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

ITU-T Y.4000 series – Smart sustainable cities – Master plan

ITU-T Y-series Recommendations – Supplement 33

ITU-T

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Supplement 33 to ITU-T Y-series Recommendations

ITU-T Y.4000 series – Smart sustainable cities – Master plan

Summary

Supplement 33 to ITU-T Y-series Recommendations seeks to provide municipalities and interested stakeholders with a general overview of the stages and technical specifications that need to be considered to effectively apply the notion of the smart sustainable city (SSC) to their respective locations. It provides a guide for the implementation of SSC based on intensive use of information and communication technologies (ICTs), and refers the reader to a series of thematic reports that addresses the specific technical aspects involved in the design and operation of SSC strategies.

While building upon expertise available in the field, this Supplement is intended to be as general and inclusive as possible. It aims to inform the design of SSC strategies of any municipality, irrespective of its size, location or resource availability, in both developed and developing countries.

History

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FOREWORD

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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.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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ITU-T Y.4000 series – Smart sustainable cities – Master plan

1 Scope

This Supplement seeks to provide municipalities and interested stakeholders with a general overview of the stages and technical specifications that need to be considered to effectively apply the notion of the smart sustainable city (SSC) to their respective locations. It provides a guide for the implementation of SSC based on intensive use of information and communication technologies (ICTs), and refers the reader to a series of thematic reports that addresses the specific technical aspects involved in the design and operation of SSC strategies.

While building upon expertise available in the field, this Supplement is intended to be as general and inclusive as possible. It aims to inform the design of SSC strategies of any municipality, irrespective of its size, location or resource availability, both in developed and developing countries.

2 Definitions

2.1 Terms defined elsewhere

This Supplement uses the following term defined elsewhere:

2.1.1 smart sustainable city [b-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.

NOTE – City competitiveness refers to policies, institutions, strategies and processes that determine the city's sustainable productivity.

3 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

EMF Electromagnetic Field

GPS Global Positioning System

HART Highway Addressable Remote Transmitter

ICT Information and Communication Technology

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

4 Building a master plan: towards an integrated management in the smart sustainable city

Emerging experiences aimed at the design and realization of an SSC have shown that there is no single approach to make a municipality smarter and more sustainable. Each city constitutes a unique system, where different actors and city agencies, undertaking a range of activities, interact on multiple scales, using different facilities and infrastructures. Recognizing the particular environmental 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 effective governance, but also to determine the most appropriate path towards becoming smart and sustainable.

Local administrations need to: prepare municipal strategic plans as frameworks for the implementation of SSC initiatives; optimize urban services and tailor them towards citizens; move away from standardized and uniform service models to models that involve the provision of personalized services; develop transparent tariff systems that reflect the real cost of providing services to citizens; collect useful information about key performance indicators (KPIs); and develop integrated technological platforms that enable the management of intelligent cities.

The SSC master plan presented in Figure 1 provides an overview of the key components and stages involved in the process of building an integrated management scheme for an SSC.

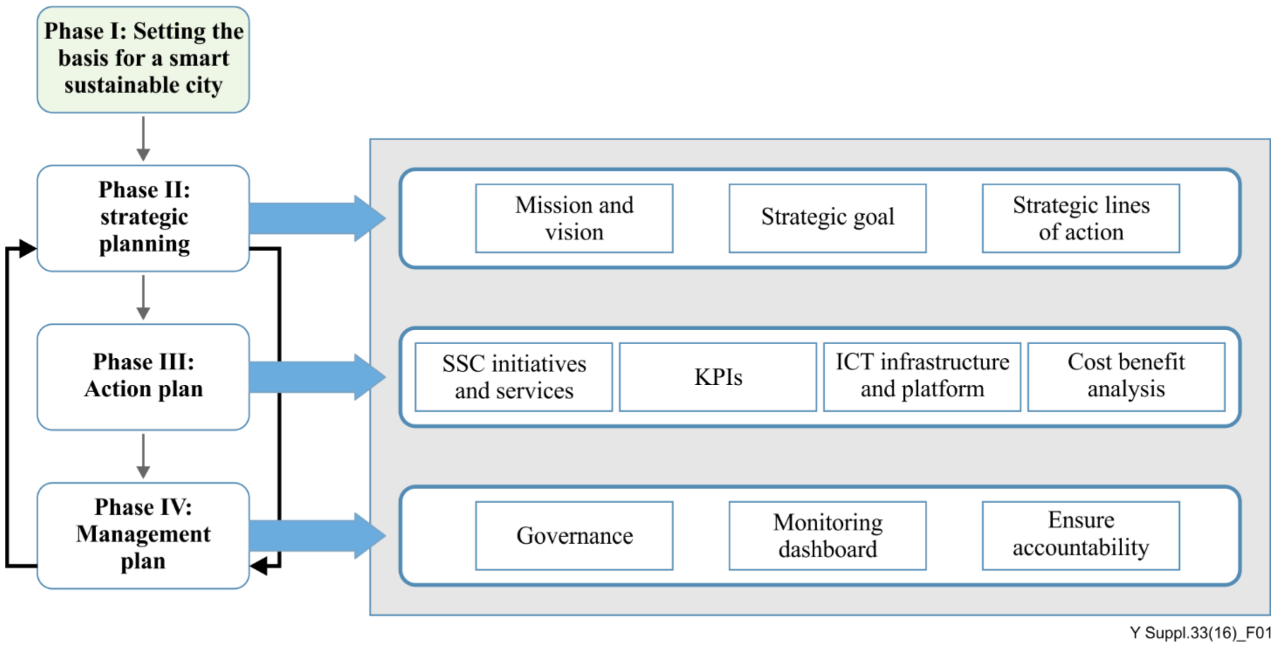

Figure 1 – Phases of action: Smart sustainable city master plan

4.1 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 this transformation on the city's governance, as well as the mechanisms needed to ensure continuous citizen 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 process would entail.

As stated in the preceding sections of the analysis, the concept of the SSC is extremely 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 also varies significantly in different regions. For instance, Latin American SSC perspectives are strongly focused on the improvement of security, local government management and mobility, Asian SSC initiatives emphasize the importance of infrastructure and services provided to citizens in the context of growing urbanization, while European SSC approaches often concentrate on the improvement of the efficiency of public services to strengthen the well-being of citizens.

Seeking to address this lack of consensus in the understanding of SSC, ITU-T worked on the identification of a comprehensive definition of SSC presented in clause 2. This definition recognizes the pivotal role played by ICTs as enablers of sustainable and efficient city services.

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 through the use of indicators.

In this regard, 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, so as 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 form 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.

The ITU-T has developed a Supplement that identifies key SSC stakeholders [b-ITU-T Y-Sup.34].

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

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

An SSC needs to promote participation in crucial aspects of the city's functioning, like participatory budgets. The citizenry can also play a key role in the provision of data to inform city-level decision-making processes (e.g., citizen 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 very 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), equip public zones with technologies to broaden the user base, and implement other programmes aimed at raising awareness and encouraging citizen engagement in the realization of the SSC strategy.

4.2 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 metropolises from a global perspective; otherwise, the effectiveness and scope of such initiatives may be severely reduced.

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. This step includes, among others, the following.

- Definition of what kind of city it should 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 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.
- Collection of relevant data on the status of the ICT infrastructure and usage at the city level, including the status of the city in regards to SSC technical specifications.
- Identification of the existing governance and organizational conditions that would allow an efficient and effective management of SSC solutions.
- Identification of mechanisms for multi-stakeholder involvement, citizen engagement, communication and information sharing throughout the SSC process. Assurance of the participation of citizens 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 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. This document would also serve as a reference for the strategic planning of the local authority.

Any SSC initiative should have strong political leadership from local government. 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 co-ordination between the relevant actors, decision-making, the overcoming of challenges and any other actions to guarantee the continuous development of the project.

4.3 Phase III: Action plan

An action plan involves turning a proposed project into something tangible. This in turn requires a clearly defined plan for integrating technology solutions into an action plan. Important considerations can include: scheduling; costs related to implementation; identification of the individuals or agencies responsible for implementation; progress indicators; 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 regards to:

- SSC services;
- SSC KPIs;
- SSC architecture;
- SSC infrastructure and integrated platform;
- SSC data security, electromagnetic fields (EMFs);
- SSC projected cost/benefit analysis.

A plan of action must be elaborated which proposes a series of realistic development measures. Such measures will be hierarchized and studies done with regards to associated costs and the appropriate period when investment should take place. A clearly established plan of action will be the guide for 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).

a) Smart sustainable cities services

Cities provide many different services to their citizens, including water management, energy, transport, waste management, healthcare, education and security. The efficiency of these services can be significantly improved with the use of ICT technologies, 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 groups has allowed the identification of several ICT services that contribute to the efficiency of city services, as summarized in the following.

- **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 socioeconomic welfare of a society without compromising the environment [b-ITU-T Y-Sup.36].
- **Smart energy management systems**: These systems use sensors, advanced meters, digital controls and analytic tools to automate, monitor and control the two way flow of energy, optimizing grid operation and usage, to ensure reliability, self-healing, interactivity, compatibility, energy saving, safety, optimal use of energy from renewable sources and

minimum carbon footprint. The ITU-T Focus Group on Smart Grids has developed several documents in this field[1].

- **Smart transportation management systems**: These systems need to move people (and goods) in an efficient, timely and cost-effective, safe and environmentally sustainable way. With that aim in mind, they need to use technology (e.g., machine to machine (M2M) communication, Wi-Fi and radio frequency identifier (RFID) technologies, global positioning systems (GPSs), sensors) and collect information (e.g., real-time traffic flow information, data analytics, prediction techniques) about mobility patterns. Some added benefits of these systems include the capability to locate and identify vehicles, and monitor and control infrastructures like roads. As a result, it is possible to reduce travel times, incident duration and traffic accidents.
- **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 upgrades will help to convert waste into a resource and create closed loop economies, fostering more sustainable and productive uses of waste.
- **Smart healthcare management**: These management 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 citizens. Examples of smart healthcare systems include the availability and improvement of remote diagnosis, remote treatment, online medical services, health management systems and remote patient monitoring systems. To achieve these goals, M2M communications will be crucial.
- **Smart education**: Education, for adults and children, may be the most important smart city service. 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. At the city level, the use of ICT in education can generate other economic and social benefits, including the improvement of tourism services.
- **Smart security**: Ensuring physical safety and security requires the use of ICTs to respond to the need to resolve incidents, provide criminal identification, as well as conduct predictive analysis and criminal pattern identification to improve citizen 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 infrastructure also has to be protected from security threats.
- **Smart buildings systems**: These systems can use data to improve building energy efficiency, reduce wastage and optimize water usage, without affecting occupants' satisfaction. These systems may include building automation, life safety and telecommunications.

The analysis conducted thus far suggests that ICT use can improve the efficiency of city services and, ultimately, strengthen the quality of life of its citizens. 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 integrate different services according to their own needs and priorities.

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1 http://www.itu.int/en/ITU-T/focusgroups/smart/Pages/Default.aspx

b) Key performance indicators, standards

KPIs are not only useful to evaluate the performance of city services, but 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.

In order to provide a complete list of KPIs that can be used for city and municipal administrations, city residents, development and other organizations operating in SSCs (e.g., producers, service providers, planning units), as well as evaluation or ranking agencies, the ITU-T has developed a series of Recommendations and Supplements: [b-ITU-T Y.4900], [b-ITU-T Y.4901], [b-ITU-T Y.4902] and [b-ITU-T Y-Sup.39].

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, city residents to know the details of development of SSC, and development and operation organizations of SSC to fulfil the tasks related to information provision.

The evaluation principles chosen to define dimensions, sub-dimensions 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 (shown in Figure 2):

- ICT;
- environmental sustainability;
- productivity;
- quality of life;
- equity and social inclusion;
- physical infrastructure.

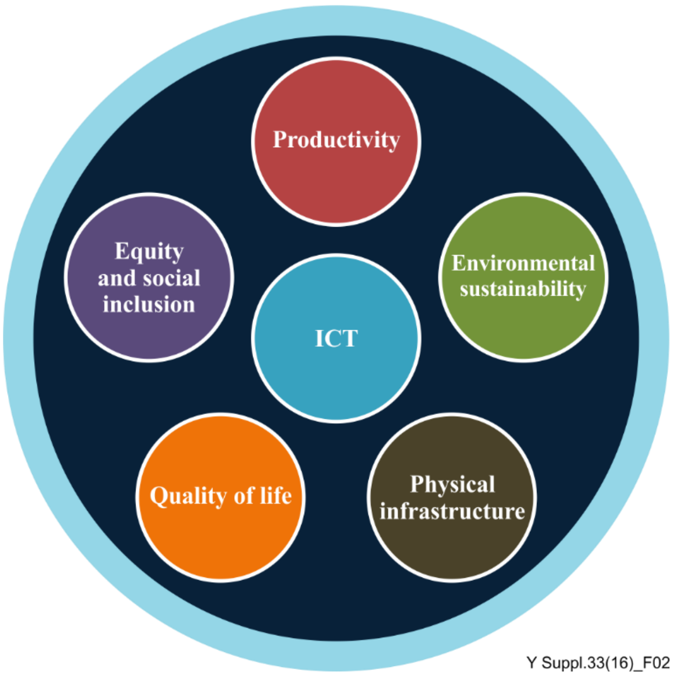

Figure 2 – Dimensions of evaluation of SSC

Source: [b-ITU-T Y.4900]

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

Table 1 – SSC: Key performance indicators, dimensions and sub-dimensions
Overview of key performance indicators in smart sustainable cities

Dimension label	Dimension	Sub-dimension label	Sub-dimension
D1	Information and communication technology	D1.1	Network and access
		D1.2	Services and information platforms
		D1.3	Information security and privacy
		D1.4	Electromagnetic field
D2	Environmental sustainability	D2.1	Air quality
		D2.5	Water, soil and noise
D3	Productivity	D3.1	Capital investment
		D3.4	Trade
		D3.8	Innovation
		D3.9	Knowledge economy
D4	Quality of life	D4.1	Education
		D4.2	Health
		D4.3	Safety and security in public places
D5	Equity and social inclusion	D5.3	Openness and public participation
		D5.4	Governance

Table 1 – SSC: Key performance indicators, dimensions and sub-dimensions
Overview of key performance indicators in smart sustainable cities

Dimension label	Dimension	Sub-dimension label	Sub-dimension
D6	Physical infrastructure	D6.1	Infrastructure and connection to services – piped water
		D6.2	Infrastructure and connection to services – sewage
		D6.3	Infrastructure and connection to services – electricity
		D6.8	Infrastructure and connection to services – road infrastructure
		D6.11	Building
Source: [b-ITU-T Y.4900]			

The corresponding indicators for each sub-dimension are detailed in [b-ITU-T Y.4901] and [b-ITU-T L.4902].

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

The architecture of smart sustainable cities has been defined in [b-ITU-T Y-Sup.27]. At a high level, a meta-architecture consists of five layers (as depicted in Figure 3), which focus on the integration between natural environment and soft infrastructure of urban spaces, while SSC services run across these layers.

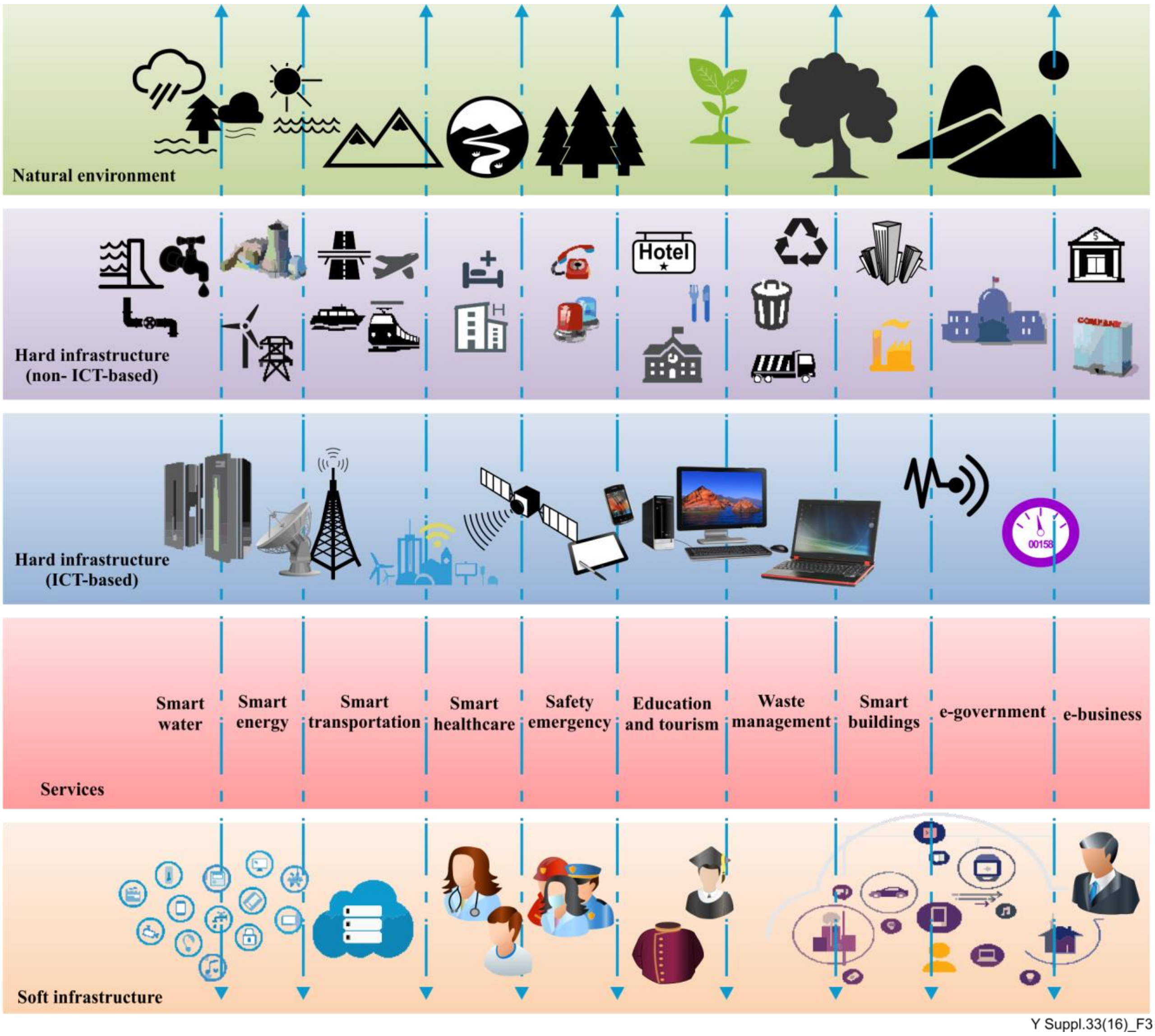

Figure 3 – Multi-tier SSC ICT meta-architecture

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 4 and 5 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 multi-tier.

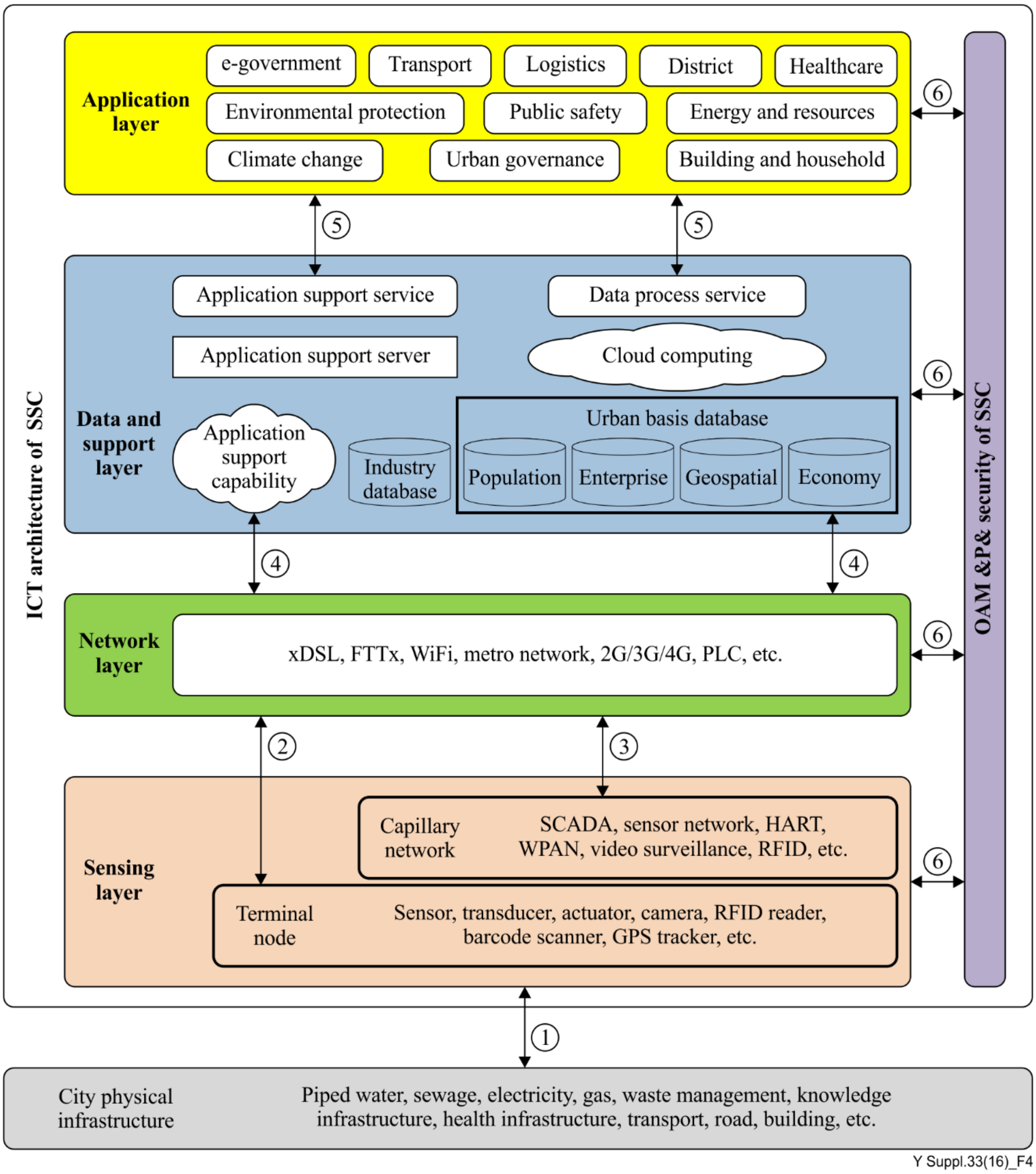

Figure 4 – A multi-tier SSC ICT architecture from a communications viewpoint, emphasizing the physical perspective

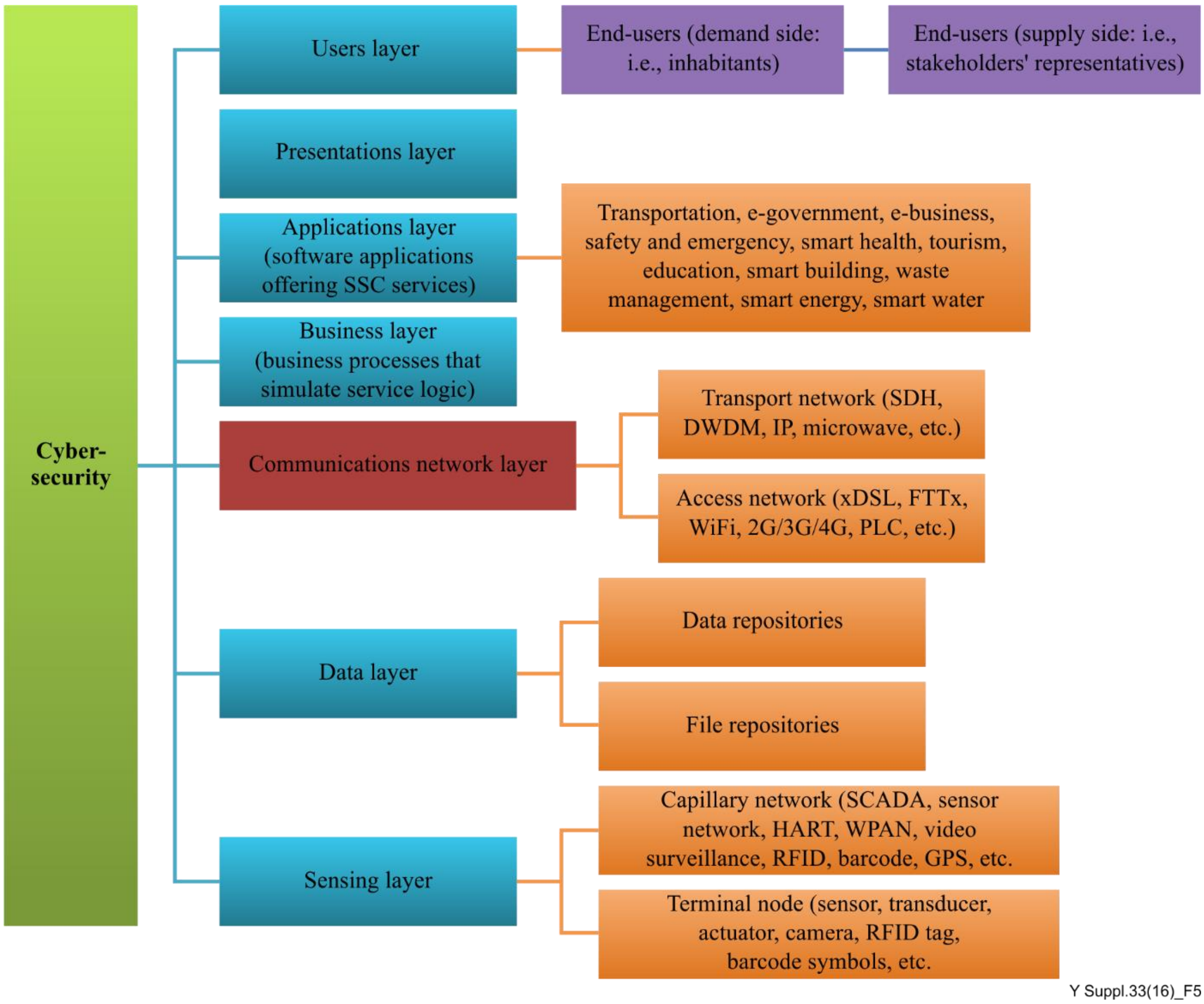

Figure 5 – A multi-tier SSC ICT architecture from a communications viewpoint, emphasizing the information flow perspective

Both Figures 4 and 5 depict valid representations 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, 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 multi-tier SSC ICT architecture from a communications viewpoint, emphasizing the information flow perspective (illustrated in Figure 5) contains the following layers:

- *Users layer* organizes the SSC service end-users into groups from both 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 architecture framework, as well as the security aspects of SSCs is available in [b-ITU-T Y-Sup.27] and [b-ITU-T TR security].

d) Smart infrastructure and integrated platform

Investing in ICT 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 citizens, 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.

In order 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 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, universities, as well as research and development (R&D) institutes.

The ICT infrastructure of an SSC contains a vast array of technologies. The most important ones, grouped into three categories, are listed in Table 2.

Table 2 – Technologies and categories of SSC ICT

Network facilities	Data layer
	Data/content centre
	Communication layer
	Transport networks
	Access networks
ICT facilities	Network management software
	ICT integrated services capacity
	Data management
	Cloud computing and data platform
	Geographic information infrastructure
	Augmented reality
Terminals, sensing and multi-device layer	Terminals and gateways
	Sensors
	Internet of things
Source: [b-ITU-T Y-Sup.30]	

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

The first one is the deployment of ICT 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 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 ICT infrastructure. These include the provision of supply incentives, using existing infrastructure for the deployment of ICT, or the adoption of strategies to incentivize demand (e.g., using ICT to improve local service management, or to improve the relationship with citizens). 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 that in mind, local governments should focus on both strategies.

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

Some of the main funding mechanisms that can be used to support the activities involved in this stage are summarized in Table 3.

Table 3 – ICT 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
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
Source: [b-ITU-T Y-Sup.30]	

e) Data security and electromagnetic fields

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

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 citizens. In an SSC, citizens' security must be expanded to data security (i.e., cyber-security and data protection) in order to protect one of its most important resources.

Considering the growing importance of this area, the FG-SSC developed [b-ITU-T TR security] to identify ways of improving cyber-security and cyber-resilience (defined by the Information Security Forum as the capacity to withstand negative impacts due to known or unknown, predictable or unpredictable, uncertain and unexpected threats from activities in cyberspace[2]).

In order to protect the city from these threats, an SSC shall be provided with security systems that offer protection in four dimensions: physical and environmental security (e.g., equipment security, disaster recovery prevention), system security (e.g., anti-virus technology, host security reinforcement and operating system security), network security (e.g., gateway anti-virus, firewall and intrusion detection) and data and application security (e.g., database encryption and database backup technologies).

2 https://www.securityforum.org/

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 healthcare, 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.

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 [b-ITU-T K-Sup.4].

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

f) SSC projected cost/benefit analysis

Given the massive expected amounts of investments needed to realize the SSC concept, it is of extreme importance to conduct cost/benefit analysis to analyse the feasibility of deploying such systems. Not only does the sustainability concept address environmental and societal challenges, but 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 is capable of estimating 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.

4.4 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 in order 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 [b-Fernandez]:

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.

5 Conclusions and key considerations

In order for an SSC initiative to be adopted and succeed, it is important to understand the need for such vision and ambition. Accordingly, some considerations must be taken into account.

- 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 co-ordination 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 success.
- 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 obtain success. 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 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.
- Citizens should be recognized as the cornerstone of any SSC. They are the main beneficiaries of the SSC model that can provide valuable data, ideas and feedback to the city. Consequently, the city has to actively promote and enable citizen 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 that allow collaboration tools and integration initiatives to be more realistic and efficient; for this reason, public–private initiatives are key. It is very important to learn from past initiatives and experiences.

It is very important to adopt, at different levels of decision, 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 continue to emerge around the globe, it is crucial to recognize that the effectiveness of SSC strategies requires a holistic, articulated approach that is not solely based on technological and infrastructural aspects, but primarily on improving the citizen's well-being.

Installing smart technologies alone will not improve city services. SSCs are about strategic integration and articulation. New technology needs to be complemented by intelligent management. In this sense, strategists will need to define how technologies and information 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 citizens. Thus, considering the different stages and components of the master plan presented in this Supplement, as well as the set of technical documents produced as part of the FG-SSC's mandate, can help to guide and inform that process.

Bibliography

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

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

[b-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*.

[b-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*.

[b-ITU-T Y-Sup.27] ITU-T Y-series Recommendations – Supplement 27, *ITU-T Y.4400 Series – Smart sustainable cities – Setting the framework for an ICT architecture.*

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

[b-ITU-T Y-Sup.34] ITU-T Y-series Recommendations – Supplement 34 (2016), *Smart sustainable cities – Setting the stage for stakeholders' engagement.*

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

[b-ITU-T Y-Sup.39] ITU-T Y-series Recommendations – Supplement 39 (2015), *ITU-T Y.4900 Series – Key performance indicators definitions for smart sustainable cities*.

[b-ITU-T TR security] ITU-T FG-SSC Technical Report (2015), *Cybersecurity, data protection and cyber resilience in smart sustainable cities*.

[b-Fernandez, 2006] 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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