United Nations E/CN.16/2016/2

Economic and Social Council

Distr.: General
26 February 2016

Original: English

Commission on Science and Technology for Development
Nineteenth session
Geneva, 9–13 May 2016
Item 3(a) of the provisional agenda

Smart cities and infrastructure

Report of the Secretary-General

Executive summary

This report presents key urbanization trends and their links to the 2030 Agenda for Sustainable Development. It provides an explanation of the term smart city, and describes the main components of smart infrastructure. It elaborates on the five main challenges encountered in the implementation of smart infrastructure projects, related to the following: (a) localization of smart infrastructure; (b) skills gaps; (c) lack of finance; (d) application of a suitable governance model; and (e) inclusivity. Finally, the report underlines the key role of science, technology and innovation (STI) communities in addressing these challenges, and provides some key principles that may help guide the design and development of smart cities.

GE.16-03074(E)

Introduction

1. The Commission on Science and Technology for Development (CSTD), at its eighteenth session in May 2015, selected smart cities and infrastructure as one of the two priority themes for the intersessional period 2015–2016.

2. To contribute to a better understanding of this theme and to assist CSTD in its deliberations at its nineteenth session, the CSTD secretariat convened an intersessional panel in Budapest from 11 to 13 January 2016. This report is based on the issues paper prepared by the CSTD secretariat,[1] the findings of the panel, country case studies contributed by CSTD members and other relevant literature.

3. The CSTD examined STI for sustainable cities and peri-urban communities as one of its priority themes for the period 2012–2013 and a detailed UNCTAD publication on this theme was issued in 2015.[2] The current theme of smart cities and infrastructure builds on this previous work of CSTD. The objective of this report is to illustrate the key role of STI, including information and communications technologies (ICTs), in the design, development and management of smart cities and infrastructure. Chapter I discusses key urbanization trends and their links to the 2030 Agenda for Sustainable Development. Chapter II provides an explanation of the term smart city, and describes the main components of smart infrastructure. Chapter III elaborates on some challenges encountered in the implementation of smart infrastructure projects and the role of STI in addressing them. Chapter IV provides some key design principles for smart cities and policy approaches. Chapter V concludes the report with a summary of the findings and suggestions.

I. Urbanization trends

4. Rapid urbanization is a global phenomenon. In 2008, for the first time in human history, there were more urban dwellers than rural. Current estimates suggest that by 2030, over 60 per cent of the global population will be living in cities, increasingly concentrated in Africa, Asia and Latin America. This fraction could rise to two thirds by 2050.[3] Comparing the projected rate of growth of urban populations across regions, it is clear that countries in the low-income category will confront far more rapid urban population growth than countries in higher income categories.[4] Recent estimates suggest that the growth of urban areas in the first three decades of the twenty-first century will be greater than the cumulative urban expansion in all of human history.[5] Cities contribute to approximately 70 per cent of global energy use and greenhouse gas emissions but occupy only 5 per cent of the Earth's land mass.[6] These trends are accompanied by an unprecedented increase in

[1] Available at http://unctad.org/en/pages/MeetingDetails.aspx?meetingid=941. All presentations and contributions to the CSTD intersessional panel cited in this report are available at this website. All websites cited in this report were accessed on 22 February 2016.

[2] UNCTAD, 2015, *Science, Technology and Innovation for Sustainable Urbanization* (New York and Geneva, United Nations publication).

[3] United Nations Department of Economic and Social Affairs, 2014, *World Urbanization Prospects: The 2014 Revision* (New York).

[4] Ibid.

[5] KC Seto and S Dhakal, 2014, Human settlements, infrastructure and spatial planning, in Intergovernmental Panel on Climate Change, *Climate Change 2014: Mitigation of Climate Change* (New York, Cambridge University Press).

[6] Scientific and Technical Advisory Panel, 2014, Sustainable urbanization policy brief, Global Environment Facility; and United Nations Environment Programme, 2015, Cities and climate change,

demand for water, land, building materials, food, pollution control measures and waste management. Cities are therefore under constant pressure to provide better quality services, promote local economic competitiveness, improve services delivery, increase efficiency and reduce costs, increase effectiveness and productivity and address congestion and environmental issues. Such pressures are motivating cities to turn to smart solutions and experiment with various smart infrastructure applications.

1.1 Urbanization and the 2030 Agenda for Sustainable Development

5. The 2030 Agenda for Sustainable Development, the Addis Ababa Action Agenda and the Paris Agreement under the United Nations Framework Convention on Climate Change provide a supportive structure for addressing this priority theme. The 2030 Agenda places great importance on issues related to sustainable urbanization, particularly in Goal 11: make cities and human settlements inclusive, safe, resilient and sustainable. However, the challenge of urbanization is also intricately linked to the other Sustainable Development Goals. It is clear that there can be no sustainable development without sustainable urban development. The United Nations Conference on Housing and Sustainable Urban Development (Habitat III) is scheduled to take place in Quito from 17 to 20 October 2016 and is expected to provide the opportunity to discuss a new urban agenda that focuses on policies and strategies that can result in effectively harnessing the power and forces behind urbanization (see http://unhabitat.org/habitat-iii-conference/). Smart cities are expected to play an important role in this new urban agenda.

II. Smart cities and infrastructure

2.1 Defining a smart city

6. There is no standardized commonly accepted definition of or set of terminologies for a smart city. In 2014, an International Telecommunication Union report analysed over 100 definitions related to smart cities, and the following definition was the outcome of this analysis: “A smart sustainable city is an innovative city that uses 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.”[7] Several efforts are currently under way to develop comprehensive key performance indicators for smart cities. A United Nations inter-agency group is developing a set of key performance indicators with the aim of turning them into a global smart sustainable cities index.[8] Analyses of different definitions of the term smart city reveal that different definitions emphasize different aspects. Governments and stakeholders thus need to work together to develop a common understanding of what smart city means in their specific national and city-level contexts.

7. The smart city concept offers different opportunities for different countries. The immediate need for cities in developing countries is to provide adequate urban

available at http://www.unep.org/resourceefficiency/Policy/ResourceEfficientCities/FocusAreas/CitiesandClimateChange/tabid/101665/Default.aspx.

[7] International Telecommunication Union, 2014, Smart sustainable cities: An analysis of definitions, Focus Group Technical Report, available at http://www.itu.int/en/ITU-T/focusgroups/ssc/Pages/default.aspx.

[8] D Carriero, 2015, United smart cities: Towards smarter and more sustainable cities, presented at the CSTD intersessional panel; and B Jamoussi, 2015, Shaping tomorrow’s smart sustainable cities today, presented at the CSTD intersessional panel.

infrastructure to meet the increasing pace of urbanization. In the process of meeting infrastructure demands, smart infrastructure applications provide a way for such cities to achieve leapfrogging in technology.[9] In developed countries, the challenge is often to maintain legacy infrastructure systems, which cannot be abandoned due to cost, space and other considerations. In such countries, smart city applications may focus more on facilitating the optimal use of existing infrastructure resources and monitoring the operations of such legacy resources. However, in both developing and developed country contexts, the primary motive behind smart infrastructure applications should be that they respond to the sustainable development needs of society.

2.2 Smart infrastructure

8. Smart infrastructure provides the foundation for all of the key themes related to a smart city, including smart people, smart mobility, smart economy, smart living, smart governance and smart environment. The core characteristic that underlies most of these components is that they are connected and that they generate data, which may be used intelligently to ensure the optimal use of resources and improve performance. This section introduces some key components of smart city infrastructure and concludes by highlighting the need for an integrated approach in dealing with such infrastructure.

Smart buildings

9. A smart building integrates the different physical systems present in an intelligent way to ensure that all the systems act together in an optimized and efficient manner. Smart building management systems can improve building energy efficiency, reduce waste and ensure an optimum usage of water, with operational effectiveness and occupant satisfaction. It is estimated that implementing smart building solutions could save as much as 30 per cent of water usage and 40 per cent of energy usage and reduce overall building maintenance costs by 10 to 30 per cent.[10] For example, in Austria, plus-energie-bürohochhaus is acclaimed as the first smart office building, feeding more energy into the grid than it uses.[11]

Smart mobility

10. Smart mobility is best described as approaches that reduce congestion and foster faster, greener and cheaper transportation options. Most smart mobility systems use data collected from a variety of sources about mobility patterns in order to help optimize traffic conditions in a holistic manner. Smart mobility systems include mass transit systems as well as individual mobility systems that feature bicycle sharing, ride sharing (or carpooling), vehicle sharing and, more recently, on-demand transportation.[12] For example, the bicycle-sharing system in Sao Paulo, Brazil, has saved 570 tons of carbon dioxide emissions since it began operations in 2012 (see http://ww2.mobilicidade.com.br/bikesampa/home.asp).[13] New disruptive business models leveraging the concepts of

[9] Deloitte, 2014, Africa is ready to leapfrog the competition through smart cities technology, available at http://www2.deloitte.com/content/dam/Deloitte/za/Documents/public-sector/ZA_SmartCities_12052014.pdf.

[10] Honeywell and Ernst and Young, 2015, Smart buildings make smart cities, available at http://honeywell.com/News/Documents/Smart_Building_Smart_City_WhitePaper_DOWNLOAD.PDF.

[11] Input from Austria to the CSTD secretariat. See also UniverCity, 2015, Overview, available at http://univercity2015.net/en/standorte/getreidemarkt/plus_energy_office_high_rise_building/overview/.

[12] Examples include bus rapid transit in Istanbul, Turkey, in Johannesburg, South Africa, and in Mexico City, and mass rapid transit in Beijing, New Delhi and Singapore.

[13] Input from the International Chamber of Commerce to the CSTD secretariat.

sharing, convenience and use of technology are emerging (such as Uber and Ola taxicabs). Further research is required to quantify the impact of such models on traffic congestion and the frequency of vehicle use in cities. Intelligent transport systems integrate the entire array of multimodal transport options in a city, including both individual mobility and mass transit, in an efficient manner. Modern intelligent transport systems normally comprise inter alia a network of sensors, global positioning system-tracked public transportation, dynamic traffic lights, passenger information panels, automatic vehicle registration plate readers, closed-circuit television systems, navigation facilities, signalling systems and, most importantly, the capability of integrating live data from most of these sources. This can lead to improvements in safety, network management, traffic congestion, environmental performance, accessibility, convenience and public perception. For example, Poznan, Poland, is currently operating a modern intelligent transport system. Some challenges that arose in implementing this project included a shortage of skilled staff, issues related to interoperability and unexpected delays in the construction of hard infrastructure components.[14]

Smart energy

11. Smart energy management systems use sensors, advanced meters, renewable energy sources, digital controls and analytic tools to automate, monitor and optimize energy distribution and usage. Such systems optimize grid operation and usage by balancing the needs of the different stakeholders involved (consumers, producers and providers). There are a number of innovations in smart energy infrastructure, such as distributed renewable generation, microgrids, smart grid technologies, energy storage, automated demand response, virtual power plants and demand-side innovations such as electric vehicles and smart appliances. Such innovations provide an extended network of intelligent energy devices across a city, with a detailed view of patterns of energy consumption, enabling community-based energy monitoring programmes and improving the energy efficiency of buildings. A key component of smart energy infrastructure is smart grids. A smart grid may be defined as an "electricity delivery system from point of generation to point of consumption integrated with ICT for enhanced grid operations, customer services and environmental benefits".[15] Smart grids are being implemented worldwide in both developed and developing countries. For example, the Kashiwa-no-ha smart city project in Japan uses a smart grid based on an area-wide energy management system combining home-energy management systems, real-time monitoring of energy supply and demand and self-sustained energy management with the optimal allocation of generated and stored energy.[16]

Smart water

12. Cities are constantly trying to solve water scarcity problems with innovative technologies and the better management of water. Improved metering and flow management are key to a good water distribution system. A smart water management system uses digital technology to help save water, reduce costs and increase the reliability and transparency of water distribution. Physical pipe networks are overlaid with data and information networks. The system typically analyses available flow and pressure data to determine anomalies (such as leaks) in real time to better manage water flow. Customers may be provided real-time information on the water situation and relevant information to help conserve water, leading to lower water bills. For example, Mumbai, India, as part of

[14] Poland, 2015, contribution presented at the CSTD intersessional panel.

[15] United States of America Department of Energy, in Cisco, 2010, Cisco smart grid: Substation automation solutions for utility operations, available at http://www.cisco.com/c/en/us/products/collateral/routers/2000-series-connected-grid-routers/white_paper_c11_593673.pdf.

[16] Japan, 2015, contribution presented at the CSTD intersessional panel.

improvements to the water supply system, has installed smart water meters that may be controlled remotely, leading to a 50 per cent reduction in water leakage.[17]

Smart waste management

13. Waste generation is increasing at a rate faster than that of urbanization.[18] Cities are increasingly finding it difficult to source, separate and use different kinds of waste that can potentially be returned to a consumer life cycle. Waste management typically includes the monitoring, collection, transport, processing, recycling and disposal of waste. Smart waste management systems reduce waste and categorize the type of waste at the source, and develop methods for the proper handling of waste. Such systems may be used to convert waste into a resource and create closed-loop economies. Their primary benefits are in improving the efficiency of waste collection, pick up, separation, reuse and recycling. One of the primary inefficiencies of waste management is the inability to predict when waste is to be picked up; trucks are often sent to collect waste when bins are not full. Sensors, connectivity and the Internet of Things offer ways to mitigate additional costs arising from such inefficiency. Smart waste management systems enable the movement of different kinds of waste to be monitored, and technology may be leveraged to better understand and manage the flow of waste from source to disposal. Such projects are currently being piloted in Santander, Spain and Sharjah, United Arab Emirates.

Smart health[19]

14. The health and well-being of urban residents are of particular concern with regard to the sustainability of urban areas and their supporting ecosystems. Smart cities can develop the capacity to use technology such as big data to develop predictions or identify hotspots of population health (such as epidemics or health impacts during extreme weather events).[20] Smart health-care management converts health-related data into clinical and business insights, which include digital health records, home health services and remote diagnoses, treatment and patient monitoring systems. It also facilitates the provision of health care using intelligent and networked technologies that help monitor the health conditions of citizens. It is enabling a shift in focus to prevention instead of cures, with a broader view of overall care, healthy living and wellness management. Smart health-care systems have a great potential in ageing societies in developed countries, and may lessen inequality in health care between high and low-income groups. Examples of smart health approaches include crowdsourcing to collect data on epidemics and predict epidemic outbreaks and take the necessary precautions, remotely collecting patient health vitals and data for diagnostic purposes and establishing automated alerts for patients with regard to medications and health check-ups. For example, in Africa, the Medic Mobile project in rural regions uses locally available mobile technology to help health workers report symptoms to the nearest clinic, receive treatment advice and emergency referrals and

[17] J Polson, 2013, Water losses in India cut in half by smart meters, *Bloomberg News*, 15 March, available at http://www.bloomberg.com/news/articles/2013-03-15/water-losses-in-india-cut-in-half-by-smart-meters-itron.

[18] D Hoornweg and P Bhada-Tata, 2012, What a waste: A global review of solid waste management, Urban Development Series Knowledge Papers No. 15, World Bank, available at http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf.

[19] Incorporates input from the Scientific Committee and the International Programme Office of the International Council for Science interdisciplinary scientific programme Health and Well-being in the Changing Urban Environment: A Systems Analysis Approach to the CTSD secretariat.

[20] S Jayasinghe, 2015, Social determinants of health inequalities: Towards a theoretical perspective using systems science, *International Journal for Equity in Health*, 14:71, available at http://www.equityhealthj.com/content/14/1/71.

provide information about the prevalence of the disease burden in a village or community (see http://www.medicmobile.org).

Smart digital layers

15. Smart digital infrastructure helps to increase understanding and the control of operations and optimize the use of limited resources in a city. One of the key value propositions of ICT in a smart city is the ability to capture and share information in a timely manner. If the information is provided in real time and is accurate, cities can potentially take action before a problem begins to escalate. One way to consider digital infrastructure is in the form of different supporting digital layers, as follows:

(a) Urban: The layer where physical and digital infrastructures meet. Examples include smart buildings, smart mobility, smart grids (for utilities such as water, electricity and gas) and smart waste management systems.

(b) Sensor: This layer includes smart devices that measure and monitor different parameters of the city and its environment.

(c) Connectivity: This layer involves the transport of data and information from the sensor level to storage and to data aggregators for further analysis.

(d) Data analytics: This layer involves the analysis of data collected by different smart infrastructure systems, to help predict some events (such as traffic congestion).

(e) Automation: The digital enabling interface layer that enables automation and scalability for a large number of devices across multiple domains and verticals.

16. Implementing smart city technologies often requires a robust, reliable and affordable broadband network, an efficient ecosystem for the Internet of Things and the capacity to make use of the big data generated.[21]

2.3 The need for an integrated approach

17. A city is made up of different infrastructure verticals forming a system of systems. However, such city infrastructure elements typically operate in silos. Smart cities need an integrated approach in order to harness the full potential of smart infrastructure. Integrated approaches are effective tools for capturing the dynamic relations between people, policies and environments. They are most often useful and effective when co-produced by scientists from multiple disciplines, policymakers, planners, managers, civil society representatives and all relevant stakeholders.

18. One commonly used approach is to aggregate the different data streams in a city under a single roof in the form of an operations centre. Such centres may act as nerve centres that help break down administrative silos. Co-locating different infrastructure components is another way to achieve the integrated development of a smart city. An example of such an approach is in Gujarat International Finance Tec-City in India, where multiple utilities are provided through a single tunnel, resulting in huge cost savings and a better management of urban space. Integrating the data collected through one infrastructure component and using it in an effective manner in the operation or maintenance of another component is another way of integrating infrastructure operations

[21] For example, one of the initial steps undertaken as part of the Wuxi smart city project in China was to equip over 3,000 buses with free Wi-Fi and establish nearly 40,000 free Wi-Fi access points and achieve full high-quality fourth generation network coverage across the city (input from China to the CSTD secretariat).

in smart cities. This approach is used, for example, in Eindhoven, Netherlands, where the data generated from the smart traffic management system is used to predict and identify dangerous road conditions and traffic density.[22] Finding such smarter integrated approaches to infrastructure development may establish the foundation for conceptualizing infrastructure systems for smart cities.

III. Implementing smart infrastructure: Some key challenges and science, technology and innovation-driven policy instruments

19. The implementation of smart infrastructure concepts, especially in developing countries, faces numerous challenges. This section discusses some of these challenges and the role STI communities can play in overcoming them, including some policy instruments driven by STI that could help to address each challenge.[23]

3.1 The need to localize smart infrastructure

20. A given smart city solution cannot simply be transplanted from one geographic region to another. Smart infrastructure concepts need to be made locally relevant and respond to local development needs. Context, culture and economics all play a role in this process. Cities should consider urban problems in a holistic manner before selecting appropriate smart technology solutions. For example, the conventional intelligent transport systems approach, involving a huge network of sensors and the aggregation of data, may be too expensive and unsuitable for developing country needs. A more localized and simpler version of intelligent transport systems may leverage more ubiquitous mobile telephone data, which may be more suited to developing country contexts. Local STI communities play a key role in addressing the challenge of localization. Some key policy instruments are highlighted in this section.

Policy instruments for promoting the localization of smart infrastructure

Harness the local innovation system: An overarching solution

21. Harnessing a local innovation system, which comprises inter alia entrepreneurs, local universities and research centres, is key to addressing the challenge of localization. For example, in South Africa, collaboration between a local university and city administration led to the design of smart shacks, which respond to urban housing needs in informal settlements.[24] Governments can allocate research funds to smart city projects and provide incentives to make such projects a priority within their STI communities. Cities need to consider how best to use existing innovation infrastructure such as science parks, technology incubators and innovation hubs to develop new smart city ideas and adapt smart city concepts. For example, in Gothenburg, Sweden, collaboration between two science

[22] International Business Machines, 2015, Traffic management for a smarter planet, available at http://www.ibm.com/smarterplanet/us/en/traffic_congestion/article/traffic-management-and-prediction.html.

[23] The challenges detailed incorporate some of the key concerns shared by member States in their inputs to the CSTD secretariat and interventions during the intersessional panel.

[24] N Modisaatsone, 2014, A different kind of smart city, available at http://www.cipe.org/blog/2014/04/11/a-different-kind-of-smart-city/#.VnF9cCuBzW4.

parks and several other stakeholders resulted in the first modern electric bus route.[25] Most importantly, cities need to create policy environments where massive amounts of small-scale innovation related to smart cities can flourish.[26]

Promote open data, open science models

22. Globally open data initiatives by Governments and the private sector have been a great impetus for smart city applications. For example, the open data platform in Singapore, promoted by the Government, successfully uses the potential of open data in promoting locally relevant smart city initiatives. In order to make the best use of open data initiatives, as well as promote further innovation, civic hacking events have been organized by various city governments and technology firms. Along similar lines, cities should encourage open science and innovation models that rely less on proprietary technology models. Such efforts can foster research collaborations and create opportunities for innovation.

Establish urban innovation units and living labs

23. Smart city applications might benefit from new institutions such as urban innovation centres. Such innovation centres and labs may provide convenient platforms to demonstrate new ideas and concepts. Another pertinent institutional arrangement that promotes smart city innovations is that of living labs, which offer real-life test and experimentation environments in which users and producers may co-create innovations.[27] Living labs methodologies have already been applied in developing countries, especially in Africa, promoted mainly through the Africa-European Union Strategic Partnership. Existing living labs networks may be used to test, incubate and promote smart city innovations.

Exploit regional innovation networks and global collaborations

24. When cities by themselves lack the capacity to conduct smart city-related research, make investments or create local adaptations, they can join with other cities confronting similar developmental challenges, as well as with technology partners, to conceptualize, finance, implement and exploit complementary competences and share lessons learned.[28] A successful example in this regard is the European Innovation Partnership on Smart Cities and Communities that, by pooling resources, aims to co-fund demonstration projects, help coordinate existing city initiatives and projects and overcome bottlenecks to transition processes (see http://ec.europa.eu/eip/smartcities/). Similar collaborative initiatives, such as the International Summit for Smart Cities in North Africa (see http://isc-summit.org/en/) and the Asia Africa Smart City Summit held in Bandung, Indonesia, and its declaration on smart cities, are nurturing partnerships across smart cites.[29]

[25] City of Gothenburg, 2015, Two science parks working with urban development and mobility, available at http://international.goteborg.se/smart-cities-sustainable-solutions/two-science-parks-working-urban-development-and-mobility.

[26] A compilation of specific policy and urban design tools for creating such environments is available at http://www.massivesmall.com.

[27] European Network of Living Labs, 2015, Frequently asked questions, available at http://www.openlivinglabs.eu/FAQ.

[28] For example, Google is working with certain city governments to design smart mobility using data (Google Europe Blog, 2015, Tackling urban mobility with technology, available at http://googlepolicyeurope.blogspot.ch/2015/11/tackling-urban-mobility-with-technology.html).

[29] United Cities and Local Governments Asia-Pacific, 2015, Commemorating the sixtieth anniversary of Asia-Africa Conference: Cities go for smart Asian and African continents, available at http://www.uclg-aspac.org/index.php/news/338/asia-africa-smart-city-alliance-set-in-bandung-indonesia.

3.2 Skills gaps

25. For a smart city to be successful in its endeavours, human resources skills need to be available to ensure that all the different facets of the city are adequately and efficiently addressed. For example, a digital or data layer must be added to all relevant operations, and more technology vendors and the integrated functioning of different departments must be dealt with. Human resources skills include planning and design, digital citizenship, data literacy, implementation and management. Investing in smart people, not only smart technology, is essential. Currently there is little research, especially in developing countries, that quantifies the exact skills deficit. Thus, to begin with, cities should conduct their own analyses of skills deficits. Some key policy instruments are highlighted in this section.

Policy instruments for addressing skills gaps

Accelerate education programmes in science, technology, engineering and mathematics

26. A significant proportion of smart infrastructure creation and maintenance jobs require a good foundation in education in science, technology, engineering and mathematics. A smart city agenda gives all the more reason to accelerate and popularize education in these fields. The popularity and success of the Science of Smart Cities Programme and the Urban Data School shows that similar programmes may help expose students to the real-life smart city applications of scientific concepts and attract more students to science, technology, engineering and mathematics at an early age (see http://engineering.nyu.edu/k12stem/sosc/ and http://urbandataschool.org/).

Reform curriculums and promote multidisciplinary learning

27. There is a need for curriculum reforms at the primary and secondary school levels and in higher educational institutions and technical and vocational education and training, in order to integrate the special skills requirements of smart infrastructure. A key characteristic of a smart city is that it is a multidisciplinary phenomenon; designing innovative smart infrastructure requires multidisciplinary teams to collaborate. Universities and schools should encourage and provide opportunities for multidisciplinary research and learning. New departments and courses related to the new urban science are already emerging in many universities. A recent analysis shows 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 city".[30] In addition, massive open online courses and other online training on different smart city skills may be good resources for mitigating skills gaps.

Partner with technology firms to train smart city workforces

28. Private sector firms are actively involved in developing smart city solutions and new innovative smart applications. The public sector can join with firms to provide much needed training to its workforce. More courses designed and conducted by technology firms could be made available to current students through existing educational infrastructures in order to fill specific skills gaps in cities. Some technology vendors are already engaging in such partnerships with city governments.[31]

[30] A Townsend, 2015, Making sense of the new urban science, available at http://www.spatialcomplexity.info/files/2015/07/Making-Sense-of-the-New-Science-of-Cities-FINAL-2015.7.7.pdf.

[31] For example the Cisco networking academy (see http://www.cisco.com/web/learning/netacad/index.html) and partnerships between universities and International Business Machines (see http://www-03.ibm.com/press/us/en/pressrelease/47364.wss).

3.3 Lack of finance and well-developed business models

29. Smart infrastructure projects require pooling public and private resources through creative financing and public–private partnership models. Policies, taxation and regulatory certainty also play an important role in this process. Governments 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 risks. Citizens must be made aware of the costs involved, the associated benefits and the prices they will be charged before the commencement of projects. Some key policy instruments are highlighted in this section.[32]

Policy instruments for meeting smart city financing needs

Develop technology-driven innovative financing models

30. As detailed in chapter II, a smart city application allows for huge efficiency gains and less waste of resources. If efficiency gains are measured through appropriate smart technologies and monetized though business models, then a part of smart infrastructure investment costs may be recovered through such gains. Such technology-driven outcomes-based payments may be a viable financing tool for smart infrastructure projects and public–private partnerships.[33] The third-party financing of projects may then be used, with the guaranteed payback of energy, water or operational cost savings. Another possibility for raising revenue is to establish customized user fees or congestion charges during peak hours in certain public spaces or city centres, enabled through sensor networks and cameras, which may help to reduce traffic congestion and promote safe pedestrian traffic. An example of an innovative technology-driven financing model is the application of smart meters in Nairobi under the Jisomee Mita programme, which helped to sustainably finance the provision of piped water in parts of Nairobi through the use of smart meters and mobile payments.[34] In Germany, the KfW Group development bank developed a scheme to monetize the energy efficiency gains of residential buildings.[35] Crowdfunding platforms can also help to acquire financing for smart city concepts. For example, Pakri Science and Industrial Park in Estonia conducted a successful crowdfunding campaign for its smart city expansion.[36]

Monetize data

31. Smart infrastructure generates data, which may be transformed by city governments to generate new insights that may be monetized and sold to different stakeholders. The key is to generate a suitable value chain for such data and an appropriate business model for the data at different layers. In addition, big data and analytics can enable increased tax collection levels by reducing tax evasion and this increase in revenue may be leveraged for

[32] See also the six sustainable business models for smart cities in R Robinson, Smart cities: Why they're not working for us yet, presented at the CSTD intersessional panel.

[33] E Bufi, Public–private partnerships for smart cities, presented at the CSTD intersessional panel.

[34] European Commission, 2013, Financing models for smart cities, available at http://eu-smart cities.eu/sites/all/files/Guideline-%20Financing%20Models%20for%20smart%20cities-january.pdf.

[35] Ibid.

[36] Pakri, 2015, World's first crowdfunding campaign for smart city expansion is launched in Pakri, Estonia, available at http://pakri.ee/world%C2%B4s-first-crowdfunding-campaign-for-smart-city-expansion-is-launched-in-estonia/.

smart infrastructure investments. However, during the process of monetizing data, the privacy and security of all citizens need to be ensured.

Generate finances through smarter use of existing public resources

32. STI-led smart city applications may lead to the more efficient use of existing public resources and generate additional financing options. Online platforms can help pool idle public resources and generate additional revenue for States. Finally, smart concepts can facilitate more efficient uses of existing resources and provide new sources of revenue for cities.

3.4 Governance: Balancing top-down and bottom-up approaches

33. Smart cities call for new governance models. Effective smart city management needs to balance both top-down and bottom-up governance approaches. On the one hand, collating the information generated by smart sensors deployed in different smart infrastructures and taking policy actions, especially during emergencies, may require strong top-level leadership and top-down execution processes. On the other hand, bottom-up governance approaches, including citizen-driven innovations and co-creation, have been the defining characteristic of much of smart city infrastructure, as discussed in chapter II. Managing a good balance between these two approaches is therefore important. Achieving such a balance helps city governments harness the synergy between various participants (such as universities, the private sector, civil society and local and municipal governments). Further, an efficient governance model for smart cities requires breaking down silos across different government departments. Information islands act as the greatest barrier to resource integration in the course of development, at both the technical and management levels of smart cities. Governance models need to be reformed in order that the data from smart infrastructure may be made available and used effectively in decision-making processes.[37] City government administrators thus face the challenge of devising new forms of governance processes that adequately place citizen needs at the core of the governance process by adequately balancing top-down and bottom-up governance approaches. Some key policy instruments are highlighted in this section.

Policy instruments for facilitating smart city governance

Promote platforms for bottom-up participatory governance

34. Several innovative and technology applications provide platforms through which city governments may actively engage with citizens in a regular manner. City governments are currently using various innovative platforms and technologies to actively engage with citizens in the management of cities. For example, in Amsterdam, a smart citizen kit was distributed to citizens to help create an air quality sensor network with their participation.[38] In Bangalore, India, the social enterprise NextDrop helps coordinate information between operations centres, water suppliers and customers using calls and short message services, with residents informed of any disruption in water services, and the mobile application serving as a social platform to discuss water-related issues.[39] In Jakarta, city officials have

[37] J Belissent, 2015, Smart cities: A coming of age, presented at the CSTD intersessional panel.

[38] Waag Society, 2014, Smart citizen kit Amsterdam, available at http://waag.org/sites/waag/files/public/media/publicaties/eindrapportage-sck-asd.pdf.

[39] R Talish, 2015, NextDrop wins contract to expand services across Bangalore city, Groupe Speciale Mobile Association, available at http://www.gsma.com/mobilefordevelopment/programme/utilities/nextdrop-wins-contract-to-expand-services-across-bangalore-city/.

used Twitter to better respond to flooding situations.[40] Such technology platforms also help create transparency and accountability, which strengthens participatory governance.

Establish smart city operations centres to break down administrative silos

35. Smart cities generate data and information that are gathered through utilities and infrastructure components and often controlled by different government entities. Without breaking down administrative silos across these entities, cities will not be able to make the best use of collected data. One common method for meeting this challenge, which several smart cities have adopted, is to establish a central operations centre to which data from multiple sources are directly fed. For example, in Rio de Janeiro, Brazil, a smart city operations centre brings together the municipality's 30 departments and private suppliers in a single monitoring room.[41] Operations centres allow for the efficient use of data by merging and collating different data types that help make more information available to decision makers. This approach is a relatively top-down one, but such centres may be game changers in times of crisis. They help ensure that top-down decision-making processes are more evidence based and transparent, as the data used to make decisions may be made public.

3.5 Designing inclusive smart cities

36. Another key challenge faced by the smart city concept is to ensure the 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 positive impacts nor disproportionately affected by any societal costs that may be imposed. For instance, the needs of vulnerable groups such as women, the elderly and persons with disabilities should be integrated into smart city strategies. The need to ensure inclusivity for such vulnerable groups is especially important because there is a significant possibility that they will lack the skills to use smart city applications or that their livelihoods may be the most affected by smart city applications. Promoting participatory governance in cities is a prerequisite for developing inclusive smart cities. Some key policy instruments are highlighted in this section.

Policy instruments for inclusive smart city development

Help formalize informal sectors through smart applications

37. Data on informal sectors and informal settlements are missing in most countries. This is one main reason why they may often be left out of city plans and programmes. However, STI-driven solutions may help in mapping informal sectors and this data can later be used to gauge the impact of various smart city projects on such sectors, as well as to design smart city infrastructures oriented to their needs. For example, there are current initiatives in Liberia, South Africa and the United Republic of Tanzania in applying mobile technology to map informal settlements and informal sectors.

[40] M Gillis, 2014, Helping Jakarta track flooding in real time to save more lives, The Official Twitter Blog, available at https://blog.twitter.com/2014/helping-jakarta-track-flooding-in-real-time-to-save-more-lives.

[41] C Frey, 2014, World Cup 2014: Inside Rio's Bond-villain mission control, *The Guardian*, 23 May, available at http://www.theguardian.com/cities/2014/may/23/world-cup-inside-rio-bond-villain-mission-control.

Provide affordable smart infrastructure for informal sectors

38. One of the main characteristics of informal sectors is that they do not have access to mainstream public utilities such as piped water or electricity. However, smart infrastructure applications may be devised to make these basic utilities available to people in informal sectors. For example, M-KOPA Solar in East Africa uses mobile technology and solar power to make available affordable high-quality solar power solutions to people excluded from the main power grids (see http://www.m-kopa.com/). Similar applications may be crucial in ensuring inclusivity in applying smart city concepts, especially in developing countries.

Make smart cities gender inclusive

39. Technology may be used in three ways to ensure gender-inclusive smart infrastructure design.[42] First, it can provide platforms for city planners to engage and interact with women in cities to understand their needs. Second, it can help in better analysing the problems faced by women in cities, using real-time data. Smart city applications may be designed to continuously collect and monitor gender disaggregated data, which can be used to better understand and adequately respond to the needs of women. For instance, evidence suggests that the mobility patterns of women, including modes of transportation, times and frequencies of journeys, are quite different from those of men.[43] Analysing such patterns can help to design suitable smart mobility systems that provide more comfortable and safer mobility options for women. Third, STI communities can work towards improving knowledge and the tools for communicating and addressing gender inclusiveness issues.

Develop smart infrastructure targeting all vulnerable groups

40. Innovative technology applications can ensure that smart cities are inclusive and friendly, including towards the elderly (who often have limited mobility) and people with disabilities. For example, smart infrastructure projects aimed at creating a trust network for the elderly and a navigation system for the visually impaired are currently under way in Barcelona, Spain and Warsaw, respectively.[44] Such innovations can make life in a city easier and more enjoyable and city governments should therefore channel the efforts of local innovation systems to continuously formulating new smart city applications that ensure inclusive development.

IV. Smart infrastructure design principles and policy approaches

41. From discussions on smart city projects worldwide as well as the issues addressed in chapters II and III, some key principles that may guide smart infrastructure projects may be distilled, as follows:

(a) People centred and inclusive: While technology in the form of smart city infrastructure is an integral part of a smart city, it should only be seen as an enabler to meet the needs of the people of the city. Smart infrastructure development should therefore rely

[42] R Peterniak, 2015, Smart cities are gender inclusive, presented at Transforming Transportation, Washington, D.C., 15 and 16 January, available at http://www.slideshare.net/EMBARQNetwork/smart-cites-are-gender-inclusive-rebecca-peterniak.

[43] M Sangiuliano, 2015, Gender and social innovation in cities: Societal Engagement in Science, Mutual Learning in Cities gender action plan and toolkit, available at http://seismicproject.eu/uploads/news/Csaba_Hungary/shared_mobilityFG/SEiSMiC%20GAP_DEF.pdf.

[44] Bloomberg Philanthropies, 2015, Mayors challenge: Winning cities from past competitions, available at http://mayorschallenge.bloomberg.org/bold-ideas/.

on a people-centric approach that responds to the sustainable development needs of people, and avoid a technology-centric approach. Smart infrastructure should be chosen and designed with a deep understanding of people's lifestyles, cultures, behaviours and needs.

(b) Resilient and sustainable: The convergence of climate change effects, urbanization and globalization presents unprecedented challenges to cities. Smart infrastructure should therefore be resilient to external shocks and ensure sustainability.

(c) Interoperable and flexible: Smart infrastructure technologies are rapidly evolving. All necessary steps should therefore be taken to ensure that smart infrastructure components are interoperable. Further, infrastructure should be designed in order to be flexible with regard to future modifications and enhancements.

(d) Risk-mitigating and safe: Smart city infrastructure components raise new risks and safety concerns, as smart infrastructure may be prone to hacking and illegal access. Ensuring the privacy of citizens is also an important concern. Therefore, smart city development should be accompanied by appropriate risk management and risk mitigation strategies. Building skills in related fields should also be a priority.

42. Smart cities are an emerging concept and therefore not yet adequately integrated into national STI and ICT strategies in most States. Governments may use ICT strategies to create the ecosystem required to facilitate core technologies related to smart cities (such as the Internet of Things). As discussed in this report, national and city governments have at their disposal a variety of policy instruments to promote smart city projects including inter alia output-based contracting, public–private partnerships, procurement policies, long-term contracting and targeted research funds. In addition, Governments may play a variety of roles in promoting smart city concepts.[45] For instance, in their roles as regulators, they need to review their regulatory frameworks to ensure that such frameworks are conducive to smart city innovations. In their roles as investors, they need to determine which skills development programme or infrastructure component they should invest in to drive innovation. City governments can effectively use their roles as consumers to support small-scale smart city innovations by giving them preference and access to public procurement contracts. Governments need to actively make use of such policy instruments and engage in these diverse roles to create and shape well-functioning markets for smart infrastructure that responds to local sustainable urban development needs.

V. Findings and suggestions

43. The main findings are as follows:

(a) The concept of a smart city is highly context specific. It is therefore important for national and city governments to work together with all relevant stakeholders to develop a common understanding of what a smart city entails in their specific national and local contexts.

(b) Smart cities and infrastructure designs need to be people centred. They should respond to the needs and challenges of specific urban systems and recognize the potential of technology as an enabler and at the same time understand its limitations.

(c) In developing smart cities and infrastructure, an integrated approach should be adopted that will help break down silos that may exist between existing infrastructure verticals and between government departments that deal with related services.

[45] For example, the City Initiatives for Technology, Innovation and Entrepreneurship framework details nine key roles (J Gibson, M Robinson and S Cain, 2015, A resource for city leadership, available at http://citie.org/assets/uploads/2015/04/CITIE_Report_2015.pdf).

(d) In designing smart cities and infrastructure, several key design principles need to be followed, namely inclusiveness, resilience, sustainability, interoperability, flexibility, risk mitigation and safety.

(e) Smart cities and infrastructure open new avenues whereby local STI communities may actively contribute to sustainable urbanization. STI communities can play a key role in addressing some of the main challenges faced by smart cities and infrastructure projects.

(f) Existing national STI and ICT policies may not adequately integrate the needs of developing smart city initiatives. Doing so requires the strengthening of a supportive ecosystem that enables the development of smart infrastructure, including human capabilities, legal frameworks, technology policies, institutional mechanisms and data use policies at both the Government level and in the workforce.

(g) Governments have at their disposal a broad array of tools to develop smart cities, including inter alia output-based contracting, public–private partnerships, procurement policies, planning and development frameworks, social and entrepreneurial investment funds, research funds and the provision of support services. Such tools can enable Governments to actively shape markets and correct market failures related to smart infrastructure.

(h) Smart infrastructure has the potential to promote inclusive development (including gender inclusiveness) in cities by helping to generate data on informal settlements and informal sectors and other marginalized groups in society (including women, the elderly and persons with disabilities). Such data can then be used to design infrastructure that specifically addresses the needs of such groups.

(i) There is significant scope for regional and cross-country collaboration and intercity learning with regard to the design, development and management of smart cities and infrastructure.

44. Member States may wish to consider the following:

(a) Adopting a participatory approach to smart city development that actively engages citizens at all stages of development, and ensuring that cultural and livelihood factors of all sections of society are adequately integrated into the design of smart city plans.

(b) Collaborating with all relevant stakeholders to define a concept and vision of a smart city that is relevant for local contexts and can help respond to specific local sustainable urban development needs, and integrating smart city agendas into national STI and ICT policies and broader national development frameworks.

(c) Strengthening the core ICT infrastructure required to support smart cities, and facilitating the development of an ecosystem that supports the key technologies required to enable smart cities and infrastructure, according to the specific needs of cities.

(d) Encouraging national STI systems (including science parks and technology hubs) to make smart cities and infrastructure a priority theme by providing appropriate incentives, and creating an enabling policy framework in order for local innovation systems to generate and implement innovative smart infrastructure concepts that respond to specific local needs.

(e) Adopting an integrated approach to the conceptualization and design of smart cities and infrastructure to promote the more efficient use of resources and provision of public services.

(f) Creating awareness among Governments of the various policy tools available, such as output-based contracting, public–private partnerships, procurement policies, long-term contracting and targeted research funds, in order to promote smart infrastructure implementation, and encouraging the use of such tools to shape markets for smart infrastructure and correct market failures.

(g) Ensuring the inclusiveness of smart city projects by adequately addressing the special needs of marginalized sections of society including inter alia the elderly, persons with disabilities and inhabitants of informal settlements and informal sectors.

(h) Ensuring gender considerations in the design of smart cities and infrastructure, through inter alia the use of data generated by smart systems to make cities safer and more responsive to the needs of women.

(i) Conducting skills gap analyses in workforces, including in public sector entities, with regard to the skills required for the design, development and management of smart cities and infrastructure, and promoting multidisciplinary learning and suitable curriculum reforms at the primary and secondary school levels and in universities and technical and vocational education and training, in order to meet skills requirements.

(j) Promoting open data and open science models to trigger local innovation, and drafting appropriate data management policies and regulations to respond to privacy concerns.

(k) Ensuring that the design and development of smart cities and infrastructure integrates principles such as resilience, sustainability, interoperability, flexibility, risk mitigation and safety.

(l) Incorporating insights obtained from data generated from smart cities and infrastructure into governance processes by making data available in a timely fashion and effectively using it in policy formulation and decision-making.

45. The international community may wish to consider the following:

(a) Collaborating with international standardization bodies, and promoting the development of interoperability standards and other standardization measures required to enable technologies related to smart cities.

(b) Promoting regional collaborations in conducting pilot projects and benchmarking projects related to smart cities and infrastructure that respond to the collective needs of regions.

46. CSTD may wish to consider the following:

(a) Advising the international community, including Habitat III and other relevant United Nations processes, of the critical role of STI communities in facilitating smart cities and infrastructure projects with the aim of achieving sustainable urban development.

(b) Providing a platform to exchange lessons learned, best practices and experiences in policy approaches in harnessing STI, towards promoting smart cities and infrastructure.

(c) Sharing and analysing evidence of successful examples of the localization of smart cities and infrastructure concepts, especially in the least developed countries, that respond to pressing urban challenges.

(d) Providing a forum to share evidence of successful business models that may incentivize local innovation systems to scale up smart cities and infrastructure projects.

United Nations E/CN.16/2016/2/Corr.1

Economic and Social Council

Distr.: General
2 May 2016

Original: English

Commission on Science and Technology for Development
Nineteenth session
Geneva, 9–13 May 2016
Item 3(a) of the provisional agenda

Smart cities and infrastructure

Report of the Secretary-General

Corrigendum

After paragraph 21, insert a new box *reading*

Harnessing a local innovation system: Case studies[27bis]

Several countries have recognized the importance of involving local innovation systems in developing smart city projects through enabling policy measures, as indicated by the following examples.

Konza Technology City in Kenya has integrated a vision of creating a cluster of knowledge industries within the city into the conception stage of the project.

Smart city challenges and competitions organized by government departments have been found useful in providing an impetus to local innovation systems in Cameroon and the United States.

Some of the challenges related to the smart mobility project in Poznan, Poland were overcome with the help of close collaboration between the local scientific and research institutions and flexible management, which led to the creation of an efficient transport system in the city.

The acceleration of standardization for smart cities in the United Kingdom and the creation of a supportive institutional framework in Nigeria have been found useful in promoting smart city innovations. In Bulgaria, linking the city-level innovation strategy in Sofia to a smart city vision was found to be effective.

Ultimately, smart infrastructure requires the participation of local communities for success. For example, a significant smart infrastructure feature of Jelgava, Latvia, is the Operative Information Centre, which ensures smart information flow and is critical in ensuring crisis management and issuing appropriate early warnings. For the Centre to attain its full potential, exercises are organized regularly to train the local community in emergency responses.

[27bis] Bulgaria, Cameroon, Kenya, Latvia, Nigeria, Poland, the United Kingdom of Great Britain and Northern Ireland and the United States, 2015, contributions presented at the CSTD intersessional panel.

GE.16-07144(E)
1607144