Reducing service gaps: how digitalization can improve the use of infrastructure

Infrastructure in Latin America's Development

ideal

CAF DEVELOPMENT BANK OF LATIN AMERICA

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Foreword

Infrastructure is a crucial factor for sustainable development and contributes to it on several levels. Infrastructure fosters economic growth. It also improves firm competitiveness, promotes integration among national and regional spheres, and diversifies productive systems. Infrastructure also supports social inclusion and environmental protection, which improve the quality of life of current and future generations.

For years, sector-specific departments and research units within international organizations, academia, consultancy firms, and other agents in the public and private sectors have conducted research in this area. Topics have evolved, from an analysis of the requirements for investment in infrastructure to attain development goals to the need for efficiency to execute and target investment and, more recently, to the adoption of a more comprehensive approach that takes into consideration the services provided by this infrastructure.

At the same time, a whole set of trends has emerged that affects and interacts with various elements of infrastructure. Without meaning to draw up an exhaustive list, one major trend over the past two decades has involved technological progress triggered by digitalization. These changes have supplemented other trends addressed in this report, including the adoption of an environmental sustainability agenda, processes to decentralize the production of certain infrastructure services, and urban population growth. More recently, economies as well as specific sectors have been shaken by the COVID-19 pandemic and have had to adapt to a new reality ushered in by the spread of the virus.

This edition of the IDEAL report focuses on the services provided by infrastructure, with digitalization as a crosscutting topic. The report prioritizes electricity and urban passenger transportation, the two sectors that are most exposed to this form of technological progress. These sectors pose multiple and diverse challenges, in terms of things like innovation and safe provision, price-setting, and subsidy policies.

This report attempts to approximate service gaps in infrastructure with a results-oriented approach. It identifies several dimensions that would require intervention based on the assets that are currently available: access to a given service, cost of provision—which affects affordability, together with whatever policy the authorities select—and quality. The report also examines recent digital developments in priority sectors, including the growth of smart grids in electricity and, in the case of passenger transportation, the development of apps to access information and plan trips, as well as new payment options.

The impact of COVID-19 has accelerated the digitalization of infrastructure services, so it is interesting to review adaptation in different sectors to address different challenges. Finally, the report features a structured discussion of different forms of intervention, in terms of regulation (including, for instance, redesigning markets and price schemes), public policies (such as social compensation policies), and the need for investment in smart infrastructure to address both service gaps and the potential impact of technological progress.

With its latest IDEAL report, the CAF makes a contribution to development in Latin America and the Caribbean by suggesting a results-based approach focused on intervention and regulation in infrastructure services. This approach enables a broad understanding of the public policies needed to improve productivity and wellbeing in different countries and communities.

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Abbreviations

AMI	Advanced Metering Infrastructure
AMR	Automated meter readings
B2B	Business-to-business
B2C	Business-to-consumers
BRT	Bus rapid transit
DDI	Digital Divide Index
DMA	District metered areas
DMO	Distribution market operator
DSO	Distribution system operator
ECAF	CAF Survey (*Encuesta CAF*)
ECLAC	Economic Commission for Latin America and the Caribbean
EPA	Environmental Protection Agency
EU	European Union
EV	Electric Vehicle
GDP	Gross Domestic Prodcut
GIS	Geographic information system
GNI	Gross National Income
GTFS	General transit feed specification
ICTs	Information and Communications Technologies
IDED	Digital Ecosystem Development Index (*Índice de desarrollo del ecosistema digital*)
IoT	Internet of Things
ISP	Internet service provider
LAC	Latin America and Caribbean
LAN	Local area network
LoRa	Long Range
M2M	Machine-to-machine communication
MaaS	Mobility as a service
MoD	Mobility on demand
NCRE	Non-conventional renewable energy
O-D	Origin-destination survey
OECD	Organisation for Economic Cooperation and Development
OUM	Observatory of Urban Mobility
PPAs	Power Purchase Agreements

RPA	Robotic process automation
RPI	Retail Pricing Index
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SDGs	Sustainable Development Goals
SITP	Integrated System of Public Transport (*Sistema Integrado de Transporte Público – Colombia*)
SUBE	Unidied System of Electronic Ticket (*Sistema Único de Boleto Electrónico – Argentina*)
V2G	Vehicle-to-grid
WEF	World Economic Forum

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Service gaps in infrastructure

Evolution of the concept of infrastructure gaps

Traditional approach to infrastructure gaps

Over the past 15 years, there has been a lot of talk about infrastructure gaps as a concept, based on investment needed globally or in a given country or region. In this context, two approaches emerged to estimate the need for investment in infrastructure: vertical gaps and horizontal gaps, which differ from each other in their reference values. Vertical gaps use factors that are specific to the country or region in question and identify the differences that emerge between domestic demand and supply in terms of infrastructure. This approach assesses whether the existing infrastructure stock can meet growing demand. Horizontal gaps use external factors like, for example, the availability of certain infrastructure compared to another country or relative to a specific goal we want to achieve (Perrotti and Sánchez, 2011, pp. 31–34).

In this context, many estimates of investment needs have been produced for Latin America and the Caribbean (LAC). Fay and Morrison (2007) calculated that investment worth at least 3% of GDP was needed to attain universal coverage in essential services, maintain existing infrastructure, and achieve moderate GDP growth, of 3% per year, for 10 years. The required investment increases to 4–6% of GDP if we want LAC to reach the level of developed countries like South Korea over a 20-year period. Dobbs *et al.* (2013) and the Global

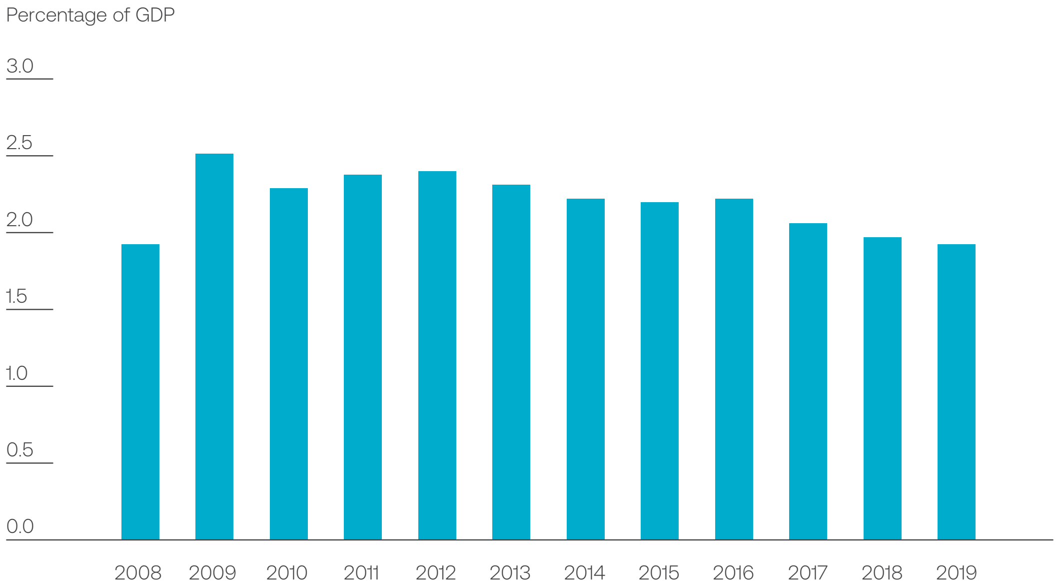
Infrastructure Hub (GI Hub, 2017) estimated that an investment in infrastructure of 3.4–3.7 trillion dollars per year was required to sustain expected growth over the next few decades. Additionally, according to GI Hub, these amounts are 19% larger than global investment trends for the previous years, and the difference is as high as 47% for the Americas.

In 2011, at the request of the Ibero-American General Secretariat (SEGIB), CAF drafted the strategic report *Infrastructure in the Comprehensive Development of Latin America* (known as IDEAL), which was presented during the 21st Ibero-American Summit of Heads of State and Government held in Asunción, Paraguay. The report contained an analysis of infrastructure in the region and put forward a strategic agenda to develop it. In particular, the report noted the following:

> "The review of these studies allows an estimate that investment in infrastructure to cover deficits and accompany expected growth, assuming a 5% annual growth of GDP (which reflects the aspiration of sustained growth), would be in the order of 4% to 5% of regional GDP. These figures are equivalent to between USD 200–250 billion per year" (CAF, 2011, p. 80).

In its 2012 report, the World Economic Forum (WEF) started to warn of the need to set priorities and to build works of infrastructure both effectively and efficiently. The 2013 IDEAL report adjusted the infrastructure gap approach to consider both the investment required and its productivity in efforts to achieve economic growth (CAF, 2013). The section titled "Hacer más con menos" ("Doing more with less") said that implementing best practice in terms of planning, project selection and design, the execution of works, demand management, and asset maintenance would enable resource optimization and a reduction in investment needs. At the same time, De Jong, Annema, and Van Wee (2013) showed that the organization of infrastructure planning and supply might have implications on three levels: the cost and execution period of works, and the quality of infrastructure (including its performance over the course of its life cycle). Dobbs *et al.* (2013) quantified these effects. Better investment might enable savings worth 1 trillion dollars per year due to improvements in infrastructure productivity. These improvements would

Figure 1
Public investment in economic infrastructure in LAC (as a percentage of GDP)
Source: Infralatam (2021).



Note: Simple average of investment by country (percentage of GDP).

stem from a better selection of projects and an optimized use of infrastructure portfolios (20% of total savings), efficiencies in the implementation of investment in infrastructure (in terms of both funds and time) (40%), and adequate use of existing assets (40%).

More recently, Izquierdo, Pessino, and Vuletin (2018) said that, given the prospects for the coming years, with fewer funds available for infrastructure, countries will need to find ways to provide these services more efficiently. The authors again stressed how important it is to choose appropriate projects and ensure greater efficiency by reducing cost overruns, preventing delays in construction, and making the most of existing assets. Finally, along similar lines, Rozenberg and Fay (2019) sought to change the focus of the debate, from "spending more" to "spending better." Beyond the efforts made to identify investment needs through gap analyses using various approaches, insufficient infrastructure development persists in LAC. Examining public investment in economic infrastructure (energy, transportation, water, and telecommunications) allows us to conclude that no significant changes have been made at a regional level over the past 10 years. Even if we add private investment (not shown on Figure 1), the region's levels have been below those suggested by various researchers. As a consequence of insufficient investment, LAC continues to lack infrastructure in line with its income level (Cerra *et al.*, 2016).

Comparative analysis with other regions shows LAC's growing lag (GI Hub, 2017). According to Cavallo *et al.* (2016), the region lacks the instruments required to funnel national savings into infrastructure. This means that further changes are needed—beyond investment promotion—to support development in these fields. For example, the report noted the need to adjust the regulatory framework, in order to remove the bottlenecks that prevent a more effective identification of needs and to enable better planning of new investment and better management of existing assets.

The previous IDEAL report (2017–2018) addressed this debate:

> "In recent years, infrastructure analysis has changed. The emphasis on required investment (to close the infrastructure gap) and potential sources of funding gradually changed to adopt a broader scope in line with sustainable development, which implied a review of traditional criteria" (Barbero, 2019, p. 12).

The report therefore stresses the limitations of estimating aggregate investment needs, which emerge by adding missing investment rather than by setting priorities. The report further says that "the concept of a gap and the use of general indicators including an investment target of 5% of GDP are not really useful or relevant to decide on a course of action." LAC must clearly

> "invest more in infrastructure, but it needs to focus on two levels: (i) ensuring adequate investment based on the goals that have been set, and (ii) investing in infrastructure and services and using them appropriately, in transparent ways, with state-of-the-art construction and operating methods and with mechanisms that ensure quality control and efficiency" (p. 96).

Traditional definitions of the infrastructure gap adopt a purely money-based approach, based on the trillions of dollars needed to attain a given target. These targets generally seek to meet people's needs in terms of coverage for a given infrastructure service. They tend to relegate other relevant aspects of service provision—like cost and quality—and are based on economic growth estimates that do not always materialize, like 3% growth targets. Finally, these definitions often focus on investment, which is one of several instruments that can potentially reduce service gaps.

The approach put forward in this IDEAL report seeks to expand the gap analysis starting with the infrastructure services received by users (in terms of coverage, quality, and efficiency), to go on to identify deficits and address them through different interventions. Investment is one of these interventions, but stronger institutions, regulation, and public policy can also help. This initiative joins recent efforts to pay more attention to infrastructure services (Fay, Andrés, Fox, Narloch, Straub, and Slawson, 2017, and, more recently, IDB, 2020).

Service gaps: A results-based approach

Background

Research on the specifications that are considered relevant for service provision in a given sector has already delivered various reports and other documents. Some of them propose applying a results-based approach to service gap analysis, with a multidimensional perspective.

For example, in the electricity sector, the Sustainable Development Goals (SDGs) include access to an affordable, reliable, sustainable, and modern power supply (see United Nations, 2015, and IEA, 2017, p. 146). The World Energy Council's Energy Trilemma identifies as relevant aspects the need to guarantee safe, affordable, and environmentally sustainable energy. Neelawela, Selvanhathan, and Wagner (2019) start out from this premise to propose a *global electricity security index*. This index shows how system coverage and stability, prices, profitability for electricity operators, and governance quality all affect the affordability and reliability of the power supply.

Along similar lines, the SDGs stress the need for safe, affordable, accessible, and sustainable transportation systems and the need to improve road safety by expanding public transportation, paying special attention to vulnerable groups (see United Nations, 2015). The New Urban Agenda (UN-Habitat, 2011) identifies three pillars to conceptualize service gaps in urban passenger transportation systems: a social pillar (based on unequal access to mobility for different groups of users and different geographical locations), an environmental pillar (based on the unequal impact of transportation on the environment and on health within a given city), and an economic pillar (based on spatial differences and on differences in the social distribution of the benefits of efficient transportation). In this context, the CAF's Urban Mobility Strategy for people and goods reflects a comprehensive vision with specific criteria for safe, well-integrated, inclusive, and clean interventions (and also for productive interventions, in the case of goods). For instance, in urban passenger transportation systems, different performance levels have been compared both for public transportation provision and for private and individual provision, based on indicators for supply, demand, service quality, and sustainability (see, for example, Scorcia, 2018, and Rivas, Suárez Alemán, and Serebrisky, 2019a).

These improvements are also apparent in two sectors that have not been prioritized in this report: logistics, and water and sanitation. In urban logistics for goods, a service gap analysis requires an integral, results-based approach that goes beyond local infrastructure needs. Thinking about logistics chains that are grouped by product characteristics enables more adequate estimates of these gaps, although it also makes broader comparisons more difficult.[1] According to SPIM-Taryet (2019), the lack of consensus about logistics performance indicators stems from difficulties to obtain reliable and systematic primary data (because there are multiple factors involved, because of the private, unregulated nature of this activity, and because there are multiple agents and the authorities pay little attention to urban logistics) and to link urban logistics areas to administrative areas.[2] Logistics services go beyond freight transportation and storage, and the considerations of urban logistics to identify service gaps at the level of logistics chains apply to these services. Various indices have proliferated in this sector that look at the availability of infrastructure along with other factors,[3] such as the components of logistics chains (timeliness, cost, and freight traceability) and regulatory and institutional components (OECD, CAF, and ECLAC, 2013).

In the case of water and sanitation systems, the Sustainable Development Goals stress

1 World Bank (2009) identified more than 150 logistics chains in urban environments. In particular, the logistics chain of electronic commerce has become more relevant in the context of the COVID-19 pandemic.

2 The Sustainable and Safe Urban Logistics (LOGUS, by its Spanish acronym) agenda proposed a set of indicators on three aspects: governance, performance, and impact. The aim was to approximate dimensions for efficiency, competitiveness, environmental impact, and congestion to social aspects in cities, to then identify strategic courses of action in logistics infrastructure, institutions, planning and monitoring, regulation and auditing, and policies concerning collaboration and innovation (SPIM-Taryet, 2019).

3 The most popular indicators are the CAF's Indilog, the World Bank's Logistics Performance Index, and the World Economic Forum's Trade Facilitation Index as well as the pillars of its Global Competitiveness Index.

universal access to drinking water and sanitation at affordable prices and with adequate quality standards (reducing pollution and untreated wastewater). These goals are held in the CAF's *Water Strategy* (2019), which, for instance, notes the importance of access to these services and of compliance with international quality standards so water is suitable and safe for human consumption, as well as the need for efficient use, ecosystem preservation, and a reduction in pollution levels. CAF (2019) also says that "it is necessary to move from a focus on infrastructure to a focus on service" (p. 32).

Digitalization in various economic sectors is the crosscutting theme of this report. The dynamics of information and communications technologies (ICTs) have affected the economy as a whole, particularly infrastructure sectors. These technologies alter the various sectors' operating and business models, trigger an increase in competition, and change users' very idea of services. The CAF's Digital Ecosystem Observatory monitors progress in this field with an integrated approach. That is, it considers both the quantitative and qualitative aspects of digital services (coverage, quality, and level of competence in terms of both institutions and regulations, among others).

In a nutshell, this service gap approach seeks to ensure homogeneity between various sectoral approaches, particularly those put together by the World Energy Council, UN-Habitat's pillars, and the United Nations' SDGs. It also assesses results in terms of service performance. And it enables the use of various tools to reduce the gaps that are identified, by putting forward alternative measures that go beyond investment—and to some extent complement it—and considering the option of making changes or adapting regulations or public policy.

Service gap dimensions: Access, cost, and quality

Starting off with the premise that infrastructure services aim to meet the needs of users (whether end users or intermediate users within value chains), deficits—or gaps—in the provision of these services can emerge in different ways, each of them associated with a different dissatisfaction level.

In the case of electricity, one of the sectors that are prioritized in this report, the literature and sectoral practice both allow us to identify aspects that are relevant for service provision. First, access to this service requires, by definition, connection to a power grid. The goal of access may be part of a national policy (by, for example, being included in the sector regulations) or reflect global goals. For example, the SDGs state that "universal access to energy" is essential and set a goal that is easy to interpret in terms of access (SDG 7), although it is not necessarily easy to attain.

Second, the cost of provision reflects the sector's efficiency to supply electricity, considering the various stages in production (power generation, transmission, distribution, and commercialization). From the system's point of view, cost is determined by various factors (for instance, generation technology, seasonality of demand, system efficiency, and leaks in transmission and distribution, among others). The price paid by end users will further depend on other aspects, including fiscal, social, and distributive policies (taxes and direct or cross subsidies). Price will determine service affordability, a more qualitative dimension concerning in particular what one might consider to be a moderate price.

Third, the quality dimension seeks to identify the various aspects that enable good service. A quality power supply gives customers uninterrupted service that enables them to meet their various needs (as end consumers or as intermediate users in a productive or commercial activity). From the perspective of demand, the quality of electricity services is usually determined by indicators that measure interruption frequency and intensity.

In the case of urban transportation, the other sector that is prioritized in this report, this classification contemplates some specific considerations. First—starting with the premise that urban mobility is decisive for cities' economic productivity as well as for citizens' quality of life and their access to basic healthcare and education services—access is not a binary variable in transportation services, as it was in the electricity sector. Instead, it involves on the one hand availability (whether this service exists) and on the other hand people's ability to access different opportunities in terms of work, education, entertainment, green spaces, and healthcare. This dimension is usually shown by indicators that reflect how easy or difficult it is to use transportation services. For example, the modes of transport available, the distance or walking time required to reach a public mode of transport, or the opportunities available—in terms of various individual modes of transport or of a combination of several modes—within a given period of time from a given starting point. In particular, collective public transportation systems (in their various formats, including bus rapid transit [BRT], feeders, systems that are organized in routes, and others) become more relevant given their capillary distribution to meet people's needs.

Second, the cost dimension can be approximated using indicators that reflect the cost for the whole (public transportation) system of carrying passengers using different modes of transport—whether public or private—and the cost for users of moving using different modes of transport. The first component of this dimension gives an overall idea of the cost of an urban mobility policy. The second component, applied to public transportation, targets service affordability, determined by the sectoral policy in place regarding service provision and the financial burden it puts on end users.[4]

Third, service quality takes into consideration a trip's non-monetary value for the user. Transportation in itself does not have economic value for the consumer, who uses this service to access other activities. This means that the quality perceived by the user is higher when trips are shorter (including shorter waits and fewer vehicle changes) and when service is reliable (in terms of frequency and predictability), comfortable (for instance, when units are clean and not crowded), and safe (in terms of both traffic and personal safety). Adopting a gender approach is particularly important in this sector, especially concerning personal safety.

These service gap dimensions also apply to other sectors. In the case of logistics—whether on a national or international scale or within urban areas—access focuses on the ability to use services, which makes logistics corridors particularly relevant whether at the national or regional level. The second dimension focuses on products' logistics costs. Finally, the quality dimension includes service reliability—for instance, delivery reliability for certain types of products and delivery speed for others—and the option of accessing customized services that reflect users' needs, among other factors. In the case of water and sanitation, dimensions can be analyzed in terms of the availability of drinking water nearby and the availability of safe wastewater management systems (access); the cost of service provision—differentiating operating costs (maintenance, restoration, repairs, or renovations) and capital costs—relative to the price paid by users (which, as in other sectors, is the result of a sectoral policy decision concerning the service that is offered and the burden that is put on end users); and water quality or pollution, service continuity, and water pressure (service quality). Table 1 shows a (non-exhaustive) summary of the elements that determine gap dimensions in the sectors that are prioritized in this report, and also in the other sectors mentioned in it.

The three dimensions selected to approximate service gaps may be interrelated, and one might expect that trade-offs will be required between them. For example, the SDGs mention ensuring "access to affordable, reliable, sustainable, and modern energy for all" by 2030. Providing a good-quality or modern service is of course costly, and such a service may be accessible for only a certain portion of the user universe. Sector policies are used to balance this (for instance, by subsidizing access for a given percentage of the population). In the electricity sector, a reduction in non-technical leaks in the distribution of energy will reduce the system's total costs, but it might negatively affect access unless compensation measures are adopted.

It may be the case that considering infrastructure sectors using a crosscutting conceptual framework focused on these three dimensions excludes certain other dimensions that would be relevant for analyses focused on specific sectors. However, describing service gaps in terms of these three dimensions is useful to assess the use and performance of the services that are provided. It also allows

4 This service's financial sustainability is the result of a local policy decision to balance efficiency, fairness, the specific situation in terms of public finance, and the externalities that are intended to be overcome through public transportation (see the conceptual discussion in Estupiñán, Gómez Lobo, Muñoz Raskin, and Serebrisky, 2007). Once these forces are considered, services can be self-sustainable (as in Medellín and Cali in 2014), rely on mixed funding (as in most cases in Latin America and the Caribbean), or be free of charge (as public transportation in Luxembourg has been since 2020). This becomes particularly relevant given the issues triggered by the COVID-19 pandemic. One initial challenge involves carrying people in a context of restricted mobility (considering the applicable permits and bans) and social distancing. A second challenge involves sources of funding for this service, in a weakened public finance context (see the discussion in Chapter 3).

Table 1
Elements that determine service gap dimensions in selected sectors
Source: Compiled by the authors.

Sector	Access	Cost	Quality
Electricity	Power grid coverage	Average/Marginal cost of service provision, prices (affordability)	System reliability (duration and number of interruptions in distribution)
Urban transportation	Service coverage	Average cost of service provision, fares (affordability)	Travel time (total, wait, vehicle changes), frequency, comfort, reliability, safety
National and international logistics	Access to logistics services	Cost for the user	Service reliability and customization
Urban logistics	Access to urban logistics services	Cost for the user	Average time/speed in freight corridors
Water and sanitation	Availability of drinking water (and safely managed water) nearby and safe wastewater management systems	Average cost of service provision, prices (affordability)	Continuity, pollution, pressure
ICTs	Connection to the network (usually measured in terms of coverage) and availability of individual or nearby common equipment	Average/Marginal cost of service provision, prices (affordability)	Connection speed, network availability, interruptions, latency

us to identify deficiencies in provision and opportunities for improvement, in a sufficiently flexible way to include aspects that only affect specific sectors. Service gaps should therefore not be defined as a need for investment in infrastructure, but rather as an improvement in service provision in relevant dimensions, which could be brought about by investment, public policy, or adaptations to technological or regulatory changes. Of course, investment remains the means to support development scenarios or to get closer to development objectives within 20–30 years, but it is only one of several available instruments to remove differences in service provision or to adapt to changing scenarios (for example, involving technology).

The selected standards for comparison enable different ways to approximate service gaps, whether in absolute or relative terms. For example, if a standard, rule, plan, or goal sets a 100% coverage target, an absolute gap will be the difference between this target and actual coverage. On the other hand, comparison could be relative to the situation of an appropriately selected group or category of users—which would enable greater flexibility and richer comparisons—within a given country, at a regional or international level, depending on income or gender (which is relevant for urban passenger transportation), the extent of technology adoption (as might be the case with ICTs in the electricity sector), and other variables that might be of interest. This kind of comparison will be important to debate the emergence of new technologies or policy measures, which may have a differentiated impact on certain users.

Finally, the fact that this approach recognizes that service gaps may evolve is one of its advantages. User needs may change in the wake of changes (technological or of any other type) within each sector. If they do, the way services are provided and the relevant dimensions that need to be taken into consideration will also need to be adapted.

Describing service gaps in three dimensions (access, cost, and quality) is useful to identify deficiencies in provision and opportunities for improvement.

Service gap diagnosis for LAC

Using for reference the definitions adopted in the previous section, we will now proceed to present and assess indicators that enable a diagnosis of service gaps in the various countries in Latin America and the Caribbean, focusing on electricity and urban passenger transportation as priority sectors.

Electricity

In LAC, the electricity sector features significant coverage. Overall, the percentage of people with access to electricity in the region has increased from 95.9% in 2010 to 98.3% in 2018. Although this is not a priority regional challenge, a review of various countries' specific situation shows differences among them and among various areas.

Using for reference the most recent year with detailed data for all countries (2018), access to electricity was above 99% in many countries in LAC. Countries with lags in this dimension are shown on Figure 2: Nicaragua (88.1% of the total population), Honduras (91.9%), Guatemala (94.7%), Peru (95.2%), and Bolivia (95.6%). Gaps are larger among the rural population. For example, rural access to electricity stood at 81.8% in Peru and 86% in Bolivia, while it topped 99% in urban areas in both countries.

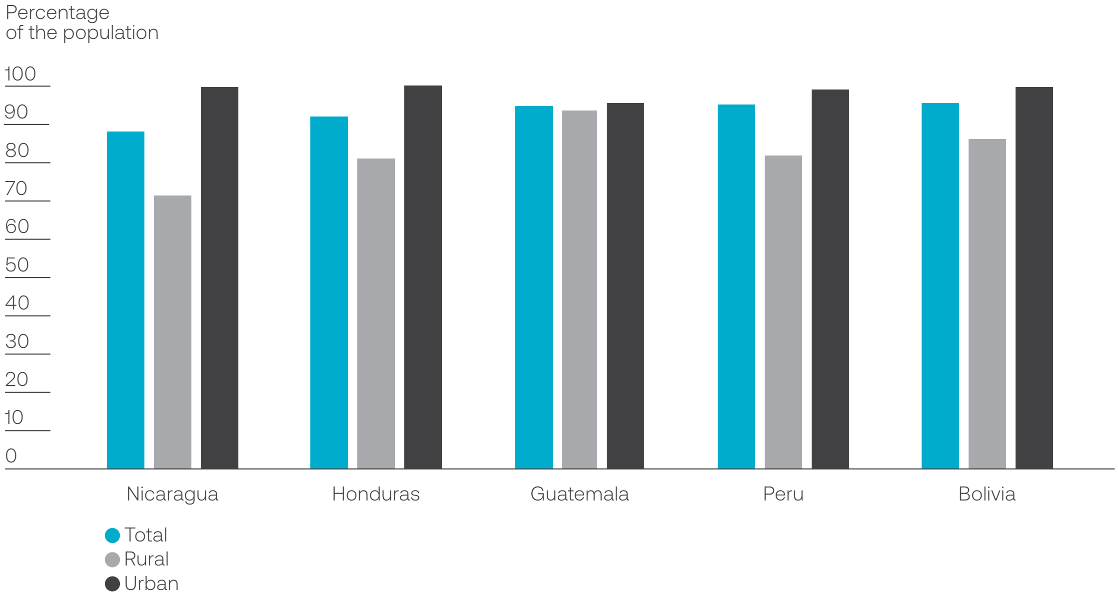
The situation in some countries has improved considerably over the past decade. Using for reference indicator levels for 2010, the greatest increase in urban coverage happened in Peru (which went from 98.1% to 99%). Peru also showed the greatest increase in rural coverage (from 55.6% to 81.8%), followed by Colombia (from 86.2% to 99.7%) and Argentina (from 89.8% to 100%).

Service affordability is a crucial factor to enable electricity use. As an indirect indicator to assess this dimension, residential electricity prices for given consumption levels are one option (Figure 3 uses a regional comparison for consumption levels of 200 kWh/month).

Nominal prices in the region (measured in US dollars) are similar to those in the United States and are far below European levels. The reasons are varied, but the energy mix (the weight of hydroelectric power, which makes power generation cheaper) and subsidies (which affect levels and structures within pricing schemes) are both key factors. However, when we compare prices in terms of GDP per capita, we find a different story. In LAC, electricity prices stand at 3.9%, more than 3 percentage points above prices in the United States (0.5%) and three times greater than prices in Europe (1.16%).

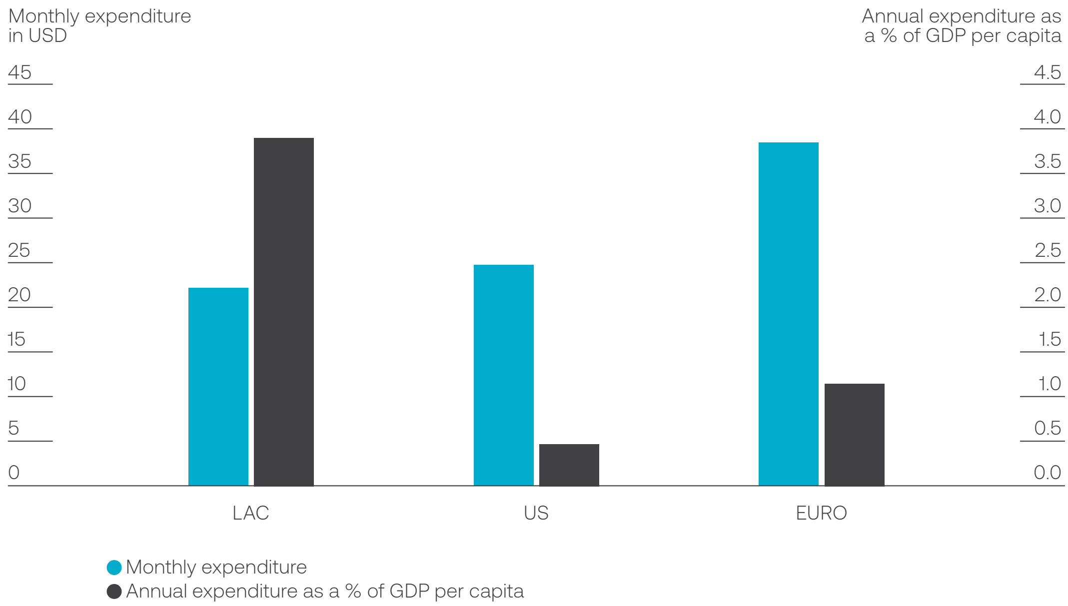
The specific scenario in various Latin American countries is shown in Figure 4, where very different values are observed —some (Colombia and Peru) above USD 30 and others (Argentina and Mexico) below USD 15.

Figure 2
Access to electricity in total, in rural areas, and in urban areas in countries with coverage deficits, 2018
Source: World Bank (2020).



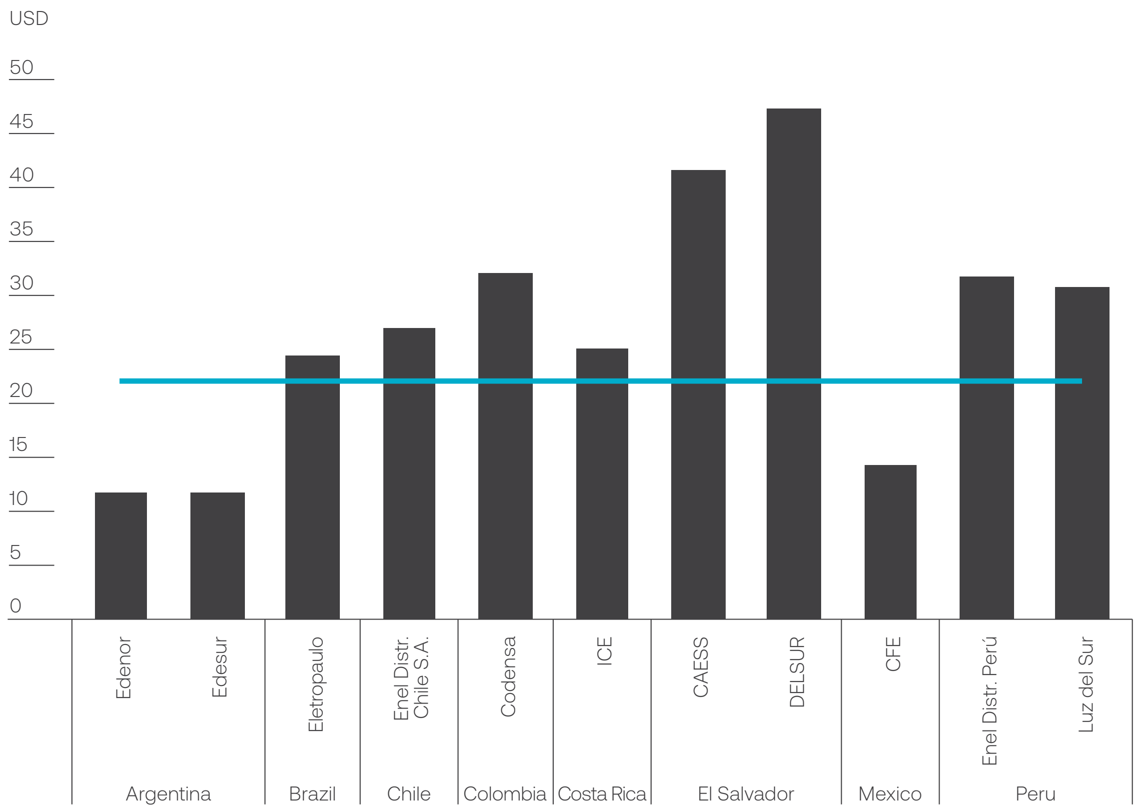
Note: Countries with access levels below 99% were selected.

Figure 3
Residential electricity pricing by region: expenditure in USD for monthly consumption of 200 kWh and annual expenditure as a percentage of GDP per capita, 2018
Source: GPR Economía (2020).



Notes: LAC data are for December 2018 and include Argentina, Brazil, Chile, Colombia, Costa Rica, El Salvador, Mexico, and Peru. European data are for the second half of 2018. US data reflect average residential prices for February 2019.

Figure 4
Residential electricity expenditure by country, for monthly consumption of 200 kWh, December 2018
Source: GPR Economía (2020).



Notes: These figures reflect basic rates, without taxes. Calculations for Colombia are based on the consumption of clients in tier 4 of the population (without subsidies). Calculations for Mexico use tariff 1 (traditionally applied to domestic use with low or intermediate consumption levels). Some countries may have explicit social tariffs.

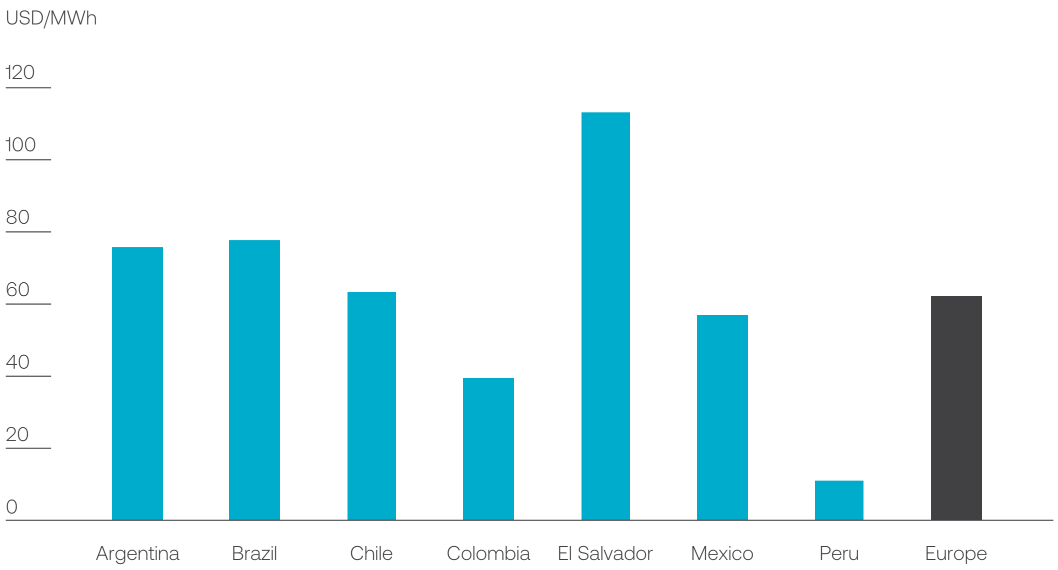
Final prices (for all types of users) are made up of the cost of the various stages in the process (generation, transmission, distribution, and commercialization), usually joined by taxes or subsidies. Generation usually accounts for a significant share of prices. Comparing average generation costs therefore allows us to confirm relative gaps in system costs across different countries (that is, in how costly it is to produce one MWh in various national systems).

Figure 5 shows a comparison of energy prices with immediate delivery (spot prices) in LAC countries and in Europe (regional average) for the year 2018. Colombia and Peru stand out on one end, and Argentina and Brazil stand out on the other (generation costs in Central America sometimes top USD 100 per MWh).[5]

Total leaks from the electricity system are often relevant to measure sector efficiency and the cost of supplying electricity in a given system. Non-technical distribution leaks could also

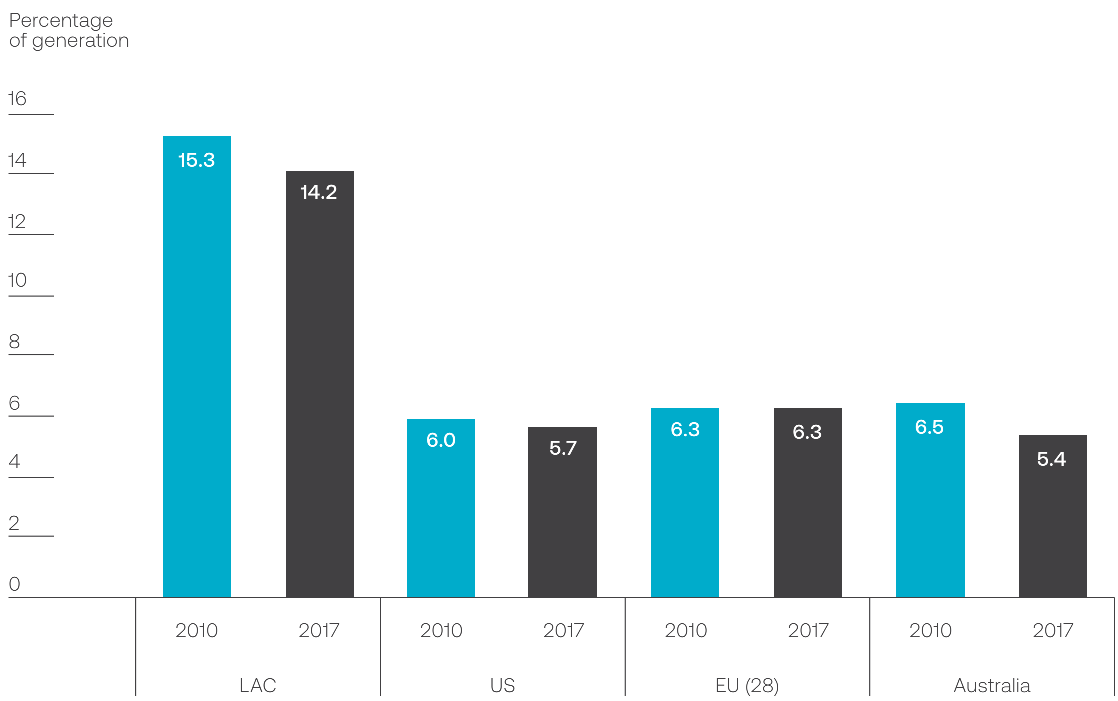
5 This information is provided for illustration purposes. Comparisons must be made with caution and with specific aims in mind. Homogeneous comparisons are very complex. They need to take into consideration the fact that generation costs are a function both of a given country's energy resources (its physical assets, the make-up of its energy matrix) and of its energy policy (particularly whether it subsidizes this sector).

Figure 5
Spot energy prices in selected countries, 2018
Source: GPR Economía (2020).



Notes: The price used for Mexico is for December 2018.

Figure 6
Total electricity leaks in various regions and countries around the world, 2010 and 2017
Source: IEA (2019a).



Electricity coverage is nearly universal, with rural access in some countries as the sole exception. Tariffs are high in terms of per capita income, compared to other regions.

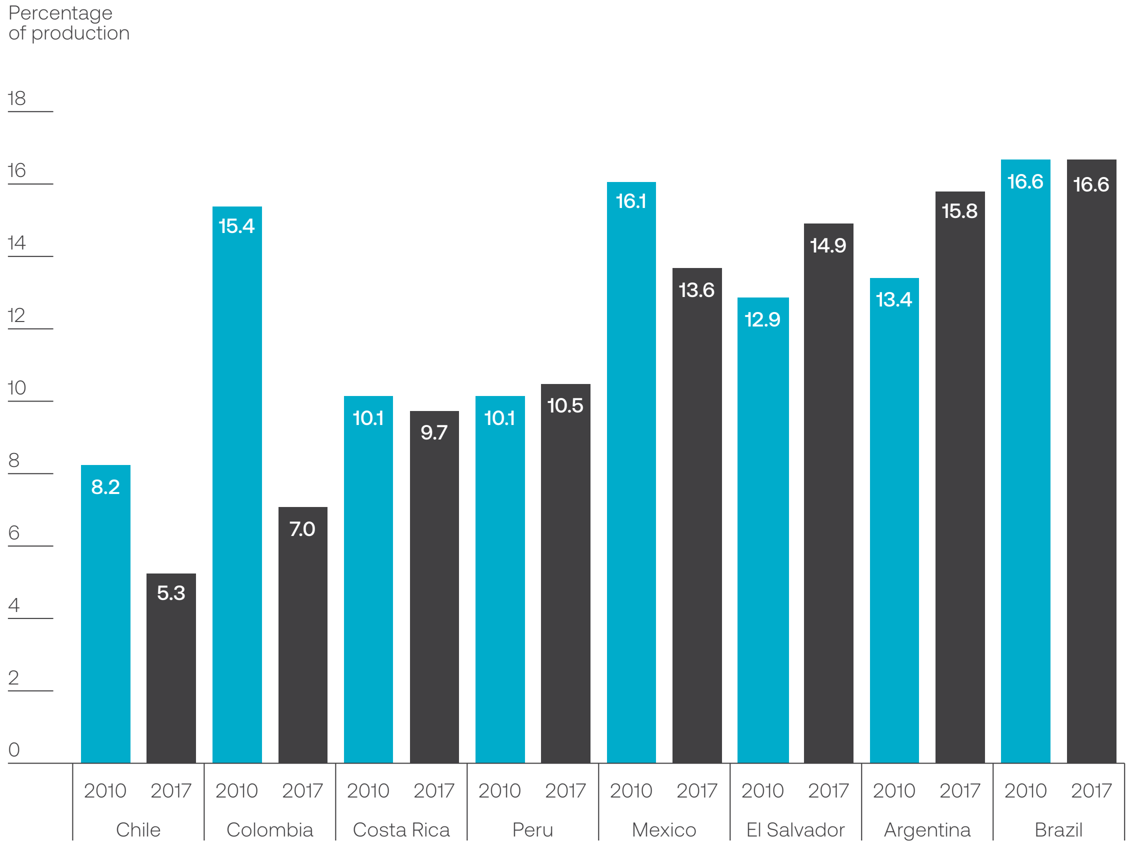
have a social policy interpretation (see the "Social policy" section in Chapter 4). Figure 6 shows total leaks of electricity in LAC, the United States, Europe, and Australia in 2010 and 2017. Leaks are much larger in LAC than they are in all other regions and countries. A major portion of the difference is caused by non-technical leaks, which can take different forms: illegal consumption (theft), tampering with measurements (fraud), non-revenue electricity use (generally, for lighting in public places or to supply electricity to "unmetered users"),[6] or administrative, accounting, and client-management mistakes.

Figure 7 shows the differences in total leaks among selected countries in LAC. Some have leak levels that are comparable to those of developed countries (that is the case with Chile and Colombia, the latter with significant improvements in 2017 compared to 2010). Others, like Brazil and Argentina, show levels that are almost three times as high as those of developed countries. Variations in leaks took different forms from 2010 to 2017. Some countries, like Chile, Colombia, and Mexico saw major improvements (2.9, 8.4, and 2.4 percentage point leak reductions, respectively). Others, like Argentina and El Salvador, had poorer performances (with 2.4 and 2 percentage point leak increases, respectively).

Finally, the indicators that are generally used to approximate electricity service quality are the System Average Interruption Duration Index (SAIDI) and the System Average Interruption Frequency Index (SAIFI). Figure 8 shows these indices for a group of countries in LAC and compares them to indices for the United States and Europe. These indices are difficult to compare, since different regions adopt different measurement methods. However, it is worth noting that service quality in LAC is far below advanced country standards. The implications of these interruptions for the economy and for productivity could be important when interruptions are significant in terms of their magnitude and duration. Power outages in cities affect electrified passenger transportation, traffic (when they affect signal systems), the supply of drinking water, elevator operations, commercial and industrial activity, and urban logistics services (particularly those that require

6 For example, in Córdoba, Argentina, the distribution company EPEC differentiates between two provincial social tariffs—one for metered consumption and one for unmetered consumption (in this case, the price is equivalent to the price of 200 kWh per month).

Figure 7
Total electricity leaks in various countries in LAC, 2010 and 2017
Source: IEA (2019a).



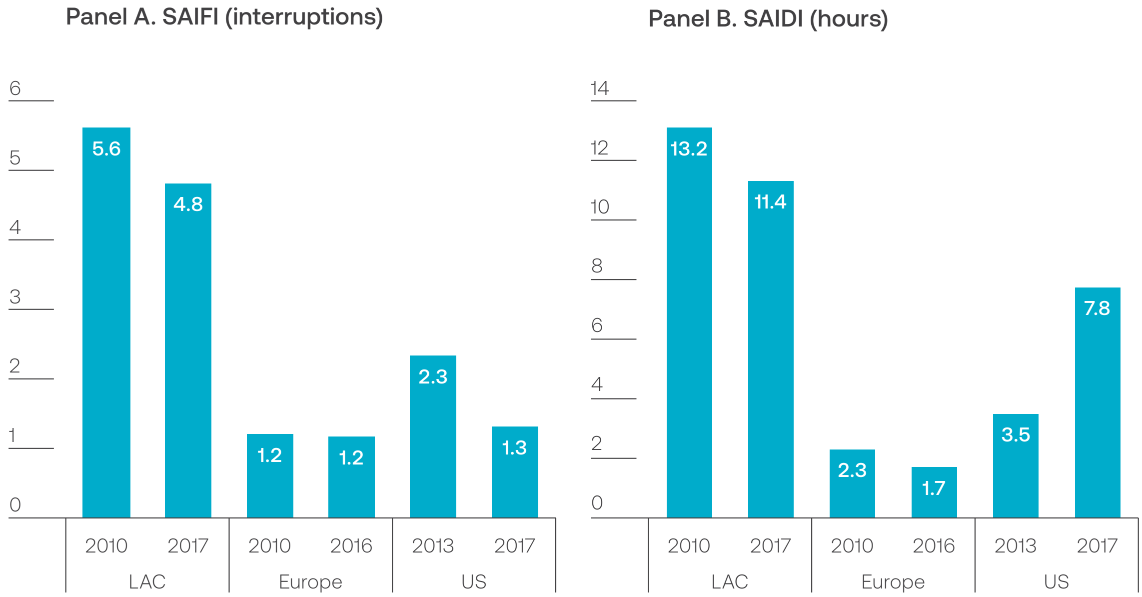
a cold chain), cooling and heating systems (when these rely on electricity), etc.[7]

This analysis can also be conducted individually for selected countries in LAC. Figure 9 and 10 show changes in SAIFI and SAIDI indicators for the main distributors in LAC countries over the period 2010–2018.

One initial observation involves the difference in indicators for LAC, which are far above those for Europe and the United States (although the United States has experienced a sharp rise in the duration of blackouts between 2013 and 2017). Second, the specific stories told by these indices vary greatly within LAC. Mexico is the best performer in terms of SAIDI and SAIFI (although the data exclude the firm CFE Transmisión). Since 2015, the country has had less than one interruption per year, with a duration of less than 30 minutes. Colombia—with a maximum of 12 interruptions in 2014 that have now been reduced to 9, despite having average SAIDI levels close to the average for all the countries included in this comparison—and Argentina—with one interruption every 1.6

7 In February 1999, an incident in the area where the firm Edesur was in charge of supply (the southern half of the Buenos Aires Metropolitan Area) left more than 150,000 residential users (equivalent to 300,000–500,000 individuals) and commercial users without electricity for over 10 days. This blackout affected users' quality of life (it happened during the summer) and caused major economic losses, estimated at USD 400 million for residential users and USD 750 million for commercial users. The distributor was required to pay a fine of USD 70 million. Conducting an economic valuation of these incidents is common in other countries (for instance, following natural disasters including hurricanes, earthquakes, and tsunamis).

Figure 8
Quality indicators (SAIFI and SAIDI) in LAC, the United States, and Europe, selected years
Source: GPR Economía (2020).



Notes: For LAC, we use the Average Interruption Duration Index (SAIDI) and the System Average Interruption Frequency Index (SAIFI) for the main distributors in each country, except for the SAIDI Index for Chile, which is a country-wide figure. For Europe, we use the planned and unplanned SAIDI and SAIFI indices (including exceptional events). For the United States, we use the SAIDI and the SAIFI indices including cases of *force majeure*.

months lasting more than 25 hours on average, despite some improvements in the last few years included in this sample—are among the countries with the worst performances.

To summarize, these countries are currently not far from attaining full coverage, with rural access in some countries (for instance, Peru) as the sole exception. End-user prices are low in nominal terms, partly because these countries have cheaper energy sources for power generation,[8] even though firms are inefficient (electricity leaks are twice as large as in other regions). However, tariffs are high in terms of per capita income, compared to other regions (the United States and Europe). And service quality is far from the standards applied in advanced countries, with interruption indices (in terms of both frequency and duration) three times as high as those for Europe and twice as high as those for the United States.

8 Depending on the country (or region) and the time, prices may include a subsidy component. For example, Argentina had an explicit subsidy for electricity prices in the Buenos Aires Metropolitan Area until 2015, as well as explicit subsidies for bulk energy operations that were factored into prices for users elsewhere in the country. These subsidies were significantly reduced (though not eliminated) between 2016 and 2018, and they were replaced with social tariff schemes. Other forms of subsidy focused on the first few consumption units within increasing tariff blocks (setting low prices for the first few units consumed, as was the case in the Argentine city of Córdoba and in countries like Brazil, Mexico, and Uruguay) or stratified tariffs (as in Colombia).

Figure 9
Changes in SAIFI (interruptions)
for the main distribution companies in each country, 2010–2018
Source: GPR Economía (2020). .

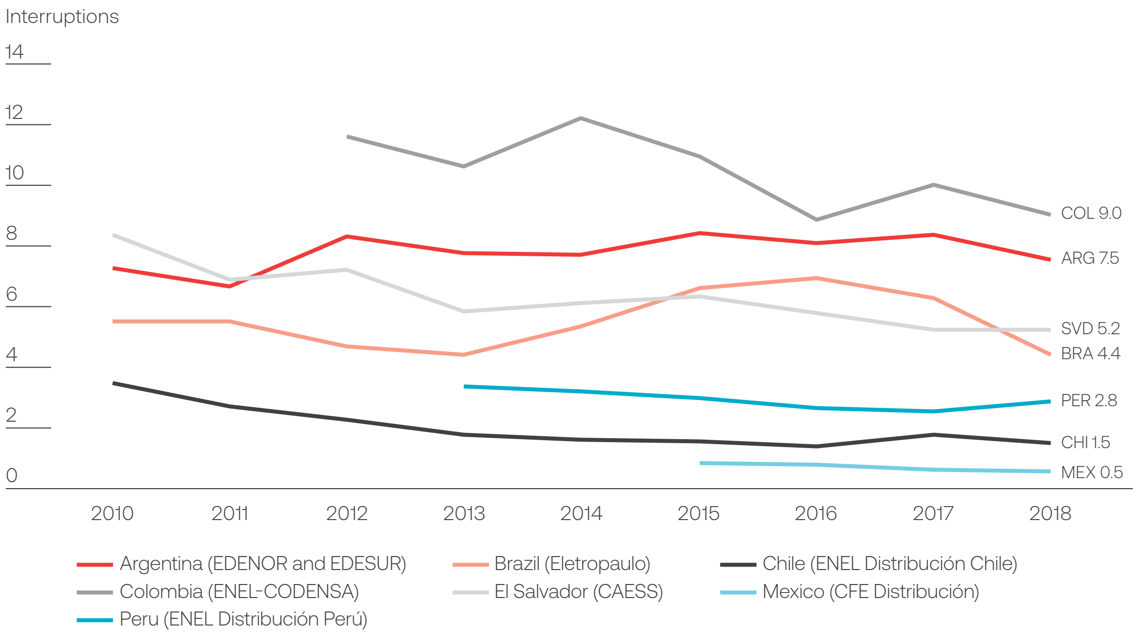
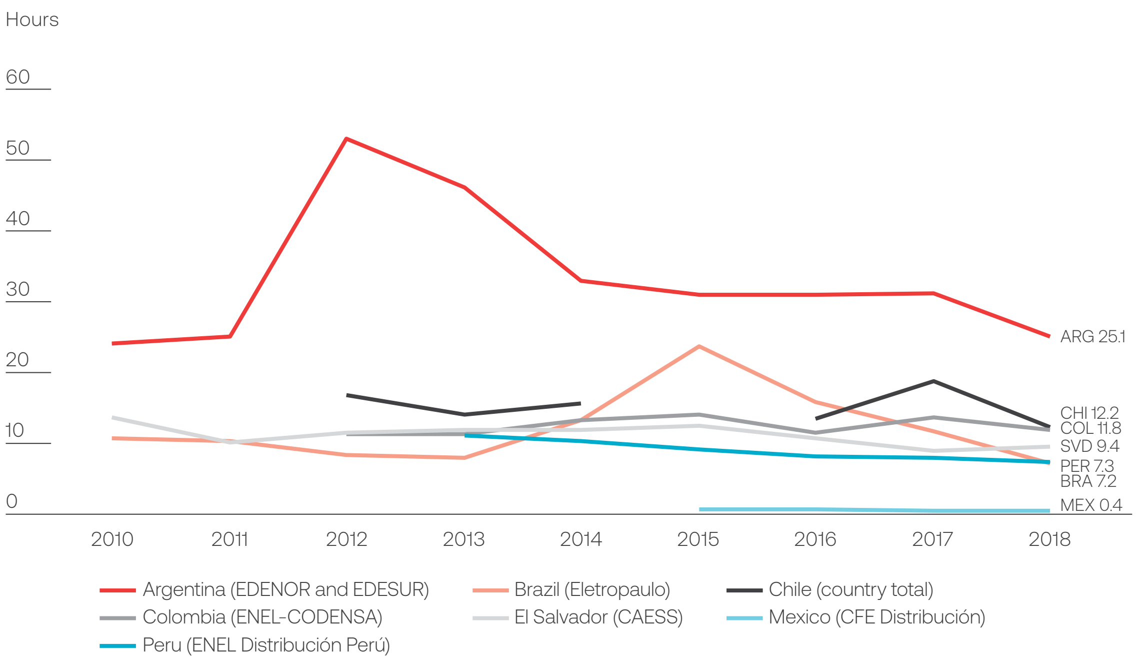


Figure 10
Changes in SAIDI (hours)
for the main distribution companies in each country, 2010–2018
Source: GPR Economía (2020).



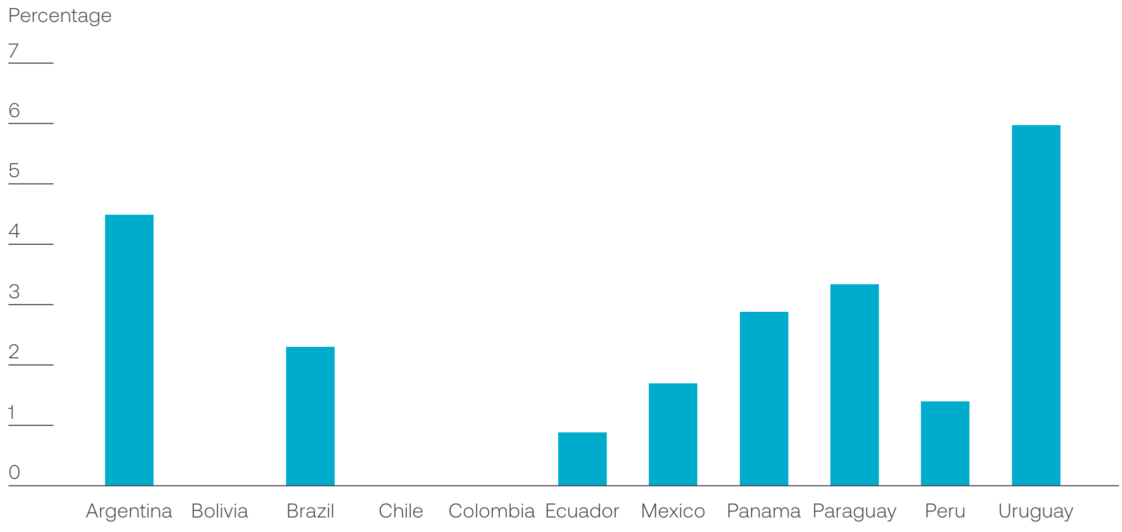
Informality in the electricity sector

Informality in the electricity sector takes two different forms: (i) users without a formal connection to the power grid (with what are known as illegal or informal connections) illegally consume electricity, and (ii) users tamper with measuring equipment to record lower levels of electricity than they actually consume. These illegal actions are one of the reasons for non-technical leaks. Given the indicators shown in Figure 6 and 7, leaks pose a serious efficiency problem in LAC. The percentage of illegal connections in selected countries in the region can be estimated based on the CAF's 2019 household survey (ECAF).[9] Figure 11 shows that illegal connections amount to less than 6% of all connections in the surveyed countries (although the survey was only conducted in major cities within each country).

Informality in the electricity sector can be due to a combination of various factors that do not always directly depend on the operations of the relevant electricity companies. One of these factors could be linked to price increases or to individuals' low incomes. Informality (in the form of electricity theft or fraud) may also be a response to the perception of a low-quality service or to deficient monitoring by companies. A further explanation involves the low propensity to pay for utilities in these sociocultural contexts, or the fact that users cannot legally access these services for lack of the relevant land titles (Jiménez, Serebrisky, and Mercado, 2014).

The latter is very common in LAC, due to population growth and to unplanned urban sprawl. This urban growth has partially taken the form of an informal occupation of land in peri-urban areas, which has stimulated the emergence of poorer neighborhoods and precarious settlements in these areas. This type of housing usually relies on illegal connections to the power grid. Solving informality issues in the electricity sector therefore requires a characterization of the target population, so the problem can be addressed without regressive effects.

Figure 11
Percentage of the population who obtain electricity through informal connections to the power grid in major cities within each country, 2019
Source: Compiled by the authors, based on data from ECAF 2019.



9 ECAF surveys individuals within households. The CAF has conducted this survey annually since 2008 in a series of Latin American cities, to collect socioeconomic data about respondents and about various characteristics of households and housing. The questionnaire includes questions about access, quality, and spending concerning urban transportation services, crime, trash collection, water, sanitation, electricity, housing type and quality, and degrees of satisfaction regarding life, housing, and crime.

Urban passenger transportation

Individuals use urban transportation to access basic rights (education, employment, healthcare and other types of care, etc.), various activities, and other services. This means that urban transportation is crucial for people's daily lives. Urban authorities therefore face the challenge of planning mobility in such a way that people can move quickly and safely, using a comprehensive transportation system able to balance accessibility, efficiency, quality, safety (in terms of both traffic and personal safety), and environmental impact.

Different modes of transport can attain the desired features in different combinations. For example, a private mode of transport (an individual's own vehicle) grants the user broad access and enables them to move comfortably and safely, but it is costly and also has an impact on the environment and on congestion. Public mass transit poses challenges in terms of minimizing travel time, providing increased access to services, being efficient regarding the

Table 2
Segmentation within the cities that were examined
Source: Compiled by the authors, based on data from United Nations (2018b), Steer (2020), and CAF (2015), and on ECAF 2019.

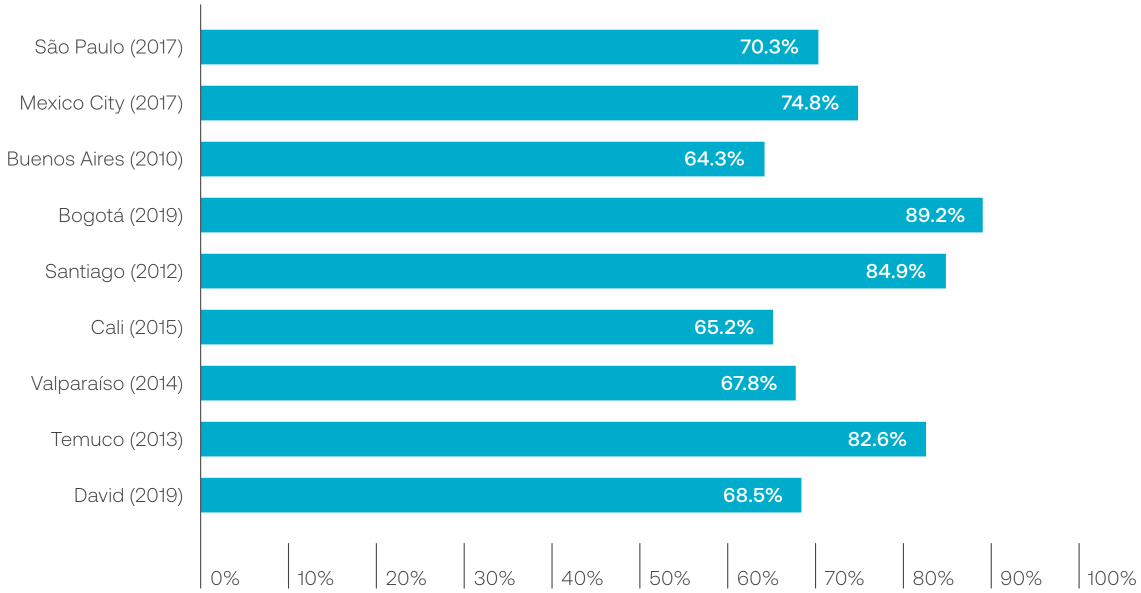
Category	City	Population (2020)	O-D survey	ECAF	OUM
Very large	São Paulo, Brazil	22,043,028	✓	✓	✓
	Mexico City, Mexico	21,782,378	✓	✓	✓
	Buenos Aires, Argentina	15,153,729	✓	✓	✓
	Bogotá, Colombia	10,978,360	✓	✓	✓
	Lima, Peru	10,719,188		✓	✓
	Santiago, Chile	6,767,223	✓	✓	✓
Large	Recife, Brazil	4,127,092			✓
	Medellín, Colombia	4,000,263			✓
	Asunción, Paraguay	3,336,562		✓	✓
	Cali, Colombia	2,781,980	✓		✓
	Quito, Ecuador	1,873,763		✓	✓
	Panama City, Panama	1,860,291		✓	✓
	La Paz, Bolivia	1,857,797		✓	
	Montevideo, Uruguay	1,752,388		✓	✓
	Rosario, Argentina	1,532,128	✓		✓
	Valparaíso, Chile	983,751	✓		✓
Small/Medium-Sized	Temuco, Chile	341,951	✓		
	David, Panama	206,658	✓		

cost of provision, and providing comfortable, safe services, among others.

Transportation services respond to people's need to move, which depends on city characteristics.[10] Table 2 shows a sample of cities grouped by population size, and subdivided into very large, large, and small/medium. In sector studies, this classification is often broader and takes into consideration additional dimensions, like topography and surface in square kilometers.[11]

One initial service gap indicator is the percentage of the population who travel (Figure 12). This indicator captures people who actually move, but it does not enable distinctions based on the reasons why everyone else does not travel (for instance, who would be able to travel and who would not). There are no apparent links between this percentage and city size, and there are for example very large cities with a smaller share of people who travel (Buenos Aires) than other cities in the same group or in some large cities, and others where this share is significantly bigger (Bogotá). The same thing happens with small and medium-sized cities compared to larger ones (such as Temuco and Valparaíso).[12]

Figure 12
Percentage of the population who travel
Source: Steer (2020).



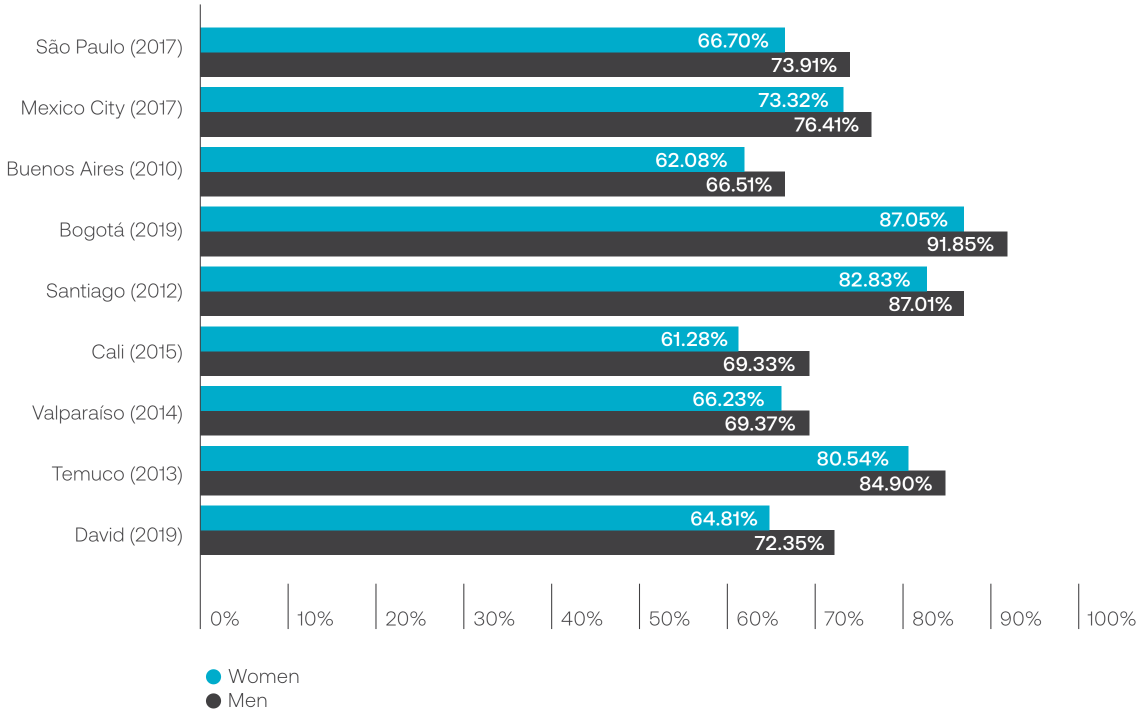
Notes: The year is the one when the corresponding O-D survey was conducted. Cities are listed in descending order of population size, based on the data presented in Table 2.

10 The COVID-19 pandemic exposed how important it is to ensure structural changes in lifestyle, by reducing travel and developing a sustainable habitat within close distances. Reductions in the number of trips and in travel time can be attained by ensuring that essential services are located geographically close to the population. As it is implemented, this paradigm shift will have implications for mobility in the medium and long terms.

11 The cities that are examined in this report were taken from three sources: cities included in the Steer (2020) sectoral report based on origin-destination (O-D) surveys; cities assessed by the Observatory of Urban Mobility (OUM) with data for the two available samples (2007 and 2014); and cities included in ECAF 2019.

12 This could be due to differences among surveys concerning the travelling that is reported or omitted, or to sampling issues. In any case, it is worth noting that surveys, particularly O-D surveys, are statistical exercises with a sampling error. Comparisons between cities must be done with care, because there may be methodological differences concerning time periods, sampling, expansion method, and days of the week that are considered for a given survey, among other aspects.

Figure 13
Percentage of the population who travel, disaggregated by gender
Source: Steer (2020).



Notes: The year is the one when the corresponding O-D survey was conducted. Cities are listed in descending order of population size, based on the data presented in Table 2.

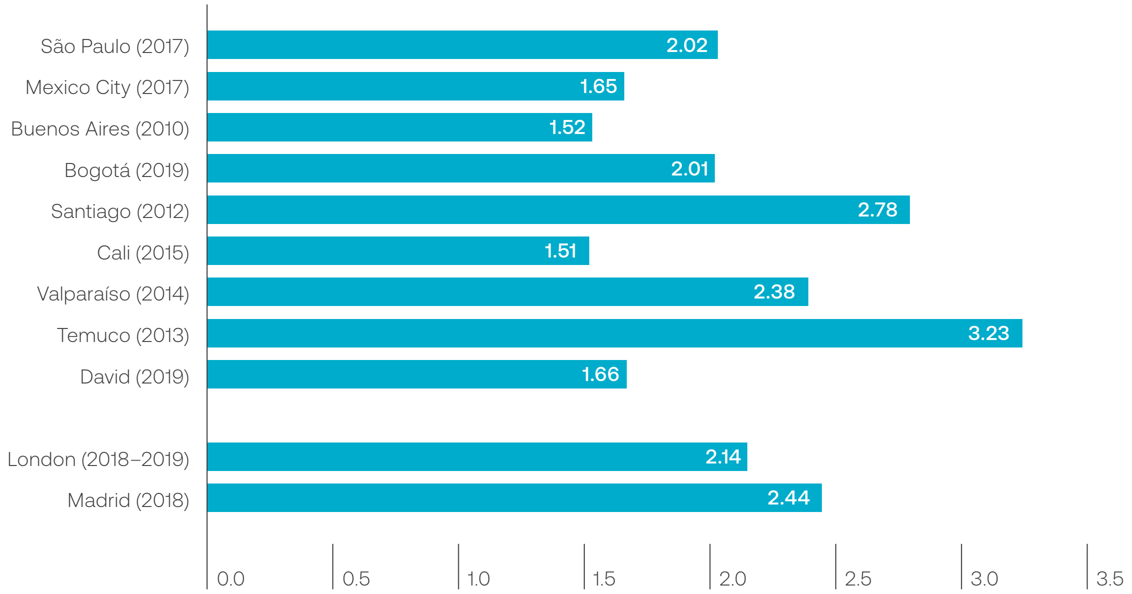
When we disaggregate this indicator by gender (Figure 13), we see that, in all the cities that were examined, the proportion of individuals who travel is higher for men than it is for women. This could be due to the roles that men and women have traditionally played within families in LAC.

A further aspect that enables us to look into mobility concerns the intensity of travel. Figure 14 compares the rate of travel per person (including individuals who do not travel) with the same indicator for London and Madrid, on a working day. Chilean cities stand out for their high rates of travel compared to other Latin American cities, with well over two trips per person per day. In other countries, there seems to be no relationship between city size and rate of travel. In some cities, this is partly explained with reference to the lower proportion of individuals who travel (Buenos Aires and Cali), but that does not always hold (Valparaíso). Compared to London and Madrid, travel intensity is generally greater in the LAC cities that have been examined, except in Chile.

Aggregate indicators might hide relative gender gaps shown on Figure 15 for the rate of travel by gender (considering only individuals who travel). In several cities, the rate of travel is higher for women (with average differences of 0.1–0.2 trips). São Paulo, Cali, and David are the exceptions. Taken together with the share of individuals who travel, this result may reflect gender inequality dynamics, where women engage in more trips but their trips are shorter, closer to home, and linked to household chores, while men take fewer trips, but these are longer and are mainly linked to work or education.[13]

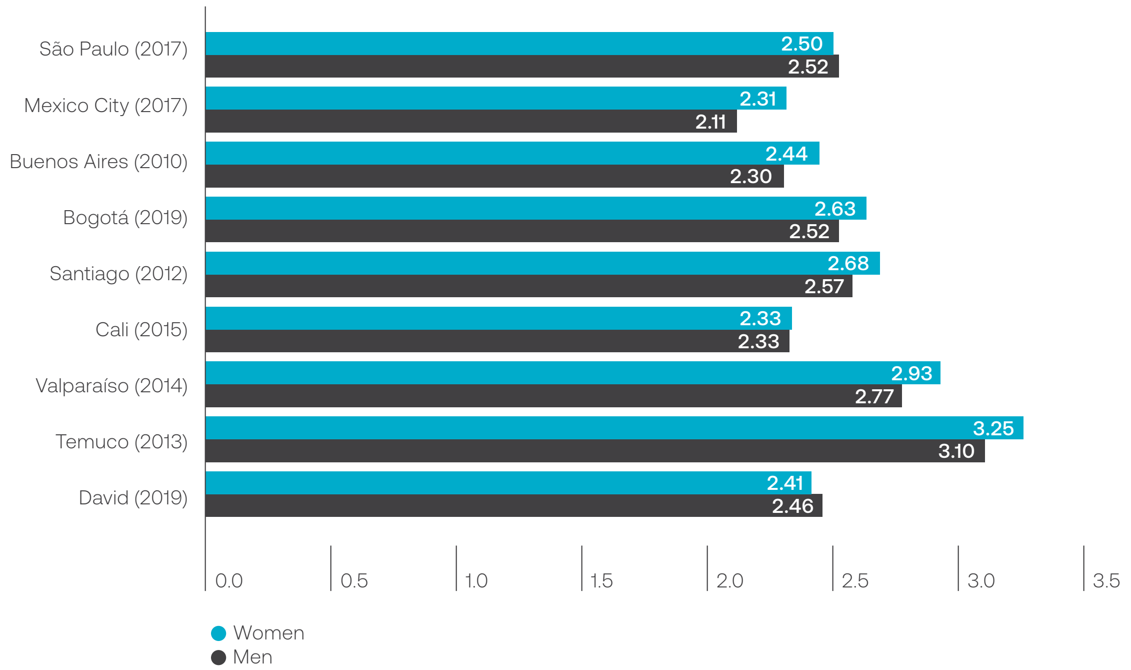
13 These results are examined for the case of Mexico City in Steer México et al. (2020), but they require more research for other cities (Steer, 2020).

Figure 14
Rate of travel per person on a working day
Source: For LAC data, Steer (2020); for London data, Transport for London (2019); for Madrid data, Deloitte and IPD (2019).



Notes: The year is the one when the corresponding O-D survey was conducted.

Figure 15
Rate of travel per person who travels on a working day, by gender
Source: Steer (2020).

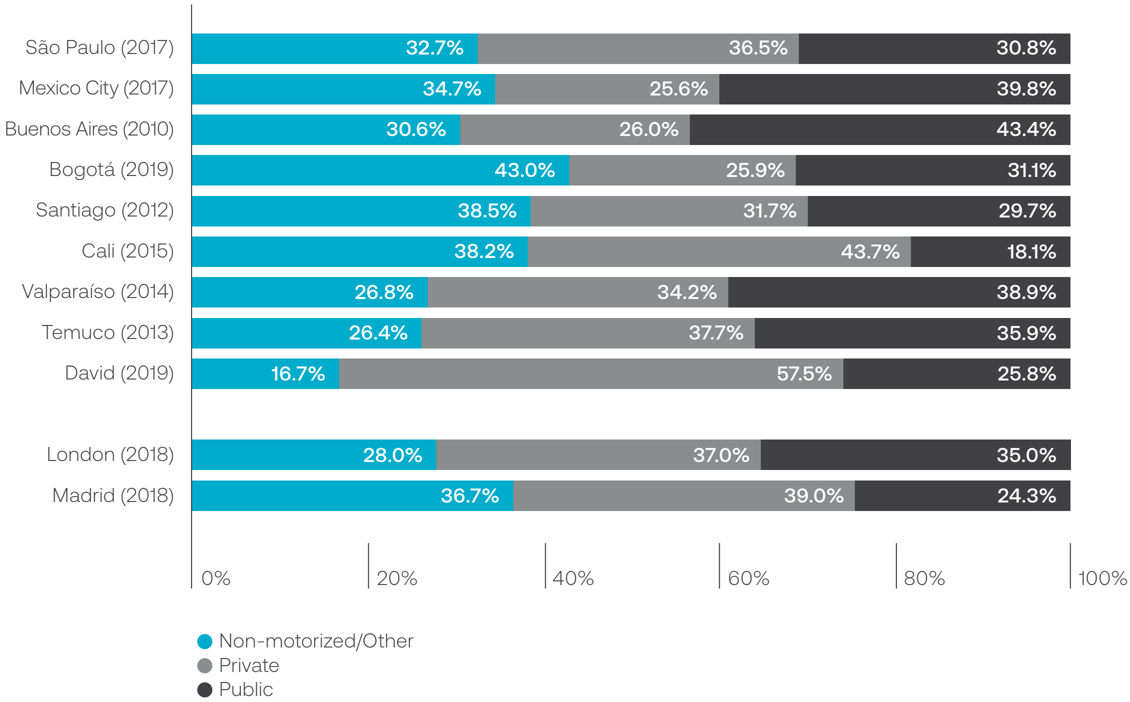


Note: The year is the one when the corresponding O-D survey was conducted.

Finally, Figure 16 shows the distribution of travel by mode of transport.[14] In very large cities, public transportation and non-motorized modes of transport have significant shares. By contrast, private modes of transport are predominant in small and medium-sized cities. For example, David is a very small city without a well-organized public transportation system—as is the case for many small Latin American cities—and this may explain public transportation's smaller share in its distribution of travel by mode of transport. Comparing European cities like London and Madrid to the large cities shown on Figure 16, private transportation only has a greater share of total travel in Cali. However, a comparison conducted by Rivas *et al.* (2019a) between Belo Horizonte, Bogotá, Montevideo, Río de Janeiro, Santiago, and São Paulo showed that private transportation's share had increased from 17% to 24% over a period of approximately 15 years, while travel by bicycle and on foot had increased from 32% to 36% over the same period. This is evidence of public transportation substitution.

In short, 65–85% of the total population travels in most of the cities in our sample (although O-D surveys do not show whether individuals who do not travel refrain from travelling for reasons related to the provision of transportation services or due to demand-side factors). When travel intensity is examined, we see that, on average, individuals take at least 1.5 trips per day (and more than 2 trips per day in Chilean cities, in Bogotá, and in São Paulo). Women evidence a higher rate of travel than men in almost all the cities we examined, reflecting gender dynamics (possibly the fact that women travel for reasons linked to household chores and childcare). Concerning

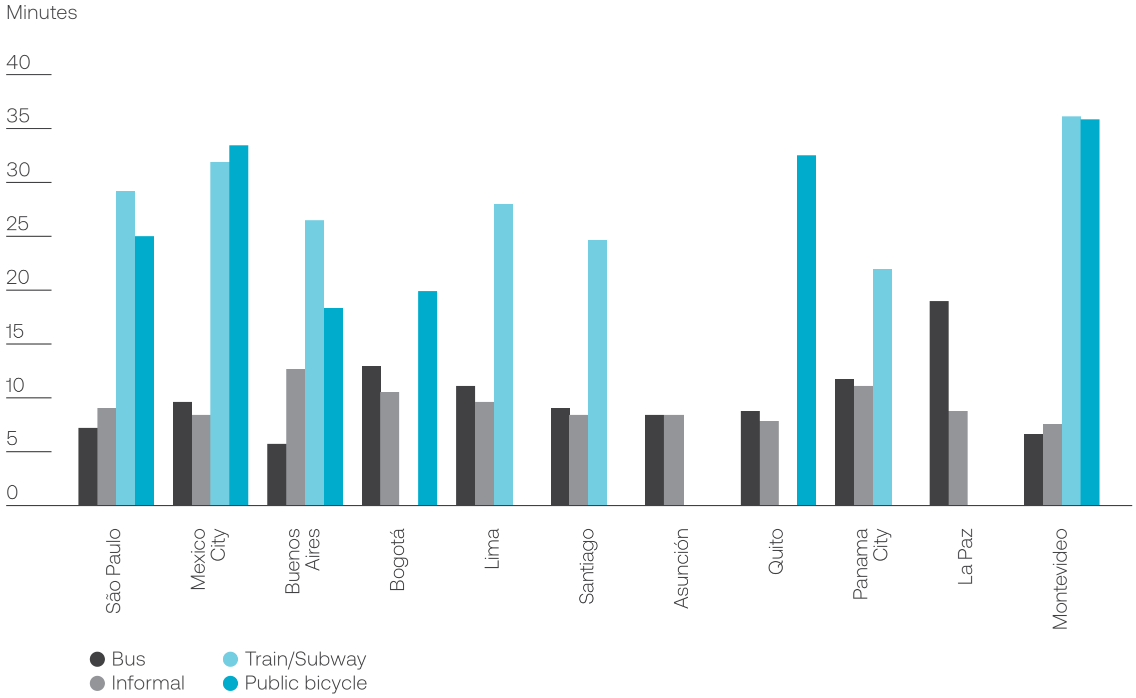
Figure 16
Percentage of trips by mode of transport on a working day
Source: Steer (2020).



Note: The year is the one when the corresponding O-D survey was conducted.

14 Non-motorized transportation includes walking and cycling. In the case of private transportation, this not only includes individuals' own vehicles, but also individual public transportation (taxis and other similar vehicles).

Figure 17
Average walking time required to access different transportation services
Source: Compiled by the authors, based on data from ECAF 2019.



the distribution of travel among different modes of transport, a certain heterogeneity is apparent in Latin America and the Caribbean: there are cities (usually larger ones) where public transportation is dominant, and others (usually smaller cities) where private transportation predominates. We will therefore go on to examine service gaps that are evident in the urban passenger transportation sector, focusing mainly on the population segment that uses these services.

Easy access is an essential element for transportation services. This dimension can be approximated using system coverage in a given area (for instance, within a radius of 300 or 500 meters) or the time taken by users to get to the closest stop or station.[15] ECAF 2019 enables an assessment of the second option for different modes of transport (bus, which is the most representative mode given its extension and capillarity; train and subway; informal transportation;[16] and public bicycles).

Figure 17 compares the average walking time required to access different modes of transport, and it prompts various observations.[17] First, buses have the greatest coverage, followed by informal modes of transport. Second, informal transportation features similar travel times to bus travel; it is cheaper in some cities (for instance, Bogotá and La Paz) and more expensive in others (like Buenos Aires), and it compensates for deficits in formal services.

15 Each of them provide different information. Population coverage enables us to approximate the whole population's theoretical access. The time taken by users to get to a stop reflects the distance (the greater the capillarity, the less time users will take). However, it also provides supplementary information, such as how long people are exposed to other risks (like crime) as they go from their homes to the point where their trips start.

16 On ECAF 2019, informal transportation includes share taxis, minibuses, multipurpose vehicles, and vans.

17 ECAF 2019 asks about walking time in three intervals: less than 10 minutes, 10–30 minutes, and more than 30 minutes. The average time is estimated by allocating a time period to each trip: 5 minutes for first-stage walks, 20 minutes for second-stage walks, and 45 minutes for third-stage walks.

Concerning other modes of transport, trains and subways are generally farther away, given the natural rigidity involved in the infrastructure to provide these services. While various public bicycle networks have been set up (in many cases along with bike lanes, to encourage safe use), this mode of transport still lacks a sufficiently capillary distribution. Buenos Aires and Bogotá stand out for having points of access that take considerably less time (less than 20 minutes, on average) than in other cities offering this service.

Deficiencies in access to formal public transportation services can lead users to resort to informal (and unsafe) modes of transport, both to travel to their ultimate destinations and to get to stops. This not only increases the total cost of the trip, but can take longer and potentially affect productivity, family life, and health, among other aspects.

Figure 18 focuses on bus transportation and identifies walks to the nearest stop in several intervals. There are contrasts among different cities that are unrelated to city size. For example, in Buenos Aires, Montevideo, and São Paulo, more than 80% of all survey respondents say they can get on a bus within 10 minutes, while that rate is below 35% in La Paz. Overall, less than 5% of all residents in the cities that have been examined need to walk for more than 30 minutes, with Panama City, Bogotá, and La Paz as the exceptions. This is evident from data on how long the average walk to a bus stop takes.

Service gaps in the access dimension are significant in cities like La Paz and Bogotá, where longer walks are needed to access transportation. Other cities, including Panama City and Lima, also show deficiencies in this field: more than 30% of all survey respondents have access difficulties, which suggests the possibility that there may be insufficient service capillarity.

Figure 18
Walking time required to access the bus service
Source: Compiled by the authors, based on data from ECAF 2019

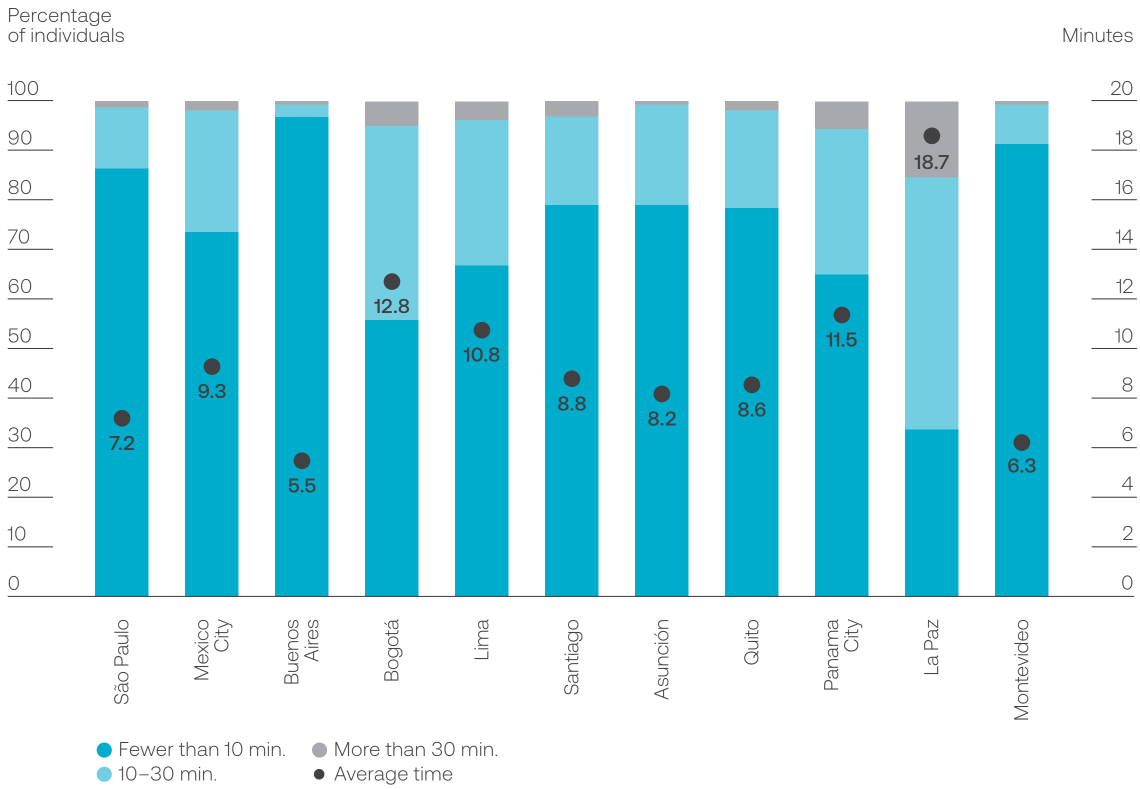
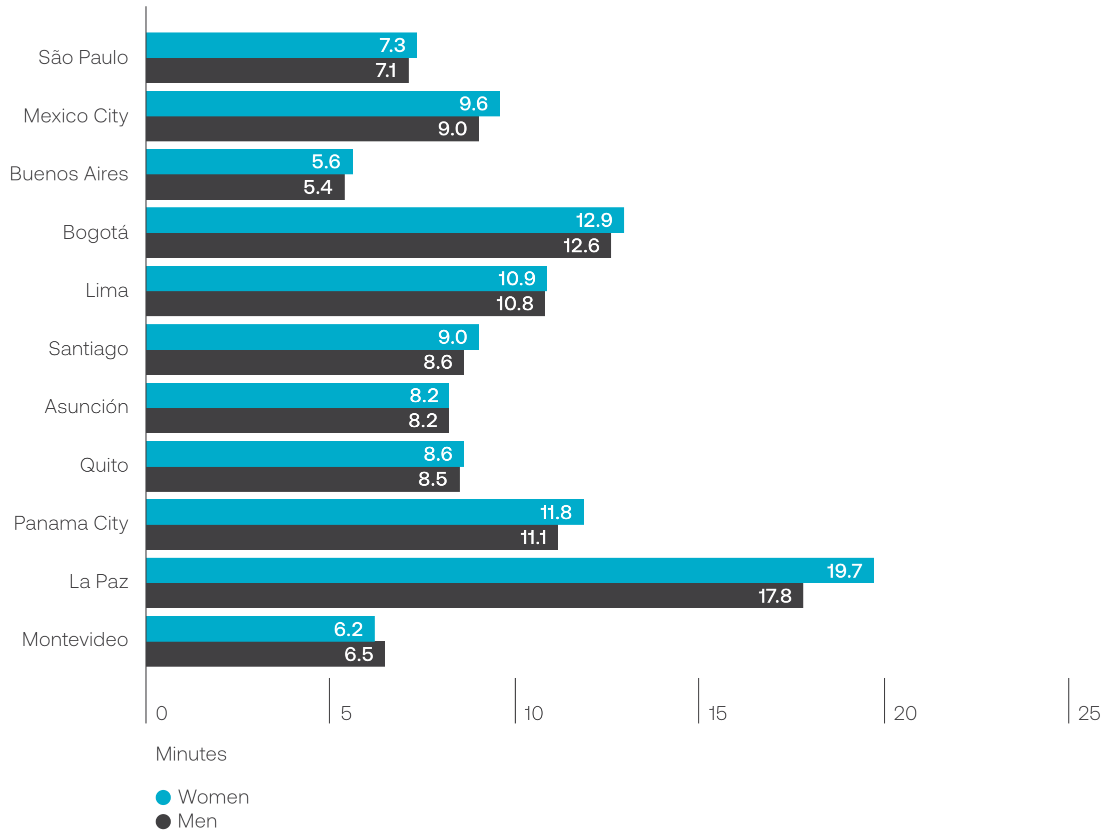


Figure 19
Average walking time required to access the bus service, by gender
Source: Compiled by the authors, based on data from ECAF 2019.



The time it takes to get to the bus stop can also be disaggregated by gender (Figure 19). In general, there are no significant differences in walking time for men and women, except in La Paz. However, the need to walk long distances to access a bus stop affects comfort and exposes individuals to crime (which is especially relevant to worsen gender-based vulnerability). Implementing measures (broader network expansion) and technologies (as explained in later chapters of this report) and ensuring better-quality public spaces (sidewalks, lighting, and the presence of security cameras, among others) could reduce exposure to these issues.

On the other hand, the concept of transportation service quality can be measured as a function of travel time, safety, and comfort (especially concerning the gender dimension). The third aspect can also be approximated through an analysis of the frequency and occupancy rate of the public transportation service.

Table 3 shows average travel time by mode of transport, with its standard deviation. Public transportation trips tend to take longer in very large cities than elsewhere, which is to be expected, partly because of the longer distances (and increased congestion) involved in travel. However, travel times in private transportation (except in Bogotá and Mexico City) tend to be similar in cities of various sizes. Travel in non-motorized modes of transport usually covers relatively short distances, so travel times tend to be more homogeneous among cities and last approximately 15 minutes per trip. Compared to Madrid, large and very large Latin American cities feature considerably longer travel times on public transportation (more than double in the case of Bogotá). Madrid has a very well-developed commuter train and subway network, which significantly

Table 3
Travel time by mode of transport (in minutes)
Source: Steer (2020) and Deloitte and IPD (2018).

City and year O-D	Non-motorized		Private		Public	
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
São Paulo (2017)	13	10	26	23	65	37
Mexico City (2017)	17	13	42	35	67	40
Buenos Aires (2010)	16	18	28	35	53	42
Bogotá (2019)	25	39	54	66	86	60
Santiago (2012)	14	13	32	29	58	39
Cali (2015)	17	20	29	27	58	35
Valparaíso (2014)	14	12	27	28	40	26
Temuco (2013)	14	11	25	37	31	18
David (2019)	18	43	29	38	42	39
Madrid (2018)	17	-	23	-	38	-

Note: The year is the one when the corresponding O-D survey was conducted.

reduces travel time.[18] In terms of private transportation, while travel time remains longer in Latin American and Caribbean cities, the difference is less significant (except in Bogotá and Mexico City).

Considering the data presented on Figure 16, these results suggest that, in most of the examined cities, longer travel times affect the major share of the population who use the public transportation service.

In the special case of public transportation, we might also mention two other important factors that determine service quality: the frequency and the occupancy rate of buses, trains, and other modes of mass transport. Frequency affects quality through total travel time (including waiting time) and through issues related to crime (due to increased exposure, as passengers wait at the stop or station). Occupancy rates affect quality through the level of comfort and personal safety during the trip (the latter is particularly relevant for women).[19]

Table 4 presents scores based on user perceptions of both factors (frequency and occupancy), on a scale from 1 to 10.

In the case of frequency, a higher score indicates higher approval. No significant differences are observed among cities of different sizes, and even cities of a similar size have different scores. In general, service tends to get a score of around 6 points, although there are scores that are close to 7 (as in Mexico City) and scores below 5 (Bogotá). In terms of occupancy, the higher the score, the higher the occupancy rate. Again, no differences are observed among cities based on their size, and

18 Travel time is affected by multiple factors, so comparisons between cities need to be handled with care. On the one hand, while the classification used in this chapter is based on population size, sprawl is also a relevant factor. On the other hand, cities may see more short trips if they have experienced more balanced economic development within their urban areas.

19 Allen et al. (2018) have researched this issue in detail for Buenos Aires, Quito, and Santiago. They make recommendations concerning regulations, infrastructure, and operational design for transport, as well as other collaborative solutions (see this reference for more information).

Table 4
Perception of the frequency and occupancy rate of public transportation
Source: Compiled by the authors, based on data from ECAF 2019.

City	Frequency			Occupancy rate		
	Total	Women	Men	Total	Women	Men
São Paulo	6.42	6.48	6.34	7.99	8.14*	7.75*
Mexico City	6.92	6.95	6.88	7.87	7.77	8.00
Buenos Aires	6.88	6.84	6.93	7.24	7.08*	7.47*
Bogotá	4.75	4.96*	4.47*	8.73	8.90*	8.50*
Lima	5.89	5.85	5.94	7.60	7.65	7.54
Santiago	5.65	5.63	5.67	8.13	8.17	8.09
Asunción	6.05	6.02	6.08	7.29	7.20	7.43
Quito	6.05	5.98	6.13	8.14	8.06	8.23
Panama City	6.29	6.42	6.16	7.20	7.11	7.29
La Paz	6.15	6.11	6.19	7.23	7.28	7.18
Montevideo	6.79	6.50*	7.18*	7.50	7.74*	7.17*

Notes: In the frequency column, higher scores indicate more positive perceptions. In the occupancy column, higher scores indicate more negative perceptions. * Differences in averages for men and women are statistically significant (at 10% or less).

there are heterogeneous scores within each group of cities. Survey respondents perceive relatively high occupancy rates, which suggests less comfortable travel.

Table 4 also allows us to identify gender-based differences. Women perceive slightly higher frequency in Bogotá and slightly lower frequency in Montevideo (although the latter's score remains high compared to those of other cities). São Paulo, Bogotá, and Montevideo present perceptions of higher occupancy rates in public transportation, while the opposite can be said of Buenos Aires.

To summarize, service gaps in the quality dimension show that travel times on public transportation in very large cities are more significant than they are on other modes of transport and on public transportation in smaller cities. At the same time, the perception of a high occupancy rate on public transportation may be a natural consequence of the design of this mode of transport. Travel times by mode of transport support the hypothesis that public transportation tends to deal with individuals who live the farthest from their places of work and study (and, in the case of women, also the places where they engage in household chores and childcare tasks). These users may therefore have less time available[20] to do other activities.[21]

Finally, it is important for (public) services to be provided at the lowest possible monetary cost for users. First, the average cost of providing a public transportation service per trip is an indicator that enables us to estimate the resources the system needs to allocate

20 O-D surveys may use, instead of a specific point, relatively broad areas to specify the origin and destination of a particular trip, which makes it more difficult to measure travel time per kilometer travelled.

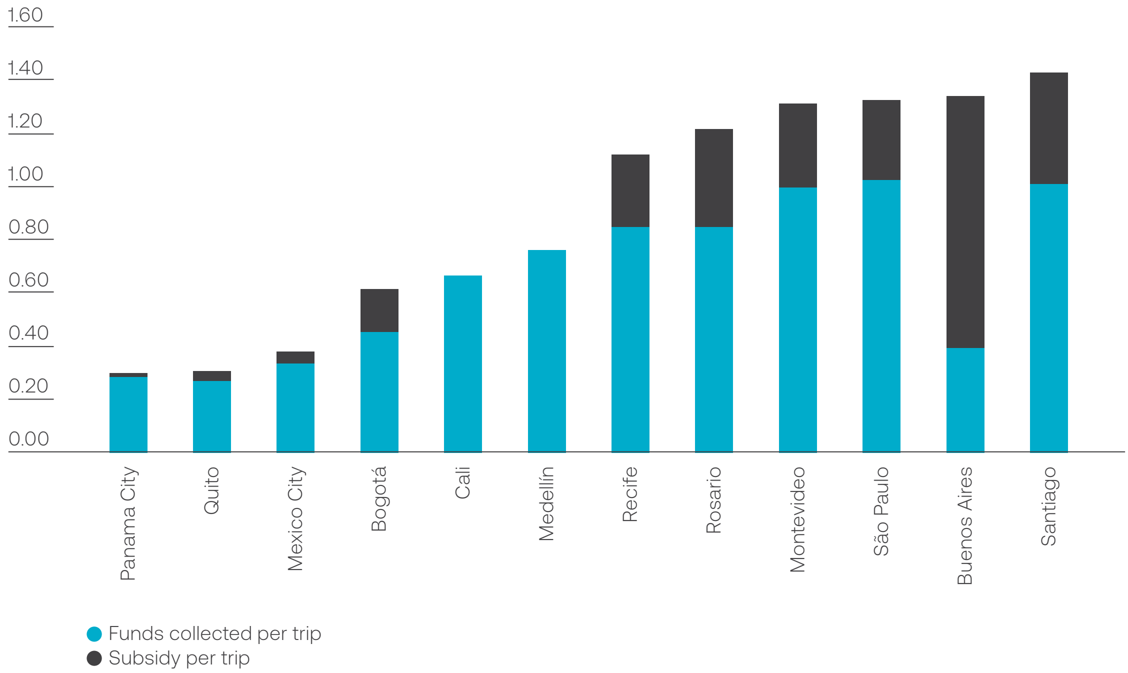
21 See Zahavi and Taltvitie (1980) for general considerations and Steer México et al. (2020) for gender considerations, especially concerning household chores and childcare.

to passenger transport. Second, the net cost of public transportation for users enables us to identify their contribution to the system's operating costs and the contributions the system receives in the form of subsidies (an outcome of transport policies based on various factors, as explained in footnote 4). Last, we can compare users' spending on public transportation with their spending on other modes of transport (typically not subsidized) to estimate the cost of travelling for the user.

Figure 20 shows the operating cost that one passenger entails for the public transportation system, along with a disaggregation by source (fares and subsidies), according to 2014 data issued by the Observatory of Urban Mobility. Two groups of cities are identified, based on the average cost of a single trip for the system. On the one hand, we find the cities where this average cost was below USD 0.80 per trip (Panama City, Quito, Bogotá, Cali, Medellín, and Mexico City). On the other hand, we find the cities where this average cost was over USD 1.20 per trip (Buenos Aires, Rosario, Montevideo, Santiago, and São Paulo). This observation warrants an exploration of the reasons why all these large cities have such different costs (which might be partially explained by relative exchange rates), since these differences are a potential indication of a cost or efficiency gap in the provision of this service.

In general, there are no systematic data available that enable an estimate of the cost of providing public transportation. This depends on urban zoning regulations, transportation coverage, and more or less explicit policies that determine operating and capital costs. The presumption—which may or may not be correct—is that urban planning ensures services are provided at the lowest possible cost.[22] In

Figure 20
Cost of public transportation services per trip, 2014
Source: Compiled by the authors, based on CAF (2015).



Note: To estimate the cost per trip, we presumed that weekends see only 30% of the trips observed on working days. In the case of Bogotá, we included the deficit that is paid with the contributions of the Fare Stabilization Fund (*Fondo de Estabilización Tarifaria*), since transfers from the District Treasury effectively function as a subsidy.

22 It should be noted that subsidy policies may be local or national, while urban policies can only be local. It may be the case that national measures are not well-coordinated with local measures, or vice versa.

The share of mass public transit relative to other modes of transport has decreased, with travel times of over 1 hour, twice as long as on private transportation.

this context, Figure 20 also shows the sources of funding for the (operational) costs of a trip for the system circa 2014. Colombian cities except Bogotá did not subsidize this service. Since 2008, Bogotá has been using resources from the Fare Stabilization Fund to cover the cost of provision. Other cities require subsidies to varying degrees. In this respect, Buenos Aires contrasts with Panama City, Quito, and Mexico City: in the former, subsidies amounted to 70.6% of all transport funding, while in the latter group they amounted to 4.5–12.6%. These extreme values contrast with the situation in other cities, where public transportation services require subsidies worth 25–30% of total income. If we compare this with the subsidies received by public transportation in cities in other regions, we can see that the heterogeneity that was mentioned above also prevails here. For example, in London, subsidies amount to 10% of operating costs, while this proportion is as high as 53% in Madrid (Scorcia, 2018).[23]

From users' point of view, the relevant direct component is how representative spending on transportation is relative to income (affordability),[24] particularly for the most vulnerable population groups. Table 5 presents an affordability ratio, defined as the ratio of spending required on 50 bus trips per month relative to the minimum wage. This table shows some disparities in the affordability of collective public transportation for low-income groups in the various cities under consideration (from 2.5% in Panama City to 20.7% in São Paulo). No trends are apparent based on city size. While any comparisons must be conducted with care,[25] some do stand out. São Paulo and Santiago, for instance, have similar unit cost and subsidy components, but the burden on low-income end users is much greater in São Paulo. Cali and Recife have similar affordability ratios at 13–15%, but the latter achieves this using a subsidy policy (with a fare that amounts to approximately 75% of the cost of a trip).

23 This comparison simply reflects the various policies adopted in the region concerning instruments to fund public transportation. This issue will surely become more relevant in the wake of the COVID-19 pandemic, since it has severely affected both households' spending capacity and public sector resources. One option to increase fares (in order to rely less on public funds) is to implement or step up targeted subsidies—social tariffs to reduce spending on transportation (and other services) among users who meet target group criteria—as is already being done in several Latin American countries.

24 A comprehensive examination should also address taxes paid to fund public transportation subsidies (in terms of efficiency, fairness, public finance, and externalities, as mentioned above).

25 Estupiñán, Gómez Lobo, Muñoz Raskin, and Serebrisky (2007) highlight how difficult it is to compare these results based on relevant parameters (whether spending is high or low) or between cities (whether the ratio is higher for one city than it is for another). These are endogenous indicators, and spending on transportation is a share of households' consumption basket. For example, users could travel long distances to buy cheaper products. In any case, they may work as an initial approximation that is useful to understand whether a given mobility policy is costly for the population (and, in particular, for vulnerable groups).

Table 5
Affordability ratio for collective public transportation, December 2014
Source: Compiled by the authors, based on CAF (2015).

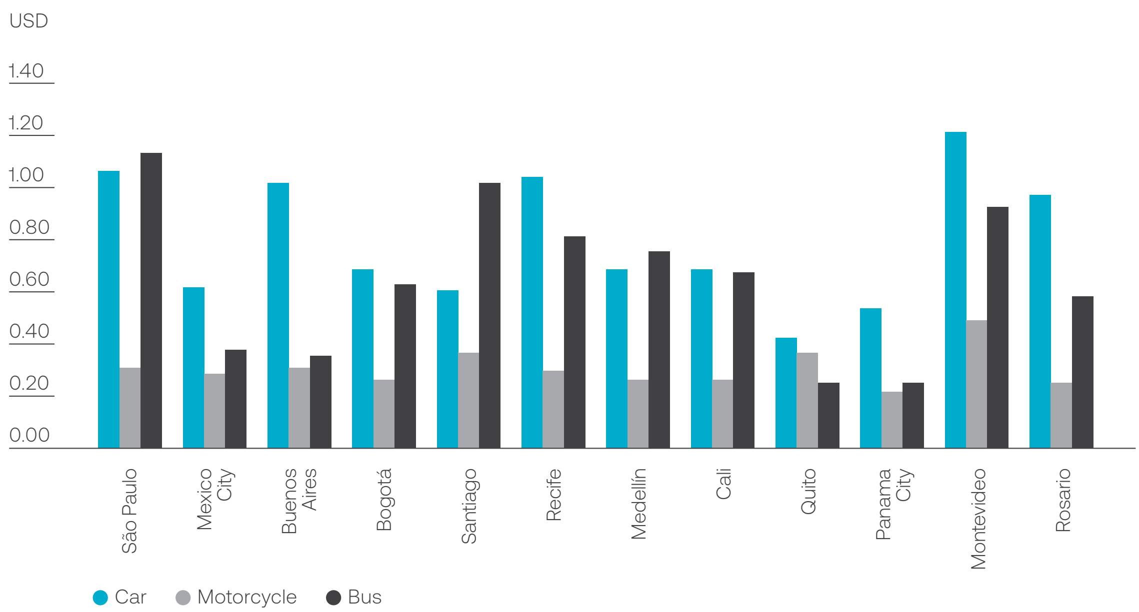
City	Affordability ratio
São Paulo	20.7%
Recife	14.9%
Medellín	14.7%
Pereira	14.6%
Cali	13.0%
Santiago	12.9%
Montevideo	12.4%
Bogotá	12.2%
Mexico City	8.3%
Rosario	5.7%
Quito	3.5%
Buenos Aires	3.4%

Note: This ratio is defined as the ratio of spending required on 50 bus trips per month relative to the minimum wage.

Figure 21 presents information about the cost of a 7 km trip using different modes of transport and in different cities. Some heterogeneity is apparent between cities when we compare the cost of a car trip with the cost of a bus ride. There are cities (Santiago, Medellín, and São Paulo) where bus travel is more expensive for users than other modes of transport, and cities (Buenos Aires, Mexico City, and Panama City) where bus travel is substantially cheaper that private transportation. There are also differences in the cost of public transportation between cities of similar types. For example, there are notable differences between very large cities like Buenos Aires and Bogotá compared to Santiago and São Paulo. This may be due to the degree of efficiency in service provision, but also to the adoption of different policies to fund capital costs or even operating costs (that is, whether each component of costs is funded with fares or subsidies).

To summarize, the share of public (and non-motorized) transportation is high in most large cities, compared to developed countries. However, there is evidence of a drop in the share of mass public transit relative to other modes of transport. Informal transportation remains an option available for people at similar

Figure 21
Cost of a 7 km trip by mode of transport, December 2014
Source: Compiled by the authors, based on CAF (2015).



distances (measured in time) to formal collective transportation, and it is sometimes more easily accessible (as in La Paz—where bus availability evidences less capillarity—and Bogotá). This is in line with user perceptions of a low frequency. The share of public bicycles—available in many of the cities that were examined—has grown significantly. However, penetration is yet to reach a level where users can access these bikes at shorter average distances. Further, walking times also highlight other aspects of urban design linked to safety.

Reducing travel times on public transportation is a pending task in several cities. Among the cities that were examined here, Bogotá, Mexico City, and São Paulo feature average travel times of over 1 hour, compared to 30 minutes on private transportation. This characteristic is complemented by passenger perceptions of a high degree of vehicle occupancy (particularly in Bogotá, but also in other cities including Santiago and Quito). Again, this dimension can have implications in terms of safety.

In the cost dimension, two groups of cities are identified: those with costs of under USD 0.80 per trip, and those with costs of over USD 1.20 per trip, based on 2014 data. While these differences could be attributed to the various exchange rates, these results stress the need to ensure service provision at the lowest possible cost, given the implications of this aspect both for the fare paid by end users and for state contributions (in a combination that will depend on local political decisions). Comparisons of affordability are useful to understand how cities balance fares and subsidies to provide a service to end users (that may be costly, even net of subsidies, as is evident when comparing São Paulo with Santiago and Recife with Cali).

In the gender dimension, women tend to engage in more trips than men (possibly explained by the fact that women travel for reasons linked to household chores and childcare). Walking time to access the bus service is similar (except in La Paz, where it is more significant) and perceptions of vehicle occupancy are also similar (except in São Paulo, Bogotá, and Montevideo, where perceptions are more negative among women). However, travelling involves exposure and has implications in terms of safety.

Later chapters will present measures and tools that may be useful to reduce some dimensions of the service gaps that have been identified. In particular, digitalization might enable a reduction in travel times and increase the capillarity of transportation services through apps that provide real-time data about the operations and location of different public modes of transport, as well as through multimodal integration and the use of sharing economy and micromobility platforms.

Evasion and informality in urban passenger transportation

Informality in the transport sector poses challenges for urban mobility (informal carriers) and for the sector's financial sustainability (fare evasion).

Evasion can have consequences for this sector (for instance, in terms of carrier funding and in terms of safety for passengers who are carried and not recorded). In some cities, it has reached high enough levels for stakeholders to take measures to counter fare evasion. We now present the cases of public transportation in Bogotá, Buenos Aires, and Santiago.

High evasion on the Transantiago, estimated at 27.9% of users in December 2017, is very relevant for a network that relies on state subsidies. The research that has been conducted shows that the main reasons for evasion in Santiago are a poor service quality perception, the high cost of transport, the small number of facilities to charge the card required for payment (known as Bip!), and the culture that prevails among users. The city of Santiago took measures to counter the problem, including the Comprehensive Plan Against Evasion (the *Plan Integral contra la Evasión*, which introduced a new auditing model), the enactment on June 5, 2018 of the Act Against Evasion (putting forward an increase in penalties and the creation of fare dodger records), the use of turnstiles, and the adoption of telemetrics (which enable bus passenger counts). These measures managed to reduce evasion to 25.7% by the second quarter of 2019.

Evasion is also identified as a relevant problem in Bogotá's Transmilenio network. Recent research conducted by the National University of Colombia (*Universidad Nacional de Colombia*, 2018) estimated an average evasion rate of 15.36% in core services in 2018. Given the problem, evasion was monitored on the Transmilenio (APCA E&Y and Iquartil Ltda., 2018). Further, since 2018, the firm Transmilenio S.A. has been drafting a Plan Against Evasion that puts forward several measures: strengthening efforts to check that users pay with an increased police presence, investing in evasion-control infrastructure (such as perimeter barriers and railings), awareness-raising campaigns, and monitoring to follow up on evasion data and on the effects of measures adopted to counter it.

In the Buenos Aires Metropolitan Area, the situation varies depending on the mode of transport. On the one hand, transportation specialists consider that there is no evasion on urban passenger transport buses (or it is hardly relevant) due to the mode of payment, where the driver is also in charge of receiving fares. Evasion may happen when trip length is underreported (so the user pays for a shorter trip than they really take, although fare differences based on distance are small) or when the social tariff scheme is inadequately applied. On the other hand, payment evasion on trains (that carry 21% of all public transportation system passengers in the Buenos Aires Metropolitan Area) was estimated at around 18% in 2018, with a variation from 4% to 42% depending on the operator, according to the National Commission to Regulate Transportation (*Comisión Nacional de Regulación del Transporte*, 2018). Evasion topped 40% following the disaster that happened at Once station on the Sarmiento train line in February 2012. That rate could only be reduced through improved fare collection, investment in railway network modernization, new trains, and improved stations and tracks, among other measures.

One issue that needs to be taken into consideration is that regulators may have little incentive to keep fare evasion in check. Each carrier's contract with the authorities is crucial for fare structure. Designing a contract that links the funds received by the carrier to evasion levels could create incentives for carriers to control and reduce evasion, as a way to receive more funds through compensation mechanisms included in their contracts.

The situation in Latin America warrants more thorough research into the real state of these systems (including causes and effects not only in terms of fare collection, but also regarding user perception and carrier reactions concerning the features and quality of the services they provide). A diagnosis of this kind would enable an identification of the best policy instruments available to control fare evasion.

Concerning informality in urban passenger transportation services, we see in Latin America an emergence of informal collective and individual public transportation services in areas or times where the formal sector is unable to provide an adequate service for various reasons (high cost, lack of road infrastructure, and areas where land is illegally occupied, among others). For example, mountainside areas, areas where land is illegally occupied, and neighborhoods that have sprung up irregularly without formal planning and development are all suitable for the emergence of informal transportation services, including motorcycle transport or the use of vehicles that are well-suited for conditions in each specific area. Crime also leads to the emergence of informal alternative services in some areas.

Informal transportation can serve to connect passengers to the formal transportation system, with last kilometer or last stretch services in suburbs. Two examples of these services are the *camperos* (and other private vehicles, usually old and deficient in technical and mechanical terms) used to feed and receive users of mass transit systems in suburban areas, and *mototaxis* as a transport alternative in many Latin American cities whose public transportation systems and road infrastructure have major deficiencies.

One specific aspect of informal services is that, in some cases, passengers pay more for them than they would in the formal system. This is particularly true in areas where formal public transportation has shortcomings of some sort that mean informal transportation has a monopoly, with services that tend to be provided by illegal groups (Steer, 2020).

Other infrastructure sectors

Drinking water and sanitation

This subsection briefly describes service gaps in the drinking water and sanitation sector in Latin America,[26] emphasizing the dimensions of access, efficiency (as an indirect cost indicator), and quality.

Access to drinking water is measured as a percentage of the population (whether urban or rural) with access to at least a basic drinking water service. In terms of urban access, all countries have virtually full coverage (over 98%), except Peru and some Central American countries. It is in rural areas where drinking water coverage differentials emerge, mainly in countries with a low GDP per capita and larger shares of the population in rural areas. Access differentials can also be examined relative to income (Figure 22). Within Latin America, only Uruguay has universal access. Urban areas in

Table 6
Service gap indicators in the supply of drinking water and sanitation
Source: JMP (2018) for access and quality indicators; ERAS (2016), SUNASS (2019), and AAPS (2019) for leaks and service continuity; and Zipitría (2020).

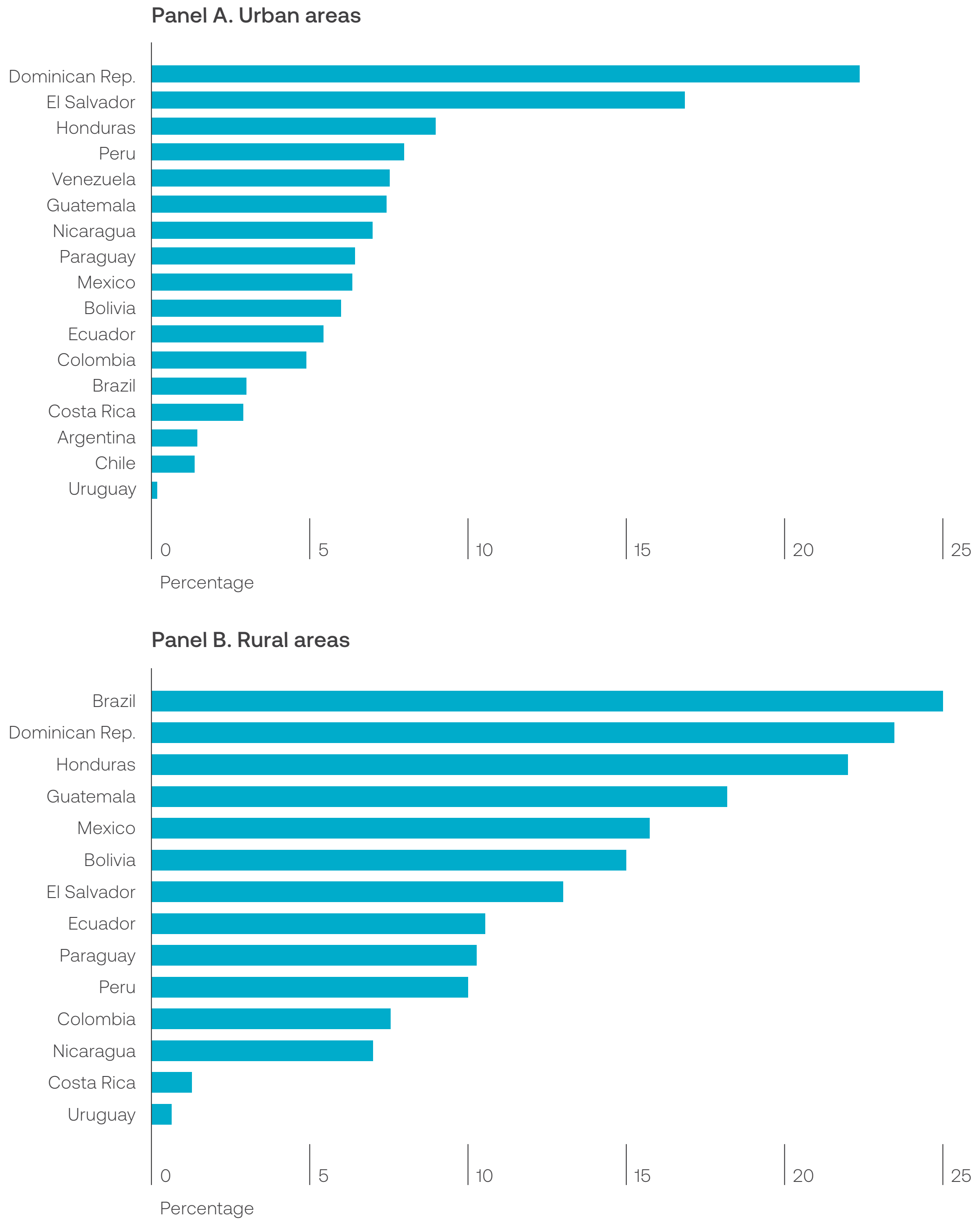
Country	Water						Sanitation			
	Access		Quality			Efficiency	Access		Quality	
	Access to drinking water		Access to safely managed water		Service continuity (water supply in hours)	Leaks (% of water supplied)	Basic sanitation		Safely managed sanitation	
	Urban	Rural	Urban	Rural			Urban	Rural	Urban	Rural
Argentina	>99	93	-	-	24.0	41.3	96	-	-	-
Bolivia	>99	78	-	-	22.2	24.8	72	36	25	-
Brazil	>99	90	92	-	24.0	36.4	93	60	52	-
Chile	>99	99	99	-	24.0	30.0	>99	>99	81	-
Colombia	>99	86	81	40	24.0	41.9	93	76	14	-
Costa Rica	>99	>99	96	84	24.0	50.6	98	96	-	-
Ecuador	>99	83	85	58	24.0	28.0	91	83	33	57
El Salvador	>99	92	-	-	-	-	91	79	-	-
Guatemala	98	90	66	46	-	-	79	51	-	-
Honduras	>99	89	-	19	21.0	-	85	76	35	-
Mexico	>99	97	-	-	-	-	93	82	52	-
Nicaragua	98	59	67	29	-	-	84	62	-	-
Panama	98	93	-	-	20.0	46.7	92	65	-	-
Paraguay	>99	>99	72	51	-	-	94	83	54	66
Peru	96	76	59	21	21.6	28.5	80	56	51	-
Uruguay	>99	95	95	-	-	51.1	97	97	-	-

Notes: Leak and service continuity indicators reflect the main companies in each country: AySA in Argentina; SABESP in Brazil; Aguas Andinas in Chile; Bogotá in Colombia; AyA in Costa Rica; EPMAPS-Q in Ecuador; Aguas de San Pedro in Honduras; IDAAN in Panama; SEDAPAL in Peru; and OSE in Uruguay. In the case of Bolivia, the figures shown are country totals.

26 A more comprehensive analysis of this sector (including water and sanitation, services associated with productive development, and water management under normal and extreme conditions) is planned to be conducted in a future IDEAL report.

Argentina, Brazil, Chile, and Costa Rica have small differentials between the first and fifth quintiles of the population in income terms. However, there are major differentials in Central American countries and in Peru and Venezuela. In rural areas, differentials top 10 percentage points in more than half the countries in the sample (including cases like Brazil and Mexico).

Figure 22
Access differentials: Difference between the wealthiest and poorest quintiles
Source: WWAP (2019).



Access to safely managed water is measured as the percentage of the population whose water service meets three criteria: (i) it comes from an improved source inside the home or its yard, (ii) it is available when needed, and (iii) it is free from contamination with fecal matter and priority chemicals. This indicator therefore considers service characteristics that affect the quality dimension. This dimension can be supplemented with service continuity (and also with water pressure). A similar approximation can be achieved for sanitation using access and service quality. Information quality is lower in these dimensions (see Table 6). It is interesting to note that countries with access problems also have service quality shortcomings (Zipitría, 2020). Another major problem in Latin America involves high rates of non-revenue water (25–50% of all the water that is produced), which become relevant in water shortage contexts.

Finally, there is little wastewater treatment in Latin America, which entails risks for city water sources, especially in larger cities. We would like to highlight the regulatory changes made to encourage wastewater treatment in Chile.[27]

Information concerning the price of drinking water and sanitation services is often rare and insufficient. Brichetti (2019) conducted research for 49 LAC providers and reported several relevant observations. First, most providers increase prices with consumption and impose strong penalties beyond certain thresholds. This type of pricing can encourage providers to expand their networks in high consumption areas. Second, in many cases, pricing structures rely on fixed charges to cover fixed costs, which may have implications for affordability (particularly for low-income users). Affordability problems are more serious at high consumption levels: residential spending (including local subsidy policies) is moderate and close to the global average for consumption levels close to 200 m^3 per year, but it increases in relative terms for high levels of consumption (see Figure 23).

Table 7
Percentage of the population whose wastewater is treated in Latin America
Source: Compiled by the authors, based on data from JMP (2018).

Country	Urban	Rural
Argentina	-	-
Bolivia	15	1
Brazil	43	5
Chile	81	17
Colombia	14	2
Costa Rica	13	3
Cuba	25	7
Ecuador	22	7
Guatemala	-	-
Honduras	23	2
Mexico	49	18
Nicaragua	-	-
Panama	-	-
Peru	47	10
Paraguay	7	1
Dominican Rep.	6	1
Uruguay	-	-
Venezuela	-	-

Figure 24 illustrates disparities within Latin America in terms of the price per m^3 of consuming 17 m^3 of drinking water per month (with low levels in Panama and Peru and a price of over USD 2.50 per m^3 in Brazil and Uruguay).

27 See Chile's Regulations on releasing liquid waste into sea water and land surface water (Norma de emisión de residuos líquidos a aguas marinas y continentales superficiales, 2001).

Figure 23
Monthly spending on drinking water by residential users with consumption levels of 17 m³ and 100 m³ (USD)
Source: Compiled by the authors, based on Brichetti (2019).

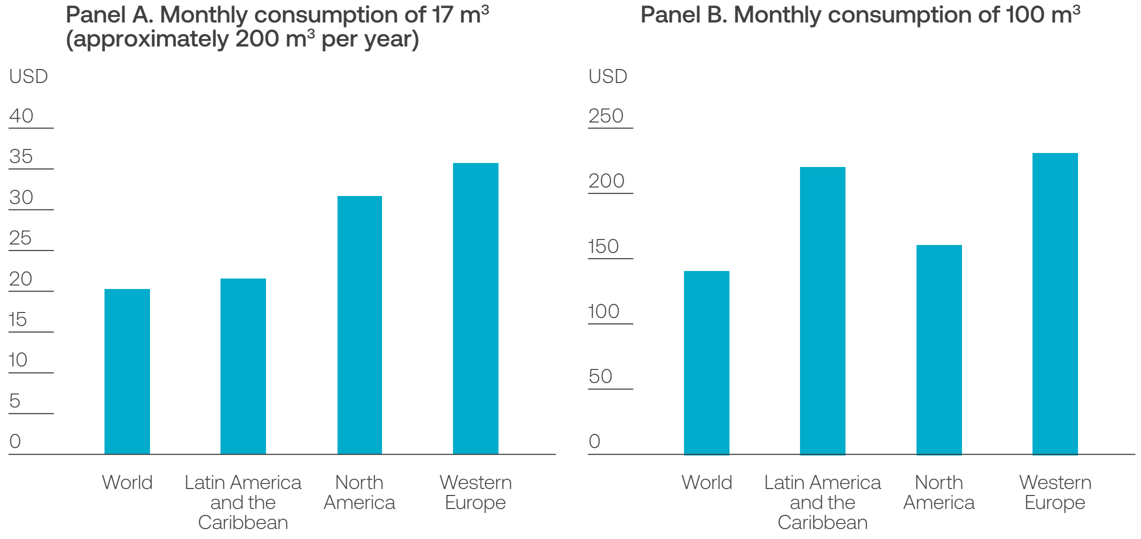
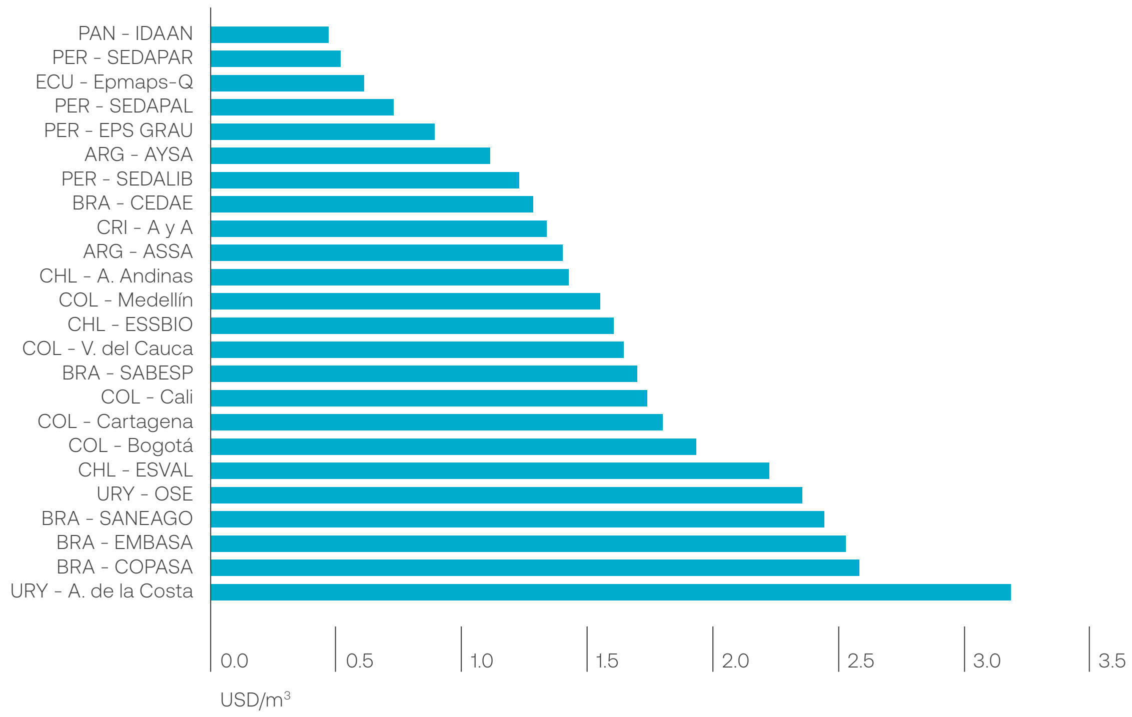


Figure 24
Price per m³ of drinking water for users with monthly consumption levels of 17 m³ (approximately 200 m³ per year), 2018
Source: Compiled by the authors.



Logistics

The lack of measurements of freight transportation performance makes it difficult to look into this sector. One of the reasons for this lack of data is that national and local governments can only intervene to a limited degree, by setting and monitoring basic rules and regulations. However, freight transportation is an important service for economic activity in many sectors, so potential service gaps should be examined. Box 1 and 2 briefly describe the characteristics of potential indicators for service gaps in urban and interurban logistics.

Box 1
Service gap indicators in urban freight transportation

Source: Steer (2020).

We could approximate gaps in urban freight transportation by considering key links in its value chain. This would enable service gap indicators to identify the factors that determine successful freight reception: delivery lag, delivery cost or share of the cost of logistics relative to the total cost of the product or service, and condition of the freight once delivered.

These factors not only enable an examination of the service gap in absolute terms, but also allow us to compare different groups based on their characteristics. These include sociodemographic characteristics (for instance, the cost and quality of medicine deliveries between two hospitals, based on the socioeconomic characteristics of the areas they are in), logistics service type, the actors involved (business-to-business [B2B] or business-to-consumer [B2C]), the applicable trade or industry code, and the group or segment for the recipient, the producer, or the seller.

However, we need to note that the lack of data makes it more difficult to think of an ideal scenario that provides a normative yardstick for any gaps. This could be solved through an absolute comparison with the most common values or the expected values in terms of time, cost, and certain delivery quality specifications that are measured. These parameters can be found in research like LOGUS (SPIM-Taryet, 2019).

Box 2
Service gap in logistics
Source: Capelli and Gartner (2020).

One proposal to look into the service gap involves conducting more thorough logistics performance research by product type and supply chain. There are precedents of product chain analysis in LAC, but it has never been systematic or uniform at a regional level.

Supply chain analysis involves examining all costs associated with certain logistics operations. One approximation of these characteristics could be more costly but would enable us to identify needs associated with specific problems and to adopt alternatives to address bottlenecks and other difficulties. It would also enable us to look into specific corridors and to compare the logistics performance of similar products for different Latin American countries and compared to other countries.

An analysis of Peru's export food chains (World Bank, 2016) exposed the main cost challenges in export logistics and made it possible to classify them into two major categories of analysis, based on chain integration. On the one hand, logistics chains for grapes and yellow onions are mostly integrated and show progress in terms of digitalization, especially concerning streamlined procedures and fleet management tools. These are important improvements, since logistics involving these products require a cold chain. On the other hand, coffee, cocoa, and quinoa have non-integrated logistics chains without digitalized processes. Different agents emerge in each link in this chain, from small farmers who produce and harvest crops to intermediaries who store crops and exporters located in the country's main cities. In general, these non-integrated chains outsource transportation at every stage and resort to informal transportation services that are highly fragmented and experience diseconomies of scale.

Vertical integration (plus digitalization) seems to have more advantages than segmented chains. This is because products with the latter type of chain usually face higher logistics costs (20–34% higher) than products with integrated chains, especially due to informality in road transportation services and to the bad state of rural roads (70% of which are in poor or very poor shape).

A further example is floriculture in Colombia (ECLAC, 2016), whose main challenge lies in the documents required in the export system, with too much bureaucracy given a flower's life cycle. The Colombian government has therefore prioritized a streamlined documentation policy, simplifying and digitalizing processes to make major progress in cost reduction.

Service gaps in infrastructure sectors

In LAC, service gaps are present in various infrastructure sectors. While deficiencies in specific dimensions are particularly common, there are basic shortcomings that remain unresolved and cause deficits in the provision of these essential services.

For example, in the case of electricity, the main problems appear to be in the quality dimension, with long and frequent service interruptions. Deficiencies are also common in the form of leaks, although these countries' energy mix means the cost of power generation is low. While the average nominal tariff (for residential users) is low compared to regions like Europe and the United States, it amounts to a higher percentage of income. Finally, access is virtually universal, although there are some lags in rural areas.

In the urban passenger transportation sector, problems emerge in the three gap dimensions: a broad capillary coverage by informal services and, in some cities, long distances to access the bus service; significant travel times in high-occupancy settings (in public transportation), with unfavorable conditions for women; and cost disparities among the cities that were examined, with some cases where the cost is too high relative to the income of the most vulnerable households.

Pending challenges that affect service gaps are also apparent in other sectors. For example, access is the main problem in the water and sanitation sector (especially in rural areas and in sanitation services), and it becomes even worse if we focus on access to good-quality services. A high proportion of non-revenue water is another recurring problem in Latin America. The price for users (at low consumption levels) is approximately the global average—partly as a result of the sector's funding policies (revenue obtained from users, compared to subsidies)—but significant disparities are apparent between countries.

In this context, digitalization can provide useful tools to reduce current service gaps, although it also poses further risks and challenges that need to be addressed so benefits can be reaped. This issue is discussed in Chapter 2.

2

Digital technology and its impact on infrastructure sectors

Changes in the ICT sector and the digital divide

Convergence among the telecommunications, electronics, and computer industries has consolidated over the past two decades. This trend has been favored by the growing geographic availability of broadband wireless access, by the widespread penetration of mobile terminals with considerable processing power, and by the decreasing costs of transmitting, storing, and processing large volumes of data. One of the main consequences of this technological expansion has been the emergence of a digital economy, where information and communications technologies (ICTs) have become a key driver for innovation in modern economic systems. These changes have fueled debate on the impact of ICTs on the conditions of production and on society's wellbeing. This accelerated process of technological change, known as the Fourth Industrial Revolution (Schwab, 2016), affects society and the economy in various ways. First, a larger share of the world's population is using global communication platforms (like social media) that enable people to connect, and to access and handle a huge amount of new information. Second, this process makes it easier for new producers and rivals to access markets (for instance, through marketing and distribution platforms). Third, consumers are increasingly involved in production and distribution chains (Xu, David, and Kim, 2018). These aspects are starting to affect and define the way commercial transactions are conducted, as well as consumer expectations on the quality of goods and services.

Traditionally, digitization has focused on data generated by individuals, firms, and governments, and by the transactions they engage in with each other. More recently, these data have started to be integrated into infrastructure, for instance through the Internet of Things (IoT). These data are transmitted through communications networks (4G, 5G, and LoRa, among others). They are cleansed, validated, and analyzed using various technologies (cloud computing, big data, Blockchain) and enable the adoption of new production equipment (involving, for example, robotics), process automation, machine learning, artificial intelligence (AI), and deep learning. On a different level, the ICT sector is undergoing structural changes with varied—and as yet not fully known—immediate effects. New technologies are multiplying the potential applications of ICTs and expanding their use in other sectors (which triggers externalities). This technological change allows us to turn assets that were originally thought of as ICTs into inputs or sources of support for activities that range from transportation, medicine, trade, and the financial sector to security and other infrastructure sectors. The activities, projects, and initiatives that are being affected by these new technologies include industrial automation, smart cities, self-driving vehicles (which interact with each other and with road infrastructure and include trucks, trains, and even aircraft), and remote execution activities (including surgery, with medical specialists who are physically somewhere else leading robotic surgery). Box 3 describes the main features of 5G technology, which facilitates a lot of these improvements.

In this context, the main features of digitalization are connectivity (the availability of access and transmission networks so individuals and objects can connect), interoperability (connections, protocols, platforms, and standardized systems that enable expanded scale and range), decentralization (systems and subsystems for management and decision-making processes), virtualization (the ability to connect physical systems with virtual models and simulations), and real-time capabilities (to facilitate decision-making processes as well as the management of infrastructure and other assets). Considering all these aspects together enables societies to optimize their benefits (see further details in CAF, 2020a).

Box 3
Fifth generation technology and standards for wireless communications (5G)

Source: Celani (2020).

5G technology promises higher speed than current 4G networks, due to a new form of spectrum management. 5G standards use a new beam steering technology that connects users through smaller, better-targeted radio signals (known as millimeter waves) transmitted from a base station, instead of a broader signal that is sent to all mobile devices. This involves an expansion of the frequency spectrum used in data transmission. The table summarizes the main differences between this technology and 3G and 4G technologies.

Table
Comparison of mobile access technologies

Characteristics	3G	4G	5G
Bandwidth	2 Mbps	10–30 Mbps for mobile connections and up to 60 Mbps for fixed-access connections	>80 Mbps for mobile connections and up to 3 Gbps for fixed-access connections
Cell coverage (mobile)	Up to 100 km in rural areas	Up to 100 km in rural areas	Up to 80 km in rural areas
Mass connectivity	2,000 users per km^2	2,000 users per km^2	>200,000 users per km^2
Ultra low latency	>100 ms	10–100 ms roundtrip time	1 ms
Ultra mobility	<200 km/h	Up to 350 km/h	Up to 1,000 km/h
Ultra low power consumption	90% more consumption than a 5G network	90% more consumption than a 5G network	Up to 10 years of battery life for low-power devices

In terms of infrastructure, 5G technology differs from its predecessors in that the new beam radiation requires a much more dense node network. A further characteristic of this network is what is known as full duplex technology, which seeks to solve the problem of signals that only transmit data in a single direction at a time. Full duplex technology makes it possible to temporarily redirect all signals transmitted in opposite directions to a single channel, using high-speed switches. Instead of clashing, signals travel along parallel paths, ensuring more efficient traffic and low latency. This is an essential property for IoT, since it enables “dialogue” between different devices.

Finally, the expected traffic volume requires larger fiber optic backup than a 4G network. This is why countries with less developed fiber optic infrastructure are likely to encounter limitations for 5G development.

The digital divide in Latin America

A high degree of ICT coverage and development is necessary to start implementing digital innovations in infrastructure. This subsection therefore presents a diagnosis of the digital technology sector in Latin America.

Divide between households and digital infrastructure components

The term *digital divide* became popular in the 1990s and was originally defined as the gap between individuals with access to ICTs and individuals who partially or fully lacked that access. Examining the digital divide in ICTs shares some dimensions with gaps in other sectors (transportation, energy, and water, among others), including access (penetration and coverage), cost (affordability), and quality.

For instance, Table 8 reports the household digitalization index developed by the CAF[28] in the context of its Digital Ecosystem Development Index. This evidences a clear divide (a relative gap) between the group of developed countries (OECD countries, with a digitalization indicator of 74.3) and LAC countries (with an average of 50.7). Individually, Chile and Brazil have smaller relative gaps with developed countries, while Bolivia and Paraguay are at the other extreme.[29] In general, Chile performs well in all dimensions, while Uruguay performs well in terms of penetration and coverage, Argentina performs well in terms of

Table 8
Access, quality, and affordability in selected countries, 2019
Source: Indicators selected from CAF (2020b).

Region or country	Household digitalization index	Household penetration	Coverage	Quality	Affordability
OECD	74.3	76.9	73.8	43.1	85.0
LAC	50.7	54.4	58.4	15.0	57.7
Chile	66.7	75.5	64.5	28.0	72.4
Costa Rica	63.5	68.8	59.0	14.2	74.1
Brazil	60.7	58.1	63.0	17.4	68.4
Mexico	57.4	55.1	59.1	13.8	72.5
Argentina	55.2	73.1	67.4	22.4	45.1
Uruguay	54.4	72.1	70.6	18.5	71.0
Colombia	52.6	55.1	62.1	12.1	56.1
Panama	47.5	62.3	52.7	20.4	66.7
Peru	45.9	47.1	50.5	14.9	60.4
Ecuador	36.4	48.0	59.9	13.9	50.9
Paraguay	29.8	41.7	55.3	13.3	42.4
Bolivia	20.3	31.4	49.2	10.4	24.3

Note: The household penetration index is made up of 10 indicators (fixed and mobile broadband penetration, telephone service, pay TV, Internet, apps, and smartphones, among others). The coverage index weights seven indicators (mobile coverage in 2G, 3G, 4G, and 5G networks and using fixed broadband services transmitted through fiber optics, electricity, or any other type of cable). The quality index is made up of six indicators (classified by download speed and critical infrastructure). The affordability index includes six indicators (affordability of fixed and mobile broadband services, pay TV, prepaid mobile data, and mobile phone services). The LAC average includes 20 countries. This table shows a subset of them.

28 The household digitalization index is an average of 20 indicators grouped in three categories: penetration (adoption, device availability, and use), affordability of digital services (whether fixed or mobile networks), and adoption of B2C digital platforms (social media, apps, e-commerce, and online services). See the methodology used to develop the CAF Digital Ecosystem Development Index in CAF (2017) and CAF (2020b).

29 To illustrate this, 67% of the region's households have Internet access (ECLAC, 2020).

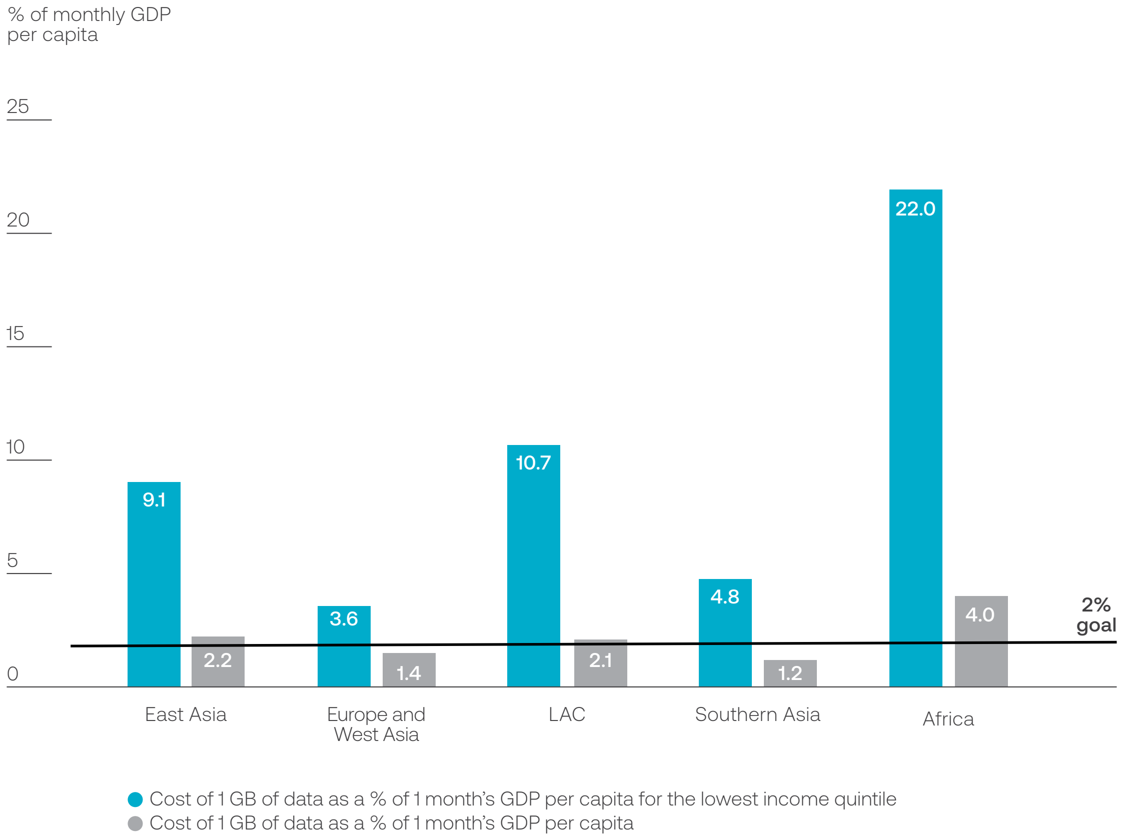
access and quality (but services are considered costly for users), and Panama has good quality indicators. At the other extreme, Bolivia and Paraguay have poor indicators in all dimensions, and they are joined by Peru for coverage and by Colombia for quality.

In most developing countries, and even in some developed nations, Internet users in rural areas have slower connections. Further, compared to users of fixed wireless services (Wi-Fi) or cable connections, people who have Internet access through mobile devices are exposed to comparatively low broadband speeds, latency periods, and much higher costs, with restrictions and traffic quotas.

The difference in the quality dimension is partly due to download speeds. For example, the average download speed on mobile broadband connections stands at 38 Mbps in the OECD and at 21 Mbps in LAC. In fact, in 2019, the OECD already had 20% 5G coverage, while this technology had not yet been implemented in Latin America.[30]

Finally, an alternative way to approximate the affordability dimension is the share of standard

Figure 25
Share of spending on data, relative to one month's GDP per capita, 2018
Source: GSMA (2019).



Note: The report does not disaggregate the data by country within each region.

30 CAF (2020b) notes that, at the company level, the adoption of basic digital technology in Latin America is similar to that in advanced countries, but digitalization within the labor force remains limited. See further details on the adoption of disruptive technologies in the next subsection.

In Latin America, progress has been made in household digitalization, but a relative divide to developed countries persists in coverage, quality, and affordability.

spending or a standard service package relative to some measurement of personal income (usually GDP or gross national income [GNI] per capita). According to CAF (2020b), a monthly subscription to mobile broadband services is equivalent to 4.6% of monthly GNI per capita in Latin America (compared to 0.8% in the OECD). Figure 25 shows estimated spending in a data package relative to average income and to the income of the first quintile of the population based on the distribution of income. Latin America has high costs relative to the global average, but these costs are particularly high when we compare vulnerable groups in different regions.[31]

In recent years, the (relative) digital divide has been assessed considering socioeconomic aspects (Tirado, Mendoza, Marín, and Mendoza, 2017). This could lead to more precise explanations concerning the adoption, use, and enjoyment of these services. One example that was mentioned above is the relative gap between rural and urban users in the quality dimension. If someone lives in a city and attains a higher educational level, they will probably use the Internet more intensely and require a higher-speed (better-quality) service. If a rural user has a similar service on offer, they will probably use it less or opt out of access because their needs are met with a lower-potential plan.

A new generation of indicators based on compound indices has addressed this issue, incorporating data that enable a classification of population groups from demographic and economic perspectives. One example of such compound indices is the digital divide index (DDI)—developed in the context of the European Union's Statistical Indicators Benchmarking Information Society (SIBIS) project—which combines four sociodemographic factors (gender, age, education, and income) relative to indicators linked to ICTs. In general, the groups with the most significant relative deficits in the European Union have been women, adults over the age of 50, individuals with low levels of education (who dropped out of formal schooling at 15 or younger), and the lowest-income group (the quartile with the lowest income among respondents). For Latin America, ECLAC (2020) says that over 90% of all rural households in Bolivia, Paraguay, and Peru have no Internet connection, while in countries with better digital development, like Chile or Uruguay, the rural access deficit stands at approximately 50%. The divide by age group, in turn, is greater among children aged 5–12 and among adults over the age of 65. Finally, 33% of all households in the region have limited or no access to the Internet, a percentage that is as high as 42% for the 40% of the population with the lowest incomes.

31 While this report does not seek to examine an affordability threshold, it is worth noting that, for broadband services, the United Nations Broadband Commission has set it at 2% of monthly GDP per capita.

Other components of the Digital Ecosystem Development Index

The analysis conducted above focused on service gap dimensions linked to household digitalization. However, as explained by the CAF's 2020 Digital Ecosystem Observatory (CAF, 2020b), the Digital Ecosystem Development Index also takes into consideration the digital economy, state digitalization (which makes up the vertical pillar, along with household digitalization), and digital infrastructure, public policies, regulations, and human capital and the labor force (which make up the horizontal pillar). Several indicators of these dimensions are linked to disruptive technologies (see examples in Box 4).

There is also a subset to digital ecosystem indicators, particularly those linked to technology development. These are summarized, for LAC countries compared to OECD countries, in Table 9. A complete outlook can be found on the Digital Ecosystem website[32] and in CAF (2020b).

Table 9 shows, on the one hand, that almost all the indicators that were selected improve after a decade, as might be expected in a technology adoption context. On the other hand, however, Latin America has not managed to close the divide relative to developed countries (represented here by the OECD). In Latin America, progress has been made in the end

Table 9
Selected indicators included in the Digital Ecosystem Development Index, 2010 and 2019
Source: Indicators selected from CAF (2020b).

	2010		2019	
	LAC	**OECD**	**LAC**	**OECD**
Digital Ecosystem Development Index	**29.5**	**52.0**	**42.4**	**65.1**
Digital economy	**16.2**	**44.2**	**22.4**	**54.7**
Digitalization of productive processes and related services	24.9	39.8	31.0	52.0
Advanced digital adoption				
Data center and equipment (index)	1.6	3.8	1.5	4.1
Penetration of machine-to-machine communication (per 100 residents)	1.4	2.0	7.0	25.0
Investment in big data (index)	3.8	5.1	3.6	5.6
Investment in cloud services (index)	1.2	3.3	1.4	4.4
Weight of digital industries	19.1	48.5	20.9	58.8
Digital manufacturing (% of GDP)	2.0	2.5	2.0	2.4
Spending on digital advertising (USD per capita)	0.2	7.8	5.0	45.6
Innovation	8.1	38.2	12.1	48.7
State digitalization	**36.1**	**59.1**	**50.6**	**71.5**
Administrative procedures and services	39.4	68.7	39.6	68.9
Customs clearance times (index)	2.4	3.5	2.5	3.6
Ease of trading across borders (index)	62.5	91.0	69.8	91.7
Electronic government platforms	21.1	37.7	54.2	70.9
Government transparency	47.8	70.9	58.1	74.6

32 The website is available on https://www.caf.com/app_tic/.

Box 4
Disruptive technology development

Source: CAF (2020a).

The ICT sector is very dynamic, so we should not be surprised that new technologies or adjustments involving existing technologies constantly emerge, each of which can be applied to different degrees to the rest of the economy. We will now list some of the main technologies that are currently growing and developing.

- Internet of Things (IoT): A system where all devices (infrastructure, vehicles, machinery, and other pieces of electronic equipment) are interconnected through one or several networks to generate and share data.
- Cloud computing: On-demand access to computer functions and applications, enabling exponentially scalable solutions and new pay-per-use models.
- Blockchain: Technology that uses algorithms to facilitate indisputable transaction records, with no need for an intermediary or a central administration.
- Big data: Use of a large volume of highly volatile and valuable data (structured data, sensor data, audio, video, and social media data) to develop intelligent solutions.
- Robotic process automation (RPA): Technology that is based on programmed software and replaces human beings to carry out manual, repetitive rule-based tasks through process automation.
- 3D printing: Technology that enables an efficient production of unique three-dimensional objects wherever and whenever they are needed.
- Artificial intelligence: Cognitive systems that combine automatic learning with the ability to interact using natural language and to create knowledge based on data.
- Digital platforms: Use of digital technology to connect individuals in new, powerful ways.
- Robotics and drones: Technologies that replace human labor on a large scale, not just in routine tasks but increasingly in service provision.

These technologies have enabled the emergence of new productive and organizational models. Some examples are co-creation (initiatives that bring stakeholders together to jointly create a valuable product, with great potential in smart cities), mass provisioning (which seeks to procure services, ideas, or content by requesting contributions from a large group of people, and especially from an online community, instead of requesting it from employees or from traditional suppliers), or the sharing economy (that uses information technology as a means to bring together supply and demand for goods, services, or data in a different way).

user sector (households), but the relative divide persists due to lags in other components. For example, disruptive technological developments linked to the digitalization of productive processes (like data centers or investment in big data) have evolved as in advanced countries, but other developments—including machine-to-machine communication (M2M)—have changed much more slowly. The technological innovation rate and digital promotion are two further aspects that show Latin America's relative lag. Finally, this table highlights the role of the state in the adoption of digitalization, by contributing to reducing both the absolute and the relative divides. This would mainly involve measures to improve state transparency and facilitate cross-border commercial transactions, without simplifying customs procedures.

Other trends in the electricity and urban transportation sectors

Long before the changes and acceleration that the crisis brought about by the COVID-19 pandemic caused in the digital sector in 2020, other trends could be observed in the infrastructure sectors prioritized in this report (electricity and urban transportation). These trends accompanied—and to some extent supplemented—the advance of digitalization.

This section reviews sectoral trends and goes on to conduct (in the next two sections) a combined analysis of each priority sector. This enables an anticipation of business models that stem from these changes and their implications concerning regulations, investment, and policy.

Electricity: Service electrification and decentralization of production and consumption

In the electricity sector, we can observe—beyond the digitalization trend that will be discussed later—changes involving the electrification of certain activities and areas, as well as a decentralization of production and consumption patterns.

The electrification of specific sectors in the economy—transportation, home appliances, and so on—is one of the trends that can prove crucial to achieve the decarbonization targets required to meet the climate objectives of the SDGs. For several years, some activities have already been switching from polluting sources of energy to electrical energy (for instance, electric cooking and heating). The electrification of transport—whether in private vehicles or public transportation vehicles—is less common, but it presents significant opportunities to optimize network use (particularly if it includes the option of distributed storage) and speed up environmental gains.[33]

A further recent trend in this sector involves the decentralization of certain activities at the level of end users, which gives these activities a more active role in the sector through innovations in the fields of distributed generation and storage, and in response to demand. This complements progress made in non-conventional renewable energy (NCRE), including wind and solar energy, biomass, biogas, and small hydroelectric generators with a capacity to generate less than 50 MW,[34] some of which (particularly solar variants) adapt well to small-scale production.

NCREs have become more relevant in this sector as their cost has fallen and as the impact of fossil fuels on climate change has become more evident. With the exception of biomass, these sources of energy have zero generation costs.

33 For this transition to achieve environmental benefits, the life cycle of electric vehicles—including, for instance, their batteries—and the incremental electricity generation they require must pollute less than the life cycle of the old vehicle and the fuel it used. For example, if marginal electricity generation is done using fuel oil or coal, exchanging a gas-combustion vehicle for an electric vehicle will not necessarily deliver these benefits. The same can be said of electric heating when it replaces heating using natural gas (in countries where this is feasible).

34 Small hydroelectric generators (with a capacity to generate less than 50 MW) are treated differently from hydroelectric dams, which are considered conventional renewable energy sources (or simply renewable energy sources).

The share of these new sources of energy has grown fast in some LAC countries. In 2017, NCRE generation amounted to 46% of total generation in Uruguay (following significant investment in this sector, particularly in wind energy), 41% in El Salvador, 22% in Costa Rica, 13% in Chile, and 9% in Brazil (see Table 10). In other Latin American countries, the share of renewable sources of energy has increased, but it is likely that their growth will face challenges over the medium term, given an abundance of conventional sources of energy. This is the case with hydroelectric power in Paraguay and Costa Rica and with power generation based on abundant fossil fuels in Argentina and Bolivia.[35]

Table 10
Percentage of renewable energy in electric power and generation, 2017
Source: Fischer (2020).

Country	Electric power		Generation	
	Renewable	NCRE	Renewable	NCRE
Uruguay	82%	48%	98%	46%
El Salvador	56%	29%	74%	41%
Costa Rica	86%	17%	98%	22%
Chile	45%	16%	43%	13%
Brazil	82%	18%	81%	9%
Panama	64%	11%	72%	6%
Mexico	25%	10%	16%	6%
Peru	43%	3%	51%	2%
Bolivia	36%	6%	26%	1%
Colombia	70%	0%	87%	1%
Argentina	32%	1%	31%	0%
Paraguay	100%	0%	100%	0%

Notes: Electric power measures generation capacity at a given point in time (in MW). Generation is total energy generated in a given period of time (for instance, GWh per year). Countries are listed in descending order in terms of NCRE generation. Data from 2017 or the closest available year.

Wind- and solar-based energy sources are being adopted fast, so these percentages may change within very few years. For example, NCRE capacity in Chile increased from 16% in 2017 to 22% (5,293 MW) in 2019 and is expected to grow by more than 50% (2,973 MW) by the end of 2021, if we consider projects that are under construction.

However, the current conditions suggest that small-scale generation with competitive costs has not yet been developed. For example, the levelized cost of solar energy on a residential scale is four times higher than the levelized cost of solar energy on a large scale (see Table 11).[36] While data in the table do not incorporate transmission costs, these savings fail to make up for higher investment costs.[37]

Despite these differences, distributed generation has expanded in Europe, the United States, and Canada[38] (with subsidies in place), although it is still early days in terms of storage capacity. This component is set to become increasingly dynamic as battery price goes down. While there are some distributed facilities available in Latin America, they are used in isolated areas with poor service quality, on the rooftops of buildings operated by companies for whom it may be convenient for financial reasons, or for ideological reasons (Fischer, 2020). This may be why non-conventional distributed generation has only experienced limited growth. For example, after the Citizen Generation Act (*Ley de Generación Ciudadana*) was passed in Chile, the number of registered facilities stood at 4,765 (by October 2019) with an electric power of almost 29 MW and a rate of growth of 1–2 MW per month. In Brazil, in 2019, the availability of non-conventional renewable distributed generation stood at 766 MW from more than 72,000 facilities and generated a total of 896 GWh. In both countries, these are tiny amounts, close to 1 thousandth of total installed capacity and generation. Given the cost of these technologies, it is likely that, if Latin American countries try to expand distributed generation,

35 In Bolivia, drops in the productivity of natural gas fields might change energy policy goals in the future.

36 The levelized cost of generating electricity with a given technology is the economic value that includes all costs throughout the project's life cycle: initial investment, operations and maintenance, capital costs, and any required inputs.

37 For reference, transmission costs in the United States are equivalent to 20% of the system's transport and management costs (which do not include generation costs), equivalent to less than USD 10/MWh (Energy Institute, 2018). In England, transmission costs amounted to 4.5% of the price paid by end users in 2016–2017 (National Grid, 2020). It is worth noting that large-scale renewable energy involves an increase in the demand for transmission, and therefore an increase in transmission costs.

38 Distributed generation refers to the generation of electrical energy, mainly from renewable sources, through small-scale plants located close to places of consumption. This entails a paradigm shift relative to centralized energy generation.

Table 11
Levelized cost of energy by type, 2019
Source: Lazard (2019).

Technology	Min (USD/MWh)	Max (USD/MWh)
Photovoltaic solar energy, residential	151	242
Photovoltaic solar energy, commercial or industrial rooftop	75	154
Photovoltaic solar energy, community-run	64	148
Photovoltaic solar energy, crystal-based, large scale	36	44
Photovoltaic solar energy, thin-film, large scale	32	42
Solar thermal energy with storage	126	156
Geothermal	69	112
Land-based wind energy	28	54
Offshore wind energy (only an average)	89	89
Gas peaking	150	199
Nuclear	118	192
Coal	66	152
Combined-cycle gas	44	68

they will need to adapt their payment schemes to distribution, as well as subsidizing residential generation to encourage the adoption of these technologies.[39]

If electric vehicle use becomes widespread, households will also be able to provide storage services, in what is known as bidirectional vehicle-to-grid (V2G) services. A standard electric vehicle has a storage capacity that enables consumption of at least 20–25 kWh. Considering average residential consumption of approximately 1.3 kWh per person per day (Colombian values) or 2 kWh per day (values for Chile and Argentina), energy stored by an electric vehicle ensures consumption for 3–6 days for a three-person household, depending on the country under consideration (2–5 days for a four-person household). This means that a household with an electric vehicle and adequate bidirectional connections can supply electricity both to the household and to others in the network during a brief power outage. Further, an electric vehicle can provide frequency stabilization services at a distribution level. All these services are valuable for the system.

The electricity sector can be decentralized through energy efficiency, as well as through distributed generation (Astarola et al., 2017). Energy efficiency refers to the efforts of different stakeholders in the electricity sector to reduce the use of energy while providing the same services. The term has been relevant in energy policy since the 1990s. One Latin American example documented in Cont and Barril (2012) is Argentina, where the National Program to Ensure a Rational and Efficient Use of Energy (*Programa Nacional de Uso Racional y Eficiente de la Energía*, PRONUREE) was introduced in 2007 with goals that included activities to raise awareness and educate society concerning the importance of energy efficiency. A further example mentioned by these authors is Brazil, where several projects linked to ensuring an efficient use of energy were implemented (Light for all [*Luz para Todos*] program, energy efficiency in public offices, etc.).

39 Subsidies for small-scale generation from renewable sources, intended to promote environmental goals, can have an impact on resource allocation (through price distortions), affect fiscal conditions (depending on how subsidies are funded), and have distributive effects (in particular, regressive effects if subsidies benefit high-income users). On distributive effects, see the subsection “Environmental policies” in Chapter 4.

Urban transportation: Urbanization and climate change

In urban areas, other trends that run alongside digitalization also require significant changes in urban transportation, both public and private: increasing urbanization and concerns about climate change.

Increasing urbanization and city size are important factors, because these are the areas where most passenger transportation is concentrated. Population growth in cities leads to increased use of transportation services and to more related externalities.

Over the past 60 years, all regions in the world have experienced increases in the share of the population living in urban areas. As shown in Figure 26, regions like Southeast Asia (or East Asia and the Pacific) have gone from having 20% of their population living in cities in 1960 to having almost 60% in 2018. Latin America and the Caribbean has seen similar urban growth trends as Southeast Asia and now has a little over 80% of its population living in cities, which makes it the world's second most urbanized region, after North America. LAC cities are also the most dense in the world, but they do not necessarily make the most of such agglomeration (in productivity terms) and instead suffer the externalities (congestion and pollution) associated with transportation (Daude *et al.*, 2017). Further, when cities expand, they face various problems. One crucial issue is the cost of providing services for all residents, which leads to accessibility problems and longer travel times. Finally, urban populations in small and large cities in LAC are expected to continue to increase (Figure 27), further extending the challenges that are mentioned here.

Figure 26
Urban population changes in several regions around the world
Source: Steer (2020), based on World Bank data.

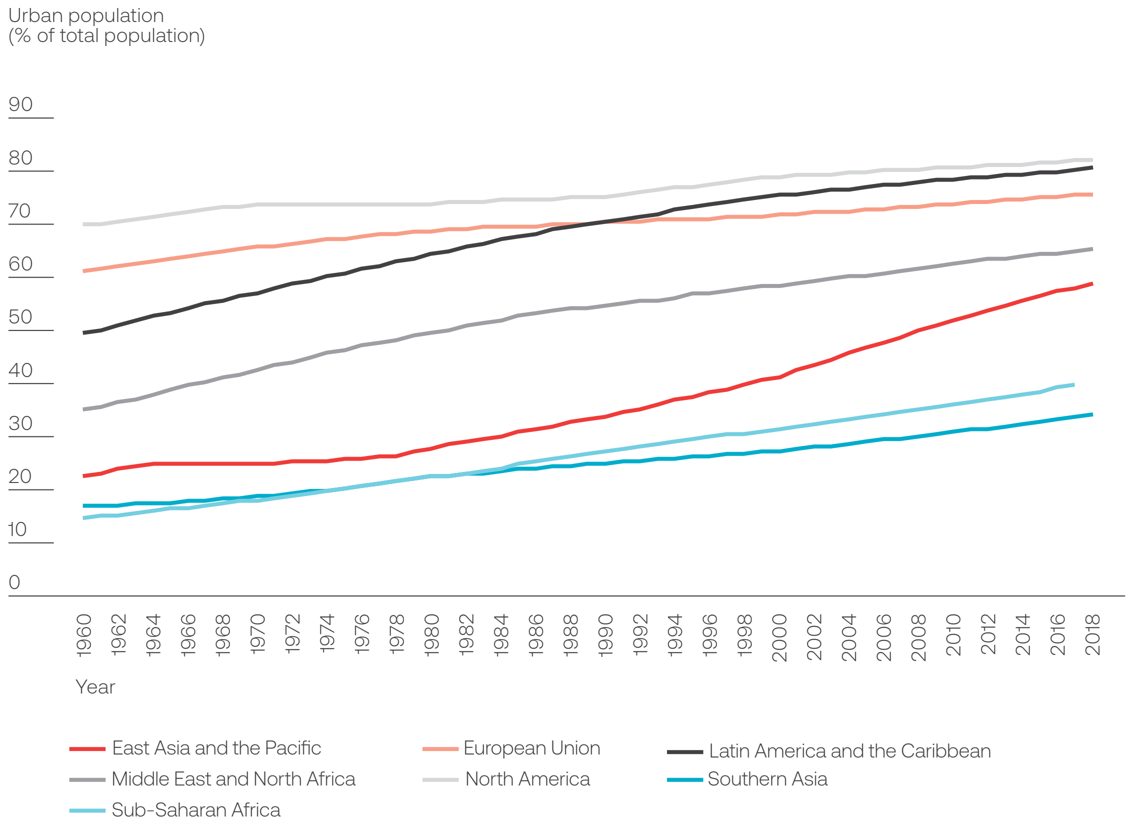
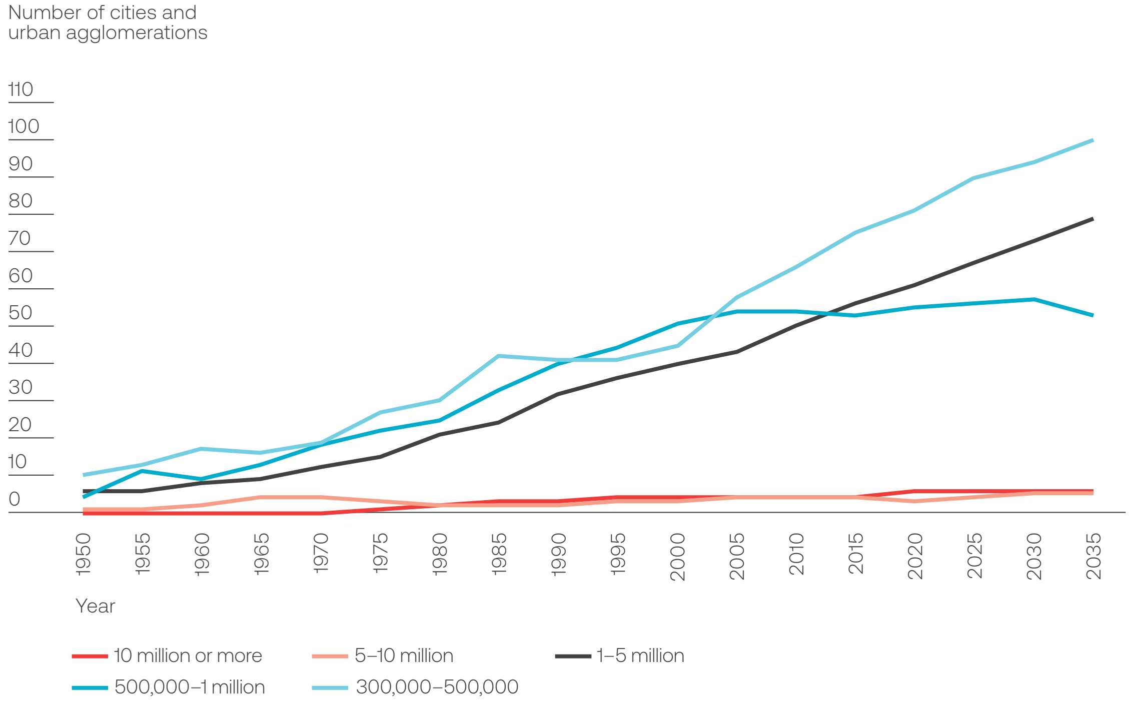


Figure 27
Expected changes in the number of cities or urban agglomerations by population size
Source: Steer (2020), based on World Bank data.



According to data issued by the United Nations Department of Economic and Social Affairs (2018a), there were expected to be more than 507 million people in continental areas of Latin America in 2020, divided in groups of cities as shown in Table 12.[40]

Another relevant current concern is climate change, reflected in Goal 13 of the SDGs. Transportation has a major effect on greenhouse gas emissions. In recent years, it has amounted to 25–35% of total emissions, depending on the country.[41] Measures aimed at reducing traffic and promoting cleaner technologies are therefore increasingly important.

Encouraging the use of public transportation is in line with the first type of measure, while increasing the number of passengers per vehicle promotes a reduction in traffic and emissions per person. With a smaller impact, encouraging shared travel has the same effect as promoting public transportation, as long as it does not involve a substitution of public transportation. Cycling and walking have also

40 Defining what is an urban agglomeration, a city, or a metropolitan area is complex and difficult to specify and apply. For the purposes of this analysis, the definition will depend on the area of study or the survey, because it is limited to the areas included in sampling processes (which do not necessarily reflect rationales linked to political-administrative procedures or to interactions between municipalities). For example, the most recent survey conducted in Buenos Aires involved the Buenos Aires Metropolitan Area, and the most recent survey for Bogotá involved Bogotá and 18 nearby municipalities that do not make up a single political-administrative unit. Recent approximations have involved an examination of the intensity of night lights captured by satellite images. This information should therefore be used with caution when dealing with other measurements. To expand the discussion on defining and specifying what a city is, see Daude et al. (2017).

41 Depending on the source: United States Environmental Protection Agency (EPA, n.d.), European Environment Agency (2019), and World Resources Institute.

Table 12
Size category, number, and population size for cities in Latin America
Source: Steer (2020), based on United Nations data.

Size category	Population size	Number of cities*	Urban population projected for 2020	Percentage of the population living in urban areas in continental Latin America
Megacities	10 million or more	6	94,134,758	18.6%
Very large cities	5–10 million	3	18,031,132	3.6%
Large cities	1–5 million	61	125,874,415	24.8%
Medium-sized cities	500,000–1 million	55	40,223,210	7.9%
Small cities	300,000–500,000	81	31,269,789	6.2%
Very small cities	Fewer than 300,000	N/A	197,643,064	39.0%
Total		**206***	**507,176,368**	**100.0%**

Notes: The data reflect urban agglomerations or metropolitan areas and are not based on political or administrative divisions.
* This is the sum of all cities identified as having more than 300,000 residents.

become more popular in recent years, in line with sustainable mobility models.[42] According to Rivas *et al.* (2019a), cycling and walking had increased their share among modes of transport, from 32% to 36% over a 15-year period, in the cities that were examined.[43]

Concerning the second type of measure, electric vehicles—both private and public—use cleaner technologies than vehicles with traditional combustion engines, which helps to reduce emissions. However, promoting the use of private electric vehicles could cause negative externalities by increasing congestion if they replace the use of public transportation. In any case, the net effect on greenhouse gas emissions of changes that encourage electrification will depend on the final impact they have on energy consumption and on the combination of sources of energy in a given country's energy matrix.

Digitalization in the electricity sector: Smart grids

Traditional electrical grids involve various transmission lines, substations, transformers, distribution lines, and equipment that make it possible to take electricity from generation units to consumers. This technology has virtually not undergone any changes over the past 100 years. The emergence of the new digital economy has opened up an opportunity to redefine the concept of an electrical grid, to assist consumers and generators in a context where better-quality, more complex services can be provided (for instance, services that involve increased automation and enable fast or even real-time decision-making). This is known as a smart grid.

42 The CAF promotes several sustainable mobility projects in Latin American cities, in an effort to develop a more competitive, fair, inclusive, safe, and environmentally sustainable transportation system.

43 Not all cities evidence this increased share. The cities examined by these researchers are Santiago (which went from 23% in 1991 to 41% in 2012), Bogotá (21% in 2005, 29% in 2015), Río de Janeiro (22% in 1994, 33% in 2012), São Paulo (stable at 37% in both 1997 and 2012), Belo Horizonte (40% in 1995, 38% in 2012), and Montevideo (43% in 2009, 36% in 2016).

Digitalization in the electricity sector is changing the way systems work through automation and communication between the various segments in the production chain (generation, transmission, distribution, and commercialization). For example, new technologies are already being used in this sector for programming and execution purposes and to identify and solve failures, among other technical uses. However, the most significant impact of digitalization does not lie in the improvements it brings to the electricity sector's current operations, but in the organizational changes it introduces, specifically in the set-up of electricity markets and in the way transactions are carried out.

From a technological point of view, smart grids are adapted electrical grids that enable bidirectional communication, artificial intelligence, and modern control systems able to even counter cyberattacks (Dileep, 2020).[44] In other words, a smart grid is basically the combination of a physical electrical grid with an information system that connects the network's equipment and components with sensors in consumers' platforms. This improves the reliability, safety, and efficiency (in terms of both cost and energy) of the electricity system, from traditional generators, through transmission and distribution networks, to end users. A growing number of end users have small-scale generation capacity (located within the scope of distribution networks) and storage resources (US Department of Energy, 2010 and 2018).

Smart grids make the most of the benefits of new technologies to turn the current network into one that makes it easier to manage the system and to ensure autonomous control, in order to improve the reliability of various components and their resilience in the face of technical failures. Applying new technologies also helps to improve efficiency in network asset management, integrate renewable energy sources into the system, and develop real-time communications between consumers and providers to increase efficiency and improve service quality. Illustration 1 shows communications and electricity flows among producers, transmission and distribution networks, and consumers in a smart grid.

Generation includes both conventional and renewable energy sources. The transmission and distribution component includes substations and control centers that are connected with sensors (fiber optics, wireless connections, IoT). Control centers include switches, meters, and other technical elements managed through automated processes and smart grid software. The consumer component integrates generation from renewable sources, electric vehicles, and smart meters. Smart meters are also interfaces that enable users to manage their smart assets. This description can be supplemented with other sources of data (that enable forecasts concerning demand, the weather, prices, and so on), which are also normally used in traditional grids but can be more valuable with smart variants.

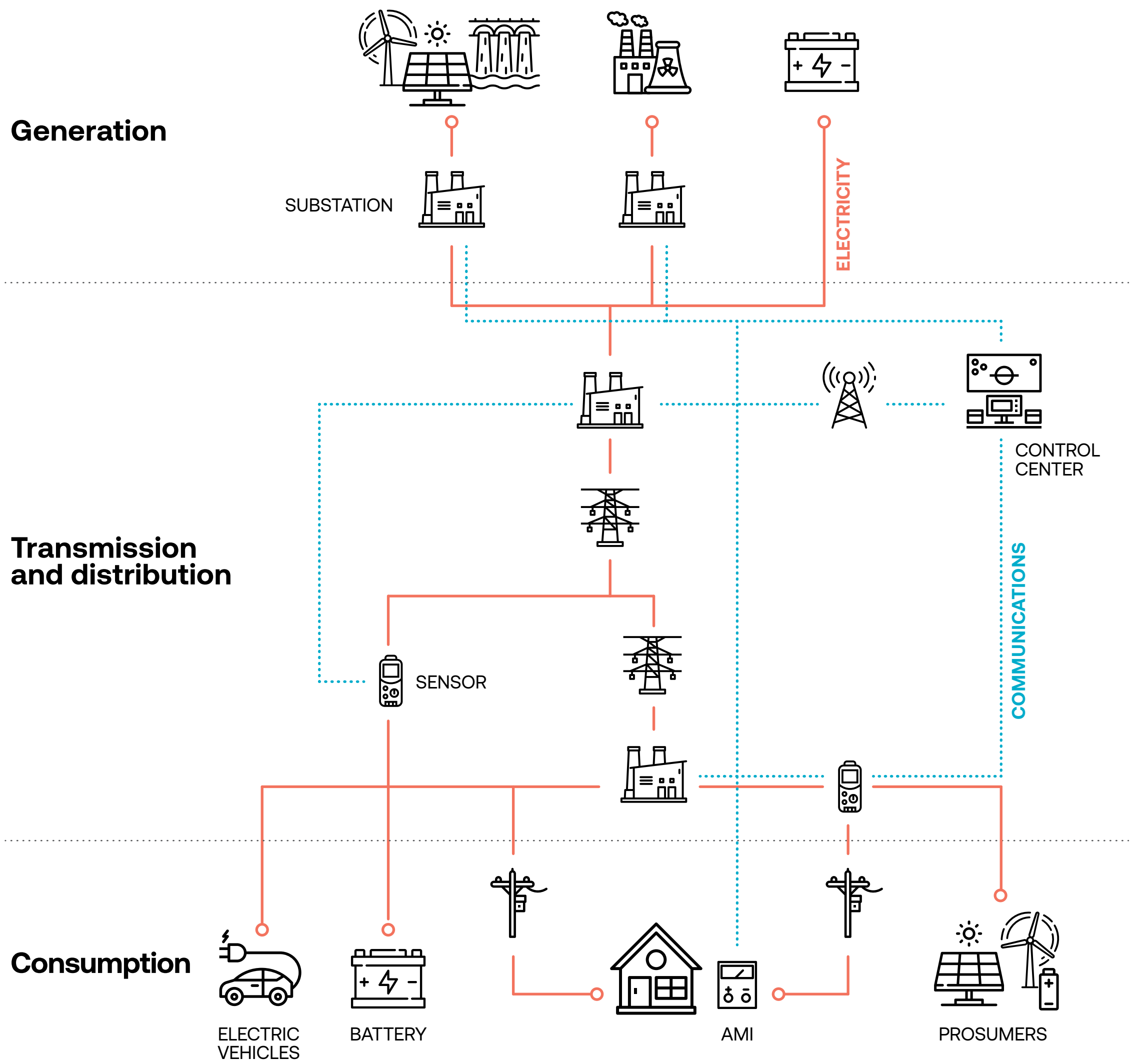
Demand can play an active role if incentives that incorporate dynamic pricing are adopted. Further, control centers are located at points within the grid that enable them to provide energy forecasts to generators and to forecast prices for consumers. The communications networks involved would be local area networks (LAN, enabling consumers to communicate within the home), private networks (set up by service providers), and the Internet (provided by an external Internet service provider [ISP]). Combining these three types of networks enables bidirectional communications between electricity companies and users. The structure of smart grids can be divided into four types of agents: internal data collectors (that is, network sensors and smart meters located at consumption points); companies that provide electricity and control centers; electricity generators; and external data sources. While external data sources are not part of smart grids, they provide information that is useful for smart grid operations.

Different countries currently feature smart grids with different degrees of development and different sizes. Figure 28 shows the technological components that help to develop smart grids with a broad scope.

Automated meter readings do not necessarily change the essence of the traditional system, since they can continue to rely on one-way communications only. These readings are therefore not considered part of smart grids, because they do not enable real-time

44 The author conducts a historical review of the concept of a smart grid. See reference for further details.

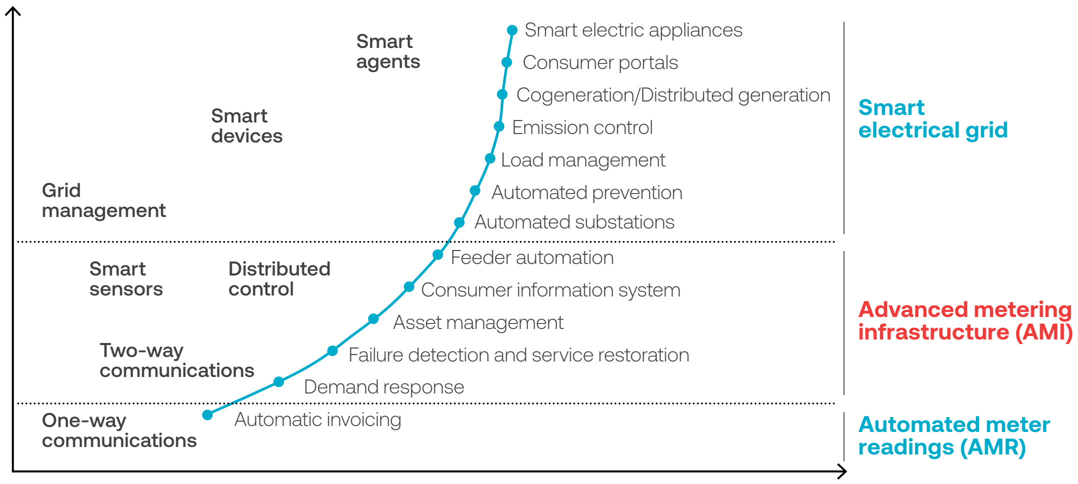
Illustration 1
Basic structure of a smart grid (energy and communications flows)
Source: Compiled by the authors.



Note: AMI (advanced metering infrastructure).

responses to changes in demand. Using advanced metering infrastructure (AMI) enables bidirectional communications with different levels of intensity of use, from responses to changes in demand, asset management, or failure detection to feeder automation. A smart grid really becomes such a thing with automated substations, and it grows more sophisticated through the deployment of chargers, distributed generation, smart devices, and so on. Bidirectional meters are essential for a smart grid to really take off, and it is these meters that allow consumers to be both producers and consumers (prosumers). These networks further enable a reduction in the cost of meter-reading and billing procedures.

Figure 28
Development of and investment in a smart grid
Source: Dileep (2020).



Using AMI systems enables the collection of instant data on individual and aggregate demand. This information is useful for consumers, who can then make decisions in real time about their electricity consumption. AMI system components include smart meters, home automation networks, smart thermostats, and networks connecting meters to local data hubs, meter-generated-data management systems, and collections of data to software platforms (Dileep, 2020). Smart meters also tell us how electricity is being lost through non-technical leaks (mainly theft) and where, which makes it possible to reduce these leaks (Donato, Carugati, and Strack, 2017).

Further, the development of IoT foretells an expansion in the use of behind-the-meter smart devices. These devices can communicate and share data with each other, and they consume electricity. These devices' data technology can improve consumer experience at various levels, including the provision of customized services for consumers and automated management of demand and consumption data per device. These behind-the-meter technologies would be integrated into smart grids and boost their impact on the system, through features like network voltage monitoring and the collection of useful data to enable automated detection of potential power outages, improve energy efficiency, and provide demand projections (Astarloa et al., 2017).

Changes in digitalization in the electricity sector in Latin America: Hurdles and risks

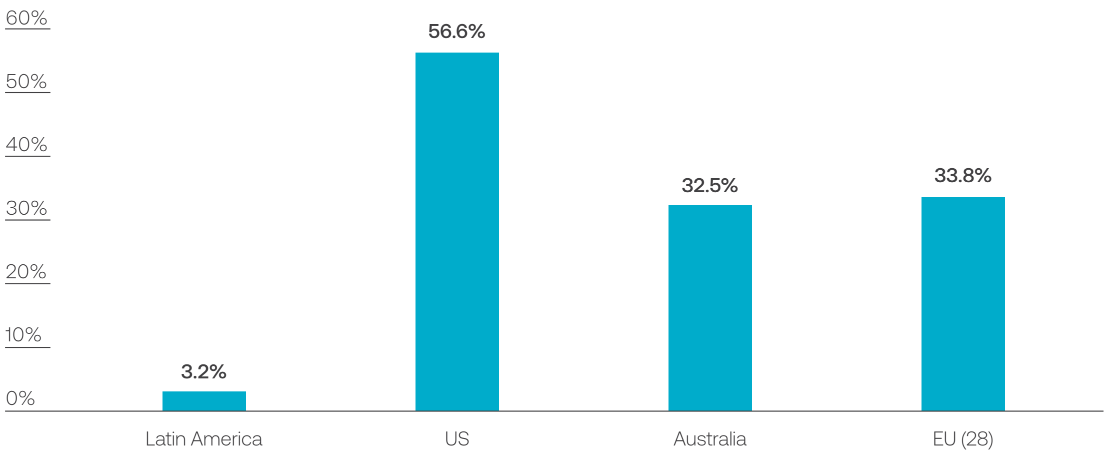
Smart grids are still relatively little developed in LAC compared to other regions, particularly Europe and the United States. However, the companies involved in rolling out smart grids in developed countries are also active in LAC. To look into the degree of convergence between the electricity sector and the new digital economy, we will examine indicators linked to smart grid components: AMI, storage and electric vehicles (EVs), and demand management.

Gaps in smart grid components

Smart metering infrastructure

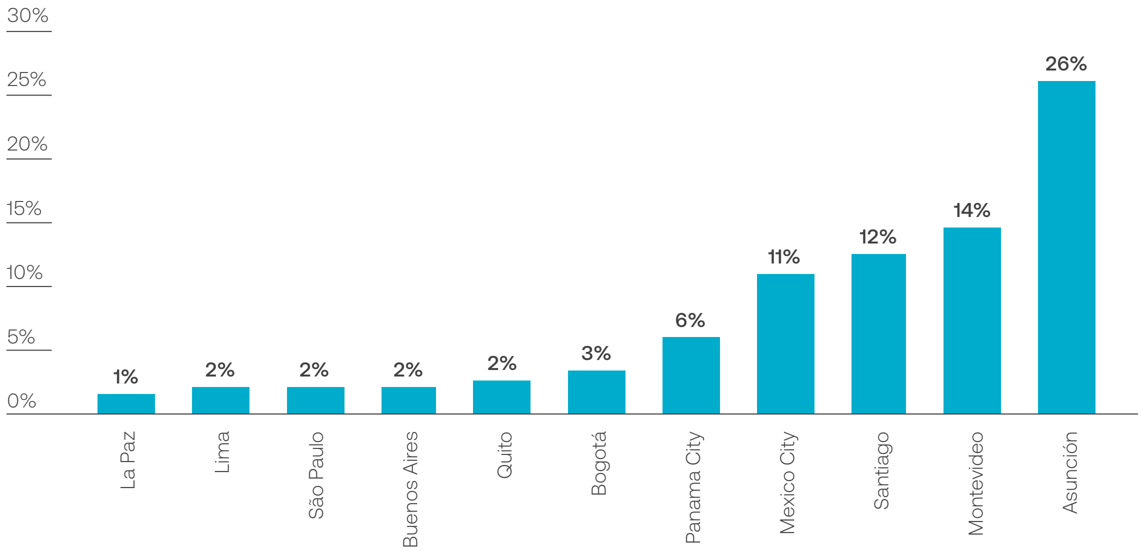
A substantial portion of investment in digital infrastructure on a global scale has focused on smart meters. Figure 29 shows smart-meter penetration in Latin America, the United States, Australia, and the European Union. The deployment of these devices in LAC is still not relevant.

Figure 29
Gap between LAC, the United States, Australia, and the EU in terms of smart meters, 2018
Source: GPR Economía (2020).



Notes: EU data (including 28 countries) show the number of smart meters relative to the total number of meters. Data for LAC, the United States, and Australia show the number of smart meters relative to the number of customers. For LAC, this includes all data for the main distribution companies.

Figure 30
Percentage of individuals who have a smart meter in their homes
Source: Compiled by the authors, based on data from ECAF 2019 for each country's main cities.



When we examine Latin America's main cities, we see—based on ECAF 2019—that 7.5% of all users said they had a smart meter in their homes, which in most cases had been provided to them by their electricity companies. There are differences within the region in terms of the penetration of these devices (see Figure 30). The largest share of smart meters (26%) is found in Asunción, as a result of an investment policy implemented by the ANDE distribution company to improve service quality and reduce non-technical leaks. While causality has not been assessed for the specific case of Paraguay, electricity leaks dropped from 32% in 2012 to 24% in 2018 (ANDE, 2019). A second set of cities (Montevideo, Mexico City, and Santiago) have shares of 11–14%, while the remaining cities included in the survey lag behind in this dimension.

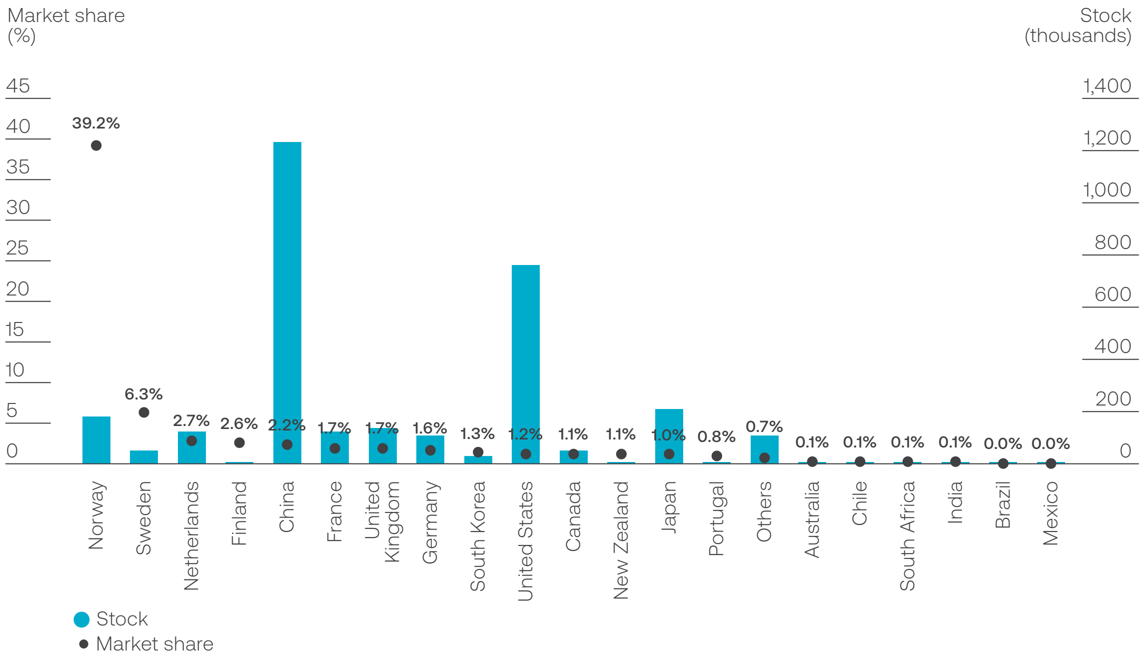
Smart meter deployment poses some problems. For example, in Chile, the adoption of this technology slowed down in 2018, when the government confirmed that distribution companies had the right to charge owners the price of these new devices. Following a series of complaints filed by consumer organizations, the government resolved that users were entitled to refunds of these payments and that smart meters should only be installed where a consumer had said they wanted one, which is set to lead to a slower adoption rate (BNamericas, 2019).

Storage and electric vehicles

Energy storage is considered a key component that can transform the current structure and operations of electrical grids. Little progress has been made so far in terms of storage, and there are few relevant data. For example, in the United States, storage systems used by distribution companies and large commercial and industrial users accounted for 0.13% of nameplate capacity (1.6 GW of the country's nominal capacity) in 2019, while those installed by households enabled consumption of 185 MWh in 2018.[45]

As explained in the section "Other trends in the electricity and urban transportation sectors" in this chapter, electric vehicles can play this role in the system (and are flexible enough to be located wherever the user needs coverage). Through vehicle-to-grid (V2G) connections,

Figure 31
Stock and percentage of new EV registrations relative to new lightweight car registrations, 2017
Source: GPR Economía (2020), based on the Global EV Outlook 2018.



45 Based on data from US Energy Information Administration (2020) and Finkelstein, Kane, and Rogers (2019). For the case of batteries used in homes, the same source reports that energy consumption is linked to storage capacity (rather than electric power).

electric vehicle batteries can be charged during valley periods and provide their electricity surpluses to the grid at peak times to enable flatter net demand for electricity curves. The Danish Vehicle-to-Grid hub is the first European example of electric vehicle connections to the grid. In September 2020, the website *v2g-hub.com* reported 67 projects spread across 17 countries (the United States, China, Japan, and Namibia, with all others in European countries).

Figure 31 shows the stock and share of electric vehicles in various countries (taking into consideration only lightweight passenger cars). In some Latin American countries (Chile, Brazil, and Mexico), a budding EV share can be observed, but it is below 0.1%, very far from Scandinavian countries at the other extreme.

New stakeholders

Digitalization has led to the emergence of new stakeholders who previously were not part of the market and, with a few exceptions, are still not included in market regulations. One example are users who have traditionally been consumers and who, as a result of investment in distributed generation equipment, are now able to produce electricity. They are known as *prosumers*.[46] As distributed generation grows, some progress has been made to integrate these new electricity market stakeholders in various Latin American countries, from their inclusion in Brazil, Colombia, Mexico, and some Argentine provinces to target-setting in Chile and Peru.

One major challenge concerning these consumers involves rate adjustments to pay for the energy they provide the network, as well as the implications of these activities for the distribution segment.[47] For example, in research conducted on Brazil, Aoki, Vicentini, and Leite (2018) admit that most users who are opting to invest are in the most expensive price categories. It is also necessary to consider whether regulations that affect large-scale generators should be applied to these new stakeholders or whether new rules should be made for them, in which case the responsibilities and risks faced by prosumers should be defined.[48] Integrating prosumers could have many advantages in the access dimension, for instance through prosumer microgrids in isolated areas. However, it can also affect the quality dimension, since this generation involves renewable sources and they (particularly NCREs) tend to be intermittent, which affects service reliability.

Demand management gap

Demand-response and demand-sharing mechanisms are a further aspect of smart grids that improves economic efficiency and contributes to a reduction in demand peaks. Grid digitalization and real-time consumption data enable dynamic service pricing, where prices directly signal surpluses or deficits in electricity flows. This allows consumers to adjust their consumption habits depending on price variations.[49] There are different dynamic pricing schemes. They include real-time pricing (RTP), time-of-use pricing (TOU), critical-peak pricing (CPP), variable-peak pricing (VPP), and critical-peak rebates (CPR).

Table 13 shows data on the number of customers involved in dynamic pricing programs in the United States, compared to the total number of customers. Over the period 2013–2018, the number of customers registered with these programs grew at an average annual rate of 9% in the country, and in 2018 the number of customers with dynamic pricing schemes topped 9 million, equivalent to 6% of the total number of customers. While this percentage remained small and the situation was heterogeneous across the US territory—with no dynamic pricing programs in place in Montana, Maine, and Pennsylvania, for instance, and states like Maryland (65%) and Delaware (57%) where major shares of customers registered for these types of programs—there

46 As storage becomes an economic network component, these users will become prosumagers (producers–consumers–suppliers of energy).

47 Other schemes that have been used in this context include pricing the balance between what the prosumer injects into the grid and what they take from the grid for consumption, and differentiated pricing for electricity that is injected into the network, decoupling the price of generation from the price paid for consumption.

48 A common aspect to encourage distributed generation has involved tax breaks for these investments, which has not only led to differentiated pricing for consumption and generation but also to differentiated pricing between different sources of energy (traditional and new distributed generation).

49 Even in rigid pricing schemes, energy efficiency policies have been implemented in an effort to change consumption patterns (Cont and Barril, 2012).

has been substantial growth in recent years, and it is expected to persist. By contrast, no widespread implementation of dynamic pricing programs is apparent in LAC (at least not on a scale comparable to US programs), and there are few data available on the adoption of these types of schemes in the region.

Table 13
Customers with dynamic pricing schemes in the United States, compared to the total number of customers, 2013–2018

Source: GPR Economía (2020), based on IEA (Annual Electric Power Industry Report).

Year	Customers	Percentage of the total number of customers
2013	5,977,281	4.10%
2014	6,894,826	4.70%
2015	7,589,060	5.10%
2016	7,950,227	5.30%
2017	8,497,720	5.60%
2018	9,219,869	6.00%

Hurdles and risks

Beyond this progress, some hurdles persist to different degrees in different regions, and they need to be overcome for smart grid adoption. First, implementation requires large investments. This poses two challenges. On the one hand, smart grids need to go through a social cost–benefit analysis. On the other hand, they may face considerable funding restrictions in developing economies. Second, smart grid development requires a legal and regulatory framework that provides incentives, defines roles and property rights for various stakeholders, regulates interactions among these stakeholders, and enables communications among different components. Third, there is no single definition of technical standards for various elements of a smart grid, which negatively affects how fast relevant public policies are adopted and private decisions are made.

In line with the first hurdle mentioned above, ICT infrastructure is a necessary condition for smart grid development. This means that, in countries where digitalization quality or its penetration in society are low or where ICT operators have no incentive to expand their investment in other sectors, it is likely that smart grid development will be slower and that some electricity companies or third parties will need to invest in ICT to implement their own digitalization projects. In the case of Brazil, Dantas *et al.* (2018) note that electricity companies have had to build their own communications networks, given the inability of phone operators to provide the services they needed, which implied higher smart grid deployment costs.

Systematic data collection on variables that are linked to smart grids is very useful to facilitate cost–benefit assessments involving these networks. A non-exhaustive list includes the number and price of AMI meters, abundant good-quality public measurements (since most regulators do not provide this information), data on distributed energy production levels by technology type, and smart grid project-monitoring data.

The transition to a new electricity system faces four further challenges: (i) electricity is still considered a commodity, which reduces consumer incentives to get involved in new technologies and complex projects (particularly among small and medium-sized consumers); (ii) current regulatory paradigms do not do enough to encourage distributed resources; (iii) uncertainty concerning the rules does not provide incentives for stakeholders to make decisions on complementary grid infrastructure; and (iv) some segments culturally resist change.

To introduce smart grids in developing countries, the specific conditions of the electricity sector in each of these countries need to be taken into consideration. This implies additional challenges, which may be technical (linked to significant leaks and a poor-quality, unreliable service), linked to governance (due to the existence of cross subsidies, companies' financial problems, low productivity, and an inability to attract investment), or economic (related to the difficulty of implementing pricing schemes that reflect the cost of using these grids) (see Jamasb, Thakur, and Bag, 2018).

One specific risk of smart grids involves cybersecurity. Without a suitable security system, smart grids are vulnerable to various types of cyberattacks that are already known from other computer-based systems (like advanced persistent threats and denial-of-

Smart grids are being developed in Latin America and face intersectoral, technical, and governance challenges, among others.

service attacks, botnet attacks,[50] and zero-day attacks[51]). This can cause user mistrust and rejection. Within the electricity sector, these risks and threats may affect smart grids only.

So far, smart grids have suffered very few service interruptions caused by cyberattacks. One known case documented by the International Energy Agency (IEA, 2018) involves two power outages in Ukraine. The first happened in December 2015, when hackers accessed the system operated by a public utility company in the west of the country and caused service interruptions that affected 225,000 people. A year later, in December 2016, there was a second attack, believed to be meant to test versatile malicious software (*malware*), that enabled attackers to see, block, control, or destroy grid-monitoring equipment.

One final aspect that may be a hurdle in developing countries is the lack of qualified individuals and institutional capacity. Smart grids could require a critical mass of human resources with training on technical, financial, and legal aspects linked to the distribution and commercialization of energy. Chapter 4 will address this hurdle in greater detail.

To summarize, smart grid development varies among different regions, depending on sociopolitical factors, regulatory aspects, technological progress, and access to funds, among others. These differences emerge quite clearly when we compare developed and developing countries. In developing countries, hurdles need to be overcome concerning low investment levels, funding problems, inadequate infrastructure, and the application of this type of digital technology to electrical grids.

Expected impact of digitalization on electrical service gaps

Smart grid deployment is set to have major impact on service characteristics. Illustration 2 shows a selection of smart grid elements and their impact on the demand for electricity.[52] Distributed generation—mainly using solar generation—enables a reduction in the demand for energy from the grid (for a given level of demand) in daytime hours, since users can supply all or a portion of the electricity they need. Distributed storage flattens the demand for electricity from the grid and smoothes peaks and valleys. This enables more efficient use of the grid and reduces the need for additional

50 This term refers to a set of computer robots (bots) that execute commands autonomously and automatically.

51 A zero-day attack seeks to execute malicious code, making the most of system vulnerabilities that are unknown to a product's manufacturer and user.

52 The impact on demand will of course affect supply. And these components will have greater impact on demand if there are dynamic pricing schemes in place.

infrastructure. Rapid storage responses to various events also make the grid more robust and increase system reliability (as well as even greater flexibility through electric vehicle connections). Finally, increased demand involvement helps to reduce consumption overall (thus increasing energy efficiency) and during peak consumption periods (to the extent that users can respond to price changes in real time).

All these aspects would reduce the gaps in electrical services that were mentioned in the previous section. More specifically, Table 14 shows some of the benefits expected from smart grids and their effects on service gaps, detailing the dimension they are likely to affect the most. As can be seen in the table, smart grids have many benefits and each of them can affect several service gap dimensions. For example, higher restoration speed following failures helps to ensure better-quality service (by reducing the duration of service interruptions), but also lowers system costs. More efficient generation and transmission have a direct impact on the quality and cost dimensions and lead to lower end prices. Reduced supply costs will directly affect user spending, if we assume automatic pass-through of production costs to prices paid by consumers. Integrating consumers and renewable energy may affect access, through the operations of isolated smart systems. Further, these benefits may also have indirect effects on other dimensions in the long run.

Illustration 2
Impact of smart grid components on the demand for electricity
Source: Astarloa et al. (2017) and GPR Economía (2020).

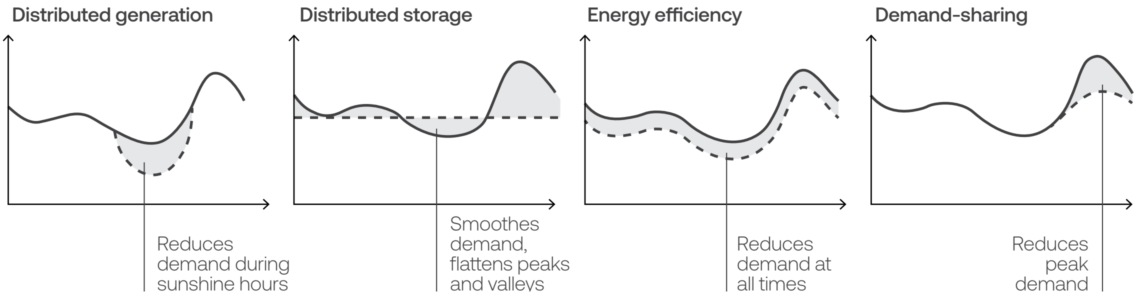
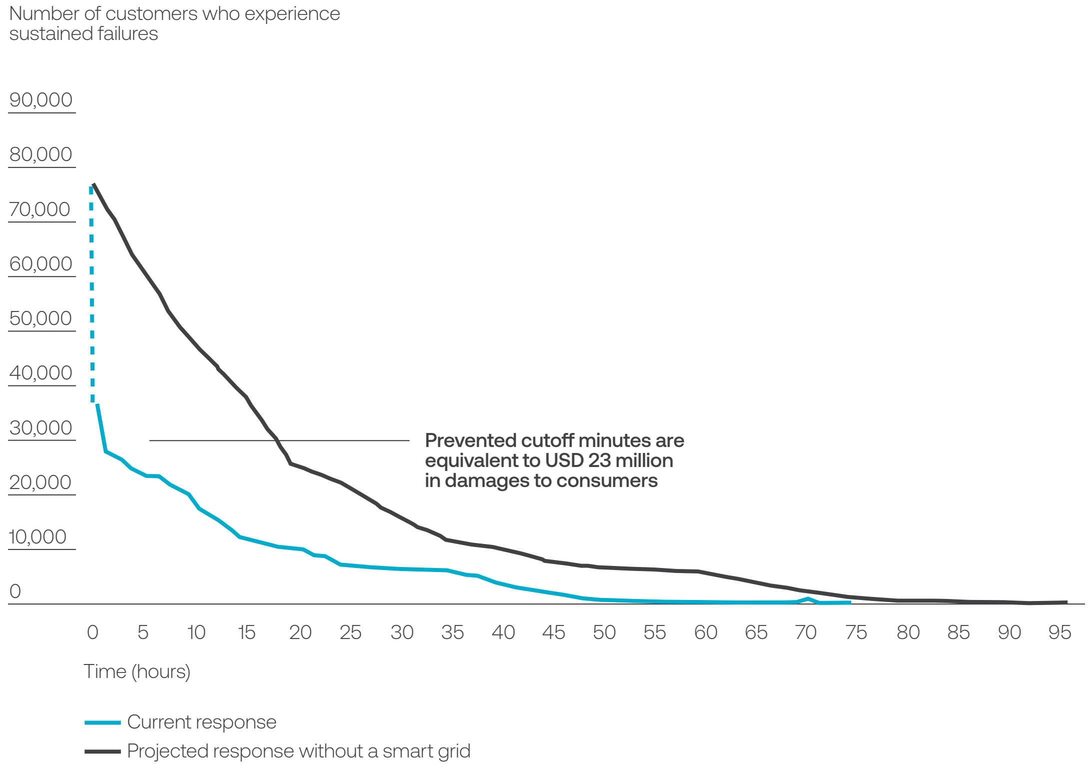


Table 14
Links between smart grid benefits and service gaps
Source: GPR Economía (2020).

Smart grid benefits	Gap dimension		
	Access	Quality	Cost
More efficient generation and transmission		X	X
Faster service restoration following failures		X	
Lower operating and maintenance costs			X
Lower peaks in demand			X
Greater integration of renewable energy	X	X	
Better integration of consumer production	X		
Safer supply		X	

Figure 32
Impact of a system failure on a smart grid in Chattanooga, compared to a traditional grid
Source: US Department of Energy (2018).



One of the benefits mentioned in Table 14 is that control and communications systems will enable the isolation of failures, and therefore faster system restoration. Not many experiences have been documented so far, but one incident recorded in Chattanooga (in the US state of Tennessee) shows the potential impact of adopting a smart grid on quality, by reducing response time in case of system failures (Figure 32). The green line shows the failure curve, measured in affected customers (vertical axis) and time (horizontal axis), caused by a wind storm in June 2012 in the area around Chattanooga, where automated distribution systems (one of the components of smart grids) were already in use. The blue line shows an estimated failure curve if this technology had not been in place. According to this estimate, system digitalization prevented an outage for 55% of the affected customers and enabled full service restoration much faster (17 hours earlier). The distribution company (EPB) estimated at approximately USD 23 million the damage prevented to consumers (US Department of Energy, 2018).

Digitalization in urban passenger transportation

Digitalization is an opportunity to optimize and make the most of existing assets (including infrastructure, vehicles, and data) to enable improved urban passenger transportation services. New technologies have an impact on system planning, management, consumption, and governance in Latin America's urban passenger transportation systems. This is because they imply various changes and opportunities, like the emergence of new transportation services, the option of obtaining real-time data (for instance, public transportation arrival times for a given stop), and transportation system management opportunities.

This section identifies the most important developments in this sector over the past 20 years, and their potential applications in Latin America, the hurdles and risks they face, and their effects on the service gaps that were mentioned above for this sector.

Technological progress in the transportation sector

One set of transformations that are affecting the transportation sector involves an abundance of data (generated through constant interconnections between millions of user smartphones) and the emergence of new transportation services that use digital apps to supply transport.

Greater data availability on aspects including location, routes, and arrival times not only affects service users—who can access a portion of this information on their phones, for instance—but also planners and transportation service providers. In this sense, the ability to analyze these data is crucial to improve and plan services. However, the emergence of new transportation services can both compete with traditional modes of transport and also complement the traditional system. Some platforms and organizational structures within the transportation service market are making the most of these complementary features. Table 15 shows the technologies that have been developed in this sector.

We will now go on to describe the main innovations that digitalization brought about in this sector, which have triggered significant transformations in urban transportation services.

Travel planning (demand) and sector planning (authority)

Apps that focus on providing data for users to plan trips or for sector authorities to plan transportation stem from the development of systems and technologies that collect real-time data on the state of the transportation system. These data include some concerning the state of traffic and routes and the operations of some modes of transport, particularly using georeferencing and general transit feed specification (GTFS) systems.[53]

Table 15
New digital technologies in urban transportation
Source: Compiled by the authors.

Category	Technology	Examples
Traffic and location data	Travel-planning apps	Waze, Google Maps, Moovit
Travel apps	Sharing-economy platforms	Uber, Cabify
	Ridesharing platforms	Uber Pool
	Carsharing apps	Awto
	Micromobility	Movo, BA Ecobici (Argentina), EcoBici (Mexico)
Transaction technology	New methods of payment	SUBE (Argentina), Bip! (Chile), contactless cards
Transport integration	Mobility-on-demand app	Shotl (US)
	Mobility as a service	Whim (Europe)

53 GTFS systems enable the development of standardized traffic databases, whether static (for data including public transportation prices and schedules) or dynamic (for data including expected arrival times for specific stops or the real-time location of given vehicles).

These apps may target different types of users, depending on whether they provide route recommendations for private transportation users (like Waze), information on the state of public transportation (Cuando Subo in Buenos Aires, TransMiSITP in Bogotá, Moovit in several cities), or even integrate both services (Google Maps). This information increases travel efficiency on both public and private modes of transport. It enables reductions in expected travel times and in uncertainty concerning travel times, by finding optimal routes or suggesting optimal combinations of different modes of transport to get to a given destination (this is particularly true of apps that provide information on multimodal transport).

For public transportation authorities, the data provided by GTFS and georeferencing systems and by travel-planning apps are more valuable in the medium run. This information can be used, along with the data obtained from bus and station monitoring equipment, to optimize operations (by scheduling vehicle deployment and monitoring operator compliance) and the fleet they require, adapt service to demand (by identifying better routes, schedules, and frequencies), and plan any necessary investment in transport infrastructure.[54]

Travel apps

There is a whole set of apps that enable travel by providing new services, based on certain characteristics.

Digital sharing-economy platforms. These platforms involve a business model that mediates between the supply of drivers and the demand for travel (for instance, Lyft, Uber, and Cabify) and enables the supply of local transportation services for individuals and small groups of users. The main features that differentiate these platforms from certain traditional transportation services are the use of dynamic pricing, the option of booking trips in advance, and flexible supply.[55] These platforms have also adapted to small freight transportation or delivery tasks (as in the cases of Uber Eats and Cabify Envíos) involving significant numbers of varied products, which increases capillary distribution modes. However, in many cities, they compete with traditional regulated services (taxis) and they are not necessarily included in the relevant regulatory frameworks.

Ridesharing apps. These apps provide a mediation service among individuals who wish to travel along the same route at the same time, to give these individuals the opportunity to share a vehicle and travel costs. Users may travel on a vehicle that provides a transportation service like that of sharing-economy platforms (as in the case of Uber Pool) or use a vehicle owned by one of the individuals who are going to travel. These apps grant users access to short-run transportation services based on demand (Novikova, 2017).

One alternative to these types of apps comes from **platforms that enable temporary use of a vehicle (carsharing)**. This service allows users to use a car when someone else has stopped using it, enabling them to rent the vehicle by the hour or for specific trips. One of the differences relative to traditional vehicle rental services is that both rental companies and individual users can offer vehicles on these platforms. These types of apps require that users share not only data on the trip the driver is planning to take, but also on the place where they are parking the car. This model is therefore based on trust among users (Chase, 2015).[56] In any case, progress of this kind also requires decisions concerning risk allocation (and any potential adjustments required in insurance systems).

54 There are other developments that are not discussed in detail in this report, like the deployment of smart systems to charge for the use of specific routes and the digitalization of traffic light systems to ensure smart interval management that reflects real traffic flows. This enables improvements in overall mobility within cities, as well as reducing travel time and improving quality of life in urban areas.

55 Some cities in the United States and Canada have started to use these platforms to replace low-demand, high-cost bus services. Research has also shown that the fact that these services are available everywhere reduces demand for public transportation (see, for instance, Graehler, Mucci, and Erhardt, 2019).

56 Carsharing apps may be subdivided into four groups, depending on whether they require ownership of a vehicle (whether a single unit or a fleet) and on the points of origin and destination involved (whether the vehicle needs to be parked where it was found initially or may be dropped at some other site specified by the relevant app). One last alternative involves joint purchase of a vehicle by a group of individuals (so it functions as a collective good).

Apps that enable travel using bicycles and electric scooters. These platforms work like carsharing apps, but they focus on micromobility, particularly bicycles and electric scooters, whether for private use, for rent (like Movo or Grin), or funded by local governments (like Ecobici in Buenos Aires). These modes of transport have entered several Latin American cities in large numbers. In some cases, there is no relevant regulation, while in other cases regulations have gradually been adapted to new conditions. Micromobility is suitable for short distances (up to 5 km). It replaces walking and also serves as a feeder for mass modes of urban transport, increasing their reach and their social profitability. However, these new modes of transport pose some problems. China provides the clearest example. With no coordination or planning, these modes of transport are often left outside subway stations and prevent access, although this problem could be solved with adequate planning (Taylor, 2018). On the other hand, these modes of transport are not safe when they are used on the same roads as motor vehicles or on poor-quality roads, and when users do not use infrastructure correctly.

Innovations in travel-payment options

Digitalization led to the emergence of new modes of payment for travel services, introducing changes in the collection and pricing systems used by transportation service providers, whether public or private.

Concerning collection systems, there are several options available. These include payment from cell phones or the use of a single electronic method of payment integrated with methods supplied by banking institutions, such as credit cards, or dedicated transport cards (some examples are the Bip! card used in Santiago and the SUBE card used in Buenos Aires, both of which enable payment for bus, subway, and train tickets). This requires infrastructure that enables these transactions, like payment machines and turnstiles.

The goal of these forms of payment is to simplify transactions for users, which in turn improves security by reducing the need to carry cash to pay for services. Further, data are consolidated as back-up, and to record demand to pay various system operators in compliance with their contracts. However, a reduction in transaction costs requires that the stakeholders who are to receive payment for transaction management intervene very little in the process, if at all.

Concerning pricing for transportation services, whether public or private, these new methods of payment facilitate the implementation of direct targeted subsidies for specific groups of users (through differentiated prices, a number of trips free of charge, or a combination of both), as well as the adoption of other mechanisms to support transportation service users.

Transport integration

Transportation service integration is a new concept relative to the traditional paradigm, since it brings together the supply of multiple modes of transport, both private and public, to facilitate mobility. Two integration methods have emerged so far: mobility as a service and mobility on demand. In both, multimodal integration can happen on three levels: physical, price-related, and digital.

The first of these methods, mobility as a service (known as MaaS), involves integrating the various modes of transport and payment options into a single service, which increases accessibility for users (Jittrapirom, Caiati, Fenero, Ebrahimigharehbaghi, and Alonso González, 2017). One specific factor in this method is the existence of subscription plans offering various packages with different numbers of trips and modes of transport depending on the plan, allowing users to choose the one that best suits their needs.

This integration method is currently available in few cities, with several variants. For example, in Helsinki (Finland), this service is run by Whim and brings together public transportation, public bicycles, taxis, rental cars, and electric scooters. There are currently four plans on offer. The most basic, exclusively for students, includes a public transportation pass, with additional payments required for other services. The second plan also includes this public transportation pass, but adds bicycles (with time restrictions on use) and grants fare reductions for other services. The third plan further includes weekend car rentals. And the fourth plan includes public transportation, unlimited car rentals, bicycles with time restrictions on use, and around 80 taxi rides over distances of up to 5 km. Another example can be found in the UK city of Birmingham, where services are also operated by Whim and currently integrate public transportation, taxis, and car rental services. Birmingham has so far implemented a pay-per-use model for individual transportation services, but it is moving on to a subscription system. Vienna (Austria) is somewhere between the cases of Helsinki and Birmingham. In Vienna, the app that is operated by Whim enables users to purchase specific passes for each mode of transport, which can involve either a given time (for public transportation, for example) or a given trip (for car or electric scooter rentals, for instance). The best-developed mobility as a service models require great coordination among the different modes of transport they bring together, intermediaries, and the mechanism that ensures payment for each mode of transport.

The second method, mobility on demand (MoD), integrates passenger and freight transportation. Broadly speaking, MoD is based on three principles: commoditizing transportation (where modes of transport have specific economic value in terms of costs, travel times, waiting times, number of transfers, and other attributes), improving efficiency within transportation networks (through multimodal travel, the management of supply and demand, and an active management of the demand for transportation), and meeting the needs of all users (Shaheen and Cohen, 2020).

This model enables the use of public transportation, car rental services, taxis, bicycles, and electric scooters, as well as carsharing and ridesharing and courier services, among others. These services can be booked using digital apps. In more advanced forms of mobility on demand, apps allow travel planning, provide real-time data on the state of given services, enable payments and advance booking (US Department of Transportation, 2017), and even provide flexible services to respond to specific requests (Yan, Zhao, Han, Van Hentenryck, and Dillahunt, 2019).

Both models differ from each other in the way they achieve service integration. MaaS is based on "packaging" (monthly subscriptions) for different modes of transport, to make the most of digital apps. MoD, in turn, integrates passenger and freight transportation (in the knowledge that courier services reduce individuals' need to travel), but it is yet to move toward packaged pricing schemes. However, both involve a search for optimized travel, which could in some cases improve access to core transportation networks (for instance, through the use of bicycles or electric scooters as "last-kilometer" modes of transport), besides enabling increased use of the transportation system.

Changes in digitalization, hurdles, and risks in urban passenger transportation

The digital technologies applied to passenger transportation services that were described above can potentially be implemented in Latin America. This section presents research on the use of technology for planning, traveling, or ridesharing, and on the options available to develop an integrated transportation service. It also identifies various challenges and risks that this sector needs to address.

Opportunities: Planning, ridesharing, and transportation-service integration

Travel planning

In Latin America, the use of information technology to plan trips is heterogeneous among different cities, and even by gender, as shown by ECAF 2019 (Table 16). Montevideo and Buenos Aires are the cities with the largest share of digital information app users (over 35%), while Mexico City and La Paz have the smallest share (less than 15%). Concerning distinctions by gender, more men tend to use these apps (except in Montevideo and Buenos Aires), with a share twice as large as that of women in the cases of Asunción and Quito.

Table 16
Percentage of information app use, by gender and for the total population
Source: Compiled by the authors, based on data from ECAF 2019.

City	Women	Men	Total
Montevideo	38.9%	40.0%	39.4%
Buenos Aires	34.2%	39.1%	36.6%
Santiago*	27.6%	35.3%	31.3%
São Paulo*	27.6%	35.4%	31.2%
Bogotá*	23.4%	32.3%	27.6%
Lima*	15.0%	27.1%	20.8%
Asunción*	13.0%	25.2%	18.8%
Panama City*	12.3%	21.5%	16.8%
Quito*	10.8%	20.4%	15.6%
La Paz*	10.4%	18.9%	14.6%
Mexico City*	11.3%	15.5%	13.2%

Notes: Percentages reflect survey respondents who used digital information apps over the week before the survey. * Differences in user percentages for men and women are statistically significant (with a level of significance of 10% or less).

Table 17 shows the purpose of using information apps for individuals who said they used these apps. Overall, users check multiple data in a given app (so the sum of all observed percentages can be more than 100%). The most popular purpose is to choose the best route, followed by estimated travel time (with the exceptions of Buenos Aires and Panama City, where the second most popular purpose is to check the most convenient mode of transport).

Traveling

Table 18 shows the percentage of use of travel apps (Uber, Cabify, EasyTaxi, and Tappsi) and public bicycles and electric scooters among users who took part in the ECAF 2019 survey. Not all cities have the same degree of penetration by these services. São Paulo is the city where travel apps are used the most, at 46.9%, while only 3.3% of respondents said they used these apps in La Paz. Overall, a little over 28% of respondents in cities examined in the ECAF survey said they used this type of service. For micromobility, the extent of use is relatively low, since this is a newer service. The overall rate of use is below 5%, although it is as high as 18% in Asunción.

Table 17
Percentage by purpose of using information apps
Source: Compiled by the authors, based on data from ECAF 2019.

City	Most convenient mode of transport	Best route	Estimated travel time	Time of next service	Estimated cost of the trip
São Paulo	14.1%	74.6%	27.0%	9.6%	8.7%
Mexico City	11.4%	58.3%	28.8%	2.3%	6.8%
Buenos Aires	39.8%	58.6%	20.4%	9.8%	1.6%
Bogotá	13.1%	59.5%	28.5%	2.6%	8.8%
Lima	14.4%	61.2%	40.2%	2.9%	7.2%
Santiago	22.4%	66.8%	40.6%	6.7%	5.1%
Asunción	10.5%	57.9%	22.6%	2.6%	4.2%
Quito	14.9%	39.0%	28.6%	1.3%	11.7%
Panama City	21.0%	55.7%	18.0%	8.4%	3.6%
La Paz	4.9%	52.1%	26.4%	3.5%	4.9%
Montevideo	8.4%	58.0%	17.8%	19.1%	2.5%

The use of travel apps is still low in Latin America, between 13% and 40% based on data from ECAF.

Table 18
Percentage of use of travel and micromobility apps
Source: Compiled by the authors, based on data from ECAF 2019.

City	Travel apps	Bicycles and electric scooters
São Paulo	46.9%	1.7%
Bogotá	39.1%	5.2%
Santiago	34.6%	2.1%
Quito	31.7%	4.4%
ECAF total	**28.4%**	**3.1%**
Buenos Aires	22.2%	4.5%
Lima	19.8%	4.1%
Mexico City	18.7%	2.5%
Asunción	16.1%	18.0%
Montevideo	14.4%	2.4%
Panama City	13.9%	2.4%
La Paz	3.3%	1.1%

Notes: The column for bicycles and electric scooters does not include bicycles that are owned by the user. The "ECAF total" reflects the average for each city's metropolitan area, weighted by its population.

Ridesharing

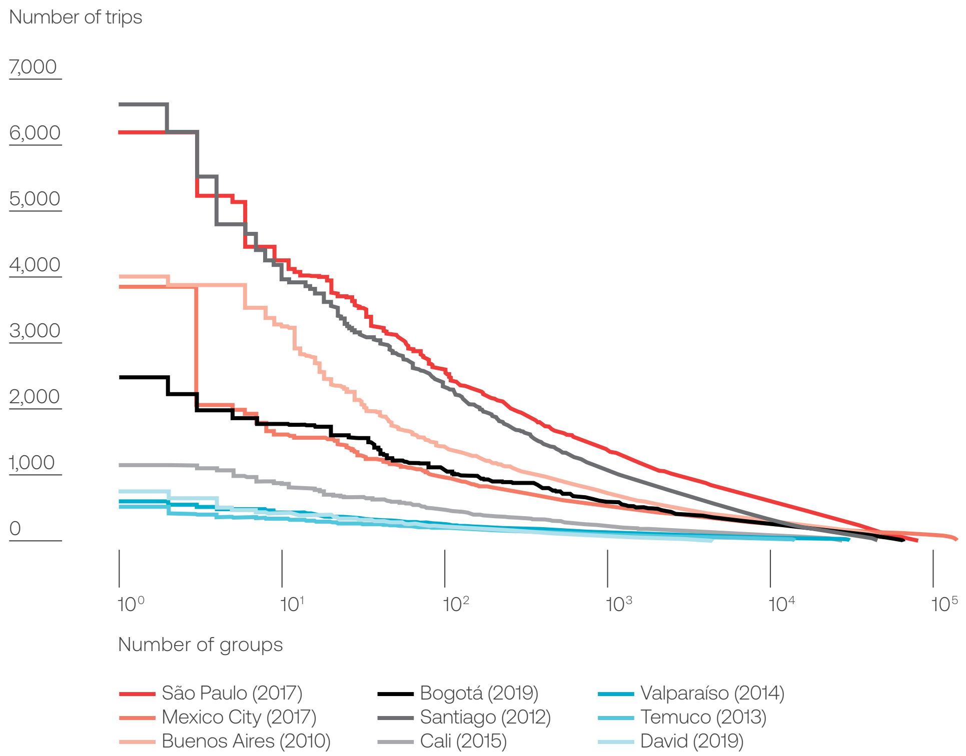
Software and digital platforms devoted to ridesharing are valuable when there is a potential demand for them and when that demand values this travel alternative. To assess the first condition (potential demand), Steer (2020) conducted a trip-identification exercise based on four criteria: place of origin, destination, time when the trip starts, and time when the trip ends. This choice is based on the premise that, for disruption using this technology to have a significant impact on transportation systems and on cities, there need to be many motorized trips that share these variables. Although this premise is very strict and fails to take into consideration other factors—like the fact that a vehicle goes through many more areas than those specified as its origin and destination (where it could also pick up users) or the fact that some trips may be flexible timewise (which would also increase the chances for ridesharing)—this exercise shows the potential for this disruption in some cities.

Using these data, various groups of four factors were put together as an instrument to describe a given trip, based on its origin, destination, and the times when it starts and ends.[57] Each group could bring together one trip or thousands of trips, depending on how many share the four characteristics.

Figure 33 shows the number of trips taken in each group of four factors for cities included in this research, arranged in descending order of the number of trips they bring together. For

57 Given that areas in origin-destination surveys can be of different sizes and have various definitions (areas and subareas), only the smallest portions were used. The times when trips start and end are defined in 15-minute intervals.

Figure 33
Distribution of the number of motorized trips per group of four factors
Source: Steer (2020).



Note. Group of four factors: Origin, destination, start, and end.

example, in Santiago, the group of four factors with the largest number of trips—sharing areas of origin and destination and starting and ending times—brings together a total of approximately 6,600 trips.

A large number of trips in one group of four factors or the existence of many groups where many trips are concentrated are evidence of the potential demand for ridesharing services. They make finding a user who is willing to share the ride (within the same area and period of time, with the same destination in terms of time and space) more likely. This trip concentration per group of four can be observed in the vertical axis in the figure. In general, megacities and large cities (particularly Santiago and São Paulo, followed by Buenos Aires, Mexico City, and Bogotá) have greater potential for the development of ridesharing apps.

This exercise was supplemented with research into the choice of a mode of transport in case of an interruption in public transportation services.

This second study also shows the potential for ridesharing. Table 19 shows potential demand—measured in terms of all the trips that resorted to some transportation service or user-owned vehicle (whether cars, motorbikes, taxis, travel apps, and other modes)—in case of a public transportation service interruption. At least 42% of the trips that would otherwise have been taken by public transportation would have switched to private transportation or other modes of transport (with as many as 70% in Mexico City and 59% in São Paulo).

A more comprehensive analysis of travel must also take into consideration how users rate it. In the latter case, one aspect that has been assessed in the literature involves the option that transportation system users might not be willing to use ridesharing apps due to the larger amounts of information they need to provide and the need to trust other users (Chase, 2015). On this point, Estupiñán (2018) uses data from ECAF 2016 to note that people would be more willing to share a vehicle with colleagues (60% of men

Table 19
Potential demand for ridesharing in Latin American cities, 2019
Source: Compiled by the authors, based on data from ECAF 2019.

City	Potential demand (given an interruption in public transportation)			No transportation
	Private transportation	Other means	Total	
São Paulo	28.9%	30.1%	59.0%	41.0%
Mexico City	34.6%	35.3%	69.9%	30.1%
Buenos Aires	9.1%	45.5%	54.5%	45.5%
Bogota	27.8%	14.3%	42.2%	57.8%
Santiago	26.9%	20.3%	47.3%	52.7%

and 46% of women) and neighbors (45% of men and 53% of women). Willingness to share a vehicle with Facebook contacts is drastically lower (6% of men and 4% of women), while very few people would travel with someone they do not know (3% of men and 2% of women). Finally, this research also suggests that young people are more willing to share. These results indicate that these services have potential for development in Latin America, and they provide data on how to adjust business models to demand preferences.

Transportation service integration

Integrating modes of transport provides an opportunity to make using these services easier for users, a simple choice among various options on offer based on the methods of payment available. A common feature of the examples that were mentioned in the previous section is that they all start off with an integrated public transportation service.

In Latin America, several public transportation services are on offer (including train, subway, and bus), alongside services like public bicycles. In several cases, progress has been made toward the adoption of a single, common fare. For example, in Santiago, Bip! card holders can use three modes of transport (bus, subway, and train) and transfer twice for the price of a single fare (depending on the time of day and the change of mode of transport, they may have to pay extra). In Bogotá, there is a similar system in place (Tarjeta Tu Llave), involving a single fare with some extra charges depending on the types of transfers. In the Buenos Aires Metropolitan Area, users can move on the same three modes of transport (bus, subway, and train) and pay any additional stages with a (growing) discount on the basic fare (Red SUBE). The subway further offers a discount for frequent travel within a single month. However, full integration—which in developed countries converges toward monthly or annual plans or subscriptions, supplemented with individual prices—has not been attained.

In many cities in LAC, employment opportunities and educational and social services are all in certain areas, while the most vulnerable groups tend to live in city suburbs. Fare integration is a first step to reduce the relative gap for access to services and opportunities, and to finetune targeted subsidies that focus on certain groups (low-income users, but also other groups who are usually granted special fares, like older adults and students).[58]

This can be implemented in a centralized way by public authorities, so they can retain control of system operations (implemented by public or private transportation service providers) with the smallest possible number of intermediaries. It can also benefit users through increased

58 This happens in the three cities that were mentioned above: Santiago (differentiated rates for students and older adults), Bogotá (differentiated rates for older adults and users with disabilities, and social tariff), and Buenos Aires (differentiated rates for the unemployed, retirees, and beneficiaries of certain social assistance programs, among others). See the details in Besfamille and Figueroa (2020).

multimodal mobility, greater efficiency, and better-targeted sector subsidies. This may be a first step to consider more ambitious integration models.

Challenges and risks of digitalization in urban transportation

The emergence and adoption of new digital technologies poses various challenges for this sector. First, new technologies require more investment in ICT infrastructure than traditional technologies, including among other factors road and vehicle infrastructure (for instance, to ensure connectivity and real-time data collection, or to provide users with information). This interaction with ICTs requires new human capital formation at the level of the transportation authority, in an area that is often considered secondary but that needs to become essential to provide better mobility services.

Second, all forms of technological progress mentioned in the previous section require changes (drastic changes, in some cases) in service provision and, in turn, generate and require major data availability, along with the corresponding need to store data (with the associated costs). The speed at which these changes happen puts pressure on transportation authorities (within public institutions) to lead efforts to set data standards and develop general urban planning policies, given that new transportation services affect mobility patterns within the city.

Third, integrating fare collection and payment systems could require the intervention of third parties (for instance, banks, fintech companies,[59] and so on). These companies must receive financial compensation for the transaction services they provide, and this will restrict transaction cost reductions.

Fourth, digitalization progress does not guarantee that all urban transportation users will be able to adequately enjoy benefits. It is likely that the groups that will benefit the most will be those with the highest incomes. For example, using technology requires that users have access to mobile devices with data services or that they have access to banking services (for some integrated payment systems). This could expand the relative gap between these groups in society in the access and quality dimensions.

Fifth, given the private nature of digital app development, new stakeholders have emerged who are not taken into consideration by traditional local regulations. One example are individual transportation apps (sharing-economy platforms that have not yet been accepted by various local authorities or services like those provided by *mototaxis*), developed—at least initially—without respecting any regulations and over whose operations the state has virtually no control or knowledge (Steer, 2020). This situation prompts a need to regulate and formalize the transportation service without triggering a loss of coverage.

Sixth, in recent years, a concern has emerged over the possibility that, in line with transport integration trends, many services will go on to operate “on demand,” based on the determination to optimize costs and reduce subsidies. This could end up reducing coverage or access for vulnerable groups or people who live in remote areas.

Seventh, digitalization progress also exposes the transportation system to various cybersecurity risks that need to be taken into consideration in sector planning. On the one hand, mobility data usually enable (with unrestricted access) individual identification. The challenge is that the relevant companies and the state use this information without violating individual privacy. On the other hand, problems that are already known in the ICT sector (system operator errors, equipment and software failures, loss of data, and so on) and in other sectors (threats caused by deliberate attacks like denial-of-service attacks, unauthorized use of transportation system data, or efforts to tamper with the relevant software) all affect the transportation sector too (Levy-Bencheton and Darra, 2015).

Taking these risks into consideration, it is important for technological progress to be controlled and supervised and to involve cooperation with the various stakeholders (including the government, private companies, users, and regulatory authorities).

59 Fintech companies provide financial goods and services based on ICTs to enable simpler processes and cheaper costs.

Technological progress should be controlled and supervised by the authorities with the cooperation of all the stakeholders.

Finally, there is one hurdle that is common to various sectors in LAC: investing in digitalization and adapting infrastructure will require funding, which is not easy to obtain in the region. If private companies fail to see the benefits of investing in these sectors, securing public funding for these investments will be difficult, considering LAC's current economic context. However, in various industries (including passenger transportation and logistics), investments in digitalization and infrastructure adjustments are already underway, which is transforming these sectors through the emergence of new services and improvements in existing services. While public agendas have other priorities and digitalization may seem like a futuristic goal in some sectors, that will not be the case in others where it is already happening.

Expected impact of digitalization on transportation service gaps

Digitalization enables a reduction in urban transportation service gaps. Some of these technologies are already being implemented in various countries in LAC, which improves the provision of these services. Table 20 summarizes the effects of digital progress and innovations on various service gap dimensions.

Table 20
Relationship between transportation technology and service gaps
Source: Compiled by the authors.

Technology	Gap		
	Access	Quality	Cost
Travel-planning apps		X	X
Sharing-economy platforms, ridesharing and carsharing	X	X	X
Micromobility	X		
Mobility as a service	X	X	X

First, travel-planning apps (for instance, Waze, Google Maps, and Moovit) have a direct impact on the service quality dimension, because they enable substantial reductions in the travel times of platform users. In the short run, however, this effect can be different for private and public transportation, because there are several countries where the latter faces more restrictions in terms of changing established routes (although users do have the chance to improve their trips by optimizing their choices among the available options). In the medium run, transportation authorities can arrange traffic in a way that reduces operating costs. Recent literature explores these types of decisions made individuals in real contexts. For example, Berggren, Brundell-Freij, Svensson, and Wretstrand (2019) look at the effect of the information that is provided by cell phone apps on planning for trips on public transportation in the area around Malmö–Lund (Sweden). They identify a reduction in waiting times at starting points and transfer points, especially in trips where vehicle frequency is over 10 minutes. This effect is also significant for trips during weekends and valley times. Van Essen, Thomas, Chorus, and Van Berkum (2019) review an experiment concerning the provision of travel information in Blacksburg (in the US state of Virginia). They identify a positive effect in the use of pre-trip information to choose the shortest routes.

Further, providing this information in real time can have additional benefits from a gender perspective (personal safety), by reducing exposure to unsafe conditions. Data could even be provided regarding the state of transportation, in terms of the number of people who are using a given vehicle, the number of seats available, or the vehicle's hygiene conditions.

Second, travel apps (Uber, Cabify, etc.) can have an impact on multiple service gap dimensions. Apps enable easier access to the core public transportation network in remote areas, and they enable users to move without having their own vehicles. Quality is the other dimension affected by ridesharing (when it replaces private solo trips), due to reduced congestion and the resulting reduction in travel time. Despite the positive effects they have on the access and quality dimensions, travel apps may also have negative effects on the cost dimension if individuals use them to replace public transportation services and thus increase the global cost of carrying individuals, as well as affecting road congestion or traffic.

Third, multimodal transport integration (like mobility as a service) could affect service gaps in the three dimensions. The access dimension might improve, because multimodal travel would become easier. A reduction in travel times and an expansion in coverage are also likely, by making alternative modes of transport easier to use on trips or portions of trips that connect users with their main mode of transport (for instance, using bicycles or electric scooters). The effect on the cost of providing this service will depend on a given innovation's capacity to arrange the supply of transportation services considering the arrival of new stakeholders (which will require better coordination), while the option of adopting transportation plans for users could make spending on mobility more predictable.

Finally, there are many benefits that are not explicitly mentioned in Table 20 and are relevant for several service gap dimensions. For example, integrating camera and real-time surveillance systems, panic buttons in stops, or data availability concerning bus arrival times improve security for users inside stations and buses. Other examples involve managing sidewalk space, coordinating traditional (passenger and freight) transportation with new mobility options, and adapting individual decisions through the use of technology (a practice known as nudging).[60]

Granularity and market formation

Progress in terms of connectivity and the proliferation of digital platforms can potentially induce substantial changes in how various markets work. In particular, it ensures more granularity in the supply of various services, reducing the number of inefficiencies associated with a combination of inelastic demand, volatile demand, and static prices. These deficiencies are very common in the electricity and urban transportation sectors.

In the former, increased granularity is possible due to smart grids. In the latter, it is achieved through sharing-economy platforms. We will now describe how these technologies affect supply and demand, and how they could change the way both markets work.

60 See Ranchordás (2020) for a discussion of the benefits of these trends and their legal and privacy-related implications.

Granularity in the electricity sector

From an efficiency point of view, a system works optimally when prices reflect the opportunity cost for society of generating one unit of energy, while demand can adjust consumption in such a way that willingness to pay equals opportunity cost. A rigid fare during the day (or over a period that may last months) does not meet these criteria, so it leaves electrical system capacity unused for many hours a day. Given this sector's nature, a system with variable prices does not do away with unused capacity. However, it could reduce the need for excessive investment in capacity, particularly the capacity needed to address consumption peaks with per-unit prices below the cost of service provision.

Depending on the country and the applicable regulations, the price of energy in wholesale markets or the variable charges paid by end users may vary depending on the time of day or the month of the year. This is generally the case for industrial and commercial users. For regulated users, when the distributor also acts as the seller, it is common for volume pricing to be applied, with variable charges that are higher than the variable cost of energy. Smart grid progress in developed countries may serve as a guide to understand likely impacts.

In principle, installing smart residential meters, with the capacity to receive real-time information from the supplier (or perhaps another stakeholder in this sector), enables users to adjust demand dynamically in line with the data they receive, and therefore to help to increase market efficiency. This technology is also the instrument that enables the implementation of distributed generation. With bidirectional connections, residential and industrial users and small and medium-sized firms who have invested in solar panels or other renewable sources of energy and are connected to the grid can generate electricity and inject energy into the network in a decentralized way. This enables the consolidation of more granular supply.

The participation of these sources of energy will be increasingly favored as small-scale renewable technology becomes cheaper. Further, technological developments in the field of electricity storage (batteries) allow distributed generators to sell their generation surplus to the grid with greater flexibility in terms of time, while electric vehicles can modulate demand by storing energy when electricity is cheap.

Granularity in urban passenger transportation

Digital sharing-economy platforms are a new business model that mediates between the supply of drivers and the demand for travel, to enable change in mobility system operations and balance. These platforms enable users to access a similar service to that provided by taxis (the traditional suppliers of local transportation services for individuals or small groups of passengers), with a few special considerations: Fares are dynamic, so they respond to demand signals; these platforms enable travel booking (although innovations in this dimension only involve the platform that is used to do this); and supply is more flexible and adapts to relative scarcity through price signals. The evidence so far shows that using these services mainly has a negative impact on other traditional modes of transport (intensive margin), including individual or small-group public transportation (like taxis), without having a clear effect on the emergence of new trips (extensive margin) (see Rayle, Dai, Chan, Cervero, and Shaheen, 2016, and Gehrke, Félix, and Reardon, 2018).

Traditional supply of this type of service involves regulations that, on the one hand, restrict market entry (licenses) and, on the other hand, restrict fares. This rigidity is not based on poor knowledge of peak-load pricing. Instead, it seeks to give more certainty to users concerning the total price of a trip. The main differences compared to digital sharing-economy platforms are clear. No license is required to operate through a platform, where meeting other criteria is enough to provide the service. Concerning prices, the digital system has evolved to a point where it specifies the applicable fare ahead of a trip and at the same time applies dynamic pricing. Platforms are also characterized by more flexible supply (in terms of time and location): drivers may decide whether to offer their services depending on the fares they expect at a certain time of day or in a certain area of a city. When the demand for travel increases, dynamic fares go up and attract drivers into the market, to restore equilibrium by adjusting local and temporary supply and demand.

The emergence of digital sharing-economy platforms has led to debate on their interaction with the rest of the system. In particular, their coexistence with traditional taxi services is being discussed, along with the impact they have on the rest of the urban transportation system.

Concerning the first challenge, platforms are considered illegal in many countries. In other countries, like Uruguay, they have been legalized. In case they are integrated as an alternative mode of urban transportation, the regulatory challenge lies in adapting these new transportation methods, given the differences between the business models of taxis and platforms. Platforms base their strategy on exploiting cross externalities between two types of users (drivers and travelers), through subsidies, to expand their market share. However, once platforms manage to achieve economies of scale, they can generate dynamics that encourage market concentration and displace traditional modes of transport and stakeholders. Future consequences will involve system replacement (with the modern system replacing the traditional system). Without regulation, this will lead to price increases for users and to higher commissions for operators, as well as to a reduction in local government revenues (as taxis are displaced) and in control over urban transportation (an issue that will be discussed in Chapter 4).

Concerning the second challenge, platforms change the decisions made by families and public transportation users. They remove incentives to purchase a vehicle, but they also replace public transportation with platforms being used instead, as noted above. If this substitution were to significantly reduce travel, it could have implications for the economic sustainability of public transportation and add a new dimension to the factors that determine pricing and subsidy policies.[61] However, the potential relative value of these platforms is also currently under consideration. They have advantages, relative to mass passenger transportation, to meet demand in areas with low population density and low capillarity in public transportation (with lower fixed costs, but with higher variable costs). No consensus has emerged so far on the alternative that provides adequate service coverage at the lowest possible cost. If it is regarded as a benefit, this could be considered a complementary feature, to play the role of feeding transfer points and, further into the future, to become a component of a mobility as a service system integrating various modes of transport in a single subscription plan.

Digitalization in other infrastructure sectors

Drinking water and sanitation

New technologies applied to the water and sanitation sector could affect service gap dimensions through different channels. Box 5 shows the technologies that enable precise measurement of water leaks in specific areas (district metered areas), the development of pipe maps using geographic information systems (GIS), and other moves to optimize infrastructure. It also shows technological progress achieved in customer portfolio management (smart measurement and real-time data collection, among other aspects), and service quality control (remote monitoring).

61 Subsidy policies for passenger transportation assess different conflicts between their distributive role (through access and the ability to pay) and their effect on efficiency (through the problem of justifying prices below the cost of alternative transportation systems, significant economies of scale or scope, or externalities that justify prices that are lower than costs).

Box 5
Digitalization in the drinking water and sanitation sector
Source: Zipitría (2020).

New technologies in this sector can be grouped together based on the activities they could improve. We will now describe some of these technologies, by activity group.

● Infrastructure controls:

- District metered areas (DMA). This technology enables precise measurements of water leaks from the system, based on data obtained from (analogic or digital) meters, geographic information systems, hydraulic and water-quality modelling, wireless and remote-transmission cell systems, and pressure transducers. These technologies enable the development of a district metered area, efforts to monitor network performance, the precise detection of water leaks, and the "surgical" reparation of any problems that arise, preventing unnecessary network replacements.
- Geographic information system (GIS). This enables georeferencing in firms' pipe networks. The data can be mapped and processed using computers.
- Hydraulic and water-quality modelling. These models apply algorithms to hydraulic systems, particularly to validate the design of new or repaired pipes.

● Customer portfolio management:

- Advanced metering infrastructure (AMI). This network component enables the company to conduct meter readings at any time, with no need for manual readers, and is applicable to areas where consumption can be measured.
- Supervisory control and data acquisition (SCADA). This software enables real-time automated data collection. These instruments use telemetrics, which enable remote data access and system control.
- Management information systems. This technology enables the integration of information that is often dispersed within a company (billing, customer relations, asset management, and so on), more appropriate monitoring of non-revenue consumption and water use, and data collection for customer service.

● Service quality control:

- Remote water-quality monitoring. These systems enable remote water-quality monitoring (turbidity, pH, conductivity, residual chlorine, total organic carbon) using a smart network system.

Box 6
Technology adoption by the Barbados Water Authority
Source: Zipitría (2020).

The Barbados Water Authority (BWA) is the institution in charge of providing services involving drinking water, sanitation, and wastewater treatment in Bridgetown and the south coast of Barbados. This company adopted a set of new technologies, including hydraulic modelling, management information systems, customer relations management systems, geographic information systems, supervision control and data acquisition, and smart metering.

According to Arniella (2017), while the BWA has increased its capacity and some of its employees have improved their ability to acquire and adopt technologies, "overall, it appears that the utility staff still lacks the necessary skills, training, and motivation to take full advantage of the benefits" of technology (p. 36).

This case highlights the importance of identifying the capacities that companies need to have to adopt technology and integrate it in existing productive processes. Once the relevant cost-effectiveness criteria have been met, implementing technological adaptation involves prior adjustments, compromises with workers, and efforts to train staff or hire experts, to ensure long-run sustainability.

Box 6 presents the experience of the Barbados Water Authority to introduce digitalization in service management. This experience serves exposes the company's inability to make the most of these developments.

Logistics

The (urban and interurban) logistics sector has been very dynamic in the adoption of the benefits of digitalization. Box 7 specifies the technologies that have been used in logistics services, particularly data-collection devices, network and connectivity technologies, software platforms, and other specific solutions. Capelli and Gartner (2020) warn about the risks that large-scale companies will make the most of this digital progress to expand their relative gap with smaller operators.

Box 7
New digital technologies in the logistics sector

Source: Capelli and Gartner (2020).

The new digital technologies that are used in logistics services can be divided into four categories: (i) new data-collection devices, (ii) network and connectivity technologies, (iii) software platforms or technology, and (iv) specific applications or solutions built over the software layer.

Table
Classifying new technologies in the logistics sector

Category	Technology
Devices	3D printing, robotics, smart transportation systems, telematics, artificial intelligence
Networks and connectivity	Internet of Things, 5G connectivity
Platforms or technologies	Automatic learning, advanced analytics and data exploitation, cloud computing, virtual or augmented reality
Specific applications and solutions	Cybersecurity, freight exchange, shared storage, Blockchain, social media, e-commerce

It is likely that many of these technologies will be adopted by large freight providers or by major logistics operators. The adoption rate for these applications reflects to a great extent the pace of innovation in the private sector.

On the other hand, while we noted that service gaps needed to be assessed by type of product and supply chain, some of these developments could have a very substantial impact, whatever the chain involved (for instance, technologies that are associated with greater data availability and the subsequent exploitation and analysis of these data), while other developments might have little or no impact in the short run (for instance, 3D printing and virtual or augmented reality).

↓

Illustration 1
Impact of technology in service gap reduction

Impact \ Applicability	Low	Medium	High
High		• Robotics • 5G connectivity • Cybersecurity • Blockchain	• Telematics • Advanced analytics and data exploitation • Freight exchange • Shared storage
Medium	• Smart transportation systems • Internet of Things • Machine learning		• E-Commerce • Cloud computing
Low	• 3D printing • Artificial intelligence	• Virtual or augmented reality	• Social media

Group

- Devices
- Connectivity
- Platforms/Technologies
- Specific applications and solutions

Box 8 shows a brief summary of the impact of digitalization on urban logistics services. There are no service gap measurements, so the effects of these developments are only conceptual for now. The boxes therefore present suggested dimensions that should be researched in future empirical work.

Box 8
Impact of digitalization on service gaps in urban freight transportation

Source: Steer (2020).

For freight distribution services, digitalization enables more efficient deliveries and therefore reduces service costs. This can be achieved, for instance, by optimizing routes with real-time route and traffic data. This means that routes can be planned to make the most of loading and unloading areas, to achieve deliveries with smaller fleets.

These information systems need to be supplemented with better coordination among distributors, carriers, and receivers, to minimize delivery lags and reduce the impact of parked trucks that are often found on public roads and even on infrastructure that was originally built for pedestrians and cyclists.

3

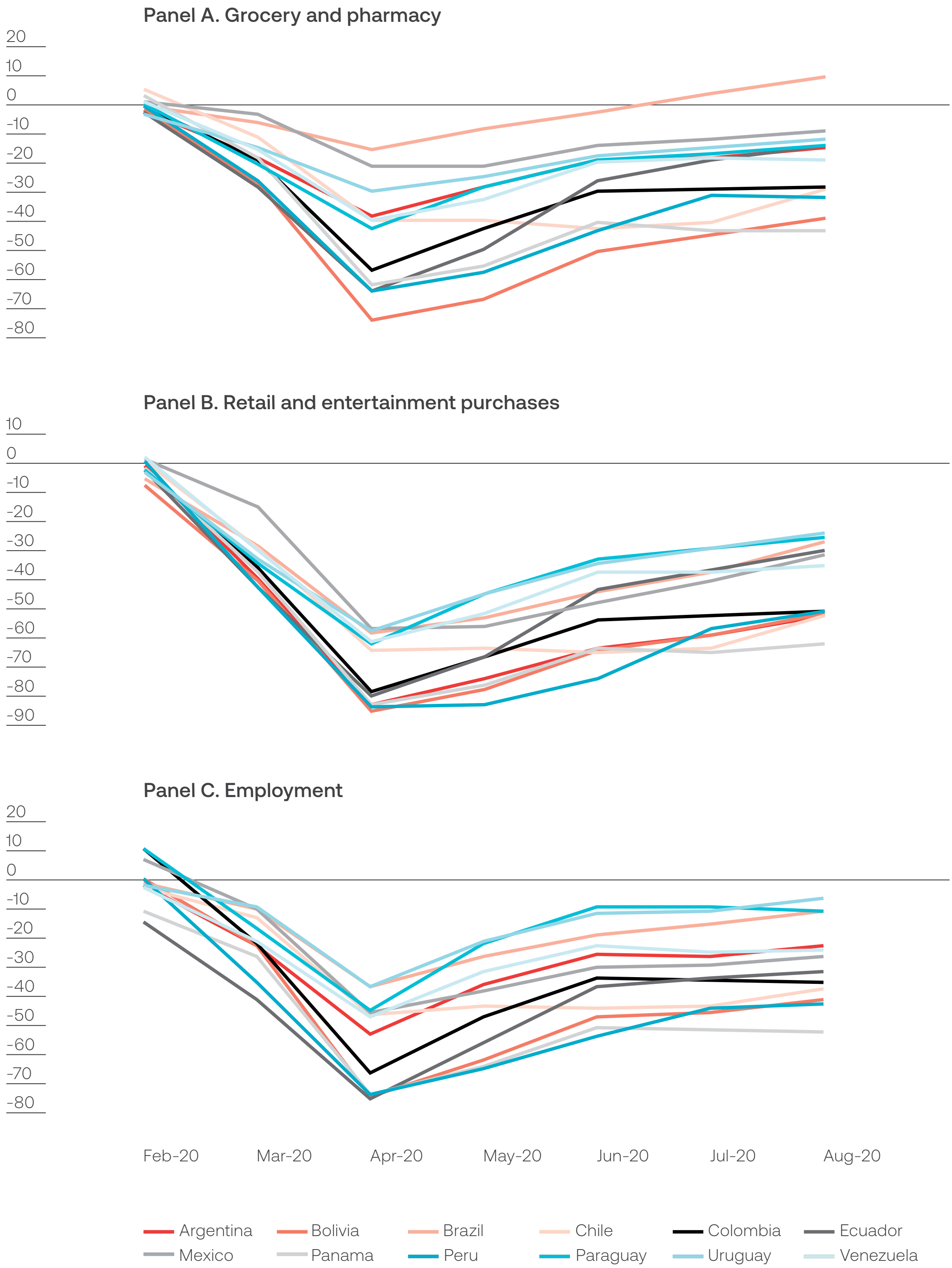
COVID-19: Faster digitalization and its implications for services

COVID-19 and faster digitalization

The COVID-19 pandemic has posed multiple challenges to economies around the world. The virus started to be seen in LAC in February–March 2020, a few months after the outbreak was announced in late 2019 in the Chinese city of Wuhan. The authorities had to take lockdown, distancing, and monitoring measures in an effort to contain the spread of the virus, and they had to address in various ways the impact of these measures on different economic and social sectors, public finance, healthcare, employment, and education.

By September 2020, there was still no sign that the virus might be in retreat, and Latin American societies started to take political action to enable a new normality where people coexisted with the virus until a vaccine became available. A few countries that had not been too badly hit by the pandemic—like Uruguay, Trinidad and Tobago, and Paraguay—were able to restore virtually normal life, with few cases of both infections and deaths. Other countries have gone through different stages to reverse their initial measures. The pandemic has had a strong impact on the region: CAF projections pointed to a 8.7-percentage-point drop in the region's GDP in 2020 (compared to a global contraction of 3.9 percentage points, according to Bloomberg's consensus). The death toll has also been significant. By September 2020, COVID-19 had claimed 470 lives per million people in Latin America (compared to 114 in the world), driven by a large incidence rate in

Figure 34
Intensity of movement in selected Latin American countries
Source: Compiled by the authors, based on Google Mobility Trends (2020).



Notes: The data reflect percentage variations (on a scale of 1 to 100) relative to the baseline date set by Google (which will not necessarily match the adoption of lockdown policies in specific economies). These data are reported as a monthly average of daily percentages.

Brazil (with approximately 20,000 infections and 600 deaths per million people) and Mexico (with 5,000 infections and 535 deaths per million) and by high rates of both incidence and mortality in Peru (with 21,500 infections and 932 deaths per million).[62]

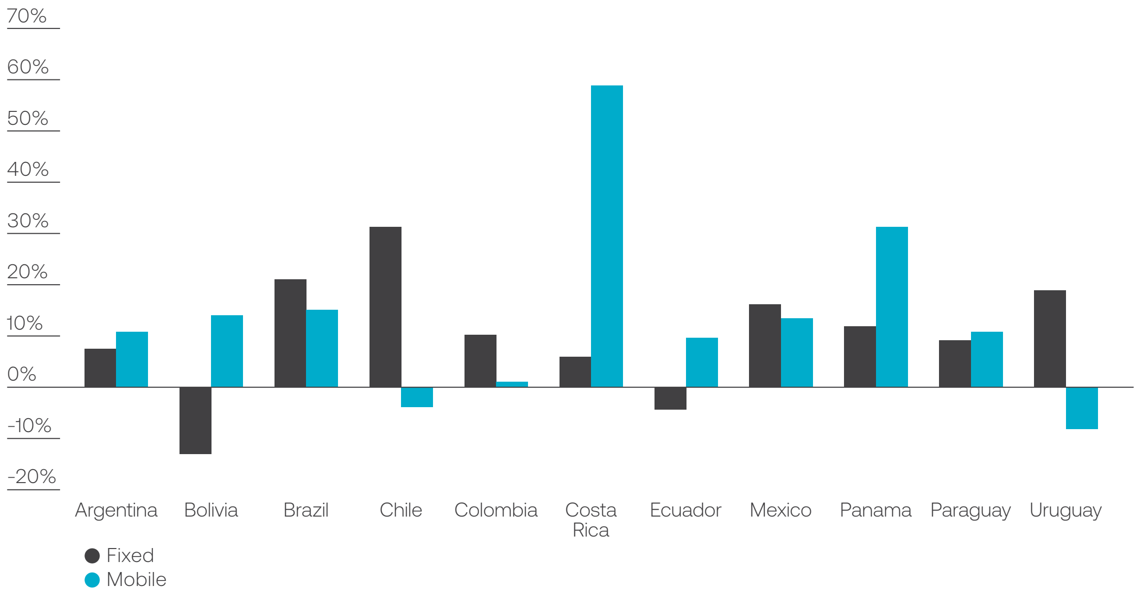
Digital technologies were essential to counter or mitigate the effects of lockdowns and to enable continued economic activity. Many changes that were expected to happen sooner or later into the future were implemented within a few months in the fields of healthcare, employment, education, e-commerce, entertainment, audiovisual communications, and various infrastructure sectors, in the form of innovations or improved operations.

According to statistics published by Google Mobility Trends, mobility fell by 40–80% during the most critical month of lockdown (April 2020), depending on the country and the sector (groceries and pharmacies, workplaces, and retail and recreation). By August 2020, restrictions on movement persisted. They were (generally) less intense and varied by country, but that did not necessarily lead to an increase in the number of trips. The most significant recovery in the intensity of movement happened in Uruguay and Paraguay (the countries with the lowest incidence of COVID-19 in the region), but also in Brazil (a country that still had many infections in August 2020) and Mexico.

At the same time, research conducted by ECLAC (2020) in Argentina, Brazil, Chile, Colombia, and Mexico showed that, between the first and second quarters of 2020, website data traffic and the use of apps increased by more than 300% due to remote working, by 150% due to e-commerce, and by 60% due to online education.

These changes in mobility patterns, from people to data, had initially caused concern about the effect of an exponential increase in traffic and work in the cloud on service quality during the first few months of the pandemic. There was indeed an impact on service quality (to different

Figure 35
Data download speed in fixed and mobile networks, July 2020 compared to February 2020
Source: Ookla/Speedtest (2020).



62 Data for mid-September 2020.

degrees) in Chile, Ecuador, Brazil, and Mexico,[63] but concerns gradually subsided based on actual experience. According to measurements taken in July 2020, broadband speed topped the levels recorded in February 2020 in most Latin American countries, with fixed broadband restrictions in specific cases including Bolivia and Ecuador (Figure 35 shows only broadband speed, but something similar happened with latency reductions).

Digital developments were very useful in many fields, and they played a dominant role in countries' socioeconomic dynamics. We will now present examples of developments in the fields of healthcare, education, and employment.

Healthcare

The healthcare sector was particularly affected by the pandemic, and suffered a direct impact. Countries took different measures to diagnose infections with COVID-19 and to monitor community transmission, as well as to treat individuals who became infected.

In this context, digitalization helped the healthcare sector through improved data use (to monitor infections and the spread of the virus), dedicated platforms (for instance, CoronaApp in Colombia, Coronavirus-SUS in Brazil, and CuidAr in Argentina), and case-monitoring systems (Peru and Uruguay).[64]

Developed countries made progress in the use of artificial intelligence (for instance, temperature monitoring in open spaces), drones (to deliver medical supplies), and robots (to disinfect public places or deliver medication). In fact, as noted by CAF (2020d), in several developed nations, the convergence of 5G technology with other advanced analytics technologies (like big data, artificial intelligence, and cloud storage) proved very useful to improve treatment for COVID-19, reduce response times and manual labor, and prevent more infections through monitoring. These developments have been less common in Latin America, given the need to focus scarce resources on staff and medical supplies.

Employment

COVID-19 has disrupted the labor market by creating a need to adapt the labor force to conducting remote activities using virtual platforms (to hold meetings, deliver reports, coordinate action, and monitor task completion within teams). These types of activities rely on countries' structural conditions (labor markets, formality levels, productive structures, and digital infrastructure quality).

For activity to remain possible, it must be feasible to work remotely using digital networks, which is more likely in professional and technical service sectors and in education and very unlikely in farming, construction, or manufacturing industries. According to ECLAC (2020), the probability of working remotely is approximately 21% in LAC as a whole (ranging from 15% in Bolivia to 31% in Uruguay), well below developed country percentages (close to 45% in Scandinavian countries and to 40% in the United States).

Education

The pandemic made it necessary to cancel in-person teaching and to migrate as far as possible to virtual formats. Virtual platforms like MS Teams, Google Meet, and Zoom were adopted or updated to do this. The potential to make the most of these solutions will depend both on connectivity and connection quality and on the availability of human resources with adequate training to teach content in innovative formats.

ICT service gaps will prevent end users (like private firms and governments) from making the most of digitalization progress in the healthcare and education sectors and in the workplace. According to the diagnosis conducted in Chapter 2, there is still a significant percentage of the population with no access to these technologies (see Table 8). This is particularly the case among adults over the age of 65, precisely the people who are most vulnerable to health problems. However, even with an Internet

63 Increased data flows to fulfil the new needs that emerged from remote working and videoconferencing for different economic, personal, and social purposes may cause congestion in networks (based on capacity) and also in key components, like home routers.

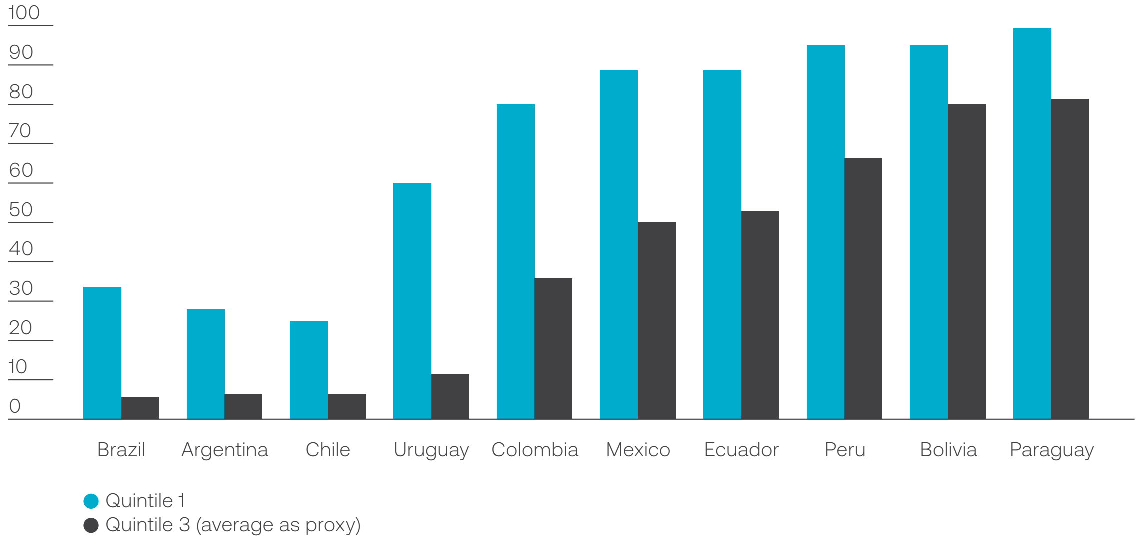
64 Implementing these platforms rekindled debate on the need to protect personal data.

ICTs have helped to mitigate the negative economic and social impact of COVID-19. However, the existing digital divides limited these benefits in education, employment and low-income households.

connection, this service may be expensive for users (as shown in Figure 25 for the quintile with the lowest income) or may have poor quality (as shown in Table 8 for the cases of Bolivia, Paraguay, and Colombia, for instance), or the usage rate may be low (see CAF, 2020d, particularly on households' digital resilience).

In the case of education, global access gaps may hide sector-specific problems. When we define access in terms of the relevant population (school-aged children), the average households in Paraguay, Bolivia, Peru, Ecuador, and Mexico face major gaps. This is particularly the case if we focus on the lowest-income households, where these countries are joined by Colombia

Figure 36
Percentage of children in households with no Internet access (average and first quintile)
Source: ECLAC (2020).



Note: The average is estimated at the third quintile.

and Uruguay. Even in countries with better connectivity, at least 25% of all children in the first quintile for income do not have digital connections (see Figure 36). Using different indicators (like the percentage of households with enough computers) would lead to the same conclusion.

To summarize, the COVID-19 pandemic has affected societies on many levels (personal, economic, and social). This unexpected crisis has caused major losses, in terms of both life and other dimensions. ICTs have helped to mitigate the negative impact of the crisis and made an impact not only in healthcare but also in other economic and social activities. However, not all people in Latin America have been able to access the benefits of digitalization, given existing digital divides—whether absolute (in terms of physical access or the ability to pay for these technologies, quality, repurposing, use of innovations, and so on) or relative (higher efficiency in low-income households, rural areas, specific users like children and older persons, or workers whose economic activities make remote working unlikely).

Impact of COVID-19 by infrastructure sector

Urban passenger transportation

The COVID-19 pandemic caused major changes in individual mobility. Depending on the intensity of this problem in different cities, countries focused on implementing lockdown, distancing, and biosecurity measures to protect users and public transportation workers. They restricted transportation system occupancy rates and favored certain passengers (such as essential workers), and they encouraged micromobility, particularly cycling (see Azan, 2020a and 2020b, for the case of Bogotá). In the most critical month (April 2020), mobility fell by 40–80% depending on the country and the activity in question (see Figure 34).[65] While this changed over time based on local strategies, it was yet to go back to normal by August 2020.

These changes have affected the performance of mass transit systems and jeopardized its financial viability. They have also started a new chapter on this dimension in sustainable mobility models in Latin America and around the world. The restrictions faced by governments to access additional resources (in the form of a larger fiscal deficit) affect financial viability, beyond countries' different cost-recovery strategies. It is therefore important to assess service provision alternatives (for instance, what quality can be achieved with the existing supply, what increases in supply are necessary to achieve different quality goals, what new conditions should be applied to service providers, and so on) and their implications for cost and funding instruments. Some authors have considered alternative funding methods, like congestion charges or appropriating a portion of the land appreciation obtained by beneficiaries outside the transportation system (Brockmeyer, in Euroclima [2020]).

A further problem affecting public transportation is linked to biosecurity, particularly the spread of COVID-19 (especially in closed modes of transport including buses and subways, with limited space and few tools to identify sick passengers or unhygienic surfaces). This problem entails risks for strategies aimed at increasing intensity of use, although there is so far no conclusive evidence that shutting down public transportation is an effective way to prevent infections and the spread of the virus (Musselwhite *et al.*, 2020).

Various strategies have been implemented around the world concerning intensity of use in transportation, in some cases supplemented with tools to prevent the spread of the virus. For example, on one end of the spectrum,

65 Tirachini and Cats (2020) estimate that the drop in the use of public transportation in the Santiago Metropolitan Area over the week that followed the adoption of lockdown measures amounted to 30–40% among low-income users and was over 70% for high-income users, which reflects a major gap (in the income dimension). These gaps could deepen if higher-income users have better options, whether using private transportation or working from home (see also Musselwhite, Avineri, and Susilo, 2020).

Mass transport face multiple challenges of: financial viability, adaptation of the use intensity to the new normality, progress of informal mobility services, personal security and gender.

capacity was restricted (12 people per bus and 32 people per railcar in Australia) or official guidelines were adopted to discourage the use of public transportation (United Kingdom, the Netherlands). In an intermediate case, authorities in Montevideo implemented a supply management strategy based on the number of passengers on board a vehicle (with the requirement to carry a maximum of 45 passengers, equivalent to all seats plus 10 standing places), adjusting the number of services or line frequencies, or even enabling new lines.[66] On the other end of the spectrum, there are cases where high occupancy rates were allowed in peak times, with recommendations to use face masks (Taiwan)[67] or not to talk during the trip (Singapore, when it reopened public transportation), and this had little effect in terms of infections. In the case of South Korea, Seoul and Seoul Metro authorities developed guidelines for subway travel. They provided information and took prevention measures (a ban on travel without a face mask), and operational measures (introducing automatically operated trains or not stopping in overcrowded stations) based on congestion levels.[68] Finally, the Collaborative Group on COVID-19 and Mobility in Colombia (*Grupo Colaborativo de Modelamiento de COVID y Movilidad en Colombia* [2020]) developed a proposal to update biosecurity regulations concerning distancing and passenger behavior[69] based on five aspects (adequate face protection, not talking, ventilation without recirculation, shorter trips, and cleaner surfaces) to prevent infection.[70]

In a different dimension, concerns emerged about the role that informal mobility services could play as a consequence of restricted

66 See data on the adaptation of public transportation in Intendencia de Montevideo (2020a) and on new lines in Intendencia de Montevideo (2020b).

67 While no precise data are available on the effectiveness of using face masks to reduce the spread of the virus, these measures (however imperfect) seem to deliver good results when they are very widely uses (see Sadik-Khan and Solomonow, 2020).

68 See Seoul Metropolitan Government (2020).

69 The proposal was based on a framework developed by the New Urban Mobility Alliance (NUMO). For more information about action taken by this alliance, see their website, https://www.numo.global/

70 According to this suggestion, operational capacity could increase from 40% to 85% for trains and trams, from 40% to 70% for articulated buses, from 40% to 55% for conventional buses and minibuses, and from 25% to 63% for cable cars. Further, spreading the start and end times of the working day (mainly in the areas with the highest concentrations of people) would reduce pressure on the system during peak times, to achieve the same average operational capacity and even increase average capacity.

intensity of use in formal systems.[71] Fears also emerged about potential increases in fare evasion resulting from measures adopted to prevent infection among passengers and between passengers and drivers (like separate driver sections, permission to enter vehicles through middle doors, and reductions in the number of ticket inspections), which would worsen financial viability issues (Tirachini and Cats, 2020).

Finally, the changes described above could have an impact on the gender dimension (Palacios, 2020). Failing to take into consideration travel associated with informal employment and other destinations linked to domestic and care activities (where women amount to a significant proportion of users) in transportation planning, and the construction or expansion of bike lanes with no lighting or security, among other factors, may widen different dimensions of this relative gap.

During the year 2020, in the context of the COVID-19 pandemic, new digital developments were adopted and existing efforts to improve travel were updated. One example are the various platforms that provide useful information to prevent overcrowding, managed by private companies (for instance, Google Maps Transit Service and Moovit) or public companies (railway services in the Netherlands and Japan, and the Singapore bus network, cited in Tirachini and Cats, 2020). Other developments sought to track individuals to monitor COVID-19 cases through cell phone use, whether general (CuidAr in Argentina, Coronavirus-SUS in Brazil, and CoronaApp in Colombia) or individual (as in Peru and Uruguay). Digital technology was also used to adapt service frequency, in an effort to maximize the number of passengers who could be carried in the available vehicles considering restrictions based on biosecurity considerations. This technology was used in the Washington, D.C., subway. It complies with the guidelines and recommendations issued by the Collaborative Group on COVID-19 and Mobility in Colombia Electronic payment systems also speed up passenger flow and help to reduce crowds.

Using electronic systems enables the option of implementing different fares at different times of day to reduce use during peak times. However, measures of this type can have an impact on relative gaps, especially when it is low-income users who change their travel patterns.

Finally, encouraging on-demand service helps to reduce the demand for mass public transportation, but possibly within smaller (contact) networks (Kucharski and Cats, 2020; see also the observations included in the section "Digitalization in urban passenger transportation" in Chapter 2).

Urban logistics

Several years ago, digitalization already encouraged the emergence of technological innovations, including transaction platforms (Mercado Libre), routing services in freight distribution, and capillary distribution services (Pedidos Ya, Rappi, Glovo). These activities, and urban logistics in particular, were affected by the COVID-19 pandemic mainly in terms of (forced) changes in consumption patterns. The e-commerce logistics chain grew relative to traditional transactions, even in a crisis context. For example, website data traffic and the use of e-commerce apps increased by more than 150% between the first and second quarters of 2020, according to research conducted by ECLAC (2020) for Argentina, Brazil, Chile, Colombia, and Mexico.

In this context, we can identify trends that have the potential to redefine the logistics service gap in Latin America, and many of these trends are apparent in urban environments.[72] First, the significant increase in the use of e-commerce platforms to purchase goods and services comes with an increased atomization of freight and deliveries to private homes. Redirecting traditional demand (from large consumption centers to local neighborhood stores) has a similar effect, although it focuses on smaller stores (probably with less loading and unloading infrastructure). Capillary distribution has specific freight patterns in the geography and time dimensions (one example are fast food restaurants for lunch or dinner). Further, platforms that had originally been developed to carry passengers (like Uber and Cabify)

71 There are a few examples of such progress available. Lima is one. While it is reasonable to think that the risk of infection is higher in informal transportation, there is no concrete evidence of this.

72 This list of trends is not exhaustive. For more information, see Capelli and Gartner (2020).

have adapted in places where they had not done so before the pandemic, to carry small packages or provide home deliveries involving many varied products (Uber Eats and Cabify Envíos). These changes affect the use of public space, specifically streets and sidewalks that were not originally designed for loading and unloading freight. For lack of planning, changes in distribution patterns (to incorporate small businesses and homes) may imply higher occupancy in public spaces, more road accidents, and more pollution (see the cases of New York City and Bogotá in Palacios, 2020).

Second, private motor vehicle use in cities based on an aversion to the use of public transportation, along with increased logistics-related local mobility, could lead to increased congestion (or to safety problems, when motorbikes are involved).

Third, changes in commercial patterns in favor of e-commerce may demand more progress in the design of safe areas (in biosecurity terms). These measures need to be implemented, for instance, in dedicated exchange and pick-up areas (like drop boxes and lockers).

Finally, product traceability can be enabled and improved (like "COVID-free" certifications and others based on different biosecurity criteria) as a way to access local (and international) markets.

Drinking water and sanitation

Drinking water and sanitation services have played an essential role during the COVID-19 pandemic, given how important water is for hygiene (with frequent handwashing using soap and water, for instance). And yet the lack of access to water was the first hurdle faced by some areas in Latin America and the Caribbean (particularly in rural areas and in vulnerable areas within urban agglomerations).

As documented by the CAF (Rojas, 2020), water companies have faced difficulties and challenges, whether operational (given demands concerning water quality and the need to restore service for users who were being deprived of access) and financial (as unpaid bills accumulate). This situation matches that of other infrastructure sectors with wide-ranging service provision obligations. While various authorities have helped by purchasing supplies and enabling the use of companies' cash reserves to cover operating costs, fiscal problems have restricted the scope for interventions of this type.

In the future, this sector will need to adjust to providing this service without knowing for sure whether collection rates will go back to pre-pandemic levels anytime soon, and without public funds as back-up (at least in the coming years). There is therefore room for planning and policies to seek alternative sources of funding and measures to ensure cost-efficient service provision.

The current crisis is an opportunity to use digital technologies that enable cost reductions and strategic water management in the medium and long runs. Box 5 (in Chapter 2) and the CAF (Alonso Daher, 2020) mention a few technological innovations that enable improvements in operational and commercial performance and have the potential to positively affect the quality and cost dimensions of this service. In the operational dimension, for instance, several technologies have been developed that enable quality control automation (through remote monitoring and chemical dosing) and hydraulic network management (using systems that adapt the supply of water to temporary and geographical criteria by monitoring reservoir level, pumping, and sectorization- and pressure-valve opening and closing mechanisms). In the commercial dimension, there are tools available that enable the automation of record management (identifying different groups of users who require some form of special treatment, whether to prioritize these users or to target social tariffs), meter reading (in areas where smart meters would be feasible), and certain other services (including electronic payment methods and remote customer service). Finally, there are planning tools that enable systems to prepare for certain contingencies (like the current COVID-19 pandemic), by assessing hypothetical scenarios, simulating the best way to address them, and designing specific procedures and mechanisms that enable in each case a continued provision of an essential service like the supply of water.

Electricity

Electricity is crucial for the operations of all the sectors—whether economic, social, or infrastructure—that have been addressed with varying degrees of depth in this chapter. The pandemic affected the electricity sector mainly through two demand channels. On the one hand, the global consumption level fell along with activity.[73] On the other hand, consumption has been redistributed, among users (from industrial and commercial consumption to residential consumption) and among geographical areas (by increasing consumption within homes, given restricted movement and remote working).

While no service quality problems were reported as a consequence of these changes, this is a dimension that will require attention if these changes become permanent. The medium- and long-term effects on demand for electricity are also not clear. In some countries including Brazil, the drop in demand was being reversed by september 2020. However, if it does persist over time, it may have implications for operational issues concerning supply in various systems.

As in the other sectors that have been reviewed, electricity companies have faced operational difficulties (in service provision) and financial difficulties (with an increasing number of unpaid bills),[74] and they may also need to address supplier payment issues. In the electricity sector in particular, these are joined by an additional factor: long-term electricity sector policies have set payments in US dollars in many supply contracts (including those for renewable sources of energy, but also long-term thermal power generation). The current conditions make it difficult to pass exchange rate fluctuations through to pricing or to ensure the absorption of these fluctuations by other sector stakeholders (distribution). This is the case for several countries whose currencies have depreciated in real terms (like Brazil, Argentina, and Mexico).

Measures for a new normal will therefore seek synergies between recovery (or growth) and climate goals. Strengthening and promoting sustainable energy will remain crucial. Several demand-related components of smart grids (discussed in Chapter 2) may be helpful in this context. For example, smart meters (and advanced metering infrastructure more generally) are useful to make decisions on energy efficiency and, at the level of the system, to improve balance management and load distribution. However, given the financial restrictions that economies are likely to face in the coming years, the transition to greener, more decentralized systems may be slower.

73 This also happened, on a global scale, in the energy sector more generally (along with a reduced demand for transportation, amid restrictions on movement imposed by different countries). Indeed, something unprecedented happened for a few days in April 2020: The price of oil became "negative."

74 Some Latin American examples illustrate measures to address user payment issues: Argentina and Ecuador banned utility shutoffs (Argentina also froze prices and tariffs), Colombia enabled users in tiers 1 and 2 (approximately one third of all users) to defer their payments, Chile also enabled payment deferrals for vulnerable groups, and Panama enabled deferrals for all users.

4

Challenges and opportunities: Investment, regulations, and public policy

Technological change has shaken up operations in the telecommunications sector, particularly by making connectivity widespread and ensuring better quality. This sector will probably continue to experience innovations (like 5G technology) that will not only affect ICTs themselves but also other infrastructure sectors, including electricity and transportation. These impacts were documented in Chapters 2 and 3. As noted above, technology in the electricity sector in many ways remains the same as 50 years ago. Technological change associated with digitalization only started to have an impact around 2010. In the case of transportation and mobility, especially passenger transportation, the past decade has also seen significant improvements based on the introduction of digitalization. This report focuses on these sectors, although there are others—like logistics—that will also undergo major changes. New technologies are also expected to enable improved and optimized service and more efficient use of resources in the field of water and sanitation, although this sector faces more basic problems including coverage (especially in rural areas), wastewater treatment, and the growing demand for and shrinking supply of water. These improvements are expected to deepen over time. It is therefore important to make sure that any necessary interventions (in the form of regulatory changes, investment, or public policy) are implemented, to ensure that infrastructure sectors can adapt fast and enjoy the benefits of technological change.

The regulatory changes that are expected to address technological change and digitalization in economic infrastructure sectors may be purely adaptive or involve major adjustments in sectoral regulatory frameworks that are common to all Latin American countries, potentially including sector restructuring. The premise for electricity is that—given specific conditions in this sector, where the demand for and the supply of electricity must be equal at every point in time—regulatory authorities need to coordinate stakeholders, and therefore also to coordinate any innovations that are adopted. One example is the need for regulatory changes to enable the efficient implementation of new technologies in the electricity distribution sector. On the other hand, it will be easier to make the most of the advantages of new technologies if the distribution segment is divided in two, with electricity commercializing companies who compete for customers and offer plans adapted to each customer's needs and a regulated network operator in each distribution area. This enables—along with the introduction of digital meters—the emergence of new services and plans for customers (including distributed generation and storage), which is less effective when networks and commercialization are integrated in a single stakeholder. In some cases, this division entails a significant change in the business model, while in others it merely incorporates small-scale users to existing commercialization activities. Another important (though independent) aspect is the need to provide incentives for the monopoly operators who manage physical grids, so they will adopt new technologies (smart meters, smart sensors, and so on) to ensure more resilient, better-quality systems that facilitate distributed generation and storage.

Concerning urban public transportation, the premise is that—while the authorities can adopt innovations—the challenges of regulating and planning transportation often focus on the need to adapt to the changes that stem from increased data availability and the emergence of new, unregulated modes of transport and transportation services. This type of market entry has increased in recent years, with platform-based travel services (like Uber and Cabify) and micromobility modes (bicycles and electric scooters) alongside the emergence of new stakeholders for the capillary distribution of goods (including variants of travel platforms as well as dedicated apps), and change is expected to continue with the option of using self-driving vehicles. Regulatory decisions focus on integrating these new modes into existing public transportation schemes, and on how to do this. They seek to improve accessibility and to reduce travel costs and improve service quality for users (in terms of travel times, safety, comfort, and so on), as well as better organizing public spaces.

Digitalization could be a valuable ally to develop infrastructure that is sustainable, resilient, and good quality, by implementing management and monitoring systems and making the most of the collection, processing, and transmission of data.[75] These improvements are important for decision-making processes involving preventive decisions (for potential disruptions) or corrective decisions (for emergency cases, to prioritize the restoration of various services in vulnerable areas or strategically important places, like hospitals and secure facilities).

This chapter starts with a brief diagnosis of regulatory conditions in Latin American countries. Later, given the technological changes that are imminent for the electricity and urban transportation sectors, we look at opportunities for intervention using three

75 This means that the systematic integration of efforts to identify risks and mitigating factors concerning system capacity, capabilities, and response times when faced with certain threats can be beneficial in terms of service-provision reliability, asset life cycles, repair and maintenance costs, and service-provision efficiency (OECD, 2018).

instruments: regulatory changes in these sectors, investment, and public policy. Illustration 3 outlines the changes and interventions that will be assessed in these three fields.

Illustration 3
Sectoral changes and interventions derived from new technologies
Source: Compiled by the authors.

Changes to the status quo

- **Emergence of new stakeholders:** Current regulations do not include them
- **New roles or activities:** Redefining responsibilities and reward schemes
- **Data availability:** Data ownership and management, user privacy, and effects on competition
- **Sectoral convergence:** ICT infrastructure that is common to all sectors
- **Distributive, environmental, and security effects**

→

Interventions

Investment

- With smart infrastructure
- With traditional infrastructure, to adapt to new technology

Regulation

- Cost–benefit analysis
- Market redesign
- New fare schemes
- Cooperation among different sectors
- New regulatory and sectoral capabilities

Public policies

- Social policies (new instruments and compensation policies)
- Policies to align technological progress with environmental objectives
- Security policies (cybersecurity, privacy)

Regulatory context in Latin America and the Caribbean

In most countries in Latin America and the Caribbean, infrastructure sectors are not very well developed in terms of their institutions, particularly when we look at institutional quality. While various regulatory models are in use, public institutions are very present in certain sectors in most of these countries, which has led over time to market dependence on the public sector. Significant subsidies—aimed at financing investment, but also at addressing operating deficits—are evidence of this dependence.

The electricity sector in LAC is generally poorly developed in terms of its market structure and institutions. In some countries, significant service integration persists, with a single firm (whether a private regulated firm or a public company) in charge of generation, transmission, distribution, and commercialization. In other countries, the electricity regulator is not independent from political authorities, and political authorities intervene at will in tariff-setting efforts, the choice of projects that are to be developed, and other technical and economic aspects. This sector's dependence on political power is also apparent in the extent to which it is subsidized. Electricity tariffs are relatively low in Latin America and the Caribbean, compared to North America and Europe (although they amount to a larger share of income in LAC). This is in part due to an energy mix that is biased toward renewable sources of energy with a low marginal cost (see the section "Service gaps in infrastructure sectors" in Chapter 1), but it may also reflect the abundance of subsidies. These subsidies could entail distortions that negatively affect the availability of energy inputs, and therefore restrict electricity generation.[76]

In terms of supply, we can find cases ranging from integrated models (Paraguay) and highly integrated models (Costa Rica) to managed power-plant dispatch models (Chile and Peru) and bidding scheme models (Colombia). In the first type of model, state-owned firms are involved in all system segments (while the private sector is also involved in generation). In the second type of model, various generation companies report technical aspects to a dispatch center or a system operator in charge of issuing orders for power plants to generate electricity as far as they can. In the third type of model, generation companies submit to the energy market their supply bids for the following day and the system operator ranks these bids by cost. In dispatch and bidding scheme models, transmission and distribution are done by different (public or private) operators, and they are overseen by a regulator.

In the commercialization of electricity, there are two dominant schemes: one for regulated customers, through distribution companies, and another for major customers, who negotiate directly with generation companies (and sometimes also with commercialization firms). Distribution companies purchase the power they need for their customers at a regulated price based on the expected cost of system energy or in long-term electricity auctions. In some countries, regulated customers have access to various pricing schemes, but the lion's share of distribution company revenues come from customers using volume-based tariff schemes, with low fixed charges and variable charges that are higher than the variable cost of providing the service faced by the firm.[77] Only commercial customers and small industries face tariffs that better reflect distribution company costs (with maximum power charges, for instance). This scheme has the problem that distribution company revenues are largest when sales are greatest (a volume-based tariff), so companies have little incentive to promote and develop alternative supply schemes that might reduce user bills (and improve energy efficiency). There is also no incentive for distribution companies to improve service quality, since, in most countries, regulators set tariffs based on technical specifications with minimum quality standards and deterrent fines for cases when those specifications are not met, but do not reward firms that exceed the required quality standards. In fact, in some countries, fines are too low to even have a deterrent effect (this is the case in Panama, according to Janson [2019]).

76 See Gertler, Lee, and Mobarak (2017), and McRae (2015).

77 Chile is one example. In Chile, 97% of all regulated customers pay the BT1 volume-based tariff, although there are 12 other tariffs available for residential customers that consider energy consumption and maximum power. The consumption of electricity of BT1 customers amounts to 45% of the distribution company's total energy sales (ISCI, 2019).

Current regulatory schemes have not fully adapted to integrate smart grid technologies, so they will not make it possible to minimize investment costs or to optimize the use of distribution networks in this new context. This is due in the first place to the fact that they were designed for a traditional electricity system and to integrate into it distributed generation, but less so microgeneration and active participation by demand agents. Second, regulatory frameworks differ in different countries, so there is no consensus on the changes that are needed. For example, in LAC, some companies face price-cap regulations, with traditional RPI–X schemes[78] and efficient company regulations, while others face cost-based schemes. Last, designs differ among different segments, specifically in distribution (price caps) and transmission (revenue caps).[79]

Smart grid deployment is not happening in similar ways in all countries in the region, and it is also not following the same pattern. Regulations emerge in line with different aspects of smart grids or whenever specific aspects are being implemented. The regulatory framework concerning smart grids is being built on a series of regulations concerning their various components (like distributed generation, storage, and electric vehicles) and smart meters (the essential elements for smart grid development). Table 21 summarizes the main regulations in place concerning distributed generation, generation from renewable energy sources, fiscal incentives for renewables, targets for the share of renewable sources of energy, and targets for electric vehicle penetration for selected LAC countries.

While legislation concerning distributed generation and renewable sources of energy is widespread, regulations on EV penetration criteria and targets and fiscal incentives involving renewables are more limited. The adoption of digital meters—whether using automated meter readings (AMR) or advanced metering infrastructure (AMI)—is mentioned in these countries' standards (or these countries have at least drafted technical standards concerning the adoption of digital meters).

Table 21
Comparing regulations in different countries
Source: GPR Economía (2020) and BNamericas (2020).

Countries	Regulations on distributed generation	Regulations on generation using renewable energy sources	Fiscal incentives for generation using renewable energy sources	Targets on the share of renewables	Regulations on EV penetration	AMI
Argentina	X	X	X	X		X***
Brazil	X	X	X			X
Chile	X	X			X	X**
Colombia	X	X				X
Costa Rica	X					X**
El Salvador	X		X			
Mexico	X			X	X	X**
Peru	X*	X				X**

Notes: * Blueprint for distributed-generation regulations. ** Deployment targets. *** At a province level.

78 RPI minus X refers to a type of price-cap regulatory scheme developed in the United Kingdom and used in many countries. The price is automatically adjusted to the previous year's retail price index (RPI), and to efficiency improvements expected during the period to which the price adjustment formula is being applied (X). X can be calculated using several procedures.

79 See further details in Li et al. (2015).

Current regulatory schemes have not fully adapted to integrate the new digital technology.

Further, legislators have set adoption targets, but most countries have not designed specific programs to attain these targets. Brazil and Colombia are among the countries that have made the most progress with a regulatory framework to implement smart grids. In Argentina, where distribution outside the Buenos Aires Metropolitan Area is regulated by each province, progress has only been made in some provinces. Mexico, Costa Rica, Chile, and Peru have already set targets for future compliance (GPR Economía, 2020). However, the international context in the wake of the COVID-19 health crisis is likely to make it more difficult to attain these targets. For example, a 25% reduction in global smart-meter shipments was expected in 2020 (BNamericas, 2020).

In the urban passenger transportation sector, the range of regulations in Latin America has been quite varied, and it has followed global cycles with public or private provision and with provision that is either decentralized or controlled by the authorities (Gómez Ibáñez and Meyer, 1993, and Vasconcellos, 2002). There is currently one highly regulated case, Brazil, where public transportation is defined by the national constitution as an essential public service and mayors' offices and municipalities are in charge of regulating and overseeing these services (CAF, 2011b). In all other Latin American countries, the degree of control depends, on the one hand, on development levels and sector policies, and on the other hand on the various authorities in charge of planning and managing urban transportation (municipal, state, provincial or departmental, and federal governments).

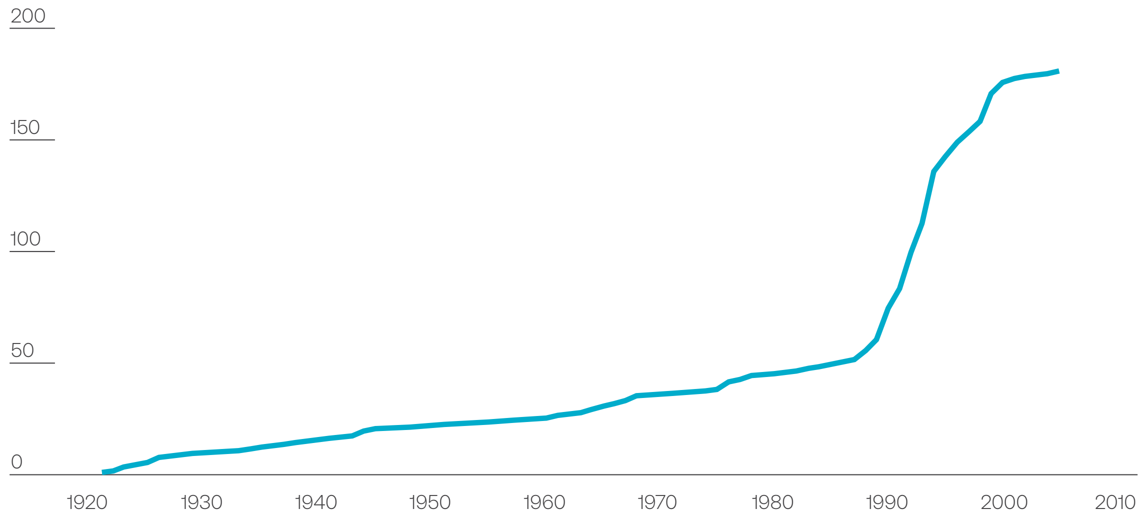
The cases researched in Besfamille and Figueroa (2020) show these differences. In the Buenos Aires Metropolitan Region, there are three public mass transit modes (buses, trains, and subways) that coexist with traditional individual modes of transport and informal modes of transport (*combis*). Since the mid-1990s, buses have operated with local regulatory frameworks, in the form of permits (tenders have been the exception) that were automatically extended every 10 years[80] along pre-determined routes (including 15 Metrobús corridors). Regulations may involve up to three jurisdictional levels (national, provincial, and municipal), depending on whether a line's route covers one or two jurisdictions (the city of Buenos Aires and Buenos Aires province). The surface railway system has seven lines (five operated by the state and two operated by private companies), while the subway (*subte*) is managed by a private operator. Finally, waterways are used on a daily basis as a transportation system by residents of the Paraná Delta in the municipalities of Escobar, San Fernando, and Tigre, in the northern portion of the Buenos Aires Metropolitan Area. In recent years, progress has been made toward intermodal integration, both physical (with transportation hubs in various parts of the city) and fare-related. Other cities have adopted better-integrated public transportation models. For example, in Santiago,

80 Work is currently ongoing to design and approve new terms and conditions to call for tenders for services with a national scope in the Buenos Aires Metropolitan Region.

there is a Metropolitan Mobility Network (*Red Metropolitana de Movilidad*, previously known as Transantiago) with a normative framework made up of a complex combination of legal statutes and regulations, judicial standards, and real practices (all under the authority of the Transport Department within the Ministry of Transport and Telecommunications).[81] Mass public transportation is provided in the form of urban buses run by private contractors that are in charge of various core and local services (of different types, including regular, express, and short-distance services), the subway network, and the Tren Central railway, with its MetroTren suburban service. Bogotá's Integrated Public Transportation System (*Sistema Integrado de Transporte Público*, SITP) is considered the backbone of the city's mobility system. It follows a delegation model divided into areas, with contractors in charge of providing public passenger transportation services under the supervision of the District Mobility Department (*Secretaría Distrital de Movilidad*) and the firm that manages the SITP (Transmilenio S.A.). This geographical area is served by buses that cover core (for articulated and biarticulated buses), dual, feeder, district, complementary, and special areas, and by a cable car (TransMiCable, for rapid urban transit in Ciudad Bolívar, south of Bogotá). Some cities have also implemented oversight policies and policies to improve public transportation services following sustainable mobility models. Some have promoted mass transit systems like BRT (for instance, Curitiba, Quito, São Paulo, and Lima) and cable cars (like La Paz, Mexico City, Caracas, and Medellín). However, these developments have experienced some implementation problems (Hidalgo, van Laake, and Quiñones, 2017).

Beyond these developments, informal systems continue to provide public transportation coverage and feed the formal system around Latin America and the Caribbean, even in cities with well-developed formal systems like Bogotá and Cali (Heinrichs, Goletz, and Lenz, 2017).[82] Similarly, informal minibuses are the most common mode of transport between La Paz and El Alto, in Bolivia, with a fare that is half the cable car fare (Rivas *et al.*, 2019a). In Panama City, the informal system accounts for 9% of all trips (Scorcia, 2018).

Figure 37
Number of regulators in Latin America
Source: Polga-Hecimovich (2019).



81 The Metropolitan Public Transportation Board (Directorio de Transporte Público Metropolitano) and the Panel of Experts on Public Transportation (Panel de Expertos del Transporte Público) are also involved.

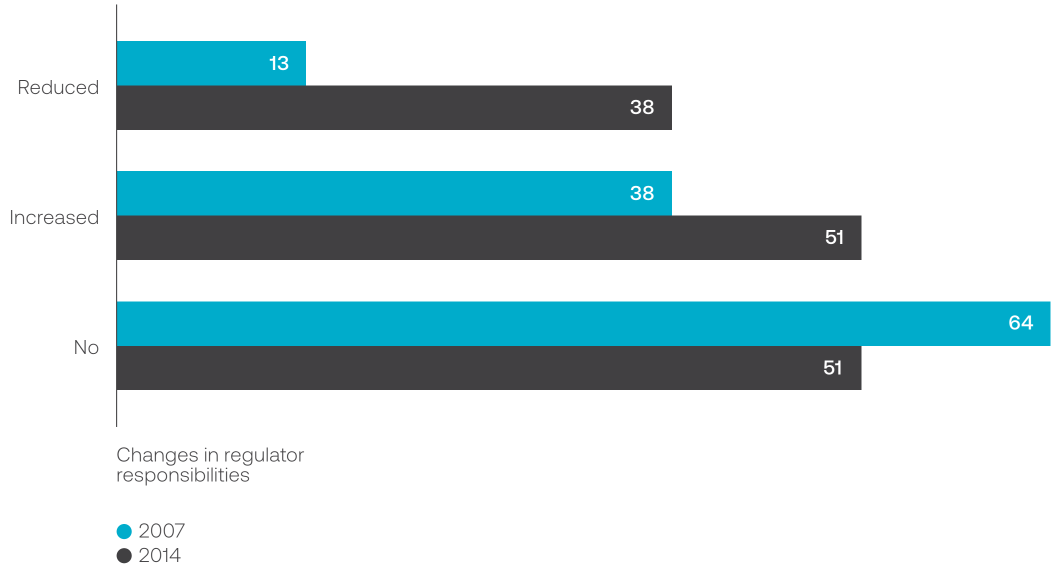
82 In Bogotá, bicycle taxis (bicitaxis) operate as feeders for the Transmilenio system in the Patio Bonito neighborhood. Informal transportation is also common in Cali, with multipurpose vehicles and motorbikes that are active as taxis in poor neighborhoods.

In many cities, mass transit systems have evolved to adopt integrated fare schemes, covering trips that combine stretches in different modes of transport over a given period of time (with alternative versions that provide discounts per stretch). Integrating pricing schemes does not change a sector where both investment and operations are often funded with subsidies (as shown in Figure 20). Usually, the relevant local authorities decide on the combination of sources of revenue required to fund service operations, which have been seriously affected by the crisis caused by the COVID-19 pandemic.

One last thing to take into consideration in this section is the important role of regulators for service efficiency and quality, and the need to foster competition to develop each sector. A regulator who depends on political authorities leaves no room for the development of a market for new services, given the uncertainty caused by the public sector's potentially discretionary intervention in the regulator's activities. Different countries have undergone changes over the past 30 years. During the 1990s, most Latin American countries created independent economic regulators to supervise contract execution by contractors (Figure 37 shows the increase in the number of regulators over the period 1920–2010, including a major hike in 1990–2000).

The regulator model gradually changed, given the different circumstances faced by utility companies. The first transformation entailed an internal change within regulators, in the wake of a reduction in their original responsibilities. This led regulators to stop being the autonomous agencies they were designed to be in the 1990s. Instead, they became technical agencies in charge of providing inputs for the relevant minister to make major decisions in each sector (Figure 38 shows how relevant these changes were over the period 2007–2014). The second transformation, outside regulators, was a consequence of the emergence of state-run companies, whether new firms or companies the state had taken over. This posed new challenges for regulators, especially in terms of their autonomy. The most recent change (still ongoing) involves a digital transformation of the public sector, concerning both data transparency and the use of digital solutions to ensure more efficient management.

Figure 38
Regulatory responsibilities of agencies in the Latin American electricity sector
Source: López Azumendi and Andrés (upcoming), based on surveys conducted in 2007 and 2014.



Regulation

The infrastructure service gaps that are evident in LAC, compared to other regions, pose major challenges. Traditional solutions would require investment, institutional mechanisms, and market redesign to introduce the right incentives for the provision of good-quality services to a broad group of users at the lowest possible cost. However, in a context of technological change, this is an opportunity to evolve toward digitalized infrastructure sectors.

Considering the diversity apparent in country regulators, this section identifies and assesses five regulatory aspects that are crucial to realize the potential of digitalization in different sectors:

1. Cost–benefit analysis.
2. Market redesign.
3. New fare schemes.
4. Cooperation among different sectors.
5. New regulatory and sectoral capabilities.

Cost–benefit analysis.

Digitalization involves both costs and benefits. In the specific case of LAC, the required investment level may be a hurdle for development.

Before adopting any new technologies that may prove costly for society, public service companies and countries more generally need to assess their current conditions and the benefits of adopting these technologies and implementing them in specific sectors. It is therefore necessary to set criteria for a thorough cost–benefit analysis at the country level, given that it will depend on many factors (direct impact on the various service dimensions, different restrictions including technical equipment specifications, and externalities like the need to reduce CO^2 emissions). This assessment should be conducted individually for each technology and for each project (smart meters, smart sensors, smart grids, travel platforms, mobility as a service, and so on). In the case of smart meters, for instance, the European Parliament's Directive 2009/72/EC says that EU members states need to ensure their implementation as long as these meters pass an economic assessment of the long-term costs and benefits to individual consumers and to the market as a whole.

Market redesign

The transition toward digitalized sectors in most cases requires market redesign to enable the entry of new stakeholders, as well as the reformulation of all stakeholder roles. The proposed redesign is based on the goal of adopting digitalization in a way that minimizes service gaps.

In the case of the electricity sector, there are many services that smart meters can provide even without institutional changes. They include better monitoring of grid status by the distribution company, a reduction in distribution leaks, faster reaction to sudden interruptions, measurements of real-time household consumption, an end to the cost of checking meters and following up on shutoffs (for non-payment), and service restoration at a low cost for the distribution company. If these are joined by institutional changes, it will be possible to realize the potential of new technologies, in terms of varied plans with new, value-added services for users, demand moderation, and—whenever this is efficient—distributed generation. These potential outcomes could reduce service gaps in the cost and quality dimensions. These are the two most important dimensions in this sector, since service coverage is high (with a few specific exceptions).

The required institutional changes include new stakeholders within the market and a reformulation of the roles of all participants. These involve:

- Separating distribution and commercialization tasks, with differentiated payment schemes.
- The emergence of a demand aggregator.
- The creation of the role of a distribution system operator (DSO).
- The emergence of a data aggregator.

Concerning the first institutional change, in a scheme where commercialization is separated from distribution, commercialization firms compete to offer customers different

The electric market redesign involves separating distribution and commercialization tasks and dynamic pricing.

electricity service plans. Commercialization companies tend not only to sell electricity, but also to send out bills and collect payments. They further pay distribution companies for the use of their networks to serve customers, generation companies for the electricity they sell, and demand aggregators for their services to reduce the cost of contracts and for other services included in customers' electricity bills. Changes in payment for the distribution component may be relatively simple where they expand to all consumers a separation that was already there for major users (when large consumers can buy electricity directly from generation companies or commercialization companies, regulations tend to have been previously updated to enable the firm to charge a toll for physical distribution). In other cases, including vertically integrated electrical systems, regulatory changes will need to be more significant. Introducing commercialization firms does not require smart meters, but the options to create different plans will be more limited without them (for instance, because plans will not be able to include hourly variations). Similarly, introducing smart meters without separate commercialization firms does not guarantee the benefits of digitalization, since the incentive structure faced by the distribution-commercialization company relies on sales rather than on efficient consumption. Combining separate commercialization companies with smart meters will enable the design of adequate plans for different hourly consumption patterns, as well as consideration of the extent of electrification and smart electrical equipment use within households, the availability of distributed generation equipment and electric vehicles, and other characteristics of users in a given distribution network.

Regulatory authorities need to set certain plan transparency criteria that enable easy comparison between different options. One example are dedicated websites where customers can find out how much their electricity bill would amount to, given different consumption patterns, based on the different contracts they are comparing. The authorities would also do well to adopt regulations that foster competition and protect consumers. Regulations to foster competition include those that prevent companies from refusing contract cancellations by customers and from making it difficult for customers to move to other providers (as happened with landline and cell phone companies before changes were adopted to enable number portability). Regulations to protect consumers include those concerning changes in contract terms and conditions and the availability of last-ditch plans for all customers (Ros *et al.*, 2018).

In schemes where commercialization is separated from distribution, the distribution company would play a smaller role than it does at the moment. It would not bill customers or supply them with electricity directly, but merely provide the grid through which customers receive electricity. Users would pay the commercialization company, who would then pay the distribution firm on behalf of its customers, at a price that would be regulated by the authorities. The distribution company would need to continue to be regulated, since it would provide a monopolistic service, and the resulting distribution margin would need to be integrated

into the bills paid by the commercialization company's customers. This set-up is already available in several countries, like Argentina, for medium-sized and large users, so adaptation along these lines would be less costly there.

The second innovation involves the emergence of a demand aggregator in sophisticated electrical systems with smart grids. Demand aggregators make the most of consumption flexibility among residential users and small stores, manufacturers, and other firms to offer the electrical system reductions in aggregate demand to flatten the short-term cost variations caused by fluctuations in supply and demand.[83] In commercialization, competition—when it goes hand in hand with the availability of smart meters and other smart equipment for households that provide consumption data in real time (or almost)—enables the emergence of firms that group electricity consumers together to enable demand reductions or increases in exchange for a fee. It is interesting to note that this is one of very few electrical system stakeholders who can emerge spontaneously, without requiring a specific legal framework for this sector.

Aggregators may sell their services to system operators (in the day-ahead market) or directly to generation or commercialization companies.[84] Aggregators negotiate by offering prospective clients alternatives to flatten the cost curves they face. One final option is to foster competition among aggregators so they offer their services to a new institution, the distribution market operator (DMO), who effectively acts as an aggregator of demand flexibility aggregators and charges the overall electrical system operator for achieving reductions or increases in demand in the area served by a given distribution company.

In a scheme with stakeholders like distributed energy suppliers, commercialization companies, and demand aggregators for distribution companies, it may be advisable to create a distribution system operator (DSO) to centralize the demand for and the supply of electricity that is being distributed. In an integrated system where it is the distribution company who supplies electricity, there is no need for an independent distribution market operator. However, things are different when the commercialization of electricity is separated from physical grid operations. The DSO centralizes real-time data concerning the demand for and the supply of electricity in the distribution network and sends that information to the system operator (often known as the transmission system operator). The DSO becomes a single net demand agent and simplifies the task for the system operator.[85] It can also reduce potential conflict among commercialization companies and aggregators, as an independent entity that receives supply and demand data within a given distribution area.[86]

The last institutional change mentioned above seeks to solve problems linked to the information that is generated. Smart meters generate consumption data that can be very useful for system operations and management. However, these data are also useful for competitive commercialization services or to implement price discrimination strategies when there is no competition. Further, in the initial stages of decoupling distribution and commercialization, the distribution company has all customer data, so it may be difficult for potential rivals to compete with this firm. Besides, the increased information gathered by smart meters may cause concern in terms of data privacy.

One option to address these problems and risks involves creating a specialized, independent institution that receives data from meters and sends them on to commercialization companies in a non-discriminatory way, subject to rules that protect customer privacy. One potential market scheme involves a data aggregator who centralizes data and sends them on to commercialization companies, so these can periodically collect payments from their

83 A description of the economic roles played by demand aggregators in different regulatory schemes is available in Burger, Chaves Ávila, Batlle, and Pérez Arriaga (2017).

84 It is foreseeable that commercialization firms may be integrated with an aggregator and offer plans including discounts in exchange for demand-response or storage services (Fischer, 2020).

85 The DSO can be a unit within the system operator or an independent entity representing the interests of demand agents and suppliers concerning distribution, so conflicts might potentially arise among these agents.

86 See Keay, Rhys, and Robinson (2014) for further details on the need to go from an integrated commercialization-network supply company that manages the system through a distribution network operator to a DMO within a disintegrated market.

customers. Alternatively, these data could be managed in a decentralized way (where each firm manages its own data), which would be an advantage in case of data breaches. In centralized schemes, the entity should have a limited scope, so it operates at low cost. Customers would fund its services with a small additional fixed fee in their bills, to keep this data aggregator independent.

In the case of urban transportation, one market redesign measure that should be considered involves adapting the regulatory framework to the existence of sharing economy platforms, like Uber, and ridesharing and carsharing apps. The emergence of these platforms has been a source of conflict for Latin American governments.

So far, various solutions have been found. In Montevideo, for instance, an agreement has been reached with digital platforms to restrict the number of vehicles with permits. This has reduced conflict with drivers of traditional taxis, although it has come at a cost for users. The biggest beneficiaries are taxi license owners (since license prices have partially bounced back) and especially platforms like Uber. This platform benefits because it applies a dynamic pricing system where rides are more expensive during demand peaks. With Uber's regular model, as price increases, more drivers will offer their services and users will face increased availability and lower prices. In Montevideo, this effect disappears, and price hikes in peak times are greater than they would be if supply was flexible. Other Latin American cities have managed this conflict through bans that have proved ineffective, so the conflict remains latent.

In any case, a regulatory solution should consider the positive effect on wellbeing of new technologies used by platforms, since they entail technological progress compared to the previous system (under which taxis operate). The new system enables service in areas where taxis do not operate, it responds to specific requests, and it tells the user in advance what they will be paying for the ride. Supply can also respond to demand, since they apply flexible pricing. An additional positive effect can be attained if more efficient interaction between supply and demand leads to a reduction in total vehicle use.

One way to regulate these services without harming users is to demand minimum standards for all individual motor vehicle transport operators. These standards include the obligation to have insurance to protect passengers, minimum requirements for drivers, transparent company data for the transportation regulator, and the duty to file detailed annual audit reports, along with worker social security and tax payments. Finally, it should also be mandatory for distributed transportation platform operators to be legally registered (incorporated) in the countries where they operate, so there is a national, legally accountable party in case of a legal dispute (for instance, with users). One might expect, on the other hand, that taxi systems as we currently know them will adapt by using their own technological platforms or issuing licenses to existing platforms. The main issue that needs to be considered is clearly the cost of a license, particularly if this is a stranded cost.[87] Overall, these measures seek to equate conditions for both transportation services in terms of regulation and competition.

One problem new services face is increased congestion due to the free entry of platform-based vehicles offering these services. While this is a valid concern, new platforms make ridesharing easier, which increases transportation efficiency, especially in low-density suburbs. These areas are not well served by buses, by other group-carrying vehicles with pre-established routes, or by taxis.[88] These platforms can be a supplement in cases where conventional bus systems are too expensive to serve certain towns (Feigon and Murphy, 2016). In shared-use modes, they could be subsidized to provide minimum demand coverage at a lower cost.

If concerns about congestion caused by digital platforms are deemed relevant (after considering potential compensations involving ridesharing and carsharing), the problem could be fixed with a congestion charge. This charge should vary by time of day (or degree of congestion) and by area and should be applicable only to taxis and platform-based

87 There are two relevant aspects that should be considered: whether the price paid for the license when it was originally issued has been amortized and whether the license can still be sold in a secondary market (once it has been amortized).

88 For further information on the benefits of ridesharing, see Chan and Shaheen (2012) and Long, Tan, and Szeto (2018).

vehicles, given the practical and political difficulties associated with its application to all private vehicles. A congestion tax would reduce the number of trips to congested areas, and partially also the congestion revenue earned through dynamic pricing.[89]

Considering digital platforms within the supply of transportation would enable progress toward comprehensive provision scenarios in urban transportation, in the form of mobility as a service. Integrating various modes of transport would be the most significant transformation in this sector and could become the norm in the not too distant future. Helsinki was the first city to implement mobility as a service (followed by others, including Birmingham and Antwerp), through an app that brings together the various modes of transport on offer depending on the monthly plan the user has paid for. Before implementing a broad integration scheme, there is room for partial regulatory improvements. Some examples involve considering new collection and payment methods for transportation services that could stem from digital progress (for instance, payment using cell phones, credit cards, or cards that are specifically for the transportation system). It is worth noting that mobility as a service can have different structures in different cases, and that it changes based on the supply of transportation services available in each city. In any case, Latin America faces several challenges. One of them is moving toward transportation system interoperability with other modes of transport and with micromobility systems. In terms of geographical coverage (whether urban or suburban), this progress would surely lead to the consideration of regional transportation areas and to interaction between different levels government. This would particularly be the case when these areas stretch across municipal and even provincial borders (as in some examples of integrated transportation systems cited in this chapter's first section). This implies developing an institutional and commercial model that enables agreements with other local and regional systems, with a single fare collection mechanism for each system even when payment methods differ. Technology, system architecture, software compatibility (ideally, the same software will be used across the system), and who controls the system (ideally, the city's transportation authorities, with Madrid's Regional Transport Consortium [*Consorcio Regional de Transporte de Madrid*] as a paradigmatic example) will all become relevant here.

Finally, micromobility creates a need to make changes in road safety and in public space management. This implies integrating the location of bicycle or electric scooter stations within urban planning, to facilitate access to these modes of transport ensuring that they will not block access to the traditional transportation system.[90]

Concerning changes in management and road safety, private-sector developments (including sensors that flag crash risks like those developed by Intel's Mobileye) are worth noting. We should also not dismiss the potential impact of future changes in forms of travel, considering the integration into the transportation system of technologies that enable inter-vehicle communications, digitalization of the urban environment (like traffic light networks), and the use of drones and other autonomous vehicles.

Service pricing

The impact of digitalization in existing gaps in the cost and quality dimensions and customer involvement in service provision will both affect pricing. The third relevant regulatory aspect therefore involves new pricing structures. In electricity, separating distribution and commercialization will enable commercialization companies to offer plans with different rates and to compete with each other for customers. These prices can be differentiated by time of day, by consumption level, by level of demand flexibility (especially for companies), by the share of supply that comes from non-conventional renewable sources of energy, and by other variables. This gives users the option

89 This is due to the fact that a tax on a service that is provided with imperfect competition will partially fall on the service provider.

90 This need for regulation runs parallel to recent developments in urban logistics (many of them deepened during 2020, as a result of the COVID-19 pandemic) and in mobility (carsharing for one-off or regular trips). The Traffic and Transportation Act (Ley de Tránsito y Transporte) passed by the Buenos Aires city legislature in July 2020 is one example.

to reduce their monthly bills, change the way they consume electricity, or choose sources of energy they consider more acceptable in environmental terms, among other potential benefits that might emerge from varied plans. Dynamic prices may take different forms, but hourly rates are the most flexible option.

Pricing regulations for the distribution segment would need to adapt to its new functions. This component of electricity tariffs no longer includes the supply of electricity: it only covers distribution infrastructure. The distribution margin will now be included in end-user electricity tariffs, along with an energy component (whether with a commercialization margin or separate from this margin) and a transmission component, so electricity bills will better reflect costs. The distribution segment will face the new challenge of covering the cost of infrastructure, through fixed and variable components, in a service whose cost structure that tends to be biased toward fixed costs. It is unclear whether volume-based tariffs (particularly those with variable costs that increase per consumption interval) are viable instruments to reward distribution, especially if we take into consideration the evidence reported in Aoki *et al.* (2018) for Brazil, in the context of the introduction of NCREs.[91] On the other hand, however, we should assess whether a scheme that is based on uniform fixed charges would cause affordability problems (particularly for low-consumption, low-income households). If it does, we will need to consider alternative schemes to pay for infrastructure (for instance, a tariff menu with a low fixed charge, high variable charge option that is only applicable to low-income users).

Passenger transportation platforms, in turn, will need to facilitate operations based on dynamic responses to demand changes within a given market. Potentially dynamic market responses entail an option to change not only supply based on demand, but also tariffs at given points in time. This aspect is the main disruption introduced by these platforms and the crux of their conflict with the traditional transportation system, since regulation does not allow taxis to adopt dynamic pricing.

Cooperation and interaction among different sectors

Interconnections among sectors based on shared infrastructure will make it necessary for those sectors to cooperate and to coordinate each sector's regulations. Different sectors' new technological developments will use the same ICT infrastructure. This will blur the lines between sectors. In the near future, they will be sharing infrastructure that is essential for service provision. This interconnection will pose challenges in terms of investment (particularly concerning who should invest in infrastructure that is to be used by several sectors) and in terms of regulations (particularly what sector should be in charge of regulating and managing these common assets).

Chapter 2 mentioned that a well-developed, good-quality ICT infrastructure is a necessary precondition for smart grid deployment, and it is not always available. Dantas *et al.* (2018) address the case of Brazilian electricity distribution firms who have had to build their own telecommunications networks to be able to implement their digitalization projects, because telecommunications operators lacked the interest or the capacity to build them.

In the case of urban transportation, the authorities would not only need greater coordination with telecommunications authorities but would also have to cooperate with technology companies. In the United States, for instance, this has been done by creating a new type of firm, known as a transportation network company, to acknowledge a new type of business activity and regulate some of its actions.

This convergence in terms of technology, platforms, and business models makes it reasonable to expect greater cooperation among sectors in the future, yet another aspect in favor of joint regulations among different sectors. Research has been conducted on the convenience of developing a multisector regulator or multiple single-sector regulators (Laffont and Tirole, 2001, and Schwartz and Satola, 2000). The literature highlights the

91 Most users who are opting to engage in this type of investment are in the most expensive tariff categories. When the pricing scheme involves rising intervals, as customers stop purchasing electricity from the distribution company (or reduce their purchases), the company will lose a major source of revenue.

advantages of single-sector regulation rather than multisector regulation. Benefits include the chance to compare regulator performances, their specialization and experience in a given sector, and the way they can provide incentives within public institutions (which can be better implemented when stakeholders focus on a specific mission). Among the aspects that favor multisector regulation, there is the optimization of scarce funds, technology, and human resources (particularly when knowledge and technical expertise are transferrable between sectors), reduced risks of capture by special-interest groups (as long as these differ among sectors), and the build-up of a record to acquire a (good) reputation concerning regulatory practices, dispute resolution, and so on. Digital transformation may be an additional factor in favor of a multisector regulator, but whether conditions are right to make significant changes in regulatory models is something that remains unclear, based both on experiences of single-sector regulators (as in the cases of Brazil, Chile, and Peru) and of joint regulation (Uruguay). Beyond these considerations, in the current context, digitalization progress may be more effective to facilitate greater cooperation and coordination among various regulators than convergence toward a single institution regulating all sectors.

Training

Digitalization also involves a range of new capabilities in institutions involved in infrastructure sectors. These abilities are necessary to ensure better performance and to reduce service gaps, and they include technical knowledge among stakeholders within each sector and among complementary actors, as well as intangible capabilities. The general principles cited by the OECD as best regulatory practice may guide the adoption of adequate governance structures in infrastructure sectors.[92]

Integrating new digital technologies into state institutions is something that has already been done in several countries. It has created opportunities to adapt the public sector's management systems and helped to implement sustainable long-term public policies. Opportunities have also emerged for the public sector to adopt a model that focuses on capacity-building with a more forward-looking vision, in line with digital environments, that covers all the activities people engage in. The challenge of capacity-building emerges both within the state and in ties between the public sector and society at large.

Once a regulatory scheme has been adopted, the next step is to adequately implement progress made possible by new technologies. The first key aspect in this context is to have a staff of individuals who are qualified to understand, operate, and communicate the changes. McKinsey Global Institute (2018) notes that governments should make it a priority to recruit technology-savvy talent, at least in specific areas. These recruitment efforts may involve employees or subcontracted workers, supplemented with tools like internal training and the development of strategic alliances (Vié, Buvat, Srivastava, and Kvi, 2015). Hiring new qualified staff or training existing employees may happen alongside the creation of a new division to centralize and take over all tasks requiring digital capabilities or may require that all workers, each from their separate divisions, handle the areas assigned to them, including those that require technological knowledge. Alternatively, certain activities could be subcontracted to a firm that focuses exclusively on the digital needs of the regulatory entity. The German electricity company E.ON, for instance, signed a five-year agreement for data center services.

In particular, taking digitalization as a disruptive factor for these regulatory frameworks requires an assessment of how basic or complementary various digital tasks are for sector development and how they should be regulated, to then consider the role of a chief digital officer.

The second key aspect is the need to update software, to consider, for instance, the use of new tools that enable larger-scale data gathering and processing. This would make it easier for the state to address new user

92 One element of these guidelines involves having clear policy objectives, considering economic, environmental, and social impacts, trying to minimize cost and market distortions, and fostering competition and innovation through incentives, all based on solid legal and empirical grounds and with clear, simple, and practical instructions for users, in line with other policies and regulations (see OECD, 2014).

demands, which change constantly as new generations reach adulthood. On the other hand, it would pose new challenges for the public sector in terms of planning and of the constant review and assessment of prior decisions, to be able to respond to changes in technological development and change cycles, based on the permanent generation of significant volumes of data that need to be taken into consideration in decision-making. For example, with generational change, "digital literacy" policies will not be necessary in the future, once a high level of digital education has been attained.

Digital transformation in various sectors had a similar impact on service provision companies and on the regulators in charge of supervising regulatory framework implementation. In the case of regulators, it started in the financial sector and in capital markets (central banks and securities and exchange commissions) and is currently expanding to regulators in public services including transportation and communications (López Azumendi, 2020).

Digitalization appears useful to solve regulators' most relevant challenge: asymmetric information on the cost of service provision, favoring regulated firms. Tools like natural language processing and artificial intelligence would enable a smart use of data. Some examples include efficient systematization of comments regarding regulatory suggestions and data interoperability concerning service quality, from all the information available in the management systems of both firms and the regulator. One example is Mexico's National Banking and Securities Commission (*Comisión Nacional Bancaria y de Valores de México*), which digitalized processes and managed to reduce costs and delays in reporting by listed companies and to improve its monitoring practices, especially those to fight money laundering and fraud (di Castri, Grasser, and Kulenkampf, 2018).

Investment

Adapting new technologies to sector infrastructure requires investment that enables adjustments in current networks and systems. This in turn requires rules to reward new investment in physically adapting networks.

Investment required to digitalize an electrical grid includes purchasing smart meters, smart sensors, and advanced switches, and new software, and strengthening the traditional grid (transformers, wiring, etc.). Further, since the quality dimension is the weakest in Latin America (Chapter 1) and since investment in smart equipment for the electrical grid enables certain service quality improvements at a lower cost than direct grid investment (Astarloa, Kaakeh, Lombardi, and Scalise, 2017, p. 15), an opportunity arises to increase investment in rapid response mechanisms (like failure location and optimized routing).

Progress in distributed generation triggered a need for bidirectional grids and smart metering equipment that enables customers to sell their energy in the market. NCRE intermittence affects system reliability. When these sources of energy have penetration rates of up to 20%, electrical systems require no major adjustments, because they tend to have a certain degree of flexibility to address unexpected variations. However, penetration rates above 20% need investment to increase system flexibility (Fischer, 2020). This could require interventions of various types. The options available to adapt the system include interconnecting several electrical systems (involving, for instance, two countries or two regions within a single country that were previously not connected), investing in gas-fired power plants that can respond fast to supply fluctuations, having hydroelectric dams that accumulate energy during the day,[93] having pumped storage available, or having excess NCRE capacity and settling for the loss of a portion of the electricity that is generated. Interventions can also address demand, increasing it at times when solar generation is greatest and reducing it when it is at its

93 In countries with large hydroelectric generation components, like those in Latin America, the first option is to save dam water during the day and to release it at dusk, so the system needs adequate price signals. This implies using dams as system batteries. However, we should be careful not to interfere with other uses of water, like watering crops and water's environmental services. One way to achieve this is to build counterdams that collect the water that is released overnight to copy natural river-flow variations (see Fischer, 2020, and Secretaría de Gobierno de Ambiente y Desarrollo Sustentable, 2019, for a classification of hydroelectric projects by mode of operation and by the capacity to regulate flows).

Adapting new technologies to sector infrastructure requires investment that enables adjustments in current networks and systems.

lowest levels (for instance, by charging electric vehicles in places of work and implementing other ways to increase demand during these periods).

The ability to influence demand requires consumers who are willing to change their consumption patterns. In this context, Figure 39 uses ECAF data to illustrate the fact that a high percentage of survey respondents said they were willing to change the times when they used certain electric appliances if this led to a reduction in their electricity bills.

In the case of urban passenger transportation, greater investment will foreseeably be needed to adapt traditional infrastructures to new technologies so the latter can be beneficial. Some examples are adapting bus stops to show expected arrival times in real time, integrating GPS technology so vehicles can be located and the relevant data can be sent to stops, and cell phone apps to provide this information to users.

These data can also be used to oversee and improve service operations, for instance using GTFS systems. Traffic data can be standardized or updated based on information concerning routes, frequencies, and fares provided by service operators.

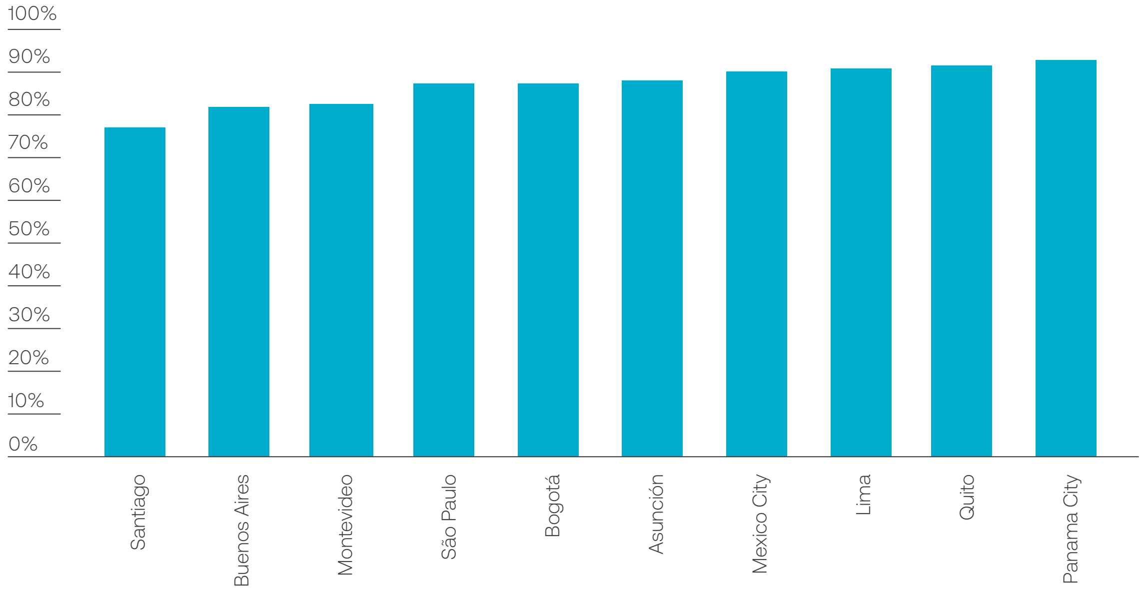
Integrated modes of payment further require investment to adapt fare collection machines to take specific modes (including payment options involving cell phones and credit and debit cards).

In any case, investment in traditional assets should not be dismissed. In an economic development context where cities are increasing in size, investment in traditional infrastructure—whether in electrical grids or in transportation systems—will remain necessary.

One aspect that is common to the electricity and urban transportation sectors and that will become increasingly important in the future involves mass use of public and private electric vehicles, which will help to reduce greenhouse gas emissions but not necessarily congestion (when they merely replace conventional vehicles). This will require strengthening specific segments of distribution networks, given increased demand for vehicle charging facilities. Electric vehicles can also provide storage services and, as in the case of distributed generation, might require bidirectional grids to be able to inject energy into the system. The need to strengthen networks may be reduced by using smart tools, so not all vehicles are charged at the same time, or so they are charged during the day, when there is more solar power available, for instance.

The risk of obsolescence is a challenge for investment in technology, in a context of rapid technological change where certain assets (known as stranded assets) are not dropped. While this is an issue in any competitive market, it becomes a significant problem when technology interacts with regulated sectors. The main danger is that investment will be lost or become too expensive *ex post* if its value drops fast. In that case, future pricing strategies that only take into consideration the

Figure 39
Share of individuals willing to change their consumption patterns if this leads to reductions in their electricity bills
Source: Compiled by the authors, based on data from ECAF 2019.



cost of technology that is efficient at that point in time will discourage investment in smart technologies until technological progress stops. However, waiting until technological change slows down might indefinitely delay investment with the potential to improve service quality and to reduce costs.

In transition processes, assets that become obsolete pose a real problem that discourages investment unless there is a commitment to reward investment in subsequently stranded assets. Legislation concerning these stranded assets needs to be cautious, because lax regulations might lead to excessive investment in assets that will soon become obsolete. While there is no easy answer to this dilemma, on way to encourage this risky investment involves a pricing mechanism that continues to pay for these technologies during their whole life cycle, even after technological progress has made them obsolete, but only under certain conditions (for instance, when the regulator previously authorized this investment). Another alternative is to valuate investment in efficient technologies authorized by the regulator at its original cost, even if future pricing decisions are made once its cost is a lot lower.[94] It is therefore advisable to adopt a policy that requires authorization by regulatory authorities, who should assess costs, benefits, and risks before approving any investment that will potentially have to be paid once it has become obsolete.

Finally, it is worth noting that investment in good-quality resilient infrastructure is essential to support the development of digitalization in the electricity and transportation sectors. It is therefore necessary for investment in infrastructure to consider resilience from the planning stage, by identifying risks and mitigating factors concerning system capacity, capabilities, and response times when faced with certain threats.

94 The literature on regulated sectors is already addressing this problem. For example, Villadsen, Vilbert, Harri, and Kolbe (2017) suggest using an options model to decide on the optimal time to invest in new network technology, in order to achieve the desired distribution of stranded assets, based on the growth and risk path of regulated assets into the future (p. 298).

Public policies

Beyond creating opportunities to improve service provision, new technologies also have redistributive, environmental, and security implications. It is therefore important to assess the role public policies can play to manage these effects. In this new environment, the state must focus on innovating through the adoption of medium- and long-term sector policies and through the adaptation of these policies to new technologies. The state must ensure continuity in the rules of the game to ensure sector stakeholders (from end users to investors) trust the system, while regulatory and sectoral authorities need to focus on policy implementation.

Social policies

Regressive redistributive effects are a consequence of the impact of technological change on low-income-users' ability to benefit from infrastructure services. They may cause or expand service gaps. However, digitalization can also enable the use of tools to implement compensation policies. In this context, there is room to foster innovative mechanisms or to refine existing tools within social programs.

In the electricity sector, likely routes for redistributive effects can be identified. First, the use of smart meters enables the detection of illegal electricity consumption, which is a major component of distribution leaks. In general, we should expect this problem to be more common in low-income areas. Reducing electricity theft will therefore mean that many lower-income households have to pay for a service they previously did not pay for. The need for a social program to compensate for this becomes apparent, as long as these users are still allowed to access the service. Since users would now be identified, a targeted social tariff scheme would be an option for the regulator or for the relevant ministry to mitigate the effect that payment would have on these households' finances.

A second route is to eliminate cross subsidies between high-demand and high-income users and low-demand users, something that would happen with the adoption of new plans once commercialization and distribution have been separated. The cross subsidy instrument is hard to keep up when the role of a commercialization company emerges, because the latter can arbitrate among stakeholders (White and Sintov, 2019). One option to neutralize this impact is to keep pre-existing pricing schemes, so no one is worse off than they were previously. However, this may require subsidies for commercialization companies per low-income, low-consumption user, to compensate firms for the losses associated with keeping up pre-reform plans under the market's new conditions. To some extent, this updates the role of social tariffs applied to the commercialization component. An alternative is to grant subsidies to low-income users so they may pay for these plans, in the context of a transfer program.[95] This prevents low-income consumers from being harmed by the changes, but it does not enable them to benefit from the changes.

A third route involves the benefits of digitalization in terms of changes in home equipment (installing distributed generation equipment, purchasing electric vehicles, and so on) and consumption adaptations. All these are more likely to happen in higher-income households (White and Stinov, 2019).

A fourth (progressive) distributive effect in this sector emerges from the development of microgrids to provide services to remote areas. Problems to provide a good electricity service in these areas start with the high cost of enabling connection to the electrical system's main grid, and they usually require subsidies. Even when a connection is made, lines are long and radial, so they have stability and voltage-drop issues. They are also prone to failures that take a long time to be fixed due to their remote location, which leads to poorer-quality services.

In the case of urban transportation, one potential effect of digitalization involves reduced travel times and a more efficient use of the transportation system. Likely distributive effects will depend on the adoption of these technologies. For users, new technologies

95 Within broad transfer programs, Chile has an explicit water module and the Dominican Republic has explicit modules on electricity and gas. These modules decouple the social component from the regulatory process and place it within social policies instead.

require certain digital tools and instruments (cell phones, apps, mobile data, and so on) and the ability to use them. As technologies are adopted, groups of users who lag behind may emerge, either because they do not have the necessary tools (most likely lower-income households) or because they do not know how to use them (older persons). In this context, not all people will be able to access the full benefits of digitalization. As ICTs become more widespread (particularly among lower-income users), it starts to appear more likely that having given tools will not be the main problem. Concerning the use of these technologies, one social program that could neutralize this effect involves developing “digital literacy” schemes that focus on individuals belonging to the groups who are lagging behind, to enable these individuals to use the information that would become available to them by using the relevant tools. For service providers, technology adoption could also happen in inequitable ways. Most technologies (at least those that are currently available) have emerged in the private sphere, and their use and benefits are not necessarily transferrable to public transportation services. Public transportation users (usually those with the lowest incomes) therefore do not get all the benefits digitalization could bring. In this context, the government needs to understand how important early adoption of the relevant technologies is to improve the urban public transportation service.

On the other hand, digitalization could enable better-targeted public transportation subsidies. For example, technology enables links between subsidy schemes and specific smartphone payment apps for lower-income groups, and the creation of electronic payment cards to pay for subsidized trips targeting these groups. Monthly subscription plans to use public transportation, possibly including targeted subsidies for certain groups, are a further available instrument, though one that is yet to be adequately explored in LAC.

A problem shared by all sectors (electricity, drinking water, and urban passenger transportation) is the fact that, as a consequence of the COVID-19 pandemic and its effects on the economy, operators are currently facing challenges to provide public services in a context of major financial difficulties. In these sectors, governments subsidize public services (to a greater or lesser extent, depending on each country) in the context of a policy to settle the necessary trade-offs between efficient allocation, cost minimization, and redistributive and environmental aspects. The current context needs more complex commitments, since it requires biosecurity measures in transportation (including vehicle use below capacity), shutoff bans, and service payment deferrals (in the electricity and water and sanitation sectors). During the year 2020, state involvement increased and took different forms (financial support, transfers, input subsidies, and so on), but these measures are not sufficient, given the current fiscal constraints and those that are expected to prevail in the coming years.

Environmental impact

Technological progress may favor the environmental agenda. Sectoral electrification (for instance, electromobility in transportation) will enable a reduction in harmful gas emissions, as long as the life cycle of electric vehicles—including, for instance, their batteries—and the incremental electricity generation they require pollute less than the life cycle and the fuel required by the modes of transport they replace. Decentralization through NCRE-based distributed generation introduces a change in the energy mix to favor renewable sources of energy. If they are adequately fostered, both trends could have positive environmental effects.

However, these benefits could possibly not be attained if it is a private agent who assesses whether investment in digitalization is convenient. In this context, the state is in charge of aligning private incentives with social benefits (including environmental aspects), and with all other distribution and security effects. It is also important for environmental policies to be in line with the remaining goals and effects of digitalization.

In the effort to develop tools for the successful implementation of environmental policies, countries have had to resort to instruments that encourage investment in renewable sources of energy, through subsidies that have redistributive effects. In the electricity sector, for instance, distributed generation subsidies have had regressive effects in several European countries. In Germany, where solar panels for home use have been subsidized, beneficiaries were mostly house residents, who usually earn higher incomes than people who live in apartment buildings, and yet the latter had to pay larger electricity bills to fund this transition (Frondel, Sommer, and Vance, 2015).

Something similar has happened in Peru, with the implementation of policies to foster the large-scale use of natural gas and hydroelectric power, which have led to an excess capacity. These policies contradict another policy that subsidizes non-conventional renewable energy sources (through power purchase agreements [PPAs]). Subsidy amounts depend on the difference between the price set in a PPA and the price in the short-term market for electricity, which is very low given the prevailing excess capacity. This combination of contradictory policies has increased the price households and other regulated users have to pay for energy.

In the transportation sector, one environmental concern involves pollution from motor vehicles, due to the emission of greenhouse gases. Public policies that tend to increase the adoption of alternatives to private transportation (public transportation, ridesharing, or active modes of transport like those put forward by micromobility platforms) or the electrification of transportation help to reduce pollution caused by urban transportation. Electrification is also happening in public transportation. Several Latin American countries are currently introducing electric buses. Electrification in this field has a positive environmental impact, although users are yet to internalize its benefits. Deepening these effects may therefore require public policies that foster the necessary changes (for instance, through subsidies to purchase electric cars).

Sustainable infrastructure agendas will remain available to guide these solutions. However, some initiatives (like the transition toward more decentralized, less polluting systems) may take time in a context with major fiscal constraints.

Security policies

In an interconnected world, security risks increase and reliability and trust vary depending on the protocols that are adopted (Connor *et al*., 2014). Introducing digital components in infrastructure sectors makes users and systems more vulnerable to threats that were previously known in computerized systems only. In this context, one key role for the state in infrastructure sectors involves ensuring that regulators pay adequate attention to security problems concerning personal data, cybersecurity, and system resilience to attacks and other incidents.

Any information systems developed in infrastructure sectors need to guarantee a secure environment for service provision, which may require significant investment in cybersecurity (Muller, 2015). The author further identifies the challenges countries face to update their legal and regulatory frameworks to incorporate ICTs, to educate their citizens on the risks and threats of these new contexts, to acknowledge and accept the risks associated with ICT adoption in other sectors, and to act on the need for interaction between the public and private sectors (since it is the private sector who owns most of what makes up the Internet).

In the electricity sector, governments, the industry, and academia have all made substantial efforts to improve smart grid security (Gunduz and Das, 2020). Even so, Leszczyna (2018) notes that debate is ongoing as to the best possible standards applicable to this technology. So far, there have not been many major cybersecurity incidents in electricity (the case of Ukraine was mentioned in Chapter 2) or in other infrastructure sectors. Operators therefore face challenges to choose (among several available options) concrete standards for specific aspects of smart grids. On the other hand, protecting data is crucial to preserve user privacy and to ensure appropriate integration of all the systems that interact with an electrical grid. Since digitalization enables the grid to be more responsive to changes in electricity generation and consumption, some authors (Wildt, Chappin, van de Kaa, Herder, and van de Poel, 2019) suggest that solving the conflict between privacy, on the one hand, and network efficiency, reliability, and sustainability, on the other, should foster acceptance of new technologies. This conflict could be solved through technological innovation, through changes in system design and organizational structures, and through communication among stakeholders.

The transportation sector, and countries more generally, have taken personal data protection seriously for many years. Levy-Bencheton and Darra (2015), however, say that transport companies are not paying enough attention to cybersecurity. These authors make the following suggestions (among others) to address this problem within the transportation sector: demanding that physical and digital infrastructure meet certain security criteria; developing and implementing recovery processes in case of attack or disaster, and having back-up copies of data in secure remote locations; separating critical systems from systems that are not critical (critical systems or functions should not be accessible through other installed non-critical systems); and implementing security checks that are monitored in real time.

More recently, the risk of infection with COVID-19 and the broader risk of spreading the virus (particularly in closed modes of transport, like buses and subways, with limited space and few tools to identify sick or unclean passengers and to ensure clean surfaces) brought to light a new security dimension: biosecurity. Policies associated with mass, intensive use of public transportation had to be reviewed to meet social distancing requirements and restrictions on movement in various countries. For example, the Collaborative Group on COVID-19 and Mobility in Colombia (*Grupo Colaborativo de Modelamiento de COVID y Movilidad en Colombia* [2020]) actively monitored the different policies implemented by the authorities. It also collected the available evidence on viral transmission mechanisms and developed a proposal to update biosecurity regulations concerning passenger behavior based on five aspects (adequate face protection, not talking, ventilation without recirculation, shorter trips, and cleaner surfaces) to prevent infection. Local policies will surely be updated as the authorities move toward a new normal.

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