LEVERAGING DIGITAL TECHNOLOGY AND DATA FOR HUMAN-CENTRIC SMART CITIES

THE CASE OF SMART MOBILITY

Report for the G20 Digital Economy Task Force

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Introductory note:

Mobility services and technologies feature prominently in smart city and community programmes, policies and actions. For this reason, the G20 Digital Economy Task Force under the Saudi G20 Presidency initiated work to outline a set of Smart Mobility Practices to help frame and facilitate the uptake of smart mobility. This document forms the technical background report to the G20 Smart Mobility Practices.

This report is broken down into four main sections. The first is a broad discussion situating smart mobility within the broader context of smart city and community approaches. The second section looks more specifically at smart mobility and outlines opportunities, tensions and principles that may help frame and facilitate smart mobility policies. The third section focuses on issues relating to technology and data governance and the frameworks that enable these to occur in a people-centric and pro-innovation way. Finally, the fourth section is comprised of a summary of DETF members' and guests' responses to a Survey on Smart Mobility initiated by the Saudi G20 Presidency.

A. Executive summary

Smart cities and communities

The terms “Smart cities” and “smart communities” evoke communities leveraging technologies – digital technologies in particular -- to boost citizen well-being and deliver more efficient, sustainable and inclusive environments as part of a collaborative, multi-stakeholder process. They are at the heart of many national, regional, and local policies and plans and mobilise both private and public sector research and investments. Their use indicates a belief that the considered application of technology can solve many persistent challenges related to the provision of services to people living in cities and communities. In many countries and communities, mobility has been the focus of ongoing smart city and community initiatives, both within the public sector and by the private sector.

However, the term “smart” remains nebulous, is rarely articulated in a consistent way, and its use in conjunction with the terms “cities”, “communities” or “mobility” often hides assumptions that are essential to understand how “smartness” aligns with public policy outcomes. The usage of the term “smart” often conflates notions of “how” with those of “what for” – e.g. the tools to be used and not what people and communities may wish to gain from the use of those tools.

While digital innovation remains central to the smart city concept, a key question is whether investment in smart technologies and digital innovations ultimately contribute to improving people’s well-being of and fostering inclusive growth. Smart city initiatives may inadvertently deepen inequalities when they lack transparency and fail to integrate community members and/or do not take into account the diverse needs of people. The use of “smart city” initiatives to advance equity and inclusion requires different shifts, including a shift from technology-centric to human-centric smart city initiatives. A smart city or community is one that is an accessible city that enables all its people high quality of life by leveraging technology and the services it enables, and by enhancing social inclusion and governance processes in line with people’s expectations.

Smart mobility

Smart mobility is one of the key components of smart city policies. Smart mobility builds on the concept of Intelligent Transport Systems (ITS), which focuses on intermeshing digital technologies amongst devices, vehicles, and infrastructure for better traffic management. The concept of Smart Mobility expands on ITS to include communicative assets (vehicles, infrastructure and other objects), mobility data platforms and shared mobility services. Taken altogether, the various intermeshed components of smart mobility have the potential to improve mobility outcomes and reduce negative externalities related to transport activity.

As with smart cities, smart mobility connotes the beneficial application of (mainly digital) technologies to improve mobility outcomes. Smart mobility is:

- *Instrumented*: sensors provide state, location and proximity awareness for portable devices, vehicles and infrastructure.
- *Computative*: data produced by sensors is processed in-sensor (e.g. edge computing), in a processing unit close to the point of sensing (e.g. on-board driving computers) or remotely (e.g. cloud applications).
- *Connective*: both data and processing outputs are shared between vehicles, mobile devices and infrastructure using various communication protocols and technologies, and

- *Reactive*: systems automatically react to changes of state via processor outputs with little or no human input (e.g. ABS braking, speed control via geofencing).

Smart mobility thus leverages multiple levels of technological innovation which in turn leverage innovative services and use cases (on-demand van services, dynamic parking charges or robo-taxis). Smart mobility promises a virtuous cycle of technological innovation, new services, and improved outcomes for people … but it does not guarantee these.

Smart mobility technologies and services act in many broad domains – they may assist or replace driving (automated cars), enable better en-route navigation for travellers (congestion-aware navigation apps), facilitate better traffic system management (traffic control centres), enable better use of transport assets (shared micro mobility and ride-hailing), improve the use of scarce public space (dynamic parking control and curb access management), facilitate energy management (smart charging infrastructure) or catalyse seamless use of multiple transport services (Mobility as a service, smart ticketing technologies).

Across all of these domains, smart mobility solutions have the potential to deliver benefits in the form of:

- Improvements in travel time
- Changes in the quality of travel time
- Safety improvements
- More efficient use of capacity (roads and vehicles):
- Reduced environmental impacts:
- Lower travel costs
- More equitable accessibility outcomes

Realising these benefits is not, however, straightforward. A number of complicating factors and feedback loops come into play, which may thwart, diminish, or even lead to overall losses. Addressing and managing these factors is central to smart mobility policies. These challenges include the following:

- Re-bound effects may generate additional travel, which may erode many potential benefits
- Smart mobility can improve equity outcomes, but it can also diminish them
- There is uncertainty and lack of robust evidence on impacts, on safety, for example
- Benefits from smart mobility may not scale well
- Tensions exist surrounding the privacy impacts of smart mobility data
- Conflicts and frictions arise from asymmetric data production and access
- Traditional regulatory tools and processes may not be adapted to new technologies and services

Governance of smart mobility

Smart mobility leverages technology, new use cases, and data to deliver benefits. Each of these requires an adapted regulatory framework that enables innovation without hindering other desired societal outcomes – like equity, safety, flexibility or efficiency. These should be interlinked where possible and the overall regulatory framework should be transparent, agile when required, and clearly linked to over-arching public policy objectives. This does not mean that governments necessarily need to regulate all outcomes – private sector actions may be guided by tools other than direct regulation – like voluntary agreements or contractual/concessionary agreements. Nor does it mean that public authorities must regulate everything that is new – an appropriate response to smart mobility deployments may be to remove existing regulation where it is no longer warranted or to adapt it. Finally, regulation of innovation requires flexibility. Beyond ensuring necessary guiderails with respect to safety, environment, and

competitive markets, smart mobility regulation should be iterative and flexible in order to account for many unknowns around the uptake and impact of technologies and services.

There may be a general tendency to address the regulation of smart mobility only from the perspective of the current regulatory framework. This approach also extends to the methods and practices that regulatory agencies employ to deliver on their mandate to protect public welfare, ensure competitive markets and avoid harms. Regulatory agencies will need to be innovative in the way they carry out their functions because many of the impacts of smart mobility initiatives are hard to know and there is little prior knowledge to help evaluate the scope and scale of these impacts.

There is a risk that regulators will either act too soon, too late, too permissively, or too restrictively with respect to smart mobility initiatives. To minimise these risks, they will need to adapt the way in which they regulate under uncertainty. A prudent approach to regulating smart mobility would combine risk-weighted, outcome-based and collaborative regulation, adaptive and flexible regulatory responses, and regulatory sandboxes and accelerators.

The role of data

Data is central to smart mobility and managing and sharing data wisely is central to ensuring broad mobility benefits. From an operational perspective, there is a need to ensure that the integrity of data is maintained to ensure ticketing, payment, and robust identification and related access rights. From a public policy perspective, this data can be useful for monitoring compliance with, and enacting enforcement of, rules related to safety, regulated uses of public space, and other public policy outcomes (e.g. competitive markets). This data can also be useful for planning purposes, helping authorities improve efficiency, equity, sustainability (including the reduction of environmental impacts), and contribute to the welfare of people.

The governance of data-sharing must address these overlapping purposes and needs as well as the capacity of stakeholders to abide by data sharing rules. Where there is public value in doing so, authorities may foster frameworks that enable targeted data-sharing that respects privacy, operational needs and commercial sensitivities of both people and companies, while guaranteeing its cyber-resilience.

Data sharing mandates on the part of public authorities should build in data minimisation concerns by default. These frameworks should link desired public policy outcomes (e.g., improved accessibility, better environmental outcomes, improved equity, improved safety, reduced congestion, liveable cities, etc.) to the regulatory and planning methods or use cases which may deliver those outcomes (e.g. congestion management, parking control, managing curb and other public space access, enforcement actions, travel activity monitoring, data to support infrastructure interventions, etc.). Outcomes and methods should then be linked to the specific data required to carry out those regulatory and planning actions – including rules relating to an appropriate level of aggregation, data handling, data retention periods and auditability, as well as data destruction protocols.

Accounting for automated decision-making systems

The increased uptake of automated and algorithmic decision-making systems, many of which support smart mobility, poses different and novel challenges that go beyond the scope of current public governance frameworks. At the same time, the full extent and type of changes in governance that may be required are still unknown. Transport authorities and those involved in mobility planning, could start

envisaging a more algorithmic future and assess how this may impact their conception and delivery of public governance.

Public authorities will have to evaluate if their institutions and working methods are adapted to potential algorithmic risks and, if not, may consider reshaping themselves for a more algorithmic world. This will potentially require bringing in, and retaining, staff with new skill sets and training existing staff to become more code-literate. Public authorities could also consider undertaking impact assessments regarding those algorithmic systems that could have a consequential effect on regulated outcomes or within the public domain.

Smart mobility and security risks

As with other digitally based systems, smart mobility systems may incorporate certain cyber risks. These may pertain to data breaches and data misuse or may relate to the cyber-security of the smart mobility technologies and systems themselves. These risks are important because they may lead not only to annoyance, as systems are diverted from their intended use, but can also lead to real harms, both moral (cyber-theft) and physical. The potential for these harms to be realised is heightened both by the development and diffusion of tools and techniques that can be employed in support of cyber-attacks as well as by the multiplication of potential attack surfaces – especially when different cyber-physical systems are connected. Going forward, the safety and security of smart mobility systems will rest not only on the combined safety performance of component hardware and software elements. It will also depend on how robust these systems are to malevolent attacks – especially when the design of connected systems may create new systemic cybersecurity-related vulnerabilities.

Country practice

Countries and sub-national governments have deployed many smart city and smart mobility programs. Many of these are highlighted in the responses of DETF members and guests to the Survey on Smart Mobility initiated by the G20 Saudi Presidency. Survey responses indicate robust engagement with smart city and community initiatives and the deployment of many smart mobility projects. They also indicate the need for a compelling set of principles to guide action and to help overcome several confounding factors relating to smart mobility deployment. These include:

- Challenges to scaling smart mobility practices
- Conflicting roles among stakeholders
- Insufficient or inconsistent coordination among stakeholders
- Lack of international standards for the deployment of smart mobility technologies

B. Smart communities and Cities -- Context setting

BOX: Note on the scope of the term "Smart City"

This technical report addresses the linkages between digitally enabled technologies and communities. The term "Smart Cities" generally encompasses this relationship. In the context of the present report "Smart Cities" should be seen as descriptive of these linkages – whatever the size of the community under consideration. Smart city technologies, systems and governance frameworks can be applicable to large cities, towns, and rural communities.

B.1. Defining "Smart" and "Smart cities"

The terms "Smart cities" and "smart communities" evoke communities leveraging technologies – digital technologies in particular -- to boost citizen well-being and deliver more efficient, sustainable, and inclusive environments as part of a collaborative, multi-stakeholder process. They are at the heart of many national, regional, and local policies and plans and mobilise both private and public sector research and investments. Their use indicates a belief that the considered application of technology can solve many persistent challenges related to the provision of services to people living in cities and communities.

The set of technologies that underpin smart communities has evolved since early urban dynamics systems developed in the 1960s and now encompass a broad range of advanced sensing, distributed computing, and communication capabilities, which, along with algorithmic and self-adjusting code, enables unparalleled services. Smart systems combine state- and location-awareness, code-enabled adaptive decision-making and ubiquitous connectivity to react more rapidly and more efficiently to changing conditions. For example, by using digital technology cities can take samples of bodies of water, analyse them, and send real-time information on pollution levels, as in Chennai, India; by using smartphones and messaging applications city residents can access services, notifications, and digital documents, as in Buenos Aires, Argentina; or adapting traffic signal timings to traffic flow, as in numerous cities, or adjusting prices for ride-sourcing services or tolls based on real time scarcity of available drivers or demand, as do many operators and infrastructure managers.

However, the term "smart" remains nebulous, is rarely articulated in a consistent way, and its use in conjunction with the terms "cities", "communities" or specific domains of city or community services, such as mobility, health, waste, farming, to name a few, often hides assumptions that are essential to understand how "smartness" aligns with public policy outcomes. Furthermore, while much of the discourse around "smart" digital solutions infers gains in *efficiency*, *what* is being made efficient, *for whom* it is becoming efficient, and *how* the answers to these questions are being elucidated are rarely expressly addressed.

Technology and communities are inextricably linked – the former aid the latter, the latter guide, deploy and/or benefit from the former. The element of "smartness" is largely descriptive and relates to how technology operates. The terms "cities", "communities" and, in the context of the present report, "mobility" all describe fora and outcomes where the purposes for which technology is applied are decided and agreed. Understanding both the tool and its potential application are at the heart of smart community and smart mobility policymaking.

Communities of all sizes are complex ecosystems that contribute to economic prosperity within their respective regions and nations. They concentrate capital and opportunity in a way that has proven resilient even in the context of a gradually de-materialised economy (Glaeser, 2015). If "smart" should be understood as a system's capacity to self-monitor, assess, and adjust to changing information (Halegoua, 2020), then cities and communities have historically displayed "smart" behaviour in that they have proven

adaptable to changing conditions and are able to leverage new opportunities. They do so by facilitating contact, access, and a certain serendipity that gives rise to new ideas and economic opportunities.

Larger communities are also those that compound some of the negative aspects of crowding and density – including congestion, sub-standard living conditions, crime, and inequity. Technology development in cities – from sanitation, to lighting and power, to mobility – has often sought to mitigate these negative outcomes while maximising the positive. Smaller communities face their own challenges – many relating to access to economic opportunity, and, more broadly, relating to equitable access. In both contexts, the deployment of new "smart" technologies continues the tradition of applying up-to-date technologies to civic challenges.

At the outset, "smart" or "intelligent" technologies – mainly leveraging digitalisation, distributed computing, and connectivity -- were deployed in urban ecosystems to monitor and bring order to heterogeneous and slightly chaotic urban environments. Their scope of application and action was often narrowly defined and problem-oriented. Urban challenges, however, are rarely isolated and are deeply linked to a broad range of other phenomena – acting on transport efficiency alone, for example, may do little to address inequitable access to housing and, in some cases, may even exacerbate it – as evidenced by the construction of urban motorways (Semuels, 2016). Early efforts to deploy smart city systems often failed to deliver desired outcomes either because they did not account for the way in which heterogeneity and spontaneity delivered benefits that underpinned urban prosperity – and therefore should not be "designed" out – or because they failed to adequately capture the complexity of human settlements. They also failed because they often included a too-narrow framing of what outcomes "smart" technologies should be delivering to people and communities. In short, they focused on the tools to be used and not on what people and communities may wish to gain from the use of those tools (Halegoua, 2020; Green, 2019). There is a fundamental difference between what "smart" *is* and what "smart" *does*.

In other words, "[t]he smartness of a city is (…) not about technology as such, but rather about how technology is used, as part of a wider approach, to help the city function effectively, both in its individual systems, and as a whole" (BSI, 2015, p. 6). The introduction of digital technology on its own does not strengthen local economies and democratic participation, foster inclusion, or improve quality of life. Cities must not only *use* digital technologies, but also *design* and *manage* them to achieve their own particular objectives (German Government, 2019). The usage of the term "smart" often conflates notions of "how" with those of "what for". The former are technological in nature and are often guided by industry actors, whereas the latter are political and social in their construction, and thus are the domain of public authorities and the mandates given to them by people.

Even though definitions of a "smart city" vary from one place to another, in most cases, smart cities have been defined as initiatives or approaches that use digital innovation (including digitally enabled innovation) to improve competitiveness in a community and efficiency of urban services (OECD, 2019). Such initiatives have the potential to expand access to public services, contribute to economic growth, and build more liveable environments. For example, data platforms and cloud-based systems enable cities to gather data and make data-driven decisions (O'Dell, Newman, Huang, & Van Hollen, 2019); digital connectivity allows people to access information, provide feedback, and connect with each other; and sensors built into smartphones and other digital devices allow city policy-makers to access an increasingly detailed, real-time picture of what is happening in the city (BSI, 2015). Succinctly put, smart cities and communities are "places where information technology is wielded to address problems" (Townsend, 2013).

This can be observed in the cities' definition of what a smart city is. For example, in the case of the City of Portland (USA), a smart city is "… the use of existing and innovative technologies, data collection and data management tools to enhance community engagement, improve delivery of public services, and address

City goals around equity, mobility, affordability, sustainability, community health and safety, workforce development, and resiliency" (City of Portland, 2018). For the city of Canterbury-Bankstown, Australia, smart city is the use of technology, community engagement and connectivity to make the city evolve and make real improvements (Canterbury-Bankstown City, 2018). For the city of Tokyo, Japan, a smart city is a vibrant city that keeps growing, a city open to the world, a city leading the world in environmental policies, and a global financial and economic center (Tokyo Metropolitan Government, 2016). The United Nations' New Urban Agenda, adopted in 2016 during the United Nations Conference on Housing and Sustainable Urban Development (Habitat III), also commits to "… adopt[ing] a smart city approach, which makes use of opportunities from digitalisation, clean energy and technologies, as well as innovative transport technologies, thus providing options for inhabitants to make more environmentally friendly choices and boost sustainable economic growth and enabling cities to improve their service delivery" (Un-Habitat, 2016, p. 19).

B.2. Smart cities and inclusive growth

Harnessing the benefits of digitalisation in cities is critical to deliver growth and wellbeing across economies and societies (OECD, 2019). Research suggests that over the next two decades, cities around the world will spend USD 41 trillion on technological applications (Stern & MacDonald, 2019). However, there might be a risk that the rapid integration of technology in all aspects of urban governance without a coherent and thoughtful approach may exacerbate cities' inequalities (Abare, 2019).

While digital innovation remains central to the smart city concept, a key question is whether investment in smart technologies and digital innovations ultimately contribute to improving people's well-being and fostering inclusive growth. The push for deploying digital technologies and promoting the concept of smart cities has, at the outset, largely been the purview of technology providers advancing a top-down, technologically deterministic view of how cities and digital technology could interact and provide value to people (Kitchen, 2014; Hollands, 2008). This approach mirrors other pathways for technology development within and for communities, but it does not guarantee that people's views are represented, or are accurately represented, in smart city initiatives and policy (Yigitcanlar et al, 2018).

Smart city initiatives may inadvertently deepen inequalities when they lack transparency and fail to integrate community members and/or do not take into account the diverse needs of people. In some cases, smart city projects have been criticised for benefitting only the high-income residents and areas of a city (Davies, 2018). City and community leaders need to ensure that smart city initiatives do not reinforce or worsen society's existing inequalities. For instance, access to ICTs is growing but remains unequally distributed across OECD countries and among firms and social groups (OECD, 2017). In particular, the elderly and the less educated are lagging behind the most.

Even in large cities, access to more sophisticated mobile internet usage, such as online purchasing or banking, is more prominent among individuals who are younger and have higher education levels and income. Similarly, while in some cities taxes can be paid using online platforms, some people still need to do so in banks or in government offices. People without access to electricity and internet cannot benefit from high-tech infrastructure developments. Low-income households and governments without resources to invest in technology or adequate capacity can easily miss out on the benefits offered by smart city initiatives.

This is why the OECD Programme on Smart Cities and Inclusive Growth defines smart cities as "initiatives or approaches that effectively leverage digitalisation to boost citizen well-being and deliver more efficient, sustainable and inclusive environments as part of a collaborative, multi-stakeholder process" (OECD,

2018, p. 10). The use of "smart city" initiatives to advance equity and inclusion requires different shifts, including a shift from *technology*-centric to *citizen*-centric smart city initiatives.

It has been argued that a smart city is the one that is an accessible city that enables all its people high quality of life (Smart Cities World). Research suggests that focusing on the needs and preferences of people and not only on the capabilities of connected infrastructure is essential to ensure inclusive smart city solutions (O'Dell, Newman, Huang, & Van Hollen, 2019). In some cases, governments invite people to co-create solutions to local problems by providing them with resources, skills and knowledge (Castelnovo, 2016; O'Dell, Newman, Huang, & Van Hollen, 2019). People's role in smart cities is seen as a fundamental underpinning of smart city initiatives besides smart economy, smart mobility, smart environment, smart governance, and smart living (Castelnovo, 2016). For example, in New Zealand, government and citizens co-produce solutions to improve data reporting from businesses; and in Helsinki (Finland), the city administration, private sector organisations, and other stakeholders are co-producing an initiative to make support services for businesses more efficient and user friendly (OECD, 2011).

B.3. How do countries approach smart cities?

Smart cities benefit from a national guiding policy framework

In general, a national policy framework can facilitate the adoption of smart city initiatives at the local level. This could be an explicit smart city policy, or an implicit objective immersed in a broader policy. In those countries where this is in place, the smart cities national framework (SCNF) would normally include a vision for the cities and a plan to maximise their potential through the use of technologies. The framework may also incorporate a diagnostic on how the national government understands the challenges, a division of responsibilities across all levels of government to contribute to the development of cities, and opportunities of cities and how government action could promote investment and growth. The aim is to ensure co-ordinated action and approaches across levels of government for public investment at the city level. Even when there is not an established national smart cities and communities framework, the national government can play a role by providing resources or other kind of support to regional and local governments and their stakeholders.

The smart cities national framework is generally designed to include cities of all size not just capital cities or the larger metropolitan areas. However, some national frameworks focus on a selected group of cities. Italy's smart city national policy focuses on 13 core cities that are actually introducing 5G facilities in partnership with 13 smaller towns. These cities are then asked to identify challenges in three areas: mobility, cultural heritage, and well-being, and then they are able to access a large portfolio of support services. Overall, the national policy framework guides the development of cities to improve their competitiveness, safety conditions, and the efficiency of the urban governance system via the digitalisation of local services and infrastructure. In the Russian Federation, for instance, the 'Digitalization of Municipal Services – Smart City' project aims to improve the economic efficiency of cities by upgrading urban infrastructure via digital and engineering solutions.

At the supranational level, in 2014, the EU Commission approved the 'Europe 2020' strategy to advance smart, sustainable, and inclusive growth by developing, among other measures, the development of Smart Cities throughout Europe and to invest in the necessary ICT infrastructure and human and social capital development (European Commission, 2014).

Some countries do not have any explicit national policy framework for smart cities, but smart city considerations are included in different plans and programmes. In Canada, for example, the Investing in Canada Plan includes the Smart Cities Challenge, which is a pan-Canadian competition open to all sub-

national level governments, including indigenous communities, to adopt a smart cities approach to improve lives of their residents through innovation, data, and connected technology. In the United Sates, smart city and community efforts and activities are a component of a broader digital economy strategy which includes pro-growth, innovation-friendly policies that support a digital economy and pave the way for technological innovation.

To achieve smart city goals, countries need to leverage complementarities and co-ordination with other national policies. Building synergies and avoiding duplicating efforts to ensure better efficiency and effectiveness is key in the implementation of smart cities strategies, as smart city goals cut across different domains. For instance, in the Russian Federation, the project on the Digitalization of Municipal Services – Smart City is co-ordinated with the goals, objectives and activities of the housing and urban environment policies, as well as with the National Programme on Digital Economy of the Russian Federation and the Transport Strategy.

Smart city policies may also be an input for broader national strategic plans or development programmes. In Saudi Arabia, the smart city strategy is a key contributor to the Saudi Vision 2030 and the National Transformation Programme. In China, the Guidance on Promoting Healthy Development of Smart City is a contribution to the National Plan on New Urbanisation 2014-2020. In Brazil, the National Strategy for Smart Sustainable Cities, currently under development, is expected to be closely co-ordinated with the National Digital Transformation Strategy.

The smart city policy framework may also contemplate reforms to the regulatory framework to facilitate investment for urban development. For instance, reforms may include aligning transport and metropolitan level planning strategies to ensure coherence for investment, improving regional coordination by establishing administrative bodies responsible for coordinating planning across municipal-level governments in a metropolitan area, and assessing how can environmental concerns permeate all planning process. In the experience of Australia, the smart city policy framework provides the foundation for ongoing reform and co-operation by guiding the action across various portfolios and outline investments commitments (Australian Government, 2016).

The existence of a smart cities national framework may help empower and guide local governments to identify their main assets, needs and opportunities. National governments do not use the national smart city framework to dictate policy or select needs and courses of action on behalf of local governments. In fact, national policy is regularly informed by sub-national levels of government and thus it should reflect the diverse challenges cities face. Such is the case of Italy, where the Strategy for Digital Growth 2014-2020 is based on the capability of municipalities to identify social and economic challenges as well as smart city solutions able to respond to people's and business' needs. The key point is that, although cities aim to adopt the smart city features, they pursue goals that reflect their own priorities and vision. Technological developments may be used differently to achieve different objectives. According to the US experience, local governments have the leadership to engage residents in identifying community goals, priorities, assessing technical options, implement programmes, and evaluate progress (Smart Cities Task Force, 2018).

The role of the national government can also be to facilitate the provision of, or to provide (depending on the context) solutions and /or resources that are adaptable to local needs, such as effective internet access, privacy and security policies, knowledge, and financial means to access technology. For example, the US NSTC 2018 Connecting and Securing Guide for Federal Agencies describes recommended practices and approaches for research, development, coordination and engagement by federal agencies in support of US cities and communities to promote their use of digital technologies to build smart infrastructure, systems and services. In Turkey, the 11th Development Plan 2019-2023 aims to establish smart cities strategies at the local level. The National Smart Cities Strategy and Action Plan provides the roadmaps and

the criteria for the selection and implementation of smart city projects taking into account priority areas and capabilities that the national government is able to provide. Projects are selected based on smart city maturity assessment and resource allocation constraints, giving priority to metropolitan municipalities and the 51 provincial municipalities.

In some cases, national plans support the deployment of supportive infrastructure. Singapore's *Smart Nation Programme* via its *Smart Nation Sensor Platform*, deploys sensors, cameras, and other sensing devices to provide real-time data on the functioning of various urban systems – including transport.

The smart city policy framework provides governments with the opportunity to examine to what extent new technologies can improve the efficiency, sustainability, and quality of public services and infrastructure projects. Local governments then need to identify strategic areas of action which could include optimising mobility and traffic flows, fostering innovation, promoting economic development, and ensuring greater transparency and people's participation. Cities are then the ones who decide what changes need to be made to adopt digital technology. For instance, in the mobility domain, the use of digital technology, the rise of the sharing economy, and access to data have the potential to improve transport services and provide a more customised service for passengers, but cities need to assess the impact of the use of those technologies on changes in traffic or urban restructuring. Moreover, cities are exploring how open data and analytics can help them come up with innovative solutions to improve mobility, the experience of travelling, reduce traffic congestion, and contribute to better environmental outcomes. The smart city policy framework serves as a statement on how national and sub-national levels of government can have greater access to data and use it in effective ways to provide more citizen-focused services and stimulate innovation.

Rural areas are not being generally included in smart cities strategies. In general, countries focus predominantly on urban and suburban areas in their smart cities strategies. Reference to rural areas is not seen as an immediate priority. One of the reasons for this is that resources and attention are devoted to generating experience and knowledge, and mature ongoing projects. Nevertheless, some countries, like the US, aim to address the challenges of cities and communities of all types including rural, suburban, urban, peri-urban, and tribal through their smart city and communities activities. Other countries expect to include towns and villages in the medium and long term, in a second generation of smart cities initiatives, as is the case in Korea and the Russian Federation.

This suggests that adoption of a smart cities approach is gradual, as it requires experimentation. It seems that large cities and their suburbs are in a better position to begin the digital transformation process due to their better capability and access to skills and resources. In the United Kingdom, much of governments' focus to-date has been on getting a strong grasp on emerging technologies and trends in transport, as this is where changes in travel will happen first and fastest, and then explore options on how local governments can benefit from this.

Table 1. G20 and partner countries' initiatives to support the development of smart cities and communities

Country	Smart cities and communities related initiatives	Administrative body in charge	Other administrative bodies involved
Argentina	Smart and Sustainable Smart Cities National Plan (currently under development)	Under-Secretariat of Open Government and Digital Nation within the Chief of Cabinet's Office	Ministries of Transport and Mobility, Environment, Education, Security and Health
Australia	Smart City Plan 2016	Department of Infrastructure, Transport, Regional Development and Communications	
Brazil	National Strategy for Smart Sustainable Cities (currently under development)	Jointly led by the Ministry of Science, Technology, Innovation and Communications (MCTIC) and the Ministry of Regional Development (MDR).	
Canada	Investing in Canada Plan	Infrastructure Canada	
China	Guidance on Promoting Healthy Development of Smart City 2014	National Development and Reform Commission (NDRC)	Over 20 ministries participate including: Ministry of Industry and Information Technology (MIIT), Ministry of Science and Technology (MOST), Ministry of Finance (MOF), Ministry of Natural Resources (MNR), Ministry of Housing and Urban-Rural Development (MOHURD), and Ministry of Transport (MOT)
Germany	National Smart Cities Dialogue Platform, and 2017 Smart City Charter	Federal Ministry of Interior, Community and Building	All levels of government participated in the elaboration of the Smart City Charter through the National Smart Cities Dialogue Platform.
Italy	Strategy for Digital Growth 2014-2020	Ministry of Economic Development	Agency for Digital Italy; National Agency for New Technologies, Energy and Sustainable Economic Development; National procurement system, representing the set of Central and Regional Purchasing bodies.
Japan	Integrated Innovation Strategy 2020	Cabinet Office Other administrative bodies involved : 10 ministries (ex. Ministry of Internal Affairs and Communications Ministry of Economy, Trade and Industry Ministry of Land, Infrastructure, Transport and tourism)	
Korea	Third Comprehensive Plan for Smart City 2019-2023	Ministry of Land, Infrastructure and Transport (MOLIT)	Ministry of Science and ICT, Ministry of Trade, Industry and Energy, local governments
Russian Federation	Digitalization of Municipal Services – Smart City	Ministry of Construction, Housing and Utilities of the Russian Federation	Federal and regional authorities, representatives of the housing and utilities sectors, technology developers, research institutions
Saudi Arabia	The Smart Cities Blueprint and the National Digital Transformation Strategy	Ministry of Municipal and Rural Affairs (MOMRA))	National Digitization Unit (NDU) Ministry of Economy and Planning Ministry of Communications and Information Technology, The Communications and Information Technology Commission, Transport Ministry and Transport General Authority,

			National Water Company, regional authorities and private organisations
Singapore	Smart Nation	Smart Nation and Digital Government Group	Ministry of Communications and Information, Ministry of National Development, Ministry of Transport
Switzerland	Smart City Switzerland	Swiss Federal Office of Energy (SFOE)	Association of Swiss Towns and Cities, Smart City Hub Switzerland, the Association of Swiss Smart Cities, and the semi-public enterprises Swiss Federal Railways, Swisscom and SwissPost.
Turkey	2020-2023 National Smart Cities Strategy and Action Plan	Ministry of Environment and Urbanisation	Presidency Councils, 16 Ministries, central government institutions, municipalities
United Kingdom	Smart Cities	No one department leads.	Department of Business Energy and Industrial Strategy, Cabinet Office, Department for Digital, Culture, Media and Sport, Department of International Trade, Department for Transport, Ministry of Housing Communities and Local Growth, Centre for Protection of National Infrastructure, Government Communications Headquarters, UK Research and Innovation and government funded initiatives.
United States	Connecting and Securing Communities: A Guide for Federal Agencies Supporting Research, Development, Demonstration, and Deployment of Technology for Smart Cities and Communities	White House Office of Science and Technology Policy (OSTP) through its National Science and Technology Council (NSTC)	14 federal departments and agencies.
European Union	Europe 2020- A European strategy for smart, sustainable and inclusive growth	European Commission	Member states

Note: Mexico does not have a national smart city strategy but there are only local initiatives. France is not included as there was no mention of any national smart city policy only the National Strategy for the Development of Self-Driving Vehicles. Canada does not have an explicit national level smart city framework, but smart city considerations are included in the investment plan.
Source: OECD/ITF Survey on Smart Mobility 2020.

Specific governance arrangements are set to implement the national policy framework

Countries use different mechanisms to co-ordinate with regional and local governments in the design, implementation, and/or monitoring of the smart city policy. For example, Australia, the Netherlands, and the United Kingdom use City Deals structured around nationally and locally informed objectives to provide public services, foster economic growth, create jobs, and reduce emissions. The advantage of this instrument is that they allow for a negotiation on a case-by-case basis depending on local objectives, challenges, and opportunities. In Korea, the Ministry of Land, Infrastructure and Transport (MOLIT) assists local governments in their preparation of their smart city plans by pre-assessing the quality of their programs through a smart city plan checklist.

Generally, there is a leading administrative unit responsible for co-ordinating the implementation of the smart cities policy framework. There is no established rule about who is better positioned to lead the national smart cities policy; this depends on the focus of the strategy adopted by the government. For instance, the Swiss Federal Office of Energy (SFOE) leads the 'Smart City Switzerland' strategy because it

focuses on the areas of smart environment and intelligent mobility. Infrastructure Canada is the lead ministry for smart cities due to the large focus on infrastructure investments to build cities, promote innovation, and enhance quality of life. In Turkey, within the scope of 2020-2023 National Smart Cities Strategy and Action Plan, the Ministry of Environment and Urbanization provides guidance to municipalities with the intent of preparing a specified strategy and roadmap according to local dynamics.

However, it must be pointed out that no single ministry or agency alone can implement the strategy. As Table 1 shows, in many countries numerous national ministries contribute to smart city efforts. China, for instance, installed an inter-ministerial co-ordination mechanism to co-ordinate the development of smart cities, strengthen guidance for local governments and explore additional support policies. In the United Kingdom, no one department is responsible for leading the implementation of the Smart City plan, its implementation depends on the efforts of different departments across the national government that have a direct or indirect impact on the achievement of smart city goals.

Partnerships and sound governance contribute to strengthening smart city initiatives

Where present, smart city policy frameworks generally outline ways in which governments can build partnerships and co-ordinate activities and investments with the private sector, NGOs, and the community as a whole. For example, Brazil introduced the National Chamber of Cities 4.0 as part of the Internet of Things Plan to bring together governments, academia, and the private sector to discuss the best technologies to serve cities. This is jointly managed by the Ministry of Science, Technology, Innovation and Communications (MCTIC) and the Ministry of Regional Development (MDR).

In 2016, Germany set up the Smart Cities Dialogue Platform to bring together experts from municipalities, districts and local authorities, federal ministries, state ministries for urban development, research organisations, and civil society to identify the opportunities and risks of digital technology at the local level. The Platform presented the Smart City Charter in 2017, that included guidelines and recommendations for ensuring the sustainability of digital transformation at the local level as part of an integrated urban development policy (German Government, 2017). Turkey established the Smart City Information Sharing Platform and launched the mechanism for information interchange between central government institutions, local governments, private sector institutions, non-governmental organisations, universities, and citizens.

The United States installed the Smart Cities and Communities (SCC) Task Force to coordinate federal action and partnerships with academia, industry, local cities, and communities to enable cities and communities of all types in accessing networking and information technologies and services (Smart Cities Task Force, 2018). This Task Force seeks not to direct, but rather, facilitate local innovation, initiatives and actions.

At the European Union level, the European Innovation Partnership on Smart Cities and Communities (EIP-SCC) brings together 6,000 stakeholders from 31 countries representing cities, industries, SMEs, investors, researchers, and other smart city stakeholders to look for more sustainable integrated solutions and address city-specific challenges from different policy areas such as energy, mobility and transport, and ICT (EIP-SCC, 2020). This initiative is organised around Action Clusters that assembly partners that work on specific smart city issues by sharing knowledge and expertise with their peers.

Building smart cities is a joint effort of different national level bodies in co-operation and collaboration with sub-national governments, the private sector and academia. This requires clear and sound governance arrangements that facilitate co-ordination, communication and the implementation of the national policy across all levels of government.

Data is at the heart of smart city strategies

National smart city policy frameworks emphasise the importance of accessing, producing, and using timely and accurate data for decision-making and public service delivery. For example, the national frameworks of Germany, Turkey, and the United Kingdom highlight the importance of ensuring high quality geospatial data, which are important foundations for smart city concepts. The aim is to enable interactive urban and landscaping planning, 3D modelling and digital land-use planning. Such data are key to achieve smart mobility goals, ranging from enabling public transport services to providing the optimal route, to facilitating effective planning and land registration processes that enable housing markets to function.

However, national strategies also stress the importance of managing data with care, ensuring the security and privacy of individuals. In Canada, smart cities projects are required to comply with Canadian legislation such as the Personal Information Protection and Electronic Documents Act (PIPEDA).

Promoting smart cities may advance equity and inclusiveness

Implicitly or explicitly, national smart city frameworks typically seek to deliver on equity and inclusiveness objectives. Smart city plans pursue goals that have a direct impact on people's lives, such as on safety, environmental care, welfare, and accessibility. Italy's Strategy for Digital Growth aims, inter alia, at meeting all citizens' needs by providing services and solutions based on real needs.

The US smart city effort focuses on projects that make communities of all types and in all regions safer, more secure, liveable, and workable for their residents. These projects are expected to simultaneously improve economic growth, generate job opportunities, and enhance workforce development for upskilling and reskilling. Explicit goals of the strategy include expanding job opportunities for economically disadvantaged communities, providing accessibility for disabled residents, including transportation and services innovations, and expanding technology access in regions without broadband connectivity.

To promote equity and inclusiveness via smart city projects, Canada's Smart Cities Community Support Program supports not-for-profit organisations to provide advisory and capacity-building services directly to communities of all sizes across the country, as they explore and implement smart cities approaches that aim to improve the lives of residents and develop specific capacity-building services for indigenous communities.

Argentina is currently developing its Smart and Sustainable Cities National Plan, which is expected to explicitly make reference to equity and inclusiveness objectives to improve the services for the whole community, promote access to information for all, reduce the digital gap in society, and generate an optimal environment for personal and business development. Gender equality will also have a preponderant role, given that it has become a top priority for the Argentine government.

Although national smart city frameworks aim to benefit all people, it is still not clear how this is achieved in practice or even measured. The answers to the OECD/ITF Survey on Smart Mobility among G20 countries, facilitated by the G20 Saudi presidency in collaboration with the G20 Digital Economy Task Force, suggest that countries expect that equity and inclusiveness will follow as a consequence of the implementation of smart city strategies. But the risk is that well-intentioned smart city projects or initiatives may deepen inequalities if they do not involve all different social groups from the early stages of the strategy or project definition.

To promote equality and inclusiveness, smart city programmes should not treat cities in a homogenous way. National and local leaders should seek to understand what the priorities and needs of people living in cities and communities are and be explicit about applying an inclusion lens to the smart city project.

One key step in promoting equity and inclusiveness from smart city-related projects may be ensuring that people of all age and backgrounds develop digital skills and literacy to be able to access and profit from technological developments. This is a central part of Singapore's Smart City efforts. In 2018, Singapore launched the Digital Readiness Blueprint that sets out a strategy to address barriers to meaningful digital participation such as lack of access, skills, motivation, and trust in utilising digital technologies. Similarly, Germany's Smart City Charter promotes the development of digital skills and life-long learning to ensure digital transformation in cities. These strategies are initiated and driven at the local level, targeting group-specific educational offers in schools, the workplace, and for the elderly.

B.4. How do cities manage their transition to digital technologies?

Cities generally adopt a specific smart city strategy to enhance economic competitiveness, foster inclusiveness, and improve quality of life via digital technologies. Cities across the world are using smart city solutions to improve public service delivery and solve issues related to public safety, water and air quality, mobility, and waste management. These initiatives are also intended to ensure that all people have access to goods and services to improve their quality of life.

A smart city plan reflects the desire of a city to transform traditional cities into smarter, more interactive, and sustainable environments. The strategies are expected to assist cities in facing the challenge of modernising and expanding infrastructure and bring government closer to people. For instance, Tokyo issued the "Smart Tokyo Implementation Strategy" in February 2020 to enhance the quality of life of residents. Rio de Janeiro's Smart City Plan includes various initiatives and projects that use technology to improve quality of life by improving citizens' digital skills and the use of technology in service delivery. New York's Smart City Strategy seeks to create a healthier civil society and a stronger democracy through the use of technology. Mexico City has been working to face its urban development challenges (i.e. disorderly urbanisation and poverty) taking advantage of technology to simplify people's lives and business operations. The *Smart London Plan* (Greater London Authority, 2013) also expressly links smart city initiatives to solving high-priority challenges in order to improve people's lives. Within Turkey's National Smart Cities Strategy and Action Plan, cities in Turkey are obliged to prepare a Local Smart City Strategy and Road Map; Istanbul-Esenler and Konya are amongst the first in Turkey to prepare smart city roadmaps considering local dynamics.

Certainly, ensuring that all individuals have access to the benefits of technology is not an easy task, as cities are not homogeneous in their level of socio-economic development and coverage of public services and access to internet. Poor neighbourhoods and slums are characteristics of many large cities in developing countries such as Rio de Janeiro and Mumbai, whose residents do not have access to services such as the internet. Even in more developed cities, like New York, London, and Paris it is possible to find neighbourhoods with lower than average levels of access to services.

The experience of some cities, such as Medellín in Colombia, shows that it is possible to be a smart city without being a tech city. The city has implemented urban projects under a people-centric approach to improve quality of life and access to services for all people. For example, the improvement of the quality and quantity of public space by means of pedestrian connection improvements, environmental parks, and urban promenades; and the Intelligent Mobility System aimed at improving safety and mobility for drivers and pedestrians.

Smart city initiatives have the potential to leverage technological developments to allow the most vulnerable residents an easier access to services. For example, people with disabilities face barriers that are not the result of their disability but of the features of the environment where they live. Some cities have therefore adopted specific projects in this respect. In London (UK), a smart city project is helping

visually impaired people to navigate the city's transport system using beacons to provide audio instructions (O'Dell, Newman, Huang, & Van Hollen, 2019). In another example, in the city of Kolkata (India), a geocoding technology project has provided postal addresses to more than 120,000 slum residents, helping them obtain documentation to access government services, open bank accounts and register to vote (O'Dell, Newman, Huang, & Van Hollen, 2019).

To manage and co-ordinate their transition to digital technologies, cities generally adopt a formal smart city strategy or insert their smart city goals within their development plans. For example:

- In 2009, Amsterdam was one of the first European cities to adopt a smart city plan to improve its economy, environment, government, living, and mobility. Evolving projects in Amsterdam's smart city plan include open data platforms, smart grids, smart housing, distributed energy storage, smart mobility, and improved connectivity.
- In the United States, Los Angeles faces challenges such as congestion, environmental pollution and threats of natural disasters. To face these challenges the city adopted a Smart City Plan to promote research and development into sustainability and data science, adopting technologies like the Internet of Things (IoT) to improve residents' quality of life. Similarly, New York City has adopted a smart city approach to become an equitable city by ensuring that all residents have access to facilities such as free Wi-Fi coverage, clean water, and an efficient waste management system.
- In Japan, in February 2020, the Tokyo Metropolitan Government published the 'Smart Tokyo Implementation Strategy - for realization of a Tokyo Version of Society 5.0'. The goal is to build a data platform through public-private collaboration in order to make data open and utilize it to achieve the Tokyo Version of Society 5.0.
- In Brazil, Rio de Janeiro has a series of strategic plans that aim to coordinate the city government's efforts to meet its urban development challenges through the smart city approach. The Strategic Plan for the City of Rio de Janeiro (2017-2020), the 'Rio 2020: more solidary and more humane', and the Plenary Plan (2017-2021) for budget management include the different strategic initiatives the city is implementing to become a smart city.
- In Australia, the City of Sydney has submitted its Smart City Framework (SCF) for consultation. The purpose of the framework is to establish an overarching vision to drive a holistic, sustainable approach to the city's smart transformation.
- In Turkey, the Ministry of Environment and Urbanization published the "2020-2023 National Smart Cities Strategy and Action Plan" to set a mutual vision and a roadmap and develop the smart city maturity with a common perspective in cities. Within the action plan, the "Reference Architectural Model" is one of the main tools that can be used as a standard in the smart city structuring of all cities to provide the management of assets in a single structure in the business, data, application and technology layer.

Similar to national governments, to enhance the transition to digital technologies, city governments engage with different stakeholders in partnerships to realise their smart city plans. These partnerships aim to foster innovation within the city to use digital technologies to solve community problems. Partnerships may involve start-ups, residents, academics and small businesses for the development of ideas that can go from smart trash bins and bike sharing programmes to installing digital infrastructure and deploying small cell technology to issuing traffic and public safety information. There are reasons for these partnerships. First, partnering with the private and academic sectors is a way to foster the city's

capacity to innovate as most of the times small firms and research centres have the data and knowledge that the public sector needs to develop solutions for improving service delivery. Second, for the private and academic sectors collaborating with government is a way to ensure their projects may access resources and get political support to be implemented. And third, these partnerships constitute a way to create synergies, share costs and risks, and contribute to local economic development by supporting local enterprises.

B.5. What are the challenges associated to smart cities?

Fitting what works in each city

There is no single model of smart city that can apply across the board. Some smart city initiatives that are successful in one place are not necessarily transferrable to another place that has different spatial, economic, environmental, social or institutional characteristics; they need to be tailored to the specific context of each place. The historical, geographic, demographic, and cultural context of every city presents city leaders with a particular set of challenges and opportunities in terms of smart city initiatives. Even though cities both in developed and developing countries are struggling to replace decades-old infrastructure, such as transport tunnels and rails, underground wiring, roads, water pipes, and drainage, the state of specific urban infrastructure may condition the success of smart cities initiatives. For example, the lack of high-quality urban roads may hinder the possibility of using autonomous vehicles for easing congestion levels. The adoption of autonomous vehicles as a means of transport may only work in settings with upgraded infrastructure and with a mature driving culture. Another potential challenge is how to generate and distribute the power required by electric vehicles and install the enormous number of new sensors required for operating autonomous vehicles. Similarly, some smart cities promote walking and cycling as a smarter, more sustainable and more inclusive means of transport, but this may be more successful in some cities like New York where people are willing to walk farther than in cities like Houston where the heat and humidity discourage walking (O'Dea, 2018). City density and urban form will also influence people's mobility behaviour.

Data protection

Data management, security, integrity and privacy concerns may create doubts about smart city initiatives and undermine efficiency. Collecting incomplete and poor-quality data may undermine the utility and trust in public data management and eventually the efficiency of the smart city initiative.

Research has highlighted that one of the barriers for a better understanding of transport issues and accessibility limitations is the level and sophistication of the data needed, which is costly and burdensome to collect, and in many cases a luxury that many cities cannot afford (Lucas, Mattioli, Verlinghieri, & Guzman, 2016). Moreover, city governments need to find a balance between quality of life and invasion of privacy. People want to have better and more convenient access to services, but they do not want to feel constantly monitored. It is essential that city policymakers understand fully the technologies used, identify the different types and sources of data, and clearly determine and explain what will be done with the data collected.

Measuring and monitoring

Measuring and monitoring the impact of smart city initiatives is a complex task. A smart city framework strategy provides the necessary orientation for the city's medium to long-term development. However, contextual changes such as global climate crisis, economic downturns, technological developments, and people's changing needs, make it necessary to review and adjust these at comparatively short intervals.

Monitoring a smart city strategy requires defining indicators or parameters that can be used to evaluate to what extent a target has already been achieved. Cities need to adopt a monitoring approach form the outset based on the long-term objectives they have set. Monitoring the performance of a smart city strategy requires the participation of employees from several public institutions and could involve the private sector, academia and civil society.

In many cases, cities lack the capacity to collect and process data and information to evaluate the achievement of their smart city strategy. This exercise also requires financial resources to be allocated and cities regularly face budget limitations. Some cities in Europe use the European Regional Development Funds to monitor and evaluate their smart city strategies, for example Vienna in 2017.

Once the evaluation of the strategy has been conducted, the challenge is how to use those results to ensure the city is on track to meet its long-term goals. Cities then require sharpening their objectives and calibrating their strategies.

Funding

Funding for smart city initiatives may be limited. Funding smart cities initiatives is a constant challenge for cities, especially as they typically entail large upfront technology costs. For projects that intend to install technological infrastructure in low-income areas or hard–to-reach populations, costs can be even higher. Approval processes for funding may be long and require multi-year budgeting practices to secure resources for the implementation of the project.

Cities may need to get funding from different sources: grants from national and regional governments, several departments contributing to a smart city fund, or funds from different programmes to which smart city objectives may be relevant, among other sources. Cities may need to upgrade their procurement practices to ensure value for money when engaging in smart city projects.

A key part of the smart cities national framework is how governments plan to prioritise investment projects to meet broader economic goals and city challenges such as affordable housing, accessibility, job creation, access to public services, and environmental protection. In some instances, governments tend to outline some alternative sources of funding for their projects that provide returns in the long-term. This is particularly the case for projects on infrastructure for transport. For instance, one of the pillars of Australia's Smart Cities Plan is for the public sector to become a smarter investor by treating infrastructure funding as a long-term investment, not a grant, and explore innovative sources of funding such as value capture to leverage the balance sheet and finance ore infrastructure projects (Australian Government, 2016). Canada's investment plan gives priority to local projects that create long-term economic growth, support the transition to a low-carbon green economy, and build inclusive communities. Thus, funding for five priority infrastructure streams is made available: public transit, green, social, trade and transportation, and rural and northern communities' infrastructure. In Turkey, new business models will be created in cases where existing business models do not meet needs (2020-2023 National Smart Cities Strategy and Action Plan).

Integration across different initiatives and actors

City management and inadequate governance arrangements may hamper smart initiatives implementation. The challenge for national and city governments is crossing traditional sectorial domains and geographic boundaries to increase efficiency and maximise resources. Inter-ministerial co-ordination and the convening power of the national government are essential to catalyse co-operation and partnerships across agencies, sectors and other interested stakeholders.

Smart city initiatives span a wide variety of domains (e.g. technology and innovation officers, urban planners, etc.). Cities are complex organisms with many organisations and infrastructures that provide services needed for them to function effectively. In some instances, local authorities only directly manage a minority of key city services and have to assume a strategic management role through partnerships with other stakeholders in the city (e.g. NGOs, private sector, community groups, individuals). In addition, city leadership also has to co-ordinate its decisions and actions with different levels of government and across other local administrations. The lack of internal communication and co-ordination processes, workforce capabilities, and governance models to break silos may therefore constitute an internal barrier to implement smart city initiatives.

Bringing all segments of society on board

Low levels of digital literacy and lack of community engagement may hamper smart city initiatives. Getting people to actively participate and take advantage of new technologies for service delivery requires not only granting them internet access, but also making sure they know how to use it. Ensuring that people have adequate digital knowledge and skills should be an integral part of a smart city initiative. In many countries, low-income people and the elderly do not know how to use the internet to find information, access services, or just to communicate. Cities may need to implement digital literacy programmes, working with local NGOs, community centres, and businesses to teach people basic skills for operating a computer, using internet, and keeping their data secure. Digital illiteracy may be the origin of the lack of engagement in some smart city initiatives of certain groups.

Smart city initiatives require involving all groups of society to be truly inclusive. Smart city initiatives are mostly taking place in urban areas with a young, active, connected population and may unintentionally exclude some segments of the population for economic, social, educational, urban planning and physical reasons. City leadership needs to consider how smart cities are affecting people's rights and participation in local policy making. The sophistication of people's participation and consulting programmes will determine whether people are involved from the early stages of the smart city initiative's design process. A key danger is to focus exclusively on affluent and technologically advanced areas and groups of society where implementing smart cities initiatives may be easier. In some cases, smart city initiatives may require technology vendors to provide solutions in a more inclusive manner and lower regulatory barriers for providers that address inclusion barriers (O'Dell, Newman, Huang, & Van Hollen, 2019).

C. Smart mobility -- Context setting

Smart mobility is often cited as one of the key components of smart city policies and strategies (Albino et al., 2015, Hollands, 2008, Batty et al., 2012). Smart mobility is largely synonymous with the concept of Intelligent Transport Systems (ITSs) which focus on intermeshing digital technologies amongst devices, vehicles, and infrastructure (Tomaszewska and Florea, 2018). ITS – and smart mobility – has the potential to improve mobility outcomes and reduce negative externalities related to transport activity (Frost and Sullivan, 2019). Ensuring that smart mobility delivers on its potential to improve mobility and contribute to better societal outcomes requires understanding both components – what is "mobility" and what is "smart".

C.1. Global mobility trends and the potential impact of smart mobility technologies and services

Mobility is a key enabler of prosperity and will grow in line with the economic growth it helps generate. How it does so – by following past patterns of growth or by switching to new trajectories – is partly a result of how various disruptions within and outside the sector will play out in the future. Smart mobility, as a disruptive element, will therefore impact overall growth in mobility in as of yet uncertain ways.

Based on the modelling work of the International Transport Forum (ITF) (ITF, 2019), it can be stated with some confidence that, globally, passenger transport will increase nearly three-fold between 2015 and 2050, from 44 trillion to 122 trillion passenger-kilometres. China and India will generate a third of passenger travel by 2050, compared with a quarter in 2015. Private vehicles will remain the preferred mode of personal travel worldwide. Travel in cities, especially, will shift towards public transport and shared mobility. By 2050, both these modes are projected to account for over 50% of total passenger-kilometres. International passenger travel is increasing globally, and growth is projected to be strongest in developing countries. Aviation passenger-kilometres in India and China alone are expected to increase almost four-fold by 2050, to 21,583 billion from an estimated 5,506 billion in 2015. Global freight demand will triple between 2015 and 2050 based on the current demand pathway.

The impacts of disruptions linked to smart mobility deployments, both on their own and combined with others, are likely to be significant. Shared mobility could halve the number of vehicle-kilometres travelled in urban areas if widely adopted. This could lead to a 30% decrease in CO_2 emissions from urban transport by 2050 relative to projections based on current trends and measures. The widespread use of autonomous vehicles would likely increase the number of vehicle-kilometres travelled and tonnes of CO_2 emissions generated in most urban regions. Simulations indicate that more teleworking could decrease global urban passenger-kilometres travelled and related CO_2 emissions by around 2% in 2050 compared to the current ambition scenario. Simulations indicate that the proliferation of long-haul low-cost aviation would increase the total number of passenger-kilometres travelled in non-urban transport and related CO_2 emissions by 1% in 2050 relative to current projections. Simulation results suggest that the availability of ultra-high-speed rail systems would increase total rail ridership by 1% while reducing CO_2 emissions from non-urban transport by less than 1%. Rapid growth in e-commerce could lead to modest increases in freight volumes of between 2% and 11%, depending on the transport mode. Freight-related CO_2 emissions would increase by 4%.

In full disruption scenarios, in which several disruptive developments coincide, projected transport demand and the related CO_2 emissions are lower in 2050 relative to the current ambition scenario in all sectors. The strongest emissions reductions can be achieved with policies in place to further decarbonise the sector and, in some cases, guide the development of disruptions. In urban passenger transport for example, the widespread adoption of shared and autonomous vehicles could cut CO_2 emissions by 73% and congestion by 24% in 2050 relative to current projections *if managed by appropriate policies*.

Taken together, the simulations show that transport policies heavily determine the impact that disruptions will have on the demand for transport and on its energy and carbon footprints. The coordinated implementation of policies designed to mitigate transport impacts in each sub-sector have multiplicative effects across all transport sub-sectors. Thus, policy makers have a crucial role to play in determining the nature and extent of change even where developments stand to disrupt transport systems considerably.

C.2. Mobility – Challenges and Outcomes

Mobility delivers on economic and social opportunities. From an economic perspective – a key factor in the ability of communities to contribute to economic growth and prosperity is their ability to reduce transaction costs. Communities concentrate opportunities, access to goods and capital, cultural activities, living, working, and "making" spaces. These activities and opportunities are spread out in space and thus communities generate a need for mobility so that people may gain access to these (Crozet, 2019).

Mobility has three components: activities/opportunities, their location, and travel. The latter helps to link the previous two – but so too does proximity. Increasing proximity (and thus density) or increasing speed of travel increases the number of opportunities and activities that individuals can satisfy for a given period of time (Crozet, 2019). From the perspective of travellers, increased speed is a proxy for physical proximity since it delivers the same result in terms of linking people to destinations. For communities, the impacts of speed are slightly different since travel time savings contribute to overall agglomeration benefits but at the same time consume a valuable and scarce public resource in communities – space.

Accessibility is the metric that measures mobility and combines all three of these elements into a unified indicator. The more activities and opportunities that can be accessed within a given amount of time (and/or budget), the more economic activity is generated and the more efficiently communities produce economic growth – up to the point where the disbenefits linked to density or movement start to overwhelm the benefits (ITF, 2019).

Transport technologies – from steam trains, clipper ships, the bicycle to the car and airplane -- have generally increased speed and the benefits they delivered came from travel time savings. Speed comes at a cost – to the traveller in terms of the capital cost of the technology concerned, the energy used to generate movement and other direct costs such as those associated with parking. Higher speed travel, and the transport technologies that enable it, benefit travellers but also generate external costs that are borne by society. These include congestion – e.g. the impedance each trip causes on others, costs linked to fatal and injury-causing crashes, costs linked to reduced health (from emissions, noise and decrease in physical activity), costs linked to paving permeable soils and surface water run-off, costs linked to climate change, costs linked to habitat degradation and destruction as well as the upstream costs of all these linked to the production of energy, vehicles and infrastructure. These are significant costs representing € 987 billion in 2016 for the EU (Schroten, A. et al., 2019).

Addressing the internalisation of external costs in transport centres on a broad discussion regarding the structure of pricing, taxes, and other features of the mobility market. Technology may also play an important role in minimising some of these costs. For example, better traffic control and speed management systems have the potential to reduce congestion and improve safety. Generally, however, smart mobility solutions rarely address the full range of externalities – and in some cases, may exacerbate these (if, for example, automated driving were to lead to an increase in overall travel – all else held equal – externalities linked to energy and climate could increase).

The experience of mobility is not uniform across spatial contexts and different types of communities. In low-density settings -- a motorway, for example – the experience of mobility is largely linked to the speed of travel and safety. These simplified environments allow for high-speed travel in relatively safe conditions. Consumer utility is generated by passing *through* these spaces, not by *stopping in them*.

Denser urban settings, including the centre of small towns and larger urban areas, are more complex environments. In these settings, consumer utility is generated by the increased range of destinations and services present. However, increased crowding generates congestion disbenefits. Likewise, increased travel speed in these complex environments generates safety disbenefits and increased levels of emissions create environmental disbenefits. Further, communities are multifunctional spaces and increasing speed or managing public street/road space only to deliver improved traffic efficiency for certain vehicles may erode other valued benefits associated with those spaces (commercial retail activities, informal street commerce, use of pavements and sidewalks for dining or shopping, quiet frontage space for residential buildings, etc.). These knock-on effects should be accounted for when framing smart mobility initiatives.

As with other sectors of human activity, sustainability imperatives have increasingly served to guide mobility policies. Mobility contributes to seven of the 17 United Nations Sustainable Development Goals (SDGs) (Sustainable Mobility for All, 2017):

- SDG 3: Good Health and Well-being
- SDG 7: Affordable and Clean Energy
- SDG 9: Industry, Innovation, and Infrastructure
- SDG 10: Reduced Inequalities
- SDG 11: Sustainable Cities and Communities
- SDG 12: Responsible Consumption and Production
- SDG 13: Climate Action
- SDG 17: Partnerships for the Goals

Smart mobility may help to deliver on these SDGs. *Sustainable* mobility – "the ease, convenience, affordability and accessibility of travelling to one's destination with minimal impact on the environment and others" (Lam and Head, 2012) – is therefore a helpful way of framing the discussion around technology deployment in support of mobility. The technology focus of smart mobility is but one of the multiple pathways – e.g. "good urban design, behaviour change, advanced technology, supportive policies, economic incentives and city engagement and leadership" (Lam and Head, 2012) that support sustainability outcomes. Of particular concern at the time of writing this report and in line with SDG 3 "Good Health and Well Being", sustainable mobility outcomes must account for the linkages between transport activity, on the one hand, and access to essential services, on the other, in the context of COVID-19 and its global impact. Smart solutions can help in this context by providing information on available capacity and crowding in public transport, alternative travel options that respect physical distancing imperatives and otherwise reducing the need for travel with teleworking and telepresence options.

C.3. Deconstructing "Smart" Mobility

As with smart cities, smart mobility connotes the beneficial application of (mainly digital) technologies to improve mobility outcomes. The technological building blocks are of the same type as for other smart city applications and broadly include sensors, actuators, processors and transmitters, and the computer code that processes and acts on the data produced. These subcomponents are combined into different technology components such as GPS positioning chips, Lidar and video scanning devices, and Wifi and

cellular-based communication protocols and nodes. The code that processes and acts on the data may be pre-determined and programmatic or self-learning and adaptive. All of these technological components are further assembled into smart systems like smartphones, traffic control centres, automated vehicles or drones. Finally, these systems are, in turn, building blocks on which new mobility-related services, including ride-sourcing, car-sharing, shared micromobility, adaptive route-finding and navigation, dynamic parking and curb side management are built.

Smart mobility is therefore:

- *Instrumented*: sensors provide state, location and proximity awareness for portable devices, vehicles and infrastructure.
- *Computative*: data produced by sensors is processed in-sensor (edge computing), in a processing unit close to the point of sensing (on-board driving computers) or remotely (cloud applications).
- *Connective*: both data and processing outputs are shared between vehicles, mobile devices and infrastructure using various communication protocols and technologies, and
- *Reactive*: systems automatically react to changes of state via processor outputs with little or no human input (e.g. ABS braking, speed control via geofencing).

Smart mobility thus leverages multiple levels of technological innovation which in turn leverage innovative services and use cases (on-demand van services, dynamic parking charges or robo-taxis). Smart mobility promises a virtuous cycle of technological innovation, new services, and improved outcomes for people … but it does not guarantee these (Lyons, 2018).

As with the broader discourse around smart cities, smart mobility implies that the potential benefits it delivers largely stem from improved *efficiency*. Here too, the fundamental questions regarding *what* is being made more efficient, *who* benefits from efficiency gains and *how* are people's views regarding these questions are rarely addressed. From a public policy perspective, these are fundamental points and addressing them is key to creating transparent and trustable smart mobility polices.

Questions surrounding what mobility technology deployment actually delivers and to whom are not new. Trains, subways and, most recently, the car, for example, all delivered significant gains in prosperity and quality of life, but they did not make mobility problem-free. Indeed, they gave rise to new problems -- as attest the significant external costs that still characterise transport. The disbenefits generated by past mobility revolutions – e.g. congestion, crashes, emissions, energy and space consumption, in the case of auto mobility – are precisely those that smart mobility seeks to address.

As with past mobility revolutions, a narrow and top-down technology-only focus for smart mobility may, once again, result in problems that will require new responses (Docherty, I *et al*, 2018). In order to guide the deployment of technologies so that they are aligned with broad sustainability and equity objectives, adapted and fair governance is required. The smart mobility value proposition thus combines technologies and the services these enable *with* a regulatory context that enables innovation, all the while ensuring that both individual *and* social value are maximised.

C.4. Smart mobility: What are the opportunities?

Smart mobility technologies and services act in many broad domains – they may assist or replace driving (automated cars), enable better en-route navigation for travellers (congestion-aware navigation apps), facilitate better traffic system management (traffic control centres, real-time traffic management, adaptive traffic signals), enhance integration of infrastructure and vehicles (vehicle-to-infrastructure two-

way communication), provide new ways of monitoring the traffic environment (pedestrian and cyclist detection and tracking), enable better use of transport assets (shared micro mobility and ride-hailing), improve the use of scarce public space (dynamic parking control and curb access management), facilitate energy management (smart charging infrastructure), catalyse seamless use of multiple transport services (Mobility as a service, smart ticketing technologies) or create new possibilities for transport provision (drone delivery services).

Across all of these domains, smart mobility solutions have the potential to deliver benefits in the form of:

- **Improvements in travel time:** Smart mobility has a strong potential to contribute to improved travel times. For example, the Seoul region integrated road and public transport traffic management data hub -- TOPIS (Transport Operation & Information Service) -- operates and manages traffic in Seoul by merging information from public transport operations, payment card data, shared mobility providers, automatic road and motorway traffic monitoring and emergency services to improve overall traffic flow in the region. Travel speeds have improved for general traffic and bus services (by 30% on average), as has bus punctuality. These improvements have contributed to a rise in the use of public transport (TOPIS, 2020). Another example of an integrated traffic control centre, the Izmir Transportation Center, also seeks to optimise total urban mobility, including public transport, and not just deliver travel time savings to car occupants.
- **Changes in the quality of travel time:** Travel time is typically valued as unproductive time and thus the value of travel time (reflecting the dis-utility cost it imposes on travellers) has underpinned policies seeking to deliver travel time reductions. However, the advent of connected technologies allows people to undertake productive or valued activities while they travel – up to the point where they are limited by other factors that increase the dis-utility of travel, like crowding in public transport. Smart mobility solutions that decrease crowding, improve the quality of the travel experience or – as promised by automated driving or ride-sourcing – allow travellers to fully engage in other activities while travelling, increase utility. The flipside of this is that the benefit from delivering time savings is mitigated as time spent travelling is no longer, or is less, unproductive (ITF, 2019).
- **Safety improvements:** There are multiple ways in which digital technologies can improve safety. Sensor-activated vehicle technologies like anti-lock braking systems (ABS), electronic stability control (ESP) and autonomous emergency braking (AEB) systems can provide activation of location data that could indicate dangerous conditions. The integration of these and other embarked technologies into Cooperative Intelligent Transport Systems (C-ITS) enables connected vehicles to openly broadcast relevant warnings. In addition to communicating with each other and with the road infrastructure, connected vehicles will be able to report on system performance in real time and throughout the entire road network. Automated driving systems have the potential to improve road safety by eliminating human driving errors that are a significant contributory factor in many crashes (ITF, 2018), (ITF, 2019). Technology can also improve safety outcomes for other transport modes. Automated headway control and sensor-triggered braking activation contribute to improved safety outcomes and decrease disruptions for regional and long-distance rail. The aviation-sector has long adopted advanced technologies to improve flight guidance and automatic flight control to maximise safety as well although experience with autopilot systems has highlighted the importance of safely handling machine-to-human handover of control.

- **More efficient use of capacity** (roads and vehicles): Advanced and adaptive signal control systems better utilise existing road capacity. These systems actively monitor traffic conditions and either coordinate control of traffic signals by adjusting the lengths of signal phases based on prevailing traffic conditions or signal to travellers' alternative travel options. Review of implementations indicate consistent high benefit-cost ratios (BCR) returns up to 60:1, mainly based on travel time savings (FHWA, 2017) (ITF, 2019). En-route, dynamic routing may reduce congestion within a single mode of travel (via alternate route suggestions), at destination (with parking availability data and parking/pick-up/drop-off slot assignment), or across modes (by suggesting alternate travel modes to avoid crowding and congestion). For individual vehicles and fleets, digitally enhanced ride- or parcel-sourcing has the potential to dramatically increase vehicle utilisation rates.
- **Reduced environmental impacts:** If traffic flows are smoothed and infrastructure/vehicle capacity utilisation is improved, all else held equal, the environmental burden linked to congestion and vehicle kilometres travelled would decrease. Smart mobility-induced shifts to lower emission technologies like electric vehicles or to more energy efficient modes, like well-used public transport, would further reduce the environmental impact of mobility.
- **Lower travel costs:** Insofar as the above benefits are indeed realised, smart mobility has the potential to reduce individuals' travel costs as well as overall societal costs linked to mobility. For individuals, cost savings primarily concern travel time savings, for society, cost savings are largely linked to congestion reduction and safety improvement. These cost savings are often taken for granted but their realisation is complicated by complex feedback loops within mobility systems as discussed below.
- **More equitable accessibility outcomes:** Disadvantaged communities and households may leverage certain smart mobility solutions to improve their accessibility options. For households without cars, ride-sourcing and micro mobility options may enhance the flexibility of their travel options by, for example, offering an alternative for poorly timed public transport services. Cross-modal navigation apps may help travellers improve the predictability of their travel. Vulnerable travellers may benefit from information regarding safe travel options outside of peak travel times. All of these outcomes are largely predicated on affordability concerns that extend not only to the cost of services but to the devices and data plans that enable access to these.

C.5. Smart Mobility: What are the challenges and trade-offs?

The potential benefits of Smart Mobility are numerous and, in some cases, could be quite high. Realising these benefits is not, however, straightforward. A number of complicating factors and feedback loops come into play which may thwart, diminish, or even lead to overall losses. Addressing and managing these factors is central to smart mobility policies.

Re-bound effects can erode many potential benefits

Many of the potential benefits linked to the deployment of smart mobility solutions – especially those that result in individual travel time savings or travel cost reductions may be eroded by the well-known phenomenon of induced demand or generated travel (Litman, 2019).

Efficiency in the context of smart mobility is often articulated in terms of gains in travel times for individuals. This may be delivered via faster travel (increased vehicle speeds, for example) or better

management of traffic flow and thus decreased congestion. Savings in travel time are important because they allow people to "consume" more activities within a given travel time budget. This budget has remained largely constant at a global aggregate level and converges to approximately 1 hour a day and about 15% of car-owning household income though deviations from this mean can be seen *between* cities even if travel time budgets are largely stable *within* urban regions (Zahavi and Talvitie, 1980; Schafer, 2017).

Constant time and monetary budgets mean that gains in travel times or decreases in travel costs are re-invested by individuals in more, faster or longer-distance travel. Induced travel effects are significant and robust across all contexts, from motorways to dense urban cores. For example, evidence indicates that vehicle kilometres travelled on US motorways have increased directly in proportion to the increase in lane-kilometres and that congestion-relief effects generally vanish after five years of capacity expansion (Hymel, 2019). Urban roadway expansion generally results in even stronger rebound effects (UK DFT, 2018). These induced travel effects hold not only for when new capacity is built, but also when existing capacity is freed – as in the case of many smart mobility initiatives.

The existence of induced travel signals that people derive value from new travel opportunities and this utility should be included into the broader appraisal of smart mobility schemes. However, induced travel can erode the initial direct benefits delivered by smart mobility investments in the short run and may eliminate them in the long run. This suggests that smart mobility solutions should look not only to decrease travel times, manage congestion or otherwise decrease the cost of travel, but should integrate or be accompanied by, measures to lock-in initial benefits. Dynamic pricing, smart capacity adjustment via hard shoulder running or re-allocating space to other valued uses all may be helpful in order to manage induced travel effects.

Benefits from smart mobility may not scale well

Benefits that are realised at the outset may not scale well. Displaced traffic due to smart routing is one example of scaling limitations linked to smart mobility technologies. In addition to rebound effects, there are effects that may be linked to displaced traffic. Centralised smart traffic control systems typically manage flows across wide networks according to unified rules relating to traffic signal timing, directed or suggested traffic re-routing and incident management functions. These systems optimise road traffic, and, in rare cases, where they also incorporate public transport or shared mobility options, can optimise overall travel across all networks. Centralised optimisation ensures that that overall benefits are maximised – but the experience of individual travellers may be that they experience avoidable dis-benefits at times.

In contrast, decentralised, technology-enabled and crowd-sourced navigation systems allow flexible trip re-routing for individuals, either on the road or in public transport systems. On-the-fly traffic prediction and personalised re-routing may alleviate time losses as long as affected traffic volumes remain low but as volume scales up, increased congestion and time losses result. The lack of uniform traffic assignment rules means that many of the new bottlenecks and increases in road traffic have a disproportional impact on other urban amenities since they now occur on streets typically not designed for those traffic flows. These displaced flows increase the risk of crashes and erode the welfare of those who live or work adjacent to these parts of the network (Macfarlane, 2019) (Bliss, 2019). Smart city policies should assess the potential for initial benefits to scale.

Smart mobility and equity

Equity concerns are often citied but rarely expressly included in the measurement of many smart mobility projects. As with more general smart city initiatives, smart mobility may deliver better equity outcomes with proper framing, but this requires addressing many challenges. These include affordability, both of

services and of data plans and technologies used to access them. It also requires a systems perspective in addressing what may be the knock-on equity impacts of smart mobility systems. For instance, smart mobility deployments that cannibalise or otherwise erode the viability of public transport systems may harm low-cost (but less flexible) travel options for low-income households. Use of smart mobility services by low income households may also represent "captive" rather than free choices due to the lack of alternatives. The high cost of these services account for a disproportionate share of low-income households. Access to smart mobility services (or to good quality public transport) is not uniformly distributed across space, putting low income households at a mobility disadvantage in comparison to others (CNT, 2019). These tensions are not unique to smart mobility, but if they are not addressed in the design of the smart mobility ecosystem, they may perpetuate or aggravate other structural inequities.

Uncertainty and lack of robust evidence on impacts

Many smart mobility initiatives claim benefits that seem plausible but are not yet supported by robust evidence. In other cases, too narrow framing of the problem may lead to underestimating overall impacts. Lack of evidence on impacts of smart mobility should elicit precaution on the part of public policy and a call for more, trustable, evidence from research and the private sector.

For example, the potential safety benefits of automated driving are significant, yet untested. These claims are generally supported by limited trials and a very significant volume of simulated travel. Automated driving promises a future where traffic automatically becomes safer as humans are taken out of the driving seat. It is not clear, however, that human-free driving will be safe. Nor is it clear that automated driving will be safer than conventional driving in every context, though there are strong reasons to believe that it will deliver better safety outcomes in some cases. Part of this uncertainty stems from the original premise that human errors are linked to over 90% of all fatal crashes. Removing human error from driving does not, however, mean a concomitant drop in fatalities.

A first element to consider when looking at the potential safety benefits of automation is that the reporting of "human error" involvement in fatal crashes may be overstated (Noy et al, 2018). A second aspect to consider when assessing the scope for automation to improve safety outcomes by removing "human errors" in crash causation is that it does not follow that all crashes attributed to human error could have been reasonably avoided by drivers (Noy et al, 2018). Finally, removing human driving error is not the same as replicated human driving performance. Automated driving may perform better than risky drivers, but evidence is lacking as to whether these systems will be as safe as good, or even average, drivers, in avoiding crashes in all contexts. A recent study concluded that only approximately one third of all US automotive crashes would likely be eliminated due to large-scale deployment of automated driving technology (Mueller, *et al*, 2019). That is a significant potential improvement – but it falls short of claims of the near-elimination of fatal road crashes.

Beyond automated driving technology, other smart mobility deployments have untested safety impacts. For instance, drivers might evade speed enforcement using smart and connected alert systems. They could also be distracted from driving by new services, from navigation and infotainment to Cooperative Intelligent Transport System (C-ITS) alerts. Further, conscious of the protection offered by active safety systems, drivers may take their eyes away from the road over sustained periods of time. Generally, driver distraction is likely to increase as smartphones, system display screens and vehicle infotainment systems compete for the driver's attention (ITF, 2019)

Another example of uncertainty on smart mobility impacts is the lack of robust evidence backing claims of energy use and environmental improvements from the deployment of smart mobility services, including ride-sourcing and app-enabled shared micro mobility. These claims typically ignore wider lifecycle impacts relating to upstream emissions, operational impacts, and the potential for these services

to replace trips taken by more energy efficient travel by public transport and active mobility. When these impacts are factored in – including the deadheading kilometres driven by ride-sourcing vehicles and the van kilometres driven to recharge and redistribute shared micro mobility vehicles – the environmental benefits of ride-sourcing and shared micro mobility are less than typically claimed, especially as compared to non-shared car- and e-scooter travel, respectively (ITF, 2020).

Mode substitution and travel generation impacts are also important to consider in evaluating the environmental impact of these services. Emerging evidence indicates that these are highly context specific. These findings do not change the fact that these smart mobility services generate tremendous consumer surplus, but they do indicate that this surplus also generates uncaptured externalities and thus may signal a role for policy (ITF, 2020)(ITF, 2020b).

From a policy perspective, it is important to note that some smart mobility benefits – like the safety benefits claimed for automated driving – can be delivered in other ways – "smart" or not -- often at lower cost and more immediate effect, e.g. speed management technologies and policies (ITF, 2018).

Tensions surrounding the privacy impacts of smart mobility data

The exponential growth in the production and storage of smart mobility-related data has been accompanied by rising concerns relating to the adequacy of regulations ensuring privacy. Location-based data is particularly vulnerable to breaches in privacy. Yet much of the mobility-related data being produced today has a geospatial component. Location-based data enhances services available to individuals and may contribute to significant improvements in safety, traffic operations and transport planning. For instance, Ecall or E-911 services that enable vehicles to report their spatial coordinates to a central server in case of a crash improve response times and accuracy. Likewise, individuals voluntarily contributing their spatial coordinates to applications have the expectation that this data will improve the quality of service they receive.

Privacy risks from even fully anonymised or pseudonymised location data rests in the strong re-identification potential for geotagged data (ITF, 2015) (Velentino-Devries, J. et al, 2018) (Thompson, S.A and Warzel, C., 2019). Rarely is location data directly linked to a unique individual – what is being tracked is a sensor-based platform. Many of these platforms (especially mobile handsets and car-based navigation systems) are intimately linked to one person's activity patterns in time and space – not just to a specific identity number. Mobile handsets are almost always on or near to their owners and cars are rarely shared outside of the household. The location data of these devices are highly privacy-revealing when linked to repetitive and predictable daily patterns of activity. Trajectory-based and time-stamped location data is a potent quasi-identifier for a single person or persons within a single household – it is (nearly) as identifiable as a fingerprint. Even coarse-grained and imprecise trajectory data can be re-identified with relatively little effort.

Research on the privacy bounds of location data has resulted in a number of high-profile re-identification cases that have successfully isolated individual mobility traces from low granularity cellular base station data. A team of researchers at the Massachusetts Institute of Technology Media Lab analysed 15 months of mobile phone data for 1.5 million subscribers. They found that even for data with a temporal resolution of one hour and a spatial resolution equal to the cellular network's base tower cells, just four spatiotemporal points were sufficient to isolate and uniquely identify 95% of the individuals (de Montjoye et al, 2013).

Location-based and trajectory data are difficult to fully and permanently de-identify. Protecting the anonymity of high dimensional data like space-time trajectories or genetic information is more complicated than anonymising low-dimensional data such as addresses, names, blood type, etc. This

suggests that the most robust data protection methods should be applied to location, trajectory and other high dimensional personal data and that smart mobility systems should adopt the principles of "privacy by design" (Cavoukian & Castro, 2014) (ITF, 2015).

Tensions and frictions arising from asymmetric data production and access

Data produced by smart mobility technologies and the way in which it informs (or not) public policy is central to the evolving relationship between smart mobility services and public authorities. Mobility-related data collection, knowledge, and insight are increasingly shifting away from the public sector and into the private sector. This shift implies a growing information asymmetry between those in charge of regulating mobility and public space and those with actionable and relevant information to do so.

That smart mobility operators seek to protect the privacy-revealing data of their customers or commercially sensitive data regarding their operations is not surprising. This contrasts with a generalised move by public authorities to open their own data in order to stimulate new services and insights. It also raises questions of effective monitoring and regulation of shared public goods. For instance, smart mobility services benefit from access roads and curbs but, without data, public authorities are limited in their ability to manage these spaces for the public good. Likewise, with automated driving, public authorities have a responsibility to ensure that these technologies are safe but without data on the frequency and nature of avoided crashes or hand-offs from the automated driving system to the human driver, making that assessment is difficult.

This has led to public authorities either purchasing data from commercial actors or compelling them to provide their data. Neither approach ultimately satisfies both parties and yet "sell me your data" or "give me your data" largely comprise the only two data discovery options considered by the public sector. Operators fear that over-broad data sharing requirements on the part of public authorities may lead to privacy breaches or exposure of sensitive commercial data. Governments, however, typically collect and process sensitive data from individuals and companies and have been able to mitigate the risks of data breaches with appropriate policies. Another concern is that public authorities may lack the knowledge and technical skills required to process the data and use it for regulatory purposes. Lastly, a final concern is that over-reliance on digitally sourced data, because it is abundant and available, may lead to asymmetries between the regulatory treatment of "smart" versus other, non- or less-digital mobility services.

Tensions around new technologies and the ability to deploy traditional regulatory tools to monitor and manage these where needed

Many smart mobility technologies and services challenge or do not fit existing regulatory frameworks. This is typically because they offer innovations that were not predicted when regulations were developed --as in the case of drone delivery services -- or that challenge existing markets in unexpected ways -- as in the case of ride-sourcing service and taxi/public transport markets. Innovation, combined with rapid scaling, puts pressure on regulators to act appropriately so that smart mobility benefits are maximised without eroding other beneficial outcomes.

Public authorities have historically adapted regulatory frameworks in accordance with changing technologies and situations, but it is the *speed* of change that has proven challenging in many contexts around the world. This has led to situations where changes in regulations and regulatory skill lag behind the pace necessary to keep abreast with market developments and technology deployments.

D. Technology and Data Governance for Smart Mobility

D.1. What role do technology, services and data play in the delivery of smart mobility?

Technology, the services built on these, and the data they generate and collect all underpin smart mobility systems. Technology, alone, does not enable transformative change but is often the enabler that allows new forms of value creation to emerge. New activities, new services, and new forms of attaining private and public value emerge when technologies are put to use. This use requires investment and actions by parties who feel the benefits of doing so outweigh the risks.

What is a unique and emergent property of many smart mobility technologies is that they produce digital data that can be used to enhance public and private value. This is perhaps the most transformative aspect of smart mobility – the production and use of data that enables insights, creates value, and feeds into other cycles of value creation. In the context of smart mobility, technology, services and data, together, form an ecosystem that delivers individual, commercial, and social value that would otherwise be difficult to realise. In this respect, it seems appropriate to approach smart mobility as a technical-social system where all three are interconnected. This ecosystem is broad and complex and extends to many other forms of technical and social organisation.

Take, for example, the case of ride-sourcing. Ride-sourcing can be of the car-based type (Didi, Grab, Uber, to name a few), of the van-based type (Via, Jetty) or of the scooter-based type (Go-jek). The core value proposition of these services is as innovative as it has proven disruptive. But the realisation of their value proposition requires the deployment of several technologies, the creation of services built on these technologies, and the harnessing of data collected and generated by these services and technologies. Ride sourcing requires:

- Cars, mini-buses and motorised two-wheelers and vans and the global production, distribution, and fuelling systems that support them – all of which mobilise significant resources and human and financial capital.
- Infrastructure on which to operate and pavements and sidewalks to pick up and deliver people. All of this infrastructure has also required agreement on standards and on the rules that relate to their siting and construction.
- Commonly accepted rules relating to how to operate those vehicles in traffic, and all the signalling, signage, and enforcement mechanisms to ensure their safe and efficient operation.
- Hand-held computing and communication devices – smart phones, tablets and/smart watches. Like for vehicles, these are built on thousands of components and patents. They too mobilise global production chains from design facilities in Cupertino, to mines in the Congo, and the Altiplano to production facilities in Shenzhen.
- Electricity production and distribution networks, constellations of geo-stationary satellites, continuously ongoing efforts to map the world in real-time, and distributed and cooled servers around the world.
- Distribution systems – the dematerialised app-stores – and payment systems that allow access these services.
- Data collected and generated by component sensor platforms relating to location, identity, payment, heading, speed, traffic behaviour, vehicle status, vehicle subcomponent status, etc.
- Code, software and algorithms, to parse, sort, process and otherwise act on the data in order to deliver outcomes

- Perhaps, most importantly, they require people. People who have a need for these services, who feel comfortable using and trust these services, and who can afford them. People who have access to a bank account, who are digitally savvy and physically able to use these services. And they require drivers to provide services, who need to find this employment gainful, satisfying, and economically worthwhile, and who need to have sufficient training and be trust-worthy.
- And finally, though this has often been an afterthought in the early deployment of ride-sourcing services, they require a clear, fair, and robust regulatory framework to ensure that the deployment of these services provides societal value just as it provides individual value to passengers and drivers.

Viewed in this context – is digitally-enabled ride-sourcing simply a technology innovation? Not only. It is, as are many other smart mobility applications, dependent on a web of socio-technological factors that encompass, but are not limited to, technology alone.

D.2. What appropriate role for regulation in smart mobility?

Smart mobility leverages technology, new use cases, and data to deliver benefits. Each of these requires an adapted regulatory framework that enables innovation without hindering other desired societal outcomes – like equity, safety, or efficiency. These should be interlinked where possible and the overall regulatory framework should be transparent, agile when required, and clearly linked to over-arching public policy objectives. This does not mean that governments necessarily need to regulate all outcomes – private sector actions may be guided by tools other than direct regulation – like voluntary agreements or contractual/concessionary agreements. Nor does it mean that public authorities must regulate everything that is new – an appropriate response to smart mobility deployments may be to remove existing regulation where it is no longer warranted or to adapt it. Finally, regulation of innovation requires flexibility. Beyond ensuring necessary guiderails with respect to safety, environment, and competitive markets, regulation should be iterative and flexible in order to account for many unknowns around the uptake and impact of smart mobility initiatives.

Mobility is already a highly regulated field, from the safety of vehicles and infrastructure, to market conditions for public transport and other services, minimising environmental impact, licensing drivers and enforcing traffic rules. Smart mobility does not obviate the need for regulatory interventions, but in many instances, it changes the scope of what is to be regulated and how.

Government action in the transport sector, like elsewhere, is guided by the twin imperatives of *enabling* people to create or take advantage of opportunities and *ensuring* that in so doing, agreed public policy outcomes are achieved and shared principles for action are upheld (Giddens, 2009). Carrying the twin function of *enabling* and *ensuring* leads governments to intervene in a number of areas under the general headings of carrying out public policy, addressing market failures, and investment as a policy tool (Docherty, *et al,* 2018). These interventions all have relevance for smart mobility initiatives as outlined in Table 2.

Table 2: Reasons for government intervention in transport governance

Purpose of intervention	Key issues today	Relation to smart mobility
Public policy-setting		
Setting overall direction of policy	Increasing recognition of the role of transport in supporting economic growth, social progress and health.	*Sustainable* Smart Mobility as an imperative.
Environmental, economic and social externalities exist	Climate change, air quality, congestion, social exclusion and inequity are not tackled through the market.	Inclusion of externalities in smart mobility markets.
Coordination of transport, land-use and economic goals	Planning to accommodate growth in many cities whilst maintaining or improving accessibility requires intervention.	Prioritising smart mobility deployment according to broad societal goals.
Setting standards and communicating with public about transport system operation	Defining levels of service and reporting on how these are met, justifying efficient spending of taxation, managing disruptive events.	Leveraging smart technology to provide overview of system performance.
Balancing the needs of different transport systems and users	Decisions on infrastructure spend and maintenance, road space allocation and legal frameworks on rights.	Ensuring transparency and public participation in framing smart mobility investments and policy.
Market failures		
Conditions for a free market do not exist	Managing monopoly infrastructure providers and limited service competition, preventing collusion	Adopting a more agile and data-driven approach to identifying and redressing market failures.
Acting as a provider or procurer of services which are not profitable	Often to ensure basic levels of service to some communities, network continuity, evening and weekend services or for bespoke services such as school or hospital transport.	Supporting smart mobility services where they deliver social value but may be uneconomic to operate by service providers
Problems of co-ordination between modes exist	Competition can exist between public transport operators within and between modes. Limited ticketing integration.	In conformity with agreed public policy objectives, ensure sufficient coordination among smart mobility services to deliver on desired outcomes.
Basic standards of operation and rules of movement	Interoperability between systems, data, standardization of laws and enforcement.	Encourage or adopt basic levels of interoperability for smart mobility services to improve value for people and predictability for operators.
Investment as policy		
Funding the provision and upkeep of infrastructure	Sets general taxes and mobility related taxes and charges at various levels of government to fund the upkeep of infrastructure and subsidy of some services. The state can borrow at lower rates than the private sector.	Ensure that taxation of smart mobility services is proportional to the costs they impose and that market entrants are not unfairly burdened as compared to incumbents.
Supporting the adoption of transport innovations	Innovations are sometimes expensive in their early stage adoption or require additional infrastructures, supported by state subsidy and investment or new regulation.	In the case of government support for smart mobility pilots, ensure that these are limited in scope and time and proportional to expected benefits.
The state is an aggregator of risk and has primary accountability	The state ultimately remains guarantor when private provision of public services fails and retains accountability via the ballot box.	Account and for and mitigate risks linked to sudden market exit of smart mobility services when these provide essential services.

Source: Adapted from (Docherty, et al, 2018)

The interventions outlined in Table 2 involve public authorities but are not necessarily dominated by them since other market actors may equally have a role to play in delivering desired outcomes. However, even if public authorities are just one actor among many in the area of smart mobility, they still retain unique responsibilities linked to their mandates and may be required to fulfil roles that others cannot (Millard, 2020x). Regulatory action is necessary in many cases, but it must be proportionate to the outcomes and to the ability of different stakeholders to contribute to the achievement of these.

Pressure to quickly regulate certain smart mobility services has been intense and has often been exacerbated by the mode of entry employed by smart mobility operators. Many ride-sourcing or shared

micromobility companies have exploited regulatory ambiguity to enter markets and establish market share quickly, displaying what (Flores and Rayle, 2016) have described as "calculated indifference to regulatory logic". Attempts to assert their right to operate outside the regulatory systems applied to competing services have necessarily raised concern within governments about their ability to address negative impacts. These factors, plus the disruptive impacts that app-based services have had in many markets, have initially led many governments to attempt to block their entry, particularly in the case of ride-sourcing. However, strong consumer demand for these services has led to rapid changes in government stances in many jurisdictions, with prohibition being replaced by the adoption of light-handed regulatory approaches. This light-handed approach has, in turn, been criticised as failing to deal adequately with negative externalities generated by these services, giving rise to demand for more interventionist approaches.

In a number of cities, early deployments of ride-sourcing services typically exploited regulatory grey areas or simply ignored existing laws. The case of Sao Paulo is illustrative. In 2014, Uber entered the Sao Paulo ride-hailing market arguing that it was neither a taxi company (taxis were regulated as one form of public transport) nor a mobility provider (arguing that it was a technology platform enabling riders to match with drivers). As such it argued it did not need a license to operate and did not seek one. Taxis and other incumbents argued that this posed unfair competition to their highly regulated (and largely unchanged) services. After a change in the national law that sought to make the distinction between providers of individual private transport and individualised public transport, Uber argued that its services were best characterised by the former and thus not subject to the same regulatory oversight as taxis. This was contested in the courts and conflicting judgements, largely based on interpretations of existing regulations, led to a situation characterised by legal uncertainty over the status of Uber's services. Addressing this uncertainty, and in an attempt to move away from a compliance-based approach to a public benefit-based one, the Municipality sought public input and proposed a new regulatory framework that recognised the value created by ride-sourcing as embodied by Uber's services and sought to regulate it in such a way to maximise these while delivering on other public policy outcomes (Zanatta and Kira, 2018). This process has been replicated in other cities from New York to Paris and for some entire countries (e.g. Germany and Japan).

Regulation should be based on a clear understanding of the dynamics of the relevant market and the identification of significant market failure(s) and/or equity issues. For example, the city of Paris decided to re-assess its permissive shared micromobility based on a voluntary charter signed by e-scooter companies when it became apparent that poorly parked devices were eroding public amenity and safety of sidewalks. It pivoted to a concession-based model, strongly limiting the number of operators and increasing the city's oversight and enforcement powers. While governments may wish to regulate ex ante, to address clearly foreseeable harms, care must be taken to ensure that the nature of new services and the emerging market in which they operate are sufficiently well-understood, to avoid imposing ineffective regulation with unanticipated costs.

While there have been rapid shifts in government approaches in some jurisdictions, a common problem is the lack of a strategic and thorough approach to reforming existing regulatory structures to reflect substantially changed market realities. On the one hand, this means removing or modifying long-standing restrictions that can inhibit incumbents from competing on a level playing-field with the disruptors, as illustrated in the ride-sourcing case in Sao Paulo above. On the other, it involves developing new regulatory structures that are better adapted to the innovative business models that have emerged.

Long-term outcomes can be maximised when regulations expressly account for specific types of smart mobility, clearly set out different actors' responsibilities and the consequences of failure to carry these out, and when there is robust alignment between smart mobility initiatives and long term public strategies

(Moscholidou, I. and Pangbourne, K., 2019). These three functions will require consistently addressing regulatory quality and accounting for the uncertainty that characterises the assessment of many smart mobility initiatives.

Ensuring regulatory quality

Calibrating the regulatory response to smart mobility must build on the foundation of good regulatory quality such that regulatory interventions achieve their stated purposes with the minimum amount of burden. The OECD Guiding Principles for Regulatory Quality (OECD, 2005) provide a guiding framework for achieving the right balance between innovation and social welfare. It states that good regulation should:

1. serve clearly identified policy goals, and be effective in achieving those goals;
2. have a sound legal and empirical basis;
3. produce benefits that justify costs, considering the distribution of effects across society and taking economic, environmental and social effects into account;
4. minimise costs and market distortions;
5. promote innovation through market incentives and goal-based approaches;
6. be clear, simple, and practical for users;
7. be consistent with other regulations and policies; and
8. be compatible as far as possible with competition, trade and investment-facilitating principles at domestic and international levels.

These principles should form the basis of sound regulation in the case of smart mobility such that final societal outcomes are maximised. They should also serve to frame the rollout of regulatory remedies moving from more general, cross-sectoral and cross-mode, application of rules to, where it is justified, the more specific application of regulations targeting smart mobility. They serve as a sound basis for undertaking *regulatory impact assessments* for smart mobility (OECD, 2012), which can clarify the relative merits of possible policy interventions. A key issue is that of determining when sector-specific regulation is the preferred tool and when broader approaches would be more effective and equitable.

How to address the congestion and pollution impacts of ride-sourcing is a good case in point. Ride-sourcing has negative impacts on congestion and pollution because of the circulation of additional private vehicles (ITF, 2020 – Forthcoming). However, congestion and pollution are problems to which the whole vehicle fleet contributes, and the most effective responses will, similarly, be those that apply to the whole fleet. Regulation that specifically targets ride-sourcing is likely to be of limited effectiveness in most circumstances, since ride-sourcing accounts for only a small part of the fleet. Even in large and very dense city centres, where taxi and ride-sourcing vehicles may account for a significant portion of the fleet, a ride-sourcing-specific congestion charge will both remain less effective than a generally applicable one and raise equity concerns. That is, such a policy imposes charges on relatively infrequent users of ride-sourcing services while exempting people who commute daily to city centres in private vehicles and are likely to be relatively high-income earners. Moreover, the flat, per-ride fees that have usually been imposed to date do not discriminate according to the time and location of the ride and are thus poorly targeted with respect to congestion.

Generally applicable congestion charges or low emission zones, which apply to private vehicles as well as ride-sourcing, are likely to prove more effective and avoid putting at risk the welfare benefits generated by the smart mobility services like ride-sourcing. At a minimum, if sector-specific congestion charges are

used they should apply equally to taxis and ride-sourcing, in order to avoid distorting competition between the sectors.

Regulating smart mobility under uncertainty

There may be a general tendency to address the regulation of smart mobility only from the perspective of the current regulatory framework – e.g. the "compliance trap" (Danaher, 2018). This compliance trap also extends to the methods and practices that regulatory agencies employ to deliver on their mandate to protect public welfare, ensure competitive markets and avoid harms. Regulatory agencies will need to be innovative in the way they carry out their functions because many of the impacts of smart mobility initiatives are hard to know and there is little prior knowledge to help evaluate the scope and scale of these impacts (Hagemann, Skees and Thierer, 2018).

A key principle is that of equal regulatory treatment of incumbents and entrants; that is, that regulation should be pro-competitive. This does not mean that all market segments must be subject to identical regulation, as different business models may require different regulatory arrangements. However, it does imply that regulation should not have the purpose of favouring incumbents over new entrants, or vice-versa and that proposed regulation that would have substantially different impacts on incumbents and entrants should be carefully reviewed. Where governments seek to cushion the impact of disruption on former incumbents, this should generally be done through other policy instruments, in order to avoid the risk of distorting competition and placing artificial constraints on welfare-enhancing innovation

The current approach to protect people, internalise impacts, and ensure competitive markets is largely to "regulate and forget" – e.g. to take the time to craft the right regulatory framework, enact it, and then infrequently update it, if ever (Eggers, Turley and Kishnani, 2018a). This approach is poorly adapted to the speed of technology and service innovation in the transport sector today. It fails to satisfactorily address the "pacing problem" where regulatory action is outstripped by market developments. Pressure to regulate rapidly, and often lightly, is exacerbated by the "global innovation arbitrage" where, in the global economy, innovation, like capital, flows to those markets where restraints on both are minimised (Theirer, 2016).

The risk for smart mobility policies is that regulators will either act too soon, too late, too permissively, or too restrictively. To minimise these risks, they will need to change the way in which they regulate under uncertainty. (Eggers, Turley and Kishnani, 2018a) outline five useful principles for doing so:

Risk-weighted regulation

Not all smart mobility deployments pose the same risks. Most are beneficial, many are benign in terms of the risks they pose, and some may impose potentially large and consequential risks. Regulation should be tailored to address these risks in a graduated and targeted manner. The most intrusive and constraining regulatory responses should be aligned with the probability and scope of identified harms and the lack of other adapted regulatory tools.

Adaptive regulation

Governments should recognise that the rapidly evolving nature of smart mobility services gives rise to substantial risks and difficulties in designing regulatory arrangements. This means that even well-designed regulation may quickly become outdated and no longer fit-for-purpose. Scheduled reviews, based on transparent and rigorous methodologies, are needed to ensure systematically that regulation is refined, improved and adapted to new realities over time. Ensuring that system performance data is being collected and analysed will contribute substantially to the quality of such reviews.

Governments could consider moving from a "regulate and forget" model of regulation to a more dynamic, iterative and responsive model better adapted to accommodate rapid changes and an uncertain

technology environment. This could improve the business environment and foster innovation, providing more certainty about the conditions in which individuals and firms will make decisions. However, the traditional approach of seeking input from a broad range of stakeholders, investing a considerable amount of time in crafting considered rules and laws, passing them, and then leaving them largely unchanged, is not adapted to the pacing problem governments face today relating to digital technologies and services. Furthermore, this approach may not allow regulators to adapt their rules easily once they see how individuals and firms respond to them, sometimes in unexpected ways.

Rather than providing certainty about *specific rules* that governments will put into place, public authorities could assure people and companies about the *process* whereby those rules will be revisited, assessed, updated or changed, as necessary. Governments will need to establish rapid feedback loops and a greater diversity of "soft law" (informal guidance, self-regulation, best practice guidance, third-party certification) as opposed to "hard law" tools. One of the principal advantages of soft law approaches is that they allow regulators to adapt quickly to changes in technology and business models and to regulate "on the fly" as issues arise (Eggers, Turley and Kishnani, 2018a).

Harnessing the value that smart mobility services may generate may require other forms of adaptation beyond regulatory accommodation. This can come in several forms. For some vanpooling services and perhaps shared micro mobility, it could imply the provision of direct subsidies to service providers to help achieve connectivity ends at lowest cost and with the highest "quality". For smart mobility services that have an impact on public space (ride-sourcing and shared micro mobility, for example) public authorities may need to increase expenditure on adapting streets to provide segregated road space and parking space and supporting regulation in areas such as speed limits and overtaking rules. This can maximise the take-up of these modes, with their wider urban policy benefits, while reducing nuisance and ensuring safety standards are maintained, by minimising modal conflicts.

Regulatory sandboxes and accelerators

In line with the adaptive regulatory approach, public authorities can create time-limited, partial exemptions from prevailing regulatory requirements. This temporarily frees deployers of smart mobility systems from red tape and allows for faster release of their systems. It also provides a testing ground for regulators, a time period where they can learn if regulation would be necessary if these new systems were to scale up, what that regulation might look like, and how to implement it. Both accelerators and regulatory sandboxes help accelerate innovation and give regulators assurances that potential unwanted, negative outcomes remain manageable and can be addressed jointly with the private sector.

Minimising regulatory barriers is particularly important where new modes and business models, with uncertain viability (such as dock-less bikeshare and electric push-scooters), are concerned. In many cases, small trial schemes, with limited regulation, can provide valuable practical experience. Governments could consider bearing the initial regulatory costs in such circumstances, rather than seeking to recover them from new businesses, as a means of encouraging innovation.

Outcome-based regulation

There has been a general shift in many areas of transport regulation turning focus from technical specifications and form to results and system performance. This has enabled more efficient delivery of public policy outcomes in many cases and propelled innovation. Specifying technologies and processes make sense in many areas, especially those relating to safety, but many regulations can be re-framed by referencing the outcomes they should ensure instead of the means whereby they do so.

Outcome-based regulations are facilitated by the development of guidelines versus hard laws. These allow rapid iteration and provide regulators the opportunity to update them as impacts and negative outcomes

become known. They also require robust and broadly accepted metrics whereby performance-based outputs can be measured and guidelines adjusted if outputs are under-delivered or not at all.

Collaborative regulation

Achieving regulatory compliance requires resources from regulated entities and regulators. This is especially the case where regulators each develop their own regulatory approach and where those deploying smart mobility systems must comply with different regulatory frameworks across regional, national and global markets. Inconsistent regulatory frameworks – e.g. regulatory divergence – increase the cost of regulation and may limit the diffusion of innovative products and services.

Much can be gained by ensuring that regulatory frameworks for smart mobility are as consistent and predictable as they can be, though there is a strong case for also taking into account local and national contexts when designing them. Collaborative regulatory approaches involving co-regulation and coordination among regulatory agencies helps lower the cost of regulation and can ensure a predictable ecosystem for the deployment of smart mobility systems. This type of collaborative approach could be applied to common smart mobility impact assessment processes and privacy protections.

Collaboratively developing regulatory frameworks for smart mobility may also help to overcome regulatory barriers to interoperability and broader, more robust efforts to ensure data security and privacy. Convergence around common standards for electric charging infrastructure are a good example of the former, where broad agreement on the types of charging interfaces can help the uptake of electric powertrains. Common approaches to the protection of data and data flows across multiple jurisdictions are a good example of the latter, where alignment of data rules and protections incentivise actors to engage in smart mobility services and data-producing technologies. For example, buyer uncertainty regarding the use of personally identifiable data generated by an Advanced Driver Assistance System (ADAS) equipped car could depress sales and prevent uptake, especially if the data were transmitted to other jurisdictions operating under a different and more permissive set of data processing rules.

D.3. Technology appraisal – when and how to guide technology deployment

Technology is at the heart of smart city initiatives and public authorities must assess when and how to help guide its deployment in line with public policy objectives as described in the previous section. While many countries and cities have Smart City or Smart Technology Strategic plans, relatively few have dedicated plans addressing smart mobility. Responses to the survey of G20 members and partners describe some of these:

> **Argentina** has highlighted smart mobility as one of the “in focus” areas of its Smart and Sustainable Cities National Plan. The national smart mobility plan has three pillars. The first is to guarantee the drivers for developing the smart mobility initiatives: data, interoperability systems, infrastructure, and cybersecurity. The second seeks to support the development of smart transport and smart mobility initiatives in accordance with the National Action Plan. The third pillar measures the real impact of smart mobility in the social, environmental, and economic dimensions of the country.
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> In February 2020, Transport **Canada**’s *Urban Mobility Task Force* released a set of interim guidance documents targeting Innovation and Technology, Financing and Funding, Governance and Land Use. These documents lay out the state of play in different domains of urban mobility and serve to stimulate discussion on how to coordinate and deploy longer term policies. The primer on innovation and technology notes five key areas that policies should address; the future of vehicles (including electric vehicles and automation, smart asset management strategies, security and

privacy, data management, resistance to change and compatibility and standardization (Transport Canada, 2020).

In **China**, the *Program of Building National Strength in Transportation* released in September 2019 states that the country will "vigorously develop smart transportation" and build a ubiquitous advanced information infrastructure and comprehensive big data center system for transportation.

The **European Union** created a *Sustainable Urban Mobility* cluster of actions under the *European Innovation Partnership for Smart Cities and Communities (EIP-SCC).* This cluster brings together cities and regions with companies to showcase innovative mobility solutions and support their replication at scale in key market segments. It aims to become the leading platform for understanding and documenting city needs, bringing stakeholders together, building the tools that support an innovation pipeline, and directly supporting individual networks and upcoming projects.

The EU also provides comprehensive guidelines for communities regarding the development and implementation of *Sustainable Urban Mobility Plans* (SUMPS) (EC, 2020). These guidelines were recently updated to include guidance on how to account for many new smart mobility technologies and services including automated vehicles, electric vehicles, intelligent transport systems, shared mobility including ride-sourcing and shared micro mobility, and mobility as a service (MaaS).

Germany has initiated a national platform on the “Future of Mobility” (NPM), headed by the Federal Ministry of Transport and Digital Infrastructure. This platform serves as the focal point for discussions on strategic decisions in the field of mobility. The NPM clarifies facts on complex topics and brings together relevant stakeholders, technical expertise and politics. Based on the results from discussions in the NPM, recommendations for action are made to politicians, businesses and society. The six working groups are; WG 1: Transport and climate change; WG 2: Alternative drive technologies and fuels for sustainable mobility; WG 3: Digitalisation in the mobility sector; WG 4: Securing Germany as a place for mobility, production, battery cell production, primary materials and recycling, training and qualification; WG 5: Connecting mobility and energy networks, sector integration and WG 6: Standardisation, norms, certification and type approval.

Turkey’s Smart City Strategy (National Smart Cities Strategy and Action Plan) addresses a number of points. A strong focus of the plan is to favour the dissemination of new generation, environmentally friendly (e.g. with alternative power system) means of transportation. The National Smart City Strategy also seeks to encourage the uptake of seamless and coordinated use of new mobility services and technologies. The plan foresees the deployment of infrastructure that supports new mobility services and use cases. Elements of the plan also address governance aspects at the national, regional and local level to help frame the organisation, resource management, planning and implementation, operational maintenance, monitoring evaluation, sustainability, interoperability, service management and coordination among stakeholders. Finally, the strategy addresses needs for data-driven logistics management that addresses greater efficiency through forward and reverse flows of goods, new services and data exchange between points of production and consumption.

The **United Kingdom**’s *Future of Mobility Urban Strategy* (March, 2019) sets out the UK's approach to responding to the uncertainty presented by innovation, ensuring that the country can take advantage of opportunities presented by emerging technologies and trends in transport, including

new jobs, more productive businesses, and economic growth. The strategy established nine Principles for shaping the future of urban mobility:

1. New modes of transport and new mobility services must be safe and secure by design.
2. The benefits of innovation in mobility must be available to all parts of the UK and all segments of society.
3. Walking, cycling and active travel must remain the best options for short urban journeys.
4. Mass transit must remain fundamental to an efficient transport system.
5. New mobility services must lead the transition to zero emissions.
6. Mobility innovation must help to reduce congestion through more efficient use of limited road space, for example through sharing rides, increasing occupancy or consolidating freight.
7. The marketplace for mobility must be open to stimulate innovation and give the best deal to consumers.
8. New mobility services must be designed to operate as part of an integrated transport system combining public, private and multiple modes for transport users.
9. Data from new mobility services must be shared where appropriate to improve choice and the operation of the transport system.

Singapore's Strategic National Project (SNP) on Smart Urban Mobility leverages data and digital technologies, including artificial intelligence and autonomous vehicles, to enhance public transport is one of the three Strategic National Projects (SNPs) - key enablers in Singapore's Smart Nation drive. To meet the challenges faced in Singapore's land transport sector, Singapore's vision is to create a car-light Singapore where people choose to 'Walk, Cycle, and Ride' public transport, taxis, private-hire cars, or shared cars (WCR), and where urban mobility can be achieved in the most resource-efficient manner. Technology and innovation are important enablers that allow Singapore to achieve this vision.

Many G20 and partner countries also provide strategic guidance or investment in specific projects or targeted smart mobility sectors. These typically involve areas where national coordination is helpful, where longer-term industrial considerations are important, or where there are no identified parties willing to bear some of the first-mover risks associated with smart mobility deployments. These areas include:

- Integrated ticketing (Argentina, Saudi Arabia)
- Automated driving (France, United Kingdom, United States, Singapore, United Arab Emirates)
- Smart Infrastructure (Canada, Italy, Saudi Arabia, Russian Federation)
- Mobility as a Service (Japan)
- Urban air mobility (United States, United Arab Emirates)

Cities and communities are at the forefront of many smart mobility initiatives and it is often on their territories that smart mobility technologies are deployed. They stand to benefit directly from these initiatives but may also bear the brunt of any unexpected impacts. For this reason, many cities and communities want to guide the deployment of smart mobility technologies and services.

A good example of a city-led smart mobility technology plan is the city of Los Angeles' *Urban Mobility in a Digital Age: A Transportation Technology Strategy for Los Angeles* (Hand, 2016). The Los Angeles Department of Transport (LADOT) developed this plan in articulation with other strategic plans targeting

mobility (Mobility Plan), safety (Vision Zero), and improving air quality by decreasing congestion (Sustainability pLAn). The technology plan was seen as an essential element in the city's policy strategies given that the smart deployment of technology could facilitate reaching all of its strategic objectives. LADOT's transportation technology strategy re-casts the department's mission around three customer service delivery goals (Hand, 2016):

> ***Data as a Service****: Data as a Service is the rapid exchange of real-time conditions and service information between service providers, customers and the supporting infrastructure. This requires a seamless data exchange with a variety of partners and stakeholders, privacy and security protections, the capacity to analyze data from a variety of resources, and the ability to integrate this insight into a data-driven decision-making process at the level of elected officials and department management.*
>
> ***Mobility as a Service****: Mobility as a Service centers on the customer or mobility consumer, a person who purchases and uses transportation for personal use. It is a single platform and payment system that offers access to a suite of transportation mode choices, often bundled together in packages. This approach requires collaboration and coordination across different transportation modes and providers and creates a potentially competitive marketplace of services to meet the real-time and changing needs of people throughout the day, week or month, effectively transforming the single-occupant automobile owner model.*
>
> ***Infrastructure as a Service****: Infrastructure as a Service proposes that the use of public infrastructure should be subject to pay-as-you-go user fees that more closely align the costs associated with providing the infrastructure itself to how the infrastructure is being used. Infrastructure as a Service more transparently reflects the costs for the City of Los Angeles and other agencies to build, maintain, and operate public infrastructure by charging fees for this service. With a solid data baseline, this approach can also support tiered fees to ensure there is equity in access to the public right-of-way. Infrastructure as a Service can help shift behavior by incentivizing shared mobility, promoting staggered commute times, and other active transportation alternatives.*

The plan sets out specific areas of action, time horizons (0-2 years, 2-6 years and beyond 6 years), and objectives for prioritizing technology development and the services it enables, in line with overall public policy goals for the city. It focuses on ensuring that regulatory frameworks and principles are both in line with a quickly changing urban mobility context and that these are future proof as well. The strategy outlines key actions in five specific areas:

1. Building a solid data foundation
2. Leveraging technology and design for a better transportation experience
3. Creating partnerships for more shared services
4. Establishing feedback loops for services and infrastructure
5. Preparing for an automated future

D.4. Data sharing and syntaxes for inter-platform interoperability

Principles for data sharing

Data is central to smart mobility and managing and sharing data wisely is central to ensuring broad mobility benefits. As noted previously, there are strong tensions regarding the way in which data is collected, by whom, for what purposes and how a balance may be struck between individual and commercial value, on the one hand, and public and social value on the other.

Transport systems and their users are generating an ever-increasing amount of data, representing a (largely untapped) potential source of improvement in transport system performance. From a public policy perspective, this data can be useful for monitoring compliance with, and enacting enforcement of, rules related to safety, regulated uses of public space, and other public policy outcomes (e.g. competitive markets). This data can also be useful for planning purposes, helping authorities improve efficiency, equity, sustainability, and contribute to the welfare of people.

The governance of data-sharing must address these concerns as well as the capacity of stakeholders to abide by data sharing rules. Where there is public value in doing so, authorities may foster frameworks that enable targeted data-sharing that respects privacy and commercial sensitivities of both people and companies, while guaranteeing its cyber-resilience.

Data sharing mandates on the part of public authorities should build data minimisation concerns in by default. These frameworks should link desired public policy outcomes (e.g., improved accessibility, better environmental outcomes, improved equity, improved safety, reduced congestion, liveable cities, etc.) to the regulatory and planning methods or use cases which may deliver those outcomes (e.g. congestion management, parking control, managing curb and other public space access, enforcement actions, travel activity monitoring, data to support infrastructure interventions, etc.) and to the specific data required to carry out those regulatory and planning actions – including rules relating to an appropriate level of aggregation, data handling, data retention periods and auditability, as well as data destruction protocols.

The EU has passed a delegated act requiring members to put in place open data frameworks for multimodal trip data (EU Delegated Act 2017/1926). Finland and France have both recently enacted ambitious data-sharing requirements in their national transport legislation, which meet the intent of the EU Delegated Act.

Finland, in its recent reform of the National Transport Code (NTC), lays the groundwork for data sharing in support of a national Mobility as a Service (MaaS) ecosystem (Table 3). Rather than focusing on data structure, the NTC addresses data availability and usability. The code calls for transport service providers and regulated entities to establish an open, easily accessible, and useable digital channel delivering a common set of data items. These provisions are meant to create an open and level playing field where both small and large operators can more seamlessly coordinate or link their services and create new innovative options or applications. Shared data items must include those outlined in Table 3 (Finnish Ministry of Transport, 2019):

Table 3: Required data reporting elements for operators providing passenger transport services in Finland

The identity of the service provider, commercial registration number and contact information that a service user can use.
Data regarding the spatial coverage of the service.
Information on payment options.
Information related to the accessibility of the service to those with mobility or other impairments.
Machine-readable information regarding scheduled service operation and spatially-referenced route information.
The location of scheduled traffic stops, stations, terminals with related timetable information.
The period(s) for which the service or timetable information is valid.
For non-scheduled services and for any potential service provider, geospatial information on predetermined stops, stations, terminals, etc.
For non-scheduled or on-demand services, information on the times the services are available.
Information on how to book or hail the services(s) with a link to the booking engine if applicable.
Information on the price of the service including the breakdown into both static and dynamic (e.g. time- or distance-based) fare components, including discounts. This information should allow for cross-service comparison (e.g. for peak hour use).
Dynamic price information and information on available capacity, or a link to the service from which this information is available.
Information regarding restrictions, conditions, extra fees or policies or available options (e.g. regarding baggage transport, policies regarding animals, carriage of children, work stoppages, etc.).
Real time trip planning and en-route data or a link to a service making this information available.
For non-scheduled services, map-based display of the location of available and/or booked vehicles or a link to the service from which the information is available.
Estimates of significant delays or cancellations in services as soon as they are available to service providers.
A link to the web site or other electronic service of the service provider.

France, in the recently approved National Mobility Law (Loi d'orientation des mobilités – 2019), sets out requirements regarding data sharing in support of smart and sustainable mobility. These data sharing requirements concern not only public transport operators, but other providers of mobility services, including ride-sourcing, taxis, shared micro mobility as well as data from connected vehicles. The uses to which this data may be put is limited to three use cases: optimizing traveler information and the offer of multimodal transport, improving travel information and other services for mobility-impaired travelers, and improving road safety and incident response capabilities. The law is silent for now on what form this data should take and whether common and shared data syntaxes will be required.

Over-arching data privacy and processing laws such as in the EU with the EU General Data Protection Regulation (GDPR) or the California Consumer Privacy Act 2018, help set the bounds for the collection, processing, use, retention, and destruction of mobility data and provide a helpful frame of reference for ensuring the privacy of that data. Where such frameworks do not yet exist, data-sharing agreements must be explicit in addressing privacy risks in their design and implementation.

Other data sharing frameworks have been developed outside the scope of national laws. Germany, for instance, plans to develop a concept of decentralized, networked mobility platforms under the aegis of the National Platform Future of Mobility (NPM). On this basis, a comprehensive mobility data network is to be created, which will be shared by private and public actors. Germany has also developed a data service called mCLOUD which serves as a data repository for Open Data from public and private sources.

The EU's SynchroniCity project supports the development of a reference architecture and design principle for open urban data platforms, based on comprehensive set of city needs and requirements. The standard was tested and further developed into Minimum Interoperability Mechanisms (MIMs) to facilitate interoperability with other urban mobility services.

Data syntaxes and data sharing

The costs of regulatory compliance on the part of operators and the reduction of regulatory burdens on regulators can be reduced if common data syntaxes are specified for the exchange of digital data. Common formats have been the rule for analogue data reporting in the past and the convergence around common reporting formats for smart mobility data is still very much relevant today. However, the rapid expansion of digitally enabled mobility services has led to a situation where smart mobility systems are not designed to produce the reporting data authorities require, and where reporting standards have not yet converged, such that operators can design their reporting systems to one format. This means that authorities may not be able to easily specify which data they need for which purpose and operators cannot design their code to produce that data easily.

The lack of settled syntaxes for reporting mandated data imposes a dual burden in that authorities may over-reach and ask for all operator data (see the discussion above) or that operators or authorities must either produce (for operators) or translate (for authorities) various data reporting formats.

For these reasons, there has been a push to develop common data reporting syntaxes. The Mobility data Specification (MDS) is a good example of an open, evolutive, data syntax that has been deployed in many cities to frame data reporting requirements by shared mobility operators.

The Mobility Data Specification (MDS) is a data standard and application programming interface (API) specification for mobility as a service (MaaS) providers, such as ride-source companies, docked and dockless bikeshare and carshare, e-Scooters, public transport and, ultimately, all future operators who will deliver transport services within the public right of way, including low-level airspace (LADOT, 2019a; LADOT, 2019b; LADOT, 2019c).

MDS has been developed to facilitate two-way communication in a regulatory environment both from regulated entities to a regulator and from the regulator to regulated entities. The specification is a way to implement data sharing, monitoring, and communication of regulatory intent for public authorities and MaaS providers. Public authorities recognise MDS as a tool to manage regulated entities and require that it be used and complied with in the licensing process.

At present, MDS is comprised of two distinct components: the provider API and the agency API.

The *provider API* is implemented by Maas providers. It enables the exchange of data and operational information that the public authority may request. The provider API allows authorities to access the record of past operations in order to monitor compliance, adjust licensing terms, or plan on the basis of revealed transport behaviours.

The *agency API* is implemented by regulatory agencies. It is a gateway that allows service providers to submit queries and integrate results directly into their work processes as algorithmic inputs during their operations. The agency API provides tools for public authorities to signal to service providers what uses are allowed for specific (geo-referenced and time-bound) parts of the public domain, the conditions for that use, and – in some cases – the cost, and convey information to providers to help plan future operations. Looking forward, the MDS agency API could be a way of providing digital input into the regulatory component of vehicles' and drones' operational design domain (ODD) rules, which set the operational parameters and constraints for automated systems.

MDS is published and maintained on GitHub as an open and collaborative initiative. It built around five core principles:

- *Open-Source:* allows any city or company to run MDS and related products as a service within their city free from any royalties or license fees.
- *Competition:* fosters a competitive market for companies to develop products as a service in cities by creating a single platform where everyone is invited to participate and build.
- *Data and Privacy:* adheres to best practices for privacy standards, commits to data collection transparency, and – above all else – protects citizen privacy.
- *Harmony:* encourages consistent regulation so that providers can offer low-cost, homogeneous services across municipal borders.
- *Sustainability:* prepares cities for regulating transportation services that are low-emission, resilient, and ultimately better for the environment

The most innovative element of MDS – the formalisation of a legal and machine-readable bi-directional regulatory framework for mobility services – is a compelling one that helps both public authorities and service providers achieve their objectives for better regulation for more innovation. Nonetheless, there are real concerns with the specific formulation of the first version of MDS, especially surrounding the detail and granularity of data collected and associated risks for individual privacy and commercial sensitivity. These tensions are indicative of the greater challenge to ensure that privacy harms are not exacerbated by the use of and design of regulatory frameworks for smart mobility systems, as previously discussed. This challenge holds for the public deployment and use of algorithmic governance frameworks (like MDS) as well as for private operators of mobility services who are governed by those same frameworks.

Going beyond data sharing

Mandated data sharing is not the only way to gain trustable information for use in regulatory oversight. One alternative to the current data "ask" is to entrust and house data with neutral third parties that mediate access to the data or its analytic outputs according to rules agreed by all. This third party could be a university or a dedicated public agency (though public universities and agencies may face similar conflicts as transport authorities in legal regimes where public authorities must adhere to "right-to-know" laws) or an audited commercial data-holding operator.

Recent changes in data science and new alternatives to data sharing provide new ways of extracting useable insight from raw data. In traditional data-sharing approaches, data itself is transmitted from where it is collected and housed to a commercial partner or to a public agency – with all of the competition and privacy risks that this might entail. That is because having the data in hand has been the best way to ensure the correctness, veracity, and trustworthiness of the analytical outputs based on the data. However, rather than relying on transmitting data between parties, new emerging approaches rely on trading trusted and vetted code – essentially transmitting code to the original data source and executing its analysis there and allowing these algorithms to run analytic operations on, and return trusted responses from, remotely-held data. The World Bank-initiated OpenTraffic project (Sharpin, Adriazola-Steil, & Canales, 2017) or the MIT-developed "Safe Answer" (de Montjoye, Shmueli, Wang, & Pentland, 2014) Open Algorithm (OPAL, 2017) and Enigma (MIT, 2017) projects are examples of this approach. Another approach is to push data protection efforts to the sensing "edge", that is – to strip data of identifiers or information that would enable easy re-identification (e.g. through aggregation, obfuscation, etc.) at the moment it is sensed or collected. Such in-flow data treatment would reduce many of the potential privacy risks posed by ubiquitous data collection (ITF, 2015).

These and other analogous approaches to sharing trustable information without sharing data rest on the ability of all partners to verify that their trust is well-placed. This means that robust auditing frameworks are required to reinforce that trust and to ensure that all stakeholders can be held responsible for breaching that trust.

Inter-platform interoperability: the case of Mobility as a Service (MaaS)

A key development in relation to smart mobility is that of the bundling of service offers involving different modes into a unified Mobility as a Service (MaaS) offer based on providing multi-modal mobility solutions that break the link between mobility and ownership of vehicles. These offers provide people with unified and simplified access to a number of different mobility services (public transport, ride-sourcing, car-sharing or shared micro mobility, taxi or car rental/lease, or any combination of these). Operators offer their services to people via an app-enabled platform that may be operated either by one of the operators themselves, by a public authority or by a dedicated third-party. In all three cases, MaaS platforms raise the question of how platform access rules are set, who serves as the gatekeeper, and how to prevent anti-competitive behaviour.

In some cases, single companies may develop their own vertically integrated platforms populated by their own or partner services. Such "walled garden" (Zipper, 2019) models can deliver significant consumer value, as all services are tightly coordinated, but the risk of anti-competitive behaviour is relevant as is uncertainty on how well these platforms may be able or willing to contribute to broader policy outcomes.

Platforms operated by public authorities ensure the integration of policy goals within the governance of the service but raise questions as to exclusionary behaviour vis-à-vis new market entrants, or favouritism by public authorities with regard to publicly supported services. Clear and transparent platform access rules and trustable auditability of platform operation may mitigate some of these risks. Third-party operated platforms may also avoid some of the risks encountered by publicly operated platforms but require the same sort of transparent operating rules, auditability and accountability towards public authorities.

Defining shared platform access standards can help reduce the transaction costs associated with delivering platform mediated MaaS services. These standards are different than data reporting syntaxes like MDS in that they enable easy and open integration of mobility services within the MaaS ecosystem. As with data reporting syntaxes, there is no settled standard for MaaS platform access, and many are under development. This data infrastructure bears some resemblance to hard infrastructure such as roads in that it represents a public good that public authorities may best deploy in order to ensure overall benefits.

Both private sector companies and public authorities have proposed open MaaS platform data architectures in order to spur the development and uptake of the MaaS ecosystem. The MaaS Alliance, a public-private association of MaaS stakeholders has, for example, developed an application programming interface (API) to help standardise MaaS access functionalities. This API has been adopted by a number of EU projects (MaaS Alliance, 2020). Another consortium led by the Netherlands has developed a similar MaaS API – the Transport Operator to Mobility Provider API (TOMP-API). This API defines the necessary scope for full interoperability between transport operators for the deployment of MaaS services in such a way as to standardise the data interface between MaaS platforms and transport operators, taking into account the entirety of travellers' intermodal journeys (TOMP-API, 2019). These MaaS platform architectures seek to standardise MaaS platform access across the full range of functionalities: general operator identification, registration and onboarding, trip planning, booking, trip execution, payment, support, asset information and other optional functionalities.

D.5. Governance challenges posed by artificial intelligence and the increased use of algorithms in mobility

The increased uptake of automated and algorithmic decision-making systems, many of which support smart mobility, poses different and novel challenges that go beyond the scope of current public governance frameworks. At the same time, the full extent and type of changes in governance that may be required are still unknown. Governments, including transport authorities, should start envisaging a more algorithmic future and assess how this may impact their conception and delivery of public governance. For these reasons, both the OECD and the G20 have identified the governance challenges posed by algorithmic decision-making systems and the concomitant need to frame the policy discourse around the deployment of these systems – especially those that are based on artificial intelligence (AI) (OECD, 2019)(G20, 2019).

Algorithms have traditionally been static, in that their code was rarely or infrequently updated. Now, however, they are increasingly more dynamic, with AI-based code now designed to re-write itself to improve outcomes. This is a fundamental shift.

For instance, a regulatory agency may licence a specific self-driving technology (both the car and the code) for use on public roads. But, as the scene selection, image processing, and image recognition algorithms all iterate and rewrite themselves to better perform in real-world driving environments, the resulting code no longer bears any resemblance to the initial licensed code. Further, later iterations of the code may have evolved so much that the regulatory agency is no longer able to understand how they function.

Having humans in the algorithmic loop is good, as code-based are systems meant to meet human objectives. But it can also be challenging when algorithmic systems are portrayed or understood as being without bias – or at least as having fewer biases than humans.

The algorithms guiding, and emerging from Artificial Intelligence (AI) and, more specifically, machine learning (ML) applications, are particularly suited to solving formerly intractable problems or improving our ability to accomplish previously difficult and time-consuming tasks. However, they raise unique legal, regulatory, and ethical challenges as well. Despite their benefits, ML algorithms may result in unintended and harmful behaviour if the wrong objective function is specified (or self-specified), if the training data is biased or corrupted, if the learning process is faulty or if an attacker were to successfully exploit system vulnerabilities. In the case of self-driving cars, these kind of unanticipated outcomes and errors have led to the deaths of drivers and other traffic participants.

For illustrative purposes, consider the generic vulnerabilities inherent in the algorithmic decision system operating a fully automated vehicle. There are many potentially relevant objects in the real world that the system must identify and interpret correctly, including traffic signs. The first step in the algorithmic processing chain (or, as seen from a malicious attacker, the "attack surface") is "seeing" the traffic sign and converting it into digital form. From that digital file, a "tensor", a mathematical object comprised of pixel values, is generated and input into a ML model written in code. The ML algorithm processes the tensor and assigns a probability of a match to a known "learned" object – a stop sign, for example. If a certain probability threshold is attained, the algorithmic system outputs the result ("this is a stop sign") to the rest of the cyber-physical system operating the vehicle. This system actuates a mechanical component – the brakes –, resulting in the car coming to a full stop. (Chakraborty et al., 2018).

In reality, the interactions are much more complex. They involve multiple iterative trade-offs and interactions according to the vehicle's model of operation – the "operational design domain" (ODD) (Czarnecki, 2018). But this simplification highlights where breakdowns could happen or unexpected outcomes could result or security vulnerabilities could be exploited. In the above example, biased data may lead to failed or incorrect object identity match at the level of the tensor or its processing. Depending

on the post-tensor processing rules and pre-determined safety thresholds regarding probable false positive or false negative outcomes, the system may or may not revert to a fail-safe operating mode. If the system does revert to a fail-safe mode and if doing so requires human take-over of the driving task, the human may not act, may not act quickly enough or may act inappropriately.

Several security vulnerabilities also could be exploited. An attacker may try to manipulate the collection of the data or its processing. This could take the form of an evasion attack in which the attacker seeks to game the system by maliciously adjusting or manipulating the sensed data. This could also be accomplished by modifying the sensed object, either at the level of the sensor itself or at the stage of the tensor definition and encoding. Alternatively, the attacker may try to poison or contaminate the training data that gave rise to the ML model as it was "learning". This would take place upstream and would require having access to this data and some way of understanding the way in which its manipulation would alter the ML model itself. Alternatively, the attacker could probe the "black box" ML model with an exploratory attack in order to gain useful and exploitable knowledge on the functioning of the algorithmic system. This could allow the attacker to understand how to carry out either of the above two attacks or, if they had write access to the code, modify the algorithm in such a way to lead to their desired outcomes (Chakraborty et al., 2018).

Physical, moral and even philosophical hazards emerge when AI systems start to drift into areas of human decision-making in ways that are analogous to, but inscrutable and fundamentally foreign to human cognisance. This may not be a problem where risks are low or potential impacts limited. But the lack of insight into AI decisions and processes challenges traditional forms of public governance when algorithmic outcomes may have significant impacts. As noted above, embedding targeted training data into image recognition machine-learning algorithms can cause these to misread objects in real life – e.g. misreading traffic signs or not recognising humans (ITF, 2019a). When such algorithms feed data directly into the control function of vehicles, crashes and deaths can result. Balancing the tremendous benefits that AI-based algorithmic systems can deliver with the potential harms they can inflict is at the heart of the policy and societal discussion around algorithmic governance.

Safety and security risks are the most immediate and material of all potential algorithmic harms. When cyber-physical systems fail or perform unexpectedly, people can get hurt and material damage may ensue. If these risks propagate across connected systems, the resulting harms can multiply and be substantial.

Algorithms are data-processing technologies. Data collection and surveillance are integral parts of the algorithmic system, but there are clear privacy risks associated with the use or release of that data. Simple approaches to data anonymisation or pseudonymisation are rarely robust enough to stand up against serious data-discovery attacks. These vulnerabilities grow in line with the capacity of adversarial algorithms to extract this data.

Algorithmic systems are highly opaque and difficult to explain to regulators, or to those affected by algorithmic decisions. Code is often created in environments that are not open to scrutiny, either because it is written by teams within companies or public agencies or because it is created in the logic space of an algorithm itself. Code is written in computer languages and follows logic patterns that are not widely understood by the population at large or by regulators. The operation and decisions of several types of AI algorithms may not even be explained by their designers.

Machine logic, especially when linked to machine learning, artificial neural networks, and other forms of AI, is not human logic. The ensuing lack of understandability is only exacerbated when individual algorithms are tethered together in broader algorithmic decisions systems. Algorithmic systems, though they may be inscrutable and hard to understand, may function – but they pose a latent risk that

breakdowns may not be traceable or "fixable" precisely because of this lack of understanding. These are important risks but can be addressed through adapted policies.

Adapting mobility governance frameworks to AI and algorithmic decision-making

Transport policy, institutions and regulatory approaches have been designed for human decision systems and bound by legal and analogue logic. These will be challenged by the deployment of algorithmic systems which function with machine logic and whose operation can have impacts on outcomes like traffic congestion or safety. Public authorities will have to evaluate if their institutions and working methods are adapted to potential algorithmic risks and, if not, begin to reshape themselves for a more algorithmic world. This will require bringing in, and retaining, staff with new skill sets and training existing staff to become more code-literate.

Adopting a proportionate and risk-based approach to governing smart mobility automated decision-making systems

Not all algorithmic systems are equally risky (or beneficial). Regulators must seek a balance between the risks and mistakes that are inherent in technology innovation and the potentially negative impacts of regulatory intervention to avoid these. They should adopt a graduated regulatory approach that minimises oversight of trivial and low-impact algorithmic decision systems and increase assessment and oversight for more and more consequential algorithmic system impacts. For instance, algorithms that provide routing *suggestions* may prove to be an issue when seeking to address system-wide traffic flows, but they are not as potentially problematic as algorithmic systems that *force* routing choices directly onto vehicle operating systems.

Converting analogue regulations into machine-readable code for use by algorithmic systems

Those coding automated decision-making algorithms interpret multiple regulations that are written in human-readable language and typically produced on analogue and dispersed supports. Where possible, authorities should strive to make regulations machine and human readable by default. For example, authorities could encode, communicate and control access rules and legally permissible uses of street and curb-space.

Assessing the performance of algorithmic systems with that of human decision-making

When assessing the potential impacts of algorithmic systems, authorities should consider what might be the impact of not deploying the algorithmic system in the first place. Is the balance of risks and benefits tilted towards having humans continue to make critical and consequential decisions instead of algorithms? If so, it is worth asking if an algorithmic system is necessary or even desirable. If the balance is reversed, then taking humans out of the decision-making framework entirely, or having them only intervene when prompted, may be the best option. This is especially relevant for higher levels of automated driving that still require human oversight and intervention.

Favouring algorithmic auditability for potentially impactful algorithms

Human-readable pseudo-code can be built into algorithms to explain what the algorithm does without revealing source code (and preserve commercial secrets). These could take the form of "legal-grade" coding. Another approach would be to use specific coding protocols for potentially impactful algorithms – like those outlined by the "Trustable software" framework. In the case of ADAS and automated driving systems, such readability can improve the allocation of responsibility if and when crashes occur. Such coding-based approaches may breakdown in the case of AI and ML systems. In these cases, "auditability"

may imply logging cyber-physical system states for use in forensic simulation in line with explainable AI approaches.

Exploring assessment approaches beyond transparency and explainability

The G20 principles on AI call on all AI actors to commit to transparency and responsible disclosure regarding AI systems. In order to do so, they should provide meaningful information, appropriate to the context, and consistent with the state of art to:

- foster a general understanding of AI systems;
- make stakeholders aware of their interactions with AI systems, including in the workplace;
- enable those affected by an AI system to understand the outcome; and,
- enable those adversely affected by an AI system to challenge its outcome based on plain and easy-to-understand information on the factors, and the logic that served as the basis for the prediction, recommendation or decision.

These principles represent the common baseline on which to build AI governance principles for smart mobility. Nonetheless, the state of understanding of the regulatory challenges implied by the rapid development of AI algorithms and the uses to which they are put – especially for transport use cases – is constantly evolving.

For example, there are limits to requiring certain AI-based algorithms to be transparent and explainable because their logic may not be readily understandable to humans. Transparency-based approaches are intuitively attractive. If regulators could "see" algorithmic code, one assumes they could assess its potential impacts. In the transport sector, there are parallels with the way in which regulators "see" vehicle technologies and assess their impacts. This is the case for aircraft and their components, including their algorithmic components, which must pass official certification. Likewise, vehicle certification standards are based on the access regulatory agencies have to the objects of regulation in order to assess their safety and road-worthiness.

Irrespective of how and how well this authority is exercised, the potential to directly scrutinise and assess new technologies has a strong tradition in the regulation of transport. This is not, however, the case for algorithmic code and algorithmic systems for a range of new use cases and transport services – including the code that enables highly and fully automated driving. Thus, the call for opening up the "black box" and exposing source code to regulatory oversight.

Transparency, alone, however, does not guarantee that an algorithmic system's functioning or potential impacts will be revealed. It may be so for simple, deterministic and relatively light code, but such systems are relatively rare. In the case of complex, multi-component, interconnected codebases, being able to read the code does not necessarily convey knowledge on its functioning (Annany and Crawford, 2018). Indeed, seeing the code does not necessarily convey an understanding on how it works and how to govern it (Janssan and Kuk, 2016). Furthermore, the operation of code is often contextual – the functioning of the system is linked to specific data inputs that may be difficult to audit in their entirety. In AI-based systems, potentially impactful algorithmic decisions are emergent properties of the machine learning processes and are not "hard coded" into the algorithm itself (Kemper and Kolkman, 2018). All of these factors are complicated by the sheer number of possible features that can be ingested and processed in ML algorithmic systems. As data starts to faithfully encode "real life", the scale and scope of algorithmic decision processes rapidly surpasses what humans can comprehend – in other words, "intuition fails at high-dimensions" (Domingos, 2012).

Furthermore, visibility of the code does not mean its function and potential impacts can be ascertained without specialised knowledge. With the exception of certain specialist agencies, like those in charge of aviation or crash investigations, most public authorities typically do not have the capacity to read raw code from either a predictive basis ("what might the code do?") nor a forensic basis ("what did the code do?").

One strategy to explore is building in explanation functionality into algorithmic systems so that the model can produce an accurate and intelligible explanation for its output. This type of "explainability by design" will entail changes in the way in which code is conceived and written – at least for applications where explainability is necessary to avoid consequential harms. It will involve setting standards, adopting industry best practice and, in some cases, may require that regulators consider stipulating this approach for critical code.

Establishing regulatory frameworks that ensure accountability for decisions taken by algorithms

Rather than focusing on transparency, explainability or interpretability as keystones of algorithmic assessment processes, regulators may consider including these into a broader algorithmic accountability framework. Ideally, a governance framework for algorithmic accountability could ensure that algorithmic systems are conceived and designed in such a way that they can be trusted to operate as intended. Under an accountability framework, those responsible for deploying the algorithmic system should be legally accountable for its decisions. When that entity is a public authority, higher and more stringent standards of accountability could be considered given the unique powers that governments wield.

Enacting clear guidelines and regulatory action to assess the impact of algorithmic decision-making

Impact assessments are common in many domains, including transport, and are well-understood mechanisms to assess potential risks and payoffs from policies and regulatory interventions. Public authorities could undertake impact assessments regarding smart mobility algorithmic systems that could have a consequential effect on regulated outcomes or within the public domain. The approach adopted by the Government of Canada in its "Directive on Automated Decision-Making" is a model approach. It links assessment to a graduated regulatory response for potentially riskier algorithmic systems. Impact assessment auditing could be based on observable and monitored impacts and not necessarily comprised of audits of the algorithms themselves. Impact assessment will also require new ways of testing and certifying systems that are enabled by AI. Such approaches may require broadening the scope of certification to include continual validation and verification of the integrity of algorithms as they are dynamically updating themselves.

D.6. Transparency and security for users of Smart Mobility services

As with other digitally based systems, smart mobility systems may incorporate certain cyber risks. These may pertain to data breaches and data misuse, as discussed earlier, or may relate to the cyber-security of the smart mobility technologies and systems themselves. These risks are important because they may lead not only to annoyance, as systems are diverted from their intended use, but can also lead to real harms, both moral (cyber-theft) and physical.

The potential for these harms to be realised is heightened both by the development and diffusion of tools and techniques that can be employed in support of cyber-attacks as well as by the extreme multiplication of potential attack surfaces – especially when different cyber-physical systems are connected. Going forward, the safety and security of smart mobility systems will rest not only on the combined safety performance of component hardware and software elements. It will also depend on how robust these

systems are to malevolent attacks – especially when the design of connected systems may create new systemic cybersecurity-related vulnerabilities.

Key attack vectors, or vulnerabilities, range from upstream designers, manufacturers and vendors all the way to the end-points – for example, vehicles -- comprised of hardware and, especially, software sub-systems. Emergent threats, vulnerabilities and consequent risks associated with the uptake and deployment of cyber mechanical components of smart mobility include:

- Designer vulnerability: Source code, architecture, component specification, and product whole life design and support.
- Manufacturer vulnerability: Component selection and manufacture (cheap/ potentially compromised), threat identification and mitigation, software/ firmware update creation, and version control
- Vendor vulnerability: Inventory management, inventory protection, version management. A special consideration is the extent to which sensing and other critical sub-components are designed manufactured and programmed with attention to security.
- Maintainer vulnerability: Version management, design integrity management, platform protection, 3rd Party Engineering/Customisation/Enhancement Compatibility and Vulnerability Management
- Infrastructure Provider Vulnerability: Direct network attack, jamming of communications and location services, spoofing, impersonation, and interfaces to/ from other public systems.
- Law enforcement and traffic management vulnerability: Direct network attack, jamming of communications and location services, spoofing, and impersonation.
- End point vulnerability: On-board interface (external or internal attack), individual system control (e.g. a car), access, disruption of operation, selective/ non-selective, and ransom, kidnapping, or theft of data.

Comprehensive cybersecurity frameworks: the case of automated driving

These multiple points of vulnerability underscore that complex "systems of systems", like those delivering automated driving, require comprehensive frameworks to ensure systemic cybersecurity. In 2017, the UK Department for Transport in conjunction with the UK Centre for the Protection of National Infrastructure released such high-level guidance for the automotive sector, the automated driving and intelligent transportation system ecosystem and their collective suppliers (DfT, 2017). The "Key Principles of Cyber Security for Connected and Automated Vehicles" outlines 8 fundamental building blocks that should underpin systemic cybersecurity best practice (Table 4).

These principles set out a comprehensive framework for addressing cybersecurity in the automated driving ecosystem, but standards are required to deliver effective cybersecurity. SAE guidance J3061 (Cybersecurity guidebook for cyber-physical vehicle systems) and J3101 (Requirements for hardware protected security for ground vehicle applications), along with numerous ISO standards relating to identity management, authentication, securing information technology systems and privacy all form the base on which to build the operational framework for securing automated driving systems. The US Department of Transport's National Highway Traffic Safety Administration has also issued guidance on cybersecurity best practices for vehicles which builds on SAE and other recommendations (NHTSA, 2016).

Table 4: UK Key Principles of Cyber Security for Connected and Automated Vehicles

Principle 1 - organisational security is owned, governed and promoted at board level
1.1: There is a security program which is aligned with an organisation's broader mission and objectives.
1.2: Personal accountability is held at the board level for product and system security (physical, personnel and cyber) and delegated appropriately and clearly throughout the organisation.
1.3: Awareness and training is implemented to embed a 'culture of security' to ensure individuals understand their role and responsibility in ITS/CAV system security.
1.4 All new designs embrace security by design. Secure design principles are followed in developing a secure ITS/CAV system, and all aspects of security (physical, personnel and cyber) are integrated into the product and service development process.
Principle 2 - security risks are assessed and managed appropriately and proportionately, including those specific to the supply chain
2.1: Organisations must require knowledge and understanding of current and relevant threats and the engineering practices to mitigate them in their engineering roles.
2.2: Organisations collaborate and engage with appropriate third parties to enhance threat awareness and appropriate response planning.
2.3: Security risk assessment and management procedures are in place within the organisation. Appropriate processes for identification, categorisation, prioritisation, and treatment of security risks, including those from cyber, are developed.
2.4: Security risks specific to, and/or encompassing, supply chains, sub-contractors and service providers are identified and managed through design, specification and procurement practices.
Principle 3 - organisations need product aftercare and incident response to ensure systems are secure over their lifetime
3.1: Organisations plan for how to maintain security over the lifetime of their systems, including any necessary after-sales support services.
3.2: Incident response plans are in place. Organisations plan for how to respond to potential compromise of safety critical assets, non-safety critical assets, and system malfunctions, and how to return affected systems to a safe and secure state.
3.3: There is an active programme in place to identify critical vulnerabilities and appropriate systems in place to mitigate them in a proportionate manner.
3.4: Organisations ensure their systems are able to support data forensics and the recovery of forensically robust, uniquely identifiable data. This may be used to identify the cause of any cyber, or other, incident.
Principle 4 - all organisations, including sub-contractors, suppliers and potential 3rd parties, work together to enhance the security of the system
4.1: Organisations, including suppliers and 3rd parties, must be able to provide assurance, such as independent validation or certification, of their security processes and products (physical, personnel and cyber).
4.2: It is possible to ascertain and validate the authenticity and origin of all supplies within the supply chain.
4.3: Organisations jointly plan for how systems will safely and securely interact with external devices, connections (including the ecosystem), services (including maintenance), operations or control centres. This may include agreeing standards and data requirements.
4.4: Organisations identify and manage external dependencies. Where the accuracy or availability of sensor or external data is critical to automated functions, secondary measures must also be employed.
Principle 5 - systems are designed using a defence-in-depth approach
5.1: The security of the system does not rely on single points of failure, security by obscuration or anything which cannot be readily changed, should it be compromised.
5.2: The security architecture applies defence-in-depth and segmented techniques, seeking to mitigate risks with complementary controls such as monitoring, alerting, segregation, reducing attack surfaces (such as open internet ports), trust layers / boundaries and other security protocols.
5.3: Design controls to mediate transactions across trust boundaries, must be in place throughout the system. These include the least access principle, one-way data controls, full disk encryption and minimising shared data storage.
5.4: Remote and back-end systems, including cloud-based servers, which might provide access to a system have appropriate levels of protection and monitoring in place to prevent unauthorised access.
Principle 6 - the security of all software is managed throughout its lifetime
6.1: Organisations adopt secure coding practices to proportionately manage risks from known and unknown vulnerabilities in software, including existing code libraries. Systems to manage, audit and test code are in place.
6.2: It must be possible to ascertain the status of all software, firmware and their configuration, including the version, revision and configuration data of all software components.
6.3: It's possible to safely and securely update software and return it to a known good state if it becomes corrupt.
6.4: Software adopts open design practices and peer reviewed code is used where possible. Source code is able to be shared where appropriate.

Principle 7 - the storage and transmission of data is secure and can be controlled

7.1: Data must be sufficiently secure (confidentiality and integrity) when stored and transmitted so that only the intended recipient or system functions are able to receive and / or access it. Incoming communications are treated as unsecure until validated.

7.2: Personally identifiable data must be managed appropriately.

This includes:

- what is stored (both on and off the ITS / CAV system)
- what is transmitted
- how it is used
- the control the data owner has over these processes
- Where possible, data that is sent to other systems is sanitised.

7.3: Users are able to delete sensitive data held on systems and connected systems.

Principle 8 - the system is designed to be resilient to attacks and respond appropriately when its defences or sensors fail

8.1: The system must be able to withstand receiving corrupt, invalid or malicious data or commands via its external and internal interfaces while remaining available for primary use. This includes sensor jamming or spoofing.

8.2: Systems are resilient and fail-safe if safety-critical functions are compromised or cease to work. The mechanism is proportionate to the risk. The systems are able to respond appropriately if non-safety critical functions fail.

Source: (UK DfT, 2017)

Need for functional isolation of critical sub-systems

At the outset, however, two fundamental design strategies condition automated driving cybersecurity. These relate to the functional isolation or not of safety-critical subsystems and whether safe system performance is conditioned on connectivity to external networks. These are not trivial design decisions. The choice of strategy will have an incidence on whether imperatives for safety and cybersecurity can be reconciled – and if so, how easily or not.

The control functions of an automated driving system rely on a complex and highly integrated network of dozens of sensors, actuators and microcontrollers. Besides creating issues of reliability and redundancy as a whole, each and every ingredient of this system also is a potential entry point for cyber-attacks. Consequently, cybersecurity does not only mean protecting data communication emanating to and from vehicles, but it also has to prevent unauthorized access to individual devices and microcontrollers or access to networks of such components in the vehicle.

In this respect, the discussion surrounding the cybersecurity vulnerabilities of automated driving systems is not dissimilar to discussions surrounding the security (and cybersecurity) of other complex systems within and outside of the transport sector (aircraft, train and metro systems, nuclear power plants, etc.) (Le Lann, 2017). In all of these systems, core safety-critical components are *isolated* on both a hardware and software level from non-critical components. In most cases, redundancies are built in to ensure critical sub-system performance even in degraded conditions.

In practical terms, automated driving safety-critical subsystems including steering control, acceleration and deceleration, should be isolated from others with independent processors, system memory, system architecture and separate (and redundant) power supply. The operating system governing these functions should undergo specific and robust cybersecurity vetting. Secure protocols are necessary for handling update policies for these systems (updates which should be the exception, rather than the rule). One part of the vetting should be to assess the cybersecurity risks of open-source code that is often bundled into various control and operating system software. Safety-critical subsystems should also integrate tamper-proof devices with independent state awareness to give the alert if the case of malevolent or accidental access to critical systems (Le Lann, 2017) (Le Lann, 2018)

There is little formal agreement today as to what constitutes safety-critical subsystems, but this is one area where accelerated work in the appropriate standard-setting bodies can prove helpful. At a minimum, cyber security for smart mobility should comply with the security requirements of respective government entities. Following best practice would entail ensuring that systems (including security systems) are reasonably protected from cyber-attack and malware, that command and control centers, communication systems, web sites and payment systems are protected using leading practices and that efforts are made to push cyber-protection to the sensing edge of smart mobility systems and to reduce potential attack surfaces as much as possible through pro-active security design.

E. Synthesis of G20 Smart Mobility Survey responses

E.1. Survey response summary

The G20 Saudi Presidency asked DETF members and guests to provide case studies and initiatives in support of smart mobility and smart cities through a Survey on Smart Mobility. The survey questions on governance structure, objectives, integrating inclusiveness in their smart cities and communities' initiatives, as well as smart mobility initiatives (see Annex A.). Responses show that a majority of responding G20 countries reference broader human-centric, inclusive, and sustainable perspectives in smart mobility and smart city initiatives at the national and local levels.

Overall Findings

This survey revealed the following common themes in G20 and Partner responses regarding smart approaches to city management in the area of mobility.

- **Smart mobility forms part of many national smart city initiatives.** Given the transport sector plays an important role in urban settings, smart mobility emerges from the survey as a crucial component of the G20 and Partner country's smart cities strategies. Smart mobility and smart city goals often overlap. Smart mobility contributes to achieving the most challenging smart city goals such as reducing the environmental footprint of the city or improving the citizen's quality of life.
- **Smart mobility initiatives are often anchored in broader human-centric visions.** While the digitalization of transport services offers many potential advantages for citizens, special attention must be paid to ensure that the opportunities are equally accessible by all. Providing vulnerable people with access to internet, devices, and training around the use of digital services, as well as ensuring the transparency of and access to government data, is essential in ensuring that certain groups are not marginalized by the move to smart city approaches.
- **Responses highlighted the role of the public sector in the smart mobility cases described but also reference collaboration with the private sector.** All G20 and Partner countries provided smart mobility cases led by national or local governments. In some countries, central governments have stepped from being the top-down initiator for smart city and smart mobility initiatives but, instead, act as one player in the broad smart city/mobility ecosystem. This has opened the possibility for a broader representation of views regarding smart city and smart mobility objectives. In this context, initiating and sustaining relationships with community groups, the private sector and universities are core to developing well-rounded and sustainable initiatives.
- **Smart mobility indicators are a key component of smart city indicators.** Almost all countries answered that their concrete smart mobility projects have a monitoring mechanism. But few provided which indicators were monitored and how.
- **Three patterns of transport-related data were evident in survey responses.** Data sharing amongst government agencies and between these and the private sector is a key element of smart mobility governance. When it comes to transport-related data sharing, the survey revealed three patterns; 1) National or local government to the public, 2) Between and amongst public authorities, and 3) Between public authorities and the private sector.

E.2. Summary of the outcomes sought by national smart cities initiatives

The review of survey responses found that the outcomes sought by national smart city initiatives could be grouped into the following categories: Digitalization (technological), Sustainability (Environmental), Productivity and Competitiveness (Economic), Inclusiveness and Quality of life (Social).

Digitalisation (technological development)

All countries responded that their smart city efforts sought to create or enhance beneficial outcomes from digitalization. In order to support cross departmental working for smart cities, many G20 countries have placed responsibility for smart city and smart mobility policy within a department that already works horizontally across national siloes (such as the Cabinet's Office). Alternatively, some are creating new units within their organizational structure to centralize diverse smart city activities. In both cases, administrations are seeking to ensure that all departments and initiatives align to a central vision. Argentina, China, Italy and Turkey provide examples of this process.

Argentina's national initiative

The Smart and sustainable Cities National Plan has been designed by the National Government considering the country´s development goals, the current state of the regional and local governments and the best practices which are referred to as smart and sustainable cities worldwide. The implementation and monitoring of the policy have been coordinated with local and regional levels. The National Government provides or helps the local governments to acquire infrastructure, connectivity, support for digital skills development and most of the digital tools which are necessary to expand digital government around the country. Specially, developing a strong digital government has a direct and positive influence over other dimensions of the cities: environment, human development, urban planning and competitiveness. Considering the holistic system of the cities, the National Government developed a model to identify the city´s strengths and weaknesses across the previous dimensions and to measure the impacts of new projects. The information needed to work the model out is provided by the local or regional government, and thanks to the results each government decides what will be done in order to improve their governance performance. Once the decision is taken, the stakeholders sign agreements and carry out the implementation and the monitoring. The monitoring of the programs is carried out by a new assessment based on the Smart and sustainable cities model.

The "Widespread" axis depends on the coordination between the Undersecretariat of Open Government and Digital Nation with the local or regional levels, meanwhile, the "In-focus" and "Concentrate" axes depend highly of the coordination among different ministries of the national level and the coordination among different levels of governments. The Plan includes the support to the development of 6 drivers: data generation, connectivity, infrastructure, interoperability, cybersecurity and skills. The data generation depends directly of the leader office, meanwhile the other drivers are developed in coordination with other areas of the national level. In order to generate data, the office has surveyed more than one hundred cities as the base to decision making and its plan is to survey almost one thousand cities in the next 4 years. In this context, the Initiative "National Quality of Cities Award" has been created to survey qualitative issues in the management of the local governments related with quality aspects and continuous improvement, all this considering main aspects for the smart and sustainable cities existence.

Italy's digital agenda

A national Smart Cities and communities strategy has been in place since 2012, in the framework of the Italian Digital Agenda (Law 5/2012, art. 47). The Digital Agenda was based on nine pillars, the first one being "the realization of technological and intangible infrastructures at the service of "smart communities", aimed at satisfying the growing demand for digital services in sectors such as mobility, energy saving, the educational system, safety, health, social services and culture".

In the first phase, 2012-2016, the Government funded pilot projects for the development and qualification of new technologies for smart city applications (sensors and ICT, smart building, info-mobility, smart grid etc.). Above all, these were monothematic experiences with the aim of demonstrating the potential of new technologies in specific application sectors and with the strategic objective of preparing an adequate production capacity for mass diffusion. In this period, the Italian Government invested more than 1 B€.

In 2015, the Government "Strategy for digital growth 2014-2020" identified smart Cities as an appropriate context to deploy digital culture, due to the high impact in terms of socio-economic effects. In this timeframe, the Government also deployed national public digital infrastructures (Digital identity, electronic payments, e-invoices, civil registry …) that are now crucial for smart city applications.

In the same period, The Multi-fund National Operational Programme Metropolitan Cities 2014-2020 (PON METRO), part of the initiatives conceived in the framework of the European Urban Agenda for cohesion policies, made available additional resources of about 800 M€ with the aim of strengthening the role of big cities and their territories. The Italian Government perceives that favorable conditions for a massive diffusion of "smart city" solutions currently exist. The strategy for the next 5 years aims at enabling the massive procurement of new solutions that are interoperable with national digital infrastructures and can be easily combined to develop smart city applications.

Sustainability (Environmental development)

Beyond the adaptation of digital technologies, Argentina, Germany, Republic of Korea and Switzerland extend their policy objectives to the broader objective of sustainable development. Their focus in this regard includes the overall environmental footprint of cities, reducing pollution and energy consumption, and preserving or creating public green space.

Smart City Switzerland

Smart City Switzerland focuses on the areas of smart environment and intelligent mobility. Smart City Switzerland supports towns, cities and municipalities with their planning and implementation of smart initiatives in cooperation with various partners, with a strong commitment on the part of residents and through the use of new technologies. Smart City Switzerland informs and networks the various stakeholders and supports the participating towns and cities with their efforts to reduce the consumption of resources and offer a higher quality of life. Smart mobility projects aim to result in positive effect on energy consumption and reduction of CO_2 emissions, as well as the reduction of noise and air pollution.

Productivity and Competitiveness (Economic development)

Australia highlighted the contribution of its smart cities polies to productivity, whereas the Russian Federation aims to increase city competitiveness.

Australia's Smart Cities Plan

Australian government's Smart Cities Plan envisions productive and livable cities that encourage innovation, support growth and create jobs. Smart Mobility elements such as disruptive new technology in transport, open data driven solutions and commercializing new innovations are highlighted as important to grow Australia's economy. The aspirational concept of 30-minute cities is presented by emphasizing the importance of an efficient and well-designed public transport network between cities.

Russian Federation's Competitive city: goes beyond digital transformation

The Russian Federation sees the Smart City project goes beyond digital transformation and process automation. Its goal lies in comprehensive improvement of urban infrastructure. The goals of the Smart City project are to improve the competitiveness of Russian cities, create efficient urban governance system, establish safe and comfortable conditions for residents. The project aims to increase the share of urban residents over the age of 14 in the process of urban development decision-making using digital technologies up to 60% in 2024. The national project Housing and Urban Environment is aimed at improving facilities and infrastructure to make the urban environment accessible to low-mobility population including creating a barrier-free environment for low-mobility citizens in public space area. The national project also provides for the creation of a mechanism for direct participation of citizens in the formation of comfortable urban environment, increase in the share of citizens involved in urban development decision-making. In addition, Basic and additional requirements for smart cities (Smart City standard) (approved by the Ministry of Construction, Housing and Utilities of the Russian Federation of 4 March 2019) include activities to increase accessibility of urban infrastructure for residents (introduction of automated lease and rent Sharing system).

Inclusiveness and Quality of life (Social development)

Argentina, Canada, Japan, United States of America and Singapore noted a focus on inclusiveness and Brazil, EU, Kingdom of Saudi Arabia, Republic of Korea, Switzerland, and Turkey linked their smart city strategies to quality of life objectives. These countries signaled the need to communicate with people the broader strategy for human-centric, inclusive, and sustainable smart cities.

Argentina's inclusive Smart and sustainable Cities National Plan

The main objectives of the Smart and sustainable Cities national plan put emphasis on inclusiveness, to improve the services for the whole community, the access to the information for everybody, to reduce the digital gap in the society and to generate the optimal environment for the personal and business development. Gender equality will also have a preponderant role, given that it a cross-topic in this new administration.

Saudi Arabia's Vision 2030 Strategy for enhancing quality of life in cities

The massive influx of local and foreign population in Saudi cities triggered large-scale development of infrastructure, housing and businesses. KSA regards Smart Cities project as an opportunity to solve issues caused by urbanization (urban sprawl). The Smart Cities Blueprint is aligned and coordinated with other national policies, such as the National Spatial Strategy and the National Digital Transformation Program, all under the umbrella of Saudi Arabia's Vision 2030 strategy. The Blueprint was published by the Ministry of Municipal & Rural Affairs (MOMRA), in cooperation with the National Digitization Unit (NDU). NDU developed the National Digital Transformation Strategy (NDTS) which has smart cities as a priority sector, with a focus on smart mobility, smart living and smart environment, aligned with KSA's Vision 2030 economic development strategy. Other stakeholders collaborate in this initiative, like the Ministry of Economy and Planning, the Ministry of Communications and Information Technology, the Communications and Information Technology Commission, the Transport Ministry and the Transport General Authority, regional authorities, the National Water Company, the Saudi Electric Company, and private sector organizations. The national government coordinated the Smart Cities strategy with local governments and organizations during the design and implementation stages. Involvement was done through workshops and meetings.

USA's Connecting and Securing Communities Guide for Federal Agencies

The smart cities effort focuses on projects that make communities of all types and in all regions safer, more secure, livable, and workable for their residents. These projects can simultaneously improve economic growth, generate job opportunities, and enhance workforce development for upskilling and reskilling. Explicit goals include Expanding job opportunities for economically disadvantaged communities; providing accessibility for disabled residents, including transportation and services innovations; and expanding technology access in regions without broadband connectivity.

EU's European Innovation Partnership for Smart Cities and Communities (EIP-SCC)

EU clarifies that Smart cities are places where traditional networks and services are made more efficient with the use of digital technologies for the benefit of its inhabitants and business. The aim of a bigger Smart Communities policy is the improvement of all EU citizens' quality of life by offering a broad range of innovative, sustainable and secure services in mobility, energy, water, waste, e-government, and others.

E.3. Summary of the outcomes sought by smart mobility initiatives and examples' outcome

The survey responses also revealed that the motivations for the smart mobility initiatives described fall into the same five categories as for smart city initiatives: Digitalization (technological), Sustainability (Environmental), Connectivity and Competitiveness (Economic), Inclusiveness and Quality of life (Social).

Positioning of Smart Mobility component in the national Smart City strategy.

Argentina, Australia, European Union, Italy, Kingdom of Saudi Arabia, Singapore and Switzerland regard Smart Mobility as one of the key components in their national Smart city strategy. The Russian Federation and Turkey have a particular focus on Smart City indicators that extend to indicators covering smart mobility initiatives. Germany has established a specific smart mobility platform -- the National Platform Future of Mobility (NPM) and United Kingdom created a strategy to tackle Smart Mobility related issues through their Future of Mobility Urban Strategy.

Germany's The National Platform Future of Mobility (NPM)

The National Platform Future of Mobility (NPM) is the focal point for discussions on strategic decisions in the field of mobility, NPM is funded by the federal special budget title for artificial intelligence and clarifies facts on complex topics and brings together relevant stakeholders, technical expertise and politics.

The Steering Committee, alongside the working groups, provides the technical and content direction of the platform. The Steering Committee identifies new topics to be addressed in the platform and makes suggestions for their implementation. It also manages the content work of the working groups, monitors their implementation and advises on results. The recommendations for action from the NPM are made by the Steering Committee. The Steering Committee meets twice a year and as required.

In a total of six working groups, experts from a wide range of disciplines address key developments in the transport sector. The working groups discuss possible technology-neutral options for action and formulate recommendations for action to the German Federal Government. The actors involved in the platform work independently and free of charge. The management and moderation of the platform are non-partisan and neutral. WG 1: Transport and climate change / WG 2: Alternative drive technologies and fuels for sustainable mobility / WG 3: Digitalization in the mobility sector / WG 4: Securing Germany as a place for mobility, production, battery cell production, primary materials and recycling, training and qualification / WG 5: Connecting mobility and energy networks, sector integration/ WG 6: Standardization, norms, certification and type approval. The Advisory Commission is the interface between the NPM and the Federal Parliament. It informs the Parliament about the results of the platform and receives comments from the Parliament. The Advisory Commission communicates its assessment to the Steering Committee.

The NPM Secretariat organizes and coordinates the Platform's activities. It informs on the progress of cooperation and is the central contact for the private sector, public sector, civil society and media. The office is headed by the Federal Ministry of Transport and Digital Infrastructure.

The NPM regularly reports on its activities and documents the progress made within the focus topic areas. The information is publicly available. In terms of policies or initiatives related to data sharing and interoperability, including open government data, NPM coordinate with the Federal Ministry for Transportation and Digital Infrastructure, Federal Ministry for Economic Affairs and Energy and Federal Ministry for the Environment, Nature Protection and Nuclear Safety including the respective subordinate authorities.

Digitalisation, technological development

All countries regard Smart Mobility as an opportunity to enhance the efficiency of the road traffic system by leveraging ICT and software applications to optimize traffic flows, support effective public transport routes, provide dynamic route guidance and collect citizens' opinions and suggestion about mobility.

Brazil's Rio de Janeiro Digital City Initiative

The city of Rio de Janeiro has Digital City Initiative as the guideline policy for Smart City. "Digital City" aims to promote improvements in the information processing capacity to support services provided to citizens, seeking to reduce the technological risks of the services offered and enhance information security. The initiative includes two major projects; 1) implementation of teleworking modality in the city of Rio de Janeiro, in order to make organizations more competitive, flexible and dynamic, as a way to stimulate a society more digital, and 2) expansion and improvement of the technological infrastructure management to support the services provided to the citizen. This project contemplates fundamental actions for technological modernization in order to support and endorse the aforementioned project, as well as enhance the services provided by City Hall, among them.

The expansion and improvement of the technological infrastructure management to support the services provided to the citizen, contemplates the Modernization of the Data Network (Siurb) used for smart mobility initiatives, such as the Rio Operation and Resilience Center and the and in the distribution of data used to create mobility applications such as Taxi Rio and Bike Rio.

In the same document, Strategic Plan for the City of Rio de Janeiro (2017-2020) smart mobility is referenced on the urban environmental dimension, within the decentralized, inclusive and connected territorial subdivision, which proposes to "Ensure the expansion and consolidation of intelligent transport / traffic systems" by improving the information control of different transport systems (Improvement of Urban Mobility Initiative); enhancing the control over fleet information and quality in each consortium, considering the components inspected (Improvement of Urban Mobility Initiative); implementation of effective traffic management with the optimization of intelligent equipment network for mobility management (ITS) and the efficient application electronic surveillance (Safe Traffic Initiative).

The Plurenary Plan (2017-2021) for budget management also refers to smart mobility mentioning the Smart Signaling project, designed to provide efficient electronic signage in terms of visibility, information and road safety, remotely controlled by Rio Operations and Resilience Center (COR); and the Intelligent Equipment and Systems activity, which aims to implement intelligent equipment and systems so that traffic control acts in the real-time, allowing interventions that minimize bottlenecks, reducing the travel time in the city.

Sustainability: Environmental development

Germany, Turkey, Switzerland highlighted the environmental impact of transport in city is one of the main motivations of their Smart Mobility initiatives.

Connectivity and Competitiveness (Economic development)

Australia and Russia see Smart mobility as a tool to foster economic development and connectivity among cities and communities.

Australia's Smart mobility as an economic driver for all

Australia regards disruptive new technology in transport, open data driven solutions and commercialising new innovations as important to grow the economy. The aspirational concept of 30 minute cities is highlighted and includes key ingredients such as an efficient and well-designed public transport network, integrated active transport and high quality, rapid transport between cities is also critical to strengthen economically metropolitan and regional centres.

Inclusiveness and Quality of life (Social development)

The United Kingdom, United States of America and Singapore signal that smart mobility initiatives could contribute to enhance inclusiveness. European Union, Kingdom of Saudi Arabia and Switzerland expect the improvement of quality of life for all citizens through smart mobility initiatives.

United Kingdom's The Future of Mobility Urban Strategy

In March 2019, the Future of Mobility Urban Strategy the UK's approach to responding to the uncertainty presented by innovation, ensuring that the country can take advantage of the wealth of opportunities emerging technologies and trends in transport are presenting, including new jobs, more productive businesses and economic growth across the nation. The strategy established nine Principles for shaping the future of urban mobility to provide a clear signal of what the UK seeks to achieve, including ensuring that the benefits of innovation in mobility must be available to all parts of the UK and all segments of society.

Government departments are considering how they best support rural areas i.e. DCMS 5G programmes and DfT developing a Future of Transport Rural Strategy. Much of Government's focus to-date has been on getting a strong grasp on emerging technologies and trends in transport as this is where changes in travel will happen first and fastest. However, DfT remains committed to exploring how the benefits of transport innovation can be enjoyed by everyone, wherever they live and intend to come forward with a Future of Mobility: Rural Strategy in due course [a commitment to this was made in the Future of Mobility: Urban Strategy published in March 2019.

DfT is currently working with academics, local authorities, businesses and others to gather the evidence to inform our Future of Transport: Rural Strategy. We already know that many rural communities feel disconnected and are dependent on petrol and diesel cars and vans to get about. DfT is working to understand the potential role of new transport technologies and business models to help solve the transport challenges faced by rural communities, and what Government can do to unlock that potential.

The Future of Mobility Urban Strategy forms part of the wider Grand Challenge on the Future of Mobility. The remit of this challenge is broader than urban areas, and we are currently scoping out a separate competition test bed on the opportunities for rural areas.

E.4. Benefits of Smart mobility referenced in survey responses

The benefits attributed to smart mobility initiatives in survey responses fall into six categories as outlined in table 5, below: More efficient use of capacity, Improvements in travel time, More equitable access outcomes, Improved safety, Lower travel costs and Reduced environmental impacts .

Table 5. Benefits of Smart mobility referenced in survey responses by G20 and Partner countries

Country	Examples	Category	Benefits in Smart Mobility					
			More efficient use of capacity	Improvements in travel time	More equitable access outcomes	Improved safety	Lower travel costs	Reduced environmental impacts
Argentina	SUBE (Single Electronic Ticket System)	Integrated Transport System	✓	✓	✓	✓		✓
Australia	Keoride	On demand transport services	✓	✓	✓			✓

Brazil	Rio Operations and Resilience Centre	Integrated Transport System	✓					
	Taxi Rio	Taxi services		✓	✓	✓		
	Bike Rio	Solar energy powered sharing bicycle system	✓		✓	✓	✓	✓
Canada	Smart cities challenge - The City of Montreal	Integrated mobility platform	✓	✓	✓	✓	✓	✓
		Car and bike sharing	✓	✓	✓		✓	✓
China	Jiangsu (City of Wuxi) National IOV (Internet of Veihcles) Pioneer Zone	Internet of Vehicles	✓	✓				✓
France	National Strategy for the development of self-driving vehicles	Automated public transport services		✓		✓		
Germany	Data platform for a Mobility Data Ecosystem	Urban mobility platform			✓	✓		
	Grant program for unmanned aircraft systems (UAS) and air taxis with special focus on urban air mobility	Unmanned aircraft system	✓	✓	✓	✓		
Indonesia	TransJakarta	Rapid transit system	✓	✓	✓	✓	✓	✓
	Jakarta MRT	Rapid transit system	✓	✓	✓	✓	✓	✓
	Smart traffic lights	Inteligent traffic system		✓		✓		✓
Italy	Milano Smart City	Urban mobility platform	✓	✓	✓		✓	✓

	Torino Smart Road	Urban mobility platform	✓	✓	✓		✓	✓
Japan	Tokyo Metropolitan Government MaaS social implementation support project	New mobility services pilot cases	✓	✓	✓		✓	✓
	Kozoji New Mobility Town Concept project	Integrated mobility platform	✓	✓	✓	✓	✓	✓
Saudi Arabia	Initiative: Digital Components Directory	Urban mobility platform	✓	✓	✓	✓	✓	
	Integrated Traffic Management & Central Control System	Integrated Transport System	✓	✓		✓	✓	✓
	Smart ticketing system	Integrated Transport System				✓		
	Riyadh Smart Parking, advanced Traffic Management System and Public transportation	Smart parking, Integrated Transport System	✓	✓				

E.5. Who initiates smart mobility initiatives

Survey responses revealed a broad range of actors responsible for initiating and managing smart mobility initiatives including public authorities at various levels, public transport operators, private companies and citizens and different combinations of these actors.

All G20 and Partner countries provided smart mobility cases led by national or local governments. In some countries, central governments have stepped from being the top-down initiator for smart city and smart mobility initiatives but, instead, act as one player in the broad smart city/mobility ecosystem. This has opened the possibility for a broader representation of views regarding smart city and smart mobility objectives. In this context, initiating and sustaining relationships with community groups, the private sector and universities are core to developing well-rounded and sustainable initiatives.

EU's Synchronicity project

Under the EIP SCC's another action cluster on 'Integrated Infrastructures and Processes', the Commission supported the development of a reference architecture and design principle for open urban platforms, based on comprehensive set of city needs and requirements. The standard was tested and further developed into the so-called MIMs (Minimum Interoperability Mechanisms) under the recent SynchroniCity project, which is IoT Large Scale Pilot aimed to open a global market, where cities and businesses could develop IoT- and AI-enabled services to improve the lives of citizens and to grow local economies. The project had several pilots in the area of Mobility-as-a-Service and non-motorized active transport (https://synchronicity-iot.eu/cities-pilots/) and comprehensive monitoring framework.

Brazil's Rio bike

Bike Rio is a public bicycle system managed, funded and operated by a private company called Tembici through a 5-year contract with the city of Rio de Janeiro, an approved company operates the city's cycle system. The incentive to use bicycles for urban mobility aims to reduce congestion rates, in addition to reducing carbon dioxide emissions and improving the population's quality of life.The bicycle stations operate powered by solar energy panels and use locks and fixing pins as a security system. The stations are interconnected by wireless communication system, connected with the Control Center 24 hours a day. The center monitors in real time the entire operation of the system, ensuring the best distribution of bicycles in the stations, and providing customer service via cell phone and call center. The Bicycles are available every day from 5 am to midnight. To use the shared system, you need to complete a registration over the internet and purchase a pass.

United Arab Emirate's Hala taxi

The Roads and Transport Authority (RTA) in Dubai and private sector E-hailing company 'Careem' launched collaborative taxi e-hailing in Dubai under a Joint Venture (JV) called 'Hala'. Hala enables Dubai residents and visitors to have smoother journeys and decrease their dependency on privately owned vehicles. This public-private-partnership (PPP) is the first of its kind worldwide between a public transport authority and a private company specializing in smart booking to uplift the public transport network and sharing mobility.

E.6. Smart Mobility indicators

Smart mobility indicators are a key component of smart city indicators. Almost all countries answered that their concrete smart mobility projects have a monitoring mechanism.

Turkey's Smart City Maturity Evaluation Model

The establishment of Smart City Maturity Evaluation Model is clearly mentioned in Turkey's 2020-2023 National Smart Cities Strategy and Action Plan to compare the maturity levels of the cities and to determine the competencies related to smart city governance and implementations. Maturity evaluation pilot studies were carried out in Konya Selçuklu and İstanbul Beyoğlu Municipalities. In the article 15.6 of the strategy aims to enhance the maturity of the Smart Mobility components to achieve reducing traffic congestion, travel times and carbon emissions, increasing traffic safety, efficient use of existing road capacities, ensuring interoperability and integration, efficient use of energy, increasing usage rate of public transportation and ensuring environmental benefits.

Russian Federation's Smart City Standard

The government of the Russian Federation presented the results of the assessment of the progress and effectiveness of the digital transformation of the urban economy in the country. The index was calculated by the Russian Ministry of Construction in conjunction with Moscow State University, It defines the basic level of digitalization of the urban economy and the effectiveness of the solutions that are implemented by the cities participating in the Smart City project. The methodology was developed, and the index counted from September to December 2019 as part of the national projects "Housing and Urban Environment" and "Digital Economy." The current "Cities I" evaluates the results of the digitization of the urban economy for 2018 in 191 cities in Russia. The index is calculated in ten areas - urban management, "smart" utilities, innovations for the urban environment, "smart" urban transport, intelligent public safety systems, intelligent social services systems, tourism and service, economic condition and investment climate, infrastructure of communication networks. These areas of digital transformation are broken down into

47 indicators for which calculations have been made. In developing the structure of the index, the requirements for "smart" cities were taken into account, as defined within the Smart City standard, setting the basic and additional requirements for those technological and organizational solutions that the city can implement in the interests of digitalization, as well as existing best practices in the regulation and measurement of digital transformation of cities, existing not only in Russia, but also abroad.

Dubai RTA Smart Mobility Monitoring Mechanism

The Roads and Transport Authority (RTA) in Dubai has also instituted robust monitoring mechanisms to monitor and track the progress of all smart mobility programs and initiatives to ensure timely and effective results upon their delivery. These mechanisms include, but are not limited to, internal Enterprise Programme Management Office (EPMO) policies, Steering Committees' Governance mechanisms for each initiative, and the RTA Board of Executive Directors governance framework. They enable multi-level oversight and high performance delivery from strategic smart mobility initiatives.

E.7. Data sharing and interoperability of Transport-related data

Three patterns of transport-related data were evident in survey responses. Data sharing amongst government agencies and between these and the private sector is a key element of smart mobility governance. When it comes to transport-related data sharing, the survey revealed three patterns: 1) National or local government to the public, 2) Between and amongst public authorities, and 3) Between public authorities and the private sector.

Argentina

In Argentina, at National level, the Smart Cities Strategy is led by the Under-Secretariat of Open Government and Digital Nation within the Chief of Cabinet's Office. Developing a strong digital government has a direct and positive influence over other dimensions of the cities: environment, human development, urban planning and competitiveness. Considering the holistic system of the cities, the National Government developed a model to identify the city´s strengths and weaknesses across the previous dimensions and to measure the impacts of new projects. The information needed to work the model out is provided by the local or regional government, and thanks to the results each government decides what will be done in order to improve their governance performance. Once the decision is taken, the stakeholders sign agreements and carry out the implementation and the monitoring. The monitoring of the programs is carried out by a new assessment based on the Smart and sustainable cities model. In terms of the SUBE integrated ticketing system, Resolution No. 18/19 of the Secretary of Transportation Management clarifies that there are different types of users to the system (jurisdictions, government entities, transport companies, etc.) who could be able to use the data coming from the SUBE system. However, the extension of the SUBE system to all country and the application of its data to the planning of the transport system is a challenge.

Australia

In Australia, Transport for New South Wales (TfNSW) provides access to public transport data through the Open Data Hub and Developer Portal. The Open Data Hub and Developer Portal provides online access to TfNSW data and resources. The Data Catalogue offers access to all our available APIs and downloadable datasets .

Brazil

In Brazil, at national level, the Ministry of the Economy (ME) and the Ministry of Science, Technology, Innovation and Communications (MCTIC) jointly coordinate the National Digital Transformation Strategy

implements a wide-ranging policy of open government data. Brazil ranks well in the Global Open Data Index (https://index.okfn.org/place/). Rio Operations and Resilience Center and Taxi.Rio share and use data from the Municipal System of Urban Information. Created in 2011, the Municipal System of Urban Information aims to: gather, manage, integrate and update the set of information about the city of Rio de Janeiro, establishing an efficient communication channel between the agencies in order to subsidize public policies of the Municipal Administration. Twelve public bodies directly responsible for implementation of the Municipality's Urban and Environmental Development Policy, pursuant to the Master Plan for Sustainable Urban Development of the City, integrate the Municipal System of Urban Information. Among them, Instituto Municipal de Urbanismo Pereira Passos is the responsible body for its coordination.

China

In China, the Guidance is developed to implement National Plan on New Urbanization (2014-2020) and Opinions of the State Council on Promoting Information Consumption and Expanding Domestic Demand. The 13th Five-Year National Plan for Information Development further clarifies the objectives and specific measures of building smart cities in China 2016-2020. The Program of Building National Strength in Transportation states that China will "vigorously develop smart transportation" and build a ubiquitous advanced information infrastructure and comprehensive big data center system for transportation. In September 2019, Shanghai, Jiangsu, Zhejiang and Anhui signed Mutual Recognition Cooperation Guidelines of Yangtze River Delta on IOVs Road Test, to jointly standardize data sharing and test results mutual recognition.

Germany

In Germany, at National level, since 2016, Germany supports data-driven innovations in mobility 4.0 with 200 million EUR via the grant programme mFUND, as part of the Open Data Strategy of the Ministry of Transport and Digital Infrastructure. Until now, the mFUND has launched more than 220 projects across all transport modes. As part of the mFUND, the mCLOUD serves as a data repository for Open Data from public and private sources. In the planned living lab, a concept of decentralized, networked mobility platforms is to be developed by the National Platform Future of Mobility (NPM). On this basis, a comprehensive mobility data network is to be created, which will be shared by private and public actors.

Russian Federation

In the Russian Federation, the specialized Smart City portal has been established in the framework of implementing the departmental Smart City and its relevant measures and initiatives, providing information on the project, relevant regulation and other documents, as well as the pool of solutions in the field of smart city development and other information. The Ministry of Construction, Housing and Utilities of the Russian Federation is leading the project. The portal is implemented under the participation of PJSC Rostelecom.

Saudi Arabia

In the case of Kingdom of Saudi Arabia, at national level, the Ministry of Municipal & Rural Affairs (MOMRA) has a platform through which it provides information on municipal laws and regulations for residents, the private sector, and other government entities. The Digital Components Directory contains

an initiative to develop a digital and interactive mapping application that provides users with specific information. This application will have a database and will involve city authorities, the Ministry of Communications and Information Technology, and other entities.

The Saudi Transport General Authority (TGA) is committed to sharing mobility related data to enable more seamless transportation, as well as encouraging new, digital business models, as long as privacy is ensured and can be protected. TGA will be embarking on developing a transportation database that acts as an aggregator of primary and secondary data from different sources. Once developed, the database will be accessibly by relevant entities within KSA including academia and businesses. The Transport General Authority's initiative to develop a Transportation Database assumes a full cooperation of all relevant partners and stakeholders. In its design, the Database assumes the interoperability and the ability to communicate easily and seamlessly with other databases around the Country. Similarly, the assumed fare collection system, as envisioned by TGA, will allow the seamless movement of people around the Country and the ability to use the different public transport systems seamlessly and easily.

In order to have a seamless transportation experience, TGA has developed other initiatives, including smart applications that are used by different sectors within the transport industry: 1) Naql. An electronic platform enabling companies and individuals to access land and maritime transport services by TGA; 2) Wasel. An electronic platform that enables the TGA Authority and the relevant authorities to continuously follow up the operations of land transport and clarifies the security and regulatory status of vehicles and drivers. Through this platform, the TGA can monitor the operation of ride-hailing services within KSA.; 3) Bayan. An electronic platform that enables carriers and freight brokers to issue a cargo statement and transport document electronically. In Riyadh city, Riyadh Urban Observatory is collecting data from deferent Government agencies and sectors within the city, based on the row data that's been collected, a project under the name Riyadh Open Data Portal will publish the data and apply the concept of city open data.

Singapore

Singapore has made transport data easily available to the public via its Open Data Platform starting in 2011. This platform is a rich depository of both real-time and static land transport data and can be downloaded by "technopreneurs" and the academia for the co-creation of innovative transport solutions. There has been an increase in the number of transport-related smartphone applications supported by the data since, which have gained traction among commuters in Singapore. There is therefore room for greater community and industry involvement to co-create innovative solutions to common problems and achieve better public outcomes.

Turkey

In Turkey, the National Intelligent Transportation Systems Strategy Document and Action Plan 2020-2023 has been prepared. One of the Strategy and Action Plan's five strategic pillars focuses on ensuring data sharing and security. Data considerations feature among many Plan's identified actions, including:

- Development of smart transportation systems architecture and setting standards
- Establishment of a cooperative smart transportation systems test and application corridor
- Smart car parking application and electric vehicle charging station installation
- Single card payment system

- Use of drones for logistics purposes
- Data collection and analysis to reduce accidents
- Dissemination of in-vehicle information and communication systems

United Arab Emirates

The United Arab Emirates has launched a data sharing tool kit for the public on their website on 14th April, 2020. In Dubai, the Roads and Transport Authority (RTA) has closely coordinated and collaborated with Smart Dubai Department and its data arm, Dubai Data Establishment, which are responsible for data governance and data related implementations at the city level. RTA has complied with all the stipulations of Dubai Data Law issued in 2015 and its subsequent regulations, standards and policies issued by Dubai Data Establishment which encompass open data, private data, and public sector data sharing. In this context, RTA has taken a leadership role in data provisioning for the transport sector in Dubai.

EU Intergovernmental cooperation for standard-based. Interoperable urban platforms

Under the European Innovation Partnership for Smart Cities and Communities (EIP-SCC)'s action cluster on 'Integrated Infrastructures and Processes', the Commission supported the development of a reference architecture and design principle for open urban platforms, based on comprehensive set of city needs and requirements. The standard was tested and further developed into the so-called MIMs (Minimum Interoperability Mechanisms) under the recent SynchroniCity project, which is IoT Large Scale Pilot aimed to open a global market, where cities and businesses could develop IoT- and AI-enabled services to improve the lives of citizens and to grow local economies. The project had several pilots in the area of Mobility-as-a-Service and non-motorized active transport (https://synchronicity-iot.eu/cities-pilots/) and comprehensive monitoring framework.EU acknowledges that urban platforms are necessary to handle the growing range of stakeholders and data across various sectors, but are also essential for innovative and cost-effective solutions, as they create open and interoperable ecosystems that can be extended to function as spaces for creative experimentation. The use of interoperable, standard-based, urban digital platforms will also ensure technological and data sovereignty (avoiding vendor lock-in) stimulate investment, promote collaboration among public and private sectors and create trust in all stakeholders.

With no legal basis for urban policy in the EU Treaties, the Urban Agenda for the EU was initiated within the framework of intergovernmental cooperation. The Pact of Amsterdam, signed on 30 May 2016 at the informal meeting of EU Ministers responsible for Urban Matters, established the Urban Agenda for the EU and set out its objectives. These include achieving a more integrated and coordinated approach to EU policies and legislation that have impact on urban areas. The Urban Agenda is implemented through Partnerships involving the European Commission (and ultimately other EU institutions), Member States, cities and stakeholders in a multi-level governance format. So far, 12 Partnerships Action Plans have been completed and have now entered into implementation phase with 114 actions in total. These actions are characterized by different degree of implementation. One of the partnerships was dedicated to digital ('Digital Transition Partnership') and several others have identified digital technologies as important enablers. All the work around urban platforms led to a mature set of standards, solutions and indicators that are ripe for deployment. Amongst other recommendations, the scaling of urban platforms also featured in the final report of the Digital Transition Partnership under the Urban Agenda. The EU aims to help cities and other stakeholders to deploy them at scale. To boost their use, European cities, regions and Member States are in the process of signing a political declaration ('Join, Boost, Sustain' Declaration) to that effect, supported by the European Commission and the Committee of the Regions. This can pave the way towards an 'EU ecosystem for the communities of the future', built on open, digital and trustworthy urban platforms, while at the same time respecting citizens' digital rights.

E.8. Country response summaries

Argentina

Smart & Sustainable Cities National Plan

The under-secretariat of Open Government and Digital Nation within the Chief of Cabinet's office leads the Smart & Sustainable Cities National Plan to achieve social welfare through planning, management and governance of the cities in a sustainable way with ICT as tools. The plan has defined 5 strategic areas of study which encloses sub-areas and specific study topics. It is a matrix that reveals a general vision of the local government state. This vision is the base to operate technically and politically over the town. The 5 strategic areas of study are: governance, environment, human development, urban planning and competitiveness.

In addition, it has defined 3 strategic axes. The first one is "Widespread", and it works on governance. The action areas of this axis are infrastructure and capabilities, services platform and open government. It also has the following sub-action areas: equipment and networks, e-Management, smart data, human resources, digital platform, on-line transactions, public connectivity, transparency, open data and citizen participation.

The second axis is "In-Focus". The axis focuses on: transport and mobility, environment and production / tourism. In this stage the proposal is to implement ICT solutions in the master plans that have been designed by the technical ministries. The goal is to have 60% of population living in urban areas with smart mobility, smart environment and smart productivity / tourism services.

The third axis is "Concentrate". It works towards the development of smart cities pilots. The level of complexity is very high, and the interventions will take place in delimited urban areas in order to test the benefits of concentrated effort across the different areas of the national government.

Smart Mobility "In-Focus" axis

Smart Mobility is highlighted in the 2nd "In-Focus" axis of the plan, aiming to 1) guarantee the drivers for developing the smart mobility initiatives: data, interoperability systems, infrastructure and cybersecurity; 2) support the development of smart transport and smart mobility initiatives in accordance with the Ministry of Transport of the Nation Action Plan; 3) measure the real impact of smart mobility in the social, environmental and economic dimensions of the country.

Example of Smart Mobility projects

Name of the project	***SUBE***
Category of the Smart Mobility	Integrated Ticketing System
Who leads	The National Ministry of Transport, through the Directorate of Implementation and Monitoring of the SUBE, under the Department of Transportation Administrative Management
Who finances	The Ministry of Transportation through resources from the national treasury
Objective	To facilitate access to public transport and improve the planning of the transport system through the data generated by the system
Monitoring mechanism	It covers the fleet management system that enables the definition of indicators for the planning, management and control of the transport system.

Data sharing and interoperability	Resolution No. 18/19 of the Secretary of Transportation Management clarifies who could be able to use the data coming from the SUBE system. The extension of the SUBE system to all country and the application of its data to the planning of the transport system is a challenge.

Australia

Smart Cities Plan

The Department of Infrastructure, Transport, Regional Development and Communications leads the smart cities Plan, envisioning productive and livable cities that encourage innovation, support growth and create jobs. It includes three pillars; Smart Investment, Smart Policy and Smart Technology.

Smart mobility as an economic driver

Smart Mobility elements such as disruptive new technology in transport, open data driven solutions and commercializing new innovations are highlighted as important to grow Australia's economy. The aspirational concept of 30-minute cities is presented by emphasizing the importance of an efficient and well-designed public transport network between cities.

Example of Smart Mobility projects

Name of the project	***Keoride***
Category of the Smart Mobility	On demand transport services
Who leads	New South Wales state government, with leading operators; Keolis Downer, AECOM, GoGet (fleet provider), Via (technology provider) and Data61.
Who finances	New South Wales state government, through Transport for New South Wales
Objectives	・To relieve congestion and provide more flexible choice to commuters ・To provide a faster and more personalized travel experience for the local community ・To reduce personal car usage, pollution and congestion
Monitoring mechanism	Evaluation Panel reviews and evaluates every 6 months.
Data sharing and interoperability	Transport for NSW provides access to public transport data through the Open Data Hub and Developer Portal.
Equity and inclusiveness	Keoride helps authorities ensure public transport is offered in low density areas or during off-peak hours, improve access to outlying districts, serve employment zones and create connections between local towns. Furthermore, Keoride provides specially-adapted vehicles (ramps and fitted spaces). In addition, Keoride focuses on drivers training in smooth driving and assisting passengers who may need extra assistance.

Internal coordination among the different levels of government

City Deals, which are a partnership among the three levels of government (Australian Government, State/Territory Government and local government), as well as the community to work towards a shared vision for productive and livable cities, are key elements for the Smart Cities plan. Following the success of the City Deals model, the Government is testing in regional centers by piloting three Regional Deals. The pilots are tailored to each region's comparative advantages, assets and challenges and reflect the unique needs of regional Australia. Under the Australian Government's Smart Cities and Suburbs Program a total of 81 projects were delivered across Australia, including projects in rural areas such as Goldenfields MyH2O App. The Program supports the delivery of innovative smart city projects that improve livability,

productivity and sustainability of cities and towns across Australia. More details on each project can be found on the Smart Cities Collaboration Platform.

Brazil

National Strategy for Smart Sustainable Cities

The National Strategy for Smart Sustainable Cities is currently being drafted, led by Ministry of Science, Technology, Innovation and Communications (MCTIC) and Ministry of Regional Development (MDR).

The strategy is well coordinated though a recently established National Chamber of Cities 4.0, which discuss and propose actions that stimulate the development of technological solutions to improve urban environments and the quality of life of the population. This will adopt International Telecommunications Union (ITU)'s Framework for Smart Sustainable Cities and closely follows the Recommendation ITU-T Y.4900/L.1600, which provides general guidance to cities and provides an overview of key performance indicators (KPIs) of smart sustainable cities (SSCs).

Several municipal-level initiatives in the area of smart cities are currently being implemented throughout the country. For example, The city of Campinas has a Smart City Strategic Plan 2019-2029, which defines basic guidelines for the transformation of being a smart, human-oriented and sustainable city. The plan starts from a diagnosis of the current situation, in which the main systems were mapped existing computerized information technology infrastructure and Communication (ICT) of the city and its services made available to the citizen. The city of Curitiba has introduced innovative solutions, and was selected as a winner of the World Smart City Awards 2019. The city of Rio de Janeiro highlights the importance of smart mobility in the Strategic Plan (2017-2020) to ensure the expansion and consolidation of intelligent transport and traffic systems.

Example of Smart Mobility projects

Name of the project	**1. Rio Operations and Resilience Center** **2. Taxi Rio** **3. Bike Rio**
Category of the Smart Mobility	1. Coordination center for Integrated Transport System 2. Public taxi services 3. Public bicycle system
Who leads	1. The Executive Office of Mayor Crivella 2. IPLANRIO, a municipal company who is responsible for the ICT in the city. 3. Tembici, a private company
Who finances	1. Municipal government 2. Municipal government 3. Private company who won the bid to operate in the city
Objectives	1. To monitor City's traffic and respond the needs to other adversities (such as heavy rains and landslides) that cause disruption in the mobility in the city. To provide real-time information to the public about traffic and transport conditions through website, application and alerts from associated channels. 2. To improve the competitiveness of taxi drivers against commercial mobility. 3. To reduce congestion rates, carbon dioxide emissions and improve the population's quality of life.
Monitoring mechanism	1. The center has a monitoring function by itself. 2. It was designed with the purpose to offer dfata to the municipality as a subsidy for the creation of transport policies. 3. It doesn't have.

Data sharing and Interoperability

The Ministry of the Economy (ME) and the Ministry of Science, Technology, Innovation and Communications (MCTIC) jointly coordinate the National Digital Transformation Strategy implements a wide-ranging policy of open government data.

Canada

The Investing in Canada Plan

The Investing in Canada Plan is a long-term (12 year) plan for building a prosperous and inclusive country through infrastructure investments of $180 billion, starting in 2016. Under the Plan, Infrastructure Canada has implemented a Canadian Smart Cities Challenge, a $300 million initiative over 10 years, allocating prizes (e.g. $5M, $10M, $50M) for transformational projects that adopt smart city approaches, encouraging communities to come up with solutions for their most pressing economic, environmental and social issues using data and connected technology.

Smart mobility is an emergent area, which is currently pilot-based and in a trial/testing period in a variety of communities across the country. The push for smart mobility is currently being led by municipalities and private sector actors, though it is not yet at scale. Smart mobility is referenced in some city-level transport, smart city, and/or innovation plans. The most common example of smart mobility technology in Canada is automated traffic systems. In rural areas or smaller communities, the focus is primarily on technology-based on-demand services, micro-transit bus routes between small towns, carpooling apps, and even contracting ride sharing services, such as Uber, to act as public transport.

Example of Smart Mobility projects

Name of the project	The Smart Cities Challenge Winner ($50M) – The city of Montreal
Category of the Smart Mobility	1. Integrated mobility platform supported by app-based trip planning 2. Innovative mobility: car sharing, bike sharing, autonomous vehicles
Who leads	The city of Montreal, Quebec
Who finances	Infrastructure Canada's Smart Cities Challenge Program
Objectives	Pillar 1: Mobility 1. To improve mobility in neighborhoods by developing alternatives to personal vehicle use 2. To centralize several mobility options on one technological platform, which will allow users to rent a shared car, a BIXI bicycle, or use public transport 3. To encourage citizen participation in projects, and take a look at municipal regulations which pose barriers to urban innovation 4. To release and share data that will break down silos and create new collaborations between municipal, private and community actors in order to make better decisions on the development of public space. Pillar 2: Food access 5. To reduce food waste and provide better access to food for vulnerable populations. 6. To build an integrated digital platform to improve the overall logistics management of the food distribution system through the city.
Monitoring mechanism	Rigorous performance measurement is a large part of the project and is defined in the contribution agreement with Infrastructure Canada.

Other Smart Mobility Initiative: Transport Canada

Canada's Council of Ministers Responsible for Transportation and Highway Safety, led by Transport Canada, established the federal, provincial and territorial Urban Mobility Task Force in January 2019 to take a renewed look at the current mobility issues affecting the Canadian urban landscape today. The objectives of the task force are to carry out a review of selected urban mobility issues and consider policy options to improve urban mobility, generally understood as the movement of people and freight within an urban region and supported by transportation systems. An Interim Report of the Urban Mobility Task Force was publicly released in February 2020. Transport Canada also works with provincial, territorial and municipal governments across Canada on examining the use of emerging automated and connected vehicle technologies and taking collective action regarding the safe testing and deployment of these vehicles on roads in Canada. This work has resulted in a series of important safety guidelines and policy principles, aimed at forging alignment and common approaches across jurisdictions in Canada.

China

Guidance on Promoting Healthy Development of Smart City

National Development and Reform Commission (NDRC) provides the Guidance on Promoting Healthy Development of Smart City in collaboration with over 20 ministries. This guide presents human-centered, market-driven and customized approach and strategies of developing smart cities in China from 2014 to 2020. This also puts forward specific action plans as regards top-level design, information development and sharing, technological and industrial application, cyber security management and capacity-building, and regulation framework.

In the Guidance, "Accelerating the construction of smart infrastructure" section explains to build intelligent systems in traffic guidance, travel information service, public transport, integrated passenger transport hub, integrated operational coordination and command systems, promote the construction of COMPASS foundation enhancement system, and develop differentiated traffic information services.

The Guidance supports the implementation of the National Plan on New Urbanization (2014-2020) and Opinions of the State Council on Promoting Information Consumption and Expanding Domestic Demand. In December 2016, the 13th Five-Year National Plan for Information Development further clarifies the objectives and specific measures of building smart cities in China 2016-2020. The Program of Building National Strength in Transportation released in September 2019 states that China will "vigorously develop smart transportation" and build a ubiquitous advanced information infrastructure and comprehensive big data center system for transportation.

Example of Smart Mobility projects

Name of the project	Jiangsu (City of Wuxi) National IOV (Internet of Vehicles) Pioneer Zone
Category of the Smart Mobility	Urban intelligent transportation system
Who leads	Jiangsu Provincial Department of Industry and Information Technology, connected with the national Internet of Vehicles Industry Development Action Plan
Who finances	National and provincial budgets plus private investment
Objectives	1. To enrich the use of IOV 2. To reduce congestion in urban area

	3. To provide convenient transportation services through large-scale deployment of C-V2X network and roadside units 4. To provide functional transformation of core system capacity of transportation facilities
Monitoring mechanism	The initiative strengthens coordination through cross-industry, cross-fora and cross-regional collaborative mechanism, and builds a security monitoring platform that integrates online monitoring, dynamic censoring and big data analysis.

Data sharing and interoperability

In September 2019, Shanghai, Jiangsu, Zhejiang and Anhui signed Mutual Recognition Cooperation Guidelines of Yangtze River Delta on IOVs Road Test, to jointly standardize data sharing and test results mutual recognition.

The European Union

European Innovation Partnership for Smart Cities and Communities (EIP-SCC)

Smart cities are places where traditional networks and services are made more efficient with the use of digital technologies for the benefit of its inhabitants and business. The aim of a bigger Smart Communities policy is the improvement of all EU citizens' quality of life by offering a broad range of innovative, sustainable and secure services in mobility, energy, water, waste, e-government, and others. The Europe 2020 strategy incorporated a commitment to promote the development of Smart Cities throughout Europe and to invest in the necessary ICT infrastructure and human and social capital development. The European Commission set up the European Innovation Partnership for Smart Cities and Communities (EIP-SCC) in 2014 for the current Multi-Annual Financial Framework, to help cities make the best use of research and innovation to improve the urban environment.

The EIP-SCC brings together close to 6.000 stakeholders from 31 countries, from cities, businesses and the investment community to implement and replicate best practices in their respective cities and communities. The platform hosts a great wealth of toolboxes, guidelines, recommendations related to standards, business models, scaling up methodologies, citizen-centric approach to data, etc. It has now reached the next phase: implementation, replication and building a European market for bankable smart city solutions (marketplace).

Sustainable Urban Mobility

In the EIP-SCC, Sustainable Urban Motility is one of the action clusters, bringing together cities and regions with companies to showcase innovative mobility solutions and support their replication at scale in key market segments. It aims to become the leading platform for understanding and documenting city needs, bringing stakeholders together, building the tools that support an innovation pipeline, and directly supporting individual networks and upcoming projects.

Example of Smart Mobility projects

Name of the project	Transforming Transport project
Category of the Smart Mobility	13 pilot projects in 7 pilot domains to showcase big data impact in the below areas: 1) Highways, 2) rail infrastructure, 3) airports, 4) urban mobility, 5) vehicle connectivity, 6) ports, and 7) e-commerce logistics

Who leads	EU, with the participation of 48 organizations from 9 countries, as the Horizon 2020 Big Data Value Lighthouse project
Who finances	EU budget of EUR 18.7 million
Objectives	To show concrete, measurable and verifiable evidence of data value that can be achieved in mobility and logistics by leveraging big data.

SynchroniCity project

Under the EIP SCC's another action cluster on 'Integrated Infrastructures and Processes', the Commission supported the development of a reference architecture and design principle for open urban platforms, based on comprehensive set of city needs and requirements. The standard was tested and further developed into the so-called MIMs (Minimum Interoperability Mechanisms) under the recent SynchroniCity project, which is IoT Large Scale Pilot aimed to open a global market, where cities and businesses could develop IoT- and AI-enabled services to improve the lives of citizens and to grow local economies. The project had several pilots in the area of Mobility-as-a-Service and non-motorized active transport (https://synchronicity-iot.eu/cities-pilots/) and comprehensive monitoring framework.

France

Example of Smart Mobility projects

Name of the project	National Strategy for the development of self-driving vehicles
Category of the Smart Mobility	Development of national framework of automated public transport systems
Who leads	National Government
Who finances	Public (National and local governments) and private funding
Objectives	1. To offer services adapted to the needs of citizens and local communities (in connection with new forms of car-sharing and on-demand transport) 2. To ensure safety of autonomous vehicles (road safety but also cyber-security and protection of personal data) 3. To encourage acceptance of self-driving technology (taking into account safety, suitability for use, impact on transport options, environmental/employment impact) 4. To develop competitiveness (for example, developing competitive technology used for detection, data processing and geo-localization) and employment (economic gains for local communities) 5. To promote European and international cooperation (with regards to the development of technical regulation for vehicles but also the financing of a European program for research, innovation and experimentation).
Monitoring mechanism	Implementing a system to monitor individual and social perception and the acceptability of self-driving vehicles

Creation of two consortiums

After two calls for projects were launched in May 2018, two consortiums were created: Security and acceptability of autonomous driving and mobility (SAM) and Autonomous shuttle experiment (ENA). The total investment for both projects reached €120 million, including €42 million of public funding (the rest being privately funded). The SAM project gathers 19 partners (including car industry), 100 autonomous vehicles and 500,000 users, covering a total of 13 areas (incl. the Greater Paris and Toulouse) and connecting key facilities (such as the Toulouse Cancer Institute and university faculties). The ENA project involves 10 industrial stakeholders in 3 areas (including rural communities). The experiment consists in

one autonomous vehicle running a distance of 20 km and connecting 5 different municipalities, 8 times a day.

Germany

National Smart Cities Dialogue Platform

The National Smart Cities Dialogue Platform, led by the Federal Ministry of Interior, Community and Building promotes national and international exchange on digital technology in the context of urban development policy. In 2017 the platform presented the Smart City Charta, including guidelines and recommendations for ensuring the sustainability of digital transformation at local level as part of an integrated urban development policy. The platform now supports the implementation and further development of the Smart City Charta.

National Platform "Future of Mobility"

The National Platform Future of Mobility (NPM), headed by the Federal Ministry of Transport and Digital Infrastructure, is the focal point for discussions on strategic decisions in the field of mobility. Changes in the mobility sector are accompanied by far-reaching technical, legal and social changes. For this reason, the NPM clarifies facts on complex topics and brings together relevant stakeholders, technical expertise and politics. Based on the results from discussion in the NPM, recommendations for action are made to politicians, businesses and society. The six working groups are; WG 1: Transport and climate change; WG 2: Alternative drive technologies and fuels for sustainable mobility; WG 3: Digitalization in the mobility sector; WG 4: Securing Germany as a place for mobility, production, battery cell production, primary materials and recycling, training and qualification; WG 5: Connecting mobility and energy networks, sector integration and WG 6: Standardization, norms, certification and type approval.

Example of Smart Mobility projects

Name of the project	Grant program for unmanned aircraft systems (UAS) and air taxis with special focus on urban air mobility
Category of the Smart Mobility	Unmanned aircraft systems (UAS) / Air taxis
Who leads	Federal Ministry for Transport and Digital Infrastructure, connected to the EU Urban Air Mobility Initiative
Who finances	Federal Ministry for Transport and Digital Infrastructure
Objectives	• Connected UAS • Medical applications • Public acceptance • Air-Traffic-Management-Systems • Take-off and landing operations • Drone detection and deterrence
Monitoring mechanism	Monitoring mechanisms are defined by German administrative law.

Data sharing and interoperability

In the planned living lab, a concept of decentralized, networked mobility platforms is to be developed by the National Platform Future of Mobility (NPM). On this basis, a comprehensive mobility data network is to be created, which will be shared by private and public actors.

Since 2016, Germany supports data-driven innovations in mobility 4.0 with 200 million EUR via the grant program mFUND, as part of the Open Data Strategy of the Ministry of Transport and Digital Infrastructure. Until now, the mFUND has launched more than 220 projects across all transport modes. As part of the mFUND, the mCLOUD serves as a data repository for Open Data from public and private sources.

Indonesia

100 Smart City Agenda

Indonesia is currently assisting the development of 100 Smart Cities across the country. Regulation regarding city management (Smart city) is set nationally and the program is coordinated among the Ministry of Communications and Informatics, the Ministry of Internal Affairs, the Ministry of Public Works and Housing, the Ministry of Planning, and Executive Office of The President of the Republic of Indonesia. This program intends to facilitate and aid public authorities in devising Smart City Master Plans to maximise the use of technology for improving public service and to improve outcomes at the local and regional level. The policy emphasises equal and accessible technology and access to e-government service to all Indonesians, including citizens in rural areas.

Example of Smart Mobility projects

Name of the project	1. TransJakarta 2. Jakarta MRT 3. Application of Smart traffic lights
Category of the Smart Mobility	1. Bus Rapid Transit (BRT) 2. Mass Rapid Transit (MRT) 3. Smart traffic lights
Who leads	The Ministry of Transportation, local governments and Indonesian National Police
Who finances	Government and private sector through Public Private Partnership (PPP)
Objectives	To reduce traffic congestion and decrease road accidents.
Monitoring mechanism	Indonesian National Police reports publicly the condition of traffic and number of road accidents.
Data sharing and interoperability	It is managed by Jakarta governor office, Ministry of transportation, and Indonesian National Police.
Equity and inclusiveness	To provide the mass of transportation facilities for people who commute to and from Jakarta.

Italy

Strategy for digital growth 2014-2020

A national Smart Cities and Communities strategy and a related policy are in place since 2012, in the framework of the Italian Digital Agenda. It aims at strengthening the role of a selected number of cities in shaping demand-driven innovation in Italy.13 Italian "Core Cities", that are actually introducing 5G facilities, with 13 smaller towns, have been asked by the three leading Ministries to identify challenges under three particular domains: smart mobility, cultural heritage, wellbeing. Through the public innovation broker, cities are able to access a large portfolio of support services, including funding, technical and administrative skills.

In 2015, the "Strategy for digital growth 2014-2020" identified smart cities as an appropriate context to deploy digital culture, due to the high impact in terms of socio-economic effects. The Government also

deployed national public digital infrastructures (Digital identity, electronic payments, e-invoices, civil registry) that are crucial for smart city applications. The Multi-fund National Operational Program Metropolitan Cities 2014-2020 (PON METRO), part of the initiatives conceived in the framework of the European Urban Agenda for cohesion policies, made available additional resources of about 800 M€ with the aim of strengthening the role of big cities and their territories. The strategy for the next 5 years aims at enabling the massive procurement of new solutions that are interoperable with national digital infrastructures and can be easily combined to develop smart city applications.

Once the challenges are identified, the Italian Digital Agency (on behalf of the three leading Ministries that are pouring financial resources for approximately 100 million Euro) announces a European-wide innovative public procurement, where companies and the research community is called to design, experiment and provide potential disruptive solutions and services. Candidate proposals are evaluated at local level through a one-year competitive dialogue scheme. Once the solutions are validated, they can benefit from a "fast-track" procurement scheme for their deployment. Italy is one of the most advanced countries for innovative public procurement schemes. Under the strategy, Smart mobility represents the first sector where smart services and solutions are going to be tested. In particular, the program is focusing on four pillars: Innovative solutions 1) to satisfy the mobility needs of low demand or less populated areas; 2) to improve the B2C mobility of goods in cities; 3) to improve mobility in historic centers and villages; and 4) to establish data driven platforms and decision support systems for the prediction of mobility scenarios.

Examples of Smart Mobility projects

Name of the projects	1. Milano Smart City (from 2013) 2. Torino Smart Road, which was awarded as the Global Road Achievement Award (GRAA) 2019, among the most prestigious recognitions at international level for innovative and avant-garde achievements in the transport sector
Category of the Smart Mobility	Both the programs are born from the early 2012 Smart City program of the Ministry of Research. Currently they are served the purpose of experimental frameworks for the national smart city and communities' policy.
Who leads	1. Municipality of City of Milano in a large partnership of Universities, Banks and private companies 2. Ministry of Transport
Who finances	Public resources from central administrations or from local administrations
Objectives	• Reduction of traffic in cities • Reduction of climate-altering emissions • Transition towards alternative and electric mobility modes • Cost savings for families and for the public administration
Monitoring mechanism	The initiatives include measurable performance indicators.

Japan

Integrated Innovation Strategy 2019

Japan announced its Integrated Innovation Strategy in 2019, emphasizing the importance of smart city as a realization of its "Society 5.0" vision. The Smart city concept underpins the Society 5.0 vision (under the fifth Science and Technology Basic Plan) aims to realize a data-driven, human-centric, next-generation

society that uses technology such as artificial intelligence and the Internet of Things to deliver better outcomes for people. This vision means that everyone, regardless of location, including the elderly population in rural areas, will receive the benefits of innovation and technology advances. Society 5.0 emphasizes solving social issues while addressing sustainability and economic growth. The Society 5.0 vision guides cities of all sizes on how to build and deploy smart infrastructure. about the focus is not only on new technologies but also centered on understanding a community's issues and providing appropriate solutions by way of these technologies.

Eleven government ministries, including the Cabinet Office, collaborate to form a "smart city task force". The government is establishing a basic policy for smart cities, building a shared reference architecture, and is proceeding with implementation in each region. It is also promoting the expansion of smart cities outside of Japan. In addition, the Cabinet Office, the Ministry of Internal Affairs and Communications, the Ministry of Economy, Trade and Industry, and the Ministry of Land, Infrastructure, Transport and Tourism have formed a "Smart City Public-Private Partnership Platform". Local governments and private companies are participating in this platform to promote smart city initiatives in various regions.

Smart Tokyo Implementation Strategy

Tokyo Metropolitan Government (TMG) has announced its own Smart city implementation strategy to realize Society 5.0 in February 2020.

Example of Smart Mobility projects

Name of the project	**1. Tokyo MaaS social implementation support initiative** [Initiatives in FY2019 supported a demonstration projects in the Tachikawa Station area, Takeshiba area, and Tokyo Water Front City area that provides a leading model conducted by consortiums of transportation service providers and other related organizations.] **2. Kozoji New Mobility Town Concept Project Case**Implemented through "Social Implementation Project for Future Technology" by Cabinet Office, which is one of the government's smart city related projects
Category of the Smart Mobility	1. Support for Mobility as a Service (MaaS) model projects 2. Integrated transport platform, MaaS, Autonomous vehicles trial projects
Who leads	1. Office for Strategic Policy and ICT Promotion of Tokyo Metropolitan Government 2. Kasugai City Kozoji New Town Leading Mobility Study Meeting (established in 2018)
Who finances	1. Tokyo Metropolitan Government's general budget 2. Tokai Hokuriku Health and Welfare Bureau, Ministry of Health, Labor and Welfare, Kasugai City, Nagoya University, taxi association and volunteer driver build a business structure
Objectives	1. To support demonstration pilot projects to improve the convenience of mobility and to create new services by using big data of mobility. 2. To set KPIs for the number of social implementation projects for new mobility services, increase in the number of people moving in and out of Kozoji New Town, certification rate for long-term care, and annual number of website visits.
Monitoring mechanism	1. In the project application guidelines, TMG has asked applicants to set items verified in the project as well as quantitative and qualitative methods. 2. Yes, the Kozoji New Mobility Town Concept Project Case has a monitoring mechanism in place.

Equity and inclusiveness

The model of social implementation of MaaS, is supposed to include the response to people with restricted access to mobility, who are expected to increase in the aging society. In addition, in the administrative division of TMG, there are some island groups in the Pacific Ocean, which are distant from the metropolis area and less developed. The strategy includes issues related to the island regions, such as how to utilize digital technologies to overcome the challenges posed by geographical distance. The island regions is one of the five pilot areas "Smart Tokyo" strategy identifies.

Lessons learnt and challenges

The transportation networks in Tokyo are highly developed and most of them are owned and operated by private enterprises. Because there are many transportation operators, promoting cooperation among these operators is an important task for the MaaS initiative in Tokyo.

Republic of Korea

Third Comprehensive Plan for Smart City

Smart City is a platform for improving the quality of life for citizens, enhancing the sustainability of cities, and fostering new industries by utilizing the innovative technologies of the Fourth Industrial Revolution.

The Third Comprehensive Plan for Smart City (2019-2023, established in June 2019), the medium- to long-term roadmap for Korea's smart city policies, is aimed at fostering an inclusive smart city that benefits all citizens. To accomplish this goal, plans for providing smart services in areas that have direct impacts on citizens' lives, such as safety, environment and welfare, are under way.

The Ministry of Land, Infrastructure and Transportation (MOLIT) is the main ministry in charge of smart city, contributing to Korea's smart city policies and assisting local governments' plans for smart city development. MOLIT assists local governments in preparing plans for smart city development by conducting pre-assessment process, which includes a smart city plan checklist and expert consulting.

Republic of Korea shares smart city policies and technologies through bilateral meetings with foreign governments and organizations at international events, smart city MOUs, conferences for cooperation. All smart city policies of Korea are available on Smart City Information Portal.

Example of Smart Mobility projects

Name of the project	The Sejong Special Self-Governing City as national pilot project
Category of the Smart Mobility	Ride-sharing, Autonomous driving and Integrated Mobility Platform
Who leads	Ministry of Land, Infrastructure and Transport (MOLIT), National Agency for Administrative City Construction (NAACC), Sejong City, and Korea Land and Housing Corporation (LH)
Who finances	Collective funds from the above organisastions, Estimated to be 22.4 billion Korean won from 2019 to 2023
Objectives	i. Improve the mobility of citizens ii. Reduce traffic congestion through encouraging using less private vehicles iii. Reduce the costs related to crowded urban place and environment problems iv. Foster an open integrated mobility platform to create new services
Monitoring mechanism	Public-private cooperation involving the central government, local governments and private actors to establish a mobility governance system to ensure monitoring and feedback.

Equity and inclusiveness

The philosophy of Sejong smart city is becoming a sustainable platform that improves the quality of life of citizens and offers them creative chances. Its principles include sharing, openness, dispersion, diversity, and decentralization through citizen participation.

Data sharing and interoperability

Sejong smart city will offer integrated services by connecting data from diverse areas such as mobility, education and healthcare. For example, connect 112 (police) or 119 (emergency) services with mobility data so that police cars, fire trucks or ambulances can arrive at the scene as soon as possible.

Mexico

Example of Smart Mobility projects

Name of the project	Miguel Hidalgo municipality: Integral Mobility Program
Category of the Smart Mobility	Integrated Transport System
Who leads	Miguel Hidalgo municipality
Who finances	Miguel Hidalgo municipality
Objectives	Accessibility, security, connectivity, affordability, environment protection
Monitoring mechanism	No

The program comprises four main areas: a) active mobility, b) vehicular mobility, c) public transport, and d) public spaces. Currently, 30 actions have been undertaken as a part of this program, including:

- Bike school: opening of two “bike school”, in which 2,000 people from 3 to 99 years have been trained.
- Bike classes for government workers: the first class was held for 40 workers; during the year more activities will be carried out.
- Improvement of designated lanes for bikes
- Mobility surveys and analyses
- Improvement and increase of pedestrian crossings

Lessons learnt and Challenges

Currently, the efforts and policies related to Smart Mobility in Mexico are being developed at the local level. The Mexican government is working to strengthen the coordination with the various levels of government, and to seek the active participation of citizens in these policies. Likewise, the national government recognizes that smart mobility initiatives must be strengthened with the use of databases and monitoring, in order to allow the decision-making based on current information at local level.

Russian Federation

Smart City – departmental project on the digitalization of municipal services

The Smart City project, approved by Order No. 695/pr of 31 October 2018 of the Ministry of Construction, Housing and Utilities of the Russian Federation (MCHURF), goes beyond digital transformation and process automation, the goals of the Smart City project are to improve the competitiveness of Russian cities, create efficient urban governance system, establish safe and comfortable conditions for residents. The project principles include the following: Human centricity; Technological effectiveness of urban infrastructure; Improving urban resources governance; Comfortable and safe environment; Emphasis on economic efficiency, including service component of urban environment. The main instrument for implementing these principles is a wide introduction of state-of-the art digital and engineering solutions in municipal and utilities infrastructure.

National Centre of Competence of the Smart City project has been established, which tasks will include development, introduction and popularization of technologies, equipment, programs aimed at increasing the digitalization level of the municipal services, as well as preparing and supporting international cooperation projects on housing policy issues, urban development and natural resources governance, first of all concerning the creation and functioning of smart cities.

Example of Smart Mobility projects

Name of the project	**Smart City Standard (Basic and additional requirements for smart cities)**
Category of the Smart Mobility	Smart traffic lights, the use of navigational systems, increasing the share of public transport in transport operations, increasing the quality of urban transport, system for automated photo-video-recording of traffic violations
Who leads	Ministry of Construction, Housing and Utilities of the Russian Federation, regional and municipal authorities
Who finances	Funded entirely by the federal budget
Objectives	1. To reduce traffic congestion 2. To reduce harmful emissions to the atmosphere and improve air quality 3. To improve accessibility of urban infrastructure for residents
Monitoring mechanism	The IQ City Indices were calculated by the Russian Ministry of Construction in conjunction with Moscow State University, it defines the basic level of digitalization of the urban economy and the effectiveness of the solutions that are implemented by the cities participating in the Smart City project. The methodology was developed, and the index counted from September to December 2019 as part of the national projects "Housing and Urban Environment" and "Digital Economy."

Data sharing and Interoperability

The specialized Smart City portal has been established to provide information on the Smart city projects, relevant regulation and other documents, as well as the solutions, led by the MCHURF in collaboration of the digital services provider PJSC Rostelecom.

Saudi Arabia (including initiatives at both the national and Riyadh City levels)

The Smart Cities Blueprint

The Smart Cities Blueprint , which was published by the Ministry of Municipal & Rural Affairs (MOMRA), in cooperation with the National Digitization Unit (NDU), aims to support the development of five Smart Cities by 2020 (Riyadh, Jeddah, Al-Madina Al Monawara, Makkah, and Dammam), transform eleven cities into Smart Cities by 2030, and ensure that three Saudi cities are ranked among the Top 100 cities in the world by 2030. The Blueprint describes future ambitions, outlines challenges and opportunities, defines

strategic goals and objectives, determines initiatives and KPIs, and summarizes these initiatives in a Smart City Roadmap under the umbrella of Vision 2030 strategy.

KSA regards Smart Cities projects as an opportunity to solve issues caused by urban sprawl. In this context, Smart mobility is one of the main dimensions of the Blueprint. Under the principle of Sustainable, Innovative and Safe Transportation, it includes several crucial components such as intelligent traffic systems, smart parking, and smart public transportation.

Examples of Smart Mobility projects

Name of the project	1. Digital Components Directory Initiative 2. Integrated Traffic Management & Central Control System 3. Smart Ticketing System for public transportation across the Kingdom 4. Riyadh Public Transportation Project (Metro and Bus) 5. Riyadh City's Traffic management and Smart parking 6. Riyadh Mobility Portal 7. Riyadh Transportation Control Center (TCC) 8. Integrated Fare Collection for Riyadh Public Transportation Network 9. Riyadh Bus Automated Vehicle Management (AVM) System 10. WIFI & LTE Services within Riyadh Public Transportation
Who leads	1. Ministry of Municipal & Rural Affairs (MOMRA), in partnership with investment company Amanat 2. Ministry of the Interior together with Transport Ministry 3. Transport General Authority (TGA), working with MOMRA and General Authority for Statistics etc. 4. The Royal Commission for Riyadh City (RCRC) 5. Private Sector 6. RCRC 7. RCRC 8. RCRC 9. RCRC 10. RCRC and the private sector
Who finances	1. Government budget, 2. Build-operate-transfer (BOT), 3. TGA, 4. RCRC 5. RCRC 6. RCRC 7. RCRC 8. RCRC 9. RCRC 10. PPP (Build-Operate-Maintain-Transfer)
Objectives	1. To increase revenue, enhance accessibility to public services, and improve traffic management and safety 2. To improve traffic safety and security, reduce traffic violations and traffic congestion, enhance traffic mobility, and lower the impact on the environment 3. To develop a policy and technology of fares collection systems, which ensure interoperability among the different operating entities and has the potential for increased transit system usage, market penetration, and Improve safety and security of operators and riders by reducing the use of cash and reducing conflict situations. 4. A world class, multi-modal public transport network that will be operated and maintained to high levels of performance and customer satisfaction in order to increase travel opportunities, and thus enhance social life and economic activities in the city. Comprising of 6 metro (Unattended Metro Operation UTO) lines, with total length of (176 Km) and (85) Stations,

	supported by a network of (160 Km) of Bus Rapid Transit (BRT) and (1740 Km) of Community and Feeder Bus networks. The Network will include (25) Park&Ride (P&R) facilities across the suburbs of the city. 5. To improve emergency vehicles response, prioritize bus passage and identify cause of congestion. 6. To increase awareness and enhance accessibility to the Riyadh Metro & Bus Networks by providing world-class journey planning, including public transport information and mapping across Riyadh City with full User Experience integration with smart ticketing, customer care, and traffic management systems. Building on that, the Riyadh aims to develop a fully-integrated "mobility-as-a-service" (MaaS) application that combines public transit and other shared mobility services through a single user-centric interface, allowing users to plan and pay for a journey across the city using multiple modes of transportation. 7. A centralized Transportation Control Centre ("TCC") that will be the primary location for monitoring the whole Riyadh Transportation Network, as well as for coordination between the involved stakeholders (Traffic Management, Bus and Metro operators, emergency services, and facilities management). The TCC will host (among other functions) the Coordination and Crisis Room (CCR). 8. Riyadh public transport passengers will need only one single "Fare Media" whatever the journey they are taking within the network (including multiple modes or lines, and P&R's). 9. All Riyadh buses will be fitted with Automated Vehicle Management (AVM) systems enabling each vehicle to be actively tracked in real time. The AVM systems will hence allow for efficient service delivery, and provide all the essential information required by passengers for their journeys to the single Real Time Passenger Information ("RTPI") system via information screens in all bus stops and stations as well as on board Buses. 10. Riyadh public transport passengers will enjoy a full fledge WIFI & LTE services in all Metro and Bus vehicles and stops and stations.
Monitoring mechanism	1. Periodic reports explaining the stages of implementation of the initiative's plans. 2. N/A 3. There are feedback and monitoring mechanisms. 4. Detailed Key Performance Indicators (KPIs) managed through 5 Operation Control Center and the Riyadh Transportation Control Center (TCC). 5. Detailed Key Performance Indicators (KPIs) managed by Riyadh Transportation Control Center (TCC) with instant reporting. 6. Detailed and step by step user experience validation through market research with Riyadh City public through RCRC defined public transport personas in addition to anonymously monitoring user activities through sophisticated system monitoring tools. 7. Real time and Periodic reports demonstrating the situation of Transportation Network. 8. The Central Compiling House (CCH, level 4) will generate and handle fare revenue reports and statistics regarding ridership. 9. Analyse, synthesize and control information flows of Bus Network in real time; and mobilize internal resources depending on the situation and coordinate staff in the field. 10. Periodic reports on WIFI & LTE coverage and costumer/passenger satisfaction.

South Africa

"Smart Community" Framework

This Smart Community Framework is anchored on how municipalities to become data-driven for efficient and effective service delivery, through the deployment of 4IR technologies such as IoT devices, sensors and other methods. The use of data in a local government context can help to transform the physical space, and develop solutions to tackle some of the most pressing service delivery issues – from provision water to mobility enhancement, from energy consumption and storage to waste management, and from urban design. This includes a governance structure for the implementation and monitoring of the framework.

"The Medium-Term Strategic Framework (MTSF) 2020-2024 refers to "identification of existing towns and cities for refurbishment and transformation into smart cities" as a goal, driven by the Department of Cooperative Governance and Traditional Affairs (DCoGTA). This shapes the framework at a national level, working with provincial and municipal governments, who are responsible for implementation. This is also

coordinated with Digital Policies and those addressing Municipal and Local Government and Transport policies. The Department of Communications and Digital Technologies has developed a national e-Strategy and an e-Government strategy in 2017. The national e-Government roadmap, which was derived from these strategies, has deliverables related to Smart City initiatives.

Smart Mobility component is one of the six focus areas in the framework; others are smart economy, smart environment, smart people, smart living and smart governance.

Example of Smart Mobility projects

Name of the project	1. Rea Vaya in Johannesburg 2. Gautrain in Gauteng 3. MyCiTi in Cape Town
Category of the Smart Mobility	1. Bus Rapid Transit (BRT) system 2. 80-kilometre commuter rail system, which links Johannesburg, Pretoria, Ekurhuleni and OR Tambo International Airport. The service offers a fast, convenient, safe and efficient public transport service. 3. Bus Rapid Transit (BRT) system
Who leads	Local government, overseen by the national department of transport
Who finances	Government with development agencies
Objectives	Affordable & quick access to public transport, less traffic congestion, less carbon emission (fewer vehicles on the road), safer transport.
Monitoring mechanism	Yes

Turkey

The 2020-2023 National Smart Cities Strategy and Action Plan

Turkey's Smart Cities Approach is defined in the 2020-2023 National Smart Cities Strategy and Action Plan. It aims to embrace all the dynamics of Turkey's urbanization processes, led by the Ministry of Environment and Urbanization.

Turkey's Smart Cities Approach has been drawn up with the aim to gain the ability of interoperability by means of bringing an integrated perspective in Smart City policies on a national level, and to ensure that the investments are utilized in the correct projects and activities by the competent and producing Smart City Ecosystem by means of prioritizing the investments that meet the requirements of the designated policies. With an integrated strategy address the needs of the stakeholders, paying regard to the current state by attaching importance to the experiences gained and evaluating the international applications, it is aimed

- To set a mutual vision and a roadmap,
- To monitor and evaluate with a systematic and open governance process,
- To accommodate new conditions,
- To develop Smart City maturity with a common perspective in the cities.

Turkey's 2020-2023 National Smart Cities Strategy and Action Plan will give acceleration to the social, economic and environmental development of Turkey by addressing Smart City transformation needs.

Focusing on “Effective and Sustainable Smart City Governance” and “Competent and Producing Smart City Ecosystem”, this strategy established its vision as “Livable and Sustainable Cities that Add Value to Life”. In line with this vision, 4 strategic goals, 9 objectives and 40 actions have been determined. Primary actions listed below:

- Smart city guidance mechanism will be established.
- Smart city capacity development works will be carried out at national and local levels.
- Smart city maturity assessments will be done.
- Guidance will be provided to municipalities with the intent of preparing a specified strategy and road map according to local dynamics.
- The common terminology of the smart city will be determined and dissemination studies will be carried out.
- NSDI (Turkey National Geographic Information System integration will be carried out by reference architecture works.

2020-2023 National Smart Cities Strategy and Action Plan have been built on a multi-level structure, including national and local layer, in a manner covering the entire Smart City geographic structure of Turkey and country's transformation, by means of taking into account the needs created by different dynamics such as socioeconomic status.

Smart City Maturity Evaluation Model

The establishment of Smart City Maturity Evaluation Model is clearly mentioned in the above plan to compare the maturity levels of the cities and to determine the competencies related to smart city governance and implementations. Primary actions listed below:

1. Smart City Maturity Development Program will be prepared for each city, and financial support will be provided for each program by taking into consideration the current maturity of cities and evaluating Smart City Capabilities prioritized in the national layer. These programs will be aligned with national strategies and policies as well as city-specific strategies.

2. A guidance mechanism will be established and implemented by the Ministry of Environment and Urbanization for Smart Cities.

· Guidelines will be prepared in the areas that will be needed in the Smart Cities field with the priority of Smart City Capabilities identified.

· The prepared guidelines will be made available to all stakeholders from the Smart Cities Information Sharing Platform.

· Training will be organized in order to expand the use of prepared guidelines.

3. Intercity Guidance Mechanism will be established by taking into consideration the maturity of cities. The rules for the guidance and financing to be provided by cities with higher maturity to less mature cities will be determined within the framework of this mechanism. Inspection and assurance activities will be planned in order to secure and evaluate the activities carried out by the Intercity Guidance Mechanism.

4. The Sustainable Smart City Guidance Program will be created with the scope of guidance to be provided for each group by identifying the city groups providing and receiving guidance through the Intercity Guidance Mechanism.

With realizing the same studies in all of Turkey's cities, the maturity model index will be created by comparing the maturity levels of the cities. The measurement method to be used within the scope of the Monitoring Evaluation Model will be the main tool that will enable the partners of the Smart Cities Ecosystem to monitor and evaluate the progress criteria of the Action Plan and the performance indicators of the actions, as well as the statuses of the Action Plan.

Example of Smart Mobility projects

Name of the project	The Institutional Strategic Plan 2020-2024 of City of Izmir
Category of the Smart Mobility	Fully Adaptive Traffic Management Control and Information System
Who leads	Izmir Transportation Center under the leadership of Izmir Metropolitan Municipality
Who finances	Izmir Metropolitan Municipality was supported by the World Bank during the initial installations of the systems. The continuity and operation of the system takes place with the municipal resources.
Objectives	- Reduced time spent by citizens in traffic. - Carbon emission also decreases with less waiting time of vehicles. - Encouraging citizens to use public transportation. - Giving priority to public transportation vehicles in signalization systems. - Reduction of faulty parks with the parking violation system. - Safer traffic environment with red light violation and speed violation systems. - With İZUM Mobile application, all public transportation vehicles can be easily seen by citizens with a single click.
Monitoring mechanism	With hundreds of cameras placed in important transportation points of the city, city traffic can be watched live both from İZUM (Izmir City Dashboard) and on mobile application and internet page.

United Kingdom

Future of Mobility Urban Strategy

Currently the national Smart City program is under development, however, there are several related programs, which ensure all UK citizens gain economic benefit, connectivity and social inclusion by implementing data driven, sustainable, resilient and prosperous, user-focused and flexible objectives. In March 2019, the Future of Mobility Urban Strategy set UK's approach to responding to the uncertainty presented by innovation, ensuring we can take advantage of the wealth of opportunities emerging technologies and trends in transport are presenting, including new jobs, more productive businesses and economic growth across the nation. The strategy established nine Principles for shaping the future of urban mobility to provide a clear signal of what we are seeking to achieve, including ensuring that the benefits of innovation in mobility must be available to all parts of the UK and all segments of society. Departments are also considering how they best support rural areas by developing Future of Transport Rural Strategy.

Example of Smart Mobility projects

Name of the project	Future Transport Zones (FTZs)
Category of the Smart Mobility	New innovative mobility services
Who leads	Department for Transport's Traffic and Technology Division

Who finances	Beyond public budget, some funding from private companies and research bodies. £90 million of funding is a top-up to the Transforming Cities Fund, which was created as part of the National government's autumn budget 2017 with £1.7 billion.
Objectives	The FTZs are designed to demonstrate a range of new mobility services, modes and models, testing transport innovations at scale. They will focus on improving mobility for consumers, evaluating what works, and providing an exportable template to allow successful initiatives to be replicated in other areas. The Zones will be part of an enabling culture for new transport technologies in the UK, attracting inward investment and creating new commercial opportunities.
Monitoring mechanism	Monitoring and evaluation is a central part of the FTZs. The Department has worked with local areas to develop appropriate monitoring and evaluation plans so that they are built into the design of the trials.
Equity and Inclusiveness	Bids for FTZs were asked to explore options for providing mobility credits, or other low-cost options for lower income households. It was up to each area to decide which options would be of most benefit to lower income households in the area and how to target initiatives at this group to maximize benefits. The learning outcomes from the trials of mobility credits will be disseminated to other areas. In addition, the FTZs will include an element of social and behavioral research to identify any barriers to older people accessing more innovative transport, including mobility as a service.

Transforming Cities Fund DfT The Government has announced, as part of the Autumn Budget 2017, the creation of the £1.7bn Transforming Cities Fund ('the Fund'), with the aim of driving up productivity and spread prosperity through investment in public and sustainable transport in some of the largest English city regions. The Fund will be focused on intra-city connectivity, making it quicker and easier for people to get around – and access jobs in – some of England's biggest cities.

United States of America

Connecting and Securing Communities Guide for Federal Agencies

The smart cities and communities activities are a component of the overall U.S. digital economy strategy, which includes pro-growth, innovation-friendly policies that support a thriving digital economy and pave the way for technological innovation. The smart cities and communities work is led by the White House Office of Science and Technology Policy (OSTP) through its National Science and Technology Council (NSTC). Fourteen Federal departments and agencies have participated in this coordinated effort. The US Smart Cities approach favors facilitating local innovation, initiative and action.

NSTC's 2018 Connecting and Securing Communities Guide for Federal Agencies envisions Federal agencies working together and engaging with industry, local leaders, civil society, academia, and other key stakeholders. The aim is to accelerate the development and implementation of new discoveries and innovations that enable cities and communities to achieve their local goals and address their most important challenges. Interagency coordination through the National Science and Technology Council ensures that Federal investments are effectively targeted; States, tribes, and localities are encouraged to self-help; infrastructure investments are well-aligned for sustained and efficient investment; and private sector capabilities are effectively leveraged for success.

The portfolio of smart city and community projects covers a wide range of smart mobility solutions in areas ranging from accessible public transport, to automated vehicles, micro-transit, first/last mile solutions, urban air mobility, farm-to-market logistics, traffic management, and more.

Examples of Smart Mobility projects

Name of the projects	Examples of smart mobility efforts include 1. NASA's Urban Air Mobility program 2. National Science Foundation's Smart and Connected Communities effort 3. Department of Transportation's automated vehicles, 4. Department of Transportation's intelligent transportation systems 5. Federal Air Administration's unmanned aircraft systems programs 6.Department of Energy's Sustainable Transportation program 7. National Institute for Standards and Technology (NIST) 's Global City Teams Challenge (GCTC).
Category of the Smart Mobility	Integrated transport system, Automated vehicles, Unmanned aircraft
Who leads	The White House Office of Science and Technology Policy
Who finances	Funding mechanisms differ by project and include a wide range of public-private partnerships and co-investment models that may involve state and local funds, private sector investments and resources, and/or Federal funds.
Objectives	Transportation is among the nation's critical infrastructures and advances in smart mobility contribute to goals ranging from further enhancing economic growth to expanding job opportunities, providing equitable access, improving the quality of life, promoting sustainability, improving public health, and beyond.
Monitoring mechanism	All Federal initiatives include provisions for monitoring and assessment. Under the President's Management Agenda, which provided for leveraging data as a strategic asset, the Federal Data Strategy leverages the value of federal data for mission, service, and the public good by guiding the Federal Government in practicing ethical governance, conscious design, and a learning culture.

G20 Partner Country Case study | Singapore

Smart Nation Singapore

Singapore's 'Smart Nation' initiative puts emphasis on re-skilling and digital inclusion, to ensure that all segments of the population benefit regardless of age, digital literacy or financial background. The initiative is led by the Smart Nation and Digital Government Group (SNDGG) as a central coordinating role to make sure that the policies across the agencies complement one another for better synergies, and to avoid duplicating efforts.

Strategic National Project (SNP) – Smart Urban Mobility

"Smart Urban Mobility", which leverages data and digital technologies, including artificial intelligence and autonomous vehicles, to enhance public transport is highlighted as one of the three Strategic National Projects (SNPs) - key enablers in Singapore's Smart Nation drive. To meet the challenges faced in Singapore's land transport sector, Singapore's vision is to create a car-light Singapore where people choose to 'Walk, Cycle, and Ride' public transport, taxis, private-hire cars, or shared cars (WCR), and where urban mobility can be achieved in the most resource-efficient manner. Technology and innovation are important enablers that allow Singapore to achieve this vision.

Example of Smart Mobility projects

Name of the projects	Examples of smart mobility efforts include 1. Rail Enterprise Asset Management System (REAMS), 2. Autonomous Vehicles (AV), 3. Common Fleet Management System (CFMS), 4. Smart Traffic Management System, 5. Mobility Assistance for the Visually Impaired and Special Users (MAVIS)
Category of the Smart Mobility	Integrated transport system, Automated vehicles
Who leads	The Land Transport Authority under the Ministry of Transport
Who finances	Funding is provided by both the Government and the industry
Objectives	Smart mobility initiatives help Singapore to overcome some of the inherent constraints, such as limited land area and scarce manpower resources. Singapore can make more efficient use of limited resources and enhance the livability of its environment, through achieving less congestion, cleaner air, and better access to public transport, among others.
Monitoring mechanism	There are mechanisms to monitor the effectiveness of these initiatives.

Data sharing and Interoperability

On the transport front, Singapore has made data easily available to the public by embarking on an Open Data Platform in 2011. This platform is a rich depository of both real-time and static land transport data and can be downloaded by "technopreneurs" and the academia for the co-creation of innovative transport solutions. There has been an increase in the number of transport-related smartphone applications supported by the data since, which have gained traction among commuters in Singapore. There is therefore room for greater community and industry involvement to co-create innovative solutions to common problems and achieve better public outcomes.

G20 Partner Country Case study | Switzerland

Smart City Switzerland

The Swiss Federal Office of Energy (SFOE) introduced Smart City Switzerland programme, which supports towns, cities and municipalities with their planning and implementation of smart initiatives to reduce the consumption of resources and offer a higher quality of life through the use of new technologies, within the framework of SwissEnergy programme. It aims to incorporate all of Switzerland's towns and cities (approximately 170), plus interested smaller municipalities (Smart Village), into the Smart City process by 2025. Through the SwissEnergy programme, the SFOE is currently supporting models of intelligent mobility initiatives in medium-sized municipalities.

Example of Smart Mobility projects

Name of the project	1. Aarau: ASHAMO – Aarau Sharing Model Town 2. Wil (canton of St Gallen): MONAMO Wil – Active, Smart, Shared mobility 3. Martigny: Martigny Smart Mobility
Category of the Smart Mobility	Intelligent mobility system
Who leads	The SFOE, SwissEnergy programme
Who finances	40% of funding by the Federal government, the rest by cities and municipalities with other partners' contributions.
Objectives	1. Avoidance of traffic (for example by promoting mobile working) 2. Shift from motorized individual transport to public transport and human-powered mobility (with the resulting positive effect on energy consumption and reduction of CO2 emissions, as well as the reduction of noise and air pollution) 3. Introduce more efficient use of energy for transport (for example through carpooling / car sharing) 4. Enhance better utilization of public transport capacities
Monitoring mechanism	Indicators for the measurement of success are defined in the various projects.

Data sharing and interoperability

Within the framework of the promotion of multi-modal mobility, the issues of data sharing and data availability are being addressed by the SFOE and the Federal Office of Transport (FOT), but not explicitly in the cited programs and projects. A concept and measures plan for supporting municipalities with Smart City, Smart Village and Smart Region initiatives has been initiated within the scope of the "Digital Switzerland" strategy. A corresponding memo was formulated by the General Secretariat of the Federal Department of the Environment, Transport, Energy and Communications (DETEC).

G20 Partner Country Case study | United Arab Emirates

Smart Dubai initiative

The Emirate of Dubai has launched Smart Dubai Initiative, with a vision of making Dubai the happiest city on earth in 2014. Smart Dubai initiative encompasses a wide spectrum of smart mobility initiatives ranging from smart pedestrian crossings to flying taxis. All the Smart Mobility initiatives in Dubai follow Dubai Universal Code for Accessibility and Inclusiveness. This code allows equity and inclusiveness to form integral parts of mobility services design in Dubai.

Example of Smart Mobility projects

Name of the project	1. Dubai Self-Driving Transport Strategy 2. Taxi e-hailing 'Hala' – Joint Venture project by RTA and Careem (E-hailing private company) 3. "Connected Mobility" – mandatory regulatory monitoring system for e-hailing companies in Dubai 4. "Sky pods in Dubai" – futuristic urban mobility system pilots
Category of the Smart Mobility	Self-driving driving, Integrated Mobility System, e-hailing services
Who leads	The Roads & Transport Authority (RTA) in Dubai
Who finances	RTA is financing these initiatives through public sector funding (e.g. annual budgets) and also through selective public private sector partnerships (PPPs). PPP mechanism has been utilized in targeted smart mobility initiatives such as e-hailing, bike-sharing and sky pods.
Objectives	• Reduction in traffic congestion • Better quality of life for the citizens, residents and visitors • Improved access to public transport • Innovation in futuristic mobility alternatives • Improved air quality • Enhanced sustainability
Monitoring mechanism	RTA has instituted robust monitoring mechanisms to monitor and track the progress of all smart mobility programs and initiatives to ensure timely and effective results upon their delivery. These mechanisms include, but are not limited to, internal Enterprise Programme Management Office (EPMO) policies, Steering Committees' Governance mechanisms for each initiative, and the RTA Board of Executive Directors governance framework. They enable multi-level oversight and high-performance delivery from strategic smart mobility initiatives.

Data sharing and interoperability

The Roads and Transport Authority (RTA) has closely coordinated and collaborated with Smart Dubai Department and its data arm, Dubai Data Establishment, which are responsible for data governance and data related implementations at the city level. RTA has complied with all the stipulations of Dubai Data Law issued in 2015 and its subsequent regulations, standards and policies issued by Dubai Data Establishment which encompass open data, private data, and public sector data sharing. In this context, RTA has taken a leadership role in data provisioning for the transport sector.

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Annex A: G20 Saudi Presidency Survey on Smart Mobility

Background

By 2050, approximately 70% of the global population is expected to live in cities and over the next 40 years, urban populations are forecast to increase by 3bn people. Population growth in cities is placing increased pressure on policymakers to efficiently and effectively deliver public services and operate urban systems. At the same time, social and technological innovation are changing the nature of urban living, as proliferating data and new digital solutions make new forms of service provision and citizens engagement possible. Emerging technologies such as Artificial Intelligence, the Internet of Things, distributed ledger technologies, and the availability of large volumes of high-quality data are already generating applications in mobility, security, healthcare, energy, sanitation, public services, education and skill acquisition, among other areas. However, technologies do not automatically benefit all urban residents, particularly those who are already marginalised. In fact, if not steered through adequate policies, technological innovation may unintentionally deepen the digital divide and other inequalities in cities. A key question is whether investment in smart technologies and digital innovations ultimately contribute to improve the well-being of citizens.

Smart Mobility is an area where a multitude of data and technology solutions are affecting service provision, such as autonomous driving, smart traffic lights, integrated solutions, global positioning systems, among others. Focus on the Smart Mobility use case can serve as a first step to advance multilateral policy discussions aimed at ensuring a common understanding of a human-centric approach to the use of data and technologies in Smart Cities and communities. Unlocking the potential of Smart Mobility – e.g. initiatives or approaches that use digital innovation (including digital-enabled innovation) to improve outcomes – poses opportunities and challenges. Foremost among these are the challenges of technology deployment, data governance and the contribution of smart mobility to fair and inclusive growth.

Survey question to delegates:

1. Is there a national-level Smart Cities and communities policy or strategy in place (or planned)?
    a. If so, which ministry(ies) leads or contributes to this policy?
    b. Does the national level co-ordinate with local and regional governments in the design, implementation and/or monitoring of this policy? If so, how?
    c. Do these policies explicitly reference equity and inclusiveness objectives? In what way?
    d. To what extent are these policies coordinated with other national policies (such as digitalisation policy, urban policy, etc.)?
    e. Do these policies include issues related to rural areas?
    f. Please provide a short description of your national Smart City policy in English (including hyperlinks if available).
2. Are aspects of smart mobility referenced in this policy?
    a. If so, which ones?
3. Can you provide 1-3 examples of smart mobility initiatives in your country?
    a. Who is responsible for leading or managing this initiative?
    b. Who finances these initiatives and how?

c. Is this smart mobility initiative connected to the national smart cities and communities policy (if one is in place)?
d. Has a formal governance structure been defined for these initiatives? If so, please describe.
e. What objectives does this smart mobility initiative intend to achieve? (ex. less congestion, better access to public transport, cleaner air)
f. Do these initiatives explicitly reference equity and inclusiveness objectives?
g. Do these initiatives explicitly define monitoring mechanisms?
h. Do these policies include policies or initiatives related to data sharing and interoperability, including open government data? If so, which ministries or government offices participate in these policies?
i. What are the main challenges that this smart mobility initiative has faced? (ex. co-ordination with the private sector, weak urban planning and policies, financing, lack of access to technology etc).

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