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Enabling digital transformation in smart sustainable cities – Master plan

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Enabling digital transformation in smart sustainable cities – Master plan

Acknowledgements

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Abbreviations and acronyms

EMF	Electromagnetic Field
GPS	Global Positioning System
HART	Highway Addressable Remote Transmitter
ICT	Information and Communication Technology
IoT	Internet of Things
KPI	Key Performance Indicator
M2M	Machine to Machine
NGO	Non-Governmental Organization
OAM&P	Operations, Administration, Maintenance and Provisioning
RFID	Radio Frequency Identifier
R&D	Research and Development
SCADA	Supervisory Control and Data Acquisition
SSC	Smart Sustainable City
Wi-Fi	Wireless Fidelity
WPAN	Wireless Personal Area Network

Executive Summary

Rapid evolution of technologies in the past few decades has facilitated the incorporation of emerging technologies across sectors for the implementation of business-model innovation, and this offers the delivery of unique engagement and services within the smart city ecosystem.

Many cities across the globe are undertaking their journey towards becoming smart and sustainable through the digital transformation process, to cater to the needs of the inhabitants and other stakeholders and improve the quality of living. Digital transformation in the smart city context aims at the continuous action of leveraging technologies to improve service delivery and design, as well as to ensure their efficiency and accessibility to inhabitants, while reducing the impact of urban operations on the environment, and provide an abode for innovation for the present and future generations.

This report aims to provide urban stakeholders, including municipalities, with a general overview of the stages and standards needed to drive digital transformation in smart sustainable cities. It provides a guide for the implementation of the smart sustainable city (SSC) concept based on the intensive use of emerging digital technologies. It also refers the reader to relevant standards and publications addressing the specific technical aspects involved in the design and overall operation of SSC and digital transformation strategies.

While building upon the expertise available in the field, this report is intended to be as general and inclusive as possible. It aims to inform the design of SSC and digital transformation strategies irrespective of the size of the city, its location or the availability of resources, in developed and developing countries alike.

This report is based on Supplement 33 to ITU-T Y.4000 series – Smart sustainable cities – Master plan.

Foreword

International Telecommunication Union (ITU)

Digital transformation is both one of the greatest opportunities and most pressing challenges for cities and communities today.

When done well, the benefits of efficient digital services and sustainable use of resources greatly improve quality of life for all inhabitants, contributing to new economic opportunities and the achievement of the UN Sustainable Development Goals. When done badly, digital transformation projects can lead to wasted resources, fragmented services, and dissatisfied inhabitants.

Cities' digital transformation strategies need to strike the right balance between people, processes, and technology. These strategies will all take different forms, as each city constitutes a unique system with different environmental, technological, and societal contexts.

Informed by ITU experience in developing international standards for smart cities, this report provides guidance on governance and technology dimensions of a people-centred smart city. It offers a comprehensive overview of the stages and technical aspects of successful digital transformation projects for city administrations in both developing and developed countries.

ITU is the primary platform for smart city stakeholders to develop international standards and associated guidance for sustainable digital transformation. Working together on the ITU platform, these stakeholders are enhancing global knowledge of how the careful integration of digital technology into city management processes can improve efficiency, transparency, and service delivery.

I thank all the experts who have contributed to this report and hope that it will prove invaluable to city stakeholders as a tool to help make our cities smart, sustainable, and inclusive.

Seizo Onoe
Director, Telecommunication Standardization Bureau
International Telecommunication Union

Foreword

UNEP Copenhagen Climate Centre

Regardless of the size or wealth of a city, all have the potential to implement and benefit from appropriate and sustainable digital solutions. Digital tools may represent opportunities to make decarbonisation occur faster and more broadly in a local context. The energy services provided by cities to their citizens are a good opportunity to make a blueprint for digital transformation; but for that to happen, proper plans and detailed specifications need to be developed.

Typical smart city applications include digitally connected street lighting, smart transport systems and intelligent building management tools. They are technically proven and commercially available, allowing for quick gains if combined with the appropriate technical mitigation measures. Connectivity through sensors and advanced data analysis and management, if implemented in combination with energy-efficient systems, can provide a reduction of greenhouse gas emissions, improve local environmental quality, and consequently the health of citizens. This report shows in an inclusive manner where the technical opportunities at the city level can be found and what are the critical steps for their implementation.

Financing availability is an important component in the introduction of digital systems and cities need a strategy that helps them formulate a robust business plan, including a creative approach to funding and financing. Innovation in market mechanisms and business models is also explored in this report so that cities can assess the best options for the implementation of these solutions.

The practical counselling and user-friendliness of this guide should make it an interesting read for all professionals with city responsibilities.

John Christensen
Director
UNEP Copenhagen Climate Centre

Foreword

United Nations University

We are experiencing rapid development in information and communication technologies (ICTs) and their ubiquitous diffusion among the sectors worldwide. The rise and developments in ICTs have advantages and potentialities but challenges for the institutions. Government agencies, particularly local governments, and affiliated institutions, are assumed to integrate emerging technologies and innovation into their daily routine to cope with the threats and challenges posed by ICTs by improving their business models within the smart city ecosystem.

Digital transformation is necessary not only for being a smart and sustainable city but also for having the inputs and feedback from the stakeholders in public decision-making processes that cover design and implementation of policies and services. Therefore, cities around the globe are expected to start and sustain their digital transformations to have the support of their inhabitants by employing ways and manners prioritizing public values such as efficiency, accessibility, balancing the interests of stakeholders, and betterment of public services provided.

This report, prepared in close collaboration with all the partners under the guidance of the U4SSC Secretariat, aims to provide the local governments and respective stakeholders with overall guidance that includes stages and technical aspects to assist them in their journeys to achieve digital transformation in the design and implementation of the Smart Sustainable City framework.

The Enabling digital transformation in smart sustainable cities – Master plan introduces a guiding framework to follow by local governments and cities around the globe, irrespective of size, location, or resources available.

Tshilidzi Marwala
Rector of the United Nations University
Under-Secretary-General of the United Nations

1 Building a master plan: towards digital transformation in the smart sustainable city

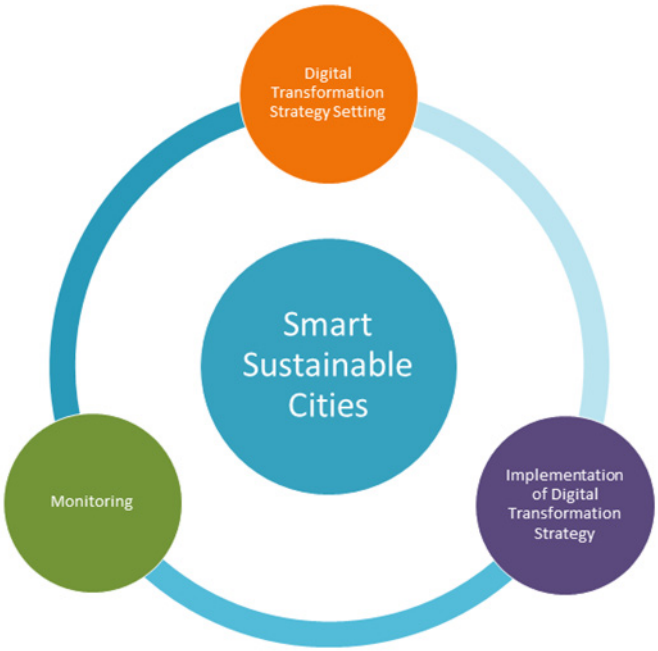
Recent experiences aimed at the design and realization of an SSC have shown that there is no single approach to make a city smarter and more sustainable. Each city constitutes a unique system, wherein different actors and city agencies undertake a range of activities, interact on multiple scales, and use different facilities infrastructures and technologies. Recognizing the particular environmental, technological and societal contexts of the "city", its purposes and priorities for action, as well as its history and characteristics, has become crucial not only to ensure the most appropriate path towards becoming smart and sustainable but also to determine it.

The smart city management plan elucidated in this report will aim to support cities in:

- driving cross-sectoral digital transformation by promoting the adoption of emerging technologies;
- enhancing the efficiency of urban services;
- improving quality of life for all inhabitants in the city;
- addressing societal, environmental and economic urban challenges; and
- improving the resilience of the smart city ecosystem to emergencies.

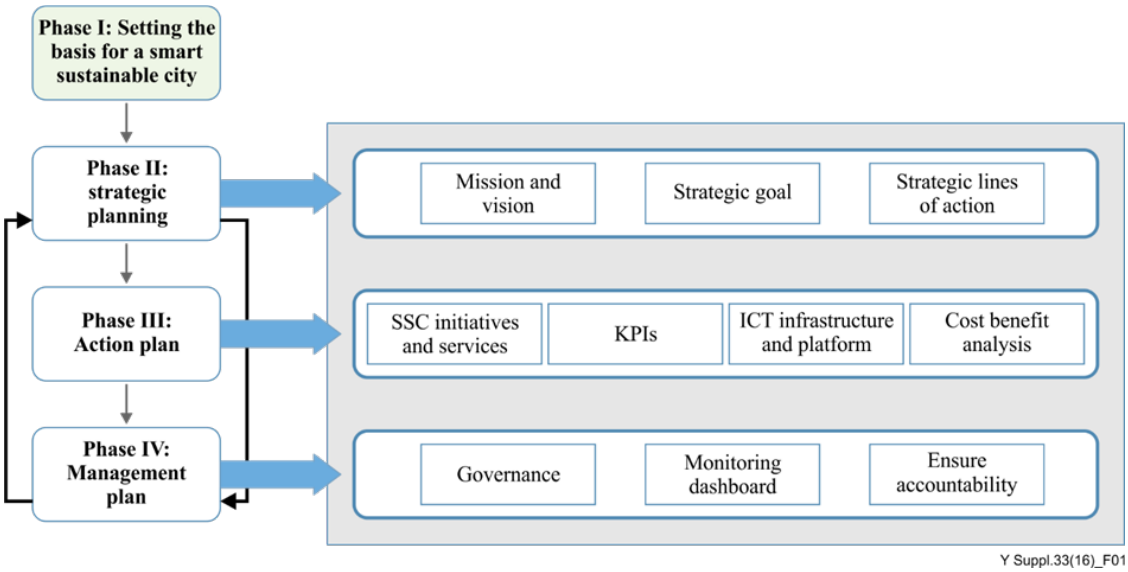
Urban stakeholders need to prepare strategic plans as frameworks for the implementation of SSC initiatives, initiate digital transformation to optimize urban services and tailor them towards inhabitants.

Figure 1: Digital Transformation in the context of Smart Cities



The SSC master plan presented in Figure 2 provides an overview of the key components and stages involved in the process of digital transformation.

Figure 2: Phases of action: Smart sustainable city master plan



Source: ITU-T Supplement 33 to ITU-T Y.4000 series

This SSC master plan corresponds to the SSC 8-step transition cycle presented in the "Guide for Smart and Sustainable City leaders: Envisioning Sustainable Digital Transformation".

1.1 Phase I: Setting the basis for a smart sustainable city

Cities that decide to become smart and sustainable have to start by determining their motivations and priorities, including the identification of the stakeholders that need to be involved, the implications of digital transformation on the city's governance, as well as the mechanisms needed to ensure sustainable inhabitant participation and feedback throughout the process (in the short, medium and long term, and across scales).

Setting the basis for an SSC consists largely of gaining a clear, yet in-depth, understanding of what it means to become an SSC and what the overall digital transformation process would entail.

As stated in the preceding sections of the analysis, the concept of the SSC is broad, and there are multiple and often competing approaches on how to achieve goals related to "smartness" and "sustainability" within urban settings. The concept of an SSC could vary significantly in different regions.

Also, involved in this first stage of implementation is the definition of a baseline identifying the strengths and weaknesses of the city, and defining clearly the priorities and objectives, as the city moves towards the attainment of SSC status. This baseline must be defined in an empirical and standardized way using indicators.

In this context, it is important to recognize that for SSC strategies to succeed over time, they need to be well articulated and aligned with existent approaches to urban planning, to ensure that smart technologies, infrastructures and city services respond to a broader, more holistic vision of the city. Understanding the urban system, its goals, operation, gaps and opportunities, is a necessary step that should precede, and serve as a foundation for, the implementation of SSC strategies.

Identifying the city's projects and existing urban planning goals will help determine the priorities for action in path of the municipality towards becoming an SSC – i.e., the common solutions the city would want to implement first, and the areas of focus in the short, medium and long term.

Thus, the identification of city purposes and priorities for action, governance and stakeholders are closely interlinked, and are vital to forming a robust basis for the design of an SSC. Along with the set of stakeholders and their roles and responsibilities within the SSC framework, decision-makers need to define a governance model and leadership strategies required for the city's transformation.

Thus, the establishment of a cross-sectorial body that can provide continuous support to city council officials and decision-makers could contribute to a coherent design and implementation of smart and sustainable cities over time. This body could help ensure the articulation of SSC strategies and the city's urban planning goals, as well as facilitate collaboration and strategic alignment between the multiple stakeholders (including city-level departments and structures at local, municipal and national levels) that need to be involved in the realization of an SSC.

ITU-T has developed a report that identifies key SSC stakeholders ITU-T Y-Sup.34 to ITU-T Y.4000 series – Smart sustainable cities – Setting the stage for stakeholders' engagement.

A crucial step for setting an inclusive and sustainable basis for SSC consists of identifying and implementing effective mechanisms for inhabitant engagement. Inhabitants are the ultimate beneficiaries of SSC functionalities, as these are aimed at increasing the access to, and boosting the efficiency of, city services in order to improve inhabitants' well-being.

While these mechanisms should be set up at the onset of the SSC's strategy, they should be maintained, monitored and adjusted throughout the process of implementation to ensure flexibility, as well as the provision of up-to-date information about the features and benefits that SSC can provide to its inhabitants.

Without relevant and timely information, inhabitants can perceive SSC projects as an unnecessary use of their taxes. It is, therefore, important to demonstrate transparency and accountability in the investments made in SSC service provision and in the way in which these investments are having an impact on the inhabitants' quality of life.

An SSC needs to promote participation in crucial aspects of the city's functioning; for example, with participatory budgets. Inhabitants can also play a key role in the provision of data to inform, city-level decision-making processes (e.g., inhabitant as a sensor, real-time reporting or monitoring using social media), as well as in the provision of innovative ideas to improve city services, or to tackle emerging challenges through cost-effective approaches. In addition, it is important to involve companies in the design of the city in order to better understand their needs and facilitate investments made on their behalf.

An SSC must be inclusive and enable access to those sectors of the population that may not have access to technology. To address this challenge, municipalities can offer training programmes targeting marginalized populations (e.g., vulnerable women, the elderly and persons with disabilities), equip public zones with technologies to broaden the beneficiary base, and implement other programmes aimed at raising awareness and encouraging inhabitant engagement in the realization of the SSC strategy.

This phase of the Master Plan would also require an overview and understanding of the cross-dimensional interactions within the urban domain. In this context, the Toolkit on Digital Transformation for People-Oriented Cities and Communities would play a pivotal role in providing insights into a diverse range of topics, including, but not limited to, data processing and management, smart energy management, smart water, digital inclusion and emergency management.

This Toolkit also contains a dedicated Module on developing a digital transformation strategy aimed at assisting cities in assessing their smartness-related capabilities, support planning resources; and in establishing a partnership model to bring key stakeholders and groups into the city's digital transformation planning and decision-making framework.

1.2 Phase II: Strategic planning

Progress needs to be made through holistic visions and transversal policies that strengthen the integrated approach, which should prevail in all SSCs. Therefore, SSC initiatives should consider cities from a global perspective; otherwise, the effectiveness and scope of such initiatives may be reduced severely.

In the first step of the cycle, local governments identify an SSC vision and assess the city's situation in order to establish the relevance and feasibility of becoming an SSC through digital transformation. This step includes, among others, the following.

- Definition of what kind of city it inspires to be. What are the overall aims of the initiative and what is the main idea to achieve specific targets?
- Identification of an SSC vision that is in line with the city's identity, political priorities, and long-term development strategy.
- Establishment of a vision of the connection between the SSC components and its guiding principle. This is necessary to provide a deeper understanding of the vision of an SSC.
- Documentation of the detailed business process of the main existing city services along with their interrelationships and dependencies.
- Strengthening the individual and institutional capacities in cities to scale-up skill development related to urban planning and digital transformation for increased reach, increased access (for people with disabilities, girls, vulnerable communities), and improved cost efficiency.
- Collection of relevant data on the status of the types of emerging digital technologies that have been adopted across sectors, along with their usage at the city level.
- Identification of the existing governance and organizational conditions that would allow an efficient and effective management of digital solutions.
- Identification of mechanisms for multi-stakeholder involvement, inhabitant engagement, communication and information sharing throughout the SSC process. Assurance of the participation of inhabitants and relevant stakeholders in SSC is essential for the transformation process into an SSC.
- Encouragement of two ways of participation: top-down or bottom-up. A top-down approach promotes a high degree of coordination, whereas a bottom-up approach allows more opportunity for the general public to participate directly.

In this phase, it is crucial to understand the city as an ecosystem. This ecosystem should be created by entities that are involved in the process of development of SSC strategies, including universities, research centres, companies, public agencies and the general public.

In this phase, local governments should obtain the necessary political approval and legitimization to ensure that the SSC strategic programme is pursued. This process consists of the adoption of the SSC programme and targets by the local council through a political decision, thus becoming an agreed document that has widespread support from all relevant stakeholders. This document would also serve as a preliminary document for strategic planning of the local authority.

Any SSC initiative should have strong political leadership from local governments. Additionally, it will be necessary to identify within institutions, organisms or businesses involved, people with a greater level of leadership. Such leadership should be conveyed through the initiative of project administration, constant coordination between the relevant actors, decision-making, the overcoming of challenges and any other actions to guarantee the continuous development of the project.

1.3 Phase III: Action plan

An action plan involves turning a proposed project into something tangible and feasible to implement. This, in turn, requires a clearly defined plan for integrating technology solutions into an action plan. Important considerations could include scheduling, costs related to implementation, identification of the individuals or agencies responsible for implementation, types of technologies adopted, progress indicators, and procedures for reporting and evaluation.

In this phase, local governments work in close collaboration with the various SSC stakeholders to design the overall plan for the SSC's implementation (e.g., objectives, priorities, initiatives and actions needed in the short, medium and long term, including SSC infrastructure investments, setting measurable SSC targets and time frames for their achievement). This step involves the identification of SSC targets and major milestones with regard to:

- SSC services;
- SSC KPIs;
- SSC architecture;
- SSC infrastructure and integrated platform;
- SSC data security;
- SSC projected cost/benefit analysis.

A plan of action must be elaborated that proposes a series of realistic development measures. Such measures will be arranged in a hierarchy, and studies will be carried out on the associated costs and the appropriate period in which investment should take place. A clearly established plan of action will be the guide for the development of actions and strategies. A strategy will be designed that produces rapid results. These results will be instrumental in the creation of the public and private support needed for the success of SSC initiatives and systems such as a) to f), below.

a) Digital services

Cities provide their inhabitants with many different services, including water management, energy services (e.g., lighting, heating, and cooling), transport, waste management, health care, education, and security. The efficiency of these services can be improved significantly with the use of ICTs, creating a new set of "smart services" that lead to improved efficiency and sustainability.

Every municipality should evaluate the different services that their city might need. The work conducted by the ITU-T Study Group 20 "Internet of Things and Smart Cities & Communities" and the United Nations-led United for Smart Sustainable Cities (U4SSC) initiative has allowed the identification of several ICT services that contribute to the efficiency of city services, as summarized below.

- **Smart water management systems**: These systems promote the sustainable and coordinated management of water (water supply and distribution, water and wastewater treatment and other municipal-related services like raw water services, drainage services or reclaimed water services) through the integration of ICT infrastructure (products, solutions and systems) in order to maximize the socio-economic welfare of a society without compromising the environment (ITU-T Y-Sup.36). Integrated water management systems can improve management of water supplies, by ensuring affordable supply and distribution, safe treatment of water and wastewater, efficient raw water catchment and drainage services.
- **Smart energy management systems**: These systems use sensors, advanced meters, digital controls, and analytic tools to automate, monitor and control the supply and demand of energy, optimizing grid operation and usage, to ensure reliability, interactivity, compatibility, energy saving, safety, optimal use of energy from renewable sources and minimum carbon footprint. Sensors, advanced metering, storage technologies, analytics and MRV systems are used to manage the supply and demand of energy and optimize grid operations. These allow for the creation of the conditions for improved access to, and reliability and safety of, energy systems. Clean energy technologies can help to minimize greenhouse gas emissions and local pollution, while analytics enable the prediction of future energy supply and demand, to facilitate grid management.
- **Intelligent transportation management systems**: These systems need to move people (and goods) in an efficient, safe and sustainable way. With that aim in mind, they need to use ICTs, wireless fidelity (Wi-Fi) and radio frequency identifier (RFID) technologies, global positioning systems (GPSs) and sensors, to be able to collect information about mobility patterns. Some added benefits of these systems include the capability to locate and identify vehicles, and monitor and control traffic. As a result, it is possible to reduce travel times, and traffic accidents. These systems allow people to travel in an efficient, timely and cost-effective manner. Vehicle tracking systems and analytics have the potential to reduce congestion, improve road safety and incident monitoring, while vehicle-to-infrastructure probes allow for more timely maintenance of transport infrastructure.
- **Smart waste management systems**: These systems will empower the implementation of waste-tracking based on their ability to monitor the movement of different kinds of waste, optimize collection routes, connect various smart waste management systems with local service providers, leverage technology to collect and share data from waste sources, and transport, dispose of and sort waste. These technologies will help to convert waste into a resource and create closed-loop economies, fostering more sustainable and productive uses of waste.
- **Smart health system**: These systems can convert health-related data into clinical and business insights, and enable secure communications and information sharing in order to improve the productivity of the service provided to inhabitants. Examples of smart healthcare systems include the availability and improvement of remote diagnosis and treatment, health management systems and monitoring systems, among other online medical services. To achieve these goals, M2M communications will be crucial.
- **Smart education**: Education, for adults and children, may be one of the most important smart city services. The use of ICT can improve education by providing students with a personalized learning environment (e.g., tailored to their progression level, interests, learning style), as well as by providing educators with new tools to design learning activities or opening new communication channels with students, parents and community members. Online learning platforms may also be used to facilitate training and accreditation of the youth and adult population. This may include broad applications to improve digital and

financial literacy, or the provision of vocational training or upskilling of individuals within productive sectors. Smart education is critical for cities as it can support a large variety of sectors by producing graduates with the know-how, practical skills to foster digital transformation across verticals in smart cities.

- **Smart security and safety**: ICT and digital technologies can help to ensuring physical safety and security to respond to the need to resolve incidents, provide criminal identification, as well as conduct predictive analysis and criminal pattern identification to improve inhabitant safety. Command and control systems shared across multiple city departments like energy, waste, transport and security will be needed to provide a holistic, city-wide view of safety patterns and trends. New ICT and digital infrastructure also must be protected from security threats. For the aspect of policing, to consider including biometrics and crime surveillance systems. Within the judicial system, relevant uses can include case management systems, online arbitration and litigation.
- **Smart Emergency System**: Connects cyber-physical systems to safeguard the urban ecosystem to save lives, detect public crises and detect potential hazards and disasters. For the aspect of emergency management, consider including hazard monitoring, early warning and alert systems.
- **Smart Land Management**: For management of land use, consider including land administration and management systems or cadastral databases. These are relevant for optimized use of public and green spaces, improved management of informal settlements, and more generally taxation and ownership.
- **Intelligent buildings systems**: These systems can use data to improve building energy and water efficiency, reduce waste, monitor indoor air quality and improve security, without affecting occupants' use of the building. These systems may include building automation and building management systems.

The analysis conducted this far suggests that ICT use can improve the efficiency of city services and, ultimately, strengthen the quality of life of its inhabitants. To assess these benefits, KPIs are needed to quantify and evaluate the transformation of a municipality into an SSC. Other KPIs that are specifically designed for each city service, are also needed to monitor performance, and assess, quantitatively, the efficiency gained through the implementation of SSC solutions.

While the list of smart services provided earlier reflects the standard or most common city services, municipalities can select different services according to their own needs and priorities.

b) Key performance indicators, standards

KPIs are useful not only to evaluate the performance of city services, they can also be used to assess, empirically, how one or a set of modifications contribute to the city's transformation into an SSC, providing grounds for standardization. KPIs can also allow comparisons between different cities to determine which one is "smarter" or more sustainable in the face of particular challenges. Evaluating these indicators can help municipalities, as well as their stakeholders, understand to what extent they may be perceived as SSCs.

This set of KPIs can be used to benchmark a city's performance and help urban stakeholders to:

- assess a given city's annual progress;
- benchmark best practices; and
- examine the impact of digital technologies.

In order to provide a complete list of KPIs that can be used for city and municipal administrations inhabitants, development and other organizations operating in SSCs (e.g., producers, service providers, planning units), as well as evaluation or ranking agencies, ITU-T has developed a

series of Recommendations and Supplements including: Recommendations ITU-T Y.4900, ITU-T Y.4901, ITU-T Y.4902, ITU-T Y.4903 and ITU-T Y-Sup.78.

These documents describe standardized KPIs that aim to provide criteria to evaluate existing cities (e.g., single cities from the administrative point of view, or the union of small cities in the same area that share some services), but not to compare them. It will enable cities and municipal administrations to understand the progress of SSC development and design suitable strategies, and will also provide city residents with the details of the SSC development, and allow SSC development and operational organizations to fulfil their obligations related to the provision of information.

Furthermore, United for Smart Sustainable Cities has developed a series of KPIs based on Recommendation ITU-T Y.4903 "Key performance indicators for smart sustainable cities to assess the achievement of sustainable development goals". These indicators have been established to support the collection and reporting of the data needed to quantify, measure, report, and monitor performance and progress towards achieving the targets enshrined in the Sustainable Development Goals (SDGs).

The evaluation principles chosen to define dimensions, sub-dimensions, categories and indicators are the following: comprehensiveness (i.e., should cover all SSC aspects), comparability (i.e., should be able to compare scientifically different phases of urban development and different cities), availability (i.e., quantitative data should be accessible and scientific), independence (i.e., the indicators in the same dimension should be mutually independent), simplicity (i.e., concepts and calculation should be simple and intuitive) and timeliness (i.e., ability to produce KPIs with respect to emerging issues in SSC construction).

The dimensions of KPIs can be categorized as follows:

- Economy.
- Environment.
- Society and Culture.

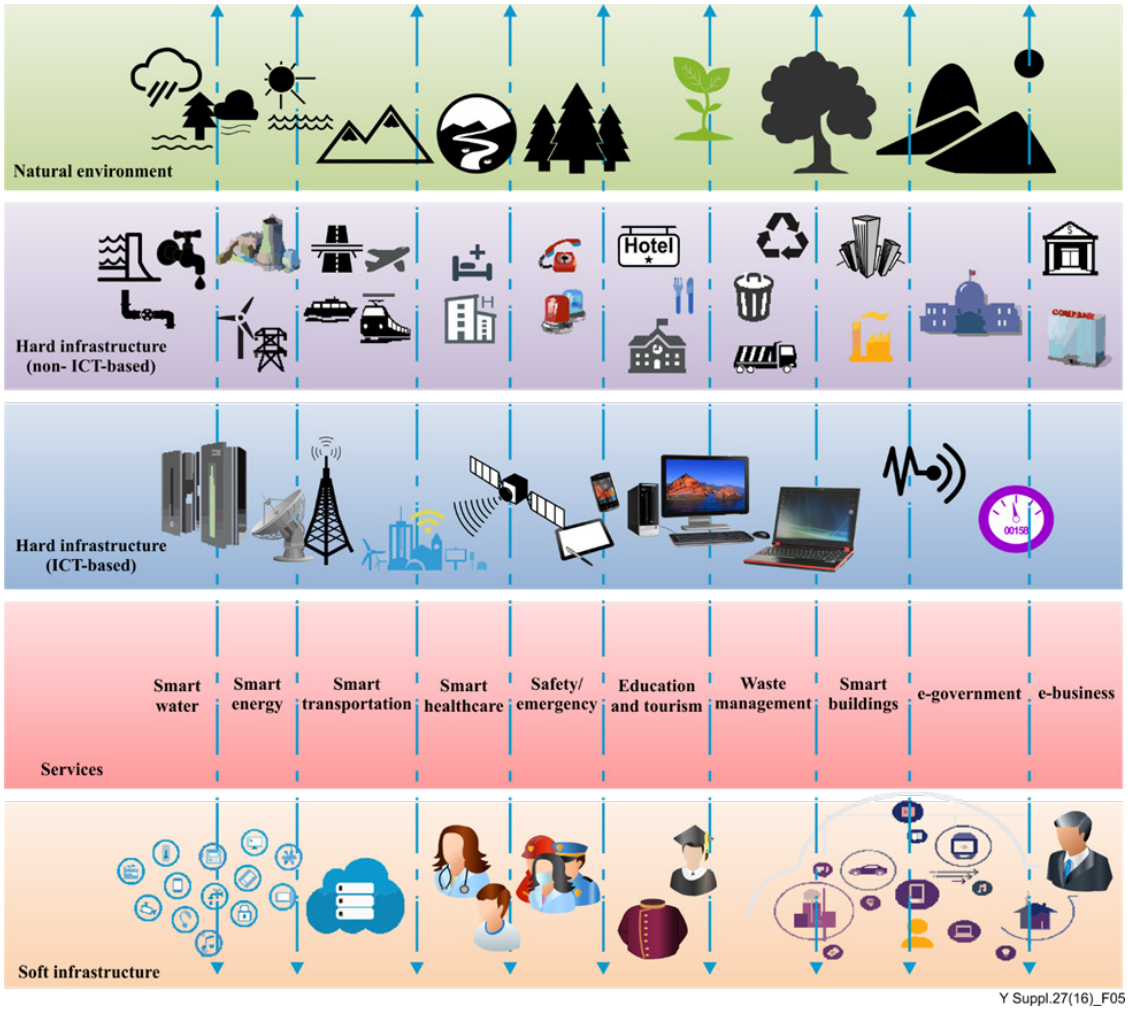
Using the evaluation principles previously explained, the KPIs of an SSC can be categorized into three dimensions, each with its respective sub-dimensions, categories and indicators (see Table 1).

Table 1: Key performance indicators for smart sustainable cities to assess the achievement of sustainable development goals

Dimension	Sub-Dimension	Category
Economy	ICT	ICT Infrastructure
		Water and Sanitation
		Drainage
		Electricity Supply
		Transport
		Public Sector
	Productivity	Innovation
		Employment
	Infrastructure	Water and Sanitation
		Waste
		Electricity Supply
		Transport
		Buildings
		Urban Planning
Environment	Environment	Air Quality
		Water and Sanitation
		Waste
		Environmental Quality
		Public Space and Nature
	Energy	Energy
Society and Culture	Education, Health and Culture	Education
		Health
		Culture
	Safety, Housing and Social Inclusion	Housing
		Social inclusion
		Safety
		Food Security

Source: Recommendation ITU-T Y.4903

Figure 3: Multitier SSC ICT meta-architecture



Source: ITU-T Supplement 27 to ITU-T Y.4400 series

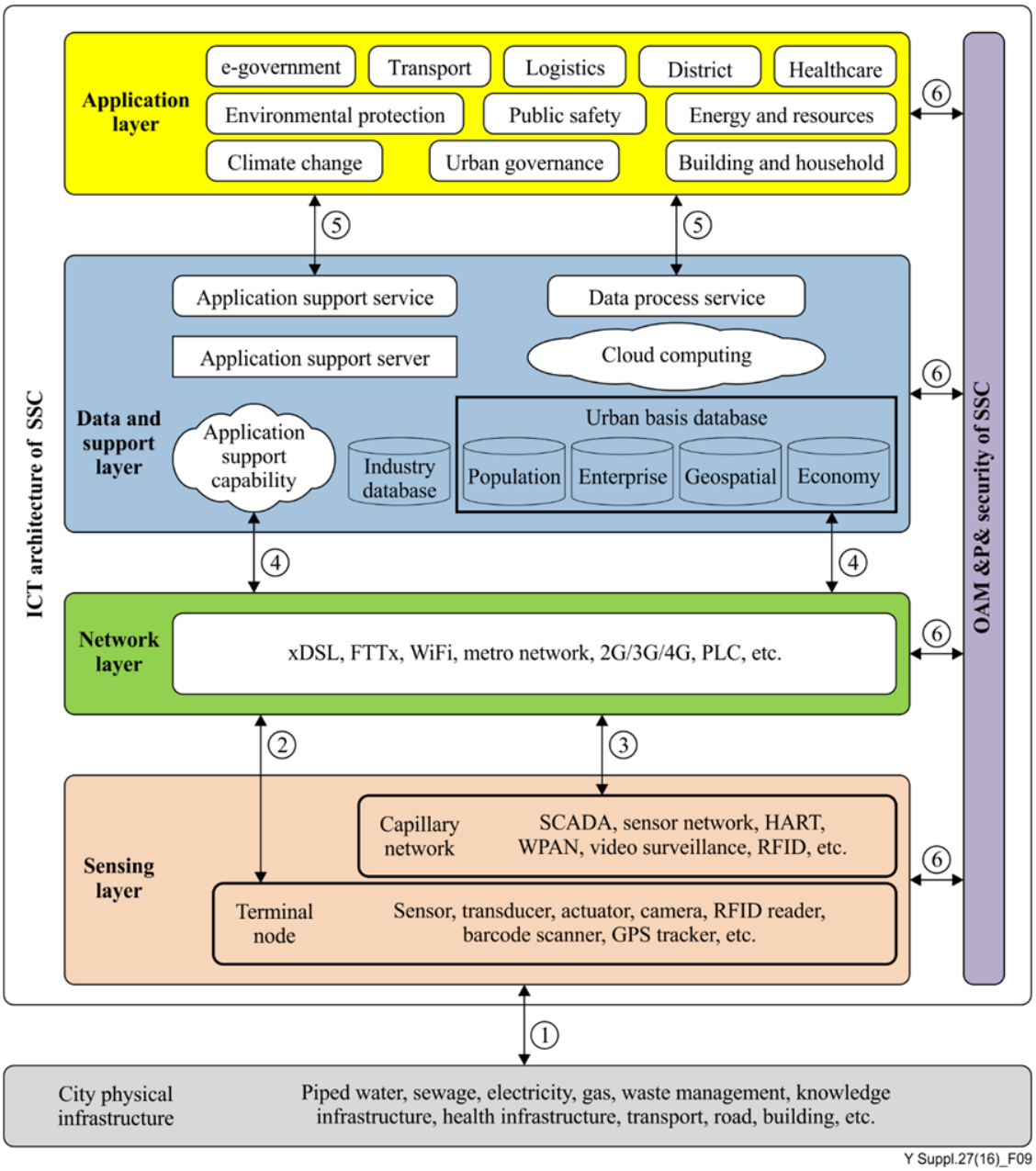
The corresponding indicators for each category are detailed in ITU-T Y.4903.

c) Setting the framework for ICT architecture of smart sustainable cities

The architecture of smart sustainable cities has been defined in ITU-T Y-Sup.27. At a high level, a meta-architecture consists of five layers (as depicted in Figure 4), which focus on the integration between natural environment and soft infrastructure of urban spaces, while SSC services run across these layers.

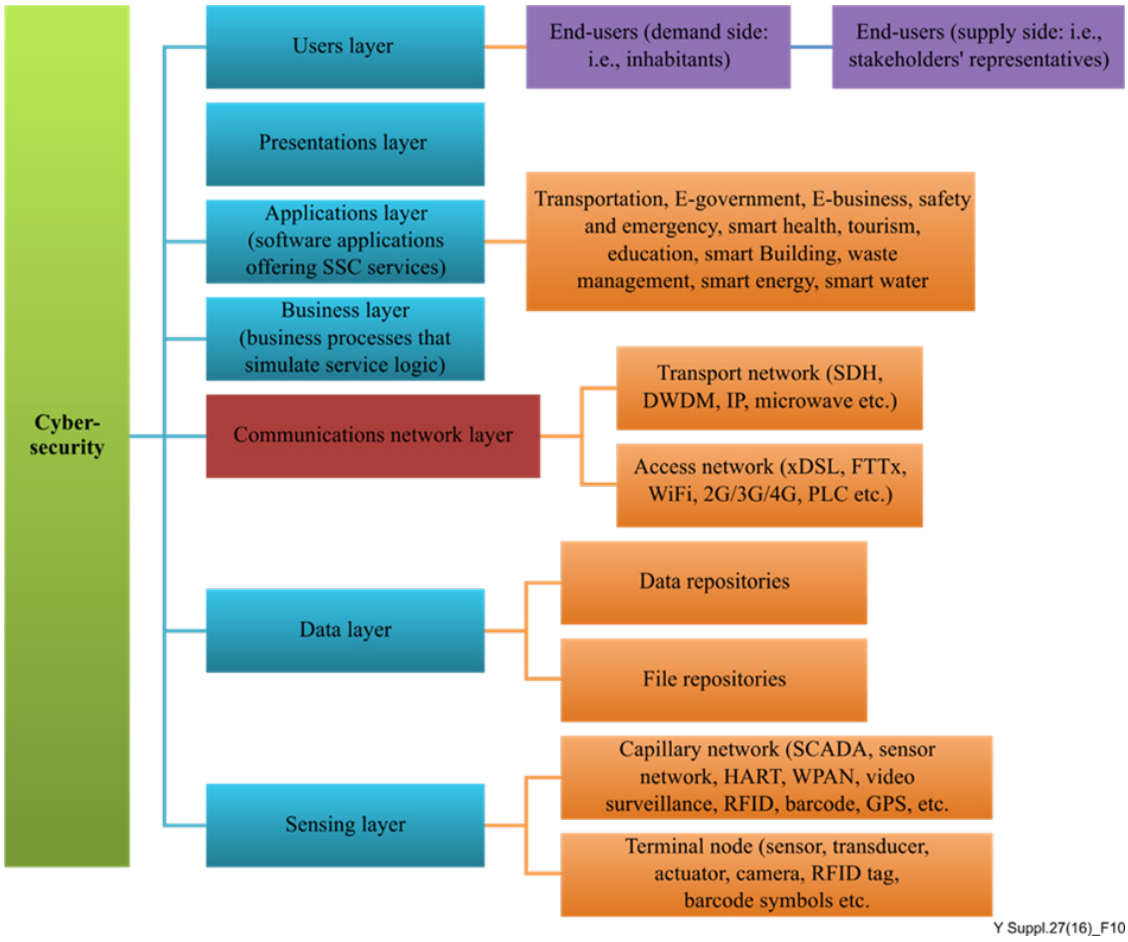
An SSC can also be considered as a system of subsystems. With regard to its technical definition, it can be viewed from different perspectives. Figures 3 and 4 demonstrate the communications view of the SSC ICT architecture, based on a physical and an information flow perspective, respectively. Both perspectives of this view are multitier.

Figure 4: A multitier SSC ICT architecture from a communications viewpoint, emphasizing the physical perspective



Source: ITU-T Supplement 27 to ITU-T Y.4400 series

Figure 5: A multitier SSC ICT architecture from a communications viewpoint, emphasizing the information flow perspective



Source: ITU-T Supplement 27 to ITU-T Y.4400 series

Figure 4 and 5 depicts a valid representation of the same architecture view, one closer to the language of the infrastructure developer, and the second more in line with the context of the information system developer. The architecture viewpoint contains the following layers (as depicted in Figure 4):

- *Sensing layer*: This layer consists of a terminal node and capillary network. Terminals (sensor, transducer, actuator, camera, RFID reader, barcode symbols, GPS tracker, etc.) sense the physical world. They provide the superior "environment-detecting" ability and intelligence for monitoring and controlling the physical infrastructure within the city. The capillary network (including supervisory control and data acquisition (SCADA), sensor network, highway addressable remote transmitter (HART), wireless personal area network (WPAN), video surveillance, RFID and GPS-related network) connects various terminals to the network layer, providing ubiquitous and omnipotent information and data.
- *Network layer*: The network layer indicates various networks provided by telecommunication operators, as well as other metro networks provided by city stakeholders or private communication networks. It is the information superhighway (infobahn), the network layer data and support layer.
- *Data and support layer*: The data and support layer makes the city "smarter". Its main purpose is to ensure the support capabilities of various city-level applications and services. The data and support layer includes the data centres from industries, local government departments, and enterprises, as well as the municipal dynamic data centre and data repository, established for the realization of data processing and application support.

- *Application layer*: The application layer includes various applications that manage the SSC and deliver SSC services.
- *Operations, administration, maintenance and provisioning (OAM&P) and security framework*: This layer provides the operation, administration, maintenance and provisioning and security function for the ICT systems of SSC.

The multitier SSC ICT architecture from a communications viewpoint, emphasizing the information flow perspective contains the following layers:

- *Users layer* organizes the SSC service end-users into groups from the demand and the supply sides.
- *Presentations layer* contains the user interfaces (web, apps, voice commands, etc.), which stand between end-users and SSC services.
- *Applications layer* contains all corresponding software applications that realize SSC services.
- *Business layer* consists of the business processes that lie behind each SSC service execution.
- *Communications layer* contains the above-mentioned networks, over which the SSC services are performed, and transactions and data flow are realized.
- *Data layer* contains the data and file repositories, where data are created or retrieved.
- *Sensing layer* consists of a terminal node and capillary network. The terminals (sensor, transducer, actuator, camera, RFID tag, barcode symbols, etc.) sense the natural environment where the SSC is located and the corresponding hard infrastructure and utilities (water, transport, etc.). It provides the superior "environment-detecting" ability and intelligence for monitoring and controlling the physical infrastructure within the city. The capillary network connects various terminals to the communication layer, or directly to the data layer or application layer providing ubiquitous and omnipotent information and data.

Detailed discussions of the ICT architecture and security aspects of SSCs is available in ITU-T Y-Sup.27 to ITU-T Y.4400 series - Smart sustainable cities - Setting the framework for an ICT architecture and ITU-T FG-SSC Technical Report (2015), Cybersecurity, data protection and cyber resilience in smart sustainable cities.

d) Smart infrastructure and integrated platform

Investing in ICT and digital infrastructure constitutes a critical component of a city's transformation into an SSC. This technology can provide crucial information for city managers to increase the efficiency of urban services, improve the quality of life of the inhabitants, ensure a tangible economic growth, strengthen prevention and management of natural disasters, simplify physical infrastructure used in some services (e.g., mobility, energy), and improve the city's sustainability.

To reduce this initial investment as much as possible, cities can adopt the notion of "convergence", by using pre-existing networks to establish new ICT and digital infrastructure.

The first step for introducing ICT technologies in cities is to consider all stakeholders involved in this process. In terms of interconnected infrastructure, the most relevant stakeholders will be the telecom operators, ICT providers, financial institutions, utility providers, emergency services, local institutions, non-governmental organizations (NGOs), regulators, funding bodies and universities, as well as research and development (R&D) institutes.

Two different aspects related to the strategic planning required for the national deployment of ICT and digital infrastructure have been defined.

The first aspect is the deployment of the ICT and digital infrastructure itself, including the formulation and implementation of related policies and strategies. It requires the involvement of all the stakeholders previously identified. The second aspect refers to improving the infrastructure deployed in order to reduce defects like perception (e.g., the infrastructure is not able to automatically perceive itself running), cleverness (e.g., the operation and application of facilities use a fixed configuration and it is unable to judge the situation automatically), lack of sharing mechanisms (e.g., lack of horizontal integration that prevents synergies), and communication restrictions (e.g., the bandwidth and reach of various branded communication facilities are uneven).

Decision-makers must consider that during the implementation of ICT and digital infrastructure, there is the risk of creating a polarization effect in zones that have more investment than others, creating (or accentuating existing) digital divides in the city. Strategies aimed at addressing these risks can include the use of public funds to invest in zones with the least development infrastructure.

Municipalities can adopt different strategies for the development of the ICT and digital infrastructure. These include the provision of supply incentives, using existing infrastructure for the deployment of ICT and digital technologies, or the adoption of strategies to incentivize demand (e.g., using ICT and digital technologies to improve local service management or to improve the relationship with inhabitants). It must be noted that supply and demand stimulate each other. An adequate supply will often push the demand, while the growth of demand can increase and improve the supply, fostering a virtuous circle. With this in mind, local governments should focus on both strategies.

All ICT and digital infrastructure implementations must fulfil the applicable laws and regulations. In cases of municipal infrastructure and deployment of projects, financing strategies tend to be very heterogeneous.

Certain funding mechanisms that can be used to support the activities involved in this stage are summarized in Table 2.

Table 2: Digital infrastructure funding methods

Funding mechanism	Description
Taxes	Pay using taxes
Redemption from taxes (tax or rates)	Local government taxing rights are exchanged for infrastructure or services
Loans + free cash flow	Initial capital comes from financial leverage from partners. After that the project can try to sustain itself
Local government as a major customer	Funds provided by city government
Advertising	Funds generated by advertising
Utilities allowance	Funds collected from other public services used to maintain infrastructure. Some regulations do not permit this system
Corporate donations	Corporations can donate funds

Table 2: Digital infrastructure funding methods (continued)

Funding mechanism	Description
Agreements with private companies	Agreement with private companies to offer funds free of charge to the public
National or multinational subsidies	Funds coming from national or multinational organizations.
Cooperative projects	Local government ends up with a project originally created as a cooperative and community project
Energy Service Companies	Companies providing energy related services in terms of building management systems, street lighting, among others will either be self-funded or financed by local governments

e) Data security and electromagnetic fields

All cities need to consider two fundamental topics in order to protect their inhabitants in a new context of smartness and sustainability: *cybersecurity and data security*, to protect inhabitants' data; and *electromagnetic fields* (*EMF*s), to address existing concerns of the public around this topic.

f) Data security

An SSC applies the use of technologies in many different areas of the city (e.g., infrastructure, resource management, public services, industrial systems, social aspects and security). They do this in more extensive and intensive ways than traditional cities, and thus generate larger amounts of valuable data. This information is needed to improve the efficiency of cities. However, its management can be challenging.

One of the principal objectives of any city is to become a safe place to live for its inhabitants. In an SSC, inhabitants' security must be expanded to data security (i.e., cybersecurity and data protection) in order to protect one of its most important resources.

As a result of their complexity and significance within the city's operation, the security of some smart city services and infrastructures must be prioritized (e.g., smart grids, intelligent transportation, connected health care, public safety and security or wireless communications and hotspots).

The information security infrastructure constitutes the technical foundation of the entire system, and as such, it provides a large number of security functions. The tasks of information security infrastructure centres include disaster recovery, emergency monitoring, key management, security management, security evaluation and identity management.

g) Electromagnetic field considerations

SSCs are based on the extensive use of wired and wireless ICTs, to provide city services in a more efficient way. Scientific research over many decades has enabled national and international health authorities to establish safety limits for human exposure to EMFs. Exposure limits vary depending on the EMF frequency and EMF source and incorporate conservative safety margins for added protection ITU-T K-Sup.4.

ICT devices and networks should be designed and deployed ensuring EMF compliance, while supporting the maximum efficiency of ICTs' utilization.

h) SSC projected cost/benefit analysis

Given the massive amounts of projected investments needed to realize the SSC concept, it is of extreme importance to conduct a cost/benefit analysis to analyse the feasibility of deploying such systems. Not only does the sustainability concept address environmental and societal challenges, it also includes issues related to the economic feasibility and long-term, break-even on the micro and macro levels.

In the process of analysing the different possibilities of achieving the set strategic targets, it is important to develop a technology market adoption model that can estimate the investment needed using different SSC technology combinations or options. The model should estimate the investment needed per SSC service sector, in addition to its financial viability and the macro-economic impact foreseen. This quantitative analysis enables policy makers to establish the right combination of policy tools and strategic directives to create a robust SSC ecosystem.

1.4 Phase IV: Management plan

This last phase includes the description of *city governance* and the setting of the *monitoring dashboard* to evaluate city performance in the future.

This stage involves close coordination and collaboration among SSC stakeholders, as well as the implementation of KPIs.

The execution of each initiative must be carried out in accordance with the action plan. The necessary information must be made available to realize the initiative and learn from experience. Additionally, it is in this implementation phase, where special attention must be paid to infrastructural needs.

This phase is also focused on evaluating, reporting and learning from the SSC process and related experiences. The results must be registered, measured and analysed in order to identify the improvements made through the different initiatives.

The level of success of the SSC initiative will be determined through the economic, social and environmental results in the long term. This evaluation contributes to informing high-level municipal decision-makers, as well as to informing the preparation of future baseline reviews to deepen SSC plans, among others. It can involve the use of various sharing mechanisms for knowledge and experience among the different SSC stakeholders.

The implementation process is the most crucial stage of any strategic plan. During this process, several challenges can be faced, including: defining the skills required for those responsible for its execution; defining the budget and related financial issues; establishing progress indicators; evaluating the results; and presenting the findings to the stakeholders.

1) *Governance of implementation*: For the purpose of implementation of the master plan, a governance committee should be set up. The members of this governance committee should be people who have worked on the development of the master plan first hand. The governance committee will be in charge of reinforcing the competences in budgetary control, and should be able to specify relevant agreements and develop a communication plan.

2) *Financing model*: Even though there are various methods to fund a project, and these methods may vary in each city, common criteria should be included when using such methods. These include stability, diversification, balance and adaptability. The members of this committee should be people who have worked on the development of the master plan first hand. However, this should reinforce the competences in budgetary control, and should be able to specify the agreements and develop a communication plan.
3) *Evaluation model*: For this model, it is important to differentiate the evaluation of specific SSC projects or examine a holistic vision of SSC developments. Furthermore, the constant monitoring of external factors and the choice of evaluation methods of key issues is needed. By doing so, it is possible to obtain better control of the evolution of the economic execution plans, deadlines and the upgrading of existing KPIs.
4) *Dissemination and communication*: The master plan will be followed by a communication strategy in order to maintain interest in the process. Instruments such as the creation of a corporate image for the project, outreach publicity, publication of technical documents (etc.) will support this objective.

2 Conclusions and key considerations

For an SSC initiative to be adopted and succeed, it is important to understand the need for such vision and ambition. Accordingly, the following must be considered:

- The SSC initiative must have a strong political leadership from the local government. Such leadership must be shown through the administration of the project, the constant coordination between the relevant actors, the decision-making, the change management, customize training, by overcoming challenges and any other action necessary to guarantee the development of the project. The designation of responsibilities is key to ensuring the success of digital transformation strategies.
- The set of objectives must be clear and must allow for the quantifiable evaluation of results obtained.
- The continued evaluation of results is fundamental to show the value of the initiatives developed and the role of KPIs is essential and must be significant.
- Develop models of public–private collaboration, as they are powerful alliances, leading the ecosystem of innovative actors to drive digital transformation. The planning must facilitate a scenario of mutual benefits between all agents, while the role of the administrator will be to facilitate the relationship between all agents.
- On the other hand, if SSCs are about efficiency and support initiating digital transformation and a better quality of life, they must support important economic savings or the implementation of new services. A serious study of the financial aspects of the initiative and also the future administration of financial resources must be conducted. Here, the public-private collaboration plays a key role.
- Inhabitants should be recognized as the cornerstone of any SSC transition and digital transformation process. They are the main beneficiaries of the SSC model that can provide the city with valuable data, ideas and feedback. Consequently, the city has to actively promote and enable inhabitant participation.

In any event, understanding the city as an open ecosystem, to promote open areas of collaboration, through co-working, accelerators programmes and urban labs, makes mechanisms available to naturally incorporate collective intelligence and areas of co-creation.

The collaboration between the ecosystem's actors in the city, as well as the collaboration between cities, can be made available and improved through the use of ICTs and digital technologies that allow collaboration tools and integration initiatives to be more realistic and efficient; for this reason, public-private initiatives are key. It is especially important to learn from past initiatives and experiences, especially in the context of digital transformation, which can have a cross-sectoral impact in smart cities.

It is very important to adopt, at different levels of the decision-making process, common and shared policies of ICT tools and solutions, combined with organizational changes and the acquisition of new skills in order to generate savings and greater productivity of the city's administration that can have a positive effect in meeting increasingly tight budgets. Investing in ICT also produces great benefits for the city's economy, boosting productivity through incentives and the creation of new jobs.

As experiences and technologies continue to emerge in the digital age, it is crucial to recognize that the effectiveness of SSC strategies requires a holistic, articulated approach oriented towards digital transformation that is not solely based on technological and infrastructural aspects, but primarily on improving the inhabitant's well-being.

Installing smart technologies and digital technologies will not, on its own, improve city services or drive digital transformation. The overarching digital transformation process requires strategic integration and articulation of adequate policies and standards. New technology needs to be complemented by intelligent management. In this sense, strategists will need to define how technologies and information/data collected will be used, considering that a key characteristic of an SSC is the breakdown of silo-based approaches, and the integration of services to improve the quality of life of inhabitants.

3 Bibliography

ITU-T K-series Recommendations – Supplement 4 (2015), ITU-T K.91 – *Electromagnetic field considerations in smart sustainable cities*.

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

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

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

Recommendation Y.4903 (2022), Key performance indicators for smart sustainable cities to assess the achievement of sustainable development goals.

ITU-T Y-series Recommendations – Supplement 27 (2016), *ITU-T Y.4400 Series – Smart sustainable cities – Setting the framework for an ICT architecture*.

ITU-T Y-series Recommendations – Supplement 30 (2016), *ITU-T Y.4250 series – Smart sustainable cities - Overview of smart sustainable cities infrastructure*.

ITU-T Y-series Recommendations – Supplement 32 (2020), *ITU-T Y.4000 series – Smart sustainable cities - A guide for city leaders*.

ITU-T Y-series Recommendations – Supplement 34 (2020), *Smart sustainable cities – Setting the stage for stakeholders' engagement*.

ITU-T Y-series Recommendations – Supplement 36 (2015), *ITU-T Y.4550-Y.4699 – Smart water management in cities*.

ITU-T Y-series Recommendations – Supplement 39 (2015),

ITU-T Y.4900 Series – *Key performance indicators definitions for smart sustainable cities*.

ITU-T FG-SSC Technical Report (2015), *Cybersecurity, data protection and cyber resilience in smart sustainable cities*. https://www.itu.int/en/ITU-T/focusgroups/ssc/Documents/website/web-fg-ssc-0090-r7-technical_report_on_ICT_infrastructure_for_resilience_security.doc.

Fernández Güell, J.M. (2006), *Planificación estratégica de ciudades: Nuevos instrumentos y procesos* [Strategic planning of cities: New tools and processes], Barcelona: Editorial Reverté.

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