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SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

ITU-T Y.4000 series – Smart sustainable cities – An overview of smart sustainable cities and the role of information and communication technologies

ITU-T Y-series Recommendations – Supplement 45

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Supplement 45 to ITU-T Y-series Recommendations

ITU-T Y.4000 series – Smart sustainable cities – An overview of smart sustainable cities and the role of information and communication technologies

Summary

Supplement 45 to the ITU-T Y-series Recommendations provides an overview of roles of information and communication technologies (ICTs) in smart sustainable cities (SSCs) primarily based on ITU-T Recommendations. An SSC aims to improve quality of life (QoL), efficiency of urban operation and services, as well as competitiveness, ensuring that the needs of present and future generations with respect to economic, social, environmental and cultural aspects of cities and communities are met.

SSCs in general, share the goal of achieving an economically sustainable urban environment without compromising the QoL of their citizenry. A smart city and community strives to create a sustainable living environment for citizens using the Internet of things (IoT), enabled by ICTs.

An IoT-based infrastructure, enabled using ICTs, can continue to play a pivotal role in SSCs by functioning as a platform for the aggregation of information and data that can help government officials and citizens understand how the city is functioning in terms of resource consumption and services.

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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ITU-T Y.4000 series – Smart sustainable cities – An overview of smart sustainable cities and the role of information and communication technologies

1 Scope

This Supplement provides an overview of smart sustainable cities (SSCs) and the role of information and communication technologies (ICTs) based on ITU-T Recommendations relevant to SSCs.

This Supplement provides information on:

– goal and city dimensions of SSCs;

– usage of ICTs in the SSC context;

– sustainability impacts of ICTs on SSCs;

– evaluation of achievements of SSCs.

This Supplement does not intend to define technical requirements or to mandate any particular technologies that could be used when developing smart cities. It does not intend to compare tools, applications or platforms that could be used in smart cities.

2 References

[ITU-T L.1302] Recommendation ITU-T L.1302 (2015), *Assessment of energy efficiency on infrastructure in data centres and telecom centres*.

[ITU-T L.1400] Recommendation ITU-T L.1400 (2011), *Overview and general principles of methodologies for assessing the environmental impact of information and communication technologies*.

[ITU-T L.1503] Recommendation ITU-T L.1503 (2016), *Use of information and communication technology for climate change adaptation in cities*.

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[ITU-T Y.4900] Recommendation ITU-T Y.4900/L.1600 (2016), *Overview of key performance indicators in smart sustainable cities*.

[ITU-T Y.4901] Recommendation ITU-T Y.4901/L.1601 (2016), *Key performance indicators related to the use of information and communication technology in smart sustainable cities*.

[ITU-T Y.4902] Recommendation ITU-T Y.4902/L.1602 (2016), *Key performance indicators related to the sustainability impacts of information and communication technology in smart sustainable cities*.

3 Definitions

3.1 Terms defined elsewhere

This Supplement uses the following terms defined elsewhere:

3.1.1 city [ITU-T Y.4900]: A urban geographical area with one (or several) local government and planning authorities.

3.1.2 smart sustainable city [ITU-T Y.4900]: 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.

3.2 Terms defined in this Supplement

This Supplement defines the following term:

3.2.1 knowledge-based economy: An economy that is directly based on the production, distribution and use of knowledge and information.

NOTE – This term and definition are based on those appearing in [b-OECD KE]

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

BAS	Building Automation System
BIM	Building Information Management
GDP	Gross Domestic Product
GIS	Geographic Information System
ICT	Information and Communication Technology
IoT	Internet of Things
IP	Internet Protocol
IT	Information Technology
ITS	Intelligent Transport System
KPI	Key Performance Indicator
NO_x	Nitrogen Oxides
QoL	Quality of Life
SCADA	Supervisory Control and Data Acquisition
SDO	Standardization Development Organization
SSC	Smart Sustainable City
SO_x	Sulfur Oxides
SWM	Smart Water Management
TCP	Transmission Control Protocol
UV	Ultraviolet
VPN	Virtual Private Network

5 Conventions

None.

6 Smart sustainable cities: goal and city dimensions

6.1 Goal of smart sustainable cities

Every city is unique. A variety of factors such as size, location, population growth projections, economy, brand, values, workforce and age profile are examples of components that impact a city and its goals. A city's vision and strategy could take into account a variety of characteristics such as these, seeking to address relevant challenges and identify opportunities. Adopting a goal-oriented strategy based on a city's unique characteristics can provide new ways to meet citizen needs and new business opportunities for local industry.

The goal of an SSC is, through efficient management of resources and infrastructure, to make the city run in a smart and sustainable way, so as to improve the quality of life (QoL) of its citizenry across multiple, interrelated dimensions, including (but not limited to) the provision of and access to water, energy, transportation, education, environment, waste management, housing and job opportunities. It requires efficient use of ICTs, while ICTs act as a platform to help meet these challenges and take advantage of emerging opportunities as cities advance in the process towards becoming smart and sustainable [b-ITU-T FG-SSC].

6.2 Smart sustainable cities landscape

With regard to the four dimensions described in [ITU-T Y.4900], city sustainability is dependent on the following four dimensions.

– Environmental dimension: The ability to protect the existing as well as the future quality and reproducibility of natural resources. The city is expected to be sustainable in its functioning for future generations, see clause 6.2.1.

– Economic dimension: The ability to generate income and employment for the livelihood of the citizens. The city is expected to be able to thrive, e.g., jobs, growth and finance, see clause 6.2.2.

– Social dimension: The ability to ensure that the welfare (safety, health, education, etc.) of citizens can be equitably delivered despite differences in class, race or gender. The city is expected to serve its inhabitants and visitors, see clause 6.2.3.

– Governance dimension: The ability to maintain social conditions of stability, democracy, participation and justice. The city is expected to be robust in its ability to administer policies and pull together the different categories, see clause 6.2.4.

6.2.1 Environmental dimension

According to [b-UN-Habitat], on a global scale, cities present the greatest environmental policy challenge, representing 75% of energy consumption and 80% of carbon dioxide (CO_2) emissions. Therefore, environmental sustainability is one of the most critical components in the functioning of any city.

The following categories of the environment dimension should be considered by cities:

- city environmental management:
  - environmental strategy,
  - integrated environmental management,
  - municipal administration on environment,
  - effective environmental conservation;
- energy and climate change:
  - CO_2 emissions (CO_2 from energy production, emissions per capita, etc.),
  - energy (energy performance, conservation, renewable energy, etc.);
- pollution prevention and waste management:
  - waste (waste management, wastewater treatment, etc.),
  - air [urban particulates and air quality, indoor air pollution, local ozone, regional ozone, nitrogen oxides (NO_x) and sulfur oxides (SO_x), etc.],

  - water (drinking water, water quality index, water stress, water management, etc.),
  - noise (noise pollution),
  - soil fertility, generation and renewal;
- ecological preservation:
  - green areas (green areas, public space, etc.),
  - native species,
  - agriculture (pollination of crops and natural vegetation, control of potential agricultural pests, biodiversity maintenance, etc.);
- radiation protection:
  - solar ultraviolet (UV),
  - electromagnetic radiation.

6.2.2 Economic dimension

A goal for SSCs is to determine an economical way to achieve sustainability without sacrificing the QoL of their citizenry. Therefore, in the economy dimension a city needs to examine whether: 1) the economy is undergoing an active or inactive process during different stages of SSC construction; 2) there is enough economic resource to carry out further SSC development.

The city should consider the following categories of the economy dimension as appropriate:

- gross domestic product (GDP);
- employment;
- financial resilience;
- capital investment;
- human capital;
- export and import;
- innovation;
- trade;
- knowledge-based economy.

6.2.3 Social dimension

In the social dimension the city needs to examine: 1) whether an SSC has reached its goal or has made progress without appreciably degrading QoL; 2) what effect an SSC has played on various aspects of social development.

The following categories of the social dimension should be assessed by a city:

- social services;
- citizen satisfaction;
- education;
- health;
- public safety;
- housing;
- culture and recreation;
- social inclusion;
- equity of income;
- equity of consumption;
- personalized services;

– access to information;
– public sector transparency.

6.2.4 Governance dimension

The city needs to examine to what extent: 1) the construction of an SSC helps improve urban administration; 2) the government plays an innovative role during SSC development; 3) local authorities are prepared and able to implement an SSC strategy.

Though e-governance promotes an automation standard and government efficiency, some stubborn urban administration problems remain, while new social challenges are emerging. Governance in an SSC is expected to enhance social conditions of stability, equity, participation, transparency, ethics and justice.

The following categories of the governance dimension should be assessed by a city:

– city infrastructure;
– equality of gender;
– equality of access to public services;
– openness and public participation;
– commitment.

Additional categories of the governance dimension commonly assessed by the city include (but are not limited to):

– city assets;
– stakeholder engagement;
– citizen-centric initiatives and access to services;
– efficiency of city management;
– ability to make informed decisions.

7 Use of information and communication technologies in smart sustainable cities

7.1 Integrated approach to smart sustainable cities

For ICT infrastructure systems managed in silos and with limited communication and information sharing among and across elements, it is essential to integrate these systems and components in cities. This can be achieved through ICTs, with ICT tools acting as the platform between the different physical and information infrastructures.

ICTs also enable the following functions, described in [b-ITU-T FG-SSC], which are keys to both achieving the goals and maximizing the performance of SSCs.

– **ICT-enabled information and knowledge sharing**: Through immediate and accurate sharing of information, cities could have better knowledge of their status and take appropriate action.
– **ICT-enabled forecasts**: Preparing for stressors such as natural disasters requires a considerable amount of data dedicated to study patterns, identify trends, recognize risk areas and predict potential problems. The city could improve its preparedness and response capability by managing this data and information efficiently.
– **ICT-enabled integration**: The city's vulnerabilities and strengths could be better understood through access to timely and relevant information (e.g., ICT-based early warning systems).
– **ICT-enabled digital modelling**: Planning and development is a key step in SSC development, for which ICTs can be used as a tool. Digital modelling can be used as a tool to develop people-cantered physical environments.

7.2 Use of information and communication technologies in city infrastructure

In addition to ICT infrastructures, such as network infrastructure, software applications, cloud computing or data platforms and access devices specified in [ITU-T Y.4900], Table 1 gives an example of ICT-based infrastructures and ICT-associated applications in SSCs.

In SSCs, ICTs could assist in the design, construction, ongoing management or operation and orchestrating various interactions between the physical infrastructure elements. ICTs systems are expected to connect a variety of public infrastructures and improve their efficiency, as well as providing much more effective services to the citizenry.

Table 1 – Information and communications technology used in urban physical infrastructure

Infrastructure topic	ICT use
Building management	• Building automation • Building control • Information technology (IT) network systems • Crisis management solution (power, infrastructure damage, etc.) • Building information management (BIM)
Data communications and confidentiality, integrity and availability	• Voice/video/data • Audiovisual • Structured cabling • Transmission control protocol /Internet protocol (TCP/IP) • Building automation system (BAS) • Virtual private network (VPN) access • Computer access • Network access • Firewalls • Managed security services and applications • Mobile broadband • Telecommunication network resiliency • Data security infrastructure • Biometrics
Smart grid/energy/utilities	• Energy logistics • Distribution (electricity, water, gas) • Utility monitor • Heat monitor • Lighting • Back-up power • Supply demand management/control functions • Leakage monitor
Physical safety	• Access control • Video surveillance intrusion detection • Perimeter and occupancy sensors • Fire alarm panels • Detection (smoke/heat/gas/flame)

Table 1 – Information and communications technology used in urban physical infrastructure

Infrastructure topic	ICT use
	• Fire suppression • Notification and evacuation
Emergency response	• Integrated fire control • Police and medical emergency services • Centralized and remote command and control • Scalable decision-making process
Transportation	• Traffic control and monitoring (rail, underground, buses, personal vehicles) • Intelligent transportation system (ITS) • 24/7 supply management (logistics)

7.3 Information and communications technology services and applications in smart sustainable cities

ICT services and information platforms can serve as the basic foundation for smart city development. Internally, it is a channel for data flow among different city departments, which can be used to form service chains, business coordination and information sharing. Externally, it is the portal for all public services and information publication. It can also provide integrated services to the public and enterprises by combining and supporting cross-department business.

7.4 Data and confidentiality, integrity and availability in smart sustainable cities

It is expected that production, acquisition, and use of data will be considered throughout the planning, design, implementation and operation of an SSC. Standards-based data formats and technology contribute to interoperability and assist in creating value from data. Centralized shared data systems, such as contracted data sharing or internal or open data hubs, can also increase value added. Tools such as data modelling should scale at every level (i.e., from individual buildings to citywide).

The following steps outline the use of data resources in smart city to generate value:

– identify relevance, quality and origin of data;
– visualize the data, for instance, with maps (e.g., distribution or movement of data points such as city buildings or traffic);
– correlate data to determine statistically significant meaning and make inferences;
– use software to model current city systems and develop models of new systems;
– implement the model developed and monitor the impact.

Cities should also consider the confidentiality, integrity, and availability of public service data and systems. As cities acquire significant amounts of data, they should consider the associated risks. Confidentiality, integrity and availability of data should be considered in every vertical sector and follow internationally recognized standards or best practices.

Examples of considerations applicable to confidentiality, integrity and availability of data in a Smart City environment include the following.

– **Energy data** – Cities should defend against potential attacks on energy systems that may lead to interruptions and also hinder data exchange between energy distribution centres and end users, thus severely compromising the delivery of energy services.

– **Transportation data** – Cities should eliminate obstacles to the flow of data that may affect the overall aim of transportation optimization. For example, traffic management could be weakened when the navigation system is hacked, leading to confusion and direction to inappropriate routes.
– **Local weather data** – Local weather data may be used to automatically control city infrastructure or prepare utilities for a change in environment. For instance, weather data may be used to automatically control river levees, particularly in months with heavy rainfall, or prepare national energy grids for added stress in periods such as heat waves. To ensure proper functioning of such systems, implementation of effective information confidentiality tools and principles, such as data integrity and access, is important.

7.5 Internet of things in smart sustainable cities

The IoT is defined as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable ITCs [ITU-T Y.2060].

Along with technological advancements, the adoption of the IoT is growing rapidly. The data from sensors could be collected, processed and analysed in real time, lowering costs.

IoT could be used to improve the efficiency of a city's functions by enabling the gathering of pertinent information.

8 Sustainability impacts of information and communications technology on smart sustainable cities

SSCs, as shown in Figure 1, incorporate four dimensions and a series of physical and service infrastructures, with ICT at the core acting as the platform that integrates all the other elements of the SSC. ICTs can be used as both a catalyst for change, enabling city leaders to set a vision and follow a strategic path into the future, as well as a solution to specific problems.

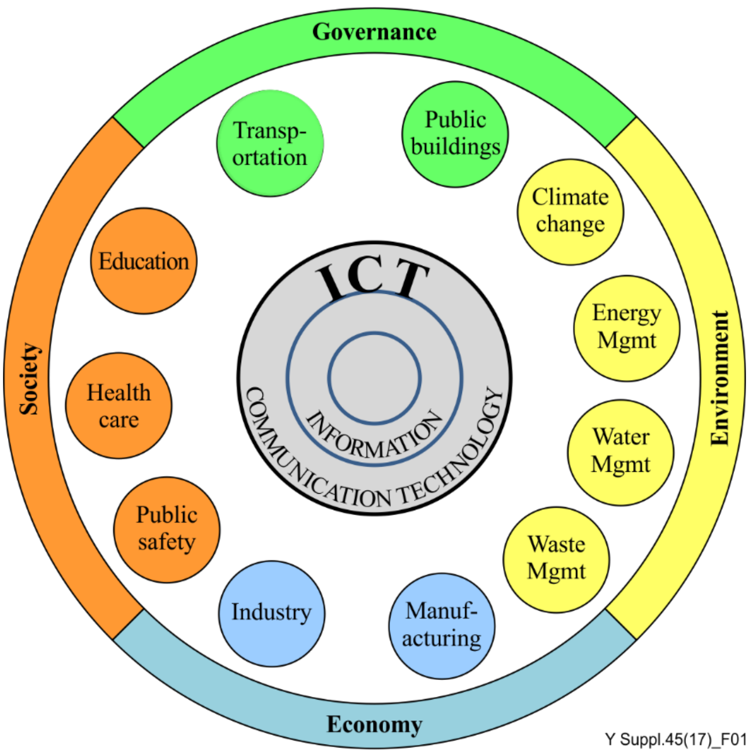

Figure 1 – Smart and sustainable city landscape

8.1 Contribution of information and communications technology to environmental sustainability

8.1.1 Climate change

ICT can change the way climate information is managed. ICT can be used to mitigate and adapt to climate change in cities in the way presented in [ITU-T L.1503].

ICT can be used to accelerate the implementation of concrete action by offering tools and applications that provide users with the means to consume in a sustainable manner. ICT solutions can be utilized to provide channels to influence other people including policy makers.

ICTs can provide easy-to-use and customized solutions to measure and deliver the environment-related information specified in [ITU-T L.1400].

8.1.2 Energy management

Cities can solve energy management problems with the development of new technologies to collect information and control energy in order to optimize urban energy consumption.

Smart energy management systems can use sensors, advanced meters, digital controls and analytic tools to automate, monitor and control the two-way flow of energy as explained in [b-ITU-T Y-Sup.36]. These systems optimize grid operation and usage by keeping consumers, producers and providers up to date about the latest technological advancements to deliver energy-efficient solutions [ITU-T L.1302]. This information can help translate real-time data to optimize grid operation and usage.

8.1.3 Water management

Smart water management (SWM) systems can use ICT-based solutions to provide access to safe water, to manage demand more efficiently and develop a better pricing mechanism. Examples include [b-ITU-T Y-Sup.36], [b-Ashton]:

– providing continuous monitoring of water quality and availability via smart sensors;
– improving water management.

SWM technologies, as described in [b-ITU-T Y-Sup.36], include:

– smart pipes and sensor networks;
– smart metering;
– communication modems;
– geographic information systems (GISs);
– cloud computing;
– supervisory control and data acquisition (SCADA);
– models, optimization and decision-support tools;
– web-based communication and information system tools.

The integration of such technologies is adapted to monitor water resources and to understand problems in the urban water sector.

8.1.4 Waste management

This challenge of waste (including e-waste) management can be addressed by source reduction, proper identification of the category of waste and recycling of waste. There may be various forward-looking solutions for converting waste into a resource and creating closed loop economies.

Smart waste management systems can enable the following areas of action [b-ST], among others:

– implementing waste-tracking systems to monitor and control the movement of different kinds of waste;
– sorting of waste without operator involvement;
– leveraging technology to collect and share data from source to transportation to disposal of waste;
– connecting various smart waste management systems with local waste management service providers.

8.2 Contribution of information and communications technology to economic sustainability

ICT has played a role in improving industrial processes, management modernization, economic growth, improved allocation of resources etc., all of which contribute to economic sustainability.

The ICT industry continues to have a positive impact. The use of ICTs can improve industrial processes through smart manufacturing, e.g., based on advanced computing and manufacturing technologies, as well as existing and evolving interoperable ICTs. This aims to support innovation and the development of products, services and technologies – improving the efficiency and reliability of manufacturing life cycle management, economic performance, safety and sustainability. Therefore, ICT provides options for economic transformation, and can assist in driving economies.

There are a range of data sources where the application of ICT can improve the efficiency of resource allocation and utilization for existing and new business. E-commerce is an example of an ICT application that can improve the efficiency of commerce and commercial transactions [ITU-T Y.4902].

8.3 Contribution of information and communications technology to societal sustainability

8.3.1 Education

ICTs can have a positive impact on education to improve QoL. Some important contributions of ICT tools to education provided in [b-Intel] include:

– provision of a personalized learning environment, based on progression level, pace, interests, learning style and background;
– teacher use to design and evaluate learning activities, including communicating with students, parents, and community members and sharing professional development experiences;
– aid to parents and communities to participate in the learning process through e-learning resources to assist increasing awareness and engagement in their education.

8.3.2 Healthcare

ICTs can have a positive impact on healthcare to improve QoL. Health data could be used to empower health specialists to improve the efficiency and productivity of patients' healthcare.

Smart healthcare can be provided through telemedicine, e-medicine and electronic health management. These services may include diagnosis or treatment, requesting an appointment online, digital records, remote home health services, health alarm systems, remote patient monitoring systems and data healthcare portability system in the case of disaster recovery.

8.3.3 Public safety

Roles of ICTs in public safety include the use of analytical tools that help to sense, respond and resolve life-threatening personal safety issues, particularly during or in response to major disasters.

Cities can integrate technologies related to public safety. Where possible, encourage relevant agencies to utilize ICT capabilities to improve personal safety and reduce life-threatening situations related to major disasters.

8.4 Contribution of information and communications technology to governance sustainability

8.4.1 Transportation

Improving mobility and decreasing traffic congestion are some of the challenges facing smart cities today. Congestion impacts on the daily lives of commuters, as well as businesses and visitors to a city. In order to address this challenge, city planners should look to transport solutions to reduce congestion, as well as optimizing the use of city public transport. This could provide efficient transportation of people and goods in a timely, safe, cost-effective, environmentally friendly and sustainable manner. ITSs can be implemented to achieve these goals by utilizing smart transport applications.

8.4.2 Public buildings

Smart buildings can improve QoL by providing more comfortable and more secure home and commercial environments. Smart building systems can utilize ICT information to increase energy efficiency, reduce emissions and optimize usage of utilities, leading to operational effectiveness and user satisfaction.

9 Evaluation of smart city initiatives and achievements of smart sustainable cities

Key performance indicators (KPIs) can be used to evaluate the performance of city services. The utilization of smart solutions and assessment of solutions may contribute to a city's transformation into an SSC. Evaluating these indicators may help cities as well as their stakeholders understand to what extent they may be perceived as an SSC.

As cities and their smart city visions are unique, there are a variety of KPIs available for governments to use. These include KPIs developed by international organizations (such as ITU, ISO and UN-Habitat), national or regional organizations (such as national standards bodies and regionally funded smart city development projects), city organization (such as smart city initiatives), academic institutions and companies [b-ITU-T Y Sup.39]. Reviewing KPI models, methods, and types can be useful for a city to identify those most useful to a specific smart city, its current status, development and goals.

A series of ITU-T Recommendations provide a set of KPIs that can be utilized to measure the achievement of an SSC (e.g., producers, service providers, planning units) [ITU-T Y.4900], [ITU-T Y.4901], [ITU-T Y.4902]. In addition, there is a range of KPIs for cities available from other standardization development organizations (SDOs) that may also be relevant [b-ISO 37120].

In addition to KPIs, there is a variety of other evaluation tools that city planners and governments can implement to develop strategies, set goals and track progress. A gap analysis can be used to determine the level of a city's current development and desired level of development, as well as assisting in prioritizing actions and initiatives. A city can quantify its effort to construct a smart city by comparing the KPI index for several years. It can also estimate its progress in various fields by examining detailed aspects, such as data resources, networks and data ecosystems.

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