



Implementing ITU-T International Standards to Shape Smart Sustainable Cities: The Case of Singapore

Acknowledgements

This case study was researched and written by John Smiciklas, Ramon Ashirangkura, Alison Hyodo, Alex Walker-Turner and Lisha Xu (MJRD Assessment Inc.-Canada).

The authors would like to thank the following: representatives from Singapore's Smart Nation initiative, Agency for Science Technology and Research; Accounting and Corporate Regulatory Authority; Building and Construction Authority; Singapore Department of Statistics; Energy Market Authority; Government Technology Agency of Singapore; Infocomm Media Development Authority of Singapore; Integrated Health Information Systems; Intellectual Property Office of Singapore; Land Transport Authority; Ministry of Communications and Information; Ministry of Culture, Community and Youth; Ministry of Education; Ministry of Health; Ministry of Home Affairs; Ministry of Manpower; Ministry of Social and Family Development; MOH Holdings; National Environment Agency; National Parks Board; the People's Association; Singapore's National Water Agency; Smart Nation and Digital Government Group; Sport Singapore Standards; Productivity and Innovation Board; and Mythili Menon (University of Geneva).

Special thanks go to Kevin Wee, Edwin Low and Gabriel Chan from the Infocomm Media Development Authority of Singapore for their invaluable support in reviewing the case study and providing input.

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This case study is intended for informational purposes only. The results and interim findings presented in this case study are a work in progress, as the KPIs (Recommendations ITU-T Y.4901/L.1601 and ITU-T Y.4902/L.1602) implemented in Singapore during the first phase of the pilot project are still being refined, in order to improve the applicability of these KPIs to all cities.

The revision of the KPIs may alter their scope and definition, as well as the required data-collection process. Consequently, readers are cautioned that the KPIs presented in this case study may not necessarily be entirely compatible with the subsequent KPIs published by ITU after the revision process has been completed.

This report is based on the pilot project conducted in Singapore between October 2015 and September 2017. Information provided is correct as of September 2017.

ISBN

978-92-61-25021-8 (paper version)

978-92-61-25031-7 (electronic version)

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**Implementing ITU-T
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Foreword

Singapore's vision is to be a Smart Nation, powered by a vibrant digital economy where we harness the power of technology to create good jobs for our workers and enable businesses seize exciting market opportunities. Importantly, technology will empower us to forge stronger communities where our people lead meaningful and fulfilled lives.

The Smart Nation Digital Government Office (SNDGO) under the Prime Minister's Office plays a key role in orchestrating a multi-agency effort to achieve the Smart Nation vision. The Infocomm Media Development Authority (IMDA) supports this effort by spearheading the digital transformation of our economy. This whole-of-government effort is evident from the wide ranging list of Key Performance Indicators (KPIs) that the ITU has developed as part of this pilot project. A total of 108 KPIs across many various were tested, and IMDA worked with more than 20 different agencies to ensure the successful completion of this project with the ITU.



It is our hope that through our participation in this pilot project, Singapore would contribute constructively to ITU's development of the KPIs, and to provide case studies to enable the rigorous development of an index on Smart Sustainable Cities. This Index can in turn guide ITU Member States to develop smart sustainable cities and communities.

Finally, I would like to take this opportunity to express my heartfelt gratitude to the ITU for charting new waters in undertaking this mammoth task of developing the KPIs, and for giving Singapore the privilege to work on this meaningful project.

Thank you.

Mr. Tan Kiat How
Chief Executive Officer,
Infocomm Media Development Authority

Cities are home to over 50 per cent of the world's population and this figure is expected to rise to over 70 per cent by 2050. Cities are powerful hubs of innovation responsible for the majority of global economic output. They are also the world's main source of energy consumption and greenhouse gas emissions. The need to transition to 'Smart Sustainable Cities' has become a key policy point for national and municipal administrations worldwide.

ITU is developing international standards for the Internet of Things (IoT) and smart cities and exploring new policy directions capable of stimulating the transition to smart sustainable cities.



The ICT infrastructure of a smart city should ensure openness and interoperability, and this can only be achieved with coordinated adherence to common standards. ITU standards support the interconnection and interoperability of cities' ICT systems, the mutually beneficial sharing and use of smart city data, and the integrated management of smart cities' cyber-physical systems. This work is led by ITU's standardization expert group for 'IoT and smart cities and communities', [ITU-T Study Group 20](#).

Policy debate is hosted by the "[United for Smart Sustainable Cities \(U4SSC\) initiative](#)". Supported by 16 United Nations agencies and programmes, this initiative advocates for public policies to ensure that ICTs, and ICT standards in particular, play a definitive role in the transition to smart sustainable cities.

Singapore was one of the world's first cities to join the pilot project implementing and reporting on the Key Performance Indicators for Smart Sustainable Cities developed by ITU and the United Nations Economic Commission for Europe (UNECE), a project promoted by the U4SSC initiative.

ITU is pleased to support the aspirations of Singapore's 'Smart Nation' vision, which aims to enrich citizens' lives by capitalizing on the potential of ICTs to improve environmental sustainability, resilience, and equitable social and economic growth.

Singapore, one of the most connected cities in the world, champions the use of ICTs to improve economic efficiency as well as the happiness and safety of its citizens. Singapore is an ideal testbed for the ITU-UNECE Key Performance Indicators. The city state is an excellent ally to ITU in raising awareness of the great potential of ICTs to improve quality of life in our cities.

This case study of Singapore's Smart Nation strategy and associated experience with the ITU-UNECE Key Performance Indicators provides a valuable reference point to other cities pursuing smart city strategies. It also offers valuable guidance to ITU standards developers responsible for the refinement of the Key Performance Indicators.

Dr Chaesub Lee
Director, ITU Telecommunication Standardization Bureau



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Executive Summary

The International Telecommunication Union (ITU), the United Nations specialized agency for information and communication technologies (ICTs) and an international standards-developing organization, has created a framework of key performance indicators (KPIs) to help cities become smarter and more sustainable. The KPIs are categorized into various dimensions, including information and communication technologies; environmental sustainability; productivity; equity and social inclusion; quality of life; and physical infrastructure.

In 2015, Singapore initiated a partnership with ITU to implement the ITU KPIs on smart sustainable cities and to refine these KPIs with the help of other United Nations agencies. These KPIs are specifically designed to assess compliance with existing indicators used by other international cities, as well as to facilitate the transition to smart cities and measure Singapore's progress towards becoming a "Smart Nation".

This case study documents the key findings from the first year of collaboration between Singapore's Smart Nation initiative and ITU. It also highlights the activities carried out by different entities to support Singapore's Smart Nation initiative.

Section 1 of this case study delves into the history of the ITU smart city pilot project and the importance of standardization in fostering smart city transitions. This section also highlights the active role played by the United for Smart Sustainable Cities initiative (U4SSC) in driving smart city transitions worldwide by facilitating knowledge sharing and preparing appropriate guidelines for smart city transformations.

Section 2 provides a description of Singapore's Smart Nation initiative and traces the journey of the city-state since the adoption of its Smart Nation initiative in 2014. This section also presents the key domains of Singapore's smart city initiative, which include "Transport", "Home and Environment", "Business Productivity", "Health and Enabled Aging" and "Public Sector Services". Following on from the launch of the Smart Nation initiative, Section 2 also highlights the scope of the ITU KPI pilot project in Singapore and underscores the three main phases of the process carried out to implement the KPIs and assess Singapore's journey towards becoming smart and sustainable.

Section 3 explores and links the various smart city activities adopted under the Smart Nation initiative, with the KPI dimensions offering a deeper understanding of Singapore's efforts in each of these domains.

Based on the findings in Section 3, Section 4 highlights the best practices for aspiring smart cities, based on Singapore's experience in implementing the KPIs. One of the key findings of ITU's pilot project in Singapore (as described in Section 4) highlighted that the city-state needed to make greater efforts in the "Environmental Sustainability" domain by launching more ICT-based applications to stimulate public interest in this area. This domain may be boosted further in Singapore by creating an innovative self-sustaining framework, which incorporates the evolution of an urban system that is compatible with the available resources and promotes minimal environmental degradation. Section 4 also offers suggestions for Singapore to strengthen its position as a growing smart city and to improve the applicability of the KPIs to the country's specific case. As one of the aims of this pilot project was to improve the feasibility and applicability of the KPIs, Singapore provided input to the existing KPI definitions along with practical solutions to improve the data collection process. The key findings from this pilot project will contribute to the development of the world's first "Global Smart Sustainable Cities Index", promoted by 16 United Nations agencies, programmes and secretariats under the United for Smart Sustainable Cities (U4SSC) initiative.



Month	Total	Profit
January	100	15
February	80	12
March	90	14
April	110	16
May	120	18
June	130	20
July	140	22
August	150	24
September	160	26
October	170	28
November	180	30
December	190	32
% Year	85.5%	3.48/28



Abbreviations & acronyms

A*STAR	Agency for Science, Technology and Research
ACRA	Accounting and Corporate Regulatory Authority
ADSL	Asymmetric Digital Subscriber Line
BASH	Building Amazing Start-ups Here
BCA	Building and Construction Authority
DOS	Singapore Department of Statistics
EMA	Energy Market Authority
EMF	Electromagnetic fields
GovTech	Government Technology Agency of Singapore
ICT	Information and Communication Technologies
IHiS	Integrated Health Information Systems
IMDA	Infocomm Media Development Authority of Singapore
IMDA	Infocomm Media Development Authority of Singapore
IPOS	Intellectual Property Office of Singapore
ITU	International Telecommunication Union
ITU-T	ITU Telecommunication Standardization Sector
JTC	JTC Corporation
KPIs	Key performance indicators
LTA	Land Transport Authority
MAS	Monetary Authority of Singapore
MCCY	Ministry of Culture, Community and Youth
MCI	Ministry of Communications and Information
MHA	Ministry of Home Affairs
MOE	Ministry of Education
MOH	Ministry of Health
MOHH	MOH Holdings
MOM	Ministry of Manpower
MSF	Ministry of Social and Family Development
NEA	National Environment Agency
Next Gen NBN	Next Generation Nationwide Broadband Network
NParks	National Parks Board
NRF	National Research Foundation, Prime Minister's Office, Singapore
PA	The People's Association
PDPC	Personal Data Protection Commission

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PUB	Singapore's National Water Agency
SNDDG	Smart Nation and Digital Government Group
SNDDO	Smart Nation and Digital Government Office
SNPO	Smart Nation Programme Office
SNSP	Smart Nation Sensor Platform
Sport SG	Sport Singapore
SPRING Singapore	Standards, Productivity and Innovation Board
SSC	Smart Sustainable Cities
U4SSC	United for Smart Sustainable Cities
UNECE	United Nations Economic Commission for Europe
WHO	World Health Organization

1. Snapshot of smart sustainable cities: The ITU perspective

The International Telecommunication Union (ITU) is committed to supporting cities around the world with their evolution to a smart and sustainable city. In line with its role as an international standards-developing organization, ITU has developed a framework of policies, standards and guidelines on the role of information communication technologies (ICTs) in creating smart sustainable cities.

In October 2015, ITU and the United Nations Economic Commission for Europe (UNECE) developed the following definition for smart sustainable cities:

“A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects”.

ITU plays a significant role in providing a consolidated platform for discussions on smart city development policies, strategies and standards. This responds directly to the challenges of developing smart city initiatives in today’s global cities. Quite often, smart city activities are undertaken in a fragmented manner by governmental agencies working in isolation without using global standards.¹ With input from leading cities and smart city experts on the standards underway, ITU has strengthened its position as a central player in the development of international standards for smart sustainable cities around the globe.

ITU-T has developed a set of key performance indicators (KPIs) through its Study Groups to assist cities in integrating ICT services into their existing urban operations. These indicators are contained in Recommendation ITU-T Y.4901/L.1601, *Key performance indicators related to the use of information and communication technology in smart sustainable cities* and ITU-T Y.4902/L.1602, *Key performance indicators related to the sustainability impacts of information and communication technology in smart sustainable cities*. The main purpose of developing these KPIs was to provide cities with a credible monitoring system for their smart city transitions. Implementing these KPIs allows urban stakeholders to expedite the transition towards a smart and sustainable city, and discern the gaps and improvements required in their respective smart city plans thereby expediting desired smart city transformations across the globe.

The ITU-T Recommendations containing the KPIs were approved as international standards by the ITU-T Study Group 5 on Environment, Climate Change and Circular Economy.²

¹ Korsak, 2016.

² ITU-T Recommendations are international standards developed by ITU-T, the standards development wing of the International Telecommunication Union.

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The ITU KPIs for smart sustainable cities are sorted into six dimensions:³

- 1) Information & communications technologies.
- 2) Environmental sustainability.
- 3) Productivity.
- 4) Equity and social inclusion.
- 5) Quality of life.
- 6) Physical infrastructure.

Following closely on the heels of Dubai, Singapore – along with Valencia, Buenos Aires, Pully, Manizales, Rimini and Montevideo among others – has initiated a unique collaboration with ITU to test and verify the KPIs on smart sustainable cities for the period 2015–2017.

Accordingly, Recommendations ITU-T Y4901/L.1601 and ITU-T Y.4902/L.1602 are being used to help Singapore and other participating cities to analyse the considerations and impacts of ICT in making cities smarter and more sustainable. More specifically, these ITU-T Recommendations will provide current and future partner cities with an effective tool for self-assessments and evaluation of their “smartness” and “sustainability” schemes and plans. These standards are also intended to be used for monitoring the city’s ongoing performance with respect to its smart city goals.

Box 1 – United for Smart Sustainable Cities initiative

United for Smart Sustainable Cities

On 18 May 2016, ITU and UNECE established the United for Smart Sustainable Cities initiative (U4SSC), which serves as the international platform for knowledge sharing and developing best practices linked to smart sustainable cities.

This global platform was created in response to United Nations Sustainable Development Goal 11: “Make cities and human settlements inclusive, safe, resilient and sustainable.” Unlike other smart city platforms, this initiative is open to all interested parties who wish to contribute to its work.

U4SSC is now a UN initiative supported by the following bodies: the Convention on Biological Diversity (CBD); the Economic Commission for Latin America and the Caribbean (ECLAC); the Food and Agriculture Organization (FAO); the International Telecommunication Union (ITU); the Regional Bureau for Sciences in Latin America and the Caribbean of the United Nations Educational, Scientific and Cultural Organization (UNESCO); the United Nations Development Programme (UNDP); the United Nations Economic Commission for Africa (UNECA); the United Nations Economic Commission for Europe (UNECE); the United Nations Entity for Gender Equality and the Empowerment of Women (UN-Women); the United Nations Environment Programme (UN Environment); the United Nations Environment Programme Finance Initiative (UNEP-FI); the United Nations Framework Convention on Climate Change (UNFCCC); the United Nations Human Settlements Programme (UN-Habitat); the United Nations Industrial Development Organization (UNIDO); the United Nations University-Operating Unit on Policy-Driven Electronic Governance (UNU-EGOV); and the World Meteorological Organization (WMO).

³ These categories have been established based on core themes that organize commonalities between the indicators.

Box 1 – United for Smart Sustainable Cities initiative (end)

Since its inception, U4SSC has endorsed the adoption of public policies to encourage the use of information and communication technologies in establishing smart, sustainable cities.

Together with 100 participants from different sectors across the globe, this initiative facilitated the development of three publications: *Connecting cities and communities with the Sustainable Development Goals*; *Enhancing innovation and participation in smart sustainable cities*; and *Implementing SDG11 by connecting sustainability policies and urban planning practices through ICTs*. Each of these documents was prepared in line with the Sustainable Development Goals.

Following the first anniversary of the U4SSC launch, the 16 coordinating United Nations agencies of the initiative have joined other participants to propose deliverables in the following topics to be developed under U4SSC in 2017:

- Guidelines on tools and mechanisms to finance SSC projects
- Guidelines on strategies for circular cities
- City science application framework
- Guiding principles for artificial intelligence in cities
- Blockchain 4 cities

Box 2 – Advisory Board for Smart Sustainable Cities initiative

Advisory Board for Smart Sustainable Cities

Within the U4SSC, the Advisory Board for Smart Sustainable Cities was created to refine the KPIs in the ITU-T Recommendations. This Advisory Board comprises 16 United Nations agencies, city representatives and recognized global smart city experts.

The cities participating in the ITU's pilot project form an integral part of the Advisory Board, as the insights and inputs garnered during the course of the pilot project are utilized for the development of the "Global Smart Sustainable Cities' Index", the first of its kind in the world.

The pilot projects being conducted by ITU in the aforementioned cities will also help assess the feasibility of the existing KPIs and allow cities to refine the ITU-T Recommendations containing the KPIs. The upgrading of the KPIs presented in the existing ITU-T Recommendations is being conducted within the Advisory Board for Smart Sustainable Cities (see Box 2),⁴ which falls under the United for Smart Sustainable Cities initiative (see Box 1).

Singapore's progress in its Smart Nation initiative makes it ideal for the implementation of the ITU KPIs on Smart Sustainable Cities. Furthermore, Singapore's involvement in ITU-T Study Group 5 "Environmental, Climate Change and Circular Economy" and ITU-T Study Group 20 "Internet of Things and Smart Cities and Communities" also boosts its role as a key stakeholder in international standardization activities linked to Smart Sustainable Cities within ITU-T.

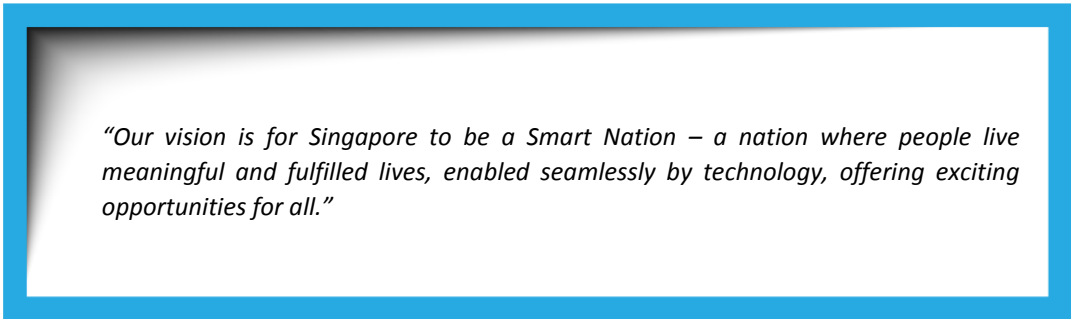
⁴ Membership of the Advisory Board is granted by invitation only. Cities participating in the ITU pilot project are subsequently invited to participate in the work of the Advisory Board.

With the active support of ITU, the first year of the pilot project in Singapore has ended. The results and key findings from the first year are presented in this case study. Based on these findings, this case study is expected to enable ITU to encourage the adoption of sustainable urban development plans by city administrators and assure other cities of similar smart city trajectories through the implementation of concrete smart strategies.

2. Conceptualizing Singapore’s “smart” and “sustainable” progress

2.1. Singapore’s Smart Nation journey

Singapore’s commitment to the smart city goals is, in part, fuelled by the need to anticipate and prepare for future megatrends. The country also faces more immediate challenges, including increasing population density⁵ and an aging population.⁶ To address these challenges, His Excellency Mr Lee Hsien Loong, Prime Minister of Singapore, has reaffirmed the country’s commitment to a sustainable future by stating:



“Our vision is for Singapore to be a Smart Nation – a nation where people live meaningful and fulfilled lives, enabled seamlessly by technology, offering exciting opportunities for all.”

In line with H.E Mr Lee Hsien Loong’s vision, in 2014, the Smart Nation Programme Office (SNPO) was established under the Prime Minister’s Office, to coordinate the city-state’s plans to build a Smart Nation. To further facilitate this transition, SNPO has identified key initiatives in five domains that are expected to have a profound impact on the quality of life of citizens in Singapore. ICTs are expected to play an integral role within these domains:

- Transport.
- Home and Environment.
- Business Productivity (known as the “Competitive Economy”).
- Health and Enabled Aging.
- Public Sector Services.

Government initiatives have been put in place to support ICT transformation in these domains. Citizens and businesses are also being encouraged to co-create impactful solutions with the government. At the same time, infrastructure, policies, and technologies were put in place to encourage innovation. This is expected to create the space for experimentation on the smart city front.

⁵ Singapore is the third most densely populated city in the world.

⁶ Villiers, n.d.

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Singapore is particularly well positioned to lead the way in transforming itself into a Smart Nation. The country's governance system simplifies the process of implementing smart city plans and allows public initiatives to be enacted relatively quickly. This is because it has a single layer of government (versus Federal and State-level administrations), allowing it to avoid the complex bureaucracies prevalent in other nations and island states. Additionally, Singapore is willing and able to dedicate funds to infrastructural enhancements designed to make its Smart Nation plans a reality.

With these advantages, Singapore has been moving to deploy sensors to increase the connectivity of its infrastructure with the cars and people who use them, in concert with advanced ICTs.⁷

In a recent development, Singapore has restructured the agencies responsible for its Smart Nation initiative.

In May 2017, the Smart Nation and Digital Government Office (SNDGO) office was founded under the Prime Minister's office (PMO). This brought together teams working on various aspects of Smart Nation and Digital Government policy, such as the SNPO, the Digital Government Directorate from the Ministry of Finance, and the Government Technology Policy Department from the Ministry of Communications and Information (MCI). The Government Technology Agency (GovTech), formerly a statutory board under the MCI,⁸ was placed directly under the PMO as the implementing arm of the SNDGO.

The move was intended to accelerate Singapore's Smart Nation efforts by enabling the government to work in a more integrated and responsive manner on Smart Nation and Digital Government matters.

SNDGO and GovTech are collectively referred to as the Smart Nation and Digital Government Group (SNDGG) within PMO.

A key role of the SNDGG is to work in partnership with government agencies, industry and citizens to (a) apply digital and smart technology to improve citizens' lives; (b) develop digital enablers and platforms for Smart Nation, to grow economic value and catalyse innovation by companies and citizens; and (c) to drive the digital transformation of the public service, strengthen government ICT infrastructure and improve public service delivery.

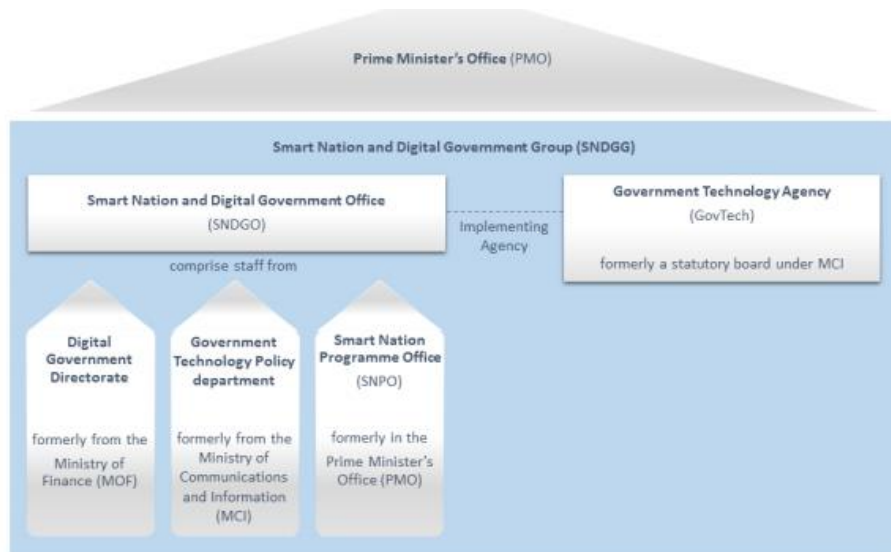
The key strategic national projects of the SNDGG include the creation of a national digital identity framework to facilitate digital transactions; the development of a national sensor platform with common infrastructure and analytics capabilities for public agencies; driving e-payments adoption; improving urban mobility; and the development of citizen-centric, user-friendly and personalised government services centred on key life moments.

⁷ GreenBiz, 2014.

⁸ GovTech was formed in Dec 2016.

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Figure 1 – Organizational chart for Smart Nation and Digital Government Group in the Prime Minister’s Office⁹



2.2. Scope of the KPI pilot project in Singapore

In October 2015, almost one year after the launch of the Smart Nation initiative, Singapore became the second city to collaborate with ITU on a two-year pilot project to evaluate the feasibility of certain KPIs for Smart Sustainable Cities. Singapore is currently one of many cities around the world that is assessing the efficiency and sustainability of its urban services using the KPIs developed by ITU.

This pilot project is the result of a cooperation agreement between Singapore and ITU signed in October 2015.

As noted by Dr Chaesub Lee, Director, Telecommunication Standardization Bureau, ITU:

“Singapore is an ideal testbed for ITU’s key performance indicators for smart sustainable cities as the city state is making good progress in its Smart Nation initiative.” “ITU is pleased to support the aspirations of Singapore’s Smart Nation vision, and we value the support that Singapore has offered to ITU’s planned development of a Global Smart Sustainable Cities Index.”

⁹ This figure has been taken directly from the following press-release: “Formation of The Smart Nation and Digital Government Group in the Prime Minister’s Office”.

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Similarly, Mr Leong Keng Thai, Deputy Chief Executive of the Infocomm Media Development Authority of Singapore (IMDA), remarked:

“Singapore is delighted to participate in this pilot exercise by ITU to trial smart cities’ indicators and develop a global smart cities index. This is an excellent opportunity for IMDA to share Singapore’s experience and learn from the other participating cities. Singapore’s Smart Nation journey is not just a process of building infrastructure, but is more importantly about improving lives of citizens and enhancing our economy by being a Smart Nation.”

This pilot project between Singapore and ITU seeks to test the KPIs developed by ITU-T, which laid the foundation for identifying the standardized requirements of smart sustainable cities. Currently, Singapore relies on various authorities and governmental departments to collect data and report on the different KPIs. Each agency is responsible for collecting the data of specific KPIs. The data and feedback were consolidated by the Infocomm Media Development Authority of Singapore (IMDA), which acted as the coordinating office for this pilot project.

This section highlights the various phases of the pilot project adopted in Singapore.

2.2.1. First phase of the pilot project

The first phase of the project involved the collection of data by various Singaporean authorities as per the Recommendations ITU-T Y.4901/L.1601, *KPIs related to the use of ICT in smart sustainable cities* and ITU-T Y4902/L.1602, *KPIs related to the sustainability impacts of ICT in smart sustainable cities*.¹⁰ These KPIs are categorized within the dimensions outlined in Table 1.¹¹

¹⁰ Approved on 5 June 2016.

¹¹ ITU and Smart Dubai Office, 2016.

**Table 1 – Six dimensions of Smart Sustainable Cities
(as categorised in the ITU-T Recommendations)**

Dimension	Description
<i>1) Information & Communication Technologies</i>	<ul style="list-style-type: none"> ▪ The KPIs within this dimension aim to assess the availability and use of ICT infrastructure in cities to facilitate smart sustainable city services. ▪ Cities should demonstrate that they have secure and reliable ICT infrastructure, services, and customer-friendly services and devices. ▪ ICT networks and information platforms should contain effective mitigation of possible risks associated with the use of ICTs (e.g. electromagnetic fields, privacy issues and child online protection).
<i>2) Environmental sustainability</i>	<ul style="list-style-type: none"> ▪ The KPIs within this dimension aim to assess the use of ICTs in supporting urban environmental services and improving the overall environmental quality in cities.
<i>3) Productivity</i>	<ul style="list-style-type: none"> ▪ The KPIs within this dimension aim to assess the use and impact of ICTs in the economic development of cities. These KPIs cover innovation, job creation, trade and productivity. ▪ These KPIs are also expected to play a pivotal role in assessing a city’s adoption of ICT to support socio-economic growth.
<i>4) Equity and social inclusion</i>	<ul style="list-style-type: none"> ▪ The KPIs within this dimension aim to assess the impact of the use of ICTs to promote urban equity, citizen participation and to enhance social inclusiveness. ▪ These KPIs focus on qualities such as equity, governance, city openness and public participation.
<i>5) Quality of life</i>	<ul style="list-style-type: none"> ▪ The KPIs within this dimension aim to assess the impact of ICTs to improve citizens’ quality of life. ▪ These KPIs focus on areas such as education, health and city safety.
<i>6) Physical infrastructure</i>	<ul style="list-style-type: none"> ▪ The KPIs within this dimension aim to assess the impact of ICTs on city infrastructure, development and sustainability. ▪ Aspects evaluated by these KPIs include infrastructure for the provision of city services such as water and waste management, energy, sewage, transport, road infrastructure and buildings.

During phase 1, ITU-T provided Singapore with guidance on the use and impact of KPIs related to ICT, in the context of Smart Sustainable Cities.

Having received the ITU-T Recommendations, Singapore reviewed the KPIs, in order to determine which agencies would be responsible for collecting the data for each indicator. IDA of Singapore (now known as IMDA) coordinated this effort and reached out to the other agencies (e.g. Singapore’s Department of Statistics and Singapore’s National Water Agency) to gather data for the relevant indicators. Most data sources came from administrative data or surveys.

For example, Singapore’s water quality parameters are measured by their National Water Agency (PUB) in accordance with the requirements of the World Health Organization (WHO) and Singapore’s National Environment Agency (NEA). These data are collected through routine and random sampling. The data are used to monitor Singapore’s compliance with drinking water regulations and are reported to senior management, regulators and the public.

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The data were also used to report on the relevant ITU KPI related to water quality as part of the overall assessment of Singapore’s smartness and sustainability (also as part of the pilot project).

The data collection process was coordinated by IMDA during the first half of 2016, with the involvement of the agencies listed in Table 2.

Table 2 – Key agencies involved in the Smart Nation Singapore initiative

Abbreviation	Entity Name	Description
A*STAR	Agency for Science, Technology and Research	This is the statutory board under the Ministry of Trade and Industry. It is the lead public sector agency that fosters scientific research and talent for a knowledge-based Singapore.
ACRA	Accounting and Corporate Regulatory Authority	This is the statutory board under the Ministry of Finance. It is the national regulator of business entities and public accountants.
BCA	Building and Construction Authority	This is the statutory board under the Ministry of National Development. It is the developer and regulator of Singapore’s building and construction industry.
DOS	Department of Statistics, Singapore	This is the national statistical authority responsible for disseminating official statistics on Singapore.
EMA	Energy Market Authority	This is the statutory board under the Ministry of Trade and Industry. It facilitates the development of a progressive energy landscape for sustained growth.
GovTech	Government Technology Agency of Singapore	This entity deploys ICT solutions within the public sector and develops the Smart Nation infrastructure and applications.
IMDA	Infocomm Media Development Authority of Singapore	This is the statutory board for Media and Communications and Information Technology. It also develops and regulates the infocomm and media sectors.
IPOS	Intellectual Property Office of Singapore	This is the statutory board under the Ministry of Law. It is responsible for legislating and registering intellectual property.
LTA	Land Transport Authority	This is the statutory board under the Ministry of Transport. It is responsible for planning, operating and maintaining land transport infrastructure and systems.
MCI	Ministry of Communications and Information	This ministry is responsible for information and communications technology, the media and design sectors, public libraries, and the government’s information and public communication policies.

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Table 2 – Key agencies involved in the Smart Nation Singapore initiative (end)

Abbreviation	Entity Name	Description
MCCY	Ministry of Culture, Community and Youth	This ministry is responsible for inspiring Singaporeans through arts and sports, strengthening community bonds and promoting volunteerism and philanthropy.
MOE	Ministry of Education	This ministry is responsible for the formulation and implementation of policies related to education in Singapore.
MOH	Ministry of Health	This ministry is responsible for providing information, raising health awareness and education, ensuring the accessibility of health services, and monitoring the quality of health services in Singapore.
MHA	Ministry of Home Affairs	This ministry is responsible for public safety, civil defence and immigration.
MOM	Ministry of Manpower	This ministry is responsible for forming and implementing workforce labour policies in Singapore.
MSF	Ministry of Social and Family Development	This ministry is responsible for nurturing resilient individuals, strong families and a caring society in Singapore.
MOHH	MOH Holdings	This organization serves as the holding company for Singapore’s health care institutions. It aims to enhance public health care by unlocking synergies and economies of scale.
NEA	National Environment Agency	This agency is the leading public organization responsible for improving and sustaining a clean and green environment in Singapore.
NParks	National Parks Board	This is the statutory board for the Ministry of National Development, responsible for providing and enhancing Singapore’s greenery.
PA	The People's Association	This association is the statutory board for the Ministry of Culture, Community and Youth. It promotes racial harmony and social cohesion.
PUB	Singapore’s National Water Agency	This is the statutory board under the Ministry of the Environment and Water Resources. This agency takes an integrated approach to managing Singapore’s water supply, water catchment areas and used water.
Sport SG	Sport Singapore	This is the statutory board of the Ministry of Culture, Community and Youth. It supports athletes and promotes sports as a platform for nation building.
SPRING Singapore	Standards, Productivity and Innovation Board	This is the statutory board under the Ministry of Trade and Industry. It is Singapore’s main agency for enterprise development.

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The involvement of ITU has helped Singapore conduct an internal review of its current ICT-related efforts, allowing the country to gain greater awareness of how ICTs can be used to monitor and improve its smart city processes and operations.

For this project, IMDA acted as the central coordinating office for data collection among other entities, but it did not play an active role in data collection. The new SNDGO may be ideally positioned to become more involved in actual data collection and review after the establishment of the Global Smart Sustainable Cities Index by the Advisory Board (see Box 2).

2.2.2. Second phase of the pilot project

After the data were collected, an independent auditor¹² performed an onsite validation and verification in July 2016. The objective of this project phase was to review and verify the data collected by the various Singaporean entities.

2.2.3. Third phase of the pilot project

The final phase of the project involved the preparation of this case study to:

- Summarize all the activities conducted during the pilot project.
- Review the suitability of the current KPIs in light of Singapore's situation.
- Provide suggestions for aspiring smart, sustainable cities.
- Offer feedback to help refine the current KPIs.

2.3. Verification methodology and findings

This independent verification aimed to examine the data submitted by Singapore, give feedback on the suitability of the KPIs and provide process insights for future revisions, based on Singapore's ability to collect and present data that were verifiable.

The verification process included:

- In-person interviews with staff and management at the various Singapore entities.
- A review of the KPI data submitted in person.
- A review of the data presented prior to the on-site assessment.
- A review of the underlying data sources.

¹² John Smiciklas served as the auditor for this process.

The verification process revealed the following findings:

Total Number of Indicators	108
KPI verified Data presented met the requirements of the KPI and were verifiable.	71
No data reviewed – KPI not verified Data was either not supplied or insufficient to allow for verification of the indicator.	37

The results were presented to Singapore in a formal verification report¹³ during the last quarter of 2016.

3. Overview of Singapore’s Smart Nation initiative (considering the KPI dimensions)

Before the start of the pilot project, Singapore had established a number of initiatives under its Smart Nation framework. These initiatives demonstrated that Singapore had already started out along the path towards becoming a smart sustainable city and as such was an ideal testing ground for the ITU KPIs. With Smart City initiatives already in place, Singapore was able to apply the KPIs to these existing initiatives and provide valuable feedback on how:

- KPIs fit into the current Smart Nation framework;
- KPIs could be used to measure an individual initiative’s progress;
- KPIs could be improved to provide better feedback; and
- new KPIs could be introduced to provide better feedback on smart city progress.

Singapore’s recent realignment of its Smart Nation programme directly under the PMO shows that this initiative is considered to be a key part of Singapore’s future. The knowledge gained through Singapore’s experience will continue to be an important part of ongoing efforts to make the KPIs and the upcoming Global Smart Sustainable Cities Index the most effective method to measure progress and provide guidance to urban stakeholders around the world on making their cities smarter and more sustainable.

The following sections will explore how each of the six dimensions of the ITU SSC KPIs fits into the current Smart Nation initiatives.

¹³ For privacy reasons, these results have not been presented publicly and the verification report has been kept confidential.

3.1. ICT dimension

The first dimension of ITU SSC KPIs relates to the implementation of ICT infrastructure and how that infrastructure is being used by a city's inhabitants. Since the mission of the Smart Nation initiative is to create an environment enabled by technology, where people can live a more prosperous and fulfilled life, the power of information and communication technologies is central to achieving Singapore's Smart Nation goals. ICT Infrastructure KPIs have been developed to measure progress in the deployment and use of various ICT technologies that are the key to a future smart sustainable city. Singapore has implemented a number of initiatives to increase the quality, reach and use of ICT technologies across the city, and these are discussed in this sub-section. These initiatives illustrate the leadership displayed by Singapore in implementing ICTs and highlight how these can form the backbone of a Smart Sustainable City.

Singapore's Next Generation Nationwide Broadband Network (Next Gen NBN) (see Box 3) is the wired network of the Next Generation National Infocomm Infrastructure (Next Gen NII). This project, under the Intelligent Nation 2015 (iN2015)¹⁴ master plan, seeks to transform Singapore into "an intelligent nation and global city, powered by infocomm."¹⁵

By offering pervasive, competitively priced broadband speeds of up to one Gigabit per second (one Gbps) and beyond, as well as other benefits, Next Gen NBN enables users to enjoy a richer broadband experience at prices comparable to Asymmetric Digital Subscriber Line (ADSL) and cable connections. Enterprises large and small will also benefit from the ease of access to ultra-high-speed broadband, and they can use infocomm more extensively to boost their productivity and competitiveness. More than 95 per cent of Singapore's homes and businesses are connected to the network. Approximately 1.1 million Next Gen NBN subscribers access fibre-based internet plans provided by more than 20 companies.¹⁶

Several of the service providers have differentiated themselves by offering targeted plans to meet the needs of specific user segments – such as "gamers" – by packaging their new ultra-high-speed broadband services with value-added services such as interactive television applications, cloud services and online learning resources. Others provide more attractive terms such as shorter, or flexible, contract periods.

¹⁴ www.iN2015.sg

¹⁵ Yang, 2006.

¹⁶ IMDA Singapore, 2017.

Box 3 – Next Gen NBN layers and functions

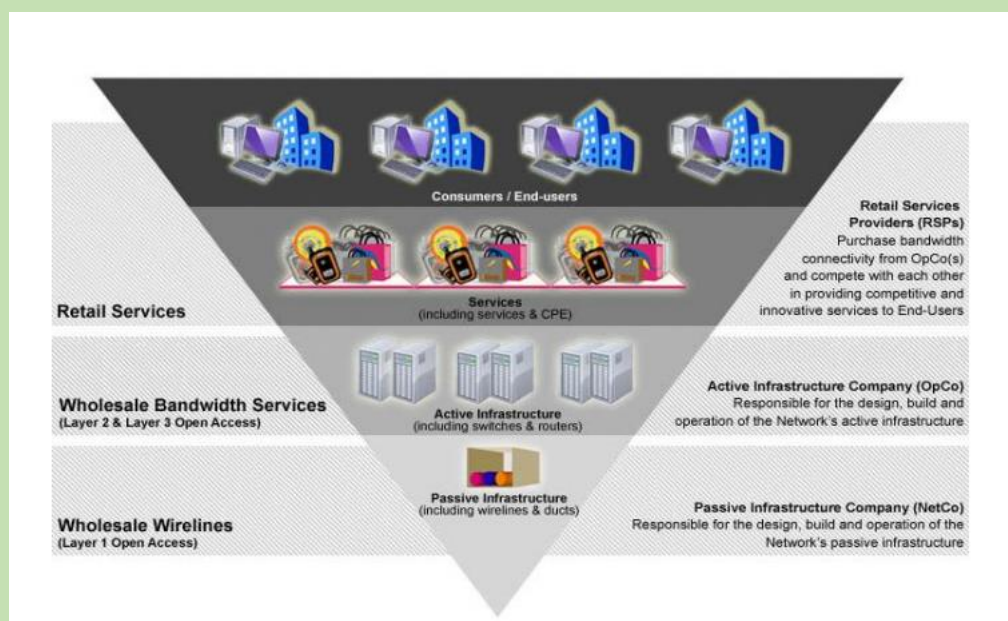
Next Gen NBN

The Next Gen NBN comprises three distinct industry layers:

- a) The Network Company (NetCo) will be responsible for designing, building and operating the passive infrastructure (such as dark fibre and ducts).
- b) The Operating Company (OpCo) will commit to offering wholesale network services over the active infrastructure, comprising switches and transmission equipment.
- c) The Retail Service Provider (RSP) layer will sell services to end users and industry as a fully competitive layer, covering markets like internet access and voice-over-IP telephony.¹⁷

For Singapore to fully benefit from the economic opportunities of Next Gen NBN, it is critical that Next Gen NBN provides effective open access to downstream operators. To achieve this, structural and operational separation was implemented at the NetCo and OpCo layers respectively. This has spurred greater vibrancy and competition at the services layer to benefit end users.

Figure 2 – Next Gen NBN industry layers



Tapping into its faster broadband and greater bandwidth, the Next Gen NBN will catalyse the creation of a greater range of innovative Next Gen services for end users in homes, offices, schools and outdoor locations. Some of the next generation services that could ride on Next Gen NBN include interactive Internet Protocol TV, telehealth, multi-user real-time gaming and cloud computing services. The Next Gen NBN will enable Singapore to exploit new economic opportunities in the digital age and enhance the vibrancy of its ICT sector. The following is an overview of some of the services Singaporeans can enjoy and the benefits they receive.

¹⁷ iDA Singapore, 2013.

Box 3 – Next Gen NBN layers and functions (end)

A. Fast upload and download speeds

With Next Gen NBN's scalable speeds of up to one Gigabit per second, uploading and downloading files will be significantly faster. Users will be able to download content in minutes rather than hours, while utilizing multiple high-bandwidth applications simultaneously. Among the many applications this technology enables are software-as-a-service (SaaS), remote data backup and file restoration and richer online gaming experiences.

B. High-definition video conferencing

From telecommuting to keeping in touch with loved ones, the way people communicate from home and office will be transformed with the emergence of high-definition (HD) video conferencing enabled by the Next Gen NBN. With HD video, voice and data communication running on the same broadband bandwidth, users will be able to conduct video conferences that are highly realistic, without the need for hefty investments and bulky setups.

C. Leveraging cloud computing

With the Next Gen NBN, businesses are well placed to make use of technologies such as cloud computing to maintain their competitiveness. Cloud services enable enterprises and end users to access huge computing power, software and data storage on a pay-as-you-go, on-demand basis. Providers of cloud services, such as SaaS and storage-as-a-service offer businesses an alternative to the conventional model of having to invest upfront on expensive infrastructure. Businesses, especially SMEs, can save by tapping into these services without incurring upfront investments in equipment and software licenses, and yet still enjoying the flexibility of scaling the applications to support their growth.

D. Facilitating services delivery, catalysing adoption

Beyond infrastructure deployment, Singapore has developed an overall strategy that focuses on catalysing the delivery, adoption and demand for services on the Next Gen NBN. An important guiding principle of the strategy is to ensure the direct engagement and involvement of the public and private sectors for a comprehensive and inclusive approach.

IMDA is also exploring the technology of the Heterogeneous Network (HetNet) to strengthen Singapore's connectivity framework. Their ultimate aim is to allow everyone and everything to be connected everywhere, at any time.

As outlined in the Infocomm Media 2025 master plan, HetNet represents the next advancement in Singapore's communications infrastructure. It is expected to support high-speed connectivity and successfully utilizes the network's resources. Users' devices will be able to switch effortlessly between data and Wi-Fi networks. IMDA states "HetNet also uses small cells to complement existing macro cells, to bolster network capacity and improve the mobile user experience. Consequently, the enhanced connectivity paves the way for innovative services to be created."¹⁸

Also, directly related to the ICT dimension KPIs is the Next Generation National Infocomm Infrastructure (Next Gen NII), which also serves as a regional telecommunication and trans-cable hub, a regional submarine cable systems and an international cable systems interconnect.

There are several additional investments in Singapore's ICT infrastructure under the Smart Nation initiative that will allow Singapore to report significant progress to various related KPIs.

¹⁸ Info-Communications Media Development Authority, 2016.

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These investments and related initiatives include:

- The Singapore Data Centre Park, a connected economic hub that attracts enterprises and MNCs to set up data centre operations.
- The Singapore Data Marketplace, which provides widespread access to large public datasets.
- The Singapore Television Audience Measurement, a system that measures traditional and digital viewership, as well as audience metrics across free and paid programming.
- The Singapore Internet Exchange, which promotes interconnectivity by providing a carrier-neutral point for internet traffic exchange.
- The IPv6 Transition Programme, through which Singapore and its resident enterprises will be transitioned to the new IPV6 internet protocol.
- Singapore's Wired initiative, which will extend fibre-optic internet connectivity to non-residential buildings via the Fibre Ready Scheme, through the IMDA ICT for Productivity and Growth programme. The investment also extends ultra-high-speed internet access to homes, schools, hospitals and government buildings through the Next Generation Nationwide Broadband Network project.

Another interesting initiative is the Smart Nation Sensor Platform (SNSP), a joint platform for government agencies, to enable greater connectivity and situational awareness by gathering and sharing useful data from sensors and other IoT devices. A harmonized suite of data fusion and analytics tools will analyse the anonymized data, providing agencies with insights on improving service delivery to citizens. This can potentially demonstrate the need for future KPIs related to IoT and their application to future smart sustainable cities.

While it is important for cities to establish a basic – and eventually an advanced – ICT infrastructure, ITU recognizes that the security of the ICT infrastructure is a key component that cannot be ignored. A lack of security can lead loss of data, loss of privacy and a loss of confidence in ICT networks. As such, the ICT dimension KPIs include cybersecurity measures.

Cybersecurity is a key requirement of Singapore's Smart Nation initiative. Singapore recognizes the risks associated with increased connectivity, and it has prioritized safeguarding efforts in relevant systems and networks that house data related to the security of citizens and the privacy of data. The government is working in partnership with public and private sector organizations, as well as residents, in order to help ensure data safety.

In October 2016, the Prime Minister, His Excellency, Mr Lee Hsien Loong launched Singapore's Cybersecurity Strategy, outlining strategies to tackle future cyber threats. The Prime Minister also laid out a plan to develop a cybersecurity pipeline of innovation and expertise and strengthen partnerships with international bodies.

While open data and data connectivity are key enablers of the Smart Nation initiative, Singapore's Government has also committed itself to making more data available to the public and third parties, in order to create greater opportunities for meaningful analysis. Data shared among government agencies are anonymized, so limiting the risk to citizens' privacy.

Moreover, Singapore's Government has moved to safeguard networks and systems. Singapore's data protection regime is managed centrally by the Personal Data Protection Commission (PDPC).

Other initiatives for consideration:

Wireless@SG

To complement Singapore's high broadband penetration, Wireless@SG is a nationwide free Wi-Fi network established by IMDA, with a total of 14,000 free hotspots. IMDA's goal is to increase the total number of hotspots to 20,000 by 2018. Currently, the hotspots are in places such as community centres, train stations, shopping malls and libraries, in order to provide the general public with free internet access.

Cross-border connectivity

Singapore is also rapidly expanding its submarine cable infrastructure. In June 2016, a consortium consisting of Singtel, China Mobile International, China Telecom Global, Global Transit, Google and KDDI started a service for a new trans-Pacific submarine cable system. A new submarine system, Super Sea Cable Networks (SEAX), was launched in October 2016, further boosting the speed of internet connections in Singapore. Singtel also announced plans to build a submarine cable linking Singapore and Perth by 2018.

Government ICT Infrastructure

The Singapore Government is building a robust data architecture, with consolidated data hubs and information platforms which serve a range of data analytics and service delivery purposes. The objective is to make it easy for agencies to pull the accurate and timely information they need, and to allow citizens to enjoy seamless transactions. **MyInfo** is one such data hub, which contains personal data from which various government digital services can immediately draw, thus saving citizens the trouble of manually keying in personal details that the government already has. The MyInfo function is also in the process of expanding to private sector services such as the opening of bank accounts.

3.2. Environmental sustainability dimension

The second dimension of ITU SSC KPIs relates to environmental sustainability and the environmental impact of a city on the environment (e.g. greenhouse gas emissions) and the impact of various factors (e.g. noise, smog) on its citizens. The KPIs also look at the use of ICTs in monitoring various environmental factors and ensuring the efficiency of utility networks. Singapore has recognized that a smart city must also be sustainable and consequently has included sustainability-related activities in its Smart Nation vision.

Singapore has implemented ICTs in the monitoring of air quality to help compliance with quality standards and in the water distribution network to improve the efficiency of delivery.

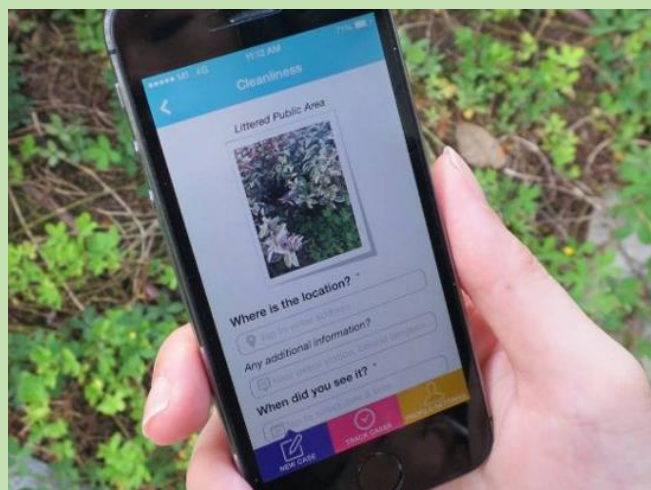
The launch of the OneService app (Figure 3) is another step forward for Singapore in this domain. To ensure that municipal services are delivered more effectively and to enhance interactions between residents and government agencies on local issues, the Municipal Services Office (MSO) and NEA have each developed a mobile app that offers the public a convenient means to receive environmental news updates or report municipal issues. The OneService mobile app adopts an issue-based approach where reported cases are routed to relevant agencies in a more efficient and coordinated manner than previous non-ICT based approaches.

Box 4 – OneService App for detect infestations

OneService app

The OneService app is also able to provide information on insect infestations that may cause health hazards. It is able to alert users if they are near dengue clusters. Users who enable the dengue cluster alert on the app will be able to see the number of cases in the neighbourhood, as well as the block of flats in which these cases are located. This helps improve the living environment and conditions for Singaporeans by potentially limiting the spread of this disease.

Figure 3 – OneService App



Other initiatives for consideration:

Smart-enabled homes

The Smart Enabled Home initiative in Yuhua estate is a collaborative effort between IMDA (then known as IDA) and HDB, in partnership with NEA, PUB and MOH, to explore opportunities to enable improved living conditions for residents in HDB households through the use of Smart Home technologies such as Home Energy Management Systems (HEMS) and the Home Water Management Systems (HWMS). In-home trials are being used to garner insights on residents' receptiveness towards smart home services and their impact on residents' behaviour in resource conservation through real-time usage trends for Energy and Water. The learning points from the trial will also guide the mass deployment of such smart home solutions throughout Singapore should the trial prove this to be feasible and financially viable.

Integrated storm management system ("Real-time sensors in drain")

Real-time sensors are progressively being deployed around Singapore to monitor the country's drainage system. These water level sensors provide data on water levels in the drains and canals, enhancing the monitoring of real-time conditions during heavy storms. An SMS alert system on the rising water level is also available on subscription and will facilitate timely updates to the public on potential flash floods. Plans are in progress to increase the number of sensors so expanding the coverage to more areas in Singapore.

24-Hour air quality monitoring network

The ambient air in Singapore is monitored through a network of air monitoring stations located in different parts of the island. Continuous analysers at the monitoring stations measure levels of particulate matter, sulphur dioxide, nitrogen dioxide, ozone and carbon monoxide. These pollutants are used in the calculation of the Pollution Standards Index (PSI). The hourly PSI is reported by region and made available to the public via a web-portal and mobile apps. The air quality network also allows tracking of long-term air quality trends to assess the effectiveness of pollution control policies.

3.3. Productivity dimension

The third dimension of ITU SSC KPIs revolves around the economy, productivity and innovation, with a particular focus on ICTs.

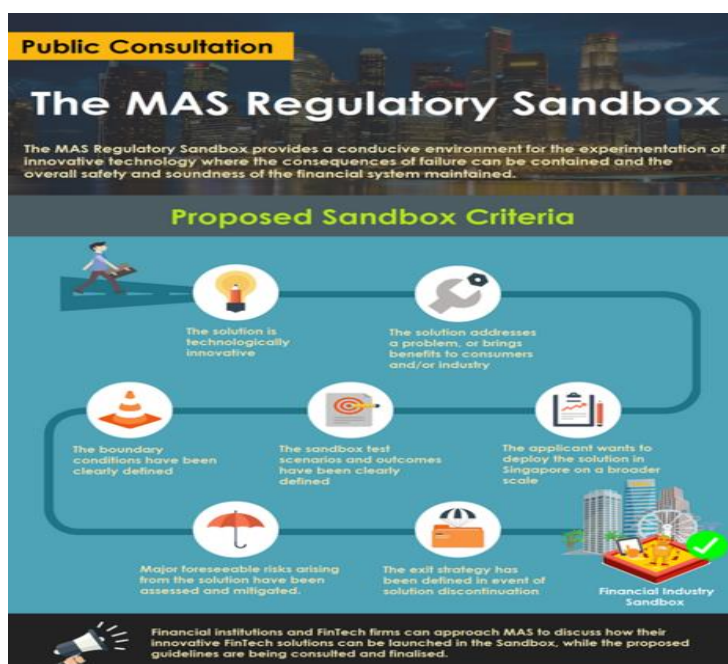
Singapore's Smart Nation's initiatives transcend internet connectivity and involve enabling technology to improve the business productivity of its economy's capital and labour force. The initiatives encompass tools and technology meant to improve inclusivity, economic growth and development into the future. Like many other developed countries around the world, Singapore faces issues of urban density and an aging population. To combat this, city-state stakeholders have engaged local universities, tech start-ups, research and development institutes and investment firms to enable big data and analytics technologies, and next-generation sensor networks. Enabling these technologies will encourage entrepreneurs from around the world to leverage Singapore's smart infrastructure and employ their solutions in Singapore. The country will create an environment in which new ideas can be tested, as the country offers itself as an "early adopter" further improving technologies that can be scaled globally. In order to advance and progress its ICT capabilities, Singapore intends to spend S\$0.4B support digital innovation from 2016 to 2020. This aligns with the ITU KPIs on investment in R&D and will continue to be measured going forward.

To drive innovation, start-up accelerators in JTC Corporation's Launchpad, IIPB BASH and Clean Tech Park are all examples of the strong presence of venture capitalists and multinational companies. The new Jurong Innovation District (JID), a technological and innovation cluster, helps to nurture creative innovations and provides enterprise exposure for different innovations to be validated and tested in the market. Singapore holds a high global ranking for its start-up ecosystem, with a top score among the countries in the Asia-Pacific region. Singapore ranks sixth in the world for global innovation and scores the highest in Global Connectedness in the Asia-Pacific region. The country also tops the global ranking for start-up talent (ahead even of Silicon Valley).

Another example of ICT and advancing a more productive ICT based economy is the Monetary Authority of Singapore (MAS) (Figure 4) opening its FinTech Innovation Lab to serve as a platform for the financial technology (FinTech) community to connect, collaborate and create with one another.¹⁹

¹⁹ Monetary Authority of Singapore.

Figure 4 – Monetary Authority of Singapore



To foster FinTech experiments and allow innovations a better chance to take root, the MAS is taking on a responsive and forward-looking regulatory approach. It released a consultation paper on proposed guidelines for a “regulatory sandbox” that will enable financial institutions and non-financial players to experiment with FinTech solutions. Plans are also in place to set up a one-stop virtual entity for all FinTech-related matters and to promote Singapore as a FinTech hub.

There has been a significant push for knowledge management, collaboration and deal-making among the start-ups that form Singapore’s tech cluster—Blocks 71, 73, and 79.²⁰ For example, in Block 79, Infocomm Investments Pte Ltd, a venture capital subsidiary of the IMDA, launched Building Amazing Start-ups Here (BASH). The programme is one-stop solution for start-ups that provides all the resources needed to scale an idea under one roof. These activities indicate alignment with the ITU KPIs measuring productivity, innovation, investment and employment.

Armed with the BASH initiative, Infocomm Investments and the IMDA plan to capitalize on Singapore’s reputation as the world’s most business-conducive country to establish partnerships with global start-up accelerators. Moreover, the nation is encouraging global start-ups to establish their presence in the growing Asian market by setting up operations in Singapore.²¹

²⁰ These blocks form the centre of Singapore's technology start-up ecosystem.

²¹ Singapore, 2015.

Other initiatives for consideration include:

Industry transformation maps

Under a S\$4.5B Industry Transformation Programme, Industry Transformation Maps will be developed for 23 industries in Singapore that cover 80 per cent of Singapore's GDP. These transformation maps will set out a suite of initiatives to raise productivity, develop skills, drive innovation (including digital innovation) and promote internationalization, so as to catalyse transformation in each industry.

SME Go Digital programme

The SMEs Go Digital programme was announced in Singapore's Budget in 2017 to help Small and Medium Enterprises (SMEs) deploy digital technology to boost their productivity and, at the same time, build digital capabilities in, for example, cybersecurity and data analytics that will enable them to thrive in the digital economy. The programme, which is administered by IMDA, will provide SMEs with access to pre-approved digital technology solutions, specialised advice on advanced digital needs such as in data analytics, and cybersecurity and Industry Digital Plans that will guide SMEs on the use of digital technology at each stage of their growth.

National Trade Platform

The National Trade Platform is being built. It will be a trade and logistics IT ecosystem connecting businesses, community systems and platforms, and government systems. This will replace Singapore's existing TradeNet as the National Single Window for permit declaration and TradeXchange as the platform connecting the trade and logistics community. It is designed as an open innovation platform into which businesses and service providers can tap to develop new applications to support evolving business needs.

3.4. Equity and social inclusion dimension

The fourth dimension of ITU SSC KPIs explores the impact of the use of ICTs in improving equity, governance, information flow and public participation. ICTs can provide the basis for engaging with citizens on a larger scale and at the same time providing those citizens with much more information on government services and performance.

In order to provide more open data and build citizen engagement, Singapore has developed an extensive ICT system, which can capture and integrate data for use by government, businesses and private citizens. Sensors and cameras across the city-state build on Singapore's existing digital system and enable the government to effectively assess traffic flow efficiency and performance, boost telecommunications signals and identify problems such as potholes and bumpy bus rides, as well as lawbreakers.²²

²² Watts & Purnell, 2016.

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By feeding data into sites such as data.gov.sg, Singapore’s Government has made much of the data collected available to businesses and citizens. Due to this open-sourced platform, data models can be created by anyone, thus increasing transparency between government and citizens and reducing research costs for Singapore’s many businesses.²³ To date, more than 100 applications have been created using the data.²⁴

In order to build a more digitally-based and responsive government, on 5 May 2016, Singapore officially launched the MyInfo application as a consent-based platform for Singapore residents to manage their personal data for government electronic transactions. After creating a profile, a user can click the “Retrieve MyInfo” button on online forms of participating e-services to retrieve and pre-fill the necessary data fields. Users give consent before any data are used in a form, and they can choose to be alerted whenever an e-service uses their personal data. MyInfo is available across 17 e-services (and counting), including applications for new flats, the Baby Bonus Scheme and polytechnic admissions.

This further demonstrates Singapore’s alignment with ITU KPIs that are measuring progress towards a more inclusive and more digitally-based Smart Sustainable City.

Singapore is also partnering with Microsoft on “Conversations as a Platform” to explore opportunities in co-creating next-generation digital government services. This includes the use of intelligent software programmes called chatbots for select public services.

Figure 5 – MyInfo platform homepage



Singapore has also recognized that ICTs can be an effective form of communicating with its citizenry, particularly if that group has adopted ICT technologies on a large scale, which has indeed happened. Mobile communication technologies and applications can be effective in facilitating emergency communication between the government and its citizens in times of crisis as the message can reach people even if they are not at a specific location. It also allows mass communication from Singapore inhabitants back to the government.

²³ Government of Singapore, 2015.

²⁴ Smart Nation Singapore, 2016.

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Consequently, MHA developed the SG Secure application. This is built on the three security pillars of vigilance, cohesion and resilience. Using the application, Singaporeans can be vigilant in reporting security threats, including any suspicious sightings. The application increases cohesion by providing alerts during major emergencies. Finally, the application increases community resilience by educating citizens on how to protect themselves and others during crises, including tips on improvised first aid skills and CPR-AED procedures.²⁵

As a tool to make citizens more engaged in decision-making, Singapore is developing Virtual Singapore, which will be a dynamic three-dimensional (3D) city model and collaborative platform, including 3D maps of Singapore. When completed, Virtual Singapore will be the authoritative 3D platform intended for public use. It will enable users from different sectors to develop sophisticated tools and applications for testing concepts and services, planning and decision-making and technology research to solve challenges in Singapore.²⁶

Other initiatives for consideration:

Digital inclusion

Singapore has a series of programmes to drive digital readiness and inclusion, which are spearheaded by agencies such as IMDA and GovTech. This is to ensure that all citizens have access to, and are confident in using, the digital technology that can improve their lives.

The programmes include:

- Enable IT Programme: Through the adoption of infocomm and assistive technology, this programme aims to enable people with disabilities to enhance their abilities in daily living activities, education and employment, as well as help them interact with others.
- NEU PC Plus Programme: This programme offers students and people with disabilities from low-income households the opportunity to own a brand new computer at an affordable price.
- Home Access Programme: This programme aims to close the digital divide by providing subsidised broadband bundle packages to low-income households without school-going children.
- Silver Infocomm Initiative: This initiative comprises various programmes to promote greater infocomm awareness and use among senior citizens, in order to help them continue to contribute meaningfully to society, to stay actively connected with their family and the community, and to avoid being left behind in our digital society. An example of this would be a customised training curriculum suitable for seniors with different interests and spoken languages. The curriculum supports informal learning in small groups, classroom workshops at Silver Infocomm Junctions, Silver IT Fest mass training or Intergen IT Bootcamp, which allows seniors of age 50 and above to go back to school and interact with their grandchildren or students from the neighbouring schools to learn basic infocomm skills. Not only do they pick up a new set of important skills, the programme is also a chance for intergeneration families to bond.

²⁵ Smart Nation Singapore, 2016.

²⁶ Retrieved from <https://www.nrf.gov.sg/programmes/virtual-singapore>

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- Digital Participation Initiative: This initiative consists of a series of programmes designed to encourage digital participation amongst Singaporeans by equipping them with computational thinking and making skills that enable them to engage meaningfully in a digitised lifestyle and allow them to seize the benefits and opportunities afforded by digital technologies.
- Better Internet Campaign: This is an annual campaign that seeks to raise awareness and educate online users on safe, civil and responsible online conduct.
- Citizen Connect Centres (CCCs): This is a network of 27 centres island-wide aimed at citizens who do not have a computer or internet access and need help to transact electronically with the government. It offers free access to the internet, with staff on-hand to help citizens and residents access the eCitizen Portal and perform online transactions.

3.5. Quality of life

The fifth dimension of ITU SSC KPIs measures and provides guidance on how to improve quality of life across education, health and safety.

Singapore acknowledges that a smart city requires citizens who have the ICT skills to build and use the smart city's functionalities. To make sure that citizens may fully benefit from the smart city tools, and use them, Singapore has created multiple initiatives, including a digital skills upgrading programme under the national SkillsFuture movement.

SkillsFuture can be described as a national movement that provides residents with the opportunity to hone their skills and realize their potential throughout their life. This movement is expected to enhance the skills, passion and contributions of every individual towards the next phase of development of an advanced economy and inclusive society. The city-state has partnered with educators such as the General Assembly to help equip people with workplace-ready ICT skills at all levels of education. Another of these initiatives is the Smart Nation Fellowship Programme, which invites experienced data scientists and engineers in Singapore or overseas to work with the government on short-term projects and create innovative solutions to solve national challenges.

SkillsFuture ensures a healthy channel for ICT skills and programmes including MyResponder and Elderly Patient Monitoring, which enable faster response times for health-care services. Designated websites also allow Singaporeans to access medical information in real time for themselves and their families.

Figure 6 – NLB mobile application



As important as a digitally literate citizenry is a dedication to ensure that future generations are enabled to participate fully in the new digital economy. A key measure of this are KPIs that relate to the use of ICTs within schools, which is fully implemented within all Singaporean schools. To further enhance education and literacy, Singaporeans can connect with library resources from their mobile devices. The NLB mobile application enables users to borrow library books or eBooks, save titles, browse and reserve spaces in library programmes, explore curated recommendations, share their favourite books and make payments online.²⁷

²⁷ Smart Nation Singapore, 2016.

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Another key area that is examined by ITU SSC KPIs is the implementation of ICTs within the health-care sector. Health care is a major expense for most governments worldwide and with an aging population (as is the case in Singapore) health-care costs can only be expected to increase. However, the implementation of ICTs has the possibility of increasing the efficiency and quality of health-care services with the potential to control costs.

In the case of Singapore, there are a number of initiatives that have been implemented to provide citizens with greater access to their medical information (see Box 5, HealthHub and Box 6: myResponder App), more information on leading healthy lives and methods for responding to medical emergencies.

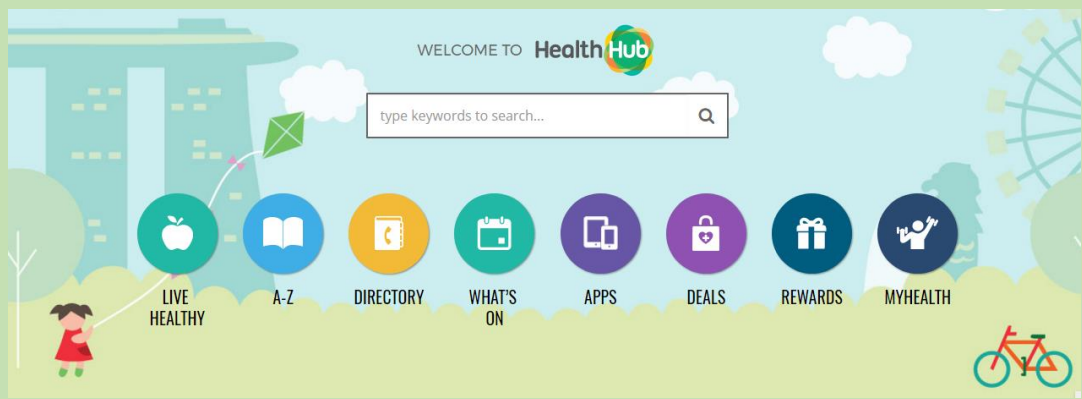
Box 5 – HealthHub

HealthHub

HealthHub is Singapore’s first one-stop, online health information and services portal and mobile application. It leverages technology to provide Singaporeans with easy access to reliable health-related content, key medical records and e-services. Medical records that can be accessed include hospital discharge summaries, medication prescription records, lab test results, health screening results, school health assessments, immunisation records and clinical care programme assessments. HealthHub aims to increase health literacy, encourage the adoption of healthy habits and nudge Singaporeans towards healthier lifestyles. It also encourages Singaporeans to take greater ownership of their own health and wellness, with personalised notification and rewards (such as NTUC Linkpoints).

HealthHub is being progressively enhanced to provide Singaporeans with reliable up-to-date, health-related content, as well as more categories of health records and health e-services. A Caregiver Access module was introduced in late 2016 that enables patients to grant permission for their caregivers to access their personal health and medical records. New features in 2017 include a new diabetes risk assessment tool and HealthHub Track, Singapore’s first free personal health management module to help users in diabetes prevention, healthy pregnancy, and weight loss.

Figure 7 – HealthHub mobile application screenshot



Box 6 – myResponder app

myResponder app

Another mobile ICT application that has been developed alerts trained first aid volunteers of any cardiac arrest victims who are within four hundred (400) meters of their location. This allows these trained individuals to administer first aid before an ambulance arrives. The purpose of the application is to increase cardiac arrest survival rates by reducing response time for such emergencies.

Figure 8 – myResponder application screenshot



Another example of the implementation of ICTs to increase health care outcomes and efficiencies is Singapore’s Elderly Monitoring System. The programmer employs smart sensor technology to detect abnormalities in daily activity and changes in vital signs with the aim to reduce the need for in-patient hospital care through increased preventive and out-patient care.

Once an abnormality is detected, the Elderly Monitoring System alerts caregivers. Elderly citizens can then request help for themselves from loved ones through wireless panic buttons.²⁸

Telehealth is defined in Singapore as the systematic provision of health-care services over physically separate environments using infocomm technologies. It enables the shift from institution-based care towards home and community care. It is also a ‘workforce multiplier’ to help health care providers improve productivity and multiply care provisioning capacity. The three key initiatives in Singapore’s Telehealth programme are Smart Health Video Consultation, Smart Health TeleRehab and Smart Health Vital Signs Monitoring.

Figure 9 – Smart Health Video consultation session



²⁸ Smart Nation Singapore, 2016.

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Smart Health Video Consultation was designed for various health care uses and settings, with high-quality video and audio for more accurate assessment of patients' conditions, and features such as multi-party video conferencing for consultation with multi-disciplinary care teams, annotation, file sharing and display of medical reports or images for reference during the consultation. This also enables our health-care teams to monitor patients more regularly than in traditional face-to-face appointments, which helps clinicians to deliver better care and improved health to the population.

Implemented in phases from November 2016, Smart Health Video Consultation is used in areas such as follow-up services for paediatric eczema pharmacy consultation, paediatric home-care services, lactation consultation, and speech therapy. It is also used for post-stroke, communicable disease, cancer patient care, mental health, geriatrics, community nursing and other conditions that do not require physical examination.

Figure 10 – Smart Health TeleRehab



Patients can enjoy greater convenience and access to rehabilitation therapy services with Smart Health TeleRehab, which was progressively rolled out from February 2017. Through wearable sensors and videos, patients can undergo prescribed rehabilitation exercises at a time and place of their choice. Easy to set up, the system detects and measures motor movements with sensors and algorithms. This enables immediate feedback to be given to patients about whether they are performing the exercises correctly. A video conferencing feature is available to enable patients to consult therapists remotely. Therapists are able to review their patients' progress asynchronously via smart dashboards. Therapists and therapy service providers will benefit from the productivity improvements.

In late 2017, Smart Health Vital Signs Monitoring will be rolled out enabling health-care providers will be able to monitor patients' vital signs at home or in the community. Importantly, this will enable more targeted and timely intervention for patients on post-discharge management and chronic disease management programmes.

Singapore introduced the National Electronic Health Record (NEHR) in 2013 as a key enabler to realise the "One Patient, One Health Record" vision. It enables authorised health-care professionals to view a patient's health-care history across Singapore's health ecosystem. Access to crucial clinical information helps health-care professionals make better informed decisions to enhance care delivery for patients and minimises duplicative tests. During medical emergencies, it could also save lives. For patients, selected information from the NEHR is available on HealthHub to empower them to manage their health better.

Figure 11 – Outpatient Pharmacy Automation System (OPAS)



In Robotics, the Outpatient Pharmacy Automation System (OPAS) enables pharmacies to handle high prescription loads safely and efficiently. It uses a combination of multi-disciplinary technologies, such as robot machines, bottle-dispensing machines, conveyor assembly, LED, barcode and RFID to automate the prescription filling process and improves manual picking accuracy for certain drugs. The system enables pharmacists to focus on reviewing the prescriptions, and has eliminated medication packing errors, significantly enhancing patient safety. By leveraging technology to automate the labour-intensive, tedious prescription filling process, OPAS has played an important role in helping our limited pool of skilled health-care staff improve their productivity and deliver quality care sustainably.

The Inpatient Pharmacy Automation System (IPAS) consists of drug packing machines, Automatic Dispensing Carts (ADCs) and medication carts that were fully integrated with Electronic Medical Record (EMR) to achieve closed loop medication management (CLMM). Each drawer of the medication carts is assigned to a patient upon barcoding the patient's wristband; the correct drawer will be opened up for nurse to serve medication. With IPAS, the "5 Rights" are met - Right Drug, Right Route, Right Dose, Right Patient and Right Time.

Figure 12 – Automated Guided Vehicles



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Automated Guided Vehicles (AGV) are used in various hospitals to transport items ranging from medication to linen to meals, around the hospital, saving on manpower. The AGVs, fitted with sensors to navigate amidst human movement, will work non-stop, 24 hours a day, seven days a week and are usually used in "back-of-house" areas. With AGVs, such transportation will be pre-determined, programmed and automated to ensure efficient day-to-day hospital operations.

Other initiatives for consideration:

School Picker

To help students and parents choose the most suitable school, GovTech has also launched School Picker, an app which shortlists schools that students might be interested in based on a set of criteria such as distance, co-curricular activities and special programmes. This is much more effective than simply listing information in a table format, which would be hard for users to use to make informed decisions.

Security

To strengthen security in our public spaces, we have installed more than 62,000 police cameras in public housing blocks and multi-storey carparks. As of May 2016, 2,300 pieces of video footage from cameras have provided useful leads which helped the police solve more than 1,100 cases. The next phase of police camera installation, named PolCam 2.0, will involve more sophisticated features such as pan-tilt-zoom and 360 degree fields of view, allowing police to automatically analyse closed-circuit television footage to detect unusual activities.

3.6. Physical infrastructure

The final dimension of ITU SSC KPIs focuses on the physical infrastructure of the city as it relates in particular to the delivery of basic utilities and public transportation facilities. These KPIs also measure the use and effectiveness of ICTs in monitoring these services, how this monitored information is communicated to the citizens and how governments can potentially use this information to provide better utility and transport services.

Singapore is a high-density nation that faces planning and infrastructure challenges given its limited land mass of about 710 square kilometres for its more than 5 million residents. As such, Singapore must balance the needs of a city – such as housing and commercial spaces – with national, suburban infrastructure needs – such as seaports, airports, utilities and military sites.²⁹

Singapore has grown significantly over the past few decades due, in part, to strategic physical infrastructure projects and the country's embrace of new technology that allows Singapore to innovate, collect better and more granular data and develop smarter tools. Recent improvements in ICT have allowed the country to make significant improvements to its traffic management, land-use planning, physical infrastructure, public transportation networks and hubs.

Singapore's infrastructure is governed by the Ministry of National Development and the Ministry of Transport.

With help from ITU, Singapore uses a set of indicators to measure the effectiveness of its smart and/or sustainable initiatives in transportation and urban development.

²⁹ Basu, 2016.

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Urban planning has a significant and long-term impact on how a city functions, and on its long-term sustainability. Poorly designed cities that focus only on private automobiles are usually inherently less sustainable and less resilient with their dependency on low-cost fossil fuels. It is also noted that cities lacking green spaces tend to have poorer air quality due to the lack of natural air filtration and cooling effect provided by green areas and trees. In response to these factors, Singapore's Urban Redevelopment Authority (URA) uses a smart information technology system to help its urban planners develop and implement plans for building a smarter and more sustainable nation. They use geospatial and real-time data for planning and development, to understand demographics for social services, and to map vehicular and pedestrian flows. These data are publicly available via the government's data-sharing portal, applications and other online sources.

The URA uses ePlanner, a geospatial urban planning application for advanced spatial visualization and data analytics. Developed in-house, ePlanner is also used by more than 25 agencies across many initiatives in Singapore, including the Housing Development Board, the Ministry of National Development and the Ministry of Home Affairs.³⁰

Figure 13 – ePlanner tool screenshot



Image Source: URA (Quek)

In land-scarce Singapore, efficient use of space is crucial as the built-up environment becomes more densely developed. With more facilities and infrastructure being built below ground level, there is an urgent need for better planning and management of underground space. BCA initiated a pilot project to convert legacy substructure plans at the Marina Bay and Jurong Lake District regions into 3-dimensional (3D) Building Information Models (BIM). This initiative, covering building basements, foundations and other subterranean structures, would enable better visualization of underground space use in these two densely built-up regions. Having such

³⁰ Singapore Government, 2016.

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3D visualization allows for optimization in the design of underground projects and enables planners to better plan the underground connections, such as from building to the mass rapid transit station. This initiative enables the Singapore Government to plan and manage future underground developments better.

Another example of the use of ICTs within an urban planning context includes the 2014 Housing & Development Board (HDB) development of a Smart HDB Town Framework to guide the development of Smart HDB Towns across four key dimensions: Smart Planning, Smart Environment, Smart Estate and Smart Living. Coincidentally, these four dimensions relate almost directly to various ITU KPIs and can be implemented to measure progress.

HDB created a Smart Town framework that augments and stretches its existing sustainability goals to make the towns more liveable, sustainable, efficient and safe. The framework maps out plans for smart towns and smart-enabled homes, focusing on the infrastructure (sensors, ICT networks and data hub) and applications that cover all facets of urban development, namely planning and urban design, estate management, quality living and community building.

Guided by the framework, HDB has deployed various smart technologies in its living laboratories, such as Yuhua and Punggol Eco-Town. Town planning is aided by environment simulations to improve thermal comfort, walkability and acoustics. Environment sensors and building sensors are deployed to capture data in a centralised data hub. With data, planning assumptions can be verified and data analytics carried out to enhance estate management. New homes are smart-enabled to facilitate the residents' adoption of smart home solutions such as utility management systems, in order to allow residents to control their energy and water consumption. Some of the residents at the Yuhua estate are the first in this pilot project to experience "smart living". The project assesses how some of the smart solutions can better integrate with residents' day-to-day lives before the technology is rolled-out in other areas.

In 2016, HDB reviewed and refined its Smart Town Framework. A fifth dimension, Smart Community was added to focus on leveraging technologies to help enhance community bonding efforts in HDB neighbourhoods and empowering communities to take greater ownership in driving greater sustainability in their living environment.

Figure 14 – Smart HDB Town Framework



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Singapore has made a conscious decision to provide low-cost, efficient and reliable public transportation that allows its citizens to participate fully in all aspects of city life. To further this goal, Singapore has developed and implemented Beeline SG, an application that utilizes crowd-sourced requests and anonymized public transport data to explore how transport networks can be made more adaptive to changing commuter demand.

Beeline introduced crowd-starting – which empowers commuters by allowing them to participate in the route designing process – in December 2016. Commuters benefit by pre-ordering passes on selected crowd-started routes, while bus operators are able to respond quicker with new routes as they learn more about the demands of their passengers. Users who have committed to crowd-start a route can easily keep track of its progress from the Beeline app since such routes are activated only after a minimum threshold of route passes have been sold. To date, eight crowd-started routes have been activated on Beeline.

Figure 15 – Example of Public Transport application in Singapore

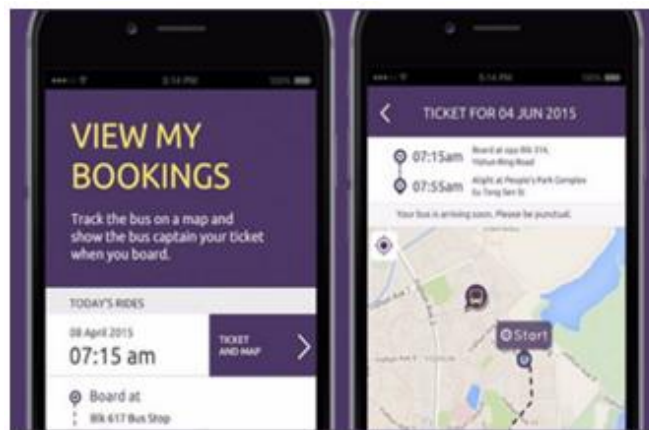


Image: GovTech

A Common Fleet Management System (CFMS), completed and installed in all public buses in mid-2017, also enables the Land Transport Authority and operators to monitor the location and performance of bus fleets. The CFMS provides live updates on bus locations, traffic accidents and arrival times, allowing bus operations to work actively with bus captains to improve bus arrival regularity.

SMART Water Grid

The SMART Water Grid system supports the mission to supply good water to its customers 24/7. More than 320 sensors and data analytic tools are deployed island-wide to detect pipe leaks, and to monitor the water pressure, flow and quality in the network. As the networks of sensors continue to expand, operators will also be equipped with the necessary data and tools for timely incident management, improving response time to serve the customers better.

4. Lessons learned from Singapore/Examining the core of the Smart Nation initiative

4.1. Best practices for aspiring Smart Sustainable Cities

In general, Singapore found that the ITU-KPIs were effective in helping the country transition into a smart, sustainable city, taking into consideration the interplay between ICT and the country's environment, economy, government, infrastructure and the residents' daily lives. However, it was noted that there are regional differences (including population density, terrain, climate, availability of resources, cultural and social restrictions) that may affect the validity of certain metrics.

Telemedicine, for instance, is often seen as a smart technology that can increase patient access and overcome geographical barriers to care for those who live in less populous regions. However, in Singapore, where all citizens already have access to brick-and-mortar health care, population distribution does not play a key role in access. Instead, in a small city like Singapore, it is not used to overcome geographical barriers but rather to support patients with mobility issues, provide greater convenience to patients through time and cost savings, and operate as a work-force-multiplier to address the challenges of shrinking manpower in the health-care sector. Furthermore, it is possible that the adoption of telehealth or telemedicine could, in some cases, increase a patient's costs per "unit of care" due to over-use of services. This could make telehealth an unsustainable practice without careful planning, re-engineering of the care process and an assessment of the business case for each type of telemedicine service with proper clinical protocols and safeguards.

As such, Singapore suggests that cities implement smart technologies, taking the implementation and additional costs into consideration, over existing brick-and-mortar health care services). Only by taking into consideration the costs associated with this step, which is aimed at improving health outcomes, can system-level cost savings, and/or increases in productivity be obtained. Given the myriad ways to leverage various technologies (e.g. image store-and-forward, real-time video communication, vital sign monitoring devices and body sensors), there is no one-size-fits-all telemedicine solution for patient populations.

As regards general data collection, for Singapore, most of the data will be collected from sensors and cameras that are embedded in its public infrastructure and will be fed to repositories, known as GEOSPACE (for 3D geospatial data) and the Smart Nation Platform (for other sensor-collected data). These repositories will be controlled by the government. Through modelling and simulations, these repositories could be used to analyse and improve the delivery of government services. For example, the government could use the data to project the spread of a disease (e.g. Zika) and develop suitable containment strategies.

However, there are groups of people who fear their privacy will be invaded through cyber-attacks and that sensitive personal information will be shared without their consent with third parties.³¹ Even before the launch of the Smart Nation initiative, Singapore had already implemented strict regulations that require each agency to protect all data in their possession against the risks of unauthorized access. Sensitive personal data, such as tax and retirement savings data, are protected under the law. For the protection of personal data, agencies are to adhere to additional safeguards, including data encryption, secure storage and transmission

³¹ Watts and Purnell, "Singapore Is Taking the 'Smart City' to a Whole New Level", 2016.

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requirements. These regulations are expected to assuage tensions and doubts regarding the protection of data, enabling Singapore to move forward with its smart city mission.

Given the strides Singapore has made in the domain of smart sustainable cities and associated policies and laws, this sub-section will highlight a few smart sustainable city best practices³² based on Singapore’s smart city activities. The following content will also feature a few additional measures that are recommended for adoption by Singapore and other aspiring smart sustainable cities around the world as a part of their smart city transitions.

4.1.1. ICTs

The key theme assessed by these KPIs is the level of implementation of ICTs. A smart city requires fixed and mobile ICT infrastructures to allow for the deployment of applications that will:

- (i) Facilitate the development of smart sustainable cities;
- (ii) Promote civic engagement; and
- (iii) Foster improvements in sustainability (gained through efficiencies in operations).

Measures adopted by Singapore	Suggested action for other aspiring smart sustainable cities (based on Singapore’s experience)
Singapore, through its Next Generation Nationwide Broadband Network and mobile operators, provides 3G and 4G services, which forms the ICT backbone of the Smart Nation initiative. The reported KPIs in the ICT domain demonstrate that Singapore has maintained a high level of development in this area; citizens have ready access to advanced internet capabilities.	Urban stakeholders, in line with their smart city goals, should also strive to maintain a high level of development and adoption of appropriate digital technologies which will facilitate their city’s smart transformation and offer their citizens improved internet access.
Singapore has adopted the WHO guidelines on Electromagnetic Field (EMF) exposure for mobile base stations. As such, the government maintains EMF levels within exposure limits and provides protection to all citizens.	It is recommended that aspiring smart sustainable cities adhere to the WHO guidelines on EMF exposure to ensure that their smart city goals do not jeopardize public health. Cities should also consider implementing ITU’s international standards (ITU-T Recommendations) on EMF management and control, taking as reference, the work carried out by ITU-T Study Group 5 on “Environment, Climate Change and Circular Economy”. ³³

³² Given the dynamic and individualistic nature of urban systems, readers are cautioned that implementing these best practices may not guarantee a high level of verifiability of the data provided. However, these best practices are expected to improve the overall applicability of the KPIs in emerging smart sustainable cities.

³³ These ITU-T Recommendations include K.52, K.74, K.78, K.83, K.87, K.100, K.113 and K.115.

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Measures adopted by Singapore	Suggested action for other aspiring smart sustainable cities (based on Singapore's experience)
<p>Within its Smart Nation initiative, Singapore recognizes that data security is critical to ensure that citizens' data are protected and that systems and applications are available and operate as needed.</p>	<p>Smart city systems tend to generate large volumes of data, including sensitive data containing personal information of citizens. As such, appropriate measures must be taken to ensure that collected data are secured and protected by law, to thwart misuse of information and unauthorized access.</p>
<p>Singapore is developing the Smart Nation Sensor Platform (SNP) to enable greater connectivity and situational awareness by gathering and sharing useful data from sensors and other IoT devices.</p>	<p>City stakeholders could introduce similar e-platforms that will foster the integration of ICTs into urban operations and create a network of devices for public use and benefit.</p>
<p>Singapore launched the "Research, Innovation and Enterprise 2020" plan, one aspect of which is investment in promoting research and development in ICTs.</p>	<p>Urban stakeholders should study the needs of their city carefully and invest judiciously in programmes through which advancements in ICT can be brought about. Such programmes should be directed at exploring the role of ICTs in facilitating (cost-effective) socio-economic growth.</p>

Further actions needed for Singapore and other aspiring smart sustainable cities

Curbing cyberbullying

Accompanying improved access to the internet among children and young adults, is an increase in cyberbullying cases around the world. Aspiring smart sustainable cities should take note of the adverse effects that cyberbullying has on the emotional development of children and young adults. Accordingly, policies and legislative frameworks should be enacted to protect individuals from trauma caused by cyberbullying and punish those responsible for it.

Note: *Singapore has adopted the Protection from Harassment Act 2014 (PHA) which criminalizes harassment, stalking and other anti-social behaviour. This statute also aims to curb cyberbullying and online harassment in the future. Singapore also places strong focus on Cyber-Wellness education to nurture students as responsible digital learners and positive peer influences to each other. Cyber-Wellness is taught in the formal curriculum in schools and reinforced through school-wide programmes and events such as the National Summit on Cyber-Wellness Student Advocacy. There are also resources provided for schools to engage students, teachers, and parents on cyber issues. Singapore has an Inter-Ministry Cyber-Wellness Steering Committee to coordinate the Government's efforts in promoting Cyber-Wellness for youths.*

4.1.2. Environmental sustainability

The key theme assessed by the KPIs in the domain of environmental sustainability is the level of ICT integration to support the city’s environmental sustainability. These KPIs also provide a baseline for future comparisons.³⁴

Data collected for the KPIs show that Singapore has a well-developed system for monitoring air and water quality. Singapore is also implementing ICT programmes to better monitor and manage progress in this area. It is noted that achieving efficient resource use via ICTs will be key to its long-term environmental sustainability, given Singapore’s limited resources (including spatial unavailability).

Measures adopted by Singapore	Suggested action for other aspiring smart sustainable cities (based on Singapore’s experience)
Singapore has deployed a well-developed ICT-based system to monitor air and water quality.	City stakeholders are encouraged to use ICT-based systems to monitor the quality of water and air to collect clear data used to inform environmental policies. It is ideal to measure water delivery efficiencies to preserve and fully utilize this limited resource.
Singapore’s 2020 air quality targets are benchmarked against the WHO Interim Targets and Air Quality Guidelines. Data showed that air quality was within the “good and moderate” range for more than 87 per cent of 2015.	City stakeholders are encouraged to review and implement the guidelines for air quality as developed by WHO to help ensure suitable air quality to protect the health of their citizens.

Further actions needed for Singapore and other aspiring smart sustainable cities

Greenhouse Gas Emission (GHG) monitoring

The release of GHG emissions into the atmosphere remains a matter of concern for global leaders. Specific targets stipulated in the Paris Agreement, Sustainable Development Goal 13 and the Connect 2020 Agenda are all directed towards lowering GHG emissions. Considering these international instruments, aspiring smart sustainable cities should incorporate relevant policies and standards into their smart city framework to ensure that their transitions will help address global warming and other climate change-related issues. Aspiring smart sustainable cities may also set up e-monitoring systems within their territories and regulate GHG emissions per sector.

³⁴ The Environmental Sustainability KPIs provide a baseline for comparison between regions, as well as between different time periods for the same city. The latter helps identify the improvements the city has made during a certain period.

Noise monitoring

Noise pollution in cities remains a major hazard, with prolonged over-exposure potentially leading to hearing loss, distortion of the sleep cycle and disturbances to animals. In aspiring smart sustainable cities with growing populations, an effective ICT-based noise monitoring system may be required to maintain the tranquillity of the urban sphere.

4.1.3. Productivity

The KPIs related to productivity are meant to help analyse the general economic well-being and innovation of a city and measure the support from ICTs in that process.

These KPIs proved slightly more difficult to report on. However, the feedback from Singapore is expected to be crucial for the KPI improvement process.

The data collected did show that Singapore, its citizens and its private sector are developing and using ICTs to further the economic growth of their city and create a culture of innovation. Singapore is a small island nation, and it cannot rely solely on an abundance of natural resources for growth. Therefore, it must focus on a knowledge economy to compete in the global marketplace, which it has done quite successfully up to this point.

Measures adopted by Singapore	Suggested action for other aspiring smart sustainable cities (based on Singapore’s experience)
Singapore has implemented, through its Smart Nation Initiative, an ICT framework and backbone that is part of its smart city transformation.	City stakeholders are encouraged to use the implementation of ICT systems as the basis for the development of a low-carbon, knowledge-based economy. This ICT backbone should be supported by public policies that encourage and reward innovation.

Further actions needed for Singapore and other aspiring smart sustainable cities

Trade

Cities are not isolated systems. As trade increasingly impacts national economies, aspiring smart sustainable cities must monitor the effect of trade on their transformations. These cities should focus on moving away from restrictive trade policies and showcase how their smart city activities could benefit from promoting trade liberalization.

4.1.4. Equity and social inclusion

The KPIs within this domain focus on the themes of openness, public participation and governance. These KPIs also proved to be challenging to collect. However, data did indicate that in terms of digital inclusion, Singapore has well-developed plans to bridge the digital divide.³⁵ Notable examples of such initiatives include iBEGIN and iLIVE that offer customised curricula for senior citizens to learn basic infocomm and digital lifestyle skills respectively.³⁶

Singapore has also made significant progress in developing a framework enabling the creation of open data platforms for public and private sector use. Such platforms lay the groundwork for more transparent and more efficient governance.

Measures adopted by Singapore	Suggested action for other aspiring smart sustainable cities (based on Singapore’s experience)
Singapore has implemented a number of public programmes targeted at those who need assistance (including senior citizens and disabled individuals) to be able to access digital services from the government.	City stakeholders are encouraged to use various tools and policies to reach those left behind in the digital divide. These policies should focus on senior citizens, disabled individuals and the economically disadvantaged to raise their digital skills and make the delivery of government services electronically possible.

Further actions needed for Singapore and other aspiring smart sustainable cities

Citizen Satisfaction

Some cities have adopted measures for increasing public participation in urban administration activities. Despite such initiatives, citizens may still hold a feeling of dissatisfaction about their involvement in urban operations and decision making. In such situations, cities should adopt policies, frameworks and initiatives to generate a feeling of social inclusion.

Note: *Singapore agencies consult citizens regularly on policies, regulations and conduct focus group discussions to test and validate our services before rolling them out fully. While agencies can proceed with their own engagement, REACH serves an agency facilitating whole-of-government efforts to engage and connect with Singaporeans on national and social issues. Ministries and agencies will post their public consultation paper on REACH portal and/or their own websites for public comments.*

³⁵ As envisioned in Goal 2 “Inclusiveness” of the Connect 2020 Agenda.

³⁶ Infocomm Media Development Authority, Singapore: <https://www.imda.gov.sg/community/consumer-education/digital-inclusion/silver-infocomm-initiative/silver-infocomm-curriculum>

4.1.5. Quality of life

This dimension is focused on measures that improve the quality of life within a city. The KPIs within this domain will also measure the extent of ICT implementation within the education, health and safety sectors.

Singapore has periodically reviewed our ICT in Education programmes. By focusing on raising teachers’ competency in teaching with ICT, developing innovative ICT teaching practices, providing optimal infrastructure to support schools and integrating ICT use in the national curriculum, Singapore has laid a strong foundation in harnessing ICT effectively to support the educational experiences of students.

Most recently, Singapore announced the launch of the Singapore Student Learning Space (SLS), an online learning portal that will support teaching and learning in all schools. Through the SLS, every student will have equal access to quality online learning resources. Learning is made more engaging through a variety of interactive resources such as videos, animations, simulations, games and quizzes. Authenticity is also enhanced, since many of these resources are developed in collaboration with industry and external partners to provide real-world context to concepts learned in class.

Singapore has also embarked on a Code@SG movement, managed by IMDA, to see coding and computational thinking taught at various levels.

Measures adopted by Singapore	Suggested action for other aspiring smart sustainable cities (based on Singapore’s experience)
Singapore has implemented an extensive ICT-based system for public safety and for disaster management. Programmes like these give Singapore a reputation as one of the world’s safest cities.	It is essential that urban stakeholders incorporate appropriate disaster risk management technologies into their existing urban operations to protect vulnerable sections of societies from natural hazards and other climate change-related disasters.
In Singapore, all students have access to ICT-enabled learning systems in schools.	Urban stakeholders are encouraged to adopt compulsory e-learning systems for students.

4.1.6. Physical infrastructure

The KPIs in this domain cover the non-ICT physical infrastructure in the city that supports the economy and provides basic services. These services include water, waste management, energy, sewage, transport, road infrastructure and buildings.

The extent and efficiency of Singapore’s public transit system is demonstrated by the fact that two-thirds of Singaporeans travel to work via public transit.

Singapore is just starting to release technologies (i.e. smart meters) that will help it gain efficiencies in its basic services infrastructure.

Measures adopted by Singapore	Suggested action for other aspiring smart sustainable cities (based on Singapore’s experience)
<p>Singapore has a high level of ICT road network monitoring, covering 81 per cent of its collector roads and 100 per cent of its expressways. Even about 50 per cent of local access roads are monitored with ICTs.</p>	<p>City stakeholders are encouraged to implement ICT systems as the basis for developing a more efficient road system, decrease traffic flows and reduce the environmental effects of congestion.</p>
<p>The BCA Green Mark scheme was launched in 2005 as an initiative to drive Singapore’s construction industry towards more environmental-friendly buildings. It is a rigorous rating scheme that looks beyond facilitating reduction in energy use and material resource usage so as to reduce potential environmental impact to the Built Environment.</p> <p>In addition, Singapore’s Green Building Council has developed and launched a suite of certification programmes on green building product labelling covering building, construction materials, as well as for the environmental sustainability consultancy services. As a direct result, the labelling scheme is recognized under the BCA Green Mark scheme, allowing certified products to accrue additional points that count towards a project’s eventual BCA Green Mark rating.</p> <p>This level of effort is not generally observed in smaller nations. As such, Singapore’s efforts in this endeavour demonstrate its resolve to be a world leader in the sustainability of its built environment.</p>	<p>Urban stakeholders should develop their own national certification programmes for building projects to ensure that buildings adhere to guidelines. These certification schemes could be developed based on existing international standards on intelligent sustainable buildings.</p>

Further actions needed for Singapore and other aspiring smart sustainable cities

Parking Systems

Given the ever-increasing traffic, aspiring smart sustainable cities should ensure that adequate public parking exists, especially in city centres. Insufficient parking leads to incidents of trespassing and illegal parking, which may obstruct traffic flow.

Sustainable Development Goals and the New Urban Agenda

Aspiring smart sustainable cities should utilize frameworks and KPIs to assist urban stakeholders in their smart city transformations and to achieve the targets of the Sustainable Development Goals and the New Urban Agenda.

Note: *Health records relating to criminal cases, severe mental illnesses, cancer treatments, birth and deaths should be maintained indefinitely.*

4.2. Methodological improvements for the Smart City KPI pilot project process

A number of KPI improvement areas surfaced during the smart city pilot project in Singapore.

As previously mentioned, Singapore's pilot project helped the KPI revision process. It is only through the dedicated efforts of the stakeholders in Singapore and their honest feedback on the challenges, strengths and weaknesses of each KPI that the existing data collection and verification processes have been improved.

Unambiguous definitions and methodologies for each KPI will improve data collection and ensure that data collected are easily verifiable and comparable against global peers. Data collected through a more defined process will help improve data quality, which will in turn facilitate credible inputs to the Global Smart Sustainable Cities Index.

Taking into consideration that the KPI definitions and data collection methodologies have been improved, Singapore and other cities are now able to collect consistent data in a structured way, develop goals and targets for each KPI and subsequently collect data regularly to track progress towards these goals.

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The United for Smart Sustainable Cities (U4SSC) collaborative initiative has provided new expert guidance for the transition to more efficient, sustainable urban environments –in the form of a collection methodology. Sixteen United Nations bodies and over 50 cities, including Singapore, contributed to the further improvement of the KPIs, a process coordinated by ITU and the UN Economic Commission for Europe (UNECE).

The U4SSC Collection methodology for the Key Performance Indicators for Smart Sustainable Cities provides cities with a methodology to collect core data and information necessary to the assessment of their progress in implementing smart city strategies. The collection methodology developed by U4SSC complements the three sets of KPIs for smart sustainable cities developed by ITU and UNECE that have been implemented in Singapore.

4.3. Improvement areas for KPIs

Following the completion of the first year of the pilot project in Singapore, some indicators that would measure “e-government activities” have been suggested by the country.

Some efforts – including the conversion of documents into an electronic format and encouraging digital communications between citizens and government – have been priorities for the city-state since the 1980s. Since that time, Singapore has integrated data, processes and IT systems across most government agencies, deploying more than 300 mobile government services. These actions indicate the country’s commitment to collaborate with its citizens.

As such, Singapore suggested that certain e-government indicators be measured. Some of these suggested indicators include:

- 1) Top 10 public services available electronically.
- 2) Percentage of citizens transacting online with the government via e-services.
- 3) Percentage of public sector procurement conducted electronically.
- 4) Percentage of public sector invoicing completed electronically.

At the end of the first year of the pilot project with ITU, Singapore found that it was already tracking most of the KPIs in each dimension. However, the Singapore Government noted that there were more efficient methods for tracking and collecting the data for the existing KPIs (see Box 7).

Box 7 – Tracking of broadband subscriptions in Singapore

Tracking of broadband subscriptions in Singapore

Singapore was previously tracking fixed broadband subscriptions per 100 inhabitants. However, only one fibre subscription is needed per household. In general, Asian households tend to have more family members under one roof than European households. Therefore, if Singapore were to measure fixed broadband subscriptions per 100 inhabitants, their results would typically be below 30 per cent, while most European countries could achieve results above 30 per cent. Through this exercise, Singapore realized that fixed-broadband subscriptions should be measured per 100 households instead of 100 inhabitants.

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The role of the various Singapore Government agencies was not only to provide data but also to provide feedback on the data and indicators. The process of assessing, evaluating and verifying the data for the KPIs includes an analysis of the KPI being measured, the feasibility of the data collection process and the applicability of these KPIs to Singapore. The feedback given on each KPI provided the ITU with a better understanding the scope of each KPI and its contribution to achieving Singapore’s vision of becoming a Smart Nation.

Singapore and ITU recognized that there is room for improvement for certain indicators. Some of the KPIs were not sufficiently defined to allow for data collection (e.g. sharing of medical resources and information KPI “14.2.3 Proportion of hospitals, pharmacies and health care providers using ICT means for sharing medical resources such as hospital beds, and medical information, especially electronic medical records”). Other KPIs did not match current data collection priorities (e.g., the noise monitoring KPI, “12.5.2 Application of ICT based noise monitoring”, which measures the proportion of the city area with applied ICT-based noise monitoring. Singapore’s agencies do not monitor aspects linked to this KPI). Considering the findings from the first year of this pilot project, ITU, together with other 15 UN agencies and programmes, reviewed the KPIs. The ITU-Singapore partnership has been mutually beneficial, as both entities have implemented new KPIs and also discovered better ways of tracking existing KPIs.

5. Conclusion



Singapore served as an ideal testbed for the implementation of the KPIs developed by ITU for smart sustainable cities, given the country's defined national strategy to transition into a smart and sustainable city in the coming years. Through the lens of its Smart Nation vision, Singapore has been using ICTs to enhance the way its citizens live, work, play and interact.

It has been more than two years since Singapore commenced its Smart Nation initiative, and one year since the country collaborated with ITU on this two-year pilot project to evaluate the feasibility of the ITU smart sustainable city KPIs. From Singapore's experience, the following conclusions have been derived:

- Singapore concluded the first phase of the pilot project. Based on the findings in this phase, the governmental agencies in Singapore have provided feedback on ITU KPIs. Many of these suggestions were directed at improving the existing definitions of the KPIs to enable a smoother data collection process.
- ICTs are a known key contributor to the Singaporean economy. Building on its strengths and maintaining ICTs as a strategic lever, Singapore has adopted vibrant policies for ICT diffusion and production. This has helped lay an excellent foundation upon which to establish a smart and sustainable city. With its effective national policies and initiatives in fostering ICT adoption, Singapore has become a leading country in ICT-readiness and e-government performance. These aspects were clearly reflected in the good performance of Singapore in the KPI dimensions of "ICT" and "Productivity".
- Despite having made significant progress in the KPI dimensions for "ICT", "Productivity" and "Equality and Social Inclusion", Singapore should divert more efforts to the dimension of "Environmental sustainability" in order to drive sustained reduction in greenhouse gas emissions; to promote noise-based monitoring systems; and to improve public perception of the capital's surroundings. Given the robust ICT-based infrastructure the city-state already has at its disposal, with a few additional networked applications, Singapore will soon be able to "climb the ladder" and become a leading international city that fosters a secure urban ecosystem, underpinning the goals and targets in the 2030 Agenda for Sustainable Development.
- As a part of the refinement process, ITU undertook a two-part approach to the indicators by preparing a basic set of core indicators³⁷ which can be easily reported by most cities along with a list of advanced indicators.³⁸ The advanced indicators can be implemented by cities that have attained good scores on the basic indicators.

³⁷ These core indicators will be divided into three types: generic, sustainable and smart.

³⁸ These advanced indicators will be divided into two types: smart and sustainable.

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- Singapore and other aspiring smart sustainable cities should implement the best practices discussed in this case study to improve the applicability of the KPIs in their country and hasten the achievement of their smart city goals in line with international instruments, including the Paris Agreement, the Sustainable Development Goals and the New Urban Agenda.
- After the creation of the first Global Smart Sustainable Cities Index by ITU, Singapore should utilize the index to measure the progress made since this pilot project.
- Following the two ITU smart city pilot projects in Singapore and Dubai, ITU has now entered the smart city playing field in cities located in developing countries. These upcoming KPI pilot projects, have allowed ITU to test and verify these indicators in a relatively newer and evolving urban ecosystem. This has helped ITU to adapt the KPIs based on a given country's resources and expertise and also provided these participating cities with a unique framework which will guide them through the smart city process by boosting innovation, facilitating skill transfer and improving the overall quality of life of their inhabitants.

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November 2017

About ITU-T and IoT and its applications including
smart cities and communities (SC&C):

<http://www.itu.int/en/ITU-T/ssc/>

**International
Telecommunication
Union**

Place des Nations
CH-1211 Geneva 20
Switzerland
www.itu.int

ISBN: 978-92-61-25021-8



Published in Switzerland
Geneva, 2017

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