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The use of ISO 37122 as standard for assessing the maturity level of a smart city

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Abstract*—Existing evaluation models of maturity of smart cities are diversified, and for this reason there is no exact model for this type of assessment. In this sense, it becomes relevant the need for the compression of a maturity model as it is highlighted in the literature. The goal of this article is to present the result of a literature review that was made to identify models of maturity evaluation responsible for measuring the smartness of a city. Results portray the comparison of the evaluation models found, indicating the main features related to their complexities and implantation proposal. In addition, we identified the optimized model that could enable initiatives maturation to promote smart cities.*

***Keywords*—Smart Cities, Models, Maturity.**

I. INTRODUCTION

The emergence of the concept of smart cities brought about several indexes and indicators, created to measure the potential of cities, as well as neighborhoods and small localities, with the purpose of developing maturity models to classify these locations [1]. Smart cities monitor and integrate operational conditions of an infrastructure that uses Information and Communication Technologies (ICTs) to innovate the essential services management model [2,3,4,5,6,7].

The term "smart city" refers more to a skill than just focusing on its aspects, if it is necessary to identify certain characteristics possible or not in relation to the domains for evaluation of a smart city. Thus, it is considered that the term smart city is used in a holistic way, varying from cities with high use of TICs, even in relation to cities whose education or intelligence of its inhabitants is recognized.In the literature there are six domains of activities that are described as the main characteristics that conceptualize intelligent cities (see Fig 1).

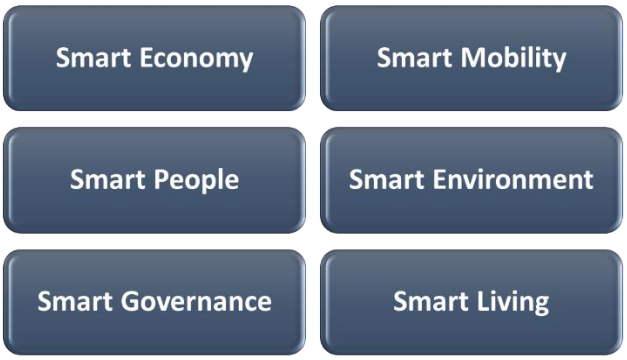

Fig. 1: Major domains of a smart city. Source: Authors.

In this context, there is great variety of classification indicators, since there are several perspectives on how cities can be classified, viewed and evaluated by different social actors understood as companies, academics, political leaders and the population in general. Most indicators used do not follow a pattern [8].

Not always a solution or standard apply in the same way to more than one location, since each region has its specific characteristics. Thus, in order to measure the performance of a smart city, the classification attribute must be decomposed into indicators, so that cities will be able to evaluate their performance based on their reality and, consequently, adopt the best solutions according to their own demands [9]].

It is observed that the perception of Smart Cities is wide due to the existence of several definitions for such, but it is not easy to know if a city is indeed smart and what methods are adopted to measure if a city can receive such status. Among the existing models, ISO 37122 is a standard for smart cities, presenting a synthesis of ideas pointing out strengths and weaknesses of each one.

The maturity models found in the literature present features and domains. Thus, ISO 37122 was used as a starting point, thus relating the main characteristics from the perspective of the main domains of a smart city as discussed in Fig 1 [1]. The goal of this article is to present the results of the literature review of the evaluation

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models applied in the measurement of smart cities. We describe these evaluation models in a comparative study, indicating their main authors and, as a result, we describe the model that results in the best adaptation both as application and usability.

II. MATERIALS AND METHODS

To reach our goal, a literature review was carried out between May and November of 2018, based on periodicals of scientific articles selected from the following databases: Google, Google Scholar, IEEE Explore, Scielo, Bon, Mendeley, Publish or Perish and Researchgate. We have used key words in Portuguese language like cidades inteligentes; maturidade; metodologias; modelos de maturidade e níveis de classificação, as well as their English correspondents (smart cities; maturity, methodologies; maturity models and classification levels), used in the context of smart cities, as to make bibliographic review better grounded. Regarding the search for digital archives, the selection included both national and international articles, with dates varying between 2000 and 2018. Studies that reported the use of other analysis modalities that did not include indices, models and maturity were excluded from this review. Thus, of the 168 articles found, 23 met research requirements.

Immediately afterwards, we sought to study and understand the main parameters and form of application used in the studies found, being categorized the following models based on their domains of applicability.

GIFFINGER-BASED MODEL

They were developed in medium-sized European cities, where dimensions, characteristics, factors and indicators were defined to measure a smart city, existing a hierarchical structure for the analysis of a city, thus defining the pillar of smart cities. Its main areas are: economy, people, governance, mobility, environment and life [1].

SMART CITY MATURITY MODEL (SCMM)

Developed in India in order to help a region of the country assess its technology readiness and implement a solution that is uniquely aligned with its resources and capabilities. The evaluation structure proposed by [9] positions itself in a city in the developmental trajectory based on its physical, social and technological infrastructure. Model [9] defines that the solution of a smart city must be only aligned with the state's social and infrastructural development to obtain greater benefits. They use governance, technology, transportation, energy, environment, water, health, safety and housing as their main domains.

BRAZILIAN SCMM MODEL

Such a model is appropriate to Brazilian realities, being quite simple and limited, with interesting application in places that are making their first steps in the smart city's movement. They use education, governance, technology, transportation, energy, environment, water, health and housing as main domains [8].

WCCD CERTIFICATION MODEL BASED ON ISO 37120

It aims at the accreditation of a city to be smart through indicators adopted in ISO 37120. The evaluation is done through a web platform called WCCD (World Council on City Data), available to any city in the world interested in taking the test to obtain certification. They use the following domains: main economy, solid finance, education, governance, telecommunications and innovation, transport, energy, environment, waste, urban planning, sewage, water and sanitation, incident and emergency response, health, recreation, safety and housing [12].

TECHNOLOGY MATURITY MODEL - TMM

It understands that a city becomes smart through a gradual process, in which the final intention is to reach an optimum level in the use of technological resources. They use education, governance, transport, energy, water and health as their main domains [13].

IDC - GOVER MODEL

It identifies the main measures, results and actions required for cities to effectively walk through the stages and progress towards the long-term goal of becoming a smart city. They use strategy, culture, processes and technology / data as main domains [14].

SMART CITY FOR ALL MODEL - SM4A

It is considered the newest maturity model, still in development stage. It aims to help cities to clearly assess their progress towards accessibility of ICTs and digital inclusion. They use strategy, culture, governance and technology / data as main domains [15].

URBAN SYSTEMS / RCSC MODEL - RANKING CONNECTED SMART CITY

It is a Brazilian model that assesses the development potential of Brazilian cities considering smartness, connection and sustainability. They useeconomy, education, entrepreneurship, governance, technology and innovation, mobility, energy, environment, urbanism, health and safety as major domains [16].

ESC MODEL - EUROPEAN SMART CITIES

It is a European index developed to verify and evaluate the performance of smart cities. In this model a methodology was developed to verify cities' performance through a digital platform, verifying the performance of European cities, which does not go so far as to classify them as more or less smart, but that allows to obtain indicators about and / or make a comparison between

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them, through information available on a website. They use as key domains economy, smart people, governance, mobility, environment and lifestyle [17].

SCIP MODEL - SMART CITY INDEX PORTUGAL

It is a study developed in order to allow the comparison of the performance of 36 Portuguese cities. The methodology of this study integrates 5 dimensions: governance; innovation; sustainability; quality of life and connectivity. They use governance, innovation, connectivity and quality of life as key domains [18].

RBCIH MODEL - BRAZILIAN NETWORK OF SMART AND HUMAN CITIES

This model was created by FNP - National Front of Mayors in 2013, focusing on cities with approximately 80,000 inhabitants. The idea behind RBCIH creation was between the partner company SATOR and Urban System, in the possibility of exchanging experiences and information with a view to fostering the development of cities for the economy of the 21st century. Based on the concept of smart cities, through a bottom-up approach, they use as key domains anthropology, governance, technology, architecture / urbanism and security [19].

NBR ISO 37120 MODEL - SUSTAINABLE DEVELOPMENT OF COMMUNITIES

This model uses 17 key domains to evaluate a smart city: economy, finance, education, governance, telecommunication and innovation, transportation, energy, environment, solid waste, urban planning, sewage, water and sanitation, response to incidents and emergencies, health, recreation, safety and housing. The norm takes sustainability as its general principle.The norm takes the sustentabilidade as its general principle. The measurement of performance occurs through 100 indicators that are typified as essential and of support, in the ratio of 54 and 46, respectively, distributed among the thematic sections cited above [20].

ISO 37122 MODEL - INDICATORS FOR SMART CITIES

It establishes indicators and definitions of methodologies to measure and consider aspects and practices that dramatically increase the pace at which cities improve their maturity results. This model has become the international reference point for smart cities. ISO specialists and the TC268 technical committee have identified the need to develop an ISO based on indicators for smart cities, and developed ISO 37122: Sustainable Development of Communities - Indicators for Smart Cities that will complement ISO 37120 and establish indicators and definitions of methodologies to measure and consider aspects and practices that dramatically increase the pace at which cities improve their social, economic and environmental sustainability results by responding to challenges such as climate change, rapid population growth, and political and economic instability, fundamentally improving how cities engage in society, apply collaborative leadership methods, work across disciplines and municipal systems, and use modern data and technology information. It uses as main domains economy, finance, education, governance, telecommunication, transportation, energy, environment and climate change, urban / local agriculture and food security, urban planning, wastewater, water, culture, health housing, security, leisure, population and social conditions and solid waste [21].

WEISS MODEL - ASSESSMENT MODEL FOR READINESS

Developed and titled as an evaluation model of TICS readiness, its application was directed to the urban management of the municipalities in order to be able to qualify how smart the cities are. This model is exclusively focused from the perspective of TICS, and propose in their evaluation a modular way, if municipalities have the necessary technologies to be classified as smart cities. The proposed model has six key domains: administration and governance, management of public services, management of public infrastructure, electronic services to the community, service platform and innovation and entrepreneurship [22].

IBMCCI MODEL - MULTIDIMENSIONAL BRAZILIAN INDEX OF SMART CITIES CLASSIFICATION

This model was inspired by the U-MULTIRANK evaluative model, focused on the national context in a way that evaded the existing traditional and classical models that inevitably gave rise to rankings. Moreover, in a not totally objective way they seek to establish criteria for cities that have different histories, different characteristics and that are in different maturing points. They use as key domains quality of life, technological readiness, innovation and environmental sustainability [23].

III. ANALYSIS, RESULTS AND DISCUSSION

To analyze and compare, it is necessary to select a model as a starting point for a proper comparison.A smart city is a city that performs well in six key domains (economy, people, governance, mobility, environment and quality of life). It is based on the premises of smart cities that have as pillar 6 key domains (see Table 1). This work takes as reference the ISO 37122 model, with indicators and specific domains for smart cities, having 19 key areas, which relate to the 6 key areas of a smart city as shown in Table 2.

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Table 1: Smart Cities Indicators

SMART CITY INDICATORS Giffinger et al. (2007)	Smart Economy	Smart People	Smart Governance
	Smart Mobility	Smart Environment	Smart Living

Table 2: 37122 ISO indicatorsforSmart Cities

ISO 37122 (2017)	Smart Economy	Smart People	Smart Governance
	Smart Mobility	Smart Environment	Smart Living

The ISO 37122 development aims to improve smart cities performance. This need arose because ISO and TC268 technical committee specialists identified the need to develop an ISO-based indicator for smart cities.

In order to assist cities with the international standard ISO 37122, it intends to help them implement policies aimed at the development of smart cities, and for this purpose it offers: Better services for citizens; Provide a better living environment in which smart policies, practices and technologies are put at the service of citizens; Achieve their environmental and sustainability goals in a more innovative way; Identify the need for intelligent infrastructure; Facilitate innovation and growth; Build a dynamic and innovative economy ready for future challenges.

This Norm defines and establishes definitions and methodologies for a set of indicators for Smart Cities. The purpose of this standard is to help cities guide and evaluate the performance management of municipal services and all service provision, as well as life quality. It considers the sustentabilidade as its general principle, "smart city" has as concept to guide the development of the cities.

Table 3 presents the domains that are treated in their respective maturity models based on ISO 37122 as the standard of measurement analysis, where what is highlighted/painted is what the model contemplates.

Table 3: Maturity Models

Giffinger et al. (2007)	Smart Economy	Smart People	Smart Governance
	Smart Mobility	Smart Environment	Smart Living
Meijeringa, Kern and Tobi	Smart Economy	Smart People	Smart Governance
	Smart Mobility	Smart Environment	Smart Living
Moraes (2018)	Smart Economy	Smart People	Smart Governance
	Smart Mobility	Smart Environment	Smart Living
Wccd (2017) Based on ISO 37120	Smart Economy	Smart People	Smart Governance
	Smart Mobility	Smart Environment	Smart Living
Gamma, Alvaro and Peixoto (2012)	Smart Economy	Smart People	Smart Governance
	Smart Mobility	Smart Environment	Smart Living
Clarke (2013)	Smart Economy	Smart People	Smart Governance
	Smart Mobility	Smart Environment	Smart Living
Artieda (2017)	Smart Economy	Smart People	Smart Governance
	Smart Mobility	Smart Environment	Smart Living
Urban Systems /Connected Smart Cities (2017)	Smart Economy	Smart People	Smart Governance
	Smart Mobility	Smart Environment	Smart Living
Junkes (2017)	Smart Economy	Smart People	Smart Governance
	Smart Mobility	Smart Environment	Smart Living
Inteli (2012)	Smart Economy	Smart People	Smart Governance
	Smart Mobility	Smart Environment	Smart Living
Rbcih (2018)	Smart Economy	Smart People	Smart Governance
	Smart Mobility	Smart Environment	Smart Living
NBR ISO 37120 (2017)	Smart Economy	Smart People	Smart Governance
	Smart Mobility	Smart Environment	Smart Living
ISO 37122 (2017)	Smart Economy	Smart People	Smart Governance
	Smart Mobility	Smart Environment	Smart Living
Weiss (2016)	Smart Economy	Smart People	Smart Governance
	Smart Mobility	Smart Environment	Smart Living
Guimarães (2018)	Smart Economy	Smart People	Smart Governance
	Smart Mobility	Smart Environment	Smart Living

Analysis of Table uses top-down approach type, which is essentially to obtain insights that will be demonstrated by the maturity models found in the literature review. The

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interpretation of Table 3 is given according to the models found in the materials and methods section following the same order, but in Table 3 we describe the analysis of domains by authors. The following are insights from the models in Table 3.

Model: Meijeringa, Kern and Tobi (2014). In the Model developed by [9] the evaluation structure is in a city in a developmental stage based on its physical, social and technological infrastructure. In this model there is a concern with the domains of economy and people and their data collection is based on public data. This model does not cover economic and people development.

Model: Moraes (2018). It is appropriate to Brazilian realities. Such a model is quite simple and limited, with interesting application in places that are doing their first steps towards the movement of smart cities. This model (see Table [3]) does not cover economic development as well as people and is still in development stage.

Model: Wccd (2017) based on ISO37120. This model aims at the accreditation of a city to be smart through indicators adopted in ISO 37120. The evaluation is done through a web platform called WCCD (World Council on City Data), any city in the world can undergo the test to obtain certification. However, the analysis and the data serve only as a source of consultation, and the techniques and methods of analyzing these data are not known. According to Table 3, it is a model that contemplates all domains but specific to cities that aim to be smart and sustainable.

Model: Gamma, Alvaroand Peixoto (2012). It is quite attractive, but it is deeply focused on measuring ICTs usage. The model only serves for a city to adjust, in an isolated and non-integrated way, its evolution or involution in the use of TICs in each domain described. There is still criticism regarding the methodology, since the calculation methodology used to evaluate the model proposed by the author was not explicit.

Model: Clarke (2013). The model identifies key measures, results and actions required for cities to effectively walk through the steps and progress towards the long-term goal of becoming a smart city. According to Table 3, this journey has many deficits, especially in areas of validation such as lack of environment and life domains.

Model: Artieda (2017). Still in developmental phase, in Table 3 we find faults in its domains for the evolution of a smart city; it is considered the newest maturity model, aiming at helping cities to clearly assess their progress in achieving ICT accessibility and digital inclusion.

Model: Urban System / Connected Smart Cities (2017): This model was initially thought to evaluate the development of Brazilian cities consideringsmartness, connection and sustainability. In Table 3, although it shows that the model includes all domains, the same focuses on interconnection and sustainability.

Model: Junkes (2017) is a European index developed to verify and evaluate the performance of smart cities in Europe and this performance evaluation is done through a digital platform. In Table 3, although all domains were included, it was not clear which methodology was used or what domains were used for evaluation at city level.

Model: Inteli (2012) is a study developed to allow the comparison of the performance of Portuguese cities. The methodology of this study integrates 5 dimensions: governance; innovation; sustainability; quality of life and connectivity. In Table 3 the model presented concerns only in the domains of mobility, governance and life, which were defined as primordial for a smart city, not forgetting the importance of technology, information and knowledge to provide higher life quality.

Model: Rbcih (2018), this model is based on the possibility of exchange of experience between cities, and the objective of creating a seal for the classification of a smart city. This model uses as indicators for evaluation the ISO 37120, which is not suitable for smart cities analysis. This model (see Table [3]) does not cover economic development for smart cities, which is premise for evaluation of a city.

Model: NBR ISO 37120 (2017) is a norm that does not seek to define what is a smart city, but rather the levels of quality of services of city halls; it has several indicators, but all aimed at measuring the performance of urban services as well as life quality. In Table 3 the norm contemplates all domains but its indicators are not specific to smart cities.

Model: ISO 37122 (2017), a norm for smart cities as a form of evaluation, establishes indicators and definitions of methodologies to measure and consider aspects and practices that dramatically increase the pace at which cities improve their maturity results. In Table 3 we see that the standard covers all domains and, most important, it is focused and specific and with indicators of evaluation for smart cities; it is the only one standardized with bias for smart cities.

Model: Weiss (2016). Titled as evaluation of the readiness of the TICS, its application is directed to the urban management of the cities, in order to be able to qualify them as smart. This model is exclusively focused from the perspective of TICS; as verified in Table 3, it leaves 3 open domains and thus prioritizing only the TICs.

Model: Guimarães (2018) focused on the national context in a way that escaped from the existing traditional and classic models that inevitably give rise to rankings. However, this model, according to Table 3, leaves a gap

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in 3 domains that are extremely important for the development of a smart city.

Based on the raised data, having as parameters ISO 37122 is possible to perceive that some of the models take care of to the demanded minimum domínios for an intelligent city.

Many models provide a set of domains and indicators that measure their dimensions. Some models list and reward smarter cities, others certify, others compare, and so each model tries to fit a single goal, which is the development towards the smart city. However, grievances that contemplate the models mentioned here need a standardization to achieve such accomplishment, and for this reason the standardization norm for smart cities (ISO 37122) is used here. Such norm involves in its completeness all the domains as well as its specific indicators for smart cities.

IV. CONCLUSION

Based on the study, it is concluded that the analyzed models present different aspects and with the same purpose: city development. Although some models are in developmental phase, they all corroborate the need for massive insertion of ICTs for such development.

Smart cities are established by essential domains for their development and among the analyzed models, correlating with the characteristics that a smart city should have. The one that best fit was ISO 37122, due to standardized definitions and methodologies for a set of performance key indicators as tools to thus become more sustainable and smarter in data development and construction.

The aim of standardization is to build a data culture and have globally comparable and standardized city data, let cities learn from each other to become smart and sustainable cities.

In order to assist cities, the international standard ISO 37122 will help them implement policies aimed at the development of smart cities, and such adoption will favor the fidelity of the application of a certification adopted by ISO 37122 in cities that claim its application, receiving then the recognition of Smart Cities.

For the above-mentioned studies it was noticed that a standard to be followed is still lacking, since each model is built in order to meet a certain demand, respecting local characteristics, so no model can be considered better, nor even more complete, since it is possible to verify that most models are undergoing maturation process. The methodologies such as those discussed in this work allow other researches to create ways of using these models and / or applying the international standardization ISO 37122.

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