COALITION FOR URBAN TRANSITIONS
A New Climate Economy Special Initiative

Working Paper

Connected Urban Growth: Public-Private Collaborations for Transforming Urban Mobility

Diego Canales, Shannon Bouton, Elaine Trimble, Julia Thayne, Larissa Da Silva, Srikanth Shastry, Stefan Knupfer and Martin Powell

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Executive Summary

Innovative, technologically sophisticated operators of ride-hailing networks, car- and bicycle-sharing systems, mobile trip-planning and ticketing apps, and other new mobility services are winning users in cities around the world. Their reception suggests that city dwellers need transport options that are more convenient and flexible than those offered by traditional private transport companies and public transit agencies. Public transit is a vital element of efficient urban transportation systems: the use of public transportation has grown steadily since 2001, with developing countries showing the fastest growth. However, many public transit systems face challenges such as rising costs, ageing assets, and rapidly increasing ridership. While private transportation services have given passengers appealing options in many cities, these services can also exacerbate problems related to safety, environmental quality, and other issues.

As new mobility services proliferate, cities will have opportunities to influence their roles so they not only improve convenience for passengers but also create wider economic and environmental benefits for all city residents. One approach, which some 70 cities worldwide have taken, is to form partnerships that allow cities to use the distinctive features of new mobility services to improve their transportation systems overall. Evaluating the possibilities associated with this approach requires an understanding of the development of new mobility services in cities around the world, the partnerships that have been formed to date, and the economic and environmental implications of complementing public transit with new mobility models.

Photo credit: *Visty Banaji*

About this working paper

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Coalition for Urban Transitions
c/o World Resources Institute
10 G St NE
Suite 800
Washington, DC 20002, USA
+1 (202) 729-7600

C40 Cities Climate Leadership Group
North West Entrance, City-Gate House
39-45 Finsbury Square, Level 7
London EC2A 1PX, United Kingdom
+44 (0) 20 7922 0300

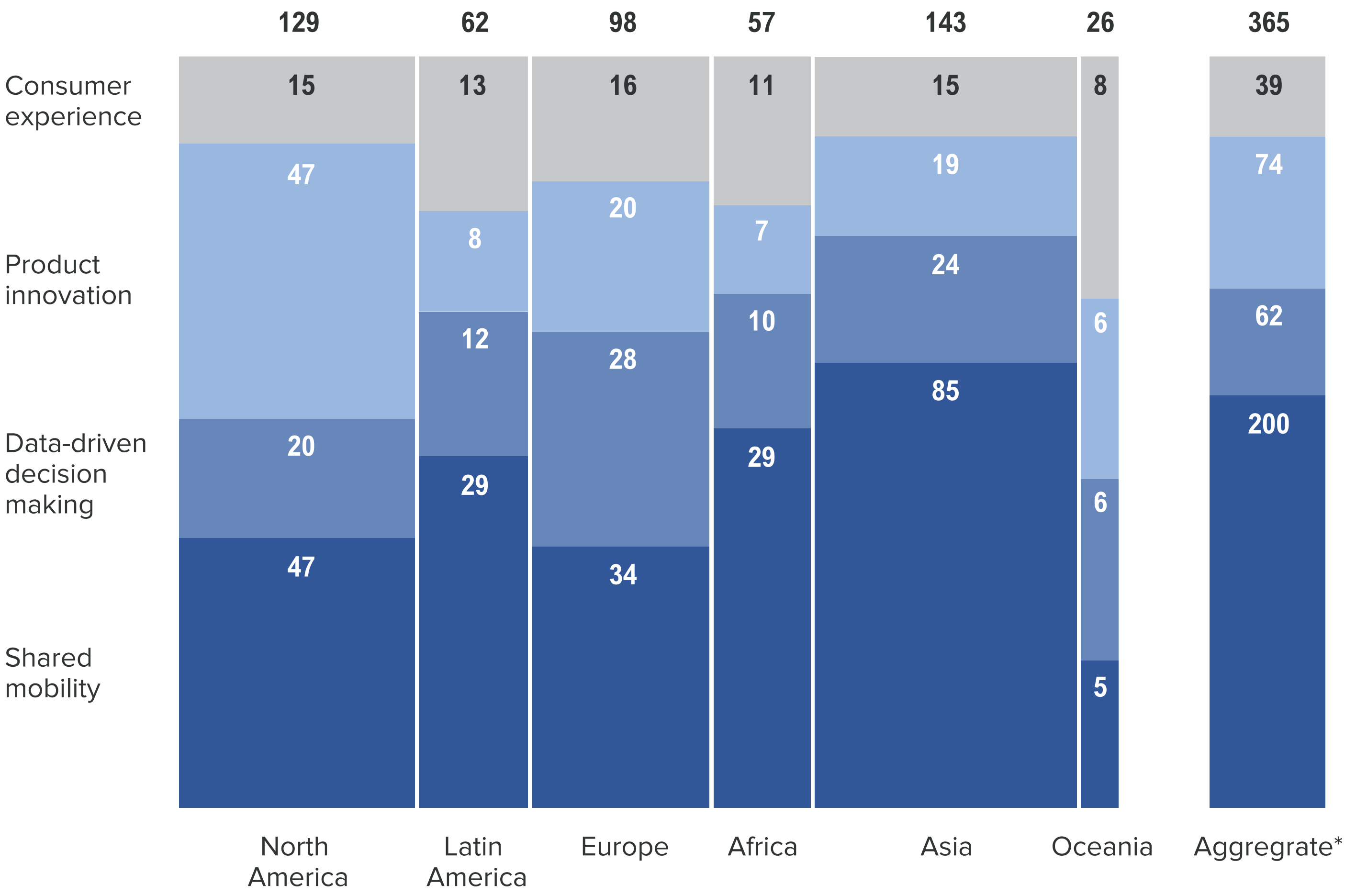
WRI Ross Center for Sustainable Cities
10 G St NE
Suite 800
Washington, DC 20002, USA
+1 (202) 729-7600

This working paper presents a working definition of the term *new mobility services*, which encompasses a broad set of emerging operating models and technologies that are intended to improve the performance of urban transportation systems. It also presents the first global survey of new mobility services, and identifies emerging trends and opportunities for decision-makers in both the public and private sectors.

More than half of new mobility start-ups fall into the shared mobility category, and every region of the world has homegrown companies of this kind (Figure ES.1). While shared mobility services include familiar varieties such as mass transit and taxi services, the newest ones are defined by their use of data and technology to streamline the dispatching and tracking of trips, as well as the user experience, from arranging the service to paying for it. Start-ups in a second category of new mobility services – product innovation – mostly concentrate on the development of self-driving vehicles and electric vehicles.

Figure ES1

More than half of new mobility start-ups fall into the shared mobility category



** The aggregate number of service providers in each category is less than the sum of the regional counts of service providers because many service providers operate in multiple regions. For the aggregate column, each of these service providers is counted only once.*

Source: AngelList, CrunchBase, authors' analysis, August 2016.

In the consumer experience category, 70% of start-ups specialise in the analysis and provision of information about public transport, an enterprise that has been greatly aided by the trend of governments providing open access to their data on transit system operations. The remainder of consumer experience start-ups offer services that allow the planning and ticketing of urban journeys that use multiple modes of transport. Finally, start-ups in the data-driven decision-making category analyse data from multiple parts of urban transit systems to help transportation agencies make better choices about management, planning, and operations.

Perhaps because new mobility services are diverse and novel, there is not yet an obvious formula for how cities can maximise the benefits of these services while mitigating their societal costs, such as worsening traffic congestion or added air pollution. But it is clear that the arrangements that cities establish between their transit agencies and the providers of new mobility services will be critically important.

Figure ES2

Three new mobility applications have the potential to make public transportation more attractive and competitive

Application 1: Dynamic trip-planning and ticketing services

Purpose: Encourage city dwellers to take multimodal journeys by enhancing access to information and simplifying ticket purchases.

Benefits: Increased transit ridership; lower environmental impats

Mechanism: Technology platform, accessed with a mobile app, that integrates information and processes payments and tickets.

Partnership model: City transit agencies use third-party technology or contract with service providers.

Application 2: On-demand minibuses

Purpose: Streamline mass-transit systems by matching service levels more closely to demand.

Benefits: Lower operating costs; easier access to transportation; lower environmental impacts.

Mechanism: Fleet of electric minibuses, hailed using a mobile app, replaces underused fixed-route services.

Partnership model: City transit agencies use third-party technology or contract with service providers to run fleets.

Application 3: First- and last-mile ride sharing

Purpose: Broaden access to transportation for underserved city areas.

Benefits: Increased transit ridership and utilization; lower system-operating costs; expanded transit access.

Mechanism: Subsidies paid to passengers for on-demand shared rides from areas with poor transit access to transit hubs.

Partnership model: City transit agencies contract with ride-hailing companies to provide shared rides.

This paper identifies three promising applications of new mobility services by public transit agencies (Figure ES.2), and presents economic, social, and environmental modelling that illustrate the value of such partnerships to mass transit systems.

One application consists of services that let consumers plan multimodal journeys based on dynamically updated information and to purchase the tickets that these journeys require. In another application, transit agencies rely on on-demand mobility services to offer public transit riders a mode of transport that is more flexible and cost-effective than fixed-route buses and subways. And a third application involves subsidising passengers' use of ride-sharing services to make short trips to and from public transit stops in neighbourhoods that have limited transit access.

Although the results of existing new mobility applications have not been widely shared, simulating these three applications in London, Mexico City, and San Francisco suggests that they could have economic and environmental benefits. Dynamic trip-planning and ticketing systems and on-demand minibus services would each require modest up-front investments that could be paid back within two years by reductions in operating costs. Subsidising the use of ride-sharing services for first- and last-mile trips to and from transit hubs can boost mass-transit ridership and generate more farebox revenues with no initial capital outlay.

Further modelling of these three new mobility applications indicates that they could offer significant environmental benefits. Dynamic trip-planning and ticketing apps could cut greenhouse gas (GHG) emissions by 500,000 tonnes per year in 2020 across the three cities, as more people use public transportation, with Mexico City benefiting most. Total emissions from transportation across the three cities could be reduced by up to 6%. Replacing fixed-route diesel buses with on-demand electric minibuses could yield improvements as well: in Greater London, GHG and fine-particulate (PM_{10}) emissions could be cut by more than 80% and nitrogen oxide (NO_x) emissions by up to 95% per bus route, while San Francisco could see even larger reductions. Deploying ride-sharing services for first- and last-mile trips to and from public transportation stops, which enables more people to use mass transit instead of their cars, could reduce per-journey emissions of GHGs and local air pollutants by 55–80%.

Finally, this paper outlines several practices that can help cities make good use of new mobility applications to enhance the overall efficiency and experience of urban transportation systems. These include: establishing consistent policies on data security and sharing; compiling open datasets on their transportation systems; setting targets for the performance of transportation systems that reflect larger policy priorities; continuously assessing the economics of mass transit so as to pinpoint opportunities to boost efficiency; forecasting and preparing to manage effects on employment; and balancing short-term improvements to transportation systems with long-term infrastructure investments that are consistent with future mobility requirements. In turn, there are opportunities for the providers of new mobility services to collaborate with public transit agencies and city governments in ways that contribute to more integrated and efficient urban transport systems. None of this will be straightforward, but the effort should be worthwhile. Partnerships that let cities bring the advantages of new mobility services to their residents should make urban transportation services more accessible, affordable, and efficient than they would be otherwise – a change that all city dwellers can look forward to.

Introduction

Ride-hailing companies, car- and bicycle-sharing networks, mobile trip-planning and ticketing enterprises, and other innovative, technologically sophisticated providers of mobility services are winning users in cities around the world. The positive reception given to these services suggests that city dwellers are in need of convenient, flexible transport options at a range of prices – and that existing private and public transportation services offer fewer options than they might like. The challenges facing public transport systems around the world are well known: rising costs, funding constraints, increases in ridership, low-density urban development, and ageing infrastructure, among others. Cities with expanding middle classes and uneven access to public transit have also seen growing numbers of households acquire motor vehicles, which can cause traffic congestion and air pollution to get worse.

Accessible, affordable, and efficient transportation helps to improve the lives of all urban inhabitants. It is not obvious, though, how cities can best ensure that private and public mobility services will properly meet their residents' needs. Public transit, and mass transit in particular, remains indispensable for moving people around quickly, preventing traffic congestion and road crashes, limiting pollution, and freeing land for more valuable uses than parking space and roadways. Private transportation companies have long complemented public transit systems by serving neighbourhoods and population segments that cannot readily access public transit – witness the popularity of informal minibus and moto-taxi services in developing-economy cities – although these services can exacerbate other urban challenges like safety and environmental quality.

As new mobility services proliferate, cities have opportunities to combine them with their urban transportation systems in ways that address the challenges that public transit systems are facing and that support broader public goals. The considerations that surround this opportunity are complex, encompassing access, convenience, cost, employment, finance, pollution, and regulation, to name a few. In this report, we offer a close look at the manner in which more than 70 cities are attempting to integrate new private mobility services: by partnering with them. Such partnerships can allow transit agencies to apply the operating models and technologies of new mobility services to making transportation more affordable and convenient for all city residents, while improving environmental outcomes. Our study consists of the following elements:

- Part 1: An assessment of the demand for public transportation in cities around the world and the pressures that public transit agencies are facing, followed by a review of trends in the development of new mobility services worldwide.
- Part 2: An analysis of three potential applications of new mobility services for public transport agencies. The three applications are derived from our review of existing partnerships between cities and new mobility companies that enable new mobility services to complement public transport. We present the results from modelling the economic and environmental impacts of the three applications, which are as follows:
  - a dynamic trip-planning and ticketing app that makes it easier for passengers to take multimodal journeys;
  - a fleet of on-demand electric minibuses deployed in place of underperforming bus routes; and
  - subsidies for e-hailed shared rides to and from transit hubs in neighbourhoods with poor transit access.
- Part 3: A roundup of the key building blocks and enablers for the implementation of the proposed applications.

We hope this report will assist authorities, public transit agencies, and national governments in evaluating a wider set of options for maintaining competitive, sustainable, and robust transit networks. The report also aims to help cities and countries with less developed transit networks to assess the possibilities for leapfrogging certain capital-intensive investments in their transportation systems. New mobility companies, too, might benefit from learning more about how they can collaborate with city governments.

Part 1: The evolution of mass transit and private mobility services

Swelling demand for low-cost, high-quality urban transportation has led to more than 15 years of sustained increases in ridership. This has put considerable strain on public transportation systems. Financial pressures are mounting too: although revenues from passenger fares have gone up, the costs of providing mass transit have gone up even faster. Cities are also concerned about the environmental impacts of their transit systems, particularly on lightly used routes, and about worsening traffic congestion as more people choose to get around in personal motor vehicles.

These conditions have created abundant opportunities for entrepreneurs. Capitalising on advances in mobile communications, cashless payments, remote monitoring, data collection, analytics, energy storage, artificial intelligence, and other technologies, new mobility services have emerged to offer urbanites a wider array of transport choices than ever. Sharing services are enhancing access to transport options and lowering the cost of transportation by making better use of vehicles. Innovative products, such as electric and autonomous vehicles, offer superior performance. Sophisticated software aggregates data from private and public transport providers so consumers can plan and take trips based on real-time information, and city officials can make better decisions about mass transit and urban planning.

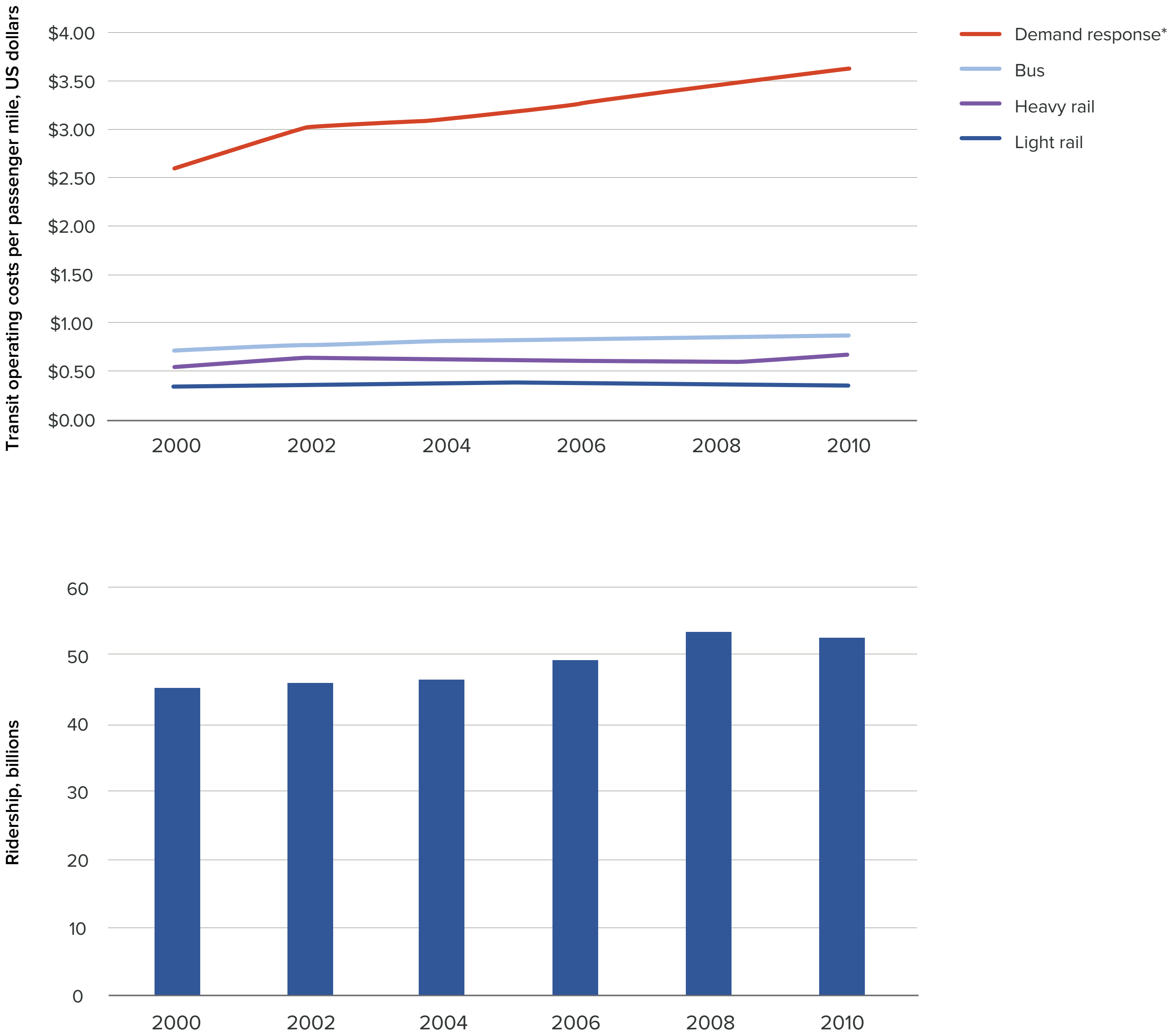
Looking at the activity of new mobility start-ups reveals how these services are developing in particular market segments and regions. Shared mobility services account for more than half of new mobility start-ups worldwide, and homegrown providers have cropped up in every region. These providers come in many varieties: in Africa, for example, e-hailed motorcycle taxi services have proven popular, while India's city dwellers have embraced on-demand shuttle services. Start-ups that provide information to riders have flourished as many cities have opened access to data about their transit systems. And mapping, navigation, and traffic monitoring applications dominate the market for data-driven decision-making services.

The growing demand for better urban transportation and new mobility services is transforming cities for better and for worse. For city officials, and public transit operators in particular, understanding the development of new mobility services will be essential to making sound choices for how to make mass transit more accessible, more cost-effective, and more efficient. In this part of the report, we explore the challenges that public transportation agencies are facing. We then turn to look at four categories of new mobility services that could help transit agencies meet these challenges, with a focus on how these services are emerging in the major regions of the world.

PUBLIC TRANSPORTATION IN CITIES: HIGH DEMAND, HIGHER PRESSURE

The use of public transportation, including buses, metro, light rail, and heavy rail, has grown steadily since 2001. This trend has played out worldwide, with developing countries showing the strongest growth, at 2.7% per year, in public transport trips per capita.[1] For many cities, increases in the use of public transit systems have coincided with increases in the cost of operating those systems. In North America, for example, the average operating cost per passenger mile increased for all modes of public transportation from 2000 to 2010: 22% for buses, 8% for heavy rail, 25% for light rail, and 39% for demand response (a mode of transport that provides passenger-scheduled trips on routes that are not fixed) (Figure 1). For the 10 largest transit agencies in the United States, average costs per mile increased by 19% from 2000 to 2010, while average fares collected per mile increased by only 10%. As a result, the average farebox recovery ratio – the percentage of operating costs covered by passenger fares – fell from 39.9% in 2000 to 36.9% in 2010.[2]

Figure 1
Operating costs for all modes of transit in North America increased from 2000 to 2010, along with passenger miles



** A mode of transportation that provides passenger-scheduled rides along routes that are not fixed.*

Source: U.S. Department of Transportation.

Falling fare-recovery rates have forced many governments to spend more on public transportation. Governments typically subsidise their transportation systems, in recognition that mass transit is needed to provide citizens of all income levels with a means of reaching homes, workplaces, essential services, and urban amenities. The degree of subsidisation can vary greatly among modes of transportation, and even among the areas of a single city (see box below).

Box 1

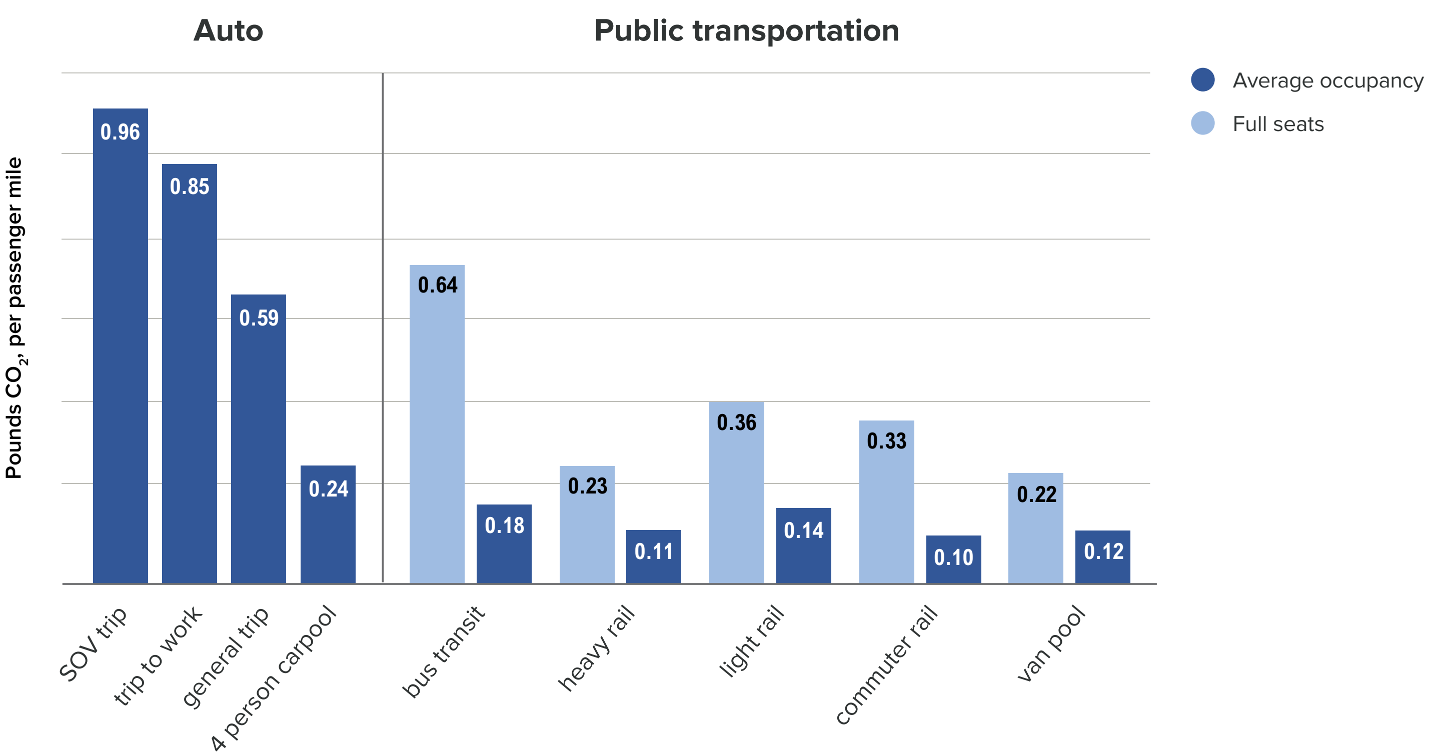
Austin, Texas identifies its most costly, least used public transit service

In 2016, Capital Metro, the public transit agency of Austin, Texas, published a study that identified its most heavily subsidised services, as well as those with the lowest ridership. The system's farebox recovery rate was approximately 10% including paratransit services (15% excluding paratransit services). The services with the lowest farebox recovery rates (6%) were Capital Metro's park-and-ride bus service, MetroExpress, and its airport shuttle service, MetroFlyer, which provide long-distance trips without turning over seats. They also receive greater per-passenger subsidies than the system average (US$5.76 average; US$7.40 MetroExpress; US$11 MetroFlyer). Local bus routes receive an average subsidy of US$4.23 per passenger; those with frequent stops average a subsidy of US$3.53 per passenger. (The most-subsidised local bus route, a senior shuttle in a particular neighbourhood, averages a subsidy of US$21.68 per passenger on Saturdays and nearly US$80 per passenger during the week, when ridership is low.) The commuter rail system, MetroRail, has a higher operating cost and thus receives higher subsidies: US$18.77 per passenger on weekdays and US$31.50 on Saturdays.[3]

The costs of operating public transit systems can inflate for any number of reasons: wage increases, service expansion, upkeep of ageing assets, or higher ridership for demand-response vehicles, to name a few. Studies suggest that the gap between fare revenues and operating costs can be narrowed by various cost reduction and revenue enhancement measures.[4] Even so, government subsidies will likely have to increase if the use of public transit continues to grow.

Figure 2

Greenhouse gas emissions per passenger mile are lower for high-occupancy vehicles and modes of transit



Source: Federal Transit Administration, 2010.[6]

Financial pressure is one reason compelling transit agencies to streamline their operations. Another is concern over environmental impact. Although significant evidence shows that public transit is often the least carbon-intensive mode of urban transport, mass-transit services running at low rates of capacity utilisation can produce more greenhouse gas (GHG) emissions per passenger mile than shared private vehicles. A typical 40-passenger diesel bus, for example, must carry at least seven passengers to be more environmentally efficient than the average single-occupancy automobile.[5] The greater the average occupancy rate for a given mode of transport, the less GHG emissions it will produce per passenger mile (Figure 2). For many cities, therefore, ensuring that trains and buses run with few empty seats is integral to producing better environmental outcomes.

A third reason for cities to maintain efficient mass-transit systems is to prevent traffic congestion, which has environmental, economic, and other costs to society. Despite the overall increase in public transport use, public transportation's share of all motorised urban trips has not increased uniformly among cities, countries, and regions. One factor is rising household incomes, which enable more people to acquire private vehicles. In emerging economies, the number of personal vehicles per capita grew 8.3% per year from 1995 to 2012.[7] For example, in the Brazilian city of Fortaleza, the number of private cars increased by 50% in just five years, while the number of people using public transport remained flat. Passengers might also gravitate from mass transit to new mobility services as future technologies, including fully autonomous vehicles, enable service providers to cut their prices.[8] More private vehicles taking to the road – including those operated by new mobility services – could cause traffic slowdowns and other negative consequences, such as increases in local air pollution, serious injuries and fatalities in crashes, and compromised public transit operations.

For fiscal, environmental, and efficiency reasons, spending more on public transit may not be the most cost-effective way of improving mobility in cities. This is particularly true when it comes to large investments in transport infrastructure or subsidies for transit services that are in light demand. New mobility services could help municipal authorities make urban transport systems more cost-effective, as well as more accessible in areas that are expensive to serve. As we explain in the next section, these services are already augmenting the transit systems of cities around the world in important ways.

THE DEVELOPMENT OF NEW MOBILITY SERVICES WORLDWIDE

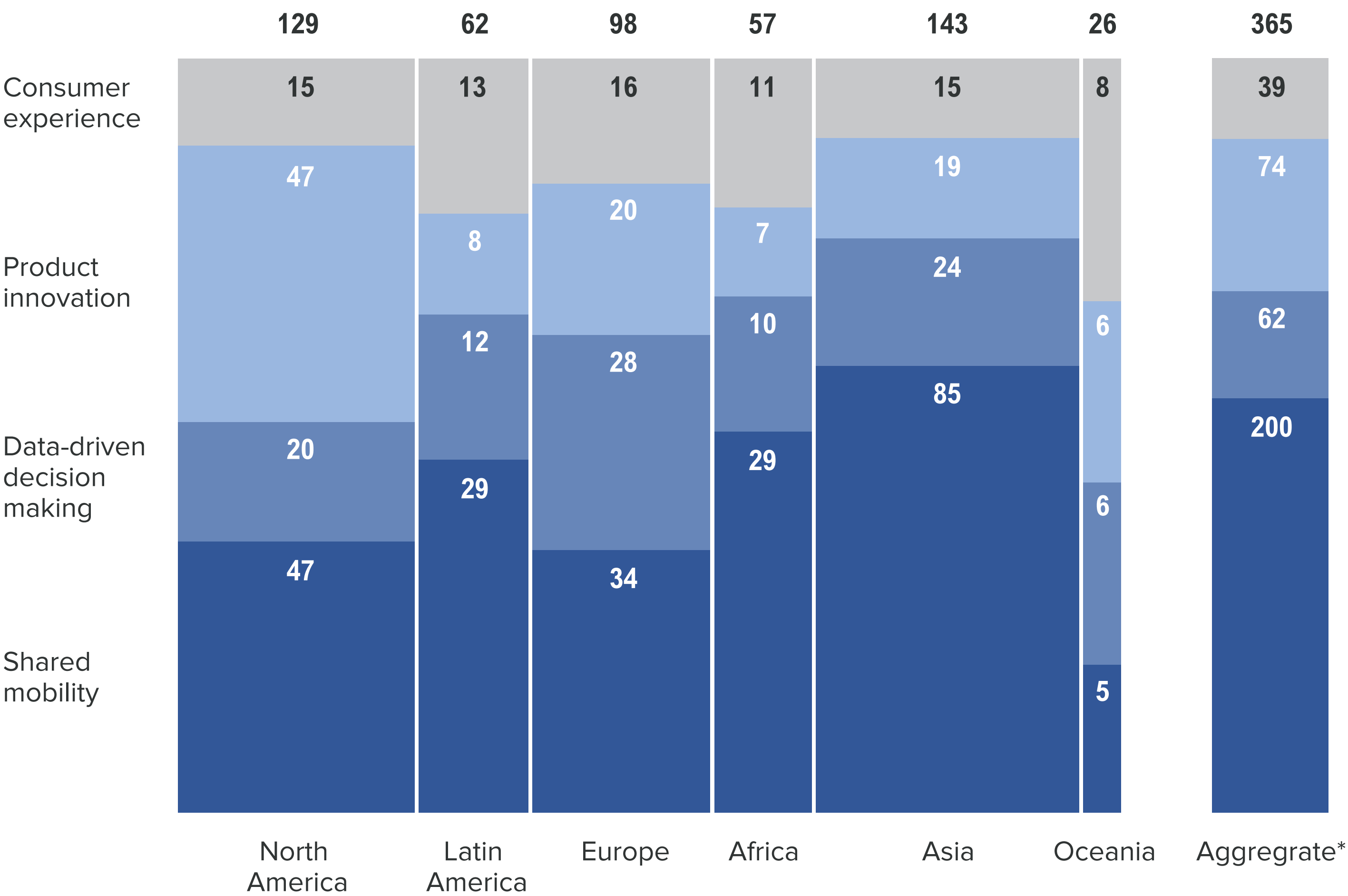
The term "new mobility services" encompasses a broad set of operating models and technologies that are used to provide transportation to people, usually without requiring them to own private vehicles.[9] Some of the most talked-about features of new mobility services are on-demand accessibility, mobile data connectivity, automation, and reliance on low- or zero-carbon energy sources. For convenience, we have grouped new mobility services into the following four categories:[10]

1. **Shared mobility:** Transportation services, including those that rely on private vehicles, for which access or ownership is shared among people either financially or physically.
2. **Product innovation:** Next-generation vehicles (including electric and autonomous vehicles) and transportation equipment that are improved based on analysis of performance data.
3. **Consumer experience:** Information services that combine timetables, fares, travel times, and other kinds of information on transportation options and make them available to users in real time, according to their preferences.
4. **Data-driven decision-making:** Services that aggregate data from multiple parts of urban transit systems and analyse these data, often using machine learning or other advanced computational methods, to improve transportation management, planning, and operations.

To understand how these four categories of new mobility services are developing around the world, we conducted a global scan of start-ups operating in this space. Specifically, we performed a region-by-region analysis of new mobility companies registered on AngelList and Crunchbase, two of the most inclusive global databases on start-ups. We chose to gauge the development of new mobility services in terms of start-up activity, rather than historical or present-day usage patterns, because entrepreneurial endeavours provide a forward-looking indication of demand for new mobility services.[11]

More than half of all new mobility start-ups around the world fall into the shared mobility category, and most of those – 63% – are in developing regions: Africa, Asia, and Latin America (Figure 3). Each region has homegrown providers of shared mobility services, such as the e-hailed motorcycle taxi services of East Africa and the e-hailed taxicab service Ola Cabs in India. The product innovation category is dominated by US-based companies and by start-ups working on

Figure 3
More than half of new mobility start-ups fall into the shared mobility category



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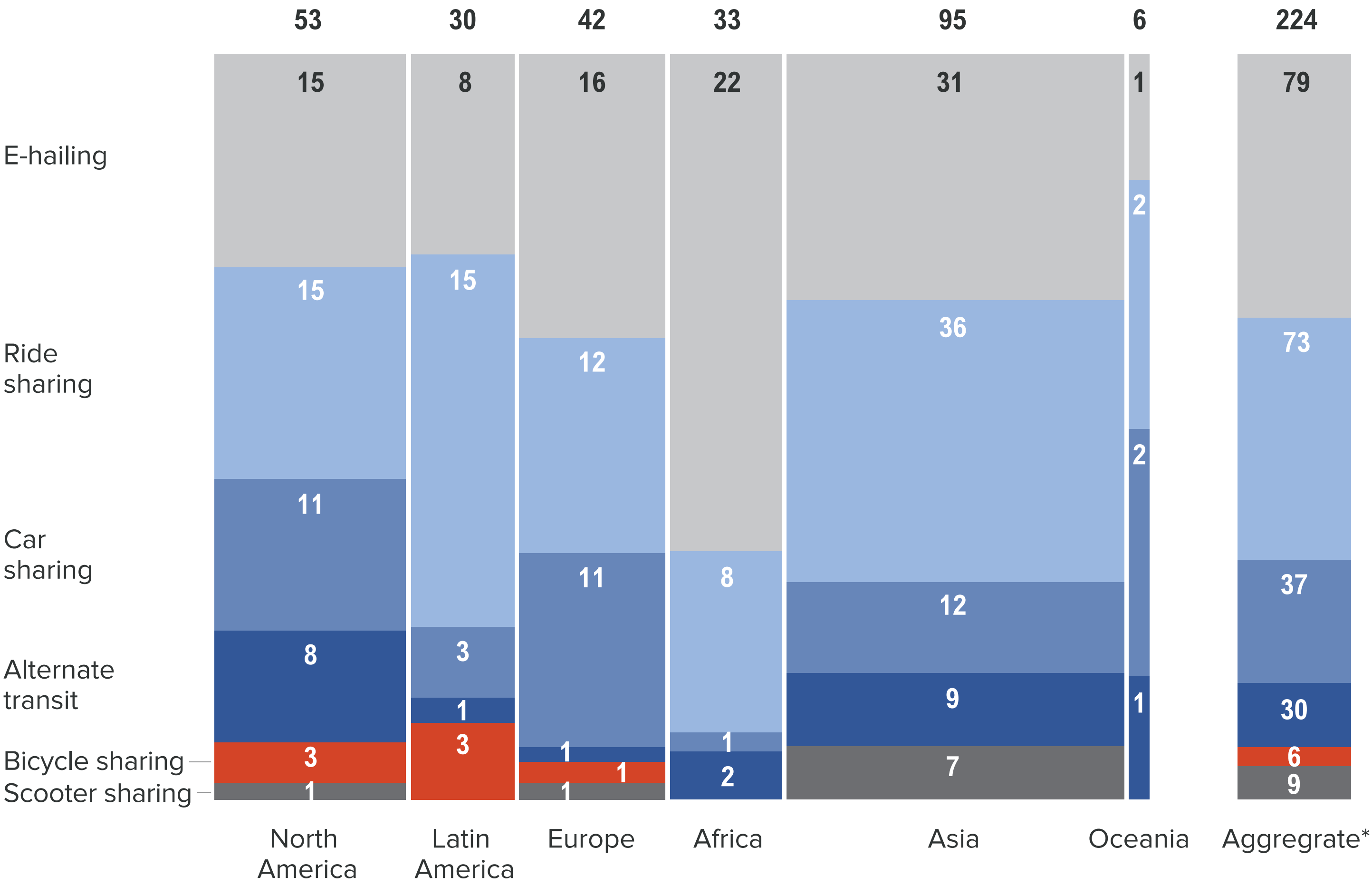
Source: AngelList, CrunchBase, authors' analysis, August 2016.

autonomous vehicles and electric vehicles. The consumer experience market is more homogeneous than the rest of the new mobility categories: 70% of the consumer experience start-ups we identified are focused on the analysis and provision of information about public transport. That enterprise has been greatly aided by the increasing availability of open data on urban transport networks. Finally, the majority of companies in the data-driven decision-making category are working on navigation, traffic monitoring, and mapping – the vital information streams for autonomous vehicles.

SHARED MOBILITY

Shared mobility services include existing forms such as mass transit, car rental, and taxi services, as well as emerging ones such as ride-sourcing, e-hailing, and bicycle sharing.[12] This study is primarily concerned with emerging models that are enabled through sophisticated uses of data and technology, rather than traditional forms, such as shared taxis and minibuses, that are commonly found in the cities of the Global South.[13]

Figure 4
On-demand mobility services represent more than a quarter of new shared mobility services worldwide



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Source: AngelList, CrunchBase, authors' analysis.

On-demand services, which include ride-sourcing and e-hailed taxi services, represent more than a quarter of the new shared mobility services across the globe (Figure 4). Every region has a major provider of on-demand services. North America, for example, has an abundance of native e-hailing applications, such as Bandwagon, Curb, and Flywheel.[14] In Africa, on-demand services make up 68% of shared mobility services. There, on-demand services largely consist of those that use technology to let riders tap more easily into pre-existing informal taxi networks.

E-hailing services for booking rides on motorcycle taxis have cropped up in East Africa and Asia, though these markets have developed in notably different ways, largely because of regulatory intervention. In East Africa, easy access to credit to purchase motorcycles, demand for affordable, quick transit, and light regulation have allowed *boda boda* hailing to take off. Some of these services have tried to distinguish themselves by offering trained drivers and helmets for passengers – unusual features for a mode of transit that has a local reputation for putting riders in danger. One called SafeBoda, which operates in Kampala, Uganda, is pursuing the goal of providing safer rides to customers, though it faces the challenge of changing their behaviour: only 40% of its customers choose to wear helmets.[15] Southeast Asian countries like Indonesia, Thailand, and Vietnam, where motorcycle taxis were already prevalent, have seen companies such as Go-Jek and Grab introduce e-hailed versions of these services.[16] In India, however, e-hailed motorcycle taxis have achieved less success as a result of regulatory disputes, a lack of customer awareness, and safety concerns. The Indian city of Bangalore imposed a ban on these services and began impounding motorcycle taxis in 2016.[17]

E-hailed automobiles have performed better than motorbikes in Asia, with native companies such as Didi Chuxing in China and Ola Cabs in India, challenging global ones.[18] Ola Cabs operates in more Indian cities than Uber (102 to Uber's 26),[19] and has more registered drivers there (550,000 to 350,000).[20]

Ride-sharing or ride-splitting services, which match passengers travelling along similar routes so they can share vehicles and fares, make up a substantial proportion of on-demand services across all regions. Many on-demand ride services now offer ride-sharing as well. These services have, however, faced regulatory challenges in a few countries over the safety of passengers and drivers, the competitive threat they pose to formal public transport, and the fact that their drivers do not always obtain the licences or permits required for the drivers of conventional taxis.[21]

Alternative transport services, mostly in the form of private shuttles, are best represented in India and the United States. Such services primarily cover well-travelled routes that lack direct public transportation links. The Indian providers Shuttl and Commut tout their comfort (air-conditioning and WiFi) and convenience (app-based seat reservations and bus tracking). Ride-sharing services like Chariot and Via in the United States aim to offer flexible routes so passengers can be picked up at convenient points. In both countries, shuttle providers have sometimes fallen foul of local authorities because the legal framework for operating in parallel with public transport is unclear.[22]

Car-sharing makes up the small remainder of shared mobility services. Car rental is an established and familiar form of car-sharing service, but not a new mobility service. Car-sharing, on the other hand typically offers more flexibility. Common features of car-sharing services include distribution of vehicles at kerbsides and parking lots throughout cities rather than at a small number of locations, vehicles that can be reserved and driven with little or no notice, simplified and largely automated transactions involving virtual payment platforms and card or phone scanners that unlock vehicles, and rental periods that are measured in short, even minute-long increments of time. Some providers locate rental stations near public transport hubs so people can make convenient connections during multimodal journeys.

PRODUCT INNOVATION

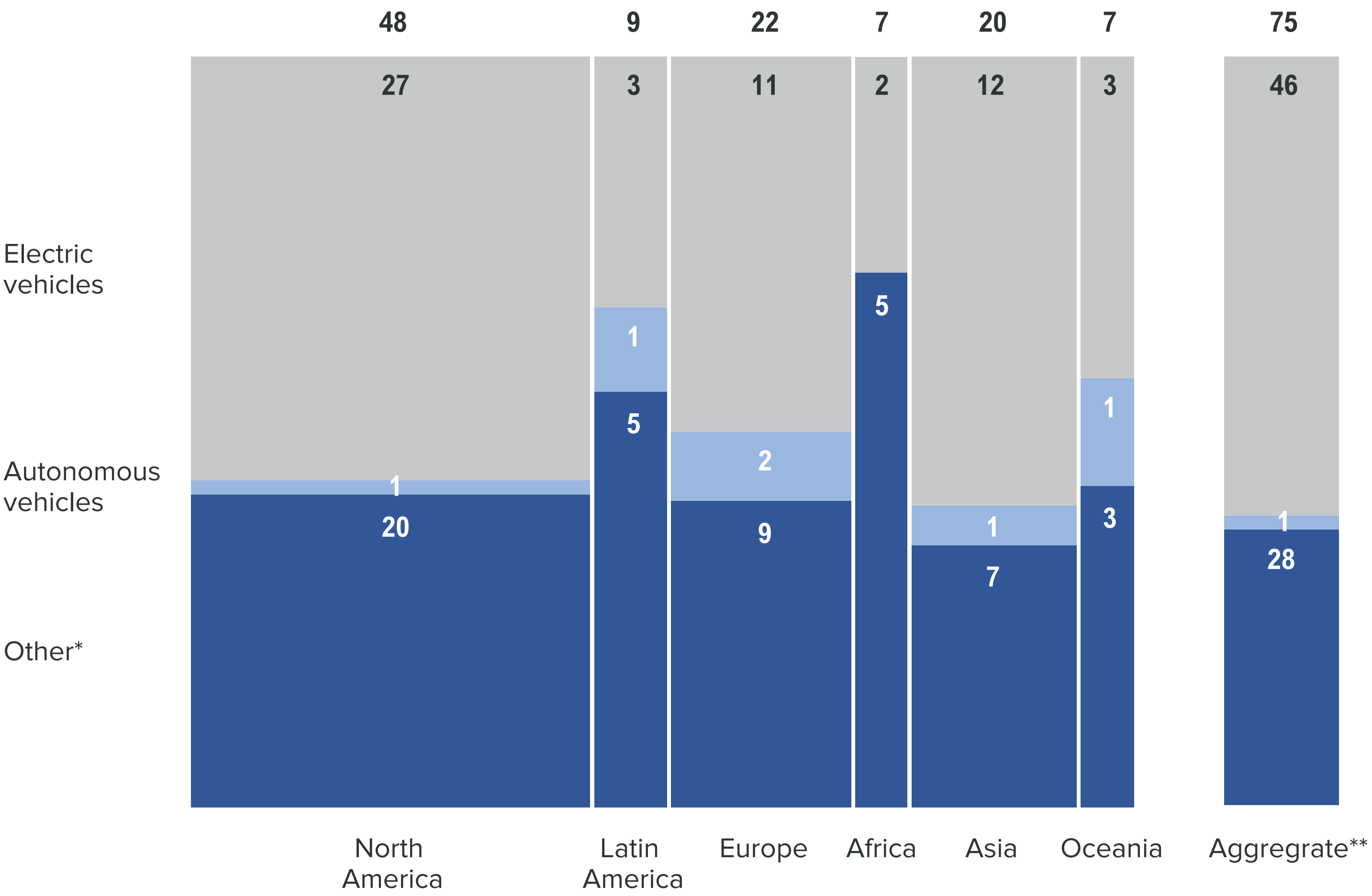
Most start-ups in the product innovation group are working on electric vehicles or autonomous vehicles (Figure 5). Others are coming up with design and engineering advances to improve vehicles' safety and fuel efficiency. Vehicle innovation is the speciality of 49% of the scanned companies, while 11% focus on bicycle design, safety improvements, and accessories, and 9% on electric bicycles. More than half of the product innovation companies we identified are registered in the United States.

Advances in autonomous and electric vehicles seem unlikely to occur at the same pace across all regions. Sales of electric vehicles (EVs) have risen quickly, thanks to factors such as generous purchase subsidies and falling battery prices, and now account for about 1% of the global market.[23] Some car manufacturers have announced their aims to increase production of EVs, while the governments of China and India have set ambitious targets for EV sales. Further increases in sales will depend on a range of considerations, chiefly battery prices, which are expected to drop within a decade to the point that EVs will become cost-competitive with conventional vehicles. Other considerations, some determined at the local level, include the development of EV charging infrastructure, changes in development and driving patterns, the relative costs of electricity and fuel, and the environmental impact of electricity generation.[24]

Autonomous vehicles (AVs) represent a more recent advance for the industry. As of 2017, some 44 companies were working on the technology, compared with 25 in 2015.[25] While fully self-driving cars (Level 4 autonomous) may not be widely available for many years, self-driving vehicles are being piloted in certain cities, and some conventional vehicles offer limited autonomous features.

The environmental benefits of vehicle electrification and automation could be profound. One recent study, which assumed that electric and self-driving shared vehicles will be in wide use by 2050, estimated that the shift to electric and self-driving vehicles alone would reduce GHG emissions from vehicles by 60% (if the electricity used to charge EVs were to come from low-carbon sources).[26]

Figure 5
Most product innovation start-ups are working on electric vehicles or autonomous vehicles



** Includes motor-vehicle design improvements and innovation in bicycles and electric bicycles.*
*** The aggregate number of service providers in each category is less than the sum of the regional counts of service providers because many service providers operate in multiple regions. For the aggregate column, each of these service providers is counted only once.*

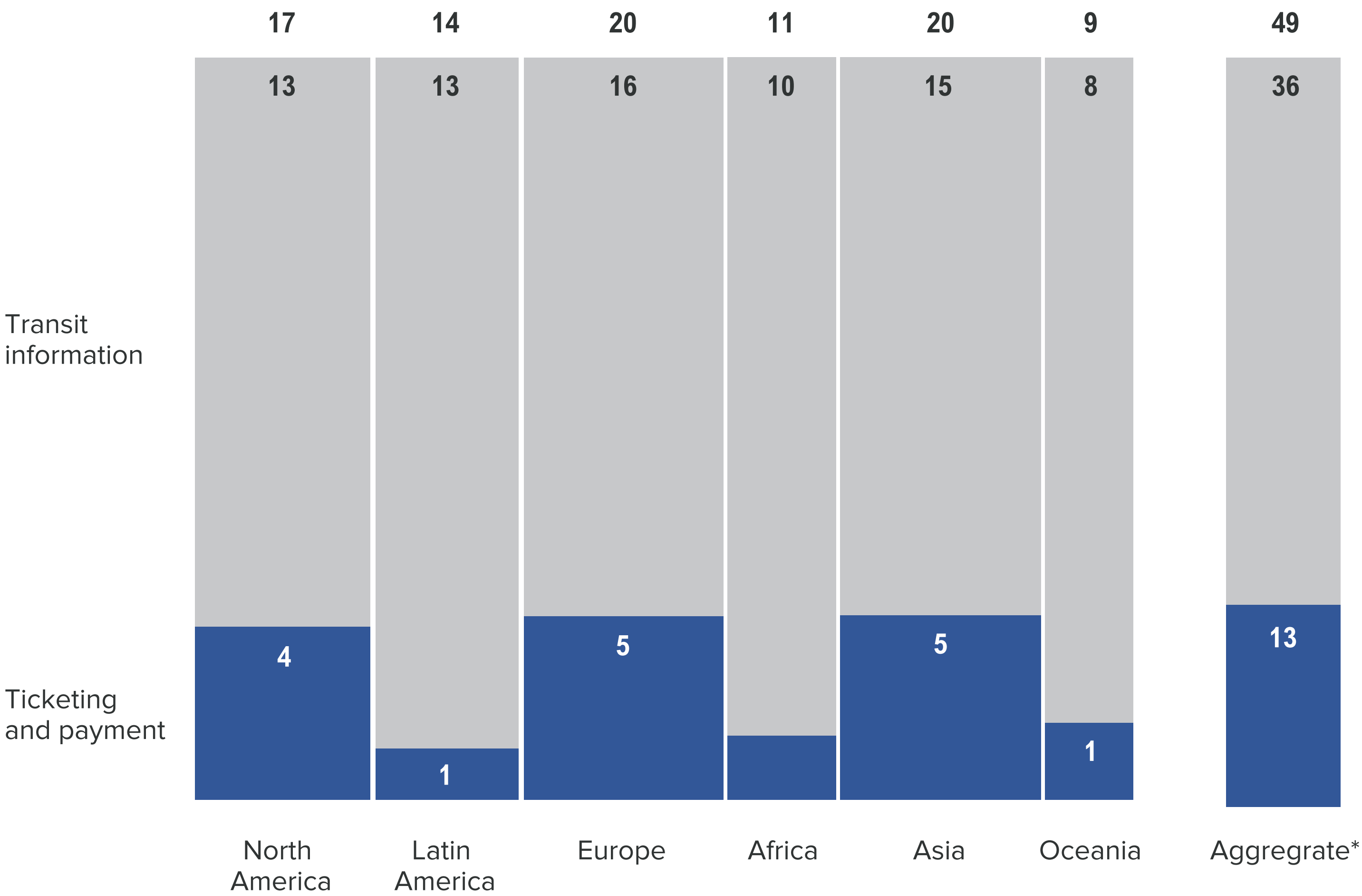
Source: AngelList, CrunchBase, authors' analysis.

CONSUMER EXPERIENCE

Consumer experience services come in two main varieties, both accessed mainly with smartphone applications. Transit information services aggregate static and real-time data about public transport from various sources, which range from transit agencies to passengers, so users can develop informed plans for multimodal journeys. Some start-ups collect data from users' smartphones to increase their stock of real-time transit information, which is particularly helpful for following buses that transit agencies do not track centrally. Citymapper, Moovit, and Transit App are among the start-ups augmenting their data services with these techniques.[27] Virtual ticketing and payment services allow passengers to purchase and use transit tickets with their smartphones. Start-ups providing these services, which include Masabi, Moovel, and Paytm, work with public transport agencies to integrate mobile payments with ticketing systems. Some, such as Ola Money in India, have set up closed-loop systems to accept payments and provide tickets.

Figure 6

Among consumer experience start-ups, transit information start-ups outnumber ticketing start-ups by about three to one globally



** The aggregate number of service providers in each category is less than the sum of the regional counts of service providers because many service providers operate in multiple regions. For the aggregate column, each of these service providers is counted only once.*

Source: AngelList, CrunchBase, authors' analysis.

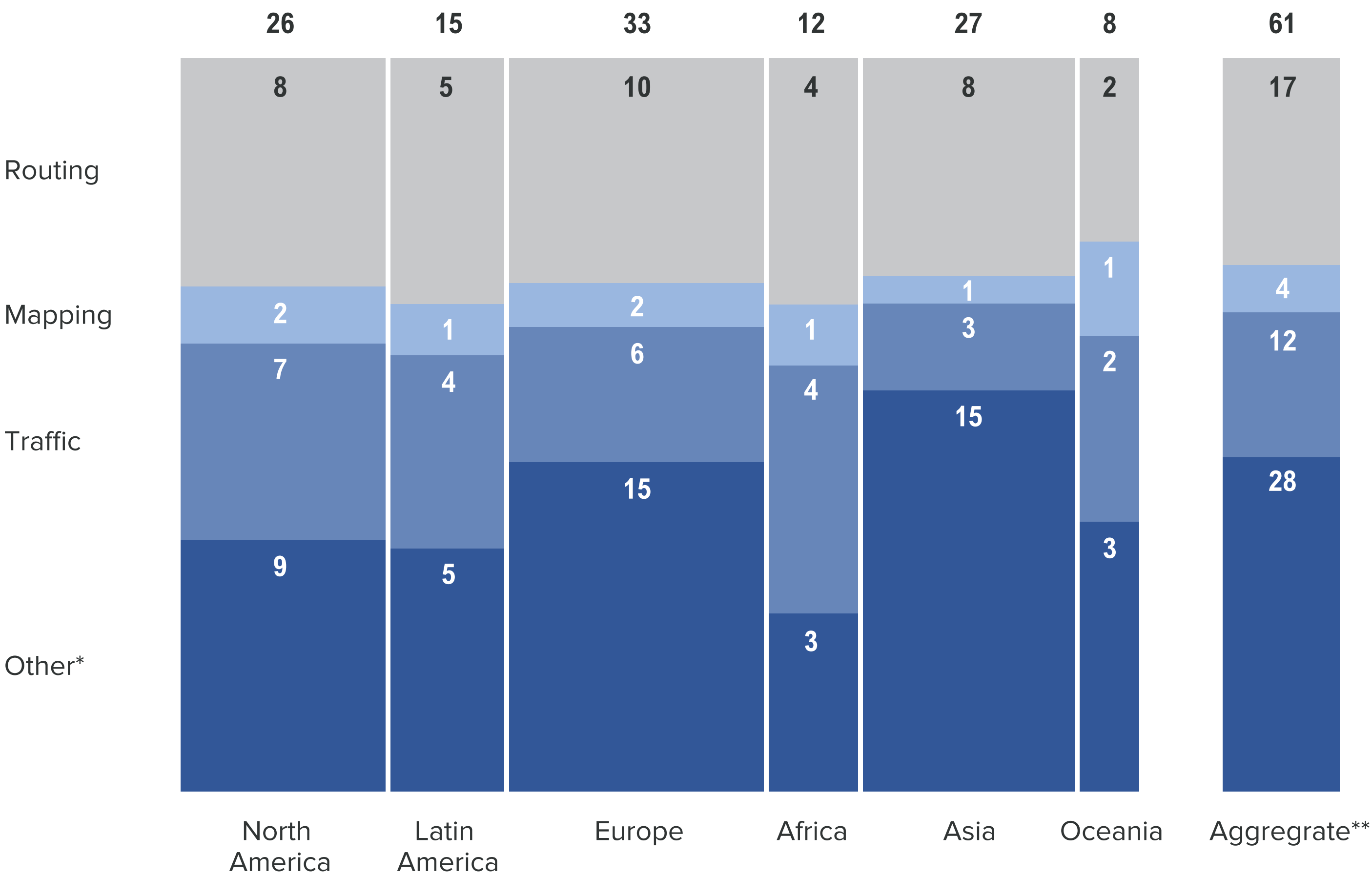
Transit information start-ups outnumber ticketing and payment start-ups by about three to one globally, and even more in some regions (Figure 6). Perhaps the biggest reason for their accelerated development has been the willingness of public transit agencies to provide access to their data. It is estimated that more than 1,500 transit operators in 38 countries have adopted open transport data.[28] The use of standardised data formats and the similarity of data sources (usually transit agencies' open data portals) has enabled transit information start-ups to expand and deploy their services into other cities quickly.[29] Some of these start-ups have begun using their data to identify gaps in transport systems and offer services that fill those gaps. Citymapper, one of London's most popular transit information services, launched a new bus service there that it configured on the basis of data collected from users.[30]

Virtual ticketing and payment platforms have proven slower to develop, in part because of regulations governing payment transactions and the complexity of processing payments to multiple transit service providers in cities where provision is decentralised. In 2016, 17 transit agencies in the United States allowed their users to purchase tickets using mobile platforms,[31] far fewer than the more than 500 US transit agencies that provide open access to their transport data using a standardised format known as General Transit Feed Specification (GTFS).[32] While these platforms usually provide transit information and route planning services that resemble those of pure transit information start-ups, fewer transit information start-ups have moved into ticketing and payment services. Nevertheless, some transit information apps are optimistic about their ability to monetise their services,[33] and several have initiated pilot programmes for virtual ticketing.[34]

DATA-DRIVEN DECISION-MAKING

Data-driven decision-making services mostly consist of mapping, routing, traffic monitoring, and other location-based services. Many of these services work on the back end of public-facing ones. Car manufacturers, for example, have begun adding features to their vehicles that draw on data-driven decision-making services to make driving safer and more fuel-efficient.[35] Such services are also vital to the operation of autonomous vehicles.[36] Nearly a third of the data-driven decision-making start-ups worldwide focus on routing information (Figure 7). Europe is home to the most firms of this kind. Other services in this category focus on the improvement of public transport operations and planning.

Figure 7
Nearly one-third of data-driven decision-making start-ups focus on routing information



** Includes services focused on improving road and public transport operations and planning; analytic services to improve road safety, driver behavior, and fleet management; and analytic services to support parking.*
*** The aggregate number of service providers in each category is less than the sum of the regional counts of service providers because many service providers operate in multiple regions. For the aggregate column, each of these service providers is counted only once.*

Source: AngelList, CrunchBase, authors' analysis.

One interesting distinction in mapping and routing services is between those that rely on proprietary systems and those powered by open and crowd-sourced data.[37] The first group includes services offered by established companies like Google, TomTom, and Here, which maintain their own maps of cities and other locations. (It is estimated that Google spends some US$1 billion each year to maintain its map data.[38]) OpenStreetMap is perhaps the most noteworthy example of a mapping business that relies on open and crowdsourced map data. Some 24 organisations offer routing services that use OpenStreetMap.[39]

Public transit agencies in cities around the world are pressed to lower their operating costs and reduce their environmental impacts while providing affordable mobility at a scale that equitably meets residents' needs and prevents increases in traffic congestion. Their efforts to meet these challenges are mounting at a time when more people are choosing to buy and get around in personal motor vehicles. Meanwhile, new mobility services are proliferating to fill gaps in today's transport networks, such as covering areas that mass transit does not serve. Some of these services also perform functions that existing urban transport systems seldom offer, like picking up and dropping off passengers at locations of their choosing, or providing passengers with real-time information about the fastest or least-expensive ways to get from one place to another. At the same time, the expansion of new mobility services could lead to worsening traffic congestion, more vehicle accidents, added air pollution, and other unwelcome effects, which some cities have attempted to forestall with regulation.

The situation that cities face, with respect to new mobility services, is complicated. So far there is no obvious formula for how cities can take advantage of, and even increase the benefits of new mobility services, while mitigating the costs that these services can impose on the welfare of urbanites. Nevertheless, cities are experimenting with arrangements between their mass transit agencies and the providers of new mobility services, and some models for such arrangements are taking shape. In the next section, we describe how cities are partnering with new mobility services, and we model the effects of three frameworks, among many possible options, for how a city can integrate new mobility models with mass transit to improve the quality of residents' lives.

Part 2: Economic and environmental impact assessment of specific applications

New mobility services have caught on quickly with many urbanites. City governments have been understandably deliberate about signalling their support, given the effects that new mobility services could have. Some cities have restricted or prohibited new mobility services. Others have taken a more permissive approach, allowing themselves to observe how new mobility services influence public transit and existing private transport providers. Elsewhere, city authorities have attempted to harmonise new mobility services with public transit. In the first part of this chapter, we offer a closer look at how cities are partnering with new mobility services to augment their transportation systems.

These cities' experiences matter because they suggest some lessons for how other urban transit agencies can achieve their aims, such as providing accessible, affordable transportation to the many city dwellers who cannot afford either motor vehicles or new mobility services; mitigating traffic congestion; and relieving the financial strain on mass transit, which remains a crucial component of a cost-effective, smooth-running, and efficient system of urban transport. Since new mobility services are evidently meeting certain demands for transportation, they could offer solutions to the challenges facing urban transit agencies. In the second part of this chapter, we analyse three models, of the many that are possible, for how new mobility services can be integrated with mass transit systems to provide benefits to passengers and all city-dwellers. Our findings suggest that new mobility services can help cities to: make transportation accessible to more people; reduce the costs of operating public transit; and lessen the environmental impact of mobility systems.

SURVEYING PARTNERSHIPS BETWEEN NEW MOBILITY SERVICES AND CITY GOVERNMENTS

As new mobility services have begun to operate in cities around the world, they have encountered a variety of regulatory environments and competitive situations. Municipal authorities, in turn, have responded in many different ways to the arrival of new mobility services. Some of these services, especially those that provide on-demand rides, do not fit neatly within regulatory frameworks that have been developed to govern more traditional private and public transport services (see box below). Some city authorities have imposed restrictions on new mobility services or prohibited them outright.

Box 2

Formal and informal mobility services

Private mobility services, including the new mobility services described in Part 1, can be formal or informal. The distinction, which largely turns on the nature of a service's relationship with municipal authorities, affects the possibilities for cities to form partnerships with new mobility service providers.

Formal mobility services are those that operate in line with most applicable regulations of their activities. Formal services might be offered by private companies or by the public sector (as is the case for more than 60% of US transit agencies).[40] In some European cities, public mobility services are operated by private companies under contracts awarded through competitive tendering processes.

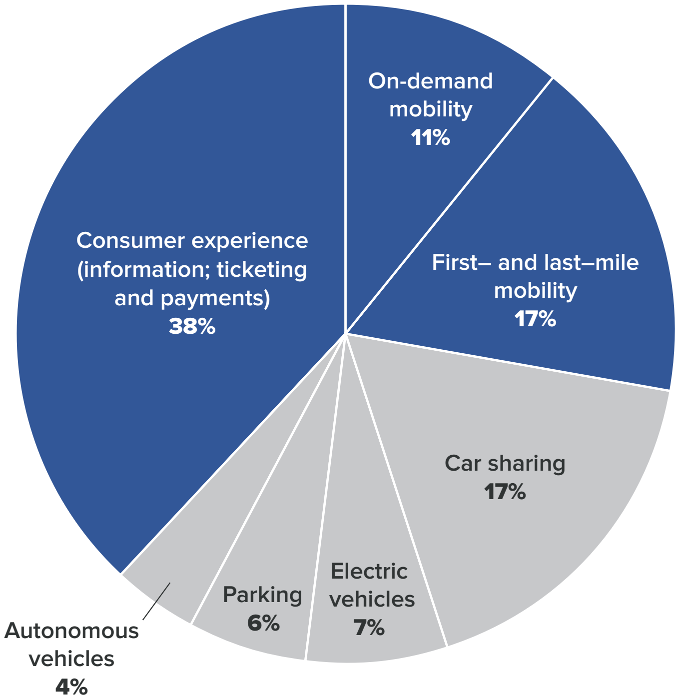
Informal mobility services are those that function in relaxed regulatory settings (including unregulated settings) and those that function without regard for regulations.[41] These services operate a variety of vehicles, of which the most common vehicle is the minibus. Suppliers of informal transport services range from individual vehicle owners to companies, which can be further organised into cartels or cooperatives.[42] Because these services tend to be affordable, productive (sometimes with multiple drivers operating a shared vehicle in shifts to maximise its utilisation), and flexible, they play a vital role in expanding access to mobility. They are most common in the cities of the Global South, where they sometimes coexist with formal mobility services.[43]

In evaluating options to partner with new mobility services, cities may wish to consider services that work with informal mobility providers as well as formal ones. New mobility services can make informal mobility providers more accessible to passengers (such as e-hailing services that allow passengers to summon independent drivers who offer rides in personal vehicles rather than formal taxis) and more efficient, both individually and collectively, by aggregating passenger demand and giving drivers a larger number of customers to choose from at any given time.

New mobility services could also prove useful to cities in the Global South that wish to formalise their informal transit systems.[44] Cities that take this approach will likely find it advantageous to adapt new mobility services to their local situations and make gradual improvements rather than drastic reorganisations.[45] For example, cities could recruit the operators of informal minibus services to provide service as part of formal on-demand minibus fleets.[46] New mobility services can also allow Global South cities to avoid making investments in older enabling technologies by leapfrogging to more sophisticated and cost-effective ones. For example, a Global South city could implement a smart card or mobile ticketing system for public transportation, without first deploying the magnetic-strip cards that some cities have used in place of paper tickets.

Elsewhere, city authorities have arranged partnerships with new mobility service providers. We have identified 71 cities that have formed such partnerships.[47] When we classified these partnerships, three common types stood out (Figure 8). One is aimed at developing consumer experience services, as described in Part 1, for planning multimodal journeys based on real-time information and purchasing the tickets that these journeys require. Another common type is between transit agencies and the providers of on-demand mobility services, which offer public transit riders a mode of transportation that is more flexible than fixed-route buses and subways. And a third type of partnership involves providing shared-mobility services to help passengers make first- and last-mile trips to and from public transit stations.

Figure 8
Three common types of partnership stood out in our survey



Source: Authors' analysis.

Most partnerships between transit agencies and new mobility services have been formed in North America (43%) and Europe (17%). Only four cities from the Global South have these partnerships.[48]

MODELLING APPLICATIONS OF NEW MOBILITY SERVICES FOR PUBLIC TRANSIT AGENCIES

The partnerships that have formed between cities and new mobility services, even at this relatively early stage in the development of new mobility services, points to the possibility that such partnerships can benefit cities and their residents. The outcomes from these partnerships, however, have not been widely reported. To help cities deepen their understanding of what they can achieve by partnering with new mobility services, we have modelled the economic and environmental effects of three new mobility applications (Figure 9). These three applications are based on the three common partnership types that are described in the previous section:

- Application 1: Dynamic trip-planning and ticketing services – Partnering with the consumer experience services described in Part 1 (i.e. transit information services and virtual ticketing and payment services) could allow cities to offer passengers an integrated platform for planning and paying for journeys that use a combination of public and private transport modes, and thereby facilitate multimodal trips and increase public transit ridership.
- Application 2: On-demand minibuses – Integrating on-demand minibuses operated by private mobility services with other forms of public transit could help transit agencies maintain or extend coverage in under-served areas, while lowering their costs of service.
- Application 3: First- and last-mile ride-sharing – By subsidising shared rides to and from public transit stations in under-served areas, cities can improve residents' access to public transit, boost ridership, and reduce the number of lengthy journeys people take using private motor vehicles.

Figure 9
Three new mobility applications have the potential to make public transportation more attractive and competitive

Application 1: Dynamic trip-planning and ticketing services

Purpose: Encourage city dwellers to take multimodal journeys by enhancing access to information and simplifying ticket purchases.

Benefits: Increased transit ridership; lower environmental impats

Mechanism: Technology platform, accessed with a mobile app, that integrates information and processes payments and tickets.

Partnership model: City transit agencies use third-party technology or contract with service providers.

Application 2: On-demand minibuses

Purpose: Streamline mass-transit systems by matching service levels more closely to demand.

Benefits: Lower operating costs; easier access to transportation; lower environmental impacts.

Mechanism: Fleet of electric minibuses, hailed using a mobile app, replaces underused fixed-route services.

Partnership model: City transit agencies use third-party technology or contract with service providers to run fleets.

Application 3: First- and last-mile ride sharing

Purpose: Broaden access to transportation for underserved city areas.

Benefits: Increased transit ridership and utilization; lower system-operating costs; expanded transit access.

Mechanism: Subsidies paid to passengers for on-demand shared rides from areas with poor transit access to transit hubs.

Partnership model: City transit agencies contract with ride-hailing companies to provide shared rides.

The working group chose to model the impact of the three mobility applications in London, Mexico City, and San Francisco. These cities were selected because they offer a variety of spatial layouts, transit-system characteristics, ridership levels, household-income distributions, and passenger demographics (including smartphone penetration) – all of which make the results relevant to a range of international cities, including those in the Global South (Table 1).[49] The cities also publish enough data about their transit systems that the three mobility partnerships could be modelled reliably.

Table 1
London, Mexico City, and San Francisco were chosen as locations for modelling the three new mobility applications

	Land area (km_2)	Population [50]	Density (population per km_2)	Public transport mode share (%)[51]	Annual ridership (billions)[52]	Average fare per ride (US$)[53]	Smartphone penetration (%)[54]
London	1,572	8,673,713	5,518	27	2,446	2.00	63.3
San Francisco	600	864,816	7,124	25	277	1.92	61.0
Mexico City	1,485	8,918,653	6,000	77	1,720	0.03	55.7

The economic modelling prioritised the overall return on investment from each mobility application, which will strongly determine a transit agency's business case for implementation. Other economic performance indicators included initial investment (capital expenditure), operational savings (change in operating expenses), and the payback period. Environmental modelling was performed using the Siemens City Performance Tool (CyPT) and produced estimates of the changes in emissions of GHGs (a key environmental metric for many cities) and two other air pollutants: PM_{10} (airborne particulate matter consisting of particles less than 10 micrometres in diameter), which is primarily generated by transportation and affects local air quality; and NO_x, a generic term for two nitrogen oxides, nitric oxide (NO) and nitrogen dioxide (NO_2). (For more details on the modelling approach, see the Appendix.) Cities that are considering partnerships with the providers of new mobility services will also need to explore the potential impacts of such partnerships on other aspects of urban life that are important to local residents and policymakers, such as access to transportation, employment and wage levels, and the safety of passengers and pedestrians.

In the following three sections of this chapter, we explain each application and place it in context; identify its potential for application, including the matters that cities should consider when evaluating it; describe significant steps along the pathway for its development; and present the economic and environmental impacts that were estimated by our models.

APPLICATION 1: DYNAMIC TRIP-PLANNING AND TICKETING SERVICES

A dynamic trip-planning and ticketing service enables city dwellers to map out journeys using one or more modes of transportation, based on real-time information about availability and performance, and purchase all the necessary tickets with one digital application. Such services make it simple for passengers to access public transit, traditional private transit, and new mobility services and to manage connections among different forms of transportation. Enhancing rider convenience with a dynamic trip-planning service has been shown to increase overall use of public transportation by almost 2%, because users can consider the transport modes available to them, as well as each mode's costs in terms of economic, environmental, health, time, and sometimes social impacts.[55] Public transit agencies can also analyse the data such services collect about users' activities (in line with applicable data privacy laws) to identify potential service improvements.

Dynamic trip-planning and ticketing services are available in several cities (see box below on Los Angeles). The Whim application, for example, offers dynamic planning and ticketing for trips using public transit, shared cars, and taxis in Helsinki, Finland and its environs.

Box 3
Case study: GoLA

The city of Los Angeles, California, partnered with Conduent, a former unit of Xerox, to develop and launch Go LA, an app for planning and paying for trips using various modes of transportation, including personal mobility (walking, bicycling, private cars), bicycle- and car-haring, ride-hailing, and public transit.[56] Based on real-time public transport and traffic data, the app suggests options for getting from one location to another, including multimodal journeys. It also lets users compare the time, cost, fitness benefits (calories burned), and GHG emissions of those trip options. About 24 providers of transport services are featured on the platform, and some allow passengers to book and pay for services using the app.

Potential for application

Cities that operate multiple modes of public transport stand to benefit from setting up dynamic trip-planning and ticketing services. Several considerations can help cities determine whether these services are suitable for their transit systems and their residents.

Public transport ridership: Large systems with many riders should benefit more than smaller systems, assuming that dynamic services produce the same percentage increases in ridership.

Penetration of smartphones: Higher rates of smartphone penetration within urban populations have been correlated with more extensive adoption of mobile ticketing systems.[57]

Current method of selling and issuing tickets: The less sophisticated a transit agency's ticketing system is, the more the agency can lower its operating costs by deploying a dynamic planning and ticketing system. Issuing paper tickets accounts for approximately 5% of total operating costs, compared with 3–4% for contactless cards and 2–3% for tickets issued using mobile apps.[58] Cities also need to factor in the initial cost of installing equipment to read mobile tickets, which is not accounted for in our analysis. This equipment should be less costly if a transit system already has contactless ticket readers in place. Implementing a contactless ticketing system has been found to be cost-effective but will extend the payback period noted below.[59]

Payment processing: Collecting cash payments is more costly (approximately 5% of fare) than charging credit cards (approximately 2% of fare), which, in turn, is more expensive than using digital payment systems (approximately 1% of fare).[60] Accepting digital payments does, however, require transit agencies and private mobility services to develop a common fare structure and a way to share the savings from payment processing. Some cities have established clearing houses to handle the exchange of transactions.

Development pathway

The cost of creating a dynamic trip-planning and ticketing system depends on various factors: the scale of the transit services that it supports, the number of expected users, the functions it provides, and whether a city builds its own system or hires a third party to do so. In modelling the cost of the system, we considered only the cost of developing and marketing the mobile app. The cost of any equipment, such as ticket readers, would be additional.

Apps made by large vendors are estimated to cost between US$500,000 and US$1 million, whereas in-house development can cost between US$150,000 and US$200,000 (for more on these estimates, see the Appendix). A city could also contract with an external service provider to develop and run the entire dynamic system, or it could develop the back-end planning and ticketing technology and outsource the development of the consumer-facing app.

Cities also need to convince residents and visitors to use their dynamic systems. Pilots of integrated ticketing platforms have demonstrated that marketing campaigns can be effective at attracting users. The cost of a marketing campaign depends on such factors as its scale and the media employed. For example, Chicago's Regional Transportation Authority budgeted roughly US$5 million for a marketing campaign to encourage drivers to switch to public transit.[61]

Economic and environmental impacts

We projected the impacts of dynamic trip-planning and ticketing services in London, San Francisco, and Mexico City, three cities that have contactless ticketing systems and continue to sell a mix of paper and contactless tickets (for more details, see the Appendix). According to our estimates, a dynamic system would cost each city between US$4 million and US$8 million to develop and market; but would lower a transit agency's operating costs by US$7 million to US$20 million per year, and generate additional revenues of US$7 million to US$70 million per year within five years thanks to an expected increase in ridership. The operational savings and increased revenues would pay back the development and marketing costs within as little as two years, if cities were to develop and deploy integrated ticketing systems themselves. Cities that opt to create their own dynamic trip-planning and ticketing services could benefit from following agile software development methods, which can shorten development cycles, lower costs, and produce better outcomes for end users.

Partnering with or contracting a private provider would have different financial implications. Hiring a private provider to create and run the dynamic trip-planning and ticketing system in return for 3% of the fares collected through the system could generate US$3 million to US$4 million per year in revenues for a transit agency, with a payback period of about three years. We also considered several ways that a transit agency could generate revenue if it chose to integrate the ticketing technology and outsource the app to a private provider: selling advertising through the app (estimated US$2 million in revenue per year, with a four-year payback period); charging users a subscription fee of US$0.99 per year (estimated US$500,000 in revenue, with a five-year payback period); or offering the app under a "freemium" model by providing basic services to users at no cost and charging them for special features (estimated US$2 million in revenue per year, with a four-year payback period).[62]

Our model suggests that dynamic services would lead to an increase in kilometres travelled by public transport and a decrease in kilometres travelled by private vehicle. This citywide modal shift would lead to significant environmental improvements: a 500,000-tonne reduction in GHG emissions across the three cities, with Mexico City benefiting most, and a reduction in all transport emissions of up to 6%.

In one city, we projected that NOx emissions would rise because of an increase in the use of diesel-fuelled buses, in spite of the city's higher environmental standards for new buses and fuel. This suggests that dynamic planning and ticketing systems would need to shift riders towards less carbon-intensive modes of transportation in order to create environmental benefits. As cities replace public transportation vehicles with models that run more cleanly, potential increases in emissions fleets resulting from modal shifts would be mitigated.

APPLICATION 2: ON-DEMAND MINIBUSES

Most forms of public transportation offer little operational flexibility on a day-to-day basis. For example, buses travel on fixed schedules along predetermined routes to established stops and can only hold certain numbers of passengers. When they run at significantly less than full capacity, the inefficiency and added expense can be difficult to sustain. But the efficiency of a bus route matters less, in some circumstances, than the service it offers to passengers, particularly in areas where public transit is scarce. Maintaining their schedules and routes lets transit agencies ensure that residents have some access to public transit.[63]

The emergence of on-demand mobility services has made it possible for cities to accommodate passengers as well as they do now, or better, while lowering their operating costs. With on-demand services, cities could adjust the routes and capacity of certain transit modes according to fluctuations in passenger demand. To explore these possibilities, we modelled the effects of replacing underperforming fixed-route bus services with on-demand public minibuses, run by the agency, which would pick up passengers at designated points in response to requests submitted with smartphones. Software algorithms would optimise the routes that minibuses travelled between requested pick-ups and drop-offs and adjust the number of minibuses in use as demand varies.

Potential for application

Cities can consider operating on-demand minibus services in place of fixed bus routes that have low capacity utilisation (lower than 30–40%) or loss-making farebox recovery rates.[64] On-demand minibus services can also provide cost-effective transportation service in low- or medium-density or low-ridership areas. Here are some of the factors that transit agencies can examine as they consider whether to introduce on-demand minibus services:

Labour costs and flexibility: Labour is the highest operational cost for many public bus operations. On-demand minibuses could allow cities to spend less on labour by scaling back some bus services, particularly services along fixed routes where buses run at high frequency but with low ridership, while increasing services during periods of peak demand. These adjustments to work schedules could, however, be difficult to implement in places where labour contracts specify the lengths of drivers' shifts. Transit agencies can work with other government departments to ensure that any efforts to reduce labour costs are planned and carried out with an eye towards other important socioeconomic goals, such as maintaining wages and employment levels for municipal workers and city residents.

Characteristics of fixed bus routes: The cost of providing service on fixed bus routes varies with the number of stops along a route, the frequency with which buses travel the route, and the length of the route. The variance in costs among routes in the same system can be significant. Our analysis shows that one London bus route where buses run at 15-minute intervals costs US$389 per revenue-hour to serve, while another route that has a similar length and a similar number of stops but shorter (12-minute) intervals between buses costs US$564 per revenue-hour.[65] Some bus routes with low ridership could become economical to operate once on-demand minibuses are activated, if the minibuses feed enough additional passengers onto those bus routes.

Passenger access and demand: Shifting from fixed-stop routes to flexible on-demand routes can improve passengers' access to public transport. This is especially helpful in areas with low population density (fewer than 2,000 people per square mile) or low ridership (fewer than 5–15 riders per operating hour). Where bus stops are widely dispersed, on-demand minibuses could serve a larger number of pick-up and drop-off sites. The use of minibuses can also allow passengers to board and exit vehicles more quickly, thereby shortening the time they spend at stops.

Development pathway

Shared mobility and data-driven decision-making companies, as well as more traditional equipment makers and transport businesses (see box below on Chariot), offer transit agencies a range of options for establishing on-demand minibus services. Companies such as RideCell and TransLoc offer routing platforms that can help transit agencies run their own on-demand minibus fleets.

Transit agencies interested in on-demand minibuses should be prepared to help passengers learn to use the new service and to make accommodations for passengers who find the service difficult to access. Regular riders of public buses are accustomed to waiting for buses at designated stops, and some are satisfied to do so when they have arrival-time signs or smartphone alerts to tell them when the next bus is coming along. Such passengers might not welcome a switch to a mode of transport that is reliable but somewhat less predictable than the current fixed-route bus system. Other riders might lack the technical knowledge or hardware to summon minibuses and make digital payments for trips, particularly if the only mechanism for performing these tasks is a smartphone app.

Some of these challenges can be surmounted with user-friendly features like reservations that can be booked with telephone calls or SMS text messages and billing by mail. But the fact remains that on-demand minibuses (and other new mobility services) are susceptible to the development of a "digital divide", where certain customers experience declines in transport access and quality.[66] This means it is incumbent on transit agencies to configure public on-demand minibus services so they can be easily used by all passengers, particularly those with limited access to transportation.

Box 4

Case Study: Chariot

Chariot is a private on-demand minibus service operating in two US cities, San Francisco and Austin, Texas. The service dispatches 14-passenger shuttles to pick up riders who hail rides using a mobile app and plans routes dynamically according to passenger demand. According to the company's founder, the service is profitable at approximately US$4 per ride.[67] Ford Motor Company announced in September 2016 that it would acquire Chariot and later said that it would expand the service to six more cities by the end of 2017.

Economic and environmental impacts

We modelled the economic impact of on-demand minibus services by comparing the cost of providing a bus service along four underperforming fixed routes in Greater London with the cost of dispatching on-demand electric minibuses to the same areas (for more details, please see the Appendix).[69] These four routes are heavily subsidised because they have low rates of capacity utilisation (approximately 20%).[70] According to our analysis, the cost to set up an on-demand minibus service, including the purchases of electric vehicles and routing software but excluding the construction and maintenance costs of enabling infrastructure such as EV charging stations, is between US$2 million and US$4 million.[71] This implies a break-even period of three to four years, after which the service becomes profitable at current ridership levels.

Our environmental projections suggested that operating electric minibuses led to higher capacity utilisation rates and reductions in distance travelled overall. This resulted in significantly lower emissions. Typical emissions changes per individual bus line across all three cities were decreases of 66–99% for GHGs, about 88% for PM_{10}, and 95–99% for NO_x. Modelling the use of gasoline-fuelled on-demand minibuses also suggests that they would improve on the environmental performance of fixed-route buses for several reasons. Most importantly, on-demand routing would increase the capacity-utilisation rates of vehicles and decrease the overall distance that minibuses would cover to provide the same level of service as fixed-route buses. In addition, minibuses produce fewer emissions per mile than diesel buses, which make up the majority of city buses around the world.

The three cities draw their electricity from different combinations of primary energy sources. These differences account for most of the variation among the environmental outcomes for the cities. San Francisco, for example, has chosen to purchase electricity that comes from sources with lower emissions than the electricity that the grid could otherwise be expected to provide. This approach, which represents a form of emissions offsetting, also creates demand for low-emissions electricity that helps to accelerate the transition to cleaner power for the city as a whole.

APPLICATION 3: FIRST- AND LAST-MILE RIDE-SHARING

The fixed points at which most modes of public transportation stop to pick up and discharge passengers are seldom if ever the same as the ultimate starting points and endpoints of individual passengers' journeys. When the distance from a transit stop to a point of origin or a destination is long, then people are less likely to use public transportation: studies conducted in the United States show that use of public transit drops by up to 90% when passengers need to walk more than half a mile to the nearest transit stop.[72] To encourage the use of public transport, cities have long sought ways to shorten the distance between riders and public transport stops, experimenting with bike-sharing systems and longer bus routes, among other approaches.

The burgeoning market for ride-sharing services has created potential solutions to the so-called first-mile/last-mile problem. One of the most practical and promising solutions is to partly cover the cost that public transit passengers pay for ride-sharing services to shuttle them 0.5–2 miles to or from public transport stops. A major benefit of such a subsidy programme is to increase the number of people who use public transport for most of a journey, rather than private cars for the entire journey. In some cases, the subsidies cost less than investments in infrastructure for enabling passengers to use public transit.

Several such programmes are up and running (see box below on Centennial). The town of Summit, New Jersey has chosen to subsidise Uber rides rather than build more parking lots near train stations; it expects to save taxpayers US$5 million to US$10 million over 20 years.[73] After voters in the Florida town of Pinellas Park rejected a proposal to add bus lines in an area that is under-served by public transport, the Pinellas Suncoast Transit Authority launched a pilot programme to subsidise rides to and from bus stops during working hours, six days a week. Paying up to US$3 for each trip with Uber and a local taxi service cost the transit authority an estimated US$40,000 per year, much less than the projected cost of adding bus lines in the under-served area.[74]

Box 5

Case study: Centennial, Colorado[75]

From August 2016 to January 2017, the city of Centennial, Colorado conducted a pilot project that offered free shared Lyft rides between one local light rail station and any point in a nearby 3.75 square mile area. Ridership at the light rail station increased 11.6% during the six-month pilot. The pilot service also completed 4.6% more trips than the city's own first- and last-mile service had made during the prior-year period. Each shared ride provided by the pilot service cost an average of US$4.70 – significantly less than the US$21.14 average cost of city-operated first- and last-mile rides during 2015. Service levels during the pilot project improved as well: advance-booking times for the pilot service averaged 5 minutes and 15 seconds, which was 95% less than the two-hour minimum advance-booking time of the city's own first- and last-mile transport service.

Potential for application

This application is particularly relevant for cities where some neighbourhoods have such limited access to public transport that residents mainly choose either to drive to public transit hubs or to rely entirely on their personal motor vehicles for transportation. We define low-transit areas as those with fewer than two high-frequency transit lines within half a mile.[76] It is not, however, intended as a substitute for transit services in places where mass transit is cost-effective and helpful for preventing traffic congestion, such as medium- to high-density urban areas. The existence of low-transit neighbourhoods is not the only consideration that cities need to account for when they assess whether this application is likely to be effective. Other factors are described below.

Availability and viability of ride-sharing services: This application requires that ride-sharing services operate in city areas where they are needed. Transit agencies must also assess the risks associated with relying on private transit providers, such as potential price increases or market exits.[77]

The make-up and needs of the target population for the subsidy programme: Restricting the subsidy programme to groups that have particular difficulty accessing public transit, such as lower-income residents or individuals with disabilities, can reduce its cost. This may also be helpful to transit agencies that wish to make sure that target groups have the means to take advantage of the subsidy programme, such as smartphones and bank accounts linked to virtual payment platforms. Reaching unbanked households can be especially troublesome. In the United States, 7% of households do not have bank accounts; among households earning less than US$15,000 a year, 25% are unbanked.[78] Worldwide, almost 40% of adults are unbanked.[79]

The amount of the subsidy: Transit agencies need to provide enough of a subsidy for each ride that a critical mass of target users will avail themselves of the benefit, thereby increasing public transit ridership.

Supportive procurement policies and processes: This new mobility application can be aided by procurement policies that are flexible enough to accommodate a private–public partnership and that foster the accountability and transparency needed to make sure that the subsidy meets the intended goal. It is important for transit agencies to be able to collect data from ride-sharing providers so they can determine whether the subsidy is bringing about its intended effects or creating other benefits. Having data on how subsidised passengers use ride-sharing services can also help a transit agency to plan future transport services.

Labour implications: Since ride-sharing subsidies are not intended to replace current transit services, it seems unlikely that they would lead to job losses within transit agencies. We are, however, cognisant that some ride-sourcing companies pursue lower operational costs through their labour practices. Transit agencies and city officials may wish to consider those practices when choosing ride-sharing providers to partner with.

Unintended behaviour changes and land-use patterns: Ride-sharing subsidies are not meant to discourage people from walking, biking, or carpooling. But if subsidies are generous or widely available, they could have the unintended effects of decreasing walking and biking trips to and from public transit stops and deterring investments in bike-sharing systems or bicycle lanes that might get more people to cycle. Lowering the cost of transportation to and from public transit stations could also promote low-density development, as people realise it is economical to live farther from transit hubs.[80]

Development pathway

As noted above, cities can begin to explore this application by performing the relatively simple exercise of identifying neighbourhoods that have limited access to public transit. Deciding how best to improve service to those neighbourhoods is a more complicated endeavour. Providing subsidies can bring about different outcomes – wider access to transit, lower operating costs, or reduced environmental impact, to name a few. But choosing outcomes almost always involves trade-offs. A subsidy programme that simultaneously tries to produce environmental, social, and economic benefits will likely come up short in one way or another.

The second step that cities can take is to set the goals of the subsidy programme. If a city's primary goal is to increase transit access for low-income households that don't ordinarily travel to transit hubs in personal vehicles, then the subsidy could have a negative environmental impact by increasing the number of vehicle trips that take place. If the goal is to avoid building park and ride facilities or extending bus lines or to increase mass-transit ridership, then it might be practical to target the subsidy towards people who normally drive alone in their vehicles. To achieve environmental benefits under those circumstances, the subsidy would likely need to come with a requirement that users travel in shared vehicles.

Identifying the right target groups for a ride-sharing subsidy is one thing; reaching them is another. Low-income households might be served most easily through existing poverty alleviation programmes. The transit agencies of Seattle[81] and San Francisco[82] subsidise public transit rides for low-income residents; incorporating a ride-sharing subsidy into such programmes could simplify its distribution. Cities will need also to assess whether the subsidy is likely to change the behaviour of the target recipients as intended, and how to configure the subsidy so that the desired behaviour changes take place.

Economic and environmental impacts

To understand the effects of subsidising shared rides to and from public transit stations, we modelled a programme that would serve the residents of San Francisco neighbourhoods that have limited access to public transit (for details, see the Appendix). Based on our assumptions, the cost of this programme varies with the scale of the subsidies provided. If the subsidy covers the full cost of shared rides, the programme would cost an estimated US$70 million, or 6% of the operating costs of San Francisco's public transport. If the subsidy pays half the cost of shared rides, the programme would cost US$34 million. Capping the subsidy at 12% of the cost of a ride, US$1.40 on average, would mean that added farebox revenue from ridership increases would pay for the programme entirely. Offering the subsidy only to households with an income of less than US$30,000 per year would incur US$6 million in annual costs. If the same subsidy were capped at US$1.10 per ride, then the additional revenues raised by an increase in ridership would cover the subsidy expenses.

We also modelled the environmental impact of a subsidy programme in San Francisco, as well as London and Mexico City. Our main finding was that such a programme would have an environmental benefit, based on the assumptions that the shared rides would bring people to and from public transport hubs in hybrid vehicles and that these multimodal trips would replace longer journeys in personal motor vehicles for some 10,500 daily commuters. Under those circumstances, the emissions that we modelled would be reduced: GHGs by 67–80%, NO_x by 54–80%, and PM_{10} by 75–81%. If these trips were actually additional, in the sense that they replace public transport or walking trips, then their environmental impact would be negative. To eliminate emissions, the ride-sharing vehicles would need to be electric cars powered by renewable energy, or hydrogen-powered vehicles running on renewably sourced hydrogen.

Representatives of one of the study cities observed that cities do not yet have data indicating whether trips taken with on-demand ride-sharing services are replacing private motor vehicle trips or public transport journeys. This makes it harder to anticipate the possible effect of a ride-sharing subsidy. If an area is under-served by public transport, it is more likely that an on-demand ride-sharing service would replace the use of private motor vehicles. A ride-sharing subsidy could have the additional benefit of allowing more people to secure employment by improving their ability to travel to and from work.

Our modelling efforts suggest that cities can benefit from these three approaches to augmenting or supporting public transit with new mobility services. Dynamic trip-planning and ticketing systems and on-demand minibus services each require modest up-front investments that would be paid back within two years by reductions in operating costs. Subsidising ride-sharing services to help city dwellers cover the first and last mile between transit hubs and neighbourhoods with poor transit access can boost ridership and generate more farebox revenues with no initial capital outlay. Dynamic trip-planning and ticketing applications can also deliver large absolute reductions in emissions of GHGs and other air pollutants. With the other two applications, cities would need to use electric vehicles in order to achieve gains in environmental performance. Each of those applications does, however, offer other benefits: higher farebox revenues and capacity utilisation levels as riders take advantage of their enhanced access to public transport. More than one of the three new mobility applications that we modelled could be deployed at once, although the benefits of combining two or three applications could be different from the sum of the expected benefits from individual applications.

To maximise the economic, social, and environmental benefits of new mobility services, cities will need to conduct more comprehensive analyses of the costs and consequences of different applications to the challenges they face, whether those are declining ridership, worsening traffic congestion, or inequitable access to affordable, efficient transit services. Such analyses should also consider whether cities should deploy new mobility services of their own or offer these services through partnerships with independent providers, and how to launch and market the services so residents can begin using them without difficulty. All of these activities would ideally be supported by policies that accommodate the flexibility of new mobility services and allow transit agencies to learn from the data and findings of the mobility-service and technology providers they work with. In the final part of this report, we set out a framework that cities can use to assess their options for integrating new mobility services with their mass transit systems.

Box 6

Opportunities for further research

We hope that the research and modelling results presented in this report will encourage more cities to investigate the possibilities for using new mobility services to supplement and enhance their public transit systems. Yet we also recognise that our analysis has its limitations, and that further study will equip cities to develop better approaches to designing, piloting, and refining new mobility applications of their own. Here we describe additional lines of enquiry that might be beneficial to city officials, as well as new mobility services companies.

Regional analysis: A more detailed analysis of trends in new mobility services would include deeper exploration of trends within individual countries, including the effects of regional demand-side forces on the supply of public and private transportation services, and the possible connection between country-specific policies and the trends in different markets and regions (e.g. large investments in Asia in the development of electric vehicles, stimulated by China's industrial development policies).

Effects of next-generation vehicles: Over the medium to long term, experts anticipate the release of vehicles that are autonomous, electric, and shared, and can be organised into fleets.[83] Such fleets, which are colloquially known as FAVES (fleets of autonomous vehicles that are electric and shared), would make it possible to develop new mobility applications that are not on the market at the time of writing, or even in development. To accommodate FAVES and maximise the benefits from them, cities would need to consider a wide range of policy factors, such as investments and policies for transportation and land use.[84] While the proposed set of applications provides cities with some guidance for how to integrate FAVES with their transit systems, further study would help cities to prepare for fundamental changes to urban mobility systems.

Modelling validation and enhancement: The models in our study estimate economic and environmental impacts based on limited knowledge of how new mobility services influence transportation use in cities. The effects of new mobility applications, such as the three we have modelled, are still playing out in the pilots we identified through our list of public–private partnerships. Measuring those effects and incorporating the findings into more sophisticated models of potential applications should make future modelling exercises more predictive of real-world outcomes.

Direct and indirect effects on employment and jobs: For some cities, improving the performance of the transit system is not an overriding policy priority. Other agendas, such as economic development and poverty reduction, matter at least as much. Because of this, transit agencies need to anticipate the effects that new mobility applications can have on the quality and number of jobs, as a result of changes such as decommissioning certain underused bus routes in favour of on-demand minibuses (in the case of Application 2). Knowing the likely effects on employment will be essential to gauging the political feasibility of any application that city officials consider.

First-mile and last-mile transportation patterns: Application 3 pertains to a problem that most transit agencies face, namely helping passengers travel the distances from their starting points and destinations to the nearest transit hubs.[85] Subsidising shared rides is but one way to address the so-called first-mile/last-mile problem. In looking for alternative applications, cities can consider factors like the price elasticity of demand for transportation services (given that new mobility applications will increase the total cost of most trips even after subsidies have been paid) and the utility losses associated with transfers and waiting time as people change modes of transport. A more thorough comparison of models for providing first-mile/last-mile service, such as bike-sharing, would help cities arrive at solutions that fit their circumstances.

Comprehensive effects of on-demand mobility services: On-demand services, particularly those carrying single passengers, can affect traffic in heavily used corridors and across a cityscape. These services can function both as complements to public transit, by providing first-mile/last-mile transport, and as substitutes for public transit, by drawing people out of subways and buses. The balance of these two opposing effects will affect vehicle miles travelled and ultimately the flow of vehicle traffic. Effective city-level policies will depend on understanding the interplay between on-demand mobility services and the entire urban transportation system, including road injuries and fatalities. Cities could begin to develop such policies by collecting data from on-demand mobility providers on their operations. Such data are also essential to modelling the effects of on-demand services in cities around the world.

Part 3: Considerations for policymakers

Innovation in technologies and business models is changing transport networks worldwide. But cities need not view the providers of new mobility services as rivals. The features they offer have created compelling economic, social, and environmental reasons for urban transit agencies to invest in certain applications of new mobility services. The public sector can approach new mobility services as potential partners for expanding access to sustainable transport in cities. To facilitate productive collaboration, we have outlined some of the issues that national leaders, transport ministries, and local transport authorities may want to consider as they determine how to best integrate new mobility services with cities' transportation systems.

DATA

Open data standards: Information is the lifeblood of virtually all new mobility enterprises. Cities can therefore foster collaboration with these enterprises by providing them with information about their transportation systems against a unified set of measurements over time. The General Transit Feed Specification (GTFS) is an example of such a standard, which can be applied to an entire transit network. More than 900 cities worldwide have used GTFS to issue data about their transportation systems. The General Bikeshare Feed Specification (GBFS)[86] and a realtime GTFS[87] are two other standards that are being deployed worldwide. Datasets compiled according to these standards make it possible for both cities and mobility companies to study the demand and use of various transportation modes in detail. This analysis lets them identify challenges with respect to desirable outcomes and draw comparisons among cities and extract insights that might be used to improve the performance of transportation systems over time.

Data security and sharing: Some new mobility services collect data of their own and compile proprietary datasets. Most rely to some extent on open datasets published by a city or transit authority. Ensuring that these data are available on a consistent basis can thus encourage innovation. For policymakers, this makes it important to consider the privacy and security implications of sharing data on public transportation systems, as well data that mobility companies gather from their customers and other private sources. Some cities may find that they have a strong interest in making sure that anonymised data from private sources can be accessed, without compromising user privacy or exposing data to competitors, so that their transit authorities can benefit from it.

INVESTMENT

Mass transit infrastructure: Mass transit, particularly for high-demand corridors, is still essential for moving people efficiently through cities and must be maintained accordingly. New mobility services also depend on mass transit systems, as well as other transportation assets such as sidewalks, bicycle paths, roads, bridges, tunnels, tollbooths, and traffic lights. This is to say nothing of next-generation infrastructure assets, equipped with remote sensors and control mechanisms linked to computer systems, which might enable cities to improve the flow of people and vehicles by making adjustments in real time as conditions change. But as our modelling in this report suggests, the expansion of new mobility services could cause substantial shifts in ridership among transportation modes. These shifts will in turn alter the need for different kinds of transportation infrastructure over the long term. Cities and countries therefore need to balance short-term spending on improvements to their existing transportation infrastructure with plans for infrastructure investments based on long-term projections of how mobility systems and patterns will evolve over decades.

Incentives for pilots and partnerships: National governments can provide incentives for cities to experiment with new mobility applications through pilot projects that are supported by partnerships with credible organisations. One mechanism for incentivising this kind of experimentation is a programme that awards grants to help cities pay for new mobility applications and monitors the pilot projects so that they can be evaluated. Such a framework can help national governments identify the most successful pilot projects and highlight them as possible models for use in other cities.

IMPACT

Evidence-driven and outcomes-based planning: National governments can help city governments to set and pursue meaningful transportation-related goals by establishing a set of relevant performance indicators. Such performance indicators can help cities to partner with new mobility companies by enabling them to better measure the effectiveness of their engagements, while ensuring accountability and transparency. While national governments may choose not to dictate what outcomes a city should aim for, they can define effective ways of measuring outcomes, such as equity, accessibility, reliability, environmental quality, and safety.

Employment: The integration of new mobility services with public transportation systems will inevitably influence wages, total numbers of jobs, and the proportions of job types within the transportation sector, as well as related sectors such as technology, engineering, and construction. Demand will increase for certain kinds of jobs and decrease for others, depending on the new mobility applications that a city pursues. Cities can forecast the likely employment effects of the new mobility applications so they can weigh these effects against the other economic and social benefits and costs of partnering with new mobility providers. City officials can also consider developing plans for social support, job training, and other programmes to help ease the pressure that some workers might experience.

Economic analysis: Regular economic analysis of transportation services can help transit agencies to focus on improvements for services with the highest subsidies and lowest levels of ridership. An economic analysis that links subsidies to ridership patterns at the route level for different transport services is valuable, but one that only a handful of cities are able to perform today. Knowledge about which parts of the transport network are subsidised, and by how much, is essential to devising strategies for turning around high-cost, low-ridership services.

APPENDIX: METHODOLOGY FOR THE GLOBAL SCAN OF NEW MOBILITY SERVICES

To identify patterns in the development of new mobility services worldwide, we conducted research on small and medium-sized mobility companies. The research was structured to recognise the diversity of new mobility services: the products, services, and technologies that they offer; the activity of these companies in different regions of the world, and the business models they are using to cater to the needs of local customers. The global scan only considered the numbers of businesses that offer products and services related to new mobility; reliable information about the market shares and numbers of users of the many new mobility companies was not available.

Our sources of information were two major online databases on start-up companies, AngelList and Crunchbase. Although other potential sources of information about mobility start-ups exist, these two databases were selected for their breadth and the level of detail they offer about individual businesses. They have been used as sources for various academic studies. AngelList contains information on 2.5 million companies, and Crunchbase more than 100,000 companies. Although the data captured by AngelList and Crunchbase do not correspond perfectly to all services in new mobility, their coverage is sufficient to yield insights into the overall development of the new mobility services market. We acknowledge that there is some uncertainty about how well these databases represent the mobility sector, and whether their data are subject to geographic or sub-sector-related bias.

We collected the information for our study in August 2016. To extract data on new mobility services from AngelList, we conducted queries on their website using location tags and market tags. The locations queried were Africa, Asia, Europe, North America, Oceania, and South America. We also conducted further searches at the country level for Brazil, China, India, and Mexico. The market tags used were “cars”, “carsharing”, “connected cars”, “ground transportation”, “mobility”, “motorcycle taxi”, “public transportation”, “ridesharing”, “taxi”, “transportation”, and “urban mobility”.

To extract data from Crunchbase, we obtained a snapshot of their database through their research access programme. Companies were identified as pertaining to mobility or transport using the following terms: “automobile”, “cars”, “misc” (a catch-all term for 32 mobility-related categories[88]), “public transport”, and “transportation”.

We identified 365 providers of new mobility services.[89] Each company was classified according to the type of service that it offers and the geographic areas where it operates. When a company was found to offer services in more than one of the four categories that we used to group new mobility services, we placed that company into the primary category to which its services correspond. We excluded from the analysis all companies for which we could not find a working website on the internet and retained only those that were shown as operating.

METHODOLOGY FOR RESEARCH ON PARTNERSHIPS BETWEEN CITIES AND NEW MOBILITY SERVICES

Understanding partnerships between cities and new mobility services was essential to identifying new mobility applications that have the potential to improve public transport. To analyse the types of partnerships that have formed between cities and new mobility services, we conducted desk and online research using a set of specific mobility-related search terms: “autonomous vehicles”, “autonomous shuttles”, “bikeshare”, “carshare”, “dynamic carpooling”, “dynamic transit”, “e-hailing”, “MaaS”, “microtransit”, “private shuttle”, “ridehailing”, “ridesourcing”, “ridesharing”, “self-driving cars”, and “shared self-driving cars”. We identified 71 cities worldwide that have established formal partnerships with providers of new mobility services.

ECONOMIC AND ENVIRONMENTAL MODELLING FOR THE THREE APPLICATIONS

The three new mobility applications that we modelled for this report were built to reflect two principal considerations: i) opportunities for cities to capitalise on the advantages of new mobility services for supporting public transportation; and ii) trends in the creation of partnerships that cities have established with new mobility services to improve the provision of public transportation.

We modelled the three applications for London, Mexico City, and San Francisco, after choosing those cities based on the availability of data about their public transit systems, their inclusion in the Siemens City Performance Tool (described below), and their representation of different geographies. For each city, we estimated the economic and environmental impact of the applications designed.

Economic modelling was performed for the deployment of Application 1 in London, Mexico City, and San Francisco; for the deployment of Application 2 in lieu of four bus routes in London; and for Application 3 in San Francisco. For each application, we estimated the following economic indicators:

- **the initial investment,** or capital expenditure, required to deploy the application;
- **the potential operational cost savings,** relative to the current situation, during the first five years in which the application is deployed; and
- **the additional revenue generated** (for example, by a possible boost in ridership), relative to the current situation, during the first five years in which the application is deployed.

Sources of information for the economic modelling exercise were publicly available data for each city and application, and estimates derived from more general reports or case studies of similar cities (see references throughout the report and further explanation for each application below).

The environmental modelling was based on two main datasets: data for London, Mexico City, and San Francisco that had been gathered during collaborations between Siemens and those cities; and estimates from the economic modelling of changes in public transit ridership (Application 1), in kilometres travelled using relevant vehicle types and fuel sources (Application 2) and in kilometres travelled using relevant vehicle types (Application 3). The environmental modelling was performed using the Siemens City Performance Tool (CyPT), which is designed to identify technologies in the transport, building, and energy sectors that have the most potential to help cities mitigate GHG emissions, improve air quality, and create jobs locally. The CyPT contains data on more than 70 technologies and accepts the input of more than 350 variables pertaining to a city's buildings, energy, and transport sectors, including the mix of energy sources used to generate electricity, the uses of all modes of transportation, and demand for building space, energy, and travel. It allows cities to model the application of multiple technologies simultaneously and estimate their effects on environmental impacts as well as the city's energy mix, the energy efficiency of its buildings and transportation system, and shifts of riders among different modes of transportation. For this study, reductions in GHG emissions were calculated by applying the relevant per-kilometre rates of emissions (emissions factors) to the estimates of kilometres travelled, by vehicle type and fuel sources, within each city's transportation system before and after implementing each application.

Assumptions and estimates for Application 1, dynamic trip-planning and ticketing services

The US$215,000–500,000 estimated cost to a transit agency of developing its own dynamic trip-planning and ticketing app was calculated based on a US$500,000 estimate for Mexico City[90] and adjusted by wages for each country as shown below:

	London	Mexico	San Francisco
Total cost of developing App adjusted to wages	$346,939	$215,195	$500,000
Annual cost of developing App depreciated over 5 years	$69,388	$43,039	$100,000

The US$3 million to US$7 million estimated cost of the marketing campaign for an integrated ticketing platform is based on the US$5 million cost of Chicago's marketing campaign for public transport.[91] The cost for each city was then adjusted using population size and wage ratio by country as shown below:

	London	Mexico	San Francisco	Chicago
Population	8,674,000	21,200,000	837,442	2,720,546
Cost of marketing adjusted to populationyears	$10,470,826	$21,981,384	$3,269,553	$5,000,000
Wage ratio country/ US	0.70	0.25	1.00	1.00
Cost of marketing adjusted to wages	$7,380,262	$5,565,917	$3,269,553	

We based estimates for the use of the dynamic services on the percentages of public transit riders using paper and contactless tickets, weighted by current smartphone penetration for each city. Our assumptions were that between 5% and 13% of current paper-ticket users and between 13% and 20% of current contactless-ticket users would switch to the dynamic trip-planning and ticketing app over three years. Under these assumptions, operational savings ranged between US$7 million and US$20 million per year after the initial payback period of two years. We also modelled a 1.7% increase in ridership, based on earlier research showing that ridership increases when public transit users have access to real-time information about the public transit system.[92] Such an increase would generate additional fare revenues (the money that public transit systems collect from passenger fares) of between US$7 million and US$70 million within five years, depending on the size of the transit system. This is equivalent to approximately 1% of total fare revenues.

Assumptions and estimates for Application 2, on-demand minibus services

When modelling the impact of on-demand minibus services for the four underperforming bus routes in London, we adjusted the level of service to match demand variations throughout the day, so that more minibuses would run during periods of peak demand (e.g. prime commuting times). This adjustment strongly affected the estimated labour costs of offering standard on-demand minibus services. Under these assumptions, the operational savings ranged from US$500,000 to US$2 million per year, divided among labour (15–25% of savings), energy (70–80% of savings) and maintenance and insurance (20–30% of savings). We also assumed that the on-demand minibuses run on electric power, whereas existing buses were assumed to run on diesel fuel, given that London's bus fleet consists mainly of diesel-powered vehicles.[93]

Assumptions and estimates for Application 3, ride-sharing services for better public transit

For the model of this application, we selected neighbourhoods in San Francisco that have fewer than two high-frequency public transit routes within at least half a mile, then calculated the number of households within those neighbourhoods.[94]

We assumed that subsidies for ride-sharing services would be available twice a day, five times a week to facilitate commuting, and limited to rides of between 0.5 and 2 miles, starting or ending at the nearest public transit stop. We also assumed that this programme would boost public transit ridership from the areas covered by up to 10% of the population of the target areas.[95] Under these assumptions, we estimated that the additional fare revenue resulting from higher ridership would offset approximately US$10 million of the cost of delivering the subsidy.

For this application, estimates of the environmental impact depend greatly on assumptions about whether ride-sharing would create trips that riders would not otherwise take or replace existing trips, and about what mode of transport was used for existing journeys. (Our assumption was that multimodal trips using ride-sharing services and mass transit would replace private motor vehicle trips.) Another assumption is that ride-sharing providers will use vehicles with hybrid gasoline-electric engines. The analysis also assumed that ride-sharing cars would have a utilisation rate equal to a taxi in the city rather than a private car, which results in less driving time when the car is occupied only by the driver. We modelled the application for San Francisco, finding that the most significant outcome was an increase in the overall distance travelled. We repeated the analysis for London and Mexico City, assuming that they would observe the same numbers of subsidised rides, at the average occupancy rates of taxis in those cities.

ENDNOTES

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ABOUT THE COALITION FOR URBAN TRANSITIONS

The Coalition for Urban Transitions, launched in 2016, is a major new international initiative to support decision makers to unlock the power of cities for enhanced national economic, social, and environmental performance, including reducing the risk of climate change.

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