ECONOMIST IMPACT

Digital Cities Index

Making digital work for cities: A global benchmark of urban technology

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Preface

The Digital Cities Index (DCI) 2022, developed by Economist Impact and supported by NEC, considers four key pillars of digital connectivity, services, culture and sustainability in order to assess the extent and impact of digitisation in 30 global cities. This white paper refers to the first iteration of the DCI, which is based on a dynamic benchmarking model constructed from 48 qualitative and quantitative indicators.

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Executive summary

Over the last decade, cities across the world have built digital infrastructure and embedded digital technologies into urban services. A suite of frontier capabilities—artificial intelligence (AI), the Internet of Things (IoT), cloud computing and 5G connectivity—are all offering municipal authorities a powerful set of tools to make cities smarter, safer, cleaner and more inclusive.

Yet the digital transformation of cities is a complex, long-term process with many challenges and pitfalls, including inappropriate technology, vendor "lock-in", cost and even social backlash and opposition. Cities now have a decade of experience to draw from to ensure they make the optimal choices in terms of technology design, acquisition, deployment and monitoring.

The Digital Cities Index (DCI) 2022 is an inaugural ranking of 30 global cities across four thematic pillars: connectivity, services, culture and sustainability. Combining quantitative and qualitative analysis, and including a survey of 3,000 residents spread across all cities in the DCI, the results show how cities are performing in terms of both quantitative metrics like internet speed and qualitative factors such as the presence of strategies, policies and plans for technologies like 5G and AI. The key findings of the DCI and white paper are as follows:

Connectivity

- **Cities can close the connectivity gap.** In many cities in the DCI, connectivity levels are too low or limited to allow for comprehensive digital transformation, with half of the cities scoring below 70 out of 100. Unaffordable, unreliable or inaccessible internet services will impact many city-level goals—especially during the covid-19 pandemic era when, for example, socioeconomically disadvantaged children have been unable to access online learning resources even in high-income areas. However, prompted by the pandemic, municipalities across the world, from Washington DC to Jakarta, have stepped up their investments in connectivity, such as offering free Wi-Fi and adding hotspots—in some cases for the first time—potentially creating a new era of more direct intervention to address digital divides.
- **Cities are "5G-ready" but rollout needs to be comprehensive to enable the full realisation of intelligent cities.** The DCI cities overwhelmingly recognise and support 5G, with all but one having a strategy in place either in a national or local initiative, while recognising multiple use-case applications such as fixed wireless access, enhanced mobile broadband, massive machine-type communications and the IoT. All but one city

have deployed 5G, whether in pilots and testing or for commercial use. Urban 5G has to date focused on site-specific initiatives like industrial facilities, sporting events, smart districts and critical transport infrastructures such as ports. To be truly transformational in areas like autonomous transport, 5G needs to be ubiquitous and comprehensive, which will require greater private sector investment, new partnership models between telecommunications companies and an enabling regulatory environment.

Services

- **E-government service leaders are found in both the high and emerging income categories.** Singapore leads the world in e-government services for residents and businesses due to a mobile digital national ID card programme and a comprehensive e-government service portal for residents and businesses. New Delhi ranks third in e-government services for residents and businesses, due in part to Aadhaar, the country's groundbreaking national digital identity scheme, as well as efforts beyond the national ID scheme, with a major increase in digital engagement during the pandemic. India's severe covid-19 crisis was likely a stimulus for governments and citizens to explore ways of avoiding crowds and transacting online.
- **Cities are embracing the health benefits of digital.** The DCI measures city healthcare performance across three indicators: the presence and adoption of telehealth and telemedicine; electronic health records; and pandemic-related applications. The majority of cities scored above 75, indicating a broad-based application of digital health tools to support urban wellbeing. The pandemic has been a significant catalyst, with the vast majority of cities having pandemic-related apps in place and available for testing and contact tracing. Urban health institutions are also using telehealth to improve citizen wellbeing, especially for non-communicable diseases such as diabetes requiring ongoing monitoring, and for lifestyle tracking, awareness-raising and community-building around healthy lifestyles.
- **Asian cities dominate in digital finance.** Asia is home to five out of the top ten cities in the DCI, with Beijing, Seoul and Hong Kong the top three. This outperformance reflects Asia's lead in digital payments and is due in part to the density of population and transactions in these cities. China and India are world leaders in digital finance and payment infrastructure innovation in terms of both supportive government regulation and private sector innovation, which in turn enable more digital payments in their respective cities, including for urban services such as public transport.

Culture

- **Digital skills levels and satisfaction with e-government portals are significantly higher in emerging-market cities, especially in Asia.** The Economist Impact survey reveals that self-reported digital skills—from basic functional skills to more advanced competencies such as coding, troubleshooting technical issues and mitigating cyber threats—are highest in emerging-market cities, with New Delhi, Dubai, Jakarta, Beijing, Mexico City, Manila and Bangkok the top seven cities. This likely reflects the greater gains that digital platforms have for daily life in infrastructure-poor geographies where citizens face more constraints, such as a lack of access to bricks-and-mortar banking services. Our survey also found that trust in e-government is highest in emerging-market cities in general and, on a regional basis, in Asia. Urban-dwellers on the continent have the highest levels of satisfaction and trust in online services offered by their government.

- **The Atlantic nations lead in open data innovation.** European and North American cities dominate the DCI in terms of open data access and use policies which cover the publishing and usage of data for accountability, innovation and social impact. London, Toronto, Paris, Dallas, New York and Washington DC occupy the top five rankings (all three US cities are tied in fourth place). Seoul is Asia's outperformer in seventh place. Open data has delivered significant economic gains for cities, such as the boom in consumer travel apps built from the open data initiatives of Transport for London (TfL), with their corresponding benefits in time saved and urban quality of life. Open and shareable data is also improving social policy interventions by, for instance, allowing cities to better pinpoint geographic distribution of poverty, as with New York's utilisation of census survey data.

Sustainability

- **Sustainability performance beats the overall DCI average, but all large emerging-market cities apart from Beijing rank below average.** Sustainability brought the highest overall scores in the DCI, with Copenhagen, Seoul and Toronto scoring at least 90 out of 100 for their use of digital technology to support urban sustainability—higher scores than achieved in any other pillar. One-third of cities achieved the highest possible score for smart utility management. Digital capabilities including AI, sensors and the IoT can all improve energy and resource efficiency across core city utilities such as water, electricity, lighting and waste management. However, many emerging-market cities ranked below average, even though their sustainability risks are among the highest. The strong performance of Beijing relative to its peers—it ranked fifth, above Amsterdam, Sydney and London—is creditable given its historical challenges with air pollution. The city has applied digital technologies not only to tackle air pollution but also to optimise its utilities and promote its sharing economy. This proves that emerging-market cities can make significant headway in using technology to tackle environmental challenges.

- **Citizen engagement is central to making the next wave of digital city innovation effective and accepted.** The first decades of "smart city" initiatives have demonstrated the power of technology to improve urban services and quality of life, but these initiatives have also tended to be top-down and technology-driven and have lacked engagement and participation from citizens. There has also been, experts warn, a lack of clarity over how technology can support specific policy goals in the city. The top-performing cities are those that: use technology to achieve clear policy goals such as inclusion or sustainability; engage citizens and stakeholders from design to delivery; monitor technology efforts to ensure adequate returns on investment; and identify unintended negative consequences.

Introduction

Over the last decade, cities across the world have built digital infrastructure and embedded digital technologies into urban services, from artificial intelligence (AI)-driven traffic management systems to smart lighting, electric mobility and even blockchain.[1] A suite of frontier digital capabilities—broadly, AI, the Internet of Things (IoT), cloud computing and 5G connectivity—are continually advancing in terms of quality, range of application and affordability, offering municipal authorities a powerful set of tools to make cities smarter, safer, cleaner and more inclusive. Smart cities' spending is forecast to reach US$327 billion by 2025, from US$96 billion in 2019, and 70% of spending on smart city technology by 2030 will come from the US, Western Europe and China.[2]

Dave Hopping, CEO of Smart Infrastructure Solutions and Services at Siemens, claims that while the idea of deploying technology to cities is far from novel, with some pilots and approaches dating back to the 1970s, the benefits are becoming more tangible and scalable thanks to three factors. "One is the sense of urgency due to macro issues like climate change and population growth. Two is the cost of technology deployment coming down. Third is the ability to deploy new business models, where public and private sectors can work together to provide 'X-as-a-service', whether energy, security or operations. These three factors have changed the narrative."

But there are many challenges to deploying digital technology in cities. In some environments, urban residents object to intrusive technology like facial recognition.[3,4] In others, there has been a sense of technological progress without civic or democratic engagement. Google-backed SideWalk Labs, a real estate pilot in Toronto which aimed to embed digital technology in its infrastructure, was discontinued in 2020. While the financial pressures of the covid-19 pandemic were one reason, it also faced criticism for the high levels of digital surveillance

[1] Iberdrola. "Blockchain technology at the service of urban management". https://www.iberdrola.com/innovation/blockchain-for-smart-cities-urban-management

[2] Valente, F. 2020. "Smart Cities to Create Business Opportunities Worth $2.46 Trillion by 2025, says Frost & Sullivan". Frost & Sullivan. October 29th. https://www.frost.com/news/press-releases/smart-cities-to-create-business-opportunities-worth-2-46-trillion-by-2025-says-frost-sullivan/

[3] Woodhams, S. 2021. "London is buying heaps of facial recognition tech". Wired. September 27th. https://www.wired.co.uk/article/met-police-facial-recognition-new

[4] Tidman, Z. 2020. "Controversial facial recognition returns to scan faces in central London". *The Independent*. February 27th. https://www.independent.co.uk/news/uk/crime/facial-recognition-city-westminster-london-met-police-big-brother-watch-a9363016.html

and data-gathering, as well as its expanding physical footprint, without civic oversight and democratic governance.[5, 6]

Certain digital technologies have led to unexpected or undesirable outcomes, further proving the need for improved transparency, monitoring and dialogue. The "on-demand" and ride-hailing sectors, for instance, are reported to be increasing congestion and emissions by putting more vehicles on the road—"flooding the circuit"—to enable rapid customer convenience.[7]

"Technology itself is neutral and it can go in all sorts of directions. It can reduce civil liberties or help increase them, it can help with carbon emissions, but it can also do the opposite," states Philipp Rode, Executive Director of LSE Cities at the London School of Economics. 5G, for instance, could intensify the digitalisation of cities in ways that increase energy use. "It's quite dangerous to think that digital by default leads to positive desirable outcomes, particularly on the social and environmental front."

Without foresight, digital initiatives can even worsen inequality. "Too often today, digital services like getting unemployment benefits or housing support from your city's website, or paying fees and fines, are not usable if you are blind or deaf or have a cognitive disability," according James Thurston, Vice President for Global Strategy and Development at G3ict. The most inclusive cities anticipate digital inequality from the design and planning phase.

The population and economy of many metropolitan cities are already comparable to those of entire countries. New York's gross metropolitan product is US$1.6 trillion. If the city were a country, its economy would rank 12th in the world. More people live in Delhi than in the whole of Australia. As the world continues to urbanise, a trend seemingly unaffected by the pandemic, cities need digital technologies to tackle their challenges. The ability of cities to offer safety, security and good livelihoods will determine whether the world achieves the Sustainable Development Goals.

Introducing the Digital Cities Index

To help urban decision-makers make the best use of digital technology, the inaugural Digital Cities Index (DCI) 2022 provides a global ranking of 30 cities across four thematic pillars: connectivity, services, culture and sustainability. Combining quantitative and qualitative analysis, and including a survey of 3,000 residents spread across all cities in the DCI, the results show how cities are performing in terms of both quantitative metrics like internet speed and qualitative factors such as the presence of strategies, policies and plans for technologies like 5G and AI.

The top-performing cities in the DCI 2022 are Copenhagen, Amsterdam, Beijing, London and Seoul, with the latter two cities tied in fourth position. Copenhagen scored very highly in all pillars except for culture. The high scores

[5] Cecco, L. 2020. "Google affiliate Sidewalk Labs abruptly abandons Toronto smart city project". *The Guardian*. May 7th. https://www.theguardian.com/technology/2020/may/07/google-sidewalk-labs-toronto-smart-city-abandoned

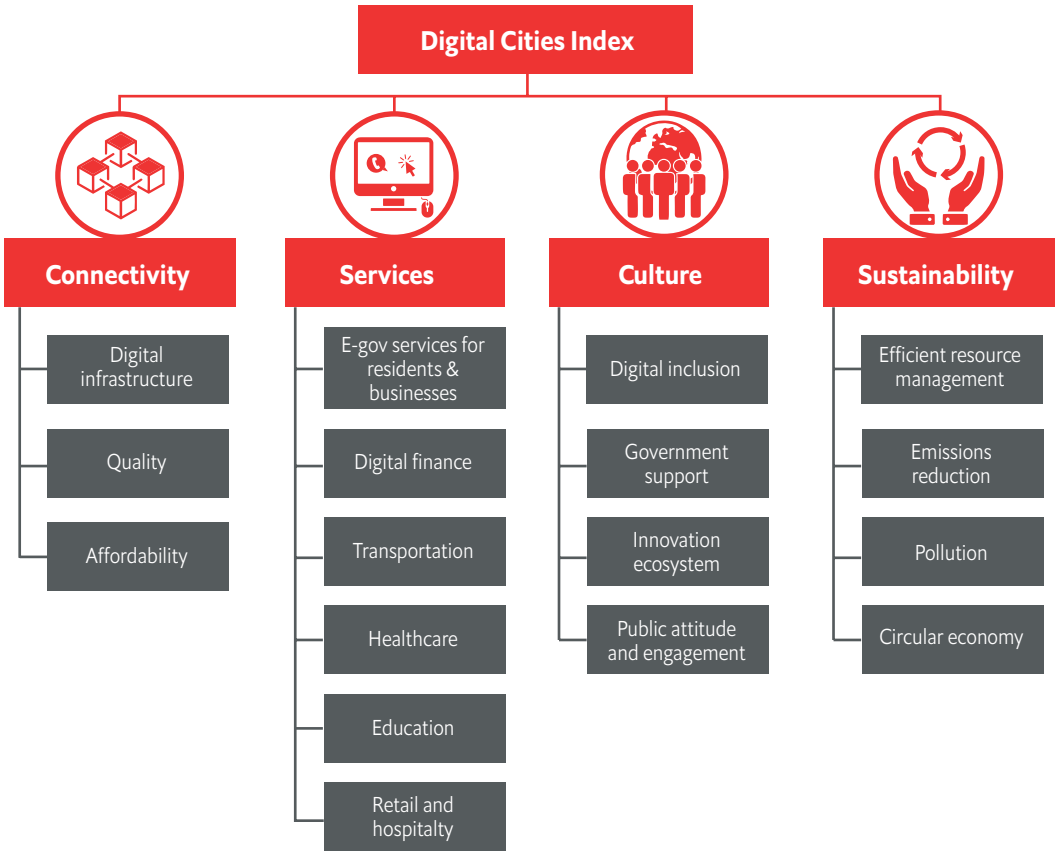
[6] Fussell, S. 2019. "The City of the Future Is a Data-Collection Machine". *The Atlantic*. November 21st. https://www.theatlantic.com/technology/archive/2018/11/google-sidewalk-labs/575551/

[7] Le Petit, Y. 2020. "Uber pollutes more than the cars it replaces – US". Transport and Environment. March 19th. scientistshttps://www.transportenvironment.org/discover/uber-pollutes-more-cars-it-replaces-us-scientists/

of Amsterdam, Beijing and Seoul were driven by their performance in the sustainability and connectivity pillars, while London scored highly in the sustainability pillar.

This white paper combines highlights from the DCI with expert commentary on the key factors determining success in the utilisation of digital technology in today's cities, and uses the rankings to benchmark performance and identify the leading cities and the best practices that got them there.

Figure 1: Framework of Digital Cities Index



Source: Economist Impact.

Chapter 1: Connectivity

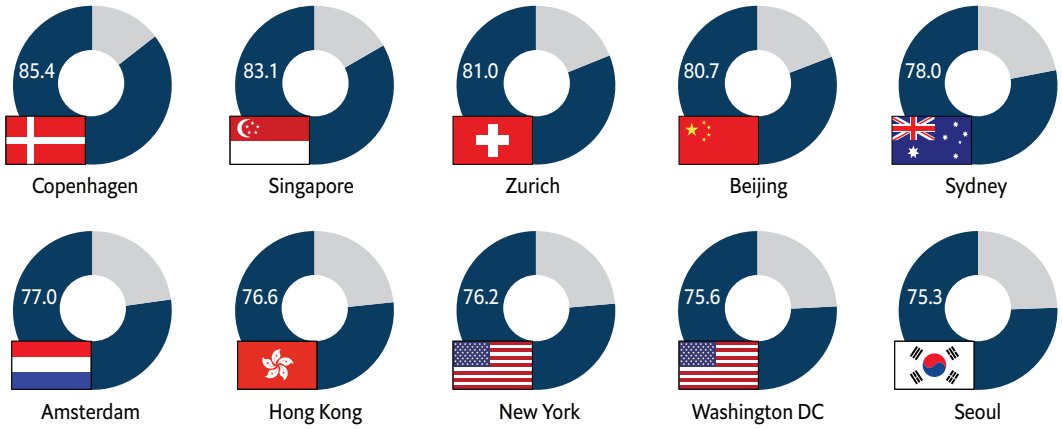
Comprehensive, high-quality and reliable internet connectivity is a precondition for any city's successful use of digital technology, as it provides the means for municipal authorities to work efficiently and effectively and can impact liveability for residents and businesses. This has been particularly the case during the covid-19 pandemic when so many daily activities and transactions have been undertaken through digital means. The DCI measures connectivity according to three indicators: digital infrastructure, quality and affordability. Key findings for the connectivity pillar include the following.

Copenhagen and Singapore are the DCI's most connected cities.

Measuring digital infrastructure (mobile and fixed broadband subscriptions and 5G readiness), internet quality (upload speeds and latency) and affordability, the Danish capital and the city-state of Singapore ranked top in the DCI, followed by Zurich, Beijing and Sydney. These results reflect the broader digital excellence in these two nations.

Denmark recently topped the European Union Digital Economy and Society Index, covering factors such as the public's use of

Figure 2: Top 10 connected cities in the DCI 2022
Overall score for connectivity pillar



Source: Economist Impact.

digital technology to interface with public services.[8] The capital city itself is among the world leaders in leveraging digital technology, evidenced through Copenhagen Connecting, a smart city initiative to support the integration of technology and services by aggregating data from different sources, including mobile phones, GPS on buses and sensors in the waste system, to support the city's goals of reducing congestion, pollution and emissions.[9]

Singapore's strategy for developing digital connectivity rests on the government's recognition that the city-state's economy cannot rely on geography or distance to build partnerships.[10] In December 2020, Singapore's Deputy Prime Minister announced at the National Research Foundation efforts to invest in AI, 5G and cyber security in order to lead the country's growth and innovation post-covid.[11] Parts of the S$25 billion in funding, covering R&D plans until 2025, will focus on quantum computing to bolster the rollout of 5G and its applications.[12] The city-state has also signed multiple digital economy agreements with countries including the UK, New Zealand and Australia.[13]

Cities can boost connectivity for citizens above national averages.

In many cities in the DCI, connectivity levels are too low or limited to allow for comprehensive digital transformation, with half of the cities scoring below 70. Unaffordable, unreliable or inaccessible internet services will impact other city-level goals, especially during the pandemic era when, for example, socioeconomically disadvantaged children have been unable to access online learning resources even in high-income areas. Half-a-million households reportedly lack a reliable internet connection in New York City, for instance.[14]

Cities can boost connectivity levels and access. Washington DC has offered low-cost or free services and devices to families unable to afford a broadband subscription.[15] By February 2021, over 30 US cities had taken an independent initiative to boost broadband access due to the pandemic, a task which few had attempted previously.

In 2020, Jakarta launched JakWifi, a programme to provide free Wi-Fi to residents

[8] Agency for Digitisation. 2021. "Denmark is the EU's Digital Champion in New Survey". Ministry of Finance. November 16th. https://en.digst.dk/news/news-archive/2021/november/denmark-is-the-eu-s-digital-champion-in-new-survey/

[9] H3B Connected. "Copenhagen wins a World Smart Cities Award". https://www.h3bconnected.com/copenhagen-wins-a-world-smart-cities-award/

[10] Subhani, O. 2021. "S'pore is developing digital economy deals to boost connectivity resilience: Chan Chun Sing". *The Straits Times*. July 16th. https://www.straitstimes.com/business/economy/beyond-ftas-spore-developing-digital-economy-agreements-to-boost-connectivity

[11] Tham, I. 2020. "Deep tech to drive digital economy in Singapore post-Covid-19 world". The Straits Times. December 11th. https://www.straitstimes.com/tech/tech-news/rie-2025-deep-tech-to-drive-digital-economy-in-singapore-post-covid

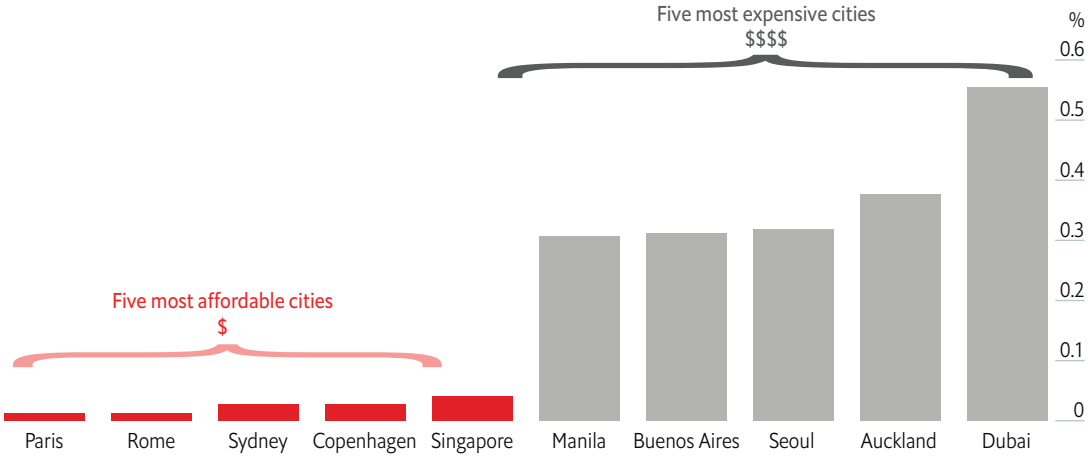
[12] CNRS. "Singapore to Invest S$25 Billion in Next 5-Year Plan for R&D, Including New Programme to Prepare for Future Epidemics". https://cnrssingapore.cnrs.fr/singapore-to-invest-s25-billion-in-next-5-year-plan-for-rd-including-new-programme-to-prepare-for-future-epidemics/

[13] Department for International Trade. 2021."UK–Singapore Digital Economy Agreement: Agreement in principle explainer". GOV.UK. December 9th. https://www.gov.uk/government/publications/uk-singapore-digital-economy-agreement-agreement-in-principle-explainer/uk-singapore-digital-economy-agreement-agreement-in-principle-explainer

[14] Poon, L. 2021. "To Bridge the Digital Divide, Cities Tap Their Own Infrastructure". Bloomberg CityLab. February 8th. https://www.bloomberg.com/news/articles/2021-02-08/cities-try-new-ideas-to-narrow-digital-divide

[15] Ibid.

Figure 3: Affordability of mobile data
Average cost of 1 GB of mobile data as a percentage of personal disposable income



Source: Economist Impact.

in the city, utilising 2,619 pre-existing internet hotspots and supplying a further 1,200 new hotspots.[16] JakWifi aimed to facilitate online learning due to covid-19, in addition to supporting government service provision. In the Philippines, at the onset of covid-19, the Department of Information and Communications Technology installed free Wi-Fi hotspots in quarantine centres across Manila.[17] The goal was to keep frontline workers and families in quarantine centres connected with loved ones, while also permitting the collection of data and allowing health officials to submit situation reports online.[18] Singapore's Infocomm Media Development Authority, under the Ministry of Communications and Information, has led a range of initiatives to digitise Singapore during and after covid-19. For example, the SG Digital Office launched the Seniors Go Digital initiative in May 2020, which mobilised 1,000 digital ambassadors to teach elderly citizens the use of basic digital tools, such as using WhatsApp and making e-payments.[19, 20]

The returns on investment (ROI) in connectivity improvements can be significant. One study of "hyper-connected" cities (defined according to a series of indicators and survey questions covering factors like maturity level of data analytics, number of digital technologies used, percentage of the city covered by Wi-Fi and level of cyber resilience and readiness) estimated sizable ROI for

[16] Nurbaiti, A. 2020. "Jakarta launches JakWifi program to provide free internet access". *The Jakarta Post*. August 29th. https://www.thejakartapost.com/news/2020/08/28/jakarta-launches-jakwifi-program-to-provide-free-internet-access.html

[17] Department of Information and Communications Technology. 2020. "DICT provides free Wi-Fi to new quarantine centers". April 15th. https://dict.gov.ph/dict-provides-free-wi-fi-to-new-quarantine-centers/

[18] Ibid.

[19] Sagar, M. 2020. "Singapore Senior Citizens Go Digital During Pandemic". OPEN GOV. August 31st. https://opengovasia.com/singapore-senior-citizens-go-digital-during-pandemic/

[20] Leong, K.T. 2020. "Singapore's COVID-19 response and digitalization following the Agenda for Action". The Broadband Commission for Sustainable Development. September 22nd. https://www.broadbandcommission.org/insight/singapores-covid-19-response-and-digitalization-following-the-agenda-for-action/

hyper-connected initiatives, from US$19.6 million for early stage implementers to US$83 million for leaders, with benefits spread across many urban services including transport, traffic and utilities.[21]

Cities are "5G-ready" but the rollout is uneven, forgoing the true gains of next-generation connectivity.

The cities in the DCI overwhelmingly recognise and support 5G, with all but one having a strategy in place either in a national or local initiative, while recognising multiple use-case applications such as fixed wireless access, enhanced mobile broadband, massive machine-type communications and the IoT. All but one city have deployed 5G, whether in pilots and testing or for commercial use. Urban 5G trials have, to date, focused on use cases including industrial facilities, sporting events and critical transport infrastructures such as ports.[22, 23]

This trend is positive since 5G is the engine for urban digital transformation. According to James Tee, CEO, Smart City and Urban Tech of Malaysian telecommunications company Green Packet, "5G enables many things that used to not be doable, like autonomous vehicles or drones." Simon Hunter, Executive Director at New South Wales Department of Planning, Industry and Environment, calls the data volumes and low latency offered by 5G a "game-changer", and says it must be ubiquitous to be effective at scale. "If autonomous vehicles rely on 5G as the only way of communicating, then 5G needs to be down every street, in every cul-de-sac; otherwise, those vehicles may not be able to operate."

Urban 5G use cases are emerging, predominantly linked to tests and pilots at specific sites and locations such as ports and manufacturing facilities, as well as for live events. 5G could deliver core benefits to urban services as it becomes ubiquitous. A 5G- enabled smart traffic initiative around the Queen Elizabeth Olympic Park in London, for instance, is aiming to achieve a 10% reduction in travel time, an £880 million increase in

Table 1: Use cases—Piloto 5G Cataluña, Barcelona[24]

Emergency response and public safety	Deliver a smarter approach to public safety.
Education	Holographic solutions to facilitate remote learning through immersive education.
E-commerce	Facilitate immersive remote shopping through augmented reality.
Automotive	Enable autonomous and connected vehicles.
Manufacturing	Optimising supply chains by reacting to real-time data.
Broadcasting	High-definition audio-visual signals for live events with a remote performance.

[21] ESI ThoughtLab. "Building a Hyperconnected City". https://econsultsolutions.com/wp-content/uploads/2019/11/ESITL_Building-a-Hyperconnected-City_Report.pdf

[22] Orange. 2021. "5G deployment: Where are we in terms of 5G?". March 23rd. https://www.orange.com/en/groupe/nos-activites/le-socle-de-la-revolution-numerique/5g-deployment-where-are-we-terms-5g

[23] UK 5G Innovation Network. "5G adoption projects, testbeds & trials in the UK". https://uk5g.org/discover/5G-projects/testbeds-and-trials/

[24] Bocigas, A. 2021. "Inside Barcelona, the 5G Smart City of the Future". SDX Central. January 17th. https://www.sdxcentral.com/articles/sponsored/syndicated/inside-barcelona-the-5g-smart-city-of-the-future/2021/01/

regional productivity and an annual reduction in CO2 emissions of 370,000 tonnes.[25] 5G will enable an estimated US$660 billion global mobility and transportation market by 2035.[26] Barcelona is among the cities leading 5G experiments in public safety, education and e-commerce (see Table 1).

Emergency response and safety are likely to be relevant use cases for 5G such as real-time video feeds for situational awareness of emergency responders, and high-quality data feeds to guide drones in disasters where direct human intervention puts responders' lives at risk.[27] 5G could enable remote vehicle control that allows human drivers to avoid working in dangerous circumstances. With 4G, image transmission between Beijing and Shanghai, for instance, lags for over 100 milliseconds (ms) and often breaks up. In a 5G network, where uplink bandwidth can reach 100–200 megabits per second (mbps), the delay of image transmission can be reduced to less than 30 ms, enhancing the feasibility of remote vehicle control.[28]

[25] Brittain, N. 2021. "5G use cases: 31 examples that showcase what 5G is capable of". 5G Radar. September 9th. https://www.5gradar.com/features/what-is-5g-these-use-cases-reveal-all

[26] Hoseini, A.K. and Peirav, M. 2021. "5G and Smart Cities". *The Smart City Journal*. November 23rd. https://www.thesmartcityjournal.com/en/articles/5g-and-smart-cities

[27] EENA. 2019. "5G Technology in Emergency Services". August 27th. https://eena.org/knowledge-hub/documents/5g-in-emergency-services/

[28] Deloitte. 2020. "5G smart cities whitepaper". June. https://www2.deloitte.com/content/dam/Deloitte/cn/Documents/technology-media-telecommunications/deloitte-cn-tmt-empowering-smart-cities-with-5g-white-paper-en-200702.pdf

Chapter 2: Services

The efficiency of municipal services impacts the lives of citizens and businesses and can be greatly aided by digital technology. Key indicators covered by the DCI include e-government portals for citizens and businesses, digital technologies for seamless travel such as biometric identification at airports and integrated public transport apps, and the availability of digital platforms for health and education. The DCI and expert interviews indicate several key trends in urban services.

E-government service leaders are found in both high and emerging income categories.

Singapore leads the world in e-government services for residents and businesses. The city-state has a mobile digital national ID card and a comprehensive e-government service portal for residents and businesses, placing it at the top of the DCI in this domain. Its Smart Nation and Digital Government Group (SGFinDex) is the world's first public digital infrastructure to use a national digital identity and centrally managed online consent system, which enables individuals to access financial information held across different government agencies and financial institutions.[29] In 2018 the Singapore Personal Access (SingPass) mobile app was launched as a portal to access government services.

São Paulo performs particularly well in e-government services for residents and businesses, ranking second after Singapore. São Paulo state introduced a digital ID programme in the midst of the pandemic to help citizens access public services securely from their homes. Within a week of the launch, 83,000 digital IDs had been issued and stored on mobile phones.[30] Facial biometric and cloud technologies have also been deployed to improve accessibility and security.

New Delhi ranks third in e-government services for residents and businesses. This partly reflects the success of Aadhaar, India's groundbreaking national digital identity scheme. But the city has also stepped

[29] FiNews.asia. 2020. "Singapore Launches World's First Public Digital Infrastructure". December 7th. https://www.finews.asia/finance/33333-singapore-fin-tech-festival-sgfindex-smart-nation-samuel-tsien-abs-ocbc-launches-world-s-first-public-digital-infrastructure

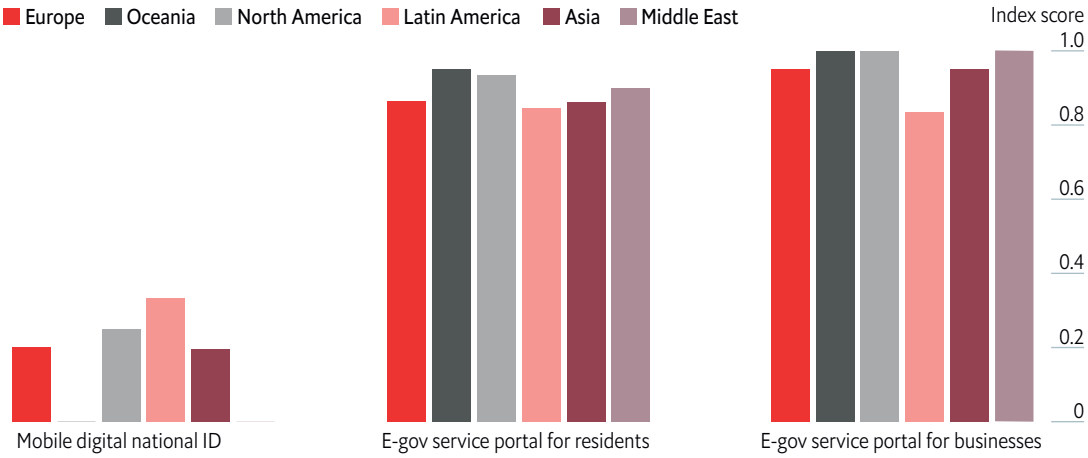
[30] Government of São Paulo. 2020. "With the RG Digital application, SP has already issued more than 83 thousand documents". August 20th. https://www.saopaulo.sp.gov.br/spnoticias/com-aplicativo-rg-digital-sp-ja-emitiu-mais-de-83-mil-documentos/

up efforts beyond Aadhaar, with a major increase in digital engagement during the pandemic.[31] India's severe covid-19 crisis was likely a stimulus for governments and citizens to explore ways of avoiding crowds and transacting online.

Across the regions, vast disparities in the availability of a mobile digital national ID card programme drive the overall score of cities in this indicator.

In the future, service provision could be aided by ambitious programmes targeting the "metaverse", an immersive augmented-reality format that will, advocates believe, move from niche applications like gaming into enterprise and everyday functions. Metaverse Seoul, announced in November 2021 by the Seoul Metropolitan Government, will provide citizens with access to government services via the metaverse.[32] Among other municipal services to be offered, Seoul citizens will soon be able to hold virtual consultations with city officials.

Figure 4: E-government services for residents and businesses
Average regional scores for the three sub-indicators, with 1 being the highest score in each



Source: Economist Impact.

Note: Oceania includes Auckland and Sydney.

[31] Mishra, A.K.N. 2021. "Surge in e-delivery of govt services in Delhi". *The Times of India*. July 1st. https://timesofindia.indiatimes.com/city/delhi/surge-in-e-delivery-of-govt-services/articleshow/84000153.cms

[32] Gaubert, J. 2021. "Seoul to become the first city to enter the metaverse. What will it look like?". Euronews.next. November 11th. https://www.euronews.com/next/2021/11/10/seoul-to-become-the-first-city-to-enter-the-metaverse-what-will-it-look-like

Covid-19: The "Chief Transformation Officer" of cities

The pandemic has forced cities to digitise at speed and scale. "Covid-19 is probably the biggest Chief Transformation Officer for cities, to try something that is different, a new normal," according to James Tee at Green Packet. Cities have launched contactless payments, built digital dashboards to track public health data and developed apps to guide citizens with information and resources.[33]

Dallas launched a chatbot—Dalbot—to help residents with city-related needs, thus avoiding physical trips to a city facility.[34] Dalbot uses AI to provide answers in English and Spanish to frequently asked questions.

Pandemic recovery spending packages could also be a boon to digitisation, as many emphasise infrastructure and the built environment as a target of public investment. This is most evident in the Build Back Better initiative of the US Biden administration, but other nations are investing in infrastructure as part of recovery spending in ways that provide an opportunity for utilising more digital technology. New Zealand, for instance, is planning to upgrade its utilities. "Recovery spending includes a lot of investment in government infrastructure and one of the things we need to think about is how we can build forward smarter with these technologies, to make cities more liveable," says Jolie Hodson, CEO at New Zealand telecommunications provider Spark.

While the pandemic is a spur for digital innovation, it is also increasing demand for tech talent, as well as limiting the flow of talent across borders, both of which create capacity problems for some cities. "The new challenge is human capital," states Tom Gao, Chief Technology and Digital Services Officer at the City of Sydney. "We've locked down our borders so there is no skilled migration and now everyone is driving the digital transformation agenda. There are a finite number of capabilities in the country so it has really pushed up the cost of resources and salaries and a significant shortage in capability. That is something we are seeing globally."

The majority of cities leverage digital technology for seamless transportation, with leaders also building digital passes to boost tourism.

Seven cities in the DCI offer both integrated public transport apps and digital identification at their respective airports. While cities in developed economies generally perform better in terms of provision of mobile apps allowing journey planning and ticketing, Jakarta is a standout among cities in emerging economies in the top tier for offering journey planning and ticketing within a single app.

Seven cities with significant tourism revenue—Bangkok, Berlin, Copenhagen, Dubai, Paris, Seoul and Zurich—have invested more significantly in digital tourist passes which offer access to attractions and transportation. The vast majority of cities do not offer such passes.

Thailand's TAGTHAi Pass has been developed by businesses in cooperation with the Tourism Authority of Thailand, providing tourists with

[33] Wray, S. 2020. "COVID-19 is accelerating city digital transformation and citizen engagement". November 19th. https://cities-today.com/covid-19-is-accelerating-city-digital-transformation-and-citizen-engagement/

[34] City of Dallas. "Dallas launches new chatbot to serve residents better". https://www.dallascitynews.net/dallas-launches-new-chatbot-serve-residents-better

payment access to various tourism-related services. The app also helps smaller tourist-related businesses such as restaurants, tourist attraction operators and museums reach a wider range of customers. The app is currently used by an estimated 180,000 Thai nationals and foreign tourists. Other cities are exploring applications of digital technology to boost tourism. In 2019, Barcelona piloted the 5G Interactive City project.[35] Passeig de Grácia, a major shopping and sightseeing avenue, was turned into a 5G zone, giving visitors a more immersive, personalised experience via augmented and virtual reality using special headsets.[36] With 5G providing the fast bandwidth, the project aims to revolutionise the tourist experience in Barcelona, allowing visitors to look at shops and sights while strolling along the streets and to access information, buy products online or book viewings via their headsets.

Cities are supporting digital health as a means to improve the urban quality of life.

Because of their population density, cities were the birthplace of epidemiology and the sanitation movement in the 19th and early 20th centuries, just as they became the epicentre of innovations like contact tracing during the covid-19 pandemic. This was particularly the case in Asia, where QR-code-based contact-tracing tools played a major role in containing the spread of the virus in the early months, most notably in cities.[37]

The DCI measures city healthcare performance across three indicators: the presence and adoption of telehealth and telemedicine; electronic health records; and pandemic-related applications. It found that the majority of cities scored above 75, indicating a broad-based application of digital health tools to support urban wellbeing.

New York is one of the global top performers. The city's efforts in recent years include a state-wide digital health accelerator programme,[38] digital health offerings from its top institutions such as the New York-Presbyterian Hospital,[39] and specific programmes like the diabetes-prevention initiative for adults which uses virtual health tools to enhance reach, convenience and engagement.[40] Reviews indicate that the programme has reduced the risk of type 2 diabetes in high-risk individuals by 58%.[41] The New York State Department of Health is also facilitating the sharing of electronic health records across regional networks.[42]

[35] 5G Barcelona."5G Interactive City". https://5gbarcelona.org/pilots/5g-interactive-city/

[36] Barcelona City Hall. "5G immersive tourism pilot project in Passeig de Gràcia". https://ajuntament.barcelona.cat/digital/en/noticia/5g-immersive-tourism-pilot-project-in-passeig-de-gracia_883650

[37] Trencher, G. and Karvonen, A. 2017. "Stretching 'Smart': Advancing Health and Wellbeing through the Smart City Agenda" July. https://www.researchgate.net/publication/318759988_Stretching_'Smart'_Advancing_Health_and_Wellbeing_Through_the_Smart_City_Agenda/link/5a7509fcaca2722e4ded11d3/download

[38] New York eHealth Collaborative. "What We Do: Provider Support". https://www.nyehealth.org/innovation/ny-digital-health-innovation-lab/

[39] New York-Presbyterian. "Digital Health: Innovation Center". https://www.nyp.org/about/digital-health

[40] New York State Department of Health. "New York State Diabetes Prevention Program (NDPP)". https://www.health.ny.gov/health_care/medicaid/redesign/ndpp/index.htm#:~:text=NYS%20Medicaid%20is%20temporarily%20allowing,the%20first%20NDPP%20core%20session

[41] YMCA of Central New York. "Diabetes Prevention". https://ymcacny.org/programs/community/diabetes-prevention

[42] Kanowitz, S. 2021. "How smart cities can mitigate the impact of health crises". GCN. January 21st. https://gcn.com/emerging-tech/2021/01/how-smart-cities-can-mitigate-the-impact-of-health-crises/315958

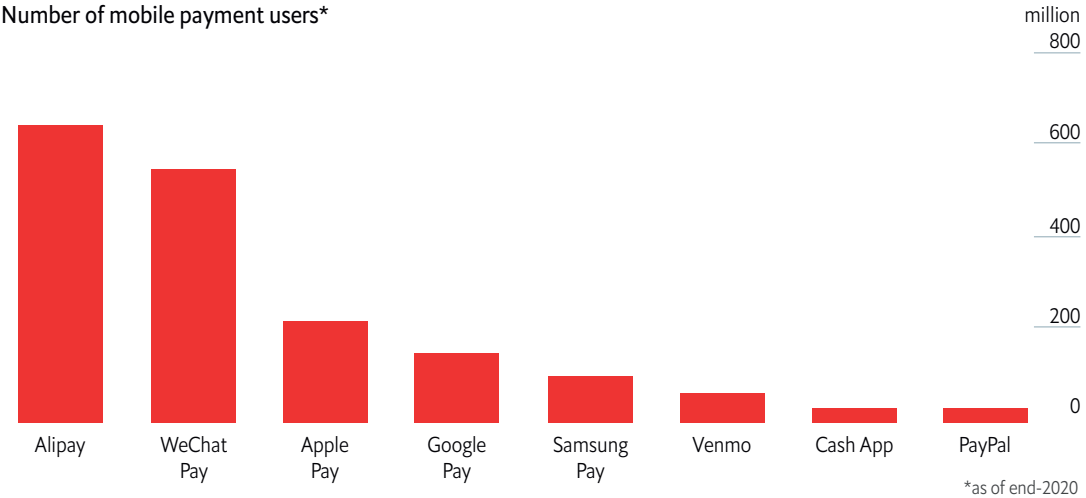
Asian cities dominate in digital finance.

In the domain of digital finance, Asia is home to five out of the top ten cities in the DCI, with Beijing, Seoul and Hong Kong the top three. This outperformance reflects the fact that Asian nations have tended to lead the world in digital payments and that, given their density of people and transactions, cities are the main hotspots of transactions activity.

China and India are two world leaders in digital finance in terms of both supportive government regulation and private sector innovation. China's AliPay and WeChat Pay platforms had by far the most mobile-payment users in 2020, and China and India had the

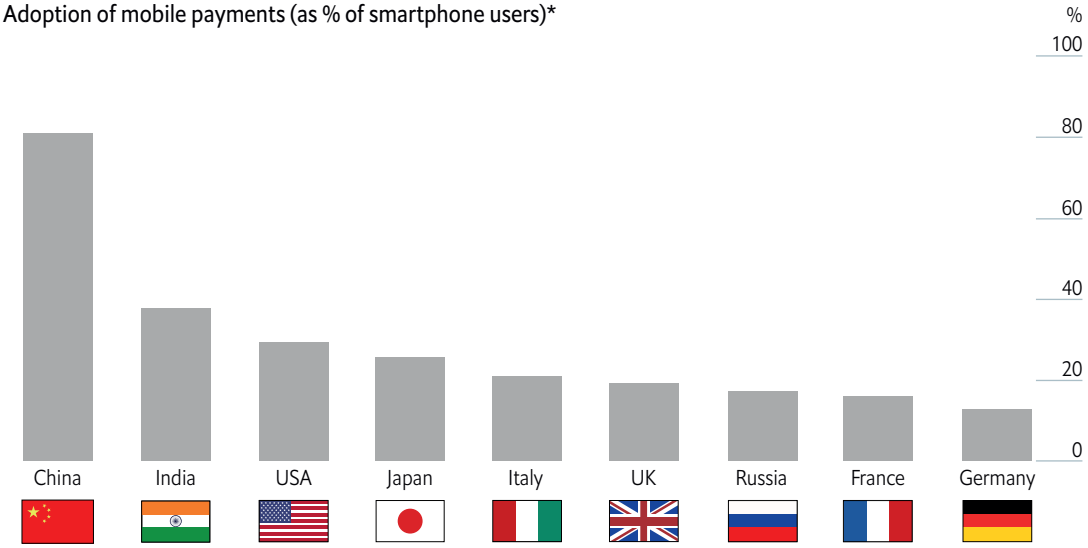
Figure 5: Adoption of mobile payments

Number of mobile payment users*



*as of end-2020

Adoption of mobile payments (as % of smartphone users)*



Source: Business of Apps; eMarketer; EIU.

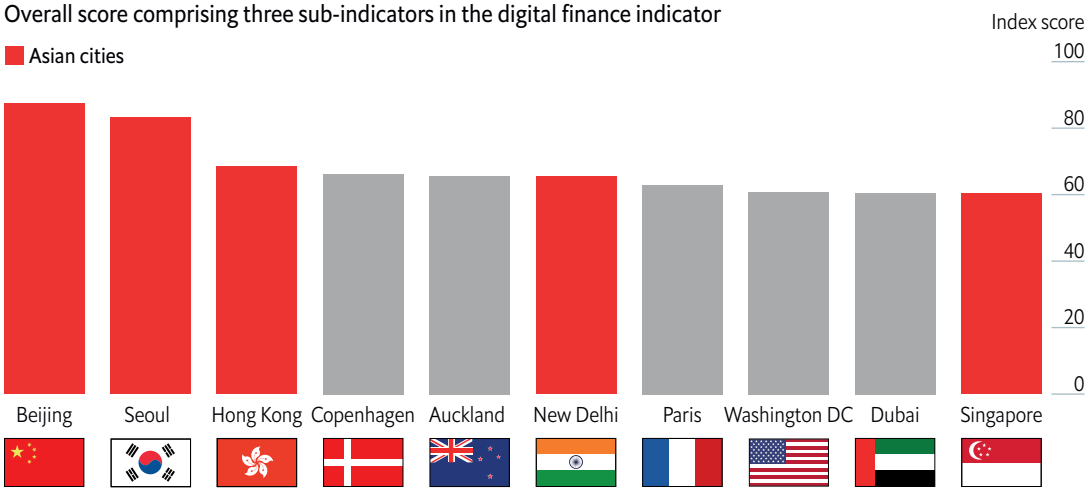
* as of end-2019

highest proportion of mobile payments as a percentage of smartphone users.

Asian governments have tended to support payment innovations like super-apps because of their financial inclusion benefits, especially in the context of physical infrastructure deficits that limit access to bricks-and-mortar banking services. Social factors have also driven uptake with, for instance, more consumer acceptance of digital payments. One study found that Chinese consumers are more accepting of facial recognition technology—which is becoming a payment authentication option—compared with US and German consumers.[43]

Digital finance affects cities by dint of their transaction density in terms of both citizens and merchants, and cities can benefit disproportionately from national trends. New Delhi's high performance in the DCI, for instance, reflects the success of India's Unified Payments Interface (UPI), a convenient payment system that powers the country's global leadership in real-time payments. UPI transactions in New Delhi grew 442% year-on-year in 2019.[44] The city has also launched specific payment modalities on the basis of the UPI, including Delhi Metro Rail Corporation, which recently launched India's first UPI-based parking facility.[45]

Figure 6: Five asian cities rank among the top 10 in digital finance
Overall score comprising three sub-indicators in the digital finance indicator



Source: Economist Impact.

[43] Kostka, G., Steinacker, L. and Meckel, M. 2021. "Between security and convenience: Facial recognition technology in the eyes of citizens in China, Germany, the United Kingdom, and the United States".
Public Understanding of Science. March 26th. https://journals.sagepub.com/doi/full/10.1177/09636625211001555

[44] Mathur. N. 2020. "UPI growing by 442% in Delhi: Razorpay report". Mint. January 21st. https://www.livemint.com/news/india/upi-growing-by-442-in-delhi-razorpay-report-11579609107876.html

[45] Singh, R.K. 2021. "Delhi: DMRC launches India's first UPI-based cashless parking at Kashmere Gate metro station". *India Today*. July 7th. https://www.indiatoday.in/cities/delhi/story/dmrc-launches-upi-based-cashless-parking-kashmere-gate-1824762-2021-07-07

Chapter 3: Culture

The third pillar in the DCI covers culture and refers to values-based performance including digital inclusion, government engagement in and readiness for digital technology, and public attitudes and trust. These background forces can determine the effectiveness and inclusivity of a city's digital technology strategy.

Digital skills levels and satisfaction with e-government portals are significantly higher in emerging-market cities.

Residents of emerging-economy cities have greater digital skills than those in developed world cities. The Economist Impact survey reveals that self-reported digital skills—from basic functional skills to more advanced competencies like coding, troubleshooting technical issues and taking precautions against cyber threats—are highest in emerging-market cities.

New Delhi, Dubai, Jakarta, Beijing, Mexico City, Manila and Bangkok are the top seven cities. This result is likely a reflection of the higher impact of digital platforms on daily life in emerging-market geographies where citizens face many more constraints in their physical environment, from accessing bricks-and-mortar banking services to the travel required to interact with other services.

Data shows that digital engagement levels are often higher in emerging economies than developed ones. This trend is evident in both e-participation on government portals and in the online public comfort indicators. Buenos Aires, Jakarta and Kuala Lumpur are among the top five cities in the comfort with sharing information online indicator. Jakarta was the "Twitter capital of the world" in 2013, with 7.5% of all tweets globally coming from Indonesia.[46] The Philippines is the current social media capital of the world, with Filipinos spending nine hours and 45 minutes per day online, on average.[47]

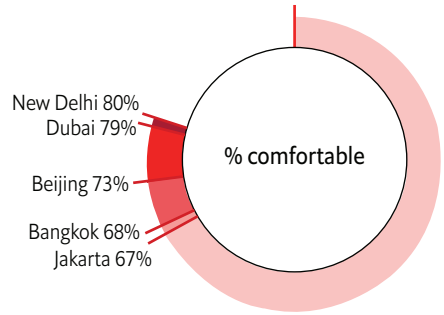
Our survey found that trust in e-government is greatest among emerging-market cities in general and, on a regional basis, in Asia. Residents in emerging-economy Asian cities have the highest levels of satisfaction with and trust in online services offered by their government. When asked if they were comfortable providing personal and financial information on e-government platforms, the largest share of respondents answering affirmatively were in New Delhi (80%), Dubai (79%), Beijing (73%), Bangkok (68%) and Jakarta (67%). Copenhagen was the top developed economy performer, with 58% of

[46] Carter-Lau, P. 2013. "Indonesia: The social media capital of the world". On Device Research. December. https://ondeviceresearch.com/blog/indonesia-social-media-capital-world

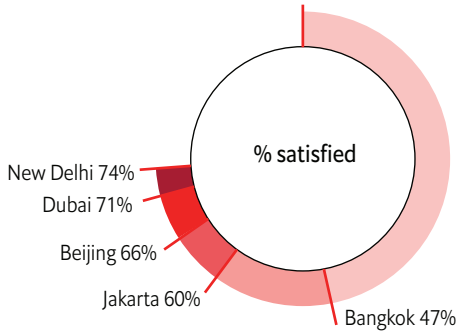
[47] Kemp, S. 2020. "Digital 2020: 3.8 Billion People Use Social Media". We Are Social. January 30th. https://wearesocial.com/blog/2020/01/digital-2020-3-8-billion-people-use-social-media/

Figure 7: Citizen engagement in e-government platforms

Comfortable with providing personal/financial details on e-government platforms
Are you comfortable providing your personal/ financial details on e-government platforms?



Satisfaction with citizen feedback services
Are you satisfied with the citizen feedback services that are provided online by your government?



Source: Economist Impact survey.

respondents confirming their comfort in using the platforms.

Europe and US cities lead the world in "AI readiness".

AI is a critical tool for cities and is deployed in a range of applications including optimising traffic, energy use, and urban services design and planning. Cities' ability to marshal an ever-growing pool of data from sensors and citizens' digital interactions can be put to effective use through the deployment of today's advanced data analysis techniques. AI can help to tackle broader policy goals, including sustainability and inclusion. AI and machine learning are being used to map the accessibility of sidewalks and pavements for people with disabilities,[48] including gauging width, gradient and surface composition.[49]

The DCI finds that AI readiness correlates closely with city and country income level, with the most AI-ready—as measured by the government's ability to effectively implement AI in public services—cities all clustered in Europe and the US, with Dallas, New York, Washington DC, London, Berlin and Frankfurt leading the world. Singapore and Seoul, among the highest-income Asian cities in the DCI, ranked seventh and eighth, respectively.

Top-performing cities are crafting their own AI strategies that balance the need for innovation with regulation and oversight. The New York City Artificial Intelligence Strategy, for example—published by the Mayor's Office of the Chief Technology Officer in October 2021—outlines the city's strategic vision of ethical AI. This includes identifying a range of biases and challenges to the effective and fair

[48] Smart Cities for All. "AI for Inclusive Urban Sidewalks Project". https://www.smartcities4all.org/ai-for-inclusive-sidewalks/

[49] Microsoft. 2021. "Open Data Campaign: Year one in review". April. https://news.microsoft.com/wp-content/uploads/prod/sites/560/2021/04/Microsoft-Open-Data-Campaign-Report_PDF_FINAL.pdf

use of AI, such as the fact that digital surveys must account for the 40% of New Yorkers who have insufficient internet access and the linguistic diversity of all citizens.[50]

Open data can power urban innovation.

European and North American cities dominate the DCI in terms of open data access and use policies, which cover the publishing and usage of data for accountability, innovation and social impact. London, Toronto, Paris, Dallas, New York and Washington DC are ranked in the top four (all three US cities are tied fourth). Seoul is Asia's outperformer in seventh place.

Open data has proven benefits for urban economies and citizen wellbeing. Transport for London's (TfL) reforms over the past decade provide a notable global case study. Dealing with more than 30 million daily journeys in the capital, TfL started releasing data such as timetables, service status and disruptions, which could be used by anyone free of charge. This fostered the development of over 600 apps and tools used by nearly half of Londoners, with engagement from companies ranging from Twitter, Google and Apple to Citymapper and Mapway.[51]

Berlin commenced its Open Data strategy in 2011, with the Open Data Portal featuring 1,200 datasets by 2016.[52] A plethora of apps have since been developed using this data, such as maps of Berlin's Christmas markets, bathing spots (eg, natural spas and swimming pools) and interactive maps outlining the frequency at which streets are cleaned.[53] European cities are also beneficiaries of EU-wide efforts to promote data openness at a regional level.

European cities, which score high on open data, may benefit from EU-wide efforts to make data sharing easier. As Léan Doody, European Cities, Planning and Design Leader at Arup, explains, "The European Commission is trying to promote the 'data spaces' idea where you have safe spaces for sharing data, where the legal details, commercial models and technologies are worked out, so that it's easy, for example, to have parking operators share their data into a city data space, which also maybe holds pedestrian footfall data and energy consumption or whatever and people can build services. At the moment that's not easy and straightforward to do."

New York is another city leading in leveraging open data for policy goals. The Mayor's Office for Economic Opportunity has developed the Poverty in NYC map which visualises the geographic distribution of poverty across the city using open data released from the New York portion of the American Community Survey, a demographic survey conducted by the US Census Bureau.[54] The goal is to use data to inform policymakers on anti-poverty interventions, providing variables that identify causes of poverty.

[50] NYC Mayor's Office of the Chief Technology Officer. 2021. "AI Strategy: The New York City Artificial Intelligence Strategy". October 13th. https://www1.nyc.gov/assets/cto/downloads/ai-strategy/nyc_ai_strategy.pdf

[51] Deloitte. 2017. "Assessing the value of TfL's open data and digital partnerships". July. https://content.tfl.gov.uk/deloitte-report-tfl-open-data.pdf

[52] Urban Sustainability Exchange. 2011 (ongoing). "Berlin Open Data Strategy". https://use.metropolis.org/case-studies/berlin-open-data-strategy#casestudydetail

[53] Ibid.

[54] NYC Opportunity. "Poverty in NYC". https://www1.nyc.gov/site/opportunity/poverty-in-nyc/poverty-in-nyc.page

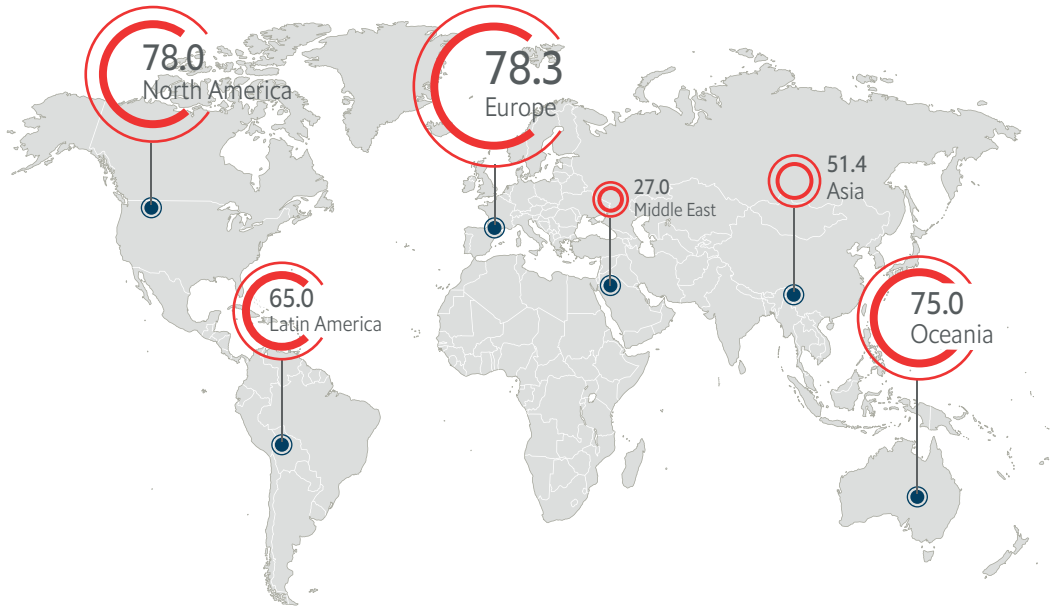
Western cities offer the strongest internet freedoms and safeguards, with Asia and the Middle East ranking last.

Internet freedom is closely linked to digital cities because digital technologies touch on many civil liberties and rights, including freedom of movement and expression, the right to privacy and the right to know how one's data is being captured and used. Experimental technologies like facial recognition and AI can and have been installed without regulation or democratic oversight. This could enable the private ownership of public data and potentially worsen inequalities through the "digital divide". The DCI finds that European and North American cities offer the strongest safeguards, while Beijing, Dubai, Bangkok, Jakarta and New Delhi score below 50.

Concerned at the potential infringement of rights by digital technology, three cities in the DCI—Amsterdam, Barcelona and New York—formed the Cities Coalition for Digital Rights in 2018. It now has 48 members, including the DCI cities of Berlin, London, Rome, São Paulo, Sydney and Toronto, under the auspices of UNESCO. Their advocacy efforts include raising techno-political awareness by fostering democratic citizenship with urban stakeholders and advancing key principles, including: ensuring that data collected for one purpose is not used for others; ensuring technology is not imposed by coercion or offering rewards; building "privacy by design" and ensuring openness so that code can be audited and verified; and ensuring fair access to technologies.[55]

Most Asian cities rank low on internet freedom except Tokyo, which reflects the broader

Figure 8: Average regional scores in the internet freedom indicator



Source: Freedom House; Economist Impact.

Note: Oceania includes Auckland and Sydney.

[55] Calzada, I., Pérez-Batlle, M. and Batlle-Montserrat, J. 2021. "People-centered Smart Cities: An exploratory action research on the Cities' Coalition for Digital Rights". Taylor & Francis. November 22nd. https://www.tandfonline.com/doi/full/10.1080/07352166.2021.1994861?nav=undefined

improvement in internet freedom in Japan over recent years, with few obstacles to access and a legal framework providing strong protections for freedom of expression. People can also freely use the internet to mobilise the community.[56]

[56] Freedom House. "Freedom on the Net 2021: Japan". https://freedomhouse.org/country/japan/freedom-net/2021

Cyber readiness: Are cities ready for quantum hackers?

The DCI shows nine cities reaching the higher cyber preparedness benchmark, as measured by advanced technical barriers to protect city infrastructure. The remainder scored either "high" or "moderate", and no city ranked in the low or very low tiers.

While this is a welcome trend, the growing sophistication of cyber attacks means cities have to continually raise their defences just to stay at their current level of resilience. Indeed, the more digital technology a city uses, the more openings are created for hackers as the "attack surface" widens. Emergency alert systems, street video surveillance and traffic signals are among the riskiest smart city technologies according to recent research.[57]

Hackers are targeting cities. One study estimates that 44% of global ransomware attacks in 2020 targeted municipalities. The City of London Corporation suffered nearly 1 million cyber attacks per month during the first quarter of 2019.[58] Attacks on Indian cyber assets grew by 207% in 2020,[59] with New Delhi ranking as the fifth most attacked city in the world according to research from Subex, a telecommunications company.[60] Rome was recently hit by one of Italy's most serious cyber attacks to date, which shut down all web services for the Lazio region, including the IT systems for managing the covid-19 vaccination programme.[61] In 2019, Singapore's defence ministry was victim to an email phishing scam involving malware sent to employee email accounts.[62]

The threat could grow in the future because the defences that cities are relying on today will not be able to withstand the assault of quantum computing, an emerging capability which will break through current cyber defences.

David Williams, CEO of Arqit, a quantum cyber security firm, argues that cities might not realise how many risks they are creating as more and more connectivity and data are embedded in built environments. "The encryption systems that we all use [for cyber security] were invented some 30 years ago and it did a great job," says Mr Williams, referring to Public Key Infrastructure (PKI), an authentication method. "PKI was designed to protect a small number of devices, having one-to-one connections with things like e-commerce websites, or directly connected with each other. The growth in PKI to cope with the complexity of our hyper-connected world has left lots of gaps through which attackers are now crawling. And that's why you're seeing so many compromises." He claims that data today is being "stored now by bad guys, including foreign hostile governments, and will be decrypted later by quantum computers".

Smart cities require many small devices and sensors to provide data about factors like movement, temperature, sunlight and water, access control and identity, and protecting these from quantum hackers through conventional cyber security algorithms would require a level of processing power that would make them impractical, David Williams argues. "Unless you can make IoT sensors small, they are too energy-intensive and large and the whole smart city project falls apart."

[57] Trapenberg Frick, K., Mendonça Abreu, G., Malkin, N., Pan, A. and Post, A.E. 2021. "The Cybersecurity Risks of Smart City Technologies: What Do the Experts Think?". Center for Long-term Cybersecurity. February. https://cltc.berkeley.edu/2021/03/16/smart-cities/

[58] Cinder, L. "City of London Hit by One Million Cyber-Attacks Per Month". DCL Search. https://www.dclsearch.com/blog/2019/08/city-of-london-hit-by-one-million-cyber-attacks-per-month

[59] Coker, J. 2020. "Local Government Organizations Most Frequently Targeted by Ransomware". Infosecurity Group. August 27th. https://www.infosecurity-magazine.com/news/local-government-targeted/#:~:text=It%20found%20that%2044%25%20of,as%20in%202019%20(45%25).&text=There%20has%20also%20been%20rise,incidents%20observed%20since%20July%202019

[60] Financial Express. 2021. "Cyber assets: New Delhi 5th most attacked city in world, says report". March 30th. https://www.financialexpress.com/industry/technology/cyber-assets-new-delhi-5th-most-attacked-city-in-world-says-report/2222802/

[61] Reuters. 2021. "Prosecutors probe terrorism among reasons behind Italy region hacking". August 3rd. https://www.reuters.com/article/italy-hack-idINL8N-2PA5N7

[62] Lago, C. 2020. "The biggest data breaches in Southeast Asia". January 18th. https://www.csoonline.com/article/3532816/the-biggest-data-breaches-in-south-east-asia.html

Chapter 4: Sustainability

Digital technologies can play a significant role in reducing emissions and resource usage in transportation and the built environment, and in pinpointing and monitoring public health risks like pollution and smog. Enabling physical infrastructures to adjust to occupancy and weather conditions, detecting water leaks and unlocking new mobility sectors like autonomous vehicles, all require sensors, the IoT, digital payments and analytics capabilities. Some cities are making innovative use of data such as social media posts to track the progression and impact of floods and earthquakes, while micro sensors are pinpointing urban "heat islands" where temperatures are higher due to the presence of heat-trapping materials like glass and concrete.[63]

Emerging-market cities lag in sustainability performance, while facing the gravest challenges from climate change.

Sustainability—measured against resource management, emissions reduction, pollution and the circular or "sharing" economy—was the best-performing of the four pillars at 66.3, relative to an overall average of 63.4. However, nearly all of the large emerging-market cities ranked below average, even though their sustainability challenges are the gravest.

Bangkok, Jakarta, Manila and New Delhi featured in the bottom five along with Mexico City. In 2021 one Indonesian court found the President negligent in tackling air pollution, which is reducing the life expectancy of Jakarta's residents by 5.5 years.[64] November 2021 saw New Delhi's worst air quality performance, recording 11 consecutive days of "severe" air pollution.[65]

Beijing's very high performance relative to its peers—it ranked fifth in the sustainability pillar, above the likes of Amsterdam, Sydney and Berlin—is creditable given its historical challenges, especially in relation to air pollution. In the late 1990s the city took major policy steps to curb emissions and pollution.[66, 67]

[63] Green, A. 2020. "Deep data helps cities prepare for disaster". Financial Times. January 29th. https://www.ft.com/content/12937096-1b6f-11ea-81f0-0c253907d3e0

[64] BBC. 2021. "Indonesia president found negligent over Jakarta filthy air". September 16th. https://www.bbc.co.uk/news/world-asia-58554331

[65] BBC. 2021. "Air quality: Delhi records worst November air in years". December 1st. https://www.bbc.co.uk/news/world-asia-india-59486806

[66] IISD. 2019. "UNEP Report Highlights Beijing's Air Pollution Control Efforts as 'Model for Other Cities'". March 14th. https://sdg.iisd.org/news/unep-report-highlights-beijings-air-pollution-control-efforts-as-model-for-other-cities/

[67] Zhao, J. 2011. "Climate Change Mitigation in Beijing, China". Case study prepared for "Cities and Climate Change: Global Report on Human Settlements 2011". https://unhabitat.org/sites/default/files/2012/06/GRHS2011CaseStudyChapter05Beijing.pdf

Beijing is in many ways a microcosm for China in terms of its increasing concern with climate change and strong policy momentum relative to its income level and per-capita emissions. Its record-breaking 2013 smog was listed as one of "nine moments that changed China's mind about climate change", according to Carbon Brief.[68] Its investments and collaborations with industry, including optimising energy infrastructure, curbing coal-fired pollution and vehicle emission controls, among other measures, brought about a 35% drop in fine particulate matter pollution between 2013 and 2017.[69] In the digital realm, the city has deployed an IoT-based initiative—Green Horizons—to predict pollution levels based on inputs like traffic, weather, humidity and wind patterns. Since its launch in 2014, Green Horizons has enabled 1-by-1 kilometre pollution forecasts 72 hours in advance, offering citizens warning and planning time.[70] Beijing has also extended its use of digital technologies in enabling other smart city functionalities such as managing utilities and developing sharing economy practices.

European cities are investing significantly in air pollution innovation. London has launched the Breathe London network, a street-by-street air quality monitoring system, to be rolled out over the next four years after an initial pilot phase that commenced in 2018.[71] Breathe London sensors are solar-powered, approximately the size of a shoebox and highly versatile, with the option of being installed on lamp posts and traffic lights, or in playgrounds, among other locations. Their data will help inform policymakers not only on overall air quality, but also on the geographic distribution of air pollution throughout the city.[72]

Some cities with good air quality are continuing to invest in digital technologies to better manage pollution at a more granular level. Auckland, the only city with a top score, has installed 5G-enabled smart lighting infrastructure that monitors air and noise pollution levels in its central business district. The data gathered allows city officials to adapt policies and improve the placement of public assets.[73, 74]

The majority of cities are investing in smart utility management.

Digital capabilities like AI and the IoT can improve energy and resource efficiency across water, electricity, street lighting and waste management—the core utilities in a city. Ten cities in the DCI achieve full marks in their use of digital technologies for smart utilities management.

[68] Liu, J. 2021. "Analysis: Nine key moments that changed China's mind about climate change". Carbon Brief. October 25th. https://www.carbonbrief.org/ analysis-nine-key-moments-that-changed-chinas-mind-about-climate-change

[69] IISD. 2019. "UNEP Report Highlights Beijing's Air Pollution Control Efforts as 'Model for Other Cities'". March 14th. https://sdg.iisd.org/news/unep-report-highlights-beijings-air-pollution-control-efforts-as-model-for-other-cities/

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Barcelona is one of the top performers. It is using the IoT to foster smarter power usage. The Barcelona Lighting Master Plan was implemented back in 2012, leading to the installation of 1,100 LED lamp posts with smart lighting sensors which also collect data on air quality. Barcelona uses the IoT for irrigation by collecting sensor data and remotely monitoring humidity, temperature and water levels, thereby allowing gardeners to optimise resource use for gardens in public spaces.[75]

The city also stands out for its open collaborative approach to sustainability more broadly. "Barcelona pioneered the idea of giving space and infrastructure for things to be tried out, for example, space on the street for smart parking trials, or electricity provision for trials," explains Léan Doody of Arup, leading their Integrated Cities and Planning network in Europe.

European cities lead in smart traffic management.

As vehicles produce more emissions when idle than when in motion,[76] digital technology can be used to keep them mobile without the unnecessary starting and stopping at traffic lights. Forecasts suggest that, by 2050, cities using smart technologies to combat congestion will cut commutes by 15–20%.[77]

Amsterdam, Copenhagen, Frankfurt and Madrid score full marks in their use of IoT-enabled traffic management. Dubai and Washington DC join them. Amsterdam ramped up its investment in smart traffic management in 2015, with use cases including: adaptive traffic light control to ease congestion and re-route traffic; traffic trend analysis to improve situational assessment and reduce the number of accidents; and camera technology for environmental zone enforcement and the restriction of non-environmentally friendly vehicles.[78]

Developments are nascent in Asia, with Manila, New Delhi, Tokyo, Bangkok, Seoul and Jakarta occupying the lowest positions. However, Asia is home to private sector entities with significant capabilities and investment in smart traffic innovations, notably Alibaba, whose City Brain platform relies on access to thousands of cameras to monitor traffic flow and is available in 23 cities in China. Its technology is reaping tangible benefits, with one initiative enabling ambulances to arrive seven minutes faster, for instance.[79] Europe is also benefiting from investments from industry players including Volkswagen and Siemens.[80, 81]

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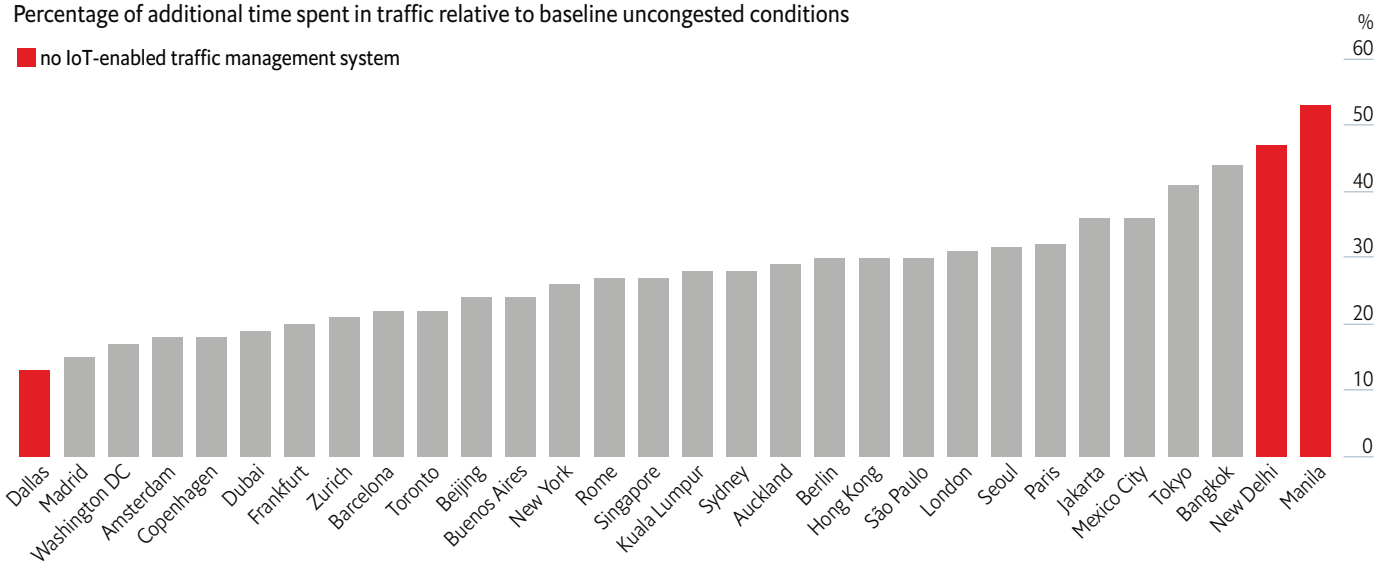
Figure 9: Congestion levels

Percentage of additional time spent in traffic relative to baseline uncongested conditions



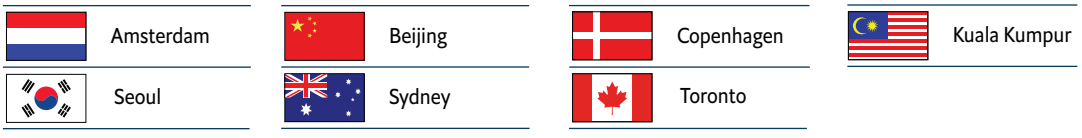
Source: TomTom Traffic Index; Economist Impact.

Most cities lack a plan to boost the sharing economy.

The sharing economy allows goods and resources to be shared by individuals and groups, thus reducing wastage—for example, car-pooling to reduce the number of cars on the road during commutes. Some cities have explicit plans, policies or frameworks to support the sharing economy: Amsterdam, Beijing, Copenhagen, Kuala Lumpur, Seoul, Sydney and Toronto. However, the majority of cities (23) have no plan in place.

Seoul implemented the Sharing City Seoul project in 2012 and one of its key components is to increase government-backed funding for sharing enterprises.[82] As of November 2017, Seoul had certified 97 sharing enterprises and groups. Sharing enterprises that received funding include a variety of services, from the car-sharing platform SoCar, to Open Closet, a company working with local government to help young job seekers borrow donated suits.[83, 84] Using Creative Commons Korea, a license suite that enables sharing of knowledge and creativity, the Share Hub online platform was also developed, educating citizens about various sharing initiatives across the city and providing them with quick access to a variety of sharing services.[85]

Figure 10: Cities with sharing economy plans



Source: Economist Impact.

[82] Johnson, C. "Is Seoul the next Great Sharing City?" Our World. https://ourworld.unu.edu/en/is-seoul-the-next-great-sharing-city

[83] The Open Closet. https://theopencloset.net/

[84] World Economic Forum. 2017. "Collaboration in Cities: From Sharing to 'Sharing Economy'". December. https://www3.weforum.org/docs/White_Paper_Collaboration_in_Cities_report_2017.pdf

[85] Share Hub. http://sharehub.kr/homeEn/shareHomeEn.do

Conclusion

Over the last decade, a growing number of cities have sought to take advantage of improving "frontier" technologies such as AI, the IoT and cloud computing—all of which have been accelerated by the advent of 5G connectivity. Covid-19 has led many to ramp up their digital platforms in ways that could prove permanent. As well as the improving quality and affordability profile of digital technologies, cities now also have a sizeable bank of experience to draw on when determining the best course of action to take.

Experts believe that the smart city agenda has become more nuanced, from an early phase of top-down technocracy and a tendency to be dazzled by impressive technology without a clear idea of the problem to be solved or the unanticipated consequences of deployment, to a new era in which all urban technology decisions are taken as part of a dialogue with urban constituents—citizens and businesses.

A clearer focus on policy goals is one best practice, according to Simon Hunter of the New South Wales Department of Planning, Industry and Environment. "It's about knowing what the problem is you're trying to solve and then using technology to fit that problem, not coming with a defined technology and then looking for a problem to solve it with." He calls on cities to focus on the "problems of their community, and on understanding what technologies are there and how they apply, so you don't get sucked into buying something shiny rather than something useful." Arup's Léan Doody concurs: "A very positive development in the last few years is that digital is now put at the service of these bigger policy objectives rather than being a thing by itself." At times, city leaders may need to wait for a technology's benefits to be clearer given the often-significant financial outlays. Tom Gao at the City of Sydney, for instance, believes that the IoT is still "in general a very costly exercise. From a return on investment perspective, it's not clear that the return is necessarily there yet."

To counter the threat of top-down digital technology imposition, cities are realising they need to engage with all their constituents. Anthony Townsend, Urbanist in Residence at Cornell Tech's Jacobs Urban Tech Hub, speaks about a shift from "optimisation to engagement" in which the first generation of smart city approaches led by the likes of IBM, Cisco and Siemens focused on top-down, efficiency-oriented applications, and has been

superseded by a more democratic approach that recognises diverse perspectives and needs.

"As the 'body public' of various countries have digested the idea of smart cities, as the technology has evolved, and as the energy has shifted from enterprise to consumer tech companies, there's been a lot of conflict around cultural and political assumptions about privacy and governance, what government does, what the private sector does. The response from a lot of cities has been to be much more deliberate about engagement, around identifying problems that technology could be used for, involving people in design evaluation, and being more aggressive about identifying risks ahead of time." Many cities are now laying out the risks of AI and automated decision-making, for example, explains Mr Townsend.

Anthony Townsend also notes the trade-offs between incrementalism and large-scale smart city initiatives. He is sceptical about greenfield smart city initiatives like Sidewalk Toronto and Songdo in South Korea, both of which have failed to attract residents or achieve their goals. "Where we've seen missteps has been where private sector companies have moved too slowly, at a scale that wasn't keeping up with shifts in the tech marketplace in terms of tech behaviour and, more often than not, that has happened because they've anchored a smart city urban tech project in a big real estate development."

He highlights Sidewalk and Songdo as examples of initiatives that were technologically "frozen in an earlier era". The challenge is "coupling the physical building of the city with your digital [version], so that the two can move at a similar pace, and thus ensure the digital layer doesn't get frozen and become obsolete before your physical layer is ready to open its doors. Then comes the political reality of large-scale smart cities wrapped in high-tech which are being rejected all over the place."

Instead, Mr Townsend believes that "incremental projects of 100 or 1,000 units rather than 10,000 is where we're going to see the private sector figure out how to do this". He considers that opportunities to deliver results lie in a smaller-scale, distributed fashion, cutting across network infrastructure, from cloud infrastructure to energy systems to mobility to construction. He cites the promising "scattered site" developments in Scandinavia and the Netherlands, like smart districts and communities.

Some cities are fostering citizen engagement through laws and regulations. The Netherlands, for instance, has a specific law about citizen participation in decision-making in regulations. "This provides a direct feedback loop into how we are deploying all of these new technologies into our cities, to make sure that it is adhering to the values and principles we want to protect," according to Tom van Arman, Founder and Director of Tapp, a smart city design cooperative in Amsterdam. This is now impacting technology deployment in the country's cities. Cities need to do more to take their citizens with them. "Cities don't do a good enough job of having a strategy and then of communicating that strategy to residents and identifying the value to them, whether it be security, resiliency, mobility," explains Siemens' David Hopping. Philipp Rode at the London School of Economics cites Amsterdam and Barcelona as standout DCI cities which are "bringing this data revolution back to questions around civility, public life, politics, democratic decisions-making and the democratic sphere".

There are technical improvements to be made too. Simon Hunter explains that the New South Wales Department of Planning,

Industry and Environment is putting in place policies to build trust, engagement and delivery, including making interoperability standards, cyber security and information protection "fundamental to everything". It is also including independent privacy assessments of projects funded through the state's acceleration programme.

"People expect governments to protect their data, to use it for defined purposes and to be clear about what those purposes are to build trust with the community. My view is trust has to be earned and maintained, and the key is listening more than you talk to citizens including taking feedback, synthesising that feedback and seeing how you can incorporate it."

Appendix 1: Digital Cities Index 2022 methodology

Index framework

The Digital Cities Index (DCI) is a global, policy benchmarking tool developed to measure access, adoption and use of digital tools to support urban growth. It encompasses 17 indicators, 48 sub-indicators and 30 cities. The DCI framework comprises four pillars – connectivity, services, culture and sustainability – which have been identified through literature review and discussions with experts. These are defined as follows:

Connectivity: Assesses the infrastructural capability of a city to be digitally connected. It encompasses three key aspects: physical infrastructure, quality of the infrastructure and its affordability. Indicators within each of these aspects aim to provide a clear indication of whether citizens are able to afford and reasonably connect to the internet.

Services: Measures the extent to which city residents can benefit from digital services and experience the efficiency and convenience they offer. It also captures the integration of different services on digital platforms, and the openness and interoperability between digital service providers.

Culture: Measures the extent to which technology has been incorporated into people's lives. The suitability of the ecosystem to allow new technologies to develop and proliferate is evaluated by assessing factors such as legal and institutional support, technical capabilities and citizens' acceptance of the use of digital tools. This pillar also assesses the extent of data security and privacy in cities.

Sustainability: Evaluates the extent to which digital technologies are used to pursue environmentally friendly growth through efficient resource management, emissions reduction, pollution management and circular economy adoption. Within each of these areas, the city is assessed on its ability to leverage new and advanced digital technologies, such as digital twins in construction and smart sensors in air pollution and agriculture, in order to use resources for longer, more efficiently and with minimal waste generation.

Within each pillar, there are several indicators and sub-indicators that measure cities' performance with regard to digitalisation. Each pillar receives a score, calculated from a weighted mean of the underlying indicator scores (see "Weights" sub-section below), from 0 to 100, where 100 = the highest digitalisation.

We would like to thank the following experts who were consulted on the design of the DCI framework:

- Amit Midha, President Asia Pacific & Japan and Global Digital Cities, Dell Technologies
- Anthony Townsend, Urbanist in Residence, Cornell Tech, Jacobs Urban Tech Hub
- Carlos Iglesias, Senior Research Manager, World Wide Web Foundation
- Tim Kelly, Lead ICT Policy Specialist, World Bank Group
- Vincent Miller, Reader in Sociology and Cultural Studies, University of Kent

Indicators

The DCI includes quantitative, qualitative and survey indicators and comprises 48 individual sub-indicators.

- **Quantitative indicators:** 19 of the 48 sub-indicators are based on quantitative data sourced from national and international statistical sources. For example, internet download speed and value of e-payments. Where there were missing values in quantitative data, regional averages have been used as estimates.
- **Qualitative indicators:** 20 of the 48 sub-indicators are qualitative assessments based on a methodology determined by Economist Impact. For example, blockchain strategies and adoption of digital technologies for urban agriculture.
- **Survey indicators:** four of the 48 sub-indicators are based on survey results from 3,000 respondents in the 30 cities. For example, adoption rates and satisfaction levels for digital banking and personal finance tools.
- **Mixed indicators:** five of the 48 sub-indicators are based on a combination of two or more of the above methodologies. For example, traffic management is assessed using both quantitative and qualitative data.

Survey

Economist Impact conducted a survey across 30 cities to gather primary insights and perspectives on aspects such as digital skills, adoption of online services, accessibility of digital IDs and online trust levels of the public. Survey questionnaires included five preliminary demographic questions to understand the background of respondents, such as age and gender. The remaining five questions were designed to understand the perceptions and individual views of city residents. The table below provides a snapshot of the selection criteria used for respondents in the survey.

Length	10 Question (5 content + 5 demographic)
Sample Size	100 respondents from each city
Age	21–80
Gender	Minimum 40% females
Education	A range (from elementary/primary school to PhD)
Employment	A range (providing a list of employment options)

City selection

The first iteration of the DCI includes 30 global cities from across the world. It contains ten cities from Europe, four from North America, three from Latin America, twelve from Asia Pacific and one from the Middle East.

Europe	North America	Latin America	Asia Pacific	Middle East
Amsterdam	Dallas	Buenos Aires	Auckland	Dubai
Barcelona	New York	Mexico City	Bangkok	
Berlin	Toronto	São Paulo	Beijing	
Copenhagen	Washington DC		Hong Kong	
Frankfurt			Jakarta	
London			Kuala Lumpur	
Madrid			Manila	
Paris			New Delhi	
Rome			Seoul	
Zurich			Singapore	
			Sydney	
			Tokyo	

Note: In the index workbook, Auckland and Sydney along with ten Asian cities are represented as APAC. For the purpose of this white paper, Auckland and Sydney are represented as Oceania and the other ten Asian cities as Asia.

Data modelling

Indicator scores are normalised and then aggregated across categories to enable a comparison of broader concepts across cities. Normalisation rebases the raw indicator data to a common unit so that it can be aggregated. All indicators in this model are normalised to a scale of 0–100, where 100 indicates the highest digitalisation and 0 represents the lowest.

Most indicators are transformed based on a min/max normalisation, where the minimum and maximum raw data values across the 30 cities are used to bookend the indicator scores. The indicators for which a higher value indicates a more favourable environment have been normalised based on:

$$x = (x - \text{Min}(x)) / (\text{Max}(x) - \text{Min}(x))$$

where Min(x) and Max(x) are, respectively, the lowest and highest values in the 30 cities for any given indicator. The normalised value is then transformed to a 0–100 score to make it directly comparable with other indicators. This in effect means that the city with the highest raw data value will score 100, while the lowest will score 0 for all indicators in the DCI.

For indicators where a high value indicates an unfavourable environment, the normalisation function takes the form of:

$x = (x – Max(x)) / (Min(x) – Max(x))$

where Min(x) and Max(x) are, respectively, the lowest and highest values for any given indicator. The normalised value is then transformed into a positive number on a scale of 0–100 to make it directly comparable with other indicators.

Weights

The weights assigned to each category and indicator can be changed in the DCI model to reflect different assumptions about their relative importance. The model provides two sets of weights:

- Expert-assigned weights
- Uniform weights

The expert-assigned weights are the default setting and are used for the basis of discussion throughout this report. They are based on extensive discussions between Economist Impact, experts and the NEC Advisory Board on the relative value of each indicator and sub indicator. The second weighting option, uniform weights, assumes equal importance of all categories and their respective sub-indicators and evenly distributes weights on that basis.

The first option, the default weighting scheme, uses expert judgement to assign weights to indicators and brings a real-world perspective to an index. This is important if an index is to guide policy actions. The second option—in which all categories are weighted equally—has the advantage of simplicity and does not involve subjective judgement. A disadvantage of this option is that it assumes that all categories are equally significant.

Customisable weightings

The DCI model provides an adjustable weightings functionality that allows users to assign more or less importance to themes and indicators that they deem to be more relevant. Using this functionality can help users better understand performance on specific issues.

DCI expert-based weightings:

Table A1.1: Overall weights

Category	Weights (%)
1. Connectivity	30%
2. Services	28%
3. Culture	21%
4. Sustainability	21%

Table A1.2: Indicator weights

Indicator	Weights (%)
1. Connectivity	
1.1) Digital infrastructure	44.44%
1.2) Quality	22.22%
1.3) Affordability	33.33%
2) Services	
2.1) E-gov services for residents & businesses	19.23%
2.2) Digital finance	15.38%
2.3) Transportation	19.23%
2.4) Healthcare	15.38%
2.5) Education	15.38%
2.6) Retail and hospitality	15.38%
3) Culture	
3.1) Digital inclusion	18.75%
3.2) Government support	31.25%
3.3) Innovation ecosystem	31.25%
3.4) Public attitude and engagement	18.75%

Table A1.2: Indicator weights	
Indicator	Weights (%)
4) Sustainability	
4.1) Efficient resource management	27.78%
4.2) Emissions reduction	27.78%
4.3) Pollution	22.22%
4.4) Circular economy	22.22%

Table A1.3: Sub-indicator weights	
Indicator	Weights (%)
1. Connectivity	
1.1 Digital infrastructure	
1.1.1 Mobile broadband subscriptions	28.89
1.1.2 Fixed broadband subscriptions	22.22
1.1.3 5G readiness	20.00
1.1.4 5G deployment	28.89
1.2 Quality	
1.2.1 Internet upload speed	28.57
1.2.2 Internet download speed	32.14
1.2.3 Mobile broadband latency	17.86
1.2.4 Fixed broadband latency	21.43
1.3 Affordability	
1.3.1 Mobile data affordability	52.17
1.3.2 Fixed broadband affordability	47.83
2. Services	
2.1 E-gov services for residents & businesses	
2.1.1 Mobile digital national ID	32.14
2.1.2 E-gov service portal for residents	35.71
2.1.3 E-gov service portal for businesses	32.14

Table A1.3: Sub-indicator weights

Indicator	Weights (%)
2.2 Digital finance	
2.2.1 Digital platforms for banking and personal finance	34.29
2.2.2 Digital investment and management tools	22.86
2.2.3 E-payments	42.86
2.3 Transportation	
2.3.1 Integrated public transport apps	53.85
2.3.2 Digital identification at airports	46.15
2.4 Healthcare	
2.4.1 Telehealth & telemedicine	31.58
2.4.2 Electronic health records	36.84
2.4.3 Pandemic-related applications	31.58
2.5 Education	
2.5.1 Digital education	100.00
2.6 Retail and hospitality	
2.6.1 E-commerce penetration	56.52
2.6.2 Digital tourist passes	43.48
3. Culture	
3.1 Digital inclusion	
3.1.1 Internet usage	36.84
3.1.2 Gap between male and female access to the internet	31.58
3.1.3 Digital skills	31.58
3.2 Government support	
3.2.1 Data protection law	20.00
3.2.2 Cyber security preparedness	20.00
3.2.3 Cyber security risk awareness	20.00
3.2.4 Availability and usage of open data	20.00
3.2.5 Internet freedom	20.00

Table A1.3: Sub-indicator weights	
Indicator	Weights (%)
3. Culture	
3.3 Innovation ecosystem	
3.3.1 AI readiness of the government	22.41
3.3.2 Blockchain technology strategy	12.07
3.3.3. Tech startup ecosystem	24.14
3.3.4 Intellectual property rights	18.97
3.3.5 Business environment	22.41
3.4 Public attitude and engagement	
3.4.1 Online public comfort	50.00
3.4.2 E-participation on government portals	50.00
4. Sustainability	
4.1 Efficient resource management	
4.1.1 Smart utility management	50.00
4.1.2 Smart urban agriculture	21.05
4.1.3 Smart construction	28.95
4.2 Emissions reduction	
4.2.1 Net-zero emission	32.43
4.2.2 Traffic management	37.84
4.2.3 Support for autonomous vehicles	29.73
4.3 Pollution	
4.3.1 Air pollution	100.00
4.4 Circular economy	
4.4.1 Development of sharing economy	61.90
4.4.2 E-waste management	38.10

Table A1.4: Detailed list of sub-indicators

Indicator	Definition	Unit	Source	Type
Connectivity				
1.1. Digital infrastructure				
1.1.1 Mobile broadband subscriptions	A measure of mobile broadband subscriptions with high-speed access to the internet. Subscriptions that have access to the internet via fixed-line networks are not included.	per 100 inhabitants	International Telecommunication Union (ITU); Economist Intelligence Unit (EIU)	Quantitative
1.1.2 Fixed-line broadband subscriptions	A measure of fixed broadband subscriptions with high-speed access to the internet, including both residential subscriptions and subscriptions for organisations. Subscriptions that have access to the internet via mobile-cellular networks are not included.	per 100 inhabitants	ITU; EIU	Quantitative
1.1.3 5G readiness	An assessment of national or local strategy or initiatives to promote 5G. Cities receive a higher score if the policy or strategy recognises multiple use cases of 5G such as fixed wireless access (FWA), enhanced mobile broadband (eMBB), massive machine-type communications (mMTC), the Internet of Things (IoT) and ultra-reliable low-latency communications (URLLC).	Score (0-3)	Qualitative scoring by Economist Impact analysts	Qualitative
1.1.4 5G deployment	An assessment of the stage of 5G deployment, varying from pilots and testing to deployment for commercial use.	Score (0-2)	Qualitative scoring by Economist Impact analysts	Qualitative
1.2. Quality				
1.2.1 Internet upload speed	A measure of the speed at which a user can send data from their mobile device to the internet.	Mbps	Ookla	Quantitative
1.2.2 Internet download speed	A measure of the speed at which a user can pull data from a server on the internet to their mobile device.	Mbps	Ookla	Quantitative
1.2.3 Mobile broadband latency	A measure of the time it takes for data or a request to go from the source to the destination when using mobile broadband.	ms	Ookla	Quantitative
1.2.4 Fixed broadband latency	A measure of the time it takes for data or a request to go from the source to the destination when using fixed broadband.	ms	Ookla	Quantitative
1.3. Affordability				
1.3.1 Mobile data affordability	A measure of the cost of 1 GB of mobile data as a proportion of individual personal disposable income.	%	Cable, EIU	Quantitative
1.3.2 Fixed broadband affordability	A measure of the cost of fixed-line broadband subscriptions as a proportion of individual personal disposable income.	%	EIU	Quantitative

Table A1.4: Detailed list of sub-indicators

Indicator	Definition	Unit	Source	Type
Services				
2.1. E-gov services for residents & businesses				
2.1.1 Mobile digital national ID	An assessment of the availability of a digital national ID that can be accessed and displayed on a mobile device in the form of a scannable code or digital replica of the physical ID card, for the purpose of online and offline verification.	Score (0-1)	Qualitative scoring by Economist Impact analysts	Qualitative
2.1.2 E-gov service portal for residents	An assessment of whether a country provides its residents with information about laws and policies; platforms offering help links, tutorials on online tools and online skills development; and functionalities that allow for the use of e-services like application for visas, ID cards and social protection.	Score (0-1)	United Nations Division for Public Institutions and Digital Government	Quantitative
2.1.3 E-gov service portal for businesses	An assessment of official government portals for business functions such as digital or remote business registration, payment of duties and grant applications.	Score (0-2)	Qualitative scoring by Economist Impact analysts	Qualitative
2.2. Digital finance				
2.2.1 Digital platforms for banking and personal finance	A measure of adoption of and satisfaction with apps or digital platforms that replace traditional functions of banking such as deposit, withdrawal, loans and monitoring spending.	%	Economist Impact survey	Survey
2.2.2 Digital investment management tools	A measure of adoption of and satisfaction with apps or digital platforms to access financial markets and manage personal investment portfolios of equities, bonds, mutual funds or other financial instruments.	%	Economist Impact survey	Survey
2.2.3 E-payments	A measure of the value of e-payments made as a share of total retail sales. E-payment platforms considered include: • Traditional card transactions such as Visa/ Mastercard • Mobile payment apps that integrate payments from traditional card issuers such as Apple Pay • Mobile payment wallets such as PayPal/Square/ Alipay	%	WorldPay	Quantitative

Table A1.4: Detailed list of sub-indicators

Indicator	Definition	Unit	Source	Type
Services				
2.3. Transportation				
2.3.1 Integrated public transport apps	An assessment of whether residents have access to integrated transport apps with journey planning and ticketing functionality for the public transit system, provided by the government or by the private sector in collaboration with the public sector.	Score (0-3)	Qualitative scoring by Economist Impact analysts	Qualitative
2.3.2 Digital identification at airports	An assessment of whether the airport supports biometric identification at immigration control and at boarding gates to enable a completely automated process.	Score (0-2)	Qualitative scoring by Economist Impact analysts	Qualitative
2.4. Healthcare				
2.4.1 Telehealth & telemedicine	An assessment of the adoption of telehealth or telemedicine services (public or private) and their provision by health authorities, with the service being provided by professional medical staff.	Score (0-2)	Economist Impact survey; qualitative scoring by Economist Impact analysts	Survey and qualitative
2.4.2 Electronic health records	An assessment of the use of electronic health record (EHR) systems in the healthcare sector.	Score (0-2)	Qualitative scoring by Economist Impact analysts	Qualitative
2.4.3 Pandemic-related applications	An assessment of the presence of apps, mobile functionalities (iOS, Google wallet pass) or physical devices and tokens to aid in the verification of vaccination or contact tracing.	Score (0-2)	Qualitative scoring by Economist Impact analysts	Qualitative
2.5. Education				
2.5.1 Digital education	An assessment of plans, policies and initiatives adopted by the government to promote digital education. Digital education is the use of digital technologies and tools in teaching and learning and is also known as technology-enhanced learning (TEL) or digital learning.	Score (0-2)	Qualitative scoring by Economist Impact analysts	Qualitative
2.6. Retail and hospitality				
2.6.1 E-commerce penetration	A measure of e-commerce sales as a share of total retail sales. The measure includes purchases on any e-commerce shopping platforms, and excludes hybrid in-store shopping experiences.	%	WorldPay	Quantitative
2.6.2 Digital tourist passes	An assessment of the availability of official digital tourist passes for access to attractions or transportation in a city. Any generic ride-sharing and hotel-booking apps that residents use day to day are excluded.	Score (0-1)	Qualitative scoring by Economist Impact analysts	Qualitative

Table A1.4: Detailed list of sub-indicators

Indicator	Definition	Unit	Source	Type
Culture				
3.1. Digital inclusion				
3.1.1 Internet usage	A measure of individuals that use the internet via a computer, mobile phone, personal digital assistant, games machine, digital TV, etc.	%	EIU; ITU; qualitative scoring by Economist Impact analysts	Quantitative and qualitative
3.1.2 Gap between female and male access to the internet	A measure of the difference between the number of women and men online.	%	ITU; Gallup	Quantitative
3.1.3 Digital skills	A self-assessment of digital skills by city residents, as captured in the Economist Impact survey. Digital skills can be defined as the ability to find, evaluate, use, share and create content using digital devices, such as computers and smartphones.	Score (0-100)	Economist Impact survey	Survey
3.2. Government support				
3.2.1 Data protection law	An assessment of whether the country/city has legislation on data protection, which is a set of privacy laws, policies and procedures that aim to minimise personal data theft.	Score (0-2)	Qualitative scoring by Economist Impact analysts	Qualitative
3.2.2 Cyber security preparedness	An assessment of the level of cyber security preparedness in the country. Cyber security is the application of technologies, processes and controls to protect systems, networks, programs, devices and data from cyber attacks.	Score (0-4)	EIU risk briefing	Quantitative
3.2.3 Cyber security risk awareness	An assessment of whether there are initiatives undertaken by citizen groups, non-governmental organisations or governments to increase cyber security risk awareness. Cyber security has become important due to the ever-increasing cyber risk landscape, prompting the need to improve citizen awareness for self-protection.	Score (0-4)	Qualitative scoring by Economist Impact analysts	Qualitative
3.2.4 Open data access and use	An assessment of how governments publish and use open data for accountability, innovation and social impact.	Score (0-100)	Open Data Barometer	Quantitative
3.2.5 Internet freedom	An assessment of freedom of the internet, taking into account obstacles to access to the internet, limits on content and violation of user rights.	Score (0-100)	Freedom House	Quantitative

Table A1.4: Detailed list of sub-indicators

Indicator	Definition	Unit	Source	Type
Culture				
3.3. Innovation ecosystem				
3.3.1 AI readiness of government	An assessment of how ready a given government is to implement AI in the delivery of public services to their citizens.	Score (0-100)	Oxford Insights	Quantitative
3.3.2 Blockchain technology strategy	An assessment of whether there is a well-defined blockchain technology strategy in the country/city. A blockchain-based digital government strategy can protect data, streamline processes and reduce fraud, while simultaneously increasing trust and accountability.	Score (0-3)	Qualitative scoring by Economist Impact analysts	Qualitative
3.3.3 Tech startup ecosystem	An assessment of the quality and quantity of startups in a city, taking into account different metrics such as number of startups, number of co-working spaces and number of accelerators, to establish the activity level of the startup ecosystem.	Score	Startup Blink	Quantitative
3.3.4 Intellectual property rights	An assessment of the level of intellectual property protection which is critical to fostering digital innovation. Without protection of ideas, businesses and individuals would not be able to reap the full benefits of their inventions.	Score (1-5)	EIU	Quantitative
3.3.5 Business environment	An assessment of the degree to which businesses can invest and operate in a free, open and competitive market, with policies and legal assurances that their rights and assets would be secure.	Score (0-100)	EIU	Quantitative
3.4. Public attitude and engagement				
3.4.1 Online public comfort	An assessment of residents' comfort in sharing their financial and personal details on various digital platforms, such as e-commerce websites, e-payment apps, e-government platforms, health and wellness apps, tracking apps (navigation, location), food delivery apps and ride-sharing apps, and the likelihood of cyber attacks and level of preparedness.	Score (0-100)	Economist Impact survey; EIU risk briefing	Survey and quantitative
3.4.2 E-participation on government portals	A measure of residents' awareness of and satisfaction with interactive e-platforms provided by the government.	%	Economist Impact survey	Survey

Table A1.4: Detailed list of sub-indicators

Indicator	Definition	Unit	Source	Type
Sustainability				
4.1. Efficient resource management				
4.1.1 Smart utility management	An assessment of cities' utilisation of technologies in managing water, electricity and waste efficiently. Digital technologies like the IoT and AI can be used to improve utility management and conserve precious resources.	Score (0-4)	Qualitative scoring by Economist Impact analysts	Qualitative
4.1.2 Smart urban agriculture	An assessment of whether the city has employed digital technologies in its agricultural activities. Smart urban agriculture refers to the use of digital technologies in farming activities within the city such that processes are smarter, sustainable and more efficient.	Score (0-1)	Qualitative scoring by Economist Impact analysts	Qualitative
4.1.3 Smart construction	An assessment of whether the city has employed digital technologies in its construction activities. Smart construction refers to the use of digital technologies in construction activities in the city to make construction smarter and more efficient.	Score (0-1)	Qualitative scoring by Economist Impact analysts	Qualitative
4.2. Emissions reduction				
4.2.1 Net-zero emissions	An assessment of whether cities' have targets in place to achieve net-zero emissions in the foreseeable future and whether there are actions being taken to meet those targets in the form of policies, reforms or laws. "Net zero" is reached when greenhouse gases going into the atmosphere are balanced by those being removed. As digital technologies also contribute to greenhouse gas emissions, it is necessary for governments to balance their economic growth against emissions.	Score (0-2)	Qualitative scoring by Economist Impact analysts	Qualitative
4.2.2 Traffic management	An assessment of whether cities have employed technologies such as autonomous traffic lights that adapt to traffic conditions or that can be remotely controlled in order to manage congestion. The use of these technologies is assessed against the severity of congestion levels to ascertain whether congestion has been adequately addressed.	Score (0-5)	TomTom Traffic Index; qualitative scoring by Economist Impact analysts	Quantitative and qualitative
4.2.3 Support for autonomous vehicles	An assessment of government support for autonomous vehicle development and operation through the evaluation of policies. Autonomous vehicles are capable of reacting to their environment, improving fuel consumption and reducing congestion.	Score (0-2)	Qualitative scoring by Economist Impact analysts	Qualitative

Table A1.4: Detailed list of sub-indicators

Indicator	Definition	Unit	Source	Type
Sustainability				
4.3. Pollution				
4.3.1 Air pollution	An assessment of whether cities are installing air sensors on multi-functional/smart poles or street lights for granular air pollution data collection. The use of these technologies is assessed against the severity of the city's pollution levels to highlight the need for smarter tools to combat particle pollution.	Score (0-6)	IQAir; qualitative scoring by Economist Impact analysts	Quantitative and qualitative
4.4. Circular economy				
4.4.1 Development of sharing economy	An assessment of government support for sharing-economy development through plans, policies, strategies or frameworks. The sharing economy is an economic model in which goods and resources are shared by individuals and groups, usually through an online platform that acts as a virtual meeting place for suppliers and consumers. This leads to more optimal use of existing resources and reduces the demand for the production of new goods.	Score (0-2)	Qualitative scoring by Economist Impact analysts	Qualitative
4.4.2 E-waste management	An assessment of whether governments have e-waste management policies/laws which target proper disposal or mandate re-use of e-waste, among other objectives. E-waste refers to discarded electrical items or electronic equipment and their parts without the intention of re-use.	Score (0-1)	Qualitative scoring by Economist Impact analysts	Qualitative

Appendix 2: Digital Cities Index 2022 results

Table A2.1: Scores and ranks based on Economist Impact weights

Overall Score		
1	Copenhagen	81.5
2	Amsterdam	74.6
3	Beijing	73.7
=4	London	73.6
=4	Seoul	73.6
6	New York	73.3
7	Sydney	72.6
8	Singapore	71.4
9	Washington DC	71.2
10	Paris	70.2
=11	Toronto	70.1
=11	Zurich	70.1
13	Barcelona	69.7
14	Frankfurt	69.1
15	Dallas	68.7

Overall Score		
16	Berlin	68.2
17	Hong Kong	68.0
18	Dubai	63.8
19	Madrid	63.2
20	Tokyo	63.0
21	Rome	61.2
22	Auckland	60.1
23	Kuala Lumpur	58.2
24	São Paulo	50.7
25	Bangkok	49.1
26	Buenos Aires	45.1
27	Jakarta	43.5
28	Mexico City	42.6
29	New Delhi	40.3
30	Manila	39.1

Table A2.2: Scores and ranks based on equal weights

Overall Score		
1	Copenhagen	80.3
2	Seoul	74.3
3	Beijing	74.0
4	Amsterdam	72.6
5	Singapore	70.5
6	New York	70.4
7	London	70.3
8	Zurich	69.7
9	Sydney	69.4
10	Toronto	69.1
11	Washington DC	68.7
12	Barcelona	68.6
13	Paris	67.8
14	Frankfurt	66.9
15	Berlin	66.4

Overall Score		
16	Hong Kong	66.0
17	Dallas	65.2
18	Dubai	64.0
19	Madrid	61.0
20	Tokyo	60.1
21	Auckland	59.8
22	Rome	59.0
23	Kuala Lumpur	58.3
24	São Paulo	51.2
25	Bangkok	50.5
26	Buenos Aires	44.7
27	Jakarta	43.4
28	Mexico City	42.0
29	New Delhi	41.6
30	Manila	40.0

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