ITU-T standardisation activities on smart sustainable cities

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Abstract: This study highlights the standardisation activities that are being carried out by the International Telecommunication Union (ITU) via its Study Group 20, the United for Smart Sustainable Cities (U4SSC) initiative and other venues, in supporting the adoption of information and communication technologies (ICTs) in smart sustainable cities (SSCs). These standards include common terminologies for the Internet of Things (IoT) and SSCs, the requirements for high performing ICT infrastructures, and the interoperability between different ICT or IoT networks. The work of ITU has encouraged the integration of ICTs into SSC, promoted sustainable and inclusive growth, and supported cities worldwide in reaching the United Nations' sustainable development goals.

1 Introduction

Rapid urbanisation has posed immense pressure globally on cities' sustainability. Today 55% of the world's population already lives in urban areas and this proportion is expected to increase to 68% by 2050, which will see another 2.5 billion people moving to cities. Metropolitan areas already account for over 70% of global carbon emissions and 60–80% of the world's energy consumption [1, 2]. Further urbanisation will mean that access to food, clean water, health care, and education. Other basic necessities will become a struggle particularly for the marginalised populations living in informal settlements, such as slums. Currently, 24% of the world's urban population lives in slum-like conditions, and it is expected that by 2030 three billion people will need proper housing, increasing the risks associated with persistent urban poverty [3]. This will likely be accompanied by significant levels of multi-layered crimes that often take place in the most deprived urban communities. Cities around the world are, therefore, increasingly looking to adopt a smart approach to urban planning that centres around using information and communication technologies (ICTs) to meet new urban sustainability challenges.

ICTs are the key medium that weaves digital intelligence into cities' fabric, establishing the foundation for innovating digital solutions that improve energy efficiency, optimise urban management, enhance the liveability of cities and provide new opportunities for its citizens. ICT devices and similar IoT applications such as smart sensors, smarter meters, smart grids, mobile and computing devices communicate and connect with one another to collect, analyse and share real-time urban data and information for managing traffic, reducing energy usage, limiting the carbon footprint, delivering early disaster warning, and improving urban operations and services [4]. ICTs can leverage artificial intelligence (AI) and other emerging technologies to further our understanding of urbanism, thereby providing vital information to tackle urban challenges and minimise climate risks that affect urban dwellers, and facilitating a platform for policymakers to engage in two-way communication with their citizens and formulate collective actions to address these concerns.

The International Telecommunication Union (ITU), the United Nations' specialised agency in ICTs, has long recognised the transformative potential of ICTs for improving the quality of life and social services in cities. To emphasise its commitment to supporting cities in leveraging ICTs for smart innovation and for meeting sustainability-related challenges, ITU has helped define and promote the concept of 'smart sustainable cities' (SSCs) when developing international standards and tools that support cities in deploying ICTs. This study highlights the key standardisation activities that are being carried out by ITU, including the preliminary study by a focus group that assembles the stakeholders, develops technical standards that harmonise the deployment of ICTs, and introduces global initiatives that encourage the use of ICTs in the area of sustainable urban development.

2 Standardisation activities in SSCs

As a standard development organisation (SDO), ITU-T brings together experts from its members, including policymakers, academia, technical experts, non-profit organisations, representatives from the private sectors and other key stakeholders in order to formulate principles and guidelines that will serve the ICT industry as a whole. In line with the World Telecommunication Standardisation Assembly Resolution 98 'Enhancing the standardisation of Internet of Things and smart cities and communities for global development', ITU-T recognises the importance of ICTs and IoT in contributing to the achievement of the 2030 agenda for sustainable development. International standards developed by ITU-T (also called ITU-T Recommendations) have supported cities in deploying, implementing, adopting, assessing and sustaining IoT for SSC while taking into consideration regional priorities. ITU-T also recognises the need to collaborate with industry forums and other SDOs in order to generate global consensus on key interoperability issues of IoT services and to accelerate strategic ICT proliferation [5].

2.1 Definition of SSC

In October 2015, ITU and the United Nations Economic Commission for Europe (UNECE) agreed to the following definition of SSC [6]:

'A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects.'

This definition is the result of the collaborative works carried out by the ITU-T Focus Group on Smart Sustainable Cities (FG-SSCs). This group provides an open platform for smart city stakeholders, such as municipalities, academia and research institutions, non-governmental organisations, ICT organisations, industry forums and consortia to share their views and expertise in the interest of identifying the standardisation frameworks needed to
support the integration of ICT services in SSCs. After reviewing ~120 existing definitions of the concept of ‘smart city’ and its variations, a total of 50 keywords were isolated [7]. These keywords were then grouped into eight categories that reflect the foundational aspects of a SSC (see Table 1). This was followed by careful analysis of each category, as a result of which a set of criteria emerged that the experts of Focus Group on Smart Sustainable Cities agreed best defined a SSC. The definition of SSC produced by Focus Group on Smart Sustainable Cities has been adopted by the United Nations.

### 2.2 Standardisation roadmap

The Focus Group on Smart Sustainable Cities proposed a framework of standards for SSCs (see Fig. 1), which can be generally classified into four categories: (i) SSC management and assessment; (ii) SSC services; (iii) ICT; and (iv) buildings and physical infrastructure. It also provided a standardisation roadmap, taking into consideration the activities undertaken by the various SDOs and forums. The intent is to provide suggestions for potential standardisation activities to ITU-T Study Groups and other SDOs [8].

Along with the roadmap, the SSC-related activities of SDOs, consortiums, and forums have been identified. The relevant standards and documents have also been collected and listed [9].

The work of FG-SSCs has concluded in May 2015 with 21 deliverables of Technical Reports and Technical Specifications on overview of SSC, SSC definition, city leaders’ guide, master plan, stakeholders analysis, infrastructure, ICT architecture, cybersecurity, open data, smart building, smart water management, climate change adaptation, electromagnetic field consideration, integrated management, key performance indicators (KPIs) and more [10]. These technical reports and technical specifications have not only promoted and supported the integration of ICTs in cities but have also become important reference points for ITU-T’s future works in SSC.

#### 2.3 ITU-T study Group 20

Much of the work at ITU-T is done via its study groups. Each study group is comprised of a diverse range of experts that are dedicated to defining the standardisation requirements or a framework of a specific area. Study groups gather experts to collaborate in order to develop interoperable systems, share best practice, and formulate principles and guidelines that will serve the interests of the ICT industry as a whole. By providing neutral platforms such as study groups for reaching global consensus, ITU offers a vital and efficient service to an industry that is already the main driver for social and economic development.

Established in 2015, ITU-T Study Group 20, entitled ‘Internet of things and smart cities and communities’ (ITU-T SG20), is the leading study group on IoT applications in smart cities and communities (SC&C). ITU-T SG20 recognises that ICTs and IoT are the key enablers of SSCs and offer significant potential towards improving energy efficiency in buildings, relieving traffic congestion, optimising resource usage in households, and improving disaster management. The group is mandated to support city governments to re-architect their city digital infrastructure and to assist the ICT industry in generating consensus on the functionality of key IoT objects. ITU-T SG20 provides a unique platform for city stakeholders to influence the development of ICT standards and their applications in urban development master plans at the international level. Currently, SG20 has seven Questions under study with the following topics:

- **Q1.** ‘End to end connectivity, network, interoperability, infrastructures and big data aspects related to IoT and SC&C’.
- **Q2.** ‘Requirements, capabilities, and use cases across verticals’.
- **Q3.** ‘Architectures, management, protocols, and quality of services’.
- **Q4.** ‘eServices, applications and supporting platforms’.
- **Q5.** ‘Research and emerging technologies, terminology and definitions’.
- **Q6.** ‘Security, privacy, trust and identification for IoT and SC&C’.
- **Q7.** ‘Evaluation and assessment of SC&C’.

The main activity that the group carries out is the development of technical standards that coordinate the development of IoT technologies, including ubiquitous sensor networks, machine-to-machine (M2M) communications and architectures, and interoperability between different ICT networks through a collaborative process.

Table 2 below lists ITU-T SG20’s key standardisation areas in IoT and SSCs.

Each category listed in Table 2 contains multiple international standards developed by SG20 that support the deployment of ICT in SSC. Table 3 below contains a list of international standards developed by SG20 in the area of SSC.

New work items are being created under each Question according to the topics. Table 4 contains a list of standards on SC&C that are under development by SG20.

In addition, ITU-T SG20 usually holds two plenary meetings every year with its members to discuss progress on work items, consent draft recommendations and approve the creation of new work items. Non-members are also invited to participate in the promotional activities organised by SG20. For example, ITU-T SG20 organised the ‘1st Forum on Artificial Intelligence and the Internet of Things in Smart Sustainable Cities in Latin America’, on 29 and 30 May 2018 in Buenos Aires, Argentina. The event brought together regional stakeholders to discuss the innovative policies and regulatory frameworks needed to leverage the potential offered by AI and IoT in Latin America. It also specifically recognised the need to build a smart city platform (SCP) where best practices and vital data can be shared, and milestones can be established. Similarly, ITU-T SG20 organised the ‘ITU Forum on Artificial Intelligence, Internet of Things and Smart Cities’ on 3 December 2018, prior to its plenary meeting on 4–13 December in Wuxi, China.

#### 2.4 Typical SSC-related recommendations – SCP series

ITU-T published two recommendations on SCPs in February 2018 [11, 12]. SCP is a core ICT infrastructure in urban information construction.

Urban information systems can be roughly divided into two categories: (i) the internal systems, managing urban services such as}

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**Table 1** Groupings of keywords and categories from the review of 120 definitions of ‘smart city’

| Category                                      | % Occurrence |
|-----------------------------------------------|--------------|
| quality of life and lifestyle                 | 6            |
| infrastructure and services                   | 17           |
| ICT, communication, intelligence, information | 26           |
| people, citizens, society                     | 12           |
| environment and sustainability                | 17           |
| governance, management and administration     | 10           |
| economy and finance                          | 8            |
| mobility                                      | 4            |
| total                                         | 100          |

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as water supply, power supply, garbage disposal, lighting, parking, traffic management etc. and (ii) external systems, such as long-distance transportation, ports, airports etc., which provide services between cities. These urban systems collect information about the status of the city, and they are managed by different types of control systems (such as internet of things (IoT) platform, supervisory control and data acquisition system, big data platform etc.). In most cases, these vertical systems are separated, non-standardised and closed, and it is difficult to share resources and data. By introducing a common SCP, multiple vertical systems are integrated and optimised to provide interaction between urban information systems to support various functionalities of urban services and ensure the convenience, security, and scalability of the platform.

A SCP directly integrates city platforms and systems (i.e. SCP functions) or through open interfaces between SCP and external providers to offer the urban operation and services supporting the functioning of the city services. As illustrated in Fig. 2, a SCP has the following SCP functions [11]:

- services support functions,
- interfacing functions,
- data/knowledge functions,
- acquisition/interconnection functions, and
- security and management functions.

The external providers include

- services and applications providers,
- data and computation providers, and
• sensing and infrastructure providers.

There are interfaces for communication between the SCP with the external systems or other platforms. These interfaces are shown in Fig. 2 as red arrows, detailed in the following list:

• Services interface – which connects SCP's services support functions and the external data and computation providers.
• Interoperability interface – which connects SCP's data/ knowledge functions interoperability and the external database and computation systems.
• Acquisition interface – which connects SCP's acquisition/ interconnection functions and the external sensing and infrastructure systems.

The interoperability of SCP through the above interfaces is required to comply with [12].

These standards on SCP have been implemented in some cities. In the future, this series of standards on SCP will continue to be developed, focusing on detailed functional descriptions, metadata, and semantics.

2.5 Typical SSC-related recommendations – KPI series

In some areas of natural science, understanding and judgment are often carried out in the laboratory. However, for social sciences, there is usually no research laboratory. If the statistical data is not sufficient, and the study presents the diversification, an alternative method may be evaluation and comparison. The main purpose of this research is to try to extract a set of indicators to describe the effectiveness of building smart cities, especially the important role played by ICT. We are expecting to understand city sustainability through the comparison and assessment of urban construction, including the comparison between different cities, and the comparison of some cities in different historical periods.

The assessment of smart cities has some implication of guide, namely, what is the effective method? Can it improve the urban functionalities, improve quality of life, and ensure the

| Table 3 | Examples of international standards developed by ITU-T SG20 |
|---------|----------------------------------------------------------|
| ITU-T Y. series | Title |
| Y.4119 | Requirements and capability framework for IoT-based automotive emergency response system |
| Y.4120 | Requirements of IoT applications for smart retail stores |
| Y.4200 | Requirements for the interoperability of smart city platforms |
| Y.4201 | High-level requirements and reference framework of smart city platforms |
| Y.4203 | Requirements of things description in the internet of things |
| Y.4204 | Accessibility requirements for the IoT applications and services |
| Y.4251 | Capabilities of ubiquitous sensor networks for supporting the requirements of smart metering services |
| Y.4408 | Capability framework for e-health monitoring services |
| Y.4450 | Overview of smart farming based on networks |
| Y.4456 | Requirements and functional architecture for smart parking lots in smart cities |
| Y.4457 | Architectural framework for transportation safety services |
| Y.4800 | Requirements and functional architecture of an automatic location identification system for ubiquitous sensor network application |
| Y.4801 | Requirements and common characteristics of the IoT identifier for the IoT service |
| Y.4805 | Identifier service requirements for the interoperability of smart city applications |
| Y.4900 | Overview of key performance indicators in smart sustainable cities |
| Y.4901 | Key performance indicators related to the use of information and communication technology in smart sustainable cities |
| Y.4902 | Key performance indicators related to the sustainability impacts of information and communication technology in smart sustainable cities |
| Y.4903 | Key performance indicators for SSCs to assess the achievement of sustainable development goals |
| Y.4905 | Smart sustainable city impact assessment |

| Table 4 | Examples of work items that are being developed by ITU-T SG20 |
|---------|----------------------------------------------------------|
| ITU-T Y. series | Title |
| Y.infra | Overview of city infrastructure |
| Y.isms | Technical framework for integrated sensing and management system |
| Y.nmm-isms | The node metadata model for integrated sensing and management system |
| Y.SC-OpenData | Framework of open data in smart cities |
| Y.ACC-PTS | Accessibility requirements for smart public transportation services |
| Y.IoT-SLF | Framework and capabilities for smart livestock farming based on internet of things |
| Y.SCC-reqts | Common requirements and capabilities of smart cities and communities from IoT and ICT perspectives |
| Y.IoT-SmartBuild | Common requirements and capabilities of smart buildings from the IoT perspective |
| Y.Sup.SCC-Use-Cases | Use cases of smart cities and communities |
| Y.SmartAirport | Services and high-level requirements of smart airports for interaction with external platforms |
| Y.smartport | Requirements of smart management of supply services in smart port |
| Y.SmartRailwayStation | High-level requirements and capabilities of smart railway station platform |
| Y.SRC | Requirements for deployment of smart services in rural communities |
| Y.AERS-mtp | Minimum set of data transfer protocol for automotive emergency response system |
| Y.SCCE-arch | Reference architecture of spare computational capability exposure of IoT devices for smart home |
| Y.AM-SC-reqts | IoT technical requirements and framework for monitoring physical city assets |
| Y.IoT-AV-Reqts | Requirements and capability framework of IoT infrastructure to support network-assisted autonomous vehicles |
| Y.disaster_notification | Framework of the disaster notification of the population in smart cities and communities |
| Y.energy-mMG | Application model for energy services on multiple microgrids |
environmental, economic and social sustainability? Simply speaking, the construction of SSC can be considered as an 'input–output' system. Input and output have linear characteristics, i.e. inputs more and gets more outputs. They also have non-linear characteristics, i.e. inputs more but gets less rewarding. This system is in alignment with the logic of the precision variation and unclear logic to unexpected changes, sometimes even shows confusion which may be difficult to understand and explain. All of these reveal the charm of this study and its difficulty lies. After tremendous efforts, ITU-T finally reached a consensus and achieved fruitful results. From June to October 2016, four standards of KPI series were published in turn.

ITU-T Recommendation Y.4900/L.1600 gives general guidance to cities and provides an overview of KPIs in the context of SSCs [6]. The proposed set of KPIs focuses specifically on a set of ICT-related indicators. The dimensions and sub-dimensions of KPIs have also been specified. To fit into the overall framework of city indicators the recommendation re-uses the categorisation of UN Habitat's city prosperity index [13]. Y.4901/L.1601 specifically provides the KPIs related to ICT adoption and use in the context of SSCs [14]. Evaluating these indicators can help cities, as well as their stakeholders, understand the extent to which they may be perceived as a SSC. The recommendation describes the applicability of KPIs, principles,
Comparability on their population growth, geographical locations, environmental indicators. The general principles for selecting KPIs are proposed:

- **Comprehensiveness**: The set of indicators should cover all the aspects of SSC. The indicators of evaluation should be aligned to the measured subject, i.e. ICT and its impact on the sustainability of cities. The index system should reflect the level of general development in a certain aspect.

- **Comparability**: The KPIs should be defined in a way that data can be compared scientifically between different phases of urban development, which means the KPIs should be comparable over time and space for the same city. It should also be possible to extend and amend the set of KPIs according to the actual development.

- **Availability**: The KPIs should be quantitative and the historical and current data should be either available or easy to collect.

- **Independence**: The KPIs in the same dimension should be independent or almost-orthogonal, i.e. the overlap of the KPIs should be avoided as much as possible.

- **Simplicity**: The concept of each indicator should be simple and easy to understand. Also, the calculation of the associated data should be intuitive and simple.

- **Timeliness**: The ability to produce KPIs with respect to emerging issues in SSC construction.

Y.4902/L.1602 specifically provides the KPIs related to ICT impacts on city sustainability in the context of SSCs [15]. Y.4903/L.1603 gives general guidance to cities and provides KPIs for SSC to help cities achieve sustainable development goals (SDGs) [16]. This recommendation has been jointly developed with UNECE and other UN agencies. The set of KPIs has been structured according to three major aspects, namely: (a) areas, (b) topics and (c) types of indicators [16]. The areas represent the more generic dimensions, which provide a framework for the set of indicators. They correspond to the three pillars of sustainability: economy, environment, and society and culture (see Fig. 3). The topic indicates a group of specific indicators, which describe an area of potential development. Nineteen major topics are identified and each indicator is assigned to one specific topic. Some topics include specific sub-topics, which can be considered as keywords that more thoroughly define the nature of indicators.

This recommendation lists 52 core indicators that have been selected as being applicable to all cities. In Appendix I, 38 additional indicators have been listed for the city to select, based on their population growth, geographical locations, environmental conditions, demography etc. All the indicators are mapped to SDG goals and targets in the city level.

ITU-T SG20 has a dedicated Question 7 ‘Evaluation and assessment of smart sustainable cities and communities’ for developing standards on methodologies to evaluate the achievements of building SSC. The recent extension of the KPI series is that two recommendations on ‘SSC impact assessment’ and ‘SSC maturity model’ have been consented, and a new work item on ‘blockchain-based unified KPI data management for SSC’ has been created.

### 2.6 Joint coordination activity on internet of things and smart cities and communities (JCA-IoT and SC&C)

The JCA-IoT and SC&C is a group that is responsible for coordinating ITU-T's work on the 'IoT and SC&C' and for providing a visible contact point for IoT and its applications, including SC&C activities within ITU-T. It also helps to coordinate with external bodies working in the field of IoT and SC&C and would enable effective two-way communication with these bodies. External bodies include relevant SDOs such as International Electrotechnical Commission, International Organization for Standardisation or relevant academia, consortia etc. [17].

The JCA-IoT and SC&C is a subgroup of ITU-T SG20. It represents a significant internal organ within ITU-T that improves the efficiency and productivity of ITU-T SG20 by being a focal point of communication. The complexity of SSC related work often involves extensive expertise covered by multiple ITU-T study groups and other SDOs. The work of JCA-IoT and SC&C has helped SG20 to avoid duplications of work, to harmonise key responsibilities, and to create a unified vision on key issues that allow ITU-T to coordinate with other SDOs.

### 2.7 United for smart sustainable cities (U4SSC)

The U4SSC is a United Nations initiative coordinate by ITU, UNECE, and the United Nations Human Settlements Programme (UN-Habitat), and supported by 13 other agencies and programmes including the Secretariat of the Convention on Biological Diversity, the Economic Commission for Latin America and the Caribbean, the Food and Agriculture Organisation of the United Nations, the United Nations Development Programme, the United Nations Economic Commission for Africa, the United Nations Environment Programme Finance Initiative, the Secretariat of the United Nations Framework Convention for Climate Change, the United Nations Industrial Development Organisation, the United Nations Environment Programme (UN Environment), the United Nations Framework Convention for Climate Change, and the United Nations Development Programme.
Nations University-Operating Unit on Policy-driven Electronic Governance, the United Nations Entity for Gender Equality and the Empowerment of Women (UN-Women), United Nations Educational, Scientific and Cultural Organisation and the World Meteorological Organisation [18]. The primary objective of U4SSC is to advocate for public policy and to encourage the use of ICTs to facilitate the transition to SSC in order to achieve sustainable development goal 11: ‘Make cities and human settlements inclusive, safe, resilient and sustainable’. The initiative is working to support the creation of legal, regulatory and institutional frameworks for SSC, to provide practical guidance for decision makers and other urban stakeholders on sustainable urban development, to foster discussions on the role of ICTs in SSC, and to raise awareness on SSC related topics. Since its creation in 2016, U4SSC has developed deliverables such as flipbook on ‘Connecting cities and communities with the SDGs’; flipbook on ‘Enhancing innovation and participation in smart sustainable cities’; and flipbook on ‘Implementing SDG11 by connecting sustainability policies and urban planning practices through ICTs’ [18].

The U4SSC is currently working on the following deliverables:

- Guidelines on tools and mechanisms to finance SSC projects.
- Guidelines on strategies for circular cities.
- City science application framework.
- Guiding principles for AI in cities.
- Blockchain 4 cities.
- Thematic group on ‘the impact of frontier technologies in cities’.
  - The impact of sensing technologies and IoT in cities.
  - The impact of AI and cognitive computing in cities.
  - The impact of data processing and computation in cities.

One of the most acclaimed achievements of the U4SSC has been the publication of the document ‘Collection methodology for key performance indicators for smart sustainable cities’ [18]. Based on ITU-T Recommendation Y.4903/L.1603, this document incorporates more indicators proposed by other UN agencies. The 91 indicators are specifically designed to evaluate the role of ICTs in the three key dimensions of a city; i.e. economics; environment; and society and culture.

Since 2015, over 50 cities worldwide have already participated in piloting the KPIs for SSC. Four cities, namely Dubai (UAE), Singapore, Bizzerte (Tunisia) and Pully (Switzerland) have been granted certificates by U4SSC initiative.

The data gathered via the KPIs will form the basis of the ‘global SSCs index’ which is currently being developed by ITU and the Smart Dubai Office. The index is intended to be a practical tool to benchmark ICTs contribution to sustainability and smartness as well as the cities’ progress in reaching the SDGs in comparison with other cities. The index will be the first coherent SSC metrics developed at the international level to showcase the SDG progress within the context of ICTs. It will be a highly useful tool for any city to improve and advance their smart city strategy and revise their city master plan.

### 3 Conclusion

While rapid urbanisation has posed unprecedented challenges on cities’ sustainability, metropolitan areas also offer the best chance to refocus efforts in meeting the needs of all city dwellers, fostering inclusive economic growth, and achieving the SDGs. Cities are the hubs of economic activities and technological innovation, thereby providing new and exciting career opportunities for many and delivering social services for the needy. Urban areas bring together people, ideas, platforms, and innovations from across sectors. Together, these offer the best chance for improving the liveability and sustainability of cities by integrating the right technologies in city operations and becoming a SSC. Global inclusive platforms such as ITU-T SG20 and U4SSC are playing critical roles in harmonising the implementation of ICTs in SSCs. Therefore, it is strongly recommended that city stakeholders utilise the work of ITU-T in making cities smarter and more sustainable.

### 4 Acknowledgments

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