An Ecosystem Approach to Reducing Congestion

Prepared by PwC Strategy&

October 2018
# Table of contents

**Executive Summary** .................................................................................................................. 6

**Introduction and Methodology: Growth of the U.S. Transportation System** .......................... 9

**Six Megatrends Fueling Congestion** ....................................................................................... 13

1. Economic Expansion .................................................................................................................. 14
2. Demographic Changes and Urbanization .................................................................................. 15
3. Transportation Disruption: TNC and Ride-hailing ................................................................. 16
4. E-commerce and Other On-Demand Delivery Services ......................................................... 19
5. Underinvestment in Infrastructure .......................................................................................... 20
6. Mixed Effectiveness of Policies and Programs ....................................................................... 21

**A Fully Autonomous Future Does Not Guarantee Relief** ....................................................... 23

Factors Impacting the Future of Autonomous Vehicles ................................................................. 23
Multimodal Transport: A Less Congested AV Future ................................................................. 24
Infrastructure Decay and Gridlock: An Uncertain Alternative .................................................. 24
L5 Autonomy: 2030 and Beyond .................................................................................................. 25
Implications for Decisions Impacting Infrastructure and Parking Today .................................... 26

**Policy Has the Potential to Create Livable Cities of the Future** ............................................. 28

1. Consider near- and long-term supply and demand levers ....................................................... 29
2. Ecosystem Approach: Cities of the Future as an Interdependent System ............................... 32
   Example: Re-envision the inner and outer rings for short and long trips ............................... 33
   Example: Mobility Hub – Park Once Approach ........................................................................ 33
   Example: Citizen-Centered Ecosystem ..................................................................................... 34
   Example: Opportunities for Parking Solutions within the Ecosystem .................................. 35
3. Foster Innovation through Collaboration, Pilots and Agile Policymaking ............................... 36
4. Develop a Financing Plan ........................................................................................................ 38
5. City Archetypes Will Drive the Mix of Congestion Solutions ............................................... 39
   Compact core and non-grid layout ............................................................................................ 40
   Urban and suburban communities ............................................................................................ 40
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Executive Summary

At the conclusion of World War II, the U.S. began a period of substantial economic and population growth—increasing from 151 million people in 1950 to 326 million people in 2018. The suburbs were created, urban sprawl increased, and U.S. car culture was born. Over time, these trends accelerated, car ownership increased, and the interstate was created. A whole new way of living emerged—but one significant downside was congestion.

Since this time, household car ownership has increased, exceeding the rate of population growth. Eighty-five percent of commuters still drive or carpool to work, a trend that has remained consistent for the last forty years. With the U.S. population projected to hit 390 million by 2050, the implications of continued growth for congestion are more urgent than ever.

Today, the cost of congestion in the U.S. is $230-$300 billion each year. This includes direct costs such as lost time and indirect costs such as increased cost of goods and services. Congestion costs about four times the amount the country spends on public transit and double its spending on roads and highways.

In 2017, the average person spent 41 hours in congestion, an increase of 8% over 2010. In 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 is likely to worsen in the short to mid-term, fueled by six main drivers.

1. **Macroeconomic conditions.** Vehicle miles traveled (VMT) are directly correlated to economic growth. VMT is expected to grow by 14% from 2017 to 2030, driven by an expected growth in gross domestic product (GDP).

2. **Urbanization.** The U.S. population is growing and shifting from rural to urban areas. Eighty-one percent of the population lived in urban areas in 2010, and that is expected to rise to 85% in 2030.

3. **Transportation network company (TNC) growth.** Ride-hailing has grown substantially and is inducing demand for transportation, shifting demand from public transit which is putting more cars on the street and contributing to congestion at the curb.

4. **E-commerce growth.** Deliveries are increasing, and they’re not reducing private-vehicle use (such as driving to shopping malls) as much as was once expected. E-commerce is on a rapid growth trajectory, rising from 0.3% of retail spending in 1998 to 8.7% in 2014.

5. **Infrastructure underinvestment.** U.S. public infrastructure was awarded a grade of D+ by the American Society of Civil Engineers (ASCE) and requires significant investment to be on par with that of other developed nations. The federal gasoline tax, which funds a great deal of transportation infrastructure expenditures, has not been raised since 1993.

6. **Policy and program development.** Current policies and programs have had mixed success in reducing congestion, with many leading to unintended consequences that can actually increase congestion.

In the longer term, fully autonomous vehicles (those categorized as attaining “Level 5” autonomy in the Society of Automotive Engineers’ classification system) will be radically disruptive, but may not provide congestion relief. In fact, congestion may worsen due to induced demand from lower transportation costs and a decrease in public transportation ridership. In any case, Level 5 autonomous vehicles are unlikely to arrive en masse before 2030.

Policymakers have a wide range of near- and long-term demand and supply levers to mitigate congestion. These can take the form of policy changes, infrastructure investment, new technologies and economic incentives and disincentives. Specifically, tools available to cities include bus lanes, bike lanes, scooter programs, public transit, new roads and highways, parking policies and pricing, TNC restrictions, transportation demand management programs,
smart city technologies, platooning, delivery drones, and Hyperloop. None of these levers can fix congestion on its own, and pulling too hard on one may exacerbate other issues. And this list is far from exhaustive. One solution that hasn’t received adequate attention is parking.

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, or its prices aren’t appropriately set on the street, travelers have more incentive to circle, cars clog streets looking for elusive spaces, and delivery trucks, taxis, and TNC vehicles cause chaos at the curb. Parking can be an effective tool to declutter roads and reduce curb congestion. Here are a few examples of parking-related levers cities can use to reduce congestion:

- **Repurpose or reprice on-street parking.** The space could be reused to add an additional traffic lane or create a drop-off point for TNCs or delivery companies, which should reduce circling.
- **Reduce or eliminate parking minimums.** Allow market demand to determine the appropriate supply of parking. This will reduce the cost of development and result in a better balance of parking supply and expected demand for the specific real estate application.
- **Explore new smart parking technologies.** These can make payments easier, improve navigation, and make prices more transparent, all of which may reduce congestion and emissions.
- **Reconsider or reprice double parking fines.** Reconsider any arrangements made with delivery services providers and others that allow them to reduce or avoid fines for certain parking violations. Enforce current regulations.
- **Leveraging parking as a “curb extension” or mobility hub.** Parking could potentially be used in new innovative ways to mitigate congestion, mainly at the curb. A few ways that parking can be leveraged as a “curb extension” include serving as short term parking for TNCs, dynamic taxi or ride-hail stands, drop-off or pick-up points for packages, or mobility hubs for shared bikes, scooters, and vehicles.

Congestion is complex and policymakers face many challenges related to congestion. We propose five guiding principles when making congestion related choices:

1. **Consider near- and long-term supply and demand levers.** A combination of supply and demand, as well as near- and long-term policies are required to drive sustainable change. Near-term solutions are quicker and cheaper to implement, meanwhile infrastructure investments, like bus, rapid transit, and lane expansion require investment over a long period of time.

2. **Take an ecosystem view to drive city livability.** Livability is an important consideration for cities that prize innovation and hope to compete globally for talent and investment. A holistic view is required to solve the complex challenge of congestion; no single tool can fix the problem alone. This requires developing city plans that integrate multiple levers (e.g., public transit, private vehicles, parking) and consider the tradeoffs associated with each action.

3. **Foster innovation through collaboration, pilots, and agile policy making.** Innovation in the transportation space is evolving at a rapid pace. The effects of new technologies and new transit are unproven and often unknown. The development of these new technologies often requires cities to experiment through pilots. This allows both parties to learn and potentially benefit without jumping in headfirst. Public-private partnerships (P3s) can be a valuable tool for cities.

4. **Develop a financing plan.** As demonstrated above, there is no shortage of options to combat congestion at cities’ disposal. But many of them are potentially quite expensive, especially those that involve construction of new roads or bridges or expansion of public transit networks. A sound strategy to pay for such investments is critical to executing successful programs.

5. **Learn from other cities of similar archetype.** Cities will learn the most from peers with similar history, built environment, and transportation infrastructure usage patterns. We provide a framework to categorize global cities into seven different models (Multimodal Core, Walking Core, Urban Hub Community, Mixed Hub Community, Suburban Hub Community, Driving Metropolis, and Efficient Metropolis) and examine case studies of exemplars of several different types, including New York, Chicago, Los Angeles, San Francisco, and Washington in the U.S. and Toronto, London, Singapore, and Paris internationally.
Congestion in the U.S. is all but certain to get worse before it gets better. The goal of this report is to provide analytical insights on the data, trends, innovations, and case studies available to inform public and private plans to reduce congestion.

Policymakers have an opportunity to take a proactive approach to affect the trajectory of mobility and create livable cities with convenient, clean, and cost-effective mobility solutions. But ill-considered and reactive choices that don’t consider the entire transportation ecosystem—including parking—are more likely to exacerbate congestion. The concept of parking as a mobility hub, where commuters park once and use multiple forms of transportation within the city, could be an efficient approach to effectively move people in and around cities.

The future is not yet written and is full of growth and change—the unknown effect AVs will have on the transportation landscape is just one example of this. Congestion, though, will continue to accompany this growth. And the challenge of mitigating congestion can often seem insurmountable. Yet collaboration that reflects consumer preference, fosters economic activity, employment and supports infrastructure optimization presents significant opportunities for smart cities of the future that act as dynamic and interdependent ecosystems.

Cities rely on employment, tourism, and corporate investment to fuel livability and economic vibrancy. Congested lanes and hard-to-find parking create a disincentive for employees and tourists to enter a city, also known as trip avoidance. It is a shared goal among the public and private sector to support smart growth with infrastructure that supports vibrant communities.

Mobility that is multimodal recognizes the role of both long trips into a city and short trips within it. New approaches to managing the curb, mobility demand and transportation infrastructure will all play a role in livable cities. Hospitals, universities, corporate campuses and event venues are all microcosms of transportation systems that are exploring multimodal transportation options for mobility as a service.

By adopting sensible policies, employing technology wisely, and investing prudently in infrastructure, cities around the world have made and can continue to make progress in reducing congestion and improving livability.
Introduction and Methodology: Growth of the U.S. Transportation System

At the conclusion of World War II, the U.S. began a period of rapid economic expansion. The rise of the middle class, a booming economy and the pursuit of the new American dream—a good job, a new house and a car in every driveway—helped to solidify the U.S. as a global superpower.

This coincided with a period of significant population growth. In 1950, the U.S. population stood at 151 million. Thanks to the baby boom, it had reached 186 million by 1960. Cities were bursting at the seams and people looked outward for space. Thus began what came to be known as urban sprawl, as people moved from city centers to newly developed suburbs.

As sprawl accelerated in the 1950s, car culture was born. At first, this was a matter of necessity, as growing suburban communities had little to no access to mass transit. Vehicle ownership accelerated, with many families owning more than one car, and the Interstate Highway System was created. A whole new way of living emerged.

The downside of this major transformation is congestion. Cars continue to be a central thread in the fabric of American life, and the number of vehicles on the road has increased from 68 million in 1958 to 270 million today. In 2017, the average person spent 41 hours in congestion, an increase of 8% over 2010. In 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.

The cost of congestion isn’t trivial and goes far beyond the frustration of sitting in a traffic jam. Congestion costs the U.S. between $230-$300 billion each year, about four times the amount it spends on public transit and double the spending on roads and highways. About 75 percent of that impact takes the form of direct costs like excess fuel consumption and the harm to people’s health from air pollution. Lost time is also in this category, and it may be the cost Americans feel most acutely. Indirect costs, passed on to consumers in the form of higher prices, make up the remaining quarter of the economic impact of congestion.

The 21st century has provided both reasons for hope and additional hurdles to overcome. The flight to the suburbs that characterized the post-World War II era is reversing, and people are moving back into cities. While this has revitalized once neglected urban cores, it has also overtaxed dilapidated infrastructure and made congestion even worse. This is being further exacerbated by new mobility business models—including transportation network companies (TNCs), car sharing and on-demand shipping of e-commerce purchases through services such as Amazon Prime—which are putting more cars and trucks on the road.

The problem with congestion is only expected to worsen in the medium term, fueled by six main drivers:

1. **Macroeconomic conditions.** Vehicle miles traveled (VMT) is directly correlated to economic growth. VMT is expected to grow by 14% from 2017 to 2030 driven by an expected growth in GDP.

2. **Population and urbanization.** The U.S. population is growing and shifting from rural to urban areas. Eighty-one percent of the population lived in urban areas in 2010, and that is expected to rise to 85% in 2030.

3. **TNC growth.** Ride-hailing has grown substantially and is inducing demand for transportation, shifting demand from public transit which is putting more cars on the street and contributing to congestion at the curb.

4. **E-commerce growth.** Deliveries are increasing, and they’re not reducing private-vehicle use (such as driving to shopping malls) as much as was once expected. E-commerce is on a rapid growth trajectory, rising from 0.3% of retail spending in 1998 to 8.7% in 2014.
5. **Infrastructure underinvestment.** U.S. public infrastructure was awarded a grade of D+ by the American Society of Civil Engineers (ASCE) and requires significant investment to be on par with that of other developed nations. The federal gasoline tax, which funds a great deal of transportation infrastructure expenditures, has not been raised since 1993.

6. **Policy and program development.** Current policies and programs have had mixed success in reducing congestion, with many leading to unintended consequences that can actually increase congestion.

While the advent of autonomous vehicles (AVs) will dramatically change the world, its impact on congestion has yet to be determined. A world of shared, electric, and autonomous vehicles could lead us into a multimodal future where congestion is eliminated and emissions are reduced. However, if consumers are unwilling to share (and the data suggests this the case) the future could be bleak. In fact, congestion could worsen as AVs drive an increase in VMT and struggle to interact with human drivers. Regardless, we do not foresee mass adoption of fully autonomous vehicles anytime soon—likely after 2030.

While mass adoption of fully autonomous vehicles is still a long way off, planning and investment is needed now to integrate them into urban transportation ecosystems. Mid- to long-term implications of AVs for parking will require considerable design changes and repurposing of facilities and locations—but not for a while.

In the near to middle term, policymakers are faced with mitigating the complex issue of congestion. They are tasked with integrating new modes of transport (e.g., e-bikes, scooters, robo-taxis) into the ecosystem and containing congestion at the curb due to ride hailing and package deliveries, all while under budgetary limitations.

Additionally, the sheer number of levers that policymakers have at their disposal can be overwhelming. They include bus lanes, bike lanes, scooter programs, public transit, new roads and highways, parking policies and pricing, TNC restrictions, transportation demand management programs, smart city technologies, platooning, delivery drones, and Hyperloop. And that list is far from exhaustive.

Given the complex environment, we propose five guiding principles for developing congestion solutions:

1. **Consider near- and long-term supply and demand levers.** A combination of policies addressing both supply and demand and with both near- and long-term effect is required to drive sustainable change. Near-term solutions, such as altering regulations, are often quicker and cheaper to implement. Meanwhile, infrastructure investments like bus rapid transit require significant investment over a long period of time.

   Parking has not historically been thought of as a solution to congestion, but it has great potential in this regard. Changing or removing off-street parking regulations and repurposing (or repricing) on-street parking are examples of actions that could impact congestion.

2. **Take an ecosystem view to drive city livability.** Livability is an important consideration for cities that prize innovation and hope to compete globally for talent and investment. A holistic view is required to solve the complex challenge of congestion while promoting livability, with no single lever able to solve the issue independently. This requires developing city plans that integrate multiple levers (e.g., public transit, private vehicles, parking) and consider the tradeoffs associated with each action. A few examples of taking an ecosystem view:

   - **Re-envisioning the inner and outer city rings.** Because a clear majority of commuters drive into the city for work, planners must start to view the inner and outer rings of a city in terms of short and long trips. Commuters travel from the outer ring in a suburban environment to an urban inner ring of a city (long trip). Once inside, workers, tourists, and residents can park and then access multiple modes of transportation to get around the city (short trip).

   - **Creation of mobility hubs with parking being repurposed.** Public transit is a key part of any transportation ecosystem, but even in cities with excellent transit networks, buses and trains can’t go everywhere. For that reason, the final leg or “last mile” of travelers’ journeys can be the most difficult. The mobility hub concept may be able to help address this problem by aggregating a variety of solutions where
they’re most needed. These can include bike-, scooter- and car-sharing services, smart parking, and more, in addition to a transit node. They pair well with parking structures that may have spare capacity.

- **Streetscape reimagined.** Streetscapes must take into account public transit usage (e.g., bus and rail), bicycles, scooters, pedestrian walking areas and parking. Parking could potentially be removed to create additional space for ride-hailing drop-offs or dedicated bus lanes.

- **Parking as an extension of the curb.** Parking could potentially be used in new innovative ways to mitigate congestion, mainly at the curb. A few ways that parking can be “curb extensions” include acting as short-term parking for TNCs, dynamic taxi or ride-hail stands, drop-off or pickup points for packages, or mobility hubs for shared bikes, scooters and vehicles.

3. **Foster innovation through collaboration, pilots and agile policy making.** Innovation in the transportation space is evolving at a rapid pace. The effects of new technologies and new transit are unproven and often unknown. The development of these new technologies often require cities to experiment through pilots. This allows both parties to learn and potentially benefit without jumping in headfirst. A few guiding principles when setting up pilots and partnerships:

   - **Clearly outline your objectives and the potential value.** A clear understanding of the objectives and the value created helps to focus the scope and understand when pilots are benefiting the city.

   - **Define scope while allowing flexibility.** Break down the scope into clearly defined phases with timelines. Given these are pilots, it’s important to understand that part of the goal is learning and this will be a process. All the answers will not be known up front. Revisiting the scope or objectives may be necessary in light of new learnings.

   - **Define success upfront.** Design clear success criteria with measurable outcomes in the beginning. This keeps pilots focused and aligns policymakers and experimenters with the same objectives.

   - **Monitor progress and collect data.** Continuously collect data to monitor progress and understanding the potential value that these new programs can create.

4. **Develop a financing plan.** As demonstrated above, there is no shortage of options to combat congestion at cities’ disposal. But many of them are potentially quite expensive, especially those that involve construction of new roads or bridges or expansion of public transit networks. How to pay for such investments is critical to executing successful programs. There are six guidelines that can aid policymakers in generating support from private and federal investors:

   - **Focus on data** to prove each project's viability.

   - **Prioritize wisely** to optimize capital projects portfolio.

   - **Consider finance options** (e.g., public-private partnerships, federal funding programs).

   - **Explore resources** to ensure adequate staffing, technology, and external support.

   - **Use a capital project excellence framework** to anticipate hurdles and maximize efficiency.

   - **Gather evidence** to demonstrate track record.

5. **The mix of solutions will differ by city archetype.** Cities will learn the most from peers with similar history, built environment, and transportation infrastructure usage patterns. We provide a framework to categorize global cities into seven different models (Multimodal Core, Walking Core, Urban Hub Community, Mixed Hub Community, Suburban Hub Community, Driving Metropolis, and Efficient Metropolis) and examine case studies of exemplars of several different types, including New York, Chicago, Los Angeles, San Francisco, and Washington in the U.S. and Toronto, London, Singapore, and Paris internationally.

The future is not yet written and is full of growth and change—the unknown effect AVs will have on the transportation landscape is just one example of this. Congestion, though, will continue to accompany this growth. And the challenge of mitigating congestion can often seem insurmountable. By adopting sensible policies, employing technology wisely, and
investing prudently in infrastructure, cities around the world have made progress in reducing congestion and improving livability.

This report was produced with the participation of the National Parking Association and its contents have been approved by the NPA and by PwC’s global advisory consulting business, Strategy&. The focus of the study is to understand 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.

This paper leverages publicly available information, as well as primary research, secondary research, and interviews from a wide range of backgrounds (e.g., technologists, parking operators, developers, policy planners, academics, venture capitalists and other investors, the startup community, and infrastructure investors).

This study is organized into four main sections:

1. **Six Megatrends Fueling Congestion.** We discuss the trends that are driving congestion on our roadways today: Economic growth, population shifts, new transportation modes, e-commerce, infrastructure investment, and policy.

2. **An Autonomous Future Does Not Guarantee Congestion Relief.** AVs will have a tremendous impact on the way we travel and on all of society. Many view AVs as one solution for congestion, although an argument exists that in the near-term AVs may increase congestion due to induced demand and challenges co-existing with human drivers. Additionally, we do not anticipate mass adoption of Level 5 AVs across the U.S. until long past 2030.

3. **Policy Has the Potential to Create Livable Cities of the Future.** Policy is critical to increasing livability within the cities. We propose five areas for policymakers to consider when developing policy solutions with the goal of driving livable cities.

4. **Conclusion.** The right mix of approaches, tailored to each city’s needs, can help bring congestion under control.
Six Megatrends Fueling Congestion

Congestion, simply put, is what happens when too many vehicles try to use a road at the same time. More specifically, it’s the breakdown in traffic flow, reduction in speed and increase in crowding that occur when a road’s capacity is exceeded. And, to be sure, capacity is strained on America’s roads.

Since 1980, the country’s overall population has risen by slightly more than 40%, but the urban population has increased by 160%—increasing the concentration of VMT within cities. Today, there are 119 million drive-to-work commuters in single occupancy vehicles (SOV) or high occupancy vehicles (HOV); 85 percent of commutes are by automobile\textsuperscript{22}. As population has grown both drive-to-work commuting and public transportation use have remained largely constant—ensuring that motor vehicles remain the dominant transportation mode.

Although it’s been a seemingly constant feature of life since the American romance with driving began in the 1950s, congestion is more likely to worsen than to improve over the coming years. Six megatrends are driving this assessment:

1. **Macroeconomic conditions.** There is a well-established link between economic growth and how much people drive.

2. **Population and demographic changes.** Population will continue to grow, reaching 355 million by 2030. And, after decades of hollowing out, many cities are growing again. That’s putting additional strain on their roads\textsuperscript{23}.

3. **Transportation disruption.** New business models enabled by the ubiquity of mobile devices, such as navigation, space finding and ride-hailing, are putting more cars on the street.

4. **E-commerce dominance.** Consumers are clamoring for fast, free shipping, and the strategies retailers are adopting to accommodate this desire are exacerbating congestion.

5. **Infrastructure underinvestment.** The woeful state of U.S. transportation infrastructure significantly worsens traffic in cities. The federal gas tax has not increased since 1993 and ASCE gives the U.S. a D+ grade on infrastructure\textsuperscript{24}.

6. **Policy development.** Some of the measures adopted to reduce congestion have had the unintended consequence of making it worse, often because of poor design or faulty implementation.

Contending with these trends and the strain they place on America’s roads will require a dramatic overhaul of the urban landscape.
1. Economic Expansion

Economists have long understood that there’s a strong correlation between the economy’s performance and how much people drive. Changes in gross domestic product (GDP) are highly correlated to the change in vehicle miles traveled per year, modified by gasoline prices. Given expectations for GDP growth and 2017’s average gas price of $2.42, we expect a 1% compound annual growth rate (CAGR) for VMT through 2030—a 14% total gain in VMT over that period, translating to a 500 billion mile increase.25


2. Demographic Changes and Urbanization

Not only is VMT increasing, but population is shifting from rural to urban areas and has been for a while. While about 26% of the U.S. population lived in rural areas in 1980, just 19% did in 2015, according to United Nations data.26 This trend shows little prospect of reversing. From 2010 to 2030, the U.S. population is expected to increase from 309 million to 355 million, a 15% increase. At the same time, the share of population in rural areas is expected to fall from 17% to 15%.

Furthermore, the share of people driving has remained steady for nearly 40 years in a range of 84-88%. Of the people that commute to work, 85% drive in SOVs or HOVs, a trend that has not changed since the 1990s.27
3. Transportation Disruption: TNC and Ride-hailing

TNC and ride-hailing companies have experienced explosive growth and completed about 2.6 billion trips in 2017, versus nearly zero in 2012. U.S. TNC VMT per month grew from 30 million in December 2013 to 500 million in December 2016, a CAGR of 150%.28

Ride-hailing services have become a valuable part of the current transportation ecosystem. Their cost and convenience contribute to the many benefits that consumers experience today.

Nonetheless, TNCs remain a small part of the overall transportation picture in the U.S. While nearly 10% of all Americans use TNCs in any given month, their rides only account for 0.5% of total trips taken. Indeed, the majority of passenger miles traveled (PMT) within the U.S. occur in private vehicles, primarily due to the economics. Utilizing TNCs for long distance trips is very expensive.

A six-mile round trip using a private vehicle would cost about $5 per mile in New York and $4 per mile in Chicago. The consumer could save close to 50% by using TNCs.30

A 40-mile round trip using a private vehicle would cost about $1 per mile in New York City and Chicago. The same trip would cost twice as much using TNC’s.

However, the economics in dense urban areas are quite different, mainly driven by the cost of parking. The length of the trip is a major factor:

- A six-mile round trip using a private vehicle would cost about $5 per mile in New York and $4 per mile in Chicago. The consumer could save close to 50% by using TNCs.
- A 40-mile round trip using a private vehicle would cost about $1 per mile in New York City and Chicago. The same trip would cost twice as much using TNC’s.
In the U.S., 70% of TNC trips are concentrated in nine large, densely populated cities: Boston, Chicago, Los Angeles, Miami, New York, Philadelphia, San Francisco, Seattle, and Washington. The impact of TNCs on congestion within these cities can therefore be quite large. According to a study of Manhattan’s central business district (CBD) by Schaller Consulting, traffic speeds declined by 15% overall and 18% during the day due to TNCs from 2013 to 2017. Average speeds decreased from 8.2 mph to 6.8 mph.

Though TNCs add value to consumers, in the short-term they cause congestion within cities in four ways:

1. **Increasing overall travel demand.** A regional survey conducted in the Denver metropolitan area found that about 12% of trips would not have been taken if ride hailing wasn’t an option. According to the Schaller Consulting study, the overall passenger trips within Manhattan’s CBD from 2013 to 2017 increased by a CAGR of 4.6%, driven by an 8% decrease for taxis and a 190% increase for TNCs. TNCs put 2.8 new vehicle miles on the road for each mile of personal driving eliminated, for an overall 180% increase on driving in city streets.

2. **Taking rides from public transit.** Other studies revealed in the absence of TNCs, about 25% of the users would have traveled using public transit. While the decline in transit may not all be attributable to TNCs, it is having a direct impact. This lines up the recent drop in public transportation with the growth of TNCs.

3. **Promoting non-productive VMTs and circling.** Various survey results indicate that deadhead miles, or miles without a passenger, account for anywhere from 20% to 50% of the total miles traveled by TNCs. Other research shows that deadhead miles for TNCs and taxis increased by 81% from 2013 to 2017 in New York’s CBD, implying an oversupply of vehicles. These deadhead miles contribute substantially to congestion, especially in highly dense areas.

4. **Traffic violations and obstructions.** About two-thirds to three-quarters of all traffic violations in San Francisco between April and June 2017 were committed by TNCs. Examples of violations include improper use
of or blocking bus only and bicycle lanes, performing illegal U-turns to pick up and drop off riders and double parking on curbsides.

While TNCs are contributing to congestion today, they are looking to incorporate many forward looking technologies (e.g., autonomous vehicles, flying cars) and are expanding current service offerings (e.g., pooling alternatives, e-bikes, scooters, robo-taxis) into the ecosystem that could potentially help congestion.

Ultimately, autonomous vehicles (AVs) will change TNC economics substantially and accelerate adoption. But, ubiquitous self-driving taxis are still many years away. In the interim, congestion is expected to continue to get worse unless effective steps are taken to mitigate the impact.
4. E-commerce and Other On-Demand Delivery Services

Much like TNCs are changing the way people travel, online retailers have leveraged technology to reshape consumer behavior when shopping. This change has occurred quickly—e-commerce grew from just 0.3% of U.S. retail spending in 1998 to 8.7% in 2014. And, it shows no sign of slowing down, with estimates suggesting that share could rise by as much as 1.2% a year through 2030.

Nothing has done more to change consumer expectations than the advent of fast and free shipping. Amazon, with its Prime membership that promises free delivery within two days, can take much of the credit for this shift. But with the 2014 launch of its Prime Now service, the company is pushing even further, promising near-instant gratification for online shoppers with one-hour delivery in select markets. The race to offer ever-faster shipping of online purchases has given rise to numerous on-demand delivery services enabled by TNCs’ ride-hailing platforms.

Now that Amazon has reset consumer expectations around delivery speed, both brick-and-mortar and exclusively online retailers are finding they need a comparable offering to remain competitive. Of course, it isn’t enough to merely provide the service; they must do so at a reasonable cost. As a result, retailers have an incentive to scale up their e-commerce and delivery platforms in order to drive down shipping costs, thereby further accelerating adoption.

Taken together, online shopping, ride-hailing and meal and grocery delivery accounted for about 80% of the $67.6 billion of “on-demand” spending in the U.S. in 2016.

It once seemed likely that on-demand delivery would prompt consumers to reduce trips to shopping malls and stores. But the expected drop in VMT never materialized due to three operational considerations:

- **Single-package delivery.** Both free shipping and on-demand delivery have driven an increase in single-package deliveries that have inflated the total number of trips made by delivery companies. Some app-based on-demand delivery services often use passenger vehicles instead of delivery vans making multiple stops, further increasing the number of trips.

- **Failed first delivery.** It is estimated that failed first deliveries range somewhere between 10 and 30%, driving repeat visits.

- **Increases in returns from online sales.** At least 30% of e-commerce orders end up being returned, compared with about 9% of traditional sales. These translate into an increased number of trips by the delivery vans to pick up the item being returned and to deliver its replacement.

 Additionally, delivery companies contribute to congestion at the curb through double parking and illegal turns. In fact, some city policies do not discourage this behavior. 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.
5. Underinvestment in Infrastructure

Transportation infrastructure is vital for the growth of the economy as it facilitates the efficient movement of goods and people within and between cities and countries. Given their vital role, roads, bridges and tunnels must be well-maintained and expanded at a pace that is in sync with overall mobility demand growth.

Unfortunately, that isn’t what’s happening in the U.S, which underinvests in its public infrastructure compared with many of its peers among the world’s advanced economies. While no single metric perfectly captures this gap, the country’s spending on public infrastructure, equivalent to 0.6% of GDP on average from 2010 to 2016, ranked 34th globally behind Switzerland (1.4%), Japan (1.1%), Norway (1.1%), and France (1%), among others37.

Much public infrastructure is federally funded through the gasoline tax, which is not indexed to inflation and has been little changed at 18.4 cents per gallon since 1993. For context, the annualized rate of inflation from 1993 to 2017 was 2.2%, translating to a total rise in prices of 73%38. This is helpful in understanding the extent to which funds available for infrastructure investment have fallen short of what’s needed.

![5-year Average Inland Transport Infrastructure Investment as a % of GDP (2010-2014)](https://data.oecd.org/transport/infrastructure-investment.htm)


The U.S.’s public infrastructure was graded at a D+ by ASCE in 201739. A primary reason for this was the large backlog of unmet capital investment needs for highways and bridges, identified at approximately $836 billion by a U.S. Department of Transportation report.

But even though these kinds of projects aren’t getting all the money they need, they’re still receiving the majority of investment. About 80% of public investment in new transportation systems is focused on highway and street projects, leaving relatively little for public transit40.

That is a significant challenge for U.S. cities. Annual spending on public transit 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 projects41.

According to the Federal Transit Administration, more than 40% of buses and 25% of rail transit assets are in marginal or poor condition. Nearly 25% bridges are structurally deficient or functionally obsolete and 33% of roads are in poor or mediocre conditions.

In many instances, budgetary restrictions exacerbate this problem through inefficient use of allocated funds, often forcing cities to “patch and maintain” rather than rebuild. This leads to wasteful spending, inefficiencies and short-term planning.
6. Mixed Effectiveness of Polices and Programs

Many cities have readily embraced emerging mobility solutions, launching pilot programs to accelerate adoption of dockless bicycles and scooters and authorizing AV testing programs. But the more traditional policies and programs they’ve turned to as they seek to ease congestion have had mixed effectiveness.

To better understand this dynamic, it’s informative to look at how decisions to dedicate part of a road or highway to transit, via high-occupancy vehicle (HOV) and bus-only lanes, have worked in cities implementing them.

In theory, these capital-intensive initiatives should curb congestion by discouraging the use of private vehicles for commuting. However, challenges with enforcement and other operational issues result in worse congestion on the general-purpose lanes by increasing induced demand and decreasing the road capacity for private vehicles.

The problem is that because vehicles in these special lanes initially move faster than in general-purpose lanes, more people want to use them. That’s easy to understand. But, counterintuitively, these special lanes’ success also provides an incentive for a portion of public transit riders to drive their cars instead—since the general-purpose lanes are less crowded. The end result is often that congestion in both special and general-purpose lanes increases, creating a lose-lose situation for commuters.

Another issue affecting the operation of HOV lanes without tolls is the illegal use of these lanes by solo drivers. As per a 2016 study in California, unauthorized drivers using HOV lanes accounted for about 24% of the total drivers during peak hours, and 19% in off-peak times\(^42\).

The objective of bus-only lanes is similar to that of HOV lanes—to shift transport demand to more sustainable modes that reduce congestion—and the evidence is likewise mixed as to their success. In some instances, non-holistic implementation of bus lanes may lead to increased congestion for three main reasons:

- **Bus lanes are often clogged with other motorists.** A lack of strict enforcement by police has led to congested lanes and slower speeds. Cameras installed to monitor unauthorized use of New York’s bus-only lanes detected 133,000 violations in 2017; the same year the city’s police department wrote a mere 2,020 summonses\(^43\). Along with traffic signals and passenger boarding, other traffic in the bus lane reduces the average speed of public buses to nearly 40% less than that of the private vehicles running on the same street\(^44\).

- **Bus lanes reduce capacity of already congested streets.** Because many dedicated lanes are already in highly congested streets, they can reduce overall capacity if buses are underutilized.

- **Ridership is falling for many bus services across the U.S.** An increasing number of commuters are opting for private vehicles, ride-hailing services or other travel modes due to the relative cost and convenience. According to a U.S. Department of Transportation report, bus ridership has declined at a compound annual rate of about 1% from 2007 to 2016.

Cities’ policies around parking can also contribute to congestion. Many Americans feel they are entitled to cheap or free parking and don’t realize that it does in fact have a cost. Parking policies are creating an oversupply of parking, thus depressing prices and driving up the demand for driving.

- **Parking requirements produce an oversupply of parking.** In the 1930s, regulators started requiring parking in building ordinances. This has produced an overabundance of parking and often causes builders to
overbuild. Without restrictions, builders would build the right amount of parking to optimize access to their business.

- **Subsidized parking induces demand for vehicles.** These subsidies are bundled into the prices of real estate and other goods and services, and hence favor driving over other modes of transport. People pay the cost whether they drive or take another mode.

Further, subsidized on-street parking also subsidizes circling. Some studies have cited up to 30% of vehicles in a particular area were looking for a parking space to open up, creating more traffic. While there is reason to believe that estimate is too high, this behavior remains a problem. Not charging, or charging very little, for on-street parking increases demand for it and contributes to congestion.
A Fully Autonomous Future Does Not Guarantee Relief

Autonomous vehicle technology can be classified into six discrete levels based on the degree of driver involvement:

- **Level 0: No automation.** The driver maintains control of all driving functions at all times.
- **Level 1: Driver assistance.** Steering or accelerating/braking are handled by the vehicle in certain driving modes, but dynamic driving tasks are performed by the driver. (Example: adaptive cruise control.)
- **Level 2: Partial automation.** Steering and accelerating/braking are handled by the vehicle in certain driving modes, but dynamic driving tasks are performed by the driver. (Example: adaptive cruise control with lane keeping assistance.)
- **Level 3: Conditional automation.** The vehicle handles all aspects of driving, including dynamic driving tasks, but with the expectation that a human driver will respond to a request to intervene. (Example: Adaptive cruise control with automated lane change.)
- **Level 4: High automation.** The vehicle handles all aspects of driving, including dynamic driving tasks, and can serve as a fallback if the driver does not respond to a request to intervene. (Example: Operates fully autonomous in a geo-fenced area under a limited number of environmental conditions.)
- **Level 5: Full automation.** The vehicle can perform all critical driving functions for an entire trip; driver is not expected to be available for control. Example: Free-roaming autonomous vehicle.

AVs currently operate with L0-L3 automation. The L5 world will be radically disruptive. The widespread adoption of L5 AVs coupled with sharing and electrification will transform the entire transportation network and infrastructure. The automotive ownership model may change as well, and urban layouts may evolve to accommodate fleets of AVs operated by TNCs or new entrants with a different business model. Cars may even look different, optimized for maximum comfort, productivity, and entertainment, rather than the driving experience.

Many technologists portray this potential future as a utopia in which emissions are reduced, congestion is eliminated and people have more free time. But the future is uncertain and unknowable. While it is possible that AVs could provide significant relief to congestion, it can be argued that a dystopian end state, in which energy consumption and congestion both increase and consumers spend more time in traffic, is equally likely.

There are several hurdles that need to be overcome for a world of L4 and L5 AVs to become a reality. Considerations surrounding cost and technology, the time it takes the installed base of vehicles to turn over, and matters of liability, ethics, and infrastructure are likely to prevent mass adoption any time before 2030, with our estimates closer to 2040.

This is not to say that L4 vehicles will not have an impact on some cities before this, particularly those with standardized layouts and warmer and more predictable climates. Additionally, use cases in geo-fenced corporate campuses and universities will yield benefits sooner.

Although the L5 future is still far away, much must be done now to prepare for the coming changes.

**Factors Impacting the Future of Autonomous Vehicles**

Many variables will determine how quickly AVs enter the mainstream, as well as the impact they will have on transportation networks. Answers to key questions about competing technological standards, emerging business and
ownership models, and evolving consumer preferences are unclear and will likely remain so for quite some time. Nonetheless, it’s possible to identify some of the key issues surrounding AVs that will help determine how much they will affect congestion and whether that impact is for good or ill.

Development of scenarios around AVs’ impact on congestion took the following variables into consideration:

**Public infrastructure development.** As with any mode of transportation, AVs’ success will be determined at least in part by the extent to which investments are made in the infrastructure they need to thrive. Likewise, since AVs have the most potential to create significant value in the multimodal mix of transport options, the level of investment in public transit, IT infrastructure and policy will also be important to monitor.

**Consumers’ willingness to share.** Whether AVs ultimately increase or decrease congestion will rest in no small part on the willingness of U.S. consumers to share—not just rides, but ownership of vehicles as well. If sharing proves palatable, it would change the economics of transport quite drastically.

**Government intervention and regulation.** Taxes, fees, and regulations can have meaningful effects on the comparative cost and convenience of different modes of transportation. Whether this redounds to AVs’ benefit or detriment will have a significant impact on their role in addressing the challenges of congestion.

**Multimodal Transport: A Less Congested AV Future**

Multimodal transport is the Holy Grail for urban transportation experts because it fulfills the vision that choices will be abundant, cost effective, efficient, environmentally sustainable, and accessible.

In this scenario, cities invest substantially in rapid transit systems to alleviate congestion. Bus and trains become accessible from the majority of the city. Further, cities develop protected bicycle lanes for shorter commutes.

AVs are used in multiple capacities within the city and consumers have become accustomed to sharing. Some people own their own AVs, but the number is small. Instead, autonomous shuttles and buses provide convenient, safe and cost-effective travel. Shared autonomous vehicles (SAVs) and robo-taxis are prevalent and provide an on-demand transportation solution.

In this scenario, cities have taken substantial regulatory action to mitigate congestion and have implemented programs within the most congested areas. Congestion falls as more people give up driving in favor of easily accessible, reliable and efficient public transit and as a result of strong policies that mitigate competition for space along the curb (such as congestion pricing and TNC drop off and pickup lanes). For shorter routes, commuters can take robo-taxis that allow for cost-effective and convenient commuting.

**Infrastructure Decay and Gridlock: An Uncertain Alternative**

In an alternative, less optimistic scenario, privately owned automobiles remain the preferred transportation mode. The cost of AVs has fallen and they are now affordable for the average consumer. TNCs, car manufacturers, and new entrants with innovative business models, may also operate fleets of AVs in this scenario.

This would increase overall VMT due to a few factors:

- **Induced travel demand.** Consumers are able to recoup time that was previously lost to driving, reducing the relative cost and increasing the convenience of private AVs.

- **An increase in private vehicle utilization miles without passengers.** Households may decide to reduce the number of vehicles they own from three to two or two to one and use a single AV to make multiple journeys with many legs that they would not have taken prior.
AV usage may also lead to a decline demand for public transport. As robo-taxis become a convenient, cost effective option for traveling, public transportation may become a less appealing option. That could prompt users to take potentially longer trips that are more productive. Cities may reduce investment in public transit due to the falling ridership.

Furthermore, AVs and non-AV drivers may not mix well. AVs may stop suddenly if cut off by cars with human drivers, thus slowing total network speeds down, for example. Absent a ban on human driving, such challenges will continue to contribute to congestion for some time after AVs become mainstream.

Congestion and its costs are significantly worse in this scenario due to these compounding effects. However, AVs alleviate some of these costs by acting as “mobile offices,” making time spent in traffic more productive. It is also highly likely that all AVs will be electric, thus the cost associated with emissions and other health factors will decline on a per-mile basis.

Yet many questions remain to be answered and a pragmatic middle ground remains to be found.

**L5 Autonomy: 2030 and Beyond**

Regardless of which of these scenarios may seem more likely today, the reality is that any changes that AVs could bring to urban transportation networks are still a long way off. AV pilot programs and geo-fenced robo-taxis will be prevalent in the near future, but several hurdles need to be overcome to realize a fully autonomous world.

- **There are many technology and cost challenges to achieve broad adoption of fully autonomous vehicles.** Advances in sensor and computing technology are required for commercialization. This will likely happen in the next several years, but extensive testing and validation will be required after. Even after technological challenges are overcome, AV adoption will be limited to premium buyers and fleets for some time due to cost.

- **It will take a while for AVs to become common due to the large installed base of legacy vehicles.** The U.S. vehicle install base is about 260 million vehicles with an average age of 12.2 years. It will take over 10 years to replace half of the cars on the road.

- **Major issues on how liability will be assessed in an accident.** The issue of liability and ethics in the case of an accident, injury, or death is still to be resolved. Questions, mostly philosophical today, such as whether the AV would choose the safety of the passenger or the pedestrian in the event of a collision, will eventually pose major, real-world ethical problems that are not even close to having a resolution.

While mass adoption of fully autonomous vehicles is far out, the important decisions that will determine whether congestion is alleviated or continues to worsen will have to be made well before self-driving vehicles become mainstream. Technology alone cannot solve the U.S.’s congestion problems.
Implications for Decisions Impacting Infrastructure and Parking Today

Even though neither scenario is imminent, cities should begin to plan for an autonomous future today. Infrastructure use and parking demand may change and affect investment in infrastructure in sub-sections of cities in the next 10 years. Big questions remain about how infrastructure will and should evolve to accommodate autonomous vehicles.

With regard to AV standards and infrastructure, there are likely more questions than answers. For example, most industry experts believe some level of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication is required for meaningful AV adoption. Policymakers will have to decide on which standards will be required and who will oversee them, as well as who will pay for, manage and maintain the infrastructure AVs will require.

The near- to mid-term parking implications are much clearer. There are two key considerations for builders, owners and operators. First, new investments must be examined carefully with an eye on location and industry served given the long financial payback periods. Missteps can be extremely costly. Second, design optionality for an autonomous future should be explored, even though it may not be economically attractive, especially for parking. It is likely to be more effective to design capacity resizing (i.e., demolition options) to adjust for future capacity. Additionally, building a structure for the autonomous future may restrict current operations, making it infeasible in the near term.

In the long term, beyond 2030, policymakers will need to think carefully about the regulation of autonomous vehicles as a part of the transportation ecosystem. How will AVs complement the current public transportation network, and what incentives or restrictions will be put in place to facilitate this? How should the streetscape evolve (if at all) to accommodate AVs? Does it make sense to provide dedicated lanes for AV’s? Should on-street parking be repurposed to accommodate bus, bicycle and/or AV lanes? Or for package drop-offs and deliveries?

Over this longer time horizon, significant changes to off-street parking will take place.

Off-street parking may need to be repurposed.

- **For residential and commercial use.** Surface lots or stand-alone structures could easily be repurposed for other real estate development or personal autonomous parking and fleet autonomous parking. Depending on the location, residential complexes or commercial office space or retail could be high-return alternatives.

- **As pickup and drop off points for TNCs.** Designated pickup or drop-off zones for ride sharing or robobus may be required in the future. Parking could be the extension of the curb in the future and fill this role.

- **For AV fleet maintenance.** Shared fleets will require a place both within and outside of city centers to clean, maintain and charge their vehicles. If relationships and new capabilities are developed, parking operators could fill this need.

- **For package warehousing and delivery centers.** Facilities may be repurposed as urban delivery hubs given the high and increasing demand for package deliveries. This hub could also be used as take-off and drop-off points for drone deliveries, the last 50 yards. Delivery companies could mitigate congestion by making drop offs in off-peak hours to the parking “warehouses” and deliveries early in the morning, when businesses have someone to receive the packages.

Parking facilities will need to be redesigned.

- **New facilities will require a higher electrical load to handle the electrification of vehicles.** Most AVs in the future will be electric. It may be advantageous (or, depending on the course of regulatory change, required) for some or all parking stalls in a facility to offer charging infrastructure.

- **The optimal layout for parking structures will change, as AVs can be packed more tightly together.** Facilities will not require the same amount of space per vehicle as they do today.

- **New technologies may increase capacity.** Lift systems or elevators may be used to pack vehicles more closely together and additional sensors for parking may be added. Automated parking technologies may allow for greater utilization of space.
• **“Curb extension” opportunities will be important to consider.** These may include drop-off and pickup zones for TNCs or include other modes to create a multimodal mobility hub (e.g., ride-hailing or bicycle, scooter and car sharing). Mobility hubs will result in changes to parking structure features.

• **The role of the parking attendant and operator may change.** Technology could automate many of the current processes and makes a centralized command center more cost effective. While amenity and concierge services will focus on increasing service levels in life, play, and work settings.

Additionally, the capabilities required for parking companies will continue to evolve. Parking operators which traditionally have strong capabilities in facility operations will need to develop new capabilities in technology with V2I communication, smart parking, and seamless payments systems. Parking operators will need to develop and manage a new set of relationships, such as with TNCs, robo-taxi companies, and other shared vehicle programs.
**Policy Has the Potential to Create Livable Cities of the Future**

Given the high cost of congestion and the likelihood that it will only get worse, a response by cities is inevitable. While it’s clear that change is needed, policymakers are having difficulty in figuring out where to start. They are plagued by issues with new modes of transport (i.e., dockless scooters and e-bikes), ride-hailing and package delivery growth, a decline in public transit ridership and a lack of funding to invest in new infrastructure and programs. Further, they are constrained by limited human and budgetary resources. And they are also challenged with operating in an environment of rapid innovation and change that often clashes with their organizational culture.

Additionally, the sheer number of levers that policymakers have at their disposal can be overwhelming. They include bus lanes, bike lanes, scooter programs, public transit, new roads and highways, parking policies and pricing, TNC restrictions, transportation demand management programs, smart city technologies, platooning, delivery drones, and Hyperloop. And that list is far from exhaustive.

Congestion is complex and policymakers face many challenges and issues in relation to congestion. We propose five guiding principles when making congestion related choices:

1. **Consider near-term and long-term supply and demand levers.** Policymakers have a wide range of near- and long-term demand and supply levers to mitigate congestion including: policy changes, regulation changes, infrastructure investment, new technologies and economic incentives and disincentives. But none of these tools can fix congestion on its own, and in fact using one may exacerbate other issues.

2. **Take an ecosystem view to drive livable cities.** Livability is an important consideration for cities that prize innovation and hope to compete globally for talent and investment. Closely watched metrics of livability place a premium on clean, affordable and ubiquitous multimodal transportation. In this context, a holistic view is required to solve the complex challenge of congestion. This requires developing city plans that integrate multiple levers and consider the tradeoffs associated with each action. For example, cities should reimagine the streetscape in a way that takes into account public transit usage, bicycles, scooters, pedestrian walking areas and parking.

3. **Foster innovation through collaboration, pilots and agile policy making.** Innovation in the transportation space is evolving at a rapid pace. The effects of new technologies and new transit are unproven and often unknown. The development of these new technologies often require cities to experiment through pilots. This allows both parties to learn and potentially benefit without jumping in headfirst. Public-private partnerships (P3s) can be a valuable tool for cities. Notably, universities, hospitals and corporate campus environments are modernizing into microcosms of transportation systems with multimodal transportation.

4. **Develop a financing plan.** A major challenge for any policy maker looking to implement their plan is coming up with the necessary resources to fund and execute its plan. A combination of exploring new funding sources and following a set of guidelines can help policymakers navigate this hurdle. An increase in public private partnerships signals the potential for investment in infrastructure projects.

5. **The mix of solutions will differ by city archetype.** Cities can be categorized into archetypes that describe their physical environments and transportation infrastructure. Globally, most major urban areas typically follow one of seven models. These help determine which set of solutions is most likely to be successful for a given city.

Cities must take a multifaceted approach in order to develop an integrated solution to their specific congestion challenge.
1. Consider near- and long-term supply and demand levers

Policymakers are armed with numerous levers to mitigate congestion. Many of these solutions may be obvious supply and demand levers such as developing public transit and imposing restrictions on TNCs, while others levers such as parking policies may be less obvious.

Given the breadth of levers, it is helpful to split these into supply and demand levers for near- and long-term solutions.

Potential near-term levers for 2019-2024. Solutions that are easier to implement and mainly policy driven that can have an immediate impact on the current state of congestion.

**Demand Levers**

- **Transportation Demand Management (TDM) programs:** Cities can partner with businesses to push employees to use multiple modes of transportation. This can be done by setting targets for employers by transportation mode, or by implementing consumer-oriented programs that focus on flex time to shift travel demand.

- **Taxi and TNC regulations:** Similar to New York City, cities battling congestion could consider restricting the supply of TNC vehicles by granting a certain number of licenses in a particular area or by limiting how many can operate in a certain area at a certain time (e.g., once the threshold is met, the TNC app does not allow additional pickups). Cities can also implement fines for low utilization, which could reduce deadhead miles. Lastly, since congested curbs often lead to congested roads, cities could consider restricting curbside drop offs and pickups or designating aside specific staging areas. The downside of higher prices and longer wait times should be considered before implementing these restrictions.

- **Fines for double parking:** Cities should reconsider any arrangements they've made with delivery services providers and others that allow them to reduce or avoid fines for certain parking violations. Since these deals give couriers an incentive to abuse the curb, cities that are interested in combating congestion would be well served to adopt regulations that discontinue such contracts. Cities should also consider increasing fines for parking violations, which could alter driver behavior and, if done correctly, increase revenue to the city.

- **Reduce or eliminate parking minimums:** Regulations that require real estate developers to include minimum levels of off-street parking should be reconsidered. Reducing or eliminating this requirement could create more transparency in the cost of parking and cause builders to make economic tradeoffs, which would shift the supply curve. Allowing the market to set the right number of stalls will reduce excess supply in some areas and drive more affordable real estate projects.

- **Market pricing or reducing or eliminating on-street parking:** Market prices will encourage parking spaces to turn over more frequently during peak periods. Circling will also be reduced since on-street parking will no longer be subsidized and prices rise in-line with off-street prices keeping people from circling for the discount. Cities will also increase revenue, which can be reinvested in the transportation system. Additionally, removing on-street parking in many areas could make sense as the space could be repurposed for ride-hail pickup or drop-offs or dedicated bus or bike lanes.

- **Smart parking technologies:** Many parking technologies are already utilized yet not widely adopted (mainly due to economics) to create services to reduce congestion. A few of these services are enabled by readily available technologies:
  - Monitoring parking stall availability. Using sensors on each stall, parking facilities can determine available stalls which will allow customers to easily locate available stalls and decrease circling in facilities.
  - Smart metering technologies for on-street payment. Upgrading the street metering allows for mobile payments and increase convenience for the user, which often leads to greater compliance in payments and allows for greater enforcement.
  - Broadcasting parking availability and prices. Whether through V2I technology or mobile and web technology, broadcasting availability and price allows vehicles to get off of the street faster.
○ **Advanced navigation.** This can provide alternative routing to parking locations based on price, distance, and consumer preferences.

○ **Frictionless payment technologies.** Near-field communication allows for faster payment processing, which reduces congestion on streets near facilities.

- **Taxes, tolls and congestion pricing:** Economic incentives such as taxes, tolls and pricing for congestion are well understood and can target specific highly congested areas or roadways to affect the demand for transport.

**Supply Levers**

- **Dedicated bus and bike lanes:** Dedicated bus lanes 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. While cities are committed to a multimodal future of which cycling is one mode, residents are more likely to use bikes if lanes are available throughout the city and bike lanes are protected (e.g., separated from city streets). Another more progressive option could be to allow bicycles on sidewalks in some areas.

**Potential long-term levers for 2025 and beyond.** 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.

**Demand**

- **Delivery drones:** Delivery services companies are investing in drones to solve the challenges of the “last mile.” To the extent they could eventually replace a portion of delivery trucks, drones may reduce road congestion.

  Amazon is testing its Prime Air delivery drones with a goal to develop a fleet to deliver packages to customers within 30 minutes. Recently, the company has been granted a U.S. patent for a delivery drone that can respond to human gestures.

- **Off-peak delivery incentives:** To reduce congestion caused by double-parked delivery trucks during periods of high road traffic, cities should 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 that must be overcome as well (receiving staff at commercial buildings may not normally work at night, for example).

**Supply**

- **Public transit infrastructure:** Public transit has the potential to increase ridership and reduce the number of private vehicles on the roads when it succeeds on two main fronts: ease of access and general attractiveness.

  The first characteristic comes down to how difficult it is for people to get into the network quickly and conveniently from various parts of the city. A key element to consider here is last-mile connectivity—when transit can’t take riders close enough to their final destination, TNCs are the beneficiary.

  The second characteristic encompasses the reliability, convenience, safety, cleanliness, and comfort of the transit system. In general, when another mode of transport does better on ease of access or general attractiveness, people will shift toward that mode.

- **Roads and highways:** Further maintaining and developing roads, bridges and highways supports the current vehicle transport system into (and out of) cities. Monitoring the status and increasing capacity of roadways can increase the total supply of vehicle transportation into the city. This should be done with care, as increasing capacity may decrease commute times in the short term but may induce greater demand in the long-term.

- **Smart lanes, motorways, and analytics:** The “smart motorway” is a concept that uses technologies and procedures to monitor and respond to fluctuating traffic conditions on highways. They can be implemented in various ways:

  ○ **Controlled motorway:** This configuration features variable, legally enforceable speed limits on each lane.
- **Hard shoulder running:** In this setting, the shoulder can be dynamically opened and closed at peak periods to reduce traffic congestion.

- **Dynamic traffic light management:** Using machine learning algorithms, traffic lights across cities can be optimized to reduce congestions in specific areas at certain times of the day.

- **Dynamic throughput lanes:** Lanes that reverse the flow of traffic based on the number of vehicles flowing in a single direction.

- **Advanced navigation technologies:** Uses a combination of artificial intelligence, V2X and mobile technologies to reroute the entering vehicle base to optimize travel times.

- **Platooning technologies:** Improvements in autonomous driving technology and V2V communication could soon allow tractor-trailers to safely drive much closer together at highway speeds. Truck manufacturers and operators are excited about this technology because of the potential for significant fuel efficiency gains for vehicles in such a convoy. But “platooning,” as it is called, is also likely to reduce congestion on highways and increase safety.

  Unlike many technological advances with the potential to improve congestion, platooning won’t reduce the number of the vehicles on the road. Rather, it will improve the utilization of the infrastructure. With platooning, the gap between the two automated trucks can be reduced to 0.3 to 0.5 seconds, compared with an average gap of 1.2 to 1.5 seconds between manually controlled trucks. Studies indicate that this reduction in the gap between two vehicles is likely to increase road capacity by over 30%.

- **Hyperloop:** Hyperloop is a potentially disruptive transportation technology that would convey passengers through low-pressure tubes in metal pods propelled by induction motors. The Hyperloop is a private-sector endeavor, and companies working to develop the concept claim the pods could have a top speed of 760 mph, though average speeds would be much lower because of the need to gradually accelerate and decelerate. Nonetheless, a successful implementation of Hyperloop technology would theoretically reduce travel times between destinations – by 50-90%, 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.

  The city of Chicago and the Boring Company are working on one such study for a project that would connect downtown to Chicago to O’Hare International Airport. The 18-mile trip, which can take over an hour in rush hour traffic, could be completed in 12 minutes via Hyperloop at a trip cost of about $25, according to the study.
2. Ecosystem Approach: Cities of the Future as an Interdependent System

Cities and governments rely on employment, tourism, and corporate relocations to fuel the livability and economic vibrancy of the city. Congested lanes and hard-to-find parking create a disincentive for these employees and tourists to enter a city—a phenomenon known as trip avoidance.

To create accessible, livable cities of the future, policymakers must address congestion holistically. While there is a wide range of levers and transportation options at their disposal, none can solve congestion on its own. In fact, pulling too hard on any one lever may cause problems elsewhere. For example, charging a high road tax without developing convenient, reliable, safe, and affordable public transportation will hurt a city’s livability and economy.

There are many types of levers (as defined in the prior section) and participants that can be used when tackling congestion: bus, rail, private vehicles, parking, taxis, ride-hailing, and more. Each ecosystem lever or participant plays a role in distributing the transit load for the movement of goods, services and people. The mix of levers pulled is not static, but often varies by city.

The ecosystem approach considers the interdependencies of the city across all levers and participants, including infrastructure wear and tear and the importance of traffic flow to help maintain equity within the city.

Important tradeoffs must be considered as policymakers develop strategies to drive city livability. These include short-versus long-term investments, cost versus convenience, and consumer choice versus policy-driven approaches. Modeling solutions at a city planning level is critical to understanding the different tradeoffs required to make informed decisions. For example, advanced analytics can help determine the impact of ride-hailing and robo-taxis on different neighborhoods within cities, informing decisions on investment and/or restrictions.
Example: Re-envision the inner and outer rings for short and long trips

In the U.S., 128 million people drive to work in a personal automobile or carpool. This means that 85% of the 150 million people who commute every day nationwide use a motor vehicle to enter the city. Commuters typically travel from the outer ring in a suburban environment to an urban inner ring of a city to work. A trip that crosses rings in this way can be thought of as a “long trip.” Once inside, workers, tourists, and residents can park and then take a “short trip” via multiple modes of transportation to get around the city. This will reduce personal VMTs within the city center, which will clear roadways to move people and freight through busy thoroughfares.

Example: Mobility Hub – Park Once Approach

Public transit is a key part of any transportation ecosystem, but even in cities with excellent transit networks, buses and trains can’t go everywhere. For that reason, the final leg or “last mile” of travelers’ journeys can be the most difficult. The mobility hub concept may be able to help address this problem by aggregating a variety of solutions where they’re most needed. These can include bike, scooter and car sharing services, smart parking, and more, in addition to a transit node. They pair well with parking structures that may have spare capacity.

Mobility hubs have the potential to connect people with destinations and reduce congestion by moving vehicular traffic out of active roadways and onto designated curb loading/unloading zones and off the street into parking structures for storage. Moving vehicles off the street and into parking hub zones relieves congestion.

The concept is being embraced in San Diego, where a regional consortium of government bodies called the San Diego Association of Governments (SANDAG) has developed a regional mobility hub strategy to address increasing population and congestion. The consortium has identified eight areas throughout the region to create mobility hub prototypes, each located in areas with unique demographics and infrastructure and including custom features to maximize effectiveness. The goal is to offer a number of services within a five-minute walk, bike ride or drive of the transit center.

According to SANDAG, the mobility hub 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 ridesharing and micro-transit services, among others. Development of the sites will begin in 2019.

Mobility hubs lend themselves to future adaptive facility design. This will include features to move traffic off the active roadway quickly through the use of shared parking logistics lanes, designated cashless ticket lanes, enhanced wayfinding navigation, and advanced reservations to find parking spaces quickly. Future adaptive facility design will likely feature first- and second-story retail, and valet amenity services for dry cleaning and/or package delivery directly to the vehicle.
Example: Citizen-Centered Ecosystem

One significant question that city planners face is whether cars will have unfettered dominance over the streets of tomorrow, or whether they can be designed to accommodate a broader, more sustainable array of transportation modes. Keeping in mind that multimodal transportation networks are a key attribute of livable cities, it seems clear that forward-looking policymakers should plan to incorporate emerging forms of mobility, in addition to automobiles, when building new roads or overhauling existing ones.

Important tradeoffs that will have to be considered include how much priority each form of transportation will be given, whether dedicated lanes for bicycles or buses will be used, how to accommodate dedicated drop-off and pickup zones for TNCs and delivery companies, and how best to provide parking, whether on-street or elsewhere.

Questions that must be considered include:

- How can the transportation ecosystem be designed to best meet varied mobility needs/preferences?
- How much priority will different modes of transit be given?
- Will there be pedestrian bridges, bike sidewalks, dedicated bicycle lanes or bus lanes?
- Will there be dedicated drop-off areas or loading zones for ride-hail, taxis and deliveries?
- How much, if any, parking will be incorporated? If there is no street parking, are there opportunities for consumers to park elsewhere?

How these questions are answered will determine the composition of the streetscape. There isn’t necessarily one right answer, and the outcome should be tailored with a comprehensive city strategy in mind.

Illustrative before and after streetscape concepts. Not meant to advocate for a particular mode of transit.

Source: PwC

Streetscape design that takes an ecosystem approach can be found in Sidewalk Labs’ smart city project in Toronto. In August 2018, the Alphabet subsidiary unveiled proposals that include a new multimodal street grid that gives priority to public transit, bicyclists and pedestrians. 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.
**Example: Opportunities for Parking Solutions within the Ecosystem**

Some ecosystem players may provide solutions in areas in which they haven't participated in the past. One example is the trend of TNCs entering the e-scooter business as a way to fill the need for cheap, convenient urban transport for short distances. Other ecosystem players will be asked to provide charging infrastructure for electric modes of transport.

Parking could potentially be used in new and innovative ways to mitigate congestion, mainly at the curb. A few ways that parking can be “curb extensions” are:

- **Short-term parking for TNCs.** Circling within city centers generates a significant amount of VMT and traffic. Partnership with TNCs or cities could help reduce circling in highly congested areas. Long-term agreements, optimizing short-term pricing and/or design changes may be required to enable this solution.

- **Dynamic taxi or ride-hail stands.** TNCs (and in the future, robo-taxis) stop on many already-congested streets. During peak hours cities may require designated areas for ride-hailing vehicles to stop, which could provide congestion relief. Other opportunities including 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.

- **Car share parking.** Many consumers use car sharing services like Zip Car, while automakers like Porsche are entering the sharing economy through shared leases—a way for drivers to choose from multiple car models to drive each time. Parking can serve as a hub shared car pickup and return.

- **Drop off or pickup point for packages and loading zones.** 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.

- **Valet services.** Valet services at hotels, condominiums, hospitals, universities, event venues and CBD offices provide enhanced customer experience and rapid loading and unloading. High occupancy parking structures may require valet stack parking.

- **Storage for shared bikes and scooters.** Dockless e-mobility solutions can clutter the curb and sidewalks. The first floor of parking facilities can act as a holding area for shared bicycles and scooters, also providing charging infrastructure for these solutions. This would provide easily accessible and out of the way.

Additionally, 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 planning process as less real estate would be needed to create the same amount of parking facilities.
3. Foster Innovation through Collaboration, Pilots and Agile Policymaking

Transportation innovation is gathering pace, and the effects of new technologies and new transportation modes are often unknown. To effectively integrate these new technologies into their transportation systems, cities often choose to experiment through pilots. This allows both the municipal government and the service provider to learn and potentially benefit without making a significant commitment.

Many cities are already taking this approach. Whether it’s the rollout of robo-taxi pilot programs, implementing new curb policies, or the creation of new P3s, the end goal is all the same—to increase livability for citizens and reduce congestion.

A few guiding principles when setting up pilots:

1. **Clearly outline your objectives and the potential value**: A clear understanding of the objectives and the value created helps to focus thescope and understand when pilots are benefiting the city.

2. **Define scope while allowing flexibility**: Breakdown the scope into clearly defined phases with timelines. Given these are pilots, it’s important to understand that part of the goal is learning and this will be a process. All the answers will not be known up front. Revisiting the scope or objectives may be necessary with new learnings.

3. **Define success upfront**: Design clear success criteria with measurable outcomes upfront. This keeps pilots focused and aligns policymakers and experimenters with the same objectives.

4. **Monitor progress and collect data**: Continuously collect data to monitor progress and understanding the potential value that these new programs can create.

Those who are seeing the greatest amount of success are the municipalities who are working collaboratively with the private sector and adjusting policies as needed to accommodate the quickening pace of innovation.

Examples include:

- **Boston 2030**. As part of its long-term planning initiative, the city has been working with companies to test next-generation mobility platforms through the Mayor’s Office of New Urban Mechanics (NUM). Prior to soliciting partnerships, NUM created a clearly defined set of protocols that companies must adhere to in order to operate within the city, including providing prior off- and on-road testing results, meeting National Highway Transportation Safety Administration (NHTSA) and Massachusetts Department of Transportation (MassDOT) vehicle safety standards, and testing only under specific conditions defined by the city. Optimus Ride and nuTonomy (both of which were spun out of the Massachusetts Institute of Technology) are working with Boston to provide piloted robo-taxi services and high-definition mapping in various parts of the city. Recently, nuTonomy was approved for on-street testing in December 2016 and Optimus Ride was approved in June 2017. The city is interested in exploring additional partnerships that can address the unique layout of the city and be part of a broader connected transportation infrastructure.

- **City of Tomorrow Challenge**. Launched in June 2018, three cities—Grand Rapids, Miami-Dade and Pittsburgh—are participating in this initiative, which provides a crowdsourcing forum in which residents can bring up mobility issues within the cities and offer suggestions. Companies can then submit proposals to address these issues and receive funding through a combination of public-private resources to rollout pilot programs. Ford, Dell Technologies, AT&T and Microsoft, among others, are sponsoring the initiative in cooperating with the cities. One of the key pillars of the program is to actively seek input from citizens to gain a better understanding of everyday issues they face related to mobility. Challenge winners from each city are provided with funding and required to produce a report to submit to city planners that summarized their findings. Each of the cities has posed a unique challenge to potential participants:

  o How might we create a seamless transportation system to improve quality of life for residents and visitors of Grand Rapids?
How might we make daily journeys fresh, easy, and adaptable to the needs of Miami-Dade residents?
How might we design commutes in Pittsburgh that are seamless, welcoming and intuitive?

While the approach to each city will undoubtedly vary, they are all seeking the same outcome, easier navigation that reduces congestion and improves livability. Some of the 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.
4. Develop a Financing Plan

As demonstrated above, there are no shortage of options to combat congestion at cities’ disposal. But many of them are potentially quite expensive, especially those that involve construction of new roads or bridges or expansion of public transit networks. How to pay for such investments is critical to executing successful programs.

Cities will find that creativity is an asset when it comes to developing a financing plan to support infrastructure investments. That’s because federal and state government support can be elusive. Still, it often pays to think regionally when considering potential sources of funding, especially if suburban commuters account for a large share of demand for transportation infrastructure.

Six guidelines can aid cities and states generate support for infrastructure projects from both private investors and federal policymakers. These six guidelines help policymakers prepare a case for support that can bolster funding and success for transportation projects.

1. **Focus on data** to prove each project’s viability.
2. **Prioritize wisely** to optimize capital projects portfolio.
3. **Consider alternative financing options** (e.g., public-private partnerships, federal funding programs).
4. **Explore resources** to ensure adequate staffing, technology, and external support.
5. **Use a capital project excellence framework** to anticipate hurdles and maximize efficiency.
6. **Gather evidence** to demonstrate track record.

Options that cities may choose to explore include:

- **Exploring P3s.** Though not as commonly used in the U.S. as in many other advanced economies, 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.

- **Tapping tech billions.** Technology companies and investors could be willing to fund cutting-edge infrastructure projects to boost their brand. The Hyperloop collaboration between Chicago and Elon Musk’s Boring Company, discussed above, is an example of this. Boring will shoulder the entire cost of the project, according to news reports. If it were to come to fruition, this would obviously provide huge benefits to both Chicago and Musk, who raised $112.5 million earlier in the year to help finance the construction of Hyperloop tunnels.

- **Raising sales taxes.** Tax increases distribute the burden of paying for improvements broadly. Los Angeles County voters passed a ballot initiative, “Measure M,” in 2016 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.

- **Raising tolls.** Increasing tolls can be an effective way to share the cost of transportation infrastructure improvements with users of the network. 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% of the additional $4.45 billion of additional revenue raised over a 25-year period will go to transit projects.
5. City Archetypes Will Drive the Mix of Congestion Solutions

To be sure, each city’s transportation needs are unique, shaped by its layout and past infrastructure investments. Nevertheless, most cities can be grouped into one of three broad archetypes – and within them seven more specific archetypes. This is a useful exercise because it makes it easier to identify which solutions may be most relevant based on their efficacy under similar circumstances.

Most cities have one or more centers of activity (i.e., downtowns) that people commute to either from within the city or from outlying areas (i.e., suburbs). Creating livable cities requires understanding the differences between these areas and how traffic flows between them.

When it comes to congestion, every city has four key characteristics:

1. **City layout and infrastructure.** This describes a city’s areas of high and low population density, whether its streets form a grid or have a circular layout, and whether its origins are medieval or modern.

2. **Travel and commute patterns of the population.** This characteristic looks at the daily and weekly travel trends of inhabitants and visitors, based on where they live, work, and travel for leisure.

3. **Maturity of public transit.** A measurement of the overall robustness of train and bus infrastructure, taking into account ease of access and general attractiveness based on reliability, convenience, safety, cleanliness, and comfort.

4. **Relative cost of driving.** Is it more expensive to drive rather than take public transit, after taking into account the cost of tolls, parking, and traffic violations?

Each of the seven models will be examined in further detail in order to outline their specific congestion challenges and future parking implications. Note that out of the seven models, only four are applicable to cities in the U.S.: Urban Hub Community, Mixed Hub Community, Suburban Hub Community, and Driving Metropolis.
**Compact core and non-grid layout**

This form consists of a densely populated core where the bulk of the mobility demand is located. Founded in medieval times, these cities have circular, non-grid layouts and narrow streets that were designed for travel by horse and on foot. Movement within the core is relatively uniform, and people don’t tend to travel within the core or to the less-dense outer areas.

**Multimodal core**

In this model, public transit (which tends to be primarily rail) is relatively mature and robust and is an attractive way for people to get around. High population density, narrow streets and limited parking mean it’s expensive to drive. It can take a long time to find a suitable place to park, which makes driving inconvenient as well as costly.

The key congestion challenge comes from the historic layout of the city – one which is not conducive to driving. As a result, the congestion solutions focus for Multimodal Core cities are to maintain robust subway or train infrastructure as travel demand grows and to encourage other select mobility options, such as bicycles, electric scooters, minibuses or shuttles, and other options conducive to the city infrastructure.

**Walking core**

Like cities of the Multimodal Core model, Walking Core cities share 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 horse-drawn cart than a modern automobile. Driving is similarly difficult and expensive, and finding adequate parking is time-consuming. The key difference is that while Multimodal 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 of cities fitting this model include Amsterdam, Florence, and Venice.

Given its unfriendliness to motor vehicles and its relative lack of good public transportation, the congestion focus for the Walking Core model is to regulate the number of motor vehicles on its tight streets and pathways and encourage options such as walking and biking that align with the layout of the city. In addition to options like motorcycles, electric scooters and mini-buses or shuttles, some Walking Core cities may consider transportation modes that suit their unique geographies (e.g., boats in Amsterdam and Venice).

**Urban and suburban communities**

Cities taking this form have small, densely populated urban cores surrounded by rings of less dense suburbs. The population movement here consists of people commuting to and from the suburban rings to the dense core, moving across various suburban rings, or traveling within the same ring. The origins of such cities are more modern and the overall layout is primarily a grid.

**Urban hub communities**

The primary hub for activity in this model is the dense urban center. Although there are suburbs surrounding the core, most people will commute to the center for work or for leisure activities. The public transit for this archetype is relatively mature and robust and the cost of parking is high, since there is a large flow of individuals into the urban core and many of them prefer to drive their own vehicles.

The key congestion challenge that cities of this model face is the high density and volume of TNC vehicles operating within the urban area, and the primary focus will be to streamline their TNC environments. In practice, this will primarily mean clearing up the curb by reducing on-street parking, designing designated drop-off and pick up areas, reducing TNC driving violations and incentivizing off-hour delivery programs.

However, this also means that Urban Hub Communities may seek to reduce overall TNC demand and supply. From a demand perspective, they may focus on enhancing other modes of mobility such as expanding bike-sharing, promoting car sharing (e.g., Zipcar and Enterprise), launching new bus routes and implementing special bus lanes, and expanding their already-robust train systems. From a supply perspective, they may begin to 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.
Mixed hub communities
Cities fitting into this model have high-activity areas in both the urban core as well as the suburban rings. This is reflected in travel and commuting patterns – while many people travel back and forth between the city and its suburbs, there are also plenty who primarily move within the urban core itself. To accommodate the significant demand for transportation from the outer rings to the center, Mixed Hub Communities 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 a driving culture.

The key congestion challenge that these types of 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 they all have capacity constraints. As a result, Mixed Hub Communities have to think about enhancing their entire mobility ecosystem.

Suburban hub communities
Although cities in this category have an urban core, most people live and work outside of the city in the suburbs. Since a majority of the movement in this archetype happens across its sprawling suburbs, public transit is immature. People historically have relied on their own vehicles to get around, and the cost of driving will be relatively low. Although parking is limited in the urban core, the inflow of vehicles is rather also limited and the tepid demand keeps prices down. Parking needs are much higher in the suburbs, but space there is plentiful and relatively cheap, hence prices tend to stay low in those areas as well.

These cities’ 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, though stronger in terms of local economy and policymaking wherewithal, lack the incentive to build public transit into the urban core and don’t see the need for it in the outlying areas. As a result, in order to control congestion, this type of city focuses on maintaining the high capacity of roads and highways.

Sprawling metropolises
These cities have relatively low or uniform population density, though many have small hubs of high activity. People mostly travel among these hubs, and while some may be nearby, others can be quite distant. The origins of such cities are more modern and the overall layout is primarily a grid.

Driving metropolis
Hubs of activity in cities of this model are scattered, and as a result people tend to travel great distances for work and leisure. Driving is the preferred mobility method.

Since the mobility patterns are more complex and spread over a larger territory in the Driving Metropolis, public transportation options are very limited. The cost of parking is relatively low due to ample supply and overall low to medium population density.

The key congestion challenge that these cities face is the city sprawl and lack of driving alternatives. Therefore, as the city population and GDP grow, so do the number of vehicles on the streets. Since few other transportation options are available, this creates significant congestion challenges. This type of a city has historically been a “driving city” and the commuting distances tend to be longer.

In order to combat traffic congestion, city governments build new roads and highways and expand those that already exist. While this strategy may improve traffic flow in the short term, it may lead to worse congestion as the higher capacity and faster travel speeds induce more people to drive (usually at the expense of the already anemic public transit system). Such cities will also leverage HOV or HOT lanes in order to increase traffic flow and efficiency.

Cities of this type need a short and long-term strategy to combat congestion. In the short-term apply a breath of levers to mitigate congestion. In the long-term these cities should develop its public transportation systems. Doing so will decrease the public’s dependence on driving and cut down on the number of vehicles on the roads.
**Efficient metropolis**

Just like the driving metropolis, the high-activity areas for this type of city are located across its entire area in small hubs. But driving is not the only mobility method. Even though people are traveling long distances, they have a multitude of mobility options.

Even though the mobility patterns are more complex and spread over a larger territory these cities, the public transportation is very mature and robust. The cost of parking is relatively high in the Efficient Metropolis due to the population density and high demand for real estate.

The key congestion challenge faced by this archetype is that as the city population and GDP grow, so does the mobility demand of its inhabitants. People need to travel longer distances and the city must maintain strong multimodal mobility options. As a result, the focus area for the Efficient Metropolis is to maintain leadership in mobility research and have the legislation in place that’s needed to drive transportation innovation.
The Condition of Cities in North America: Case Studies

Chicago

Population: 2.7 million
Time Spent in Congestion: 57 hours (up 12% since 2010)\textsuperscript{46}
Cost of Congestion: $5.5 billion
Mean Travel Time to Work: 34 minutes
City Archetype: Mixed hub community

Overview: Chicago was the eighth most congested city in the U.S. and 22nd in the world in 2017. Its drivers spent about 57 hours stuck in stop-and-go traffic, costing the city about $5.5 billion, an increase of 6% over 2016. According to the Chaddick Institute at DePaul University, the average speed of a vehicle in the city slowed by 2.4% over a period of four years to reach slightly more than 24 mph in 2017.

Key challenges: As one might anticipate for a city of the mixed hub community archetype, Chicago’s congestion challenges are driven by high demand for mobility both into and within the city center.

- Given the limits of the public transit network and moderate parking costs, there’s ample reason for people to drive their cars into the city. This causes roadway congestion, especially during peak times.
- An increase in for-hire vehicle (FHV) miles and a drop in rail and bus ridership fueled by reliability issues is contributing to increase vehicle traffic.
- Chicago is one of the country’s key freight hubs, leading to high trucking volumes on its highways.

Current approaches to reduce congestion:

- The city is focused on improving its public transit infrastructure, expanding the rail network in underserved neighborhoods and implementing BRT in the central business district.
- For shorter trips, the city is working to make bicycling a more attractive option by increasing the network of bike paths and lanes and investing in bike-share programs, with a dockless pilot launched in 2018 to complement its traditional Divvy bike-sharing network.
- To help get a handle on demand, Chicago is increasing its surcharge on FHV trips and charging TNCs more than taxis to pick up at O’Hare International Airport.

Potential solutions: Parking solutions are a key part of Chicago’s approach to reducing congestion.

- The city has proposed a system called Chicago Smart Parking Solution that would provide drivers with real time information on space availability and direct them to available facilities.
- The Chicago Metropolitan Agency for Planning’s Go To 2040 plan also recommends flexible pricing for parking, with additional funds raised earmarked for transit improvements.
- The Hyperloop is potential option to mitigate traffic from the airport into the city. Chicago announced in 2018 a potential plan to partner in development.
- The Illinois Department of Transportation has proposed to implement express toll lanes on the I-55 expressway; whether pricing will be fixed or dependent on congestion is still being studied.
Los Angeles

Population: 4 million
Time Spent in Congestion: 102 hours (up 67% since 2010)\(^47\)
Cost of Congestion: $19.2 billion
Mean Travel Time to Work: 31 minutes
City Archetype: Driving metropolis

Overview: Los Angeles residents spent an average of 102 hours in congestion in 2017, leading the world for the sixth straight year. The city’s worsening automobile traffic is adding an increasingly large bite out of its commuters’ days: During the 2010-16 period, a driver in Los Angeles spent about 33% to 45% more time traveling, regardless of the time of day, due to congestion than he or she would have taken in freely flowing traffic.

Key challenges: The city’s congestion is primarily driven by three main factors: considerable urban sprawl, rising rates of car ownership and a lack of a strong public transportation system.

- The average Los Angeles household owned 1.62 cars in 2016, more than 2.5 times more than the average New York household and significantly higher than other large U.S. cities like Chicago, San Francisco, and Washington, as well.

- This reliance on the automobile is necessitated by the region’s lack of single, dominant core and the inability of its weak public transit infrastructure to connect the disparate smaller cores that residents need to travel to for work and leisure.

- Ridership on the county’s bus lines has fallen by about 16% since 2012, while rail usage has remained more or less flat, indicating an increased reliance on cars to get around.

Current approaches to reduce congestion:

- Los Angeles launched Express Park, a program that fuses sensor-based technology with real-time updates to periodically adjust parking rates to meet changing demand. The program aims to make traveling and parking in Downtown Los Angeles easier by freeing up more parking. The system’s target is to keep the occupancy rates between 70-90%.

- The Metro ExpressLanes high-occupancy toll (HOT) lane program uses congestion-based pricing to set tolls on certain expressways. The toll for solo drivers is between 25 cents and $1.40 per mile and toll charges are directly linked to traffic levels.

- Los Angeles is developing protected bike lanes and working on expanding the bike-sharing program that it launched in 2016 by adding a total of 1,700 bikes.

- To finance further investment in public transit, Los Angeles County voters passed a ballot measure known as “Measure M” in 2016 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.

Potential solutions: Los Angeles is also advocating for shared mobility through programs that encourage car, ride and bike sharing, as well as by enhancing its bus infrastructure.

- Los Angeles plans to implement demand-based parking pricing to improve parking availability.

- A NextGen bus study was launched in 2018 to create a plan to restructure the city’s bus network.

- There is a potential plan to develop a larger rail network to efficiently move the large mass of people across the sprawl, something that will take decades to implement.
New York City

Population: 8.6 million
Time Spent in Congestion: 91 hours (up 54% since 2010)\(^{48}\)
Cost of Congestion: $33.7 billion
Mean Travel Time to Work: 41 minutes
City Archetype: Urban community hub

Overview: In 2017, New York ranked third in the world in terms of hours spent in congestion.

A driver in New York spends about 13% of his or her travelling time in congested conditions, including 11% during the day and 19% during peak hours. This has taken a toll on travel speeds, which fell in Manhattan’s central business district by 24% to 6.8 mph in 2016 from 8.9 mph in 2013. Overall, demand for mobility in New York is growing due to a robust economy—population, employment, and tourism have all posted solid gains in recent years.

Key challenges: Primary reasons for congestion in New York include a high population density with high demand for mobility within the city center, and high parking costs coupled with a significant supply of taxis and TNC vehicles to travel into and around the city.

- New York’s public transit infrastructure is in poor shape, with frequent subway service changes and poor reliability of the bus network pushing travelers away from mass transit.
- The growth of travel by FHV’s such as taxis or TNC’s has led to a significant increase in cars on the road, particularly within Manhattan’s central business district. These vehicles accounted for just 0.25% of total registrations in the city in 2016, but logged 19% of total miles driven on its streets—an increase of nearly 40% percent over 2013. FHV’s are also contributing to curbside congestion as they search for space to conduct drop-offs and pickups, which is negatively affecting parking availability in the city as well as exacerbating congestion by increasing the number of vehicles circling.

Current approaches to reduce congestion: New York is attempting to address both the supply and demand sides of its congestion problem.

- In August 2018 New York passed a series of bills that will impose a one-year freeze on new rideshare licenses within the city. New York is the first U.S. city to cap rideshare registrations, and plan on studying the resulting congestion date while the cap is in effect.
- The New York State budget authorized the city to add a surcharge on FHV trips in Manhattan—yellow cab rides will cost an additional $2.50 and traditional TNC rides will cost $2.75 more, while ride-sharing services provided by these companies will only incur a 75-cent surcharge.
- The city is setting aside parking for car-share programs like Zipcar as part of a two-year pilot and targeting an increase in the number of bicycles available under its bike-sharing platform, Citibike.
- To combat curbside congestion and free up more parking, the city has announced plans to revamp on-street parking zones and increase meter rates and is encouraging freight companies to shift deliveries to off-peak hours in the evening or overnight.
- The city is piloting a connected vehicle program to reduce the number of traffic deaths and injuries on city streets. The pilot will use V2V and V2I technology in a specialized fleet.

Potential solutions:

- New York must continue to make strides in multiple areas—focusing on increasing the availability of reliable public transit and mitigating the effects of FHV’s and deliveries. It should continue to make strides in advanced traffic management and connectivity programs. The city is well suited to further develop vehicle connectivity technologies, especially in its dense CBDs.
- Additionally, given the lack of alley ways that other cities have, daytime deliveries creates a large congestion problem. The city could further explore efforts to partner and reduce the peak time delivery load and the double parking that accompanies it.
San Francisco

Population: 884,000
Time Spent in Congestion: 79 hours (up 32% since 2010)
Cost of Congestion: $10.6 billion
Mean Travel Time to Work: 32 minutes
City Archetype: Mixed hub community

Overview: San Francisco ranked as the fifth most congested city in the world in 2017, trailing only Los Angeles and New York among U.S. cities. As a global capital of innovation, San Francisco’s battle with congestion illustrates how technology can be a cause of and a solution to excess automobile traffic while also underscoring that policy and politics (in particular, regional coordination) are still necessary to solve many congestion-related problems.

Key challenges: Primary causes of congestion in San Francisco include a growing number of TNC vehicles on the road, slow traffic due to construction, and a growing population. Like Chicago, San Francisco’s congestion issues stem from high demand for mobility both into and out of the city as well as within the city center. Public transit is unreliable and parking costs are moderate, leading people to drive into the city. This causes roadway congestion, especially during peak hours.

Current approaches to reduce congestion: San Francisco is taking steps to address both the supply and demand sides of its congestion problem.

- In 2017, the city introduced dynamic pricing for 28,000 on-street parking spaces and 14 city-run garages following a successful pilot program begun in 2011. The hourly rate is capped at $8, and the transit authority expects the program will be revenue neutral overall.
- The city is increasing enforcement of regulations designed to ensure that road construction doesn’t affect rush-hour traffic and to limit double parking and obstructions caused by delivery vehicles.
- The city is making investments to shift travelers out of cars and onto bicycles and into transit, including its “Better Market Street” plan, which includes central transit lanes and protected bike lanes on this main thoroughfare.
- It is also boosting bike-sharing programs in the city – a pilot of dockless motorized bike sharing platform was launched in San Francisco in 2018.
- To fund public transportation infrastructure investments, voters in nine counties approved a measure in June 2018 to raise bridge tolls by $3 over a period of seven years. Some 62% of the additional $4.45 billion of additional revenue raised over a 25-year period will go to transit projects.

Potential solutions:

- Due to the success of other pilot programs, San Francisco is exploring policies for scooters and many robo-taxi pilots.
- SF could explore new revenue streams that limit congestion within the core downtown and South of Market neighborhoods during peak hours. For example the Board of Supervisors requested a bill for an infrastructure impact fee on TNCs.
- In the longer term, San Francisco could consider developing its bus and rail networks so there is greater reach within and into the city limits.
Toronto

Population: 6.1 million
Time Spent in Congestion: 47 hours (up 22% since 2013) 50
Mean Travel Time to Work: 34 minutes
City Archetype: Mixed hub community

Overview: Toronto, Canada’s largest city, is also its most congested. Average commute times are 30% higher than in Vancouver. Though the population continues to rise, alternatives to driving remain relatively unpopular. For example, Toronto has developed a reputation as an unsafe city for pedestrians and cyclists, making those modes less appealing compared with automobiles. Reliability issues have also dogged its transit system.

Key challenges: A strong preference among commuters for driving alone and stagnating transit ridership are the two main drivers of congestion in Toronto.

- In 2016, about 83% of commuters drove alone, unchanged compared with 2011. However, since the city’s population has grown steadily over those years, that trend has led to many more cars on the road.

- Toronto’s transit system has given travelers little reason to leave their cars at home, as reflected by ridership levels that were little changed in 2017 compared with the three previous years. Service outages and delays were the main cause of the system’s unattractiveness: For instance, in September 2017, the city’s streetcar service ran nearly 2,800 hours fewer than budgeted and its bus lines operated 4,800 hours fewer than budgeted.

Current approaches to reduce congestion: Toronto is pursuing several strategies to invest in public transit.

- Its mayor’s 2018 budget included a 10-point plan to alleviate congestion and boost transit ridership and reliability, including adding trains to the busy Line 1 during rush hour, more proactive equipment checks, and improved system wide monitoring.

- Under its Ridership Growth Strategy, the Toronto Transit Commission plans to increase the frequency and availability of trains and buses, develop a fare product that allows for integration with other transport modes, and leverage data generated by riders using the Presto fare card to garner insights about system users’ preferences. Fare reductions are also being studied for regional and off-peak travel.

- The city is also bolstering its bicycling infrastructure. A 2016 plan identified 525 kilometers of new bike lanes, and the provincial government of Ontario provided a C$25.6 million grant to increase the city’s bike share program.

- To reduce the number of commuters driving alone, Toronto launched in 2018 an 18-month pilot of a “free-floating car share” program through which car share companies can receive up to 500 on-street parking permits for their vehicles. Permits issued through the program cannot be used on residential streets where 95 percent or more of the parking capacity is in use.

Potential solutions: In 2016, the Toronto City Council voted in favor of implementing tolls on the city’s Gardiner Expressway and Van Dolley Parkway. A hypothetical fare of $2 per vehicle was estimated to raise about $200 million to fund transit projects. However, the provincial government rejected the proposal, instead increasing the amount of gasoline tax revenue that is transferred to municipalities. Toronto officials could revisit tolls in the future if they judge that the political environment has changed.
Washington, D.C.

**Population:** 694,000  
**Time Spent in Congestion:** 63 hours (down 5% since 2010)  
**Cost of Congestion:** $6.1 billion  
**Mean Travel Time to Work:** 30 minutes  
**City Archetype:** Mixed hub community

**Overview:** Washington, D.C. ranked as the 18th most gridlocked city around the world, and sixth most congested city in the U.S., in 2017. The average driver in the area spent about 63 hours stuck in stop-and-go situations during peak hours, up 12% from 40 hours in 2013. Given its somewhat limited self-governing powers and special status as a separate political entity from the two states that surround it, coordination with surrounding suburban communities has historically been crucial for the District.

**Key challenges:** Washington, D.C. struggles with unreliable public transit which, combined with relatively inexpensive parking, encourages private vehicle use by people traveling into the city from the suburbs. Meanwhile, high demand for mobility between destinations in the city center exacerbates congestion.

- Driving alone continues to be the dominant commuting mode in the Washington metropolitan region. And an upward trend in the average distance traveled by commuters—about 63% go more than 10 miles—also contributes to the growing concerns around traffic.
- According to U.S. Census Bureau data spanning 2009-2013, of the 797,000 average daily commuters in the Washington area only about 30% originate their trips within the city, with the remainder coming from outlying counties.
- The public transit system’s extremely poor reliability helped fuel ridership declines of about 12% in the 2015-2017 time period.

**Current approaches to reduce congestion:**

- The Washington Metropolitan Area Transit Authority (WMATA) is investing in initiatives to expand capacity and improve reliability of the Metro, the region’s subway. These include increasing train lengths, improving rail stations, relieving congestion at transfer points and adding more bus priority corridors to surface streets. Nearer-term fixes include fast-tracking certain repairs and offering credits to riders who suffer delays of 15 minutes or more.
- D.C. is also seeking to shift more travelers to bicycles for short trips by building more bike lanes; the city has developed 80 miles for such lanes since 2000 and intends to open an additional 56 by 2040.
- To better monitor and control the flow of automobile traffic, it has implemented an advanced traffic management system (ATMS) called CapTOP ATMS that enables the flow of real-time data from cameras, speed sensors, and other data sources to a traffic command center where it can be processed and analyzed.
- In the D.C. suburbs, the Virginia Department of Transportation (VDOT) adopted demand-based toll pricing on I-66, which connects Northern Virginia suburbs to the capital. Tolls are calculated every six minutes according to traffic volume to maintain an average speed of 55 mph.

**Potential solutions:** Following the lead of other U.S. cities, Washington, D.C. is also piloting demand-based pricing to improve parking availability. Funded by a $1 million grant, the program installed meter sensors and mobile cameras targeting 1,000 meters in the Chinatown and Penn Quarter neighborhoods. The district’s department of transportation estimates that circling for parking accounts for 25% to 30% of congestion in Washington.
Examples from International Case Studies

Many international cities have paved the way and are fighting congestion with measures that have not yet been implemented in the U.S. It is important to note the differences in some of the city archetypes, but many learnings can be gleaned from the policies that they have been putting in place.

Paris

Population: 12 million
Time Spent in Congestion: 69 hours (up 26% since 2013)\(^5\)
City archetype: Efficient metropolis

Paris ranks among the top 10 most congested cities in the world. In 2017, the average driver spent about 69 hours per year in congested traffic, up from 45 hours in 2015. Private vehicle ownership is the biggest cause of this problem. An old city, Paris has parking for 1 million vehicles—but more than 1.5 million enter the central business district every day. This results in illegal parking in the city’s narrow streets, further increasing congestion. Plentiful intersections, traffic lights and one-way streets slow down traffic as well.

The city is considering a few very aggressive initiatives that tackle both pollution and congestion. It plans to extend its train and metro network, and it’s offering incentives for using public transportation such as waiving fares when pollution levels peak and other incentives for people to use transit instead of personal vehicles. It 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.

In order to make Paris more bike-friendly, the city will spend €150 million (about $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 also 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.

The city has two primary vehicle-sharing programs – Velib for bicycles and Autolib for electric cars. In order to minimize circling and to incentivize car sharing, the city also has dedicated parking spaces for Autolib cars.
London

Population: 8.8 million
Time Spent in Congestion: 74 hours (down 11% since 2013)\[^{53}\]
Cost of Congestion: £9.5B
City Archetype: Urban hub community

From 1991 to 2001, London’s population jumped 12.5% to 7.2 million. Over the same period, vehicle registrations in the U.K. rose by 72%, an increase of 3 million units annually.

Network speeds in central London dropped about 10% to an average of 9 mph and congestion-related delays rose by approximately 21% from 1990 to 2000, and time lost to congestion cost the city between £2 million to 4 million every week.

In 2003, after 40 years of research and development, London instituted a congestion pricing plan that charged drivers £5 per day to enter a zone in the central part of the city from 7 a.m. to 6 p.m. This rate has since increased to £11.50 per day. Additionally, London has added ancillary transportation services to further reduce congestion, including 300 new buses, improved frequency and updated routes; 8,500 park and ride spaces; and new bike and pedestrian friendly infrastructure.

In 2004 after implementing congestion pricing, there was a 20% increase in average network speed, a 14% decrease in network travel rates, and a 15% reduction in volume of traffic circulating within the charging zone. Additionally, there was a 38% increase in bus patronage and 30% decrease in additional bus wait time.

The effects of London’s example have been in question today as overall network speeds have been decreasing yet again. Much of the increase has been from for-hire vehicles (FHV), including the TNC’s. Further, technology has changed significantly for advanced traffic analysis, traffic light management and lane management that could be deployed against congestion.

In 2018, London Mayor Sadiq Khan released his draft transport strategy, which aims to have four out of five trips in the city made by public transport, cycling, or walking by 2040.
Singapore

Population: 5.6 million  
Time Spent in Congestion: 10 hours  
City Archetype: Multimodal core

Per The World Bank, Singapore’s annual population growth sat at 1.3% for 2016. However, vehicle registration grew only 0.25%, since that was the maximum allowable growth rate for vehicle ownership.

The city has addressed congestion in an organized way since the mid-1970s. So, the biggest challenge facing Singapore will be the maintenance and development of its “smart nation” concept. Essentially, the government is looking to connect the entire city through use of sensors that collect data on all aspects of urban life. Then using AI and big data, decisions can be made as to the services needed by civilians. The one predictable pushback would be privacy concerns.

Singapore also features widened sidewalks that move bicycle traffic off the roadway altogether. If also features numerous pedestrian bridges for street crossing, removing pedestrians from active roadway crossings.

Singapore was the pioneer of congestion pricing, implementing its system in 1998. The electronic road pricing (ERP) scheme, which replaced a cordon pricing program implemented in 1975, is fully automatic on specific routes, times of day, and directions of travel, with variable pricing designed to respond to congestion in real time. Vehicles are required to have an in-vehicle unit on the dashboard and a smart card with fare stored on it. Overhead gantries collect the fee, which can reach as much as $3, on a per-pass basis at more than 50 points within and surrounding the central business district. The in-vehicle unit costs $111. Fees are charged from 7 a.m. to 8 p.m. from Monday to Saturday. There is no charge on Sundays or public holidays (including after 1 p.m. the preceding day). The initial investment was $110 million; on an annual basis, operating costs are $18.5 million and net revenue $100 million.

Another measure is Singapore’s Certificate of Entitlement, the document its citizens are required to possess in order to own a car. Prices can reach as high as $50,000. Starting in February 2018, a policy took effect under which no new certificates would be issued, forcing new drivers to bid on existing certificates.

In addition, to its economic incentives, Singapore is heavily investing in its public infrastructure, expecting to spend S$20 billion in the next five years. Further, the government expects to double the reach of its train network by 2030.

While not presenting a major challenge, it should still be noted that Singapore faces an ever-aging populace. This means that the government will need to ensure that public transportation takes into account the needs of the elderly. An emphasis will be placed on safe, easily accessible modes of transport. An example of the above would include installing ramps and lifts for wheelchairs in strategic points of transport access.
Conclusion

Congestion is likely to get worse in the near term. That’s both because the six megatrends identified earlier show no signs of weakening, and because cities have not yet fully come to grips with the steps they’ll need to take to make the situation better. The good news, as this report makes clear, is that there are plenty of tools available that can help to reduce congestion and numerous examples of forward-thinking cities that have begun to implement them, both in the U.S. and around the world.

To most effectively combat congestion, government leaders, planners, and other stakeholders should keep in mind the following key takeaways of this report:

**Technology is no panacea, but can be a powerful tool.** The idea that AVs and other disruptive technologies will be decisive in the battle against congestion can be an attractive one. But the impact of self-driving cars on existing transportation networks is uncertain, and the full impact of these vehicles won’t arrive anytime soon. However, the proliferation of censors and other smart city technologies can have a more immediate impact on the quality of transportation. The ability to set highway tolls or parking fees dynamically or broadcast parking availability are examples of how these tools can help.

**Weigh solutions that work on the supply and the demand sides of the congestion equation in both the near and long-term.** Investments in bus- and bicycle-only lanes, public transit expansion, and road and bridge building can add capacity to a city’s transportation network. Various measures that can reduce demand for the roads in that network include demand-based expressway tolls and parking fees, limits on TNC vehicle registrations, surcharges on TNC or taxi rides, congestion pricing, and more. Some of these can be implemented and show results in the near term, while others require more lead time and are only effective on a longer time horizon.

**Parking is an important tool and has the ability to reduce congestion.** 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, or its prices aren’t appropriately set on street, travelers have more incentive to circle, cars clog streets looking for spaces, and delivery trucks, taxis, and TNC vehicles contribute to curb activity. The introduction of mobility hubs, curb management, adaptive design and advanced automation all provide options for improving the use of existing infrastructure and its capacity.

**Consider the entire transportation ecosystem to drive city livability.** There are many levers that policymakers have within the ecosystem: public transit and infrastructure, new technologies, regulation, parking, and economic incentives and disincentives. Strategies and policy require taking a holistic integrated approach to drive city livability. Tradeoffs will have to be made, often times with no clear answer. Furthermore, ecosystem players’ roles may evolve in the future. For example, parking can operate as an extension of the curb, mitigating congestion there (and limiting its spillover into the street itself).

**Foster innovation through collaboration, pilots, and agile policy making.** Technology is rapidly evolving, creating uncertainty. New learnings will be required to make educated and effective policies around mobility which will come through collaboration and pilots.

**The mix of solutions applied will vary across city archetypes.** The challenges that cities face will vary by archetype and thus the mix of solutions applied will also vary by archetype. Globally, most major urban areas typically follow one of seven models. These help determine which set of solutions is most likely to be successful for a given city. Policymakers have an opportunity to take a proactive approach to affect the trajectory of mobility and create livability cities with convenient, clean, and cost-effective mobility solutions. But ill-considered and reactive choices that don’t consider the entire transportation ecosystem—including parking—are more likely to exacerbate congestion than to relieve it. Public private collaboration with a focus on citizen centered mobility hold significant opportunity for an effective multimodal future.
End Notes

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Glossary

Advanced Navigation Technologies – Technology that leverages big data and artificial intelligence to dynamically route vehicles to their intended destination.

Autonomous Vehicle Levels (AV L1-L5) – The term autonomous vehicle refers to levels of automation within a vehicle.

Circling – Vehicles driving around a fixed area searching for parking; Rideshare vehicles driving around a fixed area circulating on the road while waiting for a fare.

Compound Average Growth Rate (CAGR) – Measures growth average rate of growth over a period of time periods.

Congestion – A condition on road networks that occurs as use increases, and is characterized by slower speeds, longer trip times, and vehicle backups.

Controlled Motorway – Also known as smart motorway - a section of highway that uses variable speed limits and usage of the shoulder lane to increase road capacity and traffic flow.

Curb Congestion – Congestion that is created around the curb, often times due to transportation network companies or package delivery companies.

Deadhead Miles – Miles driven by TNC's without a passenger.

Delivery Drones – Unmanned aerial vehicles (UAVs) used to deliver packages.

Demand Pricing – In parking, dynamically adjusting parking prices based on market usage; also known as market pricing.

Dynamic Traffic Light Management – Dynamically adjusting traffic lights based on congestion.

Emissions – Harmful noxious gases emitted from an automobile that contribute to pollution.

First Mile – Refers to the beginning leg of the transportation process for people or packages.

Fleet – A set of vehicles operating together or under the same ownership, referred in the context of future autonomous vehicles.

For Hire Vehicles (FHV) – Vehicles used to be paid for transportation services such as TNCs and Taxis.

Hard Shoulder Running – Using the shoulder as an extra lane to increase road capacity.

Highly Autonomous Vehicle (AV) – Refers to a driverless vehicle. A High Automation (L4) and Full automation (L5) vehicles are capable of handling all aspects of driving under most circumstances – geo-fenced and under a range of environmental conditions.

High Occupancy Tolled Lane (HOT) – A restricted access highway lane for high-occupancy vehicles to travel for free or at discounted rates.

High Occupancy Vehicle Lane (HOV) – A restricted access highway lane for vehicles with two or more passengers.

Hyperloop – Technology that leverages underground tunnels to create high-speed infrastructure.

Induced Demand – The condition where when the supply of a good is increased, it increases demand—known as latent demand in economics.

Infrastructure – The fundamental physical structures and facilities that are required for society and necessary for cities and economies to function.
**Inner City Ring** – The inside of a city ring within the city limits.

**Last Mile** – Refers to the final leg of the transportation journey for people or packages.

**Mobility Hub** – Designated areas that integrate multiple modes of transportation.

**Multi-modal** – Incorporating multiple modes of transit in a transportation system, i.e., bus, rail, vehicle, scooter, bicycle, walking, etc.

**Parking** – The act of placing a vehicle in a space on street or off street, where the vehicle is parked when not in use.

**Parking Minimums** – The minimum parking requirements for every land use, set by urban planners ensure that developers will provide enough spaces to satisfy the peak demand for free parking.

**Parking Operator** – A business that owns and/or manages the operation of parking facilities, parking services and associated services, i.e., concierges, greeters, patient transport, shuttle services, vehicle cleaning/servicing, package staging, shared vehicle staging, etc.

**Platooning** – The use of technology and automated driving systems to group vehicles to drive at a constant speed.

**Public Transportation** – Travel systems with fixed routes and set fares that are available for public usage, i.e., buses, trains, rail, subways, etc.

**Public-Private Partnership (P3)** – partnership between a government agency and the private sector in the delivery of goods or services to the public, notably used in transportation and infrastructure projects.

**Outer City Ring** – The outer ring within a city just before the suburbs.

**Robo-taxi** – A for hire autonomous vehicle.

**Smart Motorway** – a section of highway that uses variable speed limits and usage of the shoulder lane to increase road capacity and traffic flow.

**Smart Parking Technology** – technology aimed to make parking a seamless process through enhanced ticketing, navigation, and price transparency.

**Single Occupancy Vehicle (SOV)** – A vehicle with one driver as the sole occupant.

**Streetscape** – The layout of the streets.

**Transportation Demand Management (TDM)** – a program of information, encouragement and incentives provided by local or regional organizations to help people know about and use all their transportation options to optimize all modes in the system

**Transportation Network Companies (TNC)** – Mobility service provider that pairs passengers with drivers.

**Urban Sprawl** – The spread of a city created through suburbanization.

**Vehicle Miles Traveled (VMT)** – The calculation of total miles travelled by a vehicle.

**Vehicle to Everything (V2X)** – Communication technology that equips vehicles to communicate with its connected surroundings.

**Vehicle to Infrastructure (V2I)** – Communication technology that equips vehicles to communicate with smart infrastructure, such as roads and parking.

**Vehicle to Vehicle (V2V)** – Communication technology that equips vehicles to communicate with other vehicles in real time.


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