



INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

Series Y

Supplement 27

(01/2016)

SERIES Y: GLOBAL INFORMATION
INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS
AND NEXT-GENERATION NETWORKS

**Draft Supplement 27 to ITU-T Y.4400 series,
Smart Sustainable Cities - Setting the
framework for an ICT architecture**

CAUTION !

PREPUBLISHED RECOMMENDATION

This prepublication is an unedited version of a recently approved Recommendation. It will be replaced by the published version after editing. Therefore, there will be differences between this prepublication and the published version.



Documents

Document Sharing Hub

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

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.

NOTE

In this publication, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this publication is voluntary. However, the publication may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the publication is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the publication is required of any party.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this publication may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the publication development process.

As of the date of approval of this publication, ITU [had/had not] received notice of intellectual property, protected by patents, which may be required to implement this publication. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at <http://www.itu.int/ITU-T/ipr/>.

© ITU 2016

All rights reserved. No part of this publication may be reproduced, by any means whatsoever, without the prior written permission of ITU.

Draft Supplement 27 to ITU-T Y.4400 series, Smart Sustainable Cities - Setting the framework for an ICT architecture

1	SCOPE.....	2
2	REFERENCES	2
3	DEFINITIONS.....	3
3.1	TERMS DEFINED ELSEWHERE	3
3.2	TERMS DEFINED IN THIS DOCUMENT	3
4	ABBREVIATIONS AND ACRONYMS.....	3
5	THE ARCHITECTURE TERMINOLOGY	4
5.1	ARCHITECTURE.....	4
5.2	ICT ARCHITECTURE.....	5
5.3	ICT ARCHITECTURE DEVELOPMENT METHODOLOGY.....	6
5.4	SMART SUSTAINABLE CITY ICT ARCHITECTURE	7
5.5	SSC ICT ARCHITECTURE DEVELOPMENT METHODOLOGY	7
5.6	SSC ICT ARCHITECTURE INTERFACES	9
6	SSC ICT ARCHITECTURE.....	9
6.1	SSC ICT ARCHITECTURE FRAMEWORK.....	9
6.1.1	<i>Identification of needs.....</i>	<i>9</i>
6.1.2	<i>Scope Identification.....</i>	<i>11</i>
6.1.3	<i>Stakeholders Identification</i>	<i>12</i>
6.1.4	<i>Architectural Principles</i>	<i>13</i>
6.1.5	<i>Functional Requirements</i>	<i>15</i>
6.1.6	<i>SSC ICT Architectural views</i>	<i>16</i>
6.2	SSC ICT META-ARCHITECTURE	17
6.3	SSC ICT ARCHITECTURE	21
6.3.1	<i>SSC ICT system's analysis and subsystems' definition</i>	<i>21</i>
7	INDICATIVE SSC ICT ARCHITECTURAL SNAPSHOTS FROM DIFFERENT VIEWS	23
7.1.1	<i>A software engineering view of the SSC ICT architecture</i>	<i>23</i>
7.1.2	<i>A communications view of the SSC ICT architecture</i>	<i>24</i>
7.1.3	<i>Modular SSC ICT architecture approach</i>	<i>28</i>
8	GUIDELINES FOR THE SSC ICT ARCHITECTURE	31
9	CONCLUSIONS	ERROR! BOOKMARK NOT DEFINED.
	APPENDIX A.....	40
	BIBLIOGRAPHY	43

1 Scope

This Supplement describe the ICT architecture development framework of a smart sustainable city and concludes on corresponding architecture views and guides.

It is applicable to ICT architecture for Smart Sustainable Cities.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Supplement are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this supplement does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T TR SSC Def]	ITU-T FG-SSC deliverable (2014), <i>Technical Report on smart sustainable cities: an analysis of definitions</i> .
[ITU-T L.Supp.KPIs-def]	ITU-T Supplement to L.1600 series, <i>Key performance indicators definitions for smart sustainable cities</i> .
[ITU-T Y.Supp.SC-stakeholder]	Draft Supplement ITU-T Supp.SC-stakeholder, <i>Smart Sustainable Cities - Setting the stage for stakeholders' engagement</i> .
[ITU-T TR Cybersecurity]	ITU-T FG-SSC deliverable (2015), <i>Technical Report on "Cybersecurity, data protection and cyber resilience in smart sustainable cities"</i>
[ITU-T Supp.Overview-SC-infra]	Draft Supplement ITU-T Supp.Overview-SC-infra, <i>Smart Sustainable Cities - Overview of smart sustainable cities infrastructure</i> .
[ITU-T Supp.MSinfra]	Draft Supplement ITU-T Supp.MSinfra, <i>Smart Sustainable Cities - Multi-Service Infrastructure in new-build areas</i> .
[ITU-T Y.SC-overview]	Draft Recommendation Y.SC-overview, <i>An overview of smart cities and communities and the role of information and communication technologies</i> .
[ITU-T Supp.buildings]	Draft Supplement ITU-T Supp.buildings, <i>Smart Sustainable Cities - Intelligent sustainable buildings</i> .

[ITU-T TS SWM]	ITU-T FG-SSC Technical Report (2014), <i>Smart water management in cities</i> .
[ITU-T Supp.IMSC]	Draft Supplement ITU-T Supp.buildings, <i>Smart Sustainable Cities - Integrated management</i> .

3 Definitions

3.1 Terms defined elsewhere

This supplement use the following terms defined elsewhere:

3.1.1 Smart sustainable cities [ITU-T Y.SC-overview]: A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects.

3.2 Terms defined in this document

This supplement defines the following term:

3.2.1 Architecture: A definition of the structure, relationships, views, assumptions and rationale of a system.

3.2.2 SSC ICT architecture: The architecture of a smart sustainable city, which emphasizes on the role of the ICT (set of ICT components, which play individual roles within the system (i.e., authentication, data repositories, etc.) and all the components interact in order to establish the expected entire SSC role.

3.2.3 Architecture framework: The process that results in the definition of an architecture, consists of 3 steps: a) meta-architecture definition; b) architecture definition; and c) guides' definition.

4 Abbreviations and acronyms

This supplement uses the following abbreviations and acronyms:

BSI	British Standards Institute
EDA	Event Driven Architecture
FG-SSC	Focus Group on Smart Sustainable Cities

GPS	Global Positioning System
HART	Highway Addressable Remote Transducer Protocol
ICT	Information and Communication Technologies
IoT	Internet of Things
ISO	International Organization for Standardization
ITU	International Telecommunication Union
OAM & P & security	Operation, Administration, Maintenance and Provisioning, and Security
RFID	Radio Frequency Identity
SCADA	Supervisory Control and Data Acquisition
SOA	Service Oriented Architecture
SOE	State-Owned-Enterprise
SSC	Smart Sustainable Cities
UML	Unified Modeling Language
WPAN	Wireless Personal Area Network

5 The architecture terminology

5.1 Architecture

The term architecture is over-used in the context of ICTs and has been applied to aspects ranging from the structure of information to the delivery of technology, and even the technical management of an ICT solution [14; 15]. The term architecture is so wide ranging that all of these uses may indeed be valid. It may be worthwhile to draw on a familiar use for the term – the structuring of physical forms such as buildings. Architecture is defined as: *formation or construction as or as if as the result of a conscious act; a unifying or coherent form or structure; the art or science of building* [14; 15].

The key components of this definition concern something with a defined structure. The architecture of a building, for instance, is based on solid and coherent reasoning. The architect, the undertaker of the architecture, is charged with considering a wide range of aspects in the development of the architecture including , the client's will, site's requirements, legal and financial constraints, technology limitations, the building's users, and a host of other considerations that do not immediately appear to be directly related to the formation of the building. In essence, the architect

is the conduit, through which all of the factors flow in realizing the final structure of the building. This relation between alternative stakeholders' perspectives and influencing forces, impacts the architecture formulation via a shared vision (as depicted in Figure 1).

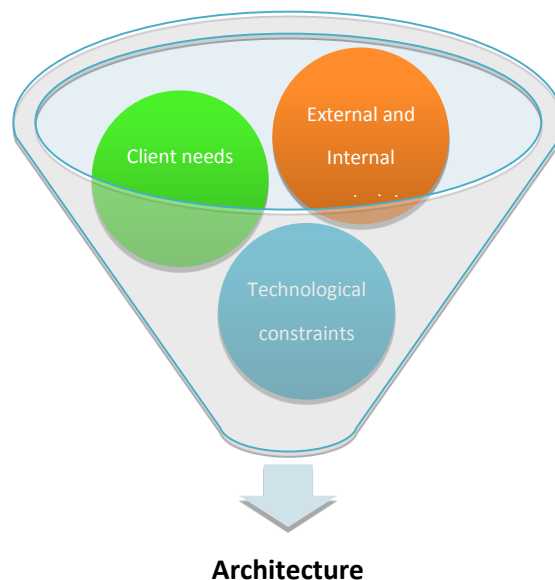


Figure 1 – Forces that impact architecture formulation

The above characteristics can result in the definition of the architecture [b-Perks]:

A pragmatic, coherent structuring of a collection of components that through these factors supports the vision of the full "user" in an elegant way.

An alternative would be [b-McGovern]:

A definition of the structure, relationships, views, assumptions and rationale of a system.

5.2 ICT Architecture

The above analysis for the definition concerns a system (collection of components) and each of the individual components can represent corresponding architectural practices. For instance, an information system consists of components, which play individual roles within the system (i.e., authentication, data repositories, etc.) and they all interact to establish the entire system's role. As such, the term architecture offers the following features:

- It is used to define a single "system".
- It describes the functional aspects of the system.
- It concentrates on describing the structure of the system.
- It describes both the intra-system and inter-system relationships.

- It defines guidelines, policies, and principles that govern the system's design, development, and evolution over time.

Each system's component has to be defined with the same or alternative architectural practices (hardware, software, data flow, business flow, management, etc.), which can represent alternative architectural perspectives, which at high level synthesize the enterprise ICT architecture [b-Perks]:

- The *information architecture* deals with the structure and use of information within the organization, and the alignment of information with the organization's strategic, tactical, and operational needs.
- The *business systems architecture* structures the informational needs into a delineation of necessary business systems to meet those needs.
- The *technical architecture* defines the technical environment and infrastructure in which all information systems exist.
- The *software or application architecture* defines the structure of individual systems based on defined technology.

All the above information underlines that an architecture *defines a framework within which a system can be accurately specified and built at a specific time frame. It functionally defines what the elements of the system do and how the data and information is exchanged between them. An architecture is functionally oriented and not technology specific, which allows the architecture to remain effective over time. It defines "what" must be done, not "how" it will be implemented.*

5.3 ICT Architecture development methodology

According to the above findings, the definition of an architecture has a lot to do with information collection and understanding of all the stakeholders' needs, together with the limitations that come from the external environment and of the laws that impact the operation of system. As such, the following process is suggested to lead the architecture development (Figure 2):

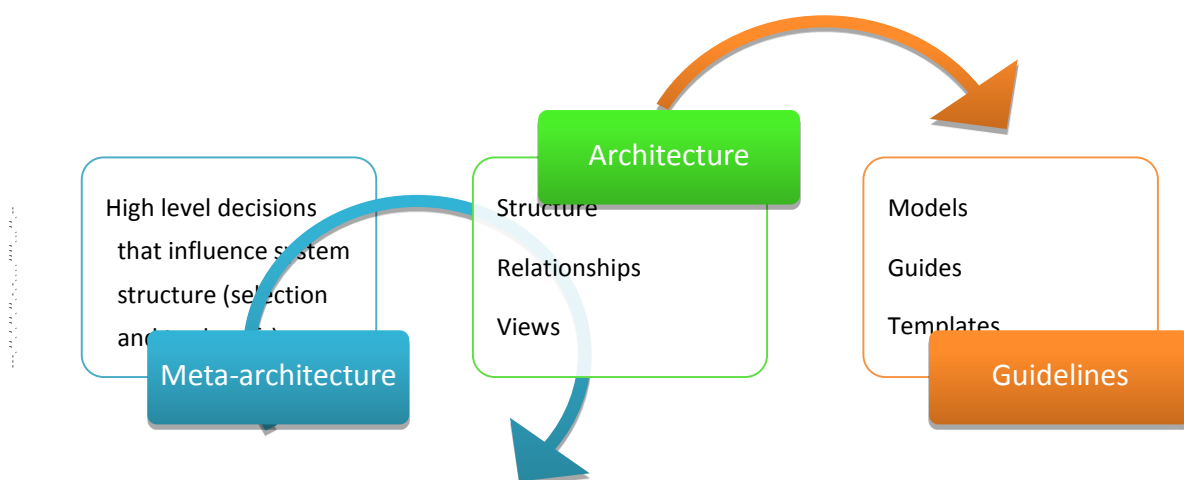


Figure 2 – ICT architecture development methodology

5.4 Smart Sustainable City ICT Architecture

This document emphasizes on the *technical architecture* from the architectural perspectives, which defines the platform on which the SSC organization (i.e., government, project coalition or business) builds and uses ICT in order to achieve in its defined mission [b-Perks]. To this end, the SSC architecture is the element, which:

- describes and defines the structure of the environment in which business systems are delivered;
- creates and maintains a set of core technology standards with which the SSC organization can measure technology projects;
- is an organizational capability – the people within (and outside) the ICT organization who provide strategic technical advice;
- is a means of resolving organizational technical issues;
- sets system (and hence software architecture), project, and corporate technology direction;
- establishes a reasoned approach for the integration of technology and business systems;
- establishes a framework for technology procurement decisions;
- both provides input to and is driven from the ICT planning process;
- allows the organization to control technology costs;
- develops a clear understanding of an organization's critical technical issues;
- provides a governance structure to support the ongoing health of the organization's technical environment;

As such, the SSC ICT architecture should be developed based on the complete architectures of its underlying systems in order to benefit from the potential integration and hence cost savings, of the underlying modules in the process of the combined city service provisioning management and control.

Accordingly, a smart sustainable city ICT Architecture document defines the types of components:

- Complex Systems (as a system of systems);
- Interconnections and Interfaces (between the Complex Systems); and
- Information Exchanges (between these Complex Systems).

5.5 SSC ICT Architecture development methodology

According to Figure 2, the methodology that this document follows concerns:

1. The definition of SSC ICT meta-architecture.
2. The definition of alternative SSC ICT architectures.
3. The definition of frameworks and patterns for the SSC ICT architecture.

The above process passes via the establishment of the following milestones (Figure 3):

1. *Identification of the needs:* This involves assessing the status quo of city services and processes. Examples from different regions should be described and analyzed in order to develop a rather generic or region-specific standardized architecture that can be found suitable for real implementation in different regions of the world.
2. *Stakeholders Identification and Needs Analysis:* This includes the roles and responsibilities of each stakeholder in developing, installing, procuring, operating, and maintaining the SSC elements is to be documented in addition to the functional and security related needs.
3. *Scope definition:* This includes the geographic boundaries and time frame that should be clearly stated at the onset of the process. The list of potential city service sectors, along with sector specific services should also be clearly identified and analyzed.
4. *Functional Requirements' definition:* This includes specifying a formal description of each subsystem belonging to a specific city service sector in order to identify the activities conducted by each subsystem.
5. *Subsystem and corresponding Interfaces' definition:* This describes how the different subsystems are connected and identifies any interfacing requirement.
6. *Dataflow Analysis:* Dataflow analysis between the different subsystems is conducted in this stage.
7. *Information Security and Privacy Requirements' definition:* Information security requirement is to be conducted based on the needs, functional, interface, and dataflow specifications of each subsystem.
8. *Systems Analysis and Final Design:* This involves analysis of the potential merge, deletion or addition of a system module to integrate different systems is to be conducted in this stage.

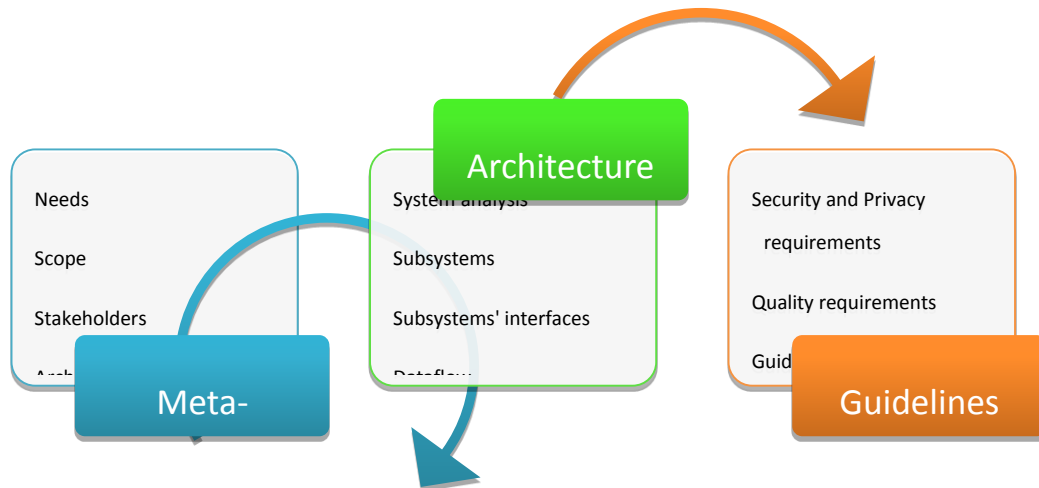


Figure 3 – SSC ICT architecture development methodology

5.6 SSC ICT Architecture interfaces

The interface is the median, which stands between the subsystems of one system [b-Perks]. There's no particular owner of an interface, neither intersystem contracts exist to describe the interfaces. Most interfaces execute typical batch jobs, while almost all require physical interventions to move generated files between subsystems. In the proposed SSC ICT architecture interfaces play the role to deliver information between discrete SSC ICT subsystems.

6 SSC ICT architecture

6.1 SSC ICT architecture framework

6.1.1 Identification of needs

The concept of Smart Sustainable Cities (SSC) has risen from the emerging urbanism phenomenon across the globe, according which the proportion of the international population that will live in cities will exceed 66% in 2050. The previously given SSC definition provides this document with the following characteristics for a smart sustainable city:

1. It concerns an urban space with innovative –not necessarily based on ICT- features. However, this document focuses on SSC architecture, where the ICT have a crucial role amongst the other innovative solutions and city facilities.
2. These innovation solutions address the following urban dimensions:

- a. *People*: in terms of discovering and meeting today and future generations' requirements;
- b. *Living*: by enhancing quality of life and social coherency, as well as efficiency regarding energy, food, water, etc.;
- c. *Environment*: which includes protection, waste and emissions control against climate change;
- d. *Governance*: in terms of ensuring urban utility and service availability;
- e. *Economy*: in terms of sustainable growth and city competitiveness (attracting habitants, visitors and businesses).

Other approaches [1, 2] discuss about urban *mobility* in terms of transportation, which can be concerned part of the above *Living* dimension; *resilience* in terms of resistance against natural disasters, pandemics, terrorist attacks, accidents, etc. [Pizzo], which can be addressed by the above *environment* and *governance* SSC dimensions (Figure 4); *innovation* in terms of urban innovation [Khare], which is mainly disruptive, although the smart sustainable city becomes steadily a social innovation [Dixon].

On the other hand, ITU has delivered its Recommendations regarding Key Performance Indicators' (KPIs) definitions, which aligns to the United Nations Habitat dimensions (Table 6.1.1).

Table 6.1.1 – ITU SSC key performance indicators (KPIs)

SSC dimension
ICT
Environmental sustainability
Productivity
Quality of life
Equity and social inclusion
Physical infrastructure

The above characteristics illustrate the complex SSC nexus (shown Figure 1), where the five dimensions match the SSC KPIs (Table 6.1.2), Matching was performed with the comparison of SSC KPIs with each of these dimensions and an important finding showing that complete matching is performed between *ICT*, *Quality-of-Life* and *Physical infrastructure* SSC KPIs with SSC dimensions, while the *Living* and *Government* SSC dimension matches to all SSC KPIs.

Table 6.1.2 – Matching between SSC dimensions and SSC-KPIs

SSC dimension \ SSC KPIs	People	Living	Government	Environment	Economy
ICT	X	X	X	X	X
Environmental sustainability		X		X	
Productivity		X	X		X
Quality of life	X	X	X	X	X
Equity and social inclusion	X	X	X	X	
Physical infrastructure	X	X	X	X	X

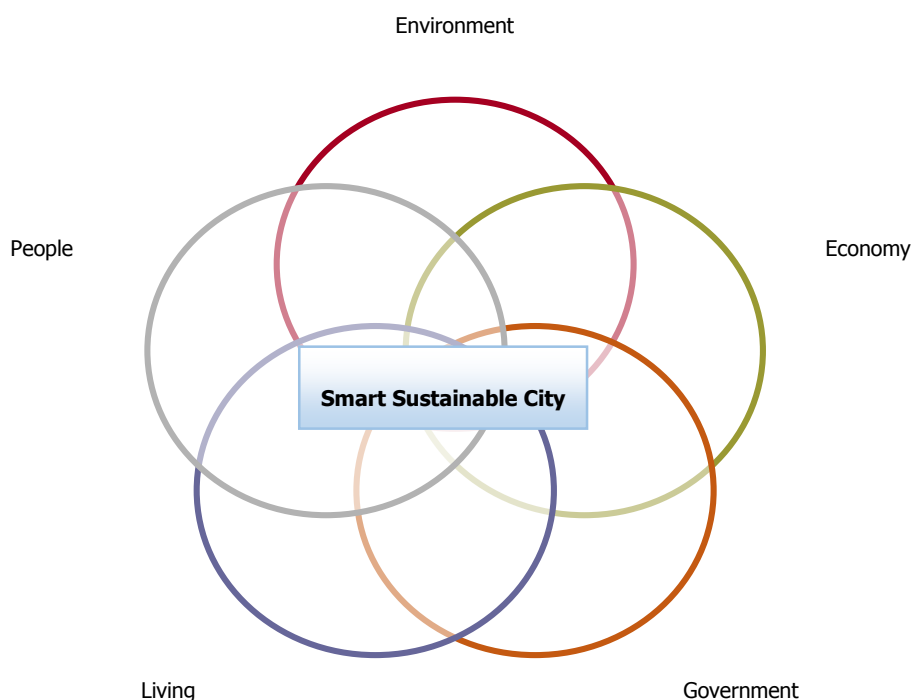


Figure 4 – Smart Sustainable City dimensions fitting to the SSC and SSC-KPIs definition

6.1.2 Scope Identification

A smart sustainable city ICT architecture has to comply with the particular requirements of all forms of cities, as well as with all alternative smart infrastructure types that have or are being followed by SSC.

Y series – Supplement 27 (01/2016) – Prepublished version

According to the above findings, ICT plays crucial role for smart sustainable city development. More specifically, it has been depicted that ICT contributes to all the SSC dimensions (people, living, government, mobility, economy and environment), which is translated that the alternative ICT solutions, as they're expressed with SSC focus group's documents (i.e., IoT, telecommunication network, cloud computing, cybersecurity, etc.), play major role in SSC development.

SSC can be classified according to the smart infrastructure type and corresponding development stage [Angelidou] to the following categories:

- a) *Hard infrastructure* based: This category refers to city innovations, which target the efficiency and technological advancement of the city's hard infrastructure systems (i.e., transport, water, waste, energy).
- b) *Soft infrastructure* based: City innovations, which address the efficiency and technological advancement of the city's soft infrastructure and the people of the city (i.e., social and human capital; knowledge, inclusion, participation, social equity, etc.).

With regard to the city development stage they're classified as the following:

- a) *New cities* (Greenfield or 'cities from scratch' or 'planned cities'): They concern smart sustainable city projects where the entire city is being developed from ground zero, even urban planning addresses the above smart city dimensions and innovative solutions are embedded in the city. Various cases of this type are under development around the world [1].
- b) *Existing cities*: They concern SSC projects where the innovative solutions are installed in existing infrastructure. Representatives of this category concern all the cities, which develop various types of innovative solutions.
- c) *Smart plants*: they concern from-scratch projects, which are developed inside existing cities (i.e., new neighborhoods, new blocks or harbors, etc.) [b-ITU-T Y.SCinfra].

Finally, SSC ICT architecture has to comply with the all potential evolution that has been followed, such as from wireless and broadband cities, to recent ubiquitous and green cities [b-Authopoulos-1], which demands flexibility from the architecture.

6.1.3 Stakeholders Identification

According to [ITU Y.Supp.SC-stakeholder], a stakeholder is defined as any entity, an institution or an individual, that has an interest in SSC or that can significantly influence or be influenced by its deployment. As such, a set of stakeholders have been identified and concern:

- a. **Municipalities, City Council and city administration:** They are responsible for city management, and therefore they are the main promoters of SSC initiatives on each specific city.
- b. **National and regional governments:** They have remit on policies that can affect SSC implementation.