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# Issues Paper

# On

# Smart Cities and Infrastructure

## Advance Unedited Draft

## NOT TO BE CITED

## Prepared by the UNCTAD secretariat[1]

[1] The paper has benefited from inputs of CSTD members. The secretariat wishes to acknowledge the inputs from Austria, China, Japan, Latvia, Nigeria, Poland and Uganda. Parts of this paper were drafted in collaboration with Prof. Sekhar Kondepudi, National University of Singapore. The secretariat also acknowledges the inputs received from Ms. Tierra Bills, Mr. Kelvin Campbell, Ms. Domenica Carriero, Mr. Andre Dzikus, Mr. Andrew Reynolds, Mr. Rick Robinson and Mr. Tim Stonor

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# 1. Introduction

## Background

Rapid urbanization is a global phenomenon. In 2008, for the first time in human history, there were more urban dwellers than rural, and the trends show that this is not going to be reversed. The United Nations estimates that by 2030, over 60% of the global population of will be living in "megacities" (10+ million), large (5-10 million), medium (1-5 million), and smaller cities and peri-urban communities, increasingly concentrated in Asia, Africa, and Latin America. This fraction could rise to two thirds by 2050[2]. The recent Intergovernmental Panel on Climate Change (IPCC) report[3] on Human Settlements, Infrastructure and Spatial planning states that the expansion of urban areas (urban centers and suburbs) is on average twice as fast as the urban population growth, and that the anticipated growth in the first three decades of the 21st Century will be larger than the cumulative urban expansion in all of human history.

With this rapid urbanization comes the increased demand for resources such as energy, water, and sanitation along with services such as education and health care. This emphasizes the necessity to use the resources efficiently or in a 'smart' way and the need to develop 'smart' cities to meet the needs of city residents. Responding to these needs, there are currently hundreds of smart city projects worldwide in both developed and developing countries. Examples abound, such as Amsterdam, Barcelona, Beijing, Cafeidian, Kashiwa-no-ha, Konza, Lavasa, Masdar, San Francisco, Santander, Sant Cugat, Shanghai, Shenyang, Singapore (Smart Nation), Songdo, Tianjin, Wuxi and a 100 smart cities initiative recently launched by the Government of India. A smart city can contribute towards improved governance and efficient management of infrastructure such as water, energy, transportation and housing and to a higher quality of life.

During the 18th annual session of the United Nations Commission on Science and Technology for Development (CSTD), *Smart Cities and Infrastructure,* was selected as one of the priority themes for the 2015-16 period. The new Sustainable Development Goals, the 2030 Agenda for Sustainable Development, the Addis Ababa Action Agenda and Paris Agreement under the Framework Convention on Climate Change provide a propitious intersection of agendas to address this priority theme. Cities and infrastructures will dominate the majority of human development for the foreseeable future and science, technology and innovation (STI), including information and communication technologies (ICT) can enable them as smarter and cleaner habitats. Accordingly, cities can be planned, designed, constructed and operated more holistically as crucibles of political power, commerce, education, and innovation with enormous potential for addressing sustainable development needs.

[2] UN (2014) World Urbanization Prospects, 2014 available at : http://esa.un.org/unpd/wup/highlights/wup2014-highlights.pdf

[3] https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_chapter12.pdf

## *CSTD's Past Work on Sustainable Urbanization*

The CSTD examined 'Science, Technology and Innovation for Sustainable Urbanization', as one of its priority themes for the period 2012-2013 and a detailed UNCTAD current studies paper on this theme was later published[4]. CSTD analyzed trends of urbanization, the role of science, technology and innovation in urban systems, sustainable urban planning in terms of spatial use, mobility and resilience against natural hazards. Prudent management of urban resources including energy, water, waste, buildings and agriculture was also discussed. The deliberations underlined the need to make urbanization a key consideration in national innovation systems, adopt innovative governance and financing models for cities, and facilitate inter-city learning wherever possible.

In addition, CSTD had discussed [5] 'ICTs for Inclusive and Social and Economic Development' during 2013-2014 and 'Digital Development' during 2014-15 periods. These discussions underlined the emerging trends in ICT including Datafication, Big Data, Data Analytics, Cloud Computing, the Internet of Things, as well as the progression of ICT from the periphery to the core of development. The current theme of 'Smart Cities and Infrastructure' builds on the previous priority themes of the CSTD related to STI, sustainable urbanization and ICTs and takes forward the research agenda of the Commission.

## *The 2030 Agenda for Sustainable development and Objectives of this Paper*

The newly agreed 2030 Agenda for Sustainable development places key importance on issues related to sustainable urbanization, and a specific goal (number 11) has been adopted towards this end, namely, *'make cities and human settlements inclusive, safe, resilient and sustainable'*. As well, a number of other goals, including, *inter alia*, those on ending poverty (Goal 1), health (Goal 3), gender equality (Goal 5), education (Goal 4), water and sanitation (Goal 6), sustainable energy (Goal 7), inclusive economic growth and productive employment (Goal 8), and climate change (Goal 13), are all linked strongly with urbanization issues.[6] Given the current urbanization trends, it is clear that there will be no sustainable development without sustainable urban development. Further, the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) is scheduled to take place in Quito, Ecuador, from 17 – 20 October, 2016. The Habitat III provides an opportunity to discuss a new urban agenda that will focus on policies and strategies that can result in effectively harnessing the power and forces behind urbanization[7].

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[4] See : Science, Technology and Innovation for Sustainable Urbanization, UNCTAD Report No. 10 (2015) and Science, Technology and Innovation for Sustainable Cities and Peri-Urban Communities - An Issues Paper ( January 2013), UNCSTD

[5] ICTs for Inclusive and Social and Economic Development – An Issues Paper (December 2013), UNCSTD

[6] https://sustainabledevelopment.un.org/post2015/transformingourworld

[7] http://unhabitat.org/habitat-iii-conference/

It is in this context that this paper builds on the CSTD's previous work on Science, Technology and Innovation for Sustainable Urbanization, as well as on various aspects of Digital Development. The key lesson emerging from these deliberations could provide key inputs to the Habitat III process, as well as to the overall process of implementation of the 2030 Agenda for Sustainable development, by helping to define the integral role of the Science, Technology and Innovation community in ensuring sustainable urban development.

The objective of this paper is to illustrate the key role of STI, including ICT, in the development of a smart city and its infrastructure. The paper provides (1) an understanding of what a 'Smart City' is, (2) what constitutes its infrastructure, (3) what the key challenges in the context of a 'Smart City', especially in developing countries are and (4) the role of science, technology and innovation (STI) in addressing these challenges.

## *Roadmap of the Paper*

This paper follows the following structure:

- Chapter 2 provides an overview of urbanization in the context of Smart Cities including a recap on global urbanization trends and the case for smart cities.
- Chapter 3 describes Smart City Infrastructure in the context of sustainable development including Smart Buildings, Transportation, Utilities (Energy, Water, and Waste), Healthcare and ICT. This chapter concludes by underlining the need for an integrated approach towards smart city infrastructure.
- Chapter 4 focuses on presenting some key challenges confronted while implementing Smart City projects and explains how science, technology and innovation (STI) can be a powerful tool in addressing these challenges, with plentiful case studies from across the world. This chapter also provides some key principles that need to be kept in mind while developing smart city infrastructure.
- Chapter 5 provides a list of questions for discussions revolving around the central themes of the paper.

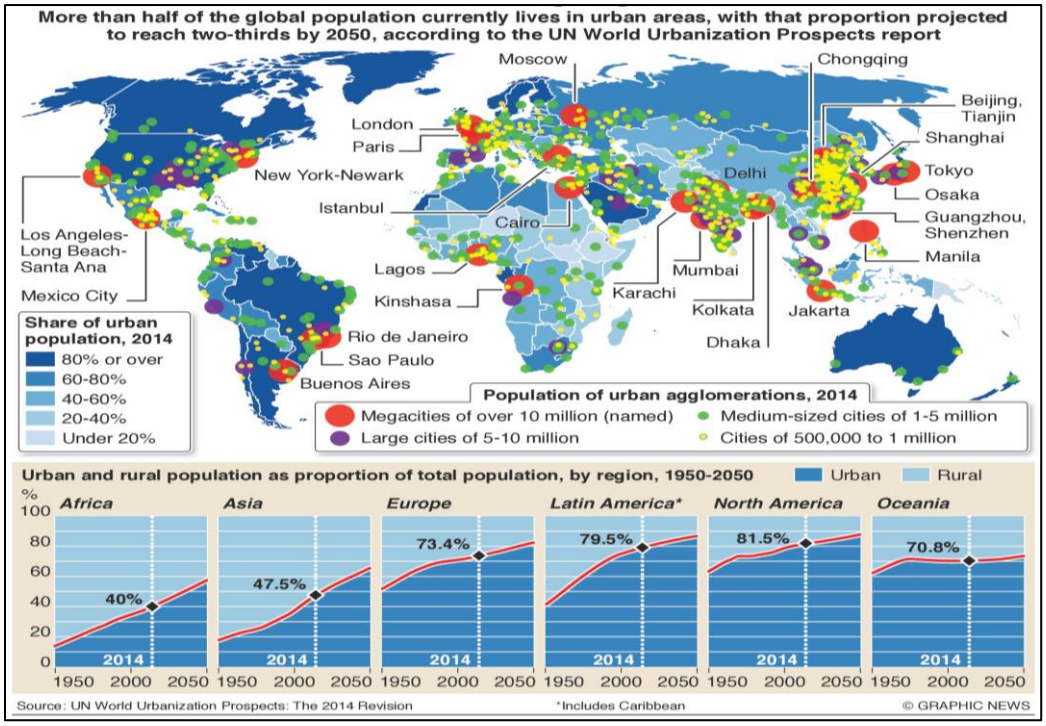
# 2. Urbanization and Smart Cities

This chapter begins by discussing some of the key urbanization trends and provides the context for the need for cities to deliver smart solutions. The chapter then summarizes the existing attempts to define smart cities. The smart city infrastructure is highly context specific and the chapter discusses some key differences between the nature of smart infrastructure in developed and developing country context. It concludes by underlining the role of key performance indicators (KPIs) in smart cities.

## Urbanization Trends

In 1950 about 65% of the population worldwide lived in rural settlements and 35% in cities and this number will be reversed[8] by 2050, where 70% will be urban and 30% rural. Almost 6 billion people will be living in urban areas by 2050. Figure 2.1 reflects the projections of urban populous by the year 2050. This urbanization trend is present across all regions albeit at different rates of growth. Comparing the projected rate of growth (figure 2.2) of urban populations across regions, it is clear that countries of low income categories will confront far more rapid urban population growth than that of higher income countries.

**Figure 2.1 Urban Population Trends[9]**




[8] UN (2014) World Urbanization Prospects, 2014 available at : http://esa.un.org/unpd/wup/highlights/wup2014-highlights.pdf

[9] https://engtechmag.wordpress.com/2014/07/22/un-world-urbanization-prospects-report-half-the-world-lives-in-urban-areas-an-annotated-infographic/

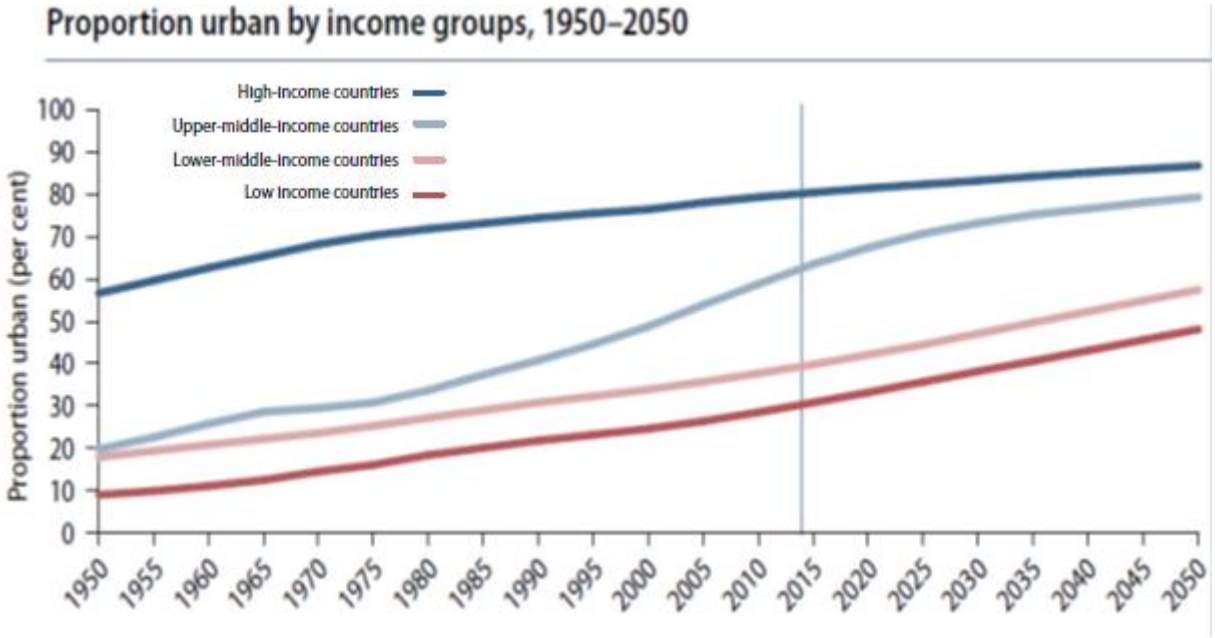



**Figure 2.2: Urban Populations by Country Income Level**[10]

Estimates from the United Nations Environment Programme[11] and the Sustainable Urbanization Policy Brief[12] suggest that cities contribute to approximately 70% of global energy use and greenhouse gas emissions but only occupy 5% of the earth's landmass. This is accompanied by the unprecedented increase in demand need for water, land, building material, food, pollution control measures and waste management from urban areas. Therefore, cities are constantly under pressure to provide better quality services, promote local economic competitiveness, improve service delivery, increase efficiency and reduce costs, increase effectiveness and productivity, address congestion and environmental issues. These pressures are motivating cities to turn to 'smart' solutions and experiment with various smart infrastructure applications.

## *A Comprehensive Definition for a Smart City*

There is no standardized, commonly accepted set of terminologies or definitions which would help to aptly describe a "Smart City". Annex 1 reflects some definitions of smart cities from different sources such as international organizations, governments and corporations. ITU[13] published a technical report in 2014 in which over 100 definitions related to smart

[10] UN (2014) World Urbanization Prospects, 2014 available at : http://esa.un.org/unpd/wup/highlights/wup2014-highlights.pdf

[11] http://www.unep.org/resourceefficiency/Policy/ResourceEfficientCities/FocusAreas/CitiesandClimateChange/tabid/101665/Default.aspx

[12] http://www.thegef.org/gef/sites/thegef.org/files/publication/Sustainable-Urbanization-Policy-Brief.pdf

[13] http://www.itu.int/en/ITU-T/focusgroups/ssc/Documents/website/web-fg-ssc-0100-r9-definitions_technical_report.docx

cities were analyzed in detail. The following definition was the outcome of the analysis by the ITU[14] :

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

For the purposes of this paper, we use this definition. Analyzing different definitions of smart cities reveal that different definitions emphasize different aspects of smart cities. However, there are several common characteristics of smart cities which may be grouped under the following broad six themes listed in Table 2.3[15], namely, smart mobility, smart economy, smart living, smart governance, smart people and smart environment. But specific factors associated with these themes evolve over time and are dependent on the specific context of each city and its stage of development. The table also lists some of the main factors associated with these key characteristics of Smart Cities.

An important classification of smart cities projects is in terms of *Brownfield* and *Greenfield* projects. The majority of smart city projects (in both developed and developing countries) fall to the category of smart interventions in existing cities and can be classified as *Brownfield* projects. However, there are also *Greenfield* initiatives, such as Fujisawa, Kashiwa-no-ha, Songdo and Masdar, which are projects started from scratch and with a vision to create 'new' smart cities. Since the good majority of smart city projects fall into the former category, the paper looks mainly at *Brownfield* smart city projects and their associated challenges, though some of the discussions would equally be relevant in the case of new Greenfield projects as well.

[14] http://www.itu.int/en/ITU-T/focusgroups/ssc/Pages/default.aspx

[15] These six characteristics of Smart Cities were proposed in 2007 by the research report "**Smart cities – Ranking of European medium sized cities**" produced jointly by the Vienna University of Technology, University of Ljubljana and Delft University of Technology in 2007. These broad groupings were later adopted by other studies , including, Prof. Boyd Cohen in the Smart City Wheel Analysis (http://www.fastcoexist.com/3038818/the-smartest-cities-in-the-world-2015-methodology) and the report produced by the ITU-T Focus Group on Smart Sustainable Cities available at http://www.itu.int/en/ITU-T/focusgroups/ssc/Pages/default.aspx

**Table 2.3: Six Key Themes Related to Smart City**

| Smart Mobility | Smart Economy | Smart Living |
|---|---|---|
| • Improved Accessibility<br>• Safe Transportation<br>• More efficient and intelligent transportation systems<br>• Leveraging networks for efficient movement of vehicles, people, and goods, to reduce gridlock<br>• New 'social' attitudes such as car sharing, car pooling, and car-bike combinations | • Regional/global competitiveness<br>• Entrepreunership & Innovation Momentum<br>• High Levels of Productivity<br>• Broadband access for all citizens and businesses for business opportunities<br>• Independent of location, helping maintain population in rural areas,<br>• Electronic business processes (e.g., e-banking, e-shopping, e-auction) | • Better Quality of Life<br>• Social Aspects - Education, healthcare, Public Safety, Housing<br>• Access to high-quality healthcare services (including e-health or remote healthcare monitoring), electronic health records management<br>• Home automation, smart home and smart building services<br>• Access to social services of all kinds. |
| **Smart Governance** | **Smart People** | **Smart Environment** |
| • Participatory Decision Making<br>• Public & Social Services<br>• Transparency<br>• Democratic processes and inclusion<br>• Interconnecting governmental organizations and administrations<br>• Improving community access to services | • Social & Human Capital<br>• Qualified, Creative and Educated Citizenry<br>• Able to utilize the ICT based smart services<br>• Delivering a more consistent educational experience in both urban and rural areas<br>• e-education solutions (remote learning and collaboration) to have citizens better informed | • Pollution Monitoring<br>• Use of Sustainable Technologies<br>• Environmental/ sustainable /Energy consumption<br>• Reducing energy consumption through novel technology innovations while promoting energy conservation and material re-use |

## *Smart City Infrastructure*

Infrastructure of a city comprises of, inter alia, housing, sanitation, water supply and sewage, electric power supply and distribution, transportation, waste management and communication. Smart city infrastructure differentiates itself from the traditional urban infrastructure through its ability to respond intelligently to changes in its environment, including user demands and other infrastructure, to achieve an improved performance[16]. Smart City Infrastructure provides foundations to all the six key themes related to a smart city namely, smart mobility, smart economy, smart living, smart governance, smart people and smart environment. But the smart infrastructure components are highly context specific and their nature is determined by the level of development of the cities as well as by the specific developmental challenges.

For a city in a developing country, the immediate need is to provide adequate urban infrastructure to meet the increasing pace of urbanization. Therefore, in the process of meeting these infrastructure demands, smart infrastructure applications provide an avenue for these cities to leapfrog, as shown by a recent study on Africa and smart cities. [17].

[16] See report by the Royal Academy of Engineering: http://www.raeng.org.uk/publications/reports/smart-infrastructure-the-future

[17] See report by Deloitte available here: http://www2.deloitte.com/content/dam/Deloitte/za/Documents/public-sector/ZA_SmartCities_12052014.pdf

Further, these smart infrastructure applications have the potential to provide foundations for new innovations that will promote efficiency and better management of resources. For example, the data generated by new smart mobility infrastructure could provide useful information for redesigning transport networks as well as to build new smart mobility apps.

In developed countries, the challenge is to maintain the legacy infrastructure systems, which cannot be abandoned due to cost, space and other considerations. Here smart infrastructure applications would focus more on facilitating optimal use of these existing legacy infrastructure resources and monitoring of operations of these resources. For example, in Paris, the existing metro network represents a huge legacy infrastructure system. As part of its modernization, automated trains were introduced in Line 1 Paris Metro network, along with new audio-visual systems and information control systems. This led to an additional capacity of 70,000 passengers per day and major reductions in passenger delays[18].

However, in both developing and developed country contexts, the primary motive behind smart infrastructure applications is that they respond to the sustainable development needs of the society. Table 2.4 provides an overview of some Smart Infrastructure solutions and how they address some of the sustainable development challenges related to urbanization. The next chapter gives details on smart infrastructure components along with case study examples.

**Table 2.4: Meeting Challenges of Urbanization with Smart Infrastructure**

| **Sustainable Development Need / Challenge** | **Example Smart Infrastructure Solutions** | **Description** |
|---|---|---|
| Improve Energy / Utility Infrastructure | Smart Meters | Metering of power, water and gas that can provide real time measurement of energy consumption |
| | Smart Grids | Re-engineering electrical systems through applications of smart meters, smart appliances, and renewable energy resources in order to attain better energy efficiency. |
| Provide affordable and high quality connectivity | High Speed Internet | Fiber to the Home and other emerging connectivity solutions, including public wifi and mobile broadband. |
| Develop urban Infrastructure – Transport / | Smart LED street lighting | Light sensors and communication devices to allow lights to communicate with other nearby lights and to be controlled at a city level. |

[18] http://w3.siemens.com/topics/global/en/intelligent-infrastructure/Pages/intelligent-infrastructure.aspx

| Sustainable Development Need / Challenge | Example Smart Infrastructure Solutions | Description |
|---|---|---|
| Parking / Buildings /Streets | Smart buildings | Array of sensors and technologies that improve safety, security, energy efficiency and usability. |
| | Electric Vehicles | Cars which operate on electricity / batteries with appropriate infrastructure for charging stations throughout the metropolis. |
| | Smart Parking | Car parks and street parking locations than transmits real-time information to users. |
| | Smart Traffic Lights | Automated sensing and management of traffic. |
| Improve environmental performance | Environmental Sensor Network | Continuous data collection about the condition of air, water, soil and related levels of pollutants. |
| Ensure public security and safety | Video Security | Public safety, crowd management and people counting using sensor networks and networked cameras. |
| Increase efficiency of City management | Smart City Operations Centre | Monitoring and management of a range of government, transport, environmental and emergency services. |
| Improve health and education services | Remote Healthcare and online education | Products and services for remote access to health services and education. |

## *Key Performance Indicators (KPIs) of a Smart City*

The previous section gave a flavour of different smart city applications. But how do we test the performance of each of these different applications? Several efforts are currently under-way to develop comprehensive KPI for Smart Cities. For example, a UN inter-agency team is currently developing a set of KPI, with an aim of eventually turning it into a Global Smart Sustainable Cities Index for cities[19]. The global Science, technology and innovation

[19] https://www.itu.int/net/pressoffice/press_releases/2015/43.aspx

community play a key role in the process, inter alia, by developing innovative ways to collect data on the performance indicators and by making better analysis of existing data possible.

# 3. Smart City Infrastructure Components

## Introduction

Infrastructure is the foundation for the development of a smart city. Smart Infrastructure can be broadly divided into two categories: (1) physical and (2) digital. This chapter provides brief descriptions of the following smart physical infrastructures: (1) Smart Buildings, (2) Smart Mobility and Transport, (3) Smart Energy, (4) Smart Water Management, (5) Smart Waste Management and (6) Smart Healthcare, with case studies and examples. In terms of the digital infrastructure, a brief discussion on ICT and Data infrastructure is also presented. The chapter concludes by highlighting the need for an integrated approach in dealing with these diverse smart city infrastructure components.

## Smart Physical Infrastructure

### Smart Buildings

Buildings play a critical role in a city, acting as a fundamental building block for a city - providing comfort and security for its citizens. People tend to spend 80 to 90 percent of their lives inside buildings, making buildings an integral part of their lives.

#### What are Smart Buildings

A smart building integrates the different physical systems present in a building (such as Building Automation System (BAS) - HVAC & Energy Management, Lighting Control System, Fire & Life Safety Control Systems, Parking Guidance and Management Systems) in an intelligent manner way to ensure that all the different systems in a building act together in an optimized and efficient manner. This integration is typically done in a reliable, cost effective, and sustainable manner with a goal to provide optimal comfort and well-being for their occupants thereby enhancing productivity and performance. In the United States[20], buildings account for 36% of total energy use, 30% of GHG emissions, 30% of waste output (nearly 136 million tons annually), 30% of raw materials used and 65% of electricity consumption. Similar numbers are true globally and this underlines the relevance of smart buildings.

#### Benefits of Smart Buildings

Smart building management systems can improve building energy efficiency, reduce wastage, and ensure optimum usage of water with operational effectiveness and occupant satisfaction. It is estimated that implementing smart building solutions[21] could save as much as 30 percent of water usage, 40 percent of energy usage, and reduce overall building maintenance costs by 10-30 percent. It has been found that energy use in existing buildings can be reduced by up to 50% through simple retrofit programmes[39]. This range of energy

[20] http://www.epa.gov/oaintrnt/projects/
[21] Energy Ensemble (2015), http://energyensemble.com/news_details.php?news_id=240
[39] http://saveonenergy.ca/Business/Program-Overviews/Retrofit-for-Commercial.aspx

savings is best illustrated through the case studies in box below, which reflect that such systems work equally well in both developed and developing countries. For example, the *Plus-Energie-Bürohochhaus* is acclaimed to be the first smart office building which feeds more energy into the grid than it uses.

### Plus-Energie-Bürohochhaus,Vienna, Austria

The *Plus-Energie-Bürohochhaus* is the world's first office tower that claims to feed more energy into the power grid than is required to operate and use the building. Moreover, it is located in the heart of a large modern city. The refurbishment of the 1970s-office tower was completed in August 2014. The coverage of the primary energy demand is accomplished with the photovoltaic (PV) system, the usage of thermal discharge from the servers and the energy recovery from the elevators. Central point for reaching the plus-energy-standard of the office building was the extreme reduction of the energy demand for all sections and components in the building, from heating to cooling and also for office computers and smaller electric components. This is seen as an international model project[22].

### Infosys Building, Pocharam campus in Hyderabad, India

Infosys, one of India's largest software companies, built a campus in Pocharam, Hyderabad called the Software Development Block (SDB). It has a total area of 24,000 square meters with occupancy of 2,500 people. The unique feature about the building is that one half of it is cooled by conventional and efficient air-conditioning and the other half by radiant cooling. The building was designed with highly efficient day lighting systems allowing more than 90% of the office space to obtain natural sunlight, reducing the need for artificial lighting during the day time[23]. The building is also aligned in a way to minimize heat exposure. The building's Integrated Building Management System (IBMS) monitors and controls various building systems with over 3,000 sensors placed throughout the building to monitor building conditions ranging from chiller plant to indoor air conditions. The building is approximately 30 to 35% more energy efficient than a comparable size building with traditional building systems.

## Smart Mobility & Transport

### What is Smart Mobility & Transport

Smart Mobility and Transport are best described to be approaches which reduce congestion and foster faster, greener and cheaper transportation options[24]. A Smart City transport infrastructure aims to optimize those journeys that take place within a city, save energy and reduce carbon emissions[25]. Most smart transportation management systems use data collected from a variety of sources about mobility patterns in order to help optimize traffic

[22] Based on inputs from Austria to the CSTD secretariat. More information may be found at : http://univercity2015.net/en/standorte/getreidemarkt/plus_energy_office_high_rise_building/overview/

[23] http://www.infosys.com/newsroom/press-releases/Pages/LEED-india-platinum-rating-hyderabad.aspx

[24] http://dupress.com/articles/smart-mobility-trends/

[25] http://www.smart-cities.eu/model_3.html

conditions in a holistic manner. According to recent estimates, the global smart urban mobility infrastructure and services market is expected to grow from $5.1 billion in 2015 to $25.1 billion in 2024[26]. Smart Mobility and Transport systems can be divided into the following areas: (1) Mass Transit (2) Individual Mobility and (3) Intelligent Transport Systems. These are discussed below.

### Mass Transit Systems

Mobility within cities has to adapt and become smarter to handle the rapidly increasing population. Primary mass transit systems for the public are either by train, subway or by city bus systems. Developed nations have long had emphasis on subway and train transport within a city's boundaries. The Singapore MRT (Mass Rapid Transit) is an example for an efficient transit system in a developed nation. This MRT is an efficient system that encompasses over 100 stations and has train services that run once in every 5 minutes and has a ridership of 2.5 million out of a population of approximately 3.5 million.[27] The MRT is one of the backbones of transport in Beijing and Delhi and new systems are being planned in many other global cities such as Jakarta.

While many cities have bus systems, they do not operate efficiently most of the times. An innovation in this regard is the concept of Bus Rapid Transit (BRT) which is a high-quality, efficient, bus-based mode of public transport. The Institute for Transport and Development Policy (ITDP) defines it as follows: "*Bus Rapid Transit (BRT) is a high-quality bus-based transit system that delivers fast, comfortable, and cost-effective services at metro-level capacities. It does this through the provision of dedicated lanes, with busways and iconic stations typically aligned to the center of the road, off-board fare collection, and fast and frequent operations*".

### Success Stories of BRT Systems

BRT systems can carry more than 40,000 commuters per hour which can be comparable to some of the world's busiest metros. It costs a tenth of an equivalent metro system and can be implemented in less than half the time[28]. BRT systems have been successfully implemented in 197 cities around the world, with roadways of over 5,000 km and carrying over 30 million passengers daily.[29]. It has demonstrated across all the geos - making it attractive to urban planners across the globe. The success of BRT is probably a consequence of increased speed resulting from infrastructure improvements such as the creation of corridors that prioritize buses over other traffic, use of GPS technologies to track and monitor bus locations and automatically adjust different rights-of-way and traffic lights in real time that give priority to buses.

[26] http://www.greencarcongress.com/2015/06/20150624-navigant.html#more

[27] Source?

[28] http://www.wricities.org/news/166-cities-worldwide-adopt-bus-rapid-transit-%E2%80%93-key-tipping-point#sthash.xEeN9KqW.dpuf

[29] http://thecityfix.com/blog/where-brt-came-from-and-where-its-going-dario-hidalgo/

### Beneficial Impact of BRT Systems[30]

The following examples show a BRT's capacity to improve quality of life by reducing commute time, better air quality, reduction in greenhouse gas (GHG) emissions, and lower traffic accidents.

- In Istanbul, the average BRT passenger saved an equivalent of 28 workdays per year in reduced travel times;
- In Johannesburg, it estimated that the travel time saved by commuters could exceed 9 million workdays by shifting to BRT systems between 2007 and 2026.
- In Mexico City, as a result of the BRT system, there was a reduction in local air pollution and emissions leading to an improvement of over 2,000 work days of lost work due to pollution related incidents. It is further estimated that this improved air pollution levels leads to over $ 4.5 Million of savings due to lower healthcare costs..

### Individual Mobility

Traditionally, 'individual' mobility in cities has been through some form of mechanized or motorized transport, mostly cars. There seems to be a movement away from cars towards transportation system design around individual mobility which feature bicycles, ridesharing (or carpooling), carsharing and more recently on-demand transport.

**Bicycle commuting:** In recent times, bicycle commuting is becoming attractive. In cities, for short distance travel, often biking is the fastest mode of transport[31]. Beijing and Shanghai, for example, are now re-introducing bicycle lanes to foster and encourage bicycles. One interesting concept related to bicycles is "bicycle sharing" or "bicing". The principle is very simple – a city resident picks up a bicycle (for a fee) from a given pickup point A, uses it to get to another point B and drops it off so that another resident can then take it from Point B to Point C and so on. This is extremely popular in Amsterdam, Budapest, Paris, San Francisco and Barcelona. For instance, in Budapest, a network consisting of 98 stations to rent and over 1,000 bicycles is established, and it has already completed over 1 million rentals[32]. The convergence of new technologies such as smart cards, mobile broadband and smart phone technologies enables a lot of innovative ways to leverage bicing– including making reservations, finding the nearest pickup and drop off points and traffic conditions coupled to the bike lane maps of a city.

## Bike sharing systems in Latin America [33]

Bicycle use has grown rapidly as an alternative means of mobility in Latin America, but it remains marginal, partly because there is no particular bicycle culture and very little

[30] http://www.wricities.org/news/press-release-new-analysis-shows-bus-rapid-transit-improves-quality-life-cities#sthash.5T4SglxF.dpuf

[31] http://road.cc/ content/news/93687-bikes-faster-public-trans- port-most-london-journeys-under-8-miles.

[32] http://molbubi.bkk.hu/gyik.php

[33] EIU (Economist Intelligence Unit). 2014. Evaluating the environment for public-private partnerships in Latin America and the Caribbean: The 2014 Infrascope. EIU, New York, NY

dedicated infrastructure. In the region, daily bicycle trips rose from 433,000 in 2007 to 1m in 2012. Bike-sharing systems are now operational in seven countries: Argentina, Brazil, Chile, Colombia, Ecuador, Mexico and Uruguay. In Chile, bicycle use has grown by 20% a year since 2005. Bogotá now offers the most extensive network (392 km) of permanent and shared bike lanes in the region, according to a 2015 study on bicycle use in 56 cities in Latin America[34]. As of 2014, Bogotá has the highest percentage of bicycle users in the Americas with a share of 5% of total trips, surpassing cities such as Mexico City or Santiago de Chile with 1.5% and 3%, respectively. Mexico City launched its first bike-sharing system, ECOBICI, in February 2010 and recorded 120,000 users in its first four years. It now has 275 docking stations, run and maintained by the city government. A study by Mexico City's environment agency estimates that the system saved the city 232 tons of carbon dioxide emissions in its first three years of operation.

**Carpooling and Carsharing:** The concept of carpooling is quite old, simple and intuitive. Carpooling utilizes empty car seats in an efficient way, thus decreasing the harmful impact on environment and making it a sustainable process. However, carpooling has been on a declining trend the past few decades. Technology advances such as GPS and mobile technologies along with software applications play an important role to counter this downward trend. Applications such as Carma[35] and Zimride[36] match drivers and passengers (who are travelling in similar routes) in real time without any advanced planning in a dynamic process, thus improving the accessibility. Though carpooling is more common in developed countries, it is not having much adoption in developing countries largely due to a combination of social norms, low car ownership rates and a lack of standardized working hours. Carsharing is a slightly different concept from car-pooling in that it allows people to rent cars by the hour. It can be considered car rental by the hour but the difference is similar to "bicing" in that there are multiple pickup and drop off points for the users, thus decreasing the parking space in city, where in the place of multiple cars, a single car can do the work. Users pay an annual membership fee or use per rental fee and can reserve cars inclusive of gas, maintenance, insurance and parking.

## Carsharing : Case Study

Zipcar, a membership-based, car sharing company serves 605,000 plus members with a fleet of over 8,000 vehicles in North America and Europe. They are very popular with college students with a presence in over 230 college campuses. In Baltimore, USA, it was found that each ZipCar reduces approximately 15 cars on the road[37]. 18 % of respondents to a survey indicated that they have sold their vehicles since joining Zipcar and 46 % stated that they

[34] Inter-American Development Bank, Biciudades(May 2013). Retrieved from: http://www.vanguardia.com/sites/default/files/informe_uso_de_las_bicicletas.pdf

[35] https://carmacarpool.com/

[36] https://zimride.com/

[37] www.smartgrowthamerica.org/2011-07-20/How-carsharing-can-help-a-city-the-impact-of-Zipcar-in-Baltimore

have avoided buying a car. 33 % of the respondents state that they walk or use public transportation to and from a ZipCar location.

**Benefits of Carsharing:** The primary advantage of car sharing is that it reduces traffic congestion and also helps alleviate a lack of parking spots. Other benefits include that fewer cars leads to less air pollution, there are monetary savings due to fuel efficiency, reduced car maintenance costs, less parking infrastructure, more resources for parks and urban green areas and some indirect benefits of more walking / use of public transport.

**On-demand ride services**: These are the truly disruptive business models leveraging the concepts of sharing, convenience and the use of technology – true smart mobility. A few on-demand mobile and GPS enabled ride services like Uber, Sidecar, Lyft allow passengers to hail rides from a pool of drivers that use their personal vehicles. Using mobile or GPS makes the process of reaching the passenger much easier and are disruptive to the traditional taxi market as we know it. These services also provide with e-billing, thus enabling pure cashless transaction. These on-demand ride services also adapt based on the country like including the famous auto-rickshaw (in India) in the options. However, the jury is still out on if these services have a beneficial impact on the traffic congestion and frequency of car use in the city. Also, these models are disrupting the established car-hire industry in many countries and also raising several challenges related to safety. But nevertheless it seems to have some positive impacts as it creates a new generation of self-employed entrepreneurs known as "driver partners" and is better at catering to people's mobility demands.

As evident from discussions above, Smartphones and mobile applications form a big part of the technological innovation towards smart mobility. It applies equally to both public transport systems like BRT and private alternatives such as Uber. A study by Deloitte in Asia found that around a third of a Chinese and Indian sample use travel apps at least once a month and despite the continuous serious concern on privacy of data, urban commuters see value in sharing information to improve their quality of their commute.[38]

### Intelligent Transport Systems

Intelligent Transport Systems (ITS) integrates the whole array of multimodal transport options in a city, including both individual mobility and mass transit options, in an efficient manner. Though ITS dates back to 1950s, its components have evolved and the contemporary versions of ITS form an integral part of smart cities mobility infrastructure. Modern ITS normally comprises of, inter alia, network of sensors, connected cars, GPS tracked public transportation, dynamic traffic lights, passenger information panels, automatic number plate readers, CCTV systems, navigation facilities, signaling systems and most importantly the capability to integrate live data from most of these sources. This can lead to major improvements in safety, network management, traffic congestions, environmental performance, accessibility, convenience and public perception. The case study of ITS application in Poznan in Poland described below explains the functioning of a modern ITS in an urban setting, along with some key challenges confronted while

[38] http://dupress.com/articles/smart-mobility-trends/

implementing this project. These challenges included shortage of skilled staff, issues related to interoperability, and unexpected delays in construction of hard infrastructure component.

## Implementation of an Intelligent Transport System (ITS) and some emerging lessons, Poznań, Poland

The main goal of the new ITS is to synchronize private and public transportation in a cross-system concept in order to optimize the overall traffic situation in the city. Real-time traffic data from more than 200 measurement points, such as intersections, parking lots and public transportation, are collected in the traffic management center, evaluated and processed. The ITS provides information on the current traffic situation, available parking spaces and the departure times of nearby public transportation. Where required, traffic light control (involving 100 traffic lights) influences the speed of the flow of public transport. More than 85 information panels at the bus and tram stations indicate the current information on relevant vehicles arrival times. All traffic information will be also forwarded to the Internet and enabled for radio stations, texting and email services. Along the roads at strategic locations 12 variable message signs (VMS) will be mounted to provide important information for driver. This project has increased transport efficiency in Poznan. By better and more efficient public transport it has reduced the number of individual car users, consequently lowering traffic congestions. It gives necessary information to users of public transport as well as individual drivers, thereby promoting traffic safety. Additionally, it contributes to environmental sustainability by reducing fuel consumption and emission of car exhaust fumes.

Three key challenges and associated lessons emerged from this project:

First of all, there was the shortage of staff qualified in the area of information and communications with relevant experience and skills in the municipal office as well as in municipal entities working together to implement the project. This was overcome by cooperation with scientific and research institutions as well as support of ICT entities from private sector.

Secondly, there was the issue of interoperability of new systems and systems already in place, so as to gain synergy. This was the more important issue because of the implementation of several other projects that were under implementation at the same time. It was necessary to avoid the use of different systems and on-board computers to be used in each project. On top of that, in order to mitigate this risk in the future it was essential to ensure openness of communications protocols.

Lastly, delays in construction of hard infrastructure and key nodes also caused some troubles. This required proper and flexible managing and good organization[39].

[39] Based on the inputs provided by Poland to the CSTD secretariat and information made available at the following source:
http://www.siemens.com/press/en/pressrelease/?press=/en/pressrelease/2013/infrastructure-cities/mobility-logistics/icmol201306023.htm&content[]=ICMOL&content[]=MO

## Smart Energy / Smart Grid

Rising energy prices, energy security and theft, depleting energy sources and the global warming caused due to the impact of energy usage are some of the key issues the city managers are looking to solve in their path towards sustainable development. Smart energy management systems are a potential solution to the above issues, using sensors, advanced meters, renewable energy sources, digital controls and analytic tools to automate, monitor and optimize energy distribution and use[40]. These systems optimize grid operation and usage by balancing the needs of the different stakeholders involved- consumers, the producers and the providers.

### What is Smart Energy / Smart Grid

The term Smart-Energy[41] comes from the philosophy of meeting energy needs in an environmentally sustainable manner utilizing a long term cost effective effort. There are a number of innovations and disruptions in smart energy infrastructure, such as: distributed renewable generation, microgrids, smart grid technologies, energy storage, automated demand response (ADR), virtual power plants, and demand side innovations like electric vehicles and smart appliances. These elements of the new smart energy infrastructure provide an extended network of intelligent energy devices present across a city providing a detailed view of patterns of energy consumption, enabling community-based energy monitoring programs, and improving energy efficiency of buildings. The key component of the Smart energy infrastructure is that of smart grids, which is discussed in detail below.

The US Department of Energy[42] defines a Smart Grid as follows:

*"An electricity delivery system (from point of generation to point of consumption) integrated with communications and information technology for enhanced grid operations, customer services, and environmental benefits."*

Smart Grids are being implemented across the globe in both developed and developing countries as illustrated below. This underscores the value and importance of the need for a smart grid.

### Smart Grid: Developing Countries [43] [44]

Brazil has started smart grid implementation using smart metering to avoid fraud in the power grid. There is a penetration of 7.5% of smart meters in 2014 expected to grow to 75% by 2030. China's Power Grid is growing at a rate slower than industry is growing and hence Transmission and Distribution efficiency and control is important. Smart meters are now being deployed aggressively (currently at 27% penetration). India's smart grid project developed by Puducherry Electricity Department, Power Grid Corporation of India includes features such as Advanced Metering Infrastructure (AMI), Virtual Demand Response (DR),

[40] http://www.slideshare.net/IMDEAENERGIA/smart-energy-management-algorithms
[41] http://smart-nrg.com/
[42] http://energy.gov/oe/services/technology-development/smart-grid
[43] A Comparative Study of Smart Grid Development in Developed and Developing Countries, by Alvarez, Ghanbari and Markendahl, 7th annual CMI conference, 17-18 November, 2014 Aalborg University Copenhagen
[44] https://apps.powergridindia.com/smartgrid/Default.aspx

Street Light Automation and Outage Management System (OMS). Based on this success, 57 other service providers across India are adopting similar measures.

## Smart Grid: Developed Countries[45]

| City and Country | Project | Project Summary |
|---|---|---|
| Amsterdam, The Netherlands | Amsterdam Smart City | Many projects related to energy and smart grid have been developed, which include smart distribution networks, smart homes, waste management, building efficiency programs and demand management. |
| Charlotte, North Carolina, United States | Envision Charlotte | Smart Energy Now project, a collaboration aimed to make Charlotte the most sustainable city in United States. This uses smart grid technologies to decrease the energy consumption in office buildings. |
| London, United Kingdom | Low Carbon London | A project led by UK Power Networks is looking at range of issues including smart meters, EV charging, renewable energy integration and smart distribution networks. |
| Sydney, Australia | Smart Grid, Smart City | Smart electric meters, energy monitoring and management technologies are used to test various smart grid programs in around 17,000 homes in Sydney. |
| Kashiwa-no-ha, Japan[46] | Area-wide Energy Management System (AEMS) based Smart Grid | Combination of Home Energy Management System (HEMS) and real time monitoring of demand and supply of Energy in the Area, self-sustained energy management through optimal allocation of generated and stored energy. |

### Benefits of a Smart Grid[47]

While there are many benefits of a "smart grid", some of the salient aspects include (1) Lower Costs, (2) Improved Economics, (3) Increased System Efficiency and (4) Cleaner Environment. Some specific benefits include (but are not limited to) reduced operational cost, increased revenues due to reduction in energy theft, improved cash flow from more efficient management of billing and revenue management, reduction in both transmission and distribution (T&D) losses, higher customer satisfaction, reductions in peak load and energy consumption, improved load forecasting, increased capability to integrate renewable

[45] Navigant Research

[46] Source: input provided by Japan to the CSTD secretariat.

[47] Adapted from http://www.powergridindia.com/_layouts/PowerGrid/User/ContentPage.aspx?PId=196&LangID=english

resources, reduction in carbon emissions from efficient operation, lower system losses, and overall increase in energy conservation.

## Smart Water Infrastructure

There are over 783 million people with no access to clean water with over 60% in sub-Saharan Africa and South Asia; 2.5 billion with no access to adequate sanitation; and annual mortality rate of 6 to 8 million people due to water-related disasters and diseases[48]. The impact of water borne diseases is greater than the combined impact of HIV/AIDS, tuberculosis and malaria. Couple this problem with urbanization and the lack of sanitation and it leads to a major challenge and problem for cities. Cities are therefore constantly trying to solve these problems with innovative technologies and better management of water and energy. Improved metering and flow management is key to a good water distribution system. In the developing world, with huge informal settlements in slums with limited access to clean water, the primary problem is metering the water usage, leakage in aging pipe networks and providing good sanitation.

### What is Smart Water Management (SWM)

A SWM[49] system uses digital technology to help save water, reduce cost and increase reliability and transparency of water distribution. There is an overlay of a data / information network with the physical pipe network. The system typically analyzes available flow and pressure data to determine anomalies (such as leaks) in real-time to better manage water flows.

A fully integrated smart water network enables the following:

- Continuous monitoring of the water utilities and remotely diagnosing problems
- Controlling the water distribution networks and optimizing them based on data-driven insights
- Providing information to consumers and provide tools for them to make informed choices
- Complying with the water policy requirements and be transparent with the regulatory authorities.

### Smart Water Meters in Mumbai[50]

Mumbai, as part of improving the water supply system installed smart water meters that can be controlled remotely. Before the installation of these meters, 50 percent of Mumbai's potable water was lost in contrast to the global average of 34 percent. It is estimated that with the installation of smart meters in Mumbai, water leakage went down by 50 percent amounting to 700 million liters (150 million gallons) a day, which was caused by broken pipes.

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[48] ITU Technical Report *"An overview of smart sustainable cities and the role of information and communication technologies"* http://www.itu.int/en/ITU-T/focusgroups/ssc/Pages/default.aspx

[49] http://bluetechblog.com/2010/06/02/it%e2%80%99s-time-for-the-smart-water-grid/

[50] http://www.bloomberg.com/news/articles/2013-03-15/water-losses-in-india-cut-in-half-by-smart-meters-itron

## Smart Water Platform – Dubuque, Iowa, USA[51]

Real-time platform monitors water consumption every 15 minutes and securely transmits anonymous data to the cloud, where it was analyzed with weather and other data. The system quickly and automatically notifies households of potential leaks and anomalies and water usage information expressed in dollar, gallon and carbon savings to improve water conservation. The information collected generates insight into water consumption trends for citizens, city policy makers and the city water department, to be used for short-term decisions and longer-term planning. Benefits generated included decreased water utilization by 6.6 percent during pilot and anticipated annual savings over 23,000 households of 64.9 million gallons, as well as increased water leak detection of 8 percent compared to 0.98 percent citywide, a 716 percent increase.

### Benefits of Smart Water Management

A smart water management system can reduce maintenance costs, save water, improve water security, reduce leaks, improve water quality metrics and provide better visibility into the water distribution network to the water utility. End customers can be provided real time information on the water situation and relevant information to conserve water, leading to lower water bills.

## Smart Waste Management

Waste generation is increasing at a rate faster than that of urbanization according to a study by the World Bank[52]. Cities are finding it difficult to source, segregate and use different kinds of waste which can potentially be brought back to the consumer life cycle. It is estimated that approximately 3 billion urban residents generated over 1.4 billion tons of waste in 2012 alone. This is expected to almost double to 2.4 billion tons by 2025 for an urban populace of 4.3 billion.

Efficient management of waste helps to improve the quality of life of city residents since it not only helps improve the environment life, leads to less health risks but can also potentially have a positive economic impact on the city through recycling, reuse and intelligent disposal. Waste management typically includes monitoring, collection, transport, processing, recycling and disposal.

### What is Smart Waste Management

Smart waste management systems are designed to address some of these challenges. Such systems reduce wastage at the source, categorize the type of waste at the source and develop methods for proper usage of waste. Smart waste management systems can be used for converting waste into a resource and creating closed loop economies.

One of the primary inefficiencies of waste management is the inability to predict when trash is to be picked up – often trucks are sent out to collect waste but the bins are not full – meaning less truck rolls are needed or at lower frequencies and at other times, the bins are

[51] http://www.cityofdubuque.org/DocumentCenter/Home/View/3116
[52] What a Waste: A Global Review of Solid Waste Management, World Bank, 2012.

overflowing, requiring more truck rolls at a higher frequency. More truck rolls means more time and fuel, thereby more cost. Sensors, connectivity and the Internet of Things (IoT) offer ways to mitigate these additional costs.

Smart waste management systems[53] will enable the monitoring of the movement of different kinds of waste. This technology can then be leveraged to better understand and manage the flow of the waste from source to disposal, as shown by the case studies discussed below.

## Smart Waste Management

**Santander, Spain**

Santander, a smart city in Spain has implemented a smart waste system[54] in order to improve the efficiency of waste collection services. Sensors collect real-time data on rubbish and recycling bin levels. The waste pickup teams try to optimize collection intervals and routes. This information is then sent back to the city control. GPS and related software located on the garbage trucks rubbish estimate the most efficient routes for the trucks to take. It reduces vehicle emissions and running costs by eliminating truck rolls to waste bins that are essentially empty and also reduce the number of cases of overflowing bins. The vehicles are also fitted with environmental sensors to measure carbon monoxide and nitrogen dioxide emissions, which will be used to dictate the city's green policies.

**Sharjah, UAE**

Sharjah in the UAE has Smart Bins[55] waste containers equipped with intelligent sensors that can measure how full they are in real-time, which can ensure that they are collected only when full, and thus help curb unnecessary clean-up and collection costs by at least 20%. The Smart Bins work with the use of small, battery-powered wireless sensors that are firmly attached and hidden under the container lids. They measure the inside of the container and that data is then sent across the cellular network to a cloud server for analysis and display. The installed sensors also provide temperature information (in the event a fire breaks out) and also work to track the bins' movements if they flip over or change positions.

### Benefits of Smart Waste Management

The primary benefits of smart waste management lie in improving the efficiency of waste collection, pickup, separation, reuse and recycle. Waste disposal can be monitored to ensure it is being done in an environmentally friendly way, waste streams can be assessed and the appropriate recycling and disposal solutions implemented. Waste collection can be streamlined across the city reducing truck rolls. The overall efficiency and performance of waste collection can be continuously monitored. As the transport of waste from collection points to disposal / recycle sites is optimized, this leads to less carbon emission and less transport loads on the city streets and roads.

[53] http://www.thecitiesoftomorrow.com/solutions/waste/challenges/circular-economies-sustainable-cities
[54] NEC and ASCAN to launch pioneering smart waste collection service in Santander, http://www.nec.com/en/press/201410/global_20141007_03.html
[55] http://www.khaleejtimes.com/article/20140630/ARTICLE/306309881/1002

## Smart Healthcare

Smart healthcare management converts the health related data into clinical and business insights, which include remote diagnoses, remote treatment, digital health records, home health services and remote patient monitoring systems.

### What is Smart Healthcare

'Smart Healthcare' refers to the provision of healthcare using intelligent and networked technologies which help monitor the health conditions of citizens. It is enabling a shift in focus to prevention instead of cure - with a broader view of overall care, healthy living and wellness management. It is applicable for both in/out patient environments ensuring the availability of appropriate health care and resources at the right time. Smart healthcare systems are being used in both developed and developing nations.

A few examples of Smart Healthcare are:

- Enablement of patient empowerment - sensors, devices and smartphone apps help enable patients to collect data that can be used to monitor and support therapies
- Remote collection of patient health vitals data for diagnostic purposes
- Use of mobile platforms to display the electrical signals produced by heart which are measured by a sensor connected to the mobile.
- Converting the smartphone to a patient specific device which measures, displays and communicates the data generated from the sensors.
- Use of sensors to determine 'blood glucose levels' which can then be seen on mobile.
- Automated alerts to patients for medication and health checkups
- Setting up notifications, alerts and workflows for pro-active next steps

### Smart Healthcare Systems [56] [57]

In Singapore, 'Smart Health-Assist' is being piloted. A patient's living environment is monitored using sensors and regularly transmitted to medical professionals accurately. These sensors could monitor vitals such as heart rate, blood pressure, body mass content, blood oxygen level and blood glucose levels. Intelligent sensors in the pills or pillboxes remind patients to take medicines on time. All this data is collected and transmitted to the physicians or healthcare providers in real-time providing an up-to-date progress on treatment and state of health.

MedicMobile[58] is a company which provides smartphone and other mobile devices in conjunction with the internet to help health workers in developing countries have a greater outreach across the following four dimensions: (1) tracking spread of disease, (2) immunizations, (3) pregnancies and (4) inventory / stock of medical supplies and drugs.

[56] http://www.mci.gov.sg/~/media/data/mci/docs/imm%202025/infocomm%20media%202025%20full%20report.pdf
[57] www.georgeinstitute.org/sites/default/.../smart-health-india-brochure.pdf
[58] www.medicmobile.org

Almost 8,000 community healthworkers are using these tools in over 21 countries across Asia, Africa and Latin America. As an example, in Namitete, Malawi, tuberculosis, HIV/AIDS and malaria are common and detecting, reporting and treating these is a challenge considering the remoteness of the region. Further, the population of over 250,000 is only served by a single hospital. Medic Mobile is being used very successfully to report symptoms to the nearest clinic, receive treatment advice, get emergency referrals, and provide information about the prevalence of the disease burden in the village or community. Running out of essential medicines (stockout) can have life-threatening consequences. In Malawi, only nine percent of local health facilities had a full complement of essential drugs, including antibiotics and vaccines. Medic Mobile is helping keep track of these inventories in real time, managing stockout situations and develop a better drug distribution system[59].

In India, 'SMART Health India', is a unique program which caters to the population of villages in India, providing low-cost yet high quality healthcare by enabling community health workers and doctors to provide healthcare to common chronic diseases. This utilizes the mobile health technologies and guides the Systematic Medical Appraisal Referral and Treatment (SMART) of individual members of the community.

### Benefits of Smart Healthcare

Smart Healthcare has many benefits for both healthcare providers as well as end consumers. Healthcare organizations and governments can improve general health of the population but also increase the number of people who are being provided healthcare. There is broader reach. Patients who may never have had access to a physician or medical diagnostics will now be able to engage with the medical establishment for better well-being and health. Preventive care is more viable which lowers overall costs since after costs to treat a condition are much more expensive than preventing the condition in the first place. Customized healthcare plans can be provided and progress can be monitored with smart healthcare.

## *Smart Digital Infrastructure*

### Role of ICT in a Smart City

A smart city makes optimal use of all the interconnected information available to better understand and control its operations and optimize the use of limited resources[60]. ICTs play an important role in this process, since they enable a digital platform from which an information and knowledge network can be created[61]. Such a platform not only facilitates the aggregation of city information for data analysis, but it also can be used to better understand how the city is functioning. City administrators and stakeholders can use this

[59] http://medicmobile.org/assets/downloads/Medic_Mobile_annual_report_2013_post.pdf

[60] http://www-03.ibm.com/press/us/en/pressrelease/27791.wss

[61] https://itu4u.wordpress.com/category/contributors/maria-paula-sartori/

information to create new policies and regulations to improve the quality of life for the citizens.

One of the key value propositions of ICT in a smart city is the ability to capture and share information in a timely manner. Even if a city is well equipped to respond to a given situation, if the information is not provided and shared quickly specific problems, such as traffic congestion or utility outrages, may not be solved rapidly. If the information is provided in real-time and accurately, cities can potentially take action before the problem begins to escalate. A Smart City, therefore, can be understood a "predictive city" [62] where specific events and incidents can be predicted resulting in an improved quality of life, and enabling citizens to be more informed about the situation, so they can make an educated decision as to the next course of action. Figure 3.1 illustrates the multi-faceted role for ICT in the development of smart cities.

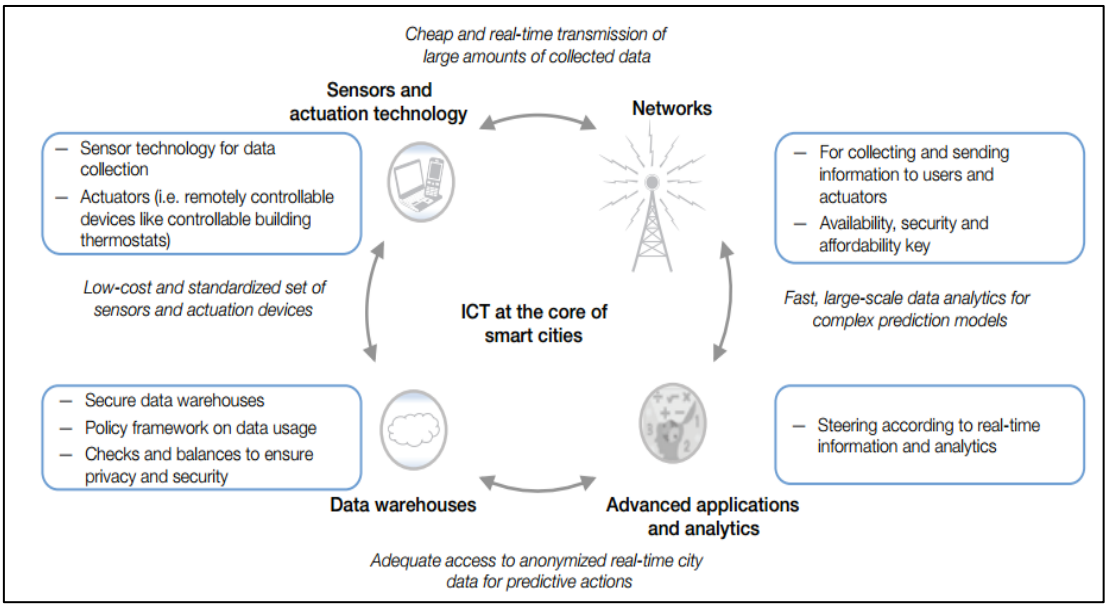


**Figure 3.1: Multiple facets of ICT Infrastructure in a Smart City [63]**

One way to look at the digital infrastructure is in the form of different digital supporting layers as described below.

**Urban layer**: This is where the physical and digital infrastructures meet. Examples include: Smart Buildings, Smart Grid (Utilities – Water, Electricity, Gas), Smart Waste and Smart Mobility.

**Sensor layer**: Smart devices which are measuring and monitoring different parameters fall into this category. The goal being to be able to sense multiple parameters such as Humidity, Water, Energy, Air Quality, Temperature, Solar Flux, Occupancy, and State of equipment.

**Connectivity layer:** This layer deals with the ability to transport the data and information from the sensor level to data aggregators and storage for further analysis. A smart city will

[62] Personal Communications, Rob van den Dam, IBM Institute for Business Value, ITU Telecom World 2013
[63] Expanding Participation and Boosting Growth: The Infrastructure Needs of the Digital Economy, World Economic Forum Report, March 2015.

have the full range from low bandwidth sensor mesh networks all the way to high bandwidth wide area networks and everything in between.

**Data Analytics layer:** Data Analytics solutions are of three principal types: (1) Descriptive, which uses business intelligence and data mining to ask: "What has happened?" (2) Predictive, which uses statistical models and forecasts to ask: "What could happen?" and (3) Prescriptive (includes Cognitive), which uses optimization and simulation to ask: "What should we do?"

**Automation layer**: This is the digital enabling interface layer which enables automation and scalability for a large number of devices across multiple domains and verticals. It enables the city as well and its ecosystem partners to develop smart services and initiatives.

To develop these ICT & Data infrastructure in a city with the aim of being 'Smart', there are three essential tasks to be implemented. They are (1) Deployment of Broadband Networks (including Mobile broadband), (2) Use of Smart Sensors and Devices (Internet of Things), (3) Use of Big Data for optimization of city operations.

**Broadband Connectivity:** Implementing smart city technologies often requires a robust, reliable, affordable broadband network. This underlines the need to continue to focus on bridging the digital divides, in order to harness the benefits of smart applications. Mobile broadband is also playing a major role especially in developing countries, where there is a lack of fixed infrastructure. The smart phone revolution with "apps" has already taken root and there are many apps related to smart cities including traffic, health, energy and water. For example, some of the initial steps undertaken as part of the Wuxi Smart City project in China were establishing nearly 40,000 free WIFI access points all over the city, equipping over 3000 buses in the city with free WIFI; and realizing a high-quality full coverage of the 4G network all over the city[64].

**The Internet of Things:** Internet of Things (IoT) as defined by Ashton[65] is 'where all objects and equipment in this world will be connected by Internet. And the data generated by all these things will let the computers know so many things about people'. It is projected that by 2020, there will be 30 billion things with unique IP address[66]. IoT can be considered as a global infrastructure which connects ICT devices all over world. IoT is not just about connecting humans with things, but things can also interact with one another, for example a leak in the pipe can be communicated to the water meter. In a study by MIT[67], researchers were able to follow close to 3000 items of trash using smart tags and found that the some of this trash travels from its source location in the United States for more than 3 months before they reach a waste disposal unit. Based on such discoveries, efficiency of systems in a city can be improved.

**Big Data:** IoT with all the connected sensors and devices will result in enormous amounts of data. Big Data refers to extremely large data sets collected in real time. Cities will be able to

[64] This is based on the contribution provided by China to the CSTD secretariat.

[65] http://www.rfidjournal.com/articles/view?4986

[66] https://www.abiresearch.com/research/service/internet-of-everything/

[67] http://senseable.mit.edu/trashtrack/

use data to help improve the maintenance and sustenance of the urban environment. The data may be collected not only by the government and public agencies, but also private entities and other stakeholders such as citizens. Information collected by the city from the various domains and verticals, when studied and analyzed in aggregate can provide insights to city officials hitherto not known. Once sensors and devices collect data, the next step is to process and analyse the data so as to better understand the current state and then use that information to predict future states. This notion of data is now becoming so valuable that some refer to it as a utility, in a similar context as other essentials in a city such as electricity, water and transport.

## *The Need for an Integrated Approach for Smart Infrastructure*

A city has many physical functions which are manifested in the different forms of infrastructure – water, waste, buildings and so on. Each infrastructure element is a system and is made up of sub-systems, components and devices which behave like a communications data network by communicating between themselves. The city is made up of these different infrastructure verticals forming a "system of systems". There is a clear nexus between these different systems, for example a building uses energy, water and generates waste and if the different individual smart systems come together, the building becomes "smart". However, in many cases these city infrastructure elements typically tend to operate in silos. Smart Cities needs an integrated treatment of all smart infrastructures. Smarter ways to develop cities will emerge when city governments and citizens start thinking and planning for infrastructure components in a holistic manner.

ICT can facilitate this process. One commonly used approach is to aggregate the different data streams in the city under a single roof. This enables the collection and integration of data from different individual domain systems across functions – creating system wide efficiencies and allowing for new insights. These operations centers act as the "nerve center" for the different smart initiatives by providing the technology foundation needed for an integrated view (more of this is discussed in the next chapter including case study from Centro de Operações Preifetura do Rio de Janeiro (COR), Brazil).

An example of such an integrated approach is explained in the case study below through the GIFT City in India, where multiple utilities are provided through a single tunnel, resulting in huge cost savings and better management of urban space. Hence, co-locating different infrastructure components is one way to achieve integrated development of a smart city. Another example of this colocation is when infrastructure components perform multiple roles which cut across conventional infrastructural domains. For instance, in some smart city projects, the smart street lighting systems also act as environmental pollution monitors, constantly recording and relaying the environmental performance data as well as security cameras ensuring safety.

Integrating the data collected through one infrastructure component and using the same in an effective manner in the operation or maintenance of another infrastructure provides another key method of integrating infrastructure operations in smart cities. This is exemplified in the case study from Eindhoven, Netherlands in the box below. The data generated form the smart traffic management system was used to predict and identify road maintenance works. Finding such 'smarter' integrated approaches to infrastructure

development should be a key component of how we conceptualize infrastructure for smart cities.

But the integrated approach towards smart infrastructure must extend beyond these measures and should percolate the way we think about infrastructure. Smart infrastructure should be seen as a system that integrates the core domains of sustainability (namely, social, economic and environmental) in the urban context. For example, by focusing on cutting-edge new renewable energy systems through smart energy infrastructure, cities are able to generate clean energy, assure cost-effectiveness and simultaneously realize technology leapfrogging.

**Co-locating smart infrastructure**

**GIFT City, India**[68]

The Gujarat International Finance Tec-City (GIFT City) is a good example of an integrated smart city – incorporating the different functions of a city – Water, Waste, Air-Conditioning, Energy / Utilities, Transport and an ICT backbone to help manage these components. It has built an infrastructure sufficient for 62 million square feet of real estate on an 886 acre landbank. Power and other utilities including the chilled water for the district cooling system (DCS) are all placed all in a common tunnel[69] accessible to material handling and maintenance vehicles. The tunnel has a cross section of 7.6-by-6.2 meters and is 15 km in length. The tunnel will carry 50 million liters per day of treated water, 200,000 tons of cooling water, 750 megawatts of power supply, and 280 million tons of solid waste. This integrated tunnel approach saved 1,500 man-hours and INR 900 million in design costs alone. Such a holistic and integrated approach of infrastructure applications is creating a new paradigm and benchmark in city development.

**Integrating Traffic Management Solutions with Infrastructure Maintenance**

**Eindhoven, Netherlands**

Eindhoven piloted a traffic management solution that collects and merges braking, acceleration and location data from in-vehicle sensors with traffic data gathered from the road. The solution also alerts drivers of traffic incidents through smartphones and built-in navigation devices, allowing them to find alternate routes. Using cloud technology and analytics, the disparate data from thousands of sensors enabled officials to respond to dangerous road conditions, accidents or growing traffic density in near real-time[70]. The data generated from the traffic management system was then used also to predict road maintenance works in advance. This proved to be an effective application of collected data generated by one smart infrastructure system for the improved performance of another infrastructure component.

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[68] Communications with Mr. Lovleen Garg, Director of Environmental Systems, GIFT City

[69] http://www.bentley.com/en-GB/Engineering+Architecture+Construction+Software+Resources/User+Stories/Be+Inspired+Project+Portfolios/India/Utility+Tunnel+Gujarat.htm

[70] http://www.ibm.com/smarterplanet/us/en/traffic_congestion/article/traffic-management-and-prediction.html

# 4. Applying Smart City Concepts: Some Key Challenges[71] and STI driven Solutions

## Introduction

The previous chapter describes some key smart infrastructure components. In applying these smart infrastructure concepts, especially in developing countries, city governments are faced with numerous challenges. This chapter discusses the key themes which represent these challenges include: **(1) Adaptation of Smart City Concepts to Local conditions (2) Skills Gap (3) Financial Constraints (4) Applying Suitable Governance Models and (5) Making Smart City Applications Inclusive.** The Science, Technology and Innovation (STI) community plays a key role in overcoming these challenges. Therefore, for each of the challenges, this chapter outlines some policy instruments driven by STI that could help to address these challenges, along with case-study examples of success stories.

## Challenge 1: The Need for Local Adaptation of Smart Infrastructure

One cannot just "transplant" a given smart city solution from one geographic region to another (whether developed to developing or within the developing world). What works in Stockholm is unlikely to work in Mumbai and what works in Beijing may or may not work in Nairobi. The context, culture, and economics all play a big role. For example, since traffic congestion is a sticking point for many cities, elevated highways or transport corridors (areas with interconnected highways, railroads or canals) are commonly being built to help alleviate the problem. This is common in many developed cities' economies such as Singapore, Europe and North America. It is also quite prevalent in developing countries such as India, China, and Thailand. However, these have the potential to create a greater flood risk in the city as exemplified in Vietnam's Quy Nhon city, when adjacent areas faced severe inundation in the aftermath of Typhoon Mirinae in 2009[72]. There are many such examples where smart technology adoption without considerable analysis and forethought has resulted in wastage of resources and project failures.

Cities should consider urban problems in a holistic manner before selecting appropriate smart technology solutions. One example in this regard is from the case of integrated transport system (ITS) described in the previous chapter. The conventional ITS approach involving a huge network of sensors and aggregation of data may be too expensive and unsuitable for developing country needs. A more locally adapted and simpler version of ITS will leverage more of the ubiquitous mobile phone data. This could be more suited for the

[71] These challenges incorporate some of the key concerns shared by member states in their inputs to the CSTD secretariat.

[72] http://www.scidev.net/global/cities/opinion/cities-techno-fixes-resilience.html

developing country contexts[73]. The local STI community plays a key role in this process. In the section that follows, some key policy instruments in this regard are highlighted.

**Policy Instruments to promote local adaptation of Smart Infrastructure**

- **Harnessing the local innovation system: an overarching solution**

Harnessing the local innovation system, which comprises of, inter alia, local universities, research centers and entrepreneurs is the key to address this challenge of local adaptation. Smart city projects have the potential to trigger innovations that improves the citizen's lives and well-being. The case studies below from Vietnam and South Africa give some examples of such successful adaptations conducted by the local innovation system on smart city concepts to generate useful products responding to local needs.

## Smart Salinity Monitoring System, Vietnam

In Can Tho, Vietnam, the Institute for Social and Environmental Transition[74] (ISET), the Center for natural resources and environment monitoring (CENRM) of Can Tho City, and the Can Tho climate change coordination office, among other institutions, developed and installed monitoring stations that collect real-time data on salinity levels in surface water. The stations transmit data every 15 minutes to a government-monitored server that, in turn, uses SMS messages to warn community members of unsafe levels. Preventing salinity itself, and so removing the hazard, is impossible. But modern technology, combined with government commitment to promoting awareness, is helping residents adapt their behaviour and avoid the health impacts of consuming saline water. This project made good use of the synergies between a local research organization, its international counterpart, and local city government in devising a locally relevant smart adaption.

## Smart Shacks, South Africa

There is an initiative to tackle inadequate slum housing in Stellenbosch, South Africa. The Stellenbosch Innovation District (SID), in collaboration with the local university, has built "smart shacks." The project is using alternative energy and mobile technology to address the needs of the people living in the shacks. The "smart shacks" are made from easy to assemble fireproof material that produces off-grid energy through roof-mounted solar panels. One can also buy electricity through mobile phones. The do-it-yourself shacks services range from $500 to $1000 depending on how much is required. Batteries are charged in the day and used at night inside the shack to charge cellphones. According to program manager, the town is also trialing electronic hubs with downloadable education resources and large-scale solar farms[75].

[73] More details on this could be found here: http://www.worldbank.org/en/news/feature/2015/05/14/information-and-communication-technologies-facilitate-the-evolution-of-transport-systems

[74] http://www.scidev.net/global/environment/water/

[75] http://www.cipe.org/blog/2014/04/11/a-different-kind-of-smart-city/#.VnF9cCuBzW4

Cities need to think of how best to use the existing innovation infrastructure such as science parks, technology incubators and innovation hubs towards developing new smart city ideas and creating adaptation of smart city concepts. Science parks began to emerge since the 1970s and innovation hubs became a fad since-2000 mainly built around ICT applications. They all provide infrastructure, skilled personnel and a spirit of entrepreneurship, all key ingredients needed for triggering innovation. City governments should tap into these existing resources and collaborate with these institutions to tailor their R&D efforts towards locally relevant smart city applications. Currently there are discussions underway on how to transform science parks and industrial parks to cater to the needs of smart cities, sometimes by integrating science parks within smart city or smart regions[76]. The case study from Gothenburg shows that resources like science parks can be effectively harnessed towards smart city development.

## Science Parks trigger urban innovation, Gothenburg, Germany

Johanneberg Science Park and Lindholmen Science Park in Gothenburg are providing platforms for collaboration between the business sector, academia and the local community regarding urban development and mobility. Lindholmen Science Park focuses on Mobile internet, intelligent vehicles and transport systems, modern media and design and Johanneberg Science Park specializes in urban development, energy, material- & nanotechnology[77]. The collaboration between these two science parks and several other stakeholders, has resulted in the 'ElectriCity' project which led to the first modern electric bus route of Gothenburg. In addition to the actual buses, ElectriCity develops and tests new bus stop systems, transport management systems, safety concepts and energy supply systems[78].

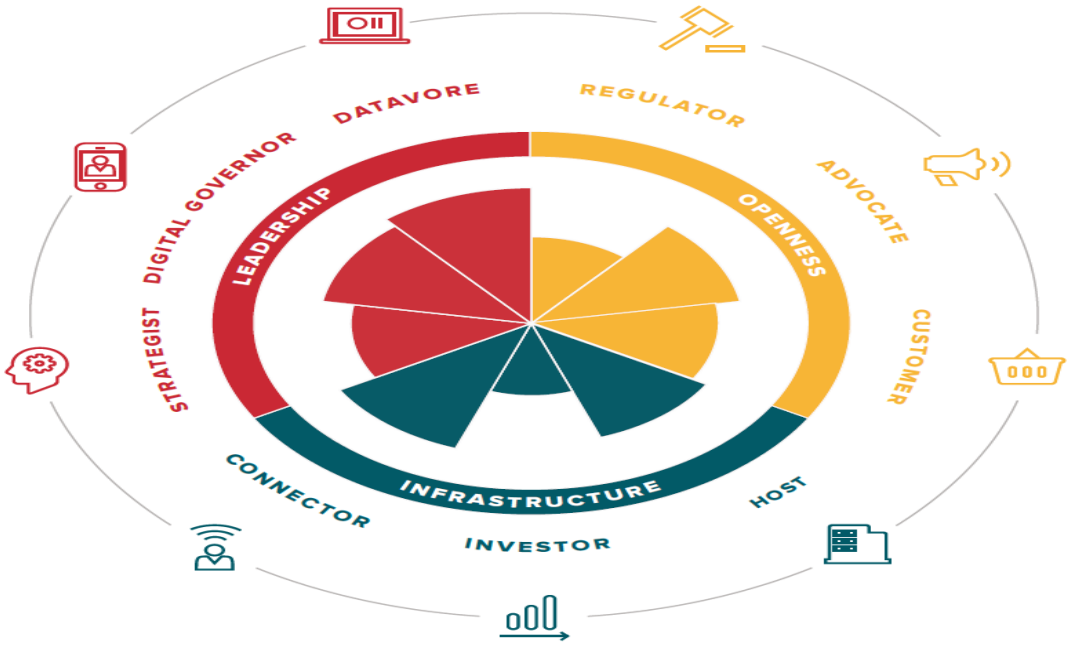
City governments can play a variety of roles in order for the local innovation system to engage in constant adaptation of smart city concepts. For instance, in their role as regulator, City governments need to review their regulatory frameworks to ensure that they are conducive for smart city innovations. In its role as an investor, City governments need to find out which skill development program or infrastructure component it should invest in order to drive innovations. As a strategist, the city governments can develop the required 'smart city vision' and 'technology plans' (as discussed earlier) to provide overall guidance to its innovation system. City governments can effectively use its role as a consumer to support the small scale smart city innovations by giving theme preference and access to public procurement contracts. The CITIE framework sets out nine such key roles that a city can play to support innovation and entrepreneurship[79], and this is given in the figures below.

[76] http://forges.forumpa.it/assets/Speeches/8095/sc_02_moreira_da_costa.pdf

[77] http://international.goteborg.se/smart-cities-sustainable-solutions/two-science-parks-working-urban-development-and-mobility

[78] http://www.johannebergsciencepark.com/en/press/johanneberg-science-park-promotes-electric-bus-route-surprise-concerts-given-top-artists

[79] City Initiatives for Technology, Innovation and Entrepreneurship (CITIE) supports city leaders to develop policy to catalyse innovation and entrepreneurship. CITIE is the product of a partnership between Nesta,




**OPENNESS**

*How open is the city to new ideas and businesses?*

**REGULATOR**
*How does the city regulate business models in a way that allows for disruptive entry?*

**ADVOCATE**
*How does the city promote itself as an innovative hub and its new business community to the outside world?*

**CUSTOMER**
*Is procurement accessible to small businesses, and does it actively seek out innovation?*

**INFRASTRUCTURE**

*How does the city optimise its infrastructure for high-growth new businesses?*

**HOST**
*How does the city use space to create opportunities for high-growth companies?*

**INVESTOR**
*How does the city invest in the skills and businesses required for innovation?*

**CONNECTOR**
*How does the city facilitate physical and digital connectivity?*

**LEADERSHIP**

*How does the city build innovation into its own activities?*

**STRATEGIST**
*Has the city set a clear direction and built the internal capability required to support innovation?*

**DIGITAL GOVERNOR**
*How does the city use digital channels to foster high-quality, low-friction engagement with citizens?*

**DATAVORE**
*How does the city use data to optimise services and provide the raw material for innovation?*

**Figure 4.1: The CITIE Framework**

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Accenture and the Future Cities Catapult, more details on the framework is available here: http://citie.org/assets/uploads/2015/04/CITIE_Report_2015.pdf

- **Open data, open science models complemented by Civic Hacking**

Globally open data initiatives by governments and private sector have been a great impetus for smart city applications. The success story from Singapore in using the potential of open data in promoting locally relevant smart applications is discussed in the box below. Along similar lines, the London DataStore provides an open data platform with over 500 datasets. This platform enables citizens to develop smart solutions to many problems of the city. In order to make best use of these open data initiatives, as well as to promote further innovation, civic hacking events have been organized by various City governments as well as tech firms. For example, weekly hack nights are organized in the City of Chicago to use open data available for developing convenient apps[80]. These civic hacking events, normally organized around a theme reflecting local needs, bring together coders, programmers, and bloggers to come together to develop innovative solutions to common challenges under the theme. Some of these ideas are later funded by city governments or awards are given for best ideas developed through such civic hacking events. On similar lines, Cities should encourage open science and open innovation models that rely less on proprietary technology models. Such open science and innovation efforts can foster research collaborations and create opportunities for innovation. A good example in this regard is the 'Bristol is Open' initiative which is a collaborative project between the Bristol City council and the University of Bristol[81]. The initiative has made 'openness' a core value guiding the development of the city and aims to create an open programmable city region that gives citizens more ways to participate in and contribute to the way their city works.

## Case study: Open Data and Civic Hacking

Singapore is striving towards becoming the world's first Smart Nation. One of the driving features in this journey is the promotion of open data. Data.gov.sg, Singapore's open data portal, was first launched in 2011 as the government's one-stop portal to its publicly-available datasets from 70 public agencies. The aims of this portal include providing a one-stop access to the government's publicly-available data, communicating government data and analysis through visualizations and articles, creating value by catalyzing application development, and facilitating analysis and research. To date, more than 100 apps have been created using the government's open data[82]. For example, private sector app developers have made use of data from the Land Transport Authority to create apps to inform motorists about car park availability and Electronic Road Pricing, while community groups have also come up with apps for topics ranging from clean public toilets to street cats[83]. The government complements its open data efforts through hackathons, civic hacks and competitions such as Apps4Sg to promote usage of open data to develop smart apps.

[80] http://chihacknight.org/

[81] http://www.bristolisopen.com/about/

[82] www.data.gov.sg

[83] https://www.ida.gov.sg/blog/insg/special-reports/singapore-makes-strides-in-open-data/

- **Establish urban innovation units and living labs**

Smart city applications might benefit from new institutions that would focus on local adaptation of smart city concepts. Urban innovation centres focused on smart city concepts and finding urban solutions suited for local needs have been found to be useful in this regard. As discussed in the case studies from Boston and Nairobi, these innovation centers and labs could provide convenient platforms to demonstrate new ideas and concepts. Some of these innovation units are placed within close proximity of the City administration, such as the Mayor's office, helping them to directly help and be involved in city administration.

## Case Study: Innovation Units

**Boston's Mayor's Office of New Urban Mechanics (MONUM)**

Boston's Mayor's Office of New Urban Mechanics (MONUM) is a city agency that was formed in 2010. It offers a platform to conduct pilot experiments that offer the potential to significantly improve the quality of City services. Boston's MONUM focuses on four major issue areas: Education, Engagement, the Streetscape, and Economic Development. To design, conduct and evaluate pilot projects in these areas, MONUM builds partnerships between constituents, academics, entrepreneurs, non-profits and City staff. Working with the City's Transportation Department, the lab is already piloting a series of programs to make it easier to find and pay for parking in Boston. This includes new mobile apps to see available parking and to pay parking tickets and several pilots towards better manage traffic flow[84]. Similar offices of new urban mechanics have been formed in Philadelphia and in Utah Valley.

**IBM Research -Africa, Nairobi**

IBM Research - Africa is IBM's 12th global laboratory and the first commercial technology research facility on the continent conducting both applied and far-reaching exploratory research. IBM Research's presence in Kenya has been encouraging and strengthening an innovative culture, and forging partnerships with businesses, research organizations and universities across Africa and around the world. The lab's research agenda includes the development of cognitive computing technologies that can be applied to address issues in public health, education and agriculture. A number of projects are already underway in the areas of energy, water, transportation, agriculture, healthcare, financial inclusion, and human mobility and public safety. For example, in association with Kenyan internet service provider Access Kenya, the lab has developed a pilot solution to enable commuters in Nairobi to use their mobile phones to get advice on driving routes through the city depending on estimates of traffic congestion. Using deep analytics and specialized algorithms to translate visual data received from CCTV cameras positioned around Nairobi, citizens can use their mobile phones to receive updates on road conditions and suggestions for alternative routes. Dubbed Twende Twende – meaning 'Let's Go' in Swahili - the system works on traditional phones via SMS-based query system and on smart phones via an app

[84] http://newurbanmechanics.org/boston/

through which users can view a map of the city showing route options and potential traffic hotspots[85].

Another pertinent institutional arrangement that promotes smart city innovations is that of 'living labs', which offers real-life test and experimentation environments where users and producers co-create innovations. A Living Lab typically conducts four main activities: (i) Co-Creation: co-design by users and producers (ii) Exploration: discovering emerging usages, behaviours and market opportunities (iii) Experimentation: implementing live scenarios within communities of users (iv) Evaluation: assessment of concepts, products and services according to socio-ergonomic, socio-cognitive and socio-economic criteria[86]. The case study below discusses the experience of a large scale living lab from Antwerp, Belgium. These living labs help to include users in all stages of the innovation process, thereby helping to gauge user's interactions to products at an early stage and shape urban innovation through an iterative process. Living labs research approach has been found to be extremely successful for smart city innovations, there are more than 180 active living labs across the world, and they are connected through the European Network of Living Labs (ENoLL)[87]. Living labs methodology has also been applied to developing countries, especially in Africa promoted through the Africa-EU Strategic Partnership. This existing living labs network can be used to test, incubate and promote smart city innovations.

## City of Things- Living Lab, Antwerp, Belgium

City of Things connects 200,000 urban citizens with developers and tech entrepreneurs through a massive amount of smart devices spread over the city of Antwerp. This realistic living lab environment offer tech entrepreneurs a lean and powerful gateway to real-time big data, ideal for the development, testing and optimization of products and services with a positive impact on citizen life and work. It also enables governments to take smart decisions and offer improved services for citizen mobility, safety and quality of life. The platform enables researchers to interact with target groups, track user behavior and develop products and services in a most lean and flexible way. The lab collects real-time data from connected citizens via their smartphones, iBeacon devices installed throughout the City of Antwerp, and point of sale systems in retail shops. Through this non-stop monitoring, the lab offers real-life data in real-time[88].

- **Exploiting regional innovation networks and global collaborations**

When cities by themselves lack the capacity to conduct smart city related research, make investments or conduct local adaptations, they can join hands with other cities, confronting similar developmental challenges, to ideate, finance, implement, and exploit complementary competence and share lessons learned. A glowing success story in this regard is the European Innovation Partnership on Smart Cities and Communities (EIP-SCC), which brings

[85] http://www.research.ibm.com/articles/africa.shtml

[86] http://www.openlivinglabs.eu/FAQ

[87] http://www.openlivinglabs.eu/aboutus

[88] https://www.iminds.be/en/succeed-with-digital-research/city-of-things/city-of-things-offer-details

together cities, industry and citizens to improve urban life through more sustainable, integrated solutions. By pooling resources the partnership aims to co-fund demonstration projects, to help co-ordinate existing city initiatives and projects, and to overcome bottlenecks that impede the transition process. This initiative has already succeeded in obtaining over 370 commitments, from over 3,000 partners from over 30 countries[89]. Similar collaborative initiatives such as the International Summit for Smart Cities in North Africa[90] and the Asia Africa Smart City Summit[91] (which led to the Bandung declaration on Smart Cities), are nurturing partnerships across smart cites.

## *Challenge 2: Skills Gap*

For a smart city to be successful in its endeavors, human resource skills need to be available to ensure all the different facets of smart cities are being addressed adequately and efficiently. One might argue that all of these skills are needed even today and that skill deficits are evident as part of running of a normal city. However, these skill deficits could become amplified in the smart city context, as one needs to add the digital or data layer to all operations, deal with more technology vendors and integrate functioning of different departments. Developing countries are facing dearth of skills in this regard, especially due to the complicated structure and sophistication of some smart infrastructure projects. These skills can be classified into five broad categories.

- **Smart City Planning and Design Skills:** As discussed in the previous section, the method of planning for smart cities could itself be different from current approaches, as cities should ideally use new platforms to gather opinions of different stakeholders and sufficiently integrate them into plans. Cities are also using new insights of information generated from satellites, 3-D models, human behavioral sciences and big data in their plans. Picking the right technology and smart application for a city and developing a technology plan all requires at least basic level knowledge of these technologies and their potential impacts.
- **Smart City Implementation Skills:** Implementing smart city projects would require new forms of partnerships and new financing and business models. In addition, this would require new skills in engineering and cross-disciplinary specializations (for example, merging of human behavioral science and city planning).
- **Smart City Management Skills**: There is a need for adequate administrative and technical professionals to manage these smart cities and infrastructure. Municipal and city governments should optimize use of technology to maintain smart cities. In parallel, the private sector will need play a role as they will be involved in not only the physical development and creation of the smart city infrastructure but also as part of the "operational" and maintenance aspects of a smart city, in some cases.

[89] http://ec.europa.eu/eip/smartcities/

[90] http://iscsummit.com/

[91] http://www.aacc2015.id/?p=detberita&id=353

Managing this diverse set of stakeholder calls for new management skills. In addition, smart city management calls for skills related to cyber-security and risk management.

- **Digital Citizenship Skills:** Citizens should be aware of new features of smart city infrastructures. It is only when they get used to a new way of constantly interacting and engaging with the city that the smart infrastructures will attain its full potential. For this basic digital literacy a whole new set of digital citizenship skills would be required.
- **Need for data literacy:** Also in the process of running a smart city a lot of data will be shared, created and acquired. Skilled data analysts are required to correlate and analyze the data. Without the ability to interpret data and understand how and why it is collected, there is a serious risk that it will be misinterpreted or ignored. This data literacy is not just a pre-requirement of smart city decision makers, but all citizens should have basic data literacy to make inferences from the data generated from a diverse set of smart utilities that they use for making intelligent decisions.

Investing in smart people, not just smart technology is essential. Currently there is very little research, especially in developing country contexts, which quantify this skill deficit. Hence, to begin with, cities should conduct their own analysis of skill deficits and interventions to mitigate these skill gaps.

**Policy Instruments for Addressing Skills Gap**

The STI community plays a big role in the success of a smart city implementation especially in terms of skills building. Some policy instruments to address this challenge are listed below.

- **Accelerate STEM education programs**

A significant proportion of smart infrastructure creation and maintenance jobs would require a good foundation in STEM education. Hence, smart city applications give all the more reasons to accelerate and popularize STEM education across countries. Smart city concepts could provide exciting opportunities for students to solve their local problems and this could be used to attract more students to take up STEM education.

The case study in the box below discusses the 'Science of Smart Cities Program' and the 'Urban Data School'. Such programs can help promote the interest in STEM education, as they focus on exposing children to real life smart city applications of scientific concepts and can attract more students to STEM education at an early age.

**Science of Smart Cities (SoSC) Program[92]**

A project of NYU Polytechnic School of Engineering's Center for K12 STEM Education, the Science of Smart Cities introduces STEM concepts through hands-on activities, demonstrations and experiments to middle school students. The program connects students through teamwork and mentorship and the students learn how to build and design more livable, efficient, sustainable and resilient cities. The program, developed and taught by School of Engineering undergraduate students, consists of four curricular modules: Energy, Urban Infrastructure, Transportation and Wireless Communications. Each module is

[92] This summary is taken from : http://engineering.nyu.edu/k12stem/sosc/

designed to total about 25 hours of instruction. Through its demonstrations and projects, SoSC introduces students to new ideas in science, engineering and technology, as well as to the scientific method and research practices. The curriculum also explores urban planning, sustainability and healthy urban living. This program was piloted in New York with high school students as a summer program which now has school campuses and institutions in New York City and has recently developed a partnership abroad in Malaysia.

**Urban Data School, Milton Keynes, UK**

Data skills are crucial civil skills required for smart city. The Urban Data School is a joint initiative by MK:Smart, The Open University smart city project, Milton Keynes Council and local schools. The Urban Data School aims to bring data literacy education to primary and secondary schools. While environmental issues are taught in most schools and pupils occasionally use sensors to collect environmental data, pupils are not trained in understanding large complex data sets. The data school enables pupils to understand the importance of data by providing them with the basic tools to critically analyze data and use data to foster an understanding of sustainability and environmental issues[93]. The Urban Data School is making smart city data produced in Milton Keynes available for school education. One example is using data from smart meters to learn to analyze home energy consumption, and in the process discover how generation of energy from solar panels is affected by weather and seasonal variations.

- **Curriculum Reforms and Promoting Multi-disciplinary Learning**

There is a need for curriculum reforms from school level to higher educational institutions to integrate the special skill requirements of the smart applications. The schools and vocational educational institutions should prepare all students in 'digital citizenship' skills, which includes basic ICT usage skills. A similar change needs to take place in universities and research centres so that there are new courses offered in smart urban planning, design, and engineering programs that cater to the needs of smart infrastructure design and maintenance. Public policy schools could offer executive education courses on smart city governance oriented at city officials.

A key characteristic smart city is that it is a multi-disciplinary phenomenon[94]. Therefore, designing innovative smart infrastructure requires multi-disciplinary teams to work together. Universities and schools should encourage and provide opportunities for multi-disciplinary research. Students should be allowed to easily enroll for courses across departments, requiring a breakdown of academic silos.

We are already seeing the emergence of new departments and courses offered in many universities related to new urban science. A recent analysis reveals that since 2005, more than a dozen new labs, departments and schools have been launched with a common purpose - to pursue deeply quantitative and computational approaches to understanding the

[93] http://urbandataschool.org/

[94] http://www.stemi.education/blog/smart-city-can-we-nurture-the-future/

city. If present trends continue, by 2030, new urban science institutions could connect thousands of researchers and students and represent more than $2.5 billion in current and future investment[95].

- **MOOCS, m-learning solutions and other ICT tools**

Readily accessible Massive Open Online Courses (MOOCS) and other online training on different smart city aspects can be great resources for developing smart city skills. Currently, the Open University, Ohio State University (on Coursera), and IEEEx (on edX) offer courses on Smart City related themes. The use of global classrooms like Khan Academy can be helpful in educating more and more people in the use of basic smart city awareness courses. Gauging from the success of the available online courses on smart cities, more such customized courses are expected to be launched in the future. This can contribute significantly towards overcoming the paucity of skills.

Smart city applications involve constant interactions between the city and its citizens. Citizens need to learn to provide their feedback and responses on a regular basis so that city officials can aggregate these responses while making city plans. This requires building of a 'relationship' between citizens and government. Such relationships can be triggered from the school level if the schools develop a relationship with students, for example via text messaging (to deliver quizzes or providing personalized feedbacks) or other widely used ICT applications[96]. Once the students are comfortable with some m-learning tools, these tools can be used by city governments to spread awareness about smart city applications and to engage with citizens.

- **Partner with Private Technology Firms to Train Smart City Workforce**

Private sector firms are actively involved in developing smart city solutions and new innovative smart applications. These firms are the biggest suppliers of smart city infrastructure solutions and they claim a large share of revenue generated from smart city applications. Public sector can join hands with these private sector firms to provide much needed smart city skills to its workforce. The box below discusses the case of Cisco Networking Academy Program and the IBM 'Academic Initiative for Cloud' which provide training in much needed core technical skills required for smart city applications. More courses designed and conducted by technology firms could be made available to current students through existing educational infrastructures to fill specific skill gaps within cities.

## Role of Technology Firms in Training

A very successful training program that has global reach and value is the Cisco Networking Academy Program run by Cisco Systems as part of its corporate social responsibility (CSR) arm. More than 5 million students have been trained by this academy to design, build and maintain computer networks. Cisco is using this as a public-private collaboration model to

[95] See the analysis by Mr. Anthony Townsend : http://www.spatialcomplexity.info/files/2015/07/Making-Sense-of-the-New-Science-of-Cities-FINAL-2015.7.7.pdf

[96] For example, see the case study of SMS education in Pakistan discussed here : http://blogs.worldbank.org/edutech/sms-education-pakistan

train students by partnering with educational institutions, non-governmental organizations and community centers. Cisco provides the learning tools, teacher training and curriculum while the organizations or educational institutions are providing the physical space[97].

Another example is IBM's partnership with 200 universities worldwide to train next-generation of Cloud Developers. The new program will create cloud development curricula using Bluemix, IBM's platform-as-a-service, in over 200 universities, reaching more than 20,000 students in 36 countries (including from developing countries)[98]. This program will introduce students to the latest cloud technologies and solutions necessary to build the transferrable skills needed to launch their own businesses or meet the needs of industry. Cloud technologies and its applications are a key component of smart city digital infrastructure.

## *Challenge 3: Lack of Finance and well developed Business Models*

Smart city applications tend to be expensive and sometimes require huge upfront investments. Clearly, the government cannot single-handedly fund the entire infrastructural investments needed for a smart city. There will be a need for considerable private investments which in turn require creative financing and business models to reduce the investment risk. Policies, taxation, and regulatory certainty remain key for investors. Governments will need to address such issues in order to encourage the private sector to grow and innovate in new, thoughtful, and increasingly strategic ways to invest in smart city projects.

Strategically funding smart city infrastructure and technology investments is critical to the realization of smarter cities. Smart city projects are often complex undertakings, involving long-time horizons, multiple stakeholders and risk[99]. Some associated challenges confronted are conducting a pragmatic cost–benefit analysis of the smart city-model as well as selecting the appropriate financial mechanism/tool at the right time, based on the unique risk and rewards of a given particular environment[100]. Many smart city technologies are yet to be fully commercialized and therefore finding financial institutions willing to invest in these technologies may be difficult. Many traditional sources of financing would shy away from such smart city projects, hence there is a need to explore innovative sources of financing business models and partnerships and be able to define the exact cost recovery mechanism of each infrastructure investment at the onset. In the case of Smart cities, the citizens must be made aware of about the costs involved, the associated benefits and signaled about the prices they need to pay before the commencement of projects. The recently launched report

[97] http://www.cisco.com/web/learning/netacad/index.html

[98] http://www-03.ibm.com/press/us/en/pressrelease/47364.wss

[99] https://www.mwcog.org/uploads/committee-documents/Z11XWl5Y20150114150624.pdf

[100] http://www.usibc.com/sites/default/files/USIBC%20%20Financial%20Strategies%20for%20Smart%20Cities.pdf

of the 'State of City Climate Finance report' highlights some of these challenges, which are also applicable to financing needs of climate resilient urban infrastructure[101].

**Policy Instruments for Meeting Smart City Financing Needs**

STI driven policy instruments use citizens' own funds in smarter ways to finance smart city applications. Some of these emerging policy instruments are discussed here.

- **Technology Driven Innovative Financing Models**

As explained in the previous chapter, a smart city application allows for huge efficiency gains and avoidance of wastage of resources. If these efficiency gains could be measured through appropriate smart technologies and monetized though business models, then part of smart infrastructure investment costs could be recovered through such efficiency gains. Such technology driven performance-based payments can be a viable financing tool for several other smart infrastructure. Third-party financing of projects could then be used with the payback out of guaranteed energy, water, or operational cost savings[102]. Another possibility to raise revenue is by establishing customized user fees or congestion charges during peak hours in certain public spaces or city centres, enabled through sensor networks and cameras. This could help to reduce traffic congestion and to promote safe pedestrian traffic[103].

The case study below describes the case of smart meters in Nairobi which led to a technology driven business model to finance provision of piped water in parts of Nairobi, Kenya. Another replicable story is from Germany, where the KfW was able to develop a scheme to monetize the energy efficiency gains of residential buildings.

**Smart Metering, Nairobi, Kenya**

Nairobi Water and Sewerage Company (NWSC) [104], in partnership with the World Bank's Africa Region team, is increasing access to piped water connections in slums under the Jisomee Mita programme ("Read Your Meter" in Swahili). Using self-metering and mobile payments, customers repay for their piped connection (financed through NWSC partnership with a local bank) through their water bills. Every home tap in Nairobi has a meter installed. Once the meter is read and the readings are texted to the NWSC, the bill is texted back. Upon mobile money transfer, customers can use the water without monthly billing hassles.

[101] This report, prepared by the Cities Climate Finance Leadership Alliance, was launched at the Climate Summit for Local Leaders, alongside the COP21 event in Paris. Please see the report for some additional innovative financing solutions for Cities: available at http://www.citiesclimatefinance.org/wp-content/uploads/2015/12/CCFLA-State-of-City-Climate-Finance-2015.pdf

[102] http://urban.cityminded.org/wp-content/uploads/2013/03/MotM_March15Webinar_CharbelAoun_SchneiderElectric.pdf

[103] These congestion charges have been found to be successful in many developed country settings, but the model becomes much more challenging in developing countries, see more discussions here on this: http://commonsabundance.net/docs/political-attents-to-reduce-car-use-in-cities/

[104] Use of Mobile Technology in Service Delivery, Philip Gichuki, World Water Week, Sept 2014. http://programme.worldwaterweek.org/sites/default/files/9_presentation_on_self_meter_reading_solution_final_version.pdf

There is a small service charge if customers don't use the smart meters for a span of one month. This will help pay for the loan payments incurred by Jisomee Mita program to bring the new water pipelines and water meters to the residents. M-PESA is a successful mobile money service to slum dwellers of Nairobi, Kenya. Among its benefits, it allows saving time from going to banks and providing safety from being robbed or fires. Grundfos Lifelink[105], the water pump provider is also linked with M-PESA and social payments to slum dwellers are also being made by NGOs using M-PESA.

**Monetizing the Energy Efficiency, Germany**

In Germany, the KfW (German government-owned development bank) initiated a guarantee scheme for monetizing the energy efficiency of buildings in 2006. kfW provided low-interest loans and grants for investments in residential buildings. It also provides advice on energy efficiency measures through in-house experts. The magnitude of the support depends on the energy savings achieved by these buildings. Once the projects are completed KfW delivers energy efficiency certificates which have become a national standard and directly affect the value of properties[106]. More energy efficient buildings are able to command a premium in the real-estate market. This appreciation of prices indirectly finances part of the energy saving investment made initially.

This model has been replicated worldwide. For example, the Asian Development Bank initiated a loan worth $20 million to a private entity (Cofely Southeast Asia Pte. Ltd) to invest in building, upgrading and expanding energy efficient infrastructure across the Asian region. Ultimately the loan is projected to save 150,000 megawatt hours of energy, avoid 90,000 tons of carbon emissions, and yield an average annual net savings of $10million by 2019[107].

- **Crowdfunding Platforms**

A variety of crowdfunding platforms help to acquire financing for smart city concepts. For example, Kickstarter and Indiegogo crowd and micro funding programs and microloan programs like Kiva[108] have encouraged entrepreneurship related to smart city applications, albeit of small scale. These online programs help pool resources to meet a larger goal. These crowdfunding platforms have already been used for successful smart city projects. The case study below discusses two recent major projects. Citizinvestor.com, a crowdfunding platform that raises money for public projects, already boasts of more than 170 cities as users. Citizinvestor Connect, a recently launched platform, will allow cities to go further by creating their own platform. This platform will help cities to source project ideas from citizens who can use the platform to raise money for an initiative that the government

[105] www.scidev.net/global/cities/feature/developing-world-city-smart.html

[106] https://eu-smartcities.eu/sites/all/files/Guideline-%20Financing%20Models%20for%20smart%20cities-january.pdf

[107] See page 29: https://www.mwcog.org/uploads/committee-documents/Z11XWl5Y20150114150624.pdf

[108] Read more on these platforms here: www.kickstarter.com and www.indiegogo.com and www.kiva.org

agrees to help implement.[109] All this shows that citizens are ready to contribute towards financing of smart city solutions and online platforms provides Cities and innovators a good way to harness these finances. These crowd-funding platforms may also be used to attract impact-investors[110] and could also be used by small-scale entrepreneurs developing new smart infrastructure applications.

**Smart City Crowd Funding Success Stories**

World´s first crowdfunding campaign for Smart City expansion in PAKRI, Estonia, achieved its funding target. PAKRI Science and Industrial park, the Smart City for greentech companies in Paldiski, Estonia sought a total of 490,000 euros through EstateGuru crowdfunding platform. The aim of the investment is to use active crowdfunding to build and renovate innovative testing ground for new greentech technologies. PAKRI is already planning to use crowdfunding in the coming year to invest in the next 3,3MW wind turbine, smart-grid network and next building constructions. Total investment potential for PAKRI Smart-City is approximately 300M euros and for PAKRI Smart-Grid approximately 50M euros.[111]

Another crowdfunding success story is from Connecting Tech City, the Centre for London's new platform bringing together education and technology business. Connecting Tech City aims to boost the connections between local young people who want to work in tech and tech firms that need young talent. It launched a crowd funding campaign for £50,000 on Indiegogo and successfully achieved this target.[112]

- **Monetizing Smart Data**

Data is an important component of Smart Cities. The sensor networks, intelligent meters, mobile phones and IoT devices all generate huge volumes of data. This generated data could be transformed by city government to generate new insights that could be monetized and sold to different stakeholders. The key would be to generate a suitable value chain for the data and an appropriate business model for the same at different layers. One example in this regard is that the information collected from automated meters could be used by government to generate insights from the aggregated data and market the same to interested third parties without compromising the privacy of individuals. In addition, big data and analytics can enable an increase of tax collection by reducing tax evasion, and this increase in revenue can be leveraged for smart infrastructure investments. However, it needs to be ensured that during the process of monetizing of data, privacy and security of all citizens are preserved.

[109] http://www.sustainablecitiescollective.com/embarq/330406/friday-fun-you-too-can-build-sustainable-city-through-crowdfunding

[110] Read more about impact investors in the urban context here: http://www.smartcitiesadvisors.com/impact-investment-funds-for-cities-insight-from-the-eus-jessica-program/

[111] http://pakri.ee/world%C2%B4s-first-crowdfunding-campaign-for-smart-city-expansion-is-launched-in-estonia/

[112] http://www.techcityinsider.net/crowdfunding-win-for-education-platform/

- **Generating finances through smarter use of existing public resources**

STI-led smart city applications can lead to more efficient use of existing public resources and generate additional financing options through such routes. An interesting success story of this is from Kirklees, United Kingdom, which was one of the winners of the 2014 Mayors Challenge in the United Kingdom. Kirklees stimulates and operates a new sharing economy to maximize untapped local resources and do more with less. The city pooled idle government assets – from vehicles, to venues, and citizens' skills and expertise – and work with non-profit sectors to make these assets available through an online platform that would organize and allow for borrowing, bartering, and time-banking to benefit both programs and residents[113]. Such smart concepts can facilitate more efficient use of existing resources and provide new sources of revenue for cities. Electronic tax payment systems at the City level are another way to boost revenue generation. For instance, Kampala (Uganda) introduced the electronic tax payment system called 'e-Citie', which allows clients to use their mobile phones to pay fees ranging from yellow fever, commuter taxi monthly revenue and property rates among others. This has led to a doubling of tax revenue collection[114].

## *Challenge 4: Applying a Suitable Governance Model*

Smart Cities call for new governance models, both during the planning phase of cities and during its execution and management. It requires breaking down of 'silos' across different government departments. Information islands acts as the biggest barrier preventing the resource integration in the course of smart city development, at the technical and management level of smart cities. On the technical level, the construction of smart cities covers many fields. Uniform industrial standards, construction standards and evaluation standards are not available to guide such construction. For example, at the data infrastructure level, though various departments in cities have accumulated a huge amount of data and information through long-term IT application, various systems are constructed independently and compartmentalized. This existing system lacks an effective information sharing mechanism, resulting in IT application islands, not conducive to the construction of basic databases required for smart cities. At the management level, horizontal coordination of city departments is difficult, as compartmentalized administration and management are prevalent[115].

Effective smart-City management needs elements of both 'top-down' and 'bottom-up' governance approaches. On the one hand, collating the information generated through smart sensors deployed through different smart infrastructures, and taking policy actions, especially during emergencies, might require strong top-leadership and top-down execution process. While on the other hand, 'bottom-up' governance approaches include citizen-driven

[113] http://mayorschallenge.bloomberg.org/index.cfm?objectid=9B3942E0-38FD-11E4-BC0E0050569A3ED0

[114] Based on input from Uganda to the CSTD secretariat, more information on this project may be found at : http://www.ugandaeconomy.com/invest-uganda/kampala-capital-city-authority-kcca

[115] This section was compiled on the basis of input provided by China.

innovations and co-creation that have been the defining characteristics of many smart city applications discussed in the previous chapter. Therefore, the key is to manage a good balance between these two approaches. Achieving such a balance helps city governments harness the synergy between various participants (e.g., universities, private sector, civil society, local and municipal government). This further helps the citizens to legitimize the plans and increase overall accountability.

In both greenfield and brownfield sites, this means that the age-old traditional policies, methods of governance and regulations need to be revamped and tested. The governance framework needs to be inclusive in nature and incorporate the needs and aspirations of all diverse stakeholders. Traditionally, city governments, especially in developing countries, have a hierarchical, centralized and 'top down' governance[116]. Such an approach or culture often leads to administrative entities being unresponsive to the needs of citizens. Hence, city government administrators are faced with the challenge of deriving new forms of governance processes that adequately place citizens needs at the core of the governance process, by adequately balancing top-down and bottom-up governance approaches.

**Policy Instruments to Facilitate Smart City Governance**

Smart governance applications themselves offer some solutions to tackle this challenge. These STI driven applications offer solutions to this challenge in three main ways. Firstly, these tools helps to break down silos across government departments, secondly, it offers new platforms to actively facilitate bottom-up governance. Thirdly, by creating collaborative overall smart city visions and strategies, all stakeholders know their expected roles within smart cities and this helps to ensure more overall participatory governance.

- **Smart City Operation Centers to Break down Administrative Silos**

Smart Cities generate data and information that are gathered through utilities and infrastructure components and often controlled by different government entities. Without breaking down the administrative silos across these entities, the City will not be able to make best use of the collected data. One common method, which several smart cities have adopted, is the establishment of a central operation center to which data from multiple sources are directly fed. These operation centers then make the efficient use of data by merging and collating different data types that help to make more information available to decision makers. It is true that that this approach is quite 'top-down', however as the case study from Brazil shows, these centers have already proved to be game changers in times of crisis response. It makes the top-down decision making process more evidence based and even transparent, as shown by the experience in Rio de Janeiro. This is achieved mainly through the fact that information and data that are traditionally controlled by different departments are merged together in these smart city operation centers.

## Case Study: Smart City Operation Centers

### Centro de Operações Preifetura do Rio de Janeiro (COR), Brazil

[116] Common governance and administrative weakness in developing countries, Shah and Andrews (2003). http://info.worldbank.org/etools/docs/library/206961/CitizenCenteredGovernanceANew.pdf

COR brings together the municipality's 30 departments and private suppliers in a single monitoring room. Here, they track real-time conditions in the city, when necessary coordinating a response to emergencies and disruptions. It is considered one of the most ambitious urban command centers in the world. A giant wall monitor is broken into a grid of status graphs, meteorological reports and live video feeds from traffic and surveillance cameras. There are Google satellite and street maps networked to the city's information systems which staff can toggle for close-ups and additional data overlays. A map might show the present location of every city bus, the nearest hospitals to an emergency or designated at-risk areas during storms. Information is shared real-time between city staff from various departments – from transportation to sanitation, health to emergency services – as well as with the private contractors that own the transit lines, do road work or collect trash. Upstairs is a room for journalists who can access much of the same information – effectively acting as COR's megaphone and helping crowdsource information back to it, thereby helping to make this approach more transparent[117].

Similar command and control centers of varying sophistication levels can be found in smart city projects in, inter alia, Madrid, Barcelona, Sao Paulo, and Zhenjiang.

- **Platforms for Bottom-up Participatory Governance**

Several technology and innovative applications provide platforms for City governments to actively engage with citizens on a regular manner. The case study of Smart City Gran Concepción, Chile discussed below shows how a bottom-up approach method can be deployed right from the planning phase to the management of smart cities.

**Case Study: Smart City Gran Concepción, Chile**

The Ministry of Transport and Telecommunications of Chile and the World Bank started a pilot Smart City Project in January 2014 called Smart City Gran Concepción[118]. It was financed by the Spanish Fund for Development in Latin America and the Caribbean. Smart City Gran Concepción adopted a bottom up citizen participatory method which is cost efficient since it makes use of the existing mobile telephony infrastructure and mobile applications. It enhanced real-time interaction of various players in the project by collaboration and co-creation unlike the high cost top-down solutions such as city management platforms, sensor networks or communications.

Smart City Gran Concepción sequentially implemented four operational phases:

- Ideation of technological solutions: Co-design of mobile applications with local and municipal government officials in the area of transport to resolve their daily technical challenges.

[117] http://www.theguardian.com/cities/2014/may/23/world-cup-inside-rio-bond-villain-mission-control

[118] http://innovatingcities.org/innovatingcities/chile/en/

- Diagnostic and strategic support plan: Cooperative development of a vision for the future and roadmap of mobility in Gran Concepción, involving local and municipal government, citizens, the private sector and civil society.
- Solutions co-creation competition: Co-creation competition and citizen engagement to develop solutions to the city's transport challenges, such as improving travel behavior and the public transport experience.
- Diagnostic and roadmap for a local innovation center: Co-design with city actors of an urban innovation center to solve local problems and to involve citizens in overall participation of all actors in the area.

This project concluded recently, and a series of activities to present the results of project among the open innovation community and to prepare to scale the model to the national level in Chile is currently underway.

The case studies discussed below lists some innovative platforms and technology tools used by City governments to actively engage with citizens in the management of cities.

## Case Studies: Citizen Participation in Managing Smart Cities

**Smart Citizen Kit, Amsterdam**

An example is the "Smart Citizen Kit[119]" by the Amsterdam City government. This kit was developed to address air quality concerns of cities. In this project, the Waag Society (a non-profit organization) and Amsterdam Smart City are creating an air quality sensor network all through Amsterdam. By involving the citizens, this becomes a very "bottoms-up" and collaborative community centric approach. Citizens attach the Smart Citizen Kit outside their houses to measure noise, humidity, temperature, CO, NO2 and light.

**Crowd Sourced Water Management, Bangalore India**

Bangalore, India has implemented a locally developed crowdsourcing data program called NextDrop[120] to better manage the water supply and help citizens. The Bangalore water supply and sewerage board uses NextDrop to coordinate information between operation centers, watermen and customers using calls and SMS. Residents are informed if there is any disruption in water service and act as a social platform to discuss any water related issues. This platform further helps to bridge the information gap between city governments, stakeholders and residents and improve water efficiency and customer satisfaction.

**Better Reykjavik Platform, Iceland**

Better Reykjavík is a platform that allows citizens to propose, debate and vote on ideas for improving their city. Top ideas from Better Reykjavík are added to the city government agenda every month and the city commits to process and answer them all, creating a dialogue between citizens and the city – a form of open policymaking. So far, 257 ideas have been formally reviewed and 165 accepted since 2011[121].

[119] https://waag.org/en/project/smart-citizen-kit

[120] http://www.gsma.com/mobilefordevelopment/nextdrop-wins-contract-to-expand-services-across-bangalore-city

[121] Open University online course content on Smart Cities.

**Using Social Media to Engage with Citizens, Jakarta, Indonesia**

City governments can use social media to connect people and projects together to build stronger communities. At present, in Jakarta, Indonesia, residents can use Twitter[122] to save lives with real time flooding information. Jakarta is an ideal testbed since it has one of the highest concentrations of Twitter users in the world. By analyzing more than 8 million flood-related Tweets in Jakarta over the past two monsoon seasons, a model for faster response times in real-world situations was developed. In addition, Twitter is being used to help deal with traffic congestion by arranging for rideshares[123]. There are 83000 Twitter followers, and 1000 requests per day are re-tweeted for ride sharing.

- **Effective Use of Overall Smart Agenda, Smart City Strategies and Technology Plans**

A smart city strategy and technology plan could be helpful tools in defining the governance process of smart cities. These strategy documents and plans would help to create a shared understanding and vision about the cities. They also help to define the roles to be played by different stakeholders and define a balance between top-down and bottom-up approaches. A recent survey conducted[124] among smart technology vendors also revealed that one of their main expectations out of Cities is to have a clear overarching smart city agenda. Cities such as Birmingham, Chicago, Dubai and Gdansk have all established such overall smart city strategies to guide their smart city developments and governance models.

## *Challenge 5: Making Smart City Applications Inclusive*

Another key challenge confronted by the smart city concept is to ensure engagement of all groups of citizens and to promote inclusivity. Smart city applications should be inclusive in terms of providing opportunities for all and ensuring that particular groups are neither left out of its positive impact nor disproportionately affected by any societal costs that it might impose. For instance, the needs of vulnerable groups such as women, people of old-age and those with disabilities should be integrated within smart city strategies. In developing country city contexts, people belonging to the informal economies, who are seldom under government taxation or regulations, also need to be ensured place, space and opportunities within smart cities. This will be a huge challenge as the scale of informal economies could be very large. For instance, the World Watch Institute estimates that the informal economy provides half the non-agricultural employment in developing countries. These informal economies account for 48% of the GDP in North Africa, 51% in Latin America, 65% in Asia and 72% in Sub-Saharan Africa[125]. The need for ensuring inclusivity to these vulnerable groups is especially important because there is a high possibility that they will lack the skills

[122] https://blog.twitter.com/2014/helping-jakarta-track-flooding-in-real-time-to-save-more-lives

[123] http://www.nesta.org.uk/sites/default/files/rethinking_smart_cities_from_the_ground_up_2015.pdf

[124] Jurgen Lasrtz and Stefan Lulf (2012) 'Partnering to Build Smart Cities', Governments Designed For New Times, McKinsey and Company.

[125] http://www.enca.com/money/informal-economy-report-shows-poverty-alleviation

in using smart city applications or that their livelihoods might be most affected by smart city applications.

The following example explains this challenge confronted by smart city planners by comparing the waste management process across countries. The solution for waste reduction is not a one-size-fits-all in most cities. Sweden is one of the most advanced countries in terms of waste management. They successfully sort, separate, recycle and incinerate (through waste to energy projects) over 90% of the "unusable" waste in a sustainable manner. Several smart waste management techniques, automation and strict recycling policies are the key to their success. On the other hand, India has different waste recycling lifestyles. In India, there is no formal recycling/reuse mechanism (in most parts), but the waste industry in India forms a significant part of its informal economy. The country as a whole recycles at least 70% of the PET bottles, while in USA these rates are only 30 percent. This is achieved through a hierarchical and tiered social infrastructure ranging from rag pickers in slums and landfill areas all the way up to small merchants. A few municipalities in India have been successful at door step segregation but there are locations where there is limited segregation, as a lot of the waste is incinerated. In this context, some of the tested smart waste management and automation procedures could be perhaps inappropriate and costly in India, especially due to the social disruptions induced on livelihoods of thousands of people. It would be perhaps be more effective and efficient to develop and design a hybrid smart waste management model which is more inclusive of the social infrastructure and in concert with reuse and recycling.

**Policy Instruments for Inclusive Smart City Development**

In addition to keeping in mind the ramifications of smart city concepts on vulnerable groups, several smart city solutions can be designed to cater to the specific needs of these vulnerable groups.The following examples bring together some of these applications, driven mostly by local innovation and adaptation.

- **Helping to formalize the informal sectors through smart applications**

Data on informal sectors and informal settlements (including slums) are missing in most countries. This is one primary reason why they often get left out of city plans and programs. However, STI driven solutions can help in mapping these informal sectors and this data can later be used to gauge the impact of various smart city projects on these informal sectors as well as to design smart city infrastructures oriented to cater to these informal sectors. The case studies discussed below give some examples of success stories in this regard.

## Smart Application to Map Informal Sectors

Slums are often left out or included only as a cursory afterthought in most urban planning exercises. However, slums in many developing economies are hotbeds of economic activity and should be included in urban planning. Monrovia[126,] Liberia's population has grown over the last five decades to over 1.6 million. This has caused its citizens an increased stress on

[126] http://capacity4dev.ec.europa.eu/article/urban-planning-creating-sustainable-and-safe-cities

water, sanitation and housing supplies. One major stumbling block to improving the situation is a lack of information on the size and scale of informal settlements and their residents. Having done this before, experienced slum dwellers from Ghana, Kenya and Uganda, are helping Monrovia with urban planning by mapping its slums A structured approach which includes slums in the formal urban planning process is essential, since it acknowledges and plans for the fact that in many developing countries, slums are integral to a rapidly urbanizing metropolis.

There is a separate initiative[127] to monitor rapid urbanization in Dar es Salaam, Tanzania, which combines up-skilling local students with utilizing smart technology. The students are given access to tablet computers, trained on an open source street mapping software called OpenStreetMap[128], and then released out into the slum and actually map the slum. For the first time the government and the city actually had a visual of what that slum looked like and what its needs were in terms of the people and the infrastructure. For the first time, the government could actually see what it was dealing with. This project also highlighted the potential for technology to boost economic development. The students involved in the project have since formed a start-up, selling their services back to the government and the private sector.

Informal retail via Spazas or small retail shops is the second economy in densely populated areas of the South Africa. They are taverns, small retail stores selling food and other retail products as part of this informal retail. Spazas offer 2.6 million employment accounting for 17% of total employment. Private sector companies are also making efforts to streamline and benefit from these informal economies. One such example is Zanusi Spaza, a digital innovation platform of Zanusi Brand Solutions. It is an immersion lab giving real time market data about the informal markets and develops brand segmentation and strategies for informal market companies. It also uses an Android based consumer and retailer engagement platform. Understanding market dynamics of this sector via real-time data collection using the Zanusi Platform will help Spaza owners map township retail and marketing as well as distribution networks and would generate new data to map this largely informal sector.[129] [130]

- **Providing affordable smart infrastructure for the informal sector**

One main characteristic of informal sectors is that they do not have access to mainstream public utilities such as piped water or electricity. However, smart infrastructure applications can be devised to make available these basic utilities to people informal sectors. The case study discussed below details the success story of M-KOPA in East Africa. M-Kopa combines mobile technology and solar power to make available and affordable high quality solar power solutions to people cut-off from the main power grids. Similar applications would be

[127] A Different Kind of Smart City, http://www.cipe.org/blog/2014/04/11/a-different-kind-of-smart-city/#.ViCRmvkrLja

[128] www.openstreetmap.org

[129] http://heyevent.co.za/event/ii4olp7tr2suoa/the-informal-retail-market-seminar-an-insider-view

[130] http://www.zanusi.co.za/news/view/9

crucial in ensuring inclusivity in applying smart city concepts, especially in developing countries.

**M-KOPA, East Africa**

Over three years, M-KOPA has developed an innovative approach to energy delivery in East Africa. This uses solar power and telecommunication technologies, mobile payments, and a motivated sales and support network to deliver a reliable service and cost savings to low income customers. Established in 2012, M-KOPA set out to address the tremendous demand for affordable off-grid energy by offering a pay-as-you-go solar energy service. To date, more than 250,000 customers have used this service. This growth has been achieved using solar home energy systems that are connected using cellular communications (GSM) technology. This allows for remote monitoring and real time control of each unit. The M-KOPA solar home systems are sold through a network of incentivized sales representatives. Customers make payments on their solar home systems with mobile-money from any location, at any time. This enables flexible payment schedules and responds to the cash-flow challenges of low-income customers. GSM connectivity to the solar devices provides the ultimate control switch: the device will not work without payment. This connectivity also provides rich data that allow detailed analysis of use, device diagnostics, and real-time customer support.[131]

- **Making Smart Cities Gender Inclusive**

Technology can be used in three[132] ways to ensure gender inclusive smart infrastructure design, firstly, it can provide platforms for city planners to engage and interact with women in city to understand their needs. Secondly, technology can help in better analyzing the problem confronted by women in cities using real time data. Smart city applications can be designed to continuously collect and monitor gender disaggregated data. Such data can be used to better understand and adequately respond to the needs of women. For example, existing evidence suggests that the mobility pattern of women, including mode of transportation, time and frequency of journey, are quite different from that of men[133]. Analyzing these patterns can help to design suitable smart mobility systems that will provide more comfortable and safer mobility options to women. One-stop crisis centers and online platforms to report harassment are parts of smart safety measures. Thirdly, STI community can work towards improving the knowledge and tools to communicate and address gender inclusiveness issues

- **Developing smart infrastructure targeting all vulnerable groups**

In addition to the informal sectors, who are predominant in developing countries, there are other vulnerable groups that exist in both developed and developing countries. Some main constituents of these groups include, inter alia, the people of old-age (often with limited

[131] http://www.m-kopa.com/

[132] This section borrows from the approach proposed by Ms. Rebecca Peterniak, http://www.fireseedsnorth.ca/blog/2015/01/gender-and-smart-cities-rebecca.html

[133] http://seismicproject.eu/uploads/news/Csaba_Hungary/shared_mobilityFG/SEiSMiC%20GAP_DEF.pdf

mobility) and people with disabilities. Innovative smart applications can ensure that smart cities are inclusive and friendly to these groups of people. Two case studies in this regard are provided below from Poland and Spain. The main lesson emerging from these case study examples is that it is possible to design smart city solutions that specifically address the needs of these vulnerable groups. These innovations can make life in city easier and more enjoyable to them and the city governments should therefore channel the efforts of the local innovation system to continuously make new smart city applications that ensure inclusive development.

**Virtual Warsaw - Urban Information System for Visually Impaired**

The City of Warsaw is creating an Urban Information System for Visually Impaired. The blind and visually impaired are too often cut off from their peers and forced to spend huge amounts of time getting around cities. This city-wide navigation system is based on thousands of transmitters that are to be placed around the city and that communicate with visually impaired users through mobile apps (sending messages to a personal handset) what facilitates their mobility (also within the public transport system, e.g. providing dynamic real time information), broadens accessibility and increases users' independence and self-sufficiency[134].

**RegionAAL, Graz, Austria**

This project aims to support elderly people in being able to reside for longer in their own surroundings, by application of various ICT. As a pilot, around 100 households will be equipped with the assistance systems in Styria's capital Graz and its periphery. A scientific evaluation with the test households, to run for one year, will assess the effectiveness of ICT in meeting stated aims.[135]

**'Trust Network' for At-Risk Elderly Residents, Barcelona, Spain**

More than one in five Barcelona residents is over 65, and by 2040, one in four will be. As lives grow longer, Barcelona – like many cities globally – is grappling with new health problems and debilitating social isolation. To address this growing problem, Barcelona will use digital and low-tech strategies to create a network of family members, friends, neighbors, social workers, and volunteers who together make up a "trust network" for each at-risk elderly resident. This will help identify gaps in care, enable coordination of support, and promote quality of life[136]. This initiative won the Mayors Challenge Grand Prize for Innovation and €5 million toward its proposal from Bloomberg Philanthropies.

[134] http://www.ceec.uitp.org/warsaw-prized-bloombergs-2014-mayors-challenge

[135] Based on input provided by Austria to the CSTD secretariat, more information on the project may be found here: http://www.regionaal.at/en/

[136] http://mayorschallenge.bloomberg.org/index.cfm?objectid=8D2508E0-3E5E-11E4-AF250050569A3ED0

## *Discussion and Conclusion*

This paper begins by providing the context of rapid urbanization, which continuously puts pressure on cities to deliver smart solutions to meet sustainable development needs. The smart city infrastructure is highly context specific and the paper discussed some key differences between the nature of smart infrastructure in developed and developing country contexts. The paper highlights that Smart City technologies are especially relevant in developing country contexts, as they offer new avenues for technology leapfrogging. It underlines the role of key performance indicators and highlights some international efforts to develop comparable KPIs.

The paper provides an overview of smart physical infrastructure components, along with case studies, related to (1) Smart Buildings, (2) Smart Mobility and Transport, (3) Smart Energy, (4) Smart Water Management, (5) Smart Waste Management and (6) Smart Healthcare and the different layers of the smart digital infrastructure required to maintain a well-functioning smart city. It emphasizes the need to adopt an integrated approach to smart infrastructure design. The final chapter analyzes five key challenges confronted by smart city infrastructure projects, namely, (1) Adaptation of Smart City Concepts to Local conditions (2) Skills Gap (3) Financial Constraints (4) Applying Suitable Governance Models and (5) Making Smart City Applications Inclusive. For each of these challenges, the paper identifies some practical STI driven solutions using case study examples. The key message that emerges from this paper is that the global STI community will have to play a major role in successful design, implementation and management of smart city projects. Therefore, governments should actively engage the entire spectrum of local STI stakeholders and their international counterparts in the Smart City projects to address the urbanization challenges and to make the best use of opportunities provided by urbanization.

### Smart Infrastructure Design Principles

From the discussions on Smart City projects worldwide as well as the discussions presented in the previous sections of this paper, it is possible to distill some key principles that could guide the smart infrastructure projects[137]. These are briefly discussed below.

**People-Centered and Inclusive Infrastructure:** It needs to be recognized that while technology in the form of smart city infrastructure is an integral part of a smart city, it should only act as an enabler to meet the needs of the people of the city. Smart infrastructure development should therefore follow a "people-centric" approach which responds to the sustainable development needs of people and should avoid a "technology-centric" approach. This is perhaps best described in the words of Ms.Tina Saaby (Chief City Architect of Copenhagen) *'consider urban life before urban place; consider urban place before technology'*[138]. The smart infrastructure should be chosen and designed with a deep

[137] See the article y Mr. Rick Robinson on 22 principles for Smart City Design at : http://theurbantechnologist.com/smarter-city-design-principles/ . This section summarizes some of the points raised in this article.

[138] http://kit.dk/2015//documents/Tina%20Saaby%20-%20Urban%20Life.pdf

understanding of people's life style, culture, behavior and needs. These might vary across geographic regions and societies, pointing further to the need for local adaptation of smart technologies. Further, all sections of society should be kept in mind while designing smart infrastructure in order to ensure inclusive development.

**Resilience and Sustainability:** The convergence of climate change, urbanization and globalization presents unprecedented challenges to cities. The resilience of cities can be defined as the capacity of cities to survive, adapt and thrive in the face of stress and shocks, and even transform when conditions require it[139]. It is in times of extreme events and other catastrophes that the people need access to infrastructure the most. Infrastructure that constitutes smart cities should be sustainable and be resilient to such extreme events.

**Interoperability and Flexibility:** As evident in the paper, smart infrastructure technologies are rapidly evolving. Therefore, all steps need to be undertaken to ensure that the smart infrastructure components are interoperable and the standards of interoperability are followed. Further, the infrastructure should be designed so that they are flexible towards modifications and enhancements in the future.

**Managing Risks and Ensuring Safety:** Smart city infrastructure components raise new risks and safety concerns, as smart infrastructure could be prone to hacking and illegal access. The issue related to ensuring privacy of citizens is also an important concern in this regard. Therefore, smart city development should be accompanied by appropriate risk management and risk mitigation strategies. Building of skills in related fields should also be a priority.

[139] Definition provided by the Rockefeller Foundation in the report titled ' The Road to Resilience' available at http://issuu.com/taruleadingedge/docs/road_to_resilience_vol.1?e=17182289/12936141

# 5. Discussion Questions

This paper provides an overview of global urbanization trends and the case for smart cities. It defines smart cities and its key physical and digital infrastructural elements. The paper then addresses the various challenges in smart city infrastructure development, and the role of STI in overcoming them.

The following are some discussion questions which will further the dialog around Smart Cities and the role of STI.

1. What other challenges are confronted while implementing smart city concepts?
2. Which organizations shall operate the city and its core functions and what is the role of STI?
3. How can we measure performance of smart initiatives?
4. Who has the rights relating to energy and water usage – can that be made public using a portal?
5. How is the government supporting and getting the stakeholders involved in smart city planning? What can STI community contribute towards?
6. Basic infrastructure – Buildings, Transport, Water and Energy is what the developing countries need. It is something that they have been working on for a long time, but with limited success. How can we leverage ICT and Technologies to help accelerate and make this basic infrastructure more streamlined, efficient and smart?
7. Smart city implementation will typically occur only in stages. Is there a step by step prioritization that should be followed – is this prioritization dependent on geography and local conditions?
8. What is needed to make innovation flourish in smart cities?
9. Can cities produce customized smart solutions locally yet tap into the global urban technologies?
10. How can we better link our universities, research centres and other components of the innovation system to smart city agendas?
11. Do smart infrastructure needs in middle income countries differ from that of developed and Least Developed Countries?

# 6. Annex 1

**Examples of Various Smart City Definitions**

| Source | Definition of Smart Sustainable City |
|---|---|
| The World Economic Forum[140] | The main objective of this initiative is to develop, share and disseminate actionable frameworks and best practices to catalyze action at the global and regional level to resolve the infrastructure gap. |
| World Bank[141] | A smart city thoughtfully and sustainably pursues development with all of these components in mind with the additional foresight of the future needs of the city. This approach allows cities to provide for its citizens through services and infrastructure that address both the current needs of the population as well as for projected growth. |
| European Council (EC)[142] | A smart city is a place where the traditional networks and services are made more efficient with the use of digital and telecommunication technologies, for the benefit of its inhabitants and businesses. |
| Gartner[143] | Gartner defines a smart city as an urbanized area where multiple sectors cooperate to achieve sustainable outcomes through the analysis of contextual, real-time information shared among sector-specific information and operational technology systems. |
| Infocomm Development Authority (Singapore)[144] | A Smart Nation means people and businesses are empowered through increased access to data, more participatory through the contribution of innovative ideas and solutions, and a more anticipatory government that utilizes technology to better serve citizens needs. |
| UK Government[145] | A Smart City should enable every citizen to engage with all the services on offer, public as well as private, in a way best suited to his or her needs |
| Hitachi[146] | Hitachi's vision for the "smart sustainable city" seeks to achieve concern for the global environment and lifestyle safety and convenience through the coordination of infrastructure. Smart sustainable cities realized through the coordination of infrastructures consist of two infrastructure layers that support consumers' lifestyles together with the urban management infrastructure that links these together using IT. |
| Fujitsu[147] | Smart cities: Innovative urban developments that leverage ICT for the management of natural energy consumption at the community level and other technologies to balance environmental stewardship with comfortable living. |

[140] http://www.weforum.org/projects/future-urban-development-services
[141] http://blogs.worldbank.org/sustainablecities/what-is-a-smart-city-and-how-can-a-city-boost-its-iq
[142] https://ec.europa.eu/digital-agenda/en/smart-cities
[143] http://www.gartner.com/newsroom/id/3008917
[144] https://www.ida.gov.sg/Tech-Scene-News/Smart-Nation-Vision
[145] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/246019/bis-13-1209-smart-cities-background-paper-digital.pdf
[146] http://www.hitachi.com/products/smartcity/vision/concept/overview.html.
[147] http://www.fujitsu.com/global/about/responsibility/feature/2012/smartcity/

| | |
|---|---|
| Telefónica[148] | We define a "smart sustainable city" as the city that uses information technology and communications to make both its critical infrastructure, its components and utilities offered more interactively, efficiently and where citizens are made more aware of them. It is a city committed to the environment, both environmentally and in terms of cultural and historical elements |
| ARUP[149] | A "smart sustainable city" is one in which the seams and structures of the various urban systems are made clear, simple, responsive and even malleable via contemporary technology and design. Citizens are not only engaged and informed in the relationship between their activities, their neighborhoods, and the wider urban ecosystems, but are actively encouraged to see the city itself as something they can collectively tune in, such that it is efficient, interactive, engaging, adaptive and flexible, as opposed to the inflexible, mono-functional and monolithic structures of many 20th century cities. |
| IBM[150] | Replacing the actual city infrastructures is often unrealistic in terms of cost and time. However, with recent advances in technology, we can infuse our existing infrastructures with new intelligence. By this, we mean digitizing and connecting our systems, so they can sense, analyse and integrate data, and respond intelligently to the needs of their jurisdictions. In short, we can revitalize them so they can become smarter and more efficient. In the process, cities can grow and sustain quality of life for their inhabitants. |
| IEEE[151] | A smart city brings together technology, government and society to enable the following characteristics: a smart economy, smart mobility, a smart environment, smart people, smart living and smart governance |

[148] http://smartcity-telefonica.com/?p=373.
[149] http://www.arup.com/Publications/Smart_Cities.aspx.
[150] http://www.ibm.com/smarterplanet/in/en/sustainable_cities/ideas/.
[151] http://smartcities.ieee.org/about.html