University of Taubaté (CEP), registered on the Brazil platform, in the CEP Consubstantiated Opinion number 3,497,793.

Table 2: Research Sample

Municipality	Population (Census 2010)	Sample	Printed Questionnaire	Online Questionnaire	Sum of Questionnaire applied
São José dos Campos (SP)	629,921	384	397	45	442
Taubaté (SP)	278,686	384	343	58	401
Pindamonhangaba (SP)	146,995	384	158	229	387
Ilhabela (SP)	28,196	379	314	72	386
Sum	1,083,798	1531	1212	404	1616

Source: IBGE (2010)

During this period, a total of 1616 valid questionnaires were applied, both printed and electronic, however, 2000 questionnaires were sent. 500 questionnaires were sent to each municipality. 384 forms were discarded due to the lack of answers and reasons for not meeting the target audience of the research, in this case, for example, people from other cities.

When using the online method, the Google Forms service platform was used, which offers an easy-to-understand interface and the use of the software to adapt to any device, such as a cell phone,

tablet, computer, or notebook. The questionnaire's electronic address was distributed through WhatsApp social networks; Facebook; messenger; and e-mail.

The application of the printed questionnaire was presented as the best approach method, probably because the researchers argue and seek the effective commitment for the filling out by the respondents, which does not occur when it is applied electronically. The survey carried out with printed questionnaires had its scope in all regions of the municipalities. It was applied in places of great agglomeration, such as squares where individuals play sports and in different residences in the municipality.

The instrument used for the development of this paper was a closed questionnaire on a Likert scale, adapted from studies carried out by Giffinger *et al.* (2007) by the University of Vienna.

The steps of the analysis of quantitative research data took place from the organization of the data, grouping them in tables, summarizing the main statistics and finally analyzing and interpreting the data.

Initially, the calculation of the average ranking (AR) was used to assess valid responses and exclude abstentions from the frequency of respondents' responses. This ranking is composed of the weighted average, in which the total frequency of each opinion is divided, for each question, by the relative weight that was assigned from 1 to 5 within the Likert scale of 5 points (OLIVEIRA, 2005).

To calculate the AR, equation 1 is used:

$$(AR) = \sum(fi.Vi) / (NR)$$

Equation 1: Average Ranking
Source: Oliveira (2005)
On what:
fi = total frequency observed in each opinion for each question
Vi = value of each answer or assigned weight
NR = number of responses: valid opinions

The closer the result is to 5, the higher the respondent's level of identification and satisfaction, and the closer to 1 the worse the conceptualization or dissatisfaction related to the question. Above 3 the recognition is positive. The results are analyzed based on the frequencies related to the weight of the relevant answers at each level, totaling an evaluation average: the average ranking.

After calculating the AR for each of the questions, they are grouped into the respective factors and the average is calculated by adding the results of the AR and dividing by the number of questions, obtaining the average of the factor. After determining the mean values of all factors that make up a domain, these factors are added up and divided by the number of factors corresponding to the domain, thus resulting in the mean AR value of the domain.

To complement the average ranking, the standard deviation of the collected data set was calculated. According to Spiegel (1993), the standard deviation is a measure of dispersion, that is, it indicates how uniform the data set is. The author adds that when the standard deviation is low it means that the data in the set are closer to the average.

In the third stage of data analysis, the following tests were developed: reliability Cronbach's alpha (AC), Kaiser-Meyer-Olkin measure (KMO) and Bartlett's sphericity. The Cronbach's Alpha (AC) reliability test shows the reliability of the internal consistency as the responses are consistent between the elements included in a measure (HAIR *et al.*, 2014). AC values greater than 0.70 were analyzed as acceptable.

The Kaiser-Meyer-Olkin (KMO) measure is used to analyze the adequacy of factor analysis. Results between 0.5 and 1.0 prove that the factor analysis is adequate and results below 0.50 prove that the factor analysis is inadequate: the higher the better. The minimum level of suitability is 0.50 (HAIR *et al.*, 2014).

The Bartlett Sphericity test, according to Tabachnick and Fidell (1996), examines the entire correlation matrix, checking if there are enough significant correlations, if there is multicollinearity, as the objective is to identify sets of interrelated variables.

For the sample to be accepted for factor analysis using Bartlett's sphericity, it is necessary to present the following conditions: (i) it must be significant, that is, sig. <.05; and (ii) chi-square must be greater than 1767,992 (TABACHNICK; FIDELL, 1996).

Finally, factorial and path coefficient analyze were performed. For Aranha and Zambaldi (2008), factor analysis is an interdependence technique, whose main purpose is to define the inherent structure between the variables in the analysis. This technique examines the interrelationships between many observed variables and seeks to explain them in terms of their common dimensions, called factors.

Hair *et al.* (2014) define factor analysis as a technique for summarizing or reducing data that does not have dependent and independent variables. It is, therefore, an interdependence technique, in which all variables are considered simultaneously.

The path coefficients inform how much one latent variable is related to another. Values range from -1.0 to +1.0. Values close to +1.0 have a very strong positive causal relationship between two constructs and values close to -1.0 have a very strong negative causal relationship between the constructs. Close to zero indicate weak relationships (HAIR *et al.*, 2014).

Results and Discussions

To achieve the objective proposed in this article, this section is divided into four steps. The first described the profile of respondents using frequency. The second stage tested the reliability of the data using Cronbach's alpha and the suitability for the factorial analysis of the sample.

The third stage described, through descriptive statistics, the aspects related to: public management, economy, environment, mobility, and citizen's daily life. Then, the factor analysis of the measurable variables and the path diagram that evidenced the factor loadings of the latent variables were elaborated.

Characterization of the Demographic Profile

The analysis began with the characterization of the demographic profile of respondents in the cities of São José dos Campos, Taubaté, Pindamonhangaba and Ilhabela, consisting of three demographic questions: gender, age group, and education level.

About gender, as shown in Table 3, masculine was predominant in most municipalities and represented 55.4% against 44.6% feminine. Only the city of Pindamonhangaba that obtained most of the feminine gender.

Table 3: Gender of Respondents

Gender	São José dos Campos Frequency	Taubaté Frequency	Pindamonhangaba Frequency	Ilhabela Frequency	Total Frequency	Valid Percentage
Feminine	205	189	205	172	771	47.7%
Masculine	237	212	182	214	845	52.3%
Total	442	401	387	386	1616	100.0%

Source: Research Data

The gender data are in line with the Demographic Census carried out in 2010 by the IBGE (2010). According to the Census, in 2010, the population of the four municipalities analyzed consisted of 50.83% men and 49.17% women.

According to Table 4, which shows the division by age, the predominant age group is formed by respondents who are between 18 and 25 years old, representing 35.5%, followed by 33.5% of people from 26 to 40 years old; 26.7% of people between 41 and 65 years old and only 4.3% with more than 65 years old.

Table 4: Age Group of Respondent

Age Group	São José dos Campos	Taubaté	Pindamonhangaba	Ilhabela	Total Frequency	Valid Percentage
	Frequency	Frequency	Frequency	Frequency		
From 18 to 25	231	194	71	78	574	35.5%
From 26 to 40	135	120	155	131	541	33.5%
From 41 to 65	66	82	142	142	432	26.7%
More than 65	10	5	19	35	69	4.3%
Total	442	401	387	386	1616	100.0%

Source: Research Data

On the issue education level of respondents, as shown in Table 5, it was found that 27.4% of respondents completed high school, 28.9% did not complete college and 16.9% complete the college. It can be said that the respondents are part of a portion of the population with an educational level that contributes to the development of the municipalities.

Table 5: Education Level of Respondents

Education Level	São José dos Campos	Taubaté	Pindamonhangaba	Ilhabela	Total Frequency	Valid Percentage
	Frequency	Frequency	Frequency	Frequency		
Illiterate	0	0	3	1	4	0.2%
Elementary school - unfinished	13	13	18	39	83	5.1%
Elementary school - finished	13	9	25	28	75	4.6%
High school - unfinished	13	8	86	35	142	8.8%
High school - Finished	107	90	123	123	443	27.4%
College - unfinished	209	159	51	48	467	28.9%
College - finished	65	77	53	78	273	16.9%
Specialist	10	33	25	33	101	6.3%
Master	7	6	2	1	16	1.0%
PhD	5	3	0	0	8	0.5%
Post-doctoral	0	3	1	0	4	0.2%
Total	442	401	387	386	1616	100.0%

Source: Research Data

According to the demographic census carried out by the IBGE in 2010, 57.8% of the population of the four municipalities have completed high school and graduate degrees; 38.04% have between elementary school - unfinished and high school - unfinished; and only 4.16% are illiterate. It is inferred, therefore, that the survey data are in line with the 2010 census.

The high educational level of respondents can be explained because the Metropolitan Region of Vale do Paraíba and North Coast has a large industrial, aerospace, automotive and mechanical hub. Among the main institutions and companies based there, stand out DCTA, Inpe, Cemaden, Embraer, Ambev, General Motors, Yakult, Petrobras, Volkswagen, Panasonic, LG, Johnson & Johnson, Avibras, Comil, BASF, Liebherr, Iochpe- Maxion, Nestle and Ball Corporation. It is also a Regional Center for Commerce and Services; with the presence of universities such as: EEAR, FATEC, FCN, ANHANGUERA, FUNVIC, IFSP, ITA, SENAI, UNESP, UNIFATEA, UNIFESP, UNIP, UNISAL, UNITAU, UNIVAP and USP.

In short, it can be said that the relationship of the analyzed profile of the population sample collected, this research characterized its population and compared it with the official data of the municipalities, supporting the validation of the objectives of this phase and contributing to the foundation of the research in the next phases.

Validation of Research Data

Before measuring the model variables using the average ranking and factor analysis, it is important to analyze the level of reliability of the sample to assess the consistency and stability of the measures attributed to the different variables. For that, Cronbach's alpha was used to measure the level of reliability that is shown in Table 6.

Table 6: Cronbach's alpha

Latent Variables	Cronbach's alpha	Cronbach's alpha Overview
Smart Economy	0.715	0.929
Smart Mobility	0.767	
Smart Environment	0.756	
Smart People	0.787	
Smart Living	0.843	
Smart Governance	0.859	

Source: Research Data

To evaluate the reliability of the results obtained in the research, it was found that the indices assigned to each model of the variable ranged between 0.715 and 0.859 and the overall Cronbach's alpha was 0.929. Given this variation, it can be said that, theoretically, the dimensions of smart economy, mobility, environment, people, living and governance can be considered reliable, as they presented values above 0.7.

After analysis using Cronbach's Alpha, it was verified whether the data were adequate for the application of factor analysis. The Kaiser-Meyer-Olkin (KMO) test was used, which, as mentioned in the methodological procedures, indicates the degree of susceptibility or adjustment of the data to the factor analysis. Another test used to verify the adequacy of the sample for factor analysis was the Bartlett sphericity test. Table 7 presents the results obtained in this test and in the KMO.

Table 7: Sample Adequacy Test for Factor Analysis

Latent Variables	KMO	Bartlett Sphericity Test	
		chi-square	Sig.
Smart Economy	0.734	2,850,537	.000
Smart Mobility	0.845	2,907,833	.000
Smart Environment	0.799	2,210,459	.000
Smart People	0.735	1,887,712	.000
Smart Living	0.815	3,546,759	.000
Smart Governance	0.867	3,492,224	.000

Source: Research Data

Analyzing Table 7, it was found that the KMO varied between 0.734 and 0.867, showing that the values obtained are adequate for the factor analysis, that is, the factor analysis is adequate for the proposed data treatment. Regarding Bartlett's sphericity test, the data are significant, as they presented a significance level lower than 0.05 and chi-square higher than 1767,992. That way, the data is suitable for factor analysis.

Descriptive Analysis of the Dimensions of Smart Cities

To know the perception of the population and their degree of satisfaction with the public services provided, based on aspects that make up the intelligence domains of a city, it was necessary to carry out a quantitative approach of average ranking (AR), which scaled the level of satisfaction ranking the frequencies of responses.

The first dimension to be analyzed was the Smart Economy, according to Table 8, which presented an average ranking of 3.44, that is, the inhabitants who participated in the survey partially agree that the dimension is important to form a smart city.

Table 8: Average Ranking of Smart Economy Dimension

Characteristic	Factor (Latent Variable)	São José dos Campos	Taubaté	Pindamonhangaba	Ilhabela	Average Ranking	
Smart Economy	Innovative spirit	4.67	3.03	3.21	2.41	3.33	3.44
	Entrepreneurship	4.02	3.54	3.24	3.11	3.48	
	Economic image and trademarks	4.43	3.51	3.54	2.58	3.52	
	Productivity	4.61	2.89	2.84	4.00	3.59	
	Flexibility of labor market	4.05	3.63	3.44	2.89	3.50	
	International embeddedness	3.98	1.51	3.33	4.06	3.22	

Source: Research Data

When analyzing the Smart Economy, it was observed that the population of São José dos Campos is creative and enterprising, however, they do not recognize that there are new companies being opened, which leaves room for interpretation for informal entrepreneurship, a reflection of unemployment arising from Covid -19. The city is nationally recognized for its companies and their products, with many multinational companies and the survey pointed out deficiencies in air cargo and passenger logistics.

In Taubaté, the research identified that the city is recognized for the large number of installed industries, mainly in the automotive sector; the unemployment rate is high, however, a good portion of the population has its own business, it is a creative population.

Pindamonhangaba have a positive economy, being recognized for the following factors: the citizen is an entrepreneur and has an innovative spirit; the city is recognized for what it produces, with brands that are nationally known, in addition to having many multinational companies. As negative points, it is possible to mention the logistical problems in the air transport of cargo and passengers, due to the dynamism of the companies that entails the lack of a more agile warehouse is evident; the city has a high unemployment rate.

Ilhabela is recognized for its tourism and for receiving many foreign tourists, promoting the entire hotel and restaurant network. The population recognizes itself as creative, mainly in the preservation of the Caiçara cultural identity, however, the respondents believe that the high dependence on a single economic activity can harm the municipality in the future.

In the urban mobility dimension, in Table 9, there was an average ranking below 3, that is, 2.87. This means that the inhabitants consider the regular urban mobility of the municipalities.

Table 9: Average Ranking of Smart Mobility Dimension

Characteristic	Factor (Latent Variable)	São José dos Campos	Taubaté	Pindamonhangaba	Ilhabela	Average Ranking	
Smart Mobility	Local Accessibility	3.02	2.41	2.89	2.97	2.82	2.87
	Intercity accessibility	3.76	2.68	1.67	1.72	2.46	
	Availability of ICT infrastructure	3.98	3.63	3.45	3.31	3.59	
	Sustainable, innovative, and safe transport systems	3.61	2.54	2.06	2.24	2.61	

Source: Research Data

Regarding smart mobility, the study highlighted that both in São José dos Campos and in Taubaté and Pindamonhangaba mobility is considered medium to poor, with attention points focused on quality and accessibility infrastructure, in addition to the lack of transport incentives sustainable public.

Already, the inhabitants of Ilhabela recognize that urban mobility in the city is bad, lacking many investments by the public power to improve accessibility. Also noteworthy is the precarious ferry system, often hindering the right to come and go of the population and tourists.

The third dimension analyzed was Smart Environment, which also presents an average ranking above 3, that is, the value of 3.09, according to Table 10.

Table 10: Average Ranking of Smart Environment Dimension

Characteristic	Factor (Latent Variable)	São José dos Campos	Taubaté	Pindamonhangaba	Ilhabela	Average Ranking	
Smart Environment	Conditions of natural attractiveness	3.91	3.85	2.17	2.27	3.05	3.09
	Pollution	3.89	3.06	3.13	2.96	3.26	
	Environmental protection	3.22	3.21	3.23	2.72	3.09	
	Sustainabel resource management	3.36	3.09	3.20	2.13	2.94	

Source: Research Data

As for the smart environment dimension, the inhabitants of Ilhabela are satisfied with the city's climate, but the green areas need to be improved. The city's pollution levels are satisfactory, they do not compromise public health, which still needs to be encouraged.

The population is environmentally aware and identifies the incentive for the municipality's environmental protection action. For sustainable energy and water resources there is an incentive from the municipality, and the population's use is conscientious.

The inhabitants of Taubaté, Pindamonhangaba and São José dos Campos are satisfied with the city's climate, but the green areas need to be improved. The levels of pollution in cities are satisfactory, they do not compromise public health, which needs to be encouraged. The population is environmentally aware and identifies the incentive for the municipality's environmental

protection action. As for sustainable energy and water resources, there are incentives from the municipalities and the population's use is conscientious.

For Boukela et al. (2016) and Colado et al. (2014), a city is considered smart when it is based on the citizen, who uses the knowledge and resources available in a sustainable way, and making use of communication technology in order to improve the public services offered, innovating without compromising the economic aspects , social and environmental, in order to improve the quality of life of the citizen, in this line of thought the role of the citizen participating in the city's transformation process, mixing the use of technology and the environment through a participatory and interactive government complete the concept.

In the Smart People dimension, it presented an acceptable average ranking, as it presented a value above 3 (3.20), as shown in Table 11.

Table 11: Average Ranking of Smart People Dimension

Characteristic	Factor (Latent Variable)	São José dos Campos	Taubaté	Pindamonhangaba	Ilhabela	Average Ranking	
Smart People	Level of qualification	4.32	3.62	3.31	2.92	3.54	3.20
	Affinity to lifelong learning	4.01	3.27	3.13	2.67	3.27	
	Social and ethnic plurality	3.44	3.22	2.76	2.36	2.95	
	Flexibility and Creativity	3.89	2.26	2.62	3.24	3.00	
	Cosmopolitanism/open-mindedness	3.75	3.60	3.39	3.29	3.51	
	Participation in Public Life	3.08	2.84	3.06	2.82	2.95	

Source: Research Data

As for the intelligent citizen, the inhabitants of Ilhabela recognize an acceptable level of qualification, lifelong learning affinity, creativity, flexibility, and citizenship. In São José dos Campos and Taubaté, the qualification levels are considered satisfactory, however, there is a lack of investments in structure (library) and in courses for all ages. There is a deficiency due to the lack of public foreign language courses. Citizenship is another strong point of the city: its residents are proud and declare that they know the city and its sights, treating visitors well.

In Pindamonhangaba, the inhabitants who participated in the survey are proud to live in the city and treat their visitors well. However, the population is not very creative and finds it difficult to find highly qualified jobs.

Komninos (2006) mentions that a population whose creativity is built, through knowledge creation institutions, digital infrastructure to manage and disseminate knowledge, forms territories with a high capacity for learning and innovation.

The penultimate dimension was Smart Living, which presented an acceptable average ranking, as it presented a value above 3, that is, 3.22, as shown in Table 12. The analysis showed that regarding the smart living dimension, the population of Ilhabela recognizes that the city has cultural events, public attractions, and sporting events. Life expectancy is very good; housing is regular, and the population is partially satisfied; public education is accessible and there is public investment, however, the quality of education and the use of technology need to be improved. Poverty and discrimination have a median rate.

Table 12: Average Ranking of Smart Living Dimension

Characteristic	Factor (Latent Variable)	São José dos Campos	Taubaté	Pindamonhanga	Ilhabela	Average Ranking	
Smart Living	Cultural facilities	4.02	3.79	3.63	3.64	3.77	3.22
	Health conditions	3.45	2.59	2.90	3.37	3.08	
	Safety	3.84	3.09	3.08	3.15	3.29	
	Housing quality	4.03	3.09	3.15	2.70	3.24	
	Edcation facilities	3.99	2.83	3.21	2.91	3.23	
	Touristic	3.33	2.85	3.13	2.89	3.05	
	Social Cohesion	3.12	2.72	2.56	3.12	2.88	

Source: Research Data

The inhabitants of Taubaté, Pindamonhangaba and São José dos Campos recognize that the municipalities have cultural events, public attractions, and sporting events. Life expectancy is very good, but the health network has a low rate of evaluation. Monitoring, public safety technology and mortality rate are satisfactory; the houses are good, and the population is satisfied.

Public education is accessible and there is public investment, however, the quality of education and the use of technology need to be improved; the tourist attraction needs improvement in its infrastructure; poverty and discrimination have a median rate.

In Table 13, the last dimension of the smart city is presented, which is smart governance, which presented an average ranking below the acceptable of 2.52.

Table 13: Average Ranking of Smart Governance Dimension

Characteristic	Factor (Latent Variable)	São José dos Campos	Taubaté	Pindamonhangaba	Ilhabela	Average Ranking	
Smart Governance	Participation in decision-making	2.61	2.42	2.54	2.05	2.41	2.52
	Public and social services	2.87	2.53	2.72	2.55	2.67	
	Transparent governance	2.99	2.54	2.39	2.00	2.48	

Source: Research Data

In the last dimension, smart governance, it was observed that the population of all municipalities is poorly represented by their politicians; the political activities and the city hall do not serve or provide services via the Internet to the population.

Smart cities according to Harrisson *et al.* (2011) has as a key factor the possibility of making visible the statistical abstractions of what is happening, and innovations in ICTs enhance social interactions and transform the relationships between government, academia, private sector, and citizens, with transparency and demand for infrastructure and services quality publics (DUTTA *et al.*, 2010; ROMAN, 2010).

Smart city projects address the issue of urban spaces with a focus on tools and devices without worrying about individuals, with not very clear benefits to citizens, and as urban spaces being composed of physical and virtual parts, they demand a more specific demand to determine which technology to apply to a given problem (BRANCHI *et al.*, 2014).

The harmonization between the physical and virtual parts must be treated harmoniously in the process of creating smart cities, there must be all subsystems of the urban system, with a focus on service provision and social and economic development, enabling people to use the technology as a source of information, interaction, and knowledge, discarding the bias of technological revolution to solve localized problems (NAM *et al.*, 2011).

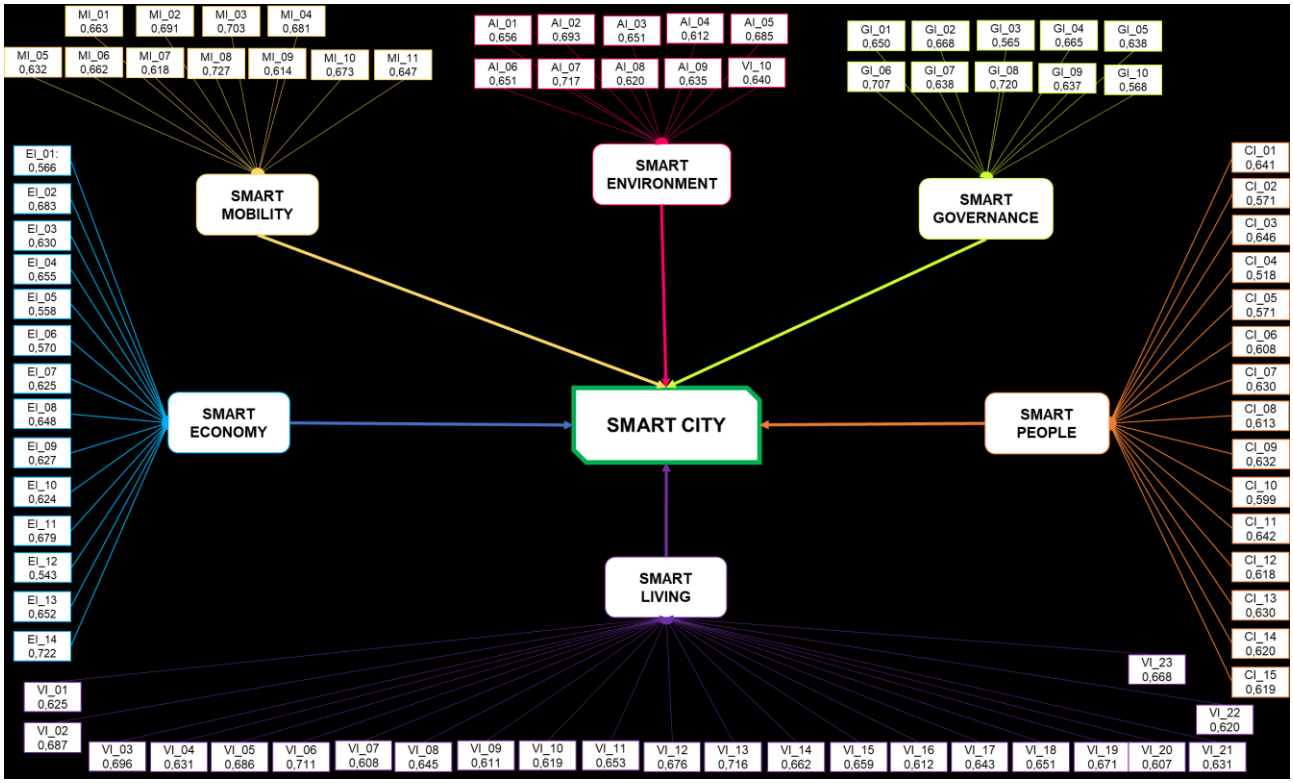
It is noteworthy that given the Covid-19 pandemic, municipalities have been working on the implementation of online services to serve the population.

Factor Analysis and Path Analysis

After analyzing the Average Ranking and identifying the population's perception of the dimensions, the path diagram was analyzed to identify the causal relationship between the dimensions of smart cities, as shown in Figure 1.

It is important to highlight that the path diagram aims to present the causal relationship between the latent variables, which for this study are the dimensions of smart cities; and, between the measurable variables (questions applied to the population) and the latent variables.

Figure 1: Path Analysis



Source: Research Data

When analyzing the factor loading of the measurable variables for the latent variable 'smart economy', as shown in Figure 1, it was found that the variables that exert the greatest influence were EI_ 14 - 'hotel structure' and EI_02 - 'specialized service offers' with loads factorials of 0.722 and 0.683, respectively.

It can be said that for the inhabitants who participated in the survey, it is necessary to invest in the hotel network to attract a greater number of visitors to the municipalities, especially business tourists, as there are many multinational companies installed in the cities. Another important point identified was the importance of offering specialized services to improve the innovative spirit of municipalities and provide an improvement in the economy.

When analyzing the latent variable 'smart mobility', it was observed that the inhabitants of the four municipalities recognize as important the investment in intelligent transport systems for the improvement of public transport in the municipality. This is clear, as the measurable variable that had the highest factor loading was MI_8 'technology used in public transport' with a value of 0.727.

Another measurable variable that showed a moderate to high causal relationship was MI_03 'public transport access network' with a factor loading of 0.703. For research participants, it is important to improve service provision in terms of access to public transport, to guarantee citizens' rights to come and go.

Thefore, for Benevolo, Dameri and D'Auria (2016), urban public transport is an essential part of a city. Ideally, they should constitute the primary means of transportation in a municipality, guaranteeing the right to come and go of its citizens. In addition, by using public transport, citizens contribute to reducing air and noise pollution, consumption of non-renewable fossil fuels and improving the quality of urban life, since fewer individual cars are used for the locomotion of people.

Complementing the issue of sustainability, the latent variable smart environment was analyzed, considering the conditions of natural attractiveness, pollution, environmental protection, and sustainable management of resources. The two measurable variables that positively influenced this latent variable were AI_7 'conscious use of water' and AI_5 'city pollution' with factor loadings of 0.717 and 0.685, respectively.

It was noted that for the respondents that, to obtain a pleasant environment for the population to live in, it is important to invest in raising the population's awareness in the conscientious use of water and in reducing the emission of pollutants into the environment.

When analyzing the smart people, it was observed that the measurable variables CI_03 'foreign language schools' and CI_01 'qualification structure for the population' had the highest factor loadings with values of 0.646 and 0.641, respectively. Thefore, in the perception of the population participating in the research, to form smart citizens, education in another language must be expanded and the qualification structure offered to everyone in the municipality must be improved.

For Angelidou (2016), the level of qualification of the population of a given city can positively contribute to the generation of qualified jobs, increase in salary levels and citizens who are more aware of the preservation of the environment in which they live.

As for the smart living dimension, it was found that the measurable variables that had the greatest influence were VI_13 'properly built dwellings' and VI_06 'number of doctors in the public network' with factor loadings of 0.716 and 0.711, respectively. It can be said that the quality of housing and health conditions are important factors to improve the quality of life of the population in the studied municipalities.

In this context, Evans *et al.* (2019) and Allam and Jones (2020) highlight that health and well-being are very complex issues and deserve attention, as they have a direct relationship with the population's quality of life. The authors complement by saying that ensuring a healthy life and promoting well-being for all, at all ages, is the third objective of the seventeen sustainable development goals (SDGs) of the 2010 Agenda of the United Nations (UN).

Allam and Jones (2020) point out that health is related not only to physical well-being, but also mental and social well-being, especially in times of pandemic, such as the one that society is facing, Covid-19.

When analyzing the last dimension of smart cities, smart governance, and the relationship with measurable variables, it was noted that GI_08 'investment in technology to improve public education' and GI_06 'public services contribute to improving the quality of life' presented the largest factorial loads with values of 0.720 and 0.707, respectively.

About public education, it is observed that, in the current situation in which we live, the importance of increasing investments in technology to improve the quality of public education. Arruda (2020) shows that Covid-19 spread rapidly around the world in 2020 and generated the unprecedented situation of 90% of the student population being isolated around the world.

He adds by saying that both public and private schools that have invested in technology so that students continue to have access to content. However, Arruda (2020) highlighted some reports showing that the governments of countries such as France, Spain, Portugal, and England have established public policies to maximize technical access to equipment, to increase equity in the teaching and learning process. Finally, it also showed that teaching using more technologies will be the new wave for the educational area in Brazil.

In short, with the factorial analysis of the measurable variables for the latent variables, it was found that the citizen of the municipalities of São José dos Campos, Taubaté, Pindamonhangaba and Ilhabela identified all analyzed variables as positive and moderate, as they presented values greater than 0.500 and it is evident that all measurable variables are important for the constitution of the smart economy, mobility, environment, people, living, and governance.

Complementing the analysis of the measurable variables for the latent, the factor loadings were calculated between the latent variables, which are the dimensions of smart cities defined by Giffinger *et al.* (2007). It was noted that all causal relationships had factor loading values above 0.980, representing an almost perfect relationship, as they had values close to 1.

The dimension that presented the highest factor loading was smart governance with a value of 0.994, which is related to the provision of social and public services, transparent governance and strategic perspectives and policies in the municipality. In the perception of the inhabitants of São José dos Campos, Taubaté, Pindamonhangaba and Ilhabela, for municipalities to become smart it is necessary to have transparent and democratic management and for the entire population to have access to basic public services to improve the quality of life for all who live there inhabit.

The second largest factor loading was smart living with a value of 0.993. It can be said that for the research participants, for municipalities to become smart, it is important to invest in cultural facilities, health conditions, population safety, quality of housing, easy access to education, tourist attraction and social cohesion.

However, the dimensions that presented the lowest causal relationship were smart environment and smart people, with factor loadings of 0.982 and 0.987, respectively, despite having presented values above 0.900.

For this study, it can be said that for the four studied municipalities to become a smart city, they need to improve the conditions of natural attractiveness, pollution, environmental protection, and sustainable management of resources. In addition to encouraging social and human capital, improving social interactions, building relationship networks, trust, and reciprocity among the population.

After the factor analysis of the measurable and latent variables, it can be said that the inhabitants who participated in the research recognize the dimensions for the formation of a smart city.

Final Considerations

This paper aimed to diagnose the dimensions of the smart city through the perception of the inhabitants of the municipalities of São José dos Campos, Taubaté, Pindamonhangaba and Ilhabela. To arrive at the results obtained, a quantitative approach was used as a resource, through the development of a questionnaire (Survey) structured as a data collection instrument, consisting of closed questions, divided into three demographic questions related to the profile of respondents and eighty questions general, appropriate to factors that identify a Smart City.

It can be concluded that to improve the provision of services to the population, in addition to changing the view of the inhabitants of the municipalities, it is important to create new public policies for government interaction with the population with projects for the use of technology in services provided to society, as in health, education, transport and security and among others.

In the health area, it is important to develop an application, or other technological means, that allows scheduling appointments, authorizing exams, having access to exam results and others, especially in times of crisis in the health system generated by the Covid-19 pandemic that devastates the country and the world.

Technological tools are also needed to improve the quality of education, provide new paths in the teaching and learning process, and train qualified professionals, helping them to discover innovative strategies to act in the market.

Therefore, it is essential that political leaders, public managers, researchers, civil society organizations, social movements and educational institutions develop public policies that contribute to configuring Pindamonhangaba as a smart city.

Despite being an important initiative for urban planning and although the objective proposed in this work has been achieved, the research carried out has limitations. The limiting factor that deserves to be highlighted was the difficulty of equalizing the answers in the municipalities. Another limiting factor was the elaboration of the diagnosis taking into account only one perception, that of the population, lacking that of the public authorities.

To contribute to the development of smart city concepts, the study leaves suggestions for future research, such as:

- inclusion of other perceptions that are important for the formation of a smart city, such as public power;
- replication of the study in other municipalities in the Metropolitan Region of Vale do Paraíba and North Coast; and
- proposal of a conceptual model for the management of smart cities for the region's municipalities.

Finally, it is possible to state that the study of the dimensions of smart cities in the municipalities of São José dos Campos, Taubaté, Pindamonhangaba and Ilhabela, in the perception of its inhabitants, was very enriching, as it produced a documentation that can be useful for both research on the subject as well as for the development of new solutions for urban planning in the municipality.

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