IEC®

White Paper

Orchestrating infrastructure for sustainable Smart Cities

Executive summary

Cities are facing unprecedented challenges. The pace of urbanization is increasing exponentially. Every day, urban areas grow by almost 150 000 people, either due to migration or births. Between 2011 and 2050, the world's urban population is projected to rise by 72 % (i.e. from 3.6 billion to 6.3 billion) and the population share in urban areas from 52 % in 2011 to 67 % in 2050. In addition, due to climate change and other environmental pressures, cities are increasingly required to become "smart" and take substantial measures to meet stringent targets imposed by commitments and legal obligations.

Furthermore, the increased mobility of our societies has created intense competition between cities to attract skilled residents, companies and organizations. To promote a thriving culture, cities must achieve economic, social, and environmental sustainability. This will only be made possible by improving a city's efficiency, and this requires the integration of infrastructure and services. While the availability of smart solutions for cities has risen rapidly, the transformations will require radical changes in the way cities are run today.

Thus developing smart cities is not only just a process whereby technology providers offer technical solutions and city authorities procure them. Building up smart cities also requires the development of the right environment for smart solutions to be effectively adopted and used.

The development of a smart city requires participation, input, ideas and expertise from a wide range of stakeholders. Public governance is naturally critical, but participation from the private sector and citizens of the community are equally important. It also requires a proper balance of interests to achieve the objectives of both the city and the community at large.

This White Paper proposes a number of answers on the *what, who* and *how* of smart city development. It calls for a wider collaboration between international standardization bodies that will ultimately lead to more integrated, efficient, cheaper, and environmentally friendly solutions.

Needs of cities differ strongly but… the main three pillars of development remain the same.

There is no single trend, solution or specific approach for smart cities. Regional trends illustrate that there are divergent urban growth patterns among major regions with different levels of economic development. Still, significant disparities in the level of urbanization can also be observed across different countries within the same region. Nevertheless, all cities aiming to develop into smart cities have to be built on three sustainability pillars:

- **Economic sustainability**

Cities need to provide citizens with the capacity to develop their economic potential, and attract business and capital. With the global financial crisis, the economic sustainability of cities has taken centre stage. The crisis has unearthed considerable weaknesses in the financial models and planning strategies of public authorities in the provision of services and in their infrastructure investments. Their financial sustainability now depends also on new financial models, as well as more efficient and better-integrated services and infrastructures.

- **Social sustainability**

A city's attractiveness for people, business and capital is closely related to the quality of life (QoL), business opportunities and security and stability, which are guaranteed by social inclusiveness.

- **Environmental sustainability**

Cities face a number of environmental sustainability challenges, generated by the city itself or caused by weather or geological events. To reduce the impact of the city on the environment resource it is important to promote the efficient and intelligent deployment of technology and to integrate infrastructures. This process can also be developed in such a manner as to increase the resilience of the city to environmental shocks.

These three pillars have one common denominator, namely the need to achieve more and better with less, i.e. efficiency. Efficiency must also be achieved in a manner that brings benefits and opportunities to citizens, making the city more dynamic and participatory.

Smart technology solutions create value.

Rather than being an expense, smart technology integration can create considerable opportunities for added value in any city. Technology integration helps cities to improve efficiency, enhance their economic potential, reduce costs, open the door to new business and services, and improve the living conditions of its citizens. A key condition for value creation through integration is the compatibility of technologies; which is best achieved through common and consensus-based standards that ensure interoperability.

Presently, however, smart city projects concentrate mainly on vertical integration within existing independent infrastructure and services silos, e.g. energy, transport, water or health. A truly “smart” city requires horizontal integration as well as creating a system of systems capable of achieving considerable increases in efficiency and generating new opportunities for the city and its citizens.

New approaches are necessary to design, implement and finance smart city solutions.

Cities are faced with a complex challenge, as the traditional processes of planning, procuring and financing are not adequate for their needs. Smart cities can only exist if fundamental reforms are undertaken.

Stakeholders are key drivers to smart city solutions.

A smart city cannot be imposed by decree, as the city is shaped by a large number of individual decisions and social and technological changes cannot be fully accounted for. With the present advances in telecommunications, information and communication technologies (ICT) and affordable energy efficiency and energy production tools are changing the relationship between citizens and city services. Citizens are increasingly becoming providers of city services and not only users. A good plan requires the participation, input and ideas from a wide range of stakeholders within the city. This means that city planning needs to allow for bottom-up processes of modernization. The stakeholders are:

- Political leaders, managers and operators of the local government (city).
- The service operators – public or private: water, electricity, gas, communication, transport, waste, education, etc.
- End users and prosumers: inhabitants and local business representatives.
- Investors: private banks, venture capitalists, pension funds, international banks.
- Solution providers: technology providers, financiers and investors.

Giving to each of these groups a true stake in smart city development is important to achieve the necessary consensus for the changes. Their concerns need to be carefully considered and acknowledged, and ultimately the direction and next steps have to be collectively approved. In the absence of proper consultation, the authorities will sooner or later face considerable additional obstacles to make their vision a reality.

Without integration rising to the level of a system of systems there cannot be smart cities.

The transformation of a city into a smart form presents its stakeholders a wide range of challenges, including benefits and consequences when such a transformation is undertaken. A promising approach to support city planners, but also standards developing organizations (SDOs), is to model a city as a collection of activity domains in an integrated virtual organization (the city), where various groups of stakeholders (local governments, public and private corporations, academia, healthcare institutions, cultural associations, religious congregations and financial firms) participate in operating and sustaining the city as a whole. Modelling the interrelations allows identifying pain points, gaps and overlaps in standardization and clarifying the technical needs for integration.

While the technologies to develop smart cities are mostly already readily available and improving, their deployment is hampered by technical, social and administrative challenges. Horizontal integration of infrastructures through technology is essential to reap the benefits of innovation and the potential and necessary efficiency.

Thus, interoperability is essential; without it, city planning is marred by unexpected inefficiencies leading to suboptimal outcomes and higher costs. The planning requirements for city authorities are very complex, as there are thousands of organizations and companies working in parallel to bring on the tools, systems and products that offer potentially affordable/sustainable solutions.

To ensure that smart integrated systems are put in place in practice, internationally agreed standards that include technical specifications and classifications in order to support interoperability (i.e. devices and systems working together) are *sine qua non*. These include technical specifications and classifications in order to support interoperability. These are metrics against which benefits can be assessed as well as best practice documents that detail controls.

Horizontal as well as vertical integration is key to creating value and interoperability.

Electric grids, gas/heat/water distribution systems, public and private transportation systems, and commercial buildings/hospitals/homes play a key role in shaping a city's liveability and sustainability. To increase their performance and efficiency, these critical city systems need to be integrated.

The successful development of a smart city will require the combining of a bottom-up systems approach with a top-down service development and a data-centric approach. Technology integration includes vertical integration from sensors, to low cost communication, real time analysis and control, and horizontal integration of historically isolated systems up to citizen based services. Combined, this creates a system of systems.

Today's smart city projects are mainly focusing on improving the integration of historical verticals, i.e. parts of existing utilities, improving e.g. energy efficiency, or reducing water leakage. The next step is horizontal integration. Data from the different sectors can be combined to better manage the city and reduce risks.

Interoperability is the key to manage systems of systems and to open markets to competitive solutions.

Interoperability is key to manage systems of systems and to open markets to competitive solutions. While we are today experiencing the internet of things (IoT) revolution (driven by the appearance of smart devices, such as wireless sensors, radio-frequency identification (RFID) tags and IP-enabled devices), different producers are generating technologies using their own communication specifications and data protocols.

Future interoperability can only be guaranteed through the existence of international standards ensuring that components from different suppliers and technologies can interact seamlessly. Continued best practice sharing and development of common standards to ensure that data can flow freely between systems is essential, while maintaining the need to protect confidentiality and individual privacy.

Common terminology and procedures have to be developed in order to also ensure that organizations and businesses can efficiently communicate and collaborate, which can also be guaranteed through standards.

Sectorial bodies need to increase collaboration.

The large efficiency gains from integration and interoperability can, however, only be realized if city departments and other stakeholders collaborate effectively and agree to share information. Smart services and infrastructures cannot develop without proper collaboration. The lack of exchange of fundamental data on customers, infrastructures and operations is one of the most important barriers highlighted by stakeholders.

There is a need to reform the way standards are developed.

The glue that allows infrastructures to link and operate efficiently is standards. Standards are necessary to ensure interoperability of technologies and the transfer of best practices. But standards are not yet adapted to the level of technology integration we are requiring. Standard bodies still operate in sectorial parallel silos, developing standards that are not easy to understand by non-specialists, for example city managers. Standards are facilitators for city planners who need to incorporate them in planning and procurement. There is thus a need to reform the way standards are produced and ensuring that they are adapted to the needs of the city planners and other service operators within the city.

The systems approach will only work if there is a coherent global approach.

There is a need for close collaboration between standard bodies themselves and collaboration with outside organizations, and particularly the city planners. A precondition for the considerable investment in, and successful deployment of, smart city solutions is a substantial worldwide agreement on the *what* and *how* decided for and with the key stakeholders. Smart cities stakeholders need to recognize that standardization efforts will involve the development, promotion, and deployment of standards series and conformity assessment schemes that enable the implementation of smart city solutions.

In addition, the multiplicity of technologies within a city now demands a top-down approach to standardization. This requires new coordination approaches between SDOs in which all the parts of the city are jointly considered by the several technical committees involved by the different organizations. This methodology is essential as systems level standards will enable the implementation and interoperability of smart city solutions.

Guiding principles and strategic orientation for the IEC and messages to other SDOs.

Electricity is core to any urban infrastructure system and the key enabler of cities development. As a result, the IEC has a specific role to play in the development of a smart city's set of standards. The IEC shall call for, take initiative, invite, and strongly contribute to a more global and collaborative approach including not only international standardization organizations, but also all stakeholders of the smart city landscape (city planners, city operators, etc.) and specifically the citizens.

Technology and system integration are critical to ensure interoperability and the IEC will support active collaboration between the relevant actors as described in the following guiding principles.

The IEC shall continue to foster technology integration (electrotechnical, electronics, digital and IT), and make sure that digital technology is fully integrated in all IEC products in a connect and share data perspective.

The IEC shall make sure digital and IT technology suppliers are actively contributing in its work. Data aspects shall become a key issue in IEC, including IoT, data analytics, data utilization, data privacy and cyber security.

The system approach shall be accelerated as a top IEC priority taking into account flexibility, interoperability and scalability. Value creation for users (citizens and city infrastructure and service planners and operators) will remain the main driver of standardization work.

Smart development requires solutions to be adapted to the specific needs of the city and its citizens, and standards have to be developed with this purpose in mind, removing technology barriers that prevent technology integration.

In the system approach, IEC shall consider an architecture framework clarifying the system-of-system concept and the basic levels and rules of interoperability and integration. This framework shall be established in collaboration with other international SDOs as well as international organizations such as fora and consortia and shall apply to greenfields and brownfields.

The IEC shall also develop work around visualization tools to model the complex interdependency of systems in city simulations.

The IEC should aim to liaise with key city stakeholders, encourage and foster their participation and inputs in the standardization work, and create the necessary collaborative working place.

The IEC shall challenge the way standards are written and promoted and specifically how the added value of standards, perceived by citizens and city actors, can be increased.

These efforts should lead to a wider market with solid standards and interoperability, which will support the expansion of replicable and more affordable technologies globally. Wider collaboration between stakeholders will ultimately lead to more integrated, efficient, less expensive and environmentally benign solutions for the world's rapidly growing urban population.

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Table of contents

List of abbreviations

Technical and scientific terms

CAPEX	capital expenditure
ERR	economic rate of return
ESCO	energy services company
ESPC	energy saving performance contract
GDP	gross domestic product
GHG	greenhouse gas
ICI	information and communication infrastructure
ICT	information and communication technologies
IoT	internet of things
M2M	machine to machine
OPEX	operational expenditure
PC	project committee (of the IEC)
PPP	public private partnership
QoL	quality of life
RE	renewable energy
RFID	radio-frequency identification
SaaS	software as a service
SC	subcommittee (of the IEC)
SDO	standards developing organization
SEG	systems evaluation group (of the IEC)
TC	technical committee (of the IEC)

Organizations, institutions and companies

ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
BSI	British Standards Institute
CEN	European Committee for Standardization

CENELEC	European Committee for Electrotechnical Standardization
CEPS	Centre for European Policy Studies
China-EPRI	China Electric Power Research Institute
DIN	German Institute for Standardization
DKE	German Commission for Electrical, Electronic and Information Technologies of DIN and VDE
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
ITU-T	International Telecommunication Union – Telecommunication Standardization Sector
JTC 1	Joint Technical Committee 1 (of ISO and the IEC)
MSB	Market Strategy Board (of the IEC)
SMB	Standardization Management Board (of the IEC)
TMB	Technical Management Board (of ISO)
UN	United Nations
VDE	Association for Electrical, Electronic and Information Technologies
WHO	World Health Organization

Examples of related efforts and organizations

ANSI Smart City Workshop (2013)

EC (EIP-SCC) European Innovation Partnership on Smart Cities and Communities (2012)

IEC SEG 1 – Systems Evaluation Group 1 on smart cities (2013)

ISO/IEC JTC 1/SG 1 – Study group on smart cities ITU-T SG 5 – Focus group on smart and sustainable cities

SSCC-CG – CEN-CENELEC-ETSI Smart and Sustainable City and Community Coordination Group

VDE Smart City Congress (2014)

Glossary

Brownfield
brownfield is an existing industrial area that is being re-built for a new purpose

Greenfield
greenfield is a new site not previously used for an industrial purpose

Technical interoperability
capability to communicate, execute programmes, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units

[SOURCE: ISO/IEC 2382-1, *Information technology – Vocabulary – Part 1: Fundamental terms*]

Section 1

Introduction

1.1 Overview

This White Paper is the fifth in a series whose purpose is to ensure that the IEC can continue through its International Standards and Conformity Assessment services to solve global problems in electrotechnology. The White Papers are developed by the IEC MSB (Market Strategy Board), responsible for analyzing and understanding the IEC's stakeholder environment, so as to prepare the IEC to strategically face the future.

The pace of urbanization at the global level is unprecedented. Every day, urban areas grow by almost 150 000 new people, either due to migration or births. Between 2011 and 2050, the world's urban population is projected to rise by 72 % (i.e. from 3.6 billion to 6.3 billion) and the population share in urban areas from 52 % in 2011 to 67 % in 2050.

The ability to effectively and efficiently manage rapid urbanization will become essential. Cities need to reach, achieve and maintain the essential objectives of economic, social, environmental and financial sustainability. For this, they will require increasing the efficiency of existing and new infrastructures and services to a level never achieved before. This will require a leap in integration of all infrastructures, whether they are public or privately funded or operated and this relates to management and operations. There is a consensus that the daily life of all citizens will be influenced by the degree of smartness of the solutions, the degree of user-friendliness as well as the costs incurred.

The fact that electrotechnical solutions underpin all city infrastructures is often taken for granted. They are the instruments of our daily lives, and ensure the integration of technologies we rely upon, guaranteeing the cities' operations and efficiency. The interoperability of components, their reliability and ease of use across cities, countries and cultures is facilitated and ensured by consensus-based standards. These standards are developed by global SDOs, and voluntarily adopted at the international, national and local levels. They allow the compatibility of instruments and machines, create and enlarge markets and guarantee a certain level of quality to the customers, whether they are public authorities, businesses or individuals. Standards are involved in the daily life of every citizen, but are often underestimated in their importance and sometimes confused with legal requirements. The full potential of the cities of today and tomorrow will most likely only be realized with efficient standards.

Getting standards right is important for all. This includes the approach of SDOs and their ability to offer user-oriented standards in supporting technological advances applicable seamlessly into both new and existing infrastructures.

In response to this, the IEC commissioned the present White Paper with a view to how best address the use of standards for integration of interoperable infrastructures and services required for smart cities.

The arrangement of this White Paper is apportioned into sections that look at the components and requirements of a smart city:

- Section 2 addresses that there is no single trend, solution or specific approach for smart cities, and four examples of city challenges are given.

- Section 3 focuses on creating value through smart technology integration that is necessary in all cities.
- Section 4 discusses stakeholders as key drivers to smart city solutions.
- Section 5 concludes with a number of guiding principles offering a strategic orientation for the IEC in its technology systems and its collaboration with other actors.

Section 2

The present framework conditions for cities

Evidence shows that the world is undergoing rapid urbanization. The speed has been unprecedented; the progress in the last 40 years is equivalent to the urbanization achieved in the preceding 4 000 years. Every day, urban areas grow by almost 150 000 new people, either due to migration or births. Between 2011 and 2050, the world urban population is projected to rise by 72 % from 3.6 billion to 6.3 billion. This means that the urban infrastructure needed to cope with this growth over the next 35 years will surpass the one built over the last 4 000 years.

This pace of urbanization, coupled with a small decline in rural populations,[1] is expected to lead to an increase in the level of the population share in urban areas from 52 % in 2011 to 67 % in 2050 [1]. According to the United Nations (UN) urban and rural population datasets, the year 2009 marked the first time in history that the number of people living in urban regions exceeded that of people living in rural regions, while the UN-Habitat [2] projects that if the trends continue, 7 out every 10 people in the world will be living in an urban environment by 2050. Notably, migration from rural to urban regions is seemingly no longer the major cause, since today the greatest part of this growth occurs from natural urban population growth ([2] [3]).

The developed and emerging worlds are expected to experience significantly different urbanization patterns. In particular, the developed regions and countries (i.e. North America, Australia, New Zealand, Japan and Europe) have already attained very high levels of urbanization, often exceeding the value of 80 % and thus, have relatively small room for further increases in their urban populations. In contrast, the emerging regions of Africa and Asia are projected to experience a large growth in urban population over the course of the next four decades. By 2050, approximately 53 % of global urban population is projected to live in Asia and around 23 % in Africa [1].

The aforementioned regional trends illustrate that there are divergent urban growth patterns among major regions with different levels of economic development. Still, significant disparities in the level of urbanization can also be observed across different countries within the same region. For example, in Africa research has shown that countries experience different levels of urbanization, depending on, among other factors, their degree of economic development. This further highlights that urbanization is by no means a homogenous phenomenon and that the stage of national economic development can be critical in determining the pace of urban growth [4].

2.1 The key pillars for cities

All cities have something in common, in-as-much as they all strive to achieve three objectives, presented here as city sustainability pillars. The first is economic sustainability, i.e. a dynamic, productive city with numerous business opportunities generating wealth. This requires from the one hand high productivity and wealthy cities and healthy and well-financed public services. The second is social sustainability, guaranteeing access by all citizens to basic services and avoiding social exclusion. The third is environmental sustainability,

1 According to [1], the world rural population will peak at 3.4 billion in 2021 and then decline to 3.05 billion by 2050.

guaranteeing environmental services and a healthy living environment. We also note an additional challenge which is financial sustainability, which simply means achieving the objectives of the city based on a financially sound plan, ensuring that the costs are fully covered and the city is not at risk of insolvency.

2.1.1 Economic sustainability

By economic sustainability, this paper refers to the business environment and wealth generation capacity of the city. It is a proxy for gross domestic product (GDP) growth, but encompasses wider criteria than just GDP. Population growth, the quality of private undertakings, the attractiveness as in investment location as well as the ability of city authorities to tax the citizens for public services, all depend of the city's ability to attract business and capital.

The development of smart cities, the financing of change and the fullest adoption of innovations by city inhabitants, require an understanding of the economic fabric of the city and the market for smart solutions. Understanding the market allows for the development of new approaches to infrastructure financing, as well as influencing citizen's behaviour through those approaches. For cities requiring public private partnerships (PPPs) and systems of cost recovery using user charges, this knowledge is of paramount importance.

Smart city services contribute to the economic sustainability and the resilience of cities to economic shocks, as those generate a new level of economic diversification.

Economic sustainability is also closely linked to financial sustainability, particularly in the wake of the financial crisis. Many cities have seen their access to capital curtailed and their credit rating deteriorate, while financial institutions have restricted the access to credit. Thus even though well-designed investments in improved efficiency can make cities more sustainable financially, short-term investment capital may be unavailable at the required scale.

Nevertheless, investing in the city structures of the future can be done using novel financial models, which monetize savings and use them to finance the reimbursement of capital expenditures. In addition, the cities of the future are expected to have much more decentralized energy services and supply provision systems, creating new economic activities and allowing PPPs. The right models should be able to combine financial sustainability with higher investment rates. Depending on the circumstances of each city, the need for special support by donors, governments and international financial institutions may arise. Cities in richer countries with limited credit access may need state guarantees or guarantees by public financial institutions to help reduce the risk rating, and thus interest rate costs. Poorer countries may in addition need financial aid by donors and international financial institutions. Financial models need to be well designed, aiming ultimately at developing cost effective and sustainable solutions, and also at attracting foreign investment. Importantly, financing models must be based on solid cost-benefit analysis, including wider socio-economic benefits where necessary.

2.1.2 Social sustainability

When large numbers of people live in agglomerations, actual or perceived social inequalities and social exclusion of sections of the population can lead to social unrest. City authorities have a key interest to ensure social inclusion, which starts with a basic level of services for all citizens. In a smart city, it is important to take into account the risks of alienating important groups of citizens. This may happen because smart services are limited to richer areas of the town, or because user charges make many important services unaffordable for certain parts of the population. All models of development of cities have to ensure that public transport, water, sanitation, electricity, and telecommunications are affordable and accessible to all population groups.

Citizens are also the ultimate beneficiaries and users of "smart" changes. Inclusiveness can be achieved by involving all relevant stakeholders from the start, and ensuring that new changes are understood and accepted, and thus inclusive.

Smart city infrastructures or services need to respond to the following questions:

- Are the expected objectives of the planned changes taking into account real behaviour of the city stakeholders?
- How can it be guaranteed that basic city services are affordable?
- Who is paying for the services? Are the users that can afford them the right target group?
- Can the new services and infrastructures be understood and used by all citizens targeted?
- Are the social and cultural values of the citizens taken into account?

Smart city approaches strongly focus on technology and often rely on sophisticated applications. Badly understood or poorly implemented, they may be pursued for their own sake and divert cities from real issues (employment, education, crime, etc.). Ideally, smart city projects should be carried out only if they help cities to meet their needs, with a quantifiable added value facilitated by technology integration, usability or cost reductions.

2.1.3 Environmental sustainability

Environmental concerns are growing in cities. Three pressures arise. The first is on resource limitations, such as water scarcity and quality, or fuel requirements. The second is on QoL and health. Not only are citizens and authorities more environmentally aware, but the economic implications of pollution can be serious, due to the impact on health and the attractiveness for businesses to operate from the city. The third is risk management and resilience to environmental shocks (such as heat waves and flooding caused by climate change).

One of the first stages to address sustainability is to increase resource efficiency in all domains, such as energy efficiency in buildings and networks, fuel efficiency in transport, water efficiency and new methods to transform waste to energy. Technology is not the only aspect required for sustainability, but is an important and necessary step forward. Efficiency gains can need significant investments, and the integration of different technologies can be complex.

Resilience and risk management need to be integrated in city planning, based on estimated future risks. The smart city is essential and possibly our best bet to move towards sustainability. The integration of different technologies in the areas of ICT, transport, energy, water etc., which form the infrastructure backbone of cities, currently offers the best prospect for sustainability.

2.2 Same objective but different challenges, trends and needs

The future challenges of urban areas will depend on many factors, which will affect the kind of investments needed. Some factors will be linked to the geographical position and the exposure of the city to climatic events, e.g. exposure to impacts from a rise of sea level, flooding from changes in river flows, increased risks of heat islands, etc. Location may also create considerable constraints for the city. Many cities in developed as well as in emerging and developing countries are considering their hinterland in the planning phase, but some cities like Singapore or Honk Kong are highly constrained in their land resources. Finally, the level of migration to cities and the kind of existing infrastructure or building stock will determine if investments are mainly greenfield or brownfield.

A greenfield approach is often related to emerging and/or developing countries, i.e. regions where new cities or economic regions are built from scratch. However, this approach can also occur in industrialized and developed countries where new districts and towns are planned in an integrated fashion. Examples are Songdo in Korea and Seestadt Aspern in Vienna, Austria. In the latter case, an entire new quarter of an existing city has been planned and built, leaving traditional frameworks behind.

The brownfield approach defines the process and the related actions to turn an existing urban infrastructure into a smart city/city of the future. In this case, key for success is the transformation/ replacement of existing infrastructures, taking into account the needs of citizens and the character of the city. In industrialized and developed countries this approach is the usual one. Due to the need to integrate or amortize existing infrastructures, the whole process could stretch beyond a decade.

In terms of the final result, there are in principle no major differences between brownfield and greenfield approaches for smart cities as the definition and parameters of the final product do not change. However, the path and time to achieve the objectives can be very different.

2.2.1 Demographic change and the implications for cities

Many challenges will come from within the city itself, and one of the key challenges will be demographic change and the impact of ageing. According to a recent study by the Global Cities Indicators Facility [5], the number of people over 65 years of age will

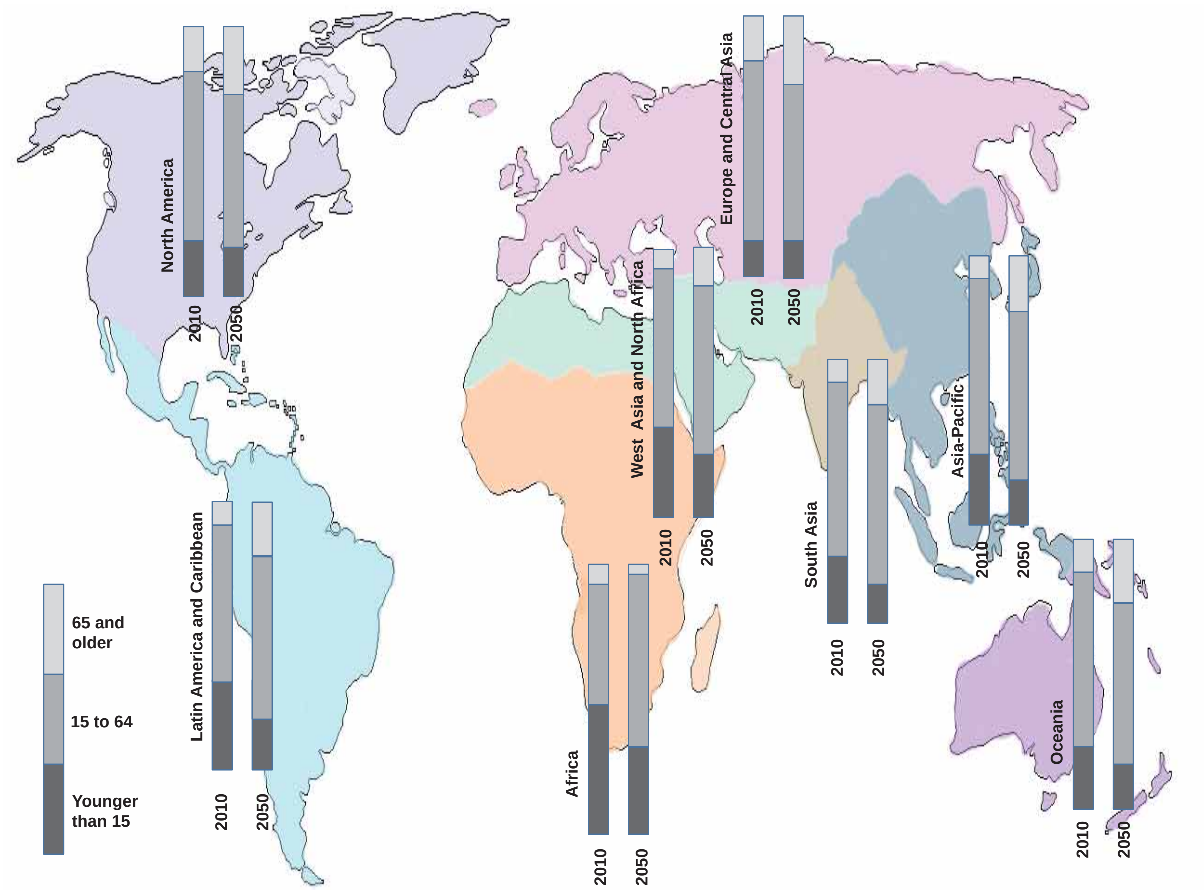

Figure 2-1 | Population distribution by age cohort and world region (2010-2050) [5]

increase by 183 % globally in 2050 compared to 2010, with astonishing spikes expected in certain regions. In West-Asia and North Africa the increase is expected to be of 366 %. In 2045, the projections show that elderly people will outnumber children under 15 for the first time in history. The countries with the largest shares of elderly population will still be Europe and North America, but in Asia-Pacific and Latin America the shares are expected to be similar in 2050, which means a stronger increase in percentage terms.

The report highlights how vast the implications for cities are in terms of physical planning and design, and in terms of economic repercussions. Cities are responsible for 70 % of the world GDP, and the impacts of ageing on productivity, labour supply, income security and housing security bring important political and economic policy challenges to cities.

2.2.2 Economic development and the financial change

Urban productivity is considered to be of key importance in determining the prosperity of any city, as it reflects the efficiency with which a city uses its resources to produce outputs that can generate additional income and thereby improve living standards. This is the reason that GDP per capita is generally used as a leading indicator of urban productivity. The use of GDP as a leading indicator of urban productivity and prosperity has been criticized for not addressing other notions of urban well-being such as QoL, social cohesiveness, environmental sustainability and availability of opportunities for business and residents ([2] [6]). However, the limited availability of data is considered to be one of the principal reasons for not adopting a broader concept of productivity, which would incorporate other factors of production, beyond land, capital and labour, such as human, intellectual and social capital [2].

Urbanization has generally been accompanied during the past 50 years by an increase in national productivity, as measured by GDP per capita. This increase in productivity is important to facilitate the necessary investments in smart solutions. As was mentioned above, smart solutions can generate new opportunities and reduce costs through economies of scale. Appropriately tailored solutions for cities using new innovative financial systems can produce economic results that outweigh investments.

However, this positive link between urbanization and national productivity has not been confirmed in all cases, as some low-income countries underwent rapid urbanization although their GDP per capita remained rather stable or even decreased [2]. This is a worrying trend, as the likely repercussion is the appearance of considerable urban poverty and the incapacity for authorities to invest in basic infrastructures ensuring the access of basic services, such as water, sanitation, health, food and education, thus fuelling poverty. Responses to such situations are needed with tailor made interventions in line with the economic circumstances and the needs of the towns.

2.3 Examples illustrating a different mix of challenges

This section illustrates how complex and different the challenges are that cities face in different parts of the world. The speed of urbanization, levels of social inequality, infrastructure needs are highly different and complex. Four examples in four continents are presented below for comparison.

2.3.1 Beijing

Beijing is a city example that illustrates the sheer scale of China's urbanization[2]. From 2000 to 2010, the city's population increased by 42 %,

2 According to [7], by 2025 China's urban population will be increased by 350 million people, while around 64 % of the country's population will live in cities.

reaching the population number of around 20 million residents, while China saw its population increasing by only 6 % during the same period. This rapid urbanization trend together with the huge investments in infrastructure has increased the city's global influence and economic competitiveness [8].

Still, a number of challenges have emerged for Beijing in response to this massive urbanization process. Low air quality affects the quality of its residents [9] and the city has been ranked by the World Health Organization (WHO) in 2014 among the most polluted places across the globe. Despite the city's investments in subway systems, an increase in private car ownership, fuelled by the increased living standards among others, has led to significant congestion problems [7]. The city has furthermore faced shortfalls in the supply of energy resources [7] as well as difficulties in managing the supply and demand for water [9]. Added to this, the huge population expansion of the city has been accompanied by rising income and wealth inequalities [8].

2.3.2 Nairobi

Nairobi's population increased from around 1.3 million in 1989 to about 3.2 million in 2009 [10], reflecting Kenya's high levels of urbanization. However, as the city expands, it faces difficulties in supporting its citizens with adequate education and healthcare services. Due to the high levels of poverty and absence of appropriate urban planning strategy, people are often forced to live in slums where they lack access to basic services such as clean water supply, sanitation and waste collection [11].

A combination of factors such as lack of appropriate infrastructure, insufficient use of technology and weak enforcement of traffic regulations is responsible for a huge congestion problem which in turn creates a loss of productivity, air pollution and has an impact on citizen QoL [12] [13]. The unreliability of energy supply also poses a threat on the city's businesses, often having an effect on their capacity to compete with companies located in other African countries. Improving safety across the city presents an additional challenge that requires the successful integration of multiple public and private information systems to improve the flow of information in case of fire, medical and security emergencies [13].

2.3.3 Boston

The city of Boston has put forward the ambitious climate change targets of reducing greenhouse gas (GHG) emissions by 25 % by 2020 and by 80 % by 2050 [14]. Transportation is one of the sectors that holds significant emission reduction potential as it is responsible for about 25 % of the city's GHG emissions, of which the majority comes from automobile traffic [14]. To accelerate progress towards reducing its emissions from the transport sector, the city needs to make the best use of the various collected transportation data which are available in a range of different formats and are often scattered over several departments. In particular, the city faces the challenge of improving the alignment and aggregation of data from several sources in order to enable easy access to key information by various possible users such as transport and urban planners, researchers and policy-makers. This will also help citizens avoid traffic congestion as well as make more intelligent travel choices [15].

2.3.4 Glasgow

Glasgow, with more than half a million residents, is the largest city of Scotland and the third largest city in the UK [16] [17]. The city hosts about one-quarter of Scotland's largest businesses [18] and is among the top European financial centres [17]. However, although the city offers many economic opportunities, it also has many income and health inequalities [19] as well as some of the most deprived areas across Scotland [17]. Aside from the economic disparities, the city faces the major challenge of alleviating fuel poverty[3] which has a major impact on social sustainability. The rising energy fuel prices, the low quality of houses, the difficulties in accessing the energy meters in many houses and the lack of understanding among citizens of energy-saving techniques have been cited as among the causes of this problem [17].

2.4 Worldwide standards as facilitators to develop tailor-made solutions

Smart cities are a necessity, and improving the framework conditions of cities to accelerate change is needed. As shown above, different cities will thus require different approaches to their smart development. Smart development requires solutions to be adapted to the specific needs of the city and its citizens. Technologies can be adapted and combined in different ways to address multiple situations. Worldwide standards would considerably facilitate the development of tailor-made solutions adapted to different circumstances. There are unfortunately still many gaps today, thereby creating a barrier to technology integration, technology transfer and thus the replication of good practices. The next section will make the case for the need to integrate infrastructures further to generate value for the cities and citizens, followed by an analysis of the essential role of standards and also the need to reform how these are created and communicated.

3 According to the Scottish Government (2012, p.8) a household faces fuel poverty if, ''in order to maintain a satisfactory heating and energy consumption regime, it would be required to spend more than 10 % of the net household income (including Housing Benefit or Income Support for Mortgage Interest) on its total energy use''.

Section 3

Value creation for citizens through smart cities

The primary function of cities is not only to house citizens, but to offer them better opportunities to develop their personal and entrepreneurial potential. Cities have to provide the right environment, backed by efficient and affordable services and infrastructures. Smart cities have to be inclusive and benefit citizens, or will otherwise fail to be smart. Smart solutions are not to be seen as a cost to the city, but as an investment, and need to be planned and implemented as such.

Developing smart cities is not only a process whereby technology providers offer technical solutions and city authorities procure them. Building up smart cities also requires the development of the right environment for smart solutions to be effectively adopted and used. One of the particularities of smart cities is the need to incentivise citizens to adopt smarter ways of living and interacting within and with the city. Citizens should also no longer be the users of city services, but also the providers and developers of smart city solutions.

The need to integrate citizens into the process of shaping the city means that smart cities cannot be built by decree, but need to naturally grow into the urban fabric. Many of the solutions do in fact need the active participation of city dwellers as users, consumers, service providers and *de facto* voters. This may not be through ballot boxes, but can also take place through their own actions, by adopting new forms of living and working.

The need to factor in citizen behaviour places city authorities in front of a daunting challenge. First and foremost the authorities need to develop a strategy, which takes into account the needs, objectives and the long-term development scenarios of the city. Second, they have to factor in that much of the developments will be out of their direct control. A smart city is expected to partially self-organize with private operators supplying services, data and even energy as prosumers (i.e. consumers and producers). Services are increasingly developed under public-private partnerships and integrated in complex systems.

Thus, city authorities at all levels will have an important role to play that goes far beyond merely procuring technologies. Within the limit of their competences, they have to develop the right planning and incentive structures. They also have to launch intelligent procurement processes that take into account the wider objectives of the city in an integrated fashion.

Through their capacity to act, city authorities can encourage – or hinder – social innovation, creativity and human interaction, employment and business opportunities. The regulatory framework is crucial, and the way city authorities organize their activities and procurement systems is a key element for the development of a smart city. As such, they need to act as a partner with industry, service providers, financiers and end users to build the smart city. In short, smart cities are complex and will ultimately be self-organizing and be run by city dwellers and private sector operators. Essentially, this means that the right markets need to be set up with the right enablers.

Standards are essential enablers when developing a smart city by guaranteeing an expected performance level and compatibility between technologies. They open the door to a larger choice of products, increased competition and thus foster the innovation drive, benefitting both cities and their citizens. They facilitate the replication of solutions and propose common metrics permitting the comparative analysis and benchmarking of solutions.

3.1 Smart infrastructure integration is essential to create value

The availability of smart solutions for cities has risen rapidly over the last decade. As a result, technical solutions exist for every city to become smarter. The challenge today is primarily to implement appropriate solutions efficiently, rather than only focusing on new technology development. Smart cities cannot be developed through a patchwork approach, but by the step-by-step adoption of incremental improvements.

Smart cities are developed by introducing smart systems, working for the benefit of both residents and the environment. Urban infrastructures will need to better meet the challenges of city environments: energy and water scarcity, pollution and emissions, traffic congestion, crime prevention, waste disposal, and safety risks from ageing infrastructures. The increased mobility of our societies has created intense competition between cities for investment, talent, and jobs. To attract skilled residents, companies, organizations, as well as promoting a thriving culture, cities must achieve the sustainability objectives mentioned in Section 2. This is only possible by becoming more efficient and integrating interoperable infrastructures and services.

The efficient integration of electrical grids, gas distribution systems, water distribution systems, public and private transportation systems, commercial buildings, hospitals and homes is essential. These form the backbone of a city's liveability and sustainability.

The step-by-step improvement and integration of these critical city systems is the road to make a smart city a reality. This process has to be driven bottom-up combined with a top-down, data- and systems-centric approach.

A smart city can thus be defined as an efficient, sustainable and liveable system of systems,

Figure 3-1 | The operating systems making a city's infrastructure [20]

designed for and shaped by citizens, businesses, organizations and technology developers with the aim of creating added value.

The movement towards smart city systems in cities opens the door to new services, new forms of economies of scale, a reduction in inefficiencies and waste and ultimately new business opportunities. There is a large potential to create economic value, but also to improve the living standards of citizens and create considerable social value. This is particularly important in the present economical context in which cities need to reduce operating costs and promote economic growth by identifying areas to invest in.

3.1.1 Reducing inefficiencies

Huge inefficiencies are present in the cities that involve complex interactions from resource use, to consumption and waste. This is due to a historical, piecemeal development without cross integration.

Systems and services enabling urban efficiency and sustainable management are already commercially available and continuously improving. For example, efficient and cost-effective urban energy infrastructure combines heat storage, electricity demand-side management and active network management. This system provides electricity generating capacity when required to support the electricity distribution network. Integration of smart technologies is already being achieved at all levels of the energy network, from power stations through distribution of heat and power to individual smart appliances and micro-renewables [21].

By the end of the current decade, many technologies critical to a smart city, including monitoring and sensor technologies, intelligent traffic systems and energy management systems for buildings, will have been deployed on every continent. A critical challenge is to ensure the pieces are combined and laid out correctly. This is why in addition to technology development and integration efforts, cities need to change their approach to planning and management.

3.1.2 Generating new economic opportunities

The rate of technological progress has been very fast in recent years; new technological breakthroughs such as cloud computing, IoT, hyper connectivity and modern analytics are providing opportunities at affordable cost that could not have been foreseen just a few years ago. Technology can ignite new applications and services, and in turn, create better living and working conditions; citizens have now access at any time to powerful smart devices [22]. The challenge is to enhance living standards, improve social equity, and ideally enable more efficient responses from authorities to the city challenges at potentially lower cost.

This creates opportunities for planners and administrations that go beyond managing construction, automation and use of infrastructure in cities. They can develop a cycle of innovation and economic activity generating business opportunities to provide new products and services to citizens.

3.2 Planning the building blocks of a smart city

The most appropriate path to a smart city is when a community takes it upon itself to define its sustainability vision and then lays out a pragmatic, step-by-step roadmap and implementation plan. Making sure the vision, roadmap and implementation plan are well thought is one of the most critical tasks in the process, and requires the support of specialists. The ability to identify the most acute bottlenecks to deploy integrated and scalable solutions and then to leverage these results into other smart cities initiatives, requires experience and strong technical and process expertise.

This vision should typically highlight the goals of the city for the medium term, i.e. where the city wants to be in 5 to 10 years in terms of efficiency, sustainability, and competitiveness, as well as being in line with even longer-term objectives, for example decarbonization by 2050.

With a vision in place, city officials should start by improving existing basic operating systems, such as electricity, water, transportation, and gas. Using a combination of connected hardware and software in metering and monitoring will deliver a tremendous volume of information which can be analyzed by intelligent software systems. This data analysis will allow cities to develop actionable information driving better and more effective and efficient services (see 4.4).

3.2.1 Integrated city planning

Selecting and turning a suggested objective into something tangible requires a clearly defined master plan developed by city managers with the active consultation of stakeholders. Cities need to prepare an integrated impact assessment or similar based upon a clear process which takes into account multiple considerations in order to ensure most elements are covered, such as:

- Fundamental analysis of the city: geographic, geodesic, population, living standards, etc.
- Fundamental framework: objectives of the investments.
- Spatial planning: usage of land (or district).
- Construction planning: prepared by developers and generally selected through procurement processes.
- Renovation: upgrade of existing buildings and infrastructures, combining modernization with preservation.
- Impact assessment: economic impact, environmental monitoring, and various assessments.
- Operation: operational requirements, human capacity requirements which the city services managers need to estimate.

3.2.2 A city for stakeholders shaped by stakeholders

One of the most important elements of setting up an effective, achievable plan for a smart city is to make it an inclusive, collaborative process. No single company or organization can build a smart city alone, nor can a smart city be created by decree. In a smart city, services will be shaped by the actions of all city actors changing the role of citizens and city managers, for example with the emergence of energy prosumers and the ability of individuals to use and supply data through smart applications.

Developing the right kind of city requires a proper balance of interests between all stakeholders:

- Political leaders, managers and operators of the local government (city).
- The service operators – public or private: water, electricity, gas, communication, transport, waste, education, etc.
- End users and prosumers: inhabitants and local business representatives.
- Investors: private banks, venture capitalists, pension funds, international banks.
- Solution providers: technology providers, financiers and investors.

Giving to each of these groups a true stake in the development of their community is important to achieve the necessary acceptance for the changes. Their concerns need to be carefully considered and acknowledged, and ultimately the plan has to be collectively approved. In the absence of proper consultation, the authorities will sooner or later face considerable additional obstacles to make the vision a reality.

Each unique smart city plan requires collaboration with global technology providers, and local organizations best suited for the specific system improvements needed. The strongest emerging smart cities will be those where solution providers collaborate rather than compete and where political differences are cast aside to bring the most comprehensive and best solutions together. This means sharing information across city departments, breaking down silos and involving global leaders, with world-class capabilities, as well as local providers and stakeholders who know their cities the best.

Incorporating the ideas and thinking of citizens is critical to successfully identifying potential problems. It also helps to win citizens' support and participation in the smart initiatives. Where appropriate, involving the local university community brings additional impetus, innovative ideas, and support. Figure 3-2 shows the different stakeholders that influence smart city development.

Examples of citizens as prosumers

- A resident that participates in a microgrid serving a smart city can draw and consume electrical power from the microgrid during high usage periods and can provide in return, electrical power from alternative energy sources, such as solar, wind or fuel cell during low usage periods.
- Individuals providing information platforms, such as applications for smart phones, which citizens can then use to exchange information.

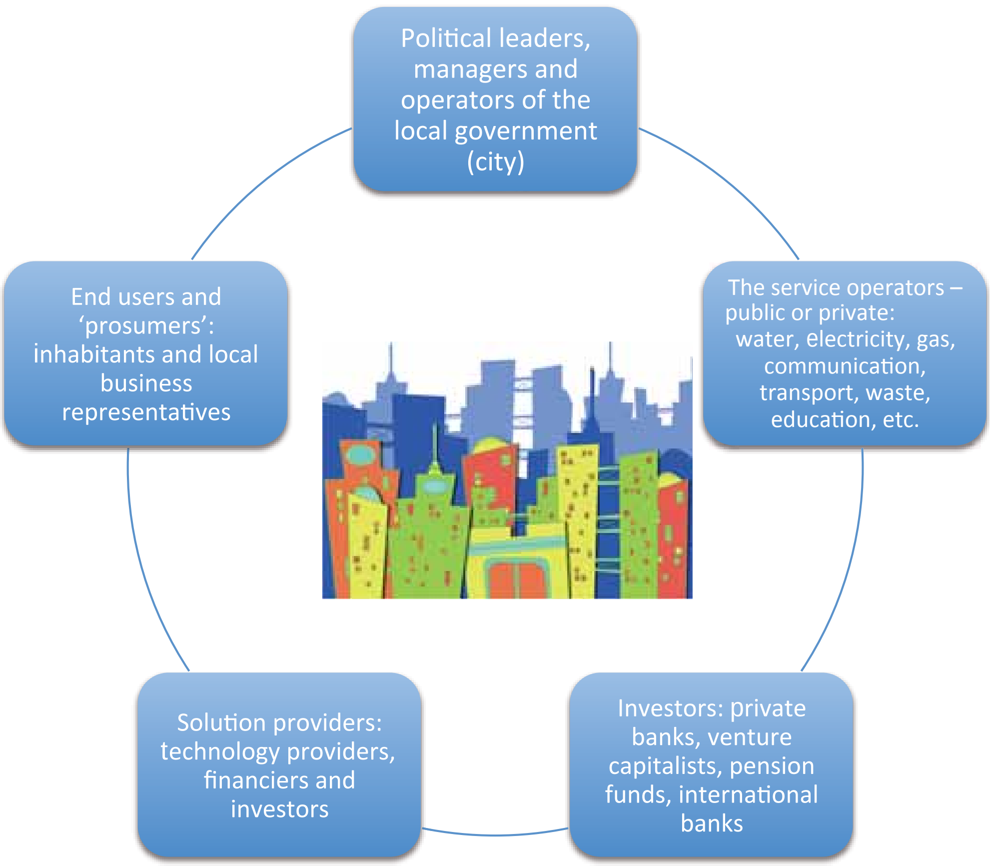

Figure 3-2 | Stakeholders involved in shaping the city

3.2.3 Strategic long term vision vs short term objectives

In many cities long term success is built upon a variety of overlapping short term achievements which requires a delicate balance. City decision makers need to have a dynamic, constantly refreshed strategic vision for what the city will look like in the long term, and make sure that the various short term projects and initiatives have a direct line of sight to the long term strategic vision.

Cities need to prepare a value case justifying why the smart city initiative is a good idea. The value case needs to investigate through an impact assessment the costs and benefits of the project areas identified as well as the economic, social and environmental impacts. City planners will require ways to assess new technologies and integrated solutions for their city. This may often require complex modelling tools that simulate the impact of potential solutions, as there is often a lack of relevant experience on the impact of a technology for a given city; one of those being visualization tools modelling the complex interdependency of systems in city simulations.

What is a visualization tool?

An interactive digital model of the existing structure and dynamics of a city which can provide a set of "before and after" views, relative to the proposed infrastructure changes using a particular configuration and operation of technical solutions. A series of "what if" scenarios can be generated and used as inputs in making the choices of the technical solutions to be deployed.

The impact assessment can be subject to a scoring system to enable selection from competing options. The scoring criteria can include:

- Applicability (e.g. integration into existing urban infrastructure, flexibility and regulation required).
- Factors describing the likely impact of the initiative (e.g. CO_2 emission reduction, affordability, potential for scale up).
- Innovative nature (e.g. progress behind the state of the art and multidisciplinary approach).

Annex A presents a possible scoring system based on a document released by the European Smart Cities Stakeholder Platform in 2013 [23].

3.3 Linking short term value and long term goals by metrics

Individual projects to improve urban efficiency and develop new services are usually developed at the sectorial or local level and can bring value by themselves while contributing to higher level objectives. Here are some examples:

- The monitoring of emissions and their impact on the city can lead to smart approaches to reduce them, potentially producing quick cost savings as well as delivering a number of associated long term benefits.
- Smart traffic management together with smarter buildings, transport and waste management reduces air pollution.

However, while the value of each project can be readily assessed on the sectorial level, it is less easy to understand the contribution of the project to the city's overarching objectives such as city wide aims of economic development, liveability, and environmental sustainability.

Impact assessments should be used to quantify the short term and long term value creation. Figure 3-3 illustrates that realizing the full value of a smart city requires an assessment of the value of positive externalities, economies of scope and scale, and the value of individual smart projects. This is a complex task as the outcomes of the former two arise from a combination of factors, are distributed across various different stakeholders and can often only be realized in the long term [22].

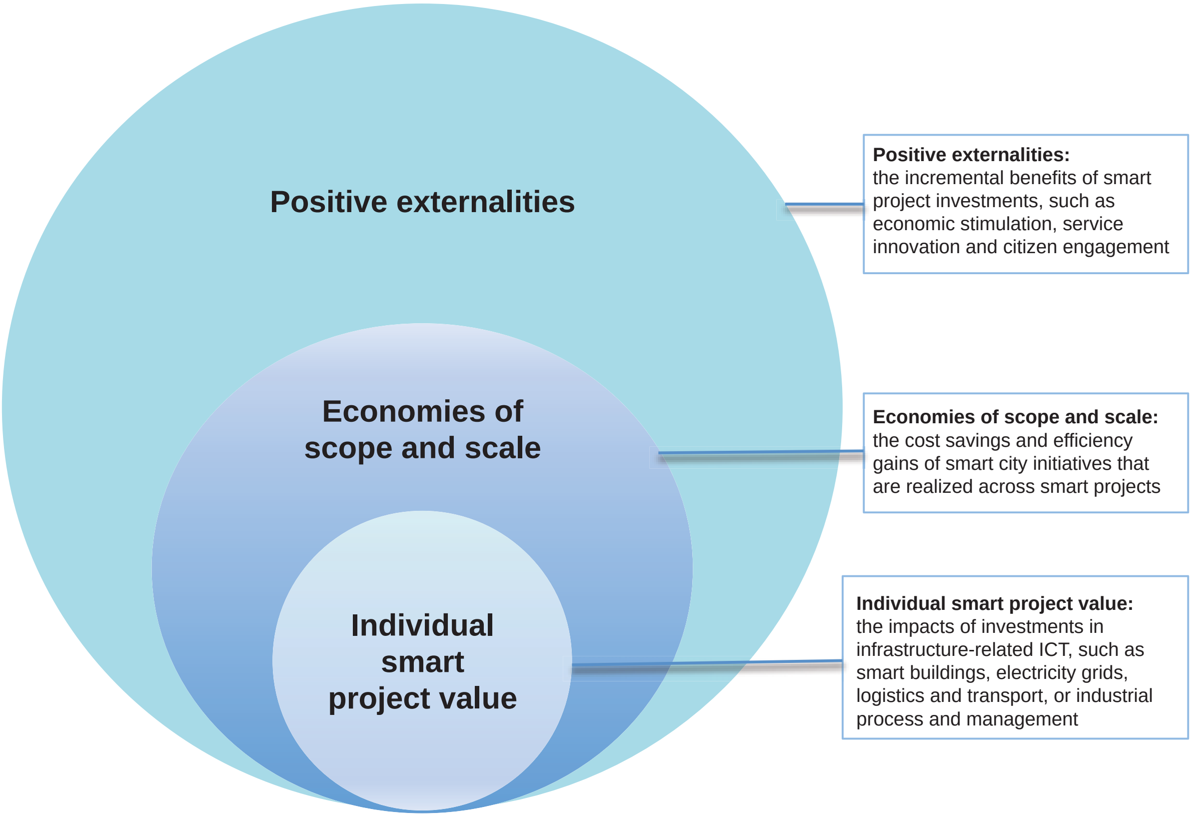

Figure 3-3 | Layers of smart city value [22]

To measure the wider contribution of projects to higher level objectives, a common and consistent suite of metrics can be developed to weigh up the contribution of individual initiatives, such as a smart buildings scheme or new smart technologies, to the city's long term strategic objectives. These metrics should include not only the overarching criteria, but also the individual projects' indicators; this will help cities to monitor their performance [22].

3.4 Reaping the financial opportunities of smart cities

The major challenge to the adoption of new technologies is financial, as many cities today have been constrained to reducing their budgets. The revenue they have must first be allocated to essential operations and staff, and there is often little left over for upgrades, retrofits, and other improvement measures.

The added need to often change existing incumbent infrastructure to introduce new approaches to energy, transport, water and waste management makes upfront capital expenditure (CAPEX) a serious concern for municipal budgets which are often higher than for traditional investments.

This is because even if the operational expenditure (OPEX) costs are lower, many city administrations work on the basis of annual budgets which are ill-fitted to handle technologies with large CAPEX.

However, a large upfront investment is not a prerequisite for a smarter city. The most progressive smart city players are tapping innovative financial and business models to make efficient infrastructure a reality. There are a variety of models available to cities, such as fully funding, joint ventures to PPPs, and other similar models, which relieve the city from the upfront costs.

It is also important that the development choices take into account the economic rate of return (ERR) which includes the socio-economic returns of investment. This means that user fees may neither be the only nor the best cost recovery method, as those fees cannot fully reflect the public benefits some of the technologies can provide. Public support may be needed to ensure that the solutions with the best returns for society are implemented; these may be in the form of grants or publicly supported financial instruments, or in the case of developing countries, aid by international financial institutions or donors. New business models combining technology and a paradigm change are today under development and demonstration which might be supported by standards, for example:

- The increasing numbers of energy service or energy savings companies (ESCOs) which are commercial or non-profit businesses offering a broad range of energy solutions (e.g. energy saving project design and implementation, retrofitting, efficient and green energy supply solutions, energy storage, energy infrastructure development or risk management).
- Demand-response services: dynamic pricing, interruptible load- or dynamic-load capping contracts for industry, commercial businesses and households, participation in balancing markets, services aggregating and optimizing demand for households. These increase system flexibility and reduce the need for generation capacity. They can reward consumers by enabling them to shift part of consumption to cheaper periods.
- Asset sharing: for example, electric cars or bicycles – they can be associated with other transportation means (railways, tramways, etc.).
- Software as a service (SaaS) covering any cloud service where consumers are able to access software applications over the internet is another interesting model. These applications are hosted in the cloud and can be used for a wide range of tasks for both individuals and organizations.

3.5 Risks of limited connectivity and collaboration

Lack of integrated infrastructures and city entities can create significant inefficiencies, risks, and will affect a city's economy. Developing integrated infrastructures with the support of integrated technologies can lead to a better service for citizens, but can also enhance the city's resilience to safety and security risks.

Urban safety and resilience are becoming a central issue in debates about the future of cities. The observed increase in extreme weather events has revealed a number of vulnerabilities of present cities. An accident in one infrastructure, such as the rupture of water pipes can affect other networks. Future infrastructure has to be designed to be resilient to such events. This resilience requires a better integration of the infrastructures and more access to open data. Presently water, electricity and telecommunications infrastructure are managed separately by different operators. These operators do not communicate and are generally ignorant on the infrastructure of operators of other services. Under the city however, electric cables, water networks, gas pipes, telecommunication cables are sharing the same space.

In fact, the American Society of Civil Engineers (ASCE) calls for the better integration of infrastructures as crucial in a recent report [24], highlighting the substantial unnecessary vulnerabilities the present state generates. Their analysis even implies that integration is not merely a technical problem; organizations responsible for critical infrastructures may inhibit a focus on safety due to their reluctance to coordinate.

The ASCE lists four guiding principles for critical infrastructure:

1) Quantify, communicate and manage risks.
2) Employ an integrated systems approach.
3) Exercise sound leadership, management, and stewardship in decision-making processes.
4) Adapt critical infrastructure in response to dynamic conditions and practice.

The four principles above have important repercussions for city management as well as the need to design the appropriate standards. To qualify, communicate and manage risks, clear data collaboration practices need to be supported by standards on the data contents, quality and format. Employing an integrated systems approach requires the necessary technical and procedural standards that will allow integrated systems to be deployed and managed. Standards need also to be designed to support the management and decision-making process. This means that standards should be well designed to support city planners, civil engineers, managers of services and ultimately those with the power to take decisions. Finally, standards have to ensure that infrastructures become responsive to dynamic conditions and practice. This means that long term infrastructure needs to be monitored and be adaptable to change. Here, the role of standards on monitoring, data processing and sensors and surveillance systems is essential to support the responsible authorities.

Examples of lack of integration risk

One risk of not having the appropriate type and level of integration of city infrastructures and services would be the simultaneous loss of electrical power, water supply, gas supply and telecommunication networks. When the different sub-systems do not have integrated backup power or control and operational systems, but are wholly dependent on a common power grid or communication network, they can become single points of failure.

Section 4

Collaboration, integration, and interoperability enabled by standards

In the last decade we have experienced an explosion in technical solutions in the area of smart technologies, supported by a rapid increase in data. This means that while technological innovations are important, it is not the main driver for the development of smart cities. What is missing today is the appropriate framework conditions enabling the large scale deployment of smart city technologies. This requires standards facilitating the communication between actors, technologies and systems.

- Management standards create a common communication tool, thus different actors have the same definition for each part of a process. This is important in benchmarking, knowledge transfer, quality assurances, project assessments and collaboration between different operators and service providers.
- Data standards will be necessary to ensure that data formats are adapted to the different needs and include the necessary security levels. This is, for example, needed to ensure the correct level of anonymity of personal data.
- Technical standards that provide the necessary connectivity, expanding markets and opportunities.

Without those standards, cities will remain a patchwork and the replication of good solutions limited. This can have serious repercussions for the economic and social development of the cities.

There is a clear demand for integrated collaborative approaches that are leading to a number of ideas coming from many SDOs and other organizations. The patchwork approach to smart cities development is reaching its limits. While the technology responses are accumulating, the transformation of cities is not following in the necessary speed and manner. Much of this is due to a lack of collaboration and clarity.

Many of standard organization initiatives have been launched. Among those is the IEC Systems Evaluation Group on smart cities (SEG 1). The purpose of SEG 1 is to summarize and evaluate the status of standardization in the field of smart cities (inside and outside the IEC and ISO), and to work out plans for new standardization work to be taken in IEC.

In 2012, ISO formed TC 268/SC 1 on smart community infrastructures. This SC published ISO/TR 37150:2014, *Smart community infrastructures – Review of existing activities relevant to metrics*. This Technical Report provides a review of existing activities relevant to metrics for smart community infrastructures. Additionally, ISO TC 268 published ISO 37120:2014 which defines and establishes methodologies for a set of indicators to steer and measure the performance of city services and QoL.

ITU-T formed a focus group on smart sustainable cities, SG 5, whose scope is to exchange knowledge in the interests of identifying the standardized frameworks needed to support the integration of ICT services in smart cities; and ISO/IEC Joint Technical Committee 1 (JTC 1) also formed a study group on smart cities, SG 1, which among other items will study and document the technological, market and societal requirements for the ICT standardization aspects of smart cities.

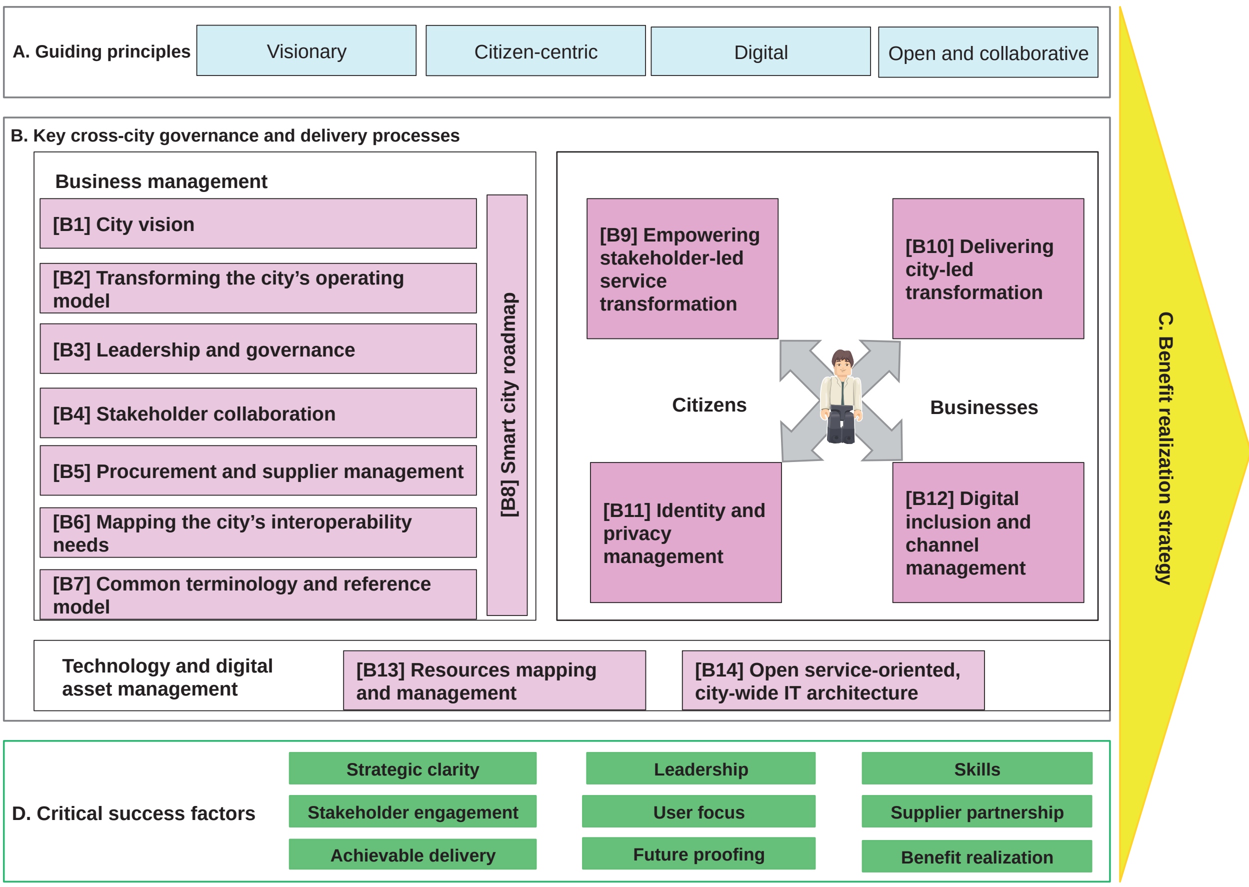

Figure 4-1 | The smart city framework [25]

Regionally, CEN-CENELEC-ETSI Smart and Sustainable Cities and Communities Coordination Group (SSCC-CG) is in place to advice on European interests and needs, relating to standardization on smart and sustainable cities and communities.

In the UK, BSI in collaboration with the Department for Business, Innovation and Skills has released in February 2014 the document *Smart city framework – Guide to establishing strategies for smart cities and communities* [25], a proposal on regulation and standardization of smart cities, see Figure 4-1;

In Germany, VDE, responsible for the daily operations of DKE German Commission for Electrical, Electronic and Information Technologies of DIN and VDE, published the German Standardization Roadmap Smart City in April 2014.

In the United States, ANSI launched the ANSI Network on Smart and Sustainable Cities one stop shop, where city authorities and others can network in researching their standardization needs.

A number of other organizations are drafting specifications for smart cities. One of the most ambitious examples is the City Protocol programme [26]. This initiative, City Protocol Society, aims to provide guidance on the procedures (required standards) and legal frameworks necessary to achieve such partnerships. The City Protocol provides "The Anatomy of City Habitat" which aims to present in a common language the key features affecting city life. These are represented by three systems (structure, society and data) and eight sub-systems or thematic areas (environment, infrastructures, built domain, public space, functions, people, information flows and performance).

One of the key aims of the City Protocol is to provide the first certification system for smart cities, developed with the guidance of over 30 organizations. The objective being to provide a framework for designing sustainable systems of systems integrating the numerous elements that creates the urban space.

One message is increasingly emerging from many stakeholders, namely, that the time for experimentation is over. It is time for a coordinated approach and critical issues to tackle are integration, including interoperability, and collaboration.

4.1 The city as an integrated, virtual organization

The transformation of a city into a smart form presents its stakeholders a wide range of challenges, including benefits and consequences when such a transformation is undertaken. A promising approach to understand where the city suffers from inefficiencies and where the opportunities lie is to model a city as a collection of activity domains, where various groups of stakeholders participate in operating and sustaining the city as a whole.

Within a city, typical examples of the bodies representing these various groups of stakeholders are local governments, public and private corporations, academia, healthcare institutions, cultural associations, religious congregations and financial firms. These different types of bodies have their respective missions and goals which form the suite of complex drivers that influence the operation, management and transformation of a city.

Each body can be viewed as some type of organization that manages its assets and deploys these as resources to conduct the main activities necessary to achieve its goals. In this context, an organization consists of a structured group of stakeholders whose combined assets are used to achieve a common goal. These organizations may be private, public, non-profit, commercial, local, state, federal, or multi-national.

In this approach, a city is modelled as a collection of a variety of interdependent organizations that have a common goal of evolving into a smart city. Unless these component organizations cooperate, coordinate and collaborate, the operation and management of a city will be inefficient and costly and the transformation of a city into a smarter form will be very difficult and unlikely.

The cooperation, coordination and collaboration of the stakeholder component organizations can be envisioned in terms of a coherent set of commitments, capabilities and characteristics associated with the city which can be considered as a single virtual composite organization. Operating, managing and transforming a city can benefit from proven practices and principles used by commercial and not-for-profit organizations and enterprises.

The approach of modelling the smart city as a virtual composite organization helps in identifying barriers and opportunities to the deployment of standards-based solutions to plan, operate and manage a smart city. This provides a backdrop for portraying the central importance of standards as key enablers to make a smart city vision reality.

The composite virtual organization (city) has to achieve a balance between the following two goals:

- Effective and efficient use of its natural environment and built environment.
- Improving and maintaining the health, safety, security, well-being, convenience, and comfort of its inhabitants.

Achieving and keeping this balance across the whole virtual organization underpins the essential value proposition of the internal value chain. A similar value proposition is shared across an external value chain formed by the other communities and sovereign regions which conduct exchanges of information, energy, and materials with a smart city virtual enterprise.

To support its socio-economic growth, sustain the improvement of city services, and enable its resiliency to catastrophic events, the smart city virtual organization has to manage the adoption of technological innovations and cyber-physical advances in smart sub-systems that are deployed within its internal value chain. A key challenge is to ensure the interoperability of the sub-systems in order to realize an integrated, smart, resilient and sustainable smart city. A similar key challenge exists in realizing the interoperability of the smart city with the other virtual organizations across an external value chain.

Using concepts, terms, and definitions pertaining to organizations and enterprises, provided in IEC and ISO International Standards, the activity domains in a smart city virtual organization can be modelled as a set of flows of services and resources (materials, goods, energy, transport units, people, information and other elements) between stakeholders.

In a smart city, these flows are facilitated by automation technologies, tools and techniques in order to realize a high quality lifestyle and standard of living for its inhabitants while maintaining a balance in the use of its built and natural environments.

One type of barrier to the interoperability of the sub-systems in the built environment within a smart city virtual organization stems from the incompatibilities in the currently deployed sub-systems, such as, information, communications, power and automation systems that have been provided by different suppliers and maintained by various agencies having distinct jurisdictions. Harmonizing the incompatible service interfaces of these sub-systems is one type of barrier to be addressed in order to achieve some level of interconnectivity.

One collaborative approach to realize an effective internal value chain with common set of outcomes shared among the stakeholders will involve the use of standards-based interfaces that enable the desired flows between the applications in a virtual organization.

Another type of barrier is the need to transform the large amount of collected information about these sub-systems and their operations into understandable and meaningful information for the different types of smart city stakeholders. This enables a stakeholder in a smart city virtual organization to make rational decisions when allocating the appropriate resources in a timely manner.

Informed and rational decisions by smart city stakeholders will lead to efficient innovative technology solutions deployed within a smart city's built environment. For example, helping to insure safer and more accessible food, efficient water distribution and wastewater treatment, more affordable and available supplies of energy, materials and goods, and more responsive and cleaner transport facilities.

Examples of desired outcomes that smart city stakeholders focus on are cost-effective risk management, lower total lifecycle cost of operations, improved asset utilization, and prompt response to emergency incidents. These outcomes can be tracked in terms of key performance indicators, similar to the concepts used in business enterprises.

Within the internal value chain of a smart city virtual (composite) organization, the main requirements to be satisfied by the component organizations can be described in terms of international standards, conformity assessment schemes, and interoperability certification programmes targeted for a smart city. Similar requirements for the participating organizations across the external value chain associated with a smart city can be elaborated in a similar manner.

4.2 Infrastructure and services integration with a system of systems

While individual projects can bring improvements to a city, from the point of view of infrastructure, to enable the development of the smart cities, there is a need of systems of systems comprising traditional infrastructure, enabled and improved by ICT.

Setting up a system of systems is mainly a technical challenge and relates closely to standardization. While the lifetime of some equipment is limited to months or years, the one for infrastructure installations, such as electricity grids as well as water and gas networks overextends decades. This problem remains independent of the approach being applied, i.e. brownfield or greenfield.

Brownfield projects often suffer from the lack of sufficient information on existing infrastructure. Many electrical, water and gas systems are not well recorded with existing documentation, or not properly updated, or even lost.

Another barrier for brownfield development is the long average lifetime of the building stock, which is of about 80 years in industrialized countries, but may for many buildings be far longer. Even in the last decades of our faster-moving world, this number has not changed significantly. This means that 80 % of existing houses will still be standing in 50 years from now. Furthermore, local protection laws for historic patrimony hinder the transformation process in very old towns.

So far, no one-size-fits-all solutions exist for smart cities and communities, but there are some essential characteristics that will have to be followed in all cities. The city of the future will be a very complex system of systems, and cooperation and collaboration between different domains is essential. This will require the development of cross-domain standards.

4.3 Opportunities in an integrated system of systems

Becoming a smart city starts with smart systems which work for the benefit of citizens and the environment. Electric grids, gas/heat/ water distribution systems, public and private transportation systems, and commercial buildings/ hospitals/homes are the backbone of a city's efficiency, liveability and sustainability. It is the improvement and the integration of these critical city systems that will make smart city become a reality.

Successful development of a smart city will require the combining of a bottom-up systems approach with a top-down service development and a data-centric approach. Technology integration includes vertical integration from sensors, to low cost communication, real time analysis and control, and horizontal integration of historically isolated systems up to citizen-based services. Combined, this creates a system of systems.

Figure 4-2 describes the path of integration starting from monitoring to increase the data availability up to the full development of a system of systems where formerly isolated domains are coordinated.

4.3.1 Vertical integration from sensors to management tools

The key ingredient to develop smart solutions for cities is data. Thus the key initial step in the process is the deployment of sensors throughout city infrastructures to collect raw data, which is then transmitted through communications networks, either wired or wireless. Data is not only necessary to plan the changes in the city, but also to gather real-time information to manage services and infrastructure use better. Real-time systems can be used to automate management of city infrastructure, which can result in significant performance and cost advantages.

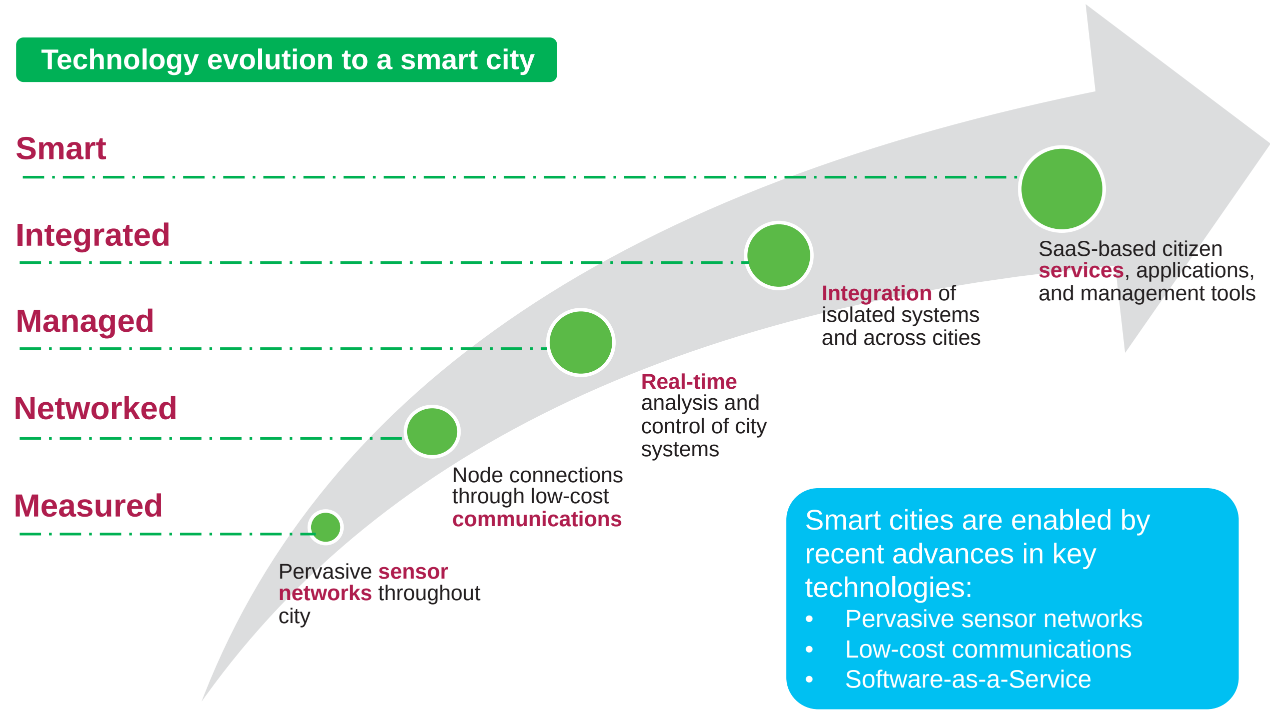

Figure 4-2 | Step-by-step approach to becoming smarter [20]

We are presently undergoing a data gathering revolution, and recent advances allow the collection of unprecedented amounts of data about city infrastructures (see also Section 4.4), for example through the following [27]:

- Pervasive sensors enable cities to collect measurement data about energy, water, transportation, and buildings systems in real time.
- Low-cost communications and new communications protocols greatly simplify information flows and reduce the cost of gathering data collected by sensors. Protocols such as Zigbee® and Bluetooth®[4], growth in machine-to-machine (M2M) networks, as well as continued improvement in wireless and wired line communications technologies, enable cities to affordably collect data from widely distributed networks of sensors.
- Real-time management systems automate the control of infrastructure systems, improving the efficiency by optimizing performance.
- Advanced analytics make use of the large amount of raw data that is collected and translates it into actionable intelligence, which a city can use to improve the performance of its infrastructure.

Once all of these factors are in place, cities can further leverage them to create value by applying advanced analytics tools to support optimization, as well as provide data back to city residents through public services which improve their daily lives in the city.

4 Zigbee® and Bluetooth® are examples of suitable products available commercially. This information is given for the convenience of users of this standard and does not constitute an endorsement by IEC of these products.

By measuring performance of city infrastructure systems, the city authorities can identify problem areas and track the effectiveness of solutions in achieving the city's long-term goals.

4.3.2 Horizontal integration of domains

Optimization and integration in historical verticals is the core of today smart cities projects and very few have started to address horizontal integration

Examples of horizontal integration are emerging, however. Some projects cover mutualisation of geographical information systems, and weather forecast or customer information systems.

Greater information about a city's operations and infrastructure can facilitate the identification and management of risks to the city. For example, real-time information about the flow of citizens around the city from combined smart transport and mobile data can help cities to deploy security services during emergencies.

Integration of isolated systems and sharing of data yields further performance benefits through coordinated actions and holistic management of the city as a system of systems.

Operational intelligence can be the base of integration supported by analytics (algorithms using data to produce information of high user value), which need to be developed in three directions:

1) Data analysis and modelling.

1) Simulation for prediction.

2) Optimization for problem solving.

Examples include:

- When monitored at the right precision, energy consumption can accurately reflect the performance of a machine, of a process, or of an organization.
- Traffic pattern identification and contextual observations (weather, type of day, events, etc.) enable traffic forecasts on different time scales.
- Real-time comfort set points calculation using predictive control models save on operational costs, while taking into account energy price variations, changing weather and occupancy conditions.

Today, smart integration addresses security, mobility, weather intelligence, and energy or environment monitoring and citizen information. City management platforms have started to be deployed, even if the services are still largely independently operated.

4.3.3 Interoperability

Interoperability is a key to manage systems of systems and to open markets to competitive solutions. The existence of standards guarantees that components of different suppliers and technologies can interact seamlessly.

We are today experiencing the IoT revolution, which is driven by the appearance of smart devices, such as wireless sensors, RFID tags and IP-enabled devices. IoT allows creation and management of ad hoc networks of autonomous devices generating and sharing data across systems.

But still, different producers are generating technologies using their own communication specifications and data protocols.

Furthermore, strict technical interoperability is not enough; there are also organizational issues at stake. Interoperability can have significant legal and organizational impacts such as issues of intellectual property (do people want to share their data?), or labour relations (are people prepared to undergo training?) and usability (can users operate the instruments?).

In fact complex system integration requires interoperability on three levels:

1) Technical and syntax level: this concerns physical and logical basic connectivity, message exchanges and data structure of messages.

3) Informational and semantics level: this concerns the business context and the concepts contained in messages exchanged.

4) Organizational level: this concerns operational processes and business procedures as well as strategic and tactical objectives shared between the businesses and can include economics and regulatory context elements.

To ensure it, internationally recognized standards are the best way to do so.

4.3.4 Architecture integrating existing systems – Progressive and open deployment

Standardized architectures will be necessary to foster integration of existing and new systems and devices, ensuring scalability through the use of open technologies such as IP and web services.

A portal server will allow for the creation of unified, even if personalized, user interfaces, taking into account individual settings such as language, see Figure 4-3. In the cloud, virtualized machines avoid investing in oversized servers remaining idle for a large proportion of time.

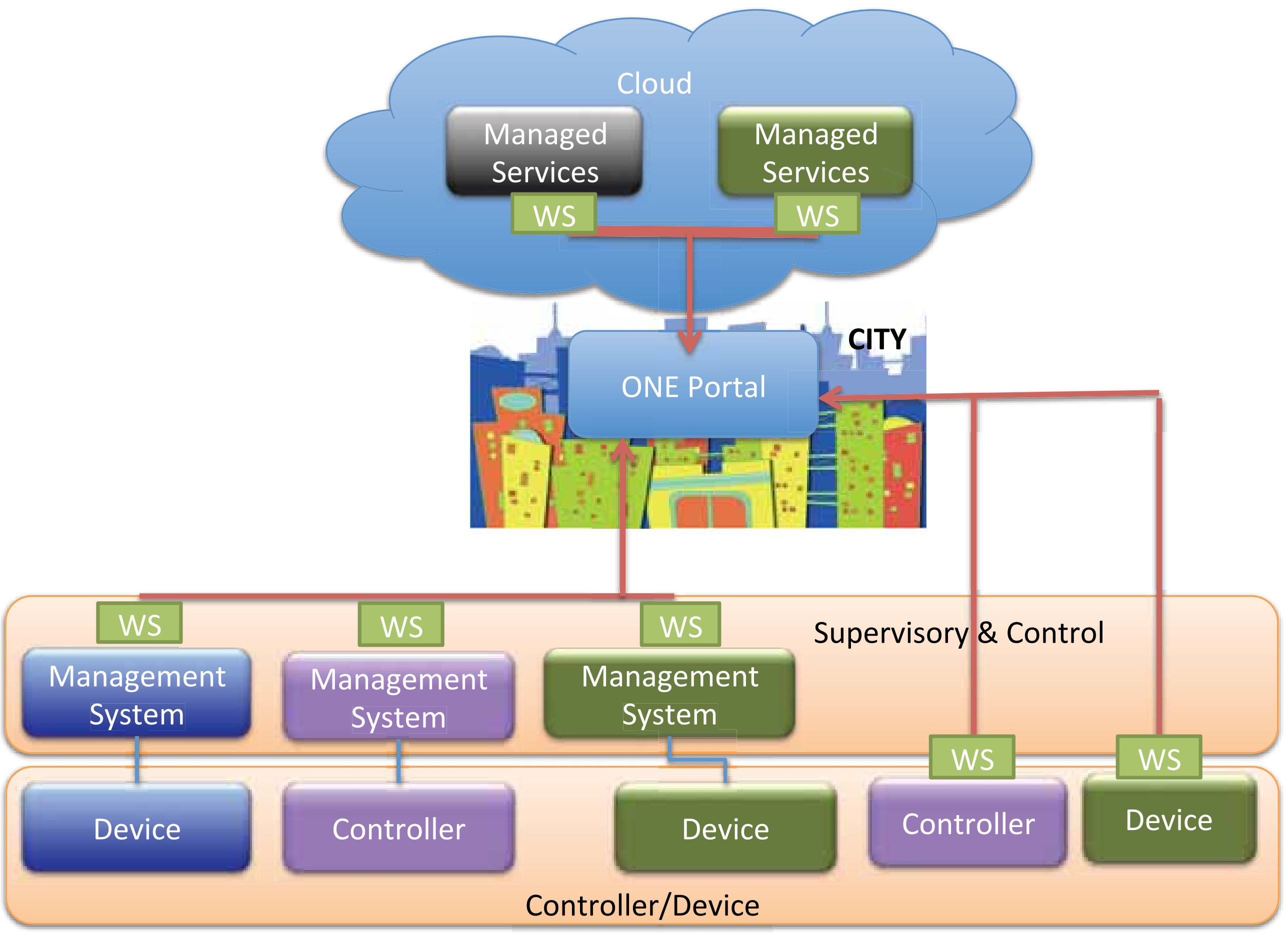

Figure 4-3 | One portal server structure, integrating systems using standards from IEC, ISO, JTC 1, ITU-T, etc.

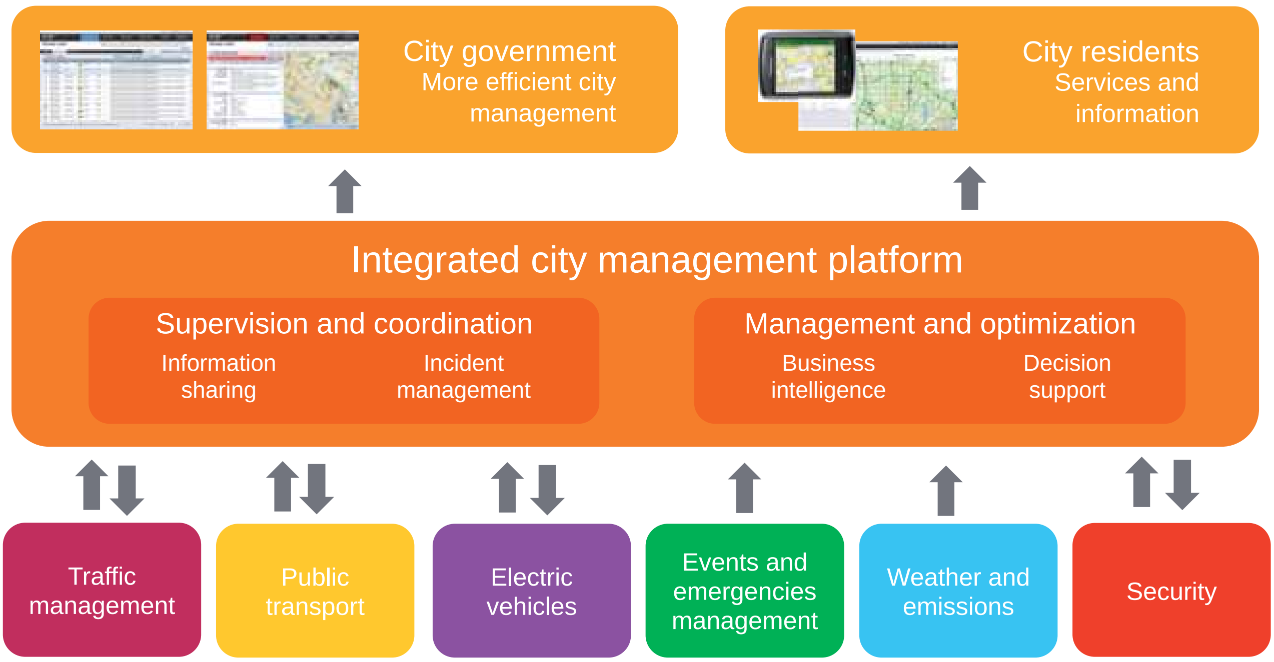

Figure 4-4 | Integrated city management platform [20]

Table 4-1 | – Infrastructure performance assessment matrix [28]

Performances (to be technically improved) \ Community infrastructures		Energy	Water	Mobility	Waste	ICT	Others
		- Power grid - Gas - Fuels	- Water process - for industry - treated water - sewage	- roads - railway - airport - port, river	- waste recovery - recycling	- Information - Internet - Carrier - Broadcast	
Residents perspective	(1) Reliability						
	(2) Availability						
	(3) Service quality						
	(4) Others						
Community Manager perspective	(5) Operational efficiency						
	(6) Maintainability						
	(7) Resilience						
	(8) Value for money						
	(9) Expandability						
	(10) Others						
Environmental perspective	(11) GHG emissions						
	(12) Pollutant emissions						
	(13) Resource efficiency						
	(14) Others						

Optimization of infrastructure efficiency and communication network(s) mutualisation will be the basis for an integrated city management platform (Figure 4-4) and shall progressively integrate the different city smart sub-systems (energy, mobility, water, buildings, public services, etc.). Collaborative and customized applications and solutions shall on top answer to city and city resident needs through information and services.

The challenge will be to develop this integrated city management platforms that balancing top-down governance with bottom-up innovation.

4.3.5 Measuring the smartness of city infrastructures

Key to efficiency in an integrated city management platform is the ability to meet the expectations of stakeholders with the optimal and effective use of available resources. By combining the various city infrastructures and performances into a matrix, we can create a table to assess the performance of infrastructures, see Table 4-1.

4.4 Open and big data as an enabler for value creation

It is important to stress the key role of data (see Annex B) in the development of smart cities. Digital data is the inexhaustible, precious, raw material of the 21st century.

Accessible and digitized data will be an essential part of cities' infrastructure and backbone of their success. It is the glue for smart cities, enabling collaboration and integration across departments, domains and systems, and will allow better decision quality and speed driven by new insights. By managing and presenting the right data at the right time to the right stakeholders, data management technology can act as catalyst for cities to move beyond pure administrative processes to deliver transformative efficiency gains and sustainable innovation that will benefit city stakeholders. It is an enabler towards a more transparent and accountable government by improving efficiency in day to day operations, as well as create the opportunity to deliver new innovations, services, and business models. Without open data, there can be no integration, no interoperability, and no smartness.

Technology continues to evolve to enable handling of large, growing, and disparate data sets, in a cost-effective manner. Best practice sharing and development of standards are needed to ensure that data can flow freely between systems while protecting confidentiality and individual privacy.

There are a number of readily apparent technical challenges usually summarized as the 3Vs: volume, velocity and variety. How and where data is gathered, how gaps in data are extrapolated, as well as data validity, quality, and aging are additional important considerations. Beyond these technical challenges, however, one of the most important opportunities is deciding what data is relevant and to whom. This is further compounded by the fact that the more insight and transparency we have as a result of this data, the more we will want to leverage yet unstructured sets of data and newly available technologies to support finding the next sweet spot for smartness in the context of our cities.

New technologies are being developed that transform large and random data into information and knowledge enabling better and smarter stakeholder decisions.

Collecting, storing, analyzing, and working with data bring many challenges related to data privacy, cyber security, and protection of intellectual property. These challenges need to be well managed as it takes a lot of effort to build trust but only one misstep to break it. Standards, technologies, and working practices will need to be refined to protect private data as well as sensitive government or business data. New and advanced privacy and cryptography technologies will help mitigating these concerns.

Examples of the economic benefits of big data

Opening US weather data led to gross receipts by the commercial weather industry of 400-700 million USD per year and created jobs at 400 firms for as much as 4 000 people. By comparison, Europe has a similar-sized economy, but with largely closed weather data, and had only 30 firms with 300 employees and receipts of 30-50 million USD a year [29].

According to McKinsey [30] open data can enable trillions of dollars in value in education, transportation, consumer products, electricity, oil and gas, healthcare, and finance sections (e.g. commuter time saving, emission reduction, etc.).

The European Commission Communication on Open Data [31] predicts that overall economic gains from opening up public data could amount to 40 billion EUR per year in the EU.

It is important to note, however, that big and open data does not mean that "Big Brother is watching you". It is rather a means to optimize outcomes, to share best practices between peers and to offer opportunities for individuals to improve their lives (e.g. comparing my energy consumption to comparable households in my neighbourhood or city with similar characteristics).

There are costs associated to support this data for the technology infrastructure and its ongoing maintenance. Cities will need different type of support resources (e.g. specialized IT personnel, even Chief Technology Officers for large cities) and investment in appropriate analytics platforms that are tuned to handle all types of data, regardless of form or function.

The cost/benefit equation is certainly one hurdle, but so is ensuring the free flow of information across systems and domains. An increased number of systems and data sets will be essential to spur innovation, but also raises the call for standards as an enabler for integration and seamless interoperability. This has been proven multiple times in industries like automotive, aerospace, or smart grid.

But the costs and efforts required are worth the benefits. We are already seeing how big and open data is being used to improve decision speed and quality, to enhance the efficiency and effectiveness of private and public entities while simultaneously enabling them to offer better products and services to their customers and citizens. Managing data well is a significant differentiation factor and will help regions, countries, and cities address social challenges, generate wealth, and improve overall QoL for their citizens.

Data can be used to discover the needs of individuals and trends of groups. City populations can be segmented to tailor actions for specific groups including customized services. One example is using real-time, geo-tagged data sets to create an entirely new set of location-based services that are moving us from basic navigation to optimized traffic routing, public transportation capacity allocation, etc.

4.5 Enhancing collaboration between SDOs to get the full benefit of standards

While standards are a central part of our daily lives and a necessity in many markets and procedures to operate efficiently, they are not well understood and often misinterpreted. Standards are voluntary and adoption tends to occur due to their usefulness. Being voluntary by nature, some companies or organizations may decide either not to follow a given standard or to create their own technical specification. Many different standards may thus exist in parallel. Ultimately, market forces and policy decisions will tend to adopt some standards in preference to others.

The adoption of standards by legislation is most likely the primary reason for the present existence of confusion between regulation and standardization, where many citizens believe that standards are legal acts. This may bring resentment and resistance against some of the standards. The adoption of standards into legislation may be a matter of concern, because specific standards adopted may benefit specific operators.

Standards by themselves are essential and positive, but the way standards are set and published needs to change. Technical standards which may profoundly affect the kind of solutions that are adopted in the case of infrastructures are written by specialists in the field. In the case of the IEC, International Standards are drafted by electrotechnical engineers for other electrotechnical engineers. However, due to the need to integrate infrastructures and services, standards should also have city managers in mind. Standards need to be understandable by non-specialists.

Integrating infrastructures and services depends strongly on interoperability (i.e. devices and systems working together), which in turn is facilitated by technical standards. The voluntary international standards agreed between technology providers have been shaping the development of our modern technology and ensure the interoperability and cross-border compatibility of technologies. Citizens' daily lives are affected by the standards that shape our built environment, such as electrotechnical and ICT devices. Much of the interoperability and compatibility that is taken for granted today has not become so by default. It is the result of complex agreements in international standard bodies and market competition between technologies, which ultimately determines what will be adopted by technology providers and users.

SDOs are the main sources of the national and international standards, assessment schemes and certification programmes that provide the bases for interoperability guidelines, frameworks, and practices. When managing the various types of physical flows within a smart city, a set of common concepts of interoperability is needed.

Presently, however, the development of standards is not overly coordinated. This can be addressed by increasing the collaboration between standardization bodies, the rise of systems-level technical standards committees and involving city planners more closely. This would improve the quality of standards and cross-operability of technologies which form the basis of functioning cities. It would also help develop a wider market of integrated solutions for cities. A wider market with solid standards and interoperability will support the expansion of replicable and more affordable technologies globally. New approaches in developing system-oriented standards, where several technical committees in different organizations are involved, will be necessary in developing standards that are intended to enable the implementations of smart city solutions.

The interoperability of sub-systems will require new forms of collaboration among related efforts of the IEC, ISO, JTC1, ITU-T and other technical committees of other SDOs. These standardization efforts will involve the development, promotion, and deployment of standards series and conformity assessment schemes that enable it within systems and sub-systems as well as between a city and its associated supply chains.

4.5.1 Within the ISO

Numerous projects with the aim of developing smart cities are in process, but there is no clear consensus of what defines a smart city or what sort of solutions can be considered smart.

In 2012, ISO TC 268 (sustainable development of communities) was set up, and subcommittee SC 1 (smart community infrastructures) was approved, aiming to clarity on the standards on smart infrastructures.

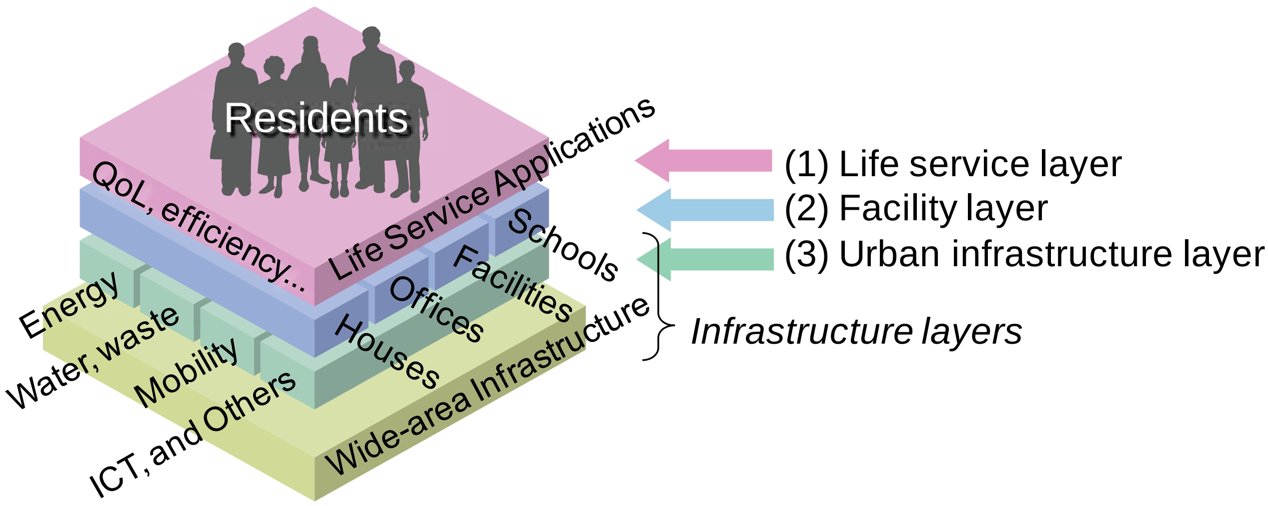

Figure 4-5 | Three layer model of city functions

One of the main concepts adopted by the subcommittee is the three-layer model depicted in Figure 4-5.

When we consider the smartness of a city, we have to take into account the smartness of the various functions of a city's infrastructures, such as:

- Basic infrastructures: energy (electricity, gas), water, mobility, information and communication infrastructure (ICI), etc.
- Public services: healthcare, education, police, etc.

We can classify these functions into the following three layer model of city functions.

Each layer is defined as follows.

1) Life service layer (community services): necessary services for urban life such as healthcare, education, police, etc., mainly provided by city administration.

5) Facility layer (community facilities): facilities such as housing, offices (buildings), transportation facilities (stations), schools, where infrastructure services are provided and also used.

6) Urban infrastructure layer (community infrastructures): infrastructures which provide fundamentally necessary physical substances for daily life, such as:
   a) energy (electricity, gas),
   b) water (drinking water),
   c) waste,
   d) mobility (public transportations, city train, bus, car), and
   e) ICI.

Beneath the urban infrastructure layer, there is the wide-area infrastructure which connects the cities wide-area energy grid, intercity transportation systems, etc.

In the context of making the city smart, the renovation and further sophistication of each function is necessary. And according to this classification, we infer that the categories of stakeholders' using each infrastructure are different. The legislation/regulations administering these various infrastructures are also different. The community infrastructure layer is managed and operated by the infrastructure operators (public/private).

The community facilities layer has two key facets, as a place where services are provided (such as a transportation hub, station), and as a place where services are used (home, office (building), commercial facilities). For example, the word "smart building" is usually used as a smart energy consuming building, so it is different from a smart grid or smart mobility which provides for a smart functionality.

The community services layer is usually managed and operated as a city administration service, so it is related to the improvement of legislative structure. For example, when we build new hospitals and schools, while such constructions entail an improvement of medical care and facilities, they also necessitate an improvement of medical systems and quality of doctors, education systems and teaching.

4.5.2 Within the IEC

Many if not most services in cities and buildings are directly or indirectly dependent on electricity and electronics. The most obvious is the electric infrastructure that carries electricity to and within buildings and in transportation, medical facilities and factories.

The IEC is actively involved in developing new International Standards to support smart projects, including smart city development. The IEC SMB (Standardization Management Board) has recently founded SEG 1 on smart cities. SEG 1 is now identifying the many electrotechnical systems that are found in cities, with a view to integrating and optimizing them. SEG 1 is currently preparing a reference architecture and standardization roadmap in cooperation with different organizations, fora and consortia.

In parallel, the IEC MSB, which brings together chief technology officers of leading international companies, prepared this high level White Paper on smart cities. The goal is to outline how cities can move towards smartness and the new business models that need to be put in place, as well as identifying the value, cost and benefit of standards in these processes. The core objective of this White Paper is to guide all relevant stakeholders towards integrated solutions that are going to be accessible, affordable and sustainable.

Many IEC TCs also enable the development of smart cities. A non-exhaustive list of these includes the following:

IEC TC 8: Systems aspects for electrical energy supply, which prepares and coordinates, in co-operation with other IEC TCs, the development of international standards and other deliverables focusing on overall system aspects of electricity supply systems. These include transmission and distribution networks and connected user installations.

Its recently-created SC 8A will develop standards for the grid integration of large-capacity renewable energy (RE) generation, which is set to play a central role in future energy supply and smart projects. International Standards prepared by IEC TC 82 and IEC TC 88 in particular, which cover generation from photovoltaic and wind energy sources, form an integral part of the overall portfolio of smart grid Standards.

IEC TC 57: Power systems management and associated information exchange, set up in 1964, covers communications between equipment and systems in the electric power industry, a central element in smart buildings, cities and grids projects.

In September 2011, IEC PC (Project Committee) 118: Smart grid user interface, was established to develop standardization in the field of information exchange for demand response and in connecting demand side equipment and/or systems into the smart grid.

IEC TC 65: Industrial-process measurement, control and automation, and its SCs, as well as TCs involved in storage (rechargeable batteries) and fuel cell technologies (TC 21 and TC 105, respectively), to name only a few, also form part of the overall IEC contribution to smart projects, without which smart cities would never become a reality.

4.5.3 Others

Various modes of joint efforts between SDOs may have to be modified to pursue these new types of standardization deliverables. For instance, the current practice of using liaison arrangements between the major international, regional and national SDOs may need to be enhanced to allow the joint development of deliverables across multiple technical disciplines and markets. These joint efforts will require working groups of experts from various disciplines to be organized in more cohesive structures at both the local and international levels. The deliverables of these joint efforts will be published, promoted, systematically reviewed and made accessible via any of these participating organizations. The conformity assessment and interoperability certification schemes will have to be designed to allow the various SDOs to assume appropriate roles in the practice of these schemes and their assimilation into regulations, as needed.

Section 5

Conclusions and guiding principles

Smart cities are necessary not only to reduce emissions, but to handle the rapid urbanization growth that the world is experiencing. Inefficiencies in urban areas bring large negative environmental and social impacts. City infrastructures are the backbone of the cities, delivering the necessary services to the population and creating the conditions for citizens to develop their professional, social and cultural activities. Infrastructures are also quintessential in guaranteeing the city's resilience to environmental risks.

Until now city infrastructures have been built independently and operated separately in parallel silos (water supply, electricity, transport). Furthermore, the citizen has mainly been a consumer of services with little direct influence on the system. In a smart city, this needs to change. First of all, efficiency requires that infrastructures are appropriately interlinked horizontally. Secondly, citizens are becoming producers and service providers. In the area of energy, individuals are starting to produce energy from renewables and thanks to the data revolution, also to deliver information and services in a number of areas. With smart systems, goods owned by citizens can be active in improving efficiency. Smart meters and electric cars can interact with the grid, data produced by the smart applications of the citizens can contribute to traffic control, improve emergency response, etc. Citizens can also use the technologies to sell new services.

This change in cities needs to be accompanied by enabling conditions, which means reforming the ways cities are governed and financed, i.e. administrative reforms and new financial systems.

However, the glue allowing infrastructures to link and operate efficiently are standards. Standards are necessary to ensure interoperability of technologies and the transfer of best practices. But standards are not yet adapted to the level of technology integration we are requiring. Standard bodies still operate in sectorial parallel silos, developing standards which are not easy to understand by non-specialists, particularly city managers. Standards are facilitators for city planners, and they need to incorporate standards in planning and procurement. There is thus a need to reform the way standards are produced, ensuring those are adapted to the needs of the city planners and other service operators within the city.

There is a need for close collaboration between standard bodies themselves and collaboration with outside organizations, in particular the city planners.

5.1 Guiding principles and strategic orientation for the IEC

- Electricity is core to any urban infrastructure system and the key enabler of cities development. As a result, the IEC has a specific role to play in the development of a smart city set of standards; however delivering the full value of standards to accelerate the development of smart cities and lower its costs clearly needs a strong collaboration of all city environment stakeholders.
- The IEC shall call for, take initiative, invite, and strongly contribute to a more global and collaborative approach including not only international standardization organizations,

but also all stakeholders of the smart city landscape (city planners, city operators, etc.) and specifically the citizens as described in this White Paper.

- Technology and system integration is critical to ensure interoperability and the IEC will support active collaboration between the relevant actors as described in the following guiding principles.

5.2 Guiding principles for technology and systems integration

- The IEC shall continue to foster technology integration (electrotechnical, electronics, digital and IT), and make sure that digital technology is fully integrated in all IEC products in a connect and share data perspective.
- The IEC shall make sure digital and IT technology suppliers are actively contributing in its work. Data aspects shall become a key issue in IEC including IoT, data analytics, data utilization, data privacy and cyber security.
- The system approach shall be accelerated as a top IEC priority taking into account flexibility, interoperability and scalability. Value creation for users (citizens and city infrastructure and service planners and operators) will remain the main driver of standardization work. Standardization shall consider a bottom-up system improvement approach together with a top-down service development. The efficient integration of electric grids, gas distribution systems, water distribution systems, public and private transportation systems, commercial buildings, hospitals, and homes is essential. These form the backbone of a city liveability and sustainability.
- Smart development requires solutions to be adapted to the specific needs of the city and its citizens. Technologies can be adapted and combined in different ways to address multiple situations. For example, the building of a digital infrastructure by implementing standards would considerably facilitate the development of tailor-made solutions and remove technology barriers that prevent technology integration.
- In the system approach, the IEC shall consider an architecture framework clarifying the system-of-system concept and the basic levels and rules of interoperability and integration. This framework shall be established in collaboration with other international SDOs as well as international organizations such as fora and consortia and shall apply to greenfields and brownfields.
- The IEC shall also develop work around visualization tools to model the complex interdependency of systems in city simulations.

5.3 Guiding principles for collaboration between actors

- The participation, input and ideas from a wide range of stakeholders within the city eco-system (city planners, city infrastructure operators, citizen organizations, etc.) are not only critical for solutions acceptance, but as well as a resource to build the most efficient answer to the pain point to solve. The IEC should liaise with these new (for IEC) stakeholders, encourage and foster their participation and inputs to the standardization work.
- Sometimes standards are considered by some actors as a burden with confusion between mandatory regulations and voluntary standards. Standards until now have been developed by technical experts to be used by technical experts. In the new field of smart cities and due to the new actors to be involved, the IEC shall challenge the way standards are written and promoted and specifically how the added value of standards, perceived by citizens and city actors, can be increased.

- Any efficient urban infrastructure and any new urban service cannot be developed without a strong electricity contribution; this gives a chance which the IEC shall seize to take initiative to create a collaborative working place going far beyond the IEC historical base and with participation of citizens, city planners, city operators, digital and IT actors for example.
- A wider market with solid standards and interoperability will support the expansion of replicable and more affordable technologies globally. Wider collaboration between stakeholders will ultimately lead to more integrated, efficient, less expensive and environmentally benign solutions for the world's rapidly growing urban population.

Annex A

Scoring table for smart city solutions [23]

Criterion	Scoring				
	1	2	3	4	5
Multidisciplinary/ multi technology approach	Integration aspects not addressed	Low potential for multi-layer integration within and between sectors*	Moderate potential for multi-layer integration within and between sectors	High potential for multi-layer integration within and between sectors	Proven record of multi-level integration within and between sectors
Flexibility	Extreme sensitivity to internal and external disturbances	Significant sensitivity to internal and external disturbances	Moderate sensitivity to internal and external disturbances	Low sensitivity to internal and external disturbances	No sensitivity to internal and external disturbances
Integration into the existing urban energy system (facilities and infrastructures)	No possibility to integrate with existing facilities and infrastructures	Significant problems to integrate with existing facilities and infrastructures	Moderate problems to integrate with existing facilities and infrastructures	Some problems to integrate with existing facilities and infrastructures	No problems to integrate with existing facilities and infrastructures
Potential for scale-up and replication	No modularity and applicability in a very specific city context	No modularity and applicability in a specific city context	Modularity and applicability in a specific city context	Modularity and wide applicability	Modularity and applicability in any city context
Barriers to market entry (e.g. vendor lock-in or non-interoperable protocols and rules)	No demand and new business models required	Low demand and no possibility to apply existing business models	Low demand and possibility to apply existing business models	Moderate demand and possibility to apply existing business models	High demand and possibility to apply existing business models
Potential for CO_2 emission reduction	Slight reduction of CO_2 emissions (<10 %)	Moderate reduction of CO_2 emissions (10-50 %)	Significant reduction of CO_2 emissions (>50 %)	Zero CO_2 emissions	Negative CO_2 emissions
Potential for increasing share of renewables	No integration of renewables	Integration of less than 10 % of renewables	Integration of less than 20 % of renewables	Integration of less than 50 % of renewables	Integration of over 50 % of renewables

Criterion	Scoring				
	1	2	3	4	5
Increasing energy efficiency	Slight reduction of energy/fuel consumption (<10 %)	Moderate reduction of energy/fuel consumption (10-50 %)	Significant reduction of energy/fuel consumption (>50 %)	Zero energy performance	Excess energy returned to the energy system
Affordability (estimated increasing energy costs for end users)	Significant cost increase (>20 %)	Moderate cost increase for end users (10-20 %)	Slight cost increase for end users (0-10 %)	No increasing costs	Cost reduction
Economic viability (period for return of capital)	Over 20 years	Up to 20 years	Up to 15 years	Up to 10 years	Up to 5 years
Potential for involving stakeholders (user friendly technology)	Interaction with stakeholders requires additional measures which are difficult to implement and involves additional high costs to society	Interaction with stakeholders requires additional measures which are difficult to implement and involves additional but affordable costs to society	Interaction with stakeholders requires additional measures with slight complexity of implementation that involves additional but affordable costs to society	Interaction with stakeholders requires easy-to-implement additional measures to improve the acceptability with no costs to the society	Easy interaction with stakeholders. No additional measures required
Innovative nature/ progress beyond the state-of-the-art	No elements of innovation	Low smartness of: of: 1) energy conversion, 2) materials, 3) power matching	Moderate smartness of: 1) energy conversion, 2) materials, 3) power matching	High smartness of: 1) energy conversion, 2) materials, 3) power matching	Exceptional smartness of: 1) energy conversion, 2) materials, 3) power matching
Regulatory requirements	Additional regulation that imply significant costs to the society required	Additional regulation that imply bearable costs to the society required	Additional regulation required with slight complexity of implementation	Additional regulation required which is easy to implement	No requirements for additional regulation

Annex B
Definition of big data

Big data represents a collection of data sets so large and complex that it becomes difficult to process using traditional database management tools or traditional data processing applications. It is remarkable to note that 90 % of the data ever created was created in the past 2 years and will double every 18 to 24 months. The volume of data will continue to increase making the need to capture, store and mine this information increasingly important, but also increasingly challenging.

While big data might once have concerned only data geeks, it is now relevant for leaders across the private and public sectors, as well as consumers of products and services who are beginning to benefit from its application. Much like it is used in enterprises to improve products and services today, big data will become a significant toolset for managing cities in the future.

Smart cities already have significantly more electrical and non-electrical smart devices than they did even a few years ago, resulting in a huge number of communication nodes including citizens participation with their smart phones. This will give cities insights to understand their processes on a more detailed level as well as the behaviours and patterns of their stakeholders in a much broader sense. Reaching a new transparency and making these data/insights accessible (open data to open city) to the relevant stakeholders (e.g. city planner, public officer, citizen) in a timely manner can create tremendous value.

It is important to note that not all data that is valuable is internal or proprietary so there is another emerging trend around the availability of open data. This is data that is useful in a number of contexts such as weather information or census results and it is becoming more fluid and being used crossing system boundaries. Open data is digital information that is freely available for everyone to use and republish, without restrictions from copyright, patents or other mechanisms of control.

Annex C

Public private partnerships

PPPs may often be used for overcoming broad public sector constraints such as lack of public capital, lack of public sector capacity, and lack of resources and specialized expertise to develop, manage, and operate infrastructure assets. In PPP projects, the private sector may be responsible for the designing, financing, constructing, owning and/or operating the whole project.

The financing model is the key factor, and there are some key parameters that should be considered when mapping/setting up financing models, which are [23]:

- Investment time horizon (short/medium/long-term)
- Revenues time horizon (short/medium/long-term)
- Maturity of technology (prototype/early market/mature)
- Maturity of the planning and implementing approach (standard/innovative)
- Type of project financing (infrastructure/buildings/products/soft measures)
- Project scale (national/regional/city wide/district/neighbourhood)

Once the investment time horizon and risk profile are identified, the financing model needs to be developed. This can take a number of different formats, which depend on the investment profile and the kind and timeline for the return to investment. Central to the smart city developments is the ability to adapt models to the often higher CAPEX which are in turn offset by higher returns from lower OPEX and savings from higher efficiency. Present procurement systems are not well suited for such cases.

In summary, the essential elements for efficient planning and investments are:

- An appropriate regulatory framework (procurement rules).
- An administration capable of coordinating different service operators and planning city developments. It should also be able to engage in PPPs.
- New financial models and PPP mechanisms to finance and run the new infrastructures and services.

Important enabling conditions, which will also help reduce the costs of projects, are:

- Standards, which can help bring down the costs of investments and facilitate integration.
- Specialized financing institutions (national or international) and public sector support, offering guarantees to reduce credit risks, grants and technical assistance.

City leaders need to focus on what gives the private and development sector sufficient assurances and clarity of revenue streams so that they are comfortable co-investing. A tested and effective system is the use of energy saving performance contracts (ESPCs), which in many countries make the funding of smart city projects possible using the cost savings.

The initial capital investment is provided by the financial community, while the actual services are delivered by specific purpose companies, or ESCOs. The financier is paid back out of the accrued energy savings, with the ESCO guaranteeing a certain level of savings or performance. If the performance standards are not met, the ESCO is responsible for paying back the loan, not the taxpayer.

Most importantly, the city and its residents receive the benefits of having highly efficient, modern systems that fulfil elements of a smart city vision.

Long-term concession-based contracts or PPP can also provide attractive propositions for both the private and public sectors, such as a street lighting concession.

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