

## **SHIFTING GEARS**

# TECHNOLOGIES, BEHAVIORS, AND THE FUTURE OF TRANSPORTATION

A report prepared by students of Johns Hopkins University, School of Advanced International Studies

## **ABOUT THE PROJECT**

This report was authored by students of the Johns Hopkins University School of Advanced International Studies (SAIS) as part of a practicum project in the Energy, Resources, and Environment Program. The practicum requires student teams to partner with key organizations to address critical energy and environmental policy challenges. Here, students collaborated with BP to further the understanding of how behavioral, technology, and policy changes may affect the transportation sector over the next twenty years.

Johns Hopkins University School of Advanced International Studies Energy, Resources, and Environment Student Practicum

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#### **EXECUTIVE SUMMARY**

We may be witnessing the next revolution in transportation. Rapidly evolving technology has led to innovative new companies and behavioral shifts that are changing how consumers navigate their increasingly urbanized and interconnected world. As investors, policy makers and citizens face the complex interdependencies of transportation networks, what are the trends that will most significantly impact our behavior over the coming decades? By examining a variety of technology, policy, and behavioral changes as seen across a selection of U.S. cities, this report considers the impact that they may have on Vehicle Miles Traveled (VMT) and how they will shape the future of transportation.

#### **The Transportation Landscape**

A key point that affects the transportation network of every urban area is the relative inflexibility of the system's overall carrying capacity. Any city has an upper limit of the vehicles on its roads, passengers on its public transit, and bicycles on its paths. The closer the network is to reaching that capacity, the more its traffic flows will be disrupted. Yet the fixed physical nature of transportation infrastructure means that any changes to the system often require high capital investments and cannot be quickly completed. Additionally, the fixed nature of many types of mass transit means that even with large investments in that infrastructure, the need to travel between and around nodal points on the system will continue to exist. The demand for interstitial movement (transportation options between fixed points in an infrastructure system) will be a key factor in shaping transportation needs.

Moreover, barring major regional population and economic decline, transportation systems seem to trend towards increased utilization of system capacity. Infrastructure additions will not lead to major changes in the utilization of system, since induced demand leads to greater usage of a transportation option as soon as its capacity is expanded. Although chokepoints in the system can be removed with judicious system expansion, this means that improving the overall transportation flows of a system in a way that significantly reduces VMT is difficult.

These underlying system trends exist in a context of increasing urbanization, spurred in part by millennials moving in large numbers into cities across the country. This has led to a lag in adequate housing growth within urban centers and placed an increasing strain on existing transportation infrastructure. While recent downturns in per-capita vehicle purchases and VMT growth seem to be primarily caused due to the economic impacts of the 2008 financial crisis, a variety of technologies, behaviors, and policies will affect future VMT. By examining their potential impacts, we can gain a deeper understanding of the dynamics of our transportation future.

#### **Changing Technologies and Behaviors**

With the proliferation of innovative companies and technologies driven by an increasingly rich appbased software ecosystem, the growing ease of multi-modal transportation behavior has the potential to radically reshape how urban populations approach transportation. Driven by greater information access and enabling on-the-fly planning, the integration of technology and transportation options has led to more freedom of choice for consumers. With a wide variety of easy-to-access travel options, including ride-hail apps, carshare, and bikeshare, there is a new flexibility to adjust to changing situations and individual transportation needs. While policymakers may need to become more innovative in their approaches to ensure equitable access for the whole population to this new transportation ecosystem, the rapid rise of companies like Uber, Lyft, and Car2Go and the growth of municipal bike-share options show that the behavioral changes they represent are already reshaping transportation dynamics. The prognosis of the trends seems clear: this technology and the business models adopted from it are out in the open and not tied to the fortune of individual companies.

Autonomous vehicles represent an additional near-future technological advancement that could lead to major transportation changes. However, their impact on existing transportation networks seems to be dependent on the level of adoption. With widespread adoption, autonomous vehicles have the potential to enhance system carrying capacity due to shorter headway between vehicles and improve traffic flows by reducing accidents and poor driving. This in turn could spur increased VMT growth. The possibilities presented by an autonomous revolution should be tempered by a number of major barriers that continue to exist. The key question is what the tipping point will be in the transition process, with many of the most significant impacts unrealized until that threshold of autonomous vehicles in the system has been reached. Widespread adoption of autonomous vehicles may be delayed in the short to medium term, with regulatory, insurance, or behavioral hurdles that depend on both the usage model (private ownership or carshare) and the continued rate of that technology's growth and public acceptance.

Other changes in technology and policy also affect transportation behavior. Increasingly, Internet-driven telework options are supplementing or replacing traditional office-based work and allowing greater work flexibility. For many employees, this flexibility in work hours has led to "peak spreading" of rush hour conditions across longer daily timeframes. This can help ease the impacts of rush hour delays that have grown due to strained system capacities. Widespread acceptance of teleworking could even lead to shifts in commuting behavior, with reductions in VMT as employees increasingly work from home instead of driving into work. In a similar way, technologies like multimodal-integrating software and Intelligent Transportation Systems (ITS) engineering can increase system capacity without major infrastructure additions, with improvements in data analytics and information communication technologies driving the use of transportation data for real time decision making. Cities are also leading

the way in reshaping their transportation landscapes, with land use changes and transportation demand management (TDM) initiatives undertaken to incentivize shifts away from car-centric neighborhoods and travel patterns.

#### **Final Word**

Cities are unique and the exact manner in which these trends impact the transportation behavior and VMT of their populations may differ. City size, rate of growth, and density (of both population and traffic) determine the total transportation needs of its citizens. The geography of infrastructure and regional traffic flows, state of transportation infrastructure, and extent to which a mix of multi-modal options exist impact the dynamics of each individual system. At the policy level, the regulatory and public buy-in and the political will for expanding infrastructure or exploring new innovations may spur quicker changes in some cities versus others. But all of these cities are similar: behavioral trends and changing technologies will affect them all, both across the U.S. and around the world.

#### **INTRODUCTION**

This report focuses on Vehicle Miles Travelled (VMT) in order to examine the impact that different technologies and behavioral shifts will have on future transportation behavior. VMT was selected due to both the extremely high rate of vehicle usage in the U.S. (and therefore the importance of vehicle travel to its transportation decisions) and a shift in many states and cities to using VMT as their primary analysis metric.<sup>1</sup> Therefore, since the report focuses on trends that impact VMT, it does not analyze technologies that would have the effect of disaggregating VMT from gas consumption or emissions, like electric vehicles (EVs) or hydrogen-fuel cell powered vehicles. In order to examine the potential impacts to VMT, however, it is first necessary to establish a baseline for future VMT that would result from a business-as-usual scenario. This analysis relies on the Energy Information Agency's Reference Case for VMT Projection<sup>2</sup>, which predicts that VMT for light duty vehicles in the United States will be 3.225 trillion miles in 2035. This represents an increase in VMT of 17% from 2015 figures and a compounded annual growth rate of 0.75%.



Recent shifts in transportation behavior have led to various interpretations and forecasts for how Americans will choose to travel going forward. Experts disagree on why car ownership and vehicle miles traveled dipped after the recession; OECD<sup>3</sup> and the Council of Economic Advisors<sup>4</sup> have both produced reports arriving at different conclusions. Some economists argue that these statistics were simply pushed down by economic forces. People stopped buying cars and driving because they were out of work. Others argue that we are witnessing the beginning of a fundamental shift in the way we get around. Perhaps millennials, early adopters of new technologies such as ridesharing and car sharing, simply don't want to purchase cars as their parents had.

We argue that while economic forces were the likely the main driver of the recent dip in vehicle miles traveled (VMT) and car ownership per capita, emerging trends may have an impact going forward. As the graphs below demonstrate, recent data suggests that the downturn in car ownership and vehicle miles traveled was probably driven by economic considerations. Changes in car ownership have tracked the consumer confidence index. Likewise, changes in VMT growth have moved in tandem with changes in GDP growth. In recent years, both have trended back upwards. Last year was the seventh consecutive year of year-over-year car sales growth in the United States, and new purchases have trended towards trucks and SUVs.





affect the extent to which vehicle ownership and VMT climb. In order to better understand these changes, we have interviewed industry experts, conducted academic literature reviews, and analyzed data from a number of sources including the Department of Transportation, the Department of Energy, the Federal Highway Administration, the US Census, and private research companies. Our report will cover the impact of multimodal transportation, rideshare, carshare, bikeshare, transportation demand management strategies, and autonomous vehicles.

#### **MULTIMODAL TRANSPORTATION**

Multimodal transportation can be seen as a broadening of a consumer's transportation diet. Rather than relying on one single means of moving within a city from point to point, the growth of a variety of easily accessible transportation options means that different approaches are available, often within the same overall trip. Driven by greater information access and enabling on-the-fly planning, the integration of technology and transportation options has led to more freedom of choice for consumers. With a wide variety of easy-to-access travel options, including ride-hail apps, carshare, and bikeshare, there is a new flexibility to adjust to changing situations and individual transportation needs.

Multimodal transportation can also improve the transit experience by providing a low cost way of facilitating interstitial movement: movement between major nodes within a transportation system that lack easy direct access to each other. One example of this is moving between mass transit stops that are physically close but that take a lot of time to reach by fixed existing routes. A common case where interstitial travel is more convenient than relying on the existing transit infrastructure is U-shaped rail systems such as the Red Line in Washington, DC (pictured below).<sup>5</sup> If one were to take the train to travel from Bethesda to Silver Spring, he or she would have to travel south into the heart of the city in

order to then travel north back into Maryland. The seamless incorporation of other transportation options between fixed points in the transportation infrastructure makes these types of commutes much more convenient.

### **MULTIMODAL TRANSPORTATION**

Without fixed connections between opposite arms of Washington D.C.'s Red Line, multimodal options are necessary for direct trips between two points like Bethesda and Silver Spring. Otherwise, a trip into and back out of the downtown area is required.



An additional example is the city of Columbus, Ohio, which was awarded the 2016 Smart City Challenge grant from the U.S. Department of Transportation (DOT) and Vulcan, Inc., a technology company.<sup>6</sup> A \$50 million dollar grant, the vision of "Smart Columbus" is to reinvent mobility, including a comprehensive, multi-modal approach to decarbonizing the city and region's transportation options. Through a combination of DOT funding, in addition to technology company partnerships and funding, one of Smart Columbus' nineteen projects will focus on multimodal transportation through developing an app to combine trip planning, whether by bus, bike, or car. Additional projects include smart mobility hubs, where a user can access multiple forms of transit, and a common payment system.<sup>7</sup> The incorporation of rideshare in multimodal transportation could have a large impact on the behavior of residents that live further from transit stops. Most people are willing to walk to up "between a quarter and a half mile" to public transit.<sup>8</sup> Households within this distance are in what is known as High Quality Transit Areas (HQTA) and tend to drive 4,400 miles less per year on average.<sup>9</sup> The seamless addition of rideshare to multimodal transportation solutions could result in a shift in behavior for those living beyond a half mile from transit resulting in a similar reduction in VMT. The images below show how multimodal transportation with ridesharing could expand the area in which households behave as if they lived by mass transit.<sup>10</sup>

#### **MULTIMODAL EXPANSION**

While the same number of High Quality Transit Areas (HQTA) exist in both images (denoted by shaded circles), multimodal expansion as seen on the right results in a significant increase in the area served by transit from fixed points in the same system. (Map data ©2017 Google)



Using a cumulative density function showing percent of the US population by distance to public transit and a negative correlation between distance and multimodal adoption, we estimate that multimodal solutions may result in a 1% decrease in projected, yearly base-line VMT.



#### **Bikeshare**

Starting last year, in most of China's first-tier cities, "little colored bikes" began to nimbly overtake vehicles on clogged streets. They were not a popular bicycle brand which sold well enough to become ubiquitous; instead they were dockless shared bikes, developed thanks to mobile apps and advanced financial technology, and operated by competing technology companies. Described as the "Uber for bikes," they are quickly becoming ubiquitous due to their convenience and ease of use. Mobile apps help riders locate the nearest bikes, unlocking them by scanning the QR code attached to each bike or generating a combination. Riders are able to drop the bike in a public space whenever their trip ends and also make direct mobile payments. Key to this concept is that there is no dock to return the bikes to.

The market for this kind of bikeshare is immense. Rapid urbanization in China has made the firstmile/last-mile problem<sup>11</sup> more severe in recent years. Despite the relatively faster speed of infrastructure construction in China, urban residents are living further away from public transit hubs in large cities. With their extraordinary flexibility and accessibility, these dock-less bikes provide a perfect solution to ride the first/last mile. The bikeshare programs also successfully target commuters and students who take public transit every day, with very affordable prices. In general, the deposit for opening an account is around \$14 to \$44 (99-299 RMB), with the time payment usually only a few cents (1-2 RMB) per hour. In only two years, over two million bikes have been put on the streets of Chinese cities. They are usually seen piling up around major metro and bus stations, where the demand for a first/last mile ride is the highest. Investors like technology companies and venture capital (VC) firms are pouring money into the new business model. Mobike, one of the leading dock-less bikeshare companies, has raised half a billion dollars of VC founding in less than one year. Ofo, a major competitor of Mobike, reached a market value of approximately 10 billion dollars after several rounds of financing in 2016 and is seeking another, with a potential market value of over 30 billion dollars upon completion.

Today, Chinese start-ups are beginning to march into international markets. This bike sharing approach provides a solution for the first-mile/last-mile problem and is equally applicable to congested urban areas across countries and regions. Recently, Mobike and its competitors have put the dock-less shared bikes in Britain and Singapore and started expanding into to the U.S., including in Washington, D.C.<sup>12</sup> But are they really replicable everywhere? Experts in the bikeshare industry have expressed some concern. With greater flexibility, the dock-less bikes are more accessible. However, at the same time, they face more serious challenges such as vandalism and theft, which is currently occurring. Despite a lack of information from the companies, both Chinese and U.S. social media reports include users adding private locks to the shared bikes, as well as parking bikes in private homes and apartment buildings.<sup>13</sup> Meanwhile, vandalism is so severe that there is now an increased demand for bike repairers from the bikeshare companies. At one repair center in Beijing, thousands of broken bikes fill a 100-yard street, with piles of bikes over 6 feet high. By comparison, DC Capital Bikeshare, a more traditional bikeshare model operated in the Washington DC metro area, only reports around 200 stolen bikes in the past 6 years. Of those, only 58 bikes were completely lost while the rest were successfully recovered.

Finally, regulation can be another obstacle for dock-less bikeshare programs, as the local authorities' cooperation can determine the program's success. For instance, are helmets required for bike riders? What public space is permitted for bike parking? Just like traditional bikeshare programs, these questions have to be answered for dock-less bikeshare programs as well. Beginning in 2017, the Chinese start-ups went international, with the three leading companies (Mobike, Ofo, and Bluegogo) landing in Singapore, Cambridge, and San Francisco. However, the initial launches were all very different from the original plans due to local regulations.

Bikeshare as a technology is not expected to have a significant impact on VMT going forward, as it primarily competes with public transportation and walking. In a recent survey conducted by DC Capital Bikeshare<sup>14</sup>, only 9% of customers reported reducing their VMT by at least 1,000 miles per year. The percentage of customers that reduced their VMT by at least 2,500 miles per year was 3.8. While bikeshare by itself is not a cause of significant VMT reductions, it could have an impact on VMT in conjunction with multimodal transportation (as described above). The incorporation of bikeshare in a seamless multimodal solution could make traveling by public transportation more attractive as it helps address the first mile/last mile dilemma.

#### Carshare

Carsharing allows its users to rent cars for short periods of time, as use is needed, and for payment only of the utilization period. It allows flexibility for urban residents who only need to use cars occasionally. With enough carshare vehicle capacity in a city, it can be convenient and affordable enough that people can easily downsize to owning just one car or even choose a path of no vehicle ownership. The flexibility that carshare services provide allows consumers to enjoy the benefits of increased mobility provided by a private car without requiring individual or additional vehicle ownership. There has been substantial growth in the popularity of carsharing across the U.S., with over 1.2 million members and almost 20 million vehicles as of January 2014 and with 79% growth observed from 2012-2014.<sup>15</sup>

While carshare companies all allow on-the-fly reservation of vehicles through mobile apps and unlocking of reserved cars by either electronic keycard or app-based codes, vehicle choices and parking requirements differ. For example, Zipcar, a leading American carsharing company, requires its members to return the cars to the exact garage or parking lot where the cars are located. On the other hand, car2go is an example of one-way carsharing, which allows its users to park in different locations from where they begin their journeys. The final parking destination can also be designated parking spots or, depending on the city, even potentially be any curbside parking area. Zipcar offers a wider range of vehicle types, while car2go is more limited in the models available, only recently beginning to offer some Mercedes-Benz vehicle models in addition to Smart ForTwos.<sup>16</sup> No matter the specific business model, these new carshare companies (with numerous competitors to Zipcar and car2go) differ from the traditional car rental business because of their greater flexibility and accessibility. The dispersed availability and variable parking models are a transition to a "dock-less" car sharing concept, breaking away from traditional rental car retail locations.

The San Francisco metropolitan area demonstrates the wide variety of carshare companies and the rapid innovations in business models seen across them. While the larger industry players (Zipcar and car2go) are both present, there are a number of existing competitors as well as newly formed operators. GM's new start-up style offshoot Maven represents an attempt by traditional auto manufacturers to begin entering the market.<sup>17</sup> City CarShare, the oldest carshare company in San Francisco, operates as a non-profit that previously competed as an independent carshare provider but now rents its fleet to another new company, Getaround.<sup>18</sup> Instead of owning its own vehicle fleet, Getaround provides a platform to pair up vehicle-seeking drivers and car owners, operating as a market maker for rentals of private vehicles. This type of peer-to-peer car-share business faces more operational difficulties and has significantly fewer vehicles than more established traditional car-sharing companies like Zipcar and car2go. If the concept succeeds, however, it represents a potentially

enormous behavioral change to vehicle ownership and use, with more efficient utilization of privately owned vehicles through their inclusion in the shared economy.

While the range of impacts on individual carshare-utilizing households are extremely broad due to varying degrees of annual use of the services, research examining car2go and its VMT impact has shown that a minority of active users (between 2%-5%) have sold their vehicles or not acquired new vehicles (7%-10%) due to their utilization of its services.<sup>19</sup> For every additional car2go vehicle on the road, a range of between 1 to 11 private vehicles have been estimated to be removed due to both sales and suppression of new vehicle purchases. This has led to estimated average reductions of 10% of net annual VMT among households using the car2go service, with Washington, D.C. exhibiting a 16% estimated reduction. Small changes in driving behavior by the majority of users coupled with significant changes by a minority of users lead to these substantial reductions from current VMT levels. These trends can be expected to be seen across other carshare platforms and their rapidly growing active user bases.

#### **Rideshare**

Rideshare services (also known as e-hailing) are app-based on-demand ride summons that function similarly to taxis. They allow booking and payment directly through their apps thanks to integrated mobile payment technology. Additionally, their algorithm-driven and app-based approach offers significant advantages over taxis. Compared to traditional taxis, improved rideshare technologies match drivers and passengers more efficiently while a less-regulated market means a much larger pool of drivers. Moreover, flexible pricing mechanism like price surges during periods of peak demand more accurately reflect market signals by rapidly matching supply and demand<sup>20</sup>. As a result, the e-hailing technology raises capacity utilization, which is measured either by the fraction of time that drivers have a fare-paying passenger in the car or by the fraction of miles that drivers log in which a passenger is in the car, among Uber/Lyft drivers significantly. In Los Angeles and Seattle, the capacity utilization rate of e-hailing services can be around 15 - 24% higher than traditional taxi services<sup>21</sup>.



The two most well-known providers are Uber and Lyft, both of which offer a traditional taxi-style private ride or a shared ride with other passengers who enter and exit the ride at different locations. The latter form of trip is more attractive when a rider is not in a rush and does not mind a short detour to pick up other passengers, because although travel time may increase the individual fare prices will be lower. While rideshare services have traditionally been seen as similar to traditional taxi services, with the low prices and greater density of users per vehicle of rideshare services, they are now becoming more comparable to mass transit. These services have quickly gained popularity in large cities. In Los Angeles, by September 2016, Lyft has grown 25 fold since it entered the market in 2014; Uber provides more than 150,000 rides per day, and ride-sharing (or pooling) services account for 25% of ride requests<sup>23</sup>.

This type of technology is not dependent on a single business, as even if Uber and Lyft vanished, the technology is out of the bag and a business model is now the key differentiating feature between companies. For example, in Austin, Texas, local companies are springing up in the wake of Uber and Lyft's exit from the market in early 2016. Following the City of Austin's passage of Proposition 1, which required mandatory fingerprinting background checks for all ridesharing drivers, Uber and Lyft left the market. As of early 2017, there are over 7 new ridesharing companies in Austin, including Rideshare Austin, which has 4,300 active drivers and provides 65,000 rides a week.<sup>24</sup> According to Austin transportation officials, before Uber and Lyft left the market, they both claimed 10,000 drivers each, although there was likely overlap, with drivers working for multiple companies.<sup>25</sup> Currently, over 12,000 rideshare drivers have been fingerprinted to work in the ridesharing sector.<sup>26</sup> Despite the exit of two of the most well-known national ridesharing companies, the ridesharing sector in Austin is thriving.

#### **RIDESHARE IMPACT ON TOTAL TRIPS**

While the number of daily trips for yellow taxis in NYC has declined almost 25% over the past two years, total average daily trips have grown up to 40% thanks to the increased use of rideshare services.



But what is the impact that rideshare companies will have on transportation behaviors? Current data suggest that when utilized in a role similar to taxis, these services may lead to increases in trips taken by hailed vehicles while removing ridership from traditional taxis (as shown in the graph to the left<sup>27</sup>). As can be seen in New York City, which offers the most robust data in the country on rideshare companies, average daily rideshare trips have grown since 2015 to almost 400,000 and have led to a 40% increase in total average daily trips, even as total

yellow taxi trips fell by about 25%.

One impact of rideshare that has yet to be fully understood is the impact it could have on mass transit. The price differential between a trip taken using rideshare vs using public transit is often still high enough that a significant numbers of riders have not replaced this segment of their commute with Uber. However, shared rides with other passengers (as seen in UberPool or Lyft Line) are beginning to be introduced to urban transportation systems across the country and bring lower prices than the taxi-like usage of rideshare. If prices and average travel times are competitive with traditional mass transit, we may see ridership shift away from those transit options and towards ridesharing. This would see an increase in VMT and a simultaneous decrease in usage of mass transit, although the extent to which that takes place would be variable on a city-by-city basis and dependent on a variety of factors including existing transit availability and traffic capacity on city streets.

#### LAND USE AND DEMAND MANAGEMENT

Increasingly, policymakers are turning to new approaches to land-use decisions to shape the transportation decisions of their populations. This involves providing more alternatives to cars, undertaking infrastructure changes that emphasize non-automated means of travel, and increasingly relying on long-range planning involving a unified stakeholder-based approach, as opposed to the previously separate planning processes of multiple city departments. The City of Los Angeles emphasized this approach in the creation of its long-range Mobility Plan 2035, realizing the importance that land use decisions play in shaping transportation behaviors.<sup>28</sup> The quality of streets for pedestrian or bicycle traffic plays a key role in individual decisions on using those alternative forms of transportation, which has led Los Angeles to reduce car lanes and narrow roads on many streets, replacing what was a car-centered streetscape with one more appealing to these alternative transportation methods.<sup>29</sup> Planning for future land use has begun to center around emphasizing the benefits of mixed-use development, clustered around transit access points where possible. This transitoriented development (TOD) approach to planning emphasizes investment in the types of infrastructure within transit corridors that spur greater density and more non-vehicular means of travel. This TOD approach can lead to the creation of new high quality transit areas (HQTAs), which have a significant impact on household behavior: as previously stated, residency in a HQTA leads to an average annual decrease of over 4,000 miles to household VMT.

In a further attempt to disincentivize vehicle travel, there has been an embrace of Transportation Demand Management (TDM) strategies by city and regional planners. Rather than trying to increase the supply of infrastructure for traditional personal-vehicle based travel, TDM processes work to reduce demand. This can be done by making alternative transportation approaches more attractive to consumers, either through direct perks or indirect incentives: for example, providing transit subsidies from the city or bicycle facilities at the workplace. The City of Los Angeles has actively pursuing these measures for quite some time, with mandated implementation of TDM measures for businesses meeting certain criteria since 1993.<sup>30</sup> This approach has been expanded to include a wide variety of different elements, including parking incentives for non-single passenger vehicles, transit pass subsidies, and indirect benefits like flex work hours and a commuter club with incentives. Of particular note is the attempt to monetarily disincentivize driving behavior, with parking cash out programs requiring businesses to offer employees a cash payment for giving up their subsidized parking spaces. This led to a 9% reduction in VMT over a four year basis among employees working for companies that offered this option during a pilot program.<sup>31</sup>

An additional approach to disincentivizing driving behavior is congestion pricing, which involves tolling vehicles either along major thoroughfares or within cordoned areas of cities during times of high demand. Congestion pricing mechanisms have been adopted in London, Stockholm, and Singapore.

They are most effective in cities in which traffic patterns involve a mass influx of vehicles into a particular area. The area of the image below shaded in red shows the cordoned tolling area in London.<sup>32</sup> These systems can be very effective at reducing the number of cars on the road.

In the case of London, congestion tolling resulted in a net reduction in cars entering the tolled zone of 20% (cars decreased by 34% while taxis increased by 22%)<sup>33</sup>.

#### **CONGESTION CHARGING ZONES**

As seen in cities including London (pictured), congestion charging zones cover major areas of the central city and apply to vehicular traffic during peak traffic periods. In London's case, this is currently 7:00 am to 6:00 pm every weekday, with an £11.50 charge for non-residents (who pay 10% of the charge).



While an effective an effective transit demand management strategy, congestion pricing is very difficult to implement, and "public acceptance is widely recognized as a major barrier to widespread adoption."<sup>34</sup> New York City was actually successful in passing the legislation needed in order to implement a cordon toll; however, it "was ultimately blocked in the State Legislature."<sup>35</sup> San Francisco has also considered this form of transit demand management over the years, but it has never been implemented.

Given the difficulty in implementing congestion tolling, we do not expect this type of transit demand management to have a material impact on national VMT going forward. It is certainly possible that a handful of cities may pass these types of systems before 2035, but when we ran a Monte Carlo simulation to see how traffic may respond to a full city cordon around Washington, DC, we calculated an expected drop in traffic that would represent less than a 0.2% reduction in national VMT. Therefore, barring any major shifts in cities across the U.S., the net impact on national VMT figures will most likely be marginal.

#### **IMPROVING SYSTEM EFFICIENCY THROUGH TECHNOLOGY**

The proliferation of multimodal transportation technology could have a profound impact on the way we commute by making transit centered transportation much more convenient. Companies such as TransLoc are partnering with public transit agencies and private companies such as Uber in order to create a seamless experience across multiple modes of transportation. The end goal is to eliminate binary decision making in your daily commute. Each day, a multimodal provider could offer you optimized routes based on current traffic and weather conditions, parking availability at your destination, connection times, and transit delays. You will no longer ask yourself whether you should drive, take transit, or bike. Routes will automatically be provided for you, and will include any combination of modes with expected travel times for each set of options. These routes could be comprised of metro, bus, rideshare, bike share, ferry, and walking. Should you prefer to take Uber for the last leg of your commute, TransLoc can arrange for a car to be waiting for you when you arrive at your last stop.

In addition to helping riders get from point A to point B more efficiently, multimodal transportation companies also give public transit agencies the data they need to make smart investment decisions. Whereas transit agencies used to make route decisions based more or less on intuition, they can now use data from multimodal providers to see where exactly their customers are coming from. This allows them to place stops at optimal locations, improving the public transit experience and increasing ridership. The introduction of Uber to the system will also allow for the addition of passengers who would otherwise be unable to access public transit. The incorporation of Uber increases transportation coverage beyond the half mile that most people are willing to walk to catch a bus or train and leads to the HQTA expansion that is projected to decrease national VMT by about 1%.

The incorporation of technology-driven decision making into the toolkit available to city officials has broader uses outside the multimodal and planning space. With increased telemetry and real-time data access capabilities, cities have begun to provide improved information on traffic and parking, including initiating pilot programs to provide real-time demand-based pricing for on-street parking spaces. While these types of policies have direct impact on consumers, further embrace of Intelligent Transportation System (ITS) technology by municipalities allows for more responsive system-level operational changes, including both real-time responsive traffic monitoring and traffic signal optimization. The City of Columbus, OH, which won the 2016 U.S. Department of Transportation's (USDOT) Smart Cities Initiative, is poised to be a leader in adopting ITS technology. In addition to a wide variety of multimodal-enabling technologies, the city's Smart Columbus initiative is focused on implementing a number of connectivity-driven ITS projects, with rollouts beginning as soon as 2018.<sup>36</sup> These included an integrated data exchange, real-time monitoring and reporting of parking and delivery zone availability, and improved real-time management of parking and traffic flows for major events. With an

ambitious portfolio of 15 projects funded by the USDOT and strong policy support for its implementation, the biggest question about the impact of Smart Columbus is how quickly other cities follow suit.

The other question about these technology-driven approaches are their actual impact on traffic and transportation behavior. While this approach leads to an improved system efficiency, previous experience in transportation suggests that those gains will not translate to any significant reduction in actual congestion levels on city streets due to the creation of generated traffic due to induced demand.<sup>37</sup> With expansion of capacity on congested urban roads (traditionally due to construction of new infrastructure, but here in more efficient utilization of existing networks), additional vehicle traffic will be generated that takes advantage of the newly-improved transportation route. In the short term, this may mean drivers willing to travel farther distances within a city and increasing their willingness to drive due to less congested streets. Longer term, this allows for greater shifts of a city's population to areas outside their core, with the increased distance outweighed by the increased travel efficiency. Both shifts can inconvenience residents of previously lower-traffic areas, as new traffic flows into those neighborhoods or smaller outlying communities. This induced demand, created by improvements to the traffic system, can therefore lead to less utilization of modal alternatives to driving and may actually even lead to increased VMT as more driving is incentivized by the improved traffic flows. The empirical effects of roadway capacity expansion on urban traffic volume have been shown to have an average increase of 9% VMT for a 10% increase in urban lane miles.<sup>38</sup>

#### **SHIFTING WORK PATTERNS**

Transportation networks in metropolitan areas are under growing strain, with the capacity of mass transit and road networks failing to adequately serve users during times of peak demand. Greater flexibility in work patterns has emerged, driven in part due to the necessity of adapting to this more congested and slower-moving reality. A combination of increased telework capabilities and growing acceptance of less traditional 9-to-5 work environments has begun to change commuter behavior. No longer confined to offices and commutes at uniform times, employees offered increased flexibility in their approach to work may be resulting in shifting demand from what were once major peaks in daily system usage. These spikes, which corresponded with the traditional start and end to the work day, may therefore begin to see a smoothing over time. Workday schedules will begin to differ in more significant ways, spreading the load on transportation networks over greater periods than what were peak rush hours.

This may have two major behavioral effects. The first is the previously mentioned impact of induced demand. Fewer vehicles on the road at peak times may actually lead to increased propensity to drive

that route instead of travel by alternate means. As levels of vehicle usage decrease from previous peaks levels, the resulting faster travel times and decrease in congestion may incentivize more driving behavior, increasing VMT over previous levels. On the other hand, the longer-term behavioral impacts of this shift in work behaviors may lead to a significant changes in the way that work is conducted.

As both employees and employers become more accepting of workloads with increasing amounts of telework, a shift away from an office-based physical presence in the workspace may emerge. Employees working from home or co-work spaces near their residences would lead to a decrease in both number and length of necessary daily vehicle trips.

Should teleworking gain in acceptance, we could see a modest decrease in VMT. Commuting currently accounts for about 28% of all VMT.<sup>39</sup> According to a Gallup poll in 2015, 37% of workers in the United States have worked from home using a computer to communicate for their job at some point in their career; however, "U.S. workers say they commute from home rather than go into the office for about two days per month, on average."<sup>40</sup> Assuming 260 workdays per year, U.S. workers telecommute on 9.2% of their workdays. As the chart below demonstrates, if U.S. workers were to increase their average telecommuting time to 25%, it would result in a decrease in annual VMT of about 4.1% compared to the reference projection. Given that "the growth in [telecommuting] appears to have

leveled off in recent years," it is probably unlikely that we would see growth of this magnitude by 2035<sup>41</sup>. If, on the other hand, average telecommuting time were to increase to 15%, there would be about a 1.5% reduction in annual VMT compared to the reference projection.



#### **CHANGING TECHNOLOGIES: AUTONOMOUS VEHICLES**

When considering the future of transportation, both within the United States and globally, there remains a large question mark: the role of autonomous vehicles (AV). With new technology companies such as Tesla, Uber, and Google, along with traditional industry stalwarts like GM, Ford, and Toyota, all aiming to develop driverless cars by 2020 (or earlier), the race for the 21<sup>st</sup> century car is on. But, how will autonomous vehicles impact transportation trends?

Currently, most research determines that autonomous vehicle's impact will be dependent on their level of adoption into the transportation system. If autonomous vehicle adoption is widespread, they have the potential to enhance how many cars a road can carry (system carrying capacity). Due to preprogrammed instructions, AV can theoretically reduce the distance between vehicles, in addition to reducing traffic accidents and poor driving. From swerving outside the driving lanes to getting tired, human drivers have weaknesses that machine drivers don't. Additionally, AV could improve traffic flow by "chaining together" vehicles, while also replacing mass transit. Also, AV adoption could also impact social behavior. For instance, instead of parking a non-AV car when running errands, an AV could be programmed to continue on its way after a passenger drop-off, by circling around the block or going back home to pick-up another passenger. In turn, these changes could spur increased VMT growth, as autonomous vehicles are used more, not less, than non-autonomous vehicles due to their unique technological capabilities.

However, a number of barriers exist regarding the adoption of autonomous vehicles. The key question is what the tipping point will be in the transition process, with many of the most significant impacts not coming until that threshold of autonomous vehicles in the system is reached. For instance, as seen in one of two recent accidents during an Uber autonomous vehicle pilot program in Tempe, Arizona, the mix of non-AV and AV vehicles on the road can be problematic.<sup>42</sup> A 2017 non-hazardous accident was caused due to human error, when a driver failed to yield to (and collided with) the self-driving Uber vehicle. Accidents during the transitional phase may also strongly impact public opinion on continued integration of autonomous vehicles into the existing traffic system or lead to delays in the adoption process. This was seen in early 2018, when an Uber AV was involved in a fatal pedestrian accident in Tempe that led to a suspension of Uber's AV pilot tests.<sup>43</sup>

In addition to the technology mix of vehicles on the road, widespread adoption of AV also requires drastic behavioral shifts. For instance, what if school buses became self-driving? Would parents feel comfortable putting their children on a bus—with no driver? Furthermore, how will regulatory or insurance systems based on traditional private ownership models adapt to new technologies? If AV adoption creates less risk for accidents, will insurance companies in the future require AV for certain driving classes, such as seniors?

Additionally, regulatory barriers exist for AV adoption, as shown in Uber's experience in both California and Arizona. In California, permits are required for autonomous vehicles and when Uber's 2016 San Francisco pilot program broke those rules, they were ordered off public roadways. Uber resumed the pilot in Arizona, a state with fewer regulatory barriers, until the fatal pedestrian accident in Tempe in early 2018 led to the State of Arizona indefinitely shutting down the program. Meanwhile, other states such as Florida, Michigan, Nevada, and the District of Columbia have enacted regulation to encourage a "driverless" future and the deployment of autonomous vehicles. It remains to be seen whether these states continue to be such eager proponents for deployment in their jurisdictions following the outcome in Arizona.

Finally, one of the largest barriers to widespread AV adoption is the increasing average age of lightduty vehicles (LDVs) in the U.S. As shown in the graph below, the average age of U.S. vehicles has been increasing over the past two decades to reach almost 12 years as of 2015. This may be driven by more advanced technologies and improvements in the vehicle manufacturing sector allowing longer functional lifecycles of LDVs. It could also be the result of a decreased willingness or ability on the part of U.S. households to engage in as fast of a turnover of their vehicles or an emerging consumer preference for used vehicles. Whatever the proximate cause may be (and it is likely a combination of multiple reasons), the U.S. is seeing a consistently older set of vehicles on its roads. Therefore, the uptake of autonomous vehicles will be slow even after they are initially introduced into U.S. markets: consumers and households will not rush out to replace their existing (and still-functional) vehicles overnight.



#### CONCLUSION

	Potential VMT Impact	
Multimodal Options		
Bikeshare		
Multimodal Expansion		
Carshare		
Rideshare		
HQTA Expansion		
Policy Shifts		
Land Use Shift		
Transportation Demand		
Management		
Congestion Tolling	$\checkmark$	
Technology Impacts		
Increased Telework		
High Autonomous Adoption		
Low Autonomous Adoption		
Behavioral Changes		
Induced Demand		

From ridesharing to congestion tolling, from telework to bikeshare, the future of transportation is upon us. As consumers incorporate new technologies into their transportation networks, the very nature of transportation is evolving. As a complex, interdependent network, the challenges of transportation intersect with new social and behavioral changes and trends. As explored in this report, and as seen in the chart above, a variety of technology, policy, and behavioral changes will impact the Vehicle Miles Traveled (VMT) metric. With investors, policy makers and citizens shifting the gears, these impacts will shape the future of transportation.

The extent to which each of these shifts will impact the U.S. depends on a variety of factors. Consumer choices and technology will intersect with public policy, sometimes in unanticipated ways. The regulatory and infrastructure decisions now made by cities and states will shape the transportation landscape for years to come, locking in legal and physical constraints to changing systems. The behaviors of consumers and transportation providers will respond to these inputs and ensure a dynamic transportation future. We can see the direction that we're heading and now it's time to discover how long it will take us to get there.

#### ACKNOWLEDGEMENTS

As the culmination of a practicum research project, our team is grateful for the help and support of our partner organization and SAIS faculty. The team would also like to acknowledge the numerous stakeholders and experts contacted during this practicum's research, especially Stephanie Dock (Research Program Administrator, Planning & Sustainability, District Department of Transportation), Doug Kaufman (CEO, TransLoc), Dr. Jonas Nahm (Assistant Professor of Energy, Resources, and Environment, Johns Hopkins SAIS), and Robert Stout, Jr. (Vice President and Head of Regulatory Affairs, BP). Without all your viewpoints and assistance this report would not have been possible. Thank you.

#### **APPENDIX: MODEL AND GRAPH DATA SOURCES**

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Bureau of Transportation Statistics (BTS). National Transportation Statistics. Available at www.bts.gov/publications/national\_transportation\_statistics/.

Table 4-11 and 4-12: Petroleum consumption and miles travelled

Table 4-23Average Fuel Efficiency of U.S. Light Duty Vehicles

Table 1-26: Average Age of Automobiles and Trucks in Operation in the United States

Table 1-35: U.S. Vehicle-Miles (Millions)

OECD (2017), Gross domestic product (GDP) (indicator). doi: 10.1787/dc2f7aec-en (Accessed on 18 May 2017)

Population: U.S. Census Bureau, Population Division. http://www.census.gov/popest/data/index.html.

US Department of Transportation: Federal Highway Administration Table VM-1

U.S. Energy Information Administration:

Energy Prices (Case Reference case Region United States)

https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2017&region=1-0&cases=ref2017&start=2015&end=2050&f=A&linechart=ref2017-d120816a.3-3-AEO2017.1-0~ref2017-d120816a.28-3-AEO2017.1-0&map=ref2017-d120816a.4-3-AEO2017.1-0&ctype=linechart&sourcekey=0. 19:02:21 GMT-0400 (EDT)

Light-Duty Vehicle Stock (Case Reference case)

https://www.eia.gov/outlooks/aeo/data/browser/#/?id=49-AEO2017&region=0-0&cases=ref2017&start=2015&end=2050&f=A&linechart=ref2017-d120816a.4-49-AEO2017~ref2017-d120816a.5-49-AEO2017~~~~~~~~ref2017-d120816a.23-49-AEO2017~ref2017-d120816a.29-49-AEO2017~ref2017-d120816a.30-49-AEO2017~ref2017d120816a.50-49-AEO2017~ref2017-d120816a.52-49-AEO2017~ref2017-d120816a.48-49-AEO2017~ref2017-d120816a.31-49-AEO2017~ref2017-d120816a.14-49-AEO2017~ref2017d120816a.15-49-AEO2017~ref2017-d120816a.13-49-AEO2017~ref2017-d120816a.12-49-AEO2017~ref2017-d120816a.11-49-AEO2017~ref2017-d120816a.10-49-AEO2017~ref2017-d120816a.11-49-AEO2017~ref2017-d120816a.10-49-AEO2017&ctype=linechart&sourcekey=1. 23:01:14 GMT-0500 (EST)

Transportation Travel Indicators Light-Duty Vehicles = 8500 lbs. (Case Reference case)

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#### **ENDNOTES**

#### INTRODUCTION

<sup>1</sup> Including the state of California replacing Automobile Level of Service Standards (LOS) with VMT as its measure of transportation impact following the passage of SB 743 in 2013 (See <a href="http://www.dot.ca.gov/hq/tpp/offices/owd/horizons\_files/CGanson-Planning\_Horizons\_Slides.pdf">http://www.dot.ca.gov/hq/tpp/offices/owd/horizons\_files/CGanson-Planning\_Horizons\_Slides.pdf</a>)

<sup>2</sup> The EIA Reference Case assumes trend improvement in known technologies, along with a view of economic and demographic trends reflecting the current central views of leading economic forecasters and demographers. It [also] generally assumes that current laws and regulations affecting the energy sector, including sunset dates for laws that have them, are unchanged throughout the projection period.

<sup>3</sup> Puentes, Robert (2012). "Have Americans hit peak travel? A discussion of the changes in US driving habits." International Transport Forum Discussion Paper, No. 2012-14, <u>http://dx.doi.org/10.1787/5k4c1s3c415b-en</u>

<sup>4</sup> Explaining the U.S. Petroleum Consumption Surprise. June 2015. Executive Office of the President of the United States.

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<sup>5</sup> VeggieGarden, "Metrorail System Map." January 6, 2013. CC0 1.0 Universal, <u>https://commons.wikimedia.org/wiki/File:DC\_Metro\_Map\_2013.svg</u>

#### **MULTIMODAL TRANSPORTATION**

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<sup>7</sup> The City of Columbus, "Smart Columbus." <u>https://www.columbus.gov/smartcolumbus/projects/</u>

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#### BIKESHARE

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<sup>11</sup> The situation when commuters have to travel a long distance from home to access a public transit station, and are still far away from their destinations after de-boarding.

<sup>12</sup> Goldchain, Michelle. "Yes, another dockless bike-share company has expanded to D.C." Curbed Washington D.C., October 10, 2017. <u>https://dc.curbed.com/2017/10/10/16453396/ofo-bike-share-dockless-dc</u>

<sup>13</sup> Prince of Petworth. "Just When I Thought I Was Out, They Pull Me Back In!" Popville, October 27, 2017. <u>https://www.popville.com/2017/10/dc-dockless-bike-share/</u>

<sup>14</sup> Capital Bikeshare. "System Data." December 6, 2016. <u>https://www.capitalbikeshare.com/system-data</u>

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<sup>15</sup> Shaheen, Susan and Cohen, Adam. "Innovative Mobility Carsharing Outlook: Winter 2016." Transportation Sustainability Research Center, University of California, Berkeley. 2016. <u>http://innovativemobility.org/wp-content/uploads/2016/02/Innovative-Mobility-Industry-Outlook\_World-2016-Final.pdf</u>, Page 2.

<sup>16</sup> Hawkins, Andrew. "Car2Go thinks we'd rather share luxury Mercedes-Benz sedans than Smart cars." The Verge, January 30, 2017. <u>https://www.theverge.com/2017/1/30/14437770/car2go-daimler-mercedes-benz-cla-gla-carsharing</u>

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<sup>22</sup> Note: These percentages show the ratio of aggregate hours with a passenger to aggregate work hours. Data are for periods between 2013 and 2015. (Cramer and Krueger, 2016), Table 1 on page 12.

<sup>23</sup> Anand, Priya. "People in Los Angeles Are Getting Rid of Their Cars -- Instead, they are riding Uber and Lyft to work." *BuzzFeed News* September 02, 2016. <u>https://www.buzzfeed.com/priya/people-in-los-angeles-are-getting-rid-of-their-cars?utm\_term=.lr5NMqy34#.gan6lgdMP</u>

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<sup>30</sup> Los Angeles Department of City Planning. "Mobility 2035." <u>https://planning.lacity.org/documents/policy/mobilityplnmemo.pdf</u>. September 7, 2016. Page 109.

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