



**Asia-Pacific
Economic Cooperation**

Advancing Free Trade
for Asia-Pacific **Prosperity**

Recommendations for Implementation of Smart Sustainable City Information and Communication Technology Infrastructures in the APEC Region

APEC Telecommunications and Information Working Group

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Abbreviations

3G	Third Generation Technology
4G	Fourth Generation Technology
5G	Fifth Generation Technology
AI	Artificial Intelligence
APEC	Asia-Pacific Economic Cooperation
CDMA	Code Division Multiple Access
CAPEX	Capital Expenditure
DWDM	Dense Wavelength Division Multiplex
EMF	Electromagnetic Field
EPON	Ethernet Passive Optical Network
FDD	Frequency Division Duplex
GB	Giga Byte
GPON	Gigabit Passive Optical Network
GPS	Global Positioning System
GSM	Global System for Mobile Communications
GSMA	GSM Association
GIS	Geographic Information System
HART	Highway Addressable Remote Terminal
ICT	Information and Communications Technology
IEC	International Electrotechnical Commission
IoT	Internet of Things
ISO	International Standard Organization
ITU	International Telecommunication Union
JTC1	Joint Technical Committee 1
KPI	Key Performance Indicator
LTE	Long Term Evolution

NB-IoT	Narrowband IoT
NB-LTE	Narrowband LTE
NFC	Near Field Communications
OAM&P	Operations, Administration, Maintenance and Provisioning
OTN	Optical Transport Network
OPEX	Operating Expenses
PDP	Product Development Partnerships
PFI	Private Finance Initiative
PPP	Public-Private Partnership
R&D	Research and Development
RFID	Radio Frequency Identification
RS	Remote Sensing
SCADA	Supervisory Control and Data Acquisition
SDH	Synchronous Digital Hierarchy
SLA	Service Level Agreement
SMEs	Small and Medium-sized Enterprises
SSC	Smart Sustainable Cities
TDD	Time Division Duplex
UN	United Nations
USA	United States of America
WCDMA	Wideband Code Division Multiple Access
WPAN	Wireless Personal Area Network

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Foreword

World populations are increasingly moving from rural to urban areas. The United Nations (UN) estimates that in 2050, around 67% of the world population will live in urban areas and that would bring challenges as well as risks for cities in terms of, *inter alia*, traffic congestion, overloaded public healthcare system, climate change, and social instability¹. In this regard, cities need to find new ways to overcome these difficulties and challenges. Applying Information and Communications Technologies (ICT) to build Smart Sustainable City (SSC) is being considered as an advanced solution to deal with the issues, for both developed and developing economies.

The overall objective of SSC is to seamlessly and efficiently mobilize a broad set of existing and new resources that serve urban areas to achieve their development goals. ICT infrastructures are key enablers for accelerating SSC deployment towards socio-economic improvement and sustainable development for the future. In this progress, ICT infrastructures play as one of the crucial elements and integrate with city physical infrastructures to:

- Improve the quality of citizens' life;
- Enhance economic growth and spur innovation;
- Manage urban operation efficiently and optimal;
- Manage environmental issue effectively;
- Provide public services faster and more effectively;
- Enhance safety, security, and privacy;
- Prevent crime.

Though each economy has different visions, strategies and development roadmaps, ICT infrastructures for SSC serve as prerequisite conditions for all

¹ United Nations Commission on Science and Technology for Development. January 2016. *Issues Paper on Smart Cities and Infrastructure*. Available at http://unctad.org/meetings/en/SessionalDocuments/CSTD_2015_Issuespaper_Theme1_SmartCitiesandInfra_en.pdf

economies to achieve better municipality in terms of socio-economic development and environment. However, Asia-Pacific Economic Cooperation (APEC) member economies are facing difficulties in deploying ICT infrastructures for SSC, such as lack of available recommendations, guidelines, and financial resources.

In October 2019, APEC Telecommunications and Information Working Group (TELWG) held a workshop on “Recommendations for Implementation of Smart Sustainable City (SSC) ICT infrastructures in the APEC Region” to discuss ICT infrastructures for SSC and share best practices among the members. This report is output and result of discussion during this workshop to address main problems and challenges in building ICT infrastructures to deploy SSC, and outline conclusions and recommendations to APEC economies in recognizing and capitalizing the benefits of ICT infrastructures for SSC.

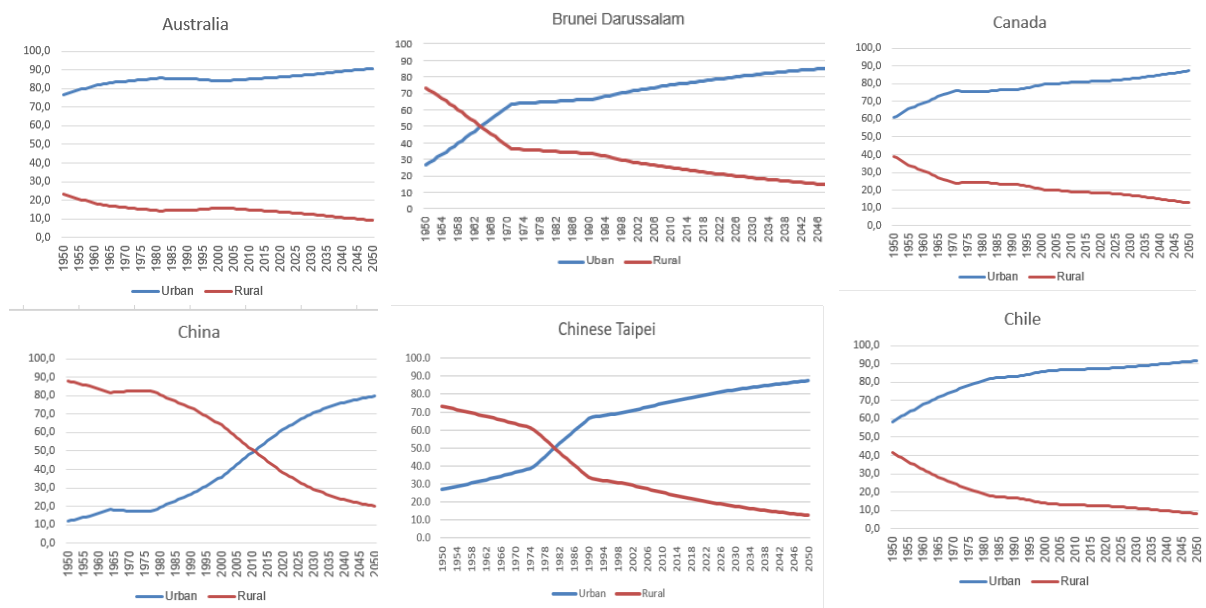
This report consists of five chapters. Chapter 1 presents an overview of SSC regarding ICT infrastructures and smart services and explores the roles of ICT infrastructures for SSC. Chapter 2 focuses on analyzing current situations of ICT infrastructures in the APEC region to identify challenges and difficulties for SSC implementation. Chapter 3 outlines standardization activities done by various international organizations to support SSC deployment. Chapter 4 talks about how to utilize emerging ICT technologies and standards for SSC. Chapter 5 briefs recommendations on policies, technologies, strategies, and standardizations to accelerate ICT infrastructures for SSC in the APEC region.

Chapter 1. Overview of Sustainable Smart City

Cities are a crucial factor of any economy; they serve as hubs of economic development and job creation to attract people from other regions. Recently, urbanization, industrialization, and modernization have been affecting migration trend from rural to suburban and urban areas. More and more people move to cities with the hope of finding a better job and getting a higher wage to improve their living.

According to a UN's forecast, urban population increases from 29.6% to 68% during the period between 1950 and 2050; and over 60% of the global population will live in "megacities" (10+ million), large (5-10 million), medium (1-5 million) and peri-urban communities by 2030².

Urbanization is also a trend in the APEC region. Data collected by the UN³ show that half of APEC population is living in urban areas, see Figure 1.



² United Nations Commission on Science and Technology for Development. January 2016. *Issues Paper on Smart Cities and Infrastructure*. Available at http://unctad.org/meetings/en/SessionalDocuments/CSTD_2015_Issuespaper_Theme1_SmartCitiesandInfra_en.pdf

³ The United Nations database, available at <https://population.un.org/wpp/Download/Standard/CSV/>

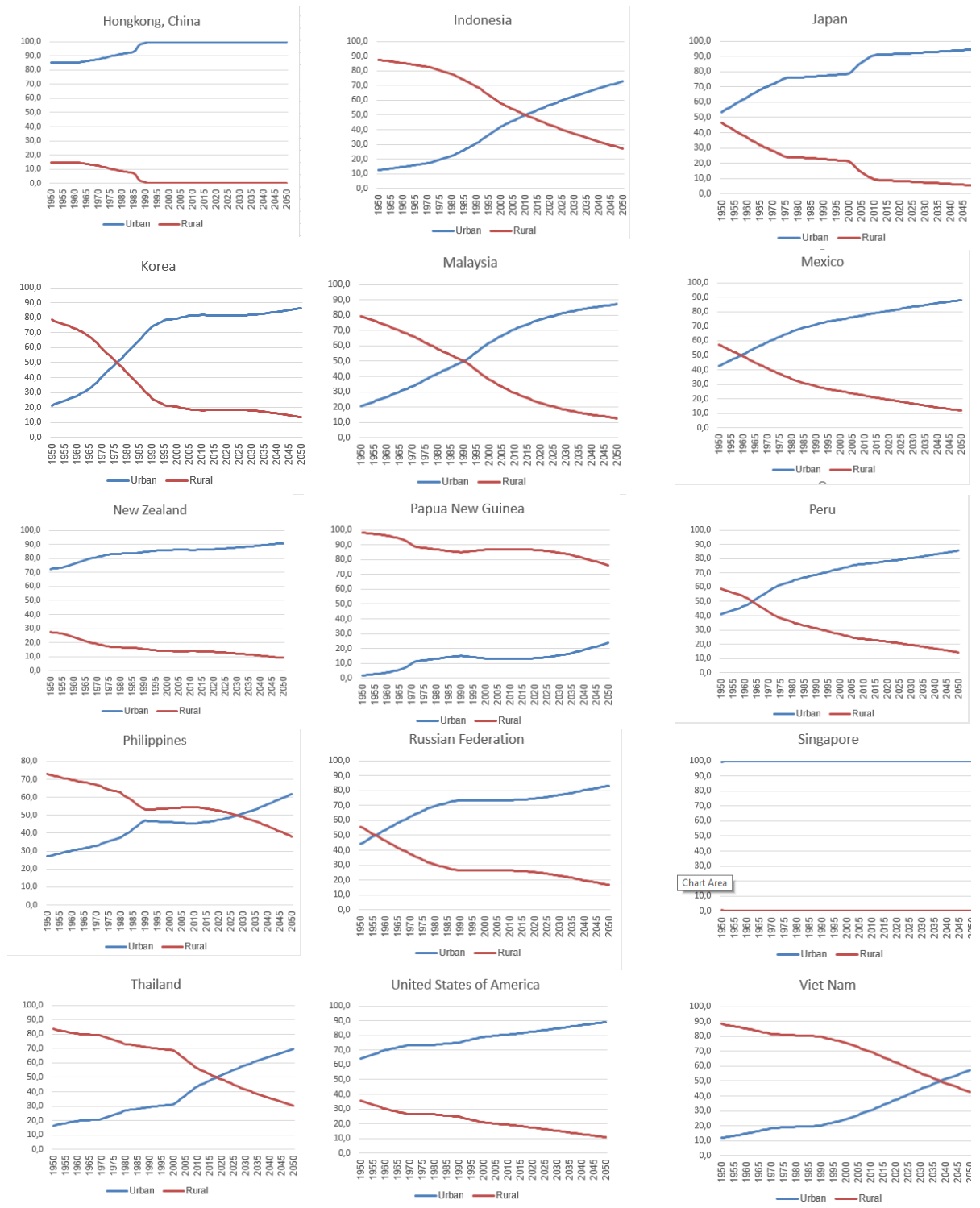


Figure 1. Urban APEC population

Source: author computed based on data collected from UN's database

Main characteristics of urbanization can be briefed as:

- The fast growth of population;
- Concentrated population in urban areas;
- The rapid expansion of urban areas.

Urbanization is an important driver of economic growth and brings a lot of benefits for economies, such as helps cities to attract talents to come to work, research and serve as roots for cities' development.

However, urbanization also creates pressures and challenges for local governments and residents. Cities are daily facing traffic congestion, overcrowding, pollution, lack of water and energy as well as other social challenges. Many cities are hard to provide enough clean water for their residents and according to a World Health Organization (WHO) report⁴, 2.1 billion inhabitants in the world lack clean water. During the period 1970-2010, the world evidences that greenhouse gas emissions rose from 30 tons to 55 tons⁵. This is also a common sight in most of the large cities in the APEC region - one of the fastest-growing regions in the world; and it creates many challenges to local governments and their inhabitants. Consequently, it calls for both central and local governments to find out new ways to overcome these difficulties and challenges. Utilizing ICT infrastructures to build SSC is being considered as an advanced solution and an upward trend in the world, both in developed and developing economies, to deal with the issues. SSC can improve the daily lives of residents in urban areas, in terms of public safety, healthcare, mobility, energy management, and economic development.

1. Smart Sustainable City Introduction

1.1 Smart Sustainable City Definition

Concepts of Smart Cities have been developing from around 2008, when underlying technologies, such as Radio Frequency Identification (RFID) sensors, wireless connectivity, electronic payments, and cloud-based software services enable new approaches to collaborative solutions to respond to urban challenges based on

⁴WHO. July 2017. *Progress on Drinking Water, Sanitation and Hygiene*

⁵Yu Jae-Hyun. October 2019. *ICT Infrastructures for SSC: Opportunities & Challenges*

extensive collected data⁶. SSC can be defined in many ways and the International Telecommunications Union (ITU) statistics identify that there are already more than 100 definitions related to smart city⁷. One of the ITU's definition about SSC is "a smart sustainable city as 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 concerning economic, social and environmental aspects."⁸

Meanwhile, the International Standard Organization (ISO) defines SSC as a "community infrastructure with enhanced technological performance that is designed, operated, and maintained to contribute to sustainable development and resilience of the community."⁹

The General Working Group of Chinese Smart Cities Standardization describes "smart city as a new concept and a new model, which applies the new generation of Information technologies, such as the internet of things, cloud computing, big data and space/geographical information integration, to facilitate the planning, construction, management and smart services of cities. Developing Smart Cities can benefit synchronized development, industrialization, informationization, urbanization and agricultural modernization and sustainability of cities development."¹⁰

The British Standards considers "smart city as the effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens."¹¹

⁶ Sanjay Bhatnagar, Deepti Garg, Manisha Bhatnagar. 2014. *Smart Cities – An Overview and the Role of ICT*

⁷ ITU. May 2015. *Smart Sustainable Cities: An Analysis of Definitions*

⁸ Mire Sam. November 2019. *Blockchain for Smart Cities: 12 Possible Use Cases*. Available at <https://www.disruptordaily.com/blockchain-use-cases-smart-cities>

⁹ ISO 37105:2019. November 2019. *Sustainable Development in Communities - Descriptive Framework for Cities and Communities*

¹⁰ ITU. May 2015. *Smart Sustainable Cities: An Analysis of Definitions*

¹¹ The British Standards Institution. 2014. *Smart City Framework: Guide to Establishing Strategies for Smart Cities and Communities*

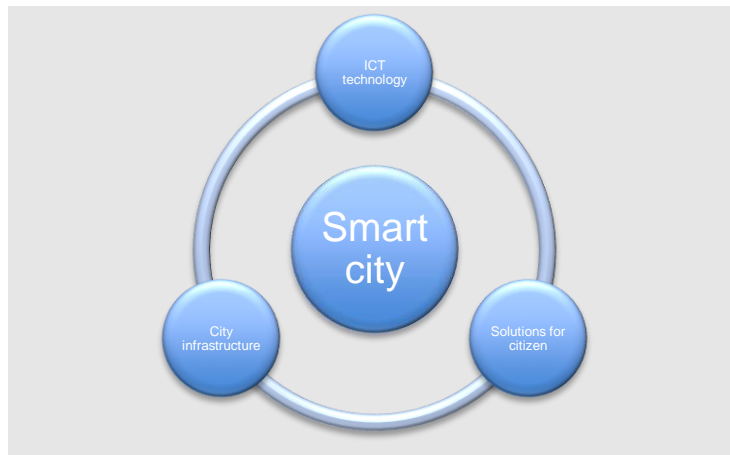
Thailand views “the smart city is a city that leverages technology, innovation and good design to increase efficiency, cut costs and innovate in relation to smart city management and service provision in order to achieve citizen's quality of life, happiness and sustainability.”¹²

The U.S. Smart Cities and Communities Guide for Federal Agencies defines the smart community concept as innovative research and development in cutting-edge technologies applied to new and legacy infrastructures with the goal of transforming a community and spurring economic growth. Small towns, farming communities, regional hubs, and urban centers across the Nation are exploring the smart community concept to drive progress in agriculture, transportation, energy, public safety, healthcare, and more.

Viet Nam refers to SSC as “a city that uses innovative, appropriate and trustworthy ICT and other means to improve quality of life of citizens, to increase the efficiency of urban operation and services by applying data analytics, enhancing citizen participation to the cities’ management, promoting innovation and economic growth as well as protecting the environment.”

These definitions show that there is no common definition about SSC and the term can be viewed and analyzed from different angles. Further, while reviewing the definitions, we can point out that there are various factors to make a city become smarter and could be grouped as below:

¹² Treethidaphat Wichai. October 2019. *Thailand Smart City Development Plan and ICT Infrastructures*



1.2 Smart Sustainable City Architecture

City architecture includes several structures, social aspects and components, and relationships among those various components. As described in Standard ISO 37105 “Sustainable development in communities - Descriptive framework for cities and communities”, city's architecture is separated into three layers, each layer is quite complex and can be considered as a system of systems itself as shown in Figure 2.

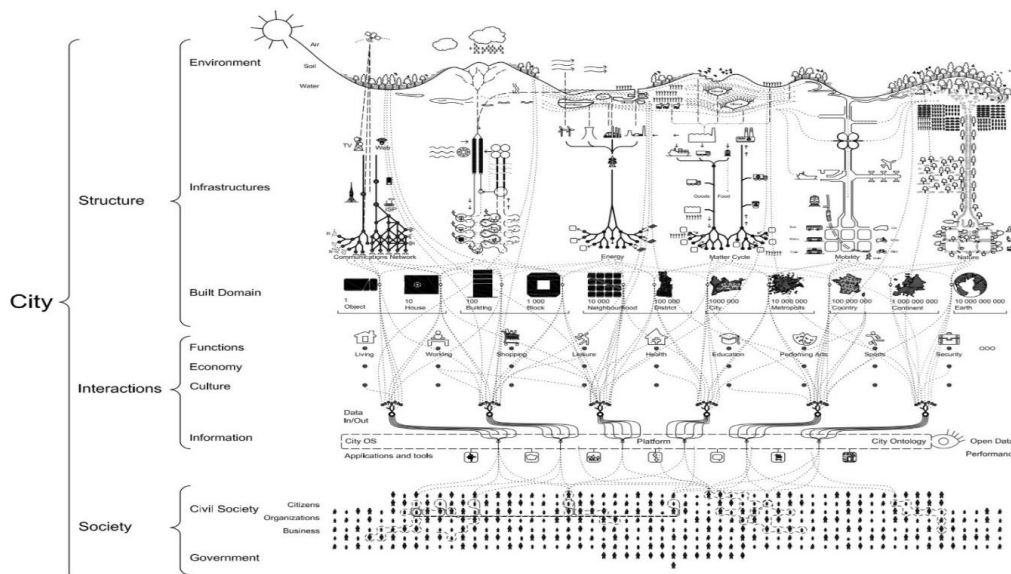


Figure 2. Components of SSC

Source: Yu Jae-Hyun, 2019

Three main layers of a city include Society, Interactions and Structure as illustrated in Figure 2; each layer has a different list of components, domains,

information and structures to implement the city's functions, such as living, working, and healthcare.

Infrastructures are “pivotal aspects of a smart sustainable city”¹³. Traditionally, there are two types of infrastructures¹⁴:

- Hard infrastructures or physical infrastructures (buildings, roads, transportation, telecommunications network, utilities like water, energy...) include ICT and non-ICT infrastructures to provide public services, optimize resources and resolve different challenges related to transportation, environment, energy and so on. ICT infrastructures play as glue to enable SSC operating efficiently and optimal.

- Soft infrastructures or non-physical infrastructures include collected data, applications and software which could be embedded into hard infrastructures to realize services for SSC.

All physical infrastructures, ICT infrastructures, and layers have close relationships among each other to create and ensure a comfortable living environment for urban residents. Therefore, a smart city is modular and compositional rather than integrated. This structure offers choices to modify and/or adjust components and layers instead of replacing all systems when necessary.

1.3 ICT Infrastructures for Smart Sustainable City

The goal of SSC is to seamlessly and efficiently mobilize a broad set of existing and new resources that support the city to achieve its development goals. The smart city has many different infrastructures and ICT infrastructures act as one of the crucial elements for integrating the city's physical infrastructures to:

- Improve the quality of citizens' life;
- Enhance economic growth and innovation;

¹³ Da Silva Ivan Nunes, Flauzino Rogério Andrade. December 2016. *Smart Cities Technologies*

¹⁴ Kondepudi Sekhar. May 2015. *An Overview of Smart Sustainable Cities and the Role of Information and Communication Technologies*

- Efficiently and optimally manage urban operation;
- Effectively manage environment issues;
- Provide public services faster, more effectively and conveniently;
- Enhance safety, security, and privacy for residents.

ICT infrastructures should be available before setting-up and offering smart public services to citizens. ICT infrastructures include 5 layers as illustrated in Figure 3 below.

The first layer is Data Acquisition Layer and composes of sensors, Radio-Frequency Identification (RFID) tags, actuators, cameras to collect information in the physical environment.

The second layer is the Network Communication Layer provided by telecommunication operators to provide communication paths among all devices and people and support information exchange between layers in SSC. This includes:

- Wired network (Fiber-to-the-Home (FTTH), Cable TV, xDigital Subscriber Line (xDSL));
- Wireless networks (2G, 3G, 4G, 5G);
- Satellite networks;
- Transmission protocols, Machine-to-Machine (M2M) connectivity;
- Other Networks as Metro-Area-Network (MAN), Wide-Area-Network (WAN)...

Computing and Storage Layer is the third layer and contains the data center, cloud computing to realize data process and application support.

The fourth layer is Data and Service Supporting Layer, which makes the city become smarter thanks to analyzing capacity and predicting citizens' requirements.

Finally, Smart Application Layer includes various applications such as smart government, smart transportation, smart education, smart home, smart campus, and smart living provided for citizens.

Data are key to smart city and they will become more valuable when the local government shares with others, following existing or new regulations for data security and privacy to address the protection and privacy of citizens' information. Therefore, the security system is presented in this model to ensure safety and privacy for citizens.

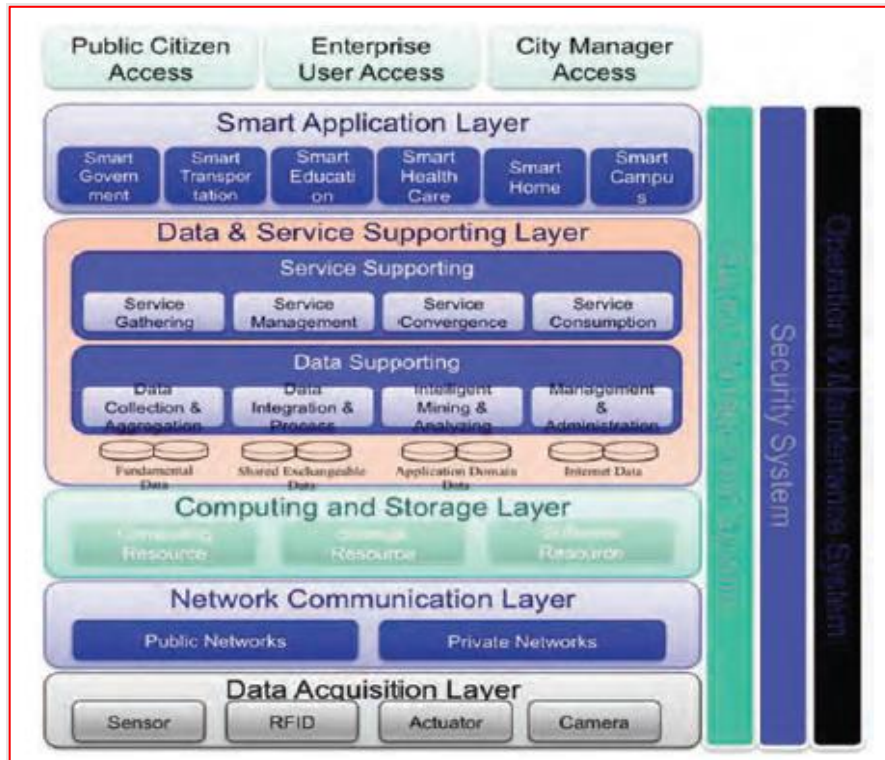


Figure 3. ICT infrastructures

Source: ISO 37105:2019

In its publication, International Telecommunications Union (ITU) analyzes¹⁵ those ICT infrastructures are divided into 4 layers (Application Layer, Data and Support Layer, Network Layer and Sensing Layer) and 6 interface points as shown in Figure 4.

¹⁵ ITU. May 2015. *Setting the Framework for an ICT Architecture of a Smart Sustainable City*

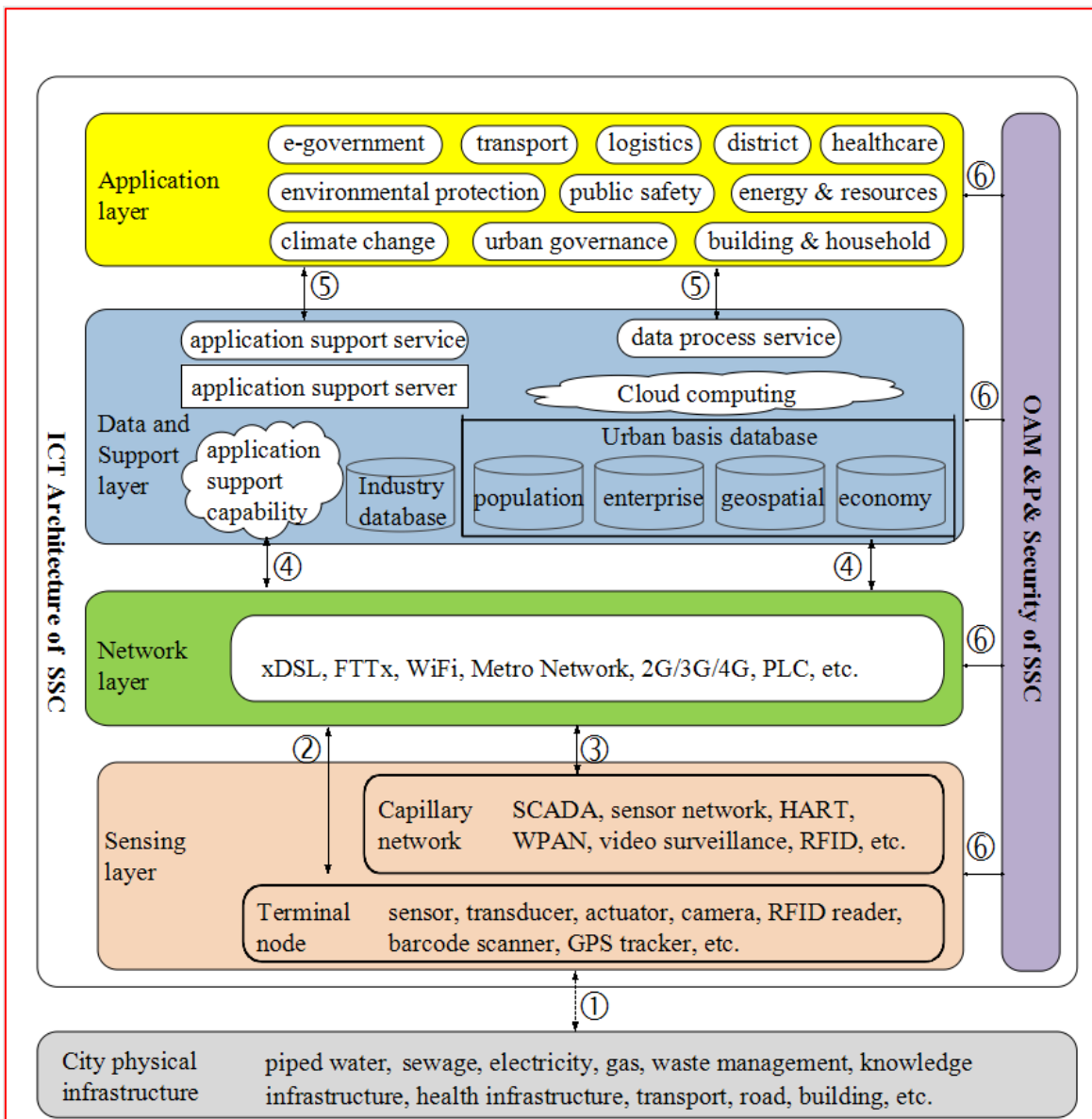


Figure 4. ICT infrastructures for SSC

Source: ITU, May 2015.

An analysis prepared by ITU and ISO shows that ICT infrastructures for smart city are multi-layer–infrastructures and include both physical hardware and software infrastructures as below:

- Sensing devices such as sensors, RFID cards, and cameras to collect information;
- Transportation includes Internet backbone, fixed broadband infrastructure (coaxial and optic fiber cable networks), mobile communications infrastructure, satellites broadband communications;

- Data and cloud computing facilities;
- Application and services for citizens.

2. Smart Services

The first and foremost goal of SSC is to improve the quality of life for cities' residents, therefore public services that strongly affect the residents' daily lives should be given high priority. The following services are broadly considered to offer inhabitants in smart cities¹⁶:

- Transportation services;
- E-government services;
- E-business services;
- Safety and emergency services;
- Smart healthcare services;
- Tourism services;
- Education services;
- Smart building;
- Waste management services;
- Smart energy services;
- Smart water services.

These services are built on different infrastructures but they interact with each other and also interact with different components of the city, therefore when local governments build and deploy any solution for SSC in their cities, they need to consider interoperability, scalability, and sustainability among infrastructures and components.

3. Chapter Conclusion

Generally, the population in the world and the APEC region, in particular, is fast growing. They are moving from rural to urban areas, and this move leads to challenges

¹⁶ ITU. May 2015. *Setting the Framework for an ICT Architecture of a Smart Sustainable City*

and difficulties for both local and central governments. Building SSC is one of the critical solutions to resolve these problems, to enhance the life quality of cities' inhabitants, and to facilitate economic development. However, deploying smart cities is a very complicated process and requires utilizing different resources, applications and infrastructures. Thanks to the ICT advancement, central and local governments have been setting up policies and strategies, applying ICT technologies into urban governance, and promoting various smart constructions to meet the public needs. Structural components of SSC are actually modular and built based on the following ICT infrastructures:

- Internet backbone;
- Fixed broadband infrastructure (coaxial and optic fiber cable networks);
- Mobile communications infrastructure;
- Satellites broadband communications;
- Data and cloud computing facilities;
- Edge computing;
- Applications and services for citizens;
- Sensing devices such as sensors, RFID cards, and cameras to collect information.

Playing as a prerequisite condition to deploy SSC, ICT infrastructures should be capable of offering fast and reliable data services. In addition to actively fostering ICT infrastructures development, local and central governments are required to analyze and thoroughly understand their inhabitants' needs to introduce suitable services and create a comfortable living environment for the cities.

Chapter 2. ICT Infrastructures and Smart Sustainable City Deployment in the APEC Region

1. Policies and Regulations on ICT Infrastructures and Smart Sustainable City Deployment in the APEC Region

In July 2019, APEC Secretariat circulated a questionnaire to the APEC member economies in order to understand their ICT infrastructures, applicable policies, and regulations for SSC deployment. Data provided by 14 APEC member economies and further sharing among speakers and participants at the APEC Workshop held in Seoul in October 2019 as well as data collected from other sources draw out an overall picture of ICT infrastructures for SSC in APEC regions. The questions and feedbacks from 14 APEC member economies (Australia; Brunei Darussalam; China; Hong Kong, China; Indonesia; Japan; Mexico; Peru; Philippines; Singapore; Chinese Taipei; Thailand; the United States and Viet Nam) are briefed in the Annex of this report.

Answers from the APEC member economies show that over 70% of them enact strategy for ICT infrastructures and SSC development as below.

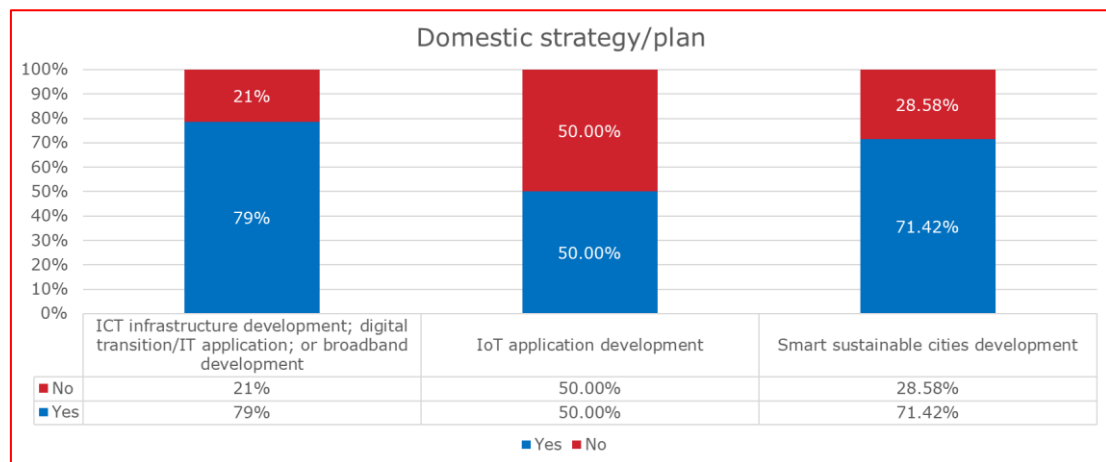


Figure 5. Policies on ICT infrastructures development for SSC

Source: Pham Thi Thanh Long, 2019

IoT system is being largely deployed in APEC cities, and its support to gather data ever easier. 50% of the APEC survey respondents release IoT technical

regulations and Key Performance Indicators (KPI) for SSC deployment and assessment as pointed out in Figure 6.

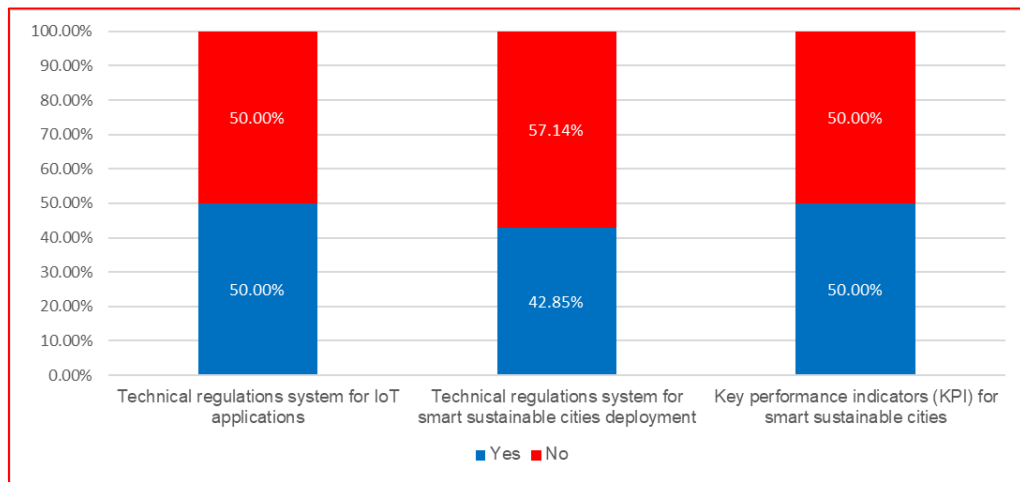


Figure 6. ICT governance for SSC

Source: Pham Thi Thanh Long, 2019

The Australian Government has committed to delivering high-speed broadband access to all Australian homes and businesses over the National Broadband Network (NBN). The Australian Government also specifically runs programs to attract co-investment in digital infrastructure in regional and remote areas. In 2016, the Smart Cities Plan was released by the Government, setting out the Government's vision for productive and livable cities that encourage innovation, support growth and create jobs¹⁷.

The Government of China publishes a strategy for ICT development and regulations and standards for IoT architectures. Those policies "aim to take a scientific and people-centric approach to develop Smart Cities in China."¹⁸ So far, China is in the phase of deploying Smart City 2.0 to enhance digitalization and solutions which focus on fields like healthcare, education, water, and energy. Together with promoting the collaboration of cross-regions and cross-ministries to resolve major problems in

¹⁷ Australian Government. December 2016. *Smart Cities Plan*

¹⁸ EU SME Centre. 2015. *Smart City in China*

the construction of new cities, China encourages to adopt new technologies such as IoT, 5G, cloud computing and big data in rolling-out ICT infrastructures.

Chile sets out a regulatory framework that considers ICT infrastructures as tools and platforms for building and managing cities to enable Chile becoming smarter and strengthening innovation and cooperation among regions.

In 2017, Hong Kong, China announced a strategy on Smart City development “to make people happier, healthier, smarter and more prosperous, and the city greener, cleaner, more livable, sustainable, resilient and competitive.”¹⁹ This strategy has, among others, set out the plan for the development of a number of ICT infrastructures such as electronic identity, Next Generation Government Cloud Infrastructure, Big Data Analytics Platform and 5G mobile networks. 5G would also be the catalyst for smart city development and the enabler of massive M2M communications for better IoT implementation.

To deploy SSC, Indonesia enacts Presidential Decree on broadband plan and E-government system. International technical standards are referred to when designing SSC. Smart mobility, smart energy, smart healthcare, and smart government are main and prioritized services to be offered. The Government of Indonesia is in the process of studying and formulating a suitable environment for 5G network.

Japan sets forth an ICT growth strategy in which Big Data and sensor networks are key technologies for creating new-value industries, improving and strengthening ICT infrastructures, and solving social problems. Japan also enhances collaboration among industries, academia, and the government to implement ICT projects, applications, and services. Projects related to data utilization, agriculture, broadcast, disaster prevention, and healthcare will be given priority in Japan.

¹⁹ Hong Kong, China. December 2017. *Smart City Blueprint for Hong Kong*

Korea is one of the first economies in the world deploying smart city projects. Since 2003, Korea has been announcing policies, plans, and strategic approaches to build ICT-based cities. In Korea, building SSC can be divided into stages from smart infrastructures and services development to innovation and creation of smart city ecology. In these stages, the central government is responsible for supporting local governments in terms of regulatory, financial and technical aspects. Public transportation, environment, and infrastructures are given priority to deploy in Korea. The central government plans to build more than 20 new smart towns throughout Korea. Integrating ICT infrastructures to cities' construction, the government constitutes policies that provide financial and practical support for incorporating ICT technologies in designing urban infrastructures, notably in designing transportation and safety/security ones. Financing these projects is being achieved by selling newly developed real estate to the private sector.

Malaysia identifies eight key aspects of Smart City, including smart governance, smart economy, smart energy, smart building, smart mobility, smart infrastructure, smart technology, smart healthcare, and smart people. Malaysia also announces policies to enhance digital infrastructures, to strengthen and expand broadband coverage; and to foster the provision of infrastructure facilities and services, skills, technology research and development for smart cities initiatives. Malaysia considers smart city development as a part of large-scale urban development projects in order to promote the dissemination of renewable energy and energy conservation. Further, advanced ICT technologies related to smart communities and smart grids are being applied to build new towns.

Peru releases a strategy for broadband development and Law No. 29904 for Promotion of Broadband and Construction of the Fiber Optic Back-bone Network. Though SSC in Peru is in an early stage, the Government of Peru identifies several

sectors to be smart, including transportation, safety, and security, culture and tourism, energy, environment, and governance.

The Philippines launched a strategy on ICT Ecosystem Framework in February 2019. This Framework outlines six strategies to develop ICT, those are participatory e-Governance, industry and domestic-wide development, ICT user protection and information security, improved public links and connectivity, resource sharing and capacity building throughout ICT and finally, enabling sustainable ICT environment. The Philippines also releases a broadband plan to promote the deployment of fiber optic cables, enhance mobile coverage and improve Internet speed.

In 2011, Papua New Guinea stated a vision called "Papua New Guinea Vision 2050", in which the Government of Papua New Guinea sets the overall direction to attain the dream to be a smart and healthy society by 2050. However, there is no specific regulation regarding the smart city in Papua New Guinea.

In Russia, the program "Digital Economy of the Russian Federation" is approved by the Government of the Russian Federation with the aim of creating favorable conditions to develop a knowledge society in Russia. The Program focuses on "improving the well-being and quality of life of its citizens by increasing the availability and quality of goods and services produced in the digital economy using modern digital technologies, raising awareness and digital literacy, improving the accessibility and quality of public services for the citizens, as well as their security."²⁰

Singapore's Smart Nation initiative was launched in 2014 and it drives the pervasive adoption of digital and smart technologies throughout Singapore. Singapore envisions a leading economy powered by digital innovation, and a world-class city with a Government that gives its citizens the best home possible and responds to their

²⁰ Batunova Elena, Trukhachev Sergey. April 2019. *CRISALIDE: Searching for Smart Solutions in Urban Development Beyond the Political Slogans: a Case of Rostov-on-Don, Southern Russia*

different and changing need. At the broadest level, the economy is the biggest domain driving Singapore's growth and competitiveness. It is supported by the Government, which is leaning forward to catalyze growth and innovation across all domains, including the public sector. Crucially, these efforts are underpinned by efforts to ensure that all segments of society are able to harness digital technologies and benefit from them

Chinese Taipei promotes the Digital and Innovative Economic Development Program (DIGI+) 2017-2025. In this Program, Chinese Taipei:

- Encourages strong partnership between public and private sectors in constructing smart cities;
- Develops people-oriented innovative life application and public services, enhances cooperation among academic/research institutes and SMEs;
- Strengthens the regional innovation ecosystem;
- Promotes the development of industries related to smart cities;
- Applies IoT in creating high-quality living spaces for the economy²¹.

Thailand has already endorsed the plan, vision, and strategy to promote the digital economy to reduce social inequitable development in all areas. Thailand identifies 6 tools for SSC development, which are digital startup investment, digital transformation, manpower, Research and Development, digital awareness, community transformation, and digital infrastructures fund. Thailand also releases regulations for any city that wants to become a smart city as well as KPIs to indicate level of smartness. Regarding ICT infrastructures for SSC, Thailand ratifies a strategy for developing soft and hard ICT infrastructures that offer incentives for investors who plan to develop ICT infrastructures for SSC deployment. Consequently, Government Data Center and Cloud Service, Government Open Data Platform, the network of smart

²¹ DIGI+ Taiwan. Available at <https://www.digi.ey.gov.tw>

poles and sensors have been constructing in recent years. Further, Thailand allows mobile operators to use unlicensed bands for IoT, NB-IoT applications and offers preferential tax policy to digital applications providers.

The United States works closely with industry stakeholders and partners to boost ICT infrastructures and develop broadband networks. The smart cities and communities' effort in the United States focuses on four effective approaches:

- Promote fundamental R&D and transition innovations to practice for smart cities/communities;
- Facilitate local efforts for secure and resilient infrastructure, systems, and services for smart cities/communities;
- Enable smart cities/communities advances through data and knowledge sharing, best practices, and collaboration; and
- Enable evaluation of progress and long-term growth of smart cities/communities.

In Viet Nam, several policies and guidelines for SSC implementation are approved by the Cabinet, relevant ministries and local governments. Those documentations recognize that ICT infrastructures development is a key to enhance and boost the economy. ICT infrastructures, include data interoperability, security, IoT and 5G network, are strongly promoted by the government to foster SSC implementation in urban areas.

2. ICT Infrastructures in the APEC Region

ICT infrastructures include all devices, networks, protocols, and procedures that are employed in telecommunications or information technology fields. ICT infrastructures are crucial for offering various digital solutions for deploying smart cities.

The APEC region has millions of optical cable networks kilometers and large mobile communications coverage. Those infrastructures strongly support

telecommunications operators and services providers in delivering high-speed Internet access to all customers and create favorable conditions for SSC deployment. ITU statistical data showed that most of the APEC member economies had fixed broadband penetration lower than 40 lines per 100 inhabitants (see in Figure 7).

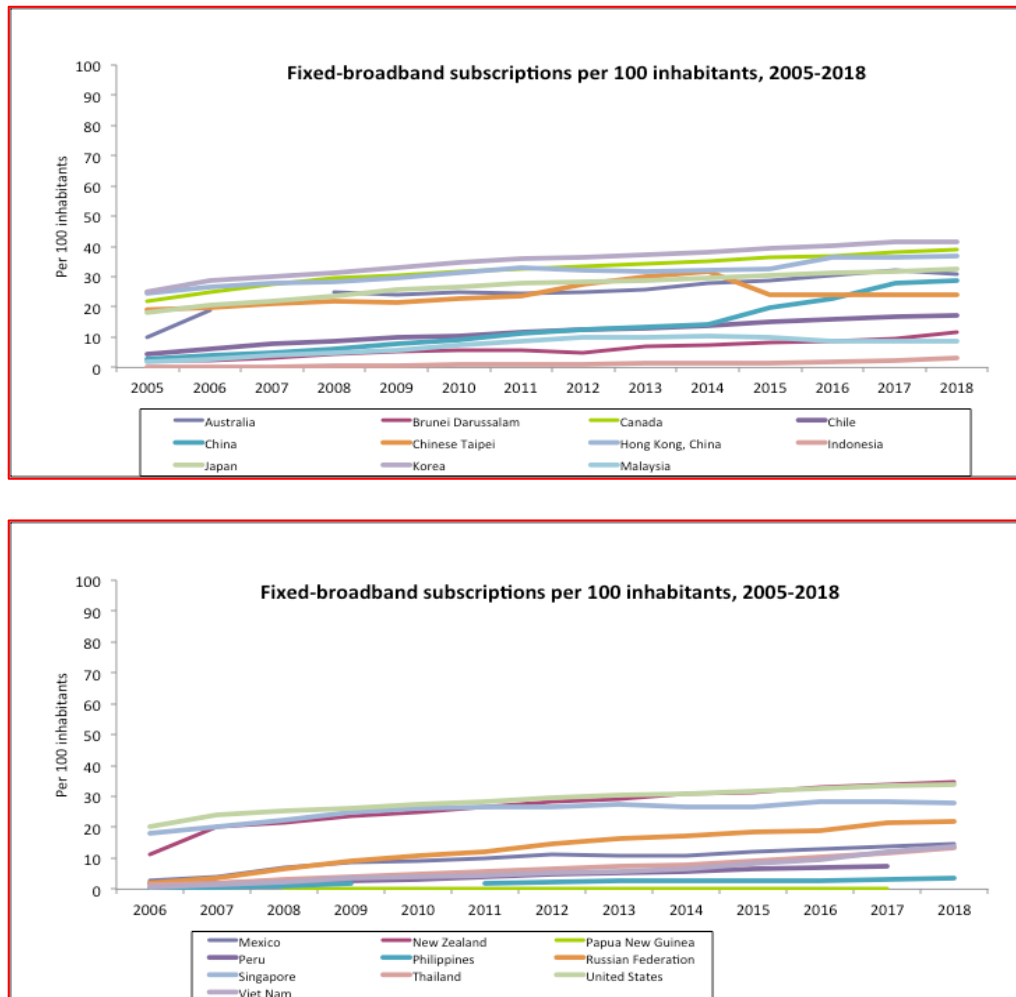


Figure 7. Fixed broadband penetration in the APEC member economies

Source: author computed based on data collected from ITU's database²²

Wireless access technologies have been rapidly advancing in recent decades and provide high-speed Internet access to end-users with more flexibility than cable network technologies. Consequently, customers increased prefer to subscriptions with mobile operators than over with fixed network providers, and customers in the APEC region are not exceptional as shown in Figure 7 and Figure 9. Almost all APEC

²² ITU. 2019. *Statistic*. Available at <https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx>

economies have excellent mobile broadband coverage and approximately 100% of cities are being served by 3G and 4G networks, see in Figure 8²³. Those mobile infrastructures afford to satisfy the needs of data-hungry users, who increasingly use high-speed Internet access through 3G and 4G networks.

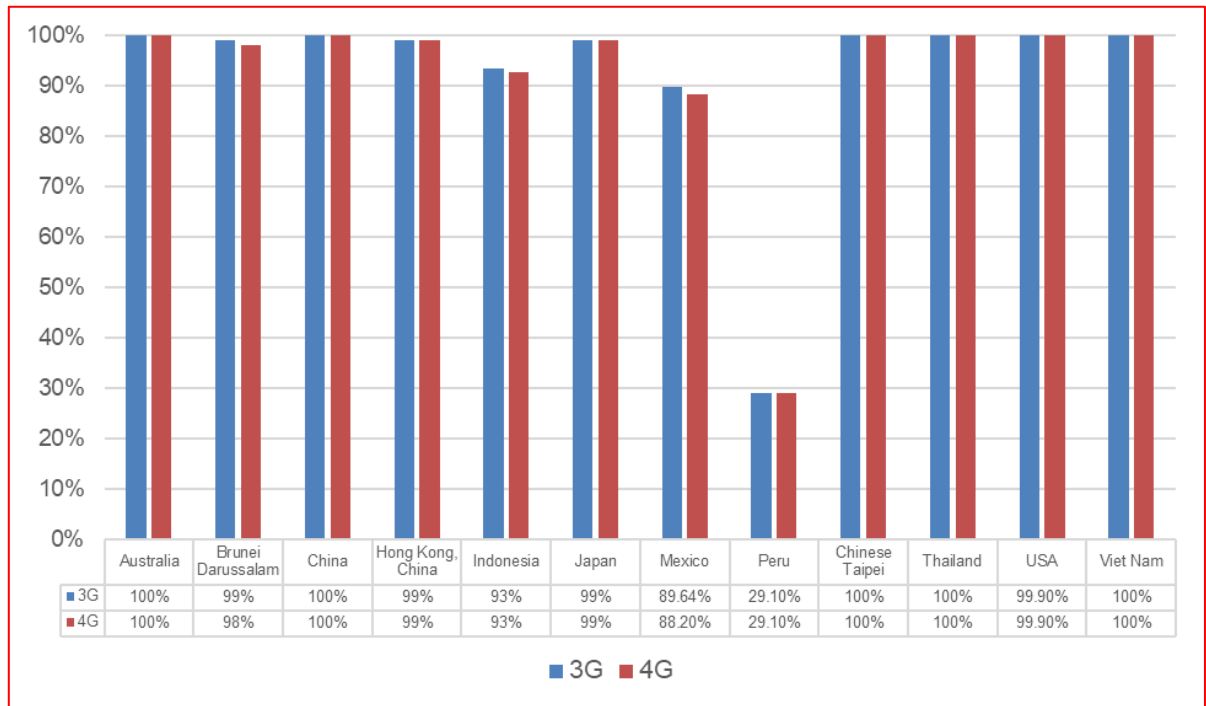


Figure 8. Coverage of 3G and 4G networks in the APEC region

Source: Pham Thi Thanh Long, 2019

In the last ten years, mobile subscriptions in the APEC region grew fastest in the world as shown in Figure 9. Particularly, mobile broadband penetrations in almost APEC economies such as Hong Kong, China; Japan; Singapore; Chinese Taipei; Thailand; Viet Nam and the United States are all above 100 subscriptions per 100 inhabitants. This is one of the advance conditions for deploying and popularizing smart services in APEC cities.

²³ Pham Thi Thanh Long. October 2019. *Building up Smart and Sustainable Cities*

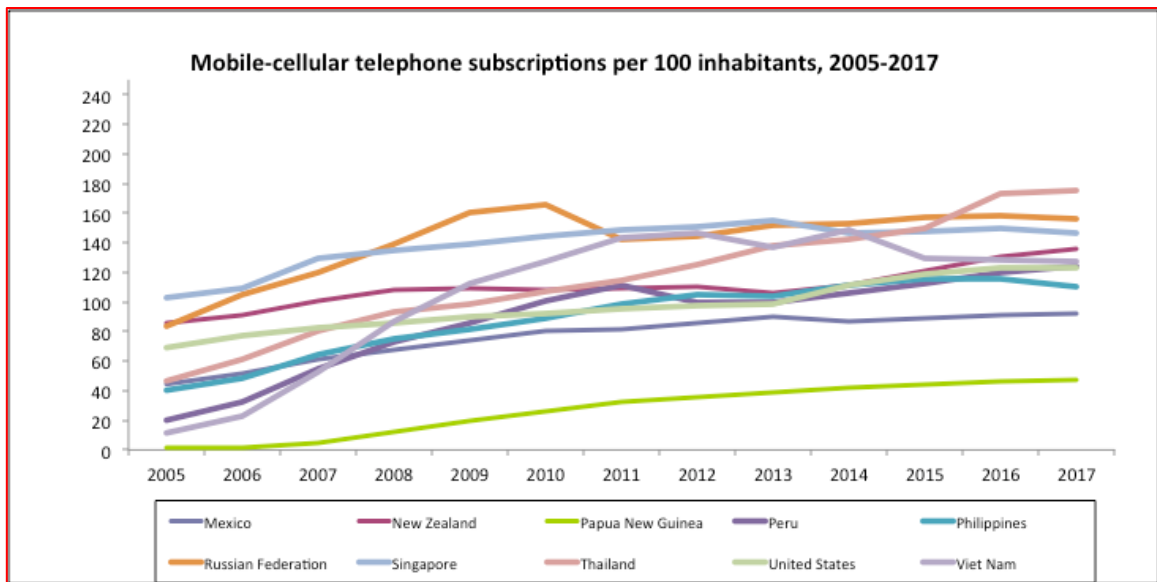
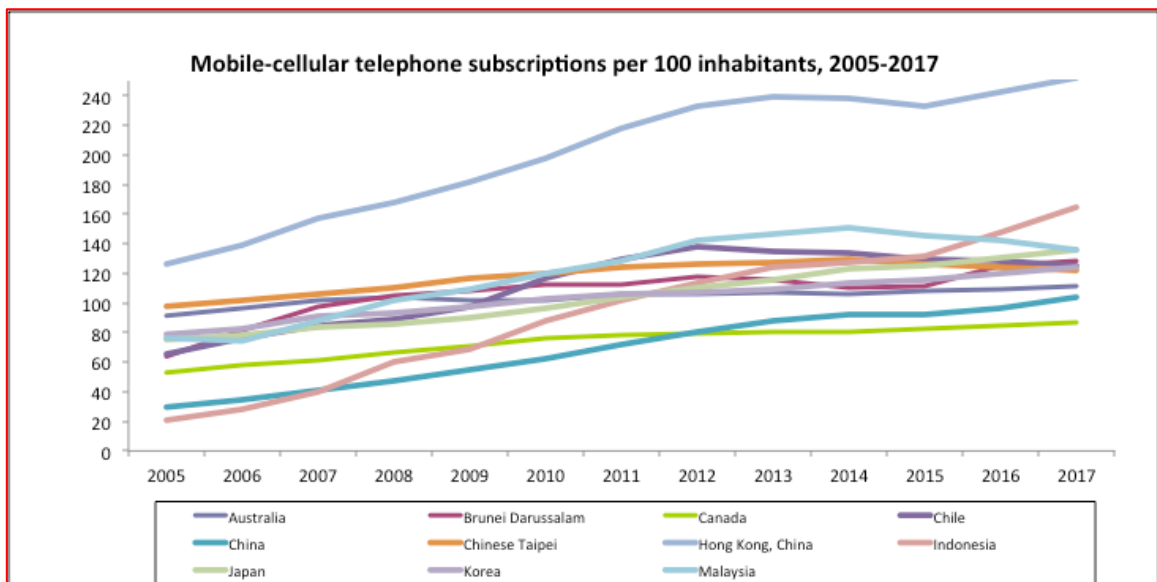


Figure 9. Mobile penetration in the APEC member economies

Source: author computed based on data collected from ITU's database²⁴

ITU data shows that from 2005 to 2017, individuals using the Internet in the APEC region have dramatically increased, see in Figure 10. It evidences both the efforts of telecommunications sectors in improving the quality of telecommunications infrastructure to attract end - users.

²⁴ ITU.2019. *Statistic*. Available at <https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx>

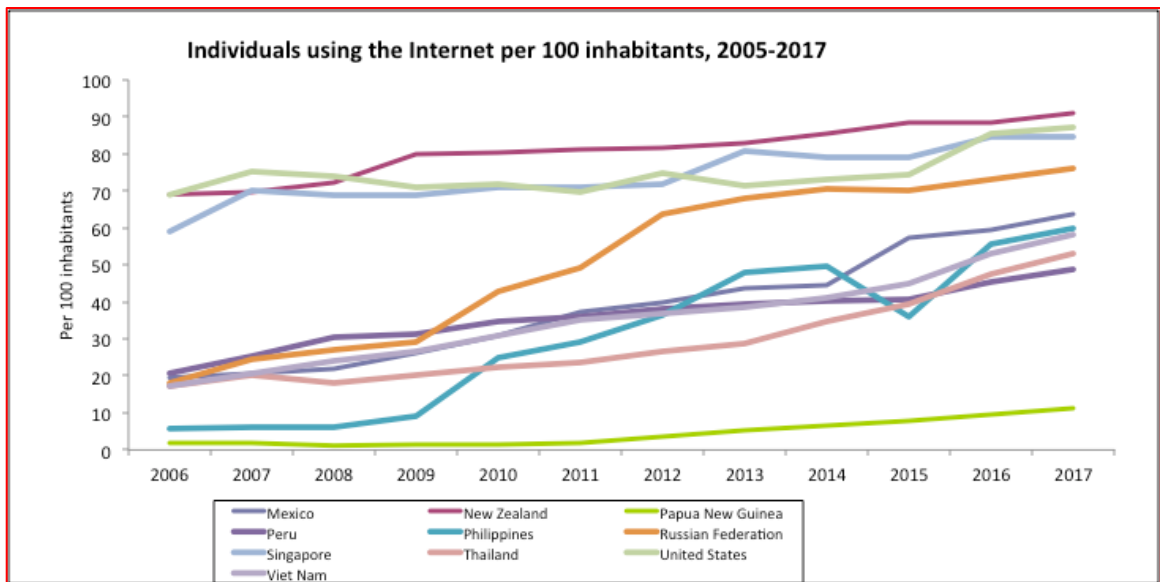
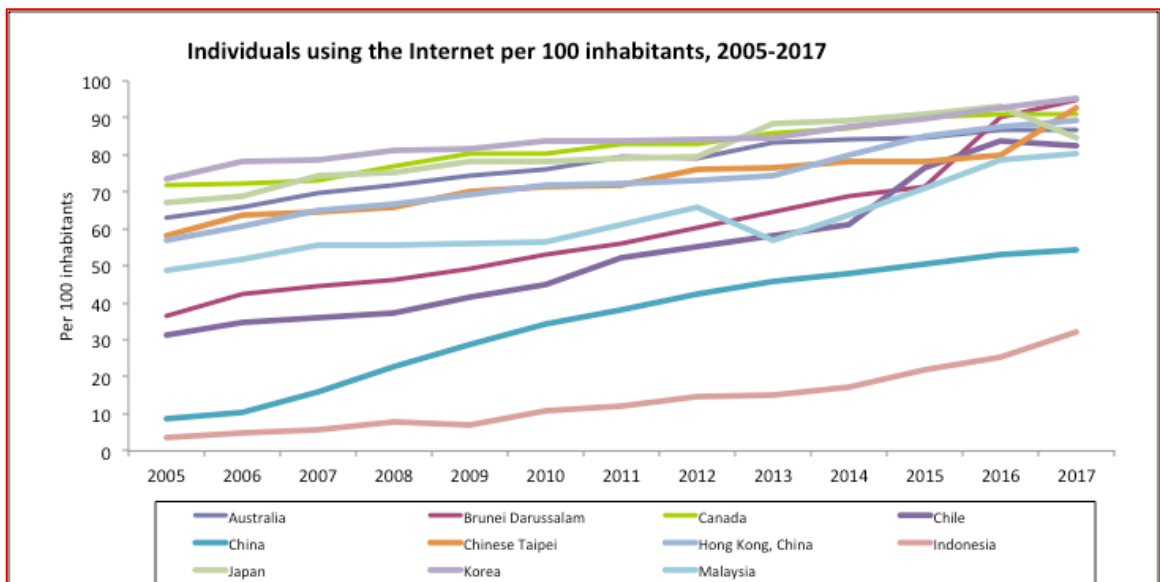


Figure 10. Individuals using the Internet in the APEC region

Source: author computed based on data collected from ITU's database²⁵

Almost all APEC economies have plans to develop 5G networks, particularly China, Japan, Korea, Singapore²⁶, Chinese Taipei, and the United States have been already commercializing 5G services. The 5G mobile networks which offer high-speed Internet access with low latency will enable people to make full use and obtain full

²⁵ ITU.2019. *Statistic*. Available at <https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx>

²⁶ Singapore, through the Infocomm Media Development Authority of Singapore (IMDA), launched a public consultation in May 2019 to seek views from the industry and public on the appropriate regulatory framework and policies for 5G. Following the consultation, Mobile Network Operators (MNO) were invited to participate in a Call for Proposal in October 2019, and the result is expected to be announced in mid-2020.

benefits of new technologies such as Artificial Intelligence (AI), cloud computing, M2M and data analytics in SSC.

3. Deployment of Smart Sustainable City in the APEC Region

Generally, cities want to improve the quality of life for their residents and build sustainable and resilient cities. In order to realize such objectives, governments establish a legal and strategic framework to facilitate SSC deployment, and subsequently the delivery of smart services for residents such as smart mobile, smart energy, smart healthcare, smart government, and smart living is offered by both public and private sectors, see Figure 11. In these processes, governments “should look for ways to partner with universities, non-profits, and the private sector”²⁷.

Smart mobility is services and applications provided by the transportation system of a city such as traffic information service, traffic telematics or traffic emergency processing. Cameras and sensors are being used to gather all the sensed information related to traffic and roads to enhance smoother transportation and reduce accident rates. It also supports local governments in optimizing current infrastructures.

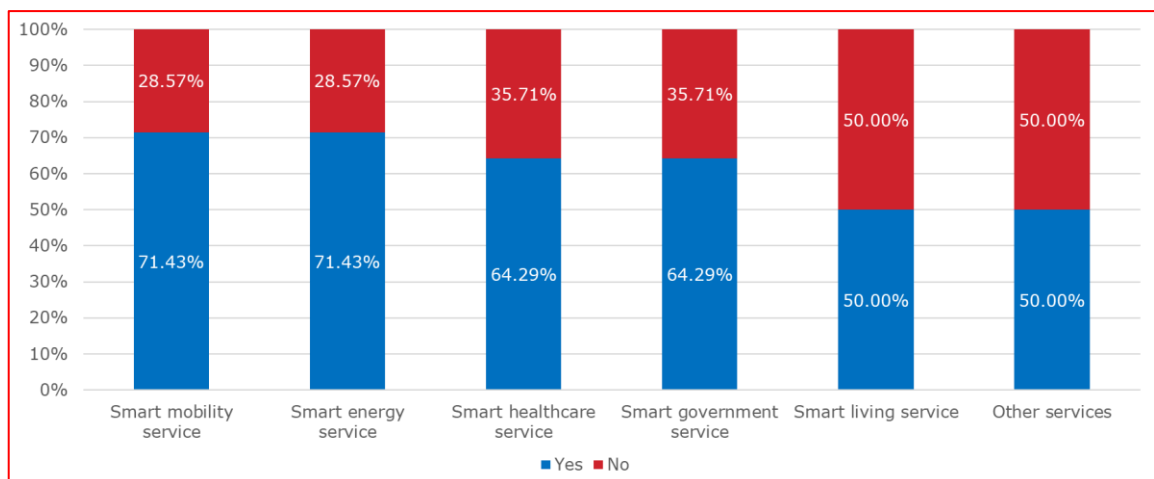


Figure 11. Smart services in the APEC region

Source: Pham Thi Thanh Long, 2019

²⁷ The National League of Cities, 2016. *Trends in Smart City Development*. Available at <https://www.nlc.org/sites/default/files/2017-01/Trends%20in%20Smart%20City%20Development.pdf>

Smart government services are being deployed in over 60% of the APEC survey respondents, which offer transparent and sharing information and exchange data to improve public services to residents.

Smart energy services, include smart power and smart lighting services, are also being applied in 70% of the APEC survey respondents to save energy.

Smart healthcare service is becoming popular in the world and brings many benefits to inhabitants. New technologies are being deployed to monitor and store medical reports of patients and elders. Doctors could refer to this stored information to predict and treat diseases more quickly and efficiently. Feedback from 14 APEC economies shows that over 60% of them are deploying smart healthcare services.

Further, feedback from those economies points out that over 50% of them are providing smart living services. Other smart services, such as smart escape, smart waste management, smart environment monitoring, and tourism or smart utilities are all in progress to be deployed.

4. Difficulties and Challenges

Many APEC member economies have excellent ICT infrastructures and applicable policies and regulations to facilitate SSC deployment, however, they are still facing difficulties and challenges in building SCC, see in Figure 12.

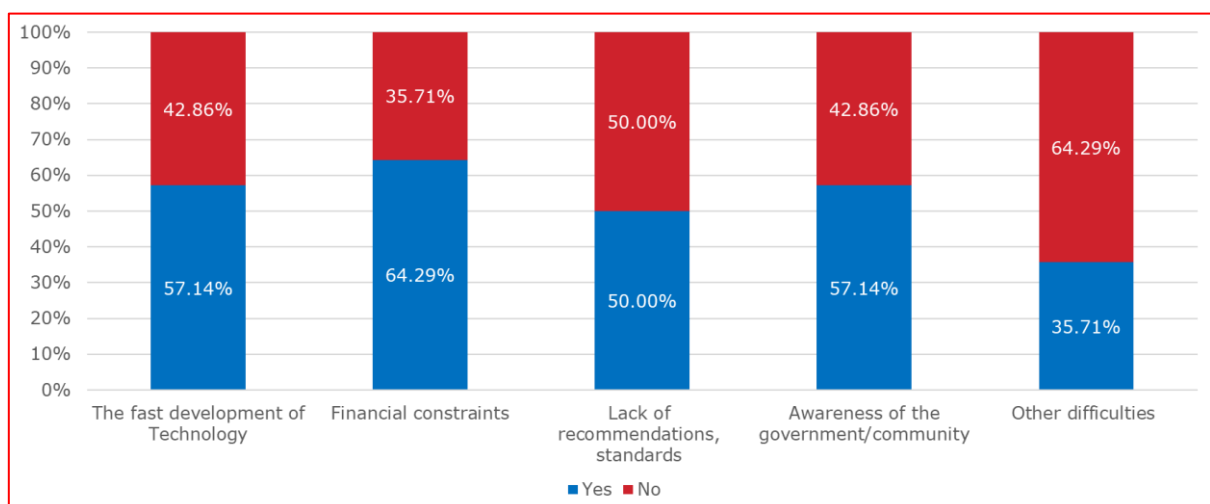


Figure 12. Challenges to developing ICT infrastructures for SSC

Source: Pham Thi Thanh Long, 2019

First, fast technology development leads to a lack of interoperability, backward compatibility, and cybersecurity; over 50% of the survey economies are facing this challenge. Existing infrastructures, existing local rules, and regulations also limit or create constraints to SSC deployment in terms of interoperability.

Second, financial constraints are a key factor affecting the success of SSC deployment, and financial stability is one of the prerequisite conditions in building SSC; over 60% of the APEC respondent economies are facing the financial obstacle. Various financial models are being proposed and applied to mobilize different sources for investing in SSC, such as Public-Private Partnership (PPP) or Private Finance Initiative (PFI), which being used in Chinese Taipei.

Third, lack of applicable recommendations and international standards are also a challenge faced by over 50% of the survey respondents. The smart city is very complicated, engages various cities' infrastructures, services and types of management as well as organization structures so that all components must work well together, and standards are key for interoperability and interaction.

Last but not least, government/community awareness is also a challenge for SSC deployment in the APEC region, including addressing privacy and security concerns of residents. Active participation and engagement of residents into innovative services are pivotal for the success of any SSC initiative. Several APEC economies are facing, *inter alia*, following challenges when building SSC:

- Lack of sustainable business policies, strategies, and plans;
- Lack of adequate stakeholders' participation;
- High product costs;
- Limited human resources;

- Limited funding;
- Limited methods for interdisciplinary planning;
- Limited plans for cybersecurity, privacy and community engagement.

ICT infrastructures are one of the key components in building a sustainable smart city. The APEC economies identify that interoperability, scalability, shareability, measurability, and cybersecurity are critical factors for ICT infrastructures development for SSC, see Figure 13.

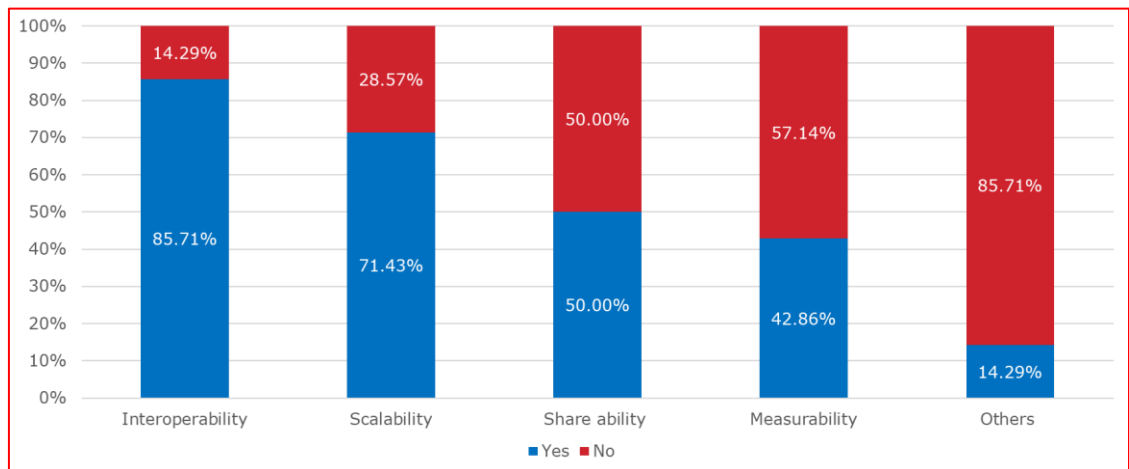


Figure 13. ICT infrastructures development for SSC - Critical factors

Source: Pham Thi Thanh Long, 2019

5. Chapter Conclusion

Smart city comprises of many components, different infrastructures, services, and organizational structures; it employs several technologies to manage different aspects of a city. However, ICT infrastructures play a crucial role in any economy and offer many digital solutions for deploying SSC. The APEC region has well-established ICT infrastructures with millions of fiber cable network kilometers, excellent wireless coverage and availability of international bandwidth capacity on a large scale. Especially, several APEC economies such as China; Japan; Korea; Singapore; Chinese Taipei and the United States have started the considerations or already commercializing 5G services, which provide high-speed Internet access with low delay

for people and machines. Together with the available IPv6 addresses and smartphones, the APEC region primarily has a good technical basis for SSC deployment.

Feedbacks from the APEC member economies show that not all APEC economies have strategy/plan for ICT infrastructure development, digital transition/IT application or broadband development; however, the APEC region is basically ready to deploy SSC and facilitate ICT infrastructures. Expanding fiber optic cables, enhancing mobile coverage and other wireless technologies, as well as improving Internet speed are being carried out by almost all APEC economies. Policies and strategies released by the region economies consider ICT infrastructures as key and platforms for building and managing smart cities.

However, the region is facing several challenges and difficulties in upgrading and expanding ICT infrastructures, which include full availability of relevant policies, regulations, cybersecurity measures, frameworks, best practices, relevant international standards, financial resources, and public awareness.

Chapter 3. ICT Standards for Sustainable Smart Cities

The role of standards to SSC is undeniable, particularly when SSC is built based on ICT infrastructures. This chapter reviews the current situation of standardization for smart cities in the APEC region.

1. Overview

Standards and relevant guidance describe exactly what things to be done, what conditions to be complied with, and which progresses to be followed, so that products, services, and processes can be fully utilized as they are initially designed. Standards can provide the following benefits to smart cities:

- Enable interoperability among systems;
- Enable integration among physical and digital components;
- Underpin common understandings;
- Attract investments/funding from stakeholders;
- Help to prevent vendor lock-in;
- Enable scaling and replicability.

2. Standardization in the APEC Region

2.1 Australia and New Zealand

The Smart Cities Council in Australia and New Zealand is a member of the International Smart Cities Council and comprises of policy makers, technology developers, and companies related to smart cities development. The Council recommends frameworks and standards for creating a culture in this industry.

The Council releases Best Practice Guides on smart cities standards²⁸, which include a list of standards and basic frameworks for developing smart cities in several

²⁸ Australia New Zealand – Smart Cities Council. July 2017. *Smart Cities Guidance Note – Smart Cities Standards*. Available at https://anz.smartcitiescouncil.com/system/tdf/anz_smartcitiescouncil_com/public_resources/SCCANZ%20Smart%20Cities%20Standards%20Guidance%20Note_ISSUE.pdf?file=1&type=node&id=5297&force=

principle categories such as information modeling, IoT, sustainable community, framework and process standards for smart cities.

The following references of smart cities standards identify a core group of standards that are considered potentially relevant to Australia and New Zealand:

- Strategic-level standards: a guide to city leadership on the process of developing a clear and effective overall smart city strategy, identifying priorities, and developing a practical implementation roadmap and an effective approach to monitor and evaluate all progress²⁹.

- Process-level standards: cover best practices in procuring and managing cross-organizational and cross-sectorial smart city projects include guidance on combining appropriate financing packages.

- Technical specifications: define practical requirements for products and services to ensure that they can achieve objectives set forth by the governments.

These standards are categorized as follows:

- Strategic-level standards: ISO 37120: 2014, ISO 37101: 1:2016, ISO 37102:2016, ISO/TR 37121:2017, ISO/TR 37152, ISO/TR 37150, ISO/IEC 30182:2017, PAS 180:2014, PD 8100, PD 8101, BS 8904: 2011, NDRC (Guidance on how to best promote “Healthy development of Smart Cities”, China).

- Process-level standards: ISO 14001, ISO 20121, ISO 50001, ISO 27001, ISO 16739, PAS 181:2014, PAS 182:2014, PAS 183:2017, PAS 184:2017.

- Technical specifications: ISO 15686, ISO 16745-1:2017, ISO 16745-2:2017, IEEE Standard 1686, IEEE Standard 1547.3, ISO 2948-1-1:2016, ISO/TS 12911:2012, ISO 16739:2013, ISO/TS 8000-1:2011, ISO 8000-8:2015, ISO/TS 8000-150:2011, PAS 1192-3:2014, BS 1192-4:2014, PAS 1192-5:2015, BS 8536-1:2015, BS 8536-2:2016, PAS 212:2016, BS 1192:2007 + A2:2016, PAS 1192-2:2013, UNE 178303

²⁹ Rodger Lea. December 2017. *Smart City Standards: An Overview*

(Requirements of proper city asset management -addressed to any local entities, Spain), TR38 and TR40 (Sensor network standards for public areas and homes, Singapore), TR47 and TR 50 (IoT reference architecture, and information & services interoperability, Singapore), Green Star (Performance-based rating tool guiding the planning, design, construction, and operation of buildings and communities, Australia/New Zealand/South Africa), IPWEA Model Specification for LED Public Lighting and Control Systems (Australia).

- The Smart Cities Council is a strong advocate for smart city standards and effectively contributes to building a thriving and influential marketplace for SSC. One of the key goals of the Smart Cities Council is to build a culture within the industry to embrace the value of standards and to support their advancement. This guidance is the first step in achieving the Council outcomes by providing information to support awareness building and capacity to act. The Council continues to research and study smart city standards, advocates and engages SSC in development, testing, and refinement activities.

2.2 China

In 2014, China established a Working Group on Standardization, Coordination, and Promotion of Smart Cities, comprised of representatives from 26 ministries and agencies. In 2016, after about two years of research, three Chinese domestic agencies released a set of criteria for assessing smart cities applied in the whole economy (GB/T 33356-2016). China also actively participates in the smart city field in all three of the largest international standards organizations (International Standardization Organization - ISO, International Electrotechnical Commission - IEC and ITU).

Standard Framework for Smart Cities issued by the Working Group includes seven categories of standards, those are general standards, and standards on support

technology and platform, infrastructures, construction, and living environment, management and services, production and economy, security and safety.

The framework also defines a master plan for the standardization of smart city development in China.

- General standards comprise of general regulations, framework, and foundation of smart cities. General standards are divided into four following standard groups: terms and definitions, reference models, models and criteria for evaluation of smart cities, and instructions for applying standards. All other standards (as below) must be built based on general standards.

- Support technology and platform standards: this is a common name for standards for software, common platforms and key technologies for smart cities. Support technology and platform standards include 10 standard groups: connectivity all things, network communications, computing and storage, models in data integration, service integration, business process collaboration, support platforms for public applications, operation center, and infrastructures.

- Infrastructures standards are those related to supporting and ensuring infrastructures for the process of development and operation smart cities. Infrastructure standards comprise five standard groups on ICT infrastructures, water source infrastructures, energy infrastructures, transportation infrastructures, and environmental protection infrastructures.

- Construction and living environment standards are comprised of four standard groups for planning and design, implementation management, operation management, and living environment.

- Management and services standards are the ones to ensure smooth operation, methods of evaluation, supervision and acceptance processes during the construction and operation of smart cities systems. This category comprises 21

standard groups for electronic administration, market surveillance, public safety, emergency management, territory management, demographic management, regional management, real estate management, transportation services, energy services, logistics services, education services, cultural services, healthcare services, employment services, social insurance services, nursing services, housing insurance services, travel services, financial services, and e-commerce.

- Production and economy standards include standards and codes of practice for production planning, upgrading and developing processes in smart cities. These are classified into three standard groups for production planning, upgrading, and developing new production industries.

- Security and safety standards are standards and codes of practice on data information security, management of key/important systems in the process of development of smart city systems. This category includes six standard groups for data security, system security, information security management, security precaution, product and technology testing evaluation, and system testing evaluation.

Based on the Standards Framework for Smart City, China publishes standards in the form of voluntary/mandatory standards, some of them are in the process of drafting or to be published. Standards that are applying to develop smart cities in China include:

- GB/T 33356-2016: Evaluation indicators for new-type smart cities;
- GB/T 34678-2017: Smart city - Technical reference model;
- GB/T 35775-2017: Spatiotemporal infrastructure for smart city - evaluation indicator system;
- GB/T 35776-2017: Spatiotemporal infrastructure for smart city - Basic specifications;

- GB/T 36332-2018: Smart city - Domain knowledge model - Core conceptual model;
- GB/T 36333-2018: Smart city - Top-level design guide;
- GB/T 36334-2018: Smart city - Specification for software service budget management;
- GB/T 36445-2018: Smart city - Application guide of SOA standard;
- GB/T 36620-2018: Internet of things (IoT) based technical application guide for smart city;
- GB/T 36621-2018: Smart city - Guide for information technology operation;
- GB/T 36622.1-2018: Smart city - Support platform for public information and services - Part 1: General requirements;
- GB/T 36622.2-2018: Smart city - Support platform for public information and services - Part 2: Directory management and service requirements;
- GB/T 36622.3-2018: Smart city - Support platform for public information and services - Part 3: Test requirements;
- GB/T 36625.1-2018: Smart city - Data fusion - Part 1: Conceptual model;
- GB/T 36625.2-2018: Smart city - Data fusion - Part 2: Specification of data encoding;
- GB/T 36625.5-2019: Smart city - Data fusion - Part 5: Data elements of basic municipal facilities;
- GB/T 37043-2018: Smart city - Terminology;
- GB/T 37971-2019: Information security technology - Framework of smart city security system.

2.3 Japan

Society 5.0 is a plan of Japan towards 17 sustainable development goals in all areas of its social life. Society 5.0 defines that standards are one of the main works for

achieving Society 5.0 in order to share the use, integration, interconnection of systems and to ensure investment efficiency. Main categories and key standardized objects for smart city management and digital transformation in Japan include:

- From the perspective of investors: considering geopolitical aspects and financial management factors;
- From intellectual property/digital content viewpoint: copyright, invention, technology transfer, and protection of personal information;
- From the solutions/services viewpoint: network security, service security, and personal information protection issues;
- From communication/networking viewpoint: Internet management issues, network neutrality, domain names, digital repositories, and collaboration;
- From the production of equipment viewpoint: taxation, import, and export policies.

Regarding KPI for smart city evaluation, Japan actively participates in smart city standards of ISO/IEC activities. Further, Japan is supporting several other regional economies in developing and implementing their KPIs (such as Viet Nam).

2.4 Korea

In 2018, Korea announced a Smart City Strategy under the leadership of a special sub-committee of the Presidential Committee on the Fourth Industrial Revolution to develop innovative future cities with key goals toward citizen-centric, sustainable development, creativity, people engagement, and hyper-connectivity. The Strategy describes:

- Differentiated approaches to urbanization maturity;
- Customization to improve values of cities and quality of life;
- Public-Private-People Partnership;

- Standards developed/adopted for domestic smart cities are recommended to comply with global standards (e.g. ISO, IEC, ITU...).

2.5 Singapore

Open Data sharing is one of the priority areas for Singapore's Smart Nation vision. By releasing data, the Singapore government aims to unlock economic value, enable quality research and deepen public participation and engagement. In 2011, Data.gov.sg was first launched as a free and open data portal where anyone can access datasets on Singapore, ranging from education, environment and health to transport. The new Data.gov.sg – launched in 2015 – aims to go beyond being a data repository. Through the active use of data visualization and data-driven blog posts, the new portal aims to make government data relevant and understandable to the public.

Standards and guides will also play an integral role in laying the foundation for a Smart Nation empowered by IoT, big data, analytics technology and sensor networks. For cyber-physical systems, Singapore has published various types of standards:

- Sensor network standards – ensure that the data collected from various monitoring devices across locations can be effectively transmitted, integrated and analyzed real-time (Two sensor network standards: TR38 for public areas and TR40 for homes);

- IoT foundational standards – provide a common set of guidelines on IoT requirements and architecture, information and service interoperability, and data protection;

- Domain specific standards – guide industry in developing new smart solutions to improve healthcare, mobility, and urban living, while ensuring user safety.

In relation to cybersecurity, Singapore has developed cybersecurity standards and guides to help the industry and home owners to better secure their IoT networks.

As Residential Gateways, which are commonly known as home routers, are often the first entry point from the Internet to residents' home networks, it is important to ensure that such devices come with baseline security. Hence, Singapore intends to specify minimum security requirements and stronger credentials for Residential Gateways that are sold and used in Singapore. In addition, Singapore has also launched an IoT Cybersecurity Guide, which provides practical steps to help enterprise users and their vendors address the cybersecurity aspect of IoT systems, when acquisitioning, developing, operating and maintaining such systems.

Singapore also actively participates in smart cities related meetings with international standardization bodies such as ISO/IEC and ITU, and complies with the international standards/recommendations.

2.6 Chinese Taipei

Chinese Taipei defines key factors for the successes of smart city development are government, know-how integration and advanced standards; and the key solution for SSC development is international standardization for different system integration problems.

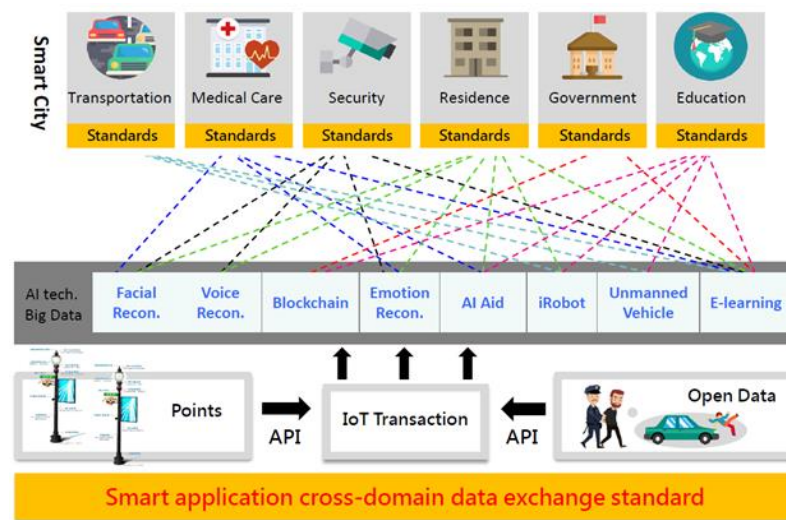


Figure 14. Smart application cross-domain data exchange standard

Source: Chiu Sammy.

Smart cities need data exchange standards for providing a common data exchange platform for manufacturers and operators of IoT hardware and software, and for supporting sensors of various smart cities to collect and analyze data in real-time. Data standardization which automatically generates chart analysis and integrates IoT services is also a prerequisite condition for SSC development.

2.7 The United States

The US Government's role in the development and use of standards and conformity assessment is guided by the National Technology Transfer and Advancement Act (NTTAA in short), OMB Circular A-119, and other federal laws, regulations, and international agreements.

The NTTAA directs Federal agencies to adopt voluntary consensus standards wherever possible (avoiding development of unique government standards) and establishes reporting requirements. Roles of the National Institute of Standards and Technology (NIST), part of the U.S. Department of Commerce, have the following objectives:

- Guide government agencies in conducting and reporting on standards and conformity assessment activities;
- Promote the use of standards developed by non-government organizations.
- Coordinate with Federal, state, and local agencies to foster greater reliance on voluntary consensus standards;
- Work through the Interagency Committee on Standards Policy (ICSP) to foster this reliance.

OMB Circular A-119, revised by the Office of Management and Budget (OMB) in January 2016, spells out the government strategy for standards development. It promotes agency participation on standards bodies, specifies reporting requirements

on conformity assessment activities, and informs agencies of their statutory obligations related to standards setting.

2.8 Viet Nam

In Viet Nam, the Master Plan for developing SSC in Viet Nam in the period 2018-2025 defines main tasks for developing a smart, sustainable city. The Strategy sets forth following standardization-related tasks:

- Setting-up plan to develop a standard system for SSC, reviewing and amending standards and technical regulations on planning, construction, and technical infrastructures;

- Developing and implementing ICT reference framework for smart cities and KPIs for smart cities in Viet Nam;

- Developing standards and technical regulations on communication and information exchange in smart cities.

The Ministry of Science and Technology, who is responsible for issuing standards, is drafting a set of standards based on ISO 37xxx family; and already issued ISO 37101:2018 “Sustainable development in communities - Management system for sustainable development - Requirements with guidance for use”; TCVN 37120:2018 “Sustainable Cities And Communities - Indicators For City Services And Quality Of Life”; and TCVN ISO TR 37121:2018 “Sustainable development in communities - Inventory of existing guidelines and approaches on sustainable development and resilience in cities”.

The Ministry of Information and Communications releases a Guidance for ICT applications for developing smart cities in Viet Nam (January 2018); ICT Reference Framework for smart cities (June 2019); and KPIs for smart cities in Viet Nam toward 2025 (September 2019).

3. Chapter Conclusion

Standards and best practices support all stakeholders, experts and especially city leaders to maximize benefits of smart approaches for cities' residents in all stages of SSC development. Main categories of technical standards, in terms of technologies, are as follows:

- Security and privacy, which covers security and privacy topics;
- IoT architecture that defines integrated/completed IoT specification solutions, including architecture descriptions;
- Applications dedicate to support applications lifecycle, include development tools/models, deployment and management; analytics, an application supporting tools and application domain-specific activities;
- Integration/interoperability contains the specification of common IoT features required to provide integration and interoperability;
- Infrastructures:
 - + Cover aspects related to the design, deployment, and management of computational platforms tailored to support IoT- based applications, attending requirements such as large-scale deployments, multi-tenant Wireless Sensor Network (WSN), “distributed computation and storage, and resource self-adaptation, among others”³⁰;
 - + Include topics such as software-defined networks, cloud computing, Mobile Edge Computing (MEC), and fog computing;
 - + Consider best practices and points-of-view of stakeholders such as infrastructures service providers (e.g. network operators) and application service providers who use these infrastructures;
 - + Contain management associated with infrastructures level.

³⁰ ETSI. December 2015. *SmartM2M IoT Standards Landscape and Future Evolution*

- Communication and Connectivity mainly cover “the specification of communication protocol layers, including PHY, MAC, NWK, Transport, Application layer, and their types, e.g., Wireless/Radio and Wireline”³¹.

- Devices and sensor technology comprise device/sensor lifecycles, including operating systems, platforms, configuration management, sensor/actuators virtualization...

To conclude, it can be briefed:

- There is no single standardization body can provide all answers for SSC standardization, so it needs to review works of all credible standardization bodies;

- Focus on standards and best practices can support to develop platforms at all different stages of SSC deployment. Local governments should work together to identify key platforms which need to be defined and standardization organizations should work together and with communities and industry to develop open, consensus-based, technology-neutral standards that meet smart city needs;

- Each economy should specify their detail and tailored requirements - especially non-proprietary and interoperability requirements, and consider standards-based solutions.

³¹ ETSI. February 2017. *IoT Standards Landscaping & IoT LSP Gap Analysis*

Chapter 4. ICT Infrastructures Implementation for SSC

1. Role of ICT Infrastructures in SSC

As discussed in Chapter 1, SSC can be defined in different ways by different organizations; and ITU statistics show that there are more than 100 definitions related to SSC. Though different definitions for SSC are available, but they all share a unique point of view about the role of ICT infrastructures for SSC deployment, that:

- "To improve the quality of life of cities' citizens;
- To ensure tangible economic growth, such as higher standards of living and employment opportunities for citizens;
- To improve the well-being of citizens, include medical care, welfare, physical safety, and education;
- To establish an environmentally responsible and sustainable approach, which meets the needs of today without sacrificing the needs of future generations;
- To streamline physical infrastructure-based services such as transportation (mobility), water, utilities (energy), telecommunications, and manufacturing sectors;
- To reinforce prevention and handling functionality for natural and man-made disasters, including the ability to address impacts of climate change;
- To provide effective and well-balanced regulations, compliance and governance mechanism with appropriate and equitable policies and processes in a standardized manner." ³²

In traditional approaches to urban development, all infrastructure systems are managed in silos with limited communication and information sharing among and across government departments, public-private partnerships, and communities. This could be detrimental not only for optimizing resources usage but also for accessing vital information when needed to inform decisions during emergency situation. A smart

³² Bhatnagar Sanjay, Garg Deepti, Bhatnagar Manisha. 2014. *Smart Cities – An Overview and the Role of ICT*

city has different approaches to be developed because they are a sort of components and services provided by the governments based on ICT infrastructures. Therefore, to become a smart city, it is essential to adopt a holistic approach that may involve creating multiple infrastructures as well as strengthening motivation for government participation, application of technologies, integration of various combined smart infrastructure management systems and citizens' collaboration³³. Basically, ICT infrastructures include ICT soft and hard infrastructure and are typically divided into different layers, namely Network, Service, Cloud Computing, Data Platforms, and Access Devices. These layers play as grounds to improve daily personal and business life of cities' residents such as transportation, healthcare, power, security, energy, building, and education, see Figure 15.

Though smart city deployment is people-centric, ICT infrastructures are also considered as the core of a smart city, therefore it acts as a platform to collect, store and analyze data to enable all services in a smart city. For example, smart energy service is actually a system to manage energy smartness. This service uses sensor systems to monitor, control and advance meter energy. This service is also used as a tool to analyze collected data and then intelligently modify them to fit with the contexts, environment, and conditions which they are being used. Furthermore, it improves efficiency, reduces waste and optimizes the usage of energy. Another example related to mobility is the case of Chinese Taipei when ICT applications are being used to find parking lots. Camera systems are being deployed to monitor and detect empty parking spaces, then transmit real-time information to drivers, so that drivers can save time in searching for a parking space. Camera systems are also used to monitor traffic on roads, provide information about traffic jams to drivers to search for other routes. And

³³ Kondepudi Sekhar. May 2015. *An Overview of Smart Sustainable Cities and the Role of Information and Communication Technologies*

ICT infrastructures are a crucial tool in supporting to provide those services to cities' residents.

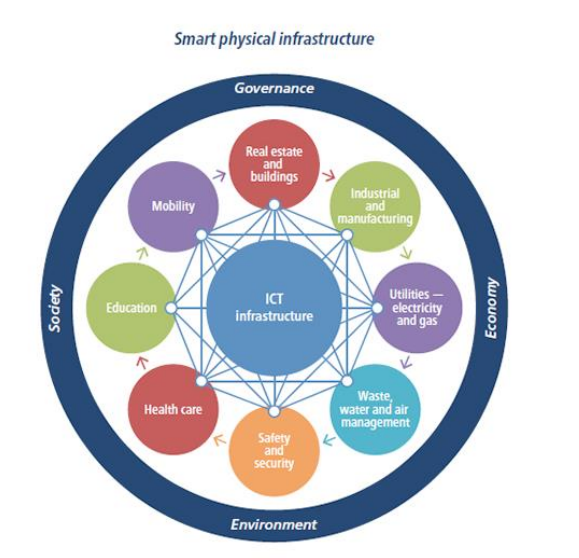


Figure 15. Smart city components

Source: ITU, 2014

Security is one of the key components of a smart city and this function appears in all layers of SSC. Data are key for the success of smart city deployment, no data no smart city, and more information means more knowledge and more vulnerability to data security³⁴. One of the challenges of deploying SSC is data sharing. Data sharing is one of the SSC typical functions that aims at utilizing value data collected from sensor networks placed everywhere. However, data sharing will can face anonymous threats, that which is why security is a useful tool to ensure the confidentiality, integrity, and accessibility of safety of citizens' data. ICT infrastructures with software and hardware devices such as firewall devices and private keys will support to prevent unauthorized access in order to protect data security. ICT infrastructures can be considered as "glue" to integrate all components and elements of SSC to create a unique foundational platform. "ICT infrastructure is at the core and acts as the nerve center, orchestrating

³⁴ Here Mobility. "Smart City Technologies: Role and Applications of Big Data and IoT" Available at <https://mobility.here.com/smart-city-technologies-role-and-applications-big-data-and-iot#pgid-1771>

all the different interactions between the various core elements and the physical infrastructure.”³⁵

2. Prerequisite Conditions to Deploy Smart Sustainable City

2.1 ICT Infrastructures

Each city has its own specific context and requirements and faces its own problems; therefore, cities and regions should find out their suitable approaches to resolve their particular urban problems. Nevertheless, smart city embodies a common method to deal with urban problems by using advanced ICT infrastructures to increase efficiency in city management and livability³⁵. Providing access to the Internet is a key factor for developing a smart city because Internet access serves as a basis for delivering and using smart services. Therefore, ICT infrastructures readiness is one of the prerequisite conditions to deploy SSC.

Almost all APEC economies have excellent fixed and mobile broadband networks. Additionally, the APEC region is one of the regions in the world that has a high penetration of Internet access. However, ICT infrastructures are not only fixed and mobile broadband infrastructures but also many other different sorts of infrastructures, then it is not enough for deploying SSC if cities have only telecommunications infrastructures. Deploying SSC needs powerful ICT infrastructures for the full range of smart services offered. Therefore, new technologies such as IoT, AI, Big Data and Cloud need to be deployed as appropriate to collect and exchange information between person and person, between people and machines, and between machines and machines.

Furthermore, ICT infrastructures should be developed based on open standards to ensure interoperability among layers and services in SSC.

2.2 Socio-economic Conditions

³⁵ Bhatnagar Sanjay, Garg Deepti, Bhatnagar Manisha. 2014. *Smart Cities – An Overview and the Role of ICT*

ICT infrastructures should be deployed to assist cities to work better and smarter, but governments' awareness and readiness to deploy SSC in their territories is also one of the key factors contributing to SSC successful deployment. Building SSC is aiming at improving the quality of citizen life, environment and economy in a city, so local governments should enact policies to accelerate and coordinate the development of SSC that is suitable for their particular social and economic conditions.

Cities in the APEC region have different shapes, sizes, and levels of development, so it is hard for them to duplicate models of each other when deploying SSC. Consequently, it is important for local governments to understand concrete situations of their cities once they plan to deploy SSC. Local governments also have to prioritize which sectors should be deployed in sequence because resources of the cities are limited.



Figure 16. People-centric cities enabled by smart and connected systems

Source: Pham Thi Thanh Long, 2019

Financial sustainability plays an essential role in successful SSC deployment. Local governments need to determine a planned budget and financial sources for deploying and maintaining SSC, and this work cannot be finish in a short time. After

determining the list of priorities, local governments need to work with multi-stakeholders such as research institutions, universities, startups and citizens to build SSC. Feedback to the APEC survey in July 2019 shows that over 60% APEC responded economies are facing to sustainable financial challenge.

3. Major Technologies of ICT Infrastructures

3.1 Technologies and Trends

A smart city requires digital connectivity such as fixed broadband, mobile broadband and IoT networks for providing smart services. These networks will offer models for services delivery, tools for monitoring, storing and analyzing collected data. To deliver smart services in SSC, several emerging ICT technologies should be considered to deploy as appropriate such as IoT, 5G and AI as examined below.

3.1.1 IoT

When deploying a smart city, data are prerequisite input; local governments need data for analyzing, then optimizing services offered to residents. IoT can generate huge of information, and it is an essential technology for building a smart city. IoT can be viewed as a global infrastructure for information society; this technology does not only support connections between humans and humans, between humans and things but also between things and every other thing. The “things” of the IoT- devices, sensors, applications and collected data that enable technology solutions to be effective³⁶. IoT can be considered as the nervous system of a smart city thank to the sensors placed everywhere and in almost all smart services. Today, sensors are found in buildings, parking areas, monitoring water systems, etc. However, sensors which are being used in smart services are facing the following challenges:

³⁶ Here Mobility. *Smart City Technologies: Role and Applications of Big Data and IoT*. Available at <https://mobility.here.com/smart-city-technologies-role-and-applications-big-data-and-iot#pgid-1771>

- Extreme miniaturization;
- Ultra-low power consumption;
- Ability to interface with networks (e.g., Wi-Fi and Bluetooth Low Energy tech);
- Application-ready outputs (e.g., signals and data).

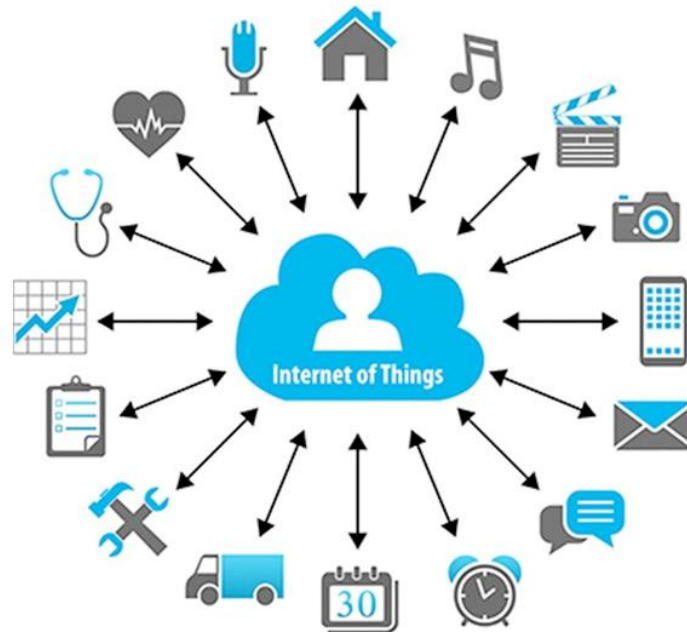


Figure 17. IoT network

Source: M. Jay, 2018

Digital transformation in cities will be enabled by breakthroughs of sensor technologies. Following major changes in sensor operations can support cities in enabling new applications, such as:

- “Color Sensor for mobile phones, tablets, and laptops that “see” the color of light as the human eye does, enabling device displays to have more natural appearances.
- Multi-Spectral and Hyper - Spectral Sensor Integrated Circuits that function as laboratory- grade spectrometers that enable food inspection and harvest analysis.
- 3D Imaging Systems-on-a-chip that are set to transform AR/VR: applications and improve gesture sensing, face scanning, and 3D modeling.

- Sensors for medical, which include ultra-accurate digital imaging devices in hospitals and miniature sensing systems-on-a-chip (e.g., for a fitness wristband) for measuring heart rate and blood oxygen levels.

- These sensors are found in digital cameras, medical imaging systems, night-vision equipment, thermal imaging devices, radars, sonars, media houses, and biometric systems. In the retail industry, these sensors are used to monitor customers visiting the store through the IoT network. In offices and corporate buildings, they are used to monitor employees and various activities through IoT networks.”³⁷ Pervasive digital surveillance can impact privacy and human rights, including the right to be free from arbitrary or unlawful interference with privacy. Governments should take this into account when developing frameworks for SSC.

Sensors in IoT systems are placed everywhere to gather information regarding the environment, energy and so on, but they have to use a communication network to connect and transfer data to upper layers as IoT services platform. Therefore, IoT solutions for 4G and 5G networks or short - range wireless networks (such as Wi-Fi, LoRA...) have been researching and deploying in recent years. IoT for short-range wireless networks has some disadvantages in terms of power and coverage. Today, IoT solutions for 5G networks are upward trends worldwide, and for economies who do not yet deploy 5G, IoT solutions for LTE or called NB-IoT are also ideal for smart cities. NB-IoT has various advantages, such as large coverage, low cost, and safe battery.

3.1.2 The 5G mobile network

5G is the fifth generation of mobile networks and it will offer several advantages over existing 4G networks, including higher speed, reduced latency, increased density, and additional functions and security measures. Most APEC economies are piloting

³⁷ Yu Jae-Hyun. October 2019. *ICT Infrastructures for SSC: Opportunities & Challenges*.

5G and some are even commercializing, such as China, Korea, and the United States. One of the differences between 5G networks and previous generations of networks is that 5G is predominantly being used for IoT application and business applications, while 2G, 3G, and 4G mainly serve communication between people. Previous generation networks, especially 4G networks with low latency and very high-speed Internet access, are enough to satisfy requirements of entertainment and conversation. However, new applications such as smart manufacturing, autonomous vehicles, and telehealth require even lower latency (as low as 1ms) and higher density in a small area. These requirements could be seamlessly afforded by 5G networks. Deloitte's report³⁸ shows that 5G will empower IoT, autonomous cars, smart cities, and new mobile applications thanks to peak data rates up to 20 times faster than 4G as well as low latency.

Like any other technology, "5G will need to be standardized before it can be widely deployed"³⁹. 5G networks are supported by large numbers of standardization organizations that hopes to boost the performance of networks and devices. These organizations, including ITU-T, ETSI, IETF, and 3GPP, are working about on requirements, architectures, protocols and radio frequency for 5G networks. Requirements which relate to speed, capacity, latency, reliability, resilience, and security are focused to be standardized focuses of the standardization efforts and as reported by the GSM Association (GSMA) reports that 5G will have the following characteristics:

- 1-10Gbps connections to endpoints in the field;
- 1 millisecond latency;
- 1000x bandwidth per unit area;

³⁸ Deloitte. 2018. *5G Mobile Technology: Are Businesses Ready to Seize the Opportunity*

³⁹ FTTH Council Europe. 2019. *Fixed-Mobile Network Convergence the Key Role of Fibre*

- 10-100x number of connected devices;
- 99.999% availability;
- 100% coverage;
- 90% reduction in network energy usage;
- Long-life battery.

Smart city technologies require connectivity to work and 5G networks provide a strong connection among millions of devices and sensors, then enable IoT to work efficiently. 5G will power many applications, including some that are not yet developed. A large number of these use cases will be for critical services that are essential to public health and safety, such as emergency services, telehealth, and autonomous vehicles.

- Smart and self-driving cars: self-driving cars use sensors to gather information regarding road, traffic and transfer to processing on the car to make instant decisions require. So self-driving cars require a connection with very low latency, which can only fully be met by 5G networks. For example, if there is an accident, a self-driving and the connected car can very quickly warn other cars behind it and make sure that various traffic and weather conditions can be rapidly communicated.

- The smart home: Smart devices at home will be able to communicate with each other and control remote, monitor consumption power all devices with the support of in-building networks.

- Emergency services: Firefighters or emergency response teams, for example, will be able to use helmets that can stream video in real time that can be transmitted instantly to supervisors who can provide advice about how to manage risky situations.

- Virtual reality health care: The low latency of 5G can enable remote delivery of health care. It will be possible for a doctor to use new robots and a connection with very low latency to remotely perform examinations or even surgery.”⁴⁰

Using high-band frequencies (above 6 GHz), and narrow targeted beams, and being designed primarily based on small cells, 5G requires a large number of base stations to ensure network coverage. As a result, huge capital needs to be invested into mobile networks; and infrastructures sharing among mobile operators and other public utility companies such as electrical or water companies is one of the best solutions for efficient and effective investment deployment. Given the vast amounts of data that will traverse 5G networks and the critical applications (e.g. telehealth, autonomous vehicles, etc.) that will depend on these networks, governments should turn to trusted vendors that adequately protect digital security to build 5G networks.

3.4. Artificial Intelligence

No data means no smart city. Data in cities collected by sensor systems placed everywhere; analyzing and optimizing data will help cities' governments and other stakeholders to save time, money and energy. However, processing collected data is very complicated because they have been collected by a huge number of sensors located at different places and in different formats. Research and analysis of International Data Corporation (IDC) shows that annual global data generation will reach 44 trillion GB in 2020⁴¹ and data have been increasing exponentially, see Figure 18. In that context, AI can be used considered as one of the best solutions to process huge data in different formats of a smart city. The design, development, and deployment of AI systems (including the data sets they are trained on and the algorithmic models they use) can also raise ethical challenges related to bias, fairness,

⁴⁰ Here Mobility. *Smart City Technologies: Role and Applications of Big Data and IoT*. Available at <https://mobility.here.com/smart-city-technologies-role-and-applications-big-data-and-iot#pgid-1771>

⁴¹ Turner Vernon, Gantz John F, Reinsel David, Minton Stephen. April 2014. *The Digital Universe of Opportunities: Rich Data and the Increasing Value of the Internet of Things*

accountability, and so on. Governments should take these considerations into account when developing SSC frameworks and promote the responsible stewardship of trustworthy AI.

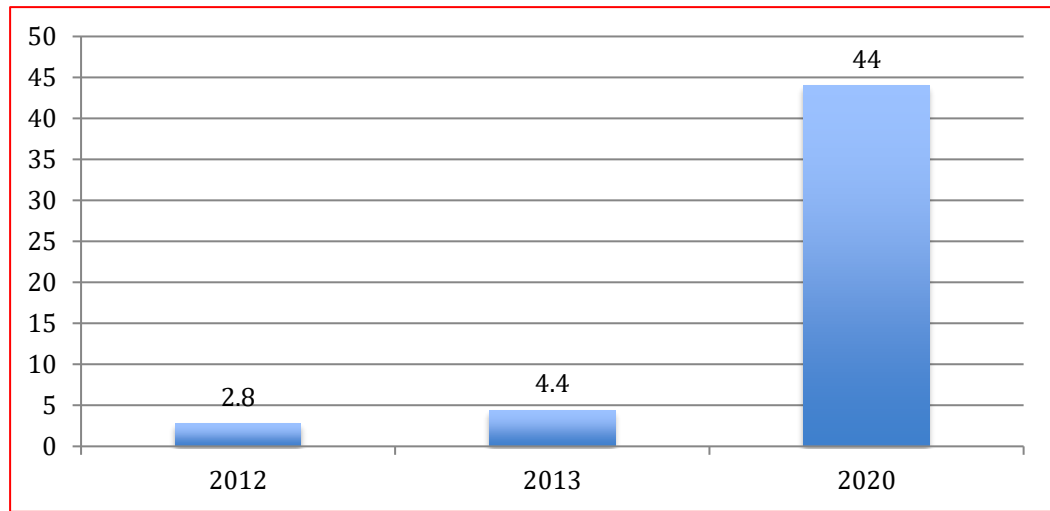


Figure 18. Data generation by IoT system

3.5 Blockchain

Blockchain is a new data storage technology, by which data are encrypted and stored in various locations in the form of a block. Each location holds a true copy of the stored information and decentralized management with a distributed ledger. Before recording in the ledger, the information will be verified by many people in different places through the consensus mechanism. There are two common consensus mechanisms, those are proof of work and proof of stake.

The two most important characteristics of blockchain are distribution and decentralization. Distribution characteristic means that the blocks contain the same data but are scattered in many different places. So, in unfortunate cases, if a place is lost or damaged, the data are still on the blockchain. Decentralization characteristic means that once information is verified and recorded in the blockchain, no one can change it because only the owner of the private key can access the information. These two characteristics of blockchain make it different and advantageous in comparison with all current data storage systems.

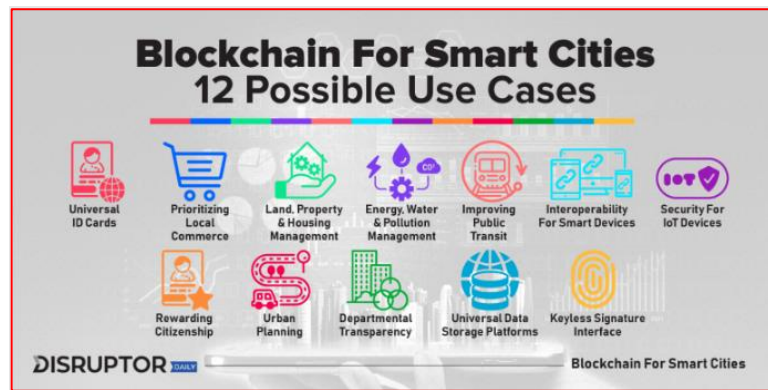


Figure 19. Blockchain for SSC

Source: Mire Sam, 2019

IoT and 5G technologies are two important components in smart city ecosystems. Information is captured and kept in cloud-based infrastructures utilized by a smart city can be encoded protected, including through a blockchain system to ensure data privacy and security in addition to other relevant rules and regulations to ensure personal data protection. The use of blockchain for “self-sovereign identification” could facilitate the delivery of many public (and private) services in a smart city.

Blockchain is “not only a platform on which the mass of new data derived from smart cities can be safely stored and accessed by those who should have access to it. The chain also may serve as the interoperable platform that gives residents of smart cities greater say in making decisions, affecting their hyper-local communities, from budgeting to elections.”⁴²

3.2 Opportunities and Challenges

Deploying SSC based on ICT infrastructures with emerging technologies will offer many opportunities as below:

⁴² Mire Sam. November 2019. *Blockchain for Smart Cities: 12 Possible Use Cases*

- Smart city used ICT infrastructures with new technologies will support local governments to manage better and easier and create new business and service models for the cities;

- Facilitate citizens' participation into city governance;

- Use targeted ICT services to reinforce the city value proposition;

- Increase foreign investments into economies;

- Deploying new technologies will support service providers gain advantages as first-movers to provide advanced services;

- Enhance environmental protection and strengthen the economies' capability to adapt to climate change.

However, cities will face several challenges when applying new technologies in rolling out ICT infrastructures:

- Some smart city solutions do not only require a substantial initial investment but also ask for sufficient financial resources for smart services operation and maintenance;

- Cities are required to create and maintain close relationships with developers, telecommunications services providers, and vendors. Experiences of 5G commercialization in Korea show that the key success factor for early 5G launch is tight cooperation among the government, telecommunications operators and vendors. The government launched early spectrum auction and announced tax support to foster 5G commercialization in Korea. Further, vendors already provided 5G devices to the market while service providers supporting consumers in terms of pricing and compelling 5G services;

- Interests among multiple stakeholders should be balanced;

- Lack of operational experiences and network infrastructures overload should be addressed by the cities' government;

- Effective models for developing, benchmarking and assessing smart city should be available and applicable.

4. Typical Roadmaps to Deploy ICT Infrastructures for SSC

4.1 Typical Roadmaps for ICT Infrastructures

As each APEC economy has its own specific context and requirements, each economy also has its own problems when deploying SSC. Therefore, economies can choose different solutions and approaches to resolve their problems and make their cities become smarter in different ways. It is obvious that ICT infrastructures have a crucial role in smart cities, therefore, utilizing ICT infrastructures is quite a popular solution to deal with cities' problems, enhance the quality life of the citizens and facilitate economic development. ICT infrastructures offer an advanced platform for implementing smart services in smart cities. There are a number of emerging technologies such as 5G networks and IoT that can be employed to provide smart services.

The availability of master plans, strategies, and visions for SSC deployment is one of the most important components to optimize investment into SSC, therefore these master-plans, strategies, and visions should be very specific and clear. Experiences in deploying SSC in Chinese Taipei evidence that SSC development is divided into several phases with different scopes. So far Chinese Taipei has three phases to deploy smart city, each phase has several projects supported by the central government. In the first stage from 2006, Chinese Taipei focused on Wi-Fi for ICT infrastructures. In the second and third stages, Chinese Taipei concentrates on smart applications and services based on LTE, citizens' engagement and financial sources mobilization from the private sector.

In Thailand, the government has a quite clear strategy and concrete goals toward a smart economy, for example achieving 1000 creative entrepreneurs by 2020

and becoming a paradise for digital workers and investors. Building local startups in IoT smart cities is also one of the government strategies.

The United States encourages cities, communities, industries, and universities to work together for SSC. It encourages public-private partnerships and bottom-up processes to secure finance and share best practices and experiences with one another to develop stronger smart cities.

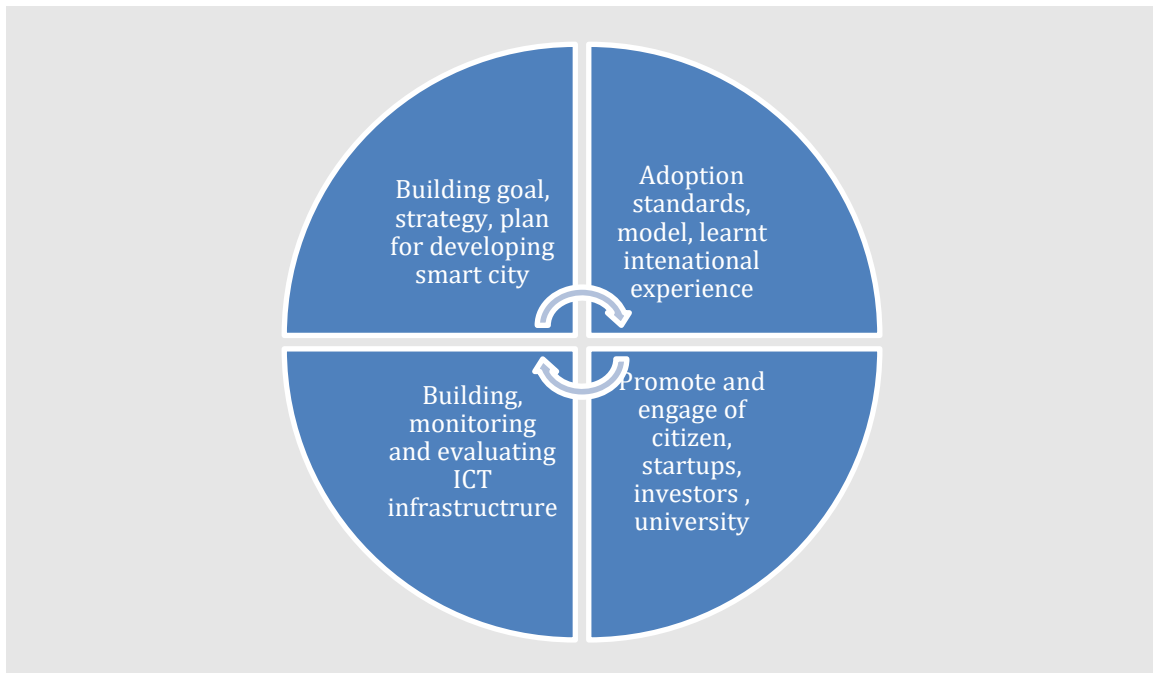


Figure 20. The roadmap toward SSC development

Comprehensive plans or roadmaps for SSC are required to have clear timelines, standards and critical developments for ICT infrastructures, connectivity, smart services, and available regulations. Following are, *inter alia*, typical SSC roadmaps.

Roadmap for ICT infrastructures

As analyzed above, ICT infrastructures readiness is a prerequisite condition for smart city deployment in any economy. ICT infrastructures provide connections to the Internet and the basis to offer smart services. However, each city or economy has different infrastructures and conditions for developing SSC, therefore, local and central governments need to gather and analyze information about their current ICT infrastructures situations before deciding their SSC approaches. Furthermore,

governments need to determine timelines, stages or phases to roll out powerful ICT infrastructures with advanced emerging technologies. Governments are also required to apply suitable standards and technologies to enhance Internet access speed, increase broadband coverage and ensure security.

Roadmap for smart services

Smart services are the main scopes of smart city, required to be provided via well-established ICT infrastructures and aiming at improving life quality and resolving daily problems of the residents.

Roadmap for smart services should indicate a clear timeline, from the pilot step to commercial step, and solutions to implement smart services. Key indicators of successful roadmaps are their attractiveness, easy to use and accessibility of smart services.

4.2 Smart Services

Local governments around the world are generally offering following smart services to their residents.

Public Lighting Management

Benefit:

- Greater control of street light poles, includes individual control, schedule-based control, and dimming. Chinese Taipei reports⁴³ that this solution helps her to save about 30% manpower;
- Enhanced maintenance, includes usage monitor, defects and automatic maintenance process;
- Reduced cost by deploying Wi-Fi Mesh infrastructure, video surveillance.

⁴³ Chao Magie. November 2019. *Sustainable Smart Cities Deployment: Case Study of Chinese Taipei*

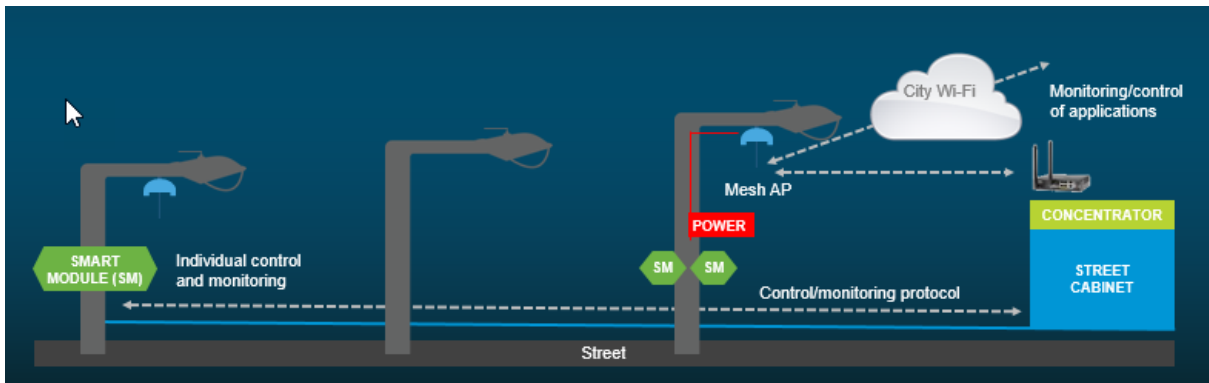


Figure 21. Street light management in smart city

Source: Yu. Jae-Hyun, 2019

Steps to develop:

- Consult stakeholders;
- Roll out necessary infrastructures such as NB-IoT, NB-LTE, Wi-Fi and 5G network;
- Install smart devices and cameras on light poles to monitor and control dimming and usage per each light point;
- Build an IoT platform to control applications.

Smart Parking for Vehicles

Smart parking service enables drivers to search, book and pay for parking spaces by directly using mobile applications.

Benefit:

- Modernize car's mobility by offering new services (parking guidance, contactless payment, information mobility);
- Improve rotation of vehicles on street parking;
- Streamline payment controls (such as the case of Singapore, when a mobile application serves as an alternative mode of payment to paper parking coupons, and at the same time allows users to extend parking duration remotely);
- Strengthen linkage between car parking policy and convenience stores (promotion campaigns and tickets);

- Reduce time to find out space parking. Chinese Taipei reports⁴⁴ that this solution helps to save up to 40% of parking space searching time and 10 % of traveling time.

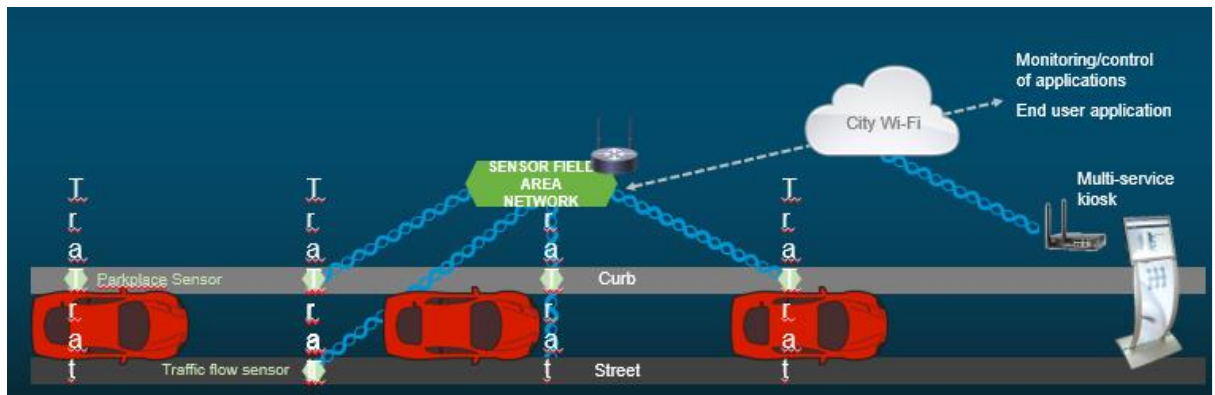


Figure 22. Parking car deployment in SSC

Source: Yu. Jae-Hyun, 2019

Steps to develop:

- Consult stakeholders;
- Roll out infrastructures such as NB-IoT, NB-LTE, Wi-Fi and 5G network;
- Install sensors on sidewalk curbs in order to track, in real-time, whether a parking lot is occupied or vacant and whether the occupied lot was paid or not. Sensors are used internal batteries to maintain communication with the server instead of power supply;
- Install video cameras on parking spaces to monitor and analyze empty spaces and provide a real-time report to users;
- Build an IoT platform to control and monitor information collected by sensors;
- Develop mobile applications for contactless payment (Near Field Communications - NFC).

Smart Traffic Incident Management

Benefits:

⁴⁴ Chao Magie. October 2019. *Sustainable Smart Cities Deployment: Case Study of Chinese Taipei*

- 'Eye' on live situations on road networks;
- Reduce time to detect incidents, verify and identify incident types, and hence manage incident times;
- Manage traffic congestion.

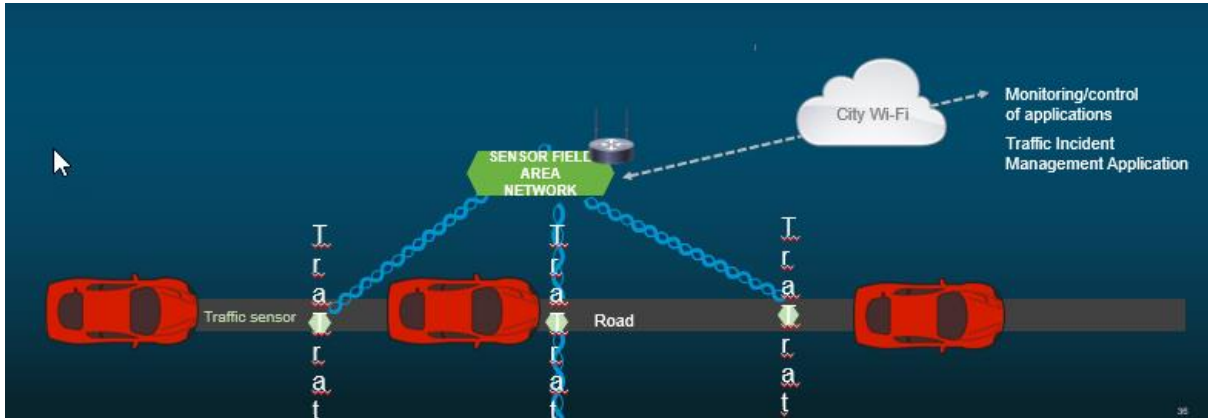


Figure 23. Smart traffic incident management in smart city

Source: Yu Jae-Hyun, 2019

Steps to develop:

- Consult stakeholders;
- Build infrastructures such as NB-IoT, NB-LTE, Wi-Fi and 5G network;
- Install sensors along with road networks;
- Install video cameras to verify incidents;
- Build an IoT platform to monitor and control applications via the Internet.

Waste Management

Benefits:

- Reduce cost for waste collection, and reduce carbon emission;
- Reduce fire risks;
- Define new contracts/Service Level Agreements - SLAs.

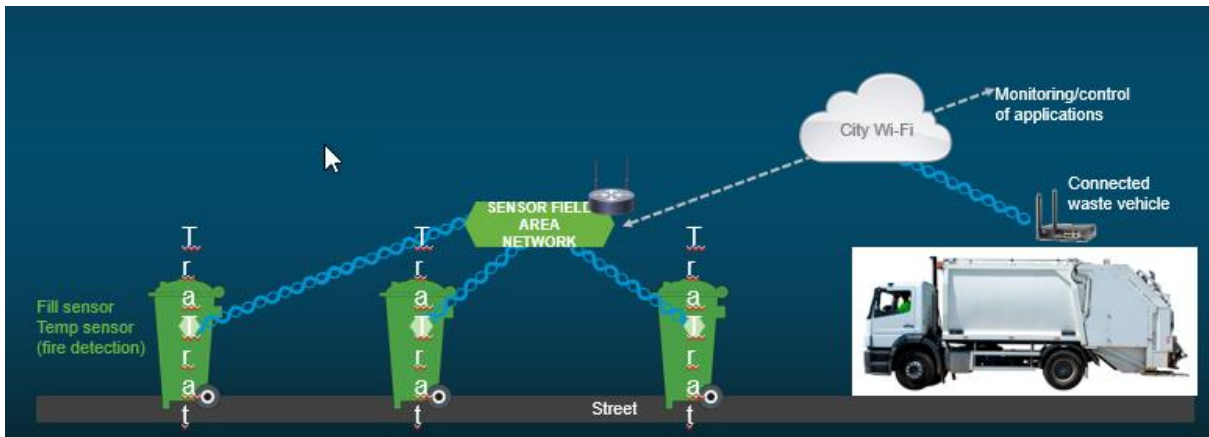


Figure 24. Waste management in smart city

Source: Yu Jae-Hyun, 2019

Steps to develop:

- Build infrastructures such as NB-IoT, NB-LTE, Wi-Fi and 5G network;
- Deploy sensors in recycling containers to monitor waste levels in real-time; send alerts and identify most appropriate collection methods based on volume and waste types;
- Build an IoT platform to monitor and control applications via the Internet.

Environment Management

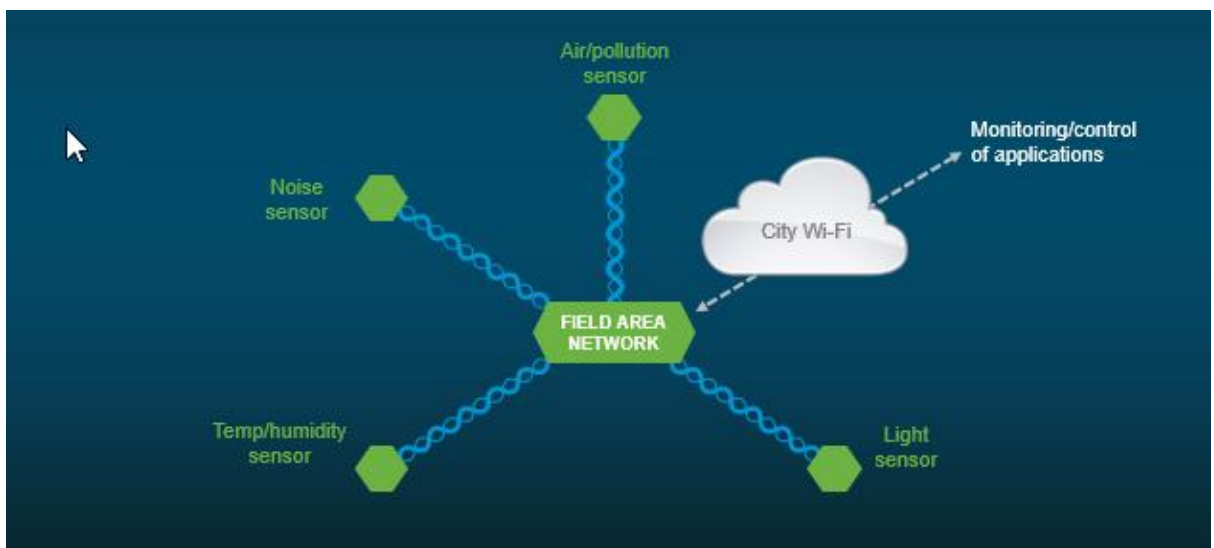


Figure 25. Environment management in smart city

Source: Yu Jae-Hyun, 2019

Benefits:

- Leverage parking sensor infrastructures;
- Provide valuable data for improving analytic applications and forecasting.

Steps to develop:

- Build infrastructures such as NB-IoT, NB-LTE, Wi-Fi and 5G network;
- Install environment sensors to collect information about air, light, humidity, noise, etc. Sensors used internal batteries to maintain communication with the server instead of power supply;
- Build an IoT platform to control application, monitor and analyze information collected by environment sensors.

5. Enable Policies and Regulations for Smart Sustainable City Deployment

SSC is a complicated concept and relates to many sectors, such as economic development, environment, technical standards, public and utility services, and ICT infrastructures. Rolling out ICT infrastructures for SSC is quite a complex and expensive work, and requires collaboration among central and local governments, residents, private sector, startups, and academia. Local, regional, and central governments can have complementary, coordinated roles in:

- Setting strategies for deploying effective ICT infrastructures with detail information about, *inter alia*, technologies, standards, spectrum, and timelines;
- Securing essential financial resources for development; engaging all stakeholders to participate into ICT infrastructures development process; and
- Facilitating stakeholder input.

Applicable policies and regulations are one of the key factors contributing to the successful implementation of SSC. However, in order to integrate urban planning with high-tech infrastructures and systems, the existing legal framework on ICT infrastructures and construction should be simplified, particularly those are related to:

- Plan, strategy, and vision for SSC deployment;
- Enable new technologies;
- Infrastructure sharing;
- Policies on innovation;
- Cross border coordination;
- Policies on the environment;
- Personal data protection and sharing policy;
- Network security;
- Financial sustainability.

Plan, strategy, and vision for SSC deployment play as basic principles to facilitate advanced ICT infrastructures rolling out for SSC; and local governments in the APEC region, in coordination with other local, regional, and central government efforts, should set-up visions, plans and strategies with clear targets for ICT infrastructures development, infrastructures sharing as well as a tax reduction.

Personal data protection and data sharing are also key for SSC implementation. Sharing data will utilize valuable data collected by sensors. Governments can setup various websites to share appropriate data while protecting privacy, and private sectors can utilize data on these websites to develop suitable applications and/or provide services. However, data are very important and required to be secured and protected. Governments should apply effective and transparent solutions to ensure data security such as improving public awareness about data security, encouraging all stakeholders to engage in privacy and data protection, including through use of APEC endorsed privacy mechanisms such as the APEC Privacy Framework and APEC Cross-Border Privacy Rules (CBPR) System.

Infrastructures sharing can be implemented based on commercial agreements among relevant entities and/or on regulatory mandates. There are several types of

infrastructure sharing such as passive and active infrastructures sharing, spectrum sharing. Various types of infrastructures sharing in mobile networks are illustrated in Figure 26.

Infrastructures sharing in SSC is not only sharing among mobile networks but also among government-owned critical infrastructures, including energy networks (such as public lightings), transportation networks, water supply and drainage networks and mobile communications networks. Several APEC economies are actively applying infrastructures sharing, for example, Canada and Malaysia enact new legal frameworks for mandatory sharing of antenna towers and sites, while the United States does not intervene in voluntary infrastructures sharing arrangements.

Enabling technologies plays an important role in deploying ICT infrastructures for SSC. Together with solutions for applications and sensors, standardized connection protocols and telecommunications networks, cloud storage, and connectivity and analytical platforms are also necessary for the wider development of SSC. Enabling technologies include enable technologies from the access layer to services/applications layer.

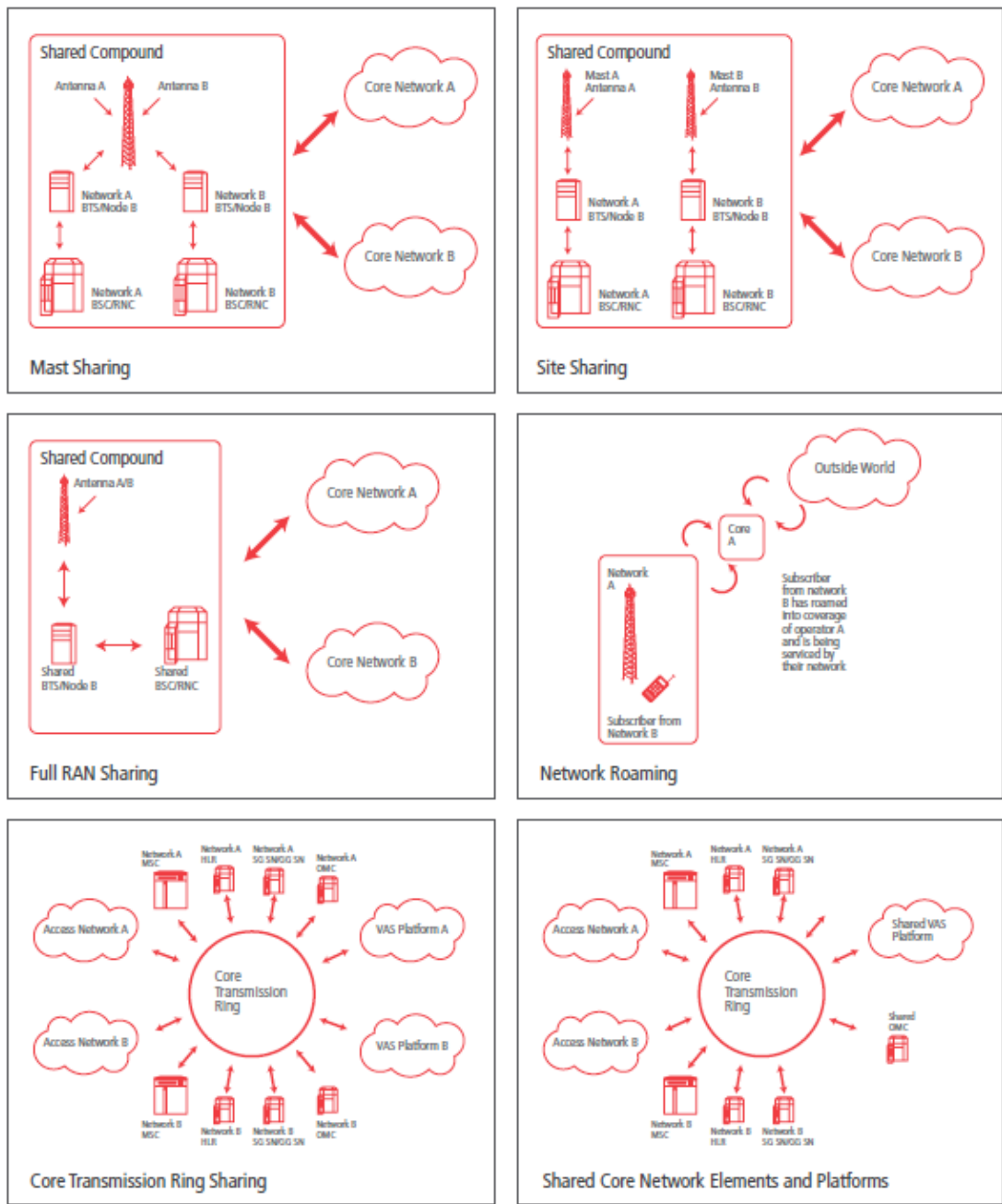


Figure 26. Mobile infrastructure sharing

Source: GSMA, 2013

Coordination among cities, regions, and economies is also a way to utilize and secure financial investment and need to be supported by governments and all other stakeholders. Governments should have available policies to attract investment from private sectors, increase efficiency and reduce cost in deploying smart services as well as in rolling out ICT infrastructures. In the APEC region, Public-Private Partnership (PPP) model is being used widely to reduce risks, effectively control budget for

infrastructures construction. In Chinese Taipei and Thailand, preferential tax policy is applied as one of the good solutions to encourage vendors who want to provide their solutions for SSC. However, local governments also need to balance the size and complexity of PPPs to ensure the optimal performance of the public sector.

6. Consideration the Best Practices and Standards

A smart city is the one where everybody is benefited from whatever data and technologies can provide. A smart city can be also seen as a place where people and infrastructures have to be managed together to work well. Therefore, adopting consensus-based standards for interoperability to build a smart city will ensure the city works better, more effective and all things fit well together. Additionally, some products and services are only completely designed and used in one particular city and difficult to duplicate in other places. That means they are not replicable easily and quite complicated to scale from one city to another city. When choosing products, services, and processes, by considering best practices and open, consensus-based standards for interoperability, cities can deploy SSC cheaper and more reliably because those products, services, and processes have been already tested in many other cities and various circumstances.

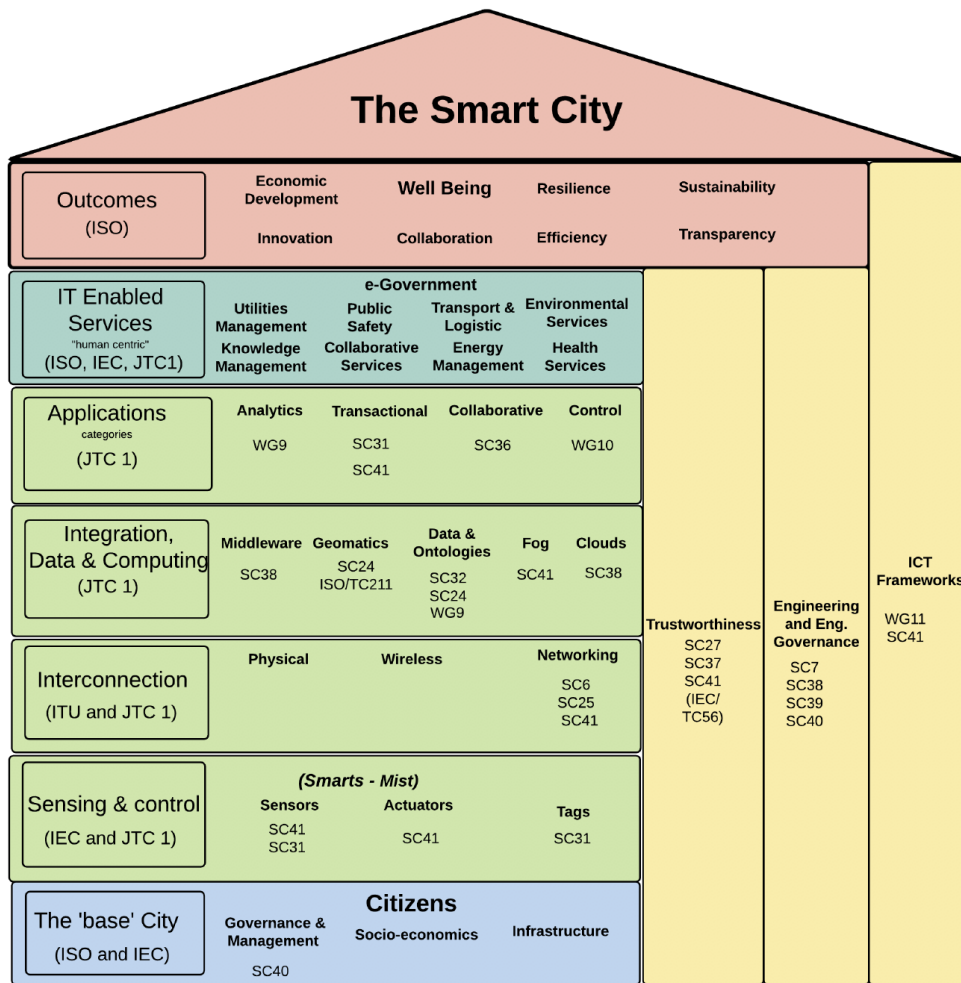


Figure 27. Key enable standards to SSC

Source: Zhang Dapeng, 2019.

However, no single standard can cover all for SSC, and standardization organizations as ISO, JTC1, ITU, IEC have been publishing many standards applied from the services layer to infrastructures layer in SSC (Figure 28). Cooperation and coordination among standards organizations can facilitate the ability of cities and communities to implement replicable and scalable smart city solutions. Each economy can choose suitable standards for SSC, depending on its own objectives, plans and strategies, see in Figure 27.

7. Chapter Conclusion

Several approaches have been proposing and applying to deploy smart city in the APEC region, and ICT infrastructures play an important role in all those approaches. Smart services offered in cities are based on ICT infrastructures to resolve problems regarding energy, socio-economic development and environment of a city. Therefore, the APEC economies would be required to implement powerful ICT infrastructures with advanced technologies such as IoT, 5G network, blockchain and AI to optimise SSC development. Depending on particular characteristics and functions of smart services, different types of sensors will be used, for example, lighting and humidity sensors need to be deployed to monitor temperature and humidity in certain areas. However, due to available resources constraints, local governments have to clearly identify their practical goals and set priorities when deploying SSC.

Cities are different in shapes, sizes, and levels of development, so policies, strategies, and plans toward SSC in cities are not identical but, in any case, strategies all should focus on citizens and their needs. Building a smart city with a clear strategy, vision and plan will ensure effective use of financial resources, save time, reduce risk and improve efficiency. Central and local governments should also release policies to engage citizens involving into SSC development. The private sector is an active player of any SSC process; they can significantly support local governments in terms of financial contribution via various cooperation schemes such as PPP and PFI.

Chapter 5. Conclusions and Recommendations

1. Conclusions

Utilizing ICT infrastructures to build SSC is being considered as an advanced solution and an upward trend in the world, both in developed and developing economies. ICT infrastructures play as a prerequisite condition to deploy SSC and they include all devices, networks, protocols, and procedures that are employed in telecommunications and information technology fields. SSC will use all of these components to provide and monitor smart services.

Statistical data show that the APEC region has the fastest urbanization speed. This fast urbanization process leads to challenges for governments in terms of socio-economic development, environment and culture. To overcome these challenges and move towards a sustainable society in the future, developed and developing economies in the APEC region can promote SSC deployment based on well-established ICT infrastructures. Most APEC economies have well-developed ICT infrastructures with millions of kilometers of fiber cable networks, excellent wireless coverage rolled-out by utilizing advanced technologies. Those ICT infrastructures serve as a key enabler for the economies to develop SSC.

However, the APEC member economies are mostly facing several challenges and difficulties in upgrading and expanding ICT infrastructures for SSC as follows:

- The need to identify policy/regulatory approaches that promote innovation and put cities and communities in the lead in their smart city projects;
- Skills gap (SSC planning and design skills, SSC implementation skills, SSC management skills, digital citizenship skills);
- Financial constraints;

- “Difficulty in replicating SSC models due to wide disparities among cities in terms of administrative, politic, cultural and infrastructure aspects”⁴⁵;

- Lack of SSC-related recommendations, consensus standards to enhance interoperability among SSC systems and equipment.

In deploying SSC, several technical standards are already adopted by the APEC economies. These standards are important for expanding ICT infrastructures and aim at:

- Ensuring the city works better and more effectively;
- Ensuring interoperability among services and devices;
- Complying with legal requirements;
- Offering cheaper products.

Main categories of technical standards for SSC focus on security and privacy, IoT, applications, integration/Interoperability and communication and connectivity, devices and sensor technology...

Along with affordable ICT infrastructures, cities should have available financial resources, clear strategy, vision and plan for building SSC. Cities also need to clearly identify their practical goals and set priorities to ensure effective use of financial resources, save time, reduce risk and improve efficiency when deploying SSC. The steps for building SSC are as below:

- Building goals, strategy, and plan for developing smart city;
- Adopting consensus-based standards, models and learning international best practices;
- Promoting and engaging all stakeholders into the SSC development process;
- The building, monitoring and evaluating ICT infrastructures;

⁴⁵ Tran Nhat Le. August 2018. *Recommendations for Implementation of Smart Sustainable City (SSC) ICT Infrastructure in APEC Region*. Available at <https://aimp2.apec.org/sites/PDB/Lists/Proposals/DispForm.aspx?ID=2225>

- Designing smart services to offer to residents.

2. Recommendations

ICT infrastructures have a critical role in deploying SSC. To expand and upgrade ICT infrastructures, the APEC economies have to clearly understand their current status of ICT infrastructures and development objectives to identify approachable goals and prioritize areas and services to be smart based on their particular available resources.

Further central, regional and local governments should have consistent strategies, clear visions, and achievable targets when upgrading and expanding ICT infrastructures. A typical roadmap for expanding and upgrading ICT infrastructures should cover:

- Goals, strategies, and plans to develop a smart city;
- Adopted and/or recognized consensus-based standards and applied models;
- Stakeholders involvement (such as public and private investors, startups, academia, and citizens);
- ICT infrastructures expansion, monitor and evaluation.

If advanced and affordable ICT infrastructures cannot be set up in a short time, then local governments are better to start in small areas to gain experience and find out best practices before expanding to larger scale projects and scopes.

Another important thing is that infrastructures sharing among sectors and companies is an effective way to save time, reduce the cost to provide smart services with enhanced quality. Additionally, increased access to and sharing of data would support and optimize smart services, but data security, privacy, and intellectual property rights must be protected.

Consensus-based standards for interoperability can promote the widespread adoption of technologies and services which will be applied and provided in SSC. Local

governments need to be able to integrate new services and technologies with their existing services and infrastructures when offering smart services to the public.

Deploying SSC is an emerging solution to resolve the increasing problems of a city and improve the life quality of residents. Well-established ICT infrastructures are critical conditions for smooth and successful SSC implementation; and IoT, 5G, AI, and blockchain are key technologies for expanding and upgrading ICT infrastructures. To mobilize the necessary financial resources for SSC, the PPP model is being used widely. Meanwhile, the PFI model is another choice to attract investment for rolling out infrastructures and offering smart services.

International coordination is also a focus on developing SSC to respond to climate change and protect our world environment because climate change and pollutions cannot be responded to or prevented by a single city or single economy.

Annex

Brief feedbacks of the APEC member economies to the survey

I. Policies/regulations on ICT infrastructure development for smart sustainable cities

Questions	Australia	Brunei Darussalam	China	Hong Kong, China	Indonesia	Japan	Mexico	Phillipines	Peru	Singapore	Chinese Taipei	Thailand	USA	Viet Nam
1. Does your economy have domestic strategy/plan for ICT infrastructure development; digital transition/IT application; or broadband development?	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes
2. Does your economy have domestic strategy/plan for IoT application development?	No	No	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	No	No
3. Does your economy have domestic strategy/plan for smart sustainable cities development?	Yes	No	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	No	Yes
4. Does your economy have domestic standards/technical regulations system for IoT applications?	Yes	No	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	No	No
5. Does your economy have domestic standards/technical	No	No	Yes	Yes	No	No	No	Yes	No	Yes	Yes	Yes	No	No

regulations system for smart sustainable cities deployment?														
6. Does your economy have domestic/local Key performance indicators (KPI) for smart sustainable cities?	Yes	No	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	No	No

II. Situation on ICT infrastructure development (readiness for smart sustainable cities)

Questions	Australia	Brunei Darussalam	China	Hong Kong, China	Indonesia	Japan	Mexico	Phillipines	Peru	Singapore	Chinese Taipei	Thailand	USA	Viet Nam
1. How many broadband subscriptions per 100 inhabitants does your economy have?					xDSL: 2,668,092 subscribers FTTH: 6,189,350 subscribers			xDSL and FTTH: 2,506,163 subscribers (2017) Mobile: 72,876,281 subscribers (2017)						
xDSL	9.7	12.5	0.4	5.6			5.7		2.3		2.53		6.7	0.27
FTTH	5.26		28.7	17.9		29	3.0		0.4	94.1 ¹	15.69		4.9	12.56
Mobile	128.1	133.2	N/A	249		188.9	70.5		72.9	151	117.58		101.0	55.89
2. How many mobile subscriptions per 100 inhabitants does your economy have?					233,534,671 Subscribers	133.9	96.0					90 million	106.4	128.08
2G	0	99.06	16.4	10.7				92.7	3.4		0			
3G	128.1	95.94	8.4	56.4		23.2		87.4	27.2	31.02	0			

4G		94.94	89.2	192.8				19.5	45.7	119.98	117.58			
3. How many cities of your economy (in number and in percentage) are served by mobile broadband network (3G or 4G)?	All major cities	3G: 99% 4G: 98%	All cities	99%	3G: 93.39% 4G: 92.70%	99%	3G: 89.64% 4G: 88.2%		Town Center: 39.6% Province : 29.1% Districts: 43.6%	N/A	All 22 cities	100%	99.9%	100%
4. Does your economy have plan to deploy 5G networks? If yes, when do you launch trial/commercial deployment?	Yes Begun	Yes 2020	Yes June, 2019	Yes, 2017 (trial) 2020 (commercial deployment)	Yes 2018	Yes	No	Yes Q3, 2019	Yes End of 2020	Yes 7/2019	Yes, end of 2019	Yes	Yes	Yes 2020
5. How is about the readiness for IoT applications in your economy?		Zero	N/A								7.36 million Ipv6 address and 1.01 million Ipv6 connect			197.6 million IPv6
6. What do you do for information security measures?														
Strategy/plan	x		x	x		x		x			x	x	x	
Technical solutions	x		x	x	x	x		x			x		x	x
Training/demonstration	x	x		x	x	x		x			x	x	x	x

Raise awareness for government/agencies/ community	x	x	x	x	x	x		x	x		x	X	x	x
Singapore: ¹⁾ Residential (household) wired broadband rate														

III. Information sharing on ICT infrastructure development for smart sustainable cities

Questions	Australia	Brunei Darussalam	China	Hong Kong, China	Indonesia	Japan	Mexico	Phillipines	Peru	Singapore	Chinese Taipei	Thailand	USA	Viet Nam
1. Has your economy deployed any Smart Sustainable City?	Yes	No	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes (Phuket)	Yes	No
2. Which services are provided in this smart city/these smart cities?														
Smart mobility	x		x	x	x	x		x		x	x	x	x	
Smart energy	x	x	x	x	x	x		x		x	x		x	
Smart healthcare	x		x	x	x	x		x		x	x		x	
Smart government	x		x	x	x	x		x		x	x		x	
Smart living - Home automation	x					x		x		x	x	x	x	
Other services: Smart Waste Management...	x		x	x				x		x	x	x		
3. Does your economy have any standard/reference ICT application design for smart city ?	Yes	No	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	No	Yes
4. Does your economy have any	Yes	No	Yes	Yes		No	No	Yes	No	Yes	Yes	Yes	No	No

standard/reference technical solution on smart city?														
5. Which are challenges on ICT infrastructure development for deployment of smart city in your economy?														
The fast development of technology	x		x	x	x	x	x	x						x
Financial constraints	x	x			x	x	x	x	x			x		x
Lack of recommendations, standards		x	x		x	x		x				x		x
Awareness of the government/community	x	x		x	x	x	x	x	x					
Other difficulties (please provide detail information)	x				x						Community consensus	x	x ⁵	
6. Which are critical factors for ICT infrastructure development for smart city in your economy?														
Interoperability	x	x		x		x	x	x	x	x	x	x	x	x
Scalability				x	x	x	x	x	x	x	x	x		x
Share ability	x		x			x		x		x	x			x
Measurability			x		x	x	x	x				x		
Others (please provide detail information)							x						x ⁶	

7. Do you have further comments or suggestions about deploying smart cities	Yes ¹	No	No	No	Yes ²	No	No	No	Yes ³	No	No	Yes ⁴	Yes ⁷	No
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Australia: ¹⁾ Strong interworking between central and local governments is needed and not common today. Local governments have limited responsibilities and must combine with central governments to cover all the areas impacted by “smart” solutions.

Indonesia: ²⁾ To implement smart cities, people, governance and culture should also be developed to support readiness of deploying smart cities and improve the quality of life.

Peru: ³⁾ The development of smart cities in Peru is at an early stage. With the support of the Korea Information Society Development Institute (KISDI) the study was carried out: "integrated management system for smart cities in Peru". In addition, an MOU was signed between the Vice Ministry of Communications of Peru, the Ministry of Land, Infrastructure and Transport of Korea, the Land and Housing Corporation of Korea and the Provincial Municipality of Piura of Peru for the development of a smart city pilot. that is currently in development of preliminary studies.

Thailand: ⁴⁾ In implementing smart cities, ICT or advanced technologies are not necessarily as important as the wellbeing of the citizens. Some citizens’ pain points can be solved by other means, which are not necessarily ICTs or advanced tech solutions.

The United States: ⁵⁾ Existing built-up infrastructure, existing local rules and regulations that can limit or constrain deployment, lack of interoperability, backward compatibility, cybersecurity concerns.

⁶⁾ Cybersecurity, privacy, state and local laws.

⁷⁾ The United States does not have a centralized, top-down approach to smart city development but have some tools/resources to facilitate collaboration and coordination among those seeking to develop smart city solutions, such as the Federal Smart Cities and Communities Programs Resource Guide. Cybersecurity and privacy are considered aparamount in implementing smart city solutions, and do have other frameworks/tools that address those topics more broadly:

- NIST Cybersecurity Framework: <https://www.nist.gov/cyberframework>.
- USG Interagency Report on the Status of International Cybersecurity Standardization for the Internet of Things (IoT): <https://nvlpubs.nist.gov/nistpubs/ir/2018/NIST.IR.8200.pdf>

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