

An ecosystem approach to reducing congestion





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Executive summary

The challenge of congestion is a perennial issue for cities around the world, and is rapidly worsening. In recent years, a number of trends have exacerbated urban congestion. These include economic expansion and increased urbanization; the rise of both ride-hailing services, which puts more cars on the roads, and e-commerce, which adds to the number of delivery vehicles; the deterioration of existing infrastructure; and the mixed success of some efforts to reduce congestion.

Based on research sponsored by the National Parking Association (NPA) in the U.S., this study explores the drivers of congestion and potential solutions in an evolving mobility landscape, including how parking can be an asset within the transportation ecosystem and implications on effective policy planning in an effort to create livable cities of the future. The research encompasses analysis of publicly available information, as well as observations and interviews with people from diverse backgrounds: technologists, parking operators, developers, policy planners, academics, venture capitalists and other investors, the startup community, and infrastructure investors.

Numerous options for reducing congestion are available to municipalities, but some are more effective than others. The most successful tend to take a comprehensive ecosystem approach, recognizing from the start that all the elements of traffic design affect one another and should be designed and developed in an integrated way. This means considering both near-term and long-range measures that affect both transportation supply (e.g., new roads and rail infrastructure) and demand (e.g., incentives for travel at non-peak times).

These approaches include fostering innovation in an experimental, agile fashion so that city planners can learn while developing new solutions; seeking a wide range of financing from public–private partnerships and other sources; and tailoring the approach to each city's unique traffic layout. There are seven archetypal city patterns — some with dense,

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non-grid cores (e.g., Singapore and Amsterdam); some with grid-based urban hubs (e.g., New York, London, and Toronto); and some with spread-out layouts and multiple hubs (e.g., Los Angeles and Paris).

Each city requires its own mix of measures to reduce congestion, and can choose from a wide array of options. These range from encouraging alternative modes of transportation (e.g., more opportunities for walking and travel by bicycle and motor scooter) to raising the real costs of inner-city access with measures like congestion pricing and variable parking fees to improving infrastructure for rail travel, bus service, or parking. (Motor scooter is the term used in this paper for all variants of powered scooters, including electric scooters and dockless scooters.) City planners can make more effective decisions about access to transportation network companies (TNCs), including ride-hailing and taxi services; establish new innovative approaches to double parking and last-mile deliveries; and prepare for new technologies, including machine learning-based analytics that can redirect traffic flows, vehicleto-vehicle connectivity that can increase highway utilization, and futuristic ventures such as drones and Hyperloop.

To take a fully holistic ecosystem approach, city planners need to consider the interrelationships among all these measures. Some efforts simply attract more vehicle traffic, while others reduce congestion by giving people multiple attractive alternatives and easy ways to switch among them. Pioneering "mobility hub" approaches, which coordinate parking, mass transit, and commuting, are now being implemented in cities around the world. Urban government and business leaders can learn from these leading-edge examples, and put new, improved innovations into practice.

Introduction

After World War II, the United States experienced substantial economic and population growth — from 151 million people in 1950 to 326 million people in 2018. Suburbs were created, urban sprawl increased, and a car-oriented culture developed. The number of motor vehicles on the road increased, from 68 million in 1958 to more than 270 million in 2018. By the mid-1980s, 85 percent of commuters were driving or carpooling to work, a trend that has remained consistent for 40 years.

The result has been a steady increase in debilitating traffic congestion. Congestion is the breakdown in traffic flow, reduction in speed, and increase in crowding that occur when a road's capacity is exceeded. Capacity is so consistently strained on America's roads that congestion is a chronic problem throughout the country. In 2017, the average person spent 41 hours in congestion, an increase of 8 percent over 2010.

Among major U.S. cities, the situation is even worse. In Los Angeles and New York, time spent in traffic is more than twice the national average. Congestion costs the U.S. between US\$230 billion and \$300 billion each year, about four times the amount spent on public transit and double the spending on roads and highways. Nearly 75 percent of the cost takes the form of direct costs, such as excess fuel consumption and harm to people's health from air pollution. Lost time may be the direct cost that Americans feel most acutely. Indirect costs, including higher prices, account for the remaining 25 percent of economic impact.

This report focuses on the United States, but the same dynamic exists in most other countries, in both industrialized and developing economies. For nearly every country with large cities, including emerging economies, congestion represents a major social and economic cost. Congested lanes and hard-to-find parking create a disincentive for employees and tourists to enter a city — a phenomenon known as trip avoidance. Cities rely on employment, tourism, and corporate investment to fuel livability and economic vibrancy, and all of these are diminished by traffic congestion. Congestion costs the U.S. between US\$230 billion and \$300 billion each year, about four times the amount spent on public transit and double the spending on roads and highways. With the U.S. population projected to hit 390 million by 2050, the implications of continued growth for congestion are urgent. The goal of this report is to provide analytical insights on the most relevant trends, innovations, and case studies to inform public and private plans for reducing congestion.

Six major trends fueling congestion

The problem with congestion is expected to worsen during the next few years, driven by six main factors:

1. Economic expansion

Economists have long understood the strong correlation between an economy's performance and the overall vehicle miles traveled (VMT) in that region. VMT, which is also affected by gas prices, serves as a reasonable proxy for potential congestion. In the U.S., given expectations for GDP growth, we expect a 1 percent CAGR for VMTs through 2030 — a 14 percent gain, or a 500 billion mile increase.

2. Demographic changes and urbanization

The U.S. population continues to grow, and to shift from rural to urban areas. From 2010 to 2030, the U.S. population is expected to increase 15 percent, from 309 million to 355 million, and the percentage living in urban areas is expected to rise from 81 percent in 2010 to 89 percent by 2050 (*see Exhibit 1, next page*). This will exacerbate an existing trend — a 160 percent gain in the U.S. urban population since 1980 — that has significantly increased VMT in cities. At the same time, motor vehicles remain the dominant transportation mode; for example, the percentage of commuters driving to work, rather than taking public transportation, has remained largely constant.

3. Transportation disruption: TNC and ride-hailing

Ride-hailing has grown, substituting for mass transit, putting more cars on the street, and contributing to congestion at the curb. Transportation network companies (TNCs) such as Uber, Lyft, Gett, and Easy Taxi tend to offer both ride-hailing and ride-sharing (the difference is that ridesharing involves two or more independent passengers on a trip). TNCs have experienced explosive growth, from just a handful of trips in 2012

Exhibit 1 **Past and expected U.S. urban and rural population growth, 1980–2050**



US urban and rural population growth

to about 2.6 billion trips in 2017. The VMT from these TNCs grew from 30 million in December 2013 to 500 million in December 2016, a compound annual growth rate (CAGR) of 150 percent.

Ride-hailing services have become a valuable part of the current transportation ecosystem. Their cost and convenience benefit many consumers. Nonetheless, TNCs remain a small part of the overall transportation picture in the United States. While nearly 10 percent of all Americans use TNCs in any given month, their rides only account for 0.5 percent of total trips taken.

The economics of TNCs favor cities, where parking expenses add to the costs of private car travel. Within cities, shorter trips favor ride-hailing over private vehicles; but the longer the trip, the more cost-effective a

private car is. In all cases, the cost of public transportation tends to be less — if public transport is available (*see Exhibit 2*).

TNCs add to congestion within cities in four ways: (1) They increase overall travel demand; (2) take rides away from public transit; (3) add to VMTs with nonproductive "deadhead" miles (miles spent circling

Exhibit 2 **Cost of transportation modes by distance in New York and Chicago**

Public transport is always cheaper, but shorter trips favor ride-hail over private vehicle while longer trips favor private vehicle



2. Private vehicle ownership is based on AAA estimates and an average of 15,000 miles, assumed to be the same for NYC and Chicago.

3. NYC parking of \$541 per month (20 days).

Source: NYC.gov; web.mta.info; yellowcabchicago.com; transitchicago.com; USA Today; Strategy& analysis without a passenger account for 20–50 percent of the miles they travel); and (4) contribute to traffic violations and obstructions.

By embracing forward-looking technologies, such as autonomous vehicles (AVs), pooled vehicles, e-bikes, motor scooters, and robo-taxis, TNCs might mitigate some of these concerns or even relieve congestion. In the meantime, congestion from TNCs will continue to increase unless steps are taken to reduce their impact.

4. E-commerce and on-demand delivery

Internet-based purchasing is on a rapid growth trajectory, rising in the U.S. from 0.3 percent of retail spending in 1998 to 8.7 percent in 2014. Estimates suggest that this share could rise by as much as 1.2 percent a year through 2030.

Offers of ever-faster shipping have given rise to numerous on-demand delivery services enabled by TNCs and e-commerce platforms. The 2014 launch of Amazon's Prime Now service provides shoppers near-instant gratification with one-hour delivery in select markets. With consumer expectations reset, other retailers need comparable offerings to remain competitive. It isn't enough to provide delivery service; they must do so at a reasonable cost. They are scaling up e-commerce and delivery platforms to drive down shipping costs, further accelerating adoption.

It once seemed likely that on-demand delivery would prompt consumers to reduce trips to malls and retail stores. But the expected drop in VMT never materialized due to three operational considerations: First, both free shipping and on-demand delivery have increased single-package deliveries and smaller vehicle loads, inflating the number of delivery trips. Second, failed first deliveries are estimated to range between 10 percent and 30 percent, driving repeat visits. Third, at least 30 percent of e-commerce orders are returned, compared with about 9 percent of traditional sales, increasing the number of trips by delivery vans to pick up the item being returned and to redeliver replacements.

Delivery companies also contribute to congestion at the curb through double parking and illegal turns. Moreover, some city policies do not discourage this. For example, New York's controversial stipulated fine program, launched in 2004, allows delivery companies to reduce or eliminate fines for certain citations by waiving their right to contest them in court. It once seemed likely that ondemand delivery would prompt consumers to reduce trips to malls and retail stores. But the expected drop in vehicle miles travelled never materialized.

5. Underinvestment in infrastructure

To limit congestion, good transportation infrastructure is critical. Roads, bridges, and tunnels must be well maintained and expanded at a pace that is in sync with overall mobility demand growth. Unfortunately, the movement back into cities has overtaxed transportation infrastructure. This has been particularly problematic for the U.S., where roads, bridges, and tunnels already suffer from lack of upgrades and upkeep. The American Society of Civil Engineers' 2017 infrastructure report card awarded U.S. systems an overall grade of D+. A primary reason for this is the backlog of unmet capital investment for highways and bridges: about \$836 billion, according to a 2015 U.S. Department of Transportation (DOT) report. The federal gasoline tax, which funds a great deal of transportation infrastructure expenditures, has not been raised since 1993. In light of a 2.2 percent annualized rate of inflation from 1993 to 2017, this suggests that funds essential for infrastructure have fallen short of where they used to be by as much as 73 percent.

According to the Federal Transit Administration, more than 40 percent of buses and 25 percent of rail transit assets are in marginal or poor condition. Nearly 25 percent of bridges are structurally deficient or functionally obsolete, and about 33 percent of roads are in poor or mediocre condition. Budgetary restrictions and short-term planning exacerbate budgetary problems. Inefficient use of allocated funds often forces cities to "patch and maintain," leading to wasteful spending and inefficiencies.

Maintaining public transit is a particular challenge for U.S. cities. Annual spending is about \$17.7 billion; U.S. Bureau of Transportation Statistics (BTS) data shows that the need is two-and-a-half times greater. Additionally, the BTS estimates that the country has a backlog of about \$90 billion in deferred public transit maintenance and replacement projects.

6. Mixed effectiveness of policies and programs

Cities have embraced a variety of mobility solutions, with mixed effectiveness. For example, high-occupancy vehicle (HOV) and bus-only lanes are supposed to justify their capital-project costs by discouraging the use of private vehicles for commuting, but they often don't. Because of challenges with enforcement and other operational issues, these solutions tend to lead to more, not less, congestion.

When they first appear, the special lanes attract drivers; in fact, a 2016 study conducted in California found that unauthorized drivers using

High-occupancy vehicle (HOV) and bus-only lanes are supposed to justify their capital-project costs by discouraging the use of private vehicles for commuting, but they often don't. HOV lanes accounted for about 24 percent of the total drivers during peak hours, and 19 percent in off-peak times. Their availability provides an incentive for a portion of public transit riders to drive cars instead. The end result is that congestion in both special and general-purpose lanes increases, a lose-lose situation for commuters.

Bus-only lanes can lead to increased congestion for three main reasons: First, a lack of enforcement has led to congested bus lanes. Cameras installed to monitor unauthorized use of New York's bus-only lanes detected 133,000 violations in 2017; that same year, the city's police wrote a mere 2,020 summonses. Along with traffic signals and passenger boarding, other traffic in the bus lane reduces the average speed of public buses to nearly 40 percent of private vehicles running on the same street. Second, there are many dedicated lanes in highly congested streets, reducing overall capacity. Third, an increasing number of commuters opt for private vehicles, ride-hailing services, or other options due to relative cost and convenience. According to the U.S. DOT, bus ridership has declined at a CAGR of about 1 percent from 2007 to 2016.

City parking policies also contribute to congestion. Regulations, sometimes dating back to the 1930s, specify that buildings include parking spaces, which often produces an overabundance of parking. In effect, this bundles parking subsidies into the prices of real estate and other goods and services, thus favoring driving over other transport modes.

Subsidized on-street parking also reinforces the behavior of circling. Some studies have found that up to 30 percent of vehicles in a particular area were looking for a parking space to open up. That estimate may be too high, but this behavior remains a problem. Not charging, or charging very little, for on-street parking increases demand and contributes to congestion. Some studies have found that up to 30 percent of vehicles in a particular area were looking for a parking space to open up.

Autonomous vehicles: Slow adoption, uncertain impact

Some observers believe that the growing number of shared, electric, and autonomous vehicles (AVs) could help eliminate congestion and reduce emissions. After all, these new forms of transport will be radically disruptive. They will change automotive ownership models, urban layouts, and the look and feel of passenger vehicles. They may use the roads in a far more efficient way, through connected-car technologies that synchronize multiple vehicles on the same road.

However, if consumers are unwilling to pool rides (and the data suggests this is the case), the future could be bleak. In fact, congestion could worsen as AVs increase VMT, interact with human drivers, and induce demand.

Part of the problem involves the slow rate of adoption. Fully autonomous vehicles will likely not be common in most cities until at least after 2030; they will require considerable design changes, repurposing of parking facilities and locations, and changes in laws. Extensive testing and validation of necessary advances in sensor and computing technology for commercialization will be required. After technological challenges are overcome, the high cost of AV adoption will limit buyers and fleets. It will also take a while to replace the large installed base of millions of legacy vehicles, which have an average age of more than 12 years. Furthermore, legal and ethical questions about liability for accidents, injuries, and deaths are still unresolved. All of these issues have to be dealt with before AVs can become mainstream.

In the meantime, roads will increasingly carry partially autonomous vehicles, where a human driver handles some of the vehicle management. This conversion to a new way of life could add to existing congestion problems, especially in the short term. Convenient and affordable robo-taxis may lessen the appeal of public transportation, prompting more individual car trips and crowding the roads. AVs and non-AV drivers may not mix well; for example, AVs may stop suddenly if cut off by cars with human drivers, slowing network speeds. To mitigate the future negative effects, there are several measures that could be considered now. These include investments in related infrastructure (including charging and docking stations), development of public transit that interacts effectively with AVs, and information technology (IT) advances. Another key measure is the promotion of ride-sharing. If ride-sharing proves more palatable to more people, it would change the economics of transport drastically and help reduce congestion. Taxes, fees, and regulations will also affect the comparative cost and convenience of AVs, contributing to their impact on congestion.

As we explore how autonomous vehicles could affect the congestion and quality of life in cities, questions to consider include: How could AVs complement current public transportation networks? How should streetscapes evolve (if at all) to accommodate them? Are dedicated lanes for AVs optimal? Could on-street parking evolve to accommodate bus, bicycle, or AV lanes? What about expanding package deliveries and making them easier to live with? Answers to questions like these can help drive long-range planning and potentially spark some shorter-term investments. If ride-sharing proves more palatable to more people, it would change the economics of transport drastically and help reduce congestion.

Guiding principles for change in your city

If you are an urban policymaker, then you are inevitably engaged in managing traffic congestion. Increasingly, your city's competitive advantages depend on finding a comprehensive, holistic solution to this problem. Look more broadly toward the overall quality of the urban ecosystem. A livable city is one with convenient, clean, and cost-effective transportation even as congestion and growth increase. A seemingly narrow lever — for example, parking policy — can be deployed on behalf of a full mobility hub: a system of multiple forms of transportation that efficiently and effectively move people where they need to go.

The number of levers that policymakers have at their disposal increases the challenges of planning. So does the need for rapid innovation and change, which may be counterintuitive for existing organizational cultures and may strain a city's limited human and budgetary resources. Policymakers must also manage new modes of transport (i.e., motor scooters and e-bikes), ride-hailing, and package-delivery growth.

Given these complexities, we propose five guiding principles for developing congestion solutions:

- 1. Consider near- and long-term supply and demand levers. A combination of policies is required to drive sustainable change to reduce traffic density. Near-term solutions, such as altering regulations, are often quicker and cheaper to implement. But infrastructure investments like bus rapid transit require significant investment over a long period of time. Similarly, your solutions must address both demand, or the needs that people have for transportation, and supply, or the facilities and infrastructure available to offer. (See Appendix, page 32, for specific examples.)
- 2. Take an ecosystem view to drive city livability. When planning is conducted for all aspects of transportation at once, you can integrate multiple forms of leverage public transit, private vehicles, and parking and reduce the tradeoffs among them. This ecosystem view should include an interplay of multi-modal transport options

and different modes of travel designed to work together: Buses and trains should be accessible from most locations; protected lanes for bicycles and motor scooters should be encouraged for shorter commutes; pedestrian walkways and bridges should be encouraged as well; and switching from one mode to another should be easy and convenient.

At the ride-hailing level, consumers will become accustomed to sharing rides. Over time, autonomous trucks, shuttles, buses, and shared robo-taxis will begin operating, generally on roadways designed for them, providing convenient, safe, and cost-effective travel on demand.

Ecosystem-style solutions include the redesign of city "inner rings" as a connection point between urban and suburban travel; mobility hubs, where a variety of transit modes come together with smart parking approaches; streetscapes that integrate bus, rail, auto, and pedestrian activity; and parking systems that mitigate congestion at the curb, with short-term drop-off points and flexible ride-hailing stands.

Solutions like these require regulatory and planning changes. Strong parking and auto travel policies (such as congestion pricing and TNC drop-off and pickup lanes) can help mitigate competition for space along the curb. Street and roadway designs must incorporate new modes of transport (for example, e-bikes, motor scooters, and robotaxis) and constrain congestion at curbside from ride-hailing and package deliveries — all under strict budgetary limitations.

3. Foster innovation through collaboration, pilots, and agile policymaking. Innovation in the transportation space is evolving at a rapid pace. The effects of new technologies and new transit are unproven and often unknown. When you experiment with new approaches through pilot projects, it allows you to learn from these trial experiments without having to jump into a full commitment headfirst. Once you see the value of an approach, then scale it through the broader municipality.

Encourage collaboration with various stakeholders in your community. Hospitals, universities, corporate campuses, and event venues are microcosms of transportation systems that might explore multi-modal transportation options.

When setting up experiments or collaborative efforts, clearly outline your objectives and the potential value you hope to create. This helps to focus the scope and better understand when pilots are benefiting the city. Break down the scope of your effort into clearly defined phases with timelines. Since these are pilots, part of your Ecosystemstyle solutions include the redesign of city "inner rings" as a connection point between urban and suburban travel: streetscapes that integrate bus, rail, auto, and pedestrian activity; and parking systems that mitigate congestion at the curb.

goal will be learning, and some aspects will not be clear at the start. Revisit your scope and objectives as necessary. At the same time, identify your criteria for success and key milestones as specifically as you can up front. This keeps your pilots focused and aligns you with others in the community. As you proceed, continuously collect data to monitor your progress and better recognize the potential value that these new programs can create. Use this to gather evidence to demonstrate your ongoing track record.

4. Develop an innovative financing plan. Many options for fighting congestion are expensive, especially those that involve construction of new roads or bridges or expansion of public transit networks. If federal and state government support is elusive, think regionally. If suburban commuters account for a large share of demand, seek suburban sources of funding. Technology companies and investors sometimes fund cutting-edge infrastructure projects to boost their brand. For example, the Boring Company (founded by Elon Musk) is expected to cover costs of a proposed Hyperloop tunnel between downtown Chicago and O'Hare International Airport.

Use referendums to seek funding for broad-based improvements. In 2016, Los Angeles County voters passed a ballot initiative, "Measure M," that raised the sales tax by half a cent until 2039 and by a full cent thereafter, bringing in an added \$121 billion in revenue through 2057 to fund transit improvements. In the San Francisco Bay area, voters in nine counties approved a measure in June 2018 to raise bridge tolls by \$3 over a period of seven years. Some 62 percent of the \$4.45 billion of additional revenue raised over a 25-year period will go to transit projects.

Public–private partnerships (P3s) can also help you attract multiple participants and reduce the cost of new programs. P3s can help cities undertake sustainable transit projects less expensively than if they relied completely on public-sector resources. A recent example is Toronto's Finch West light rail line, which will be built by a private consortium that won the contract in May 2018. When completed, the line will be operated by the Toronto Transit Commission.

5. Design efforts to match your city archetype. Cities can learn the most from peers with similar history, built environment, and transportation infrastructure usage patterns. Your city will tend to fit one of seven overarching models: Multi-Modal Core, Walking Core, Urban Hub Community, Mixed Hub Community, Suburban Hub Community, Driving Metropolis, or Efficient Metropolis (*see Which archetype fits your city?, next page*).

Which archetype fits your city?

Every city's transportation needs are unique, shaped by its layout and past infrastructure investments. Most cities can be grouped into one of seven archetypes, falling into three broad categories (*see Exhibit 3, next page*). These archetypes explain the flow of people and goods between the urban centers of activity where people work and congregate (downtowns) and the outlying areas where many people live (suburbs). Each of the seven models represents a different pattern of downtown-to-suburb traffic flow; each model has its own congestion challenges and future parking design implications that reflect its inherent constraints and opportunities. Understanding your city's model can help you identify the solutions that will work best.

To decide which archetype fits your city, look at four key characteristics. The first is the city's layout and infrastructure patterns. For example, how are roads set up between the city and its suburbs? Do its streets form a grid or a circular layout? Are its origins medieval or modern? The second comprises the travel and commute patterns that take place every day, based on the habits of inhabitants and visitors, which in turn are based on where they live, work, and travel for leisure. The third characteristic is maturity of public transit: the overall robustness of train and bus infrastructure, including ease of access, general attractiveness, reliability, convenience, safety, cleanliness, and comfort. The fourth is the relative cost of driving. After considering the cost of tolls, parking, and traffic violations, is it more expensive to drive rather than to take public transit?

Non-grid cities with a compact core

Two of the city archetypes share a compact core, non-grid layout form. Often founded in medieval times, these cities have circular, non-grid layouts and narrow streets, designed for travel by horse and on foot. There are no "compact core" cities in the United States, although some multi-modal cities like Boston and New York have urban centers with non-grid sections.

Exhibit 3 **The seven archetypes of 21st-century cities**

City layout and commuting patterns



In the **Multi-Modal Core** archetype, public transit (primarily rail) is relatively mature, robust, and attractive. High population density, narrow streets, and limited parking increase driving expense. Parking is time-consuming, and driving is inconvenient and costly. Congestion challenges are grounded in the historic layout of the city, which is not conducive to driving. The solutions would include the maintenance of a robust subway or train infrastructure system as travel demand grows and the encouragement of other mobility options, such as bicycles, motor scooters, minibuses, or shuttles. As an example of a core archetype city, we looked at Singapore.

Singapore is a multi-modal core city, with a population of 5.6 million and an average annual time spent in congestion of 10 hours - the smallest congestion time, by far, for all cities profiled in this report. A number of measures contribute to this low number. Singapore was a pioneer of congestion pricing, which started in 1998, and which is fully automatic; prices vary by route, time of day, and travel direction. The initial investment for this was \$110 million; operating costs are \$18.5 million per year, with annual revenues from fees at \$100 million. The city layout is also designed to reduce congestion, with widened sidewalks where bicycles can travel and numerous pedestrian bridges. Single-car ownership is limited to those who hold certificates of entitlement, which are no longer issued, forcing new drivers to bid on existing certificates starting in February 2018. The city also invests heavily in transportation infrastructure, and expects to double the reach of its train network by 2030.

The Walking Core cities are even more inconvenient and costly for automobiles. They have an ancient heritage, with a circular center that often features centuries-old manmade barriers like fortifications or canals and narrow, winding streets seemingly better suited for a horsedrawn cart than a modern automobile. Driving is difficult and expensive, and finding parking is time-consuming. While Multi-Modal Core cities developed a robust public transit system, Walking Core cities have not. For residents of these cities, travel on foot, bicycle, or waterway is the preferred way to get around. Examples include Amsterdam, Florence, and Venice. Given its unfriendliness to motor vehicles and relative lack of good public transportation, the congestion focus here is to regulate the number of motor vehicles, and encourage options such as walking and biking that align with the layout of the city. In addition to options like motorcycles, motor scooters, mini-buses, and shuttles, some Walking Core cities have developed distinctive forms of transit, such as the canal boats in Amsterdam and Venice.

Urban grids with suburban rings

Three city archetypes fit a broader pattern we call Urban and Suburban Communities. They have small, densely populated urban cores surrounded by rings of less dense suburbs. People tend to commute between the suburban rings and the dense core. The urban core grid is formed by rectangular city blocks, with straight streets at right angles. Though ancient grid cities have been found dating back to 2600 BC, most were laid out in the 17th century or later. The first grid city in the While Multi-Modal Core cities developed a robust public transit system, Walking Core cities have not. For residents of these cities, travel on foot, bicycle, or waterway is the preferred way to get around. United States was Philadelphia. The three variations are urban, mixed, and suburban.

Urban Hub Communities have a dense urban center with suburbs surrounding the core. Most people commute to the center for work or leisure. Public transit is relatively mature and robust. The cost of parking is high, since many people drive their own vehicles. The key congestion challenge right now is the high density and volume of forhire vehicles (FHVs), which include taxis and transportation network companies (TNCs). The best solution is streamlining TNC environments. In practice, this will mean clearing up the curb by reducing on-street parking, designing designated drop-off and pickup areas, regulating TNC driving violations, and incentivizing off-hour delivery programs. This means that Urban Hub Communities may reduce overall TNC demand and supply. From a demand perspective, they may focus on enhancing other enablers of mobility such as bike-sharing, car-sharing (Zipcar and Enterprise), new bus routes, special bus lanes, and expanded train systems. From a supply perspective, they may restrict the number of TNC licenses and how many TNC vehicles are permitted in certain areas during peak times. They may also consider a congestion tax. London and New York are urban hub communities with well-known congestion problems.

New York's population is 8.6 million, and annual time spent in congestion per person is 91 hours, up 54 percent since 2010. (According to the 2017 global traffic scorecard published by the transportation analytics firm INRIX, New York is tied with Moscow in second place for this unfortunate measure; only Los Angeles ranks higher.) Congestion costs New York about \$33.7 billion per year, and is worsening because of new corporate arrivals (such as Amazon.com), the growth of travel by taxi and TNC (which logged 19 percent of total miles driven in 2016, an increase of nearly 40 percent since 2013), and the rise of e-commerce. New York has initiated a number of approaches: a one-year freeze on ride-sharing registrations, a surcharge on cab and TNC rides, increases in its Citi Bike (bikesharing) program and Zipcar parking, and increases in parking meter rates. Other potential solutions will be needed, including the use of advanced vehicle connectivity technology and further investment in mass transit.

Mixed Hub Communities have high-activity areas in both urban cores and suburban rings, reflected in their travel and commuting patterns. To accommodate the significant demand for transportation from the outer rings to the center, Mixed Hub Communities generally have some level of public transit. However, these systems are not as robust as is typical for an Urban Hub Community. The cost of parking is moderate, stimulating driving. The key congestion challenge that these cities face is that their transportation networks have failed to keep pace with mobility demand growth as their populations and economies expand. People have plenty of options to move around in the city, but all have capacity constraints. As a result, Mixed Hub Communities have to think about enhancing their entire mobility ecosystem. Among the mixed-hub cities we studied are Chicago, San Francisco, Toronto, and Washington, D.C.

Toronto, with 2.7 million people, is Canada's largest and most congested city. Its time spent in congestion is 47 hours, up 22 percent since 2013. Though the population continues to rise, alternatives to driving remain relatively unpopular. Toronto has developed a reputation as an unsafe city for pedestrians and cyclists, and reliability issues have dogged its transit system. Toronto is investing in improving its train and bus systems and bolstering its bicycling infrastructure. In 2016, the Toronto City Council voted in favor of implementing tolls on the city's Gardiner Expressway and Don Valley Parkway. A hypothetical fare of \$2 per vehicle was estimated to raise about \$200 million to fund transit projects. The provincial government rejected the proposal, instead increasing the gasoline tax revenue that is transferred to municipalities.

Suburban Hub Communities have an urban core, but most people live and work outside of the core in the sprawling suburbs. Public transit is immature. People rely on their own vehicles to get around, and the cost of driving is relatively low. Parking is limited in the urban core, the inflow of vehicles is limited, and tepid demand keeps prices down. Parking needs are relatively high, but space is plentiful and relatively cheap. Prices tend to stay low in these communities as well. The key congestion challenge is that the urban core can't enhance public transit due to a lack of political will, economic strength, or both. Suburbs, with stronger local economies and policymaking wherewithal, lack the incentive to build public transit into the urban core. To control congestion, this type of city focuses on maintaining high-capacity roads and highways.

Large grids with scattered hubs

There are two forms of **Sprawling Metropolises**: those relatively dependent on automobiles, and those with more varied means of transportation available. Both the "driving" and the "efficient" metropolises have relatively low population density and small, scattered hubs of high activity. People mostly travel among hubs — near or far. The origins of such cities are relatively recent, and the overall layout is primarily a grid.

In **Driving Metropolises**, people tend to travel great distances for work and leisure. Driving is the preferred mobility method. Public transportation options are limited, and the cost of parking is relatively low; there is ample parking and an overall low-to-medium population density. The key congestion challenges are city sprawl, with long commuting distances, and lack of transportation alternatives. Thus, as city populations and GDP grow, so do the number of vehicles on the streets. To combat traffic congestion, city governments may build new roads and highways and expand existing ones. This strategy may improve traffic flow in the short term, but often leads to increasing congestion as higher capacity and faster travel speeds induce more people to drive (usually at the expense of an anemic public transit system). Such cities tend to put HOV or HOT lanes in place to increase traffic flow and efficiency. The key solution combines short-term levers to mitigate congestion with long-range investment in public transportation. Doing this will decrease dependence on driving and decrease the number of vehicles on the roads.

Los Angeles has ranked as the world's most congested city every year since 2012. With a population of 4 million, its time spent in congestion is 102 hours, up 67 percent since 2010. Its cost of congestion is \$19.2 billion. This is primarily driven by three factors: considerable urban sprawl, rising rates of car ownership, and a lack of a strong public transportation system. Ridership on the county's bus lines has fallen by about 16 percent since 2012. Rail usage has remained about flat, indicating an increased reliance on cars. Efforts to mitigate congestion include LA Express Park, a demand-based parking program that fuses sensor-based technology with real-time updates to adjust parking rates to meet changing demand. There is also a high-occupancy toll lane program on some expressways, as well as an expanded bike-sharing program.

The **Efficient Metropolises** represent a more effective approach to similar topography. As with Driving Metropolises, people travel among small hubs located on a larger grid, but motor vehicles are not the only mobility method. Even over long distances, people have a multitude of options. The mobility patterns are complex and spread over a larger territory in these cities. Public transportation is mature and robust. The cost of parking is relatively high, and the demand for parking is high. The key congestion challenge faced by this archetype is that as the city population and GDP grow, so does mobility demand. People need to travel longer distances, and the city must maintain strong multi-modal mobility options. As a result, the focus area for the Efficient Metropolis is to maintain leadership in mobility research and have legislation in place to drive transportation innovation. To combat traffic congestion, city governments may build new roads and highways and expand existing ones. This strategy may improve traffic flow in the short term, but often leads to increasing congestion. **Paris** is our example of an Efficient Metropolis — with a serious congestion problem. Its population is 2.2 million, and its time spent in congestion is 69 hours, up 26 percent since 2013. An old city, Paris has parking for only 1 million vehicles, but more than 1.5 million vehicles enter the central business district every day. This results in illegal parking on the city's narrow streets, increasing congestion. The city plans to extend its train and Metro network, and offer incentives for using public transportation, such as waiving fares when pollution levels peak. Paris is trying to pass legislation to ban cars in certain areas, especially around tourist spots, and has responded to air-quality crises by restricting driving for cars with odd and even final license plate digits on alternating days. The city will also spend €150 million (about US\$170 million) to develop new cycling routes, pass policies to lower speed limits for cars to as low as 18 mph, and construct parking spots for bikes. Lastly, it will promote ride-sharing and implement traffic management measures such as ramp metering and dynamic speed limits on highways to reduce congestion and rush-hour travel times.

In looking at these examples, you'll note that they all have several things in common. None of them can treat congestion as a problem that can be solved purely with single-owner automobiles. There have to be attractive (or at least palatable) alternatives to motor vehicles. Second, managing parking and driver access fees provides leverage, especially in the short term, and cities adjust. Third, as suggested earlier, the mix of short-term and long-range remedies, along with attention to both supply and demand, is critical. In the next section, we look at these solutions in more detail. These examples all have several things in common. None of them can treat congestion as a problem that can be solved purely with single-owner automobiles.

Taking an ecosystem approach

Many groups have tried to relieve congestion through simple solutions. But to create accessible, livable cities, policymakers must address congestion holistically. For example, charging a high roadway toll without developing convenient, reliable, safe, and affordable public transportation will hurt a city's livability and economy. The most comprehensive approaches are known as ecosystem solutions, because they consider the interrelationships among all the elements that affect congestion: infrastructure, finance, public transportation, private vehicles, and new forms of transit including ride-sharing, urban design, fees, and regulations. Each participant in the ecosystem plays a key role in distributing the transit load for the movement of goods, services, and people.

City planners face many significant questions, but one is paramount: whether motor vehicles, particularly single-driver passenger cars, will have unfettered dominance over the streets of tomorrow, or whether these streets should be designed to accommodate a broader, more sustainable array of transportation modes. Beyond that, the planners will have to consider how much priority to give each form of transportation, whether to set up dedicated lanes for bicycles or buses, how to accommodate dedicated drop-off and pickup zones for TNCs and delivery companies, and how best to provide parking on streets and elsewhere. There isn't necessarily one right answer, and the outcome should be tailored with a comprehensive city strategy in mind. Without an ecosystem approach, it is not possible to develop this strategy.

Ecosystem approaches convene multiple players to work together, often to tackle solutions they haven't considered in the past. One example is the trend of TNCs entering the motor scooter business as a way to fill the need for cheap, convenient urban transport for short distances. Another is the involvement of multiple industries to provide charging infrastructure for electric vehicles.

An ecosystem approach is not static; it varies by city, and changes with the changing needs of the population. It considers the interdependencies of the city, including infrastructure wear and tear and traffic flow, and it evaluates tradeoffs such as short-term versus long-range investments, cost versus convenience, and consumer choice versus policy-driven solutions. Modeling solutions at a city-planning level is critical. For example, advanced analytics can help determine the impact of ride-hailing and robo-taxis on different neighborhoods, informing decisions on investment and restrictions.

Sidewalk Labs' smart city project in Toronto takes an ecosystem approach to streetscape design. In August 2018, the Alphabet subsidiary proposed a new multi-modal street grid that gives priority to public transit, bicyclists, and pedestrians. The proposed approach, developed with support from Strategy&, involves pickup and drop-off bays, pedestrian bridges, bicycle and motor-scooter lanes, and lanes devoted to trucks with connected vehicle sensors (*see Exhibit 4*). One advantage Sidewalk Labs has is a relatively clean slate; it's planning to remake an industrial area near Lake Ontario, not an already-bustling downtown neighborhood.

The mobility hub

One example of an ecosystem approach involves solving the problem of the "last mile": the distance between the end of the mass transit hub

Exhibit 4 View of a better street design



Note: These are illustrative streetscape concepts, and are not meant to advocate for a particular mode of transit.

Source: PwC

and the final destination. Even in cities with excellent transit networks, buses and trains can't go everywhere. The mobility hub concept addresses this problem by aggregating a variety of solutions where they're most needed. They place bike, motor-scooter, and car-sharing services, along with smart parking and easy rentals, at key transit nodes. These hubs pair well with parking structures that may have spare capacity, and that reduce congestion by moving vehicles off the street.

The concept is being embraced in San Diego by a regional consortium of government bodies called the San Diego Association of Governments (SANDAG). The consortium has identified eight locations for mobility hub prototypes, each with unique demographics and infrastructure. The goal is to offer a number of services within a five-minute walk, bike ride, or drive of the transit center. The prototypes will provide services such as bike-share, car-share, neighborhood electric vehicles, bike parking, dynamic parking management strategies, real-time traveler information, real-time ride-sharing, and micro-transit services, among others. Development of the sites will begin in 2019.

Mobility hubs lend themselves to adaptive technologies and design solutions. These could include shared parking logistics lanes, designated cashless ticket lanes, enhanced wayfinding navigation, and advanced reservations to find parking spaces quickly. Future designs will likely feature retail stores with innovative delivery options, personal facilities for showering and changing clothes after a bike ride, and valet amenity services for dry cleaning and package delivery directly to one's vehicle.

Innovative parking facilities

Although its congestion-fighting potential hasn't always been recognized, parking is important to the smooth functioning of a city's transportation ecosystem. When there isn't the right type or amount of parking, or prices aren't appropriately set, travelers have more incentive to circle, cars clog streets looking for elusive spaces, and delivery trucks, taxis, and TNCs cause chaos at the curb. We've already discussed some parking improvements currently available to cities, but others require more innovation and perhaps more time to develop.

Parking could potentially be used in new and innovative ways to mitigate congestion, mainly at the curb. For example, short-term parking for ride-hailing services and other TNCs could help reduce circling in highly congested areas, and provide convenient pickup points where riders could find their cars. Long-term agreements, optimizing short-term pricing and/or design changes, may be required to enable this solution. During peak hours, cities might require designated areas for ride-hailing vehicles to stop, which could provide congestion relief. Other opportunities would include partnering for large special events like concerts, which are logistical nightmares and significant profit opportunities for TNCs. Parking can be used to increase the efficiency and generate substantially higher profits.

Parking can also serve as a hub for shared vehicle pick-up and return a way for drivers to choose from multiple car models. This would be welcomed by the growing number of consumers who use car-sharing services like Zipcar. Automakers could also participate; some, like Porsche, are already entering the sharing economy through shared leases.

There is also a great potential for synergy with delivery or valet-parking services. Cities without alleys such as New York especially suffer from double parking. In some areas, parking may be designated for use by delivery companies to prevent their vehicles from clogging the street.

Parking facilities may increasingly be used for shared bicycles and motor scooters. Dockless e-mobility solutions can clutter the curb and sidewalks, but the first floor of parking facilities could provide easy yet nonintrusive access.

In the future, automated parking technologies (or mechanical arms) can be used to pack vehicles more tightly, increasing the parking density of current facilities. This could further help in the planning process as less real estate would be needed to create the same amount of parking facilities.

Collaborative pilot projects

As new technologies for managing congestion become available, some cities are initiating comprehensive pilot projects that bring together many separate elements. These are model efforts with the same end goal: to increase livability for citizens while reducing congestion.

One such pilot is Boston 2030: a test of next-generation mobility platforms, including autonomous vehicle deployment, through the Mayor's Office of New Urban Mechanics (MONUM). Two participating companies, Optimus Ride and nuTonomy (both of which were spun out of the Massachusetts Institute of Technology), are piloting robo-taxi services and high-definition mapping in areas of Boston. nuTonomy was approved for on-street testing in December 2016; Optimus Ride was approved in June 2017. Boston is exploring additional partnerships to address the unique layout of the city and to build a broader connected transportation infrastructure.

Parking can also serve as a hub for shared *vehicle pick-up* and return—a way for drivers to choose from multiple car models. This would be welcomed by the growing number of consumers who use carsharing services like Zipcar.

Another pilot is called the City of Tomorrow Challenge. Launched in June 2018, it involves three cities: Grand Rapids, Miami (Dade County), and Pittsburgh. Companies can submit proposals to address mobility issues and receive funding through a combination of public and private resources. Ford, Dell Technologies, AT&T, and Microsoft are among the business sponsors. The program actively seeks citizen input through crowdsourcing forums. Winners of the Challenge awards are provided with funding and required to submit a report to city planners summarizing their findings. Early proposed solutions include Integrated Transportation System (ITS) displays for Miami-Dade's bus system, public-road autonomous delivery vans for last- and middle-mile delivery in Grand Rapids, and expansion of the Port Authority's ConnectCard service by allowing users to add credits to their accounts via the use of smart meters in Pittsburgh.

Conclusion

The trends that exacerbate congestion show no signs of weakening, and most cities have not yet fully articulated the steps they'll need to take to improve. Nonetheless, as we've shown in this report, plenty of tools are available that can help reduce congestion, and numerous forwardthinking cities are implementing them in the U.S. and around the world.

To most effectively combat congestion, government leaders, planners, and other stakeholders should keep in mind a few key points: Technology is no panacea, but can be a powerful tool. Weigh solutions that affect supply and demand in both the near and long term. Parking is an important tool, and has the ability to reduce congestion. Consider the entire transportation ecosystem to drive city livability. Foster innovation through collaboration, pilots, and agile policymaking. The mix of solutions applied will vary across city archetypes.

You can take a proactive approach to congestion by shifting the trajectory of mobility and making cities far more livable, with convenient, clean, and cost-effective mobility solutions. Ill-considered and reactive choices that don't consider the entire transportation ecosystem, including parking, are likely to exacerbate congestion. Public–private collaboration — with a focus on citizen-centered mobility — is an ecosystem-oriented approach that can lead us to a future where we want to live.

Appendix: Levers for reducing congestion

Policymakers have numerous levers to mitigate congestion. The challenge is to put them together in a way that helps your particular city.

To organize this comprehensive list of levers, we used the framework from our first guiding principle (on page 16): supply versus demand, and near-term (i.e., between 2019 and 2024) versus long-term (i.e., investing now for improvements that may not be usable until 2024 or later).

Near-term supply

These measures don't require high levels of capital investment, can be implemented in relatively short order, and can also help route traffic in more effective ways.

- **Reduce on-street spaces:** Repurpose them for ride-hail pickups, delivery spaces, or dedicated bus or bike lanes.
- Establish more dedicated bus lanes: These have helped some cities achieve reductions in congestion and commute times. Alas, this has not been the case everywhere. In the U.S., the data is generally inconclusive.
- Improve bicycle routing: Residents are more likely to use bikes if lanes are available throughout the city and protected from car traffic — often by separating them from city streets. Allow bicycles on sidewalks in some areas.
- **Create bicycle parking:** Secure places for commuter bike parking can attract cyclists who cannot bring their bikes to work.

Near-term demand

These solutions are relatively easy to implement, are mainly policy driven, and can have an immediate impact by providing incentives to switch to less congested modes of travel.

- Manage transportation demand: Partner with businesses to promote alternatives to passenger-car commuting. Set targets for employers by transportation mode; implement incentives for alternative commutes; use flextime and work-at-home programs to reduce travel demand.
- **Regulate taxis and TNCs:** As New York has done, reduce the supply of for-hire vehicles by limiting licenses or capping the number of pickups in particular areas. Implement fines for low utilization, which could reduce deadhead miles. Restrict curbside drop-offs and pickups or designate specific staging areas. Consider the downside of higher prices and longer wait times before implementing these restrictions.
- **Tighten restrictions on double parking:** Reconsider arrangements that permit delivery vehicles to stop in the street away from the curb. Enforce double-parking laws more strictly and increase fines for violations. Establish more designated stopping areas for deliveries.
- **Reduce parking minimums:** Reconsider regulations that require real estate developers to include minimum levels of off-street parking. Instead, allow the market to set the right number of stalls. This will reduce excess supply and promote more affordable real estate.
- Use market pricing to improve on-street parking: Increase parking-space prices, thus encouraging spaces to turn over more frequently during peak periods. Remove discounted spaces, so drivers will no longer circle blocks looking for them. Reinvest the revenue in the transportation system.
- Install smart parking technologies: Sensors in parking lots can monitor parking-stall availability, making it easier for drivers to locate open stalls and reducing circling. Frictionless technologies for street and parking-lot payment can allow drivers to pay with their phones, raising compliance rates and making enforcement easier. Web- and app-based technologies, including better coordination with navigation apps, can help disseminate information about parking availability and prices.

• **Rethink taxes, tolls, and congestion pricing:** These economic incentives are well understood and can target specific, highly congested areas or roadways to affect the demand for transport.

Long-term supply

Many of these solutions could be considered today, but due to the long investment horizon (i.e., infrastructure), the results will not be felt for years. Other solutions are based on unproven and experimental technologies, and maturation should be monitored over the next few years.

- **Improve public transit infrastructure:** Public transit has the potential to increase ridership and reduce the number of private vehicles on the roads. Design for ease of access, making it less difficult to get into and out of city hub areas quickly and conveniently. Promote general attractiveness, reliability, convenience, safety, cleanliness, and comfort.
- Maintain road and highway capacity: Monitor the amount of traffic on roadways and bridges, and plan in advance for necessary flow-through increases. Do this with care: Increased capacity may decrease commute times in the short term, but may induce greater demand in the long term.
- **Deploy smart lanes, motorways, and analytics:** Implement "smart motorway" concepts, which use sensor-based technologies to respond to traffic conditions. These include variable speed limits, dynamic opening and closing of highway shoulders, optimization of traffic lights (using machine-learning algorithms), reverse-flow throughput lanes that switch direction when commutes change, and advanced navigation technologies that reroute traffic to optimize travel times.
- Prepare for platooning technologies: Improvements in autonomous driving technology and vehicle-to-vehicle communication could soon allow tractor-trailers to safely drive much closer together at highway speeds. It won't reduce the number of the vehicles on the road, but it could improve their use of the infrastructure. With platooning, the gap between two trucks can be reduced from ~1.4 seconds (for manually controlled trucks) to ~0.4 seconds, which could increase road capacity by more than 30 percent.
- **Consider Hyperloop:** A successful implementation of this rapid tunnel-travel technology would theoretically reduce travel times by 50–90 percent, according to the results of some feasibility studies

and simulations. However, there are still significant technological and commercial hurdles to clear before any Hyperloop project becomes operational.

Long-term demand

Innovations in managing demand could help reduce congestion. They typically involve major shifts in traffic patterns or improvements in technology on the horizon.

- **Design for delivery drones:** Some companies, notably Amazon, are investing in drones to solve the challenges of "last mile" delivery to the home. Recently, the company has been granted a U.S. patent for a delivery drone that can respond to human gestures. When this technology is ready, local communities will need to be prepared with the right regulations and infrastructure support.
- **Provide off-peak delivery incentives:** To reduce congestion caused by double-parked delivery trucks during periods of high road traffic, consider mandating that deliveries occur during off-peak times. Pilot programs in certain cities, including New York, have shown early signs of success, but they can create other challenges (receiving staff at commercial buildings may not normally work at night, for example).
- **Rethink last-mile routing:** In <u>"The Rise of the Last-Mile Exchange,"</u> Strategy& authors Tim Laseter, Andrew Tipping, and Fred Duiven propose a new business model for delivery companies: platform systems where they share pickups and drop-offs, thus reducing congestion and costs.
- **Build out the inner ring:** In the U.S., 85 percent of the 150 million people who commute every day nationwide use a motor vehicle to enter a dense inner city. Much of this congestion could be avoided by converting the "long trip" all the way in to a "short trip," where residents park at the edge of the inner ring and use other modes of transportation to get around the city.

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