Review of International Standards and Policy Guidelines for Smart Sustainable Cities

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Abstract Smart cities are often criticized for preoccupation with technology, for ignoring the negative effects of technology, for irrelevance to the needs of the poor, and for ubiquitous data collection creating perfect conditions for surveillance societies and autocratic states. In response, cities pursue smartness and sustainability simultaneously, becoming global (by participation in global digital networks) and local (by addressing local needs and circumstances) at the same time. In the pursuit of smart sustainable cities, they make explicit policy decisions about how technology should serve their residents, businesses and visitors, and avoid disrupting them. Many decisions are about standards—which standards should be followed and how, and increasingly, standards and policy guidelines are adopted by cities from international organizations, circumventing national authorities. This chapter reviews international standards and policy guidelines published by international standards organizations or intergovernmental bodies, with stated goals to support member

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states in the development and management of smart sustainable cities. We conducted the review through exploratory research and comparative policy analysis. The result could be used to raise awareness and address knowledge needs among city managers, policy analysts, and smart city researchers.

Keywords Smart cities · Smart sustainable cities · International standards · International policy guidelines

Introduction

As a concept, policy, and practice, smart cities are criticized for their preoccupation with technologies at the expense of citizens, for ignoring the negative effects of the technologies upon which they are based, for irrelevance to the needs of the poor living in low-income countries, for making a naturally haphazard urban development process rigid and inhuman, for ubiquitous data collection creating perfect conditions to building surveillance societies and autocratic states, etc.

In response, we increasingly expect cities to pursue smartness and sustainability simultaneously (Estevez, Vasco Lopes, & Janowski, 2016). The former makes cities global "because they spread all over the world and emerge with similar features and interdependencies at the global level" (Paola, Benevolo, Veglianti, & Li, 2019). The latter makes them local "because each city is unique, has different problems, and should address them with specific solutions" (Paola et al., 2019). Smart sustainable cities are, therefore a prime example of the glocalization trend, "the simultaneous occurrence of both universalizing and particularizing tendencies in contemporary social, political, and economic systems" (Encyclopedia Britannica, 2020).

Treated as large socio-technical systems, what makes smart cities sustainable is that they put technology at the service of the local community. They deliver productivity, accessibility, wellbeing, livability, governance, and other outcomes expected by the local community (Yigitcanlar et al., 2018). These expectations expressed through political processes and political activism aim at influencing public policy. Thus the main types of drivers for smart sustainable cities are a community—users of city infrastructure, recipients of city services and deciders of city policies; technology—digital means to increase the quality of life for residents and visitors alike; and policy—enabling digital transformation and managing its negative effects (Yigitcanlar et al., 2018). Consistent with that, the analysis of drivers from the perspectives of applied social sciences, engineering, exact and Earth sciences, and human sciences reveals eight extremely important drivers (Azevedo Guedes, Carvalho Alvarenga, Goulart, Rodriguez y Rodriguez, & Soares, 2018): urban planning, city infrastructure, mobility, public safety, health, sustainability, public policies, and urban risks.

The responsibility for the formulation and implementation of public policies for smart sustainable cities rests with municipal governments. As the city undergoes digital transformation, so does its government. Transformation from government to

digital government requires policy interventions (Chauhan et al., 2008) in order for digital government to enable public service innovation (Bertot et al., 2016) and contribute to sustainability goals (Estevez et al., 2013; Estevez & Janowski, 2013). On the practical level, to facilitate implementation, ensure safety and compatibility, lower costs, and build upon best practices, policies for smart sustainable cities often work through standards. Standards define "what people must do to be compliant and define the bar against which that compliance will be measured" (Capgemini, 2012). In contrast, policies generally make decisions on what standards we should follow, whether we should implement them, and how the implementation should proceed (Capgemini, 2012).

We enact many smart city standards on the national level. For instance, the British Standards Institution produced a particularly useful framework (British Standards Institute, 2015). The framework divides standards into strategic—guidance on developing priorities, roadmaps, and strategies; process—procuring and managing smart city projects; and technical—technical specifications that are needed to implement smart city products and services. The US National Institute of Standards, Smart Cities Council for Australia and New Zealand, and countries in the Asia-Pacific region all undertook similar standardization initiatives (Worldsensing, 2019).

However, most city governments, national government, and even intergovernmental bodies are trying to implement standards published by the International Organization for Standardization (ISO), International Telecommunication Union (ITU), International Electrotechnical Commission (IEC), European Telecommunications Standards Institute (ETSI), and other international standards organizations, and become "certified" through them (Worldsensing, 2019). For example, the European Union adopts various standards for smart cities, such as the standards on infrastructure performance (ISO/TS 37151:2015: 2015), open data (UNE 178301:2015: 2015), resilience and smartness (ISO/DIS 37101), city services and quality of life (ISO 37120:2014: 2014), universal accessibility (PNE 178106), accessible mobility (PNE 178306), smart tourism destinations (PNE 178501), and others.

Among them, an important category of standards is those defining indicators for measuring aspects of smart sustainable cities and tracking progress in building and maintaining them over time. City managers use such indicators for "target setting, performance assessment, monitoring, management, and decision-making purposes" (Huovila, Bosch, & Airaksinen, 2019). They are also key to managing policy implementation, monitoring the success of such implementations, and facilitating learning. Indicator-driven policy implementation is particularly important considering the multidimensionality of smart sustainable cities, the difficulty of maintaining policy coherence in the presence of multiple policy instruments, and stakeholder participation.

The analysis of seven recently published indicator standards (Huovila et al., 2019) uncovered a division between standards for measuring smartness and standards for measuring sustainability, standards oriented on measuring impact versus those oriented on measuring progress toward implementation according to different

implementation steps, and different types of indicators—input, process, output, outcome, and impact.

In addition to standards published by various national and international bodies, policy recommendations and other policy initiatives are also offered by international bodies to their member states to facilitate the development and management of smart sustainable cities. Offering limited contextualization, they help bridge a design-reality gap between universal policies and standards and local goals and circumstances where we implement such policies and standards. Examples are the recommendations issued by the BRICS Smart Cities Movement (Global Policy Journal and Observer Research Foundation, 2017) or rules and recommendations issued by UNESCWA as part of the Government Summit on Smart Cities in the Arab Region (The Government Summit, 2015).

This chapter aims at reviewing international standards and policy guidelines, particularly those published by international standards organizations or intergovernmental bodies, with stated goals to support member states in the development and management of smart sustainable cities. Such standards and policy guidelines are a reflection of the glocalization trend—"increasing transnational interactions among subnational entities from different countries" and "contacts among subnational and supranational entities" circumventing the national executives' "gatekeeper position between the international and the domestic political spheres" (Encyclopedia Britannica, 2020). We conduct the review through exploratory research and comparative policy analysis. The expected outcome and contribution is a systematized inventory of relevant standards and policy guidelines allowing for analysis and comparisons, addressing the knowledge needs and raising awareness among city managers, policy analysts, and researchers.

We divide the chapter into six sections. Section "Research Methodology" presents the research questions and methodology adopted to address them, followed by the review of relevant literature to establish background knowledge in Section "Related Work", followed by the review of ten international standards and policy guidelines in Section "Policy Documents". Section "Analysis and Discussion" presents the analysis and comparison of such documents. The final Section "Conclusions" summarizes the main findings, outlines the limitations of this research, and draws some directions for possible future work.

Research Methodology

This chapter conducts a review, analysis, and comparison of international standards and policy guidelines for smart sustainable cities. We conduct the review by exploratory research of relevant documents published by international standards organizations and relevant intergovernmental bodies. Two questions guide this research. First, what international standards and policy guidelines exist to help develop and manage smart sustainable cities? What do they include, and where are they applied? Second, how can we compare such documents and the prescriptions contained

therein? The work extends exploratory research into the nature and practice of smart sustainable cities documented in (Estevez et al., 2016).

The research relies on the secondary data obtained through research and policy literature reviews. The review of research literature aimed at uncovering scientific publications on smart city policies and standards and other related work, and establish the contribution of this work. We document the results related to background concepts in the Introduction section and related work in Section "Related Work". The review of policy literature reports on the results of two kinds of Internet searches. The first explores the websites of international standards organizations and other intergovernmental organizations working in the domain of standards, smart cities, and international policies. In particular, we explored the websites of the International Organization for Standardization (ISO),[1] the International Telecommunications Union (ITU)[2], and the European Commission (EC).[3] The second search looks for relevant policy guidelines targeted at the regions like Western Asia through the United Nations Economic Commission for Western Asia (UNESCWA),[4] the BRICS[5] country group, and others. From the identified documents, those considered most relevant by the authors were selected and synthesized. We present the outcome in Section "Policy Documents". The content of this section provides an answer to the first research question. The standards and policy documents presented in Section "Policy Documents" are analyzed, compared, and presented in Section "Analysis and Discussion". The content of this section provides an answer to the second research question.

Related Work

Related work includes: "Smart Sustainable Cities—Reconnaissance Study" prepared under the auspices of the International Development Research Centre (Estevez et al., 2016); "Pre-Standardization Study Report—Technical Requirements Analysis of Unified, Secure & Resilient ICT Framework for Smart Infrastructure" published by the Bureau of Indian Standards (Bureau of Indian Standards, 2017); and "Standardization for the sustainable development of cities and municipalities" coordinated by the Austrian Federal Environment Agency (Smart City Standards Normung für die nachhaltige Entwicklung von Städten und Kommunen, 2015). For each of them, we discuss their main contributions and a comparison with the results presented here.

[1] ISO, https://www.iso.org/home.html, last visited 2020-02-01.

[2] ITU, https://www.itu.int/en/Pages/default.aspx, last visited 2020-02-01.

[3] EC, https://ec.europa.eu/, last visited 2020-02-01.

[4] UNESCWA, https://www.unescwa.org/, last visited 2020-02-01.

[5] BRICS Countries—Brazil, Russia, India, China and South Africa, http://infobrics.org/, last visited 2020-02-01.

The first study (Estevez et al., 2016) aims at assessing the state of the art and state of practice in smart sustainable cities. Based on secondary data, it conducted exploratory research of scientific publications, policy documents, and 21 case studies of smart sustainable cities. The current study is broader than the one in (Estevez et al., 2016). Regarding the analysis of policy documents, (Estevez et al., 2016) discusses the ISO 37120:2014 standard "Sustainable development of communities—Indicators for city services and quality of life" and the ITU standard on "Key Performance Indicators in Smart Sustainable Cities". In contrast, this chapter presents several major standards and policy recommendations issued by international organizations including those two standards.

In the second study (Bureau of Indian Standards, 2017), the Bureau of Indian Standards aims at identifying "standardization needs with respect to India specific requirements for Unified, Secure & Resilient ICT Backbone for Smart Cities". To this end, the report reviews a wide range of standards produced by ISO, IEC, ITU, and ETSI, as a basis for developing national policies. The study covers last-mile communication for machine-to-machine and Internet of Things applications in smart cities, common service layer requirements in ICT architecture for smart infrastructure, and comprehensive ICT reference architecture for smart cities and smart infrastructure.

The third study (Smart City Standards Normung für die nachhaltige Entwicklung von Städten und Kommunen, 2015) took place as part of the Smart City STANDARDS project, which aims to "support standardization processes for the sustainable development of cities and municipalities and to involve the key stakeholders and actors in these processes" (Austrian Society for Environment and Technology, 2015). The study categorized sets of indicators at the national and international levels, analyzed them using a focused group and presented recommendations concerning the indicator systems and their applications and standardization. Based on the results, (Tritthart, Thielen, Storch, Schrattenecker, & Purker, 2015) delineates a standardization process and provides recommendations related to smart cities in Austria.

These three studies demonstrate that countries pursue efforts to assess international standards and policies to lay the foundations for their national and local policies. The work documented in this chapter is comparable and complimentary to such efforts. The main difference is the scope. Given the vast numbers and sector-specificity of existing standards, each country has to focus on the sectors they wish to prioritize. The research presented here aims at landscaping international standards and policy recommendations for smart sustainable cities. The results could be used as a basis for such national efforts.

Policy Documents

The current section presents the identified international standards and policy guidelines that support the development and management of various aspects of smart sustainable cities, published by ISO, ITU, ETSI, European Commission, UNESCWA, and the BRICS country group. The reviewed documents are: 1) ISO/IEC JTC1 Smart Cities—Preliminary Report 2014 (ISO/IEC, 2014) (Section "ISO/IEC JTC1 Smart Cities—Preliminary Report 2014"), 2) ISO 37120:2018 Sustainable development of communities—Indicators for city services and quality of life (ISO, 2018a) (Section "ISO 37120:2018 Sustainable Development of Communities—Indicators for City Services and Quality of Life"), 3) ISO 37122:2019 Sustainable cities and communities—Indicators for smart cities (ISO, 2019a) (Section "ISO 37122:2019 Sustainable Cities and Communities—Indicators for Smart Cities"), 4) other ISO standards related to smart cities (ISO, 2012a, 2012b, 2012c, 2018b) (Section "Other ISO Standards Related to Smart Sustainable Cities"), 5) ITU-T Key performance indicators related to the use of information and communication technology (ICT) in smart sustainable cities (ITU-T SG20, 2016) (Section "ITU-T Key Performance Indicators Related to the Use of ICT in Smart Sustainable Cities"), 6) ITU-T Key performance indicators related to the sustainability impacts of ICT in smart sustainable cities (ITU-T, 2016) (Section "ITU-T Key Performance Indicators Related to Sustainability Impact of ICT in SSC"), 7) ITU-T Key performance indicators for smart sustainable cities to assess the achievement of sustainable development goals (ITU, 2019) (Section "ITU-T Key Performance Indicators for SSC to Assess the Achievement of SDGs"), 8) ETSI TS 103463 Key performance indicators for sustainable digital multiservice cities (ETSI, 2017) (Section "ETSI TS 103463 Key Performance Indicators for Sustainable Digital Multiservice Cities"), 9) UNESCWA Smart cities: Regional perspectives (The Government Summit, 2015) (Section "UNESCWA Smart Cities—Regional Perspectives"), and 10) the BRICS Smart Cities Movement Recommendations (Global Policy Journal and Observer Research Foundation, 2017) (Section "BRICS Smart Cities Movement Recommendations").

ISO/IEC JTC1 Smart Cities—Preliminary Report 2014

ISO and IEC established the Joint Technical Committee 1 (JTC1) in 1987, aimed at developing, maintaining and promoting standards in the fields of Information Technology (IT) and Information and Communications Technology (ICT). JTC1 has been responsible for many critical IT standards, ranging from the MPEG video format to the C++ programming language. Within JTC1, the Study Group "Smart Cities" (SG1), established in early 2014, published Smart Cities Preliminary Report 2014 (ISO/IEC, 2014) to explore standardization opportunities for smart cities. The report describes key concepts and relevant technologies; documents technological, market, and societal requirements for standardization; analyzes current enabling

technologies; and assesses the current state of the standardization activities. The report presents the starting point of the SG1 activities, and refers to the work of other standardization institutions active in the field of smart cities, in particular, the ITU-T Focus Group on Smart Sustainable Cities, ISO TMB Smart Cities Strategic Advisory Group, and ISO/TC 268.

The SG1 report includes at the beginning some open definitions of a smart city. Such definitions highlight special benefits that come from the development of smart city initiatives and the key role played by ICT. They also consider the "smartness" of a city as its ability to achieve the goals as effectively as possible. Based on the characteristics of smart cities, needs, and requirements are explicitly described. The report also documents several smart city models which are classified into simple models, mainly those that describe a smart city from a particular viewpoint; and complex models, the ones aiming at systematically describing all elements that should be present in a smart city. The baseline for the latter is the need to develop a detailed, systematic model for a city ontology that could be used across all city systems and by all city stakeholders. This would enable data to be easily shared city-wide, and to make them available with consistent APIs, so that common software components, so called building blocks, like payment system and user authentication, are provided and reused by different city information systems, and programmers can develop apps integrated with such systems by reusing the common blocks. The approach would also enable digital services developed for one city to be more easily adopted by another city. The models must facilitate data aggregation and heterogeneous system interoperability, as well as safe and secure data exchange between different environments.

From the factors described above, this report identifies the following challenges for the development of smart city standards: 1) to have a common conceptual model of the city as a system of systems; 2) to be able to manage privacy, security, resilience, data flows and other issues at a whole-system city level; 3) to be able to evaluate how well a city is using ICT to support its overall progress in becoming smarter; 4) to ensure interoperability between different city systems; 5) to ensure consistency between standards of others international bodies; and 6) to assist non-specialist city leader in understanding the complex and interrelated ICT issues and how to manage such issues to make the city progressively smarter.

Besides, different standardization-related projects under evaluation are described, including:

- ISO/IEC AWI 30146 Smart city ICT Indicators (ISO, 2019b) which includes six types of indicators for citizen services, efficient governance, live-able environments, smart facilities, information resources, and cybersecurity;
- ISO/IEC AWI 21972 Upper-level ontology for smart city indicators (ISO, 2020) provides a data model that supports the representation of city indicator definitions, defined using the Web Ontology Language (OWL). The definition of the indicators in OWL together with city data collected and represented in OWL can be used as inputs to software applications designed for measuring specific sets of indicators.

- ESPRESSO project (Systemic standardization approach to empower smart cities and communities) (Bareño, Lindner, Kempen, Klien, & Dambruch, 2016), co-funded by the EU Horizon 2020 programme, was used as a reference for preparing the SC1 report.
- The Bureau of Indian Standards published the report "Technical requirements analysis of unified, secure & resilient ICT framework for smart infrastructure" (Bureau of Indian Standards, 2017). It discusses global and Indian initiatives for smart city standardization and proposes a framework for unified standards underpinning a comprehensive ICT infrastructure of a city.

Finally, the report collects a series of indicators for smart cities (ISO/IEC, 2014): 1) ISO/TR 37150 survey—including Global City Indicators, the Green City Index series, and the Smart City ICT indicators proposed by Fujitsu; and 2) key performance indicators proposed by the ITU-T Focus Group on Smart Sustainable Cities (ITU-T FG SSC). Table 1 enumerates the measurement areas defined by such indicators.

ISO 37120:2018 Sustainable Development of Communities—Indicators for City Services and Quality of Life

Already in 2007, the World Bank (Hoornweg, Nunez, Freire, Palugyai, & Herrera, 2007) recognized that "there are thousands of different sets of city (or urban) indicators and hundreds of agencies compiling and reviewing them. Most cities already have some degree of performance measurement in place. However, these indicators are usually not standardized, consistent, or comparable (over time or across cities), nor do they have sufficient endorsement to be used as ongoing benchmarks." To address this problem, ISO developed the standard ISO 37120 (ISO, 2018a) to provide a set of indicators to measure city performance. The indicators are related to 19 groups such as economy, education, energy, finance, governance, health, transportation, and others. Table 2 summarizes the standard. The description includes two example indicators for each of the 19 groups. Details are included in https://www.iso.org/obp/ui/#iso:std:iso:37120:ed-2:v1:en.

ISO 37122:2019 Sustainable Cities and Communities—Indicators for Smart Cities

The ISO 37120 standard, described in *Section "ISO 37120:2018 Sustainable Development of Communities—Indicators for City Services and Quality of Life" (ISO,* 2018a), was quickly and broadly adopted by the global community as a reference for sustainable cities. However, the ISO/TC 268/Working Group 2

Table 1 Summary of the ISO/IEC JTC1 Smart Cities Preliminary Report 2014

Author	ISO/IEC JTC 1	
When	2015	
What	A preliminary work aimed at guiding the standardization processes on smart cities at ISO/IEC JTC 1. The report contains: • Smart city definitions and models • Requirement assessment for smart city standardization • Review of related technologies • Review of current standardization efforts The set of indicators identified and the areas measured by them include:	
	1. ISO /TR 37150 survey—Global City Indicators	
	• Education • Fire and emergency response • Health • Recreation • Safety • Solid waste • Transportation • Wastewater • Water • Energy	• Finance • Governance • Urban planning • Civic engagement • Culture • Economy • Environment • Shelter • Social equity • Technology and innovation
	2. ISO /TR 37150 survey—The Green City Index series	
	• CO_2 • Energy • Buildings • Transport	• Waste and land use • Water • Air quality • Environmental governance
	3. Smart City realized by ICT (proposed by Fujitsu)	
	• Service • Environmental impact • Energy	• Biodiversity • Water
	4. Key performance indicators from ITU-T FG SSC	
	• Network facilities • Information facilities • Environment • Building • Energy and natural resources • Innovation • Knowledge economy • Governance	• Transportation • Security and safety • Sanitation • Healthcare • Education and training • Openness • Participation in public life • Convenience and comfort
Where	Worldwide	

dedicated to city indicators identified the need to add the indicators specific to smart cities. Thus, in 2019, they defined the ISO 37122 Indicators for Smart Cities (ISO, 2019a). This set of indicators is structured around the same 19 areas as the previous one but includes additional 79 indicators. Table 3 summarizes the standard.

Table 2 Summary of the ISO 37120:2018 standard, Sustainable cities and communities—Indicators for city services and quality of life

Author	ISO	
When	2018	
What	The standard defines 120 indicators for measuring the performance of sustainable cities and communities. The indicators are grouped into 19 areas:	
	1. Economy	• City's unemployment rate • Youth unemployment rate
	2. Education	• Percentage of females enrolled in schools • The primary education student-teacher ratio
	3. Energy	• Total end-use energy consumption per capita • Percentage of energy derived from renewable sources
	4. Environment	• Fine particulate matter (PM2.5) concentration • Particulate matter (PM10) concentration
	5. Finance	• Capital spending as a percentage of total expenditures • Tax collected as a percentage of the tax billed
	6. Governance	• Women as a percentage of total elected officials to a city office • Voter participation in the last municipal elections
	7. Health	• Average life expectancy • Number of physicians per 100,000 population
	8. Housing	• Percentage of population living in inadequate housing • Number of homeless per 100,000 population
	9. Population	• Percentage of population living below the poverty line • Gini coefficient of inequality
	10. Recreation	• Square meters of public indoor recreation space • Square meters of public outdoor recreation space
	11. Safety	• Number of firefighters per 100,000 population • Number of police officers per 100,000 population
	12. Solid waste	• Total collected municipal solid waste per capita • Percentage of the city's solid waste that is recycled
	13. Sport and culture	• Number of cultural institutions and sporting facilities • The annual number of cultural events per 100,000
	14. Telecommunication	• Number of internet connections per 100,000 • Number of mobile phone connections per 100,000
	15. Transportation	• Kilometers of public transport system per 100,000 • The annual number of public transport trips per capita
	16. Agriculture	• Total urban agricultural area per 100,000 population • Percentage of city population undernourished
	17. Urban planning	• Green area (hectares) per 100,000 population • Jobs–housing ratio
	18. Wastewater	• Population served by wastewater collection • The compliance rate of wastewater treatment
	19. Water	• Population with potable water supply service • Total domestic water consumption per capita
Where	Worldwide	

Table 3 Summary of the ISO 37122:2019 standard, Sustainable cities and communities—Indicators for smart cities

Author	ISO
When	2019
What	The standard defines 79 indicators for measuring the performance of smart cities. The indicators are grouped into the same 19 areas as the set on indicators included in the ISO 37120:2018 (see Table 2)
Where	Worldwide

Other ISO Standards Related to Smart Sustainable Cities

We can use the ISO standards to tackle many urban challenges while supporting the development and measurement of sustainable development efforts. In particular, many individual ISO standards affect or are related to the characteristics of smart cities, and can be used to monitor their technical and functional performance. Examples of ISO Standards contributing to smart cities include but are not limited to:

- The ISO 39001:2012 standard "Road Traffic Safety (RTS) Management Systems—Requirements with Guidance for Use" (ISO, 2012a) can help reduce death and serious injuries due to road accidents. According to the World Health Organization, "Traffic injuries claim more than 1.2 million lives each year and have a huge impact on health and development. They are the leading cause of death among young people aged between 15 and 29 years, and cost governments approximately 3% of GDP" (WHO, 2015). In particular, ISO 39001 contributes indirectly to smart mobility assessment.
- The ISO 20121 standard "Event Sustainability Management System" (ISO, 2012b) was developed to assist organizations in the events-related industry in improving the sustainability of their activities, products, and services. The 2012 Olympic Games in London complied with this standard, providing a strong assurance to the success of the event within the smart city concept.
- The ISO 50001 standard "Energy Management System" (ISO, 2018b) helps organizations use energy more efficiently and at reduced costs. The standard "provides a framework of requirements for organizations to develop a policy for more efficient use of energy, fix targets and objectives to meet the policy, use data to better understand and make decisions about energy use, measure the results, review how well the policy works, and continually improve energy management" (ISO, 2018b).
- The ISO 13153:2012 standard "Framework of the design process for energy-saving single-family residential and small commercial buildings" (ISO, 2012c) is a design framework for energy saving for single-family residential and small commercial buildings. It helps architects and designers develop energy-efficient buildings well suited to their locations. The standard contributes to developing smart houses.
- The ISO 16813:2006 standard "Building Environment Design—Indoor Environment—General Principles" (ISO, 2012d) focuses on the design of

Table 4 Other ISO standards related to smart sustainable cities

Author	ISO
When and what	• The ISO 39001:2012 Road Traffic Safety (RTS) Management Systems standard includes requirements with usage guidance for assessing smart mobility. 2012 • The ISO 20121 Event Sustainability Management System standard assists organizations in the events-related industry in improving the sustainability of their activities, products, and services. 2012 • The ISO 50001 Energy Management System (ISO, 2018b) standard helps organizations enhance the use of energy, using it more efficiently and at reduced costs. 2018 • The ISO 13153:2012 standard helps architects and designers develop energy-efficient buildings well suited to their locations, contributing to the development of smart houses. 2012 • The ISO Technical Committee (ISO/TC) 205 publishes standards offering an integrated methodology for the design of high-performance indoor environments, for example, the ISO 16813:2006 Building Environment Design—Indoor Environment—General Principles standard. 2012
Where	Worldwide

high-performance indoor environments. The standard "establishes the general principles of building environment design taking into account healthy indoor environment for the occupants, and protecting the environment for future generations" (ISO, 2012d) (Table 4).

ITU-T Key Performance Indicators Related to the Use of ICT in Smart Sustainable Cities

The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the International Telecommunication Union specialized in the study of technical, operating, and tariff questions related to telecommunications. It issues recommendations in the areas of their specialization, intended at standardizing telecommunications on a worldwide basis. In 2016, ITU-T proposed a set of Key Performance Indicators (KPIs) focusing on ICT and its contribution to smart sustainable cities (SSCs). The indicators are classified based on the identified dimensions and subdimensions characterizing SSCs, which are applied to several ITU-T standards, including those described in this and the following two sections.

The Recommendation ITU-T Y.4901/L.1601 on KPIs related to the use of ICT in SSCs (ITU-T SG20, 2016) groups the indicators into six dimensions: 1) ICT, 2) Environmental Sustainability, 3) Productivity, 4) Quality of life, 5) Equity and social inclusion, and 6) Physical infrastructure; and 20 subdimensions. The ICT dimension measures: networks and access, services and information platforms, information security and privacy, and the electromagnetic field. The Environmental Sustainability dimension measures: the air quality, and water, soil, and noise. The Productivity dimension measures: capital investment, trade, innovation, and

Table 5 Summary of the ITU-T Y.4901/L.1601 Recommendation on KPIs for ICT use in SSCs

Author	ITU			
When	2016			
What	The indicators were defined in the six dimensions and subdimensions as follows:			
	Dimension		**Subdimension**	
	D1	ICT	D1.1	Network and access
			D1.2	Services and information platforms
			D1.3	Information security and privacy
			D1.4	Electromagnetic field
	D2	Environmental sustainability	D2.1	Air quality
			D2.5	Water, soil, and noise
	D3	Productivity	D3.1	Capital investment
			D3.4	Trade
			D3.8	Innovation
			D3.9	Knowledge economy
	D4	Quality of life	D4.1	Education
			D4.2	Health
			D4.3	Safety and security of public places
			D5.3	Openness and public participation
			D5.4	Governance
	D6	Physical infrastructure	D6.1	Connection to services—Piped water
			D6.2	Connection to services—Sewage
			D6.3	Connection to services—Electricity
			D6.8	Connection to services—Road infrastructure
			D6.11	Building
Where	Worldwide			

knowledge economy. The Quality of Life dimension measures: education, health, safety and security of public places, openness and public participation, and governance. Finally, the Physical Infrastructure dimension measures: connections to piped water, sewage, electricity and road infrastructure, and buildings. Because of the sharing of dimensions by the three standards, some subdimensions are numbered nonconsecutively. See Table 5.

The KPIs were selected based on six principles: 1) comprehensiveness—the indicators should cover all aspects of SSCs; 2) comparability—the indicators should be comparable for the same city over time and space; 3) availability—the indicators should be quantitative and the current and historical data should be either available or easy to collect for them; 4) independence—the definitions of the indicators in the same dimension should be almost orthogonal; 5) simplicity—the concept of each indicator should be simple and easy to understand; and 6) timeliness—producing the indicators that respond to the emerging issues in SSC construction and management should be possible.

The ITU-T KPIs were applied by several cities to measure the contribution of ICT to the development of smart sustainable cities. The Dubai experience is documented in (Torres, Guzmán, Smiciklas, and Cash, 2017) and the Singapore experience in (Smiciklas, Ashirangkura, Hyodo, Walker-Turner, and Xu, 2017).

ITU-T Key Performance Indicators Related to Sustainability Impact of ICT in Smart Sustainable Cities

The Recommendation ITU-T Y.4902/L.1602 on KPIs related to the sustainability impact of ICT on SSCs (ITU-T, 2016) presents the KPIs that measure the impact of ICT on city sustainability. The aim is to help cities and their stakeholders understand the degree to which their efforts contribute to the development of SSCs. The indicators are grouped into dimensions in Table 5 with the same or added subdimensions shown in Table 6. For example, the Environmental Sustainability dimension includes indicators in subdimensions of air quality, CO_2 emissions, energy, and water, soil and noise. The Productivity dimension comprises indicators for capital investment, employment, inflation, savings, export and import, household income and compensation, and innovation. The Quality of Life dimension measures education, health, and the safety and security of public places. The Equity and Social Inclusion dimension measures inequality of income and consumption, social and gender inequality of access to services and infrastructure, and openness and public participation. Finally, the Physical Infrastructure dimension measures connections to piped water, sewage, electricity, health infrastructure, and transport.

ITU-T Key Performance Indicators for Smart Sustainable Cities to Assess the Achievement of Sustainable Development Goals

The recommendation ITU-T Y.4903/L.1603 (ITU-T SG20, 2017) developed jointly by ISO and the UN agencies, such as UNECE, provides KPIs and guidelines for SSC developers on how to pursue the achievement of Sustainable Development Goals. We classify the indicators by area, topic, and type. Areas include economy, environment, and society and culture. Topics collect groups of indicators that describe a development area. Each indicator is assigned one topic. The indicator type describes the applicability of the indicator itself, either core global indicators for all cities or optional indicators available in "smarter" cities only. Table 7 shows the topics covered in each area.

Table 6 Summary of the Recommendation ITU-T Y.4902/L.1602 on KPIs related to sustainability impact of ICT in SSCs

Author	ITU			
When	2016			
What	The indicators were defined in the following six dimensions and subdimensions:			
	Dimension		**Subdimension**	
	D2	Environmental sustainability	D2.1	Air quality
			D2.2	CO_2 emissions
			D2.3	Energy
			D2.5	Water, soil, and noise
	D3	Productivity	D3.1	Capital investment
			D3.2	Employment
			D3.3	Inflation
			D3.5	Savings
			D3.6	Export/import
			D3.7	Household income and compensation
			D3.8	Innovation
	D4	Quality of life	D4.1	Education
			D4.2	Health
			D4.3	Safety and security of public places
	D5	Equity and social inclusion	D5.1	The inequity of income and consumption (GINI index)
			D5.2	Social and gender inequity of access to services
			D5.3	Openness and public participation
	D6	Physical infrastructure	D6.1	Connection to services—Piped water
			D6.2	Connection to services—Sewage
			D6.3	Connection to services—Electricity
			D6.6	Connection to services—Health infrastructure
			D6.7	Connection to services—Transport
Where	Worldwide			

ETSI TS 103463 Key Performance Indicators for Sustainable Digital Multiservice Cities

The European Telecommunications Standards Institute (ETSI) published the standard TS 103463 "Key Performance Indicators for Sustainable Digital Multiservice Cities" (ETSI, 2017) that defines the indicators for measuring smart cities in Europe. The standard relies on CITYKeys, an EU Horizon 2020 project that developed a framework of indicators for smart city project evaluation (Bosch et al., 2017).

The CITYkeys framework is underpinned by three dimensions of sustainability—social, environmental, and economic, and comprises two sets of indicators. One set is for measuring smart city projects and establishing their potential for propagation, which is to determine the prospects of upscaling and applying in other

Table 7 Summary of the ITU-T Y.4903/L.1603 Recommendation on KPIs for assessing the contribution of SSCs to SDGs

Author	ITU			
When	2016			
What	The indicators were defined in the following four areas:			
	Area		**Topic**	
	1.	Economy	T1.1	ICT infrastructure
			T1.2	Innovation
			T1.3	Employment
			T1.4	Trade—e-commerce (additional)
			T1.5	Productivity
			T1.6	Infrastructure—Water supply
			T1.6	Infrastructure—Electricity supply
			T1.6	Infrastructure—Health infrastructure (additional)
			T1.6	Infrastructure—Transport
			T1.6	Infrastructure—Road infrastructure (additional)
			T1.6	Infrastructure—Building (additional)
			T1.6	Infrastructure—Urban planning and public space (add.)
			T1.7	Public sector (additional)
	2.	Environment	T2.1	Air quality
			T2.2	Water and sanitation
			T2.3	Noise
			T2.4	Environmental quality
			T2.5	Biodiversity
			T2.6	Energy
	3.	Society and culture	T3.1	Education
			T3.2	Health
			T3.3	Safety—Disaster relief
			T3.3	Safety—Emergency
			T3.3	Safety—ICT
			T3.4	Housing
			T3.5	Culture
			T3.6	Social inclusion
Where	Worldwide			

contexts. The second set is for measuring smart cities themselves. The first set contains five categories: people, planet, prosperity, governance, and propagation. The second set contains the first four categories only since propagation is only relevant at the project level.

Regarding the categories, the People category refers to the long-term attractiveness of cities for a wide range of inhabitants and users. It employs the following themes: health, safety, access to services, education, diversity and social cohesion, quality of housing, and the built environment. The Planet category refers to the care of the city environment, such as water care and cleaning of the public spaces, among

others. The category is further divided into energy and mitigation; materials, water, and land; climate resilience; pollution and waste; and ecosystem. The Prosperity category contributes to measuring the prosperity and equity in the society and supporting affordable, green and smart solutions. It entails the themes of employment, equity, green economy, economic performance, innovation, attractiveness, and competitiveness. The Governance category measures the process and success in project implementation, the efficiency of administration, and whether the democracy at the city level can engage citizens. This category contains the organization, community involvement, and multilevel governance themes. The Propagation category refers to the ability of replicating smart city project solutions to other locations and improving the scalability of such solutions on a wider scale. Replicability and scalability are the themes. The categories and themes are shown in Table 8.

Table 8 Summary of the CITYkeys indicators for smart city projects and smart cities

Author	CityKeys project (co-funded by the European Commission within the H2020 Programme)			
When	2017			
What	Two sets of indicators were defined for measuring: a) smart city projects and b) smart cities. The former includes the five categories described below, while the latter defines the indicators for the first four categories only.			
	Category		**Theme**	
	1.	People	T1.1	Health
			T1.2	Safety
			T1.3	Access (to other services)
			T1.4	Education
			T1.5	Diversity and social inclusion (project level only)
			T1.6	Quality of housing and the built environment
	2.	Planet	T2.1	Energy and mitigation
			T2.2	Materials, water, and land
			T2.3	Climate resilience
			T2.4	Pollution and waste
			T2.5	Ecosystem
	3.	Prosperity	T3.1	Employment
			T3.2	Equity
			T3.3	Green economy
			T3.4	Economic performance
			T3.5	Innovation
			T3.6	Attractiveness and competitiveness
	4.	Governance	T4.1	Organization
			T4.2	Community involvement
			T4.3	Multilevel governance
	5.	Propagation	T5.1	Replicability and scalability (project level only)
			T5.2	Factors of success (for project level only)
Where	Europe			

The definitions of the indicators fulfill the principles of (Bosch et al., 2017): 1) relevance—the indicators should be meaningful for the evaluation of the process; 2) completeness—the indicators should cover all aspects considered; 3) availability—data for the indicators should be easily available; 4) measurability—the indicators should be able to provides as objective measures as possible; 5) reliability—the definitions of the indicators should be clear and unambiguous; 6) familiarity—the indicators should be easy to understand by their users; 7) nonredundancy—different indicators within the framework should not measure the same aspect; and 8) independence—small changes in the measurement of an indicator should not impact preferences assigned to other indicators in the evaluation.

UNESCWA Smart Cities—Regional Perspectives

The policy report (The Government Summit, 2015), produced by UNESCWA, analyzes 90 cities in the Arab region and their capacity for becoming smart cities. The document is oriented on political leaders and policymakers, it includes recommendations for planning strategic goals to transform a city into a smart city considering the regional context. Cities were classified based on three aspects that would affect the transformation process: a) financial resourcefulness—20 cities among 90 examined, 22%; b) history—60 cities older than 1000 years, 67%; and c) poverty—80 cities requiring financial support, 89%.

From the analysis, considering policies, strategies, and challenges that emerge from the economic, environmental, and infrastructure assessment of the cities, the study formulates three rules and four recommendations, which are presented below and summarized in Table 9.

The rules are (The Government Summit, 2015):

1. The transformation should proceed toward more comprehensive work within sectors rather than on many sectors, meaning prioritizing vertical rather than horizontal transformations. This rule promotes the execution of small and specific projects for transforming a sector of a city into a smarter one. The approach requires fewer resources for implementation.
2. The leading executive role in the transformation should be played by the partnership between academia and the private sector, while the city government should act as a steering and coordinating body. This rule takes into account the high political instability of the local governments in the Arab cities and their weaknesses that cause delays, bureaucracy, conflicts of interest, and other difficulties that city transformations typically face.
3. Strategic and long-term partnerships of the city administrations with their counterparts in other cities in the region, especially on technology issues, is highly advised. One of the main guarantees of sustainability is for city administrations to enter into long-term strategic partnerships focused on conducting similar projects with other cities in the region.

Table 9 Summary of the UNESCWA rules and recommendations for smart cites in the Arab region

Author	UNESCWA
When	2015
What	The study assesses 90 cities in the Arab world and proposes three rules and four recommendations to transform them into smart cities, as summarized below. Rules: 1. The transformation should proceed toward more comprehensive work on individual sectors rather than on many sectors (vertical rather than horizontal) 2. The leading executive role of the transformation should be played by a partnership between academia and the private sector, with city governments acting as steering and coordinating bodies 3. The strategic and long-term partnerships of the city administrations with their counterparts in other Arab cities in the region, especially for technology issues, is highly advised Recommendations: 1. Conduct a classification of cities and a selection process 2. Assess the current city status 3. Follow a piece-wise development 4. Pursue inter-regional cooperation Besides, the document defines six dimensions to consider for smart Arab cities: 1) economy, 2) people, 3) city government, 4) mobility, 5) environment, and 6) living
Where	Arab region

The recommendations include (The Government Summit, 2015):

1. *Conducting a classification of cities and a selection process*—It includes preparing an extensive list of major cities in the region with indicators such as population, history, GDP, number of residents, number of industries, number of academic institutions, infrastructure, basic service, and others. Based on such information, select the cities, their priority areas, and the sectors to be transformed within each city, and define proper metrics and indicators for such sectors. Subsequently, identify the resources required for conducting the needed changes.
2. *Assessing the current city status*—The assessment should be done in two stages. The first is a general survey assessing the policies and development strategies that are adopted for six pillars: 1) economy, 2) people, 3) city government, 4) mobility, 5) environment, and 6) living. The second stage, considering the results, identifies areas where smart applications can be developed.
3. *Following a piece-wise development*—It includes developing a task force of the stakeholders to undertake a study to identify processes, data and infrastructure to conduct project work; provide a study of possible piece-wise development by identifying vertical components such as smart services, sectoral policies, and enhancements and developments of utility and infrastructure services; and packaging the efforts into a strategic plan to develop a set of smart city projects.
4. *Pursuing inter-regional cooperation of Arab cities*—Establish a group of people, including knowledgeable professionals and experts in the region, to acts as a think-tank for regional cooperation by the Arab cities. The group should develop a cooperation framework for smart cities in the Arab world and play an advisory role in such cities and their cooperation.

BRICS Smart Cities Movement Recommendations

BRICS comprises five most important emerging or recently industrialized economies of the world—Brazil, Russia, India, China, and South Africa—. For the past years, the BRICS countries are cooperating on numerous matters of mutual interest. An important issue is the transformation of cities into smart cities. In (Global Policy Journal and Observer Research Foundation, 2017), several recommendations for smart city development are suggested based on the experience and lessons learned by several BRICS cities. The proposed recommendations would help with smart city policymaking in different areas, such as local expertise, partnerships, resilience, financing, mobility, and deployment and adoption of ICT, among others.

The policy recommendations (Global Policy Journal and Observer Research Foundation, 2017) comprises those listed below and summarized in Table 10:

1. *Establish specialized entities, sponsor programs, and industry alliances*—The aim is to institutionalize a governance model and ensure broad stakeholder participation.

Table 10 Summary of the BRICS policy recommendations for smart city development

Author	Rumi Aijaz (Editor), Global Policy Journal and Observer Research Foundation (Publisher)
When	2017
What	18 policy recommendations are classified in the following areas: 1. Governance • *Establish specialized entities, sponsor programs, and industry alliances* (R1) • *Engage more with non-state actors* (R3) • *Build resilience by capturing and attending to city diversity* (R4) • *Systematize spatial data and interactions among stakeholders* (R14) • *Facilitate citizen engagement with government through social media* (R16) 2. Capacity-building. • *Improve the expertise of local bureaucracies through training* (R2) • *Mobilize funds from a combination of sources* (R5) • *Create career opportunities for the jobless* (R6) • *Create international friendship parks* (R9) • *Map built-up structures and infrastructure networks* (R18) 3. Innovation • *Build innovation hubs* (R7) 4. Environment • *Create biophilic cities* (R8) 5. Quality of life • *Ensure public safety* (R10) • *Facilitate travel for disadvantaged groups* (R11) 6. ICT • *Increase ICT penetration* (R12) • *Use digital technologies judiciously* (R13) • *Create online data platforms* (R14) • *Use GIS and rational guidelines for the provision of social facilities* (R17)
Where	BRICS countries

2. *Improve the expertise of local bureaucracies through training*—It raises the need for building human capacity to assist in the development of successful urban projects.
3. *Engage more with non-state actors*—The identification of and engagement with committed nongovernment and private sector organizations that work toward people's welfare is important for urban restructuring processes.
4. *Build resilience by capturing and attending to city diversity*—City plans should consider and leverage their social and cultural diversity and address the special needs of the critical urban sectors, for instance, housing for the poor, flooding, and many others.
5. *Mobilize funds from a combination of sources*—Different modes and sources of funding, for instance, government grants, private sector funds and bank loans should be explored.
6. *Create career opportunities for the jobless*—Unemployed youth should be able to register in government databases to be identified and able to receive specialized services, like training, awareness of job opportunities, and others.
7. *Build innovation hubs*—The availability of public spaces where local stakeholders can discuss problems and find suitable solutions.
8. *Create biophilic cities*[6]—City planning should consider and carefully integrate nature-related issues, such as the development of green areas, green buildings, etc. Greater emphasis should be put on maintaining a balance between ecological security and economic development.
9. *Create international friendship parks*—Parks can be seen as places where artists, students, architects, designers, and other actors can join, share their creativity, and promote peace and friendship.
10. *Ensure public safety*—It highlights the prioritization of safety for all citizens of smart cities. This highlight includes raising human and institutional capacity on safety-related issues.
11. *Facilitate travel for disadvantaged groups*—The formulation and implementation of rational public transport policies that help low-income workers spend no more than a fixed percentage, for example, 6% of their salary, on public transport to commute to work.
12. *Increase ICT penetration*—Motivate the development of digital mobile-based citizen services and the deployment of video surveillance systems, and other emerging technologies in the city.
13. *Use digital technologies judiciously*—Assess and leverage the embeddedness of technology in modern life to simplify service processes. Also, design new

[6] "A biophilic city is more than simply a biodiverse city. It is a place that learns from nature and emulates natural systems, incorporates natural forms and images into its buildings and cityscapes, and designs and plans in conjunction with nature. A biophilic city cherishes the natural features that already exist but also works to restore and repair what has been lost or degraded", from "Biophilic Cities", by Timothy Beatly, ISBN: 9781597267144, https://islandpress.org/books/biophilic-cities, last visited 2020-02-01.

business models for digital financial services, like crowdfunding, peer-to-peer lending, micro-savings, and others.
14. *Systematize spatial data and interactions among stakeholders*—Promote the tools for systematizing available spatial data and interactions among actors, aimed at anticipating public policy outcomes.
15. *Create online data platforms*—The provision of online platforms containing up-to-date open data related to human development—demography, health, education, income, etc. Such data can help in understanding and effectively responding to urban inequalities.
16. *Facilitate citizen engagement with government through social media platforms*—The use of social media can stimulate citizen participation in local decisions, contributing to improved governance, higher inclusion, and higher quality of life.
17. *Use GIS and rational guidelines for the provision of social facilities*—The utilization of GIS tools assists in the planning and location of new strategic places in cities to maximize impact.
18. *Map built-up structures and infrastructure networks*—The survey of buildings and infrastructure networks, such as water, electricity, or gas, helps in the needed reconstruction processes.

Analysis and Discussion

This section aims to analyze, compare, and discuss international standards and policy guidelines for smart sustainable cities, the former presented in Sections "ISO/IEC JTC1 Smart Cities—Preliminary Report 2014" to "ETSI TS 103463 Key Performance Indicators for Sustainable Digital Multiservice Cities", and the latter in Sections "UNESCWA Smart Cities—Regional Perspectives" and "BRICS Smart Cities Movement Recommendations". Section "Analysis of International Standards" is dedicated to international standards, Section "Analysis of International Policy Guidelines" to international policy guidelines, while Section 5.3 carries out a discussion on the findings.

Analysis of International Standards

We start by making the names used in various measurement areas consistent. As shown in Section "Policy Documents", the ITU and ETSI standards apply two levels of indicators, while the ISO standards apply one level of indicators. The ITU standards call them dimensions and subdimensions, while the ETSI standards call them areas and topics. To make such names uniform, we call the first level dimensions and the second level themes.

We compare the dimensions applied by all standards based on four pillars of sustainable development—social, economic, environmental, and institutional (Estevez et al., 2016). As shown in Table 11, the standards cover all four pillars. The ISO dimensions are more detailed since they aggregate the indicators at one level. The intervention areas are those that measure: a) better life for residents in the social dimension, which is education, health, inclusion, access to basic services, recreation, sport and culture, and safety; b) economic development including economy, finances, agriculture, energy, telecommunications and productivity; c) environmental protection through clean energy, use of water, and taking care of water waste and solid waste. Finally, the institutional pillar is represented by governance and urban planning. This dimension is present for ISO and ETSI but not for ITU standards, which include governance under the equity and social inclusion dimension, at the theme level.

Comparing the themes measured by the indicators in the ISO set (Section "ISO/IEC JTC1 Smart Cities—Preliminary Report 2014"), three areas are addressed by all of them—energy, water, and environment. In the case of environment, Global City Indicators consider environment-related issues in general, the Green City Index focuses on environmental governance, while Smart City ICT Indicators on environmental impact. Also, two standards cover the area of waste: the Global City Indicators consider separately solid waste and water waste, while the Green City Index refers jointly to waste and land use.

Analyzing the KPIs defined by ISO (Sections "ISO 37120:2018 Sustainable Development of Communities—Indicators for City Services and Quality of Life" and "ISO 37122:2019 Sustainable Cities and Communities—Indicators for Smart

Table 11 Comparison of measured dimensions by the ISO, ITU and ETSI standards

	ISO	ITU	ETSI
Social	Education Health Housing Population Recreation Safety Sport and culture Transportation	Quality of life Equity and social inclusion Physical infrastructure Society and culture	People
Economy	Agriculture Economy Energy Finance Telecommunication	ICT Productivity Economy	Prosperity Propagation
Environment	Energy Environment Solid waste Water waste Water	Environmental sustainability Environment	Planet
Institutional	Governance Urban planning	*Not considered as the primary dimension*	Governance

Cities") and the KPIs defined by ITU including ITU-T FG SSC (Section "ISO/IEC JTC1 Smart Cities—Preliminary Report 2014") and the standards presented in Sections "ITU-T Key Performance Indicators Related to the Use of ICT in Smart Sustainable Cities", "ITU-T Key Performance Indicators Related to Sustainability Impact of ICT in SSC" and "ITU-T Key Performance Indicators for SSC to Assess the Achievement of SDGs", six themes are included in all of them: 1) education, 2) environment, 3) energy, 4) health, 5) safety, and 6) waste and sanitation. Besides, four of the standards consider governance and water. However, the standards consider different aspects of these areas, as shown in Table 12.

Considering the themes measured by the three ITU-T KPIs (Sections "ITU-T Key Performance Indicators Related to the Use of ICT in Smart Sustainable Cities", "ITU-T Key Performance Indicators Related to Sustainability Impact of ICT in SSC", and "ITU-T Key Performance Indicators for SSC to Assess the Achievement of SDGs") and the ones applied by the ETSI standard (Section "ETSI TS 103463 Key Performance Indicators for Sustainable Digital Multiservice Cities"), we can observe several similarities. There are four common themes—education, health, innovation and safety, the last with some variations, including safety, disaster relief, emergency, etc. The ITU-T KPIs refer to infrastructure/connection to services like electricity, health, piped water, sewage and transport, while ETSI calls them access to other services. Employment is considered in two ITU-T standards (ITU-T, 2016; ITU-T SG20, 2017). Table 13 shows how standards measure other themes related to sustainable development. Three interesting themes considered by the ETSI Standard include attractiveness and competitiveness, replicability and scalability, and success factors. Such themes are not part of the ITU-T standards, which may be related to higher levels of smart city standardization in Europe compared to other regions of the world.

An exercise of putting together all themes included in the 11 reviewed standards—ISO 37120:2018 (Section "ISO 37120:2018 Sustainable Development of Communities—Indicators for City Services and Quality of Life"), ISO 37122:2019 (Section "ISO 37122:2019 Sustainable Cities and Communities—Indicators for Smart Cities"), five other SSC-related ISO standards (Section "Other ISO Standards Related to Smart Sustainable Cities"), ITU-T Y.4901/L.1601 (Section "ITU-T Key Performance Indicators Related to the Use of ICT in Smart Sustainable Cities"), ITU-T Y.4902/L.1602 (Section "ITU-T Key Performance Indicators Related to Sustainability Impact of ICT in SSC"), ITU-T Y.4903/L.1603 (Section "ITU-T Key Performance Indicators for SSC to Assess the Achievement of SDGs") and ETSI TS 103463 (Section "ETSI TS 103463 Key Performance Indicators for Sustainable Digital Multiservice Cities")—results in 206 themes in total. Figure 1 shows a word cloud comprising all of them. The word cloud highlights the main horizontal themes—infrastructure/connection to services and physical infrastructure, and safety; and vertical themes—health, education, energy, water and innovation. Other themes include governance, urban planning, air quality, transportation, and environment.

Table 12 Comparison of the areas measured by the ISO and ITU KPIs

		ITU-T			
Common area	ISO	FG SSC	Y.4901/L.1601	Y.4902/L.1602	Y.4903/L.1603
Education	Education	Education and training	Education	Education	Education
Environment	Environment and climate change	Environment	Air quality	CO_2 emissions	Air quality
Energy	Energy	Energy resources	Infrastructure/connection-to-services electricity	Energy	Energy
Health	Health	Healthcare	Health	Health	Health
Safety	Safety	Security and safety	Safety and security public places	Safety and security public places	Safety and disaster relief Safety and emergency Safety of ICT
Sanitation	Wastewater	Sanitation	Infrastructure/connection-to-services sewage	Infrastructure/connection-to-services sewage	Water and sanitation
Governance	Governance	Governance	Governance	Openness and participation	*(not considered)*
Water	Water	*(not considered)*	Water, soil, and noise	Water, soil, and noise	Physical infrastructure water-supply

Table 13 Comparison of the themes measured by ITU and ETSI KPIs

	ITU-T Y.4901/L.1601	ITU-T Y.4902/L.1602	ITU-T Y.4903/L.1603	ETSI
Economy	Knowledge-economy Trade	Capital investments Household income/compensation Export/import Inflation	Employment Productivity Trade e-Commerce	Economic performance Green economy
Environment	Air quality Water, soil, noise	Air quality CO_2 emissions Water, soil, noise	Air quality Biodiversity Environmental quality Noise Water and sanitation	Climate resilience Ecosystem Energy and mitigation Materials, water, and land Pollution and waste
Governance	Governance	Openness and public participation	(not considered)	Multilevel governance

Fig. 1 Word cloud of the themes covered by the reviewed standards

Analysis of International Policy Guidelines

The two regional policy guidelines highlight the importance of considering the local context for any city development activity. For example, the recommendations produced for the Arab region consider history for classifying cities, whether they are older than 1000 years. While such a criterion would still be valid for Europe or Asia, it would not be for cities in Latin America. Another context-dependent recommendation is assigning city governments in the Arab region with the steering but not leadership roles due to political instability. In more stable regions of the world, we can see local governments, for instance, in London, Singapore, Seoul, or New York (Smiciklas, Ashirangkura, Hyodo, Walker-Turner, and Xu, 2017), leading the smart development of their cities.

Also, the recommendations present an interesting approach for smart city development as they propose to start with a limited scope, mainly one sector to show results, and later to replicate such results to other sectors. Given the scarcity of financial and human resources in developing countries, this could be a viable approach to adopt by cities in the developing world.

The recommendations for the BRICS countries include several key success factors identified by cities in those countries, like establishing sound governance mechanisms, ensuring multi-stakeholder participation, and building human capital on both government and civil society sides.

Both recommendations call for regional cooperation and the sharing of good practices. This is valid not only at the regional level but also worldwide, as many international think tanks are implementing knowledge repositories that document case studies and good practices in smart city initiatives.

Conclusions

The evolution of smart cities toward smart sustainable cities has been accompanied by an update to the relevant standards and policy guidelines. In response, this chapter includes a summary of international standards and policy guidelines related to smart sustainable cities. In particular, we revised 15 recently published by international bodies documents related to smart sustainable cities. These documents were chosen primarily based upon their relevance, timeliness, and scope: either global (publications by ISO or ITU) or regional (publications by ETSI, UNESCWA or BRICS).

The comparison of the standards and policy guidelines highlight common intervention areas for the development of smart sustainable cities: education, health, social inclusion, environment, innovation, safety, governance, and citizen participation. ICT plays a key role in facilitating the development of any smart city service or product. Therefore, an important component of all smart city initiatives is a reliable and secure ICT infrastructure, accessible and affordable to all city residents and businesses. Despite the identified commonalities, it is clear that each city needs to define its own priorities, sectors to develop, and paths to pursue such development according to their local needs, resources, and capacities.

While the main responsibility for transforming a city into a smart city or a smart city into a smart sustainable city rests upon the local government, the local government can make limited progress alone. To deepen the transformation and embrace changes in various city sectors, cities need the expertise, capacity of and collaboration with a variety of stakeholders and actors. Also, national governments have a role to play in city development. For instance, they can help scale up smart city initiatives to reach greater numbers of residents or define policies and guidelines for cities to consistently implement such initiatives. Having national policies present several benefits, for instance defining an instrument once and applying it many times, leveraging on the bigger capacity of national governments, providing policy

instruments for local governments with low capacity, and defining consistent and uniform city development paths country-wide.

Defining national or local policies for smart sustainable city development requires two major efforts—assessing the global state of the art and evaluating the state of local readiness. For both efforts, it is relevant to know what are the major international standards that the initiatives should consider. Besides, the standards serve as tools for highlighting major areas of intervention for smart city development. Thus, they are useful for defining a gap between the current and the aspiring level of development in a given area. This chapter contributes to this process by revising major international standards relevant to smart sustainable cities, as a basis for defining policies aimed at developing and managing such cities.

While pursuing community development, governments are also responsible for fulfilling international commitments like the achievements of Sustainable Development Goals or other regional development goals. Thus, for governments pursuing smart sustainable city initiatives, it is of high relevance to consider and contribute to regional policy instruments and related policies like e.g. the regional digital agendas.

We acknowledge that the literature reviewed in this work is not exhaustive. There may be other standards and policy guidelines that were not included, mainly because the intention was to uncover similarities and differences, not to be comprehensive. Our future work includes creating and maintaining an online repository of policy instruments for smart sustainable cities, to serve as a digital resource for various activities related to developing and managing such cities, for instance, for courses and educational programs that help build human capacity in this area.

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