

Digital Government, Smart Cities and Sustainable Development

Lei Zheng

Lab for Digital and Mobile
Governance,
School of International
Relations and Public Affairs,
Fudan University
Shanghai, China
zhengl@fudan.edu.cn

Wai-Min Kwok

Department of Economic
and Social Affairs
United Nations
kwok@un.org

Vincenzo Aquaro

Department of Economic
and Social Affairs
United Nations
aquaro@un.org

Xinyu Qi

Lab for Digital and Mobile
Governance,
School of International
Relations and Public Affairs,
Fudan University
Shanghai, China
xinyu_qi789@163.com

ABSTRACT

While the global population continues to grow, more people are living in cities. In 2018, 55 per cent of the world's population lived in cities. By 2050, this is expected to increase to 68 per cent – almost seven in every ten people will live in cities. If sustainable development is to deliver to all people, urban development plays a critical role. The 'smart city' is now the playbook for resilient, sustainable and liveable cities, and smart technologies are creating daily touchpoints that make both huge and small impacts across all walks of people's lives. Today's cities and tomorrow's smart cities are intricately linked to the United Nations' 2030 Agenda for Sustainable Development across its 17 goals. This paper first explores at-a-glance the fundamentals and layers that support smart cities, providing an overview but not a deep-dive into the technicalities. This includes, but not limited to, the policy and infrastructure frameworks, the data ecosystem including open data and big data, the device level including Internet of Things and mobile devices, and the application level in general. Three dimensions of policy integration in smart city development is suggested, namely: (i) horizontal integration across sectors and disciplines; (ii) vertical integration across different governmental levels as well as linkages between national and local development; and (iii) a whole-of-society approach in smart city development with the engagement of the private sector and civil society. The nexus of smart city goals and the global 2030 Agenda for Sustainable Development is then articulated. Building on the key issues identified, a high-level analysis of global and regional metrics in accessing smart cities is done, emphasizing the importance of the cliché - "what's get measured, gets valued".

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CCS CONCEPTS

• **Applied computing** → **Computers in other domains** →
Computing in government → *E-government*

KEYWORDS

Digital Government, Smart Cities, Sustainable Development

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1. INTRODUCTION

Every week, 1.4 million people move to cities.[1] Such rapid urbanization is straining local infrastructures and capacities. This in turn contributes to increased risks of economic and social shocks, and even natural and human made disasters. The need for cities to forge new ways to increase resilience in extremities and sustainability was highlighted by the United Nations General Secretary-General António Guterres on World Cities Day, 31 October 2018.[2] The Secretary-General also called for an overhaul for our cities and transport sectors.[3]

Out of 7.7 billion people globally in 2018, 55 per cent lived in cities, a proportion that is expected to increase by 60 per cent in 2030 and 68 per cent in 2050. This represents more than two-thirds of all humanity.[4] Close to 90 per cent of this expected increase

will take place in Africa and Asia. Together, India, China and Nigeria will account for 35% of the projected growth of the world's urban population between 2018 and 2050.[5]

This rapid growth of cities and rural-to-urban migration has led to a boom in mega-cities. In 1990, there were only ten mega-cities with 10 million inhabitants or more. By 2016, this number had tripled to 31, and there will be 43 mega-cities in 2030. Similar trends are foreseeable in the number of cities with at least one million inhabitants, which would have increased by at least 30 per cent from 512 in 2016 to 662 in 2030.[6]

Visualizing this demographic change, sustainable development cannot be achieved without significantly transforming the way we build and manage our urban spaces today. New technologies depict the playbook for sustainable, resilient and livable cities, enabling touchpoints that make huge and positive impacts of people's lives. Cities across the world are increasingly leveraging artificial intelligence (AI), Internet of Things (IoT), big data, ubiquitous connectivity and a range of other technologies to help solve their most pressing urban issues, from population growth and congestion to environmental sustainability and improved administrative efficacy. The emphasis on the role of digital government in the development of smart cities, comes at an important moment.

In this paper, the first section looks into the core aspects of smart cities, through at-a-glance fundamentals and layers that support smart cities, providing an overview but not a "deep-dive" into the technicalities. This includes, but is not limited to, the policy framework, infrastructure and network levels, the data ecosystem (including open data, big data, etc.), the device level (including IoT and mobile devices) and application level (end-user mobile apps for both service delivery and engagement). Section two illustrates the three dimensions of an integrated approach to smart cities development, namely: (i) horizontal integration across sectors and disciplines; (ii) vertical integration across different local levels as well as linkages to national digital government development; and (iii) a whole-of-society approach in smart city development, with the engagement of non-government actors including the private sectors and civil society.

In section three, the nexus of smart city goals and the global 2030 Agenda for Sustainable Development is articulated, particularly in relation to Goal 11 on Sustainable Cities and Goal 16 on effective, inclusive and accountable institutions. Building on the key messages identified in earlier sections, Section 4 evaluates current global and regional metrics in accessing smart cities through a high-level analysis of selected globally recognized metrics for smart cities.

1.1. Definition of smart cities

In order to understand the context of digital government in smart cities for sustainable development, one should first look into the definition of smart cities.

In the 2018 edition of the United Nations E-Government Survey, e-government development was assessed for the first time at the city-level through a sample of 40 cities.[7] Environmental, economic and social issues trigger smart city initiatives in many regions to take technological advancements in different domains. The Global Smart City Performance Index defines a smart city as "an urban ecosystem that places emphasis on the use of digital technology, shared knowledge and cohesive processes to underpin citizen benefits in sectors such as mobility, public safety, health and productivity." [8] On the one hand, it is stated in the IESE Cities in Motion Index that technology should not be understood as the main ingredient of a smart city but decision-makers should also consider other critical dimensions and social actors in a global vision.[9] On the other hand, the Sustainable Cities Mobility Index focuses on smart transportation systems in the future of the cities.[10] Finally, the Smart Cities Index defines a smart city as "sustainable, with a focus on clean energy and environmental protection, as well as excellent online access to governmental services and a high level of citizen participation." [11]

2. FUNDAMENTALS AND LAYERS OF SMART CITIES

The Fourth Industrial Revolution and convergence of innovative technologies, such as big data, distributed ledger, IoT, AI, virtual/augmented/mixed reality, and intelligent applications and platforms, are dramatically driving the world towards a more data-driven and machine-based society, while development challenges and social inequality continue to increase (see figure 1 on foreseeable strategic technology trends for 2019). So-called disruptive technologies are accelerating the development of smart cities in many government departments, including health, security, transportation, environment and finance.[12] The rapidity of new technologies evolution, combined with the capacity that governments already possess, present a historic opportunity for sustainable cities, as well as effective, inclusive and accountable institutions.

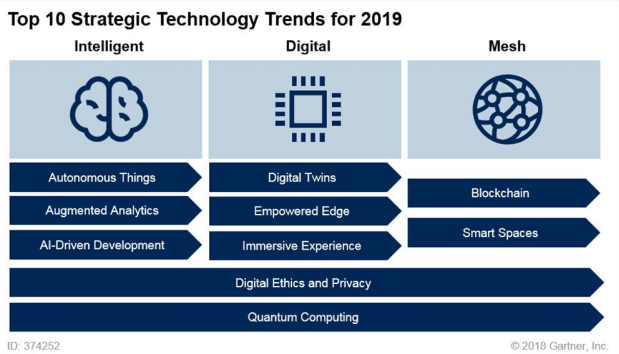


Figure 1: top 10 Strategic Technology Trends for 2019[13]

The successful transformation from a traditional city to a smart city thrives on a cohesive development strategy, which integrates all fundamentals and layers that support smart cities. First, a functional policy framework is necessary, which consists of coherent and inclusive policies that leverage and balance emerging technologies to meet the needs for developing smart cities. Second, the infrastructure and networks, the data ecosystem, the device level and application level are all essential parts of smart cities, and the following technologies and innovations could play the enabler, accelerator and multiplier roles.

2.1. Big data and open data

Big Data are vast datasets that cannot be analyzed using conventional software and analytic tools.[14] Due to its unique features on volume, variety, velocity, veracity and value[15], the potential of data itself and products obtained through analyzing data have been broadly recognized. Big data technologies could enable efficient and effective storage, processing and analysis of city data to support decision makers, encourage collaborations and enhance services. However, big data development relies on data availability, quality, integration and usage. Opening data, especially government data, to the society is critical to promote collaboration and innovation. The development of big data are also faced with challenges related to legal frameworks, policies and principles, data management and protection on privacy.[16]

2.2. Internet of Things

IoT consists of two foundational parts, the Internet and semi-autonomous devices that leverage inexpensive computing, networking, sensing and actuation capabilities in uniquely identified implementations to sense the physical world and act on it.[17] By extending the reach of the Internet and connecting human with things, new information and knowledge can be created to boost human intelligence, efficacy and productivity to enhance the quality of life.[18] Examples of IoT device types used prevalently in modern cities include wearable technology (e.g., health monitors), networked home appliances, IP security cameras, connected vehicles, environmental controls, and even smart light bulbs.[19] While widely used in both private and business sectors, IoT also finds its role in smart governance, such as street lighting, parking, water distribution management and waste management.[20] However, issues of confidentiality can become major concerns as IoT attempts to connect as much as possible[21], and the protection of privacy becomes critical when there are few clear laws that regulate how the data collected by IoT devices should be used and not be abused.[22]

2.3. Artificial intelligence and robotics

AI deals with the simulation of intelligent behaviour in computers, and encompasses multiple components, namely machine learning and deep learning.[23] Robotics and cognitive automation allow machines to replicate human actions and judgment, and potentially free people from manual tasks.[24] AI has been applied in various fields, including medicine, biology, the

service industry and government, and has powered many real-world applications, ranging from facial recognition to language translators.[25] Some governments have also adopted AI technologies to automate complex tasks and unlock previously hidden insights across the spectrum of government data. Meanwhile, some governments make advanced use of chat-bots in citizen services and of robotics in aging services centers. However, AI does not always deliver the intended benefits if not applied wisely. It may affect the morale and employability of low-wage workers' morale and henceforth increase unemployment.

2.4. Distributed ledger technology

A distributed ledger technology (DLT) is essentially an asset (financial, legal, physical or electronic) database that can be shared across a network of multiple sites, geographies or institutions. The security and accuracy of the assets stored in the ledger are maintained cryptographically through the use of 'keys' and signatures to control who can do what within the shared ledger.[26] Since information is secured using cryptography and a democratized network, blockchains serve as tools of disintermediation.[27] From its vanguard cryptocurrencies like Bitcoin, distributed ledger technology will boost innovation in fields like E-voting, smart contracts and online public services.[28] For example, citizens in Estonia use their ID cards to order medical prescriptions, vote, register their businesses and to access approximately 3 000 digital services. The approach also enables civil servants to encrypt documents, review and approve permits, contracts and applications, and submit information requests to other services.[29] However, there is also a critical concern related to the speed and effectiveness of blockchain networks, which execute peer-to-peer transactions at a high aggregate cost.[30] In addition, questions about the privacy and security of the data stored and accessible on the shared ledger also arise.[31]

2.5. Virtual, augmented and mixed-reality

Digital reality encompasses three technologies: virtual reality (VR), augmented reality (AR) and mixed reality (MR). VR creates an immersive digital environment that replaces the real-world environment. AR supplements the real world with additional information by overlaying them in see-through displays.[32] MR anchors pre-programmed virtual objects to the real environment and allows real-time interactions. Digital reality can seamlessly present digital data to humans in natural ways, providing the user with immersive experience and real-time interactivity. It helps users in processing critical information, visualizing scenarios, and improving decision-making and communications capacity[33], which can ultimately lead to increased productivity and improved efficacy.[34] VR has been used in public sectors in skill training for the military[35] and astronauts[36] by simulating relevant environments. In healthcare, VR can be used in cognitive behavior therapies to treat phobias and enhance mental health.[37] AR can also be effectively applied in education and tourism by highlighting the rich content around artefacts and ecological

phenomena.[38] AR is also used to enhance citizen engagement and e-services quality via government apps with AR features to inform citizens of important events and useful city information around them.[39] In addition, the use of ‘smart’ helmets for security officials is also a successful application. However, governments attempting to adopt digital reality technologies could face some technological hurdles. First, for real-time user interaction, VR/AR applications require immediate analysis results from a high-speed cloud with massive amount of data[40], which can be very costly and difficult to develop. Other major concerns involve issues related to cybersecurity and privacy.

2.6. Platforms, intelligent apps and other innovations

Intelligent apps are applications that use historical and real-time data from user interactions and other sources to make predictions and suggestions, delivering personalized and adaptive user experiences. Intelligent apps come into being when application development meets big data analytics, IoT and artificial intelligence.[41] It can continually learn from user interactions and other data sources to become even more relevant and useful.[42] Intelligent apps and platforms are already being used to make the correspondence and customer service of public institutions quicker and more effective, as well as less costly. In particular, they can support the process of digital payments and help manage information flows and reporting.[43] However, a significant hinderance for developing intelligent apps and platforms is a lack of internet infrastructure and technology, which may affect the development of e-government services[44] and broaden the digital gap.[45]

Other technologies and innovations can also be used in smart cities, such as the use of QR codes in fast payment, the use of GPS and geospatial technologies in transportation, the use of LiDAR (light + radar) to generate 3D models of the environment in building public housing, and the use of bio-printing in the healthcare field.

3. POLICY INTEGRATION IN SMART CITY DEVELOPMENT

Generally, the aim of smart cities is to provide core infrastructure and applications, as illustrated through the fundamentals and layers in section 2, and to give a decent quality of life to its inhabitants. It is a collective notion to build a clean and sustainable environment with application of “smart” solutions.[46] It is pertinent to note, however, that the development of smart cities is not just about the right technologies. More importantly, it is about the right policies. An integrated policy approach is key for smart cities to achieve the SDGs, especially Goal 11 on sustainable cities, Goal 16 on effective, inclusive and accountable institutions and the nexus context. Three dimensions of integrated approaches in deploying technology-related policies in smart cities are identified here, namely: horizontal integration, vertical integration and whole-of-society. (See Figure 2)

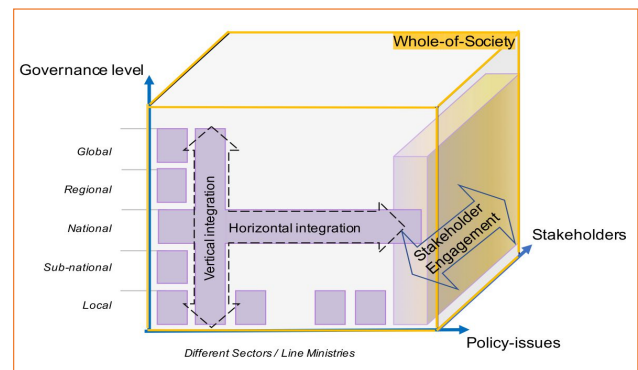


Figure 2: three dimensions of integrated approaches[47]

3.1. Horizontal Integration

Horizontal integration refers to internal integration across sectors or institutions[48], both at national and local levels. Horizontal integration needs cooperation and coordination among different agencies which could be carried out only through a whole-governance approach. More and more countries have issued policies and initiatives to promote horizontal integration and improve top-level architecture design to advance the development of smart cities. The Mayor of London established a London Office for Data Analytics (LODA) to coordinate data sharing at City Hall and across public services.[49] Singapore established internal corporate services and processes, and designs the whole-of-government infrastructure to enhance cross-agency collaboration[50] to pursue its Smart Nation Initiative.[51] Dubai has set up a dedicated agency, Dubai Data Establishment (DDE), to support the dissemination and exchange of high-priority data among government entities[52], and the position of Data Steward, who has the “custodianship” of data within departments.[53] Seoul establishes its smart administrations based on sharing and collaboration among divisions.[54]

Horizontal integration facilitates the construction of smart cities by reducing duplication of resources among agencies, improving service quality and enhancing collaborations in solving problems. However, horizontal integration still has a long way to go. In many governments, initiatives for connecting working processes among agencies maybe devised, but not effectively enacted. Many challenges for horizontal integration remain, including the potential for conflicts of interest between different government agencies. When it comes to sharing exclusive data and information, it is particularly difficult for different departments to forsake the protection of their ‘turf’ to try to cooperate genuinely on a “deliver-as-one” basis.

3.2. Vertical Integration

Vertical integration includes actions to create synergies and enhanced consistency across national and various local levels. Besides integration among different departments, smart cities’ development also requires coordination across different levels of local authorities to jointly formulate and implement strategies and policies. Vertical integration could promote a shared vision and

commitment in smart cities and efficient allocation of resources across national and local levels. For example, the Government of India embraces a vision of “100 smart cities” and has a competitive framework to advance a national urban development mission and to distribute funds to cities which develop more innovative and impactful proposals.[55]

However, challenges for achieving vertical integration are prevalent. In systems with high levels of centralization of authority and frequent episodes of centrally-imposed reform, building trust and effective working relationships take time.[56] Vertical integration efforts without coordination and structural guidance may result in cities chasing for the same model without due consideration for contextual needs and circumstances.[57] In countries with federal or centralized systems, challenges like imbalanced and unsustainable national policies, local resources and capacity constraints, limited incentives for local governments and information asymmetry have made vertical integration more difficult.

3.3. Whole-of-society

Stakeholders in smart cities include local authorities, utility companies, public and private contractors, businesses, entrepreneurs, citizens and civil society in general.[58] Smart cities’ development, therefore, also needs to include concerted whole-of-society efforts and requires a strong capability for forming and managing public-private partnerships to address risk, diversity, equity, financing and asset management.[59] Sharing data, information, capital sources and technology between the public and private sectors are all critical success factors.

Whole-of-society engagement could ensure that all initiatives are “people-centered”[60] and better reflect the needs and demands of the society. For example, open government partnerships in London bring public and private sectors together with the deliberate aim to make governments more open, inclusive and responsive.[61] Moreover, the private sector is generally at the forefront of developing new technologies and applications, and their engagement could induce the public sector to keep pace with the development of technologies.

There are many positive examples of integrated systems in schools, hospitals and transportation to overcome technical challenges through innovative and adaptive deployment of technologies. These range from beacons to help visually impaired people to find their way around in San Francisco, to the use of sensors in trash cans for more responsive and effective garbage collection in London. For latter, not only will the sensors be triggered when the garbage cans are full, but they are also able to predict when they will be full and suggest efficient driver collection routes in advance.[62]

However, it is usually difficult to promote partnerships between the public and private sectors if common interest is lacking. While private companies play important roles in offering new technologies, they may not attach high importance to research and development on new technologies, as this is often resource intensive and time consuming. Putting profits first, private companies are more likely to provide already-developed new technologies and services based on high demand and will

offer uncommon or untested solutions at high prices, while governments may be able to offer services more broadly and at lower costs. The difference in goals and standpoints has led to multi-faceted challenges in cooperation between the public and private sectors. To attract private companies to participate in developing smart cities, governments often need to provide tax cuts or grants, which also increase burdens for the public sector.

4. THE NEXUS OF SMART CITIES AND THE GLOBAL 2030 AGENDA

Today’s cities and tomorrow’s smart cities are intricately linked to the 2030 Agenda – across its 17 Goals, 169 targets and 232 global indicators, either explicitly or implicitly. Urban planning and development, by default, should include sustainable development across all sectoral areas and targets.

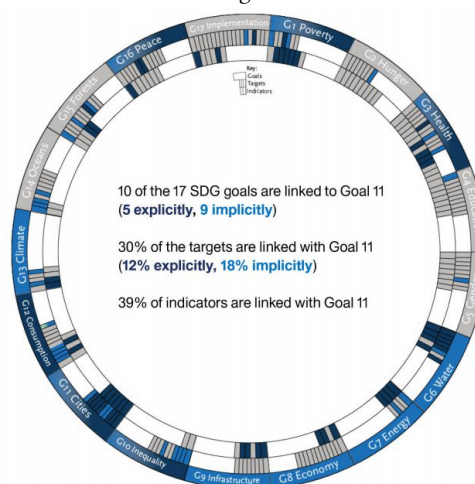


Figure 3: illustration showing the urban dimension of Agenda 2030 through explicit and implicit linkages between Goal 11 and other goals, targets and indicators[63]

The SDGs provide a definite guiding compass for urban development. Given the significance of urbanization, two Goals - namely, Goal 11 on sustainable cities and Goal 16 on effective, inclusive and accountable institutions - put the spotlight on the governance of smart cities, highlighting the need to make cities and human settlements inclusive, safe, resilient and sustainable. See figure 3 for an illustrative for the nexus relationship of Goal 11 on sustainable cities in relation to the 17 Goals.

The only way that smart cities’ development dynamics can be meaningfully understood is to simultaneously capture the driving and constraining forces at both lower (community and societal) levels and higher (global) scales. Thence, nexus analysis at a city level will have to pay attention to themes commonly associated with other scales and include the 2030 Agenda for Sustainable Development (global level), horizontal and vertical policy integration (whole-of-government, at the national level) and ecosystem (whole-of society level) approaches, as illustrated in figure 4.

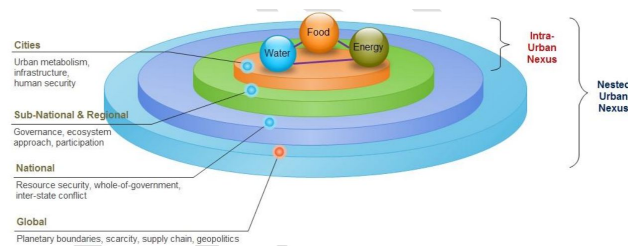


Figure 4: an illustration of Urban Nexus Perspectives[64]

For Goal 11, the connection with smart cities will be seen through the lens of its targets and indicators; whereas for Goal 16, the three key principles are expounded: effectiveness, inclusion and accountability. Other principles may also be explored, such as responsiveness and resilience (HLPF2018 theme) and equality (HLPF2019 theme, along with inclusion). Table 1 shows the list of targets as adopted by Member States of the UN in the 2030 Agenda.

Table 1: targets related to Goal 11 on sustainable cities

Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable
11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums
11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons
11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries
11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage
11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations
11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management
11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities
11.a Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning
11.b By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels
11.c Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials

4.1. Effectiveness

Smart cities add digital intelligence to existing urban systems, making it possible to do more with less. What does it mean for digital government to result in effectiveness of smart city development? Will effectiveness be at the expense of other core principles of the 2030 Agenda, including first and foremost, leaving no one behind? Are the challenges of existing urban slums, and the needs of disabled people and older people appropriately considered and taken care of?

In considering the effectiveness of smart cities, one should reasonably deduce that the contextual meaning of social equity in public administration is in the context of “fairness” in governmental action. Fairness is based on moral values and therefore different societies, institutions and individuals can have different understandings. While economy, efficiency, and effectiveness deal with the ‘how’ part of a government, equity deals with ‘for whom’ a government operates. In summary, one can deduce that social equity fundamentally is about creating a “level playing field” or equality of opportunity, and should always be considered alongside with effectiveness.[65]

4.2. Inclusion and leaving no one behind

The majority of world’s population will live in cities – and this increasingly dense population will bring social deficits and practical challenges around energy, health, and transportation, among other areas. Vulnerable groups, by their very nature, will always be at risk of further exclusion.

At the same time, local governments cannot build cities by themselves – the participation of civil society and the private sector is crucial. How can governments forge a dynamic partnership with the private and people sectors? What kinds of partnerships need to be created? What kind of capabilities and competencies should we build?

It is undeniably true that the implementation of new technologies in cities, whether in AI, robotics, genetics or geoengineering, to name but a few exciting current areas of rapid advancement, must be carefully considered and debated. With rapidly changing demographics, city planners cannot afford to put city dwellers in an unknown future without carefully exploring the deep implications – social, ethical or practical.

However, extreme poverty is also concentrated in urban spaces, and national and city governments struggle to accommodate the rising population in these areas. In 2018, 828 million people lived in slums, and the number is rising.[66] Making cities safe and sustainable means ensuring access to safe and affordable housing and upgrading slum settlements. It also involves investment in public transport, creating green public spaces, and improving urban planning and management in a way that is both participatory and inclusive.

In connection, considerations related to the broader social needs of vulnerable groups must be taken into account – both when designing ICTs for citizen engagement and for smart cities generally. For instance, success stories in related areas can be positively skewed, giving the example of mobile app research which often only provides analysis of the outcome data and ignores drop-out rates.[67] The choice to “focus on levels of engagement, interactivity and interest as a means of evaluating

the effectiveness” of apps is effective for determining the commercial success of an app, but not useful in considering those who are being left behind in particular the vulnerable population. Specifically, in connection to a study of a disadvantaged group of women’s use of a pregnancy health-app, it was noted that various factors including “social and mental health issues, financial constraints and technological ability can affect women’s engagement with a mobile phone app”.[68]

There are also challenges and opportunities facing disadvantaged older people in utilising ICTs, and the importance of design considerations should, therefore, not be undermined. This is particularly relevant for those with low literacy levels and physical impairments. In addition, the importance of training in the use of devices and technology is key, as one research demonstrated that significant improvements were made in measures such as life satisfaction, depression, loneliness and self-control when compared with a control group that did not receive the training.[69]

4.3. Accountability

Accounting for the generation of 80% of wealth worldwide, cities are facing huge global challenges: economic, demographic, social and environmental. Existing and new threats loom, ranging from the economic and social exclusion of marginalised groups, cybersecurity, data sabotage, data and personal privacy, and over-investment in technologies, among others.

In smart cities’ development, not only do local authorities need to be responsive to the needs of all strata of the population, they also need to be held accountable for the impacts of their work for the people. How can smart cities be of better account to its people, especially in budgeting and expenditure on new technologies? Can smart cities be corruption free?

Accountability mechanisms need to be inclusive and to engage all segments of the population.[70] The lack of responsiveness and accountability of government institutions towards certain individuals and groups leads to the potential non-engagement of these groups. This can lead to a backlash, including a lack of trust in public institutions and a negative perception of their legitimacy. Given particular social, political or other circumstances, it can even degenerate into various forms of alienation and social unrest. Hence, strengthening public accountability and national human rights institutions and ensuring effective enforcement of civil rights and liberties for all, including the poorest and most vulnerable, in keeping with the SDGs, is critical to tackling inequality.[71]

The value of technology-enabled services is increased when people give their feedback -- helping to identify obstacles, calling attention to remaining gaps, and responding to needs. People and non-governmental organizations can objectively report on the realities of the services they access. It is important that the criteria and indicators based on which governments and public servants are held accountable reflect the concern for poverty eradication.

5. MEASURING SMART CITIES FOR SUSTAINABLE DEVELOPMENT

The paradigm shift towards sustainable development brought economic development, environmental protection and social equity to the center of urban development. In reality, the demographic shifts affecting the motivations of decision-makers has been largely shaped by economic reasons, which have essentially led cities to become more competitive. Since the 1980s, there has been pressure on local governments to become more efficient and competitive in order to remain viable.[72] Cities do not compete with one another like countries or corporates, but they do compete for mobile investment, population, tourism and public funds.[73]

With the growing trends of urban development, today’s city rankings and indices are embraced largely by national and local governments. While the methods and effectiveness of these global and regional indices to grasp the reality is still being questioned[74], this has become another promotion strategy for cities to attract people and investors.

Within the scope of this section, several indices that measure smart cities are investigated with regard to determined goals. It should be noted that there are numerous indices that exist but only five are selected for this research, with the criteria of (i) indices that have been generated or updated since 2016; (ii) indicators that are listed for each index and their correspondence with SDG 11 and SDG 16 are evaluated. Ultimately, five indices that are included are as follows:

- 1) United Nations E-Government Survey (Chapter 7), 2018[75],
- 2) Global Smart City Performance Index, 2017[76],
- 3) IESE Cities in Motion Index, 2018[77],
- 4) Sustainable Cities Mobility Index, 2017[78], and
- 5) Smart Cities Index, 2017[79]

5.1. Metrics of smart cities in selected principles of Goal 16

The correspondence of the indices with three main principles of SDG16 are next investigated. To this end, the basic principles of responsive and effective governance for sustainable development were identified[80] as effectiveness, accountability and inclusiveness. Results are presented in Table 2 below, which illustrates the relationship between these principles and indicators.

Table 2: indices’ correspondence to relevant principles of Goal 16 on effective, accountable and inclusive institutions

	Effectiveness	Accountability	Inclusiveness
UN E-Government Survey (Chapter 7), 2018	• Information about municipality partnerships with third parties	• Budget related information • Open data policy • Open data provision	• Participatory budgeting • Participatory land use plan • Announcement of upcoming e-participation activities

Smart Cities Index, 2017	N/A	• Digitalization of Government	• Citizen Participation
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Findings reveal that only two of the indices included indicators to measure effective governance. The main pillars of this principle – competence, sound policymaking and collaboration – were addressed by the Global Smart City Performance Index and the UN E-Government Survey. On the other hand, the inclusiveness principle was identified by non-discrimination, participation, subsidiarity, intergenerational equity and leaving no one behind and this principle was observed in all of the indices.

The focus of the 2018 edition of the UN E-Government Survey was on digital governance at the urban scale and investigates the ways to improve resilience and sustainability. The result of this research revealed that the indicators used for the UN E-Government Survey comprehensively measure the participation aspect of SDG11. Nevertheless, other aspects under the same goal and other goals were not covered by the Survey. When the compatibility of the survey with the principles of SDG16 is investigated, the success of the survey could be expressed despite its specific focus on resilience. In fact, the UN E-Government Survey was the only index to cover all three principles.

5.2. Metrics of smart cities in selected areas of urban sustainable development

SDG11 focuses on actions to make cities and human settlements inclusive, safe, resilient and sustainable. Starting from this point, five areas are identified with regard to goals and indicators respectively: Urban Slums, Transportation, Participation, Disaster Risk Management and Air Quality and Risk Management. Table 3 illustrates how each matrix corresponds to SDG 11, by listing the indicators under five categories. Categories without any indicators are labelled as N/A (Not Available).

Table 3: indices' correspondence to Sustainable Development Goal 11's targets and indicators

	Urban Slums	Transportation	Participation	Disaster Risk Management	Air Quality and Waste Management
UN E-Government Survey 2018	N/A	N/A	• Real time communication • Feedback / complaint submission • Online deliberation processes • Social networking features • Reporting of occurrences in public spaces • Participatory budgeting • Participatory land use plan • Announcement of upcoming e-participation activities • Feedback about consultation processes	N/A	N/A
Global Smart City Performance Index, 2017	N/A	• Road Accident Injuries per Capita • Public Transport Journeys per Capita • Strategy to increase public transport use • Road safety strategy • Smart Street Lighting	• City Governance	• Disaster Plan • Emergency services response co-ordination	• Air Quality
IESE Cities in Motion Index, 2018	N/A	• Traffic Inefficiency Index • Bike Sharing • Metro length • Metro Stations • Bicycles for rent	• Open data platform • E-Government Development Index • Democracy	N/A	• CO2 emissions • CO2 emission index • Methane emissions • PM2.5 • PM10 • Pollution • Environmental Performance Index • Solid Waste
Sustainable Cities Mobility Index, 2017	N/A	• Access to Transport Services • Modal Split of Trips Taken • Rider Connectivity • Upkeep of the Metro System • Wheelchair Access • Uptake of the Active Commuting • Transport Applications and Digital Capabilities • Hours of Metro Accessibility • Bicycle Infrastructure • Affordability of Public Transport • Utilization of the Transport System • Public Transport	N/A	N/A	• Air Pollution • Transport Greenhouse Gas Emissions
Smart Cities Index, 2017	N/A	N/A	• Citizen Participation • Digitalization of Government	N/A	• Environment Protection • Waste Disposal
			• Municipality responsiveness to e-mails		• Feedback about consultation processes
Global Smart City Performance Index, 2017	• Public-Private Partnership Incentives • Smart City Hackathons		N/A		• City Governance
IESE Cities in Motion Index, 2018	N/A		• Corruption perceptions • Open data platform		• GINI Index • Female workers • Government response to situations of slavery • E-Government Development Index • Future Climate
Sustainable Cities Mobility Index, 2017	N/A		N/A		• Wheelchair Access

As it can be observed, none of the indices included an indicator to address urban slums. Even though upgrading slums to make way for smart cities is a highly recognized issue around the world[81,82,83], indices that rank cities according to their smart city initiatives seem to be inadequate in measuring the progress in this area.

As the frequency of man-made and natural disasters has increased and such incidents have potential to cause severe destruction in urban areas, disaster risk management and emergency response systems have gained importance in urban planning.[84,85] However, the majority of indices do not have indicators on disaster risk management. The Global Smart City Performance index included considerations of disaster plan and emergency services response co-ordination in its approach to measure initiatives for improving public safety. It can be asserted that indices include indicators to track transportation, participation, air quality and waste management categories.

6. DISCUSSION AND POLICY OPTIONS

6.1. Integrated approach

Integrated approaches are needed for governments in developing smart cities for sustainable development. Generally, policy-makers should put emphasis on the three dimensions of integration - horizontal, vertical and whole-of-society integration - in designing smart cities and engaging participants. Mechanisms should be formulated to encourage the sharing of goals, practices and replicable solutions across different agencies and institutions, national and local governments, and the public and private sectors. Integrated approaches can avoid resources waste, create incentives for all participants and provide more efficient and effective implementation circumstances, leading to sustainable and prosperous smart cities. However, despite the potential benefits, integrated approaches in developing smart cities are also faced with challenges, such as lack of coordination mechanisms, resource constraints and shortage of incentives, which need to be addressed accordingly.

There is increasing practical evidence and possible approaches for improving ownership of SDGs through the involvement of local urban stakeholders, such as city mayors, administrations, urban networks and non-state actors (including NGOs, business, academia, etc.) in the policy recommendations of the New Urban agenda.[86] The role and responsibilities of local actors should be recognized for their indispensable contribution to achieving all the 17 Goals and be commensurate with appropriate resources.

6.2. Deployment of platforms and technologies

New technologies in smart cities have developed rapidly, been spread and applied to almost every aspect of human life. In particular, they have found their way into the public sector to make the governance “smarter”. Big data analytics, sensor technologies and IoT, machine learning and cognitive computing can enable governments to better understand citizen needs and provide solutions.[87] Due to the use of new technologies, governments have improved their efficiency, citizens have enjoyed better services, and cities have become smarter.

However, new technologies may also cause problems that cannot be ignored. First, information asymmetry might become even more severe and digital divides might be further widened. Second, the high costs of developing and applying new technologies, a lack of appropriate infrastructure and legal frameworks, and concerns on security and privacy also constitute serious challenges for governments to adopt new technologies in smart cities. Some pivotal recommendations can be offered to governments and international organizations regarding the potential challenges posed by new technologies in developing smart cities.

6.3. Regulation measures

Policy makers need to carry out multi-dimensional and integrated regulations to protect data security and privacy issues triggered by emerging technologies. New technologies tend to actively collect and analyze data on users' activities and movements[88],

which can be exploited by attackers to infer private information that could lead to discriminatory treatment.[89] Policy makers should take serious measures to deal with the issue of user data acquisition, and regulate processes related to data usage by new technologies.

6.4. Infrastructure construction

In order to build a well-functioning smart city, countries need to strengthen investments in developing technological infrastructure, and to further connect technologies and tools to create an open platform that brings governments, citizens and innovative companies together.[90] To attract stakeholders' participation, respected global and local networked institutions could convene and launch stronger advocacy for new inventions.[91] Policy makers should also pay attention to people who remain offline and make efforts to bridge digital divides and ensure that no one is left behind in taking advantage of opportunities with new technologies.

6.5. Financial support

Since new inventions require arduous and long-lasting commitment in terms of time, money and other resources, private sectors often lack economic incentives to exert themselves to develop new technologies. Governments could provide favorable tax credits for business and subsidies for the research, development and manufacture of new technologies and services alike. It's also worth mentioning that a Public-Private Partnership model can be very conducive in better delivering essential financial support.

6.6. Human capacity building

To address the urgent need for diverse talent and expertise in the ecosystem, policy makers should encourage and support universities to offer technological courses on big data, blockchain and AI, as well as strategic courses. Besides, massive open online courses (MOOC) could be developed and provided for public consumption.[92] What's more, as new technologies change the job market and the way employees do their work, governments need to arrange training programs for workers to upgrade their skills and help them to survive in the new technology era.

7. CONCLUSION

Results of this research reveal some gaps between the Sustainable Development Goals and investigated indices. However, this does not necessarily mean that cities that make progress towards smartness lack in these areas. Our findings rather underline the incomplete picture of relevant dimensions of smart development provided by such indices. To eliminate the shortfalls of future methods and tools on urban slums, disaster risk management and effectiveness of the governments, the relevance of these aspects should be discussed with respect to demographic, social, environmental and economic trends. International city networks that provide consultancy services to local governments have the potential to initiate integrating these lacking points to the framework of smart growth and sustainability.

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