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ABSTRACT

This paper aims to evaluate the conditions of information and communication technologies (ICT) in Brazilian cities due to implementing the smart city concept and digital transformation. It applied an assessment of the readiness of ICT, which provided data gathering, analysis, and results demonstration capabilities by directly calculating the level of readiness of each technology and its specific functionalities and by the interactions and interfaces between the functionalities of different ICT applications analyzed through the Complex Network Analysis. Eleven cities in the state of São Paulo were considered in this analysis. The results showed that most analyzed dimensions are framed between levels 3 - Initial and 4 - Elementary. Pearson's correlation application indicates that the HDI-M and the measured ICT assessment have a strong positive correlation ($\rho = 0.89$). The proposed model embedded in the system urbeSys seeks to contribute to the theoretical and practical perspectives and to complement the existing evaluation models, focusing on verifying the readiness and application of ICT for the management of cities. Also, this work postulates a new concept for the term smart city, entering the multidisciplinary dialogue on the subject.

Keywords: Smart Cities. Digital Transformation in Cities. ICT Assessment Model. ICT Planning for Cities.

RESUMO

Este artigo tem como objetivo avaliar as condições das tecnologias de informação e comunicação (TIC) nas cidades brasileiras com vistas à transformação digital para a implementação do conceito de cidade inteligente. Aplicou-se um modelo de avaliação de prontidão das TIC com facilidades de coleta, análise e demonstração de resultados por meio do cálculo direto do nível de prontidão de cada tecnologia e suas funcionalidades específicas e pelas interações e interfaces entre as funcionalidades das diferentes aplicações de TIC analisadas por meio da Análise de Redes Complexas. Onze municípios do estado de São Paulo foram considerados nesta análise. Os resultados mostraram que a maioria das dimensões analisadas está enquadrada entre os níveis 3 - Inicial e 4 - Elementar. Por meio da aplicação da correlação de Pearson foi possível verificar que o IDH-M e a avaliação das TIC medidas têm forte correlação positiva (ρ = 0,89). O modelo proposto embarcado no sistema urbeSys busca contribuir para as perspectivas teóricas e práticas e complementar os modelos de avaliação de cidades inteligentes existentes, mas com foco na verificação da prontidão e aplicação das TIC para a gestão das cidades. Além disso, este trabalho postula um novo conceito para o termo cidade inteligente, entrando no diálogo multidisciplinar sobre o tema.

Palavras-chave: Cidades Inteligentes. Transformação Digital nas Cidades. Modelo de Avaliação de TIC. Planejamento de TIC para Cidades.

INTRODUCTION

The population growth in urban areas significantly boosts the consumption of goods and services, signaling possible restrictions on the quality of life and enhancing the scarcity of natural resources and climate change. There is also growing demands for public authorities, particularly those at the municipal level, regarding the provision of sufficient and quality public infrastructure and services. Due to the numerous challenges of intense urbanization, many cities have sought to equip themselves with several capabilities, mainly information and communication technologies (ICT). The intensive and extensive use of ICT is configured as an appropriate set of resources to configure how cities can better implement intelligence in the provision and management of public services and infrastructure. Since the information systems and related technologies employed in the management of cities are implemented as a robust and integrated system derived from a comprehensive, scalable, and interoperable architecture (Bannister; Connolly, 2018), the ICT contribute of giving rise to the notion of smart city.

In this sense, this research considered the smart cities defined as those that implement ICT to positively transform the standards of organization, learning, infrastructure management and provision of public services, promoting more efficient urban management practices for the benefit of social actors, guarding their historical vocations and cultural characteristics (Weiss, 2017).

Following these initial reflections, the question in place is how to evaluate whether cities rely on the capabilities of ICT so that they can advance in the process of digital transformation and print greater intelligence in the management and offer of infrastructure and services to social actors with a view to achieve the concept of a smart city?

Seeking a reasonable answer to this question, this study aims to propose a model of assessment and analysis of the readiness and applicability of the ICT for city management. This model, named as urbeSys, represents advances in the research field and applicability made in an initial version that has already been published in a renowned scientific-academic journal (Weiss, 2019a). In addition, this next generation of the proposed model aims to fill a gap identified in existing models currently available globally.

It was applied in eleven cities in the state of São Paulo, Brazil, to prove the applicability and practical usage of the model, using the cities of Barueri, Campinas, Itapetininga, Presidente Prudente, Registro, São Caetano do Sul, Santos, Sorocaba, Suzano, Ubatuba, and Votorantim.

Also, this work seeks to offer theoretical and practical contributions to the extent that it brings reflections about innovations in ICT as instruments for increasing the organizational capacities of the public authorities at the local level for the management of cities and postulates a new concept for the term smart city, entering the multidisciplinary dialogue on the subject.

As stated by Muvuna *et al*. (2019), despite the research efforts, there is still no methodology capable of guiding all subsystems around an innovative city system or even fully evaluate a smart city. Many conceptual models have been proposed to accomplish this task.

Efforts such as Smart Cities Ranking (SCR) of Medium-sized Cities (Giffinger *et al*., 2007); Smart Cities Integrative Framework (Chourabi *et al*., 2012); Smart Cities Maturity Model (SCMM) a self-assessment tool provided by The Scottish Government and Scottish Cities Alliance (The Scottish Government, 2014); Networked Society City Index (Ericsson, 2014); Smart Cities Readiness Guide (Smart Cities Council, 2015); European Digital Cities Index Nesta (Bannerjee, 2016); Overview of key Performance

Indicators in Smart Sustainable Cities (ITU, 2016); The European Digital City Index (European Commission, 2017); The IESE Cities in Motion Index (Berrone & Ricart, 2018), proposed by Center for Globalization and Strategy and IESE Business School's Department of Strategy; Global Power City Index (Institute For Urban Strategies, 2018); The Smart City Strategy Index (Berger, 2019); The Lisbon Ranking for Smart Sustainable Cities (Akande *et al*. 2019); Smart Sustainable Cities Maturity Model (ITU 2019); The Global Cities Index (Kearney, 2020); Innovation City Index (Innovation Cities Program, 2021); The IMD Smart Cities Index (IMD Smart Cities Observatory, 2021; The Global Livability Survey (EIU - The Economist Intelligence Unit, 2021) and the Brazilian Sustainable Cities Maturity Model (Muniz *et al*. 2021) by the Brazilian Ministry of Science, Technology and Innovations (MCTI) have served to evaluate the most different perspectives of urban dynamics. These initiatives have allowed cities to equip themselves to ascertain their attractiveness within a geographical context, in addition to equipping themselves to carry out deeper analyses of their deficiencies and define action plans to improve their positions in the regional and global context.

However, little is held on the aspects that guide the foundation of the concept: extensive use of ICT to promote increased efficiency in public management, people's quality of life, and the operating conditions of organizations. This lower attention to ICT issues can be explained by institutional, legal, or even technological characteristics, updating, and technological complexity specific to the countries where these methods and techniques are developed, the USA and Europe, in particular. On a larger or smaller scale, these techniques for scouting the city's intelligence quotient work with a truly diverse range of demographic, socioeconomic, demographic and availability indicators of public services and infrastructure; many of them even use ISO 37120 and ISO 37122 standards as support for their developments. In all cases, they aim to support public managers and society to know, understand, plan and evaluate education aimed at improving the quality of life of people and developing appropriate business capacities and environments. However, despite the value that each of them can represent, they deal with the issues of appropriation and use of ICT in a generic way, not guiding public managers, particularly at the municipal level, on what technologies are needed, what aspects and functionalities should contemplate, how they should integrate and what impacts they cause as they undergo advances or setbacks. In this sense, the model showed being adequate to cover this gap.

In the field of theoretical contributions, the model proposed in this work seeks to complement the existing evaluation models, but with a specific focus on verifying the readiness and application of the ICT for the management of cities. The proposed model considers the correlation of public service versus applicable technology, complementing a gap in existing evaluative models and, at the same time, enabling the establishment of an evolutionary map of functionalities that can be met by the technologies as well as the expected interactions between these functionalities.

For the public administration, it is intended to contribute to the proposition of a model criticized and evaluated by the academy that serves as an evolutionary guide for the implementation of technological solutions aimed at the construction of smart cities, even envisioning the possibility of being used as a tool for collaborative comparison between cities, planning of procurement of goods and services of the ICT, support for the development of public policies and also as an instrument of communication and transparency with the different local or global social actors.

For the private sector, in particular for companies that develop technologies or services aimed the creation of smart cities, it seeks to contribute to the establishment of a practical application instrument which allows greater consistency in their own evaluation processes or provides companies that do not have this type of instrument with a tooling possibility. Likewise, it intends to serve as a tool capable of bringing together public authorities and private initiative around accepted concepts and applications that can serve to establish partnerships for the adoption and dissemination of innovations in ICT for the management of cities.

For society, it is intended that this work is an instrument capable of allowing initiatives and projects of intelligent cities to be monitored and evaluated in a standardized and exempt way from interests other than the interests of society itself.

To achieve the proposed objective, this article is organized into five sections. In addition to this introductory section, the second section provides a brief theoretical background on smart cities and some prospects of digital transformation in cities. The third section describes the proposed model. In the fourth section, the results obtained from the application of the model and discussions are presented. Finally, the fifth section is reserved for final considerations, including presenting limitations and proposals for future studies.

THEORETICAL BACKGROUND

For Storper (1997), the nature of the contemporary city can be qualified as a local or regional socio-economy, whose usefulness for the forces of global capitalism is precisely the set of specific, differentiated and localized social relations that occur in it. The strategies for the insertion of cities in the global scenario are becoming more intense, resulting in greater participation of local, regional and global actors, promoting an intensive exchange of products, services and ways of life (Huang; Leung; Shen, 2007). In this sense, cities play a fundamental role in the development of the regions where they are located, configuring itself as a historical process, which requires transformation in the social and economic bases, structural changes and, above all, a strategy built jointly among the various actors in the region (Corrêa; Silveira & Kist, 2019).

Recently, the discussions about the creation of smart cities and the adoption of technologies at the local government have become a constant. It involves divergent perspectives of evolution, sometimes with a democratic view of how information should be managed, sometimes with a more centralized and controlling view by the public authorities (Stone *et al*., 2019). It also involves risk appetite, security and privacy issues, financial constraints, regulations (Abdalla *et al*., 2019), beyond the aspects of identification and diagnosis of the status quo looking for opportunities to promote socio-economic development and increase resource efficiency (Bibri, 2019).

In fact, over time, many scholars have dedicated themselves to proposing concepts capable of expressing the meaning of the term smart city, as can be seen in the following Table 1:

Table 1 | Smart Cities Table of Concepts

Author	Definition of Smart City
Hall *et al*. (2000)	It monitors and integrates all operating conditions of all critical infrastructure of the city – roads, bridges, tunnels, railways and subways, ports, communications, water, energy, buildings -, optimizing its resources, planning preventive maintenance, monitoring safety aspects and maximizing services to citizens.
Komninos (2006)	A territory with a high capacity for learning and innovation, in which the creativity of its population, its institutions for the creation of knowledge, and its digital infrastructure for knowledge management and communication are built.
Giffinger *et al*. (2007)	It performs well and acts prospectively in the economy, people, governance, mobility, environment and living conditions, built on the intelligent combination of the interest and activities of conscious, independent and decision-making citizens. In addition, it seeks and identifies solutions that allow the modern city to improve the quality of services provided to citizens.
Kanter; Litow (2009)	It innovatively connects the physical and ICT infrastructure, efficiently and effectively, converging organizational, normative, social and technological aspects in order to improve the conditions of sustainability and quality of life of the population.
Harrison *et al*. (2010)	It connects physical infrastructure, ICT infrastructure, social infrastructure, and business infrastructure to leverage the city's collective intelligence.
Caragliu; Del Bo; Nijkamp (2011)	It has investments in human and social capital, in traditional (transport) and modern communication infrastructure (ICTs), fuels for sustainable economic growth and high quality of life, with effective management of natural resources, through participatory governance.
Nam; Pardo (2011a)	Infuses information into your physical infrastructure to improve conveniences, facilitate mobility, add efficiency, save energy, improve air and water quality, identify problems and fix them quickly, recover quickly from disasters, collect data to make better decisions, deploy resources effectively, and share data to enable collaboration across entities and domains.
Bakici; Almiral; Wareham (2012)	Intensive in high technology to connect people, information and elements of the city, using new technologies to create a more sustainable, 'green', innovative and competitive trade, and increasing quality of life.
Marsal-Llacuna; Colomer-Llinàs; Meléndez-Frigola (2015)	Improve urban performance by using data, information, and ICTs to provide more efficient services to citizens, monitor and optimize existing infrastructure, enhance collaboration between different economic actors, and encourage innovative business models in both the private and public sectors.

Although the concept of smart a city is still under construction (Muvuna *et al*., 2019), it has been used to characterize the cities that appropriate of the ICT and make extensive and intensive use of them with the objective to increase and improve their capabilities (Aina, 2017; Agbali *et al*., 2019) and that operate as systems of flows of information that can be managed to provide efficiency in several areas (Grossi; Meijer; Sargiacom, 2020). As argued by Costin and Eastman (2019), beyond the usual technologies and its usage, new emerging and disruptive technologies are rising to increase the capacities for city´s design and management. Smart cities should be able to automate both management and operational processes improving its organizational capabilities (Desouza; Flanery, 2013), to eliminate duplication in efforts and data through the full collaboration between organizational boundaries (Gil-Garcia; Pardo; Nam, 2015) supported by a comprehensive ICT architecture, with horizontal and vertical integration across various e-government initiatives (Yeh, 2017). This perspective may even include encouraging the co-creation of solutions with its citizens (Alexopoulos *et al*., 2019) that aim to promote the provision of better public services for improving the quality of life of people (Agbali *et al*., 2019).

For the purposes of this paper, it were considered the smart cities those that implement ICT to positively transform the standards of organization, learning, infrastructure management and provision of public services, promoting more efficient urban management practices for the benefit of social actors, guarding their historical vocations and cultural characteristics (Weiss, 2017).

The implementation of smart cities should be seen as a process of diagnosis, planning and permanent call to action, in which the harmonization between the physical world and the virtual world is constantly sought (Castro Neto; Rego, 2019), where ICT is a means to leverage and maintain this dynamic and always with seeking to expand access and efficiency and low costs in the provision of public services (Saxena, 2017). As such as ICT allow companies increase their competitiveness and performance capabilities (Molinillo; Japutra, 2017), ICT approaches and applicability in the context of city management create new opportunities for the development of the economy and society, especially in developing countries and poor communities (Alderete, 2019). In the context of smart cities, ICT have become part of the debate on urbanization and urban sustainability (Bibri; Krogstie, 2017). Smart cities are configuring a new form of evolution of cities, particularly when the notion of development based eminently on the urban planning that privileges the physical world begins to contemplate the virtual world, transforming the economy and the governance of a city into more effective managerial (Broccardo; Culasso; Mauro, 2019) and environmental practices (Battarra *et al*., 2016; Viale Pereira; Schuch De Azambuja, 2022).

People are living in a connected society where they can satisfy most needs of commercial or financial issues or even needs and desires of leisure and well-being, reflecting the eminence of the society of sensors (Weiss, 2019b). So, it is expected that public services are not immune to this digital transformation that is observed in society (Webster; Leleux, 2018). Increasingly defended as privileged spaces for intelligent sustainability, despite criticism about possible techno-utopian and neoliberal approaches to urban development (Martin; Evans; Karvonen, 2015), smart cities are conforming across the globe and appropriating digital innovations to generate gains in efficiency and integration of the different subsystems of the urban system (Marsal-Llacuna; Segal, 2017).

Closely to the smart cities creation, digital transformation in cities should be seen as an incremental, evolutionary, collaborative and constantly generating value process for stakeholders, the result of a long-term process in which progress and results must be evaluated and communicated clearly and transparently. Day to day, thanks to the internet penetration and the pervasiveness of digital technologies, cities can implement urban sustainability by replacing physical to virtual services (Bibri; Krogstie, 2017; Tomor *et al*., 2019) while citizens and companies act to stimulate the public sector to promote changes in the governance models aiming more efficiency (Pereira *et al*., 2018).

In the scenario of the digital transformation in the cities, digital solutions must be innovative with focus on sustainable socioeconomic development (Viale Pereira; Schuch De Azambuja, 2022), capable of realigning administrative and operational processes to reduce costs and create connections between actors, creating value for stakeholders and effective support for decision-making (Anthony Jnr, 2021) and, in this context, citizens should not be seen merely as users of some technological components, but as the center of the city´s digital transformation (Larrinaga *et al*., 2021). By creating a technological framework that is consistently planned and that primarily meets the interests of the city, which also includes its participation in social networks on issues involving the city, the public sector at the local government ends up enabling actors to incorporate data that can serve for the planning of actions (Abella *et al*., 2017), for the co-production of public policies and for innovative services to be developed and made available to and by these actors (Webster; Leleux, 2018).

Despite the passions that the use of high technologies may arouse, the introduction of the state-of-the-art technologies in each urban subsystem does not guarantee the existence of a smart city (Kanter; Litow, 2009). Cities more equipped with technologies are not necessarily better cities and the number of 'smart initiatives' launched by a municipality is not an indicator of the city's performance (Neirotti *et al*., 2014), and may even be seen as a 'marketing seal' used by large companies that have the technological and economic capacity to offer and implement projects of little use to citizens, but of great financial scale for suppliers of technologies and social and political exposure for public managers (Saba *et al*., 2020). Emerging technologies such as the internet of things, artificial intelligence, big data, georeferencing, and so sophisticated, comprehensive and integrated information systems, are generally associated with the concept of smart city. The vision of the smart city, however, should not lie only in the aspects that involve the latest generation technologies to the detriment of more elementary ones, which are also capable of generating value for society, and for the public administration itself at the local level.

METHOD: PROPOSED MODEL

The model of analysis is based on the concept that consider the city as a central system – smart city – to which specific primary subsystems (domains) are connected and to each of these primary subsystems, secondary subsystems are connected (dimensions). Thus, the domains and their respective dimensions represent the areas to be covered by technologies and information systems so that the municipal government can perform its obligations with the proper technological support, as shown in Table 2.

Table 2 | Domains and Dimensions of ICT Assessment Model for Cities Management

CO - Communication and Relationship with Citizens and Companies					
COIC Information and Interaction with Citizens	COIE Information and Interaction with Businesses	COIT Information and Interaction with Tourists	COIO Information and Interaction with Other Cities	CORS Collaboration and Social Networking	COOU Ombudsman
DU - Urban Dynamic Management		**SB - Essentials Services Management**		**IU - Urban Infrastructure Management**	
DUCC-Command & Control Center DUIE- Interagency Integrations DUGE-Georeferencing Systems DUSS-Monitors & Sensors Systems DUIT-Internet of Things DUBD-Analytics & Big Data		SBSD-Health SBED-Education SBSE-Public Safety SBRL-Waste SBMO-Mobility SBZP-Public Janitor		IUTT-Traffic & Transport IUEN-Energy & Public Lightning IUAG-Water IUMA-Environment IUEE-Public Buildings IUEP-Public Space	
SD - Socioeconomic Development Services Management		**SE - Electronic Services to Citizens and Businesses**		**IE - Innovation and Entrepreneurship Support**	
SDAS- Services and Social Actions SDMH-Housing & Social SDTU-Tourism SDCT-Culture SDEL-Sports and Leisure SDTR-Labor and Income		SEAI-Access to Public Services over the Internet SEDO-Official News, Legislation and Documents SECN-Negative Certificates SETP-Permissions and Permits SETT-Tax Transactions and Fees SERE-Disputes, Appeals and Agreements		IEIV-Public Access to High-Speed Internet IEDL-Internet Training IESI-Provision of Internet Services IEDS-Development of Solutions for the City IEPD-R&D Virtual Communities IEAD-Open Data	
AR – Administrative Resources Management					
ARAT Asset Management	ARAS Supply Management	ARRH Human Resources Management	ARCP Public Purchase Management	ARGP Project Management	ARIG Management Information System
PG – Planning and Governance					
PGPP Strategic Planning	PGGC Regulatory & Legal Compliance	PGGR Risks Management	PGFP Public Finance Management	PGCC Agreements and Consortia	PGSD Decision Support System
IT- Infrastructure and IT Management					
ITRC Wide Area Network (incl. Internet)	ITR Local Area Network	ITHC Hosting & Cloud Computing	ITAQ Enterprise & Technical Architecture	ITSI Information Security & Privacy	ITGT Governance & IT Services Management

Source: Own elaboration.

The model is embedded in an expert system named by urbeSys (Weiss, 2020) which includes all the evaluation criteria and the analysis algorithms of the networks formed between the information systems and technologies under evaluation.

Each dimension is evaluated according to specific criteria corresponding to the features and facilities expected for the technologies and information systems applicable to that given dimension. Each dimension is evaluated according to a scale of evaluation and readiness levels for each one, marked between 1 and 7, as described in Table 3. The selection of the point of the qualitative scale of each dimension is due to the best descriptive adequacy of the dimension level to the reality identified by the evaluated.

Table 3 | Readiness Levels of Technologies and Information Systems for Smart Cities

Level	Description
1 - Nonexistent	The city does not perform any activities or actions related to the dimension as defined in the model.
2 - Manual	The city carries out activities or actions related to the dimension, but does not use any computer support. Everything is done manually.
3 - Initial	The city carries out activities or actions related to the dimension using basic computer support, such as spreadsheets, etc. Does not make use of structured information systems.
4 - Elementary	In addition to basic computer support, it uses isolated applications created, having as main functionality the creation of basic registration. There is no exchange of data between systems.
5 - Automated	Information systems are used for support, but without integration capabilities with other systems. Features include *online transactions* and manual file exchange.
6 – Integrated	Information systems include online transactions and advanced features and automated integrations. Artificial Intelligence features can be identified.
7 - Advanced	Artificial Intelligence features are identified at this level as well as other advanced technologies such as *blockchain*.

Source: Own elaboration.

The first form of resolution of the model is by aggregating the results of an individual dimension around its respective domain, allowing the calculation of appropriate descriptive statistics and graphic demonstration. Ultimately, the demonstration presents the level of ICT readiness for city management, and the more a given domain approaches the maximum level – Level 7 – the more these technologies are ready for employment, with particularly good capabilities of intrinsic functionalities and interfaces with other features of other dimensions.

Once the position of the evaluation scale (from 1 to 7) for a given dimension is determined, there may be one or more possibilities of connecting with other features of other dimensions, thus forming a network. According to Figueiredo (2011), in a network free of scale as stated by Barabási & Albert, the degrees of vertices are nothing like each other because we can have vertices with degrees much higher than the average with non-negligible probability. In the specific case of the model, a network formed by the connections between the dimensions allows the evaluation of a given city to be performed with the application of complex network theory, in which the dimensions (nodes) and the connections formed between pairs of dimensions (edges) determine their dynamics and resolution. The application of this possibility of resolution results in a paradigmatic city named as 'urbeSys City' which results in an adjacency matrix resulting from 'A', square, static, directed, asymmetric, with 60 nodes (n = 60) and 205 edges (E = 410). This resulting matrix has density D equal to 0.1158, resulted from the application of expression D = 2E / n (n - 1).

The collection of data regarding the existence and availability of ICT (readiness) for the management of the city is the central pillar so that the research question can be answered adequately and fully validated by the model. Thus, some cities were selected to apply the evaluation model whose analyses and results are configured as proof of the proposed concept.

The choice of cities followed five criteria defined by the researcher, namely: i) cities in the state of São Paulo; ii) different from each other in terms of economic activity, geography and cultural aspects; iii) representativeness in the region where they are inserted; iv) mentioned as smart cities by research organizations or non-governmental organizations, by the media or by the local government itself; v) possibility of access of the researcher. Considering these criteria, eleven cities were chosen as characterized in the Table 4.

Table 4 | Assessed Cities

City	Metropolitan/ Administrative Region	Population in 2021	Average monthly salary of formal workers in 2020	GDP Per Capita (R$) in 2019	HDI-M in 2010	Respondent
Barueri	São Paulo	279.704	4,0	192.647	0,786	Secretary of Innovation and Technology
Campinas	Campinas	1.223.237	3,6	54.710	0,805	City IT Manager
Itapetininga	Sorocaba	167.106	2,1	29.883	0,763	City IT Manager
P. Prudente	P. Prudente (AR)	231.953	2,4	36.663	0,806	Secretary of Information Technology
Registro	Registro (AR)	56.463	2,2	37.160	0,754	Head of Development, Science and Tech
S Caetano Sul	São Paulo	85.062	3,1	162.763	0,891	Secretary of Innovation and Technology
Santos	Baixada Santista	433.991	3,2	52.509	0,840	City IT Manager
Sorocaba	Sorocaba	695.328	2,9	54.878	0,798	City IT Manager
Suzano	São Paulo	303.397	2,6	40.453	0,765	Secretary of Urban Planning
Ubatuba	Vale do Paraíba	92.819	2,0	26.241	0,751	City IT Manager
Votorantim	Sorocaba	124.468	2,6	27.816	0,720	City IT Manager

Source: IBGE available at https://cidades.ibge.gov.br/

To data collection, the urbeSys system was used by cities' ICT managers or cities managers. The managers did log into the system where they can assess each dimension of the assessment model. For each dimension, accordingly the ICT Assessment Model for Cities Management previously explained, a specific set of functionalities and usage of the technologies and/or information systems is presented, and the evaluator can choose the level that best represents the current situation of the city (self-evaluation). In total, 60 (sixty) dimensions are presented, and 7 (seven) levels of readiness is considered for each one.

RESULTS AND DISCUSSION

It was possible to identify which dimensions of the administration of the evaluated cities are better equipped with information systems and related technologies and which dimensions are capable of improvement or even development and compare the results obtained with the results of the city model urbeSys City through the application of the model, as presented in the Table 5.

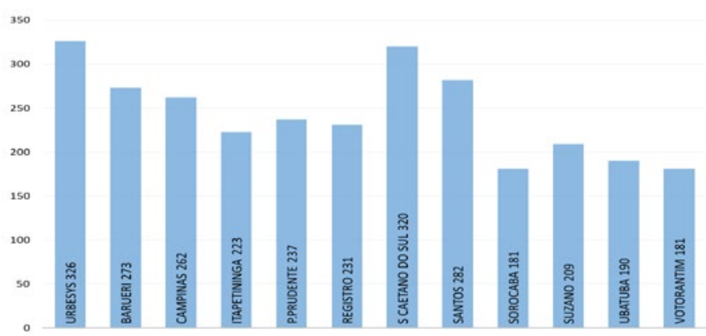
Table 5 | Summary of Results:: City urbeSys vs. Brazilian Cities

Dimension	City urbeSys	Barueri	Campinas	Itapetininga	P. Prudente	Registro	S. Caetano do Sul	Santos	Sorocaba	Suzano	Ubatuba	Votorantim
Domain :: IT - Infrastructure and IT Management												
ITRC-Wide Area Network (incl. Internet)	6	5	7	5	6	6	7	6	7	3	7	4
ITRL-Local Area Network	6	5	7	5	6	5	6	6	6	5	7	4
ITHC-Hosting & Cloud Computing	5	5	6	4	5	5	5	5	5	4	5	4
ITAQ-Enterprise & Technical Architecture	5	4	5	4	3	4	6	5	3	5	3	1
ITSI-Information Security & Privacy	5	4	5	4	4	4	6	5	4	5	4	4
ITGT-Governance & IT Services Management	5	4	4	4	4	3	6	5	4	3	3	3
Domain :: PG - Planning and Governance												
PGPP-Strategic Planning	6	4	5	5	5	4	5	5	1	3	4	6
PGGC-Regulatory & Legal Compliance	5	4	4	5	3	4	5	5	1	3	3	2
PGGR-Risks Management	6	4	4	1	5	4	5	5	1	3	1	2
PGFP-Public Finance Management	6	6	5	6	6	5	6	5	1	4	5	5
PGCC- Agreements and Consortia	5	4	5	6	5	5	5	4	1	3	3	3
PGSD-Decision Support System	6	5	4	3	4	3	5	5	1	3	1	1
Domain :: AR - Administrative Resources Management												
ARAT-Asset Management	6	4	5	5	4	4	5	5	5	3	5	5
ARAS-Supply Management	6	4	4	5	4	4	5	5	5	3	5	5
ARRH-Human Resources Management	7	5	5	4	4	5	5	5	1	4	5	4
ARCP-Public Purchase Management	6	6	5	6	5	5	6	5	5	4	4	4
ARGP-Project Management	7	4	3	4	3	3	4	4	4	3	3	1
ARIG-Management Information System	6	5	4	3	4	3	4	5	6	3	1	1
Domain :: DU - Urban Dynamic Management												
DUCC-Command & Control Center	5	5	5	2	3	2	5	6	1	4	1	1
DUIE- Interagency Integrations	5	3	2	2	3	2	5	6	1	1	2	2
DUGE-Georeferencing Systems	5	6	5	3	2	4	5	6	4	5	3	1
DUSS-Monitors & Sensors Systems	5	5	4	1	3	1	6	5	6	3	1	3
DUIT-Internet of Things	5	4	2	1	3	3	6	4	4	1	1	1
DUBD-Analytics & Big Data	5	5	3	1	3	3	4	4	4	2	1	2

Domain :: SB - Essentials Services Management												
SBSD-Health Management	6	6	5	4	5	4	6	5	1	3	3	3
SBED-Education Management	6	6	4	4	5	4	6	5	1	4	3	3
SBSE-Public Safety Management	5	5	5	4	3	5	7	6	1	5	4	4
SBRL-Waste Management	5	4	3	3	3	3	5	4	1	3	1	3
SBMO-Mobility Management	5	4	4	3	4	4	6	4	1	4	1	3
SBZP-Public Janitor Management	6	5	5	3	6	6	5	5	1	3	2	4
Domain :: IU - Urban Infrastructure Management												
IUTT-Traffic & Transport Management	4	4	4	3	3	3	5	5	1	2	2	3
IUEN-Energy & Public Lightning Management	6	4	2	4	3	3	6	4	1	3	4	3
IUAG-Water Management	5	4	6	4	3	3	6	4	1	3	4	4
IUMA-Environment Management	5	4	4	3	3	3	5	4	3	3	2	3
IUEE-Public Buildings Management	5	5	3	3	4	3	4	3	1	3	1	3
IUEP-Public Space Management	5	4	3	3	3	3	5	3	1	3	1	3
Domain :: SD - Socioeconomic Development Services Management												
SDAS-Management of Services and Social Actions	6	4	4	4	4	4	5	4	1	3	3	3
SDMH-Housing & Social Management	5	4	4	3	4	3	4	4	1	3	3	3
SDTU-Tourism Management	4	3	3	2	3	3	3	5	3	3	3	3
SDCT-Culture Management	4	5	5	4	3	4	6	5	4	3	3	3
SDEL-Sports and Leisure Management	4	4	3	3	3	3	5	4	1	3	3	3
SDTR-Labor and Income Management	5	5	4	3	3	3	4	4	4	3	1	4
Domain :: SE - Electronic Services to Citizens and Businesses												
SEAI-Access to Public Services over the Internet	6	6	6	5	6	5	7	6	6	5	6	5
SEDO-Official News, Legislation and Documents	6	6	7	5	5	5	7	5	6	5	5	5
SECN-Negative Certificates	6	5	4	6	5	6	6	6	1	6	6	6
SETP-Permissions and Permits	6	5	4	6	5	5	6	6	5	6	4	4
SETT-Tax Transactions and Fees	6	5	5	6	5	6	5	6	1	5	5	6
SERE-Disputes, Appeals and Agreements	5	3	4	4	4	4	4	3	1	3	5	2
Domain :: IE - Innovation and Entrepreneurship Support												
IEIV-Public Access to High-Speed Internet	6	4	5	3	5	3	7	5	6	2	5	3
IEDL-Internet Training	5	3	4	2	2	3	7	3	5	2	2	1
IESI-Provision of Internet Services	5	3	5	4	5	4	5	3	1	4	4	2
IEDS-Development of Solutions for the City	5	3	5	3	4	3	4	3	3	3	1	3
IEPD-R&D Virtual Communities	5	3	3	2	2	3	7	3	3	2	1	1
IEAD-Open Data	4	5	4	4	4	4	4	4	4	4	1	1
Domain :: CO - Communication and Relationship with Citizens and Companies												
COIC-Information and Interaction with Citizens	6	6	5	4	5	4	7	5	6	5	4	4
COIE-Information and Interaction with Businesses	6	6	5	4	5	5	7	6	6	4	5	1
COIT-Information and Interaction with Tourists	7	6	3	3	3	3	3	6	6	4	3	3
COIO-Information and Interaction with Other Cities	6	3	3	3	2	3	4	3	1	3	2	1
CORS-Collaboration and Social Networking	6	5	5	4	5	4	5	5	5	5	3	5
COOU-Ombudsman	5	6	6	6	3	6	5	5	6	4	6	1

The total score of the cities, the result of the individual evaluations of the dimensions, can be verified through the graph characterized in Figure 1.

Figure 1 | Totalization of dimensions. Source:



Own elaboration

The highlight is for the city of São Caetano do Sul that presented the highest total score and did not present scores higher than '3' for only two dimensions. It is followed by the city of Santos that presented good levels of readiness for most dimensions, except for the dimensions of the Domain IE-Support for Innovation and Entrepreneurship, especially with the dimensions IEDL-Internet Training, IESI-Provision of Internet Services, IEDS-Development of Solutions for the City and IEPD-Virtual Communities of R&D.

The consolidation of the evaluations of the dimensions around their respective domains allows verifying which domains are with the best conditions of support of technologies so that they are performed satisfactorily, as can be observed through Table 6, highlighting which three cities present the best evaluations according to the domains and compared to the city urbeSys.

Table 6 | Consolidation by Domains

Domains	City urbeSys	Barueri	Campinas	Itapetininga	P. Prudente	Registro	S. Caetano do Sul	Santos	Sorocaba	Suzano	Ubatuba	Votorantim
IT-Infrastructure and IT Management	32	27	34	26	28	27	36	32	29	25	29	20
PG-Planning and Governance	34	27	27	26	28	25	31	29	6	19	17	19
AR-Administrative Resources Management	38	28	26	27	24	24	29	29	26	20	23	20
DU-Urban Dynamic Management	30	28	21	10	17	15	31	31	20	16	9	10
SB-Essentials Services Management	33	30	26	21	26	26	35	29	6	22	14	20
IU-Urban Infrastructure Management	30	25	22	20	19	18	31	23	8	17	14	19
SD- Socioeconomic Dev Services Management	28	25	23	19	20	20	27	26	14	18	16	19
SE-Electronic Services to Citizens and Businesses	35	30	30	32	30	31	35	32	20	30	31	28
IE-Innovation and Entrepreneurship Support	30	21	26	18	22	20	34	21	22	17	14	11
CO- Comm and Relations with Citizens and Companies	36	32	27	24	23	25	31	30	30	25	23	15

Source: Own elaboration.

Furthermore, from the evaluations of the dimensions through the application of the model, it is possible to determine some statistical indicators and in particular, the characteristics of the networks formed by the existing functionalities in the systems and technologies adopted in the cities. As shown in Table 7, São Caetano do Sul, Santos and Barueri were the cities that presented the highest amounts of edges and consequently with the highest densities of networks, representing, respectively, 77%, 63%, and 56% proximity to the city urbeSys .

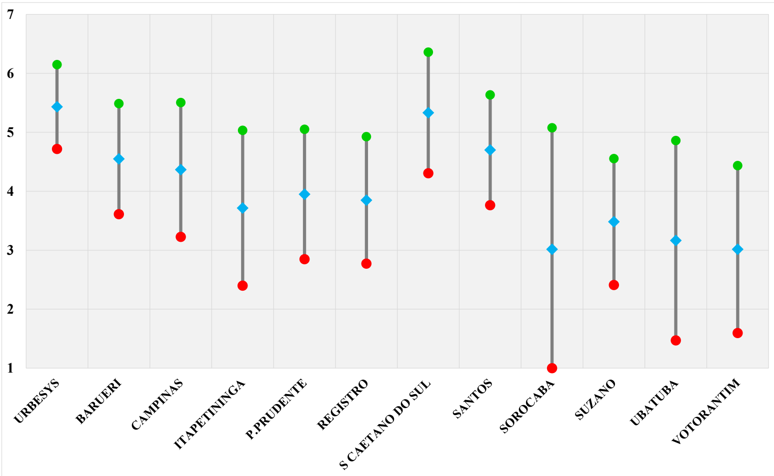
Table 7 | Statistics and Network Results

	City urbeSys	Barueri	Campinas	Itapetininga	P. Prudente	Registro	S. Caetano do Sul	Santos	Sorocaba	Suzano	Ubatuba	Votorantim
Total	326	**273**	262	223	237	231	**320**	**282**	181	209	190	181
Mean	5,43	**4,55**	4,37	3,72	3,95	3,85	**5,33**	**4,70**	3,02	3,48	3,17	3,02
Standard Deviation	0,72	**0,94**	1,14	1,32	1,10	1,08	**1,03**	**0,94**	2,06	1,07	1,69	1,42
Min	4,72	**3,61**	3,23	2,40	2,85	2,77	**4,31**	**3,76**	1,00	2,41	1,47	1,60
Max	6,15	**5,49**	5,51	5,03	5,05	4,93	**6,36**	**5,64**	5,08	4,56	4,86	4,44
Edges - Current	205	**115**	96	73	76	60	**158**	**129**	64	37	44	34
Density - Current	0,116	**0,065**	0,054	0,041	0,043	0,034	**0,089**	**0,073**	0,036	0,021	0,025	0,019
Proximity - Current	100%	**56%**	47%	36%	37%	29%	**77%**	**63%**	31%	18%	21%	17%
Edges - Goal	253	**191**	172	124	146	134	**229**	**202**	89	106	90	83
Density - Goal	0,143	**0,108**	0,097	0,070	0,082	0,076	**0,129**	**0,114**	0,050	0,060	0,051	0,047
Proximity - Goal	100%	**75%**	68%	49%	58%	53%	**91%**	**80%**	35%	42%	36%	33%

Source: Own elaboration.

These statistical characteristics of cities can also be observed in the graph characterized by Figure 2. Through this figure, it is possible to observe which cities have the best way of service and convergence of information systems and technologies related to the city model urbeSys.

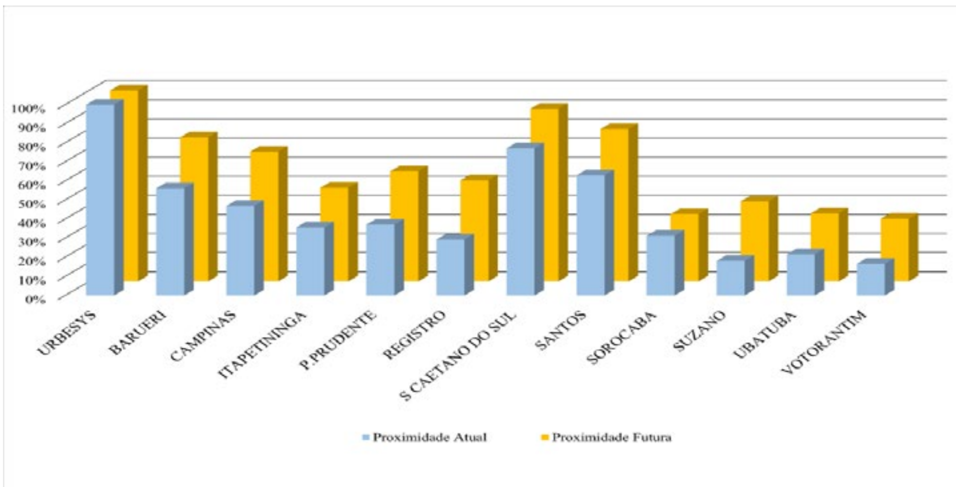
Figure 2 | Totalization of Dimensions.



Source: Own elaboration

Sorocaba and Ubatuba present a significant distance from the average, representing those dimensions are not part of the city management practice or the existence of dimensions that are not minimally assisted by information systems suitable for its support. The characteristics of the evaluative model also allow the projection of the proximity of a given city to the city urbeSys Model if specific improvements are made in certain dimensions. The graph characterized by Figure 3 shows the current and the projected situation in terms of the proximity of the networks of the cities to the model city.

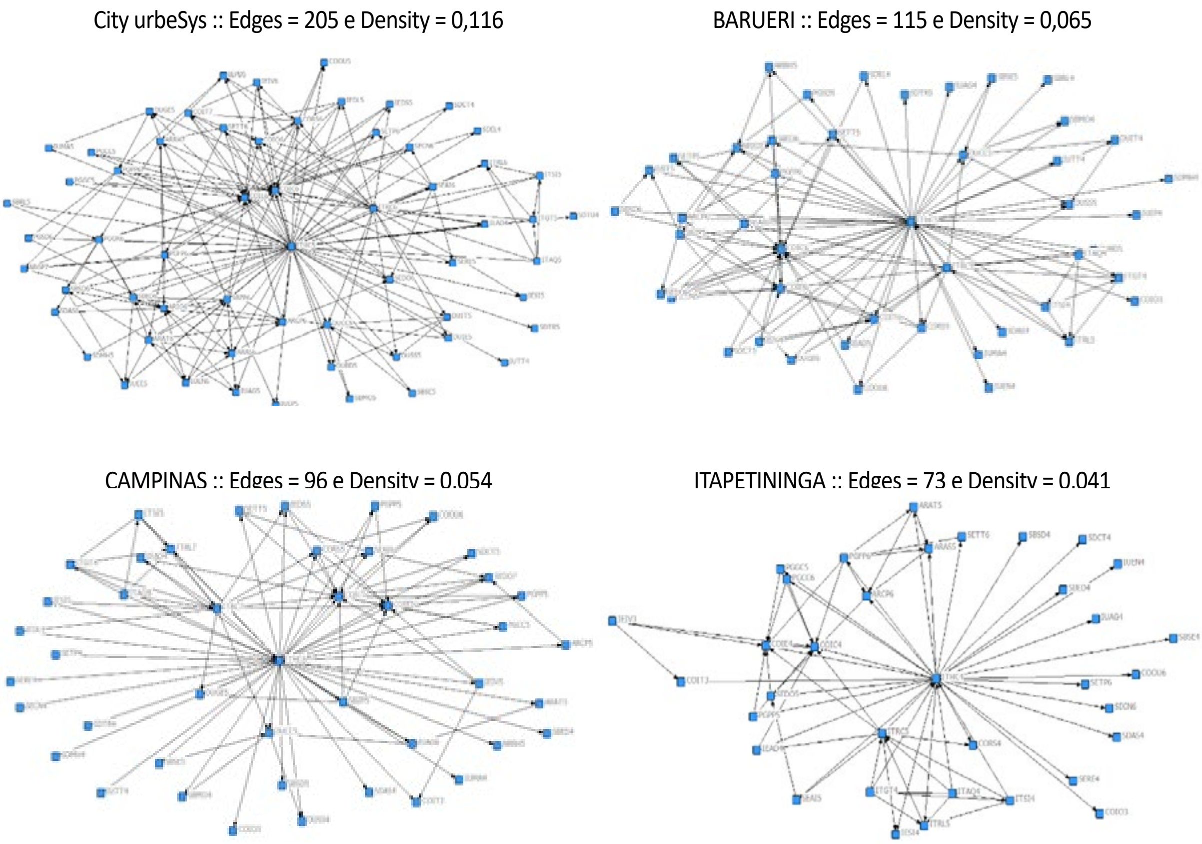
Figure 3 | Proximity of the Current and Future Networks to the city urbeSys model.



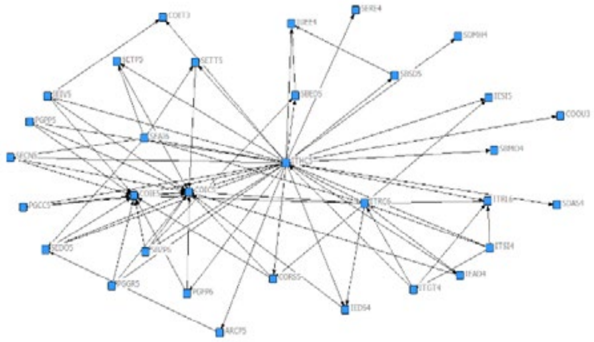
Source: Own elaboration

The consolidation of the dimensions around the domains and the respective network of city connections urbeSys model represent the basis of comparison for the cities entered in the evaluation model. The graphical representation of the network was drawn by the use of UCINET software (Borgatti, Everett; Freeman, 2002; Auber *et al*., 2004).As mentioned at the proper time, total edges represent the interoperability capabilities between information systems and related technologies. The more the evaluated city approaches the city model urbeSys (total edges equal to 205 that illustrate all interactions between dimensions), the more will be its integrated systems, and fewer digital silos can be identified. The demonstration of the results of the domains and networks can be observed in Figure 4.

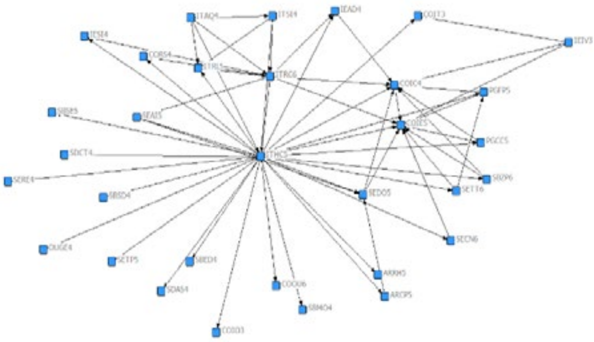
Figure 4 | Results of The Domains and Network of Connections of assessed cities.



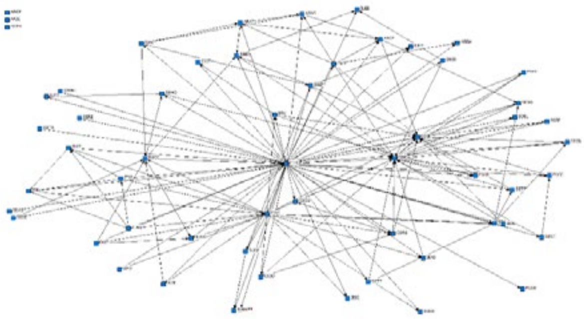
PRESIDENTE PRUDENTE :: Edges = 76 e Density = 0.043



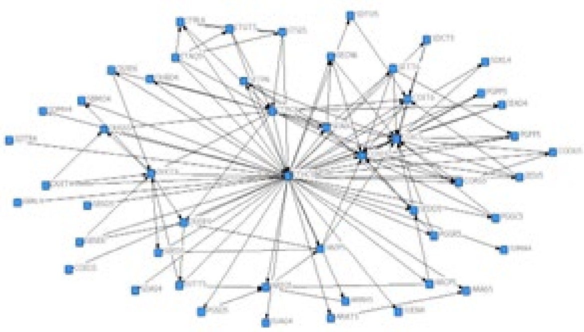
REGISTRO :: Edges = 60 e Density = 0.034



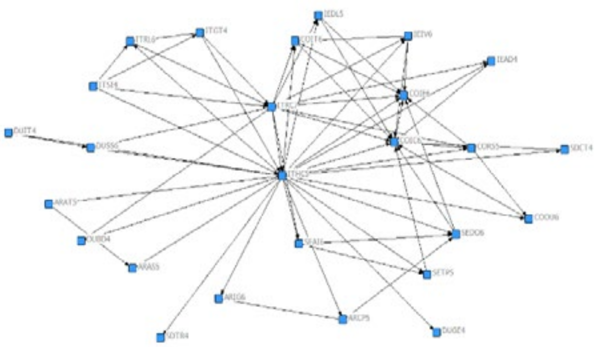
SÃO CAETANO DO SUL :: Edges = 158 e Density = 0,089



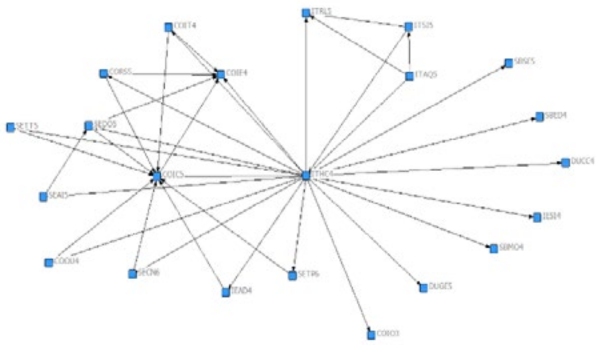
SANTOS :: Edges = 129 e Density = 0,073



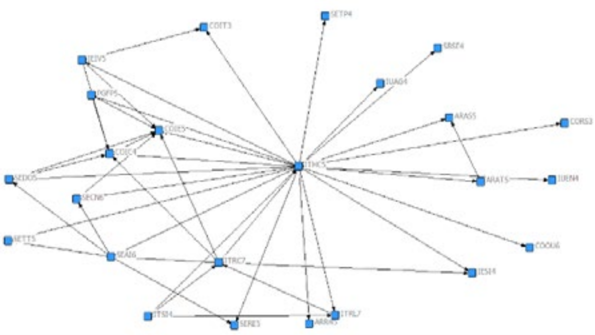
SOROCABA :: Edges = 64 e Density = 0,036



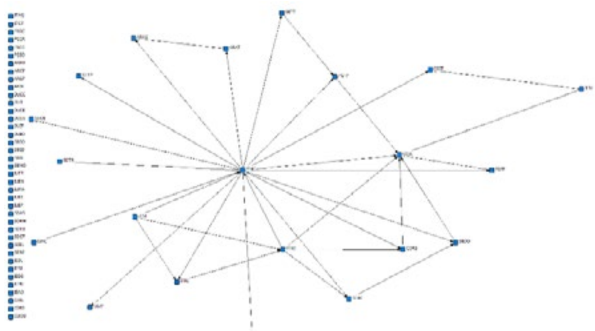
SUZANO :: Edges = 37 e Density = 0,021



UBATUBA :: Edges = 44 e Density = 0,025



VOTORANTIM :: Edges = 34 e Density = 0,019



Source: Own elaboration

DISCUSSION

As state by Gil-Garcia, Pardo and Nam (2015), the creation of smart cities is the result of a process that goes through the understanding of the reality of each ecosystem, its needs and demands. By mapping ICT in their characteristics of availability and readiness for the tasks for which they are intended; , by verifying the conditions that may or may not determine the application of these technologies, on what scale and with what expected socioeconomic outcomes; and also, by the constant training and information of public servants and society, cities can entry consistently into the track of the smart cities. In smart cities, technologies must be used in an innovative and inclusive way to inform, engage and empower society, creating a virtuous cycle of teaching-learning and increasing the capabilities of public administration. The ICT employed for smarter cities management should cover all aspects of urban dynamics (Kanter; Litow, 2009) and operate in an integrated manner focused on urban development and quality of life, leadership in business environment, social and digital inclusion, e-government, governance efficiency, incentive to creative and high-tech industries and human capital for sustainable urban development (Giffinger *et al*., 2007).

The analysis and demonstration of the capabilities provided by the model allow the individual measurement of the city regarding the use of ICT resources for each of the dimensions and the possibility of comparison with a model reference city urbeSys, idealized from the theoretical and empirical propositions of researchers and ICT industry, and also the comparison between cities.

In the case of the cities analyzed, when looking at the results provided by the model, dimension by dimension, it is possible to observe that the dimensions of the SB-Essentials Services Management, IU-Urban Infrastructure Management and SD-Socioeconomic Development Services Management domains need greater focus and investment capacity, since in most cases the technologies and systems employed in areas such as health, education, public buildings and others show low level of existence, modernity or even integration.

The results show that most dimensions are framed between levels 3 - Initial (The city conducts activities or actions related to the dimension using basic computer support, such as spreadsheets, etc. Does not make use of structured information systems.) and 4 - Elementary (In addition to basic computer support, it uses isolated applications created, having as main functionality the creation of basic registration. There is no exchange of data between systems). Thus, any investments in technologies like internet of things or artificial intelligence are welcome since if the basics have been done in favor of generating value for the citizens. Possibilities as simple as monitoring a child's school life, scheduling a medical appointment in the public health system or even requesting an official document without having to go to a personal service center at the city hall could be seen significative valuable for them.

The application of the model also allowed the establishment of comparations between cities. These comparisons allow us to visualize, in a consolidated way, the results of the dimensions and, consequently, of the domains of each city, allowing the identification of areas with potential for improvement for a given city compared to other cities. The comparative demonstration presents the direct score measured by each city, the score of each domain, the comparative measurement between the city of each dimension and the comparison of the results of the measures of centrality and adherence to the evaluation model proposed in this study.

Information systems and related technologies employed in the management of cities should function as a robust and integrated system derived from a comprehensive, scalable, and interoperable architecture, serving all the domains and dimensions of cities, guarding their characteristics and unique needs of local society, following the concept of smart city which has been adopted to support this paper (Weiss, 2017). Actually, cities should be aware the simple use of state-of-the-art technologies does not guarantee the elevation of a city to the level of a smart city not even improving people's quality of life: emerging technologies should not be adopted to the detriment of technologies more applicable to the management of the city as a whole. Not only emerging technologies as such internet of things or big data or even the artificial intelligence, but even the most elementary technologies such integrated information systems do health or education management must be employed in so that the vision of the smart city is realized. It is expected that the smart city will therefore be able to enable the proper support of ICT to the different subsystems that form the urban system. The proliferation of technologies in the urban environment does not guarantee the 'intelligence of the city' and, therefore, attention must always be focused on cities not becoming deposits of sensors without value generation to the citizens and companies or that technologies are implemented in such a complex way that requires care that cannot be minimally done by public agents and even maintained over the time, as proposed by Neirotti *et al*. (2014).

Following the perspective of Viale Pereira and Schuch De Azambuja (2022), digital transformation should not be seen yet another buzzword but as a challenge, a force, and, above all, an opportunity for cities to achieve the capabilities they need to succeed in highly dynamic environments where any change has immediate effects on society. The perspective of digital transformation of cities should cover all the various aspects of urban dynamics in an integrated way and as far as possible should also be integrated to the state and national aspects. The strategy should aim at building capabilities to fully harness the possibilities and opportunities of innovative technologies and their impacts in a faster, better and more innovative way. Digital transformation is closely related to the reinvention of organizations around people's needs through digital technologies, creating new opportunities for business organizations, business generation in the private initiative, and efficient service to citizens' demands for the public sector.

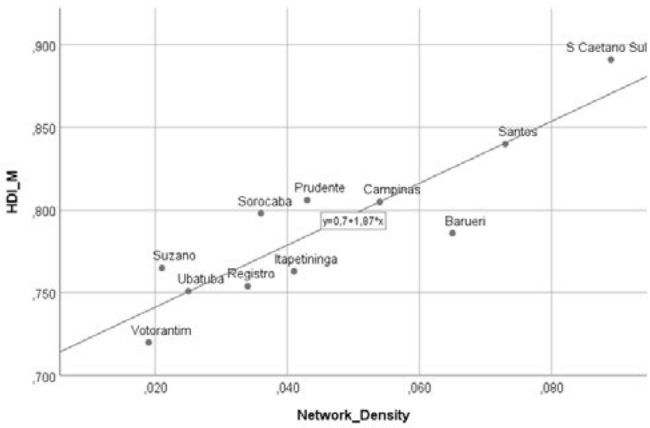
To capitalize on the opportunities brought by digital transformation, public and private organizations must be ready to adjust their operations for this new business environment properly. In other words, to differentiate itself through digital technologies it is necessary to build and maintain the right organizational capabilities, infrastructures, and culture. Cities can develop these conditions organically, at sufficient scale and speeds, consistent with their local and global challenges. This should be one of the reasons why cities, when seeking to acquire digital assets, should also seek skills and talents to maintain and perfect them. Cities need wider exposure to the winds that are in favor of digital technology, and therefore digital should be the predominant focus of their service delivery and revenue-generating activity.

In public administration, particularly in the cities administration, it represents a significant challenge. The provision of efficient public services is essential for the development of society, but many cities face essential difficulties in transforming the way their services are delivered. Effective and transparent coordination of stakeholders, despite political-party issues, strategic alignment and correct identification of real technology needs for more efficient operationalization of services are aspects that carry a certain complexity and need to be managed so that transformation initiatives can be considered successful. The effective digital transformation in (smart) cities should not be limited to the use of sensors or the distribution of endless amounts of applications that, in not uncommon situations, hold little or nothing of interoperability and eventually only show and reinforce digital silos or political and partisan divisions. The technologies and information systems employed in the management of cities and in urban dynamics must behave as a robust and integrated system – a system of subsystems – derived from a comprehensive, scalable, and interoperable architecture, meeting all the domains and dimensions of cities, guarding their characteristics and the unique needs of local society.

Finally, one aspect to be considered is precisely the possibility of establishing relationships between socioeconomic indicators and the density of networks formed by the connections between the dimensions defined in the model. One possibility of analysis is the application of the Pearson Correlation Coefficient. According to Hair *et al*. (2014), Pearson Correlation Coefficient (ρ) is a dimensionless measure that determines a linear relation between two variables that can vary from -1 (perfect negative linear relation) to +1 (perfect positive linear relation) and it is used for those who seek to verify whether one measure is related to the other, that is, whether they are connected. It indeed cannot be said that there is a cause-and-effect relationship between the variables. However, it is possible to affirm that the Human Development Index (HDI) of Municipalities and Network Density are strongly correlated, resulting in ρ = 0.893, as shown in Figure 5.

Figure 5 | Results of The Domains and Network of Connections of cities

City	HDI-M	Network Density
Barueri	0,786	0,065
Campinas	0,805	0,054
Itapetininga	0,763	0,041
Prudente	0,806	0,043
Registro	0,754	0,034
S Caetano Sul	0,891	0,089
Santos	0,840	0,073
Sorocaba	0,798	0,036
Suzano	0,765	0,021
Ubatuba	0,751	0,025
Votorantim	0,720	0,019
Pearson Correlation Coefficient		0,893



Source: Own elaboration

CONCLUSIONS

This article aimed to propose a model of assessment and analysis of readiness and applicability of ICT for city management. To prove the applicability and practical usage of the model, it was applied in eleven Brazilian cities, in the state of São Paulo, through an expert system named by urbeSys which includes all the evaluation criteria and the analysis algorithms of the networks formed between the information systems and technologies under evaluation. The assessed cities were Barueri, Campinas, Itapetininga, Presidente Prudente, Registro, São Caetano do Sul, Santos, Sorocaba, Suzano, Ubatuba, and Votorantim.

This ICT model of assessment and analysis of readiness and applicability of ICT for city management embedded in the urbeSys System represents an innovation in the context of methodologies – procedures and tools - for investigating the foundations of smart cities and aims to cover a gap identified in existing evaluation models. It focuses on the functional aspects that information systems must contain minimally to promote the foundations for digital transformation in smart cities. In addition, the proposed evaluation model proved useful for: i) to further promote ICT related to city management in terms of expected functionalities and data integration and exchange requirements, in order to promote a holistic and dependency view between domains and dimensions of city management; (ii) to promote the creation of an evaluation and evolving plan for the implementation of ICT in the management of cities, considering the increase of technological functionalities necessary for each dimension of urban management and the necessary integrations between the dimensions of the same domain or other domains; iii) support the planning of ICT procurement; (iv) support the development of public policies on the adoption and implementation of ICT in cities; v) enable the identification and management of risks inherent to the design, execution and measurement of results of ICT projects by the public authorities at the local level; vi) enable governments, non-governmental organizations, citizens, companies and other actors interested in managing cities with a tool capable of identifying, evaluating and designing the possibilities of using ICT to increase efficiency in city management aiming at the implementation of smart cities; vii) enable collaborative comparison between cities.

The capabilities of analysis and demonstration provided by the model allow the individual measurement of the city regarding the use of ICT resources and the possibility of comparisons with a reference city of the model urbeSys, idealized from the theoretical and empirical propositions of researchers and ICT industry, and the comparison between cities.

Because it is an exploratory study, the presence of subjectivity in the responses of representatives of the cities studied by the urbeSys model is an aspect to be considered as a limitation of the study. Another potential limitation to be considered deals with the number of cities submitted to the model. Regarding the evaluation model, it particularly considers the view of the public authorities on the readiness of its ICTs. Therefore, statistical aspects and acceptance and use by social actors were not considered for the purposes of this work, as well as possible correlations and extrapolations to any other indices or indicators related to public management, particularly at the local level.

It is recommended that the fields of application of the model be expanded, especially seeking other geographical realities. The expansion of the scope of application of the proposed evaluation model may constitute a relevant contribution not only to the consolidation of the model, but also to the expansion of the reasons for the development of smart cities. Likewise, establish other relationships between the data obtained using the model and possible indicators of the use of information and communication technologies made available by official bodies.

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