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|  | ITU-T Focus Group on Smart Sustainable Cities |
|  | **An overview of smart sustainable cities and the role of information and communication technologies**  |
|  | Focus Group Technical Report |



FOREWORD

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

The procedures for establishment of focus groups are defined in Recommendation ITU-T A.7. ITU-T Study Group 5 set up the ITU-T Focus Group on Smart Sustainable Cities (FG-SSC) at its meeting in February 2013. ITU-T Study Group 5 is the parent group of FG-SSC.

Deliverables of focus groups can take the form of technical reports, specifications, etc., and aim to provide material for consideration by the parent group in its standardization activities. Deliverables of focus groups are not ITU-T Recommendations.

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**An overview of smart sustainable cities and the role of information and communication technologies**

About this Technical Report

This Technical Report has been prepared as a contribution to the International Telecommunication Union's (ITU) Focus Group on Smart Sustainable Cities – Working Group 1.

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Additional information and materials relating to this Technical Report can be found at: [www.itu.int/itu-t/climatechange](http://www.itu.int/itu-t/climatechange). If you would like to provide any additional information, please contact Cristina Bueti (ITU) at tsbsg5@itu.int.

An overview of smart sustainable cities and the role of information and communication technologies

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An overview of smart sustainable cities and the role of information and communication technologies

Executive summary

This Technical Report describes the main attributes of a smart sustainable city (SSC) and provides readers with a better understanding of what constitutes SSC. It identifies the role and potential of information and communication technologies (ICTs) in SSC, and outlines at a high level the key ICT infrastructures which will enable SSC strategies.

Economy, governance, environment and society are the four primary pillars which characterize a city. These are reflected via three overarching dimensions of a city: (1) environment and sustainability, (2) city level services and (3) quality of life. Each of these dimensions have multiple attributes which characterize them, some of which overlap. Sustainability and the environment are critical to the urban landscape since cities represent 75% of energy consumption and 80% of CO2 emissions on a global basis. The primary attributes in this dimension include infrastructure and governance, energy and climate change, pollution, waste, social, economic and health aspects. As for city level services, the key attributes include technology and infrastructure (e.g. transportation, buildings, healthcare), sustainability (e.g. water, air, waste), governance (e.g. organization, administration and leadership) and economy (e.g. financial, human capital, economic strength). The final dimension is the quality of life of the citizens. This reflects how the inhabitants of a city perceive their own sense of well-being and the fact that they are constantly striving to better themselves – for example, in terms of wealth, health and education. All of the above need to be balanced for a successful smart sustainable city.

Infrastructure is a pivotal aspect of a smart sustainable city. Traditionally, there have been two types of infrastructure: physical (e.g. buildings, roads, transportation, and power plants) and digital (information technology (IT) and communications infrastructure). There is also the concept of a service infrastructure which provides services which run on top of the physical infrastructure (e.g. education, health care, e‑government, and mass transit). The digital infrastructure provides the glue to enable the smart sustainable city to operate efficiently and in an optimal manner.

Common physical and service infrastructures include: (1) smart energy, (2) smart buildings, (3) smart transportation (4) smart water, (5) smart waste, (6) smart physical safety and security, (7) smart health care and (8) smart education.

ICT has a crucial role in SSC since it acts as the platform to aggregate information and data to help enable an improved understanding on how the city is functioning in terms of resource consumption, services, and lifestyles. Examples of what ICT can achieve include: (1) ICT-enabled information and knowledge sharing (2) ICT-enabled forecasts and (3) ICT-enabled integration. Data prediction, analytics, big data, open data, Internet of things (IoT), data accessibility and management, data security, mobile broadband, ubiquitous sensor networks, all become essential in SSC and are predicated on a solid ICT infrastructure.

Therefore, a smart sustainable city has an end goal to achieve an economically sustainable urban environment without sacrificing the comfort and convenience/quality of life of citizenry. It strives to create a sustainable living environment for all its citizens through the use of information and communication technologies (ICTs).

1 Introduction

In the last 50 years, the world population has grown exponentially at an average rate of 1.2% per year. In 2007, for the first time in the history of mankind, the number of people living in cities surpassed the number of people living in rural areas. It is estimated that the proportion will exceed 70% by 2050. As the UN World Economic and Social Survey 2013[[1]](#footnote-1)1 suggested, Africa, Asia, and other developing regions will be housing an estimate of 80% of the world's urban population in the coming years. In the period from 1950 to 2010, small cities saw a net increase of 1.3 billion people, while medium cities (632 million) and large cities (570 million) saw about half as much growth1.

Given the avenues of socio-economic development that urban areas have to offer, migration to urban cities has become synonymous to opportunities and prosperity for millions of people around the world. As a result, urban areas are getting more and more congested. Along with the associated natural population growth, local and national policies, and environmental changes, urban migration and congestion are expected to be continuous trends.

While urbanization brings advantages, it also brings challenges. Rapid urbanization adds pressure to the resource base, and increases demand for energy, water, and sanitation, as well as for public services, education and health care. Consequently, social, economic and environmental issues have become tightly interconnected. Cities greatly contribute to environmental degradation on local, regional, and global scales. Studies have demonstrated that they are accountable for 70% of global greenhouse gas emissions as well as 60-80%[[2]](#footnote-2)2 of global energy consumption[[3]](#footnote-3)3.

The obvious question is: how can cities be made sustainable under such underlying conditions?

The answer lies in making cities 'smarter' by efficient management of resources and infrastructure, greener environment, and smart governance resulting in a better quality of living of its citizens. All of which can be enabled by the effective use of information and communication technologies (ICTs).

ICT tools have the ability to provide eco-friendly and economically viable solutions for cities. Potential advancements could be made in the forms of efficient water management based on real-time information exchanges, public transport systems organized through information gathered by satellites, exploring solutions to concerns related to air quality monitoring and electromagnetic fields, among others. This is where the concept of smart sustainable city comes into play.

## 1.1 Scope

Despite the wide range of literature that exists on the topic of global smart cities, there is a lack of agreement on the definition and on the specific parameters that characterize a smart sustainable city. Therefore, a comprehensive view of SSCs is vital to foster the consensus and consistency needed to advance the articulation of strategies, practice and research in this field.

In response to that need, this Technical Report seeks to: (1) provide an overview of the main attributes that make cities smart and sustainable, (2) explore the role and potential of ICTs within SSCs, and (3) acknowledge, at a general level, the key ICT infrastructure needed to enable SSC strategies[[4]](#footnote-4)4.

The intended audience of this Technical Report are stakeholders and members of the general public interested in gaining a better understanding of what constitutes a smart sustainable city, and what its main attributes are.

This Technical Report is not intended as a recommendation document for best practices, but rather as a general foundation for further, more in-depth explorations of specific topics on a smart sustainable city. It aims to provide the reader with a broad overview of issues that are the forefront of the notion of a smart sustainable city, while setting the stage for additional detailed technical reports which are part of the mandate of the ITU-T Focus Group on Smart Sustainable Cities (FG-SSC).

## 1.2 Smart sustainable city: Concept and goals

At its fifth meeting in June 2014, ITU-T's Focus Group on Smart Sustainable Cities (FG-SSC) agreed on the following definition of a smart sustainable city:

*“A Smart Sustainable City (SSC) 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 and environmental aspects”.*

Linked to this definition, the main goal for SSC is to enhance the quality of life of its citizens across multiple, interrelated dimensions, including (but not limited to) the provision and access to water resources, energy, transportation and mobility, education, environment, waste management, housing and livelihoods (e.g. jobs), utilizing ICTs as the key medium.

Despite the enormous potential embedded in the goals of SSC, it is important to acknowledge the existence of challenges associated to global urbanization, urban migration trends, environmental degradation, climate change impacts, aging infrastructure, as well as constraints in the resources and structures needed to respond to a growing demand in settlement areas, among many others.

Within these increasingly complex urban systems, ICTs can act as a platform to help overcome these challenges and take advantage of emerging opportunities, as cities advance in the process towards becoming smart and sustainable.

## 1.3 ITU-T Focus group on smart sustainable cities

ITU-T Study Group 5 (ITU-T SG5) is working on tackling environmental and climate change issues including the development of a methodology to assess the environmental impact related to ICT in cities. As part of this effort, a Focus Group on Smart Sustainable Cities[[5]](#footnote-5)5 (FG-SSC) was established in February 2013 by ITU-T Study Group 5.

The Focus Group has four (4) main working groups (WG):

* WG1 – ICT role and roadmap for smart sustainable cities
* WG2 – ICT infrastructure
* WG3 – Standardization gaps, key performance indicators (KPIs) and metrics
* WG4 – Policy and positioning (communications, liaisons and members).

This Technical Report is part of the research and analysis for the Focus Group on Smart Sustainable Cities as a working document from WG1.

FG-SSC has coordinated a series of open meetings with the participation of multiple stakeholders involved in the design and implementation of SSC initiatives around the globe, including telecommunications companies, ICT companies, governments and academia, which provide the Focus Group with diverse perspectives and a broad base of information.

FG-SSC will play a key role in fostering a platform where various stakeholders can share views, develop sets of deliverables, and showcase initiatives, projects, policies, and standards. The Focus Group will also analyse ICT solutions and projects that promote environmental sustainability in cities. Best practices will then be identified from these experiences in order to facilitate and inform the implementation of new solutions in cities, and to be standardized by ITU-T SG5.

The Focus Group will develop a standardization roadmap taking into consideration the activities currently undertaken by the various standards development organizations (SDOs) and forums. The Focus Group is also working with non ITU-T members, leveraging the role of the ICT sector to foster the growth of smart and sustainable cities worldwide[[6]](#footnote-6)6.

2 City dimensions and attributes

To begin, the notion of a 'Smart and Sustainable City' entails more than just the implementation of technologies and strategies aimed at meeting today's needs without compromising those of future generations. It is also about understanding the city itself: its identity and its goals, its stakeholders and their priorities, and in that way, identifying the attributes that would tailor to the uniqueness of each city while enhancing its overall living quality and sustainability with the support of ICTs.

This section provides an overview of the key attributes that characterize cities, thus setting the basis for identifying the role of ICTs within the SSC context (section 3). Annex 1 provides some additional background and description for some of these dimensions and attributes.

Broadly speaking, there are three overarching and closely interrelated dimensions at the core of a city:

a. environment and sustainability

b. city level services

c. quality of life

Each of these dimensions, and the attributes that characterize them, will be explored in further detail.

## 2.1 Environment and sustainability

Cities represent 75% of energy consumption and 80% of CO2 emissions on a global basis, and represent the largest of any environmental policy challenge[[7]](#footnote-7)7. Therefore, sustainability and the environment are the most critical components in the functioning of any city.

There is a clear distinction between the two terms (i.e. sustainability and the environment) that needs to be made. According to the [Brundtland Commission](http://conspect.nl/pdf/Our_Common_Future-Brundtland_Report_1987.pdf), sustainable development refers to the environmental, economic and social aspects, whereas environmental aspects refer to the physical and biological surroundings of a city.

The major attributes included under this dimension are the following:

* city infrastructure and governance
* energy and climate change
* pollution and waste
* social, economy and health

Multiple studies conducted in this field suggest that each of these attributes encompasses a series of more granular categories and components, as described below[[8]](#footnote-8)8 [[9]](#footnote-9)9 [[10]](#footnote-10)10 [[11]](#footnote-11)11 [[12]](#footnote-12)12 [[13]](#footnote-13)13.

Table 2-1 – Categories and components of the environment
and sustainability dimension

|  |
| --- |
| City infrastructure and governance |
| Policy and management | Infrastructure |
| • Integrated environmental management• Strategy• Municipal administration• Effective conservation | • Urban planning• Buildings and physical infrastructure• Mobility, transportation and traffic• Public safety |
| Energy and climate change |
| CO2 emissions | Energy |
| • CO2 from energy production• Emissions per capita | • Energy performance• Conservation |
| Pollution and waste |
| Waste | Air | Water | Noise |
| • Waste• Management• Wastewater • treatment | • Urban particulates and air quality• Indoor air pollution• Local ozone• Regional ozone• NOx and SOx | • Drinking water• Water quality index Water stress• Water management | • Noise pollution |

Table 2-1 – Categories and components of the environment
and sustainability dimension

|  |
| --- |
| Social, economy and health |
| • Social services• Citizen satisfaction• Education• Culture and recreation • Social inclusion• Demographics (aging) | • Gross Domestic Product (GDP)• Employment • Financial resilience  | • Adequate sanitation• Disease control and mitigation• Citizen health services |

The categories and components reflected in Table 2-1 evidence that the environment and sustainability dimension is pivotal to the operations of cities. At the same time, these components can be used as the basis to design indicators and methods to assess the city's performance in this field. The development of key performance indicators for SSC is the focus of one of the Technical Reports produced by FG-SSC[[14]](#footnote-14)14.

Furthermore, based on Table 2-1, it is clear that a wide variety of different attributes representing different aspects related to a city contribute to this dimension. These can be summarized as policy, infrastructure, management, climate change and CO2 emissions, energy, pollution: water, air, waste, noise and their implications on the social, health and economic well-being.

## 2.2 City level services

The second dimension of a city is its services and how they characterize a functional urban environment. Various studies [[15]](#footnote-15)15 [[16]](#footnote-16)16 [[17]](#footnote-17)17 [[18]](#footnote-18)18 [[19]](#footnote-19)19 suggest the following attributes for this dimension:

* technology and infrastructure
* sustainability
* governance
* economy

Each of these attributes and their components are described below:

Table 2-2 – Categories and components of the city level services dimension

|  |  |
| --- | --- |
| Technology and infrastructure | Sustainability |
| • Transportation• Buildings• Fire and emergency response• Health care• Urban planning• Safety and security• Education | • Environmental and natural hazards• Water: consumption, leakage• CO2: emissions, reduction• Air Quality: NO, SO, particulates• Waste: solid, water, land use• Policies: recycling, reduction• Energy: consumption, intensity |
| Governance | Economy |
| • Organization• Law and justice• Resilience• Leadership• Commitment• Environmental regulation | • Economic strength• Human capital• Institutional effectiveness• Financial maturity• Physical (financial) capital• Production/resourcing |

It can be observed that some of the attributes for this dimension are common to those discussed in the “environment and sustainability dimension”; however, while there are overlapping components, the lens through which they are viewed differ. For one, the environment and sustainability dimension views these shared attributes as the backdrop of a functional smart sustainability city, while the city level service dimension focuses on the operational aspect of these shared attributes and thus form corresponding strategies that would ensure and provide quality services.

## 2.3 Quality of life

Quality of life (QoL) is a recurrent theme in understanding the nature and operation of a city and a key dimension since it reflects how citizens or inhabitants of a city perceive their own sense of well‑being. People are constantly striving to better themselves across many facets of their lives. The trend of rapid urbanization is reflected here because of the migration to urban areas in search of better employment and hopefully improved living conditions.

The World Health Organization (WHO) defines quality of life as an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns. It is a broad ranging concept affected in a complex way by the person's physical health, psychological state, personal beliefs, social relationships and their relationship to salient features of their environment.[[20]](#footnote-20)20

The multidimensional nature of the quality of life incorporates (among others) basic needs: water, food, shelter, health, jobs (economy), safety and security, education, culture, environment, social equity, technology and innovation. Another way to look at this dimension is the concept of “well-being” – physical, material, social and emotional.

Despite the complexity of this dimension, the overarching element shared by the different natures of the quality of life is that the QoL for citizens living in an urban environment must be constantly improving in a steady pace as this is the basis for a prosperous city.

Some studies have focused on this aspect[[21]](#footnote-21)21 [[22]](#footnote-22)22 [[23]](#footnote-23)23 [[24]](#footnote-24)24, among them the Global City Indicators Facility[[25]](#footnote-25)25. Twenty "themes" are organized into two categories: (1) those which measure city services and (2) quality of life factors. City performance is measured by 115 indicators across these themes, collectively used to "tell a story." Approximately 35% of the indicators provide basic statistics and background information for comparative studies, approximately 25% of these are "core" standards, and all cities participating are expected to report on them. The remaining 40% are considered "supporting" indicators where cities in developing economies are encouraged, but not mandated to report the information, since there are differences in resources and capabilities compared to developed economies.

## 2.4 Summary

In summary, three different dimensions have been identified for a city along with key attributes. These dimensions are: (1) environment and sustainability, (2) city level services and (3) quality of life. Each of these dimensions has a number of important attributes and in some cases there is some overlap in what these attributes represent; it is recognized that the "lens" through they are viewed can vary and therefore a 360o view is important to consider.

The following reclassification into four areas (pillars), listed below, for a city is observed – representing the three dimensions and attributes. It should be noted that technology and infrastructure are discussed separately since they tend to have a broader role in a city landscape. Details of these pillars are provided in Table 2-3.

(1) **Economy** – The city must be able to thrive – jobs, growth, finance

(2) **Governance** – The city must be robust in its ability for administrating policies and pulling together the different elements

(3) **Environment**[[26]](#footnote-26)26 – The city must be sustainable in its functioning for future generations

(4) **Society** – The city is for its inhabitants (the citizens)

Table 2-3 – Core pillars of a smart sustainable city

3 ICT, infrastructure and disasters in SSC

The essential duty of a city is to facilitate the health, safety and security of its citizens. Cities may face various problems like increasing population, unprecedented weather manifestations, natural disasters, unemployment, unique geography, poverty, crime, and other social problems that pose a serious threat to the stable functioning of the city.

Governments are using technological innovations to make a paradigm-shift to tackle the above challenges in urban environments. As a result, an increasing amount of data is collected and brought together at various levels to enable police officials to provide better security, doctors and health care professionals to enhance health care treatments, and inform governmental officials to solve social problems more effectively.

'Smart' can be defined as an implicit or explicit ambition of a city to improve its economic, social and environmental standards[[27]](#footnote-27)27. The concept of smartness in terms of performance is highly relevant to technologically implementable solutions.

In many cases, if there is some form of ICT, which is present in a city, the city or its activity is considered "smart". ICT devices and services are only an enabler or purveyor which allows the “smartness” to percolate throughout a system. Just by having a personal computer (PC) or smart phone does not define "smartness" or intelligence. Specifically, the International Organization for Standardizations (ISO)[[28]](#footnote-28)28has recently released a report (ISO/TR 37150:2014) entitled: “Smart community infrastructures – Review of existing activities relevant to metrics”.

Underscoring the need for ICT in ensuring a city is truly sustainable and smart, IBM states that “a smart city is one that makes optimal use of all the interconnected information available today to better understand and control its operations and optimizes the use of limited resources”[[29]](#footnote-29)29.

The relevance of urban infrastructure has long been a critical aspect for a smart sustainable city. Traditionally, there have been two types of infrastructure: physical (buildings, roads, transportation, power plants) and digital (IT and communications infrastructure). There is a distinction between these two types of infrastructures – physical and digital, with both operating on separate fields. A convergence of the two, coupled with smart management of the different infrastructures, could provide a multiplier effect.

Disaster management is a critical component to consider when designing a smart sustainable city, as recent experiences from the recent Fukushima, Katrina and 9-11 incidents have evidenced. In the case of the 9-11 tragedy, it has been suggested that the lack of interoperability between the first respondents and other corresponding civic agencies significantly hampered rescue efforts. To this end, the exploration of the use and potential of ICT in the area of disaster management has come to light[[30]](#footnote-30)30.

## 3.1 The role of ICT in smart city solutions

The role played by ICTs in SSCs is crucial, due to their ability to act as a digital platform from which an information and knowledge network can be created[[31]](#footnote-31)31. Such a network then allows for the aggregation of information and data not only for the purpose of data analysis, but also towards an improved understanding on how the city is functioning in terms of resource consumption, services, and lifestyles. Information made amiable by these digital platforms would serve as a reference for stakeholders to take action and create policy directions that would eventually improve the quality of life for the citizens and the society as a whole.

The multiple systems (infrastructure elements) within a city can be thought of as sub-networks of a larger network, i.e. “system of systems” or a “network of networks”. When these sub-systems are integrated with one another using ICT, they can be thought of as the "Internet of things" (IoT) for cities. All of these systems comprise of sub-systems, components and devices which have nodes, end points and behave like a network in terms of their end use characteristics and interactivity with other nodes. This is completely analogous to an information technology (IT) or data communications network, so mainstream ICT-based management process and approaches can be utilized with some modifications.

a. A holistic approach to SSC[[32]](#footnote-32)32

In traditional approaches to urban development, all the infrastructure systems are managed in silos, with limited communication and information sharing among and across government departments and civil society. This could be proven detrimental not only for the optimization of resource usage, but also for accessing vital information when needed to inform decisions during emergency situations. Therefore, to become a smart city it is essential to adopt a holistic approach that may involve the creation of multiple infrastructures (as discussed above), as well as strengthening the motivation for government participation, the application of technology, and the integration of various smart infrastructure management systems combined with citizen collaboration.

This integration can be achieved through ICTs, with ICT tools acting as the “glue” between the different physical infrastructures. For example, ICT could be used as the key medium to disseminate information on the locations of electric vehicle charging stations in order to optimize traffic flows and energy usage of electric vehicles.

ICTs also enable the following functions, which are keys to achieving the goals and maximizing the performance of SSCs:

* **ICT-enabled information and knowledge sharing**: Traditionally due to inefficiency on sharing of information, a city may not be ready to solve a problem even if it is well equipped to respond. With immediate and accurate information, cities can gain an insight on the problem and take action before it escalates.
* **ICT-enabled forecasts**: Preparing for stressors like natural disasters requires a considerable amount of data dedicated to study patterns, identify trends, recognize risk areas, and predict potential problems. ICT provides and manages this information more efficiently, so that the city can improve its preparedness and response capability.
* **ICT-enabled integration**: Access to timely and relevant information (e.g. ICT-based early warning systems) need to be ensured in order to better understand the city's vulnerabilities and strengths.

Together with this concept of integration of all the individual services, urban stakeholders can implement, optimize and make the city a smarter and better place to live in.

b. Data prediction

According to Gartner, **Predictive analytics** describes any approach to data mining with four primary attributes[[33]](#footnote-33)33:

1) An emphasis on prediction (rather than description, classification or clustering).

2) Rapid analysis measured in hours or days (rather than the stereotypical months of traditional data mining).

3) An emphasis on the business relevance of the resulting insights.

4) An emphasis on ease of use, thus making the tools accessible to business users.

Predictive analysis essentially applies modern statistical techniques of modelling, machine learning, data mining facts (current and historical) to make predictions about future events. Predictive analytics has become an essential tool in business modelling. Such models exploit historical and transactional data to develop a better understanding of behavioural patterns and use them for business purposes, for example, credit scoring techniques.

Such tools can now be applied to large datasets (i.e. Big Data) in order to improve or enhance the city's development. For example, constant data sharing would be able to provide immediate warning for any fragile water pipelines to relevant government departments before it bursts, mobile applications that predict which traffic routes to avoid or use, or predict which trains will be fully occupied at a given time and modelling people flows or workflows with real-time feedback loops.

A smart city is therefore a "predictive city"[[34]](#footnote-34)34 where specific incidents, events or scenarios can be anticipated, the end result being an improved quality of life, or allowing citizens to make more informed and educated decisions on what actions to take next.

c. Data accessibility and management

Data and information availability are vital for the functioning of any smart solution. Access to data must be possible under any circumstance, thus enabling corresponding actions to be taken by city officials. This is particularly important in the case of emergency and crisis situations.

Cross-scale information sharing using ICTs as platforms allows policy makers and officials from different sectors to base their decisions on common information, and undertake coordinated courses of action. Such data exchange not only strengthens the collaborative efforts between departments and sectors, but could also be used as part of critical assessments and forecasting of various emergencies, as well as to optimize any smart solutions implemented in the city.

Therefore, it is recommended for city managers to base the implementation of smart solutions on appropriate policies and governance structures that can support and sustain such efforts in the short, medium and long term. The following are some of the key components that ensure data accessibility and management in SSC:

* **Accessibility to data**: There is a need for schemas that will promote openness and accessibility to data. While there will always be a concern in terms of “privacy” and the proprietary nature of data, most 'sensitive' data can perhaps be made anonymous before being made accessible. This question of balancing the need for both privacy and accessibility is still not well understood in terms of a legal and regulatory framework and needs to be addressed in the design of smart sustainable cities.
* **Open data**: It is recommended that data on energy, utilities, transportation, and other basic datasets are to be made public. This is vital in facilitating the cross-scale information sharing component of a smart city that was suggested above. Information sharing allows better operational decisions to be made and implemented. It is equally important to note that all data should be presented in a consistent and standardized manner. It is only when all data is based on the same parameters that it allows for meaningful exchanges and decision making, such as in the case of open application programming interfaces (APIs).
* **Managing massive data**: Cities come in various sizes and so does the information associated with them. To get an accurate view of the data from various sources and various places, this information usually comes in huge packets and should be able to provide accuracy, analytical capabilities, data security, and data storage. Therefore, data needs to be managed using highly efficient database constructs.
* **High performance**: Creating new insights from massive volumes of data needs to be complemented with digital infrastructures that are capable of high performance. Large amounts of data can place a lot of pressure on the workload and operational capacity of existing devices. To make the task optimal, the ICT systems should be reliable, ensure precise data transmission, minimize downtime, and avoid system failure. In cases of failure, the solution should be ready to handle and recover from error.
* **Maximum efficiency**: In order for ICTs to be ready to swiftly disseminate the information from one corner of the city to another, it should operate at its peak efficiency at all points of time. Improving quality and flexibility while minimizing capital and operational cost is crucial for both maximizing and maintaining the role of ICTs over time.

## 3.2 Physical and service infrastructure elements

The following physical and service infrastructures are commonly found in the literature as key aspects for a smart sustainable city:

* Smart energy
* Smart buildings
* Smart transportation
* Smart water
* Smart waste
* Smart physical safety and security
* Smart health care
* Smart education

These infrastructures are traditional and very physical in nature. The convergence with digital (ICT) infrastructures leads them to become “smart”.

a. Smart energy

Rising energy prices, energy security and theft, depleting energy sources and the global warming caused due to the impact of energy usage are only some of the main issues that drive city managers to look into city sustainability. There is a global water deficit which is a result of the tripling of water demand over the last half-century. Water shortage could quickly translate into food shortages, consequently contributing to the rising food prices. Studies suggest that between early 2007 and 2008, the prices of wheat, rice, corn and soybeans have roughly tripled around the globe. Coupled with the more frequent occurrence of record high temperatures such as in the case of the summer of 2010 in Moscow, energy management needs to be fundamentally restructured[[35]](#footnote-35)35. Cities are looking to solve these problems with the development of new technologies to collect information and control energy in order to maximize urban energy consumption levels.

Smart energy management systems use sensors, advanced meters, digital controls and analytic tools to automate, monitor, and control the two-way flow of energy[[36]](#footnote-36)36. These systems optimize grid operation and usage by keeping consumers, the producers and providers up to date with the latest technology advancements to deliver energy efficient solutions. This information can help translate real-time data into action.

b. Smart buildings

Buildings are an urban necessity, and healthy buildings contribute to improve the quality of life by providing comfortable, secure places to live in, work, and play. However, buildings are also the main contributors to greenhouse gas emissions. For example, Canadians spend about 90% of their time indoors, which suggests buildings represent a big part of a city's carbon footprint[[37]](#footnote-37)37. In the United States, buildings account for[[38]](#footnote-38)38:

* 36% of total energy use and 65% of electricity consumption
* 30% of greenhouse gas emissions
* 30% of raw materials use
* 30% of waste output (136 million tons annually)
* 12% of potable water consumption

Smart building management systems with up-to-date information can make intelligent modifications to improve building energy efficiency, reduce wastage, and make optimum usage of water with operational effectiveness and occupant satisfaction. Moreover, these modifications not only apply to new buildings but also to existing buildings that can take advantage of the new and more energy efficient solutions, and thus reduce their energy use by up to 50% through simple retrofit programmes[[39]](#footnote-39)39.

c. Smart transportation

Transportation solutions are needed in order to move people (and goods) in an efficient (time), safe (secure), cost effective (economic), and an environmentally friendly and sustainable fashion. This typically means that there is a need for some form of "smartness" and occupant satisfaction in order to realize these goals. Therefore, intelligent transport systems (ITS) have become more relevant and are being implemented.

Smart transportation management systems should use technology and collect information about mobility patterns. This information enables city managers to make sure that with the current infrastructure and with lesser investments, the city provides cleaner, efficient and smarter transportation systems. This method lessens the level of wastage and improves the level of citizens' lifestyle, thus overcoming the challenges of transporting goods, services and people from one point to another. In addition, ICT can help to reduce the overall need for transportation and travel by offering virtual alternatives to physical movements.

d. Smart water

Studies suggest that approximately 783 million people lack access to clean water, 2.5 billion lack access to adequate sanitation, and 6 to 8 million are dying per year due to water-related diseases and disasters. ICTs can play a key role in this respect through a number of technologies that contribute to a better distribution, management, and allocation of water resources.[[40]](#footnote-40)40

While the bulk of the Earth's surface is covered with water, less than 3 percent of the water on the earth is fresh water and, of that, less than 1 percent is available for human use. The global groundwater table is dwindling fast and a water crisis is looming. There are increased concerns regarding water availability, quality, lack of infrastructures and the ability to manage water in an efficient and optimal manner. The management of water systems is still nascent, and a growing science in terms of utilizing, adopting and integrating advanced information technology (IT) remains in the developmental stage.

Water pollution, water wastage, supply and transportation of portable water and the cost associated with the overall water management are some of the issues that challenge the water sector[[41]](#footnote-41)41. Lack of awareness of the problem, inadequate information, and difficulties in the ability to demonstrate investment returns are driving governments across the globe to integrate advanced IT techniques and infrastructure to improve the management of water resources[[42]](#footnote-42)42.

Smart water management systems use and apply ICT in the development and delivery of solutions to provide access to safe water, manage demand and supply, and develop a pricing mechanism. Examples include:

* Providing continuous monitoring of water quality and availability via smart sensors.
* Improving water and energy efficiency.
* Enabling better overall water management.

This acts as an important factor to connect the problems of consumers with the potential answers of the service providers.

Recognizing that the availability of water has become critical, the Focus Group on Smart Water Management[[43]](#footnote-43)43 (FG-SWM) was established by the ITU-T TSAG meeting in Geneva, 4-7 June 2013, with ITU-T Study Group 5 as its parent group. The FG-SWM had its first meeting in Lima, Peru, in December 2013.

With urbanization, the problem for sustainable water (environmentally and financially) and sanitation services is becoming a major challenge for cities. ITU aims to acknowledge the water management problems faced by cities and position the implementation of smart water management (SWM), using ICT as an enabler to address, manage and provide potential solutions to alleviate challenges.

The integration of such technologies is adapted to monitor water resources and to understand problems in the urban water sector. All aspects in a city's water system are managed by prioritizing and managing maintenance issues as well as data.

In order to realize these opportunities in cities, the FG-SWM is developing a technical report that emphasizes the need for careful design and proper coordination among all relevant sectors on SWM technologies such as:

* Smart pipes and sensor networks
* Smart metering
* Communication modems
* Geographic information systems (GIS)
* Cloud computing
* Supervisory control and data acquisition (SCADA)
* Models, optimization, and decision-support tools
* Web-based communication and information system tools

The FG-SWM Technical Report stresses the existence of further opportunities of collaboration in this field, as well as the need to foster further dialogue and discussion on these issues.

e. Smart waste

While some cities in the world are converting bird sanctuaries into landfill areas, others are importing waste to meet the ever rising demands of energy from waste. With the ever growing increase in consumer goods, the wastage also has increased exponentially. Cities are finding it difficult to source, segregate different kinds of waste and make use of a product which can be potentially bought back into consumer life cycle.

This challenge can be solved with source reduction, proper identification of the category of waste and development of a proper use for the waste. There may be various forward-looking resolutions for converting waste into a resource and creating closed loop economies, but to enable this process we need proper and correct information and advanced technology.

Smart waste management systems will enable the following areas of action, among others:[[44]](#footnote-44)44

* Implementing waste tracking systems to monitor and control the movement of different kinds of waste.
* Sorting of waste without the operator coming into contact with it.
* Leveraging technology to collect and share data from source to transportation to disposal of waste.
* Connecting various smart waste management systems with local waste management service providers.

f. Smart physical safety and security

Incidents ranging from simple "jumping a traffic signal" to high level security breaches such as in airports can be effectively managed with good information and monitoring systems. These systems provide "on-the-go" data to officials which become an important step in keeping human security-related issues under check. Examples of ICT in physical security[[45]](#footnote-45)45 include the use of analytical tools which help to sense, respond to and resolve incidents, as well as towards criminal identification, predictive analysis and criminal pattern identification.

As urbanization becomes more mainstream, the following physical safety and security-related trends will become increasingly realized:

* Security will become more critical as cities and their infrastructure evolve.
* Cities will continue to grow (i.e. urbanization), resulting in more and more anonymous threats.
* There will be increasing pressure on local authorities to cope with expected and unexpected security threats against citizens.
* There will be an increased rate of technology adoption and penetration that will enable a more "safe city".
* There will be an increased cooperation between private and public sectors.
* Agencies will strengthen their collaboration on city-wide deployments.
* There will be a growing integration of existing infrastructures.

Overall, it is expected that there will be a growing integration of technologies such as physical security information management (PSIM). Citizen and security agencies will communicate seamlessly through smart technology. Command and control systems will be shared across multiple city departments such as energy, waste, security, and transport, enabling a holistic, city-wide approach. Predictive analytics and data mining will become a mainstay.

Existing security technology such as video surveillance, video analytics, and biometrics will remain the main focus of a city's security and how the analysis of key information flow is the main area for improvement in the next generation of security. According to ITU, the visual surveillance[[46]](#footnote-46)46 service is “telecommunication service focusing on video (but also including audio) application technology, which is used to remotely capture multimedia (such as audio, video, image and alarm signals) and present them to the end user in a user-friendly manner, based on a managed broadband network with ensured quality, security and reliability.” Requirements for a good visual surveillance system with detailed specifications on functional architecture reference points, signalling and control methods, sets overall protocols for a visual surveillance system.

g. Smart health care

Smarter health care management converts health-related data into clinical and business insights. Progressive organizations and cities are working together on their health care data to enable secure communications and information sharing. This data empowers health specialists to improve the productivity of the service provided at the point of contact of patients.

Examples of smart health care include the availability of remote alternative diagnoses, remote treatment or tele-assistance, online medical services, requesting an appointment online or the possibility of having a digital record via an electronic health management system, remote home services, alarm systems or even remote patient monitoring systems.

An ITU Focus Group to study Machine-to-Machine (FG-M2M) communications was established under the management of Study Group 11 in February 2012. While M2M is considered a key enabler of applications and services across a broad range of vertical markets (e.g. health care, logistics, transport, utilities, etc.), the Focus Group is first focusing on the health care market and to identify a minimum set of common requirements. Some of the key aspects being studied by the FG-M2M include:

* A "gap analysis" for vertical market M2M service layer needs, initially focusing on applications and services for the health care market.
* Identification of a minimum common set of M2M service layer requirements and capabilities, initially focusing on e-health applications and services.

h. Smart education

Education is a crucial component of smart city services. In the long run, education may be the most important smart city service of all, for adults as well as for children. As the world rapidly globalizes, one of the only ways to stay competitive is to develop and continue to build knowledge-based skills via education. *This includes initial knowledge (e.g. through school, vocational and university* education) as well as lifelong learning. The role of schools and universities is therefore a key element to consider in the design of smart education solutions. While there are many examples of how ICT can positively impact education, the following figure adapted from Intel[[47]](#footnote-47)47 summarizes some of the key contributions of ICT tools to education.


Figure 3-1 – Potential impact of ICT on education47

Summary of physical and service infrastructures

Table 3-1 provides some examples of the eight physical infrastructure and service elements of a functioning city seen through a “smart” lens.

Table 3-1 – Examples of city infrastructure applications

| Infrastructure | Example components |
| --- | --- |
| Real estate and buildings | • Synergies between energy efficiency, comfort and safety and security • Building as a network: Integration of multiple technologies (HVAC, lighting, plug loads, fire, safety, mobility, renewable, storage, materials, IAQ, etc.) • Software: Efficiency, automation and control, analytics and big data management  |
| Industrial and manufacturing | • Data interoperability• Sustainable production and zero emissions• Networked sensors and cloud computing• Factories of the future |
| Energy and utilities | • Smart grid and smart metering: Generation/distribution/measurement• Wireless communications• Analytics and policies• Load balancing, decentralization and co-generation  |
| Air, water and waste management | • Water information systems (WIS)• Integrated water, waste and energy savings optimization schema• Sensor networks for water and air systems |
| Safety and security | • Video surveillance and video analytics• Seamless communication during natural and man-made disasters |
| Health care | • Smart hospitals• Real-time health care including analytics• Home and remote health care including monitoring• Electronic records management |
| Education | • Flexible learning in an interactive learning environment• Accessing world class digital content online using collaborative technologies• Massive open online course (MOOC) |
| Mobility and transportation | • Intelligent transportation technologies in the age of smart cities:• Traffic management: Monitoring and routing• Real-time linkage to emissions, traffic patterns, reduced fuel consumption. |

## 3.3 ICT infrastructure

There are a number of additional studies[[48]](#footnote-48)48, [[49]](#footnote-49)49, [[50]](#footnote-50)50, [[51]](#footnote-51)51 that suggest the existence of a series of key dimensions and attributes for cities that are striving for "smartness" and sustainability. Throughout these dimensions, there is a recognition of the essential aspects of an overarching ICT infrastructure that enables all these “smart” attributes to become realized.

ICT infrastructure is a very wide topic by itself. A detailed description of ICT infrastructure is not part of the scope of this Technical Report. At a general level, it is infrastructure that enables computing, communications and associated analysis. ICT infrastructure includes both hardware and software components (e.g. network infrastructure, cloud computing, business and social applications software and access devices).

While the Technical Report[[52]](#footnote-52)52 produced by ITU-T FG-SSC Working Group 2 focuses on this topic, this section provides a summary of these key components in order to contextualise the notion of SSC and its attributes.

The following topics are highly relevant to the design and functioning of SSCs:

* ICTs specific to smart sustainable cities.
* Internet of things
* Ubiquitous sensor networks.
* Data security.
* Mobile broadband.

ICTs specific to smart sustainable cities

In addition to traditional ICT infrastructures such as network infrastructure, software applications, cloud computing/data platforms and access devices, Table 3-2 is a sample list (not exhaustive) of communications-related technologies which have relevance to SSCs.

The Internet of things

An important trend that has gained prominence in the last few years is the 'Internet of things' (IoT). Ashton[[53]](#footnote-53)53 defined the term in 1998 and re-stated in 2009 that: “Today computers – and, therefore, the Internet – are almost wholly dependent on human beings for information”.

What this actually means is that all objects and equipment in the world will be connected via Internet in one way or another. Internet will be in everything including the jewelry and clothing. Today's information technology is so dependent on data originated by people that our computers know so much about things.

According to recent report by Gartner[[54]](#footnote-54)54, the Internet of things (things, people, places and systems) will create new markets and a new economy adding USD 1.9 trillion worth of economic value by 2020. It is further estimated that in the next two years, the combined IT and telecom market will hit almost USD 4 trillion.

Another example of how pervasive the Internet of things could be found from a study by MIT. Researchers from MIT followed close to 3000 items of trash using smart tags and found that the some of this trash travels from its source location in the United States for more than 3 months before they reach a waste disposal unit.[[55]](#footnote-55)55

Table 3-2 – Smart ICT-based technologies in city infrastructure

| Infrastructure topic | Technologies |
| --- | --- |
| Building management | • Building automation• Building control• IT network systems• Crises management solution (power, infrastructure damage, etc.) |
| Data communications and security | • Voice/video/data• Audio visual• Structured cabling• TCP/IP/BAS protocols• Remote VPN Access• Computer access• Network access • Firewalls• Managed security services• Mobile broadband• Mobile security• Data security infrastructure |
| Smart grid/energy/utilities | • Energy logistics• Distribution (electricity, water, gas)• Utility monitor• Heat• Lighting • Back-up power• Leakage monitor |
| Physical safety and security | • Access control• Video surveillance intrusion detection• Biometrics• Perimeter and occupancy sensors• Fire alarm panels• Detection (smoke/heat/gas/flame)• Fire suppression• Notification and evacuation |
| Emergency response | • Integrated fire department• Police and medical services• Centralized and remote command and control• Scalable decision-making process  |
| Traffic and transportation (Mobility) | • Traffic control and monitoring (rail, underground, buses, personal vehicles)• 24/7 supply management (logistics) |

A city consists of countless physical structures, layered by multiple infrastructures. It is expected that the information that a city can generate at any moment is massive. As discussed previously, ICT infrastructures are the key layer capable of managing such massive amount of data and of delivering any crucial information to any relevant actors or departments at any given moment. Furthermore, ICT infrastructures, which consist of multiple Internet of things, are not only capable of transmitting data to actors but also to buildings. By allowing communication between buildings, it is expected that efficiency would be maximized particularly in the field of energy consumption and harmful gas emissions.

By 2020, 30 billion things will be interconnected, with each item having a unique Internet protocol (IP) address, thanks to Internet protocol version 6 (IPv6)[[56]](#footnote-56)56. Despite of this seemingly large number, it is still very much possible to attach sensors or radio frequency identification device (RFID) tags in every single one of these items, and connecting them through a central platform, thus creating a network similar to the one between Internet and a server. These networks churn out huge volumes of data that is used for analytical modelling. Another revolution is that these physical information systems are now being deployed and function automatically.

Along with technological advancements, the adoption of Internet of things is growing rapidly. The data from sensors is collected, processed and analyzed in real time, and lowering costs is expected to speed their adoption.[[57]](#footnote-57)57Corporations should consider the impacts and opportunities arising from the Internet of things. IoT can be viewed as a global infrastructure for the information society, the technology that connects not just humans with things but also things with every other thing. The Internet of things (IoT) is a vision that connects technological and societal implications.

Recommendation ITU-T Y.2060[[58]](#footnote-58)58 provides an overview of the Internet of things (IoT). This protocol adds more clarity to the concept and scope of IoT, classifies the fundamental characteristics and high-level requirements of IoT and also describes the IoT reference model.

Mobile broadband

Mobile broadband is a mainstay of information and data communication. The GSMA (GSM Association)[[59]](#footnote-59)59 states that as of Q1 2013, there are over 1.6 billion mobile broadband users. Mobile broadband now accounts for a quarter of global connections at over 1.6 billion (as of Q1 2013). There are over 350 million users in Europe, almost 800 million users in Asia, 525 million in the Americas and even 60 million in Africa. High speed packet access (HSPA) makes up most of the mobile broadband connectivity and has been the fastest growing wireless technology with a rate of adoption (since its introduction six years ago) ten times faster than the uptake of the global system for mobile communication (GSM) phones when they were introduced in the mid-1990s. With the advent of 4G and long-term evolution (LTE), there is an ever bigger push towards higher speed, secure data connectivity on the go.

Full hypertext markup language (HTML) (soon to be HTML5) browsers on smart phones has made ubiquitous access to the web commonplace. Access to e-mail – anywhere, anytime has had a tremendous impact on productivity and is now an integral part of both personal and working lives. The proliferation of applications or "apps" offers convenient access to services through a rich user experience, often for free or at a low price. Voice and video are already transforming the next generation of mobile broadband with the integration of these technologies into applications such as WhatsApp, Viber, FaceTime and You‑Tube all on mobile broadband.

One example of such an application is “Waze”, (recently acquired by Google) using crowd sourcing. Waze uses data gathered from global positioning system (GPS) and location data from smart phones to inform users about traffic patterns including how fast or slow the traffic was moving. It is not difficult to imagine a series of "smart sustainable city applications" such as smart energy, smart pollution, smart water, smart noise – all of which enable the general public not only to be able be better informed, but also to interact in real time with their environment

This unprecedented uptake of smartphones, coupled with the “app revolution” and the robust mobile broadband backbone, have begun to foster widespread innovations that are expected to help make the urban landscape more inclusive, safe and sustainable.

Ubiquitous sensor networks

A related topic to the IoT is that of ubiquitous sensor networks (USN). USNs utilize wire line and/or wireless sensor networks. These networks consist of interconnected autonomous devices distributed across the location, and use sensors to collectively monitor physical/environmental conditions (e.g. temperature, sound, vibration, pressure, motion or pollutants). USNs are conceptual networks built over existing physical networks; they make use of sensed data and provide knowledge services to anyone, anywhere at any time. Context awareness contributes to the generation of information for decision-making.

Recommendation ITU-T Y.2221[[60]](#footnote-60)60 has prepared a description on general features of USN and its applications and services publicly available. It also analyses the service necessities of USN applications and services and highlights the new capabilities and requirements based on the services.

Data security[[61]](#footnote-61)61

Population growth, economic crisis, resource crisis, growing energy demands, compliance to the urgency to carbon emission targets, increasing importance to public safety and security and exposure to online data transmission are driving the cities to become smarter.

Cities access a lot of information through the ICT system. More information means more knowledge and more vulnerability to data security. The more complex a system is the higher the need is for cities to protect the data. Some examples of verticals where the data security is important include energy, transportation and health care services.

* Energy data security – Attacks on the energy systems can lead to interruptions and also hinder data exchange between energy distribution centres and end users, and severely compromise the delivery of energy services.
* Transportation data security – A small hindrance caused to the flow of data or the traffic control systems will affect the overall aim of transportation optimization. For example, traffic management could be weakened when the navigation system is hacked leading to confusion and directing to wrong routes.
* Healthcare data security – ICT in health care is now fast becoming a reality. In this context, backup, cyber security and authentication solutions can ensure that health care systems offer such reliability and integrity, as well as patient privacy.

The following is an example of a step-by-step implementation approach for data security at a city level:

* Establishing the governance framework – Identifying key stakeholders in the government administration level and citizen associations.
* Fulfilling Governance, risk and compliance – Fulfilling the duty of governance with the inputs from different stakeholders at a policy level.
* Service continuity – Cities should create a group of people or organization who can monitor and measure for data security on a continuous basis. A partner with cities for data security.
* Information Protection – The cities needs a safe data storage area. Infrastructure managing services can be practiced by protecting information through efficient tools after partnering with the organizations which provide service continuity.
* User authentication – Before and during data sharing, a strong authentication process of the user should be in place.
* Infrastructure protection – Protection of storage areas and the data management systems are important.
* Response to data security threats – Visibility to possible threats to data security and efficient threat management strategies should be in place.

## 3.4 Emergency/disaster response mechanisms

Disasters are events that exceed the response capabilities of a community and/or the organizations that exist within it. Natural hazards, building environment, political/social unrest, as well as IT and data security are potential risks to consider.

During a disaster or an emergency, a smart city must be able to provide swift responses in a time-sensitive manner, as well as disaster-specific recommendations. No plan can anticipate or include procedures to address all the human, operational and regulatory issues. Essential business transactions must function, addressing needs assessment, communication, volunteer outreach and coordination, grant applications, and community assistance under rapidly changing circumstances[[62]](#footnote-62)62.

There is an applied case of the technology to reinforce the disaster prevention that is one of the roles of the ICT in smart sustainable cities[[63]](#footnote-63)63. During a disaster or emergency situation, it is sometimes very difficult to get an accurate real-time assessment of the situation on the ground. There is a lot of data, which needs to be obtained, analyzed and shared among many different agencies, organizations and individuals. Technology, especially ICT, has the ability and potential to address and solve some of these issues by providing the appropriate (relevant) information from various sources. ICT can aggregate, create, integrate information, and search the heterogeneous and multi-domain data and deliver a comprehensive set of information, appropriate for each end user. This typically implies "Big Data" type of analysis including real-time sensing data, social sensing data from social networking services (SNS) (e.g.Twitter), web archives, and scientific databases, which are collected and accumulated via the Internet from various individuals and organizations.

A smart city should have carried out risk assessment with respect to its susceptibility to various natural disasters and should have a strategy in place to deal with natural disasters to which it is highly susceptible.

Cities worldwide are placing increasing importance on building up resilience to natural disasters. These include flooding, extreme weather, as well as heat and water stress, all linked to climate change. Sophisticated ICT infrastructure combined with analytical capabilities aid smart cities confronted by natural disasters to manage the information flow. This may be between multiple public agencies, such as transport authorities, emergency services and energy providers, and citizens. City municipalities may rely on mobile networks to reach the majority of its citizens at short notice.[[64]](#footnote-64)64

The Organisation for Economic Co-operation and Development (OECD) published a study in 2010 estimating that major coastal cities including Miami, New Orleans, Tokyo and New York, would rely on flood defences to protect as many as 150 million people by 2070.[[65]](#footnote-65)65

A smart city's disaster resilience solutions should cover observation systems, information gathering capabilities, data analysis and decision-making aids. These components matched with an intelligent and interoperable warning system will enable cities to respond effectively to natural disasters. This heavily depends on the municipality's uses of ICT infrastructure, including mobile networks, to efficiently receive, process, analyse and redistribute data, and mobilize various city services.

4 Conclusions

The end goal for a smart sustainable city is to achieve an economically sustainable urban environment without sacrificing the comfort and convenience/quality of life of citizenry.

A smart sustainable city strives to create a sustainable living environment for all its citizens through the use of information and communication technologies (ICTs). The various attributes of a smart sustainable city need to be identified and can be used as part of the metrics and reference points for defining the smartness and the sustainability of a city. This will help contribute to a better, more in-depth understanding of what constitutes a smart sustainable city.

While the actual development of key performance indicators (KPIs) for a smart sustainable city is outside the scope of this Technical Report, The latter does provide however some background towards the identification and development of such KPIs. A separate detailed report on such KPIs has been prepared by the ITU-T FG-SSC Working Group 3.

What a smart sustainable city is depends on the "lens" or viewpoint from which one looks at a city. There are three key dimensions for a city, each of which has a number of attributes:

* **Environment and sustainability** – Related to city infrastructure and governance, energy and climate change, pollution and waste, and social, Economy and health.
* **City level services** – Viewing through an "urban" lens, there are multiple aspects and indicators including: technology and infrastructure, sustainability, governance and economics.
* **Quality of life** – An improvement in the quality of life of a city's inhabitants or populace.

The above dimensions can be reclassified into four overarching pillars incorporating the different attributes (illustrated in the outer ring of Figure 4-1)**:**

* **Economy** – The city must be able to thrive – e.g. jobs, growth, and finance.
* **Governance** – The city must be robust in its ability to administer policies and pull together the different elements.
* **Environment**[[66]](#footnote-66)66 – The city must be sustainable in its functioning for future generations.
* **Society** – The city is for its inhabitants (the citizens).



Figure 4-1 – Pictorial representation of a smart and sustainable urban landscape

The above four pillars are enabled through a series of physical and service infrastructures which form a city's lifeline including (but are not limited to):

* Real estate and buildings
* Industry and manufacturing
* Utilities/energy
* Waste, water and air management
* Physical safety and security
* Health care
* Education
* Mobility

The ICT infrastructure is at the core and acts as the nerve centre, orchestrating all the different interactions between the pillars and the infrastructure elements. It is an essential ingredient, since it acts as the "glue" that integrates all the other elements of the smart sustainable city in the form of a foundational platform. ICT acts as the "great equalizer" (human-to-human, human-to-machine and machine-to-machine) to connect a variety of everyday living services to public infrastructures, such as utilities, mobility and water.

Glossary

API Application Programming Interface

BAS Building Automation System

BREEAM Building Research Establishment Environmental Assessment Methodology

BRT Bus Rapid Transit

FG-SCC ITU-T Focus Group on Smart Sustainable Cities

GDP Gross Domestic Product

GIS Geographic Information System

GPS Global Positioning System

GRP Gross Regional Product

GSM Global System for Mobile communication

HSPA High Speed Packet Access

HTML HyperText Markup Language

HVAC Heating, Ventilation, Air Conditioning

IAQ Indoor Air Quality

ICT Information and Communication Technology

IoT Internet of Things

IP Internet Protocol

IPv6 Internet Protocol version 6

IT Information Technology

ITS Intelligent Transport System

KPI Key Performance Indicator

LEED Leadership in Energy and Environmental Design

LF Labour Force

LTE Long-Term Evolution

M2M Machine-to-Machine

MOOC Massive Open Online Course

MWh Megawatt hour

NO Nitrogen Oxides

PC Personal Computer

PPP Purchasing Power Parity

PSIM Physical Security Information Management

QoL Quality of Life

R&D Research and Development

RFID Radio Frequency Identification Device

SCADA Supervisory Control and Data Acquisition

SCC Smart Sustainable Cities

SDO Standards Development Organization

SG Study Group

SNS Social Network Service

SO Sulfur Oxides

SWM Smart Water Management

TCP Transmission Control Protocol

USN Ubiquitous Sensor Network

VPN Virtual Private Network

WG Working Group

WiFi Wireless Fidelity

WIS Water Information System

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Annex 1

Smart city dimensions and attributes[[67]](#footnote-67)67

| Dimension | Attribute | Descriptor | Description |
| --- | --- | --- | --- |
|
| Environment | Smart buildings | Sustainability-certified buildings | Number of LEED or BREEAM sustainability certified buildings in the city |
| Resource management | Total energy consumption | Annual total electrical energy consumption per capita (in MWh) |
| Annual electricity consumption per capita (MWh) |
| Carbon footprint | Annual CO2 emissions per capita (in tonnes) |
| Waste generation | Annual total waste volume generated by the city per capita (kg) |
| Annual household waste per capita (in kg) |
| Sustainable urban planning | Green space per capita | Urban green open areas per capita (in m2) |
| Mobility | Efficient transport | Clean-energy transport | Percentage of clean-energy transport use (electric train, subway/metro, tram, cable railway, electric taxis, bicycles)  |
| Multi-modal access | Public transport use | Percentage of public transit trips/Total trips |
| Technological infrastructure | Access to real-time information  | Number of public transit services that offer real-time information to the public: 1 point for each transit category up to 5 total points (bus, regional train, metro, rapid transit system (e.g. bus rapid transit system, BRT, tram), and sharing modes (e.g. bike sharing, car sharing) |
| Government | Online services | Online procedures | Number of online procedures performed/total procedures |
| Infrastructure | Wi-Fi coverage | Number of Wi-Fi – 33 hotspots per km2 |
|  | Diversity of sensors | Diversity of installed sensors to monitor the following categories (1 to 5 points): air and noise contamination; waste, transit, emergency, other |
|  | Municipal human resources | Percentage of administrative employees with university degree |
| Open government | Datasets | Total number of open datasets (excluding regulations/laws) with information for the last three years |
|  | Open data | Number of publicly available applications utilizing open data |
| Economy | Opportunity | New start-ups | Number of new opportunity-based start-ups |
| R + D | Percentage of GDP invested in R&D in private sector |
| Productivity | GRP per capita | Gross regional product (GRP) per capita (in USD) |
| Local and global connection | ICT cluster | Percentage of ICT companies based in local clusters |
|  | International-held events  | Number of international congresses and fair attendees.  |
| Society | Integration | Internet-connected households | Percentage of Internet-connected households |
| Gini index | Gini coefficient of inequality |
| Education | University graduates | Number of university Graduates per 1000 inhabitants |
| Creativity | Creative industry jobs  | Percentage of labour force (LF) engaged in creative industries |
| Quality of life | Culture and well-being | Life conditions | Percentage of inhabitants with housing deficiency in any of the following five areas (potable water, sanitation, overcrowding, deficient material quality, or lacking electricity) |
| Investment in culture | Percentage of municipal budget allocated for culture |
| Safety | Crime | Number of crimes per 100,000 inhabitants |
| Health | Life expectancy | Life expectancy at birth |

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