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ITU-T Y.4902/L.1602

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TELECOMMUNICATION
STANDARDIZATION SECTOR
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Internet of things and smart cities and communities – Evaluation and assessment

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Internet of things and smart cities and communities – Evaluation and assessment

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Key performance indicators related to the sustainability impacts of information and communication technology in smart sustainable cities

Recommendation ITU-T Y.4902/L.1602

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Recommendation ITU-T Y.4902/L.1602

Key performance indicators related to the sustainability impacts of information and communication technology in smart sustainable cities

Summary

Recommendation ITU-T Y.4902/L.1602 gives a general guidance to cities and provide the definitions of key performance indicators (KPIs) related to the sustainability impact of information and communication technology (ICT) in the context of smart sustainable cities (SSCs).

This Recommendation is one of series of the Recommendations and Supplements that define KPIs. The series of KPI definitions documents also include:

- Recommendation ITU-T Y.4900/L.1600 on overview of key performance indicators (KPIs) in smart sustainable cities.
- Recommendation ITU-T Y.4901/L.1601 on key performance indicators (KPIs) related to the use of information and communication technology (ICT) in smart sustainable cities. This Recommendation lists the KPIs used for ICT use in SSC.
- Supplement ITU-T Y. Suppl. 39 on key performance indicators (KPIs) for smart sustainable cities. This document provides information regarding KPIs and evaluation index systems of smart cities, KPIs of sustainable cities, etc.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.4902/L.1602	2016-06-06	5	11.1002/1000/12662

Keywords

Cities, information communication technologies (ICTs), key performance indicators (KPIs), metrics and evaluation, smart sustainable cities (SSCs), sustainability impacts.

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FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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

NOTE

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

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

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Recommendation ITU-T Y.4902/L.1602

Key performance indicators related to the sustainability impacts of information and communication technology in smart sustainable cities

1 Scope

This Recommendation forms part of a series of Recommendations and Supplements focusing on the key performance indicators (KPIs) for smart sustainable cities (SSCs). It specifically provides the KPIs related to information and communication technology (ICT) impacts on city sustainability in the context of SSCs. Evaluating these indicators can help cities as well as their stakeholders understand the extent to which they may be perceived as SSC. The Recommendation describes applicability of KPIs, principles and dimensions as well as the definitions of corresponding indicators. To fit into the overall framework of city indicators the present Recommendation re-uses the categorization of UN Habitat´s City Prosperity Index.

The sustainability of a smart city is based on four main aspects:

- Economic: The ability to generate income and employment for the livelihood of the inhabitants.
- Social: The ability to ensure that the welfare (safety, health, education) of the citizens can be equally delivered despite differences in class, race or gender.
- Environmental: The ability to protect future quality and reproducibility of natural resources.
- Governance: The ability to maintain social conditions of stability, democracy, participation, and justice.

This Recommendation can be utilized by:

- Cities and municipal administrations, including the SSC-relevant policy-making organizations, and government sectors, enabling them to develop strategies and understand the progress related to the use of ICT for making cities smarter and more sustainable.
- City residents and their non-profit organizations, enabling them to understand the development and progress of SSCs with respect to the impact of ICT.
- Development and operation organizations of SSC, including planning units, SSC-related producers and service providers, operation and maintenance organizations, helping them to fulfil the tasks of sharing information related to the use of ICT and its impact on the sustainability of cities.
- Evaluation agencies and academia, supporting them in selection of relevant KPIs for assessing the contribution from ICT in the development of SSC.

The intention of identifying the KPIs is to establish the criteria to evaluate ICT´s contributions in making cities smarter and more sustainable, and to provide the cities with the means for self-assessments. It is desirable that cities can quantify their achievement according to their goals.

The ICT solutions include ICT goods, networks and services as well as ICT projects. An ICT project is defined as a set of activities that uses mainly ICT goods, networks and services to implement a specific task. At a city level, ICT projects particularly target the deployment of ICT in different parts of society to improve the sustainability performance in SSC. The KPIs can be used to assess the city sustainability before and after the implementation of ICT solutions.

This Recommendation lists the core indicators that are chosen to be applicable for all cities. The goals for moving towards increased smartness and sustainability differs between cities. Thus, based on their population growth, geographical locations, environmental conditions, demography etc., the cities can also select appropriate indicators among those listed in Appendix I and/or add new ones.

This Recommendation is applicable for both cities and city regions, which could be organized in different ways:

- A single city organized as one or more administrative units, or
- A union of cities in the neighbouring area that can share some services.

2 References

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

[ITU-T Y.4900] Recommendation ITU-T Y.4900/L.1600 (2015), *Overview of key performance indicators in smart sustainable cities*.

[ITU-T Y.4901] Recommendation ITU-T Y.4901/L.1601 (2015), *Key performance indicators related to the use of information* and *communication technology in smart sustainable cities*.

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

[ISO 37120] ISO 37120:2014, *Sustainable development of communities – Indicators for city services* and *quality of life*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 city [ITU-T Y.4900]: A urban geographical area with one (or several) local government and planning authorities.

3.1.2 ICT companies [ITU-T Y.4901]: Companies that provide products and/or services with respect to information and communication technologies.

3.1.3 knowledge economy [b-OECD KE]: Economies which are directly based on the production, distribution and use of knowledge and information.

3.1.4 smart sustainable city [ITU-T Y.4900]: A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental, as well as cultural aspects.

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

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AIDS	Acquired Immune Deficiency Syndrome
HIV	Human Immunodeficiency Virus infection
HLY	Healthy Life Years
ICT	Information and Communication Technology
KPI	Key Performance Indicator
PM10	Particulate Matter up to 10 micrometres in size
PM2.5	Particulate Matter up to 2.5 micrometres in size
QoL	Quality of Life
SSC	Smart Sustainable City
UN-Habitat	United Nations Human Settlements Programme

5 General principles for selecting key performance indicators (KPIs)

The selection of KPIs is based on the following principles:

- **Comprehensiveness**: The set of indicators should cover all the aspects of SSC. The indicators of evaluation should be aligned to the measured subject, i.e., ICT and its impact on the sustainability of cities. The index system should reflect the level of general development in a certain aspect.
- **Comparability**: The KPIs should be defined in a way that data can be compared scientifically between different phases of urban development, which means the KPIs should be comparable over time and space for the same city. It should also be possible to extend and amend the set of KPIs according to the actual development.
- **Availability**: The KPIs should be quantitative and the historic and current data should be either available or easy to collect.
- **Independence**: The KPIs in the same dimension should be independent or almost-orthogonal i.e., overlap of the KPIs should be avoided as much as possible.
- **Simplicity**: The concept of each indicator should be simple and easy to understand. Also the calculation of the associated data should be intuitive and simple.
- **Timeliness**: The ability to produce KPIs with respect to emerging issues in SSC construction.

6 Key performance indicators

6.1 Sub-dimensions of KPIs

The sub-dimensions for each dimension are recorded in Table 1. These have been tailored[1] from Table 1 of [ITU-T Y.4900].

[1] Note that this list only contains the sub-categories for which indicators are defined in this Recommendation. For a total set of sub-categories refer to [ITU-T Y.4900].

In Table 1, each dimension is identified by the letter Dx. The sub-dimensions are then classified by the label Dx.y where x denotes the dimension and y maps to sub-dimension.

Table 1 – Sub-dimension of KPIs

Dimension label	Dimension	Sub-dimension label	Sub-dimension
D2	Environmental sustainability	D2.1	Air quality
		D2.2	CO_2 emissions
		D2.3	Energy
		D2.5	Water, soil and noise
D3	Productivity	D3.1	Capital investment
		D3.2	Employment
		D3.3	Inflation
		D3.5	Savings
		D3.6	Export/import
		D3.7	Household income/consumption
		D3.8	Innovation
D4	Quality of life	D4.1	Education
		D4.2	Health
		D4.3	Safety/security public place
D5	Equity and social inclusion	D5.1	Inequity of income/consumption (Gini coefficient)
		D5.2	Social and gender inequity of access to services and infrastructure
		D5.3	Openness and public participation
D6	Physical infrastructure	D6.1	Infrastructure/connection to services – piped water
		D6.2	Infrastructure/connection to services – sewage
		D6.3	Infrastructure/connection to services – electricity
		D6.6	Infrastructure/connection to services – health infrastructure
		D6.7	Infrastructure/connection to services – transport

6.2 Key performance indicators of SSC

This clause defines the core indicators applicable for all cities.

Each indicator is labelled (Ix.y.z), where (i) x denotes the dimension, (ii) y, the sub-dimension, and (iii) z, the indicator.

NOTE – The numbering of indicator Ix.y.z of this Recommendation follows that of [ITU-T Y.4901].

The indicators listed in Appendix I are provided as additional indicators for consideration. Cities can select appropriate ones among those, and/or add new indicators, in order to evaluate the sustainability impacts related to the use of ICT.

NOTE 1 – This Recommendation identifies the KPIs related to ICT impacts on city sustainability in the context of SSC but does not provide any quantification method. Quantification methods will be provided separately.

NOTE 2 – This Recommendation contains ICT specific indicators and general indicators[2] which describe the sustainability impacts in the context of smart sustainable cities. Due to the complexity of cites and the wide range of factors that impact citizens' behaviour, impacts from ICT could in many cases mainly be tracked for specific projects or initiatives. For this reason, the general city level KPIs are defined for areas where ICT could have an impact, though it is not the only change lever. Thus, to understand the ICT impact on the general KPIs, depth analysis is needed based on a broad understanding of the general city development.

NOTE 3 – Although convenience and comfort is an important aspect of SSC, there are no KPIs defined for sub-dimension D4.4 Convenience and comfort [ITU-T Y.4900]. However, it is important that ICT projects are designed in a way that is convenient for the intended users. Therefore it is good to combine the use of KPIs with other assessment methods to understand the satisfaction level linked to the use of such projects and how these KPIs develop over time.

NOTE 4 – In this Recommendation the e-service concept (e.g., e-health and e-governance, etc.) is used in an inclusive way and refers to both wired and wireless services that benefit cities and city inhabitants. The mobile wireless services could also be referred to as m-services (e.g., m-health, m-banking, etc.). These ICT services and goods can be also collectively termed as smart services (e.g., smart grid, smart lighting) and smart goods (e.g., smart meters). In some cases the smart service / smart goods concept may be used instead of e-service if this terminology is more widely adopted for the referred service or goods.

NOTE 5 – In this Recommendation the term city inhabitant is used to refer to the people living in the city.

6.2.1 Environmental sustainability

This clause lists the core indicators defined for environmental sustainability.

There are ten indicators in this dimension, covering *air pollution, GHG emissions, renewable energy, energy saving in households, environment perception, quality of water resources, recycling of waste, noise and soil pollution, green areas, etc.*

Sub-dimension	Indicator	Description
D2.1 Air quality	I2.1.2 Air pollution intensity	Intensity of particles and toxic substances. (*) NOTE – This includes toxic substances and particles such as PM10 and PM2.5.
D2.2 CO_2 emissions (**)	I2.2.1 GHG emissions	Amount of GHG emissions per capita. (*) NOTE – It is preferred to distinguish between emissions emerging from industrial (manufacturing, construction), commercial, household, transport, and waste disposal, etc.
D2.3 Energy	I2.3.1 Use of alternative and renewable energy	Proportion of renewable energy consumed in the city. (*) NOTE – Renewable energy sources include geothermal, solar thermal, solar voltaic, hydro, wind, and combustible renewable sources and waste (composed of solid biomass, liquid biomass, bio-gas, industrial waste and municipal waste).
	I2.3.2 Energy saving in households	Energy saving in households compared to a baseline. (*)

[2] The general indicators are marked (*).

Sub-dimension	Indicator	Description
		NOTE – The baseline may be either a previous measurement or a reference value. NOTE – It would be preferred to distinguish between households with and without smart meters, and with and without home automation systems.
D2.5 Water, soil and noise	I2.5.3 Quality of city water resources	Quality of water resources (rivers, lakes, etc.). (*) NOTE – Pollution of water resources includes (but is not limited to) acidity, organic, floatables, alga, chemical substances and bacteria, etc.
	I2.5.4 Recycling of waste	Proportion of waste recycled compared to total collected waste. (*)
	I2.5.5 Exposure to noise	Proportion of the city inhabitants with noise levels above international/national exposure limits at home. (*) NOTE – Noise is measured as sound pressure in accordance with relevant international/national standards.
	I2.5.6 Soil pollution avoidance	Proportion of soil pollution incidents with successful early warning and emergency detection of heavy metal, chemicals, acid, etc. through ICT.
	I2.5.7 Green areas surface	Proportion of municipal territory allocated to publicly accessible green areas. (*)
	I2.5.8 Perception on environmental quality	Proportion of city inhabitants satisfied with the urban environment. (*)
NOTE 1 – Indicators marked by (*) are not ICT specific, but indicators focusing on general city sustainability. NOTE 2 – This sub-dimension marked by (**) looks into the CO_2-e/GHG emissions of the city where "-e" is "equivalent" and all other greenhouse gases are converted into CO_2.		

6.2.2 Productivity

This clause lists the core indicators defined for productivity and economic sustainability.

There are seven indicators in this dimension, covering *expenditure of ICT to improve industry productivity, service industry employment, saving, city export/import, household ICT expenditures, ICT investment, and ICT related patents, etc.*

Sub-dimension	Indicator	Description
D3.1 Capital investment	I3.1.3 Improvement of industry productivity through ICT	Productivity enhancement in industry through ICT measured as the impact of ICT on value added per person employed. NOTE 1 – This is the contribution from ICT investment. NOTE 2 – Value added per person employed is generally referred to as labour productivity.

Sub-dimension	Indicator	Description
D3.2 Employment	I3.2.1 Service industry employment	Proportion of employees working in service industry in the city compared with the total employed workforce. (*)
D3.5 Savings	I3.5.1 Saving rate	Proportion of total incomes for each household remaining after deducting consumption and expenditures. (*)
D3.6 Export/import	I3.6.1 Knowledge-intensive export/import	Proportion of export/import of knowledge-intensive goods and services within a city compared to the total industrial export/import. (*) NOTE 1 – Amount of export/import may be counted among cities, maybe in the same country. NOTE 2 – In some cases data is only available at country level.
D3.7 Household income/consumption	I3.7.1 Household ICT expenditures	Proportion of household expenditures related to ICT.
D3.8 Innovation	I3.8.2 Investments in ICT innovation	Proportion of private sector expenditures invested in ICT innovation.
	I3.8.3 ICT related patents	Number of ICT related patents granted per capita.
NOTE – Indicators marked by (*) are not ICT specific, but indicators focusing on general city sustainability.		

6.2.3 Quality of life

This clause lists the core indicators defined for Quality of Life (QoL).

There are three indicators in this dimension, covering *student ICT availability, inhabitants' health status, and emergency process to improve safety and security.*

Sub-dimension	Indicator	Description
D4.1 Education	I4.1.2 Students ICT availability	Proportion of students/pupils with access to ICT capabilities in school. NOTE – ICT capabilities include Internet connectivity, computer labs, ICT modules, digital learning, etc.
D4.2 Health	I4.2.5 Healthy life years (HLY)	Number of remaining years that a person of a certain age is expected to live without disability. (*) NOTE – The emphasis is not exclusively on the length of life, as is the case for life expectancy, but also on the quality of life.
D4.3 Safety/security public place	I4.3.3 Disaster and emergencies alert accuracy	Proportion of disasters and emergencies with timely alerts. (*) NOTE – Disasters may be natural or man-made. Emergencies concern incidents like kidnapping and missing people, etc.
NOTE – Indicators marked by (*) are not ICT specific, but indicators focusing on general city sustainability.		

6.2.4 Equity and social inclusion[3]

This clause lists the core indicators defined for equity and social inclusion.

There are 4 indicators in this dimension, covering *income inequity, gender inequity, use of online services and perception on social inclusion, etc.*

Sub-dimension	Indicator	Description
D5.1 Inequity of income/consumption (Gini coefficient)	I5.1.1 Income distribution	Income distribution in accordance with Gini coefficient. (*)
D5.2 Social and gender inequity of access to services and infrastructure	I5.2.1 Gender income disparity	Rate of income disparity between men and women. (*) NOTE – Income has potential influence on equity of access to services and infrastructure.
D5.3 Openness and public participation	I5.3.5 Use of online city services	Proportion of city inhabitants using online public services and facilities (e.g., choice of schools, booking of public sports facilities, library services, etc.). NOTE – This includes bookings, payments, etc.
	I5.3.6 Perception on social inclusion	Proportion of city inhabitants satisfied with the social inclusion. (*) NOTE – Social inclusion usually refers to members of society feeling valued and important.
NOTE – Indicators marked by (*) are not ICT specific, but indicators focusing on general city sustainability.		

6.2.5 Physical infrastructure[4]

This clause lists the core indicators defined for the physical infrastructure.

There are six indicators in this dimension, covering *piped water, sewage, electricity, health infrastructure, transport and road traffic.*

Sub-dimension	Indicator	Description
D6.1 Infrastructure /connection to services – piped water	I6.1.4 Leakage in water supply system	Proportion of water leakage in the water supply system. (*)
D6.2 Infrastructure /connection to services – sewage	I6.2.3 Sewage system coverage	Proportion of households connected to the sewage system. (*)

[3] In general equity and inclusion in relation to ICT are hard to measure by defining specific indicators. Therefore, in addition to the indicators defined in dimension D5, cities are encouraged to disaggregate and analyse their data with respect to other aspects including gender, age, income and geographic location/area.

[4] The number of various sensors (per capita) deployed in the city and accessibility to the public administration is very important.

Sub-dimension	Indicator	Description
D6.3 Infrastructure /connection to services – electricity	I6.3.2 Reliability of electricity supply system	Proportion of time during which electricity supply system works without outages. (*)
D6.6 Infrastructure /connection to services – health infrastructure	I6.6.1 Availability of sporting facilities	Number of sports training facilities per capita. (*)
D6.7 Infrastructure /connection to services – transport	I6.7.1 Use of public transport	Proportion of travellers utilizing public transportation compared to overall city population. (*)
	I6.7.2 Road traffic efficiency	Freedom from traffic congestion exposure. (*) NOTE – Traffic congestion is measured in accordance with relevant international/national standards. For example, in terms of average speed of vehicle or average delay.
NOTE – Indicators marked by (*) are not ICT specific, but indicators focusing on general city sustainability.		

Appendix I

Additional indicators

(This appendix does not form an integral part of this Recommendation.)

The indicators listed in the following table are provided as additional indicators for consideration. Cities can select appropriate ones among those, and/or add new indicators, to evaluate the contributions of ICT to their SSC goals. Each additional indicator is labelled (Ax.y.z), where (i) x denotes the dimension, (ii) y, the sub-dimension, and (iii) z, the indicator.

Sub-dimension	Indicator	Description
D2.2 CO_2 emissions (**)	A2.2.1 GHG emissions per sector per capita	GHG emissions per capita per sector including industrial (manufacturing, construction), commercial, household, transport, and waste disposal, etc. (*)
D2.3 Energy	A2.3.1 Electricity use for street lighting	Electricity used for street lighting per capita. (*)
D3.2 Employment	A3.2.1 Creative industry employment	Proportion of employees working in start-ups and creative industry in the city compared to the total employed workforce. (*) NOTE – Creative industries refer to those ones that are based on individual creativity, skill and talent with the potential to create wealth and jobs through developing intellectual property. This includes thirteen sectors: advertising, architecture, the art and antiques market, crafts, design, designer fashion, film, interactive leisure software (i.e., video games), music, the performing arts, publishing, software, and television and radio.
D3.3 Inflation	A3.3.1 Inflation rate	A city's inflation rate is based on a projection of its Consumer Price Index, which measures the rise in prices of goods and services. (*) NOTE – National inflation data may be used. NOTE – A +2% inflation rate is regarded as a target or healthy inflation rate by major international banks.
D4.2 Health	A4.2.1 Coverage of health insurance	Proportion of city inhabitants covered by health insurances. (*) NOTE – Health insurances may be either private or provided by authorities.
D5.3 Openness and public participation	A5.3.2 Interest in online access to cultural resources	On-line visits to cultural resources per capita.

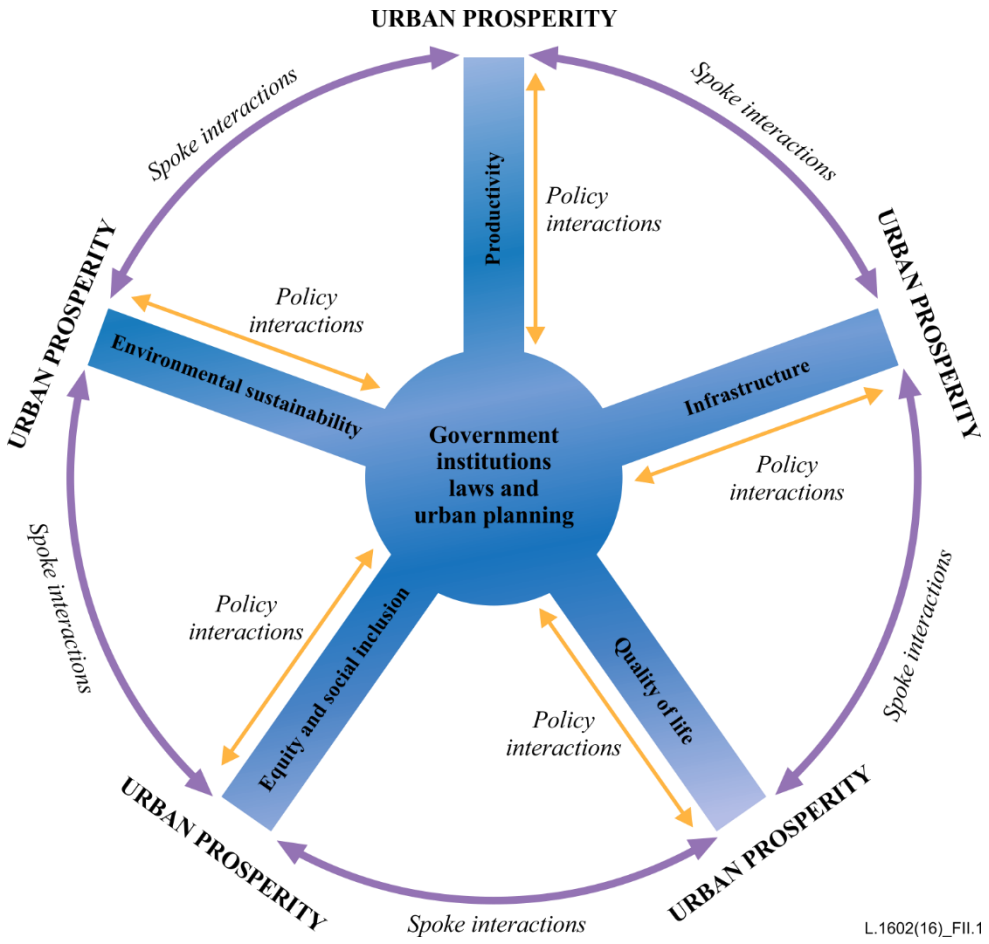
Sub-dimension	Indicator	Description
D6.1 Infrastructure /connection to services – piped water	A6.1.2 Quality of piped water	Quality of water as supplied to end users. (*) NOTE – Quality is impacted by both water treatments and distribution systems.
NOTE 1 – Indicators marked by (*) are not ICT specific, but indicators focusing on general city sustainability. NOTE 2 – This sub-dimension marked by (**) looks into the CO_2-e/GHG emissions of the city where "-e" is "equivalent" and all other greenhouse gases are converted into CO_2.		

Appendix II

UN-Habitat city prosperity index

(This appendix does not form an integral part of this Recommendation.)

In the Wheel of Prosperity, as defined by UN-Habitat, the "spokes" are the five dimensions of prosperity: productivity, infrastructure development, quality of life, equity and social inclusion, and environmental sustainability.



In the "City Prosperity Index" each dimension has its own index and it might be built up by a number of indices. The basic "City Prosperity Index" as reported in a publication consists of the following sub-indices and indicators:

Dimension	Definition/variables
Productivity	The productivity index is measured through the city product, which is composed of the variables capital investment, formal/informal employment, inflation, trade, savings, export/import, and household income/consumption. The city product represents the total output of gods and services (value added) produced by a city´s population during a specific year.
Quality of life	The quality of life index is a combination of four sub-indices: education, health, safety/security and public space. The sub-index education includes literacy, primary, secondary and tertiary enrolment. The sub-index health includes life expectancy, under-five mortality rates, HIV/AIDS, morbidity and nutrition variables.
Infrastructure development	The infrastructure development index combines two sub-indices: one for infrastructure and another for housing. The infrastructure sub-index includes: connection to services (piped water, sewage, electricity and ICT), waste management, knowledge infrastructure, health infrastructure, transport and road infrastructure. The housing sub-index includes building materials and living space.
Environmental sustainability	The environmental sustainability index is made of four sub-indices: air quality (PM10), CO_2 emissions, energy and indoor pollution.
Equity and social inclusion	The equity and social inclusion index combines statistical measures of inequity of income/consumption (Gini coefficient) and social and gender inequity of access to services and infrastructure.

Reference

UN Habitat report "State of the World's cities 2012/2013 Prosperity of Cities", Table 1.1.3, p. 18.

There is also an extended "City Prosperity Index" with more indicators and a plan to include "Governance" as a sixth dimension. Furthermore, a specific work has been made on Streets as a driver for prosperity.

UN Habitat (2013), *State of the World's Cities 2012/2013, Prosperity of Cities*: http://www.unhabitat.org/pmss/listItemDetails.aspx?publicationID=3387

UN Habitat (2013), *Streets as Public Spaces and Drivers of Urban Prosperity*: http://www.unhabitat.org/pmss/listItemDetails.aspx?publicationID=3513

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