WORLD ECONOMIC FORUM

Using Digital Technology for a Green and Just Recovery in Cities

INSIGHT REPORT

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Foreword

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Urbanization and digitalization are two of today's most important phenomena: half of the world's population now lives in cities and half of the world's population is connected to the internet.

These two trends often overlap, as the COVID-19 pandemic and the climate crisis have shown. This report details the intense digital transformation that organizations around the world are undergoing, from private enterprises to local governments.

This rapid, and in many cases, forced process contains two lessons. First, that urban centres and cities are often at the forefront of being affected by and managing these converging trends; and second, that collectively, cities must move from a technology-first approach to one oriented towards the people. Many recent "smart city" initiatives have failed to accomplish their initial goals as they took an overly technocratic approach. Conceived from the top down, they sometimes forgot one key urban ingredient: citizens. From mobility to public health, and from energy to the integration of nature into built environments, technology has the potential to overhaul many aspects to urban life. This is only possible if it can follow a "senseable" structure, grounded in the real needs of urban communities.

Each city is unique, and requires unique solutions that address its geographic conditions, local environment and demographic makeup. Cities should prioritize outcome-driven initiatives whose performance can be easily monitored, perhaps using Big Data. In this regard, local, regional and national governments need strategic and technical advice to take a measured, integrated and proactive approach to digital transformation, while meaningfully engaging their residents and ensuring human rights in digital spaces.

Taking this a step further, multistakeholder approaches must pay extra attention to the digital literacy of the local population to ensure they play an active role in materializing real positive change. According to the International Telecommunications Union, 3.6 billion people today cannot access the opportunities provided by digitalization and the internet. The ongoing COVID-19 pandemic shows that different groups and different parts of cities can be significantly affected by uneven access to the internet, affecting the education, health and livelihoods of generations. The good news is that recent work by the World Economic Forum's Global Future Council on Cities of Tomorrow on assessing and addressing the digital divide in cities shows that local governments can play a key role in improving this situation.

This report outlines 10 key actions to build digitally-enabled cities – actions on leadership, the need for a digital vision, engagement with stakeholders, the strategic role of data and other aspects, which can propel the shared ambition of fostering truly people-centred smart cities. We look forward to seeing how this report is used to digitally enable cities so that their residents can realize sustainable and productive lives.

Executive summary

Digitally empowered cities are more efficient, inclusive and sustainable. This report recommends 10 steps to get there.

Cities must digitalize systematically

Digital technologies provide an unprecedented opportunity to make cities greener and more liveable by resetting existing patterns of production and consumption. City administrations quickly and powerfully adapted digital technologies during the COVID-19 pandemic, establishing their potential. Reform-minded city leaders must now take the next step – to deploy digital technologies in an efficient and ethical way.

Yet, many city halls are still taking an outdated approach to service delivery by only upgrading offerings one at a time, and usually only in certain domains. That means most municipal administrations are not yet agile digital organizations; they are organizations just beginning to offer more digital services. To become more digitally agile, city leaders must systematically steer the use of digital technologies.

This report provides guidance for city leaders to successfully manage digital projects, to strategically utilize data in cities, and to incentivize and initiate the organizational and cultural changes required to build digitally-enabled city administrations.

Digitalization projects must be planned, designed and implemented with an outcome focus

Deploying digital infrastructure is an iterative process. Cities need to start with a pilot approach that engages the right stakeholders, and enables a feedback mechanism at every phase of the design and development cycle. If a pilot fails, it must fail fast and disperse its lessons. If it succeeds, subsequent pilots must iterate, monitor, improve and scale.

Prioritization and planning of projects should be participatory, and based on urgency and impact. When designing digital solutions, the core requirements include privacy, cybersecurity and future-proofing. Design should equally be driven by equity, i.e. ensuring the opportunities generated by the intervention extend to all demographic groups – from digital natives and knowledge workers, to vulnerable communities at risk of digital exclusion. Solutions should be co-created in close collaboration with citizens, actors from the private sector and public institutions.

Finally, successful deployment and scaling of a solution requires a well thought-out change

management approach (through communication and trainings, for instance). This approach should consider the diverse requirements of all sectors of society, include both a digital and non-digital solution during the transition phase, and monitor outcomes to ensure the desired benefits are realized.

Data should inform strategy

The use of data has a strategic role all through the digital journey of a city. For example, real-time data collection, advanced analytics and visualizations in the form of management dashboards or digital twins can guide leaders in making more informed and timely decisions. Historical data collected about citizens, accompanied with privacy safeguards, can enable a shift towards proactive service delivery, which increases service quality and helps reduce costs. For example, preventative healthcare improves efficiencies because fewer people are hospitalized and cost-intensive care is avoided.

When implementing complex data-driven models, the approach should be collaborative, open and streamlined so that data from various sources can be integrated while avoiding redundancies. For solving concrete problems, rapidly applying a trial-and-error approach to data experimentation often yields faster results than spending too much upfront time and effort on integrating various datasets. To establish a culture for evidence-based decision-making, managers should require staff to back up opinions with data whenever possible. More crucial than flashy visualizations is applying relevant data to help address real problems and create accurate semantic models.

Cities must build digital leadership and organization-wide expertise

To maximize the benefits of digital technologies, a city needs a capable organization, with the skills to develop and implement the right digital solutions at all levels. This needs committed leadership that can maintain the momentum, starting with building designated digital leadership at the top of the organization with a digital strategy that is both aligned with the city's strategy and that fits its specific context and challenges. Until recently, most cities considered the IT department to consist of "the people who make computers work". Today, most digitally advanced cities have Chief Digital or Technology Officers at the top of the organization, who are responsible for the city's IT department as well as the wider impacts of technology on city functioning.

What is also essential is that digital expertise is built across all departments, so that they can fully understand, actualize and implement digital opportunities and solutions. Cities must build a pipeline of talent with knowledge of data, software, IT architecture, agile work methods and so on.

Finally, cities must prioritize stakeholder engagement from citizens, the private sector, and other public institutions while designing and implementing digital projects in order to build strong, sustainable and inclusive cities.

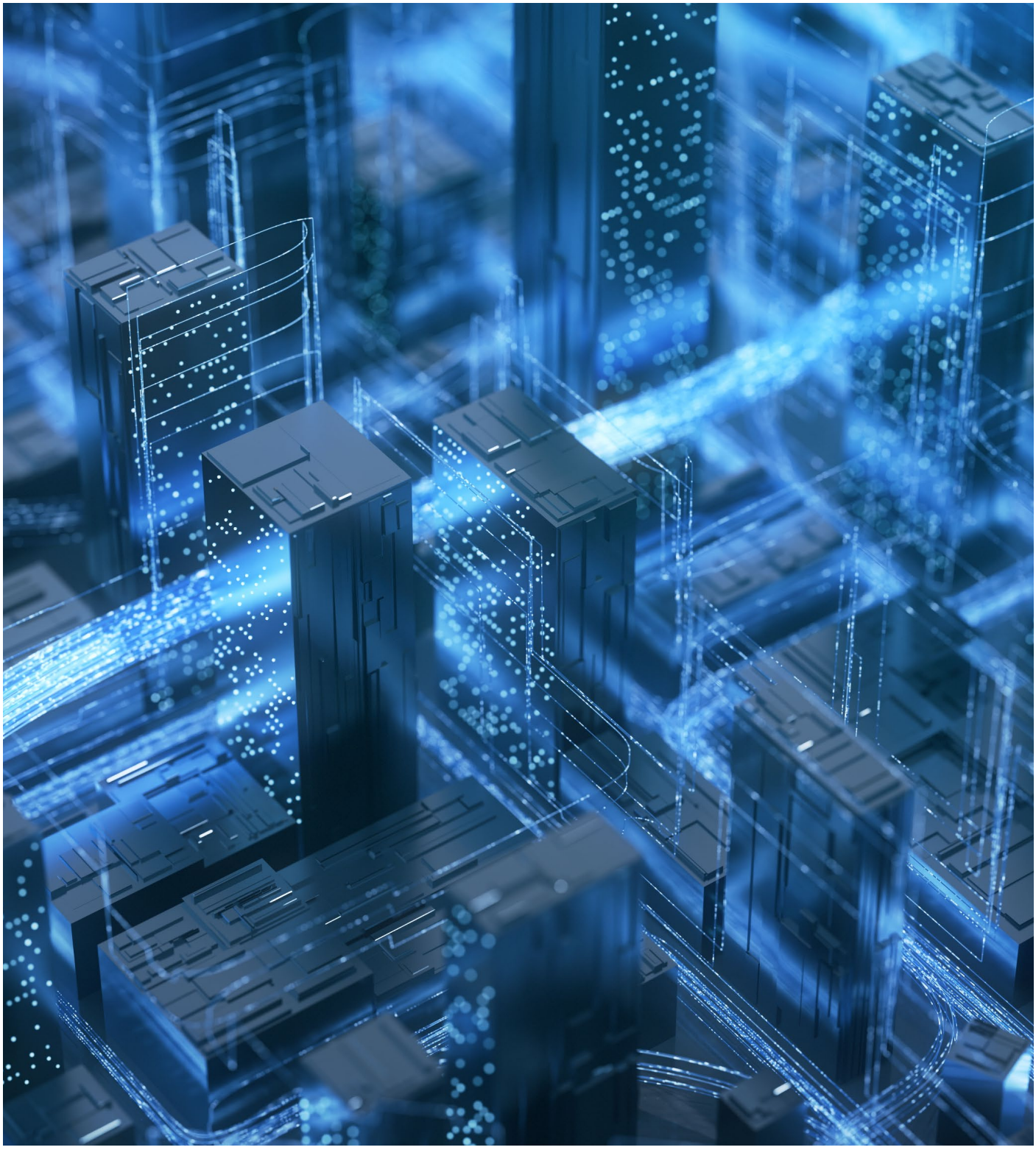
10 steps towards building digitally-enabled cities

This report builds on a 13-city survey about the most important digital technologies and solutions that cities around the world are using. The survey was conducted specifically for this report and its results form the foundation of a digital maturity model and a 10-step action plan that this report recommends.

These tools are intended to help city administrations identify where they stand in terms of digital capabilities, and to derive promising measures for their cities to develop the structures and capabilities required to utilize digital technologies for a green and just recovery.

1 Urban value creation with digital technologies

An outcome-oriented approach focuses on the unmet needs of citizens and asks how these can be better met with enabling digital technologies.



> **Despite digitalization's large potential to contribute to more liveable and green cities, its potential will only unfold if cities manage to systematically apply it to address unmet needs and create real benefits.**
>
> Alice Charles, Lead, Urban Transformation, World Economic Forum

1.1 The opportunities and challenges of urbanization

Today, over 54% of all people live in cities, a proportion that will rise to 68% by 2050.[1] Urbanization provides many opportunities for improving citizens' quality of life, and reducing per capita environmental impacts. For example, urban residents often have better access to education and more economic opportunities than people living in rural areas.[2] Urban residents often use less space for living,[3] and in some parts of the world, commute shorter distances than people living in rural areas.[4] Moreover, the share of the population with access to fast broadband internet is significantly higher in urban than in rural areas. For example, 95% of the world's urban population has access to 4G mobile networks, while the figure for rural areas is 71%. The gap is even larger for computer or internet access at home, with 72% of the urban population and only 37% of the rural population having access to a computer and/or the internet at home.[5]

Still, the rapid population growth in cities creates challenges for municipalities working to ensure a high quality of life for all residents, while also trying to protect the environment. For example, in 2014, almost a third of the world's urban population lived in slums.[6] To date, cities are responsible for more than 70% of global greenhouse gas emissions and two-thirds of global energy consumption.[7] A study by the World Health Organization (WHO) showed that 91% of the population living in urban areas breathes polluted air and 40% has no access to safely managed sanitation services.[8]

54%

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1.2 The transformative power of digital technologies

Digital technologies have penetrated all domains of social life. In 2021, many people spent more than three hours per day using their smartphone, and checked it at least every 30 minutes.[9] Digital technologies not only reshape our ways of communicating with each other, they provide an unprecedented opportunity to rethink existing patterns of production and consumption (see Figure 1). For example, multimodal mobility platforms can increase mobility and accessibility for citizens, while shifting travel to more environmentally friendly modes of transport. Intelligent building management systems can monitor weather conditions and building occupancy, and automatically adjust heating, cooling and ventilation systems to reduce energy consumption and increase comfort.

The COVID-19 pandemic made the benefits of digital technologies more clearly visible than ever before. Digital reporting and warning systems helped identify and disrupt infection chains; virtual communication and collaboration solutions facilitated remote work during a period of social distancing, enabling high hygiene standards; and high-performance computers supported the development and testing of COVID-19 diagnostics and vaccinations.[10] The pandemic has likewise accelerated the pace of urban innovation by fast-tracking technology adoption while allowing city leaders to bypass cumbersome bureaucracy in order to respond more effectively to the needs of people and businesses. Given the transformative power of digital technologies, the question is: how they can accelerate a green and just recovery, and be used to improve the quality of life and environmental protection in cities?

FIGURE 1 | **Exemplary digital applications in cities**[11]

Smart home
Internet of Things (IoT) based home automation (for security, energy, etc.)

→ Making life safer, easier and more convenient

Water
Smart water-supply management

→ Optimized monitoring and maintenance

Transport
Connected cars and public transport network

→ Traffic efficiency and less air pollution

Health
Emergency management network

→ Faster response time and higher reliability

Waste
Digitally-monitored waste disposal system

→ Higher collection and recycling rate

Energy
Smart energy supply management

→ Stable supply of green energy

Administration
Digital services for citizens

→ Enhanced efficiency and effectiveness

Security
Digital identities and authentication

→ Secure and trustworthy digital services

1.3 Utilizing digital technologies for value creation in cities

Smart cities make systematic use of digital technologies. While a large number of smart-city initiatives have been successful, they have mostly been technology-driven and focused on the widespread use of information and communication technologies (ICT).

Smart city visions often convey a futuristic image of a city, focusing on digital technologies. Let's take an example:

Mary wakes up in the morning and eats breakfast prepared overnight by her automated food processer, featuring reduced carbs because her health tracker has noticed that she barely moved yesterday. To commute to work, she uses a combination of a self-driving electric bus, a commuter train and an e-scooter. During the day, she gets several notifications: on her smartphone, about parcels arriving at her house; on her health tracker, reminding her to walk for at least 10 minutes every hour; and on her social media account, that she has made no new contacts in the last 30 days. When ordering food for lunch online, she looks out the window and sees drones cleaning the skyscrapers from outside. After commuting home in a self-driving car, she gets an email from the local police department who saw her – on a surveillance camera – cross a red light when walking to the parking lot. When putting her children to bed, she hears about the e-learnings they worked on in school that morning.

This scenario demonstrates a technocratic vision, in which digital technologies are ubiquitous and have penetrated multiple domains of social life. While many of these technologies have benefits, do they actually meet the needs of citizens, either present or future? Surveys frequently report that the actual unmet needs of urban residents are finding good and affordable housing, having good air quality in the city, working fulfilling and secure jobs, and having access to affordable and quality education and health services.[12] Thus, despite digitalization's large potential to create more liveable and green cities, this potential will only unfold if policy-makers manage to systematically apply it to address unmet needs and create real benefits. This requires listening to citizens' concerns and needs, using evidence to make decisions, building up digital competence at all levels of city governance, and initiating the organizational, procedural and cultural changes that this will need.

"While many of these technologies have benefits, do they actually meet the needs of citizens, present or future?

This report proposes an outcome-oriented approach to using digital technologies in cities. This approach does not start by asking, "What can we do with digital technologies?", but instead by asking, "What are the unmet needs and challenges in cities, and how can we better meet them in a resource-efficient way by utilizing the possibilities provided by digital technologies?"

Section 2 introduces the capabilities of digital technologies; section 3 lays out an outcome-oriented approach for planning, designing and implementing digital infrastructure projects in cities; section 4 discusses the strategic role of data; and section 5 lays out some leadership and governance approaches for digital value creation. Section 6 presents the results of a survey of city administrations, which includes insights on important digital solutions and infrastructures, digital technologies that helped in dealing with the COVID-19 pandemic and a digital maturity model for city governance. Finally, section 7 makes key recommendations in the form of a 10-step action plan.

2 The unique capabilities of digital technologies

These range from engaging stakeholders to streamlining processes and replacing physical with digital services.

> **Digital technologies provide unique capabilities that allow us to create more liveable, just, green and resilient cities. The COVID-19 pandemic created an unprecedented momentum for city administrations and businesses to initiate those digital projects that address the most pressing issues.**
>
> Jan Bieser, Senior Researcher, GDI Gottlieb Duttweiler Institute, Switzerland

Today, the "entirety of technologies used to store, process, and transmit information" has merged into a single technology – digital ICT.[13] Cities can utilize ICT to rethink existing patterns of production, and use specific ICT-based strategies to increase liveability, reduce environmental impacts and solve their most pressing issues (Table 1).

TABLE 1 **ICT for more liveable, sustainable, resilient and affordable cities[14]**

Use ICT to…	Description	Example
Inform	Advanced data collection and analytics can gather information, then process and visualize it in an informative way that benefits citizens, organizations and policy-makers.	The city of Santiago, Chile, utilized the data captured via mobile phones, as well as big data analytics, to create a Mobility Index and Spreading Model to understand the impact of lockdowns on disease spread and stop the spread of COVID-19. It enabled them to identify the high-risk zones and model the impact of reopening of public spaces (such as schools and shopping malls) on the spread of the virus.[15]
Engage	Virtual collaboration facilitates communication between many actors, and provides new possibilities for collaborating with diverse stakeholders to find solutions.	The city of Semarang, Indonesia, utilized the CollabData digital platform to capture the needs and challenges of its communities in real time during the COVID-19 pandemic, which informed interventions.[16]
Simulate	Computer simulations allow testing of solutions in a virtual world before they are realized in the real world.	A virtual twin helped the district of Maurepas, France, to simulate the impact of a new metro station on commute times, and on the architectural design of the neighbourhood.[17]
Replace	Replacing physical with digital services can increase their accessibility, availability and reliability, while reducing the cost and environmental impacts of service provisioning.	Data-driven building management using smart sensors and algorithms at the campus of Tampere University, Finland, has helped to replace 70% of the visual maintenance inspections with predictive analytics.[18]
Intensify	Digital technologies allow better coordination of access to physical infrastructure among multiple users. This allows increased utilization of infrastructure, and reduces the need for building additional infrastructure.	In Delhi, India, the Chartr app provides contactless ticketing, live tracking of buses, detection of the nearest bus stops and a travel planner. It helped regain 45-50% of the pre-pandemic ridership by September 2020.[19]
Streamline	Digital technologies allow improved process efficiency to achieve more with less (e.g. through faster feedback loops).	In the city of Zaragoza, Spain, smart energy systems were installed in historical buildings to automate energy monitoring and management. That helped to cut energy cost by 20% and operating cost by 30%.[20]

Note: See case studies for more details

CASE STUDY 1

Virtual twin
Rennes, France

The Rennes Métropole, together with 42 neighbouring municipalities, is one of the most dynamic cities in France, with around half a million citizens. A little more than 15 years ago, Rennes Métropole worked with Dassault Systèmes on a project called Virtual Rennes. They created a virtual twin city, which expanded on top of a digital 3D mock-up, to simulate the impact of new projects and policies on the city, as well as to develop collaboration capabilities by allowing stakeholders to interact in the virtual world.

For example, it tested what would happen if the Maurepas district of the city underwent an urban rejuvenation project, including the building of a new metro station. With the virtual twin, and with open data from several city departments and corporations involved in the project, the urban planning department could understand the consequences for commute times, or on the architectural design of the neighbourhood.

The virtual twin has made it possible for stakeholders from the public and private sectors to collaborate early in the planning process. It benefits elected officials who gain a more insightful vision through experimentation with alternative scenarios, especially when decision-making is challenged by increasing complexity and shorter decision-making periods.

Virtual Rennes has also intensified the dialogue between the municipal authorities and citizens. For example, the metropolis has always relied on “project houses”: local community houses where neighbours can meet and discuss how a given project will affect their everyday lives. Now, project houses use the virtual twin to inform residents about existing projects and initiate the co-construction of projects with local communities, enhancing the credibility and legitimacy of the decision-making process and ensuring buy-in.

Through this unique combination of architectural quality, outcome-based urban design and public engagement, Rennes Métropole is showing how digital technologies can improve urban development practices. The project has demonstrated that technology does not replace people or human decision-making, but can support the transformative governance that is needed. Since then, the virtual twin has been used by other local entities as diverse as the Région Grand Est in the eastern part of France and Hong Kong.

CASE STUDY 2

Virtual power plant
Lappeenranta, Finland

In order to curb climate change and build a sustainable society, the share of renewable energy production must increase. However, renewable energy production volumes fluctuate. This is a challenge for the power grid, since production and consumption of electricity must be balanced at all times. Grid balance can be maintained by either temporarily increasing the production volume, or by dynamically decreasing demand to match supply – not always viable solutions. Virtual power plants provide a solution by aggregating many small electricity loads that can be actively managed (e.g. switched off at times of low electricity supply).

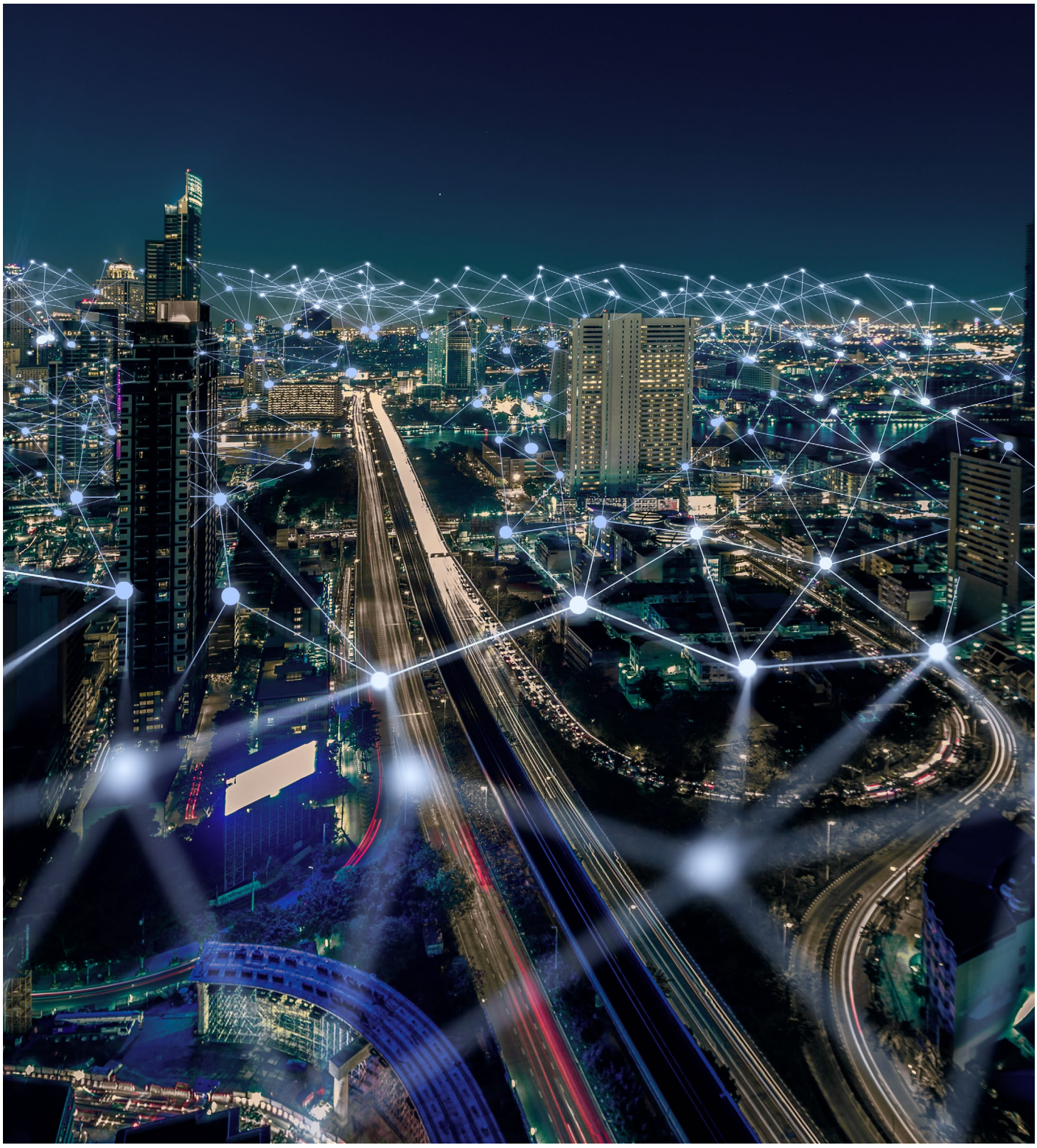
In Finland, Siemens has started a new virtual power plant service called Virtual Buildings Ecosystem Oy (Vibeco).[21] It integrates micro power loads from buildings through the Vibeco platform into the national transmission grid. At the heart of the service is cloud-based software that controls building loads. It allows operators to gain transparency on connected assets, identify flexible and distributed energy sources, optimize operational cost and participate in ancillary markets. In the city of Lappeenranta, 17 buildings, including schools and sports halls, implemented the solution. The benefits were clearly visible: transparency over energy consumption increased; energy efficiency improved; flexible energy resources that could be sold on electricity markets were identified for new revenue streams; and matching electricity demand with the available renewable supply became easier.

Virtual power plants have great potential to support the energy transition – not only in cities, but in all kinds of properties, such as industrial sites or campuses. In Lappeenranta, the service is being rolled out in 50 more buildings.[22]

The initiative demonstrates how digital technology can be used to create solutions from which property owners, grid operators and the public can all benefit. In many countries, however, the regulatory framework prevents the use of virtual power plants. In this respect, Finland is a pioneer in showing how to use grid edge technology and smart buildings to promote decarbonization.

3 Outcome-based planning, design and implementation of digitalization projects

Cities must identify and prioritize the most urgent unmet needs of citizens.



Today, most cities aspire to be human-centred and results-oriented. City leaders proclaim that their priority is to meet the needs and improve the wellbeing of current and future generations. Yet in a world of accelerating digital transformation – including the spread of 5G, cloud computing and artificial intelligence (AI) – the emphasis often tilts towards the priorities of technology rather than people. City authorities, businesses and citizen groups are understandably enthusiastic about the prospect of seamless e-governance, frictionless e-commerce and the potential of game-changing digital services. But for cities to truly meet the needs of their citizens and streamline city administration, they must plan, design and implement digital projects with an outcome-oriented approach. Equally importantly, these processes must engage citizens and all relevant private and public actors.

3.1 Data-driven and participatory planning

> **The days of centralized and closed planning are disappearing, with more and more tools available for improving the transparency and accountability of city-level decision-making.**
>
> Robert Muggah, Principal, SecDev Group and Co-Founder, Igarapé Institute

Enhancing data collection at the metropolitan scale

Most cities oversee a vast array of passive and active data collection tools that document the experiences, priorities, attitudes and satisfaction levels of their residents.[23] Not all of these are high-tech — conventional information harvesting tools include censuses, elections and surveys that various public, private and civil society groups conduct from time to time.

City service providers and private businesses also regularly collect first-, second- and third-party data on user experiences. A growing number of cities are likewise drawing data from digital platforms – from social media networks to sensor arrays – for insights into patterns of behaviour. Here, it is imperative that data be collected, retained and shared in an ethical, transparent and legal manner.[24]

Meanwhile, the private sector is accelerating the deployment of advanced technology platforms to track perception, sentiment and satisfaction, offering additional signals for a city's planning process. For example, the real-estate sector is undergoing a technological leap with the rise of "PropTech",[25] which has the potential to harvest vast amounts of real-time data on space usage, mobility, health and energy efficiency.

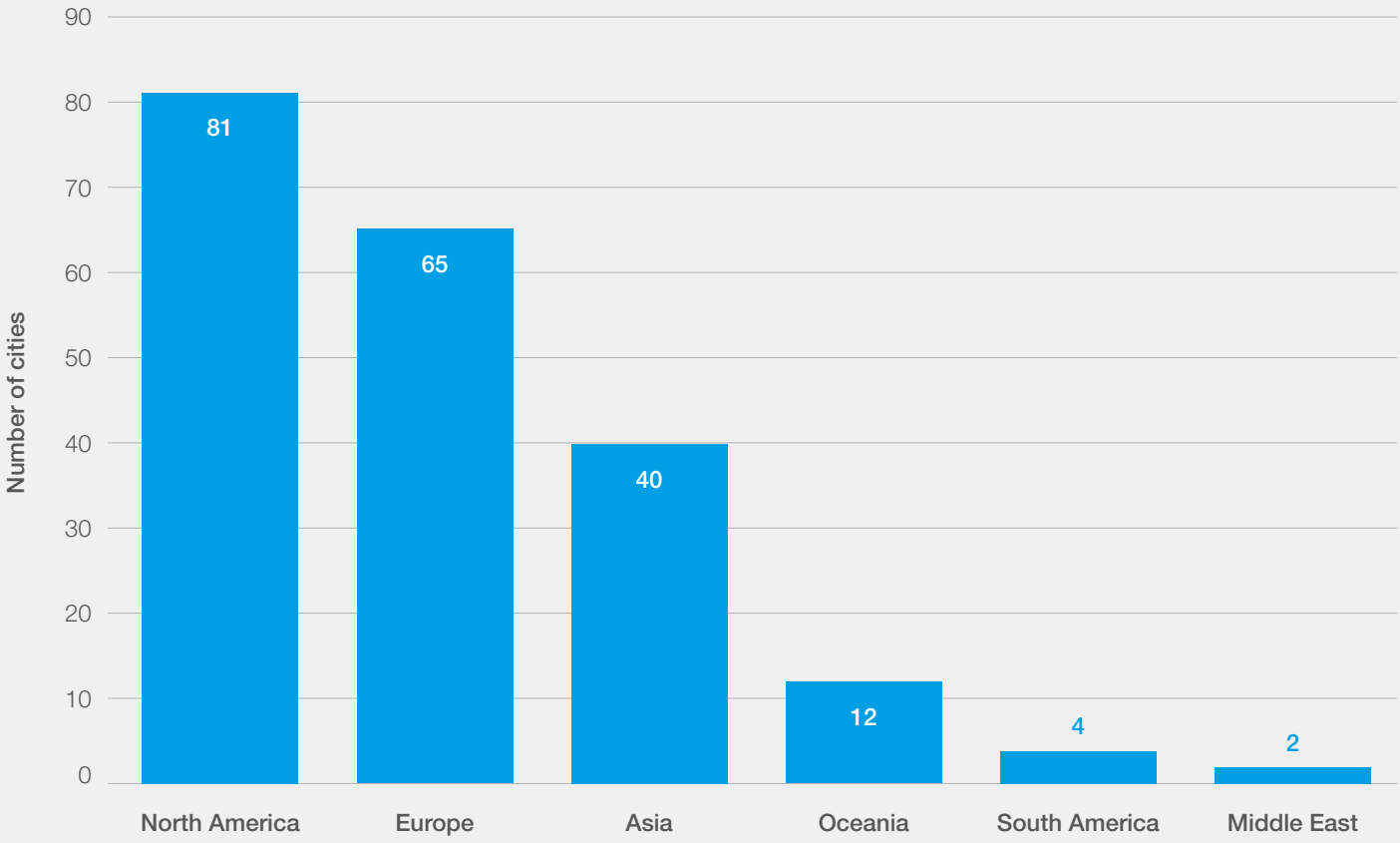
SecDev Group has produced a data visualization tool in partnership with the cities of Amsterdam, Bristol, Chicago and Los Angeles that aggregates over 40 metrics of vulnerability and resilience.[26] Platforms that simulate a range of scenarios are providing decision-makers and citizens the ability to game-out scenarios based on actual and projected social, economic and demographic conditions.[27]

While a tremendous volume of city-level data is increasingly available, it is not always well structured, organized, optimized or made seamlessly available. To address this lacuna, several cities have launched processes to standardize and open up their information to the public, including through online interfaces. At the same time, the World Council on City Data is advancing standards through the International Organization for Standardization (ISO) for a selection of city metrics.[28]

Citizens are using numerous open-source and crowd-sourced data collection and sharing initiatives such as OpenStreetMap. City residents, and not necessarily urban planners, are often the ones amplifying and actively engaging with open-data portals and dashboards.

Today, more than 80 cities and councils in, for instance, the US and Canada,[29] share city data through open-access portals. Dozens more exist in Asia, and to a lesser extent in East, Central and South Asia, Latin America and the Middle East (see Figure 2). Digital natives, hacktivists and start-ups are busily developing tools that identify city challenges and opportunities to inform decision-making and planning. Examples range from apps that pinpoint areas at risk of spreading disease or exposing vulnerable groups to insecurity, to sites that recommend up-and-coming bars, restaurants and nightclubs. While data protection and privacy are paramount, many of these platforms offer tremendous insights into the pulse of the city, and thereby facilitate the identification and prioritization of digital infrastructure projects in cities. For more information on the use of data in cities, see section 4.

FIGURE 2 | **Number of cities with aggregated open-data portals by region[30]**



Promoting co-creation and co-design of city spaces

Many cities are experimenting with more open and participatory means of engaging citizens in creating and designing city plans, programmes and services, taking a bottom-up rather than top-down approach. The days of centralized and closed planning are disappearing, with an increasing array of digital tools available for improving the transparency and accountability of city-level decision-making. When done well, harnessing citizen engagement and deepening deliberative processes improves the overall quality of laws, regulations and standards. It also strengthens their legitimacy, and builds trust between local authorities and residents.[31] By the same token, if mismanaged, collaborative processes can backfire by raising and not meeting expectations, and unintentionally excluding groups, thereby deepening mistrust.[32]

A wide range of collaborative platforms exist that can strengthen data-driven collaboration and mobilize collective intelligence at the city scale.[33] For years, a major challenge was that cities often fielded multiple stand-alone systems operating independently. This is starting to change. In addition to ArcGIS and ESRI, which dominate the city market, urban planners are deploying a wide range of 3D modelling and simulation platforms such as MapBox, Sketch-Up, City Engine, Lumion, OpenCities Planner, CityCAD, Modelur, SimWalk-360, UrbanCanvas Modeler and UrbanFootprint.[34] These and other open-source platforms allow for a much wider integration of high-resolution data, as well as opportunities to share data in a detailed yet intuitive format.[35]

A wide range of dashboards, digital planning platforms and apps make it possible for citizens to engage in urban design. Planetizen, a site that explores the future of the built environment and its connected natural environment, features various digital, participatory platforms.[36] Germany alone uses some 70 methods and tools (now compiled and available online) to enhance participation at the municipal level.[37] Some cities are also exploring ways to utilize wearables such as ChangeExplorer to enhance citizen feedback.[38] Companies such as Agile City, H.AppyCities and others promise to deploy a range of digital tools to help cities make more intelligent decisions, and empower citizens through technology.

When done well, harnessing citizen engagement and deepening deliberative processes improves the overall quality of laws, regulations and standards.

With virtual and augmented reality, as well as digital twins,[39] cities can design and trial virtual models of processes and services collaboratively with stakeholders from academia, government, industry and civil society, for everything from infrastructure planning to open platforms, marketplaces and smart mobility deployments. These kinds of tools are now widely regarded as indispensable for smart city design, development and deployment.

Strengthening monitoring and evaluation

As important as planning projects is monitoring and evaluating them to ensure they deliver their intended outcomes. Digital transformation is enabling a rapid expansion in both formal and informal means of monitoring and evaluating city plans, programmes and services. For example, city residents can use a widening array of options to make their voices and concerns heard, thanks to the dramatic spread of broadband internet and mobile phone connectivity, combined with GPS devices, cameras and social media outlets. Citizen-led initiatives are using handheld devices for collecting digital data, mobile phones for providing feedback, satellites for tracking deliveries, and online platforms for reporting back about the quality of services and ideas for improvement.

The challenge urban policy-makers face is deciding what kinds of digital tools are most appropriate, ensuring they are digitally secure, and avoiding ad hoc implementation that could reduce their effectiveness and efficiency.[40]

CASE STUDY 3

Modelling the next-generation energy grid

Paris and Toulouse, France

The world's population is growing at a pace that creates new requirements for energy supply and distribution and forces decision-makers of all countries to adapt their development strategies. ModeliScale is an energy network digital twin that allows simulation of the future energy grid.[41] The model covers multiple inputs including the electricity grid, heat networks, HVAC (heating, ventilation and air conditioning) systems, buildings, solar panels, electric vehicles and storage. By taking a realistic view of a city's complexity, it helps with the design, planning, installation, commissioning, operation and maintenance of tomorrow's energy grid.

For example, the heating network of a neighbourhood of Toulouse has been modelled in a single environment, from the very large (at the size of the city itself), to the very small (at the level of a valve). With such an approach, it has been possible to investigate the overall steady state of the heating network, including its ability to better measure the energy required and the behaviour of the boilers.

The same principles have been used to model the power grid of a 23,000-inhabitant city near Versailles, complete with a heating network, more than 700 commercial and residential buildings, a co-generation power plant, the electric grid and solar panels. Expanding to a multi-physics and multisystem approach in this case, it is possible to understand the impact of changes in future energy needs and behaviours, thus helping the city prepare for its energy transition.

The project brings together key industrial players of the French energy landscape with software providers. Industrial knowledge and experience, coupled with software capabilities, lead to important breakthroughs that make the models more scalable and accurate. The flexible simulation scenarios range from hours to seasons. Overall, the outcome is a new, powerful decision-making tool.

CASE STUDY 4

Smart City Planning
Skopje, North Macedonia

Skopje developed a Green City Action Plan to identify and prioritize investments and actions that address its environmental challenges. Designed in line with the Green City Action Plan (GCAP) methodology of the European Bank for Reconstruction and Development (EBRD), the plan focuses on the wastewater system, as Skopje is one of the few capital cities in Europe without wastewater treatment. All raw sewage collected in the city is let into the Vardar River, polluting the environment and affecting the livelihoods of people downstream – in both North Macedonia and Greece.

With financing from the European Investment Bank, the European Bank for Reconstruction and a Western Balkans Investment Framework grant, and with insights from GCAP, a new wastewater treatment plant will be built as a fully automated facility using modern sludge management technologies. Utilizing biogas produced on-site, the plant will be capable of generating its own power. It will be equipped with central and automated digital controls, as well as a system of smart sensors and algorithms to collect data to increase energy efficiency and reduce operating and maintenance costs.

Online analytics and logic controllers will continually adjust and balance the treatment process, producing a final treated effluent consistently safe for disposal, irrespective of the highly variable incoming flow. Overall, the project will help improve water quality, assure asset resilience and optimize energy consumption and costs. The project is at an advanced stage with the works contract expected to be awarded by the end of 2022.

CASE STUDY 5

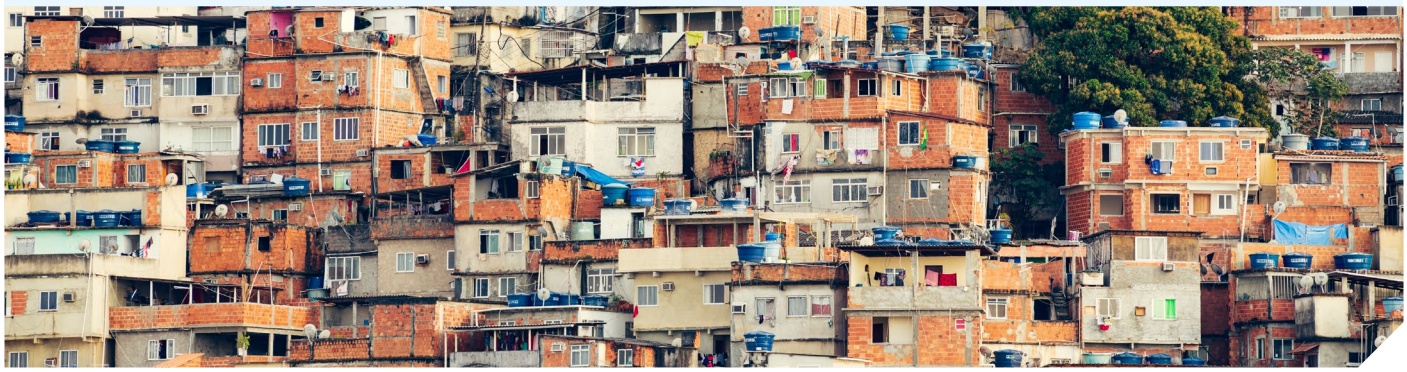
Using digital technologies to embrace the informal
Rio de Janeiro, Brazil

Favelas are informal settlements that have sprung up in Brazil since the 19th century. The communities residing there contend with social segregation and unfavourable living conditions – they often lack paved roads and have subpar utilities infrastructure. The MIT Senseable City Lab examined how favelas could become more liveable, working with the secretary of urban development for the city of Rio de Janeiro.

The Favelas 4D project employed an advanced scanning tool called LiDAR (light detection and ranging) to perform a detailed scan on Rocinha, one of the largest favelas in the city. To capture every inch of the 1.5 square kilometre neighbourhood, researchers carried 3D scanners through its narrow alleys and down the sloping hills.

The visualizations give urban planners and other stakeholders significant insight for targeting social and economic interventions. They helped establish a mapping framework, so that property records could be created, allowing people to transfer their homes with minimum cost and bureaucratic intervention. It also gave each building an address, which smoothed out the logistical flows inside the favela. It suggested where stairs could be added to improve circulation and redundant structures removed to bring in more light and air. On a wider scale, the project is helping the favela get better integrated into the formal parts of the city.

Favelas 4D can be implemented outside Rocinha too. Of the 4 billion inhabitants in cities across the globe, roughly a billion live in informal dwellings (and this is set to rise to 2 billion by 2030). The system could be adopted in shantytowns and refugee camps to improve knowledge about the most marginalized communities in society, and discover better solutions to connect them with the planned segments of the urban structure.



3.2 Design

> **Cities must aim to create secure digital infrastructure that serves citizens' needs, today and tomorrow. This will require careful planning, customer focus and future-proof concepts that must be integrated into a network that connects people, buildings, transport and infrastructure.**
>
> Marija Zima, Head, Smart Cities and Solutions, ABB

Since citizens make a city, all digitally-enabled solutions should be designed using a people-centric, data-driven approach, supported by a participatory process.

Inclusion and accessibility for everyone

Smart device apps are tools that allow a nearly infinite number of residents to use cloud-enabled services to purchase tickets, make appointments, reach customer service and manage administrative tasks in a timely and cost-effective manner. To ensure inclusion and accessibility for everyone, solutions should be rigorously tested, with user feedback driving an iterative design process.

Every solution must aim to expand opportunities for all users. While digital natives will be early adopters of such technologies, solutions must also reach those citizens who do not find it easy to switch from traditional to digital services, whether for generational, access or other reasons. Implementation plans must include digital literacy training.

When launching a new online registration portal or service, non-digital alternatives must also be provided, such as through a customer contact centre or helpline, so that all citizens can access it. Further, electronic kiosks placed in key locations, where they are easily accessible to a broader section of the population, can enable citizens to physically connect with the same cloud-enabled network of services.

> **To ensure inclusion and accessibility for everyone, solutions should be rigorously tested, with user feedback driving an iterative design process. Every solution must aim to expand opportunities for all users.**

Future-proof design

Digitalization did not happen overnight, but the pace of transformation in the last decade has been unforeseen. Common challenges that require careful planning include managing change, training personnel and maintaining compatibility of new structures with existing processes, usage patterns and paper-based databases. Fortunately, the latest future-proof digital city technologies – from building and power-grid management, to bi-directional electric vehicle charging – are designed not only to connect flexibly to existing power grids, utilities, commercial and residential buildings, but also to be cloud-enabled, and thus easily and rapidly updated as cloud technologies evolve.

By adopting the principles of open application programming interfaces (APIs), cities can allow other app developers to access the data, making the systems more flexible. By providing greater connectivity, broader access to platforms and compatibility with other applications, open APIs can help create an integrated and highly energy-efficient smart city network.

Ensuring a smooth transition towards the digital mode also helps the digital industry, which has undertaken efforts on two fronts. First, the application and platform interfaces have been increasingly documented and published to ensure that solutions are interoperable, and can be interconnected to other city systems. Second, industrial groups have been organized to promote the emerging standards and norms, in order to ensure interoperability of systems, and enforce neutral semantics that systems can use to communicate with one another. Many applications are already built with such standards in mind.

Safeguarding citizens: Cybersecurity and privacy

Cybersecurity, cybercrime and privacy are significant concerns when digitalizing city processes. Every stakeholder, whether from the industry, government or civil society, must prevent leakage and misuse of data and violation of privacy. A vast range of technical solutions are available to ensure the highest levels of protection from unauthorized data use. The legal basis for cybersecurity is constantly being developed and enhanced. However, further efforts are necessary, especially for older legacy systems. More training and awareness are also needed within the broader population about the dangers that can be encountered in the digital space.

Just like projects in the physical world, many security and privacy solutions are easier to implement at the design stage, and get more difficult as a project progresses.

CASE STUDY 6

Homeowners turn electricity producers
Switzerland

Becoming increasingly aware of their impact on the environment, citizens are adopting renewable energy more avidly. More and more people want their homes powered from communal solar panels. This transformation has been enabled by regulations such as the new Energy Act in Switzerland, which has given rise to a homeowners Association for Private Consumption (ZEV). However, the calculation and billing of electricity use has traditionally been an arduous and complex process, from meter reading to rate calculation and billing, and deters many homeowners from switching to renewable energy "prosumerism".[42]

To make this move easier and faster, Ormera, a start-up by SwissPost Finance and Bern Water and Energy, has partnered with ABB Switzerland.[43] Together they have developed a simple solution that combines smart meters with blockchain technology. The smart meters capture and bundle digital data about power production and consumption, and automatically send it to Ormera's blockchain application via a secure data connection. The application keeps the data constantly updated and trackable, eliminating the need for meter readings and time-consuming information transfers.

Users get full transparency about their personal energy consumption and costs in order to make informed choices. Administrative effort and costs are reduced to a minimum. Moreover, the data stored in the blockchain is secure, and cannot be changed or deleted unnoticed. This simplification of the home energy production and usage ecosystem will encourage many more homeowners to join the renewable energy prosumer movement, accelerating the energy transition in Switzerland. The solution can be easily commissioned and installed on any building, without the need for complicated programming.

CASE STUDY 7

Cashless travel
Surat, India

Surat has the longest bus rapid transit network in India, and an efficient city bus service with an average ridership of 210,000 per day. The city developed three systems as part of the Surat Smart City programme: an intelligent transit management system, an integrated traffic control system and an automatic fare collection system (AFCS).

AFCS aims to provide transparency in revenue, enable single-ticket travel across the city, support decision-making with regard to fleet sizes and routing, improve reliability and enhance citizens' satisfaction with the mobile app and mobile ticketing. The system is implemented across numerous electronic ticketing machines, points of sales (where tickets are purchased), pole validators in city buses (that check the ticket instead of a conductor), and turnstiles and fare gate validators at stations. Travelers can also use a mobile application for m-ticketing, further increasing convenience. More than 8,700 cards and 460,378 tickets have been issued to date.

The AFCS project's Surat Money Card reduces the use of paper for ticketing, and supports other services such as tax collection, libraries and swimming pools. Citizens benefit from faster ticket issuance, automatic fare calculation, mobile advance ticket booking and more efficient boarding and exiting. The system also ensures accurate and strict fare collection, improves on-time operation and reduces costs.

CASE STUDY 8

Digitally-enabled retrofitting of cultural landmarks
Zaragoza, Spain

Zaragoza wanted to extend its smart city concept to historical landmark buildings, including the Seminario of Zaragoza, the city hall, the police station and the Centre for Art and Technology. These buildings are notoriously inefficient, with antiquated and inefficient energy systems. Zaragoza's goal was to protect these cultural heritage sites, while modernizing the energy infrastructure to save energy and reduce emissions.

The city of Zaragoza chose to retrofit its heritage sites with a smart energy system that would automate energy monitoring and management, and make them compliant with ISO 50001, the global benchmark for energy management and efficiency.[44] Zaragoza partnered with ABB to solve the particular challenge of retrofitting swiftly and inexpensively. By attaching advanced smart sensors to existing switchboards and circuit breakers, ABB was able to digitalize and automate energy metering, protection and control functions. This plug-and-play modular digitalization made it faster and easier for Zaragoza to benefit from advanced cloud-based energy management, and supports the plug-in of additional applications in the future, even beyond energy management.

Using modular digital energy management, Zaragoza can preserve its architectural treasures while saving up to 30% of the operating cost, cutting energy use by up to 20%, and reducing its carbon footprint significantly. This solution represents an important advancement for Zaragoza's smart city concept, since faster commissioning and scalability mean that a common solution can now be replicated at all major historical buildings in the region.

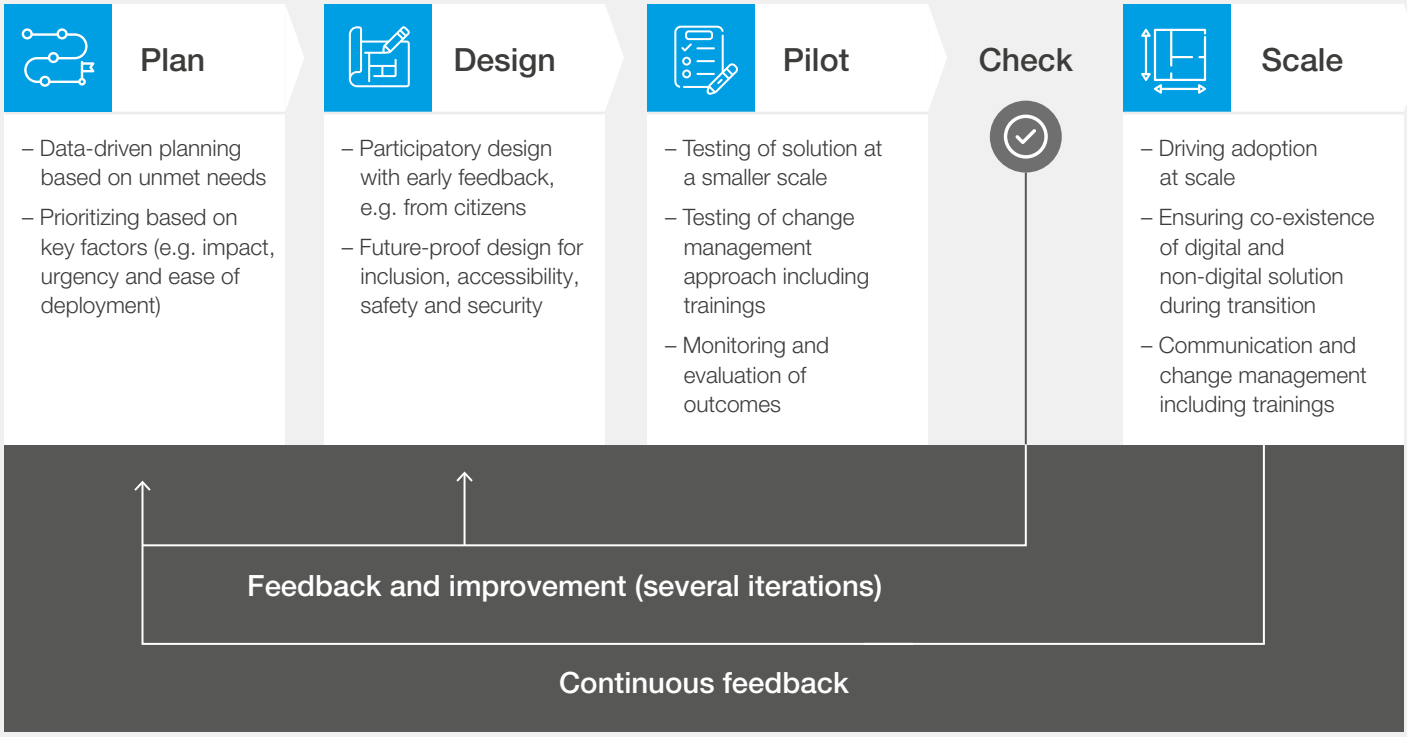
3.3 Implementation and monitoring of outcomes

> **Defining the right metrics and benchmarks for success, and adopting a more agile approach and mindset to solution development and implementation is critical.**
>
> Amit Midha, President, Asia-Pacific and Japan and Global Digital Cities Leader, Dell Technologies

Implementation, operation and monitoring are vital to assess how successful a solution has been in delivering the intended outcomes and value to citizens. Following an iterative approach (see Figure 3) can help to maintain an outcome-oriented focus at each phase of the digital solution cycle.

The following section provides further guidance on how to employ a phased and iterative approach, how to scale a working solution and how to manage change.

FIGURE 3 **Iterative process for planning, designing and implementing digital projects**



Phased and iterative process

Cities need to implement digital solutions in a phased manner, prioritizing based on, for instance, the level of impact, urgency and ease of deployment. Implementation is also an iterative process. Cities will need to design this stage starting with a pilot approach that engages the right stakeholders and users, and enables a feedback mechanism at every stage back into the design and development phase. It is critical to define the right metrics and benchmarks for success, and adopt a more agile approach and mindset to solution development and implementation.

Scaling

As the implementation of a digital solution matures and scales, administrators need to create a blueprint for further design and implementation across various scenarios, from neighbourhoods to cities to countries. This is crucial for maximizing efficiency, speed and the value of the outcomes. Digital

solutions can scale only when adoption by citizens scales. For this, cities must build awareness through strong communication, along with enablement and training to manage change. Where necessary, cities need to consider a transitionary phase of having a hybrid model of digital and non-digital processes.

In some cases, an active incentive mechanism might be needed. Also, using an open, marketplace-type approach that enables multiple solutions to be made available would not only provide greater choice to citizens so as to drive faster and higher adoption, but also catalyse innovation.

Managing change

Implementation involves not just the technological aspects of the digital solution, but also the associated people, processes, tools and infrastructure. A robust change management approach is critical for facilitating and training both the administrators and the users of the solution. Also critical is defining clear linkages and metrics between the outcomes for citizens and the respective agencies' key performance indicators, as well as establishing a robust measurement process using the relevant data.

CASE STUDY 9

Operations centre
Bristol, UK

To run a city effectively, a wide range of organizations must interact to ensure collaboration between the transport, health, emergency and other critical support services. The award-winning Bristol Operations Centre operates 24x7, 365 days a year, as a multi-functional and multi-agency centre to deliver all kinds of services. It houses an emergency control centre, a traffic control centre and community safety (CCTV) control rooms. A Super Operator is trained in eight core functions including call handling, alarm and CCTV monitoring, incident response and parking enforcement.

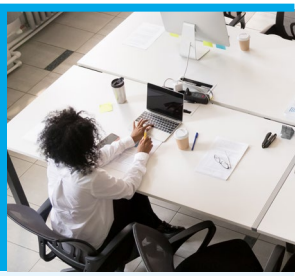
The Operations Centre helps manage a road network worth an estimated £4-6 billion. It actively reduces congestion and accidents by controlling traffic signals to prioritize buses, which helps the Bristol commuter save an average of 60 hours per year. The council's civil protection team uses 1,100 CCTV cameras across the city, which has helped reduce crime by 50% in areas covered by CCTV.

A telephone-based careline supports over 17,000 vulnerable and elderly citizens, helping them live independently in their own homes for longer. The supported people are 44% less likely to go into hospital than those without the service. In addition, this service saves the Bristol Council between £7 and £22 million in nursing home fees, as clients tend to live in their homes for seven months longer on average.

At the concept and design stage, the project team and the city's resilience partners considered it important to create and build a multi-agency incident suite alongside a state-of-the-art Operations Centre. This has proven invaluable in providing effective planning and response to the city's events, incidents, protests and demonstrations.

CASE STUDY 10

An intelligent and connected city
Curitiba, Brazil



Curitiba is at the forefront of urban innovation in Brazil. In recent decades, Curitiba has implemented measures to: eradicate poverty through employment and education; increase welfare spending to prevent crime; improve affordable housing access; and fight pollution and climate change. With strong public infrastructure to meet its accelerated growth, the city continuously invests in innovation to reduce inequalities.

Among its key policies, Curitiba has reinforced the Curitiba Tecnoparque programme,[45] which incentivizes companies to invest in technology and innovation, by reducing the service tax from 5% to 2%.[46] Curitiba has also launched "Worktiba", a freely accessible, public co-working space for all citizens. It supports the development of start-ups, provides "Fab Labs" for digital fabrication and prototyping, and brings together students, companies and communities to share knowledge and put innovative projects and ideas into practice.

In order to monitor the impact of these policies, and especially to ensure that the policies benefit all citizens, Curitiba tracked 123 indicators of criteria such as sustainability and responsibility. The monitoring showed that between 2007 and 2020, 208 start-ups benefited and 112 companies got registered. This generated 12,900 jobs, with 1,296 vulnerable families benefitting from a restoration programme in their neighbourhood.

While Curitiba is usually recognized for its urban mobility infrastructure, its experience shows it is possible to build a sustainable and innovative city that is also inclusive. The innovative solutions and measurement framework, designed to evaluate the extent to which public policies are delivering citizen well-being, now provides a practical example for peer cities to implement, manage, operate and monitor public policies on creative innovation systems.

CASE STUDY 11

Sint-Maarten Hospital
Mechelem, Belgium

Due to growing demand for healthcare services, changing expectations from patients and increasingly complex regulations, today a hospital must be much more than simply a building. At the 700-bed Sint-Maarten Hospital in Belgium, Siemens took up the task of delivering a smart hospital that would serve as a blueprint for intelligent, human-centric healthcare.[47] The solution includes a range of technologies for safety and security management, including a fire detection and extinguishing system, an access control and CCTV system, and an automatic incident alarm, which delivers alerts through mobile devices to speed up incident qualification and resolution.

Specifically, operation rooms at Sint-Maarten Hospital are equipped with integrated touchscreens, allowing scenarios for specific surgeries to be quickly set up with a single touch. Along with total room automation, and integrated room cleaning, hospital teams can plan and use operation rooms with greater efficiency. At the core of the solution is a cloud-based system for building and energy automation as well as monitoring, which aggregates all technologies into a cloud-based hospital management system.

Altogether, the solution has created a benchmark in healthcare infrastructure. It affords the highest levels of care, comfort, safety and security – for patients, staff and visitors. It also helps meet energy and operational efficiency goals. With technology playing an active role in the day-to-day running of Sint-Maarten Hospital, staff have more time to focus on productive tasks. By providing the highest level of care, patients have shorter waiting times and reduced infection risks.

CASE STUDY 12

Microgrid South Africa

Upper Blinkwater, South Africa

As things stand today, 650 million people are likely to not have access to electricity in 2030. Nearly nine out of 10 of them will be in sub-Saharan Africa.[48] Electricity is a prerequisite for developing economic opportunities in rural Africa, but it must come from renewable sources for a smaller carbon footprint. A microgrid is an ideal solution, especially in remote regions where setting up a connection to the national power gird is not economically feasible. Communities can gain independence by taking their power supply into their own hands with a microgrid.

Siemens has implemented a mini-grid in UpperBlinkwater, together with the South African National Energy Development Institute, GIZ (Society for International Cooperation) and Council for Scientific and Industrial Research.[49] The partners have installed an off-grid mini-grid, mainly fed by a photovoltaic system with a peak output capability of 75 kW. Since electricity consumption is highest in the evening, a battery storage solution with a capacity of 370 kWh was installed, along with a diesel generator as back-up to prevent power outages and to handle periods of peak demand.

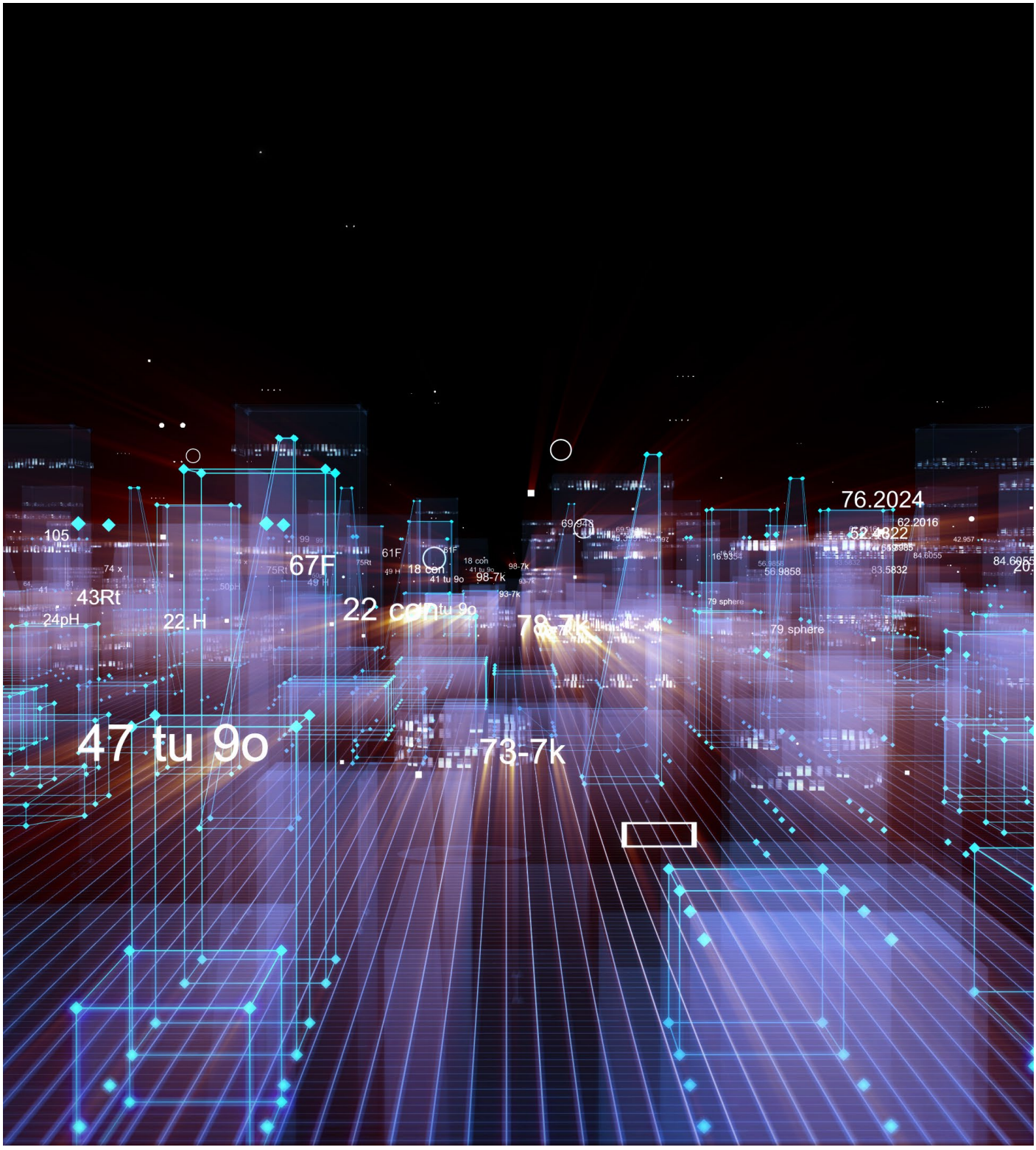
The mini-grid supplies electricity to 67 homes, as well as a school and a church. Power supply to homes, including in the evening, allows students to study and fridges to stay on. The solution also helps create better opportunities for development in off-grid regions, and slows down migration from rural areas. The mini-grid can be expanded to meet the community's growing demand for electricity.

650 million

As things stand today, 650 million people are likely to not have access to electricity in 2030. Nearly nine out of 10 of them will be in sub-Saharan Africa.

4 The strategic role of data

Data can be utilized for evidence-based decision-making and more proactive service delivery to citizens.



Addressing citizens' needs proactively brings indirect benefits for the city as well – for example, preventative healthcare helps to save costs as fewer people are hospitalized and expensive intensive care is avoided.

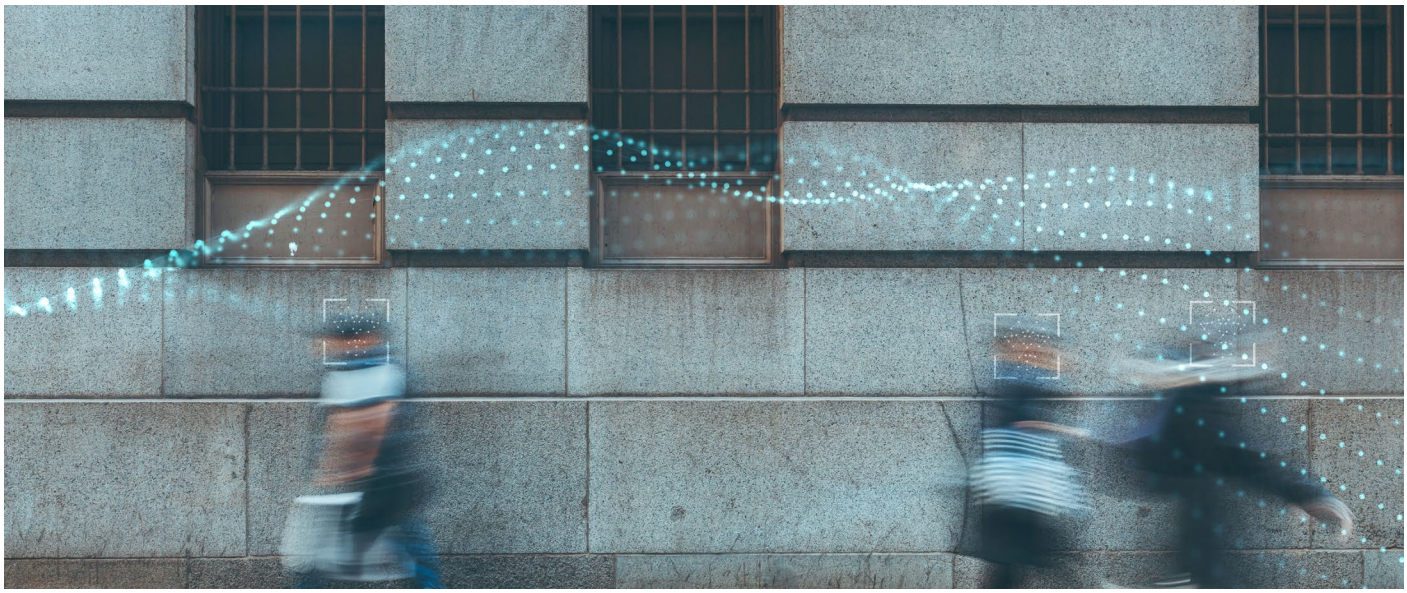
The amount and types of data available to cities has increased significantly in recent years. Cities can utilize a vast amount of data from various sources – data generated by citizens when using city services, captured via IoT sensors, gathered by statistical departments, and more.

While data are primarily collected and needed for providing city services, they can be utilized for a range of other purposes that benefit the city and its citizens. Two key benefits are: a new kind of data-driven decision-making, and proactive and personalized services.

In the first instance, a city collects real-time data from its services and infrastructure; uses advanced analytics such as machine learning to derive insights from it; and provides the insights to its leadership to help them make decisions. While the city management benefits directly, citizens and businesses benefit indirectly from better informed and timely decisions that lead to a better functioning city.

In the second instance, a city can use data to develop personalized and proactive services for its citizens. Based on historical data collected about its citizens, a city can identify similar segments or clusters of citizens, recognize their key life events, and use predictive analytics to make recommendations from its service portfolio to best fit each citizen's individual needs and life situation. Such use of data directly benefits citizens in the form of more relevant, timely, personalized and proactive services. Addressing citizens' needs proactively brings indirect benefits for the city as well – for example, preventative healthcare helps to save costs as fewer people are hospitalized and expensive intensive care is avoided.

The following sections explore these two data use cases, and discuss the success factors and the capabilities required to advance these approaches.



4.1 Data-driven decision-making

The global COVID-19 pandemic has illustrated the importance of real-time dashboards and predictive models that can be used to monitor the phenomenon, to make informed decisions, and to better target preventive actions.

Dyan Currie, Chief Planner, Brisbane City Council

Management dashboards

Real-time dashboards have proved their worth during COVID-19, and the more accurate and timely the data, the better it supports decision-making.[50] For example, predicting the need for hospitals and intensive care based on pandemic data and a susceptible-exposed-infectious-recovered (SEIR) model can help target resources in a timely and cost-efficient manner.[51] Accurate predictions and targeted preventative measures ultimately save lives.

In a city context, a management dashboard is a major undertaking. A city's operating environment and services essentially encompass all aspects of human life, covering transportation, housing, healthcare, employment, education, cultural and leisure services. Management dashboards must have a clear structure and relevant data. Sometimes less is more – if there is too much data, or data is poorly presented or is otherwise not actionable, it has little value.

Digital twins

Modern 3D modelling capabilities allow the creation of complete 3D models of a city that go beyond conventional dashboards, and allow simulation and analysis of diverse phenomena. Proposed plans can be visualized, and actions can be tested virtually before implementation in the real world. Such digital twins enable the analysis of everyday activities in the city, and can help in tackling societal problems such as climate change. For example, the city of Helsinki has recently published the Helsinki Energy and Climate Atlas 2.0 tool that allows them to analyse the potential of solar and geothermal energy, energy consumption, CO_2 emissions, and the impact of renovation activities for each building individually.

Essentials of good visualization

Visualizations are key to making data actionable. Too often management dashboards are created with flashy data visualization in mind, forgetting its most important goal of enabling better decision-making. Each element of a visualization must help the decision-maker to make a more informed decision. For this, decision-makers need to be engaged early on when defining the functional and data requirements.

Similarly, instead of focusing on a detailed mesh-based 3D visualization for the digital twin, it is essential to include an accurate semantic model and integrate data into it. For example, analysis of CO_2 savings from renovating buildings requires an accurate semantic model of wall, roof and window surfaces, as well as incorporation of energy consumption data into the model.

The simplest approach to evaluating whether a given problem can be solved with a particular dataset is to gather and experiment with the data as early on as possible. Before spending too much time and effort integrating various data, rapid experimentation yields faster results about their usefulness. Experimenting with data often provides further insights that can then be discussed and iterated to set the right direction early on.

Effective data storage

Data should be stored only once, and only those data should be stored that are really needed. The focus should be on optimizing data flows from the source to the consumers (for instance, in case of management dashboards, digital twins and algorithms) as seamlessly as possible. Data should be machine-readable through APIs. Data virtualization eliminates the need to store unnecessary copies in data warehouses and data lakes. However, in some specific cases, such as comparing and reporting data over a long period of time, it may still be necessary and perfectly justified to collect historical data in a data warehouse or use a similar solution.

When considering implementing a complex data-driven model such as a digital twin, it is essential to adopt a collaborative and open approach. Implementing a digital twin is a complex effort that is best done through collaboration with other organizations, by using open standards. For example, the open CityGML standard, and its application domain extensions (ADE), can help to integrate the work done and the data produced by others into a given model. Furthermore, by open-sourcing a model and its extensions, third parties can develop complementary solutions based on open data for which the resources at hand may not be best suited.

“ Implementing a digital twin is a complex effort that is best done through collaboration with other organizations, by using open standards.

4.2 From a reactive to a proactive city

> **Utilizing personal data and predictive analytics enables cities to offer citizens individual, targeted and proactive services when they are needed.**
>
> Jan Vapaavuori, Senior Adviser, NREP; Board Member, Miltton Group; Mayor, City of Helsinki (2017-2021)

A proactive approach is a major paradigm shift

A city is a service organization that provides value-added services to its residents. Digitalization has enabled cities to provide digital services that are available independent of time and place, which offers convenience as well as better service for citizens. However, better use of data can enhance service quality and the overall user experience. Utilizing personal data and predictive analytics enables cities to offer citizens individual, targeted and proactive services when they are needed. For example, the city of Helsinki piloted proactive pre-school student placement in two of its school districts in January 2020, wherein 1,000 families with pre-school children were proactively sent an SMS proposing pre-school placement in a nearby school. The pilot was a success, with around 84% of families accepting the school placement with a single SMS (see full case study below).

Proactive services can have bigger implications for the city. The entire public sector, and cities in particular, are facing a major challenge in the future as people live longer, placing additional demand on public services. Employee salary levels track private sector increases, but public sector funding is not commensurate with these rising staff costs. The paradigm shift of moving from a reactive to a proactive city can help address this gap. Meeting citizens' needs in a proactive manner often helps to avoid costly services at later stages, which is often the case in the reactive mode.

Creating the required data capabilities is imperative

Proactive services require two kinds of core data-related capabilities: use of advanced algorithms (e.g. for machine learning), and a human-centric approach for utilizing personal data.

First, machine learning is needed to enable the following capabilities:

- Citizens can be profiled (e.g. using clustering).
- Citizens' significant life events can be recognized (e.g. using classification).
- Personalized recommendations can be made (e.g. using recommendation algorithms).

Second, a human-centric approach is needed when dealing with personal data. Citizens should be given better control over the use of their personal data. Helsinki has adopted MyData principles to allow citizens to give informed consent for the use of their personal data.[52] In addition to providing the possibility of consent, the use of personal data is fully disclosed so that citizens know when, for what purpose and on what legal premise their personal data is used.

When implementing proactive digital services, various legal and ethical considerations regarding personal data come into play. For example, processing of personal data, especially sensitive personal data such as patient data, may not be possible in cloud-based environments, which can hamper data analysis capabilities. Profiling persons and cross-utilizing data across registries is also restricted by data protection laws in Europe. For these reasons, data protection and other legal issues need to be considered early in the service development. Also, proactive services often entail a level of automated decision-making. To avoid bias and other ethical issues, the reasoning and logic used in providing services should be transparently disclosed to data subjects through an AI registry or a similar service.

Finally, in a city context, services are often used across city borders. For example, people may live and work in multiple cities. Personal data should be interoperable and roam across borders, but only on citizens' terms. For these purposes, standardization efforts are needed to ensure interoperability, both at the national and international levels.

4.3 Creating a culture for a data-driven city

Managers across businesses and public bodies have the responsibility to promote a culture in which opinions without supporting data have little value. This cultural prerequisite will not only foster the use of data at scale for informed decision-making but will also facilitate data-sharing between government and business, taking into account the objectives and arguments of all stakeholders – including citizens.

Simon Huffeteau, Government coordinator of the building energy efficiency renovation plan, Ministries Ecology Energy Territories, Government of France; Vice-President, Infrastructure & Cities Strategy, Dassault Systèmes (2019–2022)

Data or complex dashboards with predictive models have little value if nobody is using them. City executives, and officials responsible for the services, need to derive value from the use of data. Asking the right questions is a good starting point. For example: "What do we need to know to better carry out our daily work?" or "What information would be most useful for making operational and strategic decisions?"

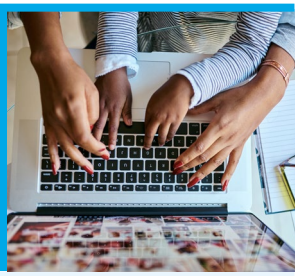
The mayor may ask: "How do we reduce homelessness?" A city data team can translate this question into analytics questions, such as: "What is the total number of homeless people, and where are they are located in the city?" "Is there data available on the reasons for homelessness?" "Are there factors that have a strong correlation with homelessness (e.g. mental health problems)?"

Data are typically dispersed in various systems and formats, and their quality varies. Poor data quality and integrity is a common challenge. In a massive organization such as a city, it is unrealistic to carry out centralized data cleansing and quality control. Instead, organizations need to promote a culture in which data ownership and governance are distributed. Business units should be responsible for their own data and its quality, as well as for the APIs through which data can be used. Interoperability requires coordinated actions between various parties.

Promotion of human-centred design thinking improves the quality of digital services and their adoption. Similarly, organizations should ask themselves what data-driven design approaches will advance data use. When managers promote a culture in which opinions without supporting data have little value, they drive their organizations to use data better for informed decision-making. Once the value derived from better use of data is evident at all levels of the city organization, it can drive further adoption of data and analytics in the design, development, training and management of services.

CASE STUDY 13

Datastore
London, UK



The London Datastore is an initiative of the Greater London Authority (GLA) to release as much of London's data as possible.[53] Initially, the London Datastore primarily provided information on the strategic activities and spending of the Mayor and the GLA. Since then, the London Datastore has integrated a huge amount of data on areas such as jobs and employment, environment, housing, health, transport and community safety. These datasets have been used to tackle some of London's most important problems, from easing road congestion to improving air quality.

In 2018, the London Datastore evolved to become both an open data portal and a closed platform for secure data sharing. The platform gained the capability to share privately held data, as well as restricted and/or licensed data, with trusted partners. Unlike other ad hoc sharing measures, the platform puts in place data sharing mechanisms that help break down organizational silos, and encourages greater data cooperation among jurisdictions and other levels of government. This greater ease of access and sharing, of both public and private sector data, can help generate meaningful insights that anticipate future trends and risks and improve public service delivery.

For example, the UK Department for Education's National Pupil Database has shared data with the GLA to develop a number of innovative education-related initiatives. One example is the London Schools Atlas, an interactive online map of the capital city with uniquely detailed and comprehensive information on primary and secondary schools, their current patterns of attendance, and potential future demand for school locations across London. To modernize the city's approach to data, the city hall is working on "Datastore 3.0", a revamp and expansion effort that aspires to become the central register of metadata for all major datasets in London, both open and closed.

CASE STUDY 14

Understanding the social and economic impacts of COVID-19
Brisbane, Australia

Since COVID-19 hit, cities have faced no greater challenge than responding to and attempting to reverse the economic and social impacts of the pandemic. Within Brisbane, the use of data and analytics has been crucial to gaining visibility into the pandemic's impact, particularly regarding movement and activity within the Central Business District (CBD), the city's economic hub, and about which areas of the city were most vulnerable.

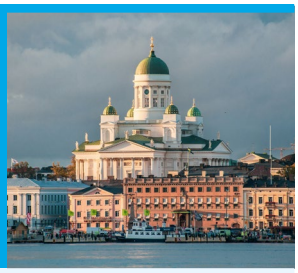
When Brisbane entered lockdown in March 2020, the need for reliable data to understand the extent of the impact, and implement and monitor recovery initiatives for businesses and residents, became clear. The economic development team focused on analysing data from a range of sources, and bringing these into a single view to help the city council develop a raft of recovery measures. To protect vulnerable communities, economic analysis included data on the number of people and businesses receiving financial support, spending patterns by suburb and the number of jobs lost during lockdown. Data on pedestrian and bicycle traffic counts, the amount of road traffic and congestion, public transport usage and e-scooter usage patterns were also collected.

The analysis allowed the council to directly compare the shift between different transport modes – for example, the movement away from public transport into private vehicles at the height of the pandemic – and how quickly people were reverting to pre-COVID travel behaviours. It is also allowing the council to gain an understanding of how quickly the CBD's economy is recovering, as outlets reopen and workers return to the city.

Versions of these reports have been presented at public forums to give citizens insights into how COVID-19 has impacted their city, and encourage them to support local businesses. It has also helped businesses understand how quickly the CBD is returning to pre-COVID activity levels.

CASE STUDY 15

"Most usable and used data in the world"
Helsinki, Finland



The City of Helsinki has an ambitious goal to have the most usable and used data in the world by 2025. One of the goals of the strategy is to use data "to create a city that proactively responds to residents' service needs on their terms".[54] Two very concrete examples of how Helsinki is working towards this goal are the city's Health Benefit Analysis, and its "Kindergarten place via SMS" service.[55]

Health Benefit Analysis is a digital tool that provides evidence-based electronic decision-making support to medical professionals.[56] The tool makes the need for treatment easier to predict, enabling healthcare professionals to offer clients timely support. The city aims to shift from an approach that corrects health and well-being problems to one that prevents problems and addresses them proactively.

Another way in which Helsinki is taking a proactive stance is with regard to pre-primary school enrolment. Pre-primary education is compulsory for children in the year they turn six, and the city is by far the largest provider of this service. As discussed before, the "Kindergarten place via SMS" service offers parents of children who turn six a spot at an early childhood education facility, which they can accept via a simple text message.[57] Parents do not need to fill any forms, as the city uses the data already available to contact families when their children reach the appropriate age.

Helsinki wants to ensure that the "sharing of data drives business and the utilization of external resources". This goal is being advanced, for example, through the Helsinki Energy and Climate Atlas, as discussed before, produced with 3D city information models.[58] The Atlas has a wealth of information related to building energy use that anyone, including property owners, city planners and companies, can use freely. Data types include: the amount of solar radiation buildings are subject to; municipal records, e.g. the volume and building material of buildings; and simulated heating energy demand, and its effects on energy-related renovations. Since its launch in 2018, the Atlas has been accessed more than 16,000 times. Some of the Atlas's source data can also be downloaded as open data from the Helsinki Region Infoshare service, run by the city of Helsinki along with the region's other cities.[59]

CASE STUDY 16

Ethical data governance and responsible innovation
Bristol, UK

Responsible innovation is a key part of Connecting Bristol, a smart city strategy.[60] Supporting the ambitions of its One City Plan, the Bristol city council is seeking to harness data to make Bristol more sustainable, prosperous and inclusive.[61]

As part of the mission to deliver responsible innovation, the council is working in partnership with the Centre for Data Ethics and Innovation (CDEI), an independent organization set up by the national government in 2018, with a remit to help the UK navigate the ethical challenges presented by AI and data-driven technology.[62] In 2020, the CDEI and the city council embarked on a 12-week review of the current data governance practices, and took the first steps towards developing an ethical data governance framework. This framework aims to enable the development of digital capabilities, which will deliver valuable insights and improve public services, while ensuring data privacy and security.

Based on this work, and CDEI's recommendations, the council has undertaken a discovery project to look at the practicalities of further embedding data ethics into its Think Family Database (for troubled families), and will be linking to other subregional councils and key agencies.[63] Scaling up this approach to other cities will require greater resources and government guidance.

5 Leading and governing for digital value creation

Cities must build digital skills throughout the administration and citizenry.

To utilize digital technologies, cities need a skilled and powerful organization capable of creating and implementing digital solutions. This means every department should have people who understand technology, its potential and it risks. This section describes how cities can manage this change by introducing the right organizational, leadership and governance structures, by diffusing digital skills across the organization, and by deploying various partnership and financing models.

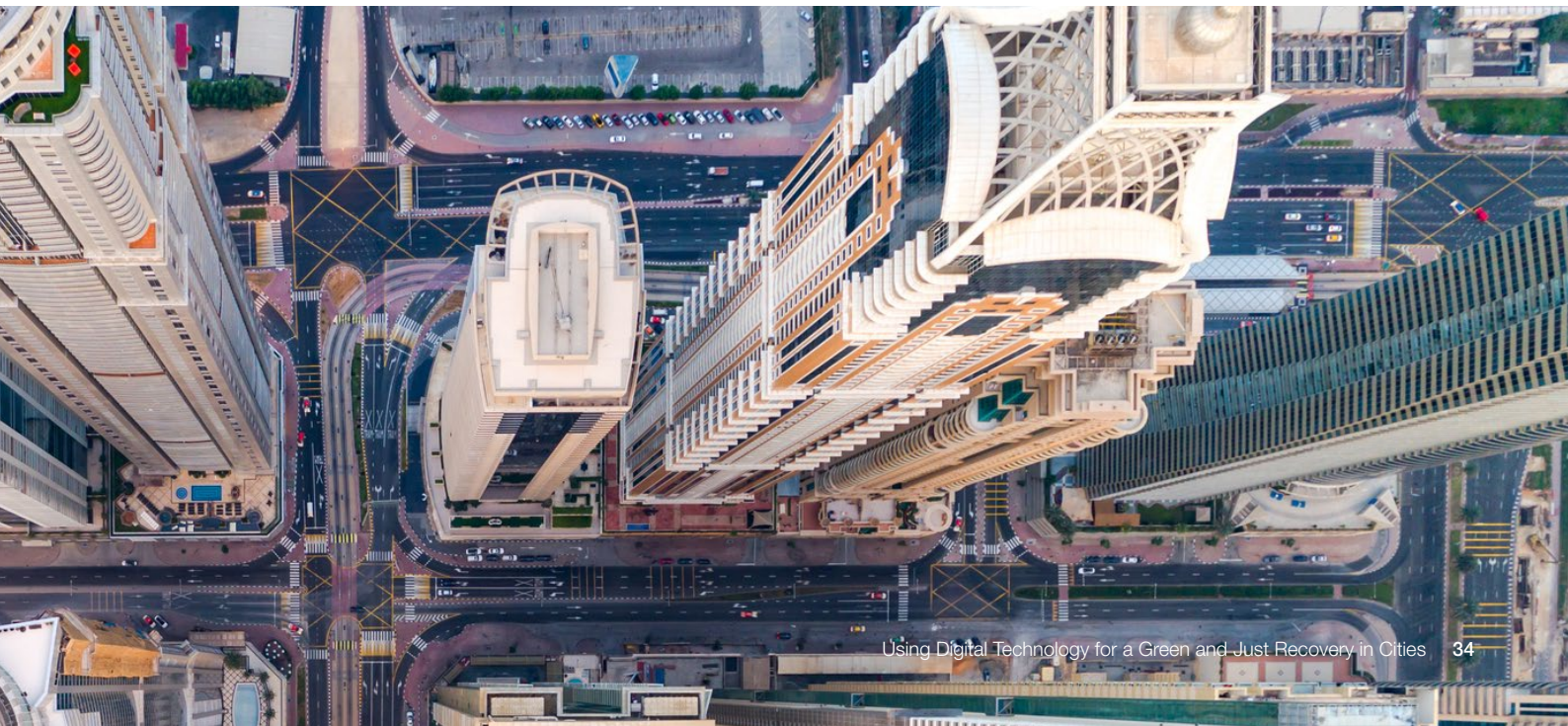
5.1 Leadership and organization

> **Most digitally advanced cities now have Chief Innovation/Technology/Information/ Digital Officers or deputy mayors at the top of the organization, who are not only responsible for the city IT, but also for the impact of technology on the city.**
>
> Ger Baron, Chief Technology Officer, Government of Amsterdam

Until a few years ago, most cities considered the IT department nothing more than "the department that made computers work", restricted to a back-office function in the catacombs of the city hall. This perception has evolved in many cities. When the Obama administration in the United States (US) instituted a Chief Technology Officer in the White House – Aneesh Chopra, in 2009 – it proved a game changer for many governments, including in cities. At the same time, the hype around Smart Cities fuelled an agenda that pushed cities to invest in technology, which dramatically changed the way that municipalities operated. The impact on the lives of residents started to become visible, increasing both operational efficiencies and convenience (e.g. through more accessible government services). Cities that were early adopters of this approach include Amsterdam, Barcelona, Brisbane, Dubai, Helsinki, New York City, Reykjavik, Singapore and Tallinn.

Establishing leadership

In any organization, progress requires a commitment from leadership to maintain momentum. Cities that saw the potential of technology early on created a department dedicated to advancing their technological transformation. These cities built their capacity and designated a leadership function to oversee the integration of technology and to advance their digitalization strategy. Some cities even have mayors who are pushing the digital agenda, as Helsinki did. And this is where digitalization currently finds its place: city leaders must take charge because it impacts everything citizens do in their daily lives. Meanwhile, Neelie Kroes's appointment as European Commissioner for "a digital agenda" has been an impetus for cities all around the globe. Such leadership is central to the city's strategy, and plays an essential role in identifying how technology fits into the organization's objectives. Likewise, having a digital arm is becoming important at a political level. Governments that engage and interact with residents via digital platforms are generally more successful in achieving their objectives.



Developing and aligning digital city strategies

Once the leadership is in place, the city must determine what to prioritize, align the digital strategy with the city strategy, and empower the technology leader to enable change. Because the political landscape can drive the decision-making process, many cities need to determine their objectives and the political ramifications of their actions before embarking on the digital transformation journey. Cities get their own profile, their own "flavour", and their own applications. For example: Barcelona came out against big tech; London prioritizes inclusivity and more accessible services; New York City prioritizes digital access and digital literacy; Helsinki wants to be efficient; and Amsterdam wants to be "free and inclusive".

This also means cities are organizing themselves in different ways. Some key priorities are the same for every city, such as migration to cloud services, data integration and creation of operational efficiencies. Cybersecurity and data privacy are also rising upwards on many cities' agenda. How a city views working with private companies can impact whether it will collaborate with private companies, and how it will communicate with its residents about their privacy and digital rights.

Building digital competence

Leadership, both political and from civil servants, is different in many cities. European cities like Helsinki, Barcelona and Amsterdam strongly believe that governments should be able to own and operate their own technology, but many US cities outsource a lot of their tasks to big tech companies. There is no correct or incorrect perspective, but it influences how a city is governed. Whichever way a city develops, it must have knowledge about technology, its impact and its potential. It must invest in digital leadership, and build a pipeline of talent that has knowledge about data, contracting, software, IT architecture, agile work methods, and more.

Every employee in the organization needs basic knowledge about technology and the processes needed for redesign (see section 5.2 on digital skills). It takes leadership on many levels to change the culture and structure of an organization, but a sense of urgency to evolve is a must. Platform companies will push current rules and regulations to their boundaries, start-ups will disrupt every industry, and traditional companies will change at a high velocity – else they will die. The reality is not so different for city governments: change is imperative, and leaders must pick up the gauntlet.

CASE STUDY 17

The Golden Mile
Vijayawada, India

In India, roughly 13 million people migrate annually in search of a better livelihood. The Indian government launched the Smart Cities Mission to develop 100 smart cities, with funding from central and state governments, in order to better serve city residents. Cisco partnered with the state government of Andhra Pradesh and the municipality of Vijayawada to deploy a smart city showcase to demonstrate how smart cities could provide next-generation services and transform urban centres in India.[64]

The "Golden Mile" is India's first smart street, a 3-km section of road in Vijayawada city equipped with free Wi-Fi, intelligent street lighting, smart parking, information kiosks and live transport updates. All the equipment along the Golden Mile is controlled and monitored by the City Digital Platform of the Vijayawada Municipal Corporation. The solution has helped to increase the availability of parking space, realize energy savings in lighting, and monitor and improve air quality.

While solutions to make cities smarter number in the thousands, the challenge for city authorities is to understand which ones are the most effective so that they can deliver the best value for money and the maximum benefits to residents. A smart city demonstrator is an easy and low-risk way to test smart city deployments before rolling them out city-wide. Thanks to the Golden Mile, smart lighting and city surveillance were identified as the most relevant smart city use cases, and were deployed in the following cities: Vijayawada, Jaipur, Nagpur, Gurugram and New Delhi. The success of the project also led to the deployment of two additional smart city demonstrators in Gujarat International Fintech City and Hyderabad.

CASE STUDY 18

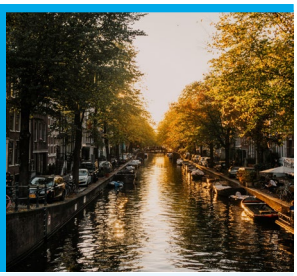
Creating a digital foundation
Helsinki, Finland

As stated before, Helsinki wants to be the city in the world that best capitalizes on digitalization. In 2020, the city of Helsinki launched a major multi-year project to reform its "digital foundation" – a platform that provides centralized infrastructure and basic IT services to all employees across city divisions. The ambition is to create a foundation on which efficient and reliable services can be built to cater to the city's employees and residents. For example, records of the city's various IT devices are currently managed by each department individually. Consolidating these into a single system will allow automation of the management of IT devices centrally. Reliability is key, as a telecommunication network outage can paralyse the city's operations and cause personal safety risks, reputational risks and financial losses.

The ambition of the digital foundation is to offer services and information proactively, automatically and as easily as possible. Some goals of the programme are: for the city to own its own backbone network and connections to strategic offices; to offer new joint services within the scope of the integrated strategy for services, applications and cloud computing; to expand remote support for 24x7 coverage across the city; and to offer adequate self-service opportunities.

CASE STUDY 19

Digitalization and innovation
City of Amsterdam, Netherlands



Technology and innovation have driven change in social structures, the economy and physical infrastructure, and sometimes in government and governance. The digital revolution is causing similar effects, but at an unprecedented speed. To better handle this change, in 2014 the city of Amsterdam decided to found a new department – an Innovation Team, with a chief technology officer (CTO) at its head. The CTO Innovation directly reports to the mayor, deputy mayor and chief information officer (CIO), but always works together with the domain-specific departments. The team pursues three main tasks:

1. Harness technological innovation: In three years from 2014 to 2017, digital technology was put on the agenda in such a way that every single department would experiment with the new possibilities it provides. In 2018, the CTO Innovation team defined six focus areas: smart mobility, democracy, cyber security, digital and the city, circularity, and energy and innovative procurement. Currently, some 100 professionals are working in these areas, building tangible products such as eHubs (for sharing vehicles, for instance), a new mobility management centre, real-time crowd information systems, circular housing (that recycles components and materials at the end of a building's life-cycle) and a cyber resilience centre. Hundreds of smaller citizen projects have been initiated to improve neighbourhoods.
2. Improve "future-readiness": Cities can't predict the future, but they can monitor what is happening in the world. Amsterdam organizes sessions based on Socratic Design, in collaboration with businesses and knowledge institutes.[65] Based on an annual updated technology roadmap, Amsterdam works with a small, dedicated team to think about the potential impacts of technology on the city, and define potential measures.
3. Creating a digital-ready organization: In 2020, after long preparation, the city of Amsterdam launched its digital transformation programme, increasing spending on digital technologies by 15% and aiming to restructure the organization. In three years, every department will have a new digital support structure that enables it to operate digitally-first. A group of design thinkers, Socratic designers, data scientists and agile specialists are supporting this transformation.

5.2 Digital skills

> **Cities need to democratize digital skills and responsibilities throughout local government – making it clear that these can no longer be the purview of only the IT department.**
>
> James Anderson, Head of Government Innovation, Bloomberg Philanthropies

One of the few positive things to come out of the pandemic was the manner in which cities accelerated digitalization, quickly moving in-person services online so they could protect residents and maintain operations. With the potential of this rapid, under-pressure shift established, what are the next steps for reform-minded city leaders? It will most likely start with building the skillsets and mindsets of the city leaders and civil servants.[66]

City governments, like all organizations, adapted quickly and powerfully to the digital mode in the face of the pandemic. London moved 95% of its public-service workforce to a virtual setup.[67] Bogota purchased 100,000 digital tablets and computers to ensure children could continue their schoolwork from home.[68] Seattle, which was one of the first US cities to be hit by the virus, raised two free testing sites, with online registration portals, that tested nearly 500,000 people in the first six months of the pandemic.[69]

Nevertheless, most city halls still take an outdated approach to service delivery, upgrading offerings one at a time and, even then, usually only in certain domains. This means most local governments aren't yet agile digital organizations, as much as they are organizations just beginning to offer more digital services. In other words, cities are still mostly putting public-facing documents on websites, rather than upending their management, back-end processes and organizational structures so that they can excel in the kind of feedback loop-informed, trial-and-error planning that can dramatically improve public value.

To make this important transition, local governments will need to ramp up their in-house digital skills and competencies. This means closing the experience gap, and the asymmetric sense of what's possible, between digital service providers and city employees. While a small number of cities have successfully recast themselves as powerful platforms for the development of digital services, most lack the required internal capacity and know-how. Cities need to democratize digital skills and responsibilities throughout local government, making it clear that these can no longer be the purview of the IT department alone. If cities are to fully understand, actualize and implement digital opportunities, digital expertise must also reside within, for instance, homeless services, education providers and small-business agencies. Consider the experiences of Helsinki, which created a programme to train every middle manager in the fundamentals of AI; or Barcelona, which fused the positions of technology officer and chief architect to create a single office that brings together the best of both worlds on the street.

Yet cities like Barcelona and Helsinki are exceptions rather than the rule. While civil servants are often dedicated, hardworking and extremely creative,

most of them were trained for an analogue world, and are unaccustomed to applying the lens of digital opportunity to their work. Meanwhile, the data and digital experience that cities do possess is typically siloed away from the programme managers responsible for delivering high-quality services. Good examples for spreading digital skills among employees can also be found in the private sector. For example, AirBnB launched a Data University to empower all employees to make data-informed decisions.[70] Democratizing digital skills will help tear down these long-standing silos, creating efficiencies for the frontline by encouraging cross-agency collaboration around the many complex challenges that cities face.

The residents who will use digital services must also have digital skills. While administrations need to make sure that services can be accessed independent of a citizen's digital literacy, they must also ensure citizens can acquire the skills they need to access services. Accessibility and equity considerations have to be addressed early in the design stage of new digital services (see also section 3.2). Cities must provide access to and actively promote digital literacy trainings (e.g. in schools or community centres), specifically for groups at risk of exclusion. For example, Bilbao's city council initiated a digital literacy programme that includes digital trainings and courses for citizens (see case study).

CASE STUDY 20

Developing the digital skills of groups at risk of exclusion

Bilbao, Spain

To raise its status as a competitive city with high levels of well-being and quality of life, Bilbao seeks to reinvent itself as an inclusive city by taking advantage of the opportunities brought about by digitalization. One of Bilbao's main challenges is the loss of economic competitiveness. It is estimated that 98% of companies in the city are SMEs (small and mid-sized enterprises), with low levels of cooperation among knowledge agents and other regions. The increased competition for talent between cities in the region and the country, and the slowdown in job creation, have led to a youth talent drain.

To address this situation, Bilbao's city council promotes an inclusive growth model that encourages innovation, creativity and talent development, shifting from being an industry-focused city to a knowledge-based one.[71] Towards this end, the city administration seeks to improve the capacities and digital resources of society, particularly for groups at risk of exclusion such as the elderly, women and those with disabilities. Its KZGunea centres offer an extensive catalogue of free courses and services related to the use of new information and communication technologies such as the NagusiWeb, which is a programme focused on training the elderly. Further, the Basque employment service Lanbide, and the digital portal for lifelong learning Hiru, offer access to training courses and publish educational material.

Over the years, the city has also developed a network of centres for the digital renewal of citizenship. Moreover, as part of the recovery plan from the COVID-19 pandemic, Bilbao's government offers digital training services and support for innovation to retail companies, micro-SMEs and self-employed people.

Bilbao's experience in promoting inclusive and smart city policies shows that being a smart city is not just about the use of new (digital) technology, rather how this technology is used and for what purpose.

CASE STUDY 21

AI leadership courses
Helsinki, Finland

The city of Helsinki recognized that the business administration departments of its four divisions didn't always have the expertise in modern data analytics to understand how data could effectively be used to achieve each division's objectives. It is therefore working on building data and AI knowledge among business and other personnel.

An example of this capacity building effort for city staff is the Helsinki Data Science Certificate programme, which is run by the city in collaboration with Aalto University's Executive Education and Fitech programmes, making extensive use of the Elements of AI and Ethics of AI courses offered by the University of Helsinki using the massive open online course (MOOC) model.[72] Taking the programme, participants learn the basics of the programming language Python, and how it can be used for machine and deep learning. The goal of the one-year certificate programme is to spread machine learning skills and create a skilled community across the city administration.

Employees from all city divisions took part in the programme in 2021, which included making presentations on their data analytics projects designed to deploy machine learning capabilities to benefit both the participants' home divisions and the city as a whole.

5.3 Governance

"The governance of a digital city will only work if citizens and stakeholders trust that their input to policy-making is in safe hands, and contributes to social change.

Aziza Akhmouch, Head, Cities, Urban Policies and Sustainable Development Division, Centre for Entrepreneurship, SMEs, Regions and Cities, Organisation for Economic Co-operation and Development (OECD)

Governance is much broader than government. It has political, institutional and administrative dimensions, and includes the various rules, practices and processes – formal and informal – through which decisions are taken and implemented. It also includes mechanisms for stakeholders to articulate their interests and have their concerns addressed, as well as for decision-makers to be held accountable. Further, it encompasses the private sector, civil society and a wide range of stakeholders.

Good governance is crucial in the current context of digitalization and digital innovation. Digital technologies bring opportunities to improve public sector efficiency, support the effectiveness of policies, and create more open, transparent, innovative, accountable and participatory governments. But new technologies, and the collection and use of data, may also give rise to new types of risks that governments need to address.

While cities are often leading the charge, national governments have a pivotal role to play in guiding, enabling and accelerating a digital transition in cities.

Digital solutions to put citizens back at the centre of the city

Promoting stakeholder engagement in the design and implementation of urban policy is a key factor of success in shaping strong, sustainable and inclusive cities. Engagement modalities can vary from unilateral communication of basic information, which represents the weakest form of engagement, to full co-production, co-delivery and co-evaluation, which implies a balanced share of responsibilities among stakeholders.

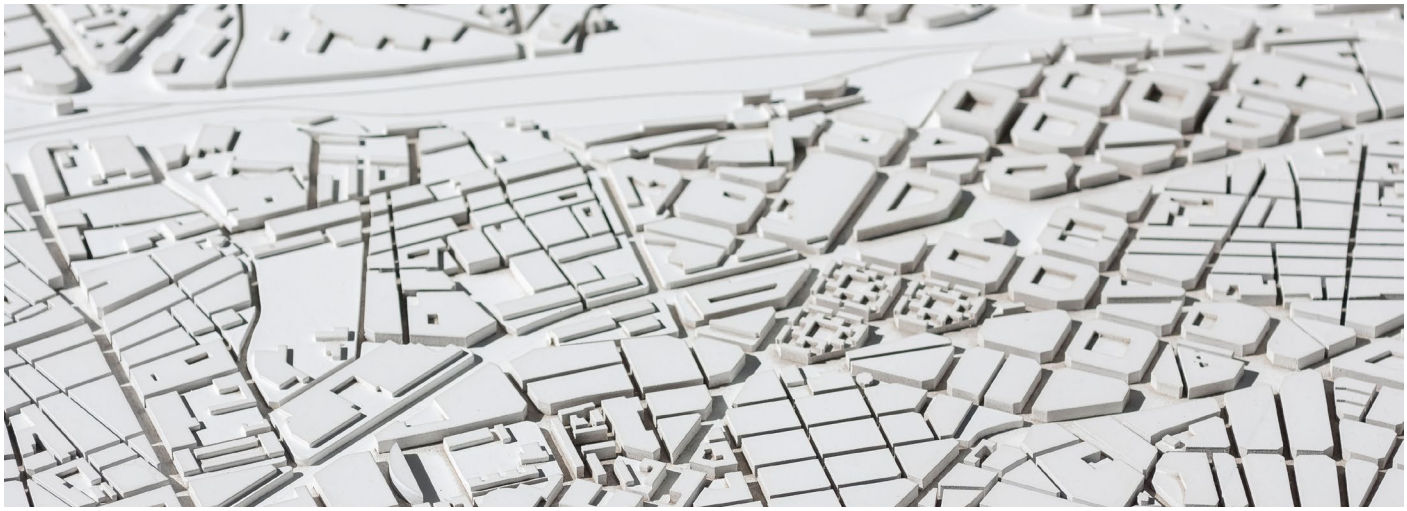
Over the past decades, digital technologies have offered new tools to engage citizens and other stakeholders in defining a city's vision for its future, its main challenges and their potential solutions.[73] For example, city governments increasingly use crowdsourced data to collect real-time, detailed information on the location of potholes, broken traffic lights, stray garbage or other urban challenges, and to provide adequate policy responses. An illustration can be found in Curitiba, which developed a smartphone application that allows residents to send photos of urban management issues, with GPS location, to the city authorities.

The COVID-19 pandemic has propelled digital stakeholder engagement tools to the fore, as a key component of cities' emergency measures. Tools range from monitoring contagion risks and social distancing in Seoul and Newcastle, to ensuring the continuity of public services and economic activities in Riga and Istanbul. Such tools, and the rapid changes they entail in people's daily habits, are likely to remain a permanent feature of the post-pandemic urban paradigm as cities learn to live with the virus. The crisis has prompted many cities to step up their pursuit of digital solutions in the long term, as part of participatory processes to define recovery plans. For example, Tallinn organized an online hackathon to seek creative post-COVID-19 ideas, while Antwerp and Cologne launched calls for innovative start-ups to help overcome COVID-19 challenges. Madrid specifically focused its call on economic recovery, redefining interpersonal relationships, and responding to the special needs of vulnerable population groups.[74]

Joining forces at various government levels

While cities are often leading the charge, national governments have a pivotal role to play in guiding, enabling and accelerating a digital transition in cities. Some countries have set up a national policy framework to provide guidelines and incentives to help cities digitalize, such as Singapore's Smart Nation programme, Brazil's National Strategy for Smart Sustainable Cities and Italy's Strategy for Digital Growth 2014-2020. Other countries do not have a dedicated national policy, but digital city considerations are included in various national plans and programmes. For example, the Investing in Canada plan includes the Smart Cities Challenge, which is open to all subnational levels of government and indigenous communities, and aims to stimulate innovative uses of technology and data to improve people's quality of life in cities of all sizes.

To ensure effective digital city strategies, it is critical to align goals, initiatives and resources across different levels of government and among all stakeholders. In Korea, for example, the Ministry of Land, Infrastructure and Transport assists local governments in preparing smart city plans by pre-assessing the quality of their programmes using a smart city plan checklist. Australia, the Netherlands and the United Kingdom use City Deals (programmes to enhance effective collaboration across governmental levels) to join national and local forces around common objectives such as providing public services, fostering economic growth, creating jobs and reducing emissions, including through digital technologies and infrastructure.



Better measurement and monitoring of the outcomes

There is no guarantee, however, that cities using digital tools and infrastructure to empower stakeholder engagement will automatically improve all residents' well-being. The governance of a digital city will only work if citizens and stakeholders trust that their input to policy-making is in safe hands, and contributes to social change. With uncertainty over individual data privacy, and concerns about potential misuse, some municipalities have actually restricted or barred sharing platforms, for example by putting limits on ride-sharing services, or on the number of days residents can rent out their properties on accommodation-sharing sites. It is therefore essential to better measure and monitor the outcomes of a digital city strategy.[75] This will help ground policy intervention in solid evidence, guiding decision-makers at both national and local levels in setting realistic targets, understanding where cities stand vis-à-vis their objectives, tracking progress and adjusting policy interventions for greater efficiency and effectiveness. Ultimately, better measurement and monitoring will help citizens gauge how well governments deliver on their commitments, and thus enhance accountability.

CASE STUDY 22

OnDijon
Dijon, France

OnDijon is Dijon Metropole's smart city project, rolled out in 2019.[76] It remotely manages urban equipment in all 23 municipalities of Dijon's metropolitan area, home to 260,000 people, including geolocating service vehicles. It does so from a centralized and connected control centre, which is a unique initiative in France and Europe, both in terms of the innovative solutions it provides and in terms of its territorial scope.

The control centre remotely manages urban equipment such as street lighting, waste removal, street cleaning, urban traffic regulation and surveillance of public areas. The aim is to simplify the coordination of interventions and maintenance work of the Metropole's services; ensure public safety and security through crisis management; and coordinate the means of transport and travel across the metropolitan area.

In addition to controlling Dijon's urban equipment, the control centre also processes calls received through a platform dedicated to citizens' requests. People can relay real-time information through an app on their smartphone, which is then coordinated digitally. This solution improves the participatory process and citizen engagement by developing a more transparent information exchange between citizens and the local government through real-time communication with municipal services. It also improves the response time and efficiency of local services, evident from a 40% cut in service costs.

At the same time, the control centre contributes to achieving sustainability objectives by reducing environmental footprints. It will enable energy savings of 65% over 12 years by monitoring pedestrian traffic at all times, replacing more than 34,000 lights (100% with LED)s and automatically regulating the amount of light used in streets.

Dijon Métropole is able to invest in new equipment and innovative services using the money saved from the creation of the control centre (which replaced six centres), the reduction in electricity consumption and the rationalization of interventions. It has put in place local governance of data, while also facilitating data sharing to provide new services to residents, and leading a voluntary policy of personal data protection.

CASE STUDY 23

Smart Cities Challenge
Canada

National governments have a crucial role to play in advancing smart cities, by creating the framework conditions that allow cities and communities to implement smart solutions. Often, local governments lack the financial resources needed to implement smart city initiatives.

In Canada, a federal department, Infrastructure Canada, decided to aid the implementation of local smart city initiatives by instituting an experimental programme called the Smart Cities Challenge.[77] This competition aimed to promote innovative, community-driven ideas to address complex economic, environmental and social problems. The winning ideas would focus on outcomes, and be scalable and/or replicable. In addition, applicants were advised that the jury would award special consideration to evidence that the proposed projects and expected impacts were informed by consultations and engagement with residents.

To ensure that all communities would be able to participate, the government put in place a series of incentives to help small cities build up capacity and develop their proposals. In total, the government received 130 applications, covering a wide range of solutions in areas such as food security, integration of migrants, accessibility for people with disabilities, and reducing isolation of the senior population.

The four winners who received funding for implementing their ideas were towns, cities and communities with projects that leverage digital technology (including data science, mobile applications, electric vehicles and digital platforms) to solve challenges facing many Canadian communities, such as energy poverty, mental health, food security and mobility. The winning projects are: a multi-modal transportation app and electric vehicle service to improve mobility for neighbourhood residents; an integrated digital platform to heighten food security by managing food inventory, sales, donation and delivery; a platform to strengthen resilience and improve mental health among young Nunavummiut (an indigenous population in northern Canada); and an energy monitoring system to address energy poverty through data and connected technology.

CASE STUDY 24

Harnessing technology to improve urban governance and services
Kochi, India

With the IT boom of the last few years, the city of Kochi has grown rapidly. This has affected urban governance, leading to gaps in service delivery. Multiple organizations handle various amenities, which makes it harder to access and disseminate information to the relevant stakeholders. The situation is exacerbated during an emergency or when disaster strikes, as happened during floods in 2018 and during the COVID-19 pandemic.

Kochi was one of the first 20 cities selected to be part of the central government-funded Smart Cities Mission (SCM) initiative.[78] An Integrated Command, Control and Communication Centre (IC4) was established in June 2020 to integrate city information into a single source, to process and disseminate information among city stakeholders, to support planning and simulations, and to act as the city's emergency and disaster management platform.[79]

The IC4 seamlessly captures data from various systems for smart streetlighting, adaptive traffic control, traffic enforcement and public bike sharing. An analytics platform is capable of real-time operations monitoring, prescriptive/predictive analytics, ad-hoc reporting and analysis, complex event processing and data visualization. Smart Kochi, a mobile app and web portal that is part of this project, is intended to enable citizens to digitally access all government-to-citizen services at their convenience.[80] During the COVID-19 pandemic, the IC4 was acting as a COVID war room for the Ernakulam district, which was hit severely by the second COVID-19 wave in 2021. A team of more than 50 people monitors and updates data on the availability of beds and oxygen supply, in both government and private hospitals in the district.

The facility is state-of-the-art in terms of scale, infrastructure, technology and functionality.

5.4 Financing and partnering

> **The early involvement of a wide group of stakeholders in the planning process results in greater transparency, a united vision and potential innovative ways of funding.**
>
> Hazem Galal, Global Leader, Cities and Local Government, PwC

One of the key takeaways of COVID-19 is the importance of digitalization for building resilience into urban infrastructure and for the delivery of services. Despite this recognition, cities seeking to invest in digitalization currently have less money to spend due to the pandemic's impact on their budgets. Yet 60% of smart city project budgets come from public funding in the form of national funds or grants, while 26% come from the local government budget, 11% from public-private partnerships, and 1% from a franchise/revenue-sharing model with vendors.[81]

One way to deal with tightening budgets is to make better use of what cities already have, i.e. to use existing infrastructure better. For example, at the University Properties of Finland, Siemens implemented a solution to interlink existing maintenance management systems, which did not require large upfront investment and reduced the visual inspections required by 70% (see case study). Another way is by finding new funding approaches to procurement and financing. Ultimately, successful partnerships with committed stakeholders bring innovative thinking and expertise when embracing digitalization. The early involvement of a wide group of stakeholders in the planning process results in greater transparency, a united vision and potential innovation in finding funding.

Innovative ways for financing city digitalization projects

Digitalization projects can be financed through direct government funding as well as debt and equity financing, or a combination of these options.[82] The suitability of the different financing options depends on the nature of the digitalization project, since different investors will have different financial assessment criteria. Thus, it is important for cities to set up and structure their projects in a way that fits the intended funding options (i.e. with respect to investment horizons and risk profiles).

Vendor financing is one approach, in which the vendor/supplier fully finances the upfront expenditure of the project. This approach reduces the immediate financial burden on cities by spreading the payback by the city over a longer period of time, but can result in higher prices, since the vendor will seek higher payments to compensate for more risk. Nonetheless, vendor/supplier financing does reduce the strain on public budgets, and allows cities to share the risk of digital projects. Examples of vendor financing are illustrated in Figure 4.

FIGURE 4 **Examples of vendor financing instruments**

Instrument	Example
Outcome-based financing Financing through investments in exchange for outcomes generated by the solution, such as cost savings or revenues.	The City of Erie is leveraging this model to deploy an IoT and intelligence platform to deliver insights that help reduce costs for the delivery of urban services and increase revenue.
Consumption-based financing Financing provided by the supplier/vendor while the project sponsor pays for technology based on usage.	Useful for a cloud-based solution where the project sponsor pays based on the number of licenses; as the city grows, the licenses needed may grow, increasing payment to the supplier.
As-a-service A subscription-based model, i.e. technology is financed by the supplier and the project utilizes the technology, paying for it as a service.	Can be useful for smart streetlight projects where lighting companies require cities to pay a subscription to make use of their control and management systems.

> Engaging with the private sector during the planning and design stages – before funding starts – helps ensure that the total costs and expected returns over the life of the initiative are mutually beneficial.

Delivering through innovative partnerships

Digitalization initiatives require innovative partnerships and new technological alliances that optimize costs, maximize asset utilization and leverage cities as living labs to advance socio-economic and environmental research and development. Such partnerships usually take a number of forms, with varying degrees of stakeholder involvement.[83] These include:

Joint/majority-owned ventures: The city and its digital transformation partner(s) enter into a joint partnership to form a new child company in which each entity has a share, 50-50 in case of joint ventures. Such partnerships can be:

- **Common platform partnerships:** For cities looking to expand potential sources of revenue, and expand into citizen service offerings they don't already provide, the addition of a partner's common platforms can benefit citizens in terms of time, cost and efficiency gains. It can also add potential sources of data monetization through these platforms. For example, Kansas City partnered with Cisco Systems and other community stakeholders, who brought their suite of capabilities for creating new business models. The city invested in developing real-time visualizations of available parking, traffic flow and pedestrian hotspots in order to inform urban infrastructure maintenance decisions, provide smart interactive kiosks for tourist information and free public Wi-Fi.
- **Sector-specific partnerships:** Cities can drive sectoral innovation and optimize service delivery by engaging in strategic partnerships with the private sector and the academia, as the Boston city government has done. The Boston Mayor's Office for New Urban Mechanics acts as a testbed for smart city interventions deployed in collaboration with the private sector under the Imagine Boston 2030 programme.
- **Strategic partnerships:** The city and the digital transformation partner enter into a contractual relationship to pool resources and capabilities. The city benefits from having direct access to market innovation, and the partner benefits from having access to the broader market (citizens), which establishes economies of scale and enables customized/personalized offerings. The Manchester CityVerve, a government-funded programme designed to accelerate the UK IoT industry, was a partnership that leverages collaboration of between the public sector, private sector and academia. The programme focused on bringing together pioneers and leaders in IoT technologies to explore solutions to challenges identified by various entities including the city council, universities, hospitals and private businesses. It encouraged entities in four focus sectors – culture and public realm, health and social care, energy and environment, travel and transport – to share and provide access to their data in order to enable cross-sectoral data analysis to ultimately deliver improved and smarter services to citizens.

Engaging partners for success

Working with the private sector, either through innovative public procurement or through public-private partnerships (PPPs), brings the needed investment, risk sharing and expertise. The private sector can further ensure greater efficiencies around implementation and maintenance of innovative urban projects. For these partnerships to be successful, it is critical to engage early with a wide group of stakeholders to secure buy-in for the proposed approach. In this regard, the non-profit sector (civil society and academia) can play a vital role by gaining public support for the process. Early dialogue will also help maximize the longer-term economic, social and environmental impacts of the digitalization initiative throughout its life-cycle.

Leading digitalization projects engage private sector stakeholders early in the process – be it for solution design, development, securing funding, seeking niche expertise, advancing the physical and technical infrastructure or operating and maintaining city initiatives. Engaging with the private sector during the planning and design stages – before funding starts – helps ensure that the total costs and expected returns over the life of the initiative are mutually beneficial.

CASE STUDY 25

Modernizing building management through data-driven services

Tampere, Finland

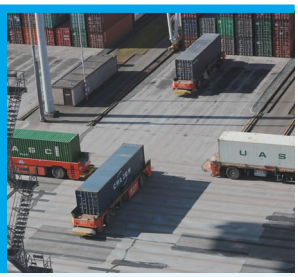
The University Properties of Finland (SYK) manages and maintains the buildings of many Finnish universities, including those of Tampere University.[84] SYK is both a landlord and a service provider. The City Campus of Tampere University faced constant complaints about stuffy air, insufficient heating and defects in the heating and lighting systems. Despite regular inspections, checklists and campus rounds, the SYK team and its service providers did not have a detailed picture of the status of their equipment, of how the premises were being used and of the conditions at any given time. Using digitalization, SYK and Siemens completely revamped the maintenance model at Tampere University in just two years. With maintenance management driven by data, the status of the equipment began to be monitored constantly and the indoor climate evaluated centrally, making it possible to respond faster – in real time.

No large investment or installation of new technology was needed, as no new infrastructure was built. Instead, simply interlinking existing infrastructure and implementing good ideas yielded success, thanks to close cooperation between the partners working on campus. It all began with a co-creation workshop to map all daily work steps, processes and responsibilities. Different teams shared their knowledge and connected different systems and data. They identified quick wins and areas where urgent action was needed. This led to big changes: moving away from static routines and checklists towards smart monitoring and demand-driven work; a campus equipped with sensors constantly measuring what is happening around it; and smart algorithms using the cloud to harness data. One result of this was the integration of forecasted weather data into the building management system. For example, data from ground temperature and weather predictions are now used to alert the system to clear snow on campus walkways in the event of snowfall, so as to prevent accidents. The overall solution reduced complaints by 50%, and replaced 70% of visual inspections with data analytics.

The campus has been digitalized to such an extent that further use cases are emerging, including installation of a virtual power plant. The data generated by the buildings is used in such a way that the university's energy requirements can be adapted to the power grid's supply in an agile manner, resulting in more stability for Finland's grid, and a new business model for SYK.

CASE STUDY 26

Digitizing the port of Rotterdam
Netherlands



The Port of Rotterdam is a major logistical gateway for Europe, and critically important to the economy. It is an asset of strategic and historical importance, and must continuously innovate to remain an attractive location ahead of competing European and international ports. The port wants to become the most innovative in the world, and be ready for autonomous ships by 2030.[85]

As part of a 10-year strategic partnership with Cisco and IBM, the port proposed 200 unique use cases to help achieve its 2030 goal. One of the use cases is the collection of data from a large number of water- and land-based sensors to calculate the buoyancy of vessels. This data is used to tell ships when it is safe to enter the port without running aground. Cisco invested in the initial proof of concept, which has now been deployed, and forms part of daily operations at the port.

Another use case deployed in October 2020 is remote management of patrol vessels. Following a successful field trial, the port will equip its entire fleet of patrol vessels with Cisco Edge Intelligence, an IoT software solution, which securely delivers data from connected assets at the network edge to multi-cloud application destinations. The patrol vessels, which assist with safety inspections, monitor the port's assets and provide firefighting, will now generate thousands of data points per second. The data will be delivered to the port's analytics application, and will enable predictive boat maintenance, help reduce costs, maximize vessel availability and improve emergency response time.

In the future, a digital twin will be established that will give the port a live view of all its physical assets in a digital environment, reduce the risk of damage to vessels, and allow the port to engage in predictive analysis and real-time planning. These upgrades and innovations will make the port of Rotterdam a sought-after destination for international shipping companies, and increase the services the port can export to other ports around the world.

CASE STUDY 27

Smart Mobility Living Lab
London, UK

The Smart Mobility Living Lab (SMLL) is part of the UK government's efforts to bring the connected autonomous vehicle (CAV) technology to the UK, and position the country at the forefront of global thinking on transport and mobility. With over 90% of road accidents caused by human error, and with increasing pressure on infrastructure and services in growing urban areas, CAV technology offers a real opportunity to reimagine transport and mobility systems to deliver societal benefits.

Cisco has partnered with the Transport Research Laboratory (TRL) to set up living labs at two test sites – London's Olympic Park and the Royal Borough of Greenwich – that will allow SMLL to test connected autonomous vehicles in real-world environments.[86] The test sites allow vehicles to be monitored as they progress along a complex 24-kilometre section of London's road network. The core network installed allows vehicles to navigate their route from A to B, while also connecting with other vehicles to identify the safest and most efficient path to take. Vehicle progress is monitored from a central data platform, with the core network protected by cybersecurity solutions.

CAVs are the next step in driverless cars. By connecting to other vehicles and sensors on the road, CAVs receive data on dangerous road and weather conditions, upcoming collisions or diversions, and critical data for safe manoeuvring in a dynamic environment. SMLL is a testbed for vehicle manufacturers, city authorities and technology companies to collaborate to transform the UK's urban mobility. As a living lab, it is supporting organizations to bring CAV solutions to market faster by enabling CAVs to be trialled and validated in a real-life environment.

The work being done at SMLL is helping to define the role of "digital" in the future of mobility, as well as the new roles and responsibilities of road operators and highway authorities. The results from the testbed demonstrate that significant strides have been made in the route to safe operation of CAVs in dense urban environments. The UK government's 2021 announcement that self-driving cars will be allowed on UK roads at speeds of up to 37 miles per hour is a welcome development in the future of CAV technology in the UK.

CASE STUDY 28

Bridging the digital divide and unlocking economic value with digitization

City of Erie, US

Erie had witnessed a prolonged economic downturn due to a shift away from manufacturing, and its inability to transform itself into a digital economy. Nearly 40% of its households living below the poverty line could not afford broadband connectivity. This growing digital divide was affecting the academic performance of students and the job prospects of citizens.

Erie decided to overhaul its digital infrastructure across eight "opportunity zones" – low-income neighbourhoods earmarked for attracting investments and spurring economic growth through job creation. By setting up free public Wi-Fi, the city planned to not only bridge this digital divide, but also give itself a medium to disseminate critical information and monetize related services.

The cost for setting up and deploying Wi-Fi services was estimated at roughly $1 million. Quantela agreed to provide half of the required funding, which enabled the city to acquire a matching Appalachian Grant to cover the other half of the cost. The city government had limited monetary resources, but Quantela's outcome-based financing model helped Erie fund up to 90% of the capital cost, with the repayments linked to outcomes. Erie was able to repay the capital cost using savings from switching to LED street lighting with smart controls, and a new revenue stream from advertisements on the Wi-Fi landing page.

Today Erie has 160 Wi-Fi access points, with usage time averaging 45 minutes per citizen. This has enabled local businesses to make targeted offers to citizens, and has improved the prospect of footfalls and sales. It has improved citizen engagement by enabling citizens to receive safety alerts, pay for city services and participate in surveys on proposed policies.

> **Erie decided to overhaul its digital infrastructure across eight "opportunity zones" – low-income neighbourhoods earmarked for attracting investments and spurring economic growth through job creation.**

6 City perspectives

Cities must identify and prioritize action areas based on their lived realities.

Digital technologies helped to deal better with COVID-19. Still, many cities were not prepared for this situation and had to build up the required technologies and capabilities on the go. Now, more than ever, it is essential for cities to utilize the momentum created during the COVID-19 pandemic to establish the digital infrastructure, governance structures and capabilities required not only to deal with COVID-19, but to build greener and more just cities through digital technologies.

Cheryl Benini, Head of Vertical Markets and Partner Development, Siemens Smart Infrastructure

The Global Future Council on Cities of Tomorrow conducted a survey with city administrations asking about the most important digital technologies and solutions in cities, and for digital solutions that helped (or would have helped) to deal better with the COVID-19 pandemic. The questions were open-ended, and administrations from 13 cities in Europe, Asia, Africa, South America and Oceania answered (see Figure 5). The answers helped create a digital maturity model intended to assist city administrations in identifying their status with respect to digital capabilities and the important actions they need to take.

FIGURE 5 **Cities that responded to the city survey**

1 Amman
2 Amsterdam
3 Berlin
4 Brisbane
5 Bristol
6 Buenos Aires
7 Chengdu
8 Helsinki
9 Izmir
10 Johannesburg
11 Melbourne
12 Rio de Janeiro
13 Tirana

Digital infrastructure, capabilities and governance structures

Figure 6 provides an overview of important digital infrastructure, as well as capabilities and governance structures, that are or will be applied in the cities that responded to the survey. The overview can help all cities identify the actions required to utilize the power of digital technologies for building more liveable and green cities. While some key priorities are the same for every city, such as fast broadband connectivity, each city must identify and prioritize action areas according to its own needs.

FIGURE 6 | **Digital infrastructure, governance and capability requirements as per city survey**

Digital infrastructure

Connectivity and computing

- Fixed broadband connectivity (e.g. fiber-optic)
- Mobile broadband connectivity (e.g. 4G/5G)
- Public access to broadband Internet (e.g. public Wi-Fi hotspots)
- Connectivity for the Internet of Things (low-power wide area network or LPWAN)
- High-performance computing infrastructure (e.g. data centres)

Data and analytics

- Monitoring of city data with sensors
- Data-sharing among public and private actors
- Streamlined data gathering, storage and access processes
- Open data platforms
- Data analytics tools to inform decision-making (e.g. dashboards)
- Digital (3D) modelling and simulation tools (e.g. digital twins) to inform decision-making

Digital services

- Single point of entry service portal with search functionality
- Online authentication for citizens and businesses
- Standardized online forms
- Online mailbox
- Online payment
- Virtual communication and collaboration tools and processes (e.g. for remote work)

Accessibility

- End-user equipment for groups at risk of exclusion
- Digital skills among citizens focusing specifically on groups at risk of exclusion
- Designing tools that can be accessed by all (design for inclusion)

Digital capabilities and governance structures

Strategy and collaboration

- Digital strategy that is aligned with other city strategies
- Breaking down of strategic visions into short-term actions
- Cross-departmental collaboration and breaking down of silos
- Stakeholder and partner management

Digital skills and innovation

- Digital literacy courses for management and staff
- Hiring of staff with digital skills
- Online learning platform for (digital) skills
- Platforms and management processes to facilitate and streamline innovation
- Citizen engagement and information portal

Regulation and standards

- Adequate data governance framework and regulations (e.g. ownership, data protection and security, ethics)
- Adequate IT governance framework and regulations (e.g. interoperability, standardization)

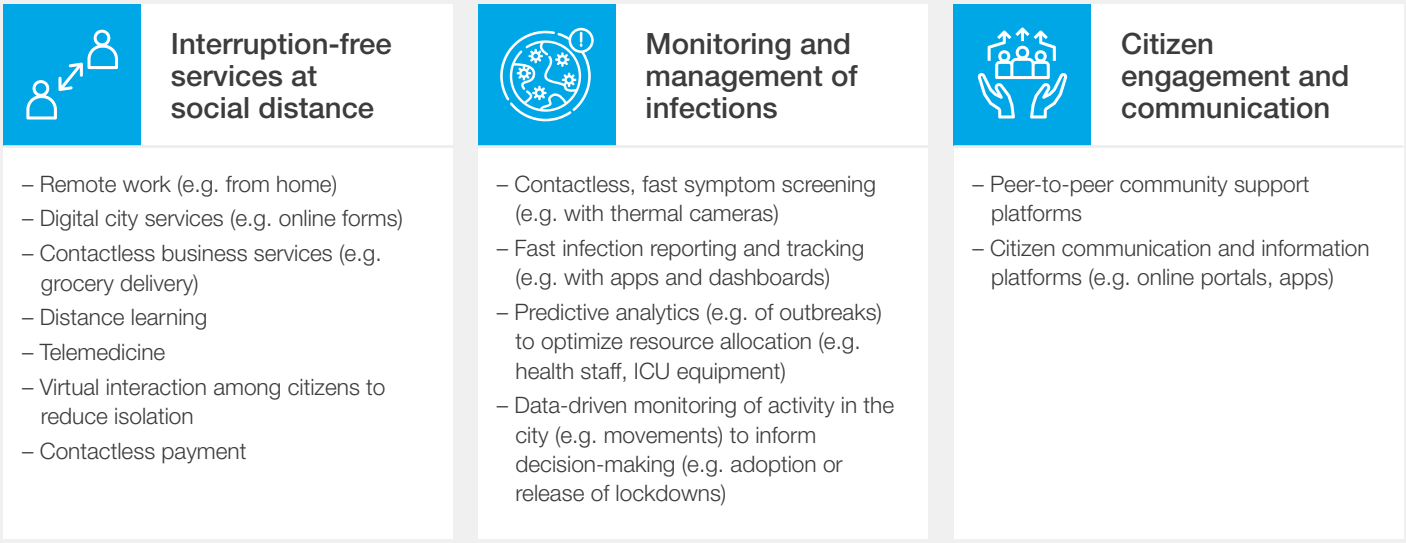
Partnerships and financing

- Creation of budgets for digitalization projects
- Innovative partnerships and business models for financing digitalization projects (e.g. outcome-based-financing)

Digital technologies during COVID

Figure 7 highlights the most frequently mentioned digitally-supported solutions that helped cities to deal better with COVID-19. Unsurprisingly, the possibility of continuing activities at times of social distancing was very frequently mentioned. This includes remote work, distance learning, online delivery of city services (e.g. through online forms) and business services (e.g. online shopping for groceries), telemedicine and the ability to keep in touch with social contacts to reduce feelings of isolation. Digital technologies also helped to identify, report and track COVID-19 infections, and to predict outbreaks, which was important to efficiently allocate limited resources (e.g. health staff and intensive-care equipment). Finally, digital citizen communication platforms helped cities keep in touch with citizens, inform them about recent developments and continuously changing policies, and create a community support system for citizens to help each other at times of crisis.

FIGURE 7 **Responses to the question: "What are the top 5 benefits provided by digital technologies in dealing better with COVID-19 in cities?"**



The survey also asked cities to list digital technologies that would have helped them deal better with COVID-19, but were not available at the beginning of the pandemic. Cities frequently mentioned:

– The equipment, tools and processes required to switch from a physical to a virtual presence (e.g. for remote work or distance learning, electronic health records for telemedicine, digital city service delivery), including sufficient coverage of fast internet access, whether fixed or mobile.

– Better systems to communicate with citizens (e.g. to inform about lockdowns).

– More effective systems to gather, share and analyse relevant data to inform decision-making (e.g. on movements in the city during lockdowns, or on infection outbreaks and chains).

Clearly, many cities were not prepared for the pandemic and had to build up the required technologies and capabilities on the go. Now, more than ever, it is essential for cities to utilize the momentum created during the pandemic to establish the digital infrastructure, governance structures and capabilities required not only to deal with COVID-19, but to build greener and more just cities through digital technologies.

Digital maturity model for cities

Table 2 shows the digital maturity model that consists of nine criteria in the categories of governance, organization and processes, people and technology.

TABLE 2 **Digital maturity model**

Category	Criteria	Emerging	Advanced
 Governance	Leadership and vision	– No dedicated digital strategy – Lack of leadership commitment to digital topics	– Aligned, cross-departmental digital strategy and implementation – Dedicated digital leadership and innovation team
	Stakeholder involvement and partnerships	– No systematic stakeholder engagement strategy	– Co-creation with private sector, civil society, academia and citizens – Strategic partnerships for digitalization initiatives
	Regulation and standards	– Unclear requirements in terms of privacy and security – No IT standards	– Controlled environment for testing new technologies and collecting citizen inputs to inform new regulation – Clear privacy/security/human rights regulations that allow for innovation and future-proof IT standards
 Organization and processes	Digital services and work	– Non-digital citizen services – Mainly in-person work from the office	– Digital citizen service provisioning – Agile workforce embracing hybrid working (in-person & virtual)
	Agile processes	– Inert development processes – No systematic evaluation of outcomes	– Agile development processes that embrace a culture of rapid experimentation – Evaluation of outcomes and continuous improvement
 People	Digital skills	– Digital skills centralized in IT department	– Digital expertise in all departments – Digital skills considered in recruiting processes
	Digitally literate citizens	– Diverging digital literacy skills across demographic groups	– Digitally literate citizens throughout the city – Digital infrastructures and technologies that are accessible for all citizens
 Technology	Digital city infrastructure	– Diverging broadband coverage – Low availability of (high performance) computing infrastructure	– City-wide broadband and IoT connectivity – Scalable (high performance) computing infrastructure
	Data and analytics capabilities	– Undefined data value chain – Little evidence-based decision-making	– Streamlined data value chain and open data – Culture of evidence-based decision-making

CASE STUDY 29

Enabling contactless public transport
Delhi, India

In the pre-COVID-19 world, Delhi buses had a ridership of more than 3.2 million each day, while the Delhi metro served a daily ridership of 2.9 million. Close to 47.5% of total trips in Delhi are undertaken for work and business, and as the city reopened post-lockdown, these trips were expected to resume immediately. At the same time, a large percentage of Delhi's bus users were captive riders, i.e. people who did not own a private vehicle. Insufficient public transport services, along with the fear of infection, could have led to an increase in private vehicle ownership, a possibly irreversible and undesirable shift.

An immediate transition to a cashless ticketing system was essential to reduce the risk of infection, ensure better accessibility and prevent further revenue losses. Thus, Delhi constituted a task force in June 2020 for timely coordination and implementation of contactless ticketing in all public buses. The task force identified an app-based ticketing system as the most accessible form of contactless ticketing, and developed the Chartr app in August 2020, which has since been tested across the bus fleet in phases. The app's features include QR-coded tickets and passes for single and group passengers, live tracking of buses, location of the nearest bus stop and a travel planner. After every trial phase, the learning for improving the app architecture, as well user experience, was duly recorded to update the app. Coupled with other initiatives for making public transport safer, the city was able to regain 45-50% of its original ridership within a month by September 2020. Today the app can be used across all public buses in Delhi.

CASE STUDY 30

City Planning Labs
Indonesia

An urban data revolution has taken shape over the last decade, as cities all over the world have started mobilizing geospatial data to address complex urban challenges.[87] Yet evidence-driven planning is often still limited due to siloed functions in city departments, a lack of data governance, gaps in the capacity of staff to effectively leverage geospatial data and the digital divide among citizens. Addressing these limitations requires a mindset shift for those in city governments and their development partners, to think about data as infrastructure.

The World Bank is helping Indonesia "geo-power" its cities through a unique data ecosystem paradigm under the City Planning Labs (CPL) Technical Assistance Initiative.[88] CPL seeks to strengthen local governments' data foundations and helps them sustainably leverage digital intelligence through its signature Municipal Spatial Data Infrastructure (MSDI) approach.

MSDI has four pillars; institutions, people, data and system. Three cities in Indonesia with different levels of geospatial capacity – Semarang, Denpasar and Balikpapan – are partnering to operationalize the approach in a way that would be scalable within and beyond Indonesia. All three CPL cities have established data governance frameworks in the form of One Data Mayoral Decrees, which aim to break data silos and promote inter-agency collaboration and data-sharing. CPL's unique One Data Portal mirrors the institutional arrangements, and brings spatial and non-spatial data on one platform. It is also capable of handling 3D data and connecting to multiple agency portals. The portal has dual sides, internal and public facing, and users can access it with practically any web browser to search for data, download or read metadata with different restriction levels, and even analyse the data with customized integrated tools.

With a strong understanding of data-driven decision-making and powered by urban planning tools, the cities have been able to mount an effective response during COVID-19. For example, as cases began to mount, Semarang leveraged CPL's CollabData digital platform to capture the needs, challenges and ground realities of its communities, and tailor interventions to reach the communities most in need. Beyond the pilots, the CPL MSDI framework and tools are being implemented in Indonesia under the National Urban Development Project (NUDP). With the continued support from the Swiss State Secretariat for Economic Affairs (SECO), CPL is also being scaled up globally.

CASE STUDY 31

Informes de Movilidad data collaborative

Santiago, Chile

To stop the spread of COVID-19 in Chile, lockdowns were implemented at a localized level, shutting down small administrative zones (comunas) rather than the whole country or large regions. To understand if these local lockdowns were effective, the central and local governments needed to find a way to collect data on mobility and its impact on the spread of COVID-19. Creating "smart lockdowns" would allow the government to minimize the risk of spreading the virus, while avoiding complete closure of the economy.

Cisco partnered with the Instituto Data Science UDD and Telefonica to create a mobility index and spreading model. It was designed to understand the impact of lockdowns on disease spread, identify high-risk zones, and model the impact of socio-economic factors and the re-opening of public spaces (such as schools and shopping malls) on viral spread. Big-data analysis processed large volumes of anonymized data from mobile phones. All data was anonymized and aggregated to create 340 reports at the regional and country levels, with mobility data freely available.

The team also developed a risk index, and mobility analysis risk maps at the zone level (much smaller than comunas). Socio-economic modelling showed that poorer areas were disproportionately impacted by the pandemic, as individuals could not limit their mobility as much as in wealthier areas. The data collected enabled the team to model the impact of re-opening of schools and shopping malls, showing that high-school students were the most mobile (compared to kindergarten and primary school students), and identifying which malls could be opened in order to maximize the number of people that have access to shopping facilities while reducing mixing between different comunas.

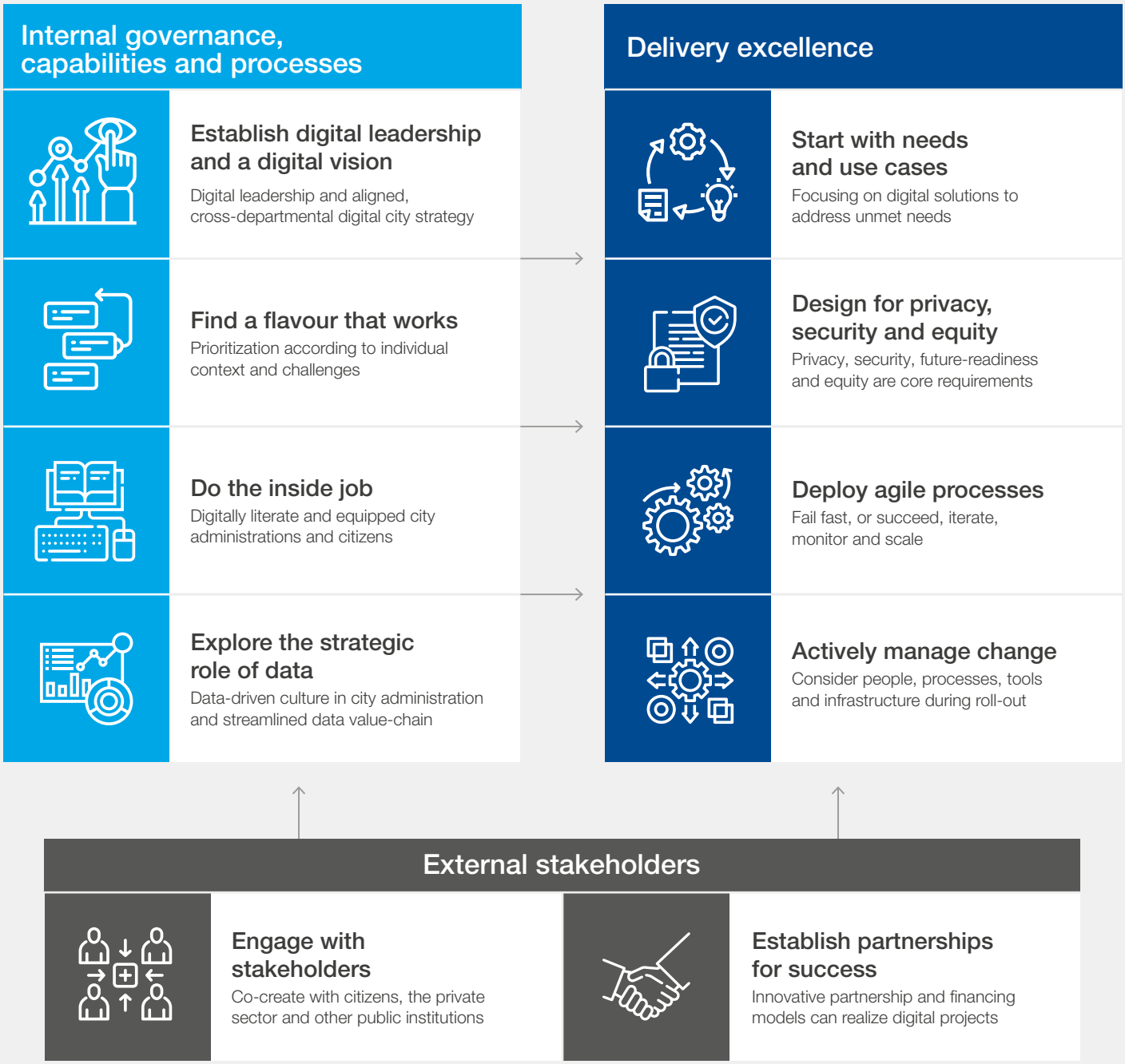
The Informes de Movilidad data collaborative is an excellent example of how data collaboratives can meaningfully impact decision-making and public policy at the national level. As of July 2022, over 92% of the population of Chile was vaccinated against COVID-19 and "smart lockdowns" were no longer required.[89] The methodologies used in the project can be applied to new data sources for projects beyond COVID-19 (e.g. transportation planning) and the integration of diverse big data sets for data-driven public policy.

7 Utilizing digital technology in the city of tomorrow

Cities can effect change along 10 pathways to improve governance and citizens' lives, ensuring a sustainable and inclusive future for all.

Now more than ever, cities can build on the momentum created by the COVID-19 pandemic and initiate the procedural, organizational and cultural changes required to seize the opportunities that digital technologies bring, in order to build more liveable and green cities. This report recommends 10 key actions to build truly digitally-enabled cities.

FIGURE 8 **Ten key actions to build truly digitally-enabled cities**



Internal governance, capabilities and processes

Establish digital leadership and a digital vision: Cities require commitment from leadership to maintain momentum. This requires designated digital leadership at the top of the organization. Once the leadership is in place, the city must determine what to prioritize, align the digital strategy with the city strategy, and empower the technology leader to enable change.

Find a flavour that works: Some key priorities are the same for every city, such as data integration and cybersecurity. Yet, cities need to develop their individual digital strategies, accounting for their particular contexts and challenges. This includes prioritizing digital projects that address their most urgent unmet needs, as well as the management approaches (e.g. outsourcing or in-house) that fit their culture. But whichever way a city develops, it needs knowledge about technology, its potential and its impact.

Do the inside job: Cities need to democratize digital skills and responsibilities throughout city administrations. All departments must have digital expertise to fully understand, actualize and implement digital opportunities. Cities must create a pipeline of talent that has knowledge about data, software, IT architecture, agile work methods and so on. Every single employee in the organization needs basic knowledge about technology and the processes needed for redesign.

Explore the strategic role of data: A vast amount of data, if used purposefully, can enable more evidence-based decision-making, as well as more proactive and personalized services for citizens. Likewise, all infrastructure projects benefit from data-driven monitoring and evaluation of outcomes. Successful data strategies adopt a collaborative, open and streamlined approach that allows data from various sources to be integrated. For solving concrete problems, rapidly experimenting with data by applying a trial-and-error approach often yields faster results, rather than first spending too much time and effort integrating various datasets. To establish a culture of evidence-based decision-making, managers should require staff to back up opinions with data whenever possible. Applying relevant data that helps to address real problems, along with accurate semantic models, is more crucial than flashy visualizations.

Delivery excellence

> Cities should start by asking, "What are the unmet needs and challenges, and how can we better meet them in the future, in a resource-efficient way, utilizing the possibilities provided by digital technologies?"

Start with needs and use cases: Smart cities often convey a technocratic vision of future life in a city, in which digital technologies are ubiquitous and have penetrated multiple domains of social life. While many digital technologies may provide benefits, do they actually meet the needs of citizens, both today and in the future? Instead of asking, "What can we do with digital technologies?", cities should start by asking, "What are the unmet needs and challenges, and how can we better meet them in the future, in a resource-efficient way, utilizing the possibilities provided by digital technologies?"

Design for privacy, security and equity: When designing digital solutions, the core requirements are privacy, cybersecurity and future-readiness. Design should equally be driven by equity: opportunities generated by the intervention must extend to all demographic groups, from digital natives and knowledge workers to vulnerable communities at risk of digital exclusion. For this reason, solutions must be co-created in close collaboration with citizens, the private sector and other public institutions.

Deploy agile processes: Deploying digital infrastructure is an iterative process. Cities need to start with a pilot approach that engages the right stakeholders, and enables a feedback mechanism at every phase of the design and development cycle. Pilots must succeed, iterate, monitor and scale rapidly, or fail fast and learn fast. It is critical to define the right metrics and benchmarks for success, and adopt a more agile approach and mindset for solution development and implementation. Tools such as digital twins can help simulate projects in a virtual world before deployment in real life, and also provide a forum to engage stakeholders.

Actively manage change: Implementation does not just involve the technological aspects of the digital solution, but the associated people, processes, tools and infrastructure. Cities must take a robust approach to change management and organizational transformation, including building awareness through strong communication of the solution, and enablement of citizens to use digital solutions through digital literacy training. A transitionary phase may require a hybrid model of both digital and non-digital processes.

External stakeholders

Engaging stakeholders: Promoting engagement from citizens, academia, the private sector and other public institutions as stakeholders is key during the design and implementation of digital infrastructure projects. Digital technologies help in engaging stakeholders, which may include passive collection of citizen data (e.g. from social media and from mobility data collected via smartphones), and active engagement of stakeholders (e.g. through online discussion forums or surveys).

Establish partnerships for success: To deal with tightening budgets, cities need to adopt innovative partnership and funding approaches for digital infrastructure projects. Successful partnerships with committed stakeholders bring innovative thinking and expertise in embracing digitalization. Early involvement of various groups of stakeholders in the planning process will result in greater transparency, a united vision, potentially innovative ways of funding and a mutually beneficial partnership.

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