World Smart Cities Outlook 2024

UN-HABITAT

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ACRONYMS

3DP	3D printing technology
AI	Artificial Intelligence
AR	Augmented Reality
ASEAN	Association of Southeast Asian Nations
AST	Active School Travel
CAF	Development Bank of Latin America and the Caribbean
CCTV	Closed-Circuit Television
CNIL	Commission Nationale de l'Informatique et des Libertés
CSIS	Center for Strategic and International Studies
EU	European Union
EV	Electric Vehicle
FWT	Freetown Waste Transformers
GIS	Geographic Information Systems
GPS	Global Positioning System
GSMA	Global System for Mobile Communications
IATP	International Association of Public Transport
ICT	Information Communications Technology
IEA	International Energy Agency
IEC	International Electrotechnical Commission
ILO	International Labor Organization
IRENA	International Renewable Energy Agency
IOM	International Organization for Migration
IoT	Internet-of-Things
ISO	International Organization for Standardization
IT	Information Technology
ITU	International Telecommunication Union
LDC	Least Developed Countries
LEV	Low-Emission Vehicles
LGBTQIA+	Lesbian, Gay, Bisexual, Transgender, Intersex, Queer/questioning, Asexual
MaaS	Mobility-as-a-Service
MR	Mixed Reality
OECD	Organization for Economic Cooperation and Development
PPGIS	Public Participation Geographic Information Systems
SDG	Sustainable Development Goal
SEVIMS	Socio-Economic Vulnerability Information Management System
SGMB	Spatial Group Model Building
STEM	Science, technology, engineering, and mathematics

U4SSC	United for Smart Sustainable Cities
UN	United Nations
UN-DESA	United Nations Department of Economic and Social Affairs
UN-Habitat	United Nations Human Settlements Programme
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations International Children's Emergency Fund
UNITAC	United Nations Innovation Technology Accelerator for Cities
UNITAR	United Nations Institute for Training and Research
US	United States
USD	United States Dollar
UK	United Kingdom
VHR	Very-High-Resolution
VR	Virtual Reality

Foreword

World Smart Cities Outlook 2024

In today's digital urban era, leveraging technology to improve the quality of life for all in our cities and communities is urgent. To do so, we must maximize the benefits for people inclusively, while managing associated risks. This is why, at the second session of the United Nations Habitat Assembly in 2023, 193 countries made a clear request for UN-Habitat to develop **international guidelines on people-centred smart cities**. This mandate reflects the urgent need to ensure that cities are built on principles of inclusivity, sustainability, and the responsible use of technology. To fulfil this task effectively, it is essential that the development of these guidelines is grounded in robust empirical data and real-world evidence from cities around the globe.

The **World Smart City Outlook** is a critical step in this process, offering a comprehensive analysis of the current state of smart city development. It provides essential insights into how cities are navigating the twin transitions of digitalization and urbanization, with a particular focus on the principles of people-centred design. Through in-depth analysis and case studies, the report highlights both the successes and challenges faced by cities as they strive to leverage technology for the benefit of their citizens.

One of the key findings of this report is the persistent **digital divide** that threatens to undermine progress in smart city development. While some cities have advanced rapidly, others, particularly in the Global South, struggle with limited access to digital infrastructure, insufficient technological capacity, and inadequate governance frameworks. The **digital divide** not only exacerbates existing social inequalities but also limits the ability of cities to harness technology in ways that improve public services, promote sustainability, and enhance resilience.

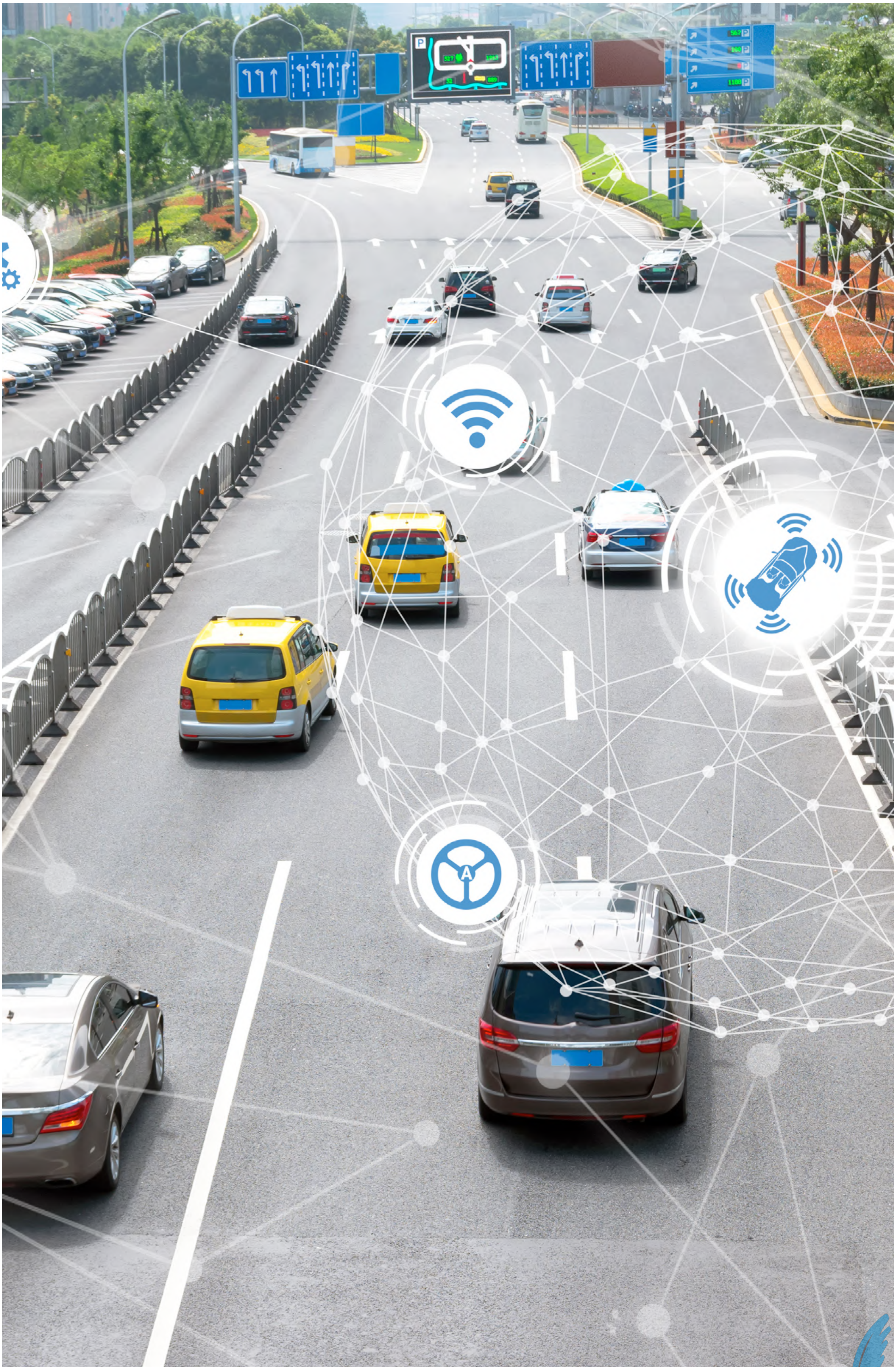
Addressing these disparities is crucial to achieving the vision of people-centred smart cities evenly and globally. **Equitable access** to technology is imperative to ensure that all urban residents—regardless of their socio-economic status—can benefit from digital transformation. This includes investing in infrastructure, promoting cross-sectoral solutions through partnerships and innovative procurement models, enhancing digital literacy, and developing regulatory frameworks that protect human rights and promote transparency.

The report also underscores the need for cities to adopt responsible Artificial Intelligence (AI) practices, highlighting the ethical considerations that come with integrating AI into urban systems. Ensuring that AI technologies are transparent, accountable, and free from bias is essential for building trust among citizens and creating truly inclusive cities.

As we move forward, it is clear that cities must not only embrace technology but do so in ways that are inclusive, sustainable, and resilient. The findings of this report constitute a foundational resource in the development of the international guidelines on people-centred smart cities and UN-Habitat programmatic priorities, providing the empirical evidence needed to create globally applicable frameworks.

UN-Habitat remains committed to guiding cities on this journey, ensuring that the digital transformation is both people-centred and grounded in the realities of urban life today. By fostering innovation, promoting responsible governance, and addressing the digital divide, we can create cities that truly leave no one and no place behind.

Anacláudia Marinheiro Centeno Rossbach
Under-Secretary-General and
Executive Director, UN-Habitat



Executive Summary

In an era marked by two significant transitions, vast urbanization and technological progress, our cities and countries globally are facing complex urban challenges related to inclusivity, sustainability and the responsible use of technologies. People-centred smart cities can help to tackle these challenges by harnessing digital innovation while ensuring that the design and implementation of technologies are driven by the needs of urban communities and by full consideration of their broader societal and environmental impacts.

Nevertheless, the transformative potential of these urban initiatives has yet to be fully leveraged globally, as the practice and maturity level of cities remains uneven within and across the world regions. To promote equitable development on a global scale, the ***World Smart Cities Outlook*** 2024 provides a comprehensive overview of the current state-of-the-art of people-centred smart city practices, drawing on a mix of qualitative and quantitative data. An in-depth review of existing approaches, ongoing challenges and emerging trends is conduced, focusing on six primary areas: ***Strategic Agendas***, ***Policies and Regulations***, ***Public Sector Leadership***, ***Collaborative Ecosystems***, ***Urban Digital Infrastructures***, and ***Smart City Applications for Public Services***.

Drawing on multiple datasets from UN agencies and third parties, the findings of this analysis confirm that municipal governments worldwide are leading people-centred smart city development in collaboration with a wide range of local and non-local actors. The data available indicate that 69% of municipalities have a strategic agenda for smart city development. Digital development or e-government nationwide plans have also been adopted by 69 and 81% of the world's nations, respectively. In 56% of the cities, the implementation and monitoring of these strategies have been led by administrative units specifically tasked with the coordination of smart city projects: an approach that helped to overcome organizational silos within and across public sector departments as well as to build more successful smart city partnerships with non-public actors. However, skills and resource shortages in municipal governments emerged as a major obstacle to effectively exerting leadership over multiple aspects of smart city development, such as the monitoring of projects and their impacts, the engagement of citizens in the design of digital services, and the compliance with national and international regulations.

The resource constraints experienced by worldwide cities are a direct consequence of ongoing austerity policies, although survey data has evidenced that the implementation of smart city projects still relies predominantly on funding from municipal budgets (65% of cases) or national schemes (46%). Conversely, private investors have been reported as a prominent source of funding by only 13% of cities. More broadly, survey data highlighted the reluctance of private enterprises to participate in smart city initiatives, especially in Latin American and African countries, where more than two-thirds of municipalities have experienced such an issue. The rigidity of public procurement processes and regulations emerged from multiple data sources as a major deterrent to the engagement of external partners in local initiatives, as confirmed by 6 out of 10 municipalities.

As to national funding, their relevance has been higher in Asian (51%) cities, compared to municipalities in North America (31%) and Africa (29%). Other data sources, however, evidenced that the involvement of national public organizations can vary significantly across the world regions and the different phases of smart city development. While Asian cities show the lowest level of collaboration between local and national governments, multilevel governance has emerged as a global challenge in multiple aspects of people-centred smart city development, including the regulation of digital infrastructures, the definition of ethical guidelines for digital technologies, and the setting of standards for data sharing. Municipal governments worldwide are addressing existing policy and regulatory gaps by establishing their own guidelines, often leveraging the expertise of universities (identified as contributors to capacity building by 85% of the municipalities) and national or international networks of cities (already joined by 74 and 59% of the municipalities).

Skills gaps, however, are not limited to the public sector but are also observed within the general population, with significant differences within and across the world regions. A 20% digital skills gap in the percentage of the population with basic computer skills also exists between developed and developing countries, and even in high-income countries, specific social groups (such as elderly people and migrants) are less likely to possess digital skills. Furthermore, the availability of Internet services remains heterogeneous across the world regions, especially in Africa, where 4G networks only cover 64% of the population. Overall, it has been estimated that 39% of the world population is not using the Internet, albeit having access to it. This usage gap particularly affects rural areas, where the adoption of Internet services is 1.8 lower. A 5% gap in the use of the Internet also persists between men and women at the global level: a gap that rises to 15 percentage points in low-income countries.

Multiple sources have confirmed that the digital divide significantly compromises the extent to which local communities are capable of contributing to the planning, implementation and monitoring of urban innovation, with 87% of cities reporting that their residents have shown little willingness to participate in smart city projects. Consistently, municipal governments worldwide have been engaging with multiple tools and measures to boost the digital inclusion of their citizens, combining digital skills training (in 59% of cities), free public Wi-Fi (63%), and monetary subsidies (26%).

In this context, the design of inclusive and accessible technologies and applications used in city services also becomes of paramount importance. Nonetheless, the evidence currently available indicates that only 5% of municipal portals globally were compliant with accessibility standards as of 2024. Furthermore, multiple data sources have underlined that local governments are struggling to navigate the privacy and security concerns raised by emerging technologies: concerns that further undermine the acceptance and adoption of digital services among local communities.

This urges for the definition of national and international guidance on critical legal and ethical matters, such as digital human rights, data protection, and the ethical use of technologies. Whereas data protection is now normed in 70% of the world's nations (with a lower incidence among low-income countries and small island developing states), survey data have confirmed that the lack of guidance on digital human rights represents, at least to some extent, a constraint to smart city development for 82% of municipalities. In response to this, across the world regions, local governments have been taking the lead in the policymaking of emerging technologies with 36% of municipalities declaring to have already adopted citywide ethical guidelines for the responsible use of artificial intelligence.

The environmental impact of digital technologies is another area where local governments require further guidance to fully harness the potential of smart city services and digital infrastructures so to curb climate change and make cities more resilient. It is undoubted that innovation can significantly help mitigate the effects of climate change and enhance the environmental sustainability of urban communities by, for instance, promoting the integration of renewable energy in urban spaces and introducing innovative approaches to urban mobility. On the other hand, the proliferation of digital infrastructures and services may also exert additional pressures on environmental ecosystems, because of their high energy consumption, reliance on unsustainable mining practices, and generation of electronic waste, among others. Survey data well exemplify how cities struggle to deal with these contradictions: 89% of cities declared to include environmental objectives in their smart city plans, but only a minority has been effectively monitoring their environmental impacts. The lack of comprehensive policies and regulations, at national and international levels, on crucial environmental issues (such as e-waste and the emissions of digital technologies) further undermines the efforts of municipal governments to tackle climate change and other urban sustainability challenges.

By dissecting the challenges addressed and faced by key actors in the people-centred smart cities landscape, the ***Outlook*** illustrates major shortcomings of existing urban practices and policies, while also identifying promising experimental approaches that are being deployed by local and national governments across the world regions. The findings presented in this report provide both local and national practitioners (either within or outside the public sector) with a diverse range of perspectives to assess their smart city practices and a rich repository of inspiring case studies to inform their future decisions. In addition, a set of recommendations is purposely made to further harness the potential of innovation in urban contexts across seven dimensions:

Inclusion, Equity, and Human Rights

- National governments, in consultation with local authorities and international institutions, should devise and enforce comprehensive policy guidance for the design of inclusive smart city solutions.
- International organizations should establish regulations on human rights and the ethics of technology in cities..
- Municipal governments and their partners should build local capabilities to enhance the monitoring of smart city projects through the collection and analysis of granular, disaggregated data.
- • Ex-ante and ex-post human rights impact assessments should be consistently carried out and enforced by municipal governments and their partners, including developers and private companies, civil society organizations, academic institutions and citizens.

Community Participation and Collaboration

- Municipal governments, in collaboration with representatives of the local civil society, should tailor the citizen engagement's strategies to the local context, leveraging a mix of online and offline tools.
- Municipal governments should establish community partnerships to build a relationship of trust with citizens.
- Local governments and civil society organizations should work with academic institutions to build the capabilities needed to sustain participatory planning processes.
- Municipal governments and their partners should implement communications and feedback processes to ensure that local communities are always kept informed on the progress of smart city initiatives.

Digital Literacy

- National authorities should partner with stakeholders such as local governments and research institutions to establish metrics and processes to rigorously monitor the state of the digital divide in urban contexts.
- Local and national actors should collaborate to devise comprehensive strategies to address ongoing and emerging digital divides.
- Local and national actors should assess the digital

literacy gaps in public administration and create learning programmes to upskill public employees.
- Local and national actors should assess the level of citizens digital literacy and offer incentives and learning opportunities to fill the literacy gaps where more pronounced.
- Local governments should partner with civil society organizations and educational institutions to create dynamic approaches for the capacity-building of local communities.
- Municipal governments and civil society organizations should leverage alternative media to sensitize local communities on the multifaceted impacts of digital services and infrastructures.

Shared Prosperity

- Governments at all levels should work with universities and other research institutions to develop detailed, data-driven assessments of the impacts of digital transformation on urban economies.
- Governments at all levels should lower the barriers for small businesses and startups to participate in public tenders by updating existing procurement regulations and adopting flexible approaches for the public procurement of innovation.
- Municipal governments should create synergies with other local authorities to bridge economic and social gaps by providing access to information, services and markets across neighbouring communities, especially for marginalized groups.
- Local and national governments should formulate a long-term financial plan to sustain both the experimentation and the continuation of smart city projects.
- Local and national policymakers, private companies and academic institutions should lead the experimentation of innovative mechanisms to build trust-based, long-lasting cross-sector partnerships.

Environmental Sustainability

- National and international policymakers should harmonize their environmental regulations to facilitate the embedding of environmental objectives in people-centred smart cities.
- International institutions should work with universities, research institutions and community organizations to refine methods and metrics for the measurement of the environmental impacts of digital infrastructures and services.
- Policymakers at the national and international levels should work with industry players to establish standards for the sustainable design and implementation (e.g. emissions) of digital technologies.
- Municipal governments should include lifecycle impact assessments in the strategic planning of smart city projects.

Governance and Regulations

- Local and national governments should introduce coordination mechanisms for the alignment of local and national smart city agendas.
- Municipal and national administrations should establish structural and procedural arrangements to enhance the multilevel governance of smart city initiatives.
- Municipal governments should be empowered to experiment with innovative practices for the recruitment and exchange of talent from within and outside the public sector.
- Public administrations should leverage change management techniques to build a culture of digital innovation that is people-centred and aligned with public values.

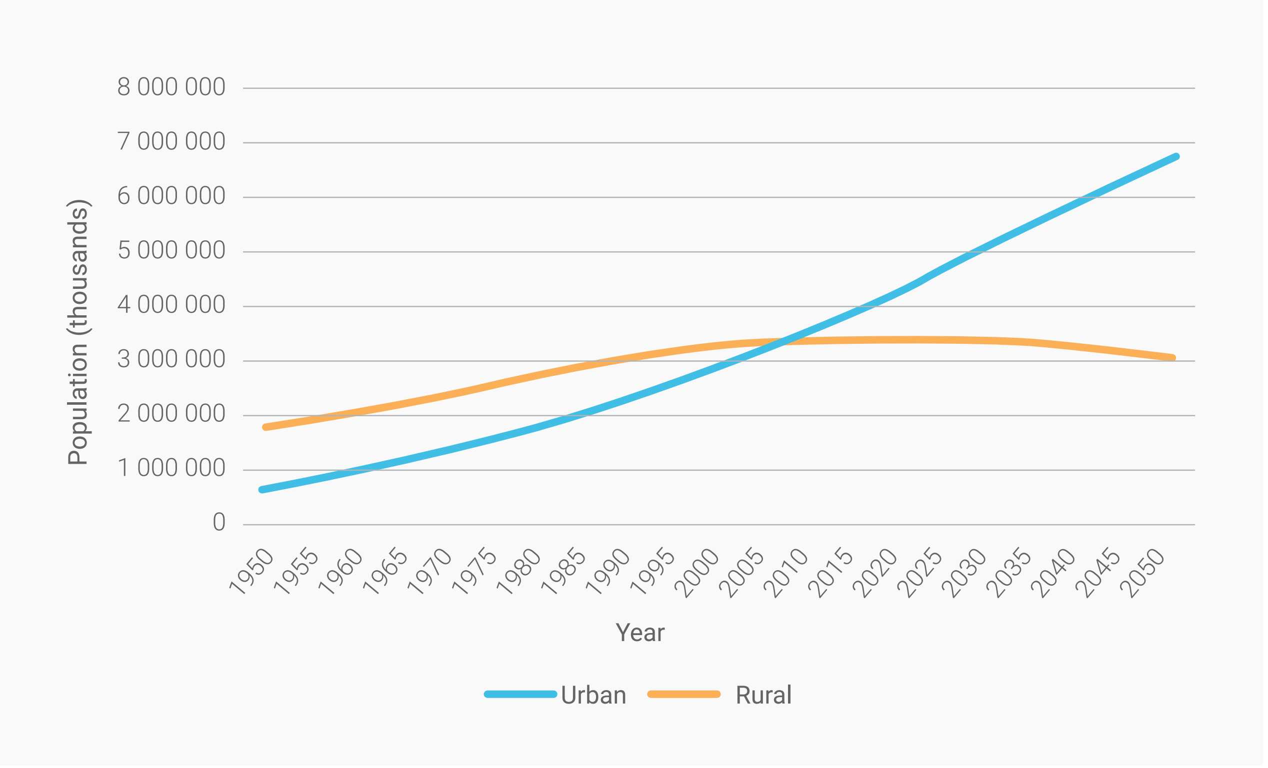
Digital Infrastructure and Smart City Services

- Public oversight over critical infrastructures and essential services should be strengthened through the involvement of local communities and the reinforcement of regulatory authorities.
- Municipal governments should establish ad-hoc programmes to support local entrepreneurial efforts aimed at tackling urban challenges through social and digital innovation.
- National and international policymakers should modernize procurement regulations to incorporate innovative practices for the sourcing of digital services and infrastructures.
- Municipal governments should partner with each other to nurture collaborative partnerships facilitating the co-creation of scalable and adaptable urban innovations.
- Local and national governments should work with private suppliers and research institutions to leverage alternative business models for digital infrastructures and services.

Introduction

Cities have historically played a crucial role in driving innovation, economic development and social change[1], and their influence is only destined to grow, as rapid urbanization continues across the world regions. As of 2023, urban areas hosted 57% of the world's population, but this percentage is predicted to increase to 68% by 2050 (Figure 1). As a result, municipalities worldwide are now confronted with several societal and environmental challenges, including (but not limited to) overcrowding, traffic congestion, pollution, and growing socio-economic inequalities[2,3].

Figure 1: Global urban and rural population (actual from 1950-2018, predicted from 2019-2050).



Source: United Nations Department of Economic and Social Affairs (UN-DESA), 2019

Digital transformation has the potential to address and mitigate these challenges, by enabling the integration of digital technologies into all aspects of urban life[4]. Consequently, cities are among the actors contributing the most to driving the global spending on digital transformation, which reached USD 1.85 trillion in 2022 and is expected to double by 2027[5,6], with the market of smart city technologies forecast to grow even faster, from USD 121 billion to USD 301 billion between 2023 and 2032[7].

Technology alone, however, is not the answer. The integration of digital services and infrastructures in urban areas also raises concerns about their potential impact on human rights and the environment, just to name a few[8]. Consequently, it is of paramount importance to ensure that the digital transformation of cities is shaped and governed by the collaboration of multiple local stakeholders, in alignment with municipal national and international strategies, policies and regulations norming the design and implementation of digital infrastructures and services[9].

In this scenario, people-centred smart cities have emerged as a promising paradigm for harnessing the power of digital innovation in urban contexts[10]. Whereas the smart city concept has attracted criticisms in the past because of its excessive focus on technological innovation with little consideration for its social, environmental and ethical implications[11], people-centred smart cities are committed to putting local communities at the centre and lead of urban digital transformations, conceiving technological progress as a means rather than an end in itself. To fully leverage their transformative potential, however, it is fundamental to explore how the interplay of urbanization and technological progress is unfolding across the different world regions, generating multifaceted impacts on diverse urban communities.

Purpose and structure of the report

This report provided an in-depth, holistic, and up-to-date analysis of people-centred smart city development at the global level. Drawing on a rich dataset of quantitative and qualitative data, it sheds light on both common patterns and diverging trends across the world regions. It both assesses the current state-of-the-art with regards to ongoing challenges to the design, use, implementation, and governance of digital technologies in cities and highlights upcoming trends. By comparing ongoing smart city initiatives, the *Outlook* builds a systematic evaluation of their impacts, strengths, and limitations, ultimately identifying best practices and recommendations to inform future developments.

Following the smart city governance framework outlined in the ***Managing Smart City Governance Playbook*** by the United Nations Human Settlements Programme (UN-Habitat)[12], the analysis is structured into six sections, focusing on complementary thematic areas representing the core pillars of people-centred smart city development:

- **Section 1** illustrates how local and national governments worldwide are defining, implementing, and monitoring ***strategic agendas*** steering the development of people-centred smart cities.
- **Section 2** tracks the global development of ***policies and regulations*** relevant in the context of people-centred smart cities, shedding light on existing regulatory voids and ongoing policymaking efforts to overcome such gaps.
- **Section 3** investigates how the structure, culture, and resources of public sector organizations shape the ***public sector capacity and leadership*** of people-centred smart cities.
- **Section 4** explores global trends in ***smart city collaborative ecosystems***, highlighting enablers and constraints to the collaborative partnerships underpinning people-centred smart cities.
- **Section 5** analyses the global state of ***urban digital infrastructures*** for people-centred smart cities, assessing their socio-economic and environmental outcomes within and beyond urban areas.
- **Section 6** reviews the ***smart city applications for public services*** that are being implemented worldwide, providing comprehensive insights into their benefits, risks, and impacts.

Conclusions and a set of recommendations, addressing the challenges and limitations emerging from the analysis, are outlined at the end of the report.

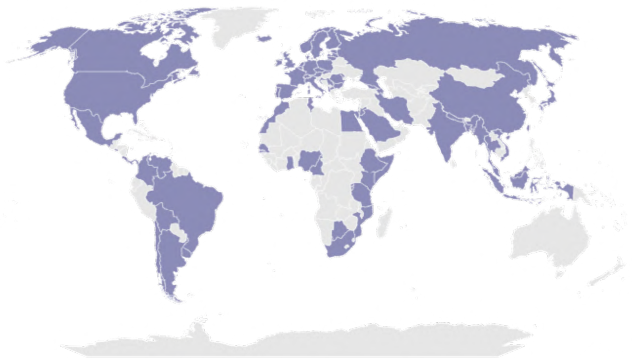
Methodological approach

This report builds on a mix of quantitative and qualitative data, combining both primary and secondary sources. Quantitative data include primary survey data collected through the ***Global Review on Smart City Governance Practices***[13] (hereinafter referred to as "Global Review"), which was launched in 2022 by UN-Habitat, CAF (Development Bank of Latin America and the Caribbean), and Edinburgh Napier University. Additional secondary data have been collected through desk research from international organizations and companies' databases. All quantitative data sources consulted for this ***Outlook*** are listed in Annex 1.

To complement the analysis, one-to-one interviews, a review of the literature and an extensive collection of best practices (through a call for input) provided additional information to the study. 155 interviews were conducted with a series of stakeholders, ranging from smart city leaders, industry, academia, and non-profit organizations representatives. The interviews, covering 54 countries across five continents (as detailed in Annex 2), shed light on the challenges and opportunities that people-centred smart city development poses at the local, national, and international levels. Their insights also helped with the interpretation of global and regional trends. The 48 case studies collected from 32 countries enriched the analysis providing novel evidence of successful approaches and applications for the development of people-centred smart cities. A total of 15 case studies are directly included in the report (see Annex 3).

The collection of primary data (via the Global Review survey, interviews, and call for input) had a global reach, as illustrated in Figure 2. However, certain subregions, such as Central Asia and West and Central Africa, were underrepresented in the sample. This gap was mitigated by incorporating complementary secondary data sources, which provided additional insights and evidence from various countries and regional contexts. It should be noted, though, that a limitation of the analysis lies in the fact that some secondary datasets only provided national-level insights rather than city-level details. Nonetheless, feedback from global and stakeholder groups, consulted by UN-Habitat as part of developing the international guidelines on people-centred smart cities, played a crucial role in reviewing and validating the information collected in this study.

Figure 2: Geographic coverage of primary data collection



(Source: author)

A new era for smart cities: focusing on people

Prior to delving into the assessment of people-centred smart cities, it is worth clarifying the scope and perimeter of this report to develop a common understanding of what people-centred smart city development entails. In anticipation of the development of international guidelines on people-centred smart cities, we refer to the definitions included in the *Resolution adopted by the UN-Habitat Assembly on 9 June 2023*.[14]

In line with the definition adopted by the United for Smart Sustainable Cities (U4SSC), the UN smart city platform coordinated by the Economic Commission for Europe (UNECE), the International Telecommunication Union (ITU) and UN-Habitat[15]:

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

Moreover, building on UN-Habitat's Flagship Program on People-Centred Smart Cities, *"a smart city is 'people-centred' when it uses digital technologies in an ethical, inclusive and sustainable way to make sure that no one is left behind"*[16].

SECTION 1. Strategic agendas

To steer and coordinate the development of people-centred smart cities, local governments have defined strategic agendas to set both the overarching orientations and the implementation plans underpinning smart city initiatives. These agendas should be co-designed with all partners involved in smart city development, to agree upon common objectives and shared priorities.

To fully deliver the vision and mission of people-centred smart cities, municipal governments, and their partners are urged to set a strategic agenda defining both the overarching orientations and the implementation plans steering the development of digital infrastructures and services in alignment with the needs and priorities of urban communities[17]. This agenda serves as a compass for all parties involved in smart city initiatives, articulating the objectives and principles driving their design and implementation, and a roadmap to ensure that these objectives and principles are pursued.

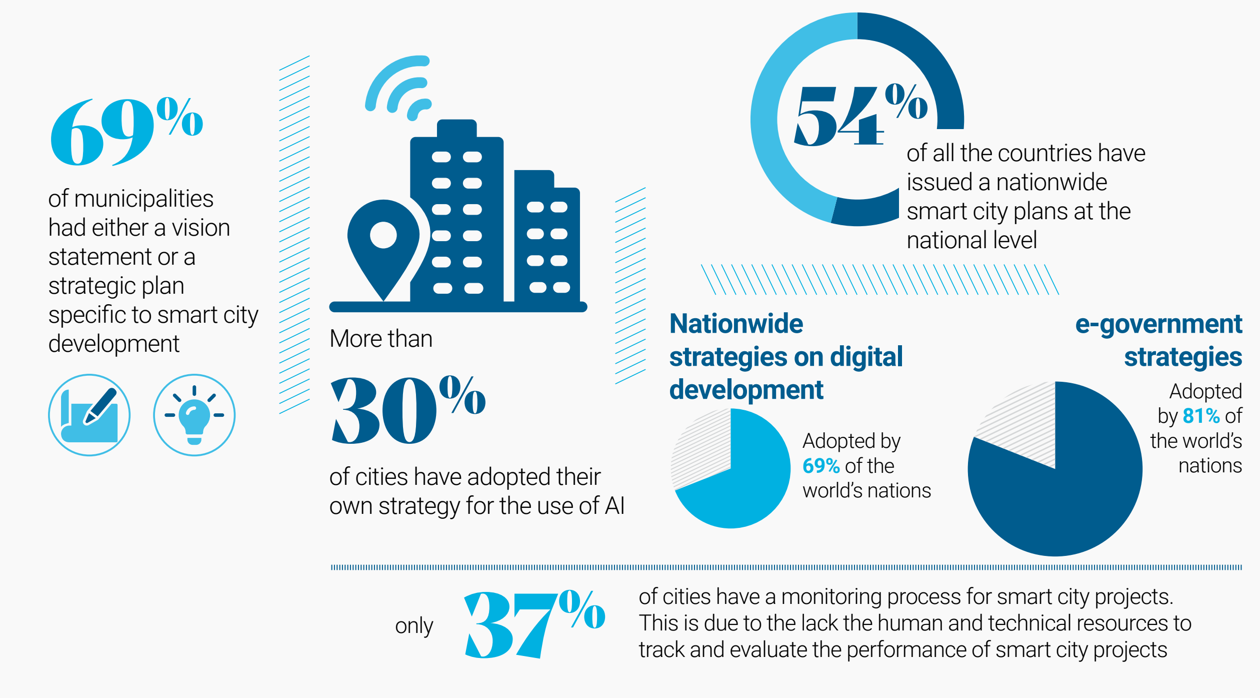
Major challenges

- Multiple strategic agendas of relevance for people-centred smart city development coexist, without being fully integrated and aligned.
- Participatory planning processes struggle to effectively include marginalized groups and vulnerable communities.
- Municipal governments struggle to enforce the monitoring frameworks and indices currently available for the evaluation of smart city projects and policies.
- The environmental impacts of smart city projects are the most difficult to assess compared to social and economic outcomes.

Key priorities

- Develop coordination mechanisms and procedures for the integration of local and national smart city agendas.
- Build local capabilities (within and outside the public sector) to sustain participatory planning processes.
- Develop systematic frameworks for both the ex-ante and the ex-post impact assessments of smart city projects and policies.
- Build local capabilities for the collection and analysis of granular, disaggregated data on the multifaceted impacts of people-centred smart cities.

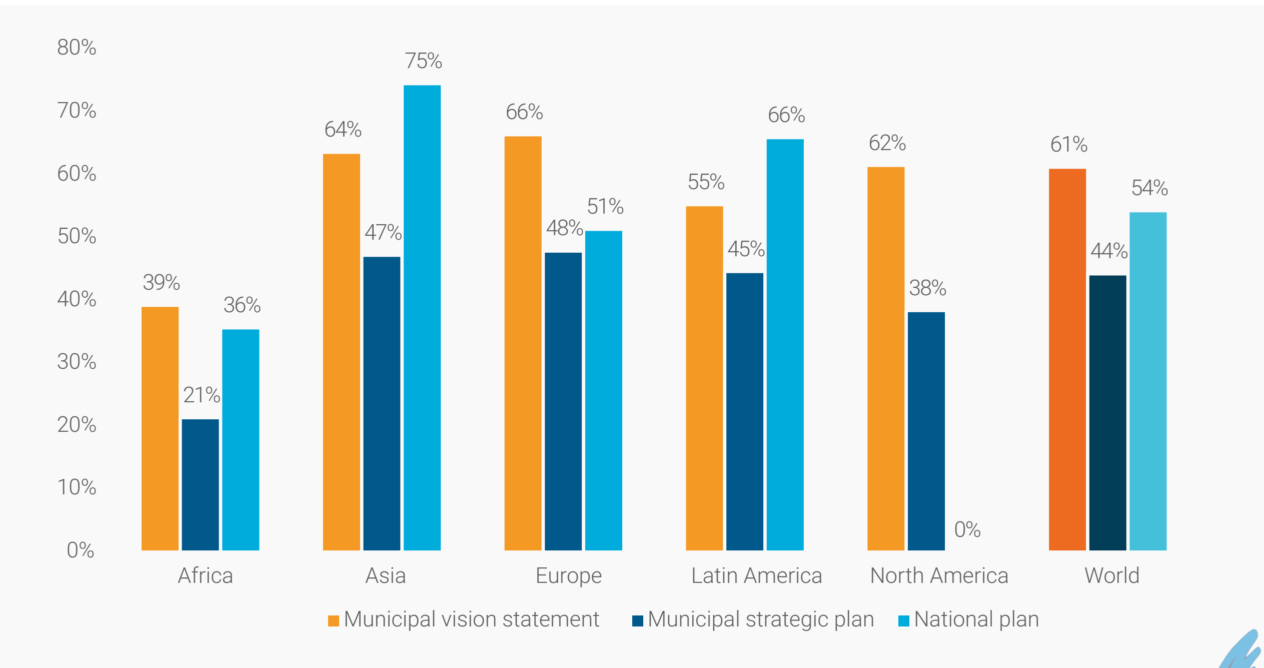
According to the latest data, 69% of municipalities have already adopted either a smart city vision or a smart city plan. Survey results showed that vision statements were the most popular format of strategic agenda, adopted by 61% of the sampled municipalities, as indicated in Figure 3. Strategic plans, instead, were only available in 44% of the cities participating in the study. However, the diffusion of strategic plans was much lower in Africa, where they were adopted by only 21% of the sampled municipalities included in the sample. African municipalities also showed the lowest rate of adoption of vision statements (39%).



Alongside smart city plans and visions, other strategic documents adopted locally may be relevant and influential in the context of people-centred smart cities. The interviews revealed that smart city plans are often an emanation of broader strategic documents setting a vision for the future of the city. Furthermore, municipalities worldwide are increasingly setting plans and objectives for additional strategic areas. For instance, Cocody (Cameroon) has launched a Green City Plan that aims to reduce urban carbon emissions by 70% by 2030[18]. Likewise, the *Global Assessment of Responsible AI in Cities* has revealed about 30% of the municipalities have defined their own AI strategies[19].

At the national level, smart city strategies have been established in 54% of countries covered by the Global Review. The percentage was higher among Asian participants (75%) while nationwide strategies were not reported by any of the North American respondents. ITU and UN-DESA confirmed the same trends in 2022. According to ITU 69% of the countries worldwide have adopted a national strategy for digital development, but the percentage was lower in the Americas (60%)[20]. Likewise, UN-DESA indicated that e-government strategies have been adopted by 64% of North American countries against a global average of 81%[21].

Figure 3: Percentage of municipalities and countries with strategic documents for smart city development



(Source: Global Review, 2022)

The interviewees agreed on the importance of setting a formalized strategic agenda to facilitate smart city development. As remarked by a smart city leader from Bangladesh, without a strategic plan or vision statement, "smart city partners have no common agenda to work together" (Interview 13) and this inevitably affects the levels of engagement and participation of multiple stakeholders, both within and outside the public sector.

Nonetheless, the definition and implementation of strategic agendas remain sometimes an arduous task for municipal governments. Three major challenges emerged from the analysis of primary and secondary data: first, ensuring alignment between national and municipal strategies, second, making the planning processes participatory and truly inclusive, and last, monitoring of execution of implementation plans. Each of these issues is analyzed in detail in the following subsections.

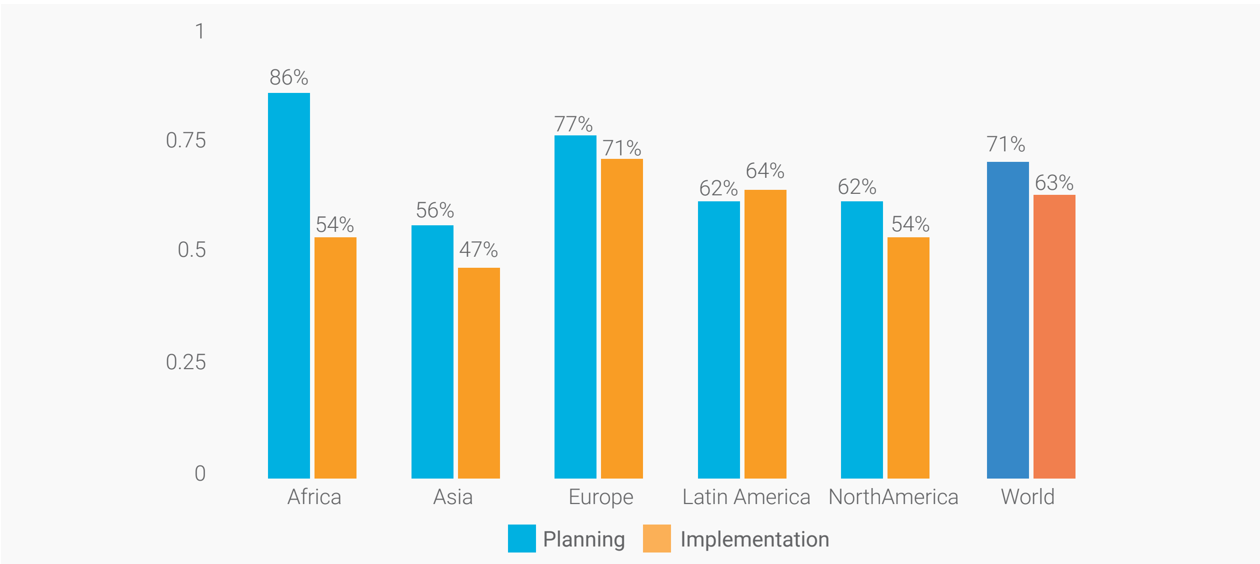
1.1 Aligning national and local strategies

Both the interviews and the literature[22] confirmed that the benefits of having a national strategic reference are manifold. First of all, national strategies can offer valuable guidance on a wide array of topical issues, such as data governance, the use of open-source software, and the achievement of environmental goals, thereby favoring a harmonized and consistent approach to such topics at the local level. Additionally, national policies have been praised for "enabling the development of startup ecosystems supporting the design of technological solutions to be used both locally and globally", as noted by an interviewed expert from Tunisia (Interview 141).

Evidence from the Global Review further suggests that the presence of nationwide policies may contribute to streamlining the collaboration between national and municipal actors involved in smart city development. In fact, the coordination between local and national governments was described as effective by 57% of the participants based in countries with nationwide smart city policies, against 39% of those based in countries without such a national reference. However, despite the evident benefits of combining both nationwide and localized approaches to the strategic-making for people-centred smart cities, it remains unclear the extent to which national and municipal plans are effectively integrated and aligned in the context of people-centred smart cities.

As shown in Figure 4, 71% of the respondents reported collaboration of their local government with national administrations in the planning of smart city initiatives. Such a collaboration emerged as less frequent in Asian (56%), North American (62%) and Latin American (62%) cities, while it was stronger in African countries (86%). National governments have also been described as involved in the implementation of smart city initiatives in 63% of the sampled municipalities, with a lower incidence in Asia (47%).

Figure 4: Percentage of municipalities where national public organizations are involved in the planning and implementation of smart city initiatives



(Source: Global Review, 2022)

The extent to which local authorities have a say in the design of nationwide strategies remains unclear. The interviews rather emphasized the lack of coordination mechanisms and institutional arrangements for the multilevel strategy-making of people-centred smart city strategies. As a result, nationwide smart city plans tend to be top-down and technology-driven, as they focus primarily on the coordinated experimentation and rollout of digital technologies without consideration of the specific needs of diverse local communities[23].

The ***National Urban Policy Program*** of UN-Habitat offers a good example for national governments on how people-centred approaches can be mainstreamed in the core of urban development. Some interviewees also advocated for the adoption of international plans for people-centred smart cities, to facilitate the sharing of best practices and the harmonization of policy interventions across borders. A good practice in this area is represented by the ***Digital Transformation Strategy for Africa***, which included the development of 'technology and innovation cities' among the objectives and actions to boost the digital economy in Africa's Continental Free Trade Area[24].

Overall, whereas additional efforts are required to harmonize and coordinate smart city initiatives at national levels, it must be stressed that the strategic agendas set by national governments should always be seen as a complement to the vision and plans set by municipal governments and their stakeholders. This is crucial to ensure that smart city initiatives remain place-based and people-centred. As highlighted by a German municipal leader, it would be detrimental to have "national smart city programs defined by people that don't know the local context and have never dealt with local politics on a small scale" (Interview 87).

Furthermore, both scholars[25] and policymakers[26] have been endorsing the coordination of smart city plans and initiatives across local authorities belonging to the same province or region. In France, for instance, the ***Direction générale des Entreprises - Ministère de l'Économie*** has promoted "smart territories" as a distinctive model for the digital transformation of French communities[27]. French interviewees explained that their municipalities have adopted joint digital roadmaps with other local authorities belonging to the same metropolitan area or province to coordinate the deployment of critical digital infrastructures and adopt harmonized regulations concerning, for example, transport intermodality and citizens' engagement.

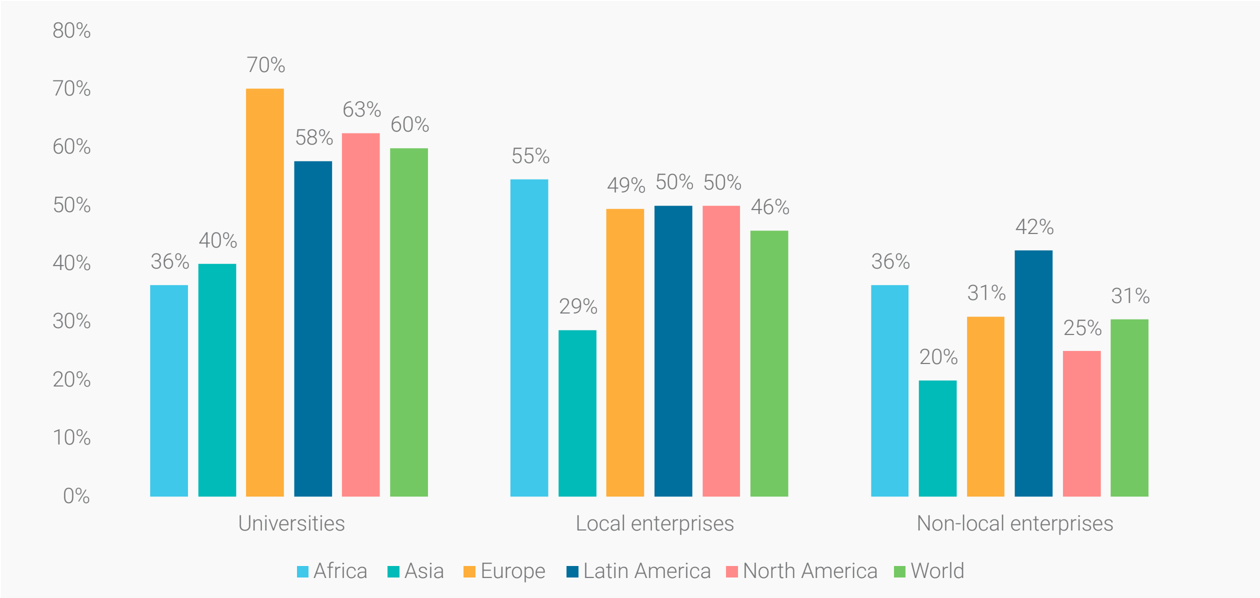
This territorial approach is expected to generate synergies in the implementation of digital technologies but has also the potential to reduce existing digital divides between urban and rural areas by enhancing the inclusivity of smart city initiatives. As remarked by an expert from Mauritius, to be people-centred, "smart city solutions should really benefit everybody, not only immediate residents within a predefined boundary" (Interview 103).

1.2 Participatory planning

Smart city scholars and professionals have agreed that the strategic and operational planning of smart city projects should draw on participatory processes, open to and inclusive of all local stakeholders involved in and affected by smart city development. The Global Review has confirmed that this is already a widespread practice worldwide. Out of 128 municipal governments with a smart city plan, only 14% had not involved any external actor in the definition of their strategy. Similarly, only in 19% of the 177 cities with a smart city vision, this strategic guidance has been set up by the municipal governments without any external contribution. This tendency was more frequently reported by Asian and Latin American respondents.

As shown in Figure 5, universities resulted as the most involved actors in the definition of vision statements for smart city development (being cited by 60% of the respondents), but their participation appeared much lower in African (36%) and Asian (40%) cities. Conversely, the involvement of local and non-local enterprises emerged as higher in African and Latin American countries, respectively.

Figure 5: Participation of different stakeholders in the definition of vision statements for smart city development



(Source: Global Review, 2022)

As to citizens and civil society organizations, their contribution to the setting of smart city visions was confirmed by 43% and 40% of the respondents, respectively. The participation of residents was more significant in North America (63%), while Latin American respondents reported the highest level of engagement for civil society organizations (62%). On the contrary, Asian cities showed lower levels of involvement for these actors (23% for residents and 14% for civil society organizations).

Similar patterns emerged on the definition of smart city plans. Universities were the most frequently involved actors (in 62% of the sampled municipalities), but only 50% of the respondents from Africa and Asia listed them among the contributing actors to the strategy-making of local smart city initiatives. African and North American cities showed the highest levels of involvement for local enterprises (83% and 100%, respectively), against a global average of 52% (and Europe lagging behind the other continents, with only 40% of respondents listing local enterprises among the contributors of smart city strategies). The involvement of non-local enterprises was more homogeneous (on average 37%).

The interviews explained that participatory planning relies on a wide range of tools and mechanisms, similar to those utilized by municipal governments to foster the engagement of local stakeholders in the collaborative ecosystem (see Section 4.3). As an example, field visits and face-to-face interactions with local stakeholders were at the core of the participatory process that led to the definition of a smart island plan for South Malekula, an island of Vanuatu[28]. In Bogota (Colombia), instead, the Mayor's Office leveraged on a virtual assistant, Chatico, to engage more than 140,000 residents in the development of the *District Development Plan 2024-2027*. The user-friendliness and accessibility of Chatico, which can be accessed via any smartphone with WhatsApp contributed to the success of this initiative.

AAnother methodology specifically used in the context of smart city planning is participatory budgeting, which allows local stakeholders to propose projects and initiatives for public budget allocation[29]. According to the ***UN-DESA e-government survey***, 31% of the municipalities have already used this tool[30], According to the UN-DESA e-government survey, 31% of the municipalities have already used this tool[31].

Several sources, however, have questioned the inclusivity of the current methods applied for the participatory planning of smart city initiatives. Many interviewees reported that citizens often do not have time to engage in in-person events or are not confident enough to use digital tools for online participatory activities (as further discussed in Section 4.3). A study focusing on participatory budgeting also questioned its effectiveness in fostering the participation of disabled people and members of ethics minorities[32]. More broadly, the literature has warned against the risk of reducing participatory planning to a formal exercise, with no effective impact on decision-making processes[33]. In this context, as stressed by a smart city leader from the US, it becomes crucial to "close the loop", that is, "to inform the residents at the beginning and then at the end and show them how their feedback was used" (Interview 148) to shape local strategies, their implementation and their revisions.

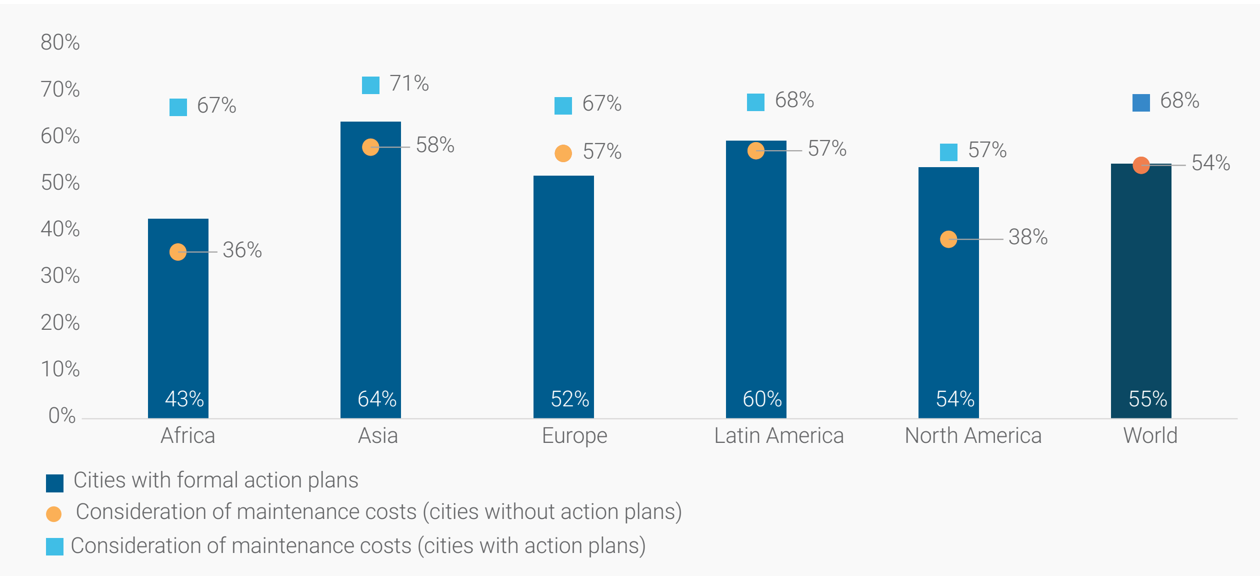
To overcome the limitations of existing approaches to participatory planning, municipalities worldwide are experimenting with novel methods to make participation more appealing to their citizens: these include, for example, citizen science methods, citizen advisory boards, facilitated dialogues, and living labs. Regardless of the tools deployed, local governments should always implement ad-hoc measures to explicitly promote the involvement in strategy-making processes of those groups that are usually excluded, such as migrants and homeless people. As remarked by a German expert, to achieve truly participatory planning, it is fundamental "to integrate all the people that are part of the city, not just the businesses or the civil society" (Interview 75)

1.3 Implementing and monitoring people-centred smart cities

Strategic agendas need to be translated into implementation plans guiding the delivery of smart city projects and ensuring their alignment with the overarching objectives of the city. 55% of the cities partaking in the Global Review declared to have implementation plans in place. As shown in Figure 6, the adoption of formal implementation plans has been more common in Asian municipalities (57%), and less common in African countries (43%). The interviews clarified that these action plans are often structured around thematic areas (e.g., climate change and social inclusion) or sectors (e.g., housing, mobility, and e-government), encompassing multiple projects with their own objectives and roadmaps.

Figure 6 also shows the different extent to which municipalities consider maintenance costs when planning their smart city initiatives. The evidence from the Global Review suggests that cities with a formalized action plan are more likely to properly estimate the maintenance and implementation costs of new technologies: a trend observed globally, although the gap with the cities without formalized plans is broader in Africa and North America. The interviews clarified that these plans could help improve the cost-effectiveness of smart city projects, by ensuring that both upfront and recurring costs are considered when selecting the technological solutions to be implemented.

Figure 6: Percentage of cities with formalized action plans for smart city development and considering maintenance costs in the planning phase



(Source: Global Review, 2022).

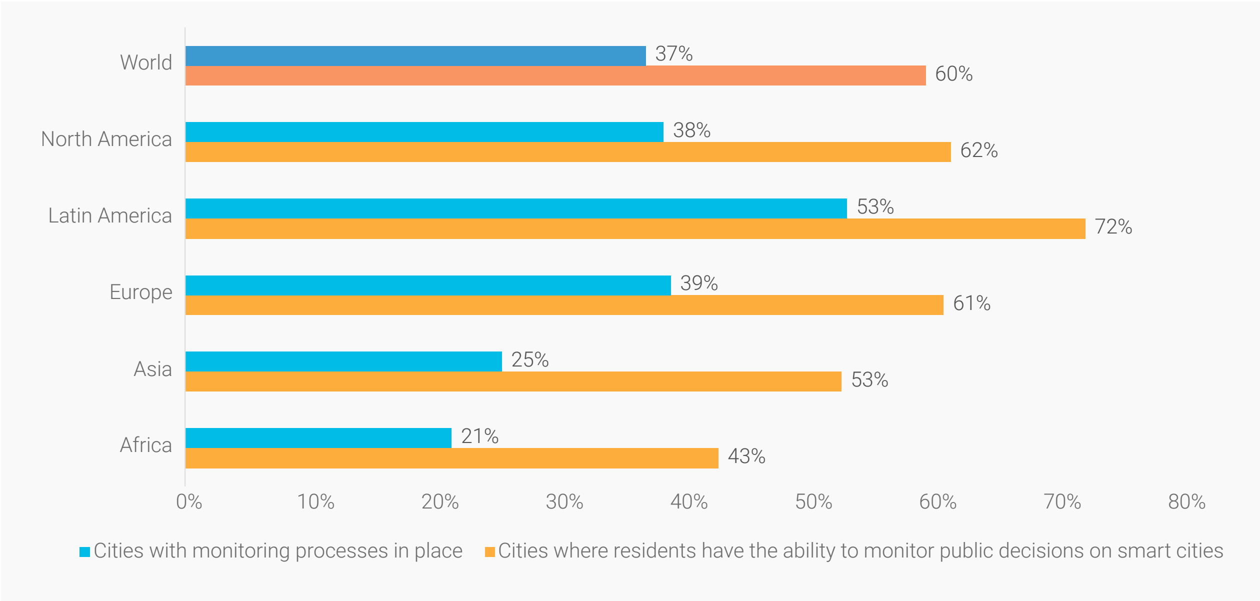
In general, implementation plans should include clear and consistent guidance for the selection of the technologies and applications to be adopted as part of different smart city projects[34]. The interviewees confirmed that this is a common approach, although they also expressed doubts about its effectiveness. On the one hand, the criteria set in the plans may ultimately reinforce technological path dependencies, by prioritizing solutions already in use and existing suppliers within the local administration. On the other hand, private partners may still make most of the decisions regarding the technologies to be implemented in specific projects, as contractual agreements do not necessarily align with the orientations and criteria set in the strategic agendas.

The enforcement of implementation plans is an aspect of people-centred smart city development that deserves further scrutiny to fully understand how municipal governments can best leverage these strategic tools. This also calls for an enhancement of monitoring practices and processes in the context of smart cities, which currently remain underdeveloped. Survey data confirmed that only 37% of cities have been monitoring the overall impact of their smart city initiatives.

As shown in Figure 7, based on the Global Review, Latin America wass the only continent where more than half of the sampled municipalities hada monitoring process in place. Conversely, only 39% of the respondents in Europe and North

America reported that the impact of smart city initiatives is monitored in their municipalities. The percentage was even lower among African and Asian participants (21% and 35%, respectively). Nevertheless, the survey reassured on the ability of local communities to monitor public decisions on smart city development: overall, 62% of the sampled municipalities confirmed to empower local stakeholders to monitor smart city projects , with a higher incidence in Latin America (72%) and a lower incidence in Africa (43%).

Figure 7: Percentage of municipalities monitoring the impact of their smart city initiatives



(Source: Global Review, 2022)

The challenges that monitoring smart city plans and projects entails are well debated in the literature[35], which has identified both methodological and operational shortcomings hampering the ability of municipal governments to assess the outputs and outcomes of their initiatives. This was confirmed by the interviewees, who mentioned the lack of established metrics, systematic indicators, and granular data as major limitations to the evaluation of smart city projects, aggravated by the lack of data analytics skills within the municipal administration. Furthermore, disclosing the outcomes of smart city projects may sometimes be perceived as risky by municipal leaders and elected officials, discouraging the implementation of rigorous monitoring processes.

According to survey data, monitoring processes cover different types of outcomes, with societal impacts being the most commonly assessed by municipalities (94%), followed by economic (86%) and last, environmental impacts (81%). However, great disparities were observed across the world regions, with environmental impacts being tracked in North American and African by only 40% and 50% of the sampled cities, respectively. In both regions municipalities have prioritized the monitoring of social outcomes, which also appeared as the most likely to be monitored in Asian countries (in 93% of cases, versus 71% for economic benefits and 79% for environmental impacts). Latin America and Europe, instead,showed lower levels of variance.

The interviewees further highlighted the risk of overseeing and underestimating the impacts that smart city technologies may have on the environment, thereby urging for the definition of ad-hoc indicators to measure the environmental sustainability and resilience of smart city projects. Indeed, at both national and international levels, public organizations and research institutions have already been developing frameworks and metrics for the assessment of smart city projects: examples include the ***OECD Smart City Measurement Framework***[36], the standard ***ISO37120***[37], and the KPIs set by U4SSC, based on the ITU standard Y.4903[38].

These frameworks and indices, however, have yet to be enforced locally, as several obstacles to their application remain in place. As highlighted by a municipal expert from Slovakia, "very few people know how to implement these tools to the local level" (Interview 123): this is a consequence of the broader skills gaps observed in the public sector (and further discussed in Section 3.2). Additionally, the interviewees reported that, in most cases, municipal governments and their partners lack harmonized methods for data collection and data analytics, and this undermines the consistency, comparability, and meaningfulness of monitoring and reporting processes.

To ensure rigor and transparency in the evaluation of smart city projects and policies, clear roles and responsibilities for monitoring should be established, along with accountability mechanisms for to make detailed and updated information available to the public. In 83% of the municipalities responding to the Global Review , the administrative units coordinating smart city initiatives (hereinafter, "smart city units") is have also been tasked with monitoring and evaluation responsibilities: a trend observed across all the world regions. The literature has agreed that a centralized monitoring prevents the production of fragmented evaluations built on diverse methods and metrics[39]. However, the interviewees highlighted that the effectiveness of this approach largely depends on the extent to which smart city units possess the skills and autonomy required to carry out impartial evaluations. These aspects are further examined in Section 3.1.

Alternatively, in some cases the monitoring of smart city initiatives has relied on the independent scrutiny of third parties, either internal or external to the public sector. An example is the committee purposely established by the national government of Brunei to monitor and assess the development of smart city initiatives across the country. Civil society organizations are another key actor in this domain: for instance, in India, local authorities have worked with Janaagraha, a nationwide grassroots movement, to define bespoke metrics to assess the performance of public infrastructures and services[40].

The academic literature[41] has also suggested that open data platforms could become a powerful tool to enable both internal and external evaluations of smart city initiatives. This is testified by the experience of ***De Olho na Metas***, an online platform that uses data from public organizations in Sao Paulo (Brazil) to help civil society track the progress and performance of urban projects[42]. However, as discussed in Section 5.3, the limited data literacy of local stakeholders inhibits their involvement in monitoring processes relying on open data platforms.

A successful example of citizen-led monitoring is rather represented by *Citizen Eye* and *Secret Shopper*, two smartphone applications developed by Aswan City (Egypt). Through the former residents can submit a complaint and then track and assess the interventions put in place by the municipal administration. The latter enables the users of public services to rate their delivery, providing the local governments with real-time insights into the performance of different units and processes. The experience of Aswan City also proves that the engagement of local communities with these monitoring tools largely depends on their perceived privacy and trustworthiness. These issues are further elaborated on in Sections 2.4 and 3.4.

All the monitoring approaches discussed so far consist of ex-post evaluations of outputs and outcomes of smart city projects. Academic research, however, has underlined that people-centred smart cities could also benefit from systematic ex-ante impact assessments, to preemptively estimate the risks and benefits of technological and infrastructural developments[43]. For instance, Data Protection Impact Assessments have been advocatedas a tool to enhance the fairness and privacy of digital services[44], although they may not be sufficient to boost the equity and inclusivity of smart cities[45]. Human rights impact assessments can also enhance the transparency, accessibility and inclusivity of digital urban projects[46], while environmental impact assessments should be performed to assess the environmental impacts of urban digital infrastructures over their lifecycles[47].

Indeed, recent regulatory decisions, such as the *AI Act*, further endorse the usage of risk assessments in the context of digital transformations (see Section 2.5). Data Protection Impact Assessments are also mandated by the *General Data Protection Regulation* of the European Union (EU). Yet concerns were raised among scholars on the implementation of these regulatory measures at a local scale . The economic and technical feasibility of Data Protection Impact Assessments in smart city projects featuring several data streams has been questioned by a recent study focusing on Flemish cities[48]. Other researchers have emphasized that these tools have the potential to enhance the protection of fundamental rights in smart cities, only if members of the local communities, including the most marginalized ones, are involved and consulted in the process to include their diverse perspectives in the evaluation of data practices[49]. Overall, the evidence available suggests that additional guidance is required to improve the enforcement of ex-ante impact assessments in urban contexts and adjust these overarching evaluative frameworks to the local contingencies of people-centred smart cities.

SECTION 2: Policies and regulations

This section reviews current trends in the policymaking of five areas (digital infrastructures, technical standards, data governance, digital human rights, and environmental sustainability) critical for the development of people-centred smart cities.

Alongside traditional national and municipal initiatives to foster the supply of digital infrastructures, cybersecurity is becoming a key priority for policymakers. Cybersecurity laws have been adopted by 71% of the world's countries, but they have been difficult to enforce according to 23% of the municipal governments.

Likewise, local administrations worldwide are struggling to enforce the technical and data standards purposely established to enhance the interoperability of smart city services. Meanwhile, only 51 countries are mandating the use of open-source technologies (with a higher concentration in Europe and the Americas).

Data protection laws, instead, are more widespread, although 58 countries were still lacking any regulation on this matter, as of 2023. About 35% of the Global Review respondents admitted difficulties in the enforcement of data protection within smart cities, while the interviews stressed the need for additional guidance on data sharing and data governance.

Cities worldwide are also finding it difficult to deal with digital rights and ethics of technology. National and international institutions are increasingly intervening in this domain. Meanwhile, 74 cities across the globe have launched 216 initiatives to enhance the fairness and ethical use of AI.

Finally, new regulations and policies are being established to tackle the environmental impact of digital technologies. Consistently, 89% of the smart city initiatives already included environmental objectives, with a lower incidence in African countries.

Major challenges

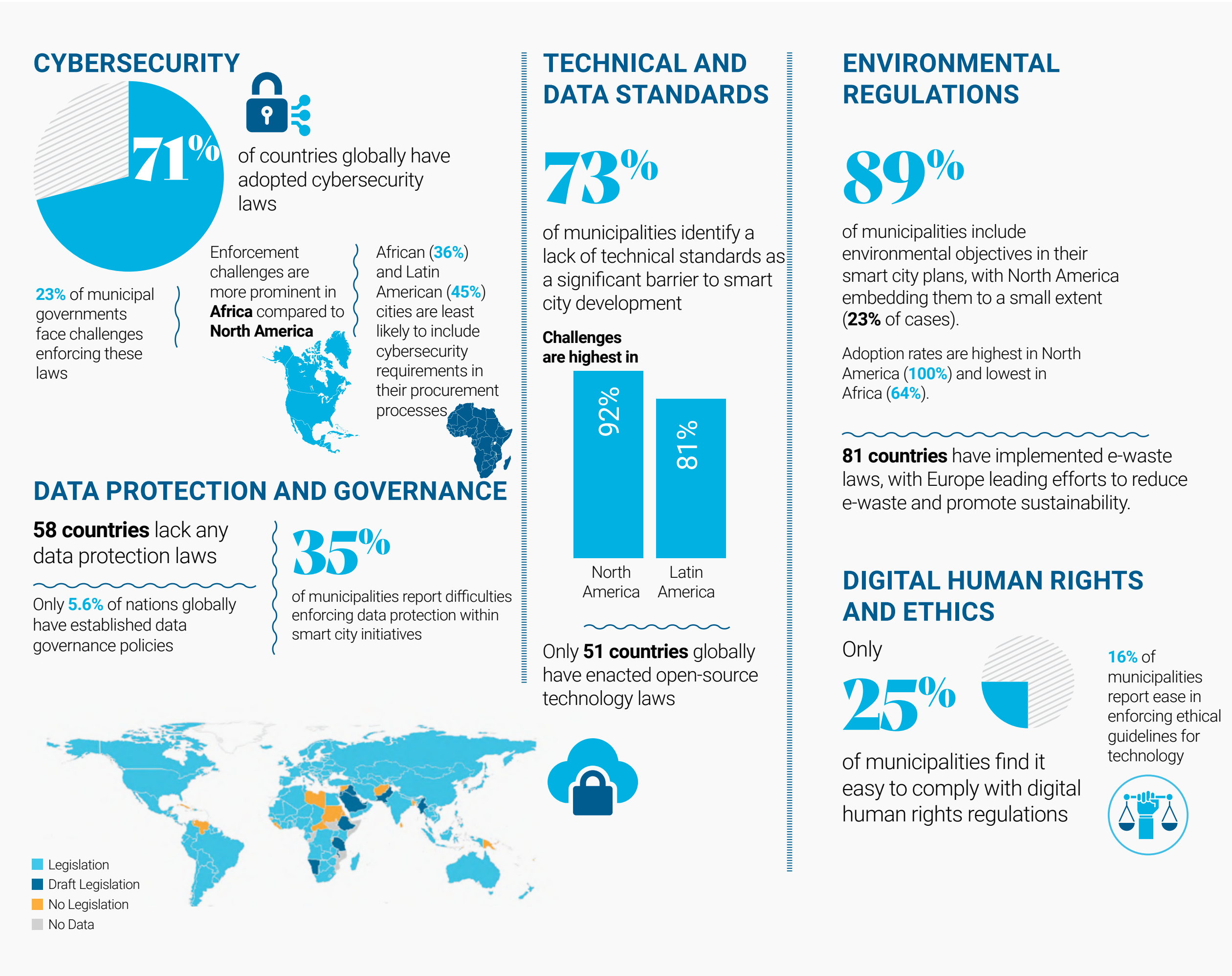
- Local governments lack the skillset and expertise to enforce complex technical regulations and deal with the ethics of technology.
- Limited coordination among regulators and legislators at different administrative levels results in fragmented policy frameworks.
- Local governments and their partners struggle to enforce existing technical and data standards.
- There is a lack of integration between digital and environmental policies.

Key priorities

- Build local capacity, within and outside the public sector, to tackle the ethical and security challenges posed by emerging technologies.
- Reinforce public oversight over critical digital infrastructures.
- Develop national and international guidance on digital human rights and the ethics of technology..
- Develop national and international guidance on digital human rights and the ethics of technology.
- Harmonize environmental and digital regulations to facilitate the embedding of environmental objectives in people-centred smart cities.

People-centred smart cities are place-based and locally driven but are also inevitably affected by policymaking decisions made at the national or international levels. These decisions are becoming even more crucial as emerging technologies potentially pose new societal, ethical, and environmental threats that could offset their benefits, as further discussed in Sections 5 and 6.

This section presents policy-making trends in five critical areas for the development of people-centred smart cities, namely regulations and policies for digital infrastructures, technical and data standards, data protection laws and data governance regulations, digital human rights frameworks, and environmental regulations and policies. For each of these areas, we discuss the effects of existing policy and regulatory intervention (or the lack thereof) on both the development of people-centred smart cities and their impact on urban communities.

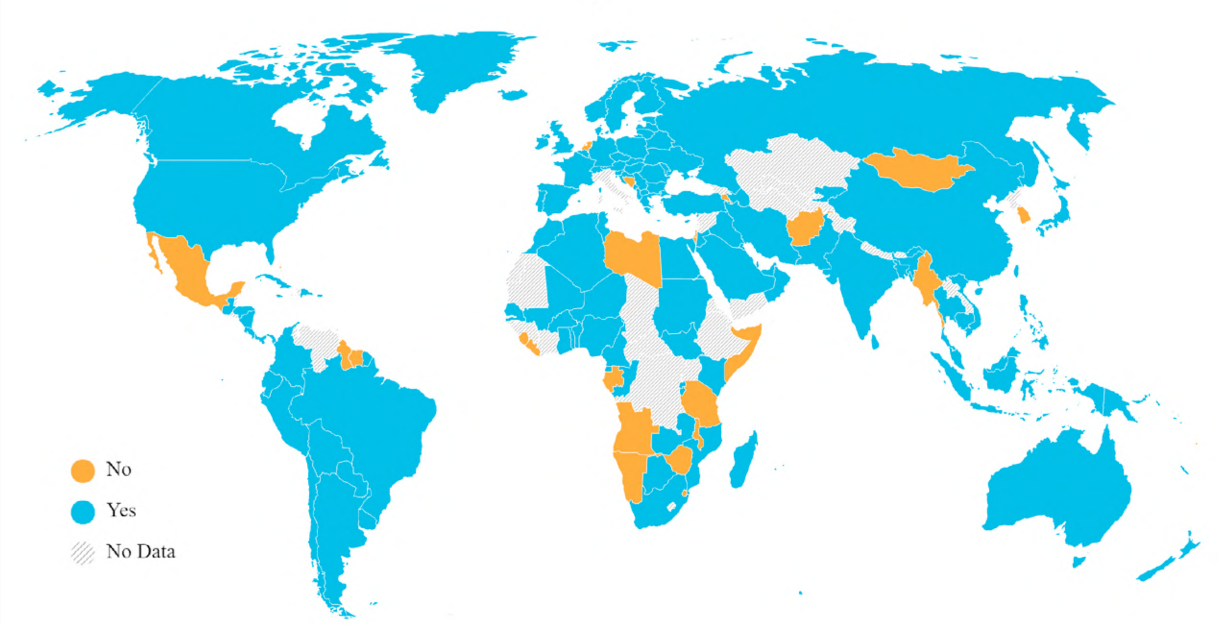


2.1 Regulating urban digital infrastructures

Primary references for the implementation of digital technologies in urban contexts are the policies and regulations adopted nationally or locally to govern digital infrastructures, such as broadband and sensor networks. According to the ITU, by 2020, 66% of the world nations had already adopted national broadband plans (see Figure 8), whose primary goal is to expand the provision of digital infrastructures and to promote the adoption of digital services among the general population[50].

These policies often integrate nationwide Information Communications Technology (ICT) plans, aimed at fostering the digital transformation of traditional sectors through the development of the digital economy: such measures are in place in 70% of countries around the globe, based on the latest data made available by the ITU Data Hub[51].

Figure 8: Countries with a national broadband plan



(Source: ITU Data Hub, 2020).

At the local level, municipal authorities have also promoted the development of digital infrastructures through a variety of policy measures. Local regulations incentivizing the reuse of existing poles or ducts and the coordination of engineering works between utility and broadband providers have been recognized as the most cost-effective remedy to expand the supply of broadband in urban contexts[52]. Across the world regions, there have been several cases of municipal governments directly involved in the supply of broadband through the deployment of networks funded and owned by local utilities or other local entities belonging to the public administration[53]. These initiatives have been praised for expanding the supply of capillary, affordable digital infrastructures in urban areas, thereby contributing to reducing the digital divide[54]. However, they have also been contested for discouraging private investment in digital infrastructures and not being financially sustainable in the long term[55].

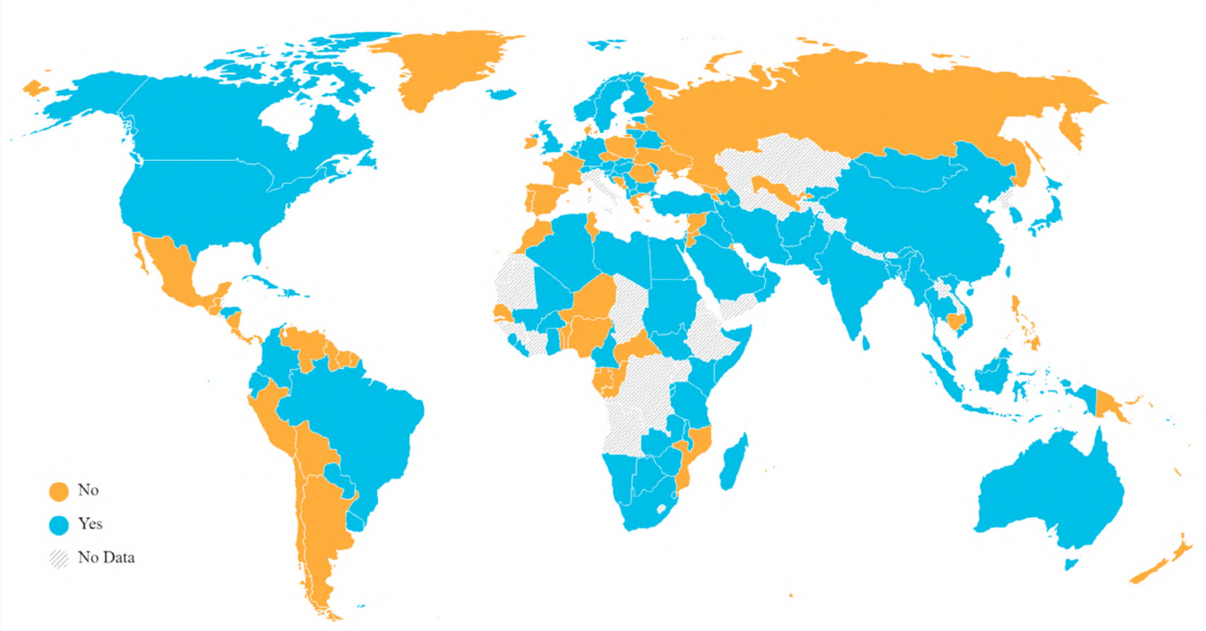
Beyond the specificities of municipal broadband networks, the public control of digital infrastructures has lately returned a central topic in the debate over the regulation of digital transformations[56]. Public control over these facilities is expected to boost their inclusivity and adherence to the needs of local communities, but it is also seen as a way to safeguard democracy and national security, given the strategic role that digital infrastructures have assumed in the political and economic life of all nations[57].

In 2022, 82% of the world's countries had a public independent regulatory authority overseeing digital infrastructures and ICT markets[58]. These authorities have normally been established after the liberalization of the telecommunications sector, safeguarding both market competition and consumers' rights through the enforcement of non-discrimination principles, transparency requirements and cost-control measures[59]. Lately, a push for the re-nationalization of digital infrastructures has been observed, especially in Europe, in the attempt to obtain technological sovereignty and guarantee public control over critical facilities, such as broadband networks and data centers[60].

The benefits of state ownership have, however, been questioned by some activists and academics, seeing it as a potential threat to democracy and freedom of expression[61]. IIndeed, the latest statistics showed that, between 2016 and 2021, Internet shutdowns have been used by the governments of 74 countries to stop protests and censor online speech[62]. CConsequently, both scholars and non-government organizations have advocated for the creation of community-led digital infrastructures, whose ownership and scrutiny remain within local communities[63]. International institutions are also increasingly acknowledging the potential of community-owned networks and platforms to boost digital inclusion and address distortions in digital markets, although raising concerns over their security and sustainability[64].

In general, policymakers at different administrative levels have stressed the issue of digital infrastructures' security for people-centred smart cities (as explained in Section 5). This has resulted into the elaboration of dedicated regulations. Data from ITU[65] showed that, in 2022, 71% of the world countries had enforced cybersecurity laws (see Figure 9) concerning multiple areas, such as cybercrime (in 62% of the cases), child online protection (50%), network security (49%), critical infrastructure protection (48%) and online frauds (45%).

Figure 9: World nations with cybersecurity legislations or regulations



(Source: ITU Data Hub, 2022).

However, the implementation of these laws appears to be still difficult for 38% of African respondents to the Global Review, while North American participants were the most confident with the enforcement of cybersecurity laws and regulations (13%). African (36%) and Latin American (45%) cities also appeared to be the least likely to include specific requirements on cybersecurity as part of their procurement processes, which instead emerged as a common practice in 65% of the sampled cities. When only countries with national cybersecurity laws and regulations are considered, the percentage of cities including cybersecurity requirements in procurement processes surges to 77%, globally, and it also increases significantly in Latin America (59%) and Africa (62%), although both regions still lag behind compared to the rest of the world.

Overall, the evidence available shows that policymaking for digital infrastructures remains heterogeneous worldwide, although a convergence can be observed with regard to cybersecurity policies and the adoption of national broadband plans. A one-size-fits-all approach for the regulation of these infrastructures would be anyway hardly achievable and is not recommendable, given the variability of local contexts, even within the same country. However, providing overarching guidance to local administrators is of paramount importance to harmonize regulatory interventions and facilitate the successful implementation of people-centred smart cities. In the words of a smart city expert from Malaysia, "some projects cannot scale up until we actually resolve the policy and regulatory matters that reside between different public authorities" (Interview 102).

2.2 Technical and data standards

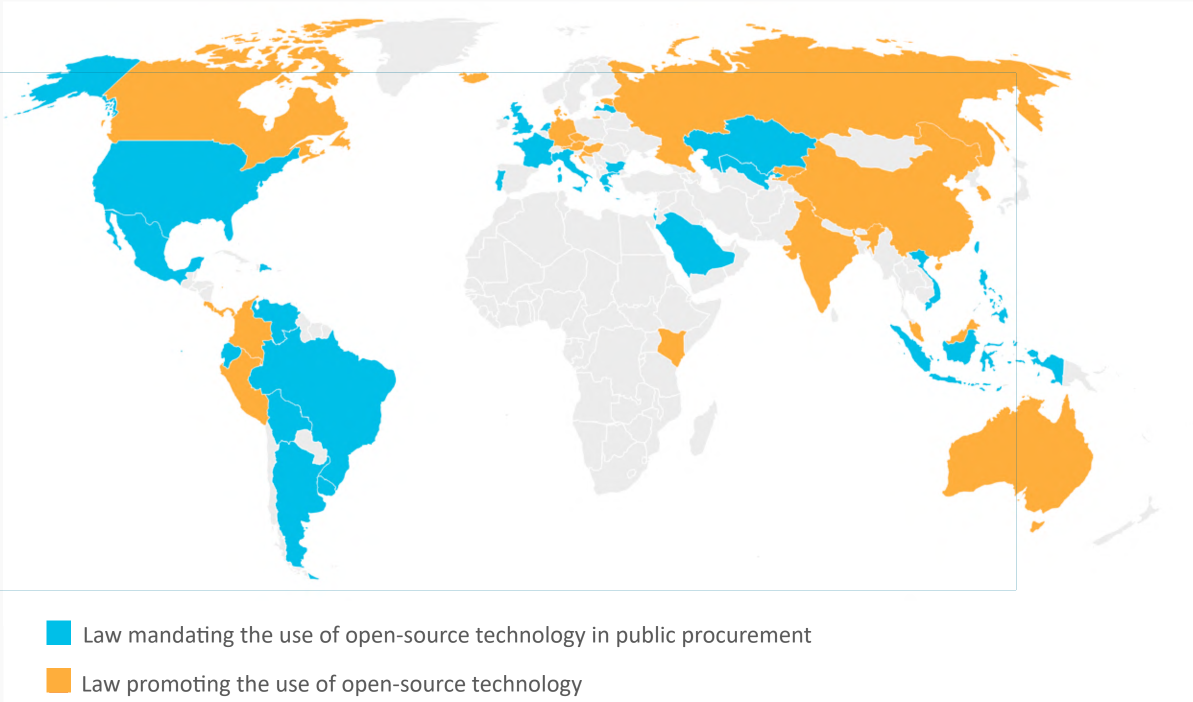
Technical and data standards, defined as formal documents outlining the specifications and operation of agreed technical solutions and data-driven applications, play a critical role in facilitating the deployment of digital infrastructures and services in urban areas. These standards enable technological and data interoperability, reduce the risk of vendor lock-in and help lower the maintenance and operational costs of urban digital services. As of August 2024, the EU Observatory for ICT Standardization listed 22 standards specifically established internationally to norm the design and monitoring of smart city technologies[66]. These included, for example, a comprehensive set of indicators defined by the IEC and ISO to assess the adoption and use of ICT in urban environments[67] (***ISO/IEC 30146:2019***), and the ***Recommendation ITU-T Y.4905***, which provides a holistic impact assessment framework to evaluate the socio-economic and environmental impact of digital innovation in cities[68].

Alongside these global standardization bodies, multiple local, national and international initiatives are promoting technical standards for the interoperability of smart city services and infrastructures. Since 2015, several municipalities across Europe, South America, Asia, and Oceania have joined the Open and Agile Smart Cities (OASC) network, whose mission is to develop technical specifications and practical capabilities for the adoption of minimal interoperability mechanisms[69]. Similarly, standardization organizations from different regions (Japan, China, the EU, the US, Korea, and India) have teamed up to set a global standard for machine-to-machine communications across multiple application domains, including smart cities[70].

Nonetheless, 73% of the Global review espondents indicated the lack of technical standards as a significant barrier to developing people-centred smart city development, especially in regions such as Latin America (81%) and North America (92%). Although existing standards have been beneficial for managing smart city initiatives, only 17% of the sampled municipalities found it easy to enforce technological interoperability, with North America reporting the highest difficulty (77%).

Interviews further clarify that proprietary solutions often impede interoperability, as these solutions are not designed for integration with third-party systems. Indeed, countries with policies and regulations promoting open-source and interoperable technologies are still a minority. According to the ***Government Open-Source Software Policies*** repository curated by the Center for Strategic and International Studies, as of 2022, only 51 nations had enacted laws and regulations on the use of open-source technologies and 38 had made it compulsory to prioritize open-source technologies over proprietary solutions in public procurement. As shown in Figure 10, the adoption of open-source regulations remains uneven across the world regions. In Africa, Kenya stands out as the only country to have adopted such legislation

Figure 10: Countries with laws promoting the use of open-source technologies



(Source: author, using data from Centre for Strategic and International Studies, 2022)

Timeliness and complexity of standardization processes emerged as another major issue from the interviews . Creating global standards is a protracted process and implementing them at national and municipal levels can be even more challenging. According to a smart city expert from Morocco, "the challenge is to find the right alignment between the local genius and international standards for smart cities" (Interview 108). Coordination among various standardization bodies was also cited as a concern, particularly in developing data standards crucial for data sharing and interoperability in people-centred smart cities.

Multiple initiatives have already been launched globally to bridge existing gaps in the standardization of data formats. The Open Data Standards Directory[71] curates a repository of data standards developed by diverse local, national and international institutions in different domains, from real-time transit to road construction and building permits. The Open Geospatial Consortium[72] is devoted to the design of standards for various types of geospatial data. The Open Contracting Partnerships[73] has developed data standards for public procurement in order to facilitate the sharing and transparency of information on public contracts.

Nevertheless, 30% of cities partaking in the Global Review admitted s that no data standards are in use within their smart city initiatives. The incidence was significantly higher among North American participants (62%), while Latin American municipalities emerged as being the most likely (53%) to enforce such standards. The ***Global Assessment of Responsible AI in cities*** provided even more negative figures on the use of data standards, which have reportedly been adopted by only 32% of the municipalities included in their survey.

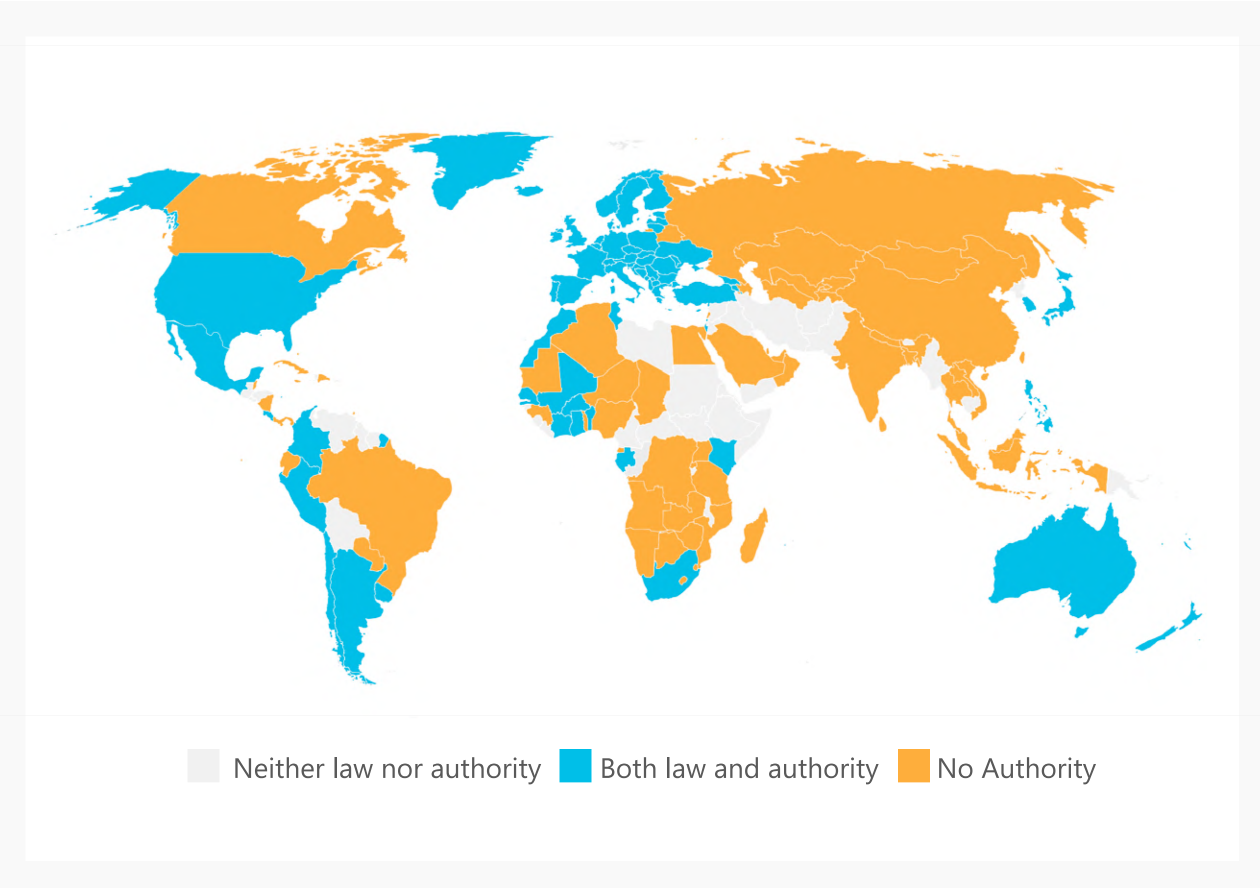
Interviewees emphasized the need for policies that stimulate data sharing and ensure that data collected by different partners in smart city initiatives is interoperable and accessible. They called for the creation of standard templates and protocols to provide a legal and practical framework for data sharing between municipalities and their partners. These efforts should aim to harmonize local practices rather than impose uniform standards globally. As a national expert from the US stated, "we can build international level standards but with some level of alignment around local values and local cultures" (Interview 154).

2.3 Data protection and data governance

As most smart city services rely, at least to some extent, on personal and non-personal data from citizens and public spaces, it has become of paramount importance to ensure that the collection, storage, access and usage of such data are aligned with the principles and rules set by data protection and data governance regulations[74]. The development of these policies is, however, heterogeneous at the global level., as shown in Figure 11.

According to the Commission Nationale de l'Informatique et des Libertés (CNIL)[75], as of 2023, there were still 58 countries without any data protection law: the majority of these were small island developing states (SIDS) in the Caribbean and Oceania, and low-income countries in Africa and Asia. Furthermore, the CNIL dataset evidenced that most African, Asian, and North American countries have approved a data protection law but have yet to establish an independent authority to oversee its implementation.

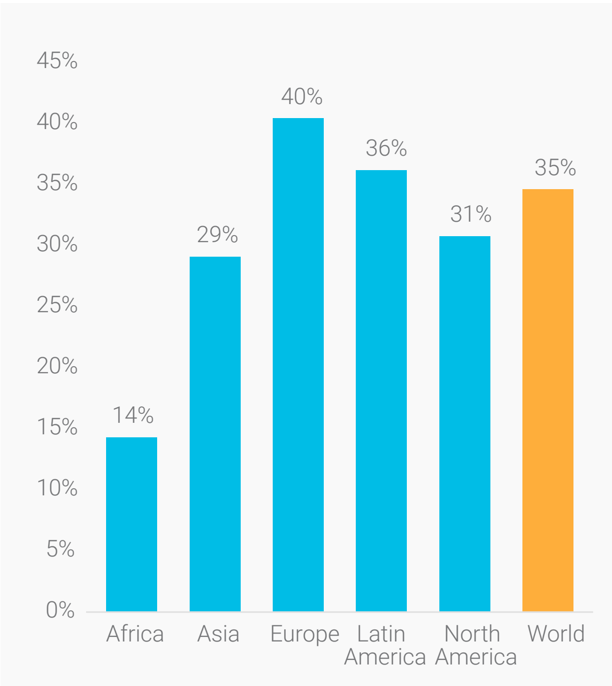
Figure 11: National adoption of data protection laws and authorities



(Source: author, using data from CNIL, 2024)

With regard to the application of data protection laws at municipal levels, the Global Review provided a mixed picture. According to 35% of participants, the application of such regulations did not entail significant challenges, but the percentage of respondents who found it easy to enforce data protection laws dropped to 14% among African cities (as shown in Figure 12). The interviews clarified that the red tape imposed by data protection laws is particularly burdensome for municipal governments, especially when they are understaffed and lack the resources to hire professionals with expertise in this domain. Indeed, the Global Review confirmed that smaller cities, on average, struggle more to comply with data protection laws.

Figure 12: Percentage of municipalities that find it easy to enforce data protection in smart cities



(Source: Global Review, 2022).

Data governance is another crucial policy area for people-centred smart cities that remainSunderdeveloped from a regulatory standpoint. Only recently have national and regional institutions started to address this issue through legislation. The European Commission ***Data Governance Act***[76], approved in 2022, regulate and incentivize the sharing of personal data while safeguarding the rights of data subjects. In the same year, Brazil federal government incorporated specific provisions on data governance as part of its broader strategies for digital transformation[77]. Overall, policy interventions on this matter remain limited worldwide, with only 5.6% of nations having a data governance policy as of 2024, according to the ITU[78].

In the absence of general frameworks for data governance, some municipalities have taken the initiative to establish their own rules. The ***UN-DESA e-government survey*** reported that, as of 2024, 33% of their sampled municipalities had open data policies. Such policies were also in use in 56% of municipalities covered by the Global Review, with a higher incidence in North America and Latin America where they had been adopted by 92% and 66% of the sampled municipalities, respectively. Their presence, instead, appeared more limited in African (39%) and Asian cities (47%).

Despite these global advancements, both the existing literature and the interviews highlighted the urgent need for more comprehensive policy efforts across different administrative levels. Strengthening the enforcement of current regulations and promoting equitable data-sharing practices remain top priorities. Scholars have called on national and international regulators to address emerging challenges requiring additional safeguards, such as the handling and sharing of non-personal data and the governance of data utilized to train and sustain AI-powered systems. Furthermore, interviewees emphasized that national governments should bolster their support to municipal governments, which often face difficulties in enforcing data protection and governance regulations. This could include creating ad-hoc training programs to build the capacity of data professionals within local administrations.

2.4 Human rights and ethical considerations

Besides the technical regulations and standards concerning digital infrastructures and data, the development of people-centred smart cities requires policy and regulatory interventions to promote and safeguard human rights in the digital space. Such interventions have become even more urgent since the advent of new technologies, such as AI and facial recognition, which pose new ethical and societal challenges. In this context, ethics is a useful vehicle to flag and address potential harms and unintended consequences concerning the use of emerging technologies in contexts where regulation is still lacking.

On this matter, the Global Review provided quite a worrying picture, with only 25% and 16% of the respondents declaring it easy to comply with digital human rights and ethics of technology, respectively. No significant differences were observed across the world regions, except for Northern American countries where digital rights and ethics were described as difficult to enforce by 62% and 58% of respondents, respectively. The survey data also evidenced the persistence of legal and regulatory voids in this area, especially in North America and in low-income countries. Likewise, it emerged that, across the world regions, ethics of technology and human rights considerations have yet to be fully integrated into procurement processes, as this is still an emerging policy field.

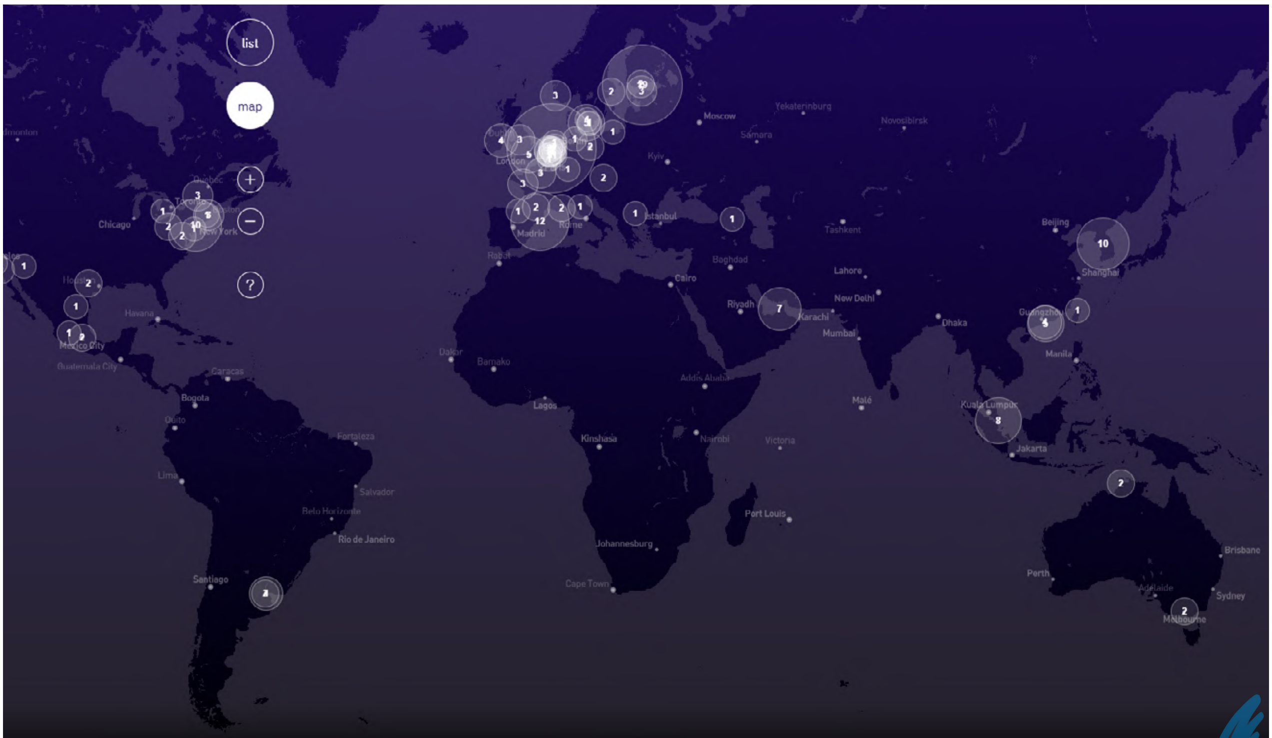
The interviewees lamented the limited awareness of these crucial ethical and legal matters, both within and outside the public administration. Municipal governments as well as local communities were described as often unfamiliar with these concepts and not fully equipped to assess and mitigate the negative impacts of digital technologies on human rights. The lack of clear, coherent policy guidance has made it even more difficult to instruct effective measures and to properly address these issues in the strategies and operational plans underpinning smart city development.

Nonetheless, worldwide we are witnessing a surge of initiatives to reinforce digital human rights and promote an ethical use of digital technologies. These practices are pioneered at both local and national levels, offering a wide range of promising approaches that can be integrated into national or international legislation, as well as translated and adapted to local contexts. For instance, the *Global Assessment of Responsible AI in Cities* reported that 36% of the municipalities included in their sample have defined ethical guidelines for the use of AI.

Privacy is certainly the area where legislators and regulators have been the most proactive, drawing on the data protection laws discussed in Section 2.3. Additional measures have recently been adopted to address privacy concerns associated with the proliferation of sensor networks and surveillance technologies (see Section 5.2). The Office of the High Commissioner for Human Rights (OHCHR) has developed a toolkit to protect human rights in the context of peaceful protests, providing guidance for law enforcement officials on the compliance of digital technologies with human rights legislation and ethical principles. This document explicitly bans the use of facial recognition and biometric identification technologies to track individuals[79]. Likewise, the European Commission ***AI Act*** has identified facial recognition and biometric identification as high-risk AI systems subject to ex-ante fundamental rights impact assessments[80].

Protecting privacy and boosting transparency have also been prioritized by the municipal and national interventions undertaken so far to enhance the fairness and ethical use of AI. As of October 2024, the Atlas of Urban AI[81] counted 216 such initiatives, spread across 74 cities (mostly in Europe, North America, and South-East Asia as shown in Figure 13). Privacy protection was central to 107 of them, while 40 also aimed to enforce fairness and non-discrimination principles. As an example, Vicente López (Argentina) has adopted an ***AI Ethical Principles Declaration*** that sets out a list of guidelines for the implementation of AI in the city, emphasizing the protection of equality and inclusion[82]. In Dubai, a toolkit has been created to guide the development of ethical AI-based applications, identifying fairness, transparency, accountability, and explainability as core principles for the design and implementation of AI systems[83].

Figure 13: Cities that have adopted initiatives to rule the development of AI



Source: Atlas of Urban AI, 2024

Additionally, a growing number of local and national initiatives are attempting to enhance the transparency and explainability of AI systems and algorithms, in order to make these technologies more accountable and respectful of human rights. Algorithmic transparency is at the core of a project coordinated by the Eurocities' Digital Forum Lab and involving seven European cities (Amsterdam, Barcelona, Brussels, Eindhoven, Mannheim, Rotterdam, Sofia): it aims to identify what information municipalities should provide to their citizens to enable their understanding of the usages and purposes of algorithms within the municipal administration[84]. Similar initiatives have been launched by the government of the Netherlands[85], as well as the Asociacion Espanola de la Economia Digital[86].

Finally, increasing regulatory efforts are being directed towards the protection of human rights in online spaces through the enforcement of individual freedoms in cyberspace and the repression of online antisocial behaviors. Holistic legislation and guidelines to govern digital markets[87] and digital services[88] have been adopted by the EU and intergovernmental organizations, such as the United Nations Educational, Scientific and Cultural Organization (UNESCO)[89] and the International Labor Organization (ILO)[90]. Additional measures have been defined to address specific issues affecting the users of digital platforms, including, online speech[91], the transparency of online intermediation services[92], and the proliferation of misinformation[93]. As of 2022, ITU also counted 85 countries with child online protection laws, 105 with specific norms on cybercrime, and 52 regulating online gambling and gaming[94]. These pieces of legislation are of crucial relevance in the context of people-centred smart cities, as they are pivotal to reinforcing participatory democracy and safeguarding the transparency, safety and fairness of online interactions.

Equally important are those policy measures, adopted at different administrative levels, which aim to boost the inclusivity and accessibility of online services. The World Wide Web Consortium is at the forefront of enhancing digital accessibility by developing standards and supporting materials for the design of inclusive technologies[95]. Nonetheless, the ***UN-DESA e-government survey*** revealed that only 5% of city portals included in their sample are aligned with these standards[96]. The need for equality impact assessments in smart cities has also been emphasized by recent research, calling for the application of intersectional perspective and disaggregated data to evaluate the potential impact of digital technologies on different groups of users[97].

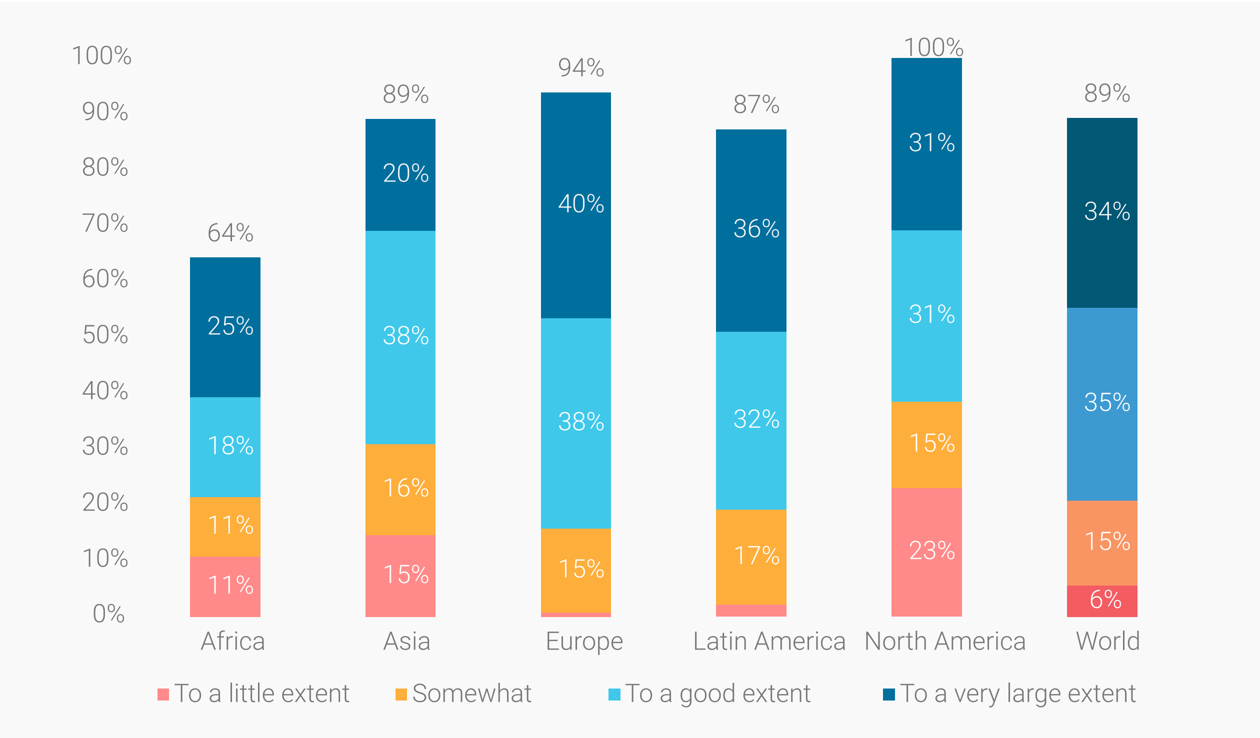
Overall, digital human rights are being tackled from different angles and through a variety of regulatory and policy interventions, but these remain fragmented and fail to provide a coherent, holistic framework applicable to a global scale. Furthermore, the lack of coordination between local, national and international decision-makers risks broadening the gaps already existing within and across countries with regard to the protection of digital rights and ethical use of technology. The interviewees, therefore, urged for the definition of global guidelines to set universal principles, which can be later translated into local contexts and adapted to the local circumstances. To sustain this process, municipal governments can already rely on knowledge-exchange networks, such as the Cities ***Coalition for Digital Rights***, which are playing a pivotal role in supporting the capacity-building of local authorities and favoring the dissemination of best practices in the policymaking of digital human rights.

2.5 Environmental regulations and policies

National and local agendas around smart city development are also influenced by policies and regulations, adopted at different administrative levels, to protect the environment and promote more sustainable modes of production and consumption. Two major trends can be observed worldwide. On the one hand, smart city projects are increasingly conceived and designed as public interventions to mitigate the effects of climate change and minimize the environmental impact of urban activities[98]. On the other hand, policy measures are being adopted to prevent or counteract the potentially detrimental consequences that digital transformation processes may have on the environment, for example, in terms of the production of e-waste, rise in the consumption of power[99] and water[100], and growth of mining and extraction activities[101].

The first trend is well documented in the Global Review, wherein 89% of the respondents declared that, at least to some extent, environmental objectives are already included in the smart city plans of their municipalities. As shown in Figure 14, though, significant differences can be observed within and across the world regions. 100% of the participants from North America reported environmental objectives to be pursued by the smart city initiatives of their municipalities, compared to 64% of the African respondents. At the same time, within North America, in 23% of the cases, environmental objectives were embedded in smart city initiatives only to a small extent. Europe, instead, emerged as the region where smart city strategies are more likely to give high importance to environmental outcomes.

Figure 14: Extent to which municipalities include environmental objectives in their smart city initiatives



(Source: Global Review, 2022)

Multiple sources agree that the integration and fulfillment of environmental objectives within smart city projects are largely driven by the presence of overarching environmental policies setting clear goals and directions in this domain[102]. The interviewees noted that, once climate and environment are embedded as key policy priorities in citywide or national strategies, all parties involved in smart city development also "have to look at how their decisions in the long term will affect the different climate issues and energy use", as remarked by a municipal expert from Estonia (Interview 63). A recent academic study focusing on China has further demonstrated that sustainable urban innovation flourishes in metropolitan areas where environmental policies and digital policies co-exist and complement each other[103].

Indeed, the integration of digital and green policies is an ongoing but slow process. Of the 1,159 initiatives listed in the portal on Science, Technology, and Innovation Policies for Net Zero[104], only 8% were explicitly linked to digital transformation and 1% specifically focused on the implementation of smart cities. These initiatives are mostly taking place in Europe or in ASEAN countries, two regions where the interplay between digital and green transitions has been at the center of recent key policy decisions, such as the ***European Green Deal***[105] and the ***EU-Asean Global Gateway***[106].

Additional guidance from international organizations could ultimately help emerging economies forge new policies and regulations recognizing the strict interplay between green and digital transitions. Global institutions could also contribute to reaching a higher level of harmonization in the regulation of environmental impacts of digital transformation processes, which are currently the objects of national and local interventions with little or no coordination at a international level.

According to the Global E-waste Monitor, as of 2023, 81 countries had implemented laws and regulations on e-waste, but the number of nations adopting such policies every year is reducing[107]. European countries are currently at the forefront of regulating e-waste; an example is the law approved by the French Parliament in 2020 to promote the circular economy,

which also banned the planned obsolescence of technological products[108]. Additional policies have been adopted at the EU level, such as ***the Right-to-repair Directive***[109] and the ***EU-wide scheme for rating the energy performance of data centers***[110]. The former aims to reduce e-waste by obliging manufacturers to provide spare parts and repair information, while the latter identifies a set of sustainability indicators to assess the energy efficiency and climate impact of data centers.

Again, these policy interventions represent important steps forward but may not be sufficient to provide a cohesive approach to assessing and regulating the environmental impact of digital technologies at local, national and international level. This affects also the evaluation of smart city projects, as it emerged from the Global Review, where one-third of the sampled municipalities admitted that the environmental impact of their smart city initiatives is not monitored (see Section 1.3 for further details).

Without a proper monitoring system in place, it proves hard to appraise the contribution of smart city projects to climate change mitigation and other environmental challenges, with the risk of undermining the vision driving people-centred smart cities. Having said so, people-centred smart cities are showing their potential as a means to enact environmental policies and promote sustainable practices. For example, UNECE[111] has noted that more and more local communities and non-governmental organizations are developing their own smartphone applications and digital tools to collect data on environmental issues and use such information to advocate for their right to a clean, healthy and sustainable environment, a principle recently recognized by the United Nations General Assembly[112].

SECTION 3: Public sector capacity and leadership

Worldwide, municipal governments are orchestrating the development of people-centred smart cities in collaboration with numerous local and non-local partners. To strengthen their leadership, they have often established dedicated entities (hereinafter, smart city units) to oversee and coordinate smart city projects. According to the Global Review, smart city units were in place in 56% of the sampled cities (with a lower incidence in Africa and Asia).

Scholars and practitioners generally agree that these units are pivotal to overcoming organizational silos within the public sector and boosting the implementation of smart city projects, by streamlining the coordination among multiple partners. Nonetheless, their effectiveness may be undermined by broader resource constraints in the municipal administration.

Across the world regions, city budgets and national funding remain the primary sources of funding for smart city projects. Attracting private investment has proved difficult so far, potentially due to a lack of sustainable business models for smart city services, as emerged from the interviews. Public organizations also face digital skill gaps, as highlighted by 70% of the respondents to a global survey from Deloitte. In this context, the contribution of academic institutions is crucial to support the capability-building efforts of local administrations..

Organizational culture is equally important to reinforce public sector leadership in urban projects. 42% of the Chief Information Officers responding to a survey from Gartner identified resistance to change as a primary barrier to the implementation of digital solutions in the public sector. Alongside multiple initiatives to nurture a culture of innovation among public employees, the entrepreneurial mindset of political leaders emerged from the interviews as a major driver of cultural change within the local administration.

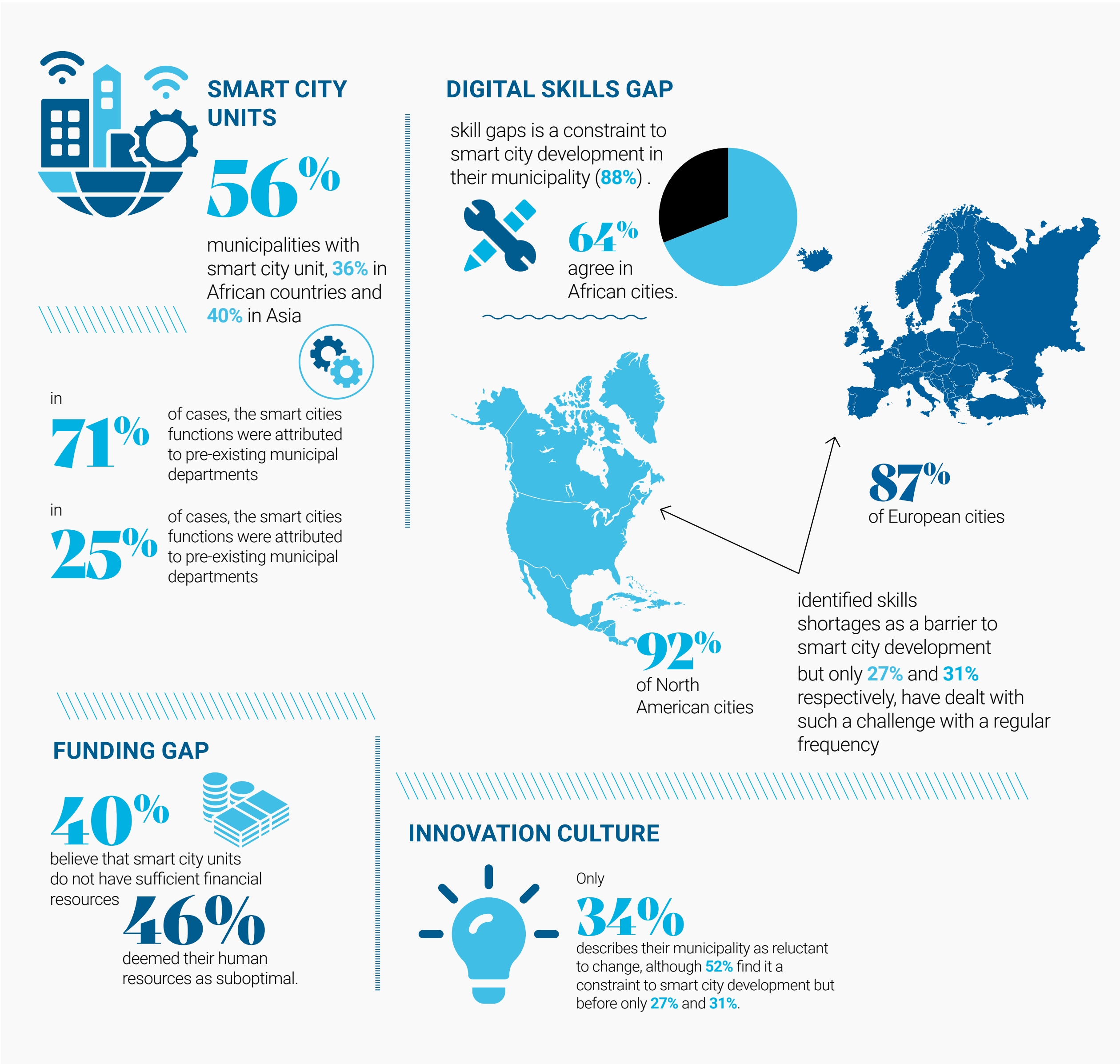
Major challenges

- Skills shortages in the public sector remain a global issue and are destined to grow, as emerging technologies pose new technical, ethical, and societal challenges.
- Budget constraints in the public sector and the lack of sustainable business models undermine the economic feasibility of smart city projects.
- Resistance to change discourages public organizations from embracing a culture of innovation.

Key priorities

- Partner with educational institutions to develop ad-hoc curricula and lifelong training for public employees.
- Promote inclusive education programs to increase diversity within public employment.
- Develop new funding programs and fiscal policies to sustain smart city projects in the long term.
- Build a culture of digital innovation that is people-centred and aligned with public values.

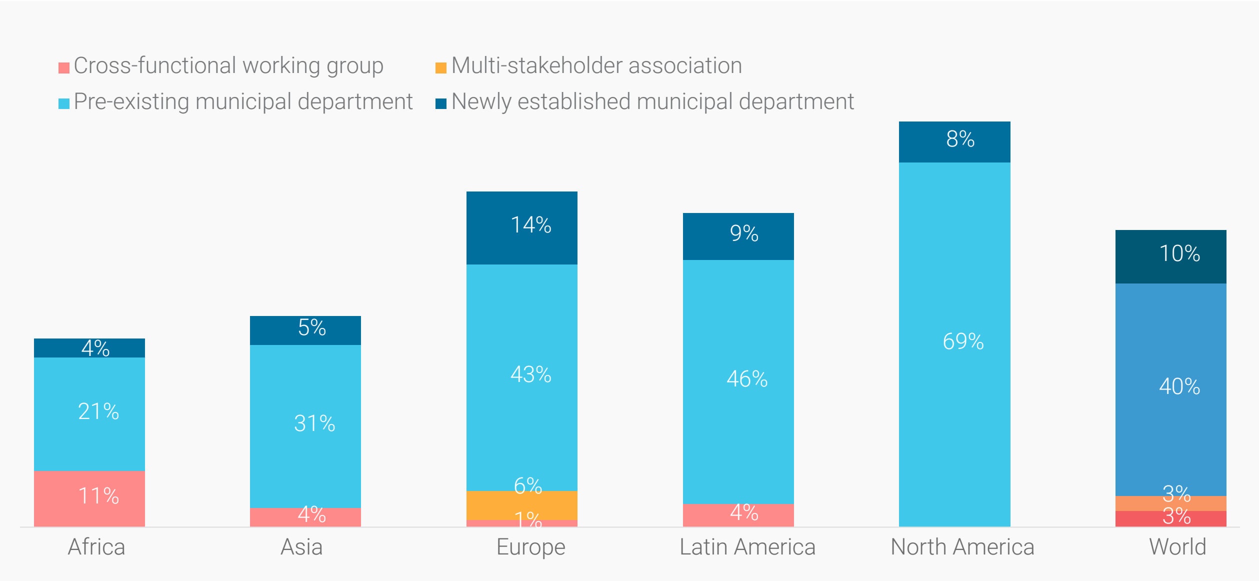
There is widespread agreement, among researchers and practitioners, that the development of people-centred smart cities should be led by municipal governments, acting as orchestrators of the collaborative ecosystems (see Section 4) in which smart city services and infrastructures are designed and implemented[113]. To successfully exert their leadership, however, municipal governments are required to adapt and renovate their internal organization, with a focus on their structure, capabilities, financial resources, and culture. The following sections discuss how each of these four dimensions is affecting people-centred smart city development at the global level, and how they are being tackled both locally and nationally.



3.1 Administrative structures and processes

To effectively govern smart city transitions, municipal governments worldwide have renovated their structures and processes to become more agile, efficient, and effective in the governance of urban innovation. This has usually entailed the establishment of dedicated entities in charge of coordinating and supervising smart city projects across multiple stakeholders and application areas, in close collaboration with existing (digital) policy departments. 56% of the participants in the Global Review declared that their municipality already had such an entity (often referred to as 'smart city unit'), although the percentage dropped to 36% in African countries and 40% among Asian respondents, as shown in Figure 15.

Figure 15: Percentage of cities with a smart city unit



(Source: Global Review, 2022)

In 71% of cases, the functions of the smart city unit have been assigned to a pre-existing municipal department or agency, a trend observed across the world regions with no significant differences. The interviews further clarified that the Information Technology (IT) and Urban Planning departments are the most likely to be tasked with this role.

Alternatively, 25% reported that, in their municipality, the functions of the smart city unit have been assigned to a new organizational entity still belonging to the local administration. These entities have taken the form of either cross-functional teams (6%) or purposely established municipal departments (19%). As shown in Figure 15, the former became more common in African cities. For instance, interviewees from Kumasi (Ghana) and Durban (South Africa) reported that in their metropolitan areas, the coordination of smart city projects is the responsibility of working groups including managers and officers from different municipal departments. Conversely, the establishment of new departments acting as smart city units emerged as a more widespread practice in European municipalities it is the case, for example, of Sofia (Bulgaria) where smart city projects are under the remit of a new municipal structure specifically created to oversee and manage digital transition processes. Some European cities, such as Porto (Portugal) and Genova (Italy), have followed a third approach, which consists of delegating the coordination of smart city projects to a multi-stakeholder association formed by the municipal government, and multiple partners from the private sector, academia and the civil society.

A crucial aspect to be considered in the configuration of smart city units is who these organizational entities respond to. From the interviews, it emerged that they are usually under the remit of apical managerial positions within the municipal government (for example, the Chief Executive Officer or the Chief Innovation Officer, as observed in many US cities) or even to the mayor or deputy mayor (as in the case of Bogota, Colombia, and Gdynia, Poland). In line with previous studies[114], interviewees have agreed that establishing a direct and strict connection between the smart city unit and the leading figures within the municipal government is vital to building political consensus around people-centred smart cities and ensuring their successful development over time. In the words of a municipal expert from Portugal, "when you have municipal leaders that understand innovation, it is easier to make things happen because this creates the conditions so that all the municipality departments and all the municipal entities work together to reach better results" (Interview 94).

Overall, the qualitative and quantitative data underpinning this study have evidenced the variety of configurations, functions and responsibilities that smart city units may assume, even within the same country. This variance largely reflects either local circumstances (such as the human and financial resources available within the municipal government, and the vision of smart city development shared by local stakeholders) or path dependencies in public administrations (for instance, pre-existing distributions of powers among municipal departments, or long-standing governance arrangements in place between municipal, regional and national governments). Therefore, prescribing a specific approach for structuring and governing these coordinating entities would probably backfire, as smart city units inevitably need to be tailored to the specific needs, objectives and contexts shaping the development of people-centred smart cities.

Nonetheless, data confirms that establishing a smart city unit is fundamental to ensure accountability, coordination, and ultimately improve the orchestration and oversight of smart city projects. In addition to the positive experiences reported in the literature[115] and discussed by our interviewees, the Global Review has confirmed that the municipalities with a smart city unit clearly show higher levels of cooperation. Within the sample, the coordination among different municipal units was described as effective by 77% of the respondents whose municipality has set up a smart city unit, with no significant differences across the world regions. This percentage, instead, dropped to 56% of the municipalities without such an entity. Likewise, the active participation of municipal departments in smart city projects was 15% lower in the local authorities without a smart city unit. It must be noted, though, that these discrepancies were more significant in some regions than others. Among African and North American respondents, the levels of participation and coordination were more than twice as high in the presence of smart city units, while the contrast was less wide in the other regions.

At the same time, many cities expressed concerns about the resources available to their smart city units: 40% of them indicated that these entities did not have sufficient financial resources, while 46% also deemed their human resources as suboptimal. North American participants expressed the most pessimistic views, while Asian respondents appeared less concerned about the resources available to the smart city units of their municipality.

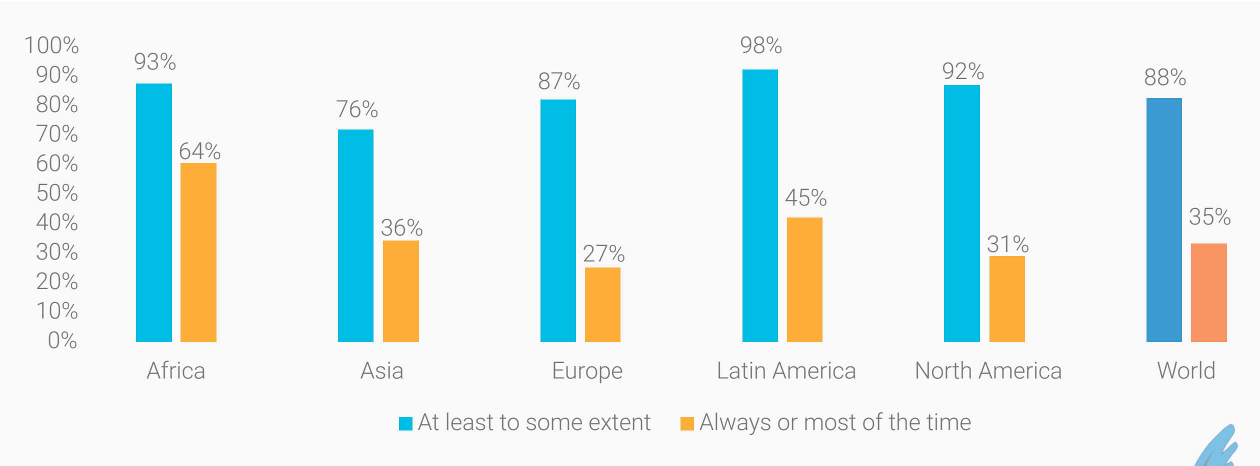
The survey data also showed that these resource constraints affect cities of all sizes. The interviews clarified that in small municipalities the limited allocation of human resources to smart city units may be driven by efficiency considerations. As noted by a Dutch expert, “in a small municipality, if you only have 500 full-time equivalent members of staff, you are not going to spend one full-time equivalent on a smart city officer” (Interview 111). In larger cities, instead, the limited resources available to smart city units reflect the broader skill shortages within the municipal administration, as further discussed in Section 3.2.

3.2 Competences and capacity needs

Skills gaps within the public sector are a well-known challenge to the development of people-centred smart cities. It must be underlined that these initiatives do not only require technical and managerial competencies: many commentators have emphasized the need for municipal governments to hire qualified staff with complementary skills and expertise. For instance, the ***Digital Competency Framework*** by UNESCO has identified three competency domains for civil servants to effectively deal with digital transformation and AI: digital planning and design, data use and governance, and digital management and execution[116]. The Urban Learning Centre[117] has added community engagement, sensemaking, foresight, and monitoring competencies to its list of critical skills for urban innovation.

As shown in Figure 16, 88% of the respondents to the Global Review have confirmed that skill gaps within the local administration are, at least to some extent, a constraint to smart city development in their municipality. African respondents were the most concerned, with 64% of them reporting skills shortages as a major constraint always or most of the time. Conversely, although 87% of European and 92% of North American cities included in the sample identified skills shortages as a barrier to smart city development, only 27% and 31% of them, respectively, have dealt with such a challenge with a regular frequency.

Figure 16: Percentage of municipalities experiencing skill shortages as a barrier to smart city development



(Source: Global Review, 2022).

These figures are in line with a survey of government officials conducted by Deloitte, wherein 70% of the participants shared the view that public sector organizations are lagging behind private organizations in terms of digital capabilities[118]. Additional insights on the extent and nature of these skills gaps can be derived from a recent study conducted by the OECD[119], which identified digital skills, ethics or integrity, teamwork, and communication as the main learning and development priorities for non-managerial civil servants. When focusing on senior managers in the public sector, leadership competencies emerged as the top priority, followed by digital skills, change management, ethics, and innovation.

Regarding the implementation of AI in urban contexts, the ***Global Assessment of Responsible AI*** recently conducted by UN-Habitat has highlighted significant skill shortages in awareness of AI risks, model development skills, and knowledge of AI and data regulations among municipalities. Such AI-related skill shortages were reported by 72% of the respondents, with a higher incidence in Africa and Latin America.

The interviews shed further insights into the causes of these capability gaps. The lack of advanced competencies within the public sector was often associated with budget constraints, uncompetitive salaries compared to the private sector, and lengthy, rigid recruitment processes that make it difficult for municipal governments to attract and retain professional experts. This issue is particularly severe for smaller municipalities: as highlighted by a smart city expert from Israel, "small cities are not able to hire high-level or good quality staff because the salary levels that they can offer are very low due to their size" (Interview 33).

The mainstream mindset within the public sector was also cited as an obstacle to capacity building, as municipal staff may not have enough incentive and time to engage with continuous learning and development: indeed, 19% of the respondents to the Global Review agreed that their municipal government does not provide its staff with sufficient opportunities to improve their capability to manage smart city initiatives (with no significant differences across the world regions). Finally, the skill shortages observed within the public sector arguably reflect broader societal challenges, as ongoing technological advancements make it challenging for educational institutions to provide adequate training and up-to-date curricula.

Nonetheless, the aforementioned study by the OECD showed that public sector organizations are engaging with a plurality of tools to deliver capability-building programs. Almost the totality of the respondents to their survey have reported that online or in-person training is being provided, along with regular seminars. eLearning platforms and mentorship programs were also in use in more than 80% of cases, while job shadowing programs and mobile learning apps were utilized in less than half of the organizations partaking in this study. The same survey has highlighted that about 40% of the OECD member states have no strategy for reskilling within the public sector, although more than 10% have training programs and official guidelines for the reskilling of public employees.

The interviews have also provided evidence of promising practices to address the existing skills gap in the public sector, by either enhancing the attractiveness of public employment or expanding the capabilities of existing staff. The former category includes graduate programs purposely designed to attract young professionals with advanced skills (as experimented in the Netherlands by the government of the province of Gelderland) or joint projects with academic institutions that enable local administrations to, at least temporarily, access the expertise of early-career researchers. As an example, a smart city leader from the US explained that "two research fellows from Harvard are working with our procurement team to revamp our procurement practices, and this has been an immense help to develop new pilot programs in a way that abides by procurement policies" (Interview 148). In addition to addressing existing skills shortages, these measures could help mitigate the age divide existing within the public sector as worldwide young people represent only 6% of the public sector workforce (while they account for 16% of employees in the private sector)[120].

In addition to these ongoing efforts to attract skilled professionals and upskill public employees, some interviewees predicted that the diffusion of no-code and low-code solutions could further contribute to mitigating skills constraints in the public sector. Thanks to their intuitive and standardized interfaces, these solutions are expected to reduce the need for advanced technical competencies. Their potential is testified by the experience of the government of Kobe (Japan). During the COVID-19 pandemic, the local administration applied a low-code development approach to rapidly launch a new integrated dashboard and an automated phone inquiry line. Both services enabled the local community to promptly access up-to-date information, resulting in a 90% reduction in calls to the city's contact center[121].

Nevertheless, the ethical and societal challenges posed by the advent of AI and other emerging technologies will still require local governments to expand their competencies and expertise in non-technical domains, such as the governance and protection of personal and non-personal data. Accordingly, any effort to boost the know-how and competencies of public sector employees cannot succeed without the development of a long-term vision and innovative culture sustaining lifelong learning approaches, both within and outside the public sector.

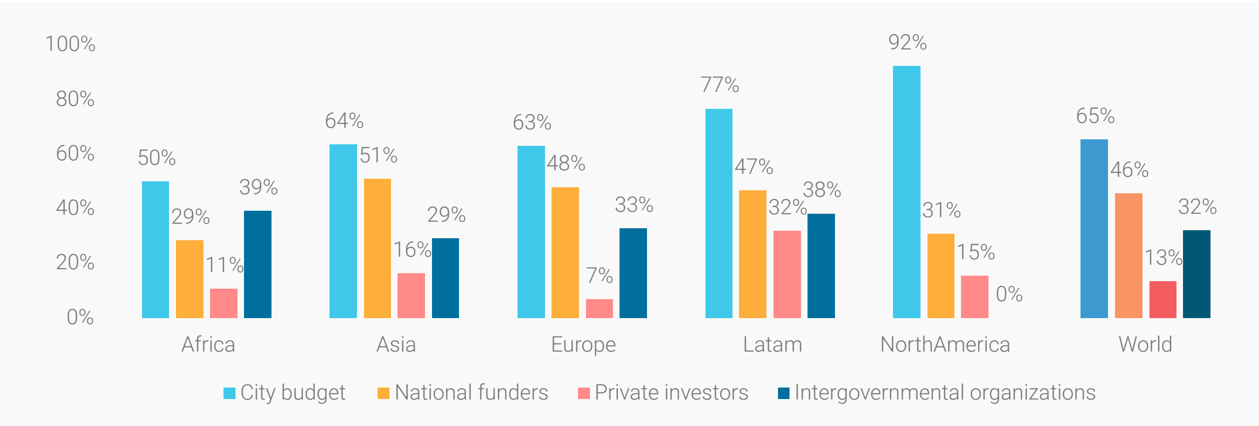
In particular, to sustain a people-centred digital transformation of cities, it is crucial to promote STEM education among those demographics traditionally excluded from these careers, such as women and ethnic minorities[122]. Likewise, it is fundamental to address gender and racial biases still existing in labor markets, especially for managerial and leadership roles. As evidenced by the latest *Gender Equality in Public Administration* report by the University of Pittsburgh, although women averagely count for 46% of the public sector workforce, only 30% of top leaders and senior managers in the public sector are female[123].

3.3 Financing mechanisms

Alongside adequate human capital, the development of people-centred smart cities also requires sufficient financial resources to cover the capital investment and operational expenses associated with the design, delivery, and maintenance of digital infrastructures and digital services. The Global Review has revealed that city budgets remain the predominant sources of funding. As shown in Figure 17, 65% of the respondents declared that their smart city initiatives most largely rely on municipal resources, with a higher incidence in North American (92%) and Latin American (77%) countries. In African countries, the weight of the municipal budget in funding people-centred smart cities was lower than the average (50%). National funders have also been indicated as a significant source of capital in 46% of cases, although this percentage drops to approximately 30% if we only consider African and North American countries. Furthermore, intergovernmental organizations were described as significant sources of funding by about one-third of the respondents, but none of the Northern American respondents identified them as crucial funders for smart city projects.

From the interviews, it emerged that the reliance on diverse funding sources largely reflects path dependencies in the financing of local administrations. Accordingly, smart city projects in some European cities have benefitted from the cohesion funds that the EU allocates to support regional development. In African municipalities, instead, crucial has been the contributions of international donors, including both intergovernmental agencies and philanthropic organizations. Nationwide funding schemes for smart city development have been common in Asia, while most North and Latin American cities have struggled to obtain financial support from their federal governments.

Figure 17: Percentage of municipalities relying largely on funding from city budgets, national agencies, private investors, and intergovernmental organizations



(Source: Global Review, 2022)

Private capitals were identified as a prominent source of funding by only 13% of the respondents, but their incidence tripled among Latin American municipalities (32%), as outlined in Figure 17. Such a limited reliance on private capital can only partially reassure the independence and impartiality of smart city initiatives. The literature has underlined that corporate vendors still exert a significant influence on smart city development, given their market power in the supply chain of technological solutions[124]. About 25% of respondents to the Global Review confirmed this, reporting that municipal governments still find it difficult to ensure that the interests of technology providers align with the development needs of their cities. As remarked by a municipal expert from the US, "many companies tend to see the community as a business" (Interview 150), hence their priority remains to sell technological solutions regardless of whether these are effectively addressing the needs of local users.

Consequently, the survey data on the distribution of funding sources could be interpreted as further evidence that taxpayers currently bear most of the costs associated with smart city projects, although large corporations hugely benefit from citywide deployments of digital technologies and services.

In people-centred smart cities, these considerations assume even higher relevance, given their commitment to prevent and discourage extractive business models potentially undermining the privacy of end-users.

About 24% of the survey participants also lamented that national and international funders may set conditions that negatively influence the planning and/or implementation of smart city initiatives. As clarified by the interviewees, the resources made available by these funders are often tied to the execution of temporary projects or limited to the implementation of infrastructural investment and predefined technological solutions. As a result, municipal governments still need to provide for the long-term operational expenses associated with digital services and infrastructures, including maintenance and upgrade costs, which are often overlooked in the planning phases.

These extra costs are to be covered by municipal budgets, and this raises additional challenges to the development of people-centred smart cities. Not only has the funding available to local governments drastically reduced worldwide as a consequence of ongoing austerity policies[125] but existing rules on public spending and public budgeting have also emerged as a constraint to urban innovation projects (as reported by 25% of the respondents to the Global Review). In particular, the interviewees lamented the excessive red tape associated with public procurement, which inevitably entails additional costs for municipal governments. As explained by a smart city leader from Spain, local authorities have "to justify and verify all the expenses they make, and this requires a lot of time and resources" (Interview 129).

To overcome these ongoing issues in the financing of people-centred smart cities, a change of paradigm would be necessary. Rather than relying on piecemeal funding schemes, these initiatives would benefit from comprehensive long-term funding programs informed by wide-ranging and forward-looking visions. A good example is the ***Vision for a Digital Garden City Nation***, launched by the government of Japan to foster rural-urban integration by leveraging digital transformation[126]. The program is organized around four strands (digital infrastructures, digital skills, digital services, and measures to leave none behind) to tackle multiple obstacles to rural-urban integration through a long-term cohesive plan articulated in a series of complementary holistic place-based interventions.

Furthermore, the interviewees advocated for the development of international financial instruments prioritizing sustainable finance[127] and place-based partnerships to support the piloting and scaling of people-centred smart cities, with the support of private funders. In the words of a national expert based in Germany, "each place will have to figure out what are the right funding mixes for smart city projects and when private investment is [...] acceptable and desirable by people" (Interview 74).

The financial constraints experienced by municipal governments also emphasize the urgent need to develop sustainable business models for smart city solutions. Regulatory and business model sandboxes can help in this regard, as further explained in Section 4.2. City-to-city collaborations are also fundamental to developing scalable and replicable business models: a good example is provided by the ***Smart Cities Marketplace***, a project funded by the European Commission, which has entrusted 120 cities to pilot sustainable business models for innovative solutions in the context of smart mobility and clean energy[128].

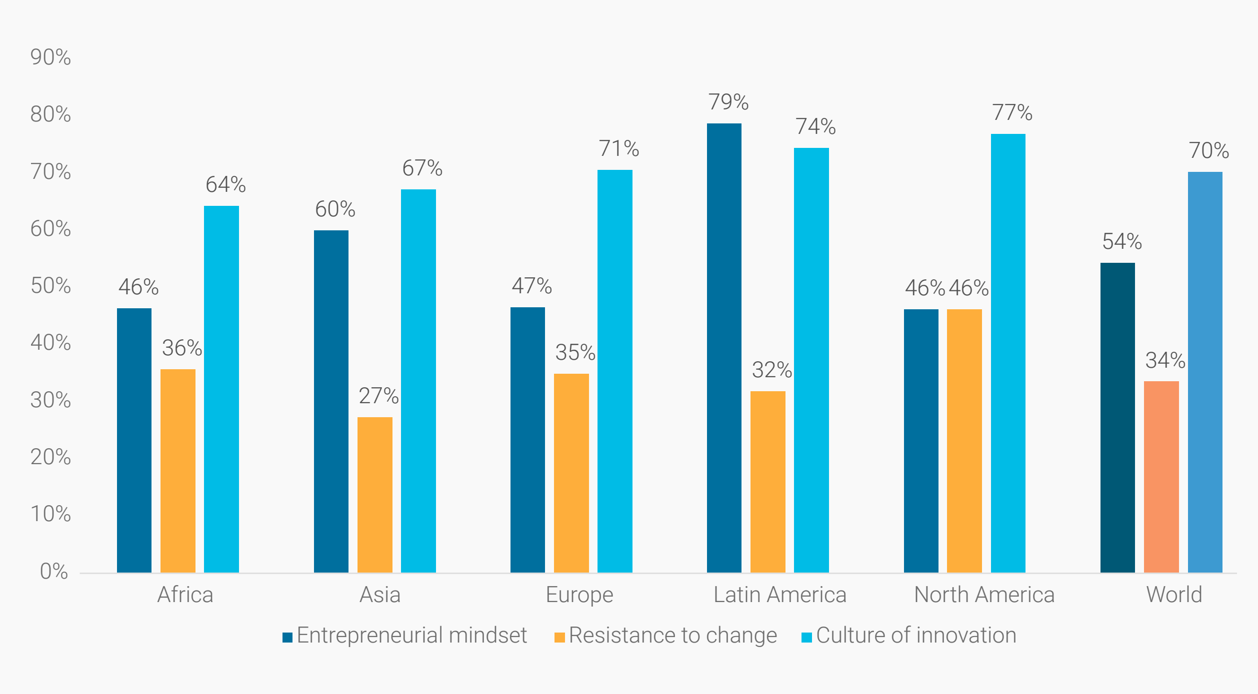
3.4 Organizational culture and values

Finally, to successfully govern people-centred smart cities and benefit from their opportunities, municipal governments need to adopt a culture favorable to innovation and open to experimentation. The grey and academic literature indeed tends to depict the public sector as risk-averse and less prone to embrace technological innovations, even though a recent stream of research has emphasized the leading role played by public agencies in the development of digital technologies[129].

The Global Review also provided a mildly optimistic picture. Only 34% of the respondents described their municipality as reluctant to change, although 52% reported that resistance to change in the public sector is oftentimes a constraint to smart city development. Asian respondents tended to be more optimistic about the attitude to change of both their municipal governments and the public sector, in general. Conversely, as shown in Figure 18, North American participants were more inclined to describe their municipality as resistant to change, while the attitude to change of the overall public sector emerged as a major concern among Latin American (74%) and African (61%) respondents.

Nonetheless, local governments were praised for nurturing a culture of innovation by 70% of the survey participants, with no significant regional differences. An entrepreneurial mindset, however, emerged as a more common feature of Latin American and Asian municipal governments (79% and 60% of the sampled cities, respectively), compared to other regions (approximately 46%), as outlined in Figure 18.

Figure 18: Percentage of municipal governments showing an entrepreneurial mindset, resistance to change, or a culture of innovation.



(Source: Global Review, 2022)

Similar figures resulted from the aforementioned survey administered by Deloitte to 1,200 civil servants. According to 19% of them, the lack of entrepreneurial spirit in the public sector is a major barrier to digital transformation. The limited sharing and collaborative culture of public organizations was, instead, identified as a barrier by only 13% of the respondents[130]. Nonetheless, 85% of the organizations partaking in the study cited culture as a challenging aspect of managing digital transformation processes. Likewise, citing data from Gartner, UNESCO concluded that the reluctance to change of public organizations remains a major challenge to implementing digital solutions in the public sector, as remarked by 42% of the Chief Information Officers responding to their survey[131].

Generating and maintaining a positive attitude toward innovation within the public sector is pivotal to encouraging lifelong learning, supporting capacity building, and creating an environment favorable to cross-sector collaborations. The interviews showed that this cultural shift can be facilitated by two main factors. First, having political leaders with an entrepreneurial mindset or a professional background in innovation and creativity: their vision and support are key to maintaining smart city transitions as a priority in the political agenda of the municipal government. Being located in a city or region characterized by a high presence of innovative companies was also recognized by the interviewees as an enabler and stimulus to adopt an innovative culture within the local administration.

Furthermore, qualitative data have indicated a plurality of measures and initiatives that have helped global cities nurture the creative and innovative mindset within the public sector. These include knowledge exchange initiatives involving external partners and other local administrations, coaching programs for public managers, and the recruitment of experts from the innovation sector. The interviewees, however, also agreed on the importance of adapting internal procedures and strategies to incentivize their staff to take on risks and engage with uncertainty. In this context, the importance of change management was underlined to sustain the digital transformation of both the processes and the culture of local administrations: although this transformation may be hampered by "the very limited capacity for change management in municipal governments", as highlighted by an Estonian expert (Interview 65).

It must be underlined that, when developing a pro-innovation culture, municipal administrations should refrain from uncritically embracing the narratives normally associated with digital transformation processes. As such narratives are primarily framed and shaped within the private sector, they may not align and integrate with the values and mission of public organizations. In the Global Review, 10% of the respondents admitted that their municipality struggled to balance economic and social interests in smart city development and to ensure that the objectives of smart city projects are consistent with the overall urban development goals. The incidence of this trend was higher among participants from African countries, with 25% of them reporting such issues.

A primary challenge for municipal leaders is, therefore, to integrate a pro-innovation culture in the public sector without losing sight of its core values, principles, and mission. People-centred smart cities go naturally in that direction by leveraging data and digital technologies to pursue public values rather than just focusing on the deployment of digital services and infrastructures. Nonetheless, additional guidance is needed to help cities identify the best approaches to develop and sustain this cultural shift, especially in those national contexts where the mainstream culture is less open to innovation and experimentation. Furthermore, municipal governments could benefit from the definition of guidelines and best practices for the governance of urban innovation ecosystems. This would ensure the mainstreaming of innovative and collaborative practices into the ordinary urban development process, and the alignment of urban innovations with the municipality's overarching needs and priorities.

SECTION 4: Collaborative ecosystem

For the development of people-centred smart cities, municipal governments are expected to collaborate with a wide range of local and non-local actors: private enterprises, citizens, universities and research centers, and civil society organizations. The effectiveness of these collaborations is affected by a plurality of factors, often reflecting idiosyncrasies of the ecosystem in which these actors operate.

With regard to private partners, the data available show that local enterprises tend to be more engaged than non-local companies, especially in the implementation phases. The rigidity of procurement processes and the lack of sustainable business models emerged as a major deterrent to the participation of private enterprises: an issue experienced by 64% of the Global Review respondents (with a higher proportion in Africa and Latin America).

The low engagement of local communities recurred as another key challenge. Despite the broad variety of participatory tools deployed to boost citizens' engagement in people-centred smart cities, only 20% of the Global Review respondents described citizens as active or very active in smart city development (with no significant differences across the world regions).

As to universities and civil society organizations, both have provided municipal governments with complementary expertise to manage specific aspects of smart city projects (such as their monitoring or the inclusion of local communities). However, the contribution of these actors generally appeared lower in African and Asian cities, compared to the other world regions.

Major challenges

- The complexity of existing procurement processes discourages the participation in smart city projects of small and innovative enterprises.
- The limited digital literacy of citizens and their lack of trust in governments undermine the engagement and participation of local communities in people-centred smart cities.
- How to structure the collaboration with universities and civil society organizations beyond single projects remains unclear.

Key priorities

- Revise procurement regulations, drawing on innovative practices being globally experimented with.
- Establish ad-hoc programmes to support entrepreneurial efforts to tackle urban challenges through social and digital innovation.
- Create a dynamic, comprehensive strategy to boost both the digital literacy and the trust of local communities.
- Devise innovative mechanisms to build trust-based, long-lasting cross-sector partnerships.

It is well established that people-centred smart cities result from and rely on the collaboration of municipalities with a multitude of local and non-local actors from different sectors. Whereas the contribution of public organizations to the strategy-making and policymaking of digital technologies has already been discussed in Sections 1 and 2, this section focuses on the cooperation of municipal governments with four types of non-public actors: local and non-local private companies, citizens, universities and research centers, and civil society organizations. For each of these collaborative relationships, current and emerging trends are outlined, followed by an examination of major challenges and opportunities emerging from the empirical evidence available to date.

CITIZEN ENGAGEMENT

only **20%** find citizens as active or very active in smart city development

COMMUNITY PARTICIPATION

51% find difficult to engage local communities especially in North America (**62%**) and Asia (**61%**)

87% of cities globally finds citizens having low interest in participating in smart city projects

UNIVERSITIES AND RESEARCH CENTERS

indicated as active or very active partners by **71%** of cities, but their participation is considerably lower (**45%**) in African and Asian countries

CSOs

Civil society organizations involvement in the planning and implementation of people-centred smart cities is higher in North American and European cities, while limited in Asian and African municipalities

COLLABORATIONS

PRIVATE SECTOR

between **66%** and **62%** (local and non-local) of private companies are engaged in smart cities projects with higher participation in the implementation phase

public procurement processes are a major challenge to private sector engagement according to **58%** of cities globally.

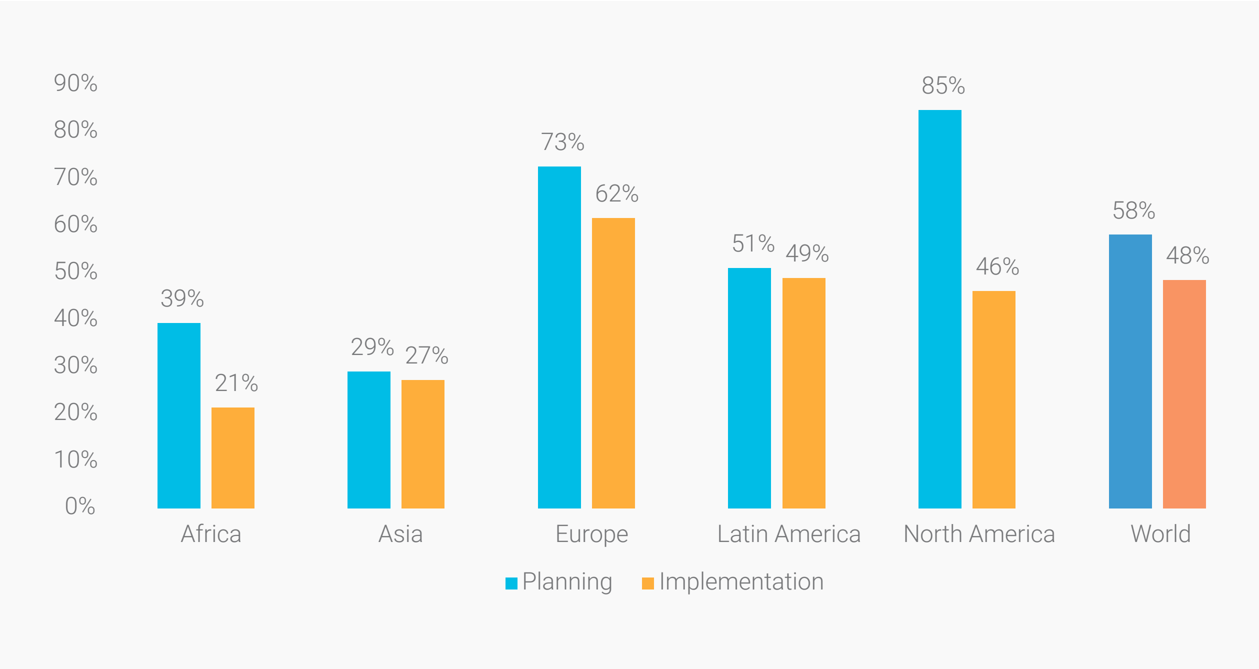
85% and **72%** agree in North America and Latin America respectively

4.1 Community engagement and participation

The active participation and inclusion of people are key tenets of people-centred smart cities. To ensure that these initiatives are aligned with the needs and values of local communities, municipal governments are expected to continuously engage with them through a variety of channels and in various phases of smart city development.

The Global Review provided an in-depth overview of the levels of citizen engagement and participation in smart city projects worldwide. The survey revealed that local communities have been involved in the planning and implementation of smart city projects in 58% and 48% of the sampled municipalities, respectively. However, noticeable cross-country differences also came into sight, as shown in Figure 19. With regard to the participation of citizens in the planning phase, respondents from North America and Europe reported much higher rates than those from Asia and Africa. As to the implementation phase, European municipalities again showed higher levels of engagement than the world average, while Asian and African cities lagged behind.

Figure 19: Percentage of municipalities where citizens are involved in smart city development



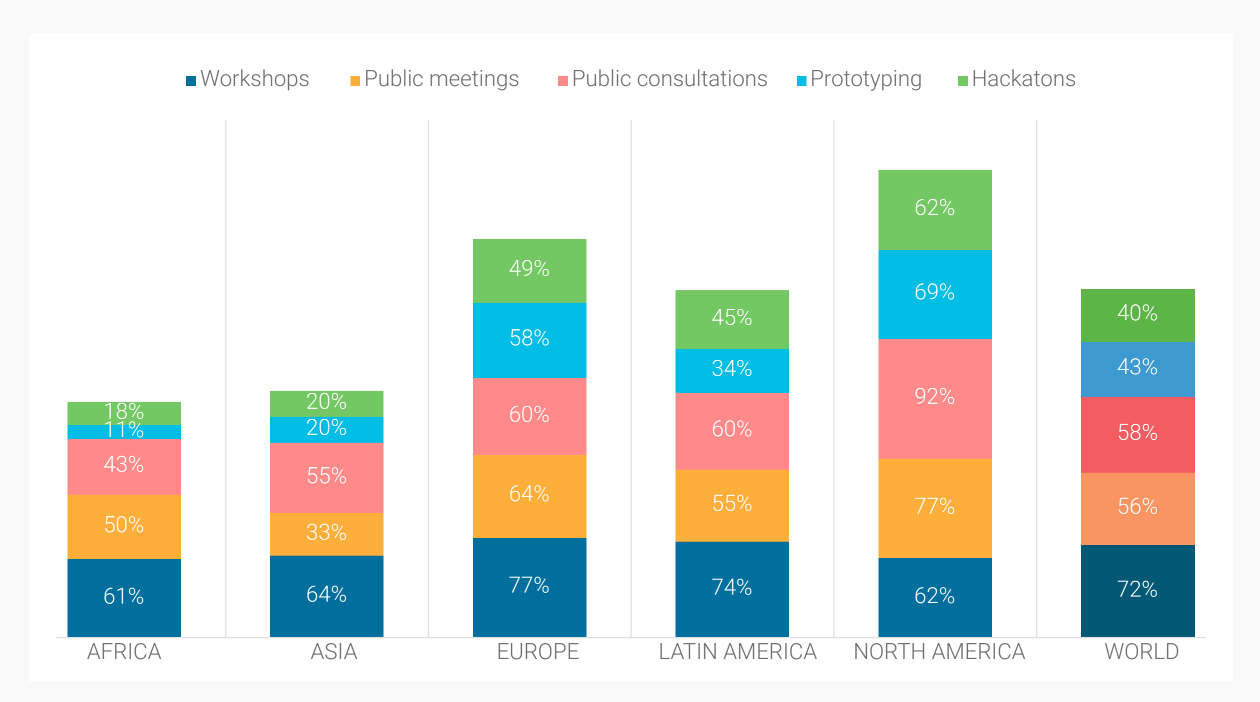
(Source: Global Review, 2022)

It must be added, though, that only 20% of the respondents described citizens as active or very active in smart city development, and this trend recurred across the world regions with no significant differences. In fact, in most cases, the contribution of citizens was limited to giving feedback on the quality of urban services, a practice already in place in more than 70% of the sampled municipalities, although with a lower incidence in African countries (55%). These data align with recent statistics from UN-DESA, confirming that in 66% of the countries covered by their survey, citizens can leave feedback through public portals .

Another issue clearly highlighted by the Global Review is how difficult it can be for cities to effectively involve citizens in smart city development. 51% of the participants admitted that their local government has encountered some challenges in engaging local communities, with a higher incidence in North America (62%) and Asia (61%). Furthermore, 87% of the sampled cities confirmed that, at least to some extent, their citizens have shown little willingness to participate in smart city projects: a trend observed across all world regions.

To stimulate the participation of local communities in people-centred smart cities, cities worldwide have employed a variety of instruments. The analysis of city portals conducted by UN-DESA revealed that online deliberation processes have been implemented in 40% of the sampled cities, but e-voting is only available in 18% of them . From the Global Review, instead, public workshops emerged as the most common type of engagement tool (employed in 72% of the municipalities partaking in the survey), followed by public meetings (58%), public consultations (56%), the testing of prototypes (43%) and hackathons (40%). The diffusion of these tools, however, varied significantly across the world regions, as shown in Figure 20. Asian and African municipalities generally lagged behind the world average while North American local governments were the most likely to use all tools, except for public workshops.

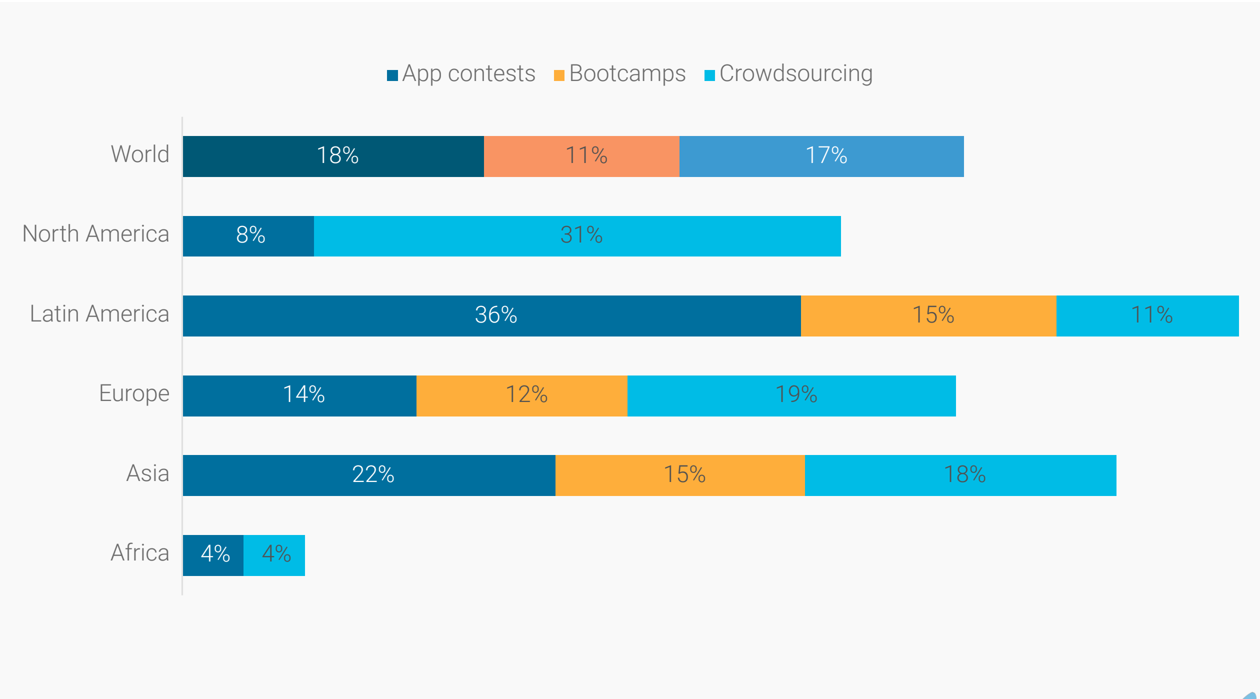
Figure 20: Diffusion of different public engagement activities across the world regions



(Source: Global Review, 2022)

The use of other instruments appeared less widespread, with bootcamps, app contests, and crowdsourcing techniques being applied in less than 20% of the municipalities covered by the survey. As reported in Figure 21, app contests have been particularly popular in Latin America (36% of the sampled cities), while crowdsourcing techniques have been used in 31% of the North American cities covered by the survey, and less frequently in Europe and Asia (19% and 18%, respectively).

Figure 21: Diffusion of app contests, bootcamps and crowdsourcing techniques across the world regions



(Source: Global Review, 2022)

The interviews shed additional light on the advantages and disadvantages of the alternative participatory tools employed in people-centred smart cities. The inclusivity and representativeness of in-person events have been questioned, as members of low-income households and peripheral communities may have limited time to attend these meetings, especially when hosted in locations far from their neighborhoods. The interviewees also noted that people with caregiving responsibilities tend to be excluded from these events, unless the organizers provide them with on-site childcare or compensation for temporarily hiring a caregiver. Furthermore, simultaneous translation and interpretation services should also be offered to ensure that non-native speakers and individuals with hearing impairments can effectively partake in these events.

Compared to in-person interactions, online tools for citizen engagement offer the advantage of being remotely accessible from multiple locations at the same time, thereby incentivizing the participation of peripheral communities or individuals with mobility constraints. Their effectiveness and inclusivity, however, are still subjects of debate. A major criticism emerging from the literature and the interviews is that online participatory platforms remain accessible only to people who have necessary skills, technical resources, and time to engage in participatory bottom-up policymaking processes. Others have highlighted the risk of tokenism in citizens' participation, reflecting the fact that they may be allowed to express their opinions or advance ideas, but without really being empowered to change the status quo .

Data from the *UN-DESA e-government survey*, indeed, confirmed that, at the global level, the engagement of vulnerable groups in online consultations had been suboptimal: as of 2022, only 42 countries had offered e-consultation mechanisms tailored to youth and people with disabilities. Similar measures in favor of women's and older people's participation were observed in 36 and 29 countries, respectively. Nonetheless, the same report highlighted that, as of 2022, specific measures to support the e-participation of vulnerable groups had been adopted in 61% of the countries included in the sample, with a higher incidence in Asia (70%) and Africa (63%) compared to Europe (58%), the Americas (59%) and Oceania (29%).

Regardless of the engagement tools employed by municipalities, both the literature and the interviews have stressed the importance of promoting the media literacy and digital skills of local communities to maximize their engagement with smart city applications. The digital skills of individuals condition the extent to which they can use and benefit from access to digital technologies (as further discussed in Section 5.1). Additionally, media and information literacy are also crucial for building informed, resilient, and empowered communities, able to evaluate and use information responsibly as well as to understand evolving communication technologies and their social and environmental implications . This understanding is crucial to fostering a fruitful collaboration between local governments and their citizens, as remarked by a municipal leader from Cameroon: "when the population is really made aware of smart city projects and what they imply, they work together to provide as much useful data as possible" (Interview 26).

In addition to digital literacy gaps, trust was also highlighted by the interviewees as another major determinant of citizens' participation in smart city projects. On the one hand, some groups, such as migrants and LGTBQIA+ people, may be reluctant to partake in public engagement activities because they have little trust in what the local government is going to do with their data. On the other hand, the willingness of citizens to collaborate with local governments may be frustrated by the common belief that their input will be neither taken seriously nor translated into effective actions. One-third of the respondents to the Global Review, indeed, admitted that their municipalities do not always act upon the feedback of people, with a higher incidence among low-income countries. Similarly, the *UN-DESA e-government survey* reported that only 25% of the cities covered in their analysis provided feedback about the results of public consultations .

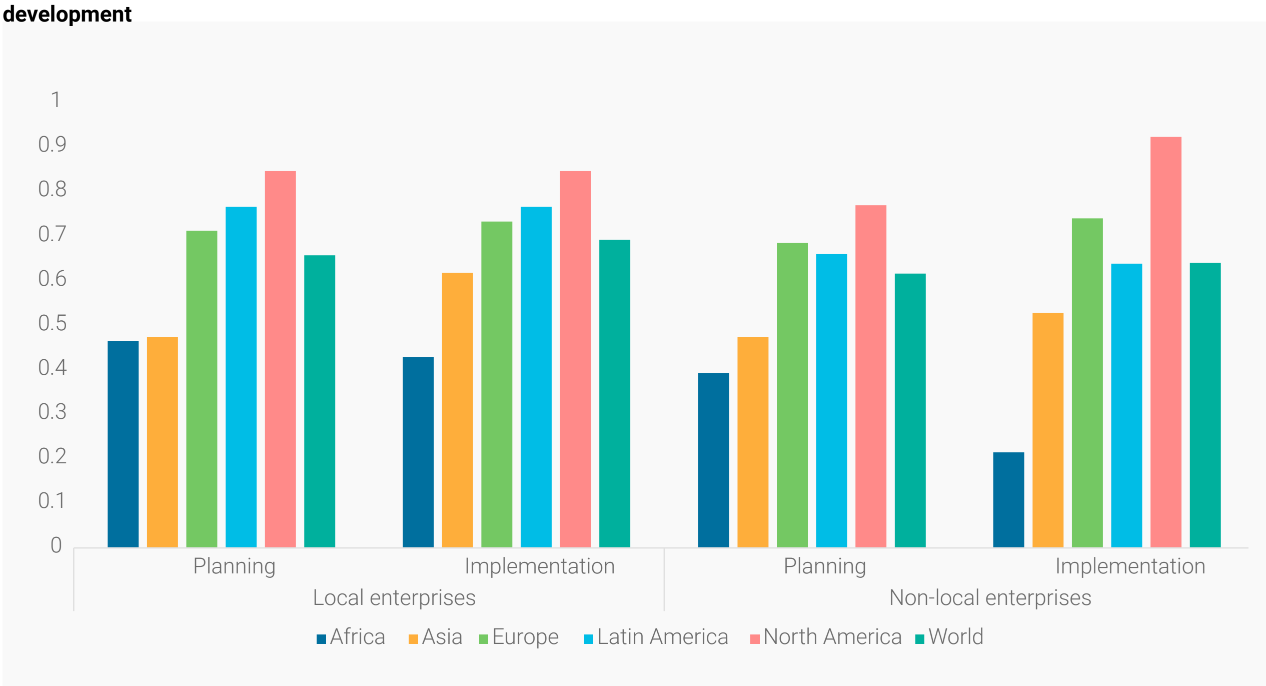
In this context, communication plays a vital role in both raising awareness and building a relationship of trust with citizens. A major challenge, however, remains to forge a language that is clear enough for all local stakeholders. As underlined by a smart city expert from Mexico, "municipal governments need to make sure that the residents understand what they are trying to do" (Interview 105), avoiding technical jargon and building shared narratives of what smart city means in the local context. Working with community leaders and civil society organizations also contributes to building and reinforcing a relationship of trust between citizens, municipal governments and other smart city partners, as further explained in Section 4.4.

4.2 Collaboration with private sector organizations

Private organizations from the smart city technology market (whose global annual turnover is expected to grow from USD 121 billion to USD 301 billion between 2023 and 2032[132]) are key contributors to the development of people-centred smart cities. Examples of these organizations include global companies supplying critical technological components for digital services, national infrastructure providers, local start-ups and social enterprises developing place-based technological solutions, and consultancy firms with expertise in urban planning and the design of user-centric applications[133].

The Global Review showed that local and non-local private companies were involved in the planning of smart city projects in 66% and 62% of the sampled municipalities, respectively. As shown in Figure 22, their involvement was slightly higher in the implementation phase. Overall, the participation of private enterprises was lower in African countries and higher in Northern American cities.

Figure 22: Percentage of municipal governments partnering with local and non-local enterprises in smart city development



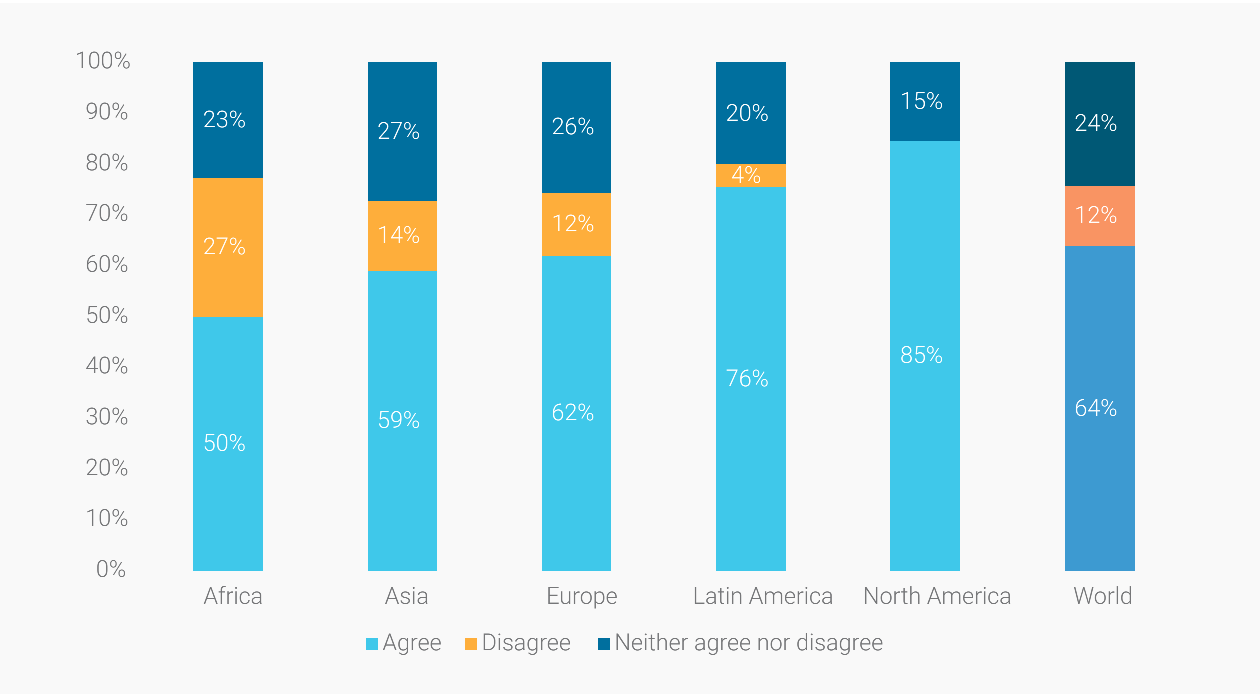
(Source: Global Review, 2022)

Across the world regions, respondents from small cities reported much lower levels of engagement, with less than half of them counting private companies as partners in both the planning and implementation phases. As explained by a municipal expert from Spain: "smaller cities are not a priority for private companies, no matter how big the project is" (Interview 134). The literature has, indeed, highlighted that technology suppliers have a lower incentive to partner with small-sized local authorities because their limited scale undermines the economic sustainability of smart city projects and their ability to generate positive returns in the short and medium term[134]. To overcome this issue, municipal governments could partner with each other when negotiating with bigger private companies, although this could limit their ability to procure technological solutions tailored to their local context and needs.

In general, the Global Review confirmed that the unwillingness of private companies to participate in smart city initiatives remains a significant constraint, experienced – at least to some extent – by 64% of respondents, with a higher proportion in Latin American (79%) and African (75%) countries. From the interviews, two major deterrents emerged with regard to the participation of private enterprises in people-centred smart cities: shortcomings in existing procurement processes and regulations, and the lack of sustainable business models for smart city services and applications.

As shown in Figure 23, 58% of the respondents to the Global Review agreed that public procurement processes represent a major challenge to the engagement of private companies in smart city projects, with the highest incidence among North (85%) and Latin American (72%) respondents. These figures are in stark contrast with those captured by UNESCO, drawing on survey data from Gartner, showing that only 13% of the sampled Chief Information Officers considered inadequate procurement approaches as a primary challenge to the implementation of digital solutions.

Figure 23: Percentage of respondents agreeing that public procurement poses a major constraint to the engagement of external partners in smart city initiatives



(Source: Global Review, 2022)

Nonetheless, both the UNESCO report and the interviews conducted for this study stressed the importance of overcoming the rigidity of existing procurement processes for digital transformation projects. Across the world regions, interviewees reported that small businesses and start-ups are struggling to partake in public tenders for smart city projects because they do not have enough resources to prepare all the documentation mandated by public procurement regulations. The timeliness of procurement processes was also considered by many interviewees as not compatible with the fast pace of innovation and the uncertainty associated with the development of cutting-edge urban solutions.

To address such issues and sustain the participation of small enterprises and start-ups in smart city projects, municipalities worldwide have been trialing innovative approaches to procurement with encouraging results. These approaches often entail a competitive contest or problem-based challenge, in which small ventures can advance their ideas and solutions rather than just respond to a public tender. It is the case, for example, of the outcome-based procurement applied in Singapore, which enables government agencies to source digital applications without specifying the underlying technology by stating what problem they need to address and setting the key performance indicators that potential suppliers need to meet with their proposed solution[135]. An alternative approach to public procurement, endorsed by the European Commission, consists of first aggregating the demand of multiple public buyers and then communicating to market players the intention to source a large amount of innovative services or products. This stimulates scale-up processes on the supply side, reducing uncertainties and costs in the production of novel technological solutions[136].

Furthermore, local authorities can support the development of local enterprises through a variety of measures, including but not limited to financial subsidies or a local public innovation fund, focused on the specific challenges of a city and facilitating purposeful public-private partnerships, as in the case of the City of Oakland[137]. Another best practice in this context is the ***Cordoba Smart City Fund***, a public venture capital initiative set up in Cordoba (Argentina) to sustain civ-tech and smart city start-ups. Every year, the municipal government allocates 1% of its commercial and industrial tax revenues to this Fund, which is also supplemented by capital coming from institutional investors, such as the CAF. Since its inception, 16 start-ups from Argentina, Colombia, and Chile operating in multiple industries (such as urban farming, inclusive education, and civic participation) have received support from the Fund, for a total investment of USD 1.7 million[138].

More frequently, municipal authorities have undertaken specific initiatives to promote entrepreneurship, in general, or within specific groups (such as women and migrants). Incubation and acceleration programs, offering nascent entrepreneurs mentoring, seed funding, and physical spaces for collaborative practices, have long been a cornerstone of people-centred smart cities. Empirical evidence from 157 European cities has confirmed a positive correlation between business incubation and smart urban development[139], yet the inclusiveness and openness of incubators and accelerators have been questioned by scholars, as these spaces tend to be less accessible to people from deprived backgrounds[140].

Accordingly, promoting entrepreneurship among traditionally disadvantaged groups has become a priority for public institutions, often in partnership with civil society organizations. For instance, the Ministry of Science and Technology in China, along with the All-China Women's Federation and the China Association for Science and Technology, has adopted a set of measures to support female entrepreneurship in Science, Technology, and Innovation[141], while the United Nations Conference on Trade and Development (UNCTAD), the Office of the United Nations High Commissioner for Refugees (UNHCR), the International Organization for Migration (IOM) and the United Nations Institute for Training and Research (UNITAR) have launched an e-learning entrepreneurship program for migrants and refugees[142]. Similarly, between 2017 and 2021, , three cities in the UK (Coventry, Birmingham, and Wolverhampton) ran a capacity-building program for refugees and migrants which led to the creation of 16 start-ups, across different sectors, from arts and creativity to translation services and IT development[143].

Another major issue emerging from the interviews concerned the lack of sustainable business models for people-centred smart cities, affecting both digital infrastructures and digital services. The former, like any other infrastructure, is characterized by externalities that make it difficult to capture and capitalize on the value generated. As explained by a German expert: "cities have to understand how to measure the potential value of a digital infrastructure but often they do not have the right cost-benefit analysis tools to systematically map its impact" (Interview 74).

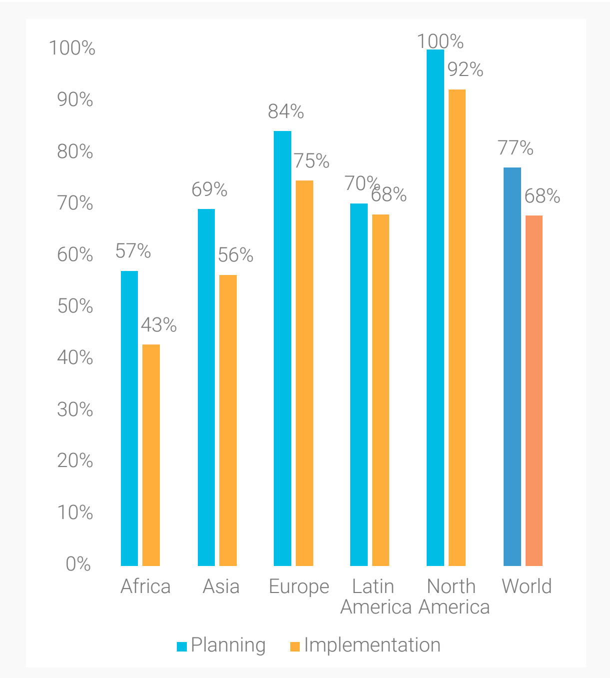
As to the digital services, the interviewees agreed on the need to develop new models for funding their scale-up and operations in the medium-long term, beyond the start-up phase. Regulatory and business model sandboxes, allowing for the testing of technological solutions and regulatory measures in protected environments, were identified as promising tools to "resolve the policy and regulatory challenges that constrain the scalability of smart city applications", as underlined by an expert from Malaysia (Interview 102). Alternatively, to enhance the scalability and financial sustainability of their digital services, municipal governments could adopt a federated model, enabling the sharing of development costs as well as the adaptation of digital applications to local contexts[144]. This is the approach followed, for instance, by car-sharing cooperatives across Europe, which have established a common digital platform (The Mobility Factory), which is then adapted and implemented locally to adjust to the needs and habits of local users[145].

Finally, the interviewees highlighted the difficulties that municipal governments encountered in forming effective and flexible partnerships, where the interests of public and private parties are aligned and mutually adjusted over time. Cities worldwide have experimented with a variety of legal forms and organizational structures, consistent with the importance of designing place-based, bespoke cooperation agreements that best leverage the resources and characteristics of local partners[146]. Nonetheless, intellectual property rights and data governance emerged as major sources of tensions between local administrations and their partners, partially reflecting the lack of overarching policies and regulatory guidance on these matters.

4.3 Collaboration with universities and research institutions

Other players playing an active role in people-centred smart cities are universities and research institutes; as seen in Figure 24, data show that these entities have been involved in both planning and implementation phases in 77% and 68% of the sampled cities, respectively. Their participation, however, was considerably lower in African and Asian countries. African respondents also were the least likely to describe universities and other research institutions as active or very active (45%). In contrast, in the other regions, these actors were indicated as active or very active partners by 71% of the participants.

Figure 24: Percentage of municipalities partnering with universities and research institutions in smart cities development



(Source: Global Review, 2022)

The interviews provided in-depth insights into the role played by these organizations in the context of people-centred smart city development. In addition to directly contributing to the design and prototyping of smart city solutions, universities and research institutions often act as knowledge intermediaries, supporting the capacity-building of municipal governments (as examined in Section 3.2) and providing advanced technical expertise in various domains of smart city development. For instance, in North America, academic partners have been tasked by municipal governments with the writing of grants and project proposals, while in some European cities, they have been leading the monitoring of smart city projects.

Across the world regions, research institutions have also helped local and national governments to devise ad-hoc policy guidelines on crucial matters, such as data protection and the ethical use of facial recognition. More than 60% of the cities analyzed in the *Global Assessment of Responsible AI* confirmed that universities and research centers are very important partners in the definition of AI policies[147].

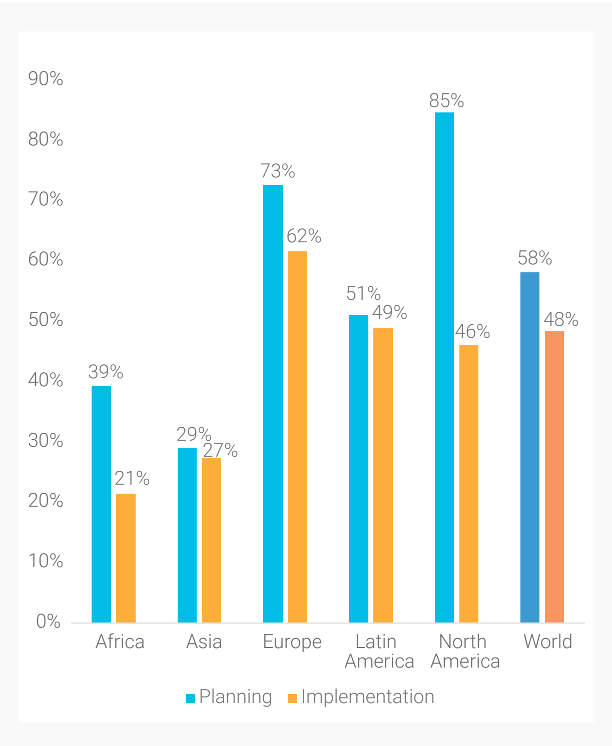
The collaboration between local authorities with these organizations has generally been perceived as fruitful, with 86% of the participants in the Global Review agreeing that universities and research institutes contribute to expanding public sector capabilities . This trend was consistent across the world regions and across cities of different sizes. Yet both the survey data and the interviews highlighted that such cooperation is less effective in low-income countries, where universities tend to be underfunded and "do not have a common agenda to work together with local governments and enterprises", as highlighted by a smart city expert from Bangladesh (Interview 13). In high-income countries, some interviewees rather lamented a lack of collaboration between universities and private enterprises due to the lack of shared incentives between academic and industry players, especially with regard to the protection of intellectual property rights and the diverging timeframe of research and commercial activities.

Another issue emerging from the interviews concerned the short-term nature of public and private collaborations with academic institutions. These partnerships are often tied to the completion of specific projects, and they are normally discontinued once the related funding is used up. This tendency is detrimental to knowledge sharing and the generation of sustainable innovation: hence, building long-term R&D alliances remains a key challenge and priority for people-centred smart cities.

4.4 Collaboration with civil society organizations

Municipalities worldwide are also forming partnerships with civil society organizations, such as local charities, neighborhood associations, grassroots collectives, and other community groups. According to the Global Review, these actors have been involved in the planning and implementation of people-centred smart cities in 62% and 56% of the sampled municipalities, respectively. As shown in Figure 25, their participation has been higher in North American and European cities, whereas it remained limited in Asian and African municipalities.

Figure 25: Percentage of municipalities partnering with civil society organizations in smart city development



(Source: Global Review, 2022)

From the interviews, it emerged that the contribution of local charities and associations has primarily focused on supporting people's' participation and their digital inclusion through various approaches. The most common involves the joint promotion of digital skills (an issue further discussed in Section 5.1): municipal governments worldwide have outsourced digital skills training to local associations already working with digitally divided communities and therefore better positioned to identify their skills gaps and educational needs. Additionally, many cities – especially in the Americas - have contracted civil society organizations as facilitators of public engagement activities. Their involvement in the design of public consultations or the delivery of public events is expected to encourage the participation of residents, given that these organizations "have the ability to establish trust with local people", as highlighted by an expert from Canada (Interview 30).

Whereas there is no doubt that the partnership between municipal authorities and civil society organizations can significantly benefit the development of people-centred smart cities, how to structure, sustain, and continue these collaborations remains unclear. Often, the partnerships between civil society and public sector organizations are limited to single projects and depend on temporary funding sources. This tendency undermines the contribution of community groups, charities, non-profit organizations, and foundations to the implementation of people-centred smart cities.

The interviews have also clarified that the effective participation of these organizations is largely affected by structural characteristics of the civil society at the city and national level. Some interviewees noted that in their country, civil society is not developed enough to qualify as a relevant partner. As explained by a smart city expert from Azerbaijan, "in many cases, civil society is not even present because the governance system is different (…) and citizens are not believing in that" (Interview 12). In other countries, instead, the third sector was described by some as too vast and fragmented, making it difficult for smart city leaders to identify reliable partners in civil society. Across the world regions, these organizations are constantly under-resourced, which compromises their ability to participate in public tenders and build stable relationships with other smart city partners.

SECTION 5. Urban digital infrastructures

Broadband networks, sensor networks, and data platforms are a critical part of the development of people-centred smart cities, contributing to the merger of digital and physical layers of urban environments across a wide range of domains. The diffusion and usage of these infrastructures, however, remain heterogeneous across the world regions, reflecting the uneven distribution of technical resources and competencies as well as the persistence of policy gaps and regulatory voids.

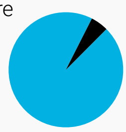
To date, the coverage of fixed broadband networks remains circumscribed to the most advanced economies, but the availability of 4G networks is also considerably lower in Africa (64%) compared to the rest of the world (90%). Furthermore, in Sub-Saharan Africa and Asia, more than half of the population served by mobile broadband is still not using Internet services. The limited affordability of connectivity services and the lack of digital skills among the population contribute to this adoption gap, with both issues disproportionately affecting low-income countries and vulnerable social groups over others.

URBAN DIGITAL INFRASTRUCTURES

Mobile network

3G mobile networks are available to

95%



of the global population. African countries are lagging behind (84% coverage).

4G networks availability is lower in Africa (**64%**) compared to the rest of the world (**90%**)

Fixed Broadband

19%

of the world population has a fixed broadband subscription, while only

0.8%

in Africa

SENSOR NETWORKS

83 billion sensing devices estimated to be installed globally in 2024

Adoption Rates by Region:

- North America: **92%**
- Europe: **82%**
- Africa: **43%**

SECURITY AND PRIVACY CONCERNS

- Risks of cyberattacks on critical infrastructures
- Privacy issues due to increased surveillance
- Need for policies to enforce data protection and human rights

ENVIRONMENTAL AND OTHER CONCERNS

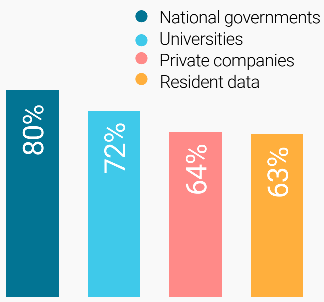
- Maintenance and sustainability concerns due to short lifecycles and high costs
- Sensor networks contribute to e-waste, with 5 billion kg generated in 2022

DATA PLATFORMS

80%

of cities use data for decision-making (2022)

Main Data Sources:



Challenges:

- **84%** of municipalities lack integrated dashboards
- Only **57%** use open data platforms (Africa: **32%**, Asia: **44%**)
- Data silos, lack of standards, and limited data sharing hinder effectiveness

Open Data Portals:

81%

of countries have an open data portal (2024)

ENVIRONMENTAL IMPACT

Data centers use **1-1.5%** of global electricity, with **1%** of global emissions

In Europe, data centers consume up to **5%** of energy in the Netherlands and **19%** in Ireland

To address affordability barriers, 63% of the municipalities partaking in the Global Review have been offering public Wi-fi, while monetary subsidies for devices and broadband services have only been offered by 26% of them. More than half of the sampled cities have also been promoting digital literacy through training and IT workshops, complementing nationwide measures in support of digital inclusion (which, according to UN-DESA, are already offered by 80% of the world nations).

As to sensor networks, these infrastructures have been implemented in 73% of the cities included in the Global Review, with a higher incidence in North America and Europe (82%). Their implementation, however, is oftentimes affected by security, environmental, and privacy concerns, undermining their acceptance among local stakeholders.

With regard to data platforms, existing evidence confirms the growing adoption of open data portals at both local and national levels. Nonetheless, data siloes remain in place within the public sector, hampering the potential of big data analytics for people-centred smart city development.

Major challenges

- The availability and adoption of broadband services remain uneven both within and across countries.
- Cities may not be fully equipped to guarantee the resilience and security of digital infrastructures.
- Sensor networks may pose risks to data protection and data security.
- Data platforms and data visualization tools often do not comply with global accessibility standards.

Key priorities

- Reinforce ongoing interventions to bridge ongoing and emerging digital divides.
- Develop a new mindset and know-how about cybersecurity in the public sector.
- Define local guidelines and national regulations to boost the security and privacy compliance of digital infrastructures.
- Establish standards for the sustainable design of digital technologies.

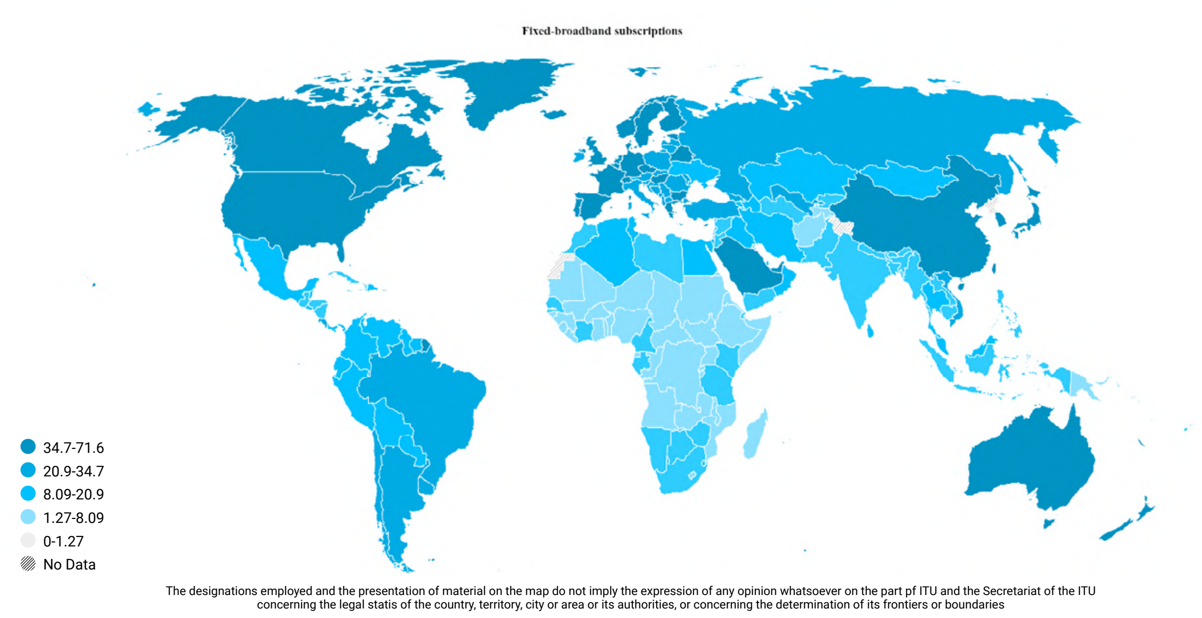
Digital infrastructures refer to the physical and virtual facilities that enable the storage, processing, and transmission of data: broadband networks, sensor networks, data platforms and data centers. For each of these types of digital infrastructure, this section illustrates current and upcoming trends captured by multiple datasets and discusses the main benefits and risks associated with their deployment in urban contexts. Drawing on our global dataset of best practices, we also identify promising approaches to better manage the opportunities and challenges posed by these infrastructures.

5.1 Broadband networks

In the context of people-centred smart cities, both fixed and mobile broadband networks are of crucial relevance to providing access to the Internet and the connectivity that underpins the delivery of digital services. A wide range of technologies are currently applied in the deployment of broadband, with optic fiber offering the best performances for fixed networks and 4G and 5G representing the latest generations of mobile communications[148].

Based on ITU's latest figures[149], 19% of the world population had a fixed broadband subscription, as of 2023, but the adoption rate varied significantly across the countries, as shown in Figure 26. In fact, the penetration of fixed broadband in Europe (36%) is twice the global average, while only 0.8% of people in Africa had a fixed broadband subscription as of 2023.

Figure 26: **Fixed broadband subscription per 100 inhabitants**



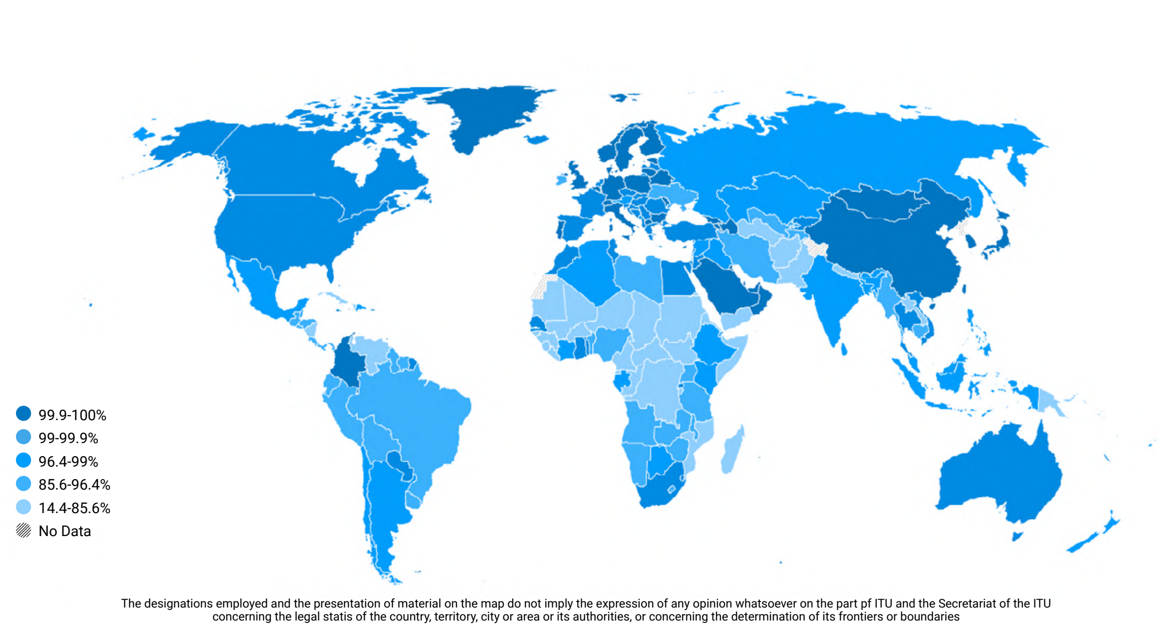
(Source: ITU, 2023)

Cross-country gaps are even broader when we only consider very –high capacity networks offering the fastest connections (above 100 Mbit/s) and relying (mostly or entirely) on optic fiber. In the EU, the overall coverage of very-high-capacity networks reached 79% in 2023, but the percentage of connected households varied from 100% in Malta to less than 38% in Greece[150]. In Latin America, five countries (Trinidad and Tobago, Chile, Uruguay, Barbados, and Brazil) had reached coverage of very high-capacity networks higher than 75%, as of 2022, while in eight states full-fiber broadband was available to less than 50% of the households[151]. In the Asia-Pacific region, Singapore and the Republic of Korea are global leaders in the diffusion of full fiber networks[152], while the availability of fixed broadband remains limited in small island developing states and South and South-West Asian countries, where only 10% of the population has fixed broadband subscriptions[153].

In addition to these regional differences, significant variations in the coverage of fixed broadband also persist between rural and urban areas within the same country or region. Detailed data on the rural-urban digital divide for fixed broadband is not available for most countries, but the latest statistics show that in the US, 17% of the rural population did not have access to a fixed broadband connection providing at least 25 Mbit/s in download[154]. In the EU, as of 2023, the coverage of very-high-capacity networks in rural areas was limited to 56% of the premises (that is, 23% below the average coverage across the 27 Member States)[155].

Overall, the data available confirms that, at the global level, the coverage of fixed broadband networks remains heterogeneous. Hence, in most countries mobile broadband is still to date the main (if not the only) source of internet access for the vast majority of the population. According to the ITU[156], mobile networks offering at least 3G were available to 95% of the global population, as of 2023. African countries were lagging behind (with a coverage of 84%), but significant differences persisted within the continent (as shown in Figure 27), with South Africa and Ghana having coverage rates higher than the global average. A wide gap can also be observed within Latin America, where Paraguay and Colombia have reached a 3G coverage close to 100%, while Venezuela (82%) and Nicaragua (85%) lag behind compared to the rest of the world.

Figure 27: Population covered by mobile networks offering at least 3G



(Source: ITU, 2023)

These regional divides are even broader when we consider the availability of 4G and 5G networks. As of 2023, 4G was available to 64% of the African population, against a global average of 90%. In the least developed countries (LDCs), the coverage was even lower and equal to 56%. Within Africa, South Africa showed coverage rates comparable to Europe, while in most countries in Central and Eastern Africa, more than 50% of the population had yet to be reached by 4G. As to 5G networks, in 2023 they were already available to 38% of the world population, but their coverage was eleven times higher in Europe (68%) compared to Africa (6%)[157]. As noted by GSMA, the uneven diffusion of these networks is broadening the quality divide between world regions, as the high-income countries are now recording average speeds that are twice those available in medium and low-income countries[158].

Beyond the coverage gaps discussed so far, GSMA has also reported that 38% of the world population with access to mobile networks have yet to adopt mobile internet, and 95% of them reside in low- and middle-income countries[159]. This usage gap is broader in Sub-Saharan Africa and Asia, where more than half of the population covered by mobile broadband is not using mobile Internet. The percentage drops to 19% in Europe and 14% in North America. Even within the same region, though, some divergences can be observed. For example, mobile Internet adoption in Southern Africa (33%) is twice the adoption rate in Central Africa (17%).

Furthermore, data from the ITU show that a rural-urban digital divide also persists with regard to the adoption of Internet connectivity. As of 2022, the use of the Internet was 1.8 higher in cities compared to rural areas, where the percentage of dwellers using the Internet remained limited to 46% (while in urban areas it totaled 82% of the population). This gap was even broader in Africa, where only 23% of the rural dwellers were online, compared to 64% of the individuals residing in urban areas[160]. With specific regard to mobile broadband, the GSMA reported that in low and middle-income countries, rural communities are 29% less likely to use mobile Internet[161].

In addition to cross-country and rural-urban divides, several sources have documented the tendency of some social groups to display lower levels of Internet usage and broadband adoption. ILO[162] and GSMA[163] have found evidence that the adoption of digital devices is lower among disabled people, and this applies to both low-income and high-income countries. UNHCR has estimated that 57% of refugees were unable to use e-learning services during the pandemic[164].

A gender digital divide has also been observed by multiple sources. As of 2023, worldwide the percentage of women using the Internet (65%) was 5% lower compared to the percentage of Internet users among the male population (70%). Such a gap, however, increased to 10% in Africa and the Arab States, while it was limited to 2% in Europe and the Americas. The gender divide in the use of the Internet was even broader in low-income countries, where only 20% of the female population was an Internet user, compared to 34% of men[165]. Additionally, according to the GSMA, across the world regions, women are 13% less likely than men to own a smartphone; in middle and low-income countries, they are 19% less likely to use mobile Internet[166]. A study by UNICEF also found that in low-income countries, as of 2021, for every 100 young men using the Internet, there were only 44 young female Internet users[167].

Contributing to these adoption gaps are multiple factors of diverse nature. Some of these reflect the uneven distribution of critical infrastructures – both digital and non-digital. Others are correlated with demographic variables that influence both the affordability of broadband access and the digital skills that individuals possess.

In addition to broadband networks, the usage of connectivity services is dependent on the availability of reliable infrastructures for the provision of electricity, which is essential for the functioning of both broadband connections and digital devices. Consequently, the poor quality of energy infrastructures has been identified as an additional cause of the rural-urban digital divide, especially in Sub-Saharan Africa, which, as of 2022, accounted for 80% of the world population without access to electricity[168]. However, interviewees from African and Asian countries also discussed how power cuts and energy blackouts affect the reliability and quality of digital infrastructures in their smart cities. Furthermore, recent research has found that the negative impact of energy poverty on Internet use is higher among middle-aged and young individuals[169].

Another major barrier to Internet usage is the affordability of digital devices and broadband connections, an issue affecting some world regions more than others. For instance, GSMA reported that in the Middle East. North Africa and Sub-Saharan Africa more than 30% of the total population cannot afford a smartphone. Likewise, the ITU[170] estimated that fixed broadband basket prices amounted to 18.5% of the gross national income per capita in LDCs, while, globally, the average ratio is 3%. For data-only mobile broadband, the incidence on the gross national income per capita reduced to 1.3% worldwide, and 6.5% in LDCs.

Finally, the limited adoption of connectivity services reflects the lack of digital skills among certain groups of users and within certain regions. Although granular data on digital literacy levels are lacking at the global level[171], recent estimates suggest a 20% gap in the percentage of the population with basic computer skills between developed and developing countries[172]. Other sources noted that even in the EU, 45% of the citizens aged between 16 and 74 years old lacked basic digital skills[173] as of 2023. The percentage rose to 72% of the population aged between 65 and 74 years old.

Indeed, age has long been identified as a major determinant of Internet adoption along with income, as older people and less affluent households are less likely to possess digital skills due to their lower levels of education[174]. A youth digital divide, however, also exists; it has been estimated that during the COVID-19 pandemic, one-third of the students across the world were excluded from remote learning because their households did not have access to the Internet or to proper digital devices[175]. The reliance of young people on smartphones has also been identified as a factor potentially affecting their digital skills and causing new digital inequalities[176].

As to the gender digital divide, the correlation with digital skills is more complex and heterogeneous. In Europe, the percentage of males and females with basic digital skills is comparable, as of 2024, but only 20% of ICT specialists are females[177]. In the Global South, the gender skills gap remains generally broader, but with significant cross-country variations. In 10 out of 12 nations covered by the Mobile Gender Gap Report[178] by GSMA, women showed lower levels of confidence in their digital skills, with a gap between males and females higher than 10% in Senegal, Bangladesh, and Pakistan. In India and Guatemala, conversely, women were more confident than men in their ability to perform digital tasks. Similarly, in the aforementioned study by UNICEF, female youth were found to have more digital skills than young males in seven countries (Tunisia, Suriname, Turks and Caicos Islands, Fiji, Tuvalu, Cuba, and Tonga), while in the other 21 low and lower-middle income countries included in their sample, male youth resulted more skilled[179].

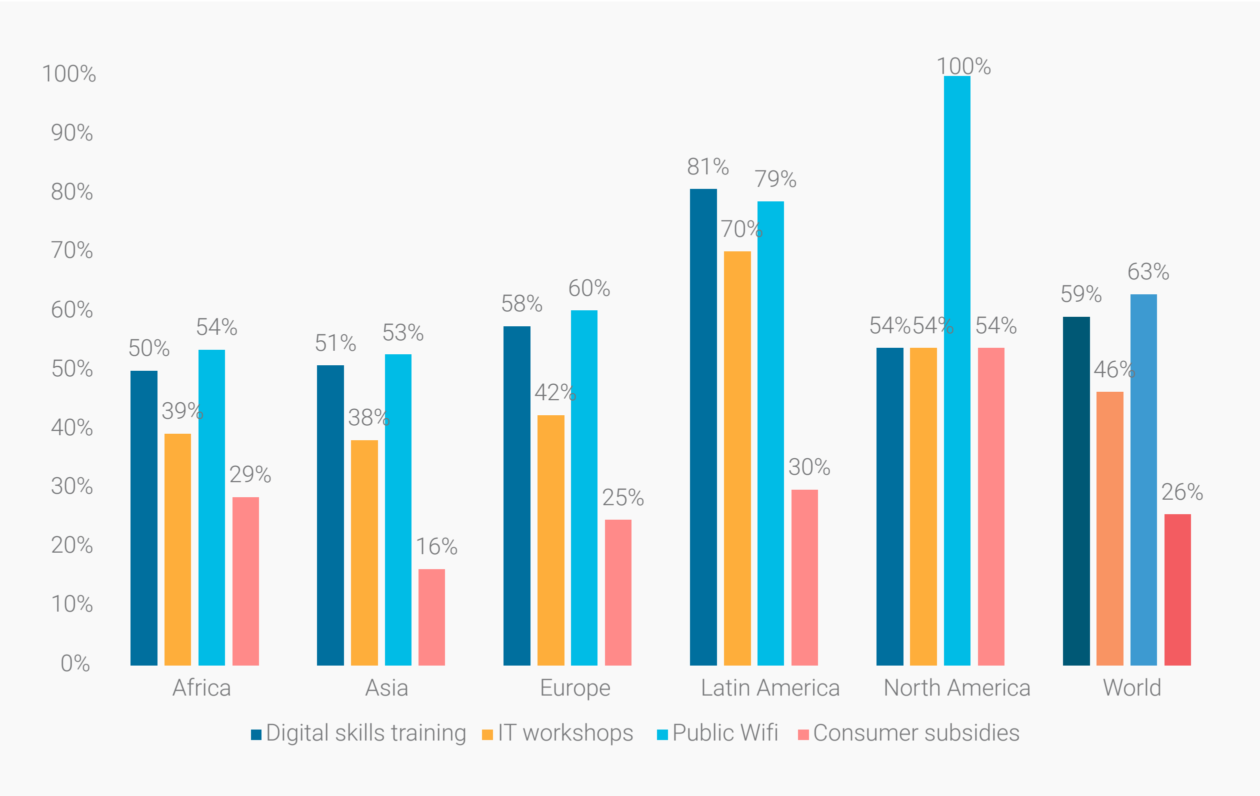
Tackling the digital divide has long been a priority for policymakers, at both local and national levels. The expansion of broadband supply has been at the core of both national and municipal interventions (as discussed in Section 2.1). Furthermore, the Global Review revealed that a variety of measures have been put in place by local governments to promote digital inclusion by addressing both affordability and skills barriers.

63% of the sampled municipalities have been offering public Wi-fi to make internet access available to residents who cannot afford their own broadband connection. As shown in Figure 28, this measure was present in 100% of the North American cities participating in the survey and 79% of the Latin American municipalities. African and Asian respondents suggested a lower rate of adoption (54%), although municipal Wi-Fi was reported as a recurring practice in South Africa, Mozambique and China. North American municipalities resulted as the most inclined to offer subsidies for devices and broadband services, a measure otherwise adopted by only 26% of the sample cities.

With regard to the promotion of digital literacy, digital skills training and IT workshops have been provided by 59% and 46% of the local governments covered in the Global Review. The proportion was higher among Latin American participants, as shown in Figure 28. At national levels, UN-DESA reported that 80% of the world nations have adopted specific measures to boost the digital literacy of vulnerable groups, although the incidence of these initiatives has been much lower in the LDCs (68%) and small island developing states (41%)[180].

As discussed in Section 4.4, civil society organizations play a vital role in promoting digital literacy in cities worldwide. Interviewees from Latin America clarified that the civil society partners supporting these efforts vary significantly, from "community associations that work on basic digital competencies" (Interview 42) to "foundations providing training on software development, robotics, and 3D printing" (Interview 5). However, from the interviews, there also emerged a clear need to get educational institutions at different levels involved in the delivery of digital literacy training. As emphasized by an expert from Nigeria, "we need to bring digital training in schools and universities, to integrate digital transformation in their curricula" (Interview 112).

Figure 28: Percentage of municipalities using alternative measures to boost the digital inclusion of their residents



(Source: Global Review, 2022)

All the public interventions in support of broadband supply and usage are justified by the significant benefits and opportunities that these infrastructures are expected to generate for both the economy and society. Recent evidence from 1,348 regions across the EU indicated that expanding the provision of broadband can accelerate annual per capita growth in both urban and rural areas[181]. Similarly, a study on 10 African countries showed that a 1% increase in ICT led inclusive growth to rise by 0.066%[182], while a 10% increase in the speed of mobile broadband was found to generate a 0.2% productivity increase in low-income countries[183]. At municipal levels, it has been estimated that broadband expansion can boost export trade (up to 19%, based on data from Chinese cities)[184], attract innovative businesses, and increase the value of properties[185].

In addition to its economic returns, it is undoubted that broadband connectivity also generates important social benefits by enabling access to the Internet and to the opportunities that digital innovation provides to both individuals and businesses. Fast broadband is nowadays vital to access educational resources, with recent studies showing that higher rates of broadband adoption correspond to better student performances, especially in low-income households belonging to ethnic minorities[186]. Access to broadband also propels digital entrepreneurship[187], which, in turn, has been found to promote female empowerment and gender inclusion[188]. Finally, broadband networks have paved the way for new modes of delivery for public services, making them more cost-efficient and accessible from remote locations[189].

However, concerns have recently been raised with regard to the environmental impact of these infrastructures as well as their security and resilience. Recent estimates suggest that broadband infrastructures can account for up to 24% of the greenhouse emissions of the ICT sector[190], although fixed networks tend to be less energy-hungry than mobile networks, which account for 60% of the energy consumed by telecommunications operators[191]. Another study, based on data from 181 countries over 18 years (2002-2020), has confirmed that the introduction of mobile broadband initially increases CO_2 emissions but, over time, its impact on the environment becomes positive. Specifically, it was found that a 10% increase in mobile broadband penetration could result in a 7% reduction of CO_2 emissions per capita, although this relationship was only significant for high-income countries[192].

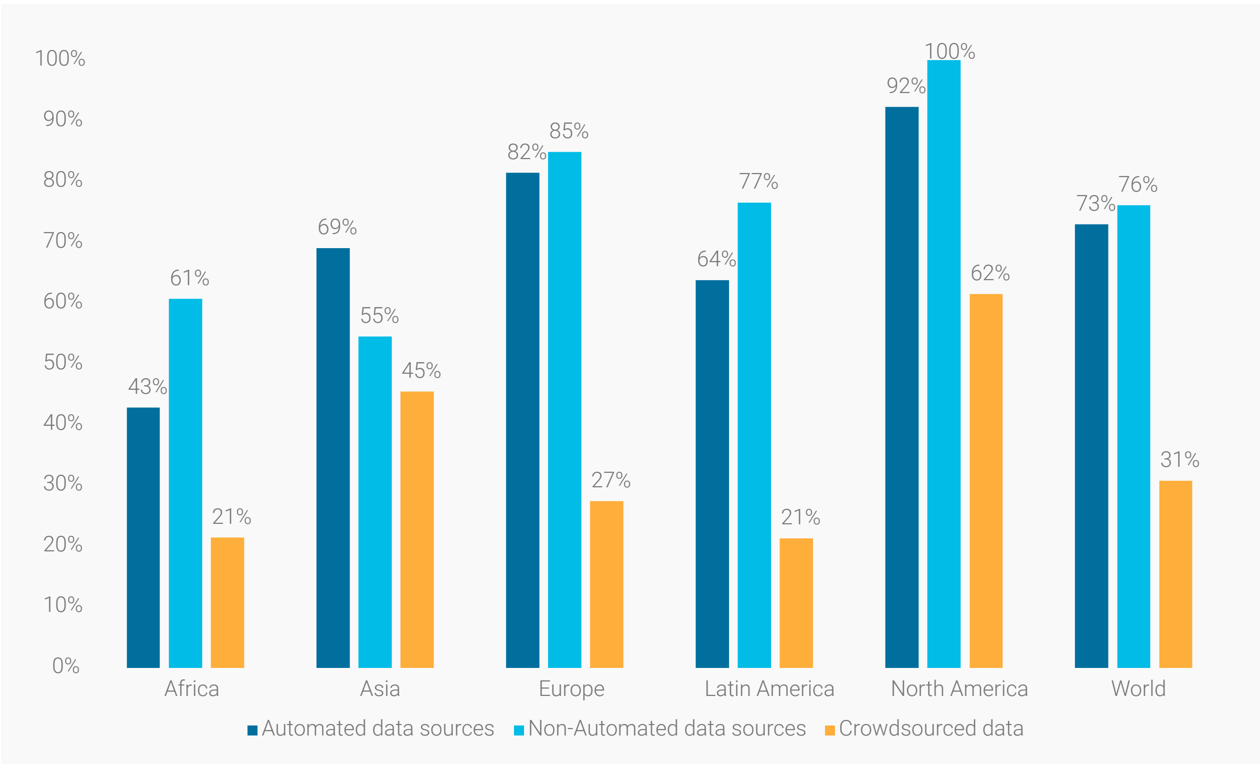
Our interviewees have also emphasized the resilience and security of broadband networks as increasingly crucial matters for the digital transformation of urban communities. With many essential services being increasingly interconnected and relying on networks potentially exposed to cyberattacks, natural disasters, and power outages, the maintenance of these infrastructures is expected to become a crucial priority and a challenge for most municipal administrations. To address these risks, local governments cannot only rely on additional technical and human resources: they also need to develop a new mindset around cybersecurity. As highlighted by a smart city expert from the UK, "cybersecurity is totally undervalued at the moment in local governments" while it should be treated as an essential requirement: "not at the end of the list, but something vital like the air that we breathe" (Interview 147).

5.2 Sensor networks

Sensor networks are digital infrastructures dedicated to real-time data collection through sensing devices. These devices capture signals from the surrounding environment and convert them into a digital format. Examples include Closed-Circuit Television (CCTV) cameras utilized for security purposes, aerials for the monitoring of weather conditions, accelerometers to measure the speed of street vehicles, and Internet-of-Things (IoT) applications deployed both in public and private space, such as smart bins, real-time trackers of public transport and streetlights controlled remotely to minimize energy consumption[193].

It has been estimated that by the end of 2024, there will be 83 billion sensing devices[194] installed globally. The Global Review clarified that these infrastructures have already been implemented in 73% of the cities included in the study, with a higher incidence in North America (92%) and Europe (82%), as shown in Figure 29. The use of automated data sources, however, was lower in Africa (43%), where it was limited to South Africa, Tunisia, and Rwanda.

Figure 29: Usage of different data sources across the world regions



(Source: Global Review, 2022)

It must be stressed that sensing devices are not the only instrument to gather data in cities. Non-automated data sources, such as surveys and censuses, play complementary roles in data collection. Indeed, the usage of these alternative data sources was more common across almost all world regions, as evidenced in Figure 29. The crowdsourcing of data, instead, emerged as a secondary practice, although its diffusion was quite prominent in North American and Asian cities, especially in China.

Compared to non-automated data sources, sensor networks have the advantage of allowing for the ongoing collection of real-time large datasets, which are expected to conduct more effective and efficient decisions in smart city contexts[195]. The interviews particularly emphasized that the implementation of sensor networks is proving helpful in tracking environmental outcomes in urban contexts, by combining data coming from multiple sources, such as outdoor systems monitoring the air quality and sensing devices tracking traffic congestions. More examples of smart city applications leveraging sensor networks to tackle environmental issues are presented in Section 6.

Furthermore, on-time data collection through sensors is enabling municipal administrations to augment their understanding and knowledge of urban areas characterized by high levels of informality, which are normally overlooked by official censuses and statistics. For instance, in eThekwini (South Africa), the municipal government is collaborating with the United Nations Innovation Technology Accelerator for Cities (UNITAC) to develop a machine-learning application using data from on-ground monitors, satellite images, and aerial photographs to complement census information on informal settlements[196].

Nonetheless, both the academic literature and the experience of local and national smart city experts confirm that deploying and managing sensor networks entail several significant challenges, concerning both the maintenance of the sensing devices and the governance of the data collected by them. The economic and environmental sustainability of these infrastructures has also been questioned, along with the social, political, and ethical implications related to their installation in public spaces[197].

From the interviews, it emerged that the costs of operating and maintaining sensors in smart cities can quickly escalate, possibly outweighing their benefits. Empirical studies from the railway and automotive sectors further support this trend, highlighting that the installation and maintenance costs of sensors can drastically reduce their convenience compared to conventional manual inspections[198] and alternative data sources[199]. Additionally, the interviewees noted that exposure of sensors to external agents and variable weather conditions can significantly increase their fault rate, suggesting the necessity for frequent replacements.

The short lifecycle of sensing devices has raised concerns about their environmental impact. Whereas specific data on the e-waste associated with sensor networks are not available, these devices and infrastructures contribute to the e-waste produced by small telecommunications equipment, which amounted to 5 megatons in 2022 according to the latest Global E-waste Monitor[200]. Most of this waste is informally disposed of and illegally dumped in developing countries: the European Environment Agency has estimated that 60% of the e-waste generated in Europe does not get collected or recycled, and 15% of it is exported, mostly to West Africa and Asia[201]. Furthermore, the diffusion of sensor networks is contributing to the growing demand for lithium and other rare earth minerals, whose mining is causing conspicuous environmental damage in low-income countries[202]. Finally, the excessive energy consumption of sensor networks has also been highlighted by interviewees and scholars[203].

To mitigate the mentioned challenges, national institutions are adopting regulations on e-waste and the reuse of critical raw materials (see Section 2.5), while technology suppliers and researchers are developing protocols and algorithms that maximize the energy efficiency of sensing devices[204]. Likewise, much emphasis is being placed on developing standards for interoperable sensor networks[205], which could boost their sustainability as well as their security[206]. The latter is another major preoccupation in the context of people-centred smart cities. As sensors are often connected with strategic infrastructures, such as power grids and water mains, their security is of paramount importance to prevent cyberattacks that could impinge on the safety and delivery of critical public services[207].

Enforcing cybersecurity is also crucial to protect the data of citizens and other urban actors from malicious attacks aimed at unlawfully acquiring sensitive information from sensor networks[208]. This echoes broader concerns about the privacy impacts of these infrastructures. The proliferation of sensing devices in urban spaces has been criticized for favoring the excessive surveillance of citizens and for enabling commercial suppliers to control large volumes of personal data[209]. A recent study confirmed that privacy concerns around the use of IoT applications have a direct impact on the acceptance and adoption of smart city services[210]. The Sidewalk Toronto project in Canada further exemplifies how the adversity of local communities towards pervasive sensing technologies can lead to the failure of smart city projects[211].

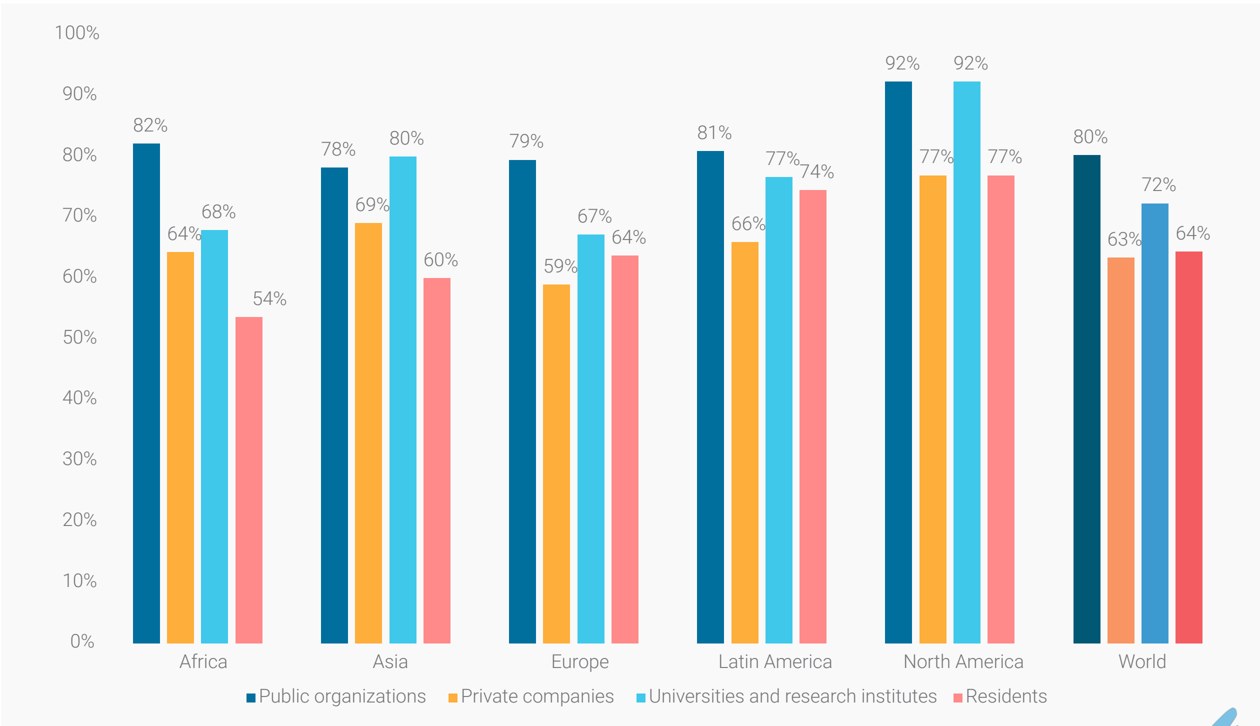
To enhance the security and privacy of their sensor networks, municipal governments are cooperating with technology suppliers and academic institutions to develop resilient and privacy-safe devices and infrastructures. These technological developments, however, may not be sufficient to counteract the public's negative perception of sensing devices. As emphasized by a national expert from the US, it is crucial to find "a more holistic view of the responsibilities around these technologies and how they are governed, to determine what happens if someone, either legally or illegally, gets access or controls over sensor networks" (Interview 154). This reiterates the importance of specific policies and regulations to enforce data protection and protect human rights in digital spaces (discussed in further detail in Sections 2.3 and 2.4).

Data from ITU, indeed, confirms that the regulation of sensor networks is still in its infancy. As of 2024, only 12 countries have adopted specific regulatory frameworks for IoT, but 20% of the world nations are undertaking policy reviews on this matter[212]. Local governments in Europe and North America are addressing these policy voids by defining their own policy guidelines and local regulations for the governance of these infrastructures. For instance, in Portland (US), the municipal government has adopted a set of privacy and information protection principles to norm the collection, analysis, and use of data[213]. Local communities were also consulted through a series of public engagement events to develop a citywide policy on surveillance technologies[214]. In Amsterdam, instead, the municipal administration has created an online map[215] reporting the position, ownership, and usage of all sensors installed by public and private entities. The creation of a national sensor registry has also been endorsed by Dutch researchers and professionals, as a tool to keep track of the proliferation of sensing devices in public spaces and encourage the participation of residents in the governance of these infrastructures[216].

5.3 Data platforms

Within people-centred smart cities, municipal governments are called to collect, govern and analyze diverse types of data sourced from multiple actors. Data platforms encompass all the physical (such as data centers and servers) and virtual infrastructures (such as cloud services, data lakes, and data warehouses) enabling the storage, integration and maintenance of multiple datasets, whose analysis is expected to enhance decision-making processes at the local level. Indeed, both the Global Review and the ***UN-DESA e-government Survey*** reported that 80% of the cities were using data to inform decision-making, as of 2022, with the first shedding light also on the type of data local governments rely on. National governments and universities have been cited among the data sources for smart city projects by 80% and 72% of the sampled municipalities, respectively, with no significant differences across the world regions. As shown in Figure 30, the use of data from private companies and residents was less common but still a widespread practice occurring in 63% of the sampled municipalities (with Europe lagging behind the other regions). Data from residents were also utilized by 64% of the municipalities partaking in the Global Review, with a higher incidence in Latin and North America.

Figure 30: Reliance of municipalities on data from alternative partners



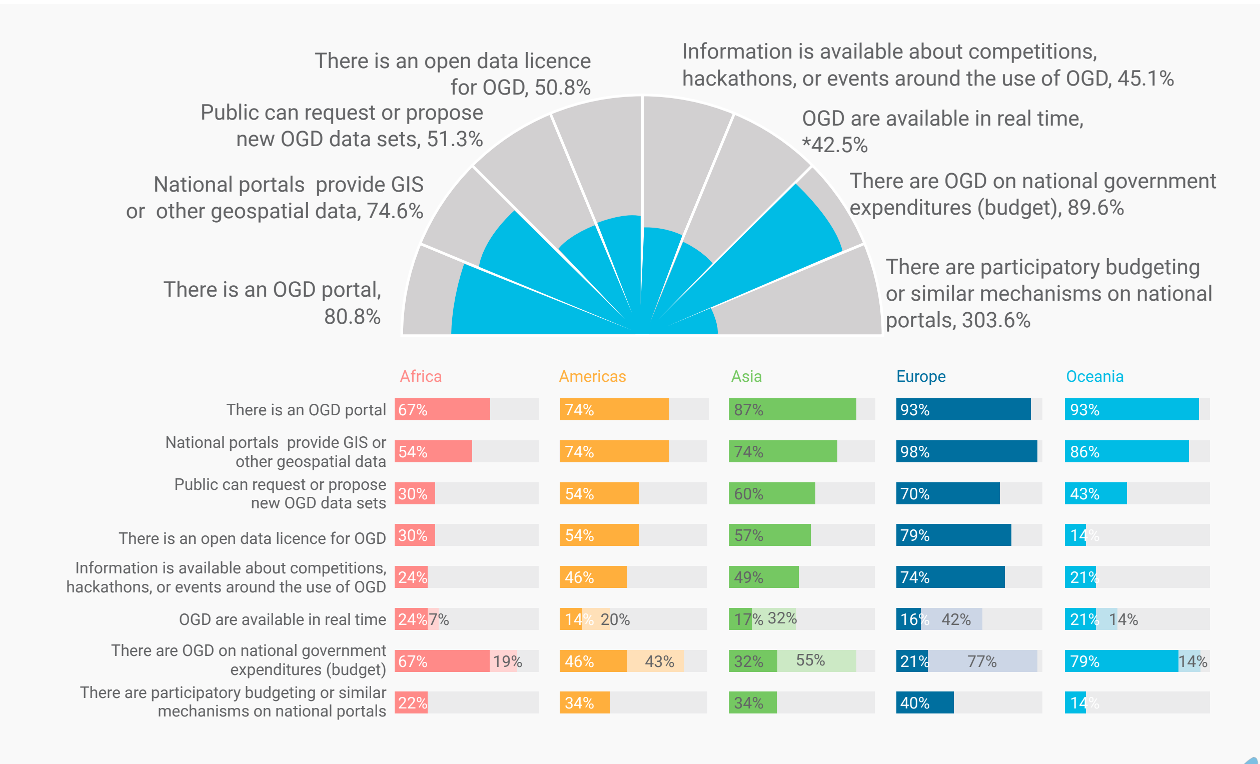
(Source: Global Review, 2022)

The interviewees agreed that managing and integrating data platforms can prove challenging, especially due to the limited diffusion of data standards, the lack of holistic regulations on data governance (as discussed in Section 2.3), and the persistence of a siloed approach to data storage within the public sector. Within municipal administrations, it is not rare to find units and departments employing data platforms that are neither interoperable nor integrated. Likewise, public organizations at different administrative levels tend to use data standards and platforms that are not interoperable. These behaviors undermine the potential of big data in cities, stifling synergies in both data analytics and data visualization. Consequently, "the majority of the data that is collected in smart cities is not being used" (Interview 76), as remarked by a smart city expert from Germany.

Municipalities adopting a single dashboard for the visualization of data are a minority (only 16% within the sample). Even smaller municipalities reported the co-existence of multiple dashboards and data visualization tools. More common appeared the use of open data platforms, which was reported by 57% of the participants, although, with a lower incidence in Africa (32%) and Asia (44%). On the same matter, less optimistic figures resulted from the ***UN-DESA e-government survey***, according to which open government data sharing is implemented in 37% of the municipalities responding to their questionnaire, as of 2024.

However, 81% of countries also had an open government data portal. As shown in Figure 31, nationwide open data initiatives are more common in Europe and Oceania. Worldwide, most of these portals offer open data on national government expenditures and geospatial data, while only a minority offer participatory budgeting features or other mechanisms for residents' engagement.

Figure 31: Percentages of countries with open government data portals and various aspects of open data governance



(Source: UN-DESA, 2024)

The interviews shared some examples of how open data are being leveraged locally to inform new academic research (as reported by smart city experts in Teheran, Iran, and Porto, Portugal) and improve city operations, especially in relation to mobility services (such as in the case of Milton Keynes, UK). Nonetheless, the interviewees also highlighted that the effectiveness of open data initiatives is undermined by the persistence of data silos in the public sector as well as the reluctance of other smart city partners to open their data. Regulatory voids regarding data governance (previously highlighted in Section 2.4) further inhibit the use and potential application of open data. As explained by a municipal leader from Switzerland, "we are not in the Open Data business because we do not have a clear vision of what can be effectively shared in terms of security, infrastructure risk and the protection of personal data of residents or others" (Interview 139).

Additionally, the interviews stressed the importance of the quality and reliability of the public datasets underpinning people-centred smart city applications. Continuous engagement with local communities has been advocated for to ensure that the data possessed and shared through data platforms are up-to-date and representative of the actual population. This is to prevent incomplete and inaccurate data from eventually reinforcing existing biases in decision-making processes and undermining the inclusivity and equity of people-centred smart cities[217].

In this context, promoting data literacy and data analytics becomes crucial to leverage the potential of big data in cities while safeguarding the privacy of residents and enforcing the security of data platforms. As noted in Section 3 and Section 4, digital literacy is underdeveloped both within the public sector and among the general population. Studies have warned that, without advanced data analytics skills, neither civil servants nor citizens can take full advantage of the benefits of open data platforms, particularly undermining their potential application for the monitoring of urban projects[218] and the launch of data-driven entrepreneurial ventures[219]. Specific attention, however, must also be paid to the design of data visualization tools. Municipal governments should ensure that their dashboards and data portals are user-friendly and accessible to all urban stakeholders.

A final matter to be further considered is the environmental impact of data platforms. Whereas the shift towards cloud computing has enhanced the energy efficiency of data storage[220]; the land, energy, and water consumption of data centers has recently raised significant concerns[221]. The continuous expansion of big data, further boosted by the diffusion of AI, is requiring the construction of a growing number of data centers, especially in rural areas, which have considerable impacts on the local landscape and the consumption of land[222]. In addition, these facilities require vast quantities of water for air-conditioning (up to 1.5 billion liters per day, according to US-based estimates[223]), which is causing extra stress on the water supply of the communities hosting these facilities.

Overall, the International Energy Agency (IEA) has estimated that data centers account for about 1-1.5% of global electricity use and are responsible for 1% of greenhouse gas emissions[224]. The environmental impact of these infrastructures, however, is not homogeneous across different countries and is expected to grow exponentially. Within Europe, it has been noted that data centers account for 1.8-2.6% of the overall energy consumption, but this percentage rises to 5% in the Netherlands and 19% in Ireland[225]. TThe interviewees, instead, emphasized that the energy consumption of data centers and digital infrastructures, in general, put additional stress on energy infrastructures, with the risk of undermining the stability, resilience, and security of both power provision and digital services.

To address these issues, specific regulatory interventions are being adopted nationally and internationally, as discussed in Section 2.5. Additionally, at the municipal level, the creation of clean energy zones has been proposed as a solution to mitigate the environmental impact of data centers by limiting their installation in urban areas purposely planned to ensure access to cost-effective renewable energy[226].

SECTION 6. Smart city applications for public services

This section examines how smart applications can enhance urban services and address challenges across nine key public domains: urban and spatial planning, housing, mobility, energy, water management, waste management, prevention and management of natural disasters, safety and security, and welfare. Based on the evidence available from primary and secondary data sources, it offers a comprehensive assessment of the benefits, risks, and impacts of these services and applications, focusing on how they contribute to boosting the quality of life and sustainability of urban areas globally.

Across the above-mentioned domains, a wide array of technological and non-technological innovations are complementing traditional modes of public service delivery. These solutions often combine digital technologies with participatory approaches to harness data effectively and foster inclusive, collaborative practices in urban governance.

Current findings indicate that these innovations enhance both predictive and corrective interventions across different urban sectors. However, concerns about the data privacy, security, and affordability of smart city applications are frequently highlighted, alongside an uneven distribution of these services across regions. Additionally, assessing the long-term impacts of these solutions remains challenging, as many implementations are still limited to small-scale projects and localized trials.

The analysis suggests that the success of smart applications for city services hinges on both technical capabilities and local socio-economic and cultural contexts. This reiterates the importance of involving local communities in the design and governance of smart city services, to improve their outcomes, mitigate their risks and establish public trust which is essential for the broader adoption of these technologies.

Major challenges

- The environmental and social impacts of smart city applications remain unclear, requiring more in-depth assessment.
- Without careful design and implementation, these technologies risk amplifying existing inequalities.
- Municipalities and their partners struggle to develop sustainable and scalable business models for people-centred smart city applications.
- Fragmented pilots and experiments lead to duplications and hinder scalability.
- Siloed approaches across urban services and a lack of integration in digital governance knowledge hinder cohesive development.

Key priorities

- Develop robust frameworks to evaluate the social, environmental, and economic impacts of people-centred smart city services.
- Implement regulatory standards to guide the responsible planning and deployment of new technologies in cities.
- Nurture collaborative partnerships enabling cities to co-create adaptable urban solutions across different services.
- Reinforce global knowledge-sharing platforms by leveraging expertise and know-how gained through local pilots and experiments.

This section examines smart applications implemented in nine urban sectors: urban and spatial planning, housing, mobility, energy, water management, waste management, prevention and management of natural disasters, safety and security, and welfare. These sectors were selected based on their responsiveness to both current and anticipated urban challenges, where innovations—both technological and non-technological—are having a meaningful impact[227]. For each sector, the analysis explores the innovative applications most commonly adopted in people-centred smart cities, as well as those demonstrating significant growth potential. Drawing on a comprehensive dataset of best practices and case studies (listed in Annex 3) this review presents evidence of both positive and negative impacts. Where available, it also identifies regional differences in the adoption of these applications, along with the primary drivers and barriers to their broader implementation.

SECTOR-SPECIFIC USE OF SMART CITY APPLICATIONS

Urban Planning: Growth in GIS tools and digital twins; high adoption in North America, Asia-Pacific, and Europe

Housing: 3D printing and digital twins reduce costs and environmental impact

Mobility: LEVs make up 18% of vehicle sales in 2023 (60% in China); shared mobility services projected to reach 7% of urban transport mix by 2030

Energy: 100+ cities generate 70% of electricity from renewables; Europe leads in solar and wind energy

Water Management: Smart meters reduce leakages; Water ATMs expand access in the Global South

Waste Management: Smart bins reduce pickups by 80%; urban mining and circular economy practices gaining traction

Disaster Management: AI for prediction and response; drones aid in damage assessment

Safety: along with CCTVs, crowdsourced maps and smartphone apps are being developed to tackle gender-based violence

Welfare: E-learning and e-health expanding; 38% e-learning adoption in China

6.1 Urban and spatial planning

Urban and spatial planning shapes how cities function and has been acknowledged as playing a key role in the sustainable development of metropolitan areas[228]. Its formulation is becoming even more critical in the context of vast urbanization, as 68% of the world's population is expected to live in cities by 2050[229]. As a result, urban areas are increasingly exposed to several environmental and societal pressures, such as peri-urbanization[230], the growth of informal settlements[231], and the consequences of climate change[232].

Despite its significance, urban and spatial planning expertise remains limited in many regions: in African countries, there is less than one accredited planner per 100,000 people[233]. Innovative approaches are, thus, being utilized and experimented with worldwide to support and complement the work of urban planners, as outlined in Figure 32.

Figure 32: **Innovative approaches to urban and spatial planning**

Public Participation Geographic Information Systems tool (PPGIS) is among these innovative approaches, specifically applied to enhance public engagement in planning processes by combining geographic information systems (GIS) with participatory methods[234]. Spatial Group Model Building (SGMB) also leverages GIS so that different stakeholders can communicate and work directly on physical maps for model development[235]. This makes SGMB particularly promising for tackling challenges associated with peri-urbanization by developing solutions at urban-rural interfaces. For instance, in Bihar (India), participatory GIS tools enabled farmers and traders to visualize market locations and transport routes, leading to an improvement in their decision-making processes[236] (Case 1).

Compared to traditional tools (e.g. public hearings and written statements), PPGIS and SGMB facilitate citizens' engagement across various scales and planning phases[237] and foster a more inclusive design of urban spaces[238]. Its impacts on urban planning outcomes, however, remain in question as their implementation is still affected by the barriers to public engagement already discussed in relation to other participatory tools (Section 1.2 and Section 4.3), the lack of well-established data governance practices and the unavailability of participatory GIS tools at various locations, as evidenced by the experience of six Indonesian cities (see Case 2)[239]. Whereas the data on the global diffusion of PPGIS and SGMB remain limited, recent estimates suggest that the global market of GIS tools, valued at approximately USD 11 billion in 2023, will double by 2032[240]. North America, Asia-Pacific, and Europe are currently the most mature markets for these services[241], but the Asia-Pacific region is expected to have the most rapid growth in the next decade.

Other technologies that have shown potential in enhancing urban and spatial planning are digital twins and very –high resolution (VHR) satellite images. The former creates a virtual representation of physical systems using IoT, extended reality, and AI[242]. They have been endorsed by researchers, practitioners, and policymakers as promising tools to optimize urban planning by leveraging real-time data and advanced analytics for the comparison and assessment of alternative simulations of real-life scenarios[243,244]. Their potential is being currently explored by many public administrations, such as the government of Bavaria (Germany), which has developed a guidance framework to help municipal administrations apply digital twins in the planning of several infrastructural interventions, from energy efficiency to flood prevention (Case 3). The implementation of digital twins, however, poses some challenges concerning data governance and analytics, as further detailed in Section 6.2.

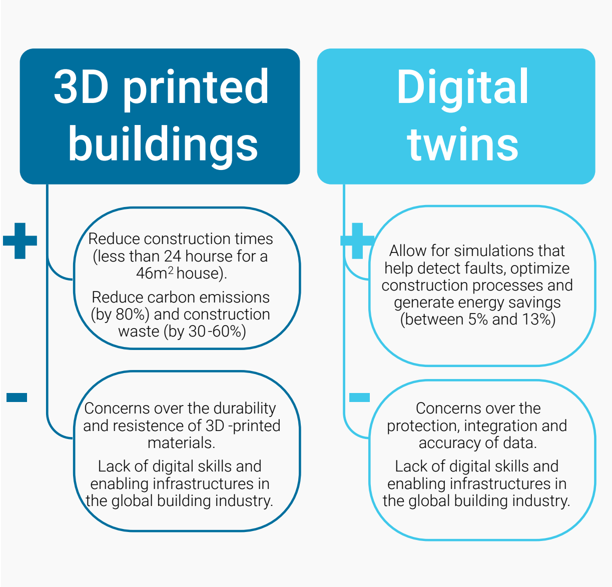
As to VHR satellite images, they have proved to enhance spatial planning by improving the mapping of informal settlements, which currently host around a billion urban residents worldwide (with Asia and Sub-Saharan Africa harboring 80% of these dwellings)[245]. Satellite images are enhancing their detection and tracking, thereby paving the way for targeted urban planning interventions[246]. For instance, in Badoa (Somalia), the data from VHR images and on-field surveys have allowed the creation of a local cadaster, which is, in turn, helping enhance tax collection for the delivery of new urban services[247]. Overall, though, the application of this technology remains limited due to the high costs of acquiring and storing VHR satellite images. To address this challenge, open data from volunteer geographic information (such as crowdsourced maps or user-generated geo-referenced data) have emerged as a valid, complementary source to boost the accuracy and quality of slum detections[248].

6.2 Housing

With the ongoing urbanization trends, an estimated 3 billion people may require decent and affordable housing by 2030, exacerbating the existing housing deficit[249]. This crisis affects both developing nations and developed countries, where housing prices vastly exceed the median family income[250]. Furthermore, environmental regulations are adding further pressure on the construction industry in an attempt to curb its significant impacts on CO_2 emissions, land use, and waste production[251]. In this scenario, technological innovation has become a necessity to boost both the productivity and the sustainability of construction companies. 3D printing and digital twins, in particular, have emerged as the most promising applications to deliver affordable housing solutions while mitigating environmental harm[252].

3D printing technology (3DP), initially used for prototyping, is now being utilized to construct entire buildings. As outlined in Figure 33, the application of this technology offers multiple benefits. Not only does 3DP increase productivity by shortening construction time[253] and lowering costs[254] but it also enables complex designs that are impractical for traditional methods and offers tailored housing solutions. For example, in Nacajuca (Mexico), non-profit organizations and companies used 3DP to build 500 earthquake-resistant houses in a region with high seismic risk and half of the population living below the poverty line[255] (see Case 5). Additionally, 3DP promotes sustainability, with 3D-printed polymers reducing carbon emissions by 80% compared to common types of cement[256] and cutting construction waste by 30-60%[257].

Figure 33: Benefits and shortcomings of 3D printing and digital twins applied to the construction industry



As to digital twins, it has been estimated that 57% of real estate firms globally were already adopting these solutions by 2023, with 15% of them using it operationally, 22% in the early planning stages, and 30% in the piloting phase[258]. As summarized in Figure 33, digital twins have proved to optimize construction processes by reducing waste, generating cost savings and improving decision-making[259]. Their application can also lead to energy efficiency improvements[260], as seen in the *+CityxChange project* in Limerick, Ireland (refer to Annex 3, Case 6), where digital twins were used to analyze the environmental footprint of the Georgian Innovation District, resulting in energy savings comprised between 5 and 13%[261]. Additionally, digital twins can be leveraged to improve the design and resistance of 3D-printed houses, preventing faults in the construction process[262].

Despite their advantages, both 3DP and digital twins face several adoption challenges. For 3DP, these include outdated regulations[263] and limited compatible materials[264]. Exemplary is the experience of Muscatine (US), where 3D-printed houses were demolished due to concerns over the resistance and durability of the concrete utilized in the building processes[265]. Digital twins, instead, face issues with data integration, accuracy, security, and privacy[266,267], which may eventually hinder their application on a large scale.

For both technologies, ongoing digital divides represent a major obstacle to their diffusion and implementation worldwide. On the one hand, the global construction industry is facing a widespread shortage of digital skills, which is even more difficult to bridge because of its high turnover rates[268]. On the other hand, urban communities in low-income countries may particularly struggle to take advantage of both 3D printing and digital twins because of the high costs of these technologies and gaps in the availability of the digital infrastructures supporting their implementation[269].

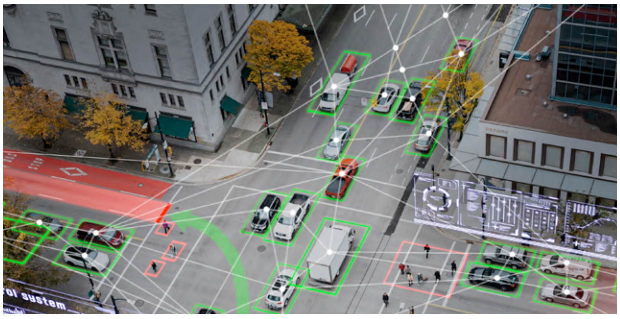
6.3 Mobility

Improving urban mobility is a key priority to create environmentally sustainable and socially equitable cities[270]. Transportation is the second sector after electricity and heat to contribute the most to greenhouse gas emissions, responsible for approximately 23% of greenhouse gas emissions from fuel combustion[271] and 28% of energy consumption[272]. Cities worldwide are also coping with growing levels of air and noise pollution due to traffic congestion[273], especially in emerging economies with a rising number of private vehicles. Globally, the number of cars is set to double to 2 billion by 2040[274]. On the other hand, the increasing demand for mobility, fueled by rising urban populations, has made it difficult for public authorities to optimize urban transportation systems[275].

To address these challenges, local, regional and national governments have experimented with a wide array of technological innovations to promote greener and smarter mobility services. These include real-time traffic management systems, low-emission vehicles, mobility-as-a-service, shared mobility, and active mobility programs.

Real-time traffic management systems have long been used by local authorities worldwide to monitor and control traffic flows and prevent road congestion. Relying on sensor networks, these systems continuously gather data on traffic conditions, including vehicle speeds, congestion levels, and traffic volumes. This data can then be used to optimize traffic flows, especially during peak hours, by dynamically adjusting signal timings and the duration of traffic lights.

The experience of the ***Barcelona Urban Lab*** (Spain) shows that smart management systems can reduce traffic jams by 30% and increase the efficiency of public transportation by 15%[276] (refer to Annex 3, Case 4). Similarly, in several Indian cities like Greater Hyderabad and Warangal, the setting up of an Adaptive Traffic Signal Control system, which adjusts signal timings in real-time based on traffic density, has reduced congestion with a 15% increase in travel speed[277]. However, the benefits of real-time traffic management can go beyond improved traffic control: they also encompass improvements in the urban economy and a reduction of the environmental impacts of cities[278]. The ***Automated Traffic Surveillance and Control System*** implemented in Los Angeles (US) has contributed to reducing fuel consumption by 12.5% and air emissions by 10%[279] (refer to Annex 3, Case 7).

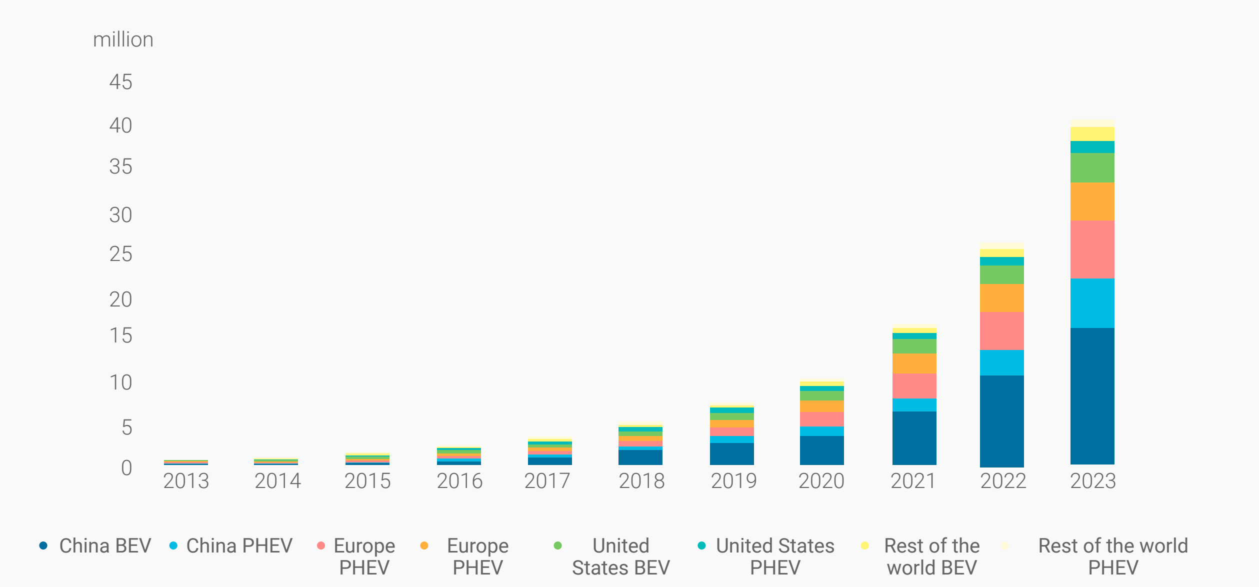


A successful adoption of traffic management systems, however, requires addressing various challenges, including high implementation costs, reliability issues, and privacy concerns[280]. Particularly in lower-income countries, the effective implementation of traffic management solutions is hindered by the high costs associated with these systems, inadequate infrastructures, and a lack of governmental coordination. To address these hurdles, prioritizing public transport has emerged as the most feasible, cost-effective, and sustainable approach to real-time traffic management[281], as exemplified by the ***Amman Bus project*** launched in 2019 in Amman (Jordan). AI technology and real-time data have been integrated into a smartphone app that allows public transportation users across the Greater Amman Area to locate nearby stops, identify the quickest routes, and settle their fares online before boarding[282] (refer to Annex 3, Case 8).

To directly curb CO_2 emissions and air pollution, both local and national governments are also gradually pushing for the replacement of public and private vehicles with Low-Emission Vehicles (LEVs), such as biofuels, hybrids, and electric vehicles. Despite variations, LEVs generally emit fewer pollutants than conventional vehicles, with electric vehicles (EVs) like electric buses, cars, and scooters, notably producing zero direct emissions. Furthermore, LEVs contribute to reducing noise pollution and promote energy security (by lessening reliance on volatile fossil fuels[283]).

Despite their promising effects, the penetration of LEVs remains limited worldwide, as shown in Figure 34. The IEA reported that 18% of all vehicles purchased in 2023 were electric cars (up from 14% in 2022) but the vast majority of these were sold in China (60%), Europe (25%), and the US (10%)[284]. Nonetheless, based on current policy orientations, IEA estimated that the sales of LEVs will reach 55% of total car sales worldwide. Many countries, such as the Dominican Republic, Rwanda and Pakistan, are also incentivizing the electrification of two and three-wheelers: according to IEA, electric two- and three-wheelers could account for 60 to 75% of global sales by 2035[285].

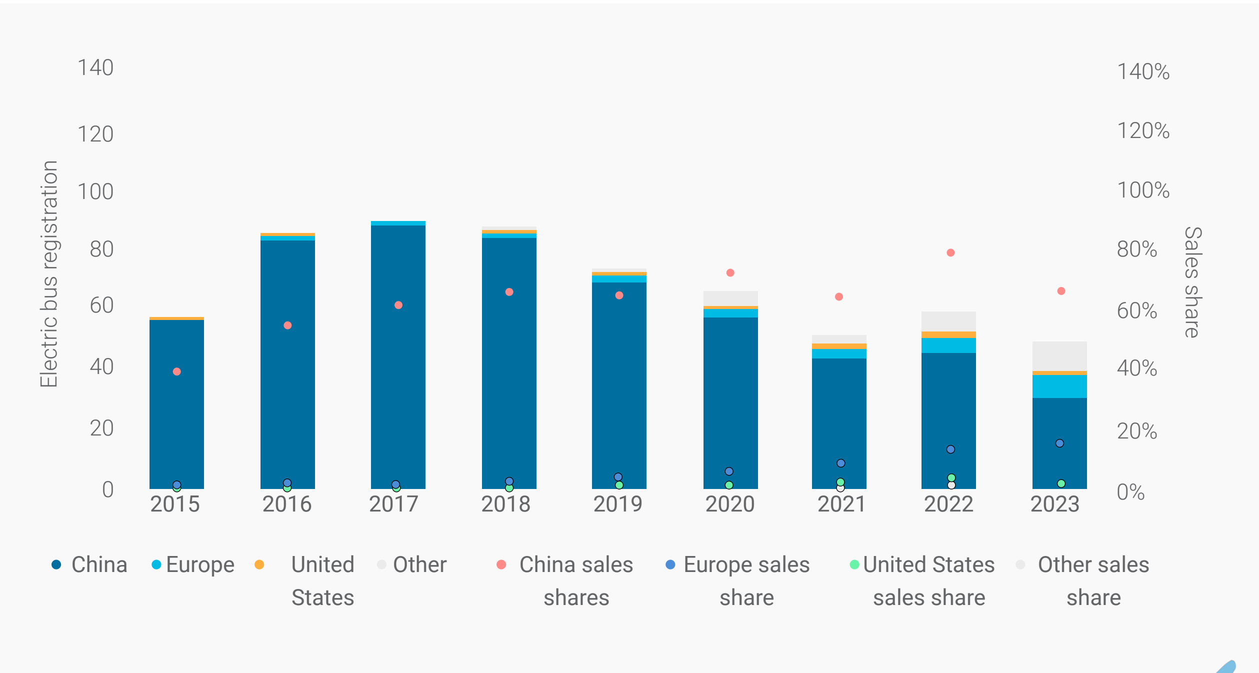
Figure 34: Global electric car stock (2013-2023)



(Source: IEA, 2023)

Likewise, the diffusion of electric buses remains predominantly circumscribed but is projected to grow globally. As of 2023, as shown in Figure 35, China accounted for 50% of the global sales of electric buses, followed by Europe (13%)[286]. Within Europe, however, some significant differences could be observed, with Belgium, Norway, and Switzerland reaching a sales share of electric buses above 50%. In the Global South, the adoption of electric buses is being driven by large capital cities (such as Dakar, Bogota and Santiago) that have recently invested to electrify their bus fleets. National governments – for instance, in Ecuador, Nepal and the Solomon Islands – have also launched specific policies to decarbonize their public transportation systems. Based on current trends, IEA estimated that by 2035 electric buses will represent 30% of the buses sold globally[287].

Figure 35: Electric bus registrations and sales share by region



(Source: IEA, 2024)

One of the major obstacles to EV adoption is the lack of adequate infrastructure for the recharging of these vehicles, especially in densely populated cities where access to private charging points is usually more limited. To address this challenge, municipalities worldwide are actively supporting the rollout of public charging points, which represented 90% of the EV charging points installed globally, as of 2023[288]. Furthermore, local administrations have leveraged digital technologies to optimize the usage of power grids for recharging EVs, as experimented in Kyoto (Japan), where the ***EV Charging Management Centre*** has been using real-time data to minimize grid congestions and improve the experience of EV drivers (refer to Annex 3, Case 9).

Other strategies implemented locally to sustain the LEV market growth include the integration of these vehicles into urban logistics systems and the creation of low-emission zones (LEZs). The first approach consists of combining electric trucks and electric cargo bikes to reduce the pollution and traffic congestion deriving from freight transport. An initiative successfully conducted in Bogota (Colombia) exemplifies this approach, where solar-powered e-bikes have been deployed for last-mile deliveries, contributing to minimizing CO_2 emissions (refer to Annex 3, Case 10). Overall, it has been estimated that cargo bikes and electric bicycles can contribute to cutting CO_2 emissions by 71%[289]. Likewise, LEZs also have a direct impact on the air quality of metropolitan areas: in London (UK), they have been found to curb the emission of air pollutants by 12%[290] from 2008 to 2019, with a potential reduction of up to 40%[291].

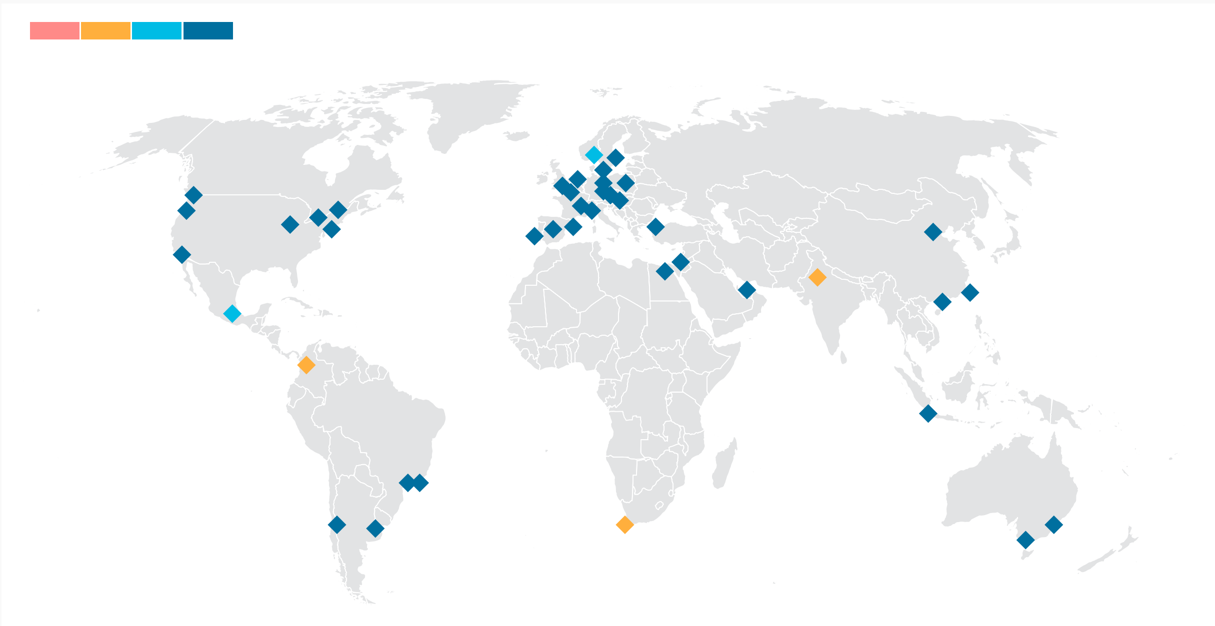
Nonetheless, when assessing the lifecycle environmental impact of LEVs and associated measures, it is crucial to remember that these vehicles are among the major ones responsible for the increasing consumption of rare earth minerals, such as lithium and cobalt, whose mining is causing severe environmental damage in several low-income countries[292]. Additionally, battery recycling, particularly for lithium-ion batteries, is emerging as a critical challenge as improper disposal poses significant environmental hazards[293] and can cause both water and land pollution[294]. Localizing the production of LEVs could be an answer to these environmental concerns, as demonstrated by the ***Net Zero Accra*** project in Ghana (refer to Annex 3, Case 11), which promoted the local manufacturing of electric cargo bikes, using recycled materials.

The complex and ambiguous impacts of LEVs have urged municipal leaders to also experiment with mobility-as-a-service (MaaS) and shared mobility, two innovative paradigms for urban mobility that could potentially lead to a reduction in the total number of private vehicles circulating in cities. MaaS has become a widespread tool to incentivize the use of public transportation by integrating multiple transport options into a single platform, serving as a unique access point to collect information and pay for intermodal mobility services[295]. Shared mobility, instead, proposes to downsize the reliance of urban residents on privately owned vehicles by giving them access to shared vehicles that can be easily rented through a smartphone app.

The latest evidence shows that the diffusion of both innovations is not homogeneous across the world regions. Most MaaS pilot projects and schemes have so far taken place in Europe[296], where the success of MaaS has been driven by the presence of supportive regulations, and strong public-private partnerships[297]. In contrast, in North America, the large-scale adoption of Maas has been hindered by the dominance of private cars, combined with fragmented public transit and limited political support[298]. In the other world regions, MaaS is gradually gaining attention after a slow take-up, with an emphasis on revisiting its core characteristics to better adapt to local contexts[299], for example by exploring alternative offline access methods or utilizing a low-tech approach that minimizes the need for platform integrators[300].

As to shared mobility, a report by the International Association of Public Transport (IAPT) focusing on 46 metropolitan areas across five continents (see Figure 36), noted that bike-sharing is the most common among these services (available in 43 cities), followed by shared e-scoters (39), car-sharing (38)[301], and shared mopeds (15). Within their sample, Casablanca (Morocco), Johannesburg (South Africa) and Bangalore (India) were the only global cities lacking any shared mobility offering, while 13 of them were offering all four services (Beijing, China; Berlin, Germany; Brussels, Belgium; Budapest, Hungary; Istanbul, Türkiye; London, UK; Madrid, Spain; Milan, Italy; New York, US; Prague, Czech Republic; Sao Paulo, Brazil; Taipei, Taiwan; and Wien, Austria). Overall, shared mobility is projected to account for 7% of the urban transport mix by 2030 (from 3% in 2023), while the weight of personal vehicles is expected to decrease from 54 to 28%[302].

Figure 36: Diffusion of shared mobility services



(Source: IAPT, 2022).

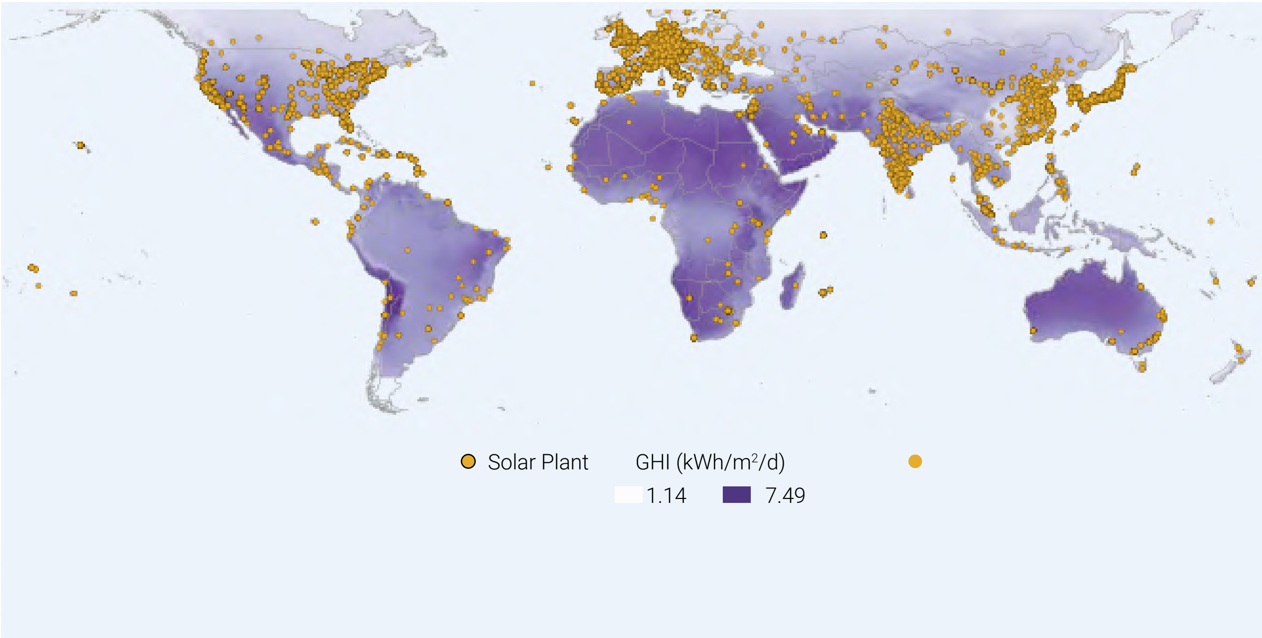
It must be noted that, based on a recent literature review, the environmental outcomes of shared mobility remain ambiguous[303]. Whereas car-sharing has been found to produce less CO_2 emissions and air pollutants when compared to private cars, its overall impact may turn negative, if the availability of shared cars disincentivizes the utilization of public transport and active modes of traveling. The lifecycle emissions of bike-sharing are even higher than those produced by private bikes, because of the CO_2 associated with the smartphone applications, sensors, and docking stations enabling shared bike use[304]. Furthermore, the economic sustainability of shared mobility has raised concerns, as both public and private providers are struggling to identify robust and resilient business models to make these services profitable[305].

To ultimately enhance the environmental sustainability of urban systems, many municipalities worldwide have also launched active mobility programs to incentivize those transportation modes that do not entail the usage of any motorized vehicles, such as walking or cycling for personal use, and cargo bikes for the movement of goods[306]. In addition to reducing traffic congestion and CO_2 emissions, these initiatives have the advantage of promoting healthier lifestyles and potentially improving the mental and physical well-being of urban communities[307]. For example, the cycle-to-work scheme implemented in Jönköping (Sweden) has reduced the rates of absenteeism among the public employees joining the program (refer to Annex 3, Case 12). In Brisbane (Australia), instead, the *Active School Travel* initiative has contributed to reducing car trips to schools by 35% (refer to Annex 3, Case 13).

6.4 Energy

In addition to curbing the pollution and emissions caused by traffic congestions and legacy transportation systems, cities worldwide are pressured to embrace energy transitions, that is, a systemic shift in how energy is produced, distributed, and consumed within urban areas[308]. According to recent estimates, more than 100 global cities (over a sample of 620) are already generating 70% of their electricity from renewable sources, as of 2022[309]. Yet, other datasets evidenced the uneven distribution of such sources across the world regions[310]. As shown in Figures 37 and 38, most of the solar and wind power plants near cities are located in Europe, North America and Asia. These three regions account for approximately 95% of the total installed capacity for energy production from solar plants and 99% of the wind power plants located in urban contexts.

Figure 37: Geographic distribution of solar power plants near cities



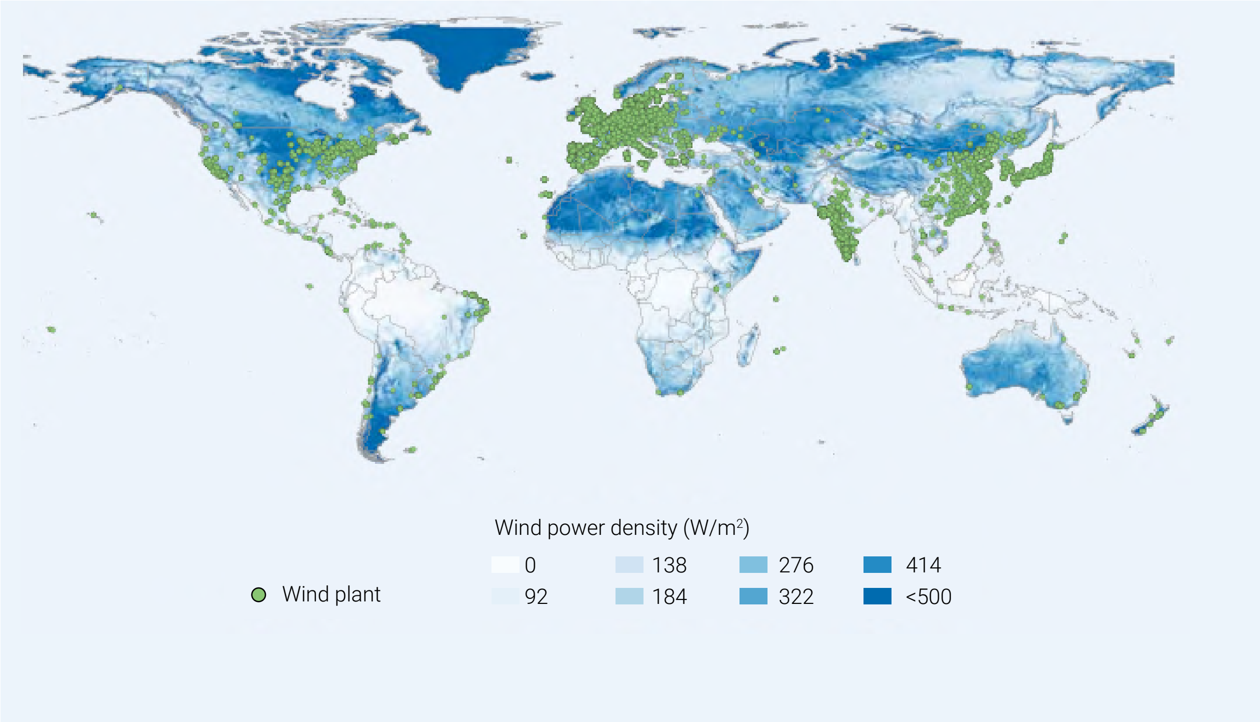
(Source: IRENA, 2020).

As to hydropower plants near cities, Europe is again leading the ranking (39% of the global distribution of hydropower generation capacity), followed by Asia (36%) and North America (14%). A similar pattern is observed in the generation of energy from biomass and waste[311], as shown in Figure 39.

Smart cities represent the ideal environment for the experimentation and implementation of renewable energy sources[312]. At the same time, renewable energies have been recognized as a cornerstone of people-centred smart cities, consistent with their commitment to promoting sustainability and improving livability in urban contexts[313]. For instance, the usage of renewable energies has become the main focus of smart city interventions in four cities in Taiwan (Chiayi, Taoyuan, Tainan and Taipei), which have leveraged alternative strategies to fulfill a wider strategy to achieve net-zero emissions by 2050[314]. While Chiayi[315] and Taoyuan[316] focused on the installation of solar panels on public buildings, Tainan prioritized the employment of renewable energy in their R&D activities[317]. In Taipei, the ***Green Energy Districts*** project led to the full integration of smart energy solutions into residential and commercial areas, which led to a decrease in energy costs by up to 40%. In China, instead, municipal governments have been offering both fiscal and non-fiscal incentives to promote the development of relevant technologies and infrastructures functional to the production of energy from green hydrogen[318], which represents a novel clean and versatile energy source to be potentially utilized in a wide range of urban application domains, from fuel cells to electric vehicles[319].

In addition to these municipal interventions, to successfully support the energy transition, collective efforts are also required from the supply and demand sides, combining both technological advancements and social innovations[320]. An example of the former are smart grids and smart meters. Smart grids are electricity networks that use real-time data and IoT technologies to reliably and efficiently control the flow of electricity generated from various sources[321]. Smart meters, instead, combine sensors and connectivity networks to collect and visualize real-time data on the energy consumption of individual users[322].

Figure 38: Power density and geographic distribution of wind power plants near cities

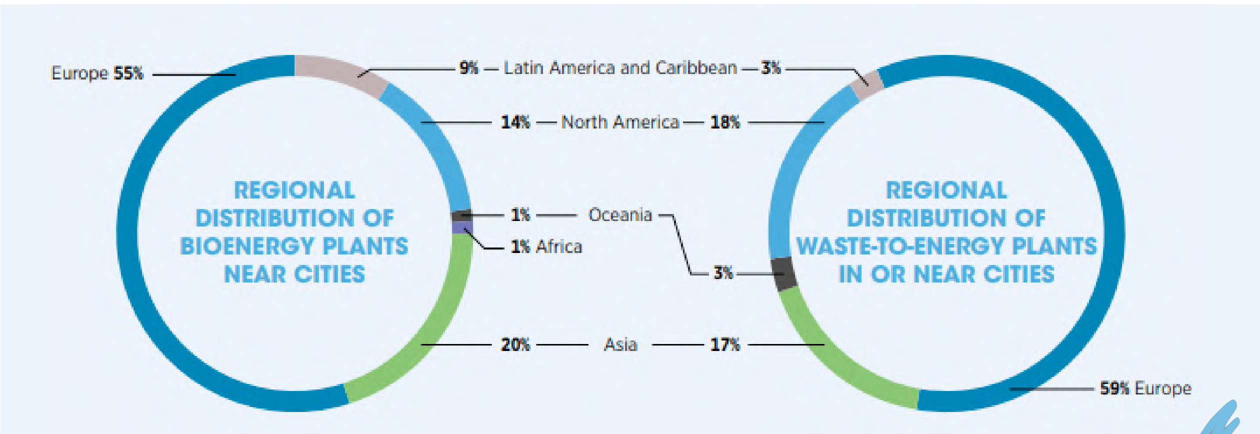


(Source: IRENA, 2020).

A report by Fortune Business Insights (2024) paints a bright picture of the global IoT market for energy management, projected to grow from USD 71 billion in 2023 to USD 223 billion by 2030[323]. In 2022, the Asia-Pacific region dominated the global market with a share of 36%, as a result of broader initiatives promoting the large-scale deployment of smart meters to improve energy efficiency[324]. By 2030, Europe, the Middle East, Africa and South America are also expected to show notable growth rates driven by an increasing focus on local and national policies on efficient energy usage.

Another factor crucial for the expansion of smart grids and smart meters is the development of comprehensive frameworks for the governance and protection of energy data[325]. The EU has been a pioneer in this: the ***Electricity Directive*** (EU/2019/944) and ***Regulation 2023/1162*** have recently been introduced to enforce data protection and data interoperability in the energy sector[326]. Despite this common framework, however, some EU Member States have yet to start a large-scale rollout of smart meters[327]. A recent study focusing on France has highlighted that, in some provinces, municipal governments are even resisting the implementation of these sensing devices, due to concerns over their ownership and their risk to health and data security[328].

Figure 39: Distribution of bioenergy and waste-to-energy plants by region



(Source: IRENA, 2020).

Alongside these ongoing technological advancements in the production and transmission of energy, local communities worldwide have also been experimenting with community energy initiatives[329] (also known as local/citizen energy communities). These projects entail the construction and installation of energy infrastructures partially or entirely owned by local communities[330]. A typical example is represented by the collective ownership of solar panels, usually installed in public spaces, such as in the case of ***Rau Kūmara Solar Farm*** in Ōtaki (New Zealand)[331]. This community energy initiative produces clean energy from community-owned solar panels installed on the local college and wastewater treatment plan. The profits originating from the sales of electricity are then reinvested in the community to tackle energy poverty and foster environmental education (refer to Annex 3, Case 14). Indeed, the final purpose of community energy initiatives goes beyond the mere production of clean, affordable energy: they also aim to enhance the efficiency and resilience of energy systems[332] as well as to promote the participation of local communities in the governance of green transitions[333].

These initiatives have been endorsed by academic researchers as a promising avenue to boost the development of smart, sustainable cities[334]. Yet, to date, their global diffusion remains, limited. Most of these projects have been launched in Europe[335], with Germany[336] and Denmark being at the forefront of the community-led production of renewable energy[337]. Some communities in Brazil and Costa Rica have also experimented with this innovative model: but these experiences remain limited in their coverage and relevance[338]. Furthermore, the evidence available suggests that these projects may struggle to survive in the long term due to a mix of internal and external factors[339]. These include the lack of practical support to integrate community energy into local operations, the bureaucracy associated with setting up cooperative projects, as well as their limited attractiveness to external investors and local users (who may not be willing or capable of paying a premium for renewable energy)[340]. Accordingly, some local authorities have launched specific measures, such as co-creation events or sustainability festivals, to stimulate public interest towards community energy and place-based green transitions[341].

6.5 Water management

Water management is another critical area for sustainable urban development, where cities worldwide are facing growing challenges, due to a rapid increase in their population[342] combined with climate change impacts, like droughts and floods[343]. These issues are further exacerbated by aging and undersized infrastructure leading to water leaks[344] and contamination[345], particularly in some regions of Africa. As a result, around 25% of the global population still lacks access to safe drinking water, with informal settlements being the most affected[346,347]. Despite improvements in rural areas, the UN's 2023 Sustainable Development Goals (SDGs) report showed stagnation or even a decline in urban water access[348]. This reinforces the need for technological advancements in the management of water in urban areas, through multiple applications, as summarized in Figure 40).

Figure 40: Smart city applications for the management of water resources.

Water smart meters

- The collection of real-time data on water consumptions can help detect water leaks and improve water loss assessments, enabling a more efficient and sustainable usage of water resources.
- Their global market is expected grow from USD 24 bn to USD 53 bn by 2032.

Water ATMs

- Water ATMs offer an accessible and affordable alternative to municipal water supply, especially in informal settlements and periurban areas.
- Their diffusion is limited to some Asian and African countries, where the need to involve local communities in the design and management of Water ATMs as emerged as a necessity to boost their beneficial impacts.

IoT systems for quality monitoring

- IoT monitoring systems can be integrated with data and observations collected from citizens to boost the monitoring of aquatic ecosystems.
- Data interoperability and digital skills, however, may hamper the effective contribution of local communities to citizens science.

Water smart meters are increasingly being adopted worldwide to monitor water consumption in urban areas. Utilizing IoT technologies[349], these meters enable remote readings and real-time recording of water usage[350]. Their piloting in global cities is already proved their potential benefits for urban communities as these applications have been found to enhance water leak detection[351], improve water loss assessments[352], and induce behavioral changes that result in reduced water consumption[353]. For instance, the rollout of smart water meters in Seosan City (South Korea) has led to a decrease in water leakages by 190,000 m³ per year, which in turn helped the city to better contrast the consequences of droughts (refer to Annex 3, Case 15).

Despite their potential, the widespread adoption of water smart meters is not without challenges. Concerns have, in particular, been raised with regard to their high installation costs and risks to data privacy[354]. Furthermore, their diffusion may be affected by the availability of digital infrastructures and the existence of bespoke government policies[355]. Indeed, numerous governments across the globe are increasingly endorsing their large-scale adoption and implementation. For instance, in the United Arab Emirates, both the *Abu Dhabi Water Security Strategy 2036* and *Dubai's Integrated Water Resource Management Strategy 2030* have promoted the integration of smart technologies to ameliorate the distribution and management of water resources[356]. Likewise, the government of Botswana has recently launched a nationwide plan to roll out smart prepaid water metering solutions, starting in urban areas[357]. Overall, recent forecasts estimated that the market size of water smart meters will more than double between 2023 and 2032, from USD 24 billion to USD 53 billion[358].

Water ATMs, also known as 'any-time water kiosks', are another innovation that addresses issues concerning water supply[359] mostly used in the Global South India, Pakistan, Kenya, Ghana, South Africa, and Tanzania leading their implementation in both urban and rural areas[360]. These automated water vending machines are digitally monitored (most commonly through smart cards and IoT-based systems) and self-contained with clean water. They represent a promising alternative to municipal water supplies, contributing to expanding access to drinkable water for vulnerable and marginalized communities, such as residents in slums, informal settlements and peri-urban areas. An example of this is provided by Yawkwei, a growing peri-urban community in the Ashanti region of Ghana[361], where water ATMs have been the most used water source for residents, who particularly their reliability compared to traditional modes of water provision (refer to Annex 3, Case 16).

Being a relatively new development, the usage of water ATMs is still subject to further evaluation. Recent case studies have shown that their implementation may generate different outcomes in different geographical and social settings. For instance, a study comparing the experience of Nairobi (Kenya) and Delhi (India) showed that the location of water ATMs and the availability of alternative cheaper options determined the extent to which poorer households benefitted from these resources[362]. The introduction of new digital water delivery systems has also been found to result in a redistribution of costs, risks and benefits across the different parties involved[363], thereby suggesting that geographical, social and institutional factors should be considered when designing these initiatives[364].

In addition to the aforementioned innovations in water supply and distribution systems, substantial efforts have lately been directed towards developing innovative solutions to control and improve the quality of both domestic water and aquatic ecosystems (seas, rivers, and lakes). The health and biodiversity of the latter are crucial for both wildlife and human well-being but are increasingly exposed to many risk factors, including (but not limited to) water pollution caused by human activities[365].

In this context, data-driven and IoT technologies have been successfully leveraged to enhance the accuracy and pervasiveness of monitoring activities, through the collection of real-time data and their integration into ad-hoc data platforms. For example, an IoT-based monitoring platform has been deployed in Xuan Dai Bay (Vietnam) to track the conditions of the aquatic ecosystem[366] (refer to Annex 3, Case 17).

As an alternative, citizen science offers a promising approach to enhance water monitoring through the involvement of local communities in the collection, analysis and dissemination of data[367]. The experience of Uzungöl, a lake in northern Türkiye, further exemplifies how the contribution of citizens in monitoring activities can be combined and enhanced with digital technologies[368]. In this specific case, an open-source mobile application was made available to integrate the data coming from sensors with the observations of citizens (refer to Annex 3, Case 18).). This initiative, however, also evidence that the success of participatory approaches to water monitoring is largely determined by the local availability of digital skills and digital infrastructures.

6.6 Waste management

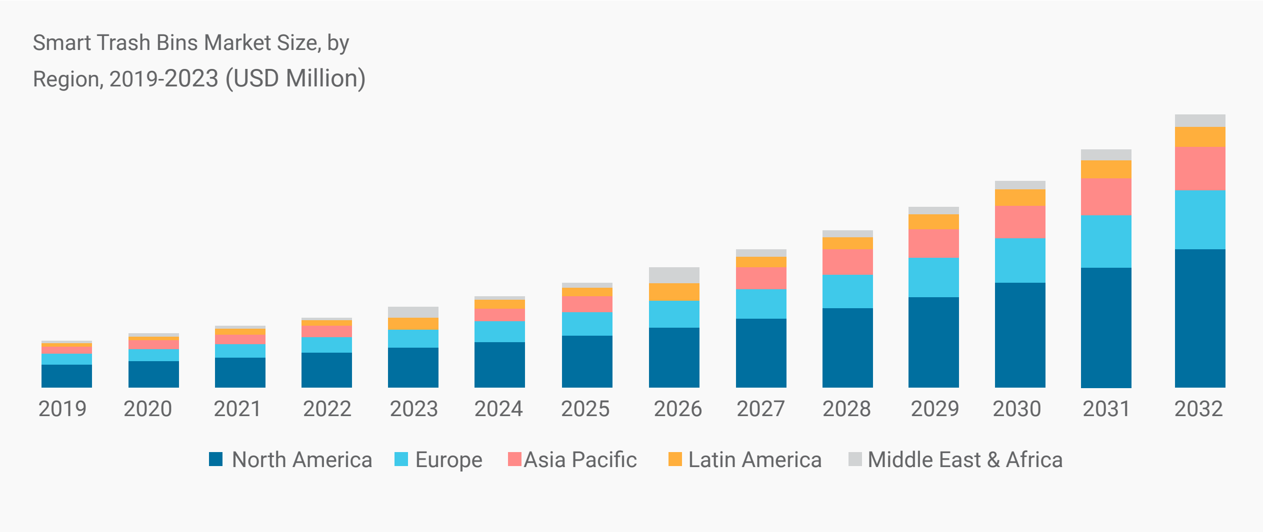
Waste management is another critical component of environmental protection in urban areas[369]. In this domain, local and national governments have been combining environmental regulations (see Section 2.5) and innovative technologies to both improve the efficiency of waste collection in urban areas and foster a circular economy, where the majority of urban waste gets recycled to minimize its environmental impacts and maximize its economic value[370].

Various technological solutions have been adopted worldwide to boost the efficiency and sustainability of waste management in urban areas. For example, the ***Waste Wise Cities Tool***, developed by UN-Habitat, has been implemented in 74 cities across Africa and Asia, enabling them to design data-driven, place-based solutions for the optimization of solid waste management[371,372]. Smart bins utilizing sensor networks and real-time data[373,374] have also been deployed in several cities, in the attempt to minimize the costs and emissions associated with unnecessary pickups[375]. For example, it has been estimated that the solar-powered smart bins installed in Wyndham City (Australia) have reduced garbage truck trips by 80% in only six months, thereby generating both cost savings and environmental benefits (refer to Annex 3, Case 19).

The advantages of smart bins can be further enhanced by integrating machine learning and AI-based systems capable of classifying and sorting urban waste. As successfully experimented in Medellín (Colombia), combining machine learning techniques with high-resolution imagery and GIS data can help distinguish among various types of street litter with a very high level of accuracy (up to 95%)[376] (refer to Annex 3, Case 20). A review of current smart city applications for waste management confirmed that AI-powered systems can contribute to reducing the costs of waste collection by up to 13% and generate time savings by up to 28%[377]. Nonetheless, another study noted that the implementation of these applications remains limited worldwide due to the lack of adequate standards for sensing devices[378].

Despite the lack of detailed data on the current adoption of innovative waste management solutions, market growth estimates confirm that the diffusion of smart bins is destined to grow globally, with a forecast compound annual growth rate of 15% between 2022 and 2032[379]. As shown in Figure 41, North America is dominating the market of smart bins, followed by Europe, and this is not expected to change in the next decade, even though all world regions will be experiencing significant growth rates.

Figure 41: Size of the smart bins' market (2019-2032)



(Source: Polaris, 2022)

The promotion of the circular economy in waste management has been pursued globally through a combination of regulatory measures (see Section 2.5) as well as social and technological innovations. Examples of such practices include urban mining, a term encompassing a wide range of techniques to extract valuable materials from e-waste[380], and digital sharing platforms, enabling the peer-to-peer or business-to-consumer sharing of recyclable and reusable goods[381].

Urban mining has long been an activity relegated to the informal economy, contributing to poverty alleviation in African and Latin American cities[382]. More recently, cities in Europe have also started to explore the potential of these practices as part of their broader commitment to foster the circular economy. It is the case, for instance, of Rotterdam (the Netherlands), which has set the ambitious goal to halve the use of primary raw materials by recovering them from e-waste, unwanted vehicles and demolished buildings[383] (refer to Annex 3, Case 21).

Overall, it has been estimated that urban mining techniques could potentially generate value for USD 54 billion at the global level, but their implementation remains constrained by logistics issues as well as concerns over the health risks associated with the disposal of electronic devices[384]. Some attempts have also been made to build partnerships between informal e-waste recyclers from metropolitan cities in the Global South with recycling companies in the Global North: but the impacts of these initiatives on vulnerable communities have been questioned[385].

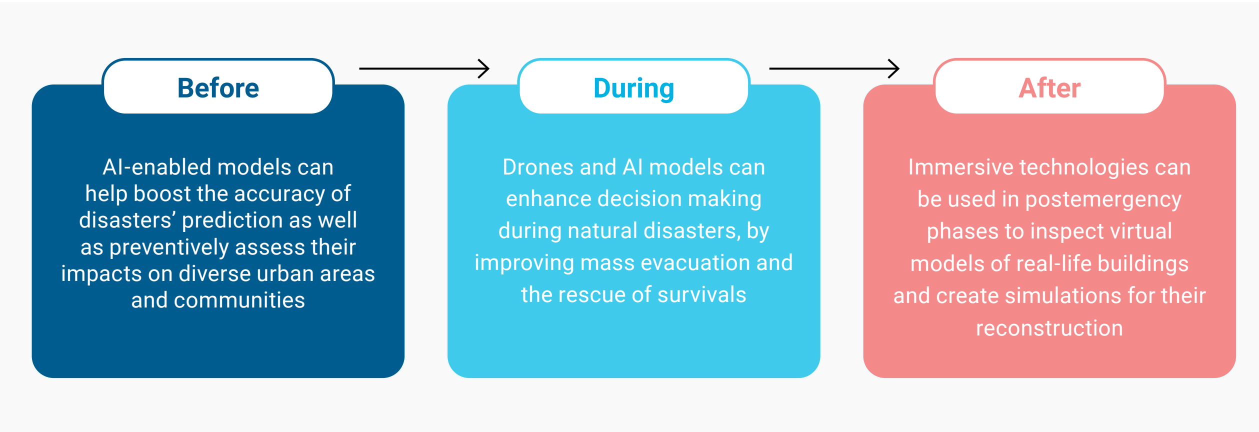
As digital sharing platforms, these include both global organizations, such as Olio[386], and local initiatives, such as Swinga[387] in Sweden. In both cases, the contribution and commitment of local communities are vital to the creation and continuation of these platforms, although the support of public authorities and other local actors has also been recognized as crucial for their upscale[388]. For example, in Freetown (Sierra Leone) the City Council has partnered with waste management companies, community groups and mobile operators to develop a smartphone app supporting the work and capacity-building of waste collectors (refer to Annex 3, Case 22).

Despite these encouraging experiences, recent research has warned that the diffusion of digital sharing platforms tends to be limited, especially in developing countries[389]. Nonetheless, it must be underlined that mapping the actual diffusion of these platforms remains arduous, as many of the circular economy initiatives taking place in global cities are led by grassroots efforts that are not necessarily formalized in stand-alone organizations.

6.7 Prevention and management of natural disasters

Cities worldwide have long been dealing with the aftermath of natural disasters, whose frequency and gravity are destined to increase as a result of climate change and global warming[390]. The impact of digital technologies in this domain could be truly transformative, as big data and AI applications promise to significantly boost the capability of local and national governments to predict the occurrence of these hazardous events and minimize their consequences[391]. Furthermore, AI applications are expected to boost decision-making for the management of natural disasters, while immersive technologies offer new opportunities for the reconstruction phases[392] (Figure 42).

Figure 42: Applications of smart city technologies before, during and after the occurrence of natural disasters



AI-enabled predictive technologies are being used to complement current forecasting models[393] to compensate for the shortcomings of traditional disaster responses in five key areas: disaster analysis, target tracking and searching, high-risk rescue operations, assistant decision-making, and effect evaluation[394]. For instance, in the Far North region of Cameroon, a novel AI model combining machine learning with GIS and remote sensing has been tested to enhance the accuracy of flood predictions and create early warning systems and vulnerability assessments (refer to Annex 3, Case 23). Likewise, new AI techniques involving spatiotemporal correlations among historical earthquake data have been leveraged to improve the forecasting of earthquakes in Tabriz (Iran), where the AI-based system has also been applied to assess the vulnerability of each neighbourhood. This has allowed the municipal governments to develop prevention strategies bespoke to diverse groups of residents[395] (refer to Annex 3, Case 24). Furthermore, predictive technologies are being applied to improve waste management after the occurrence of natural disasters. Using both historical and real-time data, AI models can forecast waste production and optimize collection routes, reducing operational costs and improving response times. These applications have been found to outperform traditional waste management models by 66%, offering considerable monetary and time savings[396].

In addition to these predictive models, AI-powered technologies can enable rapid and effective decision-making during and after the occurrence of natural disasters, contributing to enhancing the effectiveness of mass evacuations and the rescue of survivors. In particular, deep neural networks for image classification are expected to be more efficient than traditional search methods for the location of survivors trapped in earthquake rubble[397]. Similarly, deep learning techniques applied to big data on historical earthquakes and mobility patterns allow for a better understanding of human behaviours in mass evacuations during disasters with an accuracy rate of 88%[398]. To operationalize these AI technologies, drones play a key role by capturing aerial imagery and data in real-time, which can help effectuate comprehensive damage assessments, particularly in inaccessible areas, as recently experienced in Vietnam[399] and Türkiye[400]. The information collected by the drones, once fed into AI systems, also enables more accurate decision-making for disaster response, further improving the speed and efficiency of rescue, evacuation, and waste management efforts.

Immersive technologies, such as Virtual Reality (VR), Mixed Reality (MR) and Augmented Reality (AR), offer another set of innovative applications for the management of natural disasters in urban contexts. By enabling the simulation of alternative disaster scenarios, they can be used for training purposes[401]. Alternatively, they can be leveraged in post-emergency phases to create virtual replicas of damaged buildings, reducing the need for on-site inspections, and to simulate alternative reconstruction scenarios[402].

Whether the potential of both AI-enabled and immersive technologies is extensively debated in academic research, their implementation often remains constrained to pilot schemes and research projects, hence making it difficult to assess their actual utilization in urban contexts. At the same time, studies have already highlighted several factors that may ultimately hamper their large-scale adoption. These include the lack of advanced digital skills among government officials, widespread concerns over data protection and security, and the upfront costs required to acquire and install the data platforms and digital infrastructures underpinning these systems[403].

Furthermore, scholars have questioned the overall effectiveness of these techno-centric solutions due to their limited engagement with local communities, undermining the design of place-based responses to natural disasters[404]. Accordingly, to effectively minimize the consequences of these hazardous events, the application of predictive and immersive technologies cannot be decoupled from informative campaigns, training and other educational activities to boost the preparedness and awareness of local communities[405].

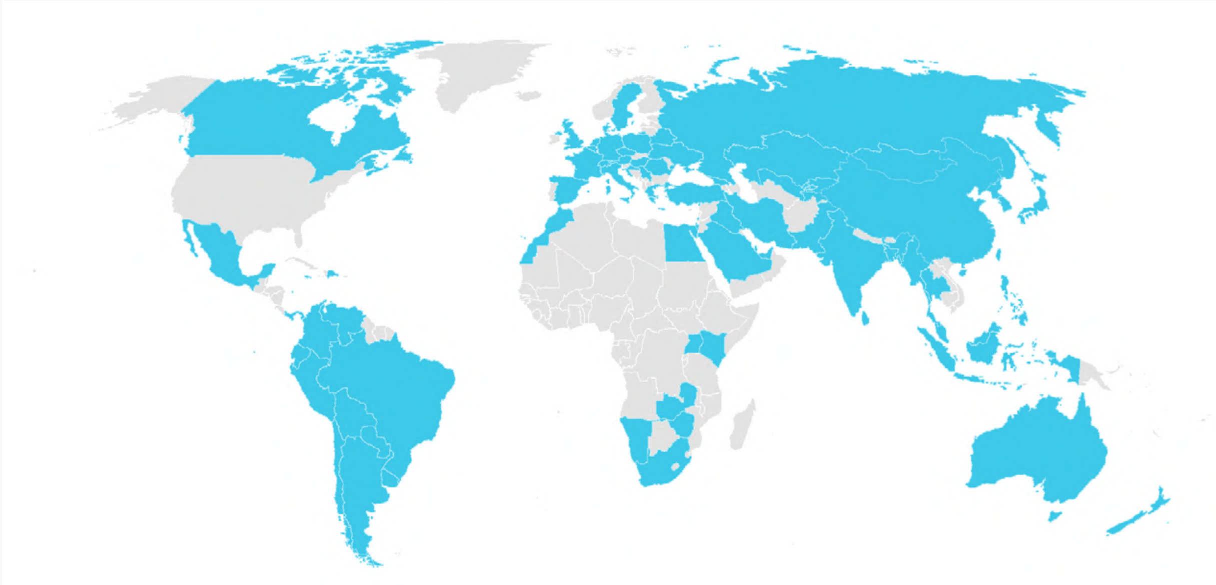
6.8 Safety and Security

Recent estimates show that around 83 million urban residents worldwide suffer from the consequences of crime and violence[406]. Despite global efforts to enhance urban safety and security, many countries are still struggling with ineffective legislative frameworks and poor criminal justice responses. Technological solutions are, therefore, being developed by municipal governments and other local actors to improve crime prevention and detection, often generating mixed reactions in local communities.

Closed-circuit televisions (CCTVs) represent the most common technology for security enforcement in urban contexts, relying on public and private sensors for the real-time video monitoring of urban spaces[407]. Their implementation has contributed to generating negative sentiments towards smart city projects, due to concerns over their security, privacy and compliance with human rights (as previously discussed in Section 5.2).

Even more contested is the usage, in urban spaces, of AI-powered tools for surveillance and predictive policing. As of 2022, such systems have been implemented in approximately one-third of the world's nations[408]. Facial recognition was in use in 78 countries, with a higher prevalence in Asia, Europe and Latin America. A similar distribution could be observed concerning smart policing, which has been adopted in 67 countries (Figure 43).

Figure 43: Countries that have implemented facial recognition



(Source: author, using data from Carnegie Endowment for International Peace, 2022)

Although claims supporting these systems highlight a potential crime rate reduction of 30 to 40%[409], legislators at different administrative levels are increasingly concerned about the use of predictive policing and other AI applications for surveillance purposes because of their potentially harmful impacts and incompatibility with human rights (see Section 2.4). For example, the Mayor of Chicago (US) has recently discontinued an AI-based gun-shot detection system that resulted biased towards ethnic minorities (refer to Annex 3, Case 25).

Indeed, the academic literature has long questioned the effectiveness of predictive policing and other digital applications for crime prevention because of biases and inaccuracies resulting in erroneous crime rate estimations[410]. Initial studies suggest that these biases could be mitigated by introducing techniques to improve algorithm fairness[411], enhancing the transparency and explainability of algorithms [412], and integrating AI with human supervision[413]. However, it is agreed by scholars and practitioners that the implementation of surveillance technologies and predictive policing should remain subject to stringent policies to ensure their alignment with overarching frameworks for the protection of digital human rights[414] (see Section 2.4).

A more promising approach to enhance the safety and security of urban spaces through digital technologies is represented by crowd-sourced maps and smartphone applications developed by local communities to prevent gender-based violence. Examples of these initiatives have been reported worldwide over the past decade: for instance, in Quito, transport authorities and non-profit organizations have introduced a mobile app that facilitates the reporting of sexual harassment episodes on public transportation (refer to Annex 3, Case 26). In Delphi (India), the smartphone app ***Safetipin*** has been providing crowdsourced maps of various locations reflecting the safety scores given by local users (refer to Annex 3, Case 27).

Based on a systematic search of app stores conducted by a group of researchers, as of 2020, there were 171 smartphone apps addressing gender-based violence. Most of them had been launched in South Asia (26%) and Europe (25%), while their diffusion appeared more limited in Sub-Saharan Africa (10%) and in the Middle East (6%)[415]. The same study identified data protection and security as critical weaknesses of these applications, along with the fact that they mostly leverage real-time data to tackle emergency solutions with little consideration for the prevention of gender-based violence, a limitation also observed by other analyses of these applications[416].

6.9 Welfare

Welfare encompasses societal efforts to ensure all individuals have access to basic needs, with education and healthcare being central pillars. Normally the competence of national governments, the availability and effectiveness of welfare services have also direct implications on the quality of life in urban areas and their sustainable development. Although the quality of schools is usually higher in cities rather than rural regions[417], barriers to education remain in place also within metropolitan areas, reflecting the persistence of social and racial inequalities among neighborhoods and urban districts[418]. Likewise, in healthcare the main problems involve unequal access to medical services[419], reflecting insufficient healthcare infrastructures, rising costs, and workforce shortages[420]. Digital technologies can help alleviate these challenges through a variety of innovative solutions, as summarized in Figure 44.

Figure 44: Digital applications in education and healthcare

Education

- eLearning platforms expand educational opportunities, especially for communities with limited access to schooling and low -income families.
- Intelligeting Tutoring Systems can assist learners with personalized educational plans.
- Globally, 1/3 of the population has expressed concerns on the application of AI in education.

Healthcare

- eHealth applications expand access to healthcare and help deal with shortages in the availability of health professionals.
- AI offer support for clinical decisions with advanced diagnostics.
- Both patients and health professionals often lack the digital skills required to fully harness eHealth and AI applications

E-learning platforms and digital resources are expanding educational opportunities, especially for remote communities and for individuals with low income who cannot afford to study full-time. Similarly, e-health applications are enhancing access to medical services and contributing to more efficient use of time for doctors and patients[421], especially in rural areas or low-income countries, where the availability of health professionals is limited and can be compensated with remote consultations.

The diffusion of both innovations has surged during the COVID-19 pandemic[422], but regional differences persist. China is leading the e-learning adoption (38%), followed by India (22%), and the US (7%)[423]. As to e-health, a global review of current practices[424] revealed that the usage of eHealth is more advanced in North America and Asia, compared to the other world regions. The same study also underlined that the implementation of these solutions is often driven by local initiatives, as only 26% of the countries included in their sample had a nationwide approach to telemedicine.

More recently, alongside e-learning platforms and e-health services, AI has been deployed to boost the delivery of both education and healthcare services. In the former case, AI offers opportunities to improve online courses, identify learning gaps, and personalize learning experiences[425], such as in the case of Intelligent Tutoring Systems, which elaborate on individual students' data to assess their progress and develop personalized learning support[426]. Likewise, AI promises to improve the operational efficiency of healthcare services by fostering patient-centred care[427] and supporting clinical decisions with advanced diagnostics capabilities[428]. For example, in Daegu (South Korea), a portable X-ray machine with instant AI diagnostic has been used during the COVID-19 pandemic to quickly diagnose lung diseases with an accuracy of 99% (refer to Annex 3, Case 28).

Despite their promising potential, these AI applications often encounter the resistance of local communities. A global survey captured that, on average, one-third of the world population is concerned about the potential negative impacts of AI in education, with Indonesians (66%), Argentinians (63%) and Portuguese (62%) being the most skeptica ones[429]. The perception of AI in healthcare is generally less negative, although significant differences have been observed between Latin America and the rest of the world, as 75% of health professionals in the former region have expressed doubts over the outcomes of digital transformation on the healthcare sector[430].

Indeed, researchers have warned that ongoing digital divides (as discussed in Section 5.1) will eventually undermine the extent to which certain groups and communities can benefit from e-learning and e-health[431]. The shortage of digital skills in the public sector (see Section 3.2) also constrains the effective implementation of AI and other digital technologies in both the healthcare and the education sector[432]. Finally, the digitalization of health records and medical consultations has raised concerns about the security and protection of personal data[433].

Whereas these technological advancements require further scrutiny to fully assess their implications for urban communities, local actors are also developing innovative applications to support welfare enhancement in local communities through data-driven, evidence-based interventions[434]. An example is the ***Socio-Economic Vulnerability Information Management System*** (SEVIMS) set up in Beni (Nepal), which combines different real-time and predictive analytics to track socio-economic vulnerabilities and human development progress within the local area. The information elaborated by SEVIMS then is leveraged by the local government to improve both the delivery of public services and the effectiveness of policy-making processes[435] (refer to Annex 3, Case 29).

Conclusions

The factual findings outlined in the previous sections have highlighted that, overall, the maturity level of cities in terms of digital transformation and people-centred smart city development remains uneven within and across the world regions. Whereas European and North American municipalities have extensively experimented with a variety of smart applications, their Asian and African counterparts are still burdened with infrastructural gaps that undermine the implementation of digital technologies. Similarly, European and Latin American countries are usually at a more advanced stage in the definition of snational regulations on key socio-technical issues, such as data protection, technological interoperability and ethical and human rights considerations, while regulatory voids persist in other world regions, leaving local governments with little guidance to address ethical and security challenges associated with digital technologies. As a result, local governments are tackling these policy gaps by defining their own guidelines and regulations on the use of emerging technologies. This approach could, in the long-term, generate new inequalities within and across the world regions if an attempt to harmonize emerging regulations is not made.

Previous sections evidenced a series of factors that hinder the ability of global cities to harness the potential of people-centred smart cities and maximize their positive impacts on urban communities. A major obstacle remains the lack of digital skills and other advanced competencies, both within the public sector and in the general population. Worldwide, local governments are struggling to source the skillsets required to manage digital transformation, while local communities are still affected by broad digital divides that impact their participation in the design and governance of digital technologies. Whereas several efforts are already in place to sustain the capability building of municipal governments and other urban actors, little can be achieved if resource constraints and barriers to knowledge exchanges are not tackled, both locally and globally.

Another recurring issue observed across the world regions and different urban sectors, is the chronic lack of updated, detailed data on the actual outcomes of smart city projects. Worldwide, cities are struggling to monitor the performance of their initiatives and measure their social and environmental impacts. Although monitoring frameworks and metrics have been developed by multiple organizations, their practical implementation remains limited due to both structural and legal impediments to data and knowledge sharing. These issues do not only affect the thorough assessments of smart city projects and impacts: municipalities across the world are struggling to identify sustainable models for the scalability of digital applications and infrastructures in urban environments.

Recommendations

Building on this evidence, some recommendations are made, for consideration by policymakers, urban practitioners and other actors in the city environment. These recommendations are grouped across seven thematic areas to promote integrated solutions and reduce silos in approaching cross-cutting issues related to people-centred smart cities.

Inclusion, Equity, and Human Rights

1. *Devise and enforce comprehensive policy guidance for the design of inclusive smart city solutions:* national governments, in consultation with local authorities and international institutions, should define cohesive regulatory frameworks and harmonized standards to reinforce the accessibility, fairness, transparency, and inclusivity of digital services and infrastructures.
2. *Establish national and international regulatory guidance and oversight on digital human rights and the ethical use of technology:* international institutions should harmonize and coordinate their policies on the ethical use of digital technologies and digital human rights to provide local governments with clear, consistent guidance. The local enforcement of digital human rights regulations should be sustained and monitored by national regulatory authorities.
3. *Build local capabilities for the collection and analysis of granular, disaggregated data*: to enhance the monitoring of smart city projects and their impacts on diverse groups and communities, municipal governments and their partners should develop skills and procedures enabling the collection and analysis of data disaggregated for specific categories (such as gender or age) in compliance with existing data protection regulations.
4. *mplement ex-ante and ex-post human rights impact assessments at the local level throughout the technology development and implementation lifecycle:* public entities at different administrative levels should cooperate with civil society organizations, academic institutions and citizens to build holistic frameworks for evaluating ex-ante the impacts of smart city projects in terms of inclusion, equity and fairness, and to enforce human rights diligence in public and private organizations.

Community Participation and Collaboration

1. *Develop context-specific strategies for citizens engagement, leveraging a mix of online and offline tools*: municipal governments, in collaboration with representatives of the local civil society, should identify existing barriers to residents' engagement and identify the optimal mix of online and offline participatory tools to be deployed to maximize the participation of local communities in the different stages of people-centred smart city development.
2. *Establish community partnerships to build a relationship of trust with residents:* municipal governments should partner with other local public organizations (such as schools, community hubs, recreation centers and libraries), community groups, and civil society organizations to overcome the mistrust of citizens towards the public sector and digital technologies.
3. *Build local capabilities to sustain participatory planning processes*: local governments and civil society organizations should work with academic institutions to assemble the skills and know-how needed to implement participatory processes that are truly inclusive and capable of engaging those groups of citizens that currently do not engage in smart city initiatives.
4. *Implement communications and feedback processes to ensure that local communities are always kept informed on the progress of smart city initiatives they contributed to:* in order to enhance the transparency and accountability of smart city projects, municipal governments and their partners should commit to keeping residents regularly informed on the progress of the decisions that were made with their input. A mix of online and offline channels should be leveraged to ensure that all residents and other stakeholders are kept in the loop and can monitor the advancement of people-centred smart city development.

Digital Literacy

1. *Establish metrics and processes to rigorously monitor the state of the digital divide in urban contexts:* local businesses and educational institutions should be involved in the monitoring of digital skills to map their local diffusion and identify emerging capacity and skills' needs National authorities should also collaborate with local governments and research institutions to establish a systematic process for collecting and analyzing up-to-date data on digital services involving their availability, affordability and adoption.
2. *Devise comprehensive strategies to address ongoing and emerging digital divides*: local and national actors involved in the reduction of the digital divide and the promotion of digital literacy should define joint action plans to coordinate their interventions and ensure complementarity among their proposed measures, starting from a systematic recollection and measurement of the various sources of digital divide affecting local communities.
3. *Create dynamic approaches to sustain the capacity-building of local communities*: local governments should partner with civil society organizations and educational institutions to devise a long-term strategy for the lifelong learning of residents through a varied mix of educational resources aimed at enhancing the digital literacy, technical skills and ethical awareness of local communities.
4. *Leverage alternative media to sensitize local communities on the multifaceted impacts of digital services and infrastructures*: through communication campaigns, public events and training, municipal governments and civil society organizations should work together with local communities to increase their awareness of societal, economic and environmental impacts of digital technologies.

Shared Prosperity

1. *Develop detailed, data-driven assessments on digital transformations' impacts:* governments at all levels should collaborate with universities and research institutes to create detailed, data-driven assessments that evaluate the impacts of digital transformations on urban economies. These assessments should focus on key areas such as sustainable economic growth, inclusive employment opportunities, and the creation of new market prospects.
2. *Update procurement regulations to incorporate innovative practices to facilitate the participation of small and medium enterprises in public tenders for the sourcing of digital services and infrastructures:* national and international policymakers should update the laws and regulations norming procurement processes to reinforce their flexibility and openness, by prioritizing interoperable technical formats and intellectual property rights arrangements that enable unrestricted flows of data and knowledge among public and private parties.
3. *Create synergies with other local authorities to share and maximize the benefits of smart city development:* to guarantee that the benefits of smart city projects are equally shared in neighbouring communities, local governments within the same province or territory should work together to develop joint action plans and projects spanning across multiple administrative borders, ultimately targeting economic inequalities in the territory.
4. *Formulate a long-term financial plan to sustain both the experimentation and the sustainability and scalability of smart city projects:* local and national governments should leverage alternative funding sources to guarantee the continuation of smart city projects beyond their piloting phase, while still supporting new entrepreneurial efforts (especially from communities usually under-represented).
5. *Experiment with innovative mechanisms to build trust-based, long-lasting cross-sector partnerships:* local and national policymakers with private companies and academic institutions should lead conjoint efforts to conceive new formal and informal mechanisms for the long-term coordination and collaboration of smart city partners from different sectors, with a specific focus on the safeguard of intellectual property rights, data sharing and data governance.

Environmental Sustainability

1. *Harmonize environmental regulations to facilitate the embedding of environmental objectives in people-centred smart cities:* national and international policymakers should coordinate and integrate their policies and regulations concerning the green and digital transitions to facilitate the definition and monitoring of environmental outcomes within smart city initiatives.

2. *Refine methods and metrics for the measurement of the environmental impacts of digital infrastructures and services:* international institutions should work with universities, research institutions and community organizations to harmonize and streamline existing approaches to the collection, analysis and sharing of data on the environmental impacts of digital services and infrastructures.
3. *Establish standards for the sustainable design of digital technologies:* at the national and international level, policymakers should work with industry players to define and enforce universal standards for the design of sustainable digital technologies to regulate their direct and indirect emissions, minimize their impact on natural ecosystems, and make their recycling more efficient.
4. *Include lifecycle impact assessments in the strategic planning of smart city projects:* municipal governments should work with civil society organizations, industry players and academic researchers to develop rigorous methodologies for the lifecycle impact assessments of smart city services and infrastructures, to be embedded in their implementation plans and procurement processes.

Governance and Regulations

1. *Introduce coordination mechanisms for the alignment of local and national smart city agendas:* local and national governments should identify a set of participatory procedures to coordinate and align their strategic agendas while ensuring that smart city visions and plans remain place-based, community-led and context-specific.
2. *Establish structural and procedural arrangements to enhance the multilevel governance of smart city initiatives:* municipal and national administration should revise their multilevel configurations and processes to foster knowledge and data sharing among public organizations, enhance the coordination of complementary policies and regulations, and promote long-term programs in support of people-centred smart city development.
3. *Experiment with innovative practices for the recruitment and exchange of talents from within and outside the public sector:* to overcome existing skills shortages, municipal governments should be given the opportunity to implement innovative practices for the attraction of professionals with advanced expertise and the sharing of human resources with third parties, internal and external to the public sector.
4. *Build a public sector culture of digital innovation that is people-centred and aligned with public values:* change management techniques should be leveraged within local and national administrations to promote a cultural shift at both the organizational and the sectoral level, integrating public values with a pro-innovation and pro-collaboration mindset.

Digital Infrastructures and Smart City Services

1. *Reinforce public oversight over critical infrastructures and essential services*: to facilitate and guarantee the enforcement of cybersecurity and digital human rights, national regulatory authorities should be granted additional powers to oversee the governance of digital infrastructures and services, while local communities should be actively involved in their design and monitoring.
2. *Establish ad-hoc programmes to support local entrepreneurial efforts aimed at tackling urban challenges through social and digital innovation:* municipal governments should employ a mix of financial and non-financial measures to sustain grassroots initiatives and entrepreneurial ventures harnessing digital and social innovation to develop place-based smart city applications.
3. *Nurture collaborative partnerships among municipalities to facilitate the co-creation of scalable and adaptable urban innovations:* municipal governments should partner with each other to collaboratively design technological solutions and innovative governance practices that can be transferred and adapted to diverse local contexts.
4. *Leverage alternative business models for digital infrastructures and services*: local and national governments should work with private suppliers and research institutions to devise, test and implement innovative business models for inclusive and people-centred digital services and infrastructures.

Annexes

ANNEX 1: SOURCES OF QUANTITATIVE DATA

Dataset	Source	Year	Description	Link
Atlas of Urban AI	Global Observatory of Urban AI	2024	Global repository of municipal initiatives to enhance the fairness and transparency of artificial intelligence.	https://gouai.cidob.org/atlas/
Government Open-Source Software Policies)	Center for Strategic and International Studies	2022	Repository of open-source software policies	https://www.csis.org/programs/strategic-technologies-program/resources/government-open-source-software-policies
Data Protection Around the World	Commission Nationale de l'Informatique et des Libertés	2023	Repository of national data protection policies	https://www.cnil.fr/en/data-protection-around-the-world
Global assessment of responsible AI in cities	UN-Habitat	2024	Global survey on the use of artificial intelligence in cities (Sample: 122 municipalities)	https://unhabitat.org/global-assessment-of-responsible-ai-in-cities
Global Review of Smart City Governance Practices	UN-Habitat	2022	Global survey on governance practices in smart cities (Sample: 289 municipalities)	https://unhabitat.org/global-review-of-smart-city-governance-practices
Mobile Gender Gap Report 2024	GSMA	2024	Global survey on gender gaps in the use of mobile services (Sample: 13,600 individuals across 12 low- and middle-income countries)	https://www.gsma.com/r/gender-gap/
The State of Mobile Internet Connectivity Report 2023	GSMA	2023	Global analysis on the availability and use of mobile services	https://www.gsma.com/r/somic/
ITU Data Hub	ITU	2024	Multiple datasets tracking the global progress of digital infrastructures' use and diffusion, and of the related policies adopted at national levels.	https://datahub.itu.int/
Global eWaste Monitor	ITU	2024	Global study on the management and policymaking of eWaste	https://ewastemonitor.info/global-e-waste-monitors/
UN-DESA eGovernment survey 2024	UN-DESA	2024	Global survey on national and municipal practices related to e-government (Sample: 193 cities, 151 municipal portals)	https://publicadministration.un.org/egovkb/en-us/Reports/UN-E-Government-Survey-2024

ANNEX 2: SOURCES OF QUALITATIVE DATA

Interview Code	Role of the interviewee	Country
Interview 1	National expert	Argentina
Interviews 2-5	Municipal expert	Argentina
Interview 6	National expert	Austria
Interview 7-9	Municipal expert	Austria
Interviews 10, 11	National expert	Azerbaijan
Interview 12	Municipal expert	Azerbaijan
Interview 13	Municipal expert	Bangladesh
Interviews 14, 15	National expert	Belgium
Interview 16	Municipal expert	Belgium
Interview 17	Municipal expert	Bolivia
Interview 18	National expert	Botswana
Interview 19, 20	National expert	Brazil
Interview 21-25	Municipal expert	Brazil
Interview 26	Municipal expert	Cameroon
Interview 27- 29	Municipal expert	Canada
Interview 30	National expert	Canada
Interview 31-39	Municipal expert	China
Interview 40-45	Municipal expert	Colombia
Interview 46	Municipal expert	Costa Rica
Interview 47	Municipal expert	Czechia
Interview 48-55	National expert	Denmark
Interview 56,57	National expert	Denmark
Interview 58	National expert	Egypt
Interview 59	National expert	El Salvador
Interview 60-68	Municipal expert	Estonia
Interview 69	Municipal expert	Finland
Interview 70	National expert	France
Interview 71,72	Municipal expert	France
Interview 73	Municipal expert	Gambia
Interview 74-79	National expert	Germany
Interview 80-87	Municipal expert	Germany
Interview 88	National expert	Ghana
Interview 89	Municipal expert	Ghana
Interview 90	National expert	Iceland
Interview 91	Municipal expert	India
Interview 92	National expert	Indonesia
Interview 93	Municipal expert	Iran
Interview 94	Municipal expert	Israel
Interview 95	National expert	Israel
Interview 96-99	Municipal expert	Italy
Interview 100	National expert	Japan
Interview 101	National expert	Lithuania
Interview 102	Municipal expert	Malaysia
Interview 103	National expert	Mauritius
Interview 104	National expert	Mexico
Interview 105	National expert	Mexico
Interview 106	National expert	Moldova
Interview 107,108	National expert	Morocco
Interview 109	Municipal expert	Mozambique
Interview 110,111	Municipal expert	Netherlands
Interview 112	National expert	Nigeria
Interview 113	National expert	North Macedonia
Interview 114	National expert	North Macedonia
Interview 115	Municipal expert	State of Palestine
Interview 116	Municipal expert	Poland
Interview 117	National expert	Portugal
Interview 118, 119	Municipal expert	Portugal
Interview 120	Municipal expert	Romania
Interview 121	National expert	Russia
Interview 122	National expert	Senegal
Interview 123	Municipal expert	Slovakia
Interview 124-126	National expert	South Africa
Interview 127	Municipal expert	South Africa
Interview 128	National expert	South Africa
Interview 129-135	Municipal expert	Spain
Interview 136-139	Municipal expert	Switzerland
Interview 140	National expert	Tunisia
Interview 141, 142	Municipal expert	Tunisia
Interview 143,144	National expert	United Kingdom
Interview 145-147	Municipal expert	United Kingdom
Interview 148-153	Municipal expert	United States
Interview 154-155	National expert	United States

ANNEX 3: CASE STUDIES

Case 1 – Using SGMB to improve horticulture value chains in Bihar, India.

Bihar, located in Eastern India, is the country's third most populous state. The SGMB approach was used to map the fruit and vegetable value chain[436]. This helped to uncover location-specific barriers, such as toll booths and traffic jams, hindering market access. Different participants in the SGMB, including farmers and traders, had the opportunity to use participatory GIS tools to visualize market locations, transport routes, and other factors within quantitative system dynamic models, leading to an improvement in their decision-making processes. These tools also enabled open discussions on future scenarios for the value chains of fruit and vegetable markets.

Case 2 – Collaborative spatial data for urban planning in Indonesia.

To address urban challenges in Indonesia, the World Bank's City Planning Labs and CAPSUS team have proposed three interrelated urban planning tools: Urban Hotspots (UH), Urban Performance (UP), and CollabData[437]. These tools were tested using geospatial data from six Indonesian cities (Balikpapan, Bandung, Banjarmasin, Denpasar, Semarang, and Solo). These pilots demonstrated several advantages such as the effective identification of strategic locations for new urban services, the evaluation of spatial plans by developing scenarios, and the facilitation of public consultations and social monitoring. They also highlighted a major concern regarding the quality and maintenance of the datasets used for spatial planning. In this regard, it has been suggested that open data portals could help overcome such risks, by allowing data to be directly pooled and kept up to date.

CASE 3 – Digital twins as digital planning models for Bavaria.

Bavaria, located in the southeast of Germany, is the country's second most populous state. In 2023-2024, the Bavarian State Ministry for Digital Affairs launched the TwinBy program to support municipalities in creating digital twins. Funded projects benefited from consultancy services and utilized a common academic framework, the Smart District Data Infrastructure, developed by the Technical University of Munich. This framework is meant to enable municipalities to plan and implement projects in different urban sectors at lower costs and with reduced timeframes. For example, as part of the "Inter-municipal 3D Energy Planning 4.0" project, digital twins have been used to better estimate the costs of solar systems to install on individual buildings, improving their implementation efficiency[438]. Another project, simulating flooding scenarios in Schwabach, has demonstrated the advantages of digital twins in advancing the prevention and protection from natural disasters[439].

Case 4 – Urban Lab: dynamic traffic forecasting in Barcelona.

Barcelona Urban Lab has implemented a smart traffic management system that combines video analytics and sensors installed at parking spots to gather real-time data on parking availability and current traffic conditions. This data is then used to optimize traffic flow in the city, one of the busiest in Spain. This initiative has led to significant positive outcomes, including a 30% reduction in traffic congestion, shorter commute times, improved air quality, and a 15% increase in the efficiency of public transport services. These improvements not only benefited residents and visitors but also had positive economic impacts, enhancing accessibility for businesses and improving delivery services. Barcelona's experience, therefore, highlights the importance of traffic management systems in creating smarter, more sustainable cities, offering valuable insights for urban areas worldwide facing similar challenges amid rapid urbanization[440].

CASE 5 – Mexico pioneering the first 3D-printed house community.

Nacajuca is a city in southeastern Mexico, in a jungle region where about half of its inhabitants live below the poverty line. A project involving non-profit and construction organizations delivered the construction of a neighborhood with 500 houses of 46 m2, making it the world's first community with 3D-printed houses. The construction is simple and fast: a tablet or smartphone controls the printer, requires only about three workers, and can finish a house in less than 24 hours without sacrificing quality. Also, the houses are adapted to local conditions: Nacajuca is in a seismic zone, and the houses there have already withstood a 7.4-magnitude earthquake.

CASE 6 – Limerick employing digital twins to promote urban energy sustainability.

Limerick, a city in Mid-West Ireland, is part of the EU Horizon 2020 +CityxChange project, whose aim is to establish a sustainable, zero-emissions urban ecosystem and create smart positive energy districts, generating more energy than they consume. Digital twin technologies, integrating data from Open Street Maps and other socio-economic sources, were utilized to create a model of the Georgian Innovation District, to analyze CO2 production and energy use within the district. Digital twins of each building were created, incorporating virtual energy models and an artificial intelligence algorithm where data was lacking. Simple operational measures across the buildings led to collective energy saving ranging from 5% to 13%.

Case 7 – Traffic control system in Los Angeles.

The city of Los Angeles (USA) introduced an automated Traffic Surveillance and Control system (ATSAC) which leverages real-time data from sensors embedded in the roadways to adapt signal timings according to the current traffic demand. Through this dynamic optimization of signal timings, the ATSAC system performance concluded that stops were reduced by 35%, intersection delay by 20%, travel time by 13%, fuel consumption by 12.5%, and air emissions by 10%[441].

Case 8 – The "Amman Bus" project.

Amman Bus was launched in 2019 to modernize the public transport system of the Jordan capital by integrating AI technology and real-time data[442]. Operating along 27 planned routes spanning the Greater Amman Area, the service provides the passengers of public buses with real-time information on delays and schedule updates, delivered through a smartphone app. This app also enables bus users to locate nearby stops, identify the quickest routes, and settle their fares online before boarding. The success of the Amman Bus project demonstrates that AI-driven solutions can be both cost-effective and accessible to a wide demographic. By leveraging similar models, other cities within developing nations can potentially replicate this approach, showcasing that sophisticated traffic management systems need not be expensive or exclusive to more developed regions.

Case 9 – Managed Electric Vehicle charging in Kyoto.

The clustering of electric vehicles (EVs) during charging can strain local distribution grids, hindering the uptake of Low-Emission Vehicles (LEVs), particularly among private vehicle owners. To address this, Kyoto (Japan) established an EV Charging Management Centre, which utilizes a 3G network to collect data on EVs and advise drivers on optimal charging times and stations to avoid grid congestion[443]. Results from trials showed a significant reduction in recharging volume during peak demand periods, indicating the effectiveness of the system in managing overload. Success is attributed to incentives offered to participants who adhere to demand response requests, such as gaining shopping points. This approach could be adopted by cities interested in supporting LEVs but concerned about grid strain caused by clustering.

Case 10 – BiciCarga: Pilot for last-mile distribution with cargo bikes.

BiciCarga in Bogota (Colombia) deploys electric cargo bikes for last-mile deliveries to reduce transport pollution and increase efficiency. The project uses a cross-docking platform where electric trucks consolidate products into e-cargo bikes, powered by solar energy. It assesses smart energy management and last-mile operations for scalability. During the pilot, the partnership replaced trucks and motorcycles with electric bikes, avoiding significant CO_2 emissions and reducing daily working hours for drivers. It substantially increased deliveries per hour and per kilometer. A financial model was created to determine when using cargo bikes is more efficient and sustainable, especially in areas with high customer density. This initiative aligns with Colombia's commitment to reduce greenhouse gas emissions by 51% by 2030, focusing on decarbonizing the last-mile urban freight sector, crucial in a city like Bogota where 48% of emissions come from freight transport[444].

CASE 11 – Electric cargo bikes in Accra, Ghana: Supporting net zero decarbonization efforts.

Net Zero Accra is a collaborative project between Impact Hub Accra and Siemens Stiftung, that aims to support Ghana's decarbonization efforts by 15% by 2030[445,446]. Its initial success showcases the multifaceted impact of smart city mobility services on social inclusion, economic growth, environmental sustainability, and policy advocacy. The project focuses on electric mobility, specifically 'Made in Ghana' electric cargo bikes, which are manufactured locally in Accra and Tamale, proportionally using recycled materials. It also involves a lease-to-own financing system to make electric bikes accessible to disadvantaged populations and has created green jobs and training opportunities. Additionally, the project has fostered collaboration among regional stakeholders in conducting research and development of electric vehicle technology. Through various engagements, the project has established parameters for test bikes with the Ghana Standards Authority and facilitated communications with the Transport Ministry and its agencies to support the Drive Electric policy. Despite benefits, several constraints need to be addressed to foster the adoption of electric mobility, such as financing options that facilitate expanded production, adaptable regulations on taxes and licenses, charging infrastructure, social acceptance, and technological access to test various components of electric vehicles.

Case 12 – Cycle-to-work scheme in Jönköping Municipality.

In 2016, the Swedish municipality of Jönköping launched a cycle-to-work scheme for its staff, allowing them to rent a maximum of two bicycles for up to three years. After this period, the municipal employees joining the scheme have been given the possibility to decide whether to acquire the bicycle or return it for free. Between 2018 and 2023, approximately 20% of the municipal staff took advantage of this initiative and 90% of them decided to keep their bicycle at the end of the 3-year period. A study of this program has estimated a benefit-cost ratio comprised between 4.11 and 7.15 (depending on different parameters and scenarios), which means for every dollar invested in this scheme, the city has obtained benefits that can be quantified between USD 4.11 and USD 7.17[447]. These benefits include a reduction of air and noise pollution, optimized travel time, and lower rates of absenteeism as a consequence of better health and well-being of municipal employees.

Case 13 – Brisbane Active School Travel (AST).

Since 2004, the city of Brisbane (Australia) has run the AST program to encourage the active mobility of students and teachers through a range of resources and incentives. Schools joining the program are assisted by a dedicated Council expert and provided with customized travel maps and training sessions on cycling and public transportation uses[448]. Gamification is also employed to stimulate the participation of students, through class and school leaderboards[449]. Over the years the program has involved more than 147,000 students from 177 schools. In 2023, it has been estimated that, in the first year of joining the program, schools increase their active travel by 17% on average. Another study has concluded that the program has contributed to replacing 35% of single-family car trips with active modes of transportation[450].

Case 14 – Rau Kūmara Solar Farm, a community energy project in New Zealand.

The Rau Kūmara Solar Farm is a community-led renewable energy project initiated by the Energise Ōtaki Charitable Trust in 2015[451]. With financial support from the Wellington Community Trust in 2019, the project aims to generate clean energy for the local community. It involves the installation of solar arrays at Ōtaki College and the Ōtaki wastewater treatment plant. Revenue generated from these installations, through power purchase agreements at commercial rates, are used to support community initiatives such as alleviating energy poverty and promoting environmental education. One of the key challenges in such a project was mobilizing key stakeholders. A successful approach might involve leveraging the positive reputation of other local energy initiatives. A well-aligned team with a clear plan was also instrumental in overcoming this challenge.

Case 15 – Smart water management in Seosan City.

Seosan City, situated on South Korea's west coast, was the home of 173,715 people in 2015. In 2016, the city launched the Smart Seosan City project in response to the challenge of drought[452]. The initiative employed smart water metering utilizing remote and digital meters. This resulted in a reduction in water leakage (190,000 m3 per year) and an improvement in revenue water ratio (20%). Additionally, customer satisfaction increased thanks to prompt complaint handling and enhanced service delivery.

Case 16 – Water ATMs in Ghana.

Yawkwei is a growing peri-urban community within the Asante Akim South Municipal Assembly in the Ashanti region of Ghana. Since they were installed in 2018, water ATMs have been the most used water source in the community, besides private standpipes and community boreholes[453]. While users perceived water ATMs as providing more reliable and faster access to water compared to other types of water provision, water ATMs were not always effective in saving users' costs (e.g. due to the machines' operational characteristics) or in enhancing social relations and empowerment (e.g. due to the digital disparities among households).

Case 17 – An IoT platform for water monitoring in Vietnam.

In 2020, researchers from the Ho Chi Minh City University of Technology and the University of Technology Sydney launched a pioneering IoT-based sea environment monitoring platform in Xuan Dai Bay, Vietnam's south-central province of Phu Yen[454,455]. The platform can provide real-time data on offshore environmental conditions and is of special importance for Vietnam's aquaculture industry, as it favors the prevention of fish disease prevention and the protection of marine biodiversity. The project has also allowed the local government to better plan for aquaculture and other local activities, such as sustainable tourism[456].

Case 18 – Citizen science and sensors for lake water quality monitoring.

Citizen science was utilized as part of a research project conducted in 2018 and aimed to monitor and protect the water ecosystem of Uzungöl, a lake in northern Türkiye[457]. In this project, citizen science entailed the identification of key water quality parameters and training volunteers from the community who subsequently collected water quality data for analysis at four sampling locations. An open-source mobile application was also developed for citizens to collect and store data. The project's results indicated the potential of citizen science as a complementary and valuable tool for not only increasing data collection and community engagement but also raising citizens' awareness of water quality and environmental issues. Nevertheless, some challenges also emerged, concerning the motivations of volunteer groups, the interoperability between the data collected by residents and by sensors, and the high cost of the latter.

Case 19 – Smart bins in Wyndham City, Australia.

Wyndham City was one of the first councils in Victoria, Australia to install smart garbage and recycling bins in 2017[458]. These solar-powered bins automatically compress waste, increasing their capacity fivefold compared to traditional street bins. Additionally, sensors notify the council staff when bins are nearly full, reducing the need for frequent emptying. In the first six months of implementation, these smart bins significantly reduced garbage truck trips by 80%, leading to cost savings and environmental benefits.

Case 20 – Machine learning and image techniques to detect street litter in Medellín, Colombia.

Smart cities have increasingly experimented with machine learning and deep learning models, such as Convolutional Neural Networks, to enhance the accuracy of waste detection and classification[459]. A recent study conducted in Medellín, Colombia, exemplifies this approach[460]. Researchers developed a model that integrated machine learning techniques with high-resolution (VHR) imagery and GIS data to differentiate various types of street litter. The model exhibited promising results with high accuracy levels of waste detection (from 73.95% to 95.76%).

Case 21 – Urban mining in Rotterdam, the Netherlands.

The urban mining approach employs recycling and circular solutions aiming to reduce waste by recovering and reusing material value[461]. Rotterdam's ambitious circularity goals in 2030, such as reducing the use of primary raw materials by 50%, have seen a focus on this approach[462]. The city will explore opportunities for resource recovery and reuse by identifying materials in buildings scheduled for demolition, e-waste, or unwanted vehicles. Despite its potential, broader adoption of urban mining seems to be slow in the Netherlands, with only 8% of materials reused. Several obstacles may be related to the affordability of circular products and refurbishment costs. This underlines the need to strike a balance between environmental benefits and economic feasibility in circular solutions.

Case 22 – Transforming waste management system in Freetown, Sierra Leone.

Freetown, the capital of Sierra Leone, embarked on an ambitious plan to significantly improve waste collection and disposal rates by 30% to 60%, from 2021 to 2022[463]. To achieve this goal, the City Council joined forces with Freetown Waste Transformers (FWT) company and mobile network providers to create a digital waste management system. FTW's solutions, supported by a 2-year GSMA Innovation Fund for Digital Urban Services, have demonstrated benefits to 46,552 Freetown residents[464]. The core element involved the DortiBox app. This app used Global Positioning System (GPS) to track waste collectors and allows residents to schedule pickups and pay for services, leading to improved waste collection efficiency and increased city revenue. FWT also collaborated with the Waste Collectors Management Association to train 322 waste collectors on the new system. Additionally, a successful pilot project generated 12,205 kWh of clean energy from about 12 tons of organic waste from landfills, demonstrating the viability of a waste-to-energy solution. Despite benefits, challenges remain, such as smartphone access and mobile money penetration, which need to be addressed for wider adoption.

Case 23 – AI systems to prevent floods in the Far North region of Cameroon.

The Far North region of Cameroon, home to about 3.5 million people, is highly vulnerable to climatic hazards, experiencing a 9-month dry season and a 3-month rainy season. This region frequently suffers from floods, causing significant loss of life, destruction of homes, crops, and grazing areas, and disrupting economic activities. Due to the scarcity of (expensive) ground-based meteorological stations, real-time measurement of hydrological variables is challenging. Conversely, AI systems, leveraging machine learning and deep learning, offer a more reliable alternative for flood forecasting[465], learning from limited observed data. Also, AI is providing a practical alternative to computationally intensive physical-based models[466]. By combining AI with traditional techniques, their performance can be enhanced, improving the accuracy and reliability of flood forecasts in the Far North region of Cameroon.

CASE 24 – AI-enabled mapping of the social vulnerability to earthquakes in Iran.

Tabriz, located in northwest Iran, is a major industrial center with a population of over 1.39 million, ranking as Iran's fourth most densely populated city. It has a significant industrial base, including automotive, machinery, cement, oil, and petrochemical industries. The city's rich history is marked by numerous historical monuments, many of which have suffered earthquake damage due to its proximity to the North Tabriz Fault. To mitigate the social impact, it was developed a novel AI-based framework to evaluate social vulnerability, highlighting the importance of understanding vulnerability patterns for effective urban planning and policy formulation. Based on diverse sources of data, the AI assessment identified five vulnerability zones in the city: very high, high, moderate, low, and very low with a high accuracy of 95.6%[467]. These findings have been invaluable in helping policymakers and urban planners mitigate earthquake risks, reduce damage, and minimize casualties through informed decision-making and targeted strategies.

CASE 25 – Major US cities discontinuing gunshot detection systems.

Since 2018, the city of Chicago (United States) has invested USD 49 million in gunshot detection systems, which employ AI and microphones to identify gunshots within a certain area. From September 2024, however, this system will no longer be in use, following the decision of the City's Mayor to cease the contract with the supplier of the underlying technology. This decision has been opposed by local police leaders arguing that technology is essential for modern policing. Police data, indeed, shows a downward trend of violent crime with a 30% drop in homicides[468]. Nonetheless, the gunshot detection system has been contested by community safety groups in Chicago for reproducing racial biases and directing police to predominantly Black and Latino neighborhoods[469]. Similar issues with the system's accuracy have led other cities, such as Atlanta and Portland, to discontinue their contracts[470].

CASE 26 – Bájale al Acoso (Turn Down Harassment) – Quito, Ecuador.

"Bájale al Acoso" is a pioneering initiative implemented in Quito, Ecuador, to combat sexual harassment in the public transport system by enabling instant reporting via text messages. The project emerged from the city's commitment to addressing sexual violence issues, following protocols established in 2014 and joining the UN Women's Safe Cities Global Initiative in 2016. Initially piloted on municipal buses, it was eventually expanded to all public transport systems. Over two years, 2,800 cases of harassment were reported, resulting in legal action against 73 perpetrators. Beyond legal repercussions, the project has fostered widespread awareness of gender violence, contributing to a cultural shift towards a safer, more inclusive society. Its success has prompted replication in other cities like Buenos Aires, Argentina, highlighting its potential for broader impact and societal empowerment of women[471].

CASE 27 – Safetipin – Delphi, India.

Safetipin, a mobile app, emerged from a collective effort by women's rights advocates in India following the aftermath of the tragic Nirbhaya rape case in 2012[472]. This app empowers users to evaluate the safety of various locations based on factors such as lighting, openness, and visibility, among others. By aggregating these assessments, Safetipin generates safety ratings for different areas, enabling individuals to make informed decisions about their routes and destinations. The app also facilitates location sharing, enhancing users' sense of security. The data collected through crowdsourcing is then shared with local authorities to enhance city infrastructure, including improvements in lighting and pathways.

CASE 28 – Hospitals in South Korea using portable AI-powered X-ray machines

Daegu, a city in North Gyeongsang province, is the nation's fourth-largest metropolitan area with over 2.3 million residents. During the COVID-19 pandemic, Daegu used an AI-based portable chest X-ray camera, roughly the size of a professional photo camera, to speed up patient triage. This device, equipped with an AI algorithm, can detect abnormalities in chest X-rays within three seconds with an accuracy of 99%[473]. Along with COVID-19, it aids in the diagnosis of major lung diseases such as lung cancer, tuberculosis, and pneumonia. It played a crucial role in prioritizing patients during the pandemic by classifying intensive care cases[474]. As digital data, the diagnoses could be easily integrated into patients' electronic health records. Daegu has developed a Smart City Data Hub, designed to manage and integrate the city's data, which includes the electronic health records of 96.64% of its population[475]. The city's effective response to the COVID-19 pandemic highlighted the advantages of a robust healthcare system, supported by advanced technology and data management, in managing public health crises.

CASE 29 – The Socio-Economic Vulnerability Information Management System (SEVIMS) of Beni, Nepal.

Beni, a city in the Himalayan range of Myagdi district, serves as the gateway to Manang and Mustang. Despite its population of over 30,000, the city struggles to provide services due to rapid population growth and challenges like the 2015 earthquake, labor migration, and the COVID-19 pandemic. To address these issues, a web-based system was developed by UNDP Nepal in partnership Pokhara University and Mid-West University to create SEVIMS, aiming at tracking human development, identifying vulnerabilities, and delivering timely services[476]. Key technologies in SEVIMS include a QR-based house identification linked to GPS for precise service delivery, predictive analytics to forecast socio-economic and environmental risks, and real-time data analysis to help authorities respond promptly. These technologies help improve service delivery, support proactive management of socio-economic risks, and foster accountability[477]. After development, the system was handed over to the municipality.

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