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AN INTEGRATED PERSPECTIVE ON THE FUTURE OF MOBILITY, PART 3: SETTING THE DIRECTION TOWARD SEAMLESS MOBILITY

Urban traffic is getting worse. Here is how city and business leaders can act to forge a better outcome.

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The age of modern transit began in 1863, when the first underground railway began rolling in central London. The line was short and smoky, and nothing like it had ever been seen before. But it worked, and cities around the world began to follow London's lead. Over time, city authorities came to see providing transportation as one of their core responsibilities, and governments often owned and ran transit systems themselves.

Urban mobility is complex, and in many cities, traffic is getting worse. From 2010 to 2016, congestion rose in London by 14 percent, in Los Angeles by 36 percent, in New York by 30 percent, and in Paris by 9 percent.[1] Congestion also carries health consequences. With the exception of New York, the largest cities in six of the seven largest economies—Berlin, London, Mumbai, Paris, Shanghai, and Tokyo[2]—all have air quality below guidelines set by the World Health Organization.[3] At the same time, many cities are committing to improving their environmental performance. For example, the C40 Cities Climate Leadership Group of 96 cities, home to more than 650 million people, has pledged to act to reduce greenhouse-gas (GHG) emissions.[4]

Demographic trends will only increase the pressure. Cities are already home to more than half the world's population. By 2030, that figure is projected to reach 60 percent,[5] with urban residents accounting for 91 percent of global consumption growth.[6] Greater population density means greater demand for transit; that could lead to higher GHG emissions and worse pollution. And it's not only about moving people. E-commerce is also growing fast (by a projected 85 percent from 2015 to 2020), adding to the demand for urban commercial transport.[7]

We have a vision for a future that addresses these challenges: seamless mobility. Leaders from both the public sector and the private sector will need to work together to achieve this future. To do so, they can use tools that optimize supply, optimize demand, and improve sustainability, as well as a wide range of business models, innovations, and technologies.

In this approach, the boundaries among private, shared, and public transport are blurred, and travelers have a variety of clean, cheap, and flexible ways to get from point A to point B.[8] Seamless mobility could be cleaner, more convenient, and more efficient than current options, accommodating up to 30 percent more traffic while cutting travel times by 10 percent. We have identified five indicators to evaluate mobility systems: availability, affordability, efficiency, convenience, and sustainability.[9] Seamless mobility improves all five. Cities have an opportunity to set the direction toward seamless mobility. In this report, we identify a set of tools and explore their effects on these five factors. This tool set allows cities, in partnership with the private sector, to take an active role in determining the future.

A future of seamless mobility could create new possibilities for many industries. By 2030, 40 percent of today's transportation-revenue pool—the money that residents in dense, developed cities like New York, Paris, and Tokyo spend on transit—could be served by modes of transport that don't even exist now. For established companies, succeeding in seamless mobility will likely require going beyond their existing boundaries to offer new products. Among carmakers, for example, that might mean moving from just selling cars to selling mobility more broadly. For public-roads agencies and the engineering and construction companies that support them, it could be about equipping the roads they build with sensors for traffic management, predictive maintenance, and autonomous-vehicle (AV) communication. Seamless mobility has real benefits for cities, travelers, and the private sector. In this report, we describe how urban leaders and private companies can forge a strategy to make seamless mobility happen.

One baseline, three scenarios

Even in cities where public-transit networks are well developed, cars provide a significant proportion of passenger-kilometers, often more than rail and bus services combined. Vehicles that are fully autonomous do not yet exist in meaningful numbers, and electric vehicles (EVs) still make up only a small percentage of the global vehicle fleet. This is today's reality—the baseline for any future scenario.

From that starting point, we created three scenarios of how mobility trends could play out over the next dozen years in a big, dense, developed city, like London, New York, or Seoul. We did so by modeling a set of short (less than two kilometers), medium (two to ten kilometers), and long (more than ten kilometers) trips, differentiating between trips within the city business district and trips to and from the city and the suburbs. We also simulated the trade-offs that people make—for instance, deciding between a more convenient but pricier autonomous shuttle and a less convenient but cheaper bus—and estimated how these decisions could affect congestion in 2030. Finally, we accounted for "induced travel"—the concept that when it is easier or cheaper to travel, demand tends to rise.[10]

Scenario 1: Business-as-usual urbanization

In this scenario, the city manages its transport systems largely as it does today, even as its population grows; there is little innovation in technology, pricing, or policy. Complicated traffic patterns, setbacks in technology development, and delays in consumer adoption deter AVs from being deployed on a large scale. In this scenario, transport demand increases in line with population growth (about 15 percent by 2030). Residents travel in mostly the same ways as they do now, and private cars continue to account for 35 percent of passenger-kilometers. There are more cars and buses on the streets and denser crowds on the trains (Exhibit 1). Average travel times increase by 15 percent, because capacity is strained. If vehicles do not electrify in large numbers, GHG emissions could rise.

Scenario 2: Unconstrained autonomy

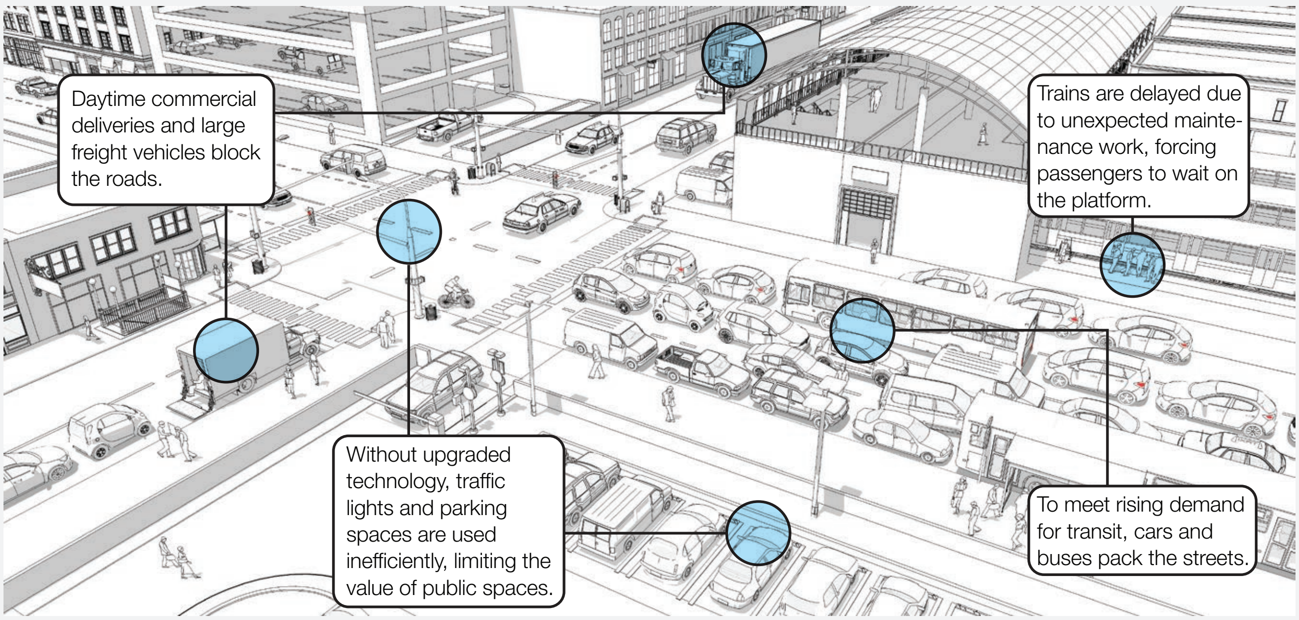
By 2030, shared AVs, such as robo-taxis, could offer an attractive alternative to private vehicle ownership, assuming that they can navigate to, from, and within the central business district.[11] Our analysis suggests that robo-taxis, once they are available, will cost about the same per mile as owning a moderately priced private vehicle.

Technologies often create externalities that spur new regulation. In the unconstrained-autonomy scenario, robo-taxis and autonomous shuttles are allowed, but regulators do little to incorporate them in terms of infrastructure upgrades or policy. The risk is that, without such support, these new technologies will fall short of their potential.

Unconstrained autonomy could look like something like the early days of bikesharing or e-hailing, in which change came faster than did the policies needed to guide them. The rollouts of bikesharing systems in Beijing, Hangzhou, and Shanghai are examples. Millions of bicycles arrived on the roads, and then many were abandoned.[12] Regulations—for example, marking restricted parking areas—eventually addressed the problem. In San Francisco, the introduction of e-hailing services has added 45,000 for-hire vehicles to the existing taxi fleet of 1,800. The San Francisco County Transportation Authority estimated that the new fleets accounted for over half of the average speed decline on the roadways since 2010.[13] E-hailing providers contested the findings, citing simultaneous increases in tourism and freight deliveries and pointing to their recent efforts in micromobility, such as shared electric bicycles.[14] There is agreement that congestion has increased, and both e-hailing companies and local government leaders have both supported the idea of "congestion pricing"—that is, charging vehicles to travel on certain roads at busy

Exhibit 1

Scenario 1 shows a typical intersection under business-as-usual urbanization in 2030.



times.[15] In the unconstrained-autonomy scenario, we estimate that travelers will adopt robo-taxis for about 25 percent of their travel by 2030. This is a major mobility disruption, even more than e-hailing, because robo-taxis offer the convenience of e-hailing at lower cost.[16] Autonomous shuttles would also be widely available. They would be less expensive than robo-taxis but also less convenient, and they could make up 10 percent of passenger-kilometers by 2030.

Compared to the first scenario, unconstrained autonomy has some advantages (Exhibit 2). The partial displacement of fixed-route buses by robo-taxis and autonomous shuttles with flexible routing increases the share of point-to-point trips. If the robo-taxis and autonomous shuttles are electric, GHG emissions are likely to fall, and air quality should improve.

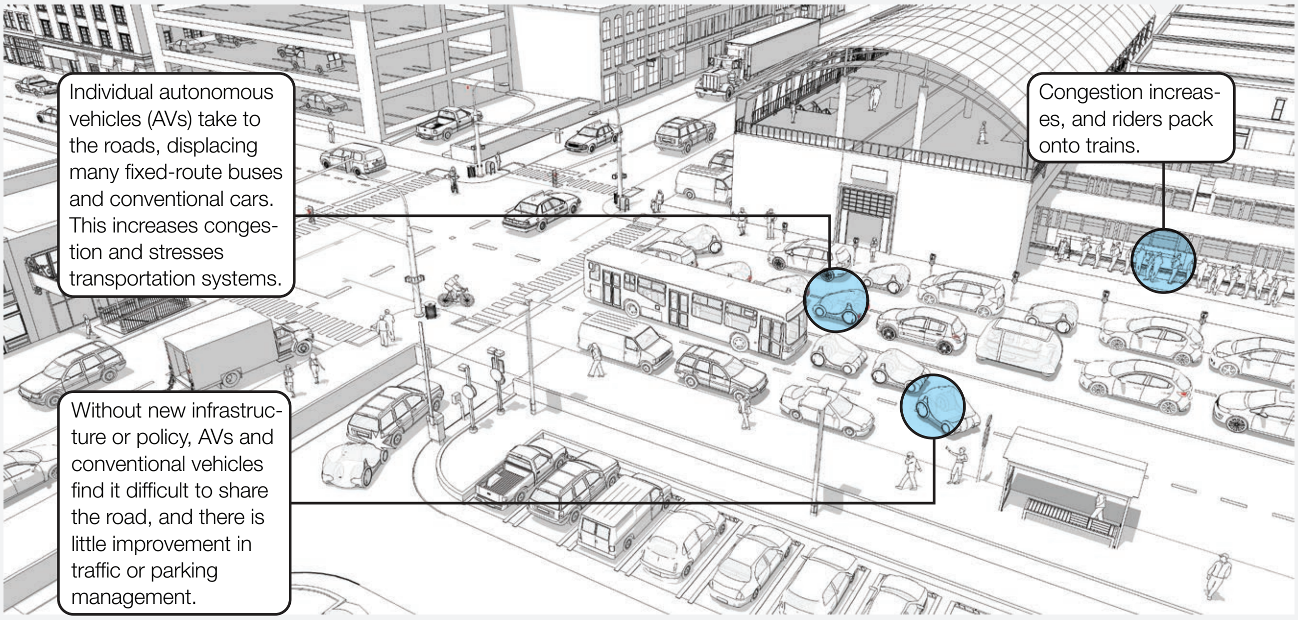
Congestion, however, probably will not improve compared with the baseline, and it could get worse. The average time for a private car trip could increase as the increased convenience of robo-taxis draws more users onto the roads. Other travelers, anxious to avoid the crowded roads, might pack into trains. In all, average travel times could be 15 percent higher compared with the baseline and no better than in the business-as-usual scenario.

Scenario 3: Seamless mobility

Connectivity, autonomy, sharing, and electrification are already disrupting the transportation status quo (see sidebar, "The role of technology"). These four technologies, if implemented effectively, could unlock seamless mobility. Under this scenario, cities look radically different. Residents have reliable mobility, facilitated by a range of technologies, including robo-taxis, autonomous shuttles, intelligent traffic systems,

Exhibit 2

Scenario 2 shows a typical intersection under unconstrained autonomy in 2030.



advanced rail signaling, and predictive maintenance. Through effective regulation and incentives, cities encourage the use of shared AVs while controlling the size and composition of the AV fleet to achieve specific goals, such as availability, efficiency, affordability, convenience, and sustainability, or some combination.

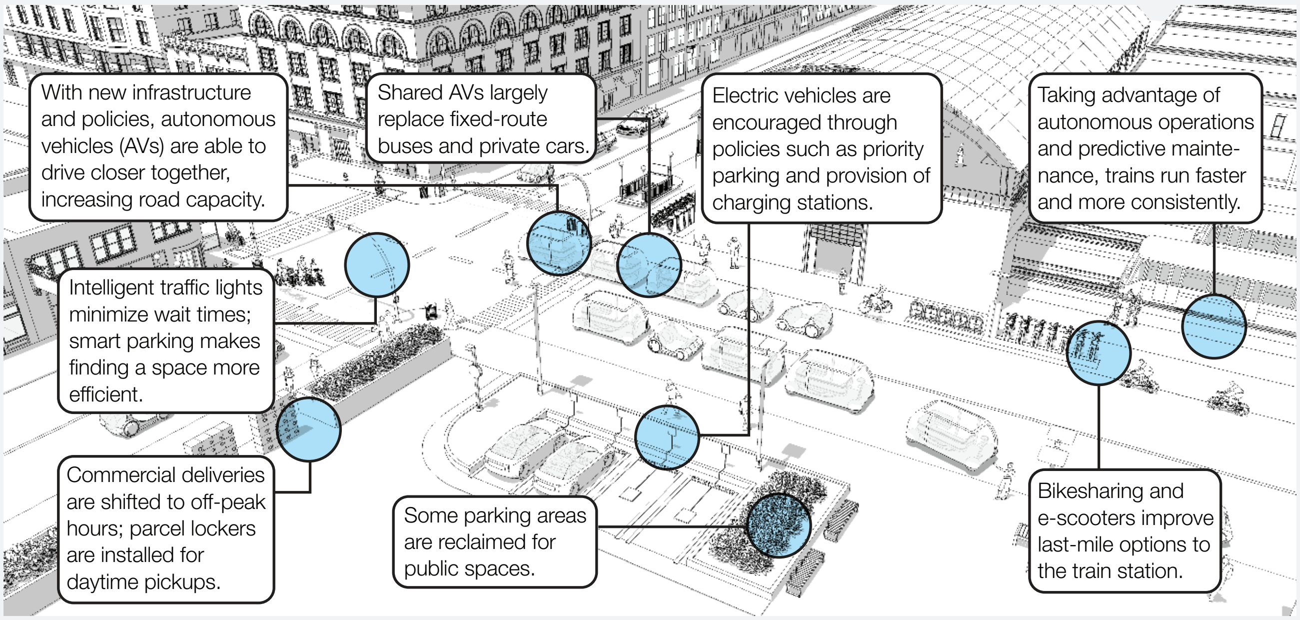
With seamless mobility, private cars and robo-taxis could provide about 30 percent of passenger-kilometers in 2030, compared with 40 percent for private cars today. Residents could "mix and match" rail transit and low-cost, point-to-point autonomous travel in robo-taxis and autonomous shuttles (Exhibit 3). Compared with the unconstrained-autonomy scenario, pooled autonomous shuttles would account for more travel. Rail would remain the backbone of the urban transit system, delivering about 40 percent of urban passenger-kilometers.

Seamless mobility could improve performance on all five indicators that characterize a transit system: availability, affordability, efficiency, convenience, and sustainability (Exhibit 4).[17] It could accommodate up to 30 percent more passenger-kilometers (availability) while still reducing average time per trip by 10 percent (efficiency). It could cost 25 to 35 percent less per trip (affordability), increase the number of point-to-point trips by 50 percent (convenience), and, if AVs are electric, reduce GHG emissions by up to 85 percent (sustainability).

These indicators define the promise of seamless mobility, but there are also big challenges. Demands on the transit workforce are likely to shift dramatically as automated trains and buses replace those operated by people. While new jobs will also emerge, the challenge for labor is clear—and the politics of making that adjustment may be difficult.

Exhibit 3

Scenario 3 shows a typical intersection under seamless mobility in 2030.



Setting the direction toward seamless mobility

Of the three scenarios, seamless mobility offers the best outcomes with respect to meeting demand (Exhibit 5), but it is also the most complex one to achieve. Cities have the opportunity to set a vision for seamless mobility and define a strategy to get there. In this section, we explore how a city might actively shape this future.

We identified 40 tools that cities could use. Many of these have been analyzed individually; what may be more important, though, is how these tools could interact with each other. For instance, to the extent that predictive maintenance improves the reliability of rail services, it could also increase ridership. And if a city adds congestion pricing on the roads to the mix, that might nudge even more people onto trains. The whole may be greater than the sum of its parts.

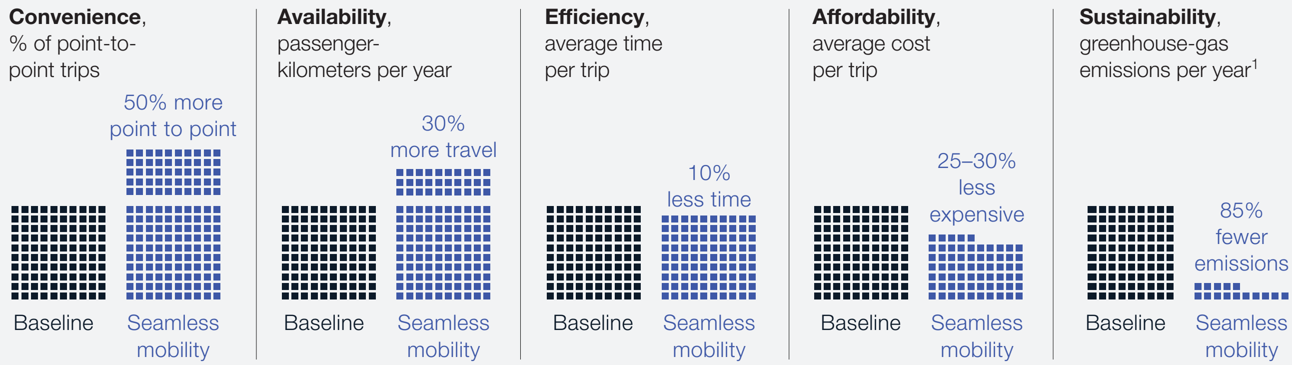
Different places, depending on their goals and local conditions, will choose different tools. A city whose priority is to reduce congestion might focus on investing in rail, while another place might see bikesharing as the better first step. Even cities with the same goal might make different choices. Given its high bus usage, Bogotá might deal with congestion by upgrading its bus system.[18] New York City, with its extensive subway system, might focus on rail.

At the highest level, there are three ways for cities to get to seamless mobility: optimizing supply, optimizing demand, and improving sustainability. In each of these categories, connectivity, autonomy, sharing, and electrification can help deliver the desired outcomes. In this report, we focus on these new tools. To get a sense of how this high-level analysis might play out on the roads and rails of

Exhibit 4

Seamless mobility has the potential to improve all system indicators.

System indicators, change over baseline



[1] Assuming that all electric vehicles and autonomous vehicles are powered by no-emissions sources.

a real city, we applied it to one city in depth. We found that, by deploying 12 tools, this city could substantially improve its baseline indicators and put itself well on the road to seamless mobility.

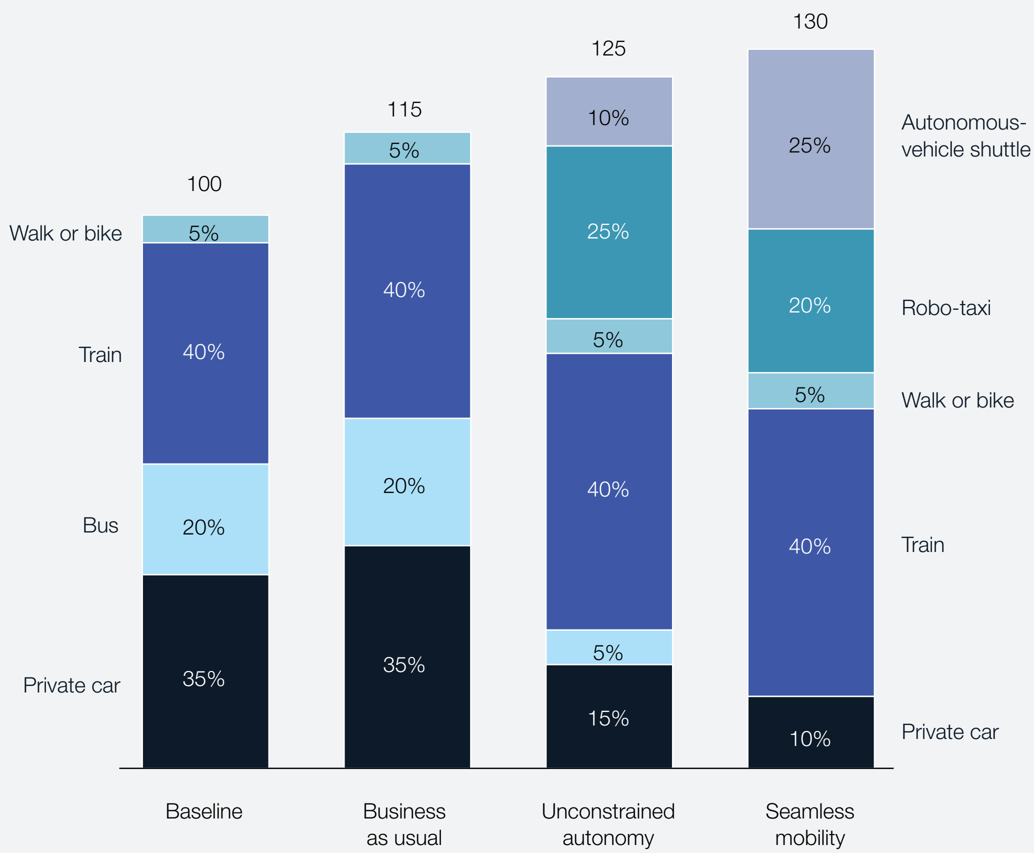
When we talk about optimizing the supply of transit, we are referring to adding infrastructure and rolling stock or increasing the utilization of existing infrastructure and rolling stock. The traditional approach to optimizing supply is to build more roads, bridges, rail lines, and other infrastructure, but doing so can be difficult and costly in dense, developed cities. In our example city, we therefore focused on tools that could increase utilization of existing infrastructure. We found that six could go a long way: intelligent traffic systems, smart parking, condition-based and predictive maintenance, automated rail, advanced rail signaling, and preparing for AVs by setting standards for connected-car communication.

Optimizing demand refers to changing how passengers use the transit system, by decreasing the demand for transit, moving trips away from peak times, or moving trips onto shared transport modes. In the example city, we selected the following five tools to optimize demand: dedicated lanes for shared vehicles, new modes to access rail stations, congestion pricing, a licensing system for robo-taxis and autonomous shuttles, and allowing off-peak deliveries.

Improving sustainability refers to finding ways to decrease environmental harm and improve public health that do not otherwise affect the supply or demand for transit. This could include tightened emissions standards for internal-combustion-engine (ICE) vehicles or moving from electricity sources that emit carbon dioxide to sources that do not. In our example city, we assumed that all robo-taxis and buses were electric and charged by

Exhibit 5 **The type of transportation people gravitate toward would vary by scenario.**

Type of travel by scenario,[1] passenger-kilometers per year[2]



[1] Example is for developed, dense metropolitan area.
[2] Index (baseline = 100).
Source: McKinsey analysis

no-emissions power sources, such as nuclear, hydro, solar, and wind.

These are the high-level options. Here is what they could mean at the ground level.

Optimizing supply: Rail

In the baseline estimates, rail provides nearly 40 percent of passenger-kilometers. In our example city, we looked at three tools: autonomous train operations, advanced signaling, and condition-based and predictive maintenance.

Dozens of autonomous train operations already exist, both for metro lines and for site-specific systems, such as airports. We assumed that autonomous operation and advanced signaling would reduce space between trains and move more people on the same rails. There is evidence for this: when Paris automated its oldest metro line, the average speed rose 20 percent.[19]

Condition-based and predictive maintenance mean collecting performance data and using statistics to identify and fix problems before they can cause breakdowns. When Transport for London installed remote monitoring for signal equipment on the Victoria line in 2014, the system identified failures sooner, reducing outages due to the equipment by 58 percent. More broadly for rail operators, we believe condition-based and predictive maintenance can reduce maintenance costs by up to 15 percent.[20]

Optimizing and future-proofing supply: Roads

Roads account for about 35 percent of passenger-kilometers traveled in the 2018 baseline, and connectivity can help to get the most out of existing streets. We considered two tools for the example city: intelligent traffic systems and smart parking. Intelligent traffic systems include lights that sense traffic and communicate with each other to minimize wait times and maximize movement. They also allow for dynamic lane allocation, which shifts lanes to the direction with more traffic. Smart parking technology connects vehicles to infrastructure and informs users where parking is available. This reduces the amount of time (and frustration) needed to find a space.

These two technologies have already proved themselves in individual pilots in real cities. Intelligent traffic systems reduced commuting time in Buenos Aires by as much as 20 percent, in San Jose and Houston by 15 percent, and in Mumbai by 12 percent. Meanwhile, smart parking reduced time spent searching for parking by about five minutes in both San Francisco and Johannesburg.

While connectivity is available today, AVs are not. But they are deployed on a large scale in both the second (unconstrained-autonomy) and third (seamless-mobility) scenarios and account for a substantial fraction of passenger-kilometers by 2030. Therefore, roads need to be ready for them. This will require careful coordination and synchronization of insurance regulations, safety rules, data standards, and communication protocols at local, state, national, and international levels. On the infrastructure side, roads need to be in a state of good repair and feature clear signage to enable AV operation.

Further, the benefits of connectivity are greater when there are agreed-upon communications standards, whether these are set by governments or through coordinated private action. Allowing vehicles to communicate with each other enables them to drive closer together. Studies have estimated that such vehicle-to-vehicle communication could increase the effective capacity of roads by 5 to 10 percent,[21] although the exact benefits will depend on the degree of penetration.

Optimizing demand: From private to shared modes of travel

In our example city, we found that optimizing supply alone simply shifted road traffic to rail, which could require a big, expensive, and time-consuming system expansion. To balance the system, we turned to tools that optimize demand—that is, getting people to shift to shared-transportation options and to move some traffic to off-peak hours.

We first investigated moving passengers from private to shared options. If people move away from driving themselves to using rail, bus, shared robo-taxis, or autonomous shuttles, existing infrastructure can carry more passengers without substantially increasing congestion, and maybe reducing it. We selected the following three tools:

- *Dedicated lanes for shared vehicles.* Dedicated shared lanes can be restricted to buses or high-occupancy vehicles to encourage passengers to share. They have a history of reducing travel times. The TransMilenio bus system in Bogotá reports reducing travel times by more than 30 percent on average.[22] Brussels has bus-priority lanes over a fifth of its bus network.[23]

- *Use of e-scooters and bicycles to shorten "last-mile" transit to rail.* One barrier to using rail is the last mile—the final journey from a person's location to the station. In this report, our example city makes it easier for travelers to get to mass-transit stations, whether on e-scooters, bicycles, or other, new forms of transit. While these modes are still in their infancy, early anecdotes suggest that e-scooters and shared bikes be linked to transit lines. For example, bikesharing has been correlated with increased public-transit usage in Beijing, Melbourne, New York City, and Washington, DC.[24]

- *Active management of the for-hire fleet.* Many cities regulate the number of taxis and e-hailing vehicles, and these restrictions could someday also be extended to robo-taxis. These licensing systems are meant to manage competition, by supporting the price of rides, and to curb congestion, by limiting the number of vehicles. However, doing so can also limit service and have disproportionate impacts on certain parts of the market.[25]

Optimizing demand: Shifting traffic to off-peak hours

The second element of optimizing demand is moving traffic to off-peak hours. If people take trips at times when others do not, the same infrastructure and rolling stock can carry more traffic with the same, or less, congestion. There are two promising approaches that could make a noticeable difference.

First, there is congestion pricing, in which vehicles pay to enter busy urban areas at certain times. Several cities, including London, Milan, Singapore, and Stockholm, have instituted congestion pricing and have concluded that it shifts passenger traffic. In London, congestion charges have helped to decrease the number of vehicles in the city center by 22 percent between 2007–08 and 2016–17.[26]

Another area to look at is shifting some commercial deliveries to off-peak hours. Goods transport accounts for almost 20 percent of congestion.[27] By allowing night deliveries, for example, cities can take stop-and-go commercial vehicles off the streets during the day. The concept has been piloted in cities, including Barcelona and New York City, reducing travel times for all users by as much as five minutes.[28] Along the same lines, shifting government or academic business hours can help to spread the rush hour over a longer period.

Improving sustainability: Electrify transit

In all three scenarios, roads continue to carry the largest percentage of passengers. Reducing GHG emissions and improving air quality, then, requires making road transit cleaner. EVs do not emit pollutants like nitrogen oxide or sulfur oxide—and if EVs are charged with low- or no-emissions sources, their GHG emissions can be at or near zero.

One tool that cities can use to encourage EVs is to create low- or zero-emissions zones, as some European cities, like Stuttgart, are doing. Another is to encourage electrification of shared, fleet, and government vehicles, which are used more intensively. Amsterdam has made special citywide parking permits available for electric-car-sharing fleets,[29] and Los Angeles International Airport recently purchased electric buses for its airside operations.[30]

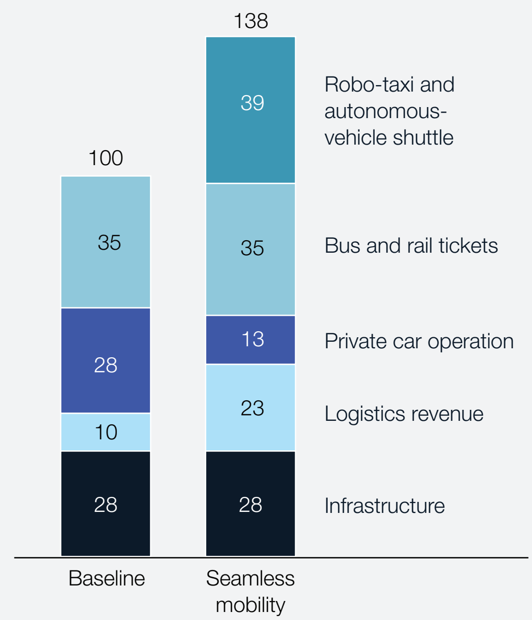
In our scenarios, we assumed that by 2030, all robo-taxis and autonomous shuttles would be electric and charged by no-emissions sources. This may appear ambitious, given the baseline. Even in China, the world leader, only 30 percent of buses sold in 2016 were electric. As for cars, EVs account for a tiny share of the global market, largely because of concerns about cost and range, compared to conventional ICE cars. However, because robo-taxis and autonomous shuttles are likely to be used more intensively and frequently as part of fleets, the total cost of ownership of an EV could become competitive with ICE vehicles by the mid-2020s.[31]

If the example city deployed all these tools, we believe it would achieve seamless mobility. While the benefits would be significant, we recognize that the changes are large as well. It may require a shift in mind-set for urban leaders, from seeing themselves as providers of public transit to being enablers of different transport options.

Exhibit 6

Under seamless mobility, new kinds of transport could create revenues equivalent to almost 40 percent of today's spending.

Breakdown of revenues related to urban mobility,[1] % of baseline[2]



Note: Baseline is greater than 100, because of rounding.

[1] Example is for developed, dense metropolitan area.
[2] Index (baseline = 100).

Source: *Financial Times*; Mayor of London; McKinsey analysis

Toward seamless mobility: Getting the private sector involved

Governments have many tools to optimize supply, optimize demand, and improve sustainability. But the public sector cannot achieve seamless mobility on its own. A flourishing transportation system also encompasses a wide range of private companies, from carmakers to e-hailing services to bikeshare operators. Achieving seamless mobility therefore also depends on tapping into the private sector's capabilities, business models, innovations, and technologies.

As noted, by 2030, new modes of transit could create additional revenues equivalent to as much as 40 percent of today's revenues (Exhibit 6). In a city like London, that could add up to more than $10 billion each year.

At the same time, getting to seamless mobility could also put some conventional private-sector business models at risk. In our baseline in the example city, conventional carmakers might sell 300,000 vehicles per year, representing nearly $10 billion in sales.[32] If the car market became entirely electric and transportation heavily reliant on robo-taxis, as in seamless mobility, this could put a significant share of revenue at risk. If a carmaker did not adapt its portfolio, it could find itself in big trouble. Infrastructure companies could also be affected. Take, for example, a builder working on a public–private partnership for a major transit hub. That builder might have borrowed heavily, in the expectation of making money back by operating the hub. If passengers get around differently—as anticipated in seamless mobility—that investment may not pay off.

To understand the business opportunities, risks, and role of the private sector in the evolution of seamless mobility, we divided the urban mobility system into four layers—infrastructure, rolling stock, digital and analytics, and user interface (Exhibit 7). Once private-sector players understand each layer, they will be better poised to adapt their business models and capture future opportunities.

Infrastructure

The base layer of an urban transit system is made up of its physical infrastructure (such as roads, rails, stations, and parking facilities) and the energy infrastructure that fuels it. For example, Singapore's 2018 budget included $12 billion for transportation development, with $6 billion dedicated to its rail system.[33] Under seamless mobility, these kinds of hard assets are not only necessary, but they also need to be smart and connected—equipped with sensors for traffic management and predictive maintenance and with dynamic lanes and traffic lights.

Seamless mobility also may require new kinds of assets, such as storage and maintenance facilities for shared autonomous fleets, fast-charging infrastructure, and dedicated AV lanes equipped with vehicle-to-infrastructure communications and IT systems. All of this comprises a significant new area of opportunity for infrastructure companies to design, build, and operate—and one for new forms of public–private partnerships.

The different energy profile associated with seamless mobility will also affect energy infrastructure, notably utilities and oil-and-gas retailers. Utilities have traditionally been the sole providers of electricity, but recent moves by adjacent energy players, such as Shell's acquisitions in the vehicle-charging sector, illustrate how charging could become a new area of competition. Moreover, when EVs begin to hit the road in substantial numbers, utilities will need to respond to increasing peak loads, which could grow by as much as 30 percent in residential EV hot spots. One way for utilities to adapt could be to work with consumers to alter their charging behavior. By increasing the number of people charging up their vehicles at times of excess local generation and low local demand, or by throttling it down at moments of low production and high local demand, the utilities could minimize the impact on the grid. They could also work with EV owners to offer valuable system-balancing (frequency-response) services.[34]

Oil-and-gas retailers also should take notice. As EVs get more popular, demand for light-vehicle

Exhibit 7

The urban transit system features four layers of business opportunities.

The role of technology

Four trends will help to shape the future of urban mobility: connectivity, autonomy, sharing, and electrification.

Connectivity

The spread of the Internet of Things (IoT) to infrastructure and vehicles has enabled newer forms of travel, such as carsharing and e-hailing. It has also made traditional modes more efficient—for example, by making trains run more smoothly and routing buses more efficiently. In some US cities, portions of the bus fleets travel along flexible networks, based on rider orders placed through an app rather than fixed schedules. Our analysis shows that IoT sensors allow train operators to shift to condition-based and predictive maintenance, reducing maintenance costs by 10 to 15 percent.[1]

Autonomy

Autonomous technology is being rolled out on rail and is being piloted for roads. Berlin and Detroit are experimenting with limited road applications, such as driverless shuttles on selected routes. Applications that offer full services in a limited area could be seen in the next three to five years, paving the way for a host of new kinds of transit, such as robo-taxis and fully autonomous shuttles and buses.[2] Autonomous passenger-rail services are already common.

Sharing

Shared mobility solutions, such as carsharing, e-hailing, and bikesharing, are all growing, and the potential is enormous. The emergence of shared, autonomous electric vehicles (EVs) that are less expensive than owning a private car could transform urban mobility.[3] Bikesharing has also grown rapidly in the past decade. In the United States, the number of bikeshare trips increased from 2.3 million in 2010 to more than 35 million in 2017.[4]

Electrification

While electrification of urban rail has been standard for decades, electrification of road transport is still relatively new. But it is beginning to grow quickly. Urban buses are already electrifying at scale. Global sales of electric passenger vehicles passed a million units in 2017 and could reach 5 percent of the global light-vehicle market by 2020.[5] EVs are quieter than conventional cars, emit fewer greenhouse gases (and none if they are charged with no-emissions sources), and do not contribute to smog. Electric bikes are also finding their place; they make urban cycling accessible to those who are less fit, and to those in cities that are hilly or less dense.

[1] *The rail sector's changing maintenance game*, February 2018, McKinsey.com; Shafiq Dharani, Tom Isherwood, Diego Mattone, and Paolo Moretti, "Telematics: Poised for strong global growth," April 2018, McKinsey.com.

[2] "Autonomous-driving disruption: Technology, use cases, and opportunities," November 2017, McKinsey.com.

[3] Aditya Dhar, Dev Patel, Rahul Raina, and Paolo Sandrone, "What US consumers think of shared mobility," November 2017, McKinsey.com.

[4] "Bike share in the U.S.: 2017," National Association of City Transportation Officials, 2017, nacto.org.

[5] Patrick Hertzke, Nicolai Müller, Stephanie Schenk, and Ting Wu, "The global electric-vehicle market is amped up and on the rise," May 2018, McKinsey.com.

fuels may decline sharply (by as much as 75 percent in 2015–30 in metropolitan areas that accelerate to seamless mobility).[35] If that happens, there will be fewer trips to the pump, and local oil-and-gas retailers will take a hit—not only because they are selling less fuel, but also because of fewer visits to their on-site convenience stores. They could compensate by providing fast-charging services, at least in urban areas, for the robo-taxis and autonomous shuttles that meet almost half of the transit demand under seamless mobility.

Rolling stock

The next layer of the urban transit system consists of the physical rolling stock: cars, buses, subway and train coaches, bicycles, and scooters. For manufacturers of these and related items, seamless mobility will require a rethinking of their product portfolios and business models. Driver-operated conventional vehicles account for about 35 percent of passenger kilometers in the baseline scenario, but only 10 percent under seamless mobility. Meanwhile, AV shuttles and robo-taxis could replace most driver-operated buses. And these new types of vehicles may have different user requirements, such as private space in enclosed vehicles to encourage sharing.[36]

For manufacturers, the question is not only about what products to make; they will also need to decide how to compete. They could choose to focus on the development and sales of autonomous and electric vehicles. Or they could move away from selling vehicles and toward selling mobility—for example, by offering subscription services, a shared-mobility service, or a connectivity platform.

Data and analytics

The third layer of the urban transit system consists of data and analytics, such as traffic-flow management, real-time public-transit information, vehicle routing, maps, and vehicle tracking. Transport is increasingly reliant on new technologies, particularly with respect to autonomy and connectivity. Infrastructure companies, transit operators, carmakers, and other manufacturers will need to work with technology providers on everything from developing new sensor applications to enabling mobility-as-a-service platforms. For example, Uber developed technology to improve GPS performance in cities, aiming to make pickups more efficient and increase vehicle utilization.[37] Carmakers interested in new business models may want to explore developing similar capabilities, possibly by collaborating with technology providers.

User interface

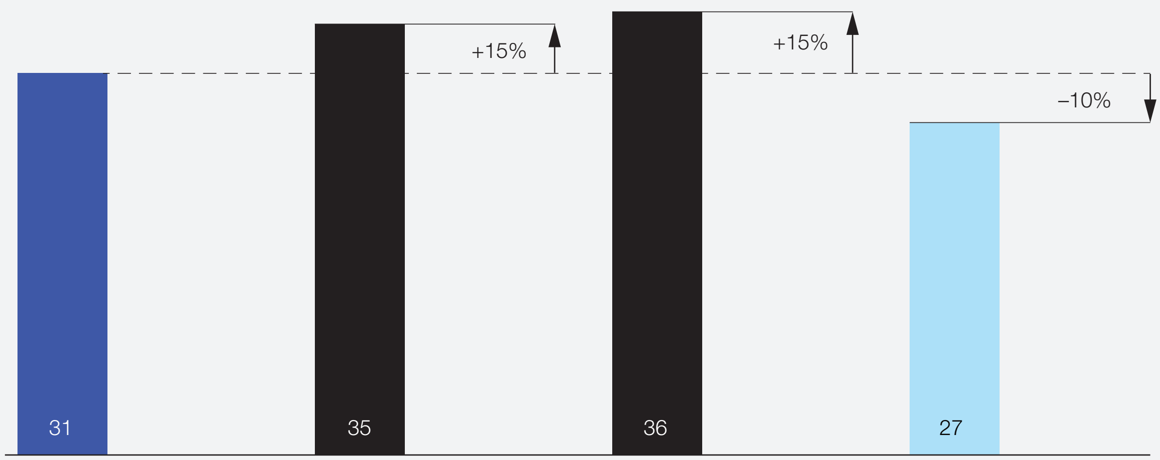
The final layer is the interaction with passengers themselves, occurring through navigation apps, mobile applications for mobility companies, and even associated mobile-payments platforms. These interfaces have already changed how people use the infrastructure, rolling stock, and data on the transit system—making it easier for them to plan trips that use different kinds of transport, helping them pick which roads they use, or moving trips from private cars to shared options. The companies that operate these interfaces are now going beyond mobility, integrating businesses such as retail promotions, local recommendations, and micropayments.

User interfaces can influence how passengers travel. For instance, the navigation apps searching for quicker routes have sent traffic to suburban roads from Tel Aviv to Los Angeles to New York City.[38] Meanwhile, research suggests that multimodal navigation apps have increased the use of public transit by making it easier for users to plan trips confidently. Over the longer term, e-hailing platforms could make multimodal travel easier and thus reduce private car ownership.[39] These interfaces are also exploring adjacent business opportunities in payments and retail. Go-Jek, an e-hailing service provider in Indonesia, started by offering rides on a fleet of 20 motorbikes through its app. Today, it is a major payments platform and offers more than 15 additional applications, from food delivery to house cleaning to ticket sales.[40] Google Maps now features a tab that guides its users to local shops and restaurants. These and similar applications require sophisticated software and marketing skills that are most often associated with the private sector.

Exhibit 8

Urban congestion increases from the baseline in all but the seamless-mobility scenario.

Estimated change in average travel time by scenario, 2018–30,[1] minutes



Baseline
This dense, developed city faces significant challenges, with an average trip time of more than 30 minutes.

Business as usual
Urbanization will increase demand for mobility. Congestion could therefore worsen as more people make more trips.

Unconstrained autonomy
Robo-taxis and autonomous shuttles will be on the roads, but more people will travel, and congestion does not improve.

Seamless mobility
Shared travel and the use of autonomous vehicles eases congestion by up to 10%, even as demand increases.

[1] Example is for developed, dense metropolitan area.

Conclusion

Cities around the world are under pressure to improve mobility. If they do little or nothing, the trends related to urbanization, population, and e-commerce are likely to make congestion and pollution worse. Seamless mobility offers a different, potentially better path (Exhibit 8). To get there will require significant financial investments, imaginative policies, and substantive collaboration with the private sector.

While seamless mobility may seem like a leap, the past offers hope. Cities have reimagined transport before and then did what was necessary to improve mobility, and thus the lives of their people. Go back to that first underground railway. London not only permitted eight years of construction through one of the most crowded districts in the city, but it also established a public–private partnership and invested £200,000.[41] "Those who devised and carried out this undertaking would be entitled to the highest praise and gratitude of the people," noted one speaker at the ceremony to commemorate the opening. "This line was not only an honor to the country, but a solid advance in civilization." True enough then—and, perhaps, it will be true again in the future.

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