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Human Behavior and New Mobility Trends in the United States, Europe, and China

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Summary

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Keywords: Mobility, Human Behavior, Transport, Sharing Mobility

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Abstract

New mobility trends such as shared mobility, autonomous vehicles, and mobility as a service are poised to disrupt the way the world moves. Since transport behavior is rooted in human behavior, how these trends are adopted will be influenced by behavioral preferences as well as cultural trends. This literature review looks at the behavioral preferences that will influence the uptake and impact of new mobility in the three largest markets: the United States, Europe, and China. The author finds that factors such as cost, time, comfort, convenience, safety, identity creation, and environmental concern are all important in transport modal choice. Larger societal trends such as changing preferences amongst younger generations as well as differences between urban and rural riders will also influence uptake of new mobility. Ultimately, the sustainability of new mobility in terms of reduced emissions and congestion will depend upon the adoption of shared models over private car ownership, which will require behavioral changes that could be incentivized with smart public policy.

Keywords: mobility, human behavior, transport, sharing mobility.

Introduction: Factors Influencing Modal Choice

To understand the relationship between new mobility trends and human behavior, we must first understand what behavioral factors go into transport mode choice with current existing modes of transport. People choose mode of transport based on many factors and perceptions, some of them rational and others emotional, sometimes based on real observations, at other times based on perceptions. While past discussion often focuses on individual decision-making when in comes transport, newer studies such as Cairns (2014) examine how these individual decisions are based off of social practices that are influenced by one's culture and social groups as well as their individual realities. There are regional influences, which is why this report will be focusing on three main markets: the United States, Europe, and China, but there are also megatrends that are having global impacts on mobility decisions, such urbanization and younger generations changing how they travel. In general, people want their travel experience to be safe, comfortable, fast, and cheap. The bulk of transport research focuses on how adjusting the cost and time variables affects decisions, but this literature review will look beyond that narrow focus and consider a wider range of factors that influence modal choice.

Impact of Cost and Time on Modal Decisions

Cost

Cost is one of the primary and most studied factors that influences modal choice. Travel cost typically includes all fees related to the mode of transport: fuel, tickets, parking spot, and maintenance costs. Cost tends to be inversely related to the likelihood of using a given method of transport (Polydoropoulou, 2012). For example, lowering the cost of private car travel encourages people to switch to private vehicles from public transit. Private vehicles also tend to be inefficiently priced when considering societal impacts. There are many external costs to personal vehicle ridership, which are not factored into the price of driving, such as congestion, land use consequences, air pollution, greenhouse gas pollution, and noise. Without these externalities priced in the benefits of driving a personal vehicle will exceed the personal cost making traffic jams and pollution almost unavoidable (Litman, 2011). The incomplete pricing of private vehicles has led to their dominance as a form of transport, especially in the United States.

In a study of car commuters in an English city, the perceived lower cost of car travel was one of the core reasons for choosing a private vehicle. However, this was just a perception of lower cost as the respondents systemically undervalued car-related monetary costs (Gardner, 2006). The perception of cost may be more important in modal choice than actual cost. While an often cited reason for modal choice, very infrequently do people choose the modes with the least total cost of personal ownership, which includes the purchase price of the vehicle plus depreciation, fuel, maintenance, insurance and other ongoing costs. In many countries the travel modes with the lowest total cost of ownership such as public transit, active travel, and small, efficient cars are often the modes with the lowest market share (Axsen, 2019). Cost impacts modal choice, but not as directly as many would believe. There must be other factors that have a strong impact on transport modal choice in addition to cost.

Time

Another important and often studied factor impacting modal choice is the amount of time a particular mode of transport will take to get the traveller from point A to point B. The less time it takes, the more likely travelers are to choose it. One of the core motivators for choosing to commute by car is perceived saved travel time. Many economic studies have used calculations of travelers' value of time, or the monetary value that they would assign to the time spent on a particular activity, in this case travelling. The value of time can change depending on the purpose of the trip, e.g. daily commute versus leisure trip. For a leisure trip time is less important than for functional journeys, like a commute. Just as with cost, people are bad at estimating how much time different modes of transport will take. Participants in the Gardner (2006) study tended to estimate car travel times based on congestion-free roads, viewing traffic jams as a irregular occurrence, thus underestimating time spent driving. With public transit, however, respondents tend to factor in the possibility of delay into their calculations, overestimating how long a public transit journey would take (Gardner, 2006).

The value of time can also be different for different groups of people and interact with other factors, such as how important monetary spending is. For example, a retired pensioner would likely have a low value of time and a higher value of money and would try to save money at the expense of time. A busy executive would likely do the opposite. The value of money can interfere with observations about value of time in cases where value of time and value of money are both high or low. For example, a low-income, employed single parent with little time will have high value of time and value of money and a retired person with a lot of money saved up will have both a lower value of time and value of money. Traditional studies would categorize the low-income parent as having a low value of time and the rich pensioner as having a high value of time, but Goodwin (2019) argues that the true value of time for each of these two cases is indeterminate, since both could be indifferent about whether they spend more money or time (albeit for different reasons). This can be problematic from a equitability standpoint as projects are often funded based on the assumption that the rich are more willing to pay for time-savings than the poor, despite the fact that both the rich and the poor have a high value of time.

In addition, if other factors relevant to transport improve, the value of time for a traveller may decrease. For example, value of time is often lower where comfort is higher and vice versa. People are more willing to spend a longer period time travelling if they are comfortable. Those that use active modes of transport, such as walking and biking, may find that the health and environmental benefits are more important than the speed of transport. Other factors that may make transport time less important include noise levels, air quality, access to telecommunication signals and the conditions to use them, impact on social status, desire for variety, desire for habitual reassurance, enjoyment of either company or privacy, conditions suitable for productive work or private enjoyment, access to refreshments and toilets (Goodwin, 2019). Due to people's inability to accurately estimate travel cost and time and the way both interact with other factors, understanding modal choice must involve understanding a suite of factors that go beyond simply money and time.

Moving Beyond Cost and Time in Modal Choice

Comfort

As mentioned above, comfort influences transport modal choice. Elements that impact the comfort level in a mode of transport include sharing a space with strangers, crowding, having private space, and noise level. Sharing a space with strangers and crowding negatively affect comfort. Crowding is the factor that most discourages people from the use of public transport (Tyrinopoulos, 2013) and the likelihood of available seats in public modes strongly affect the decision to use public transport (Polydoropoulou, 2014). On the other hand, using a car is perceived as creating personal space (Mann & Abraham, 2006). The privacy and comfort of cars were among the core reasons for choosing cars in the Gardner (2006) study. Subjects cited that cars allowed for protection from contact with undesirable others and freedom from observation (which was sometimes used for activities such as singing loudly).

The ability to sing loudly in the car to one's own music is also part of the soundscape of a private vehicle. People find that modes of transport that have personalizable soundscapes (the ability to choose one's own audio or relative silence) to be more comfortable. By this measure, private vehicles are the most comfortable, but portable electronics help make the soundscapes in shared and public transit more tolerable (Cairns, 2014). In many ways, private vehicles allow for the most comfort and any attempt to discourage private vehicle use and encourage low-carbon modes of transport should take privacy and sound levels into account.

Safety

Safety and security are fundamental human needs as identified in Maslow's hierarchy of needs (Maslow, 1943). Safety and perceptions of risk therefore affect modal choice. Safety concerns range from worries about the likelihood of accidents, likelihood of personal injury and theft, to assaults from drivers or other passengers. Concerns about safety can significantly impact public transit ridership. Without trust in the mode of transport or the people sharing the vehicle, citizens are more likely to chose a private vehicle. Ridership then drops and public transit collects less in revenue while traffic and air pollution increase. In Washington, D.C., trust has been declining in the Metro transit system due to safety and maintenance issues resulting in 40,000 fewer riders between 2010 and 2014 (Ounpuu, 2017). Concerns about personal safety also impact decisions to use active transport. The likelihood of cycling is impacted by concerns about traffic accidents and personal safety (Mundorf, Redding, & Paiva, 2018). Availability of wide sidewalks and bicycle paths encourage walking and cycling as they lower concerns about collisions with motor vehicles (Polydoropoulou, Kamargianni, & Tsirimpa, 2014).

Concerns about safety are not evenly shared across populations and disproportionately affect the travel behavior of more vulnerable groups such as women, children, and the elderly. For example, a high share or women constrain their travel behavior because of feeling unsafe. They may change routes, times, and travel modes as a result (Stark & Meschik, 2018). Safety concerns also deter older citizens from public transit. Negative incidents such as difficulty boarding, poor visibility at a station, theft, erratic driving, were more likely than positive incidents to change travel behavior (Sundling et al., 2016). General feelings of unsafety

about the outdoors and strangers have resulted in far fewer children using active or public modes of transport without accompaniment.

Convenience

Convenience in transport carries many qualities: flexibility and the ability for spontaneity as well as reliability and ease of use. The more convenient a transport mode is the more likely it is to be used. For example, faster route planning and more route optimization tools help encourage the use of more public transit. Public transport ridership is negatively impacted when it is less convenient. Studies conducted in the United States show that use of public transit drops by up to 90 percent when passengers must walk more than half a mile to the nearest transit stop (Bouton, Canales, & Trimble, 2017). Perceptions of public transit are also negatively impacted by strikes, signal failures, weather delays, and other instances that delay or make the system less convenient (Goulding & Butler, 2018).

Effort minimization is also a core motivation for choosing driving. The extra effort to walk, wait, change lines, get tickets, is often viewed as an unnecessary hassle. The inconvenience of public and active transit often outweighs the potential health benefits of physical exertion (Gardner & Abraham, 2007). Availability or lack of parking spaces often factors into the perception of convenience of a personal vehicle (Tyrinopoulos & Antoniou, 2013). Convenience can even be more important than the prestige or status that a particular mode of transport brings. Wealthy respondents in a McKinsey survey prefer having a free ride-sharing than a free car (Dhar, Patel, Raina, & Sandrone, 2017). The ultimate inconvenient mode of transport is one that is not available and as more forms of transit are made available to more places, convenience and travel behavior will change.

Identity Creation

Modern global consumerist culture encourages people that they can, indeed must be whoever they want to be. Identities must be defined and constructed. Consumer products have become more important partly out of this need to self-create identities (Sally Cairns, Harmer, Hopkin, & Skippon, 2014). Cars, and their various brands, have been a way to participate in this cultural practice of identity-creation. They can operate not just as modes of transport, but also as symbols that convey freedom, power, speed, status, control, adulthood, role as a caretaker, aesthetic taste, and other values depending on the time and the culture. Everything from the choice of brand, color, even license plate, is designed and interpreted by many as a direct refection of the driver's tastes, lifestyle, and attitudes (HERE Technologies, 2017).

Car dependence can be both an objective phenomenon—as in the lack of other modes of transport necessitates the use of cars, as well as a subjective phenomenon—where people assume that access to a car is necessary to maintain their quality of life and identity (Sally Cairns et al., 2014). Subjective car dependence is just as, if not more, widespread than objective car dependence. For example, many feel that car use is a way of maintaining autonomy in travel (Gardner & Abraham, 2007). Owning a car can help define a new social role, such as a young person becoming an adult. It can also help perform or validate an identity, such as a mini-van allowing a parent to care for their children, as well as signal that they are a parent (Sally Cairns et al., 2014).

Since cars are such potent identity-creation symbols, policies to reduce car use would also have to address the benefits other than transport that people derive from their automobiles. For example instituting "walking buses" or groups of children chaperoned by two or more adults walking to school or other nearby location could help not just get the children to where they need to go, but also enable parents to care for their kids. People also tend to underestimate the role identity plays in choosing car over public transport. There is a general preference for modes of transport which allow for feelings of autonomy and control, of which the car is usually one. Phenomena such as transportation congestion, overcrowding, subway breakdowns, etc. can create a dehumanizing environment that can erode the passenger's sense of identity and deter people from public transit (Yago, 1983).

While cars have historically been a strong way of broadcasting one's identity, they may no longer be the most prominent way. With the rise of social media and smart phone technology, people, especially younger generations, are much more frequently defining themselves by how they present themselves online, rather than on the street. New mobility trends such as carsharing, ridesharing, bikesharing, which have grown in popularity in part because of their ability to offer a degree of individual control and convenient short-term ownership, also bring about opportunities for the creation of novel identities (Sally Cairns et al., 2014). Online identity curation may help decrease subjective dependence on cars.

Environmental concerns

One identity or set of values of particular interest to those wanting to decrease emissions from transport is that of the environmentally concerned. To what extent does being environmentally conscious impact travel behavior and emissions? Choosing environmentally friendly modes of transport can be based on a sense of moral obligation to act in a sustainable fashion. However, these values are thought to influence behavior indirectly, rather than directly (Lind, Nordfjærn, Jørgensen, & Rundmo, 2015). In the UK, environmentally conscious consumer groups willing to make changes to their daily commute to reduce emissions and pollution, but were much less willing to change mode of transport for holiday and vacation travel. This is because tourism is often categorized differently than daily travel, allowing for exceptions to their standard travel behavior. These tendencies and fundamental motivations need to be understood to encourage more "green" travel behavior. In addition, those with the greenest travel behaviors were not the most environmentally conscious, but those who were reluctant public transit users. Reluctant public transit users were defined as those who use public transit out of lack of choice rather than preference, who tend to be older and retired, and who have less access to private motor transport (Barr & Prillwitz, 2012). Based on these results, it is more effective to market sustainable transit based on other properties such as affordability and convenience instead of its sustainability to encourage more ridership.

Behavioral Trends in the United States

Trends in Transport Mode Usage

Travel behavior in the United States has historically been linked to high private car use. The U.S. has about 766 cars for every 1000 persons, compared to Europe's 507 and China's 74. Some of this may be due to the fact that the U.S. has a lower population density, only 34 persons per square kilometer. Europe and

China, for contrast, have 114 and 144 persons per square kilometer respectively (Bormans, 2018). The U.S. also has a high share of the population with drivers' licenses—70% (Keeney, 2017). The dominance of the private car may be lessening slightly as travel behavior in the United States is going through a period of significant change. While the U.S. is still heavily reliant on personal vehicles for passenger mobility, trends in demographics, technology, economics, and attitudes are starting to shift and redefine how Americans move.

Growth in vehicle miles traveled (VMT) as detected through nationwide traffic sensors has been going through its longest period of stagnation since late 2007 with the Great Recession (Martin et al., 2016). Not only are miles traveled stagnating, but also the number of average daily trips, which was 4.3 in 1995 and 3.4 in 2017. The largest reduction in trips comes from fewer outings to shop and run errands, which is consistent with increased e-communication and commerce (Polzin, 2018). People do not necessarily anticipate these reductions. According to the 2019 Deloitte Global Automotive Consumer Study, people expect to use their own private vehicle in the next three years in much the same way they have used it in the past. While private vehicles still make up the largest modal share in the U.S., among commute trips the share of private vehicles decreased slightly from 92.8% in 2001 to 91.4% in 2009. The shares of public transit, walking, and bicycling have each increased to varying degrees in different regions. In addition to a gradual modal shift, the stagnation of VMT is likely also in part due to the rise of telecommunications technology that allows more people to work from home, although lack of surveys from employers makes it difficult to measure its extent (Martin et al., 2016).

Person miles traveled (PMT) attempts to measure how many miles each individual, instead of vehicle travels. It includes all non-motorized modes, unlike VMT, but it is a lot more difficult to gather accurate data on. While private vehicle travel still has the largest share of PMT in the U.S., there has been a shift away from private vehicles for shorter trips. Americans choose to walk or bike more if the trip distance is within a reasonable distance for that mode. The growth of the shares of public transport, cycling, and walking have not been uniform across the country. In the southwest public transit use as a share of total transportation has even decreased. Public transit use increased as a share more in places where there are existing means of public transit, rather than as a result of new systems being built. Cycling for transport has mainly been rising in urban centers (Martin et al., 2016).

Car Ownership

Car ownership rates are declining in the U.S. From 2006-2012 there were 5-6% drops in the measures of vehicles per person, vehicles per driver, and vehicles per household. The most pronounced decline is for the millennial generation (Bouton, Knupfer, Mihov, & Swartz, 2015). While current low rates are in part due to the economic downturn that started in 2008, peak ownership rates all happened before 2008, implying that the decline is not solely economically related. Those living in areas with higher population densities are more likely to own fewer vehicles, and the U.S. population has been urbanizing (Berg, 2012). There has also been a slight increase in the percent of households with zero to one vehicle, and a slight decrease in households with two or more vehicles (Martin et al., 2016).

The famed American love for driving may also be fading, and fueling part of the decline in car ownership. One study shows that the loyalty that American attach to their personal vehicles may have slipped. Perhaps

related is the 7.6% decrease in the average number of miles driven by Americans compared to a decade ago (Giffi, Vitale, Rodriguez, Gangula, & Schmith, 2014). Car demand has also slightly dropped in the U.S. by 0.4% (ACEA, 2019). Despite these slow-downs, people expect to maintain the status quo in terms of how much they use their own private vehicle in the next three years (Vitale et al., 2019).

The decline in car ownership in the U.S. is not related to perceptions of public transit, which remain very low. Many people think that public transit is dangerous, dirty, slow, inconvenient, and only for those who have no other transport options ("Branding Public Transportation," 2017). According to a Pew Center study, only 11% of adults use public transit on a regular basis (Anderson, 2016).

Demographic Changes

The U.S. Census projects that by 2060, the country's population will reach around 417 million. During this time, the population is also expected to age, with one in five Americans aged 65 and over by 2030. Despite the aging of the population, the U.S. population will still remain relatively young compared to other developed economies such as Japan, South Korea, and Germany. Immigration is sustaining U.S. population growth and limiting the overall aging of the population (Martin et al., 2016). Now we will examine the differences in travel behavior between two of the largest and most influential generational cohorts.

The U.S. population is aging and at the forefront of this trend is the generation born after World War II 1946-64 (Dimock, 2019) commonly known as "baby boomers." In the past, as generations aged, they tended to travel less (Polzin, 2018). However, since 1995, trip-making has declined significantly for all age groups except for those over 65, bucking past tendencies (McGuckin, 2018). Further research should be done to determine the relationship between technology literacy and the reduction of trips as more activity can be conducted online. Baby boomers, who are less technologically literate than younger generations may be making trips for work, shopping, and socializing, that younger generations may be doing online. Baby boomers are also leading the country in terms of automobile purchases. The peak probability of purchasing a vehicle per licensed driver is now among the 55 to 64 age range. It used to be among those who were between 35- and 44-years old (Martin et al., 2016).

Another generation having impactful travel behaviors are the millennials, born 1981-96 (Dimock, 2019). Car ownership amongst American millennials has dropped more than it has than for any other generational cohort. It will likely not rebound as a good indicator of future car ownership is the number of young people who get their driver's license, and that rate has hit an all time low in the U.S. (Bliss, 2016). Millennials are also three times more likely than consumers from other generations to abandon their personal vehicles (Giffi et al., 2014). The lack of cars is somewhat made up for with higher usage of other modes. Those aged 25-34 are the most likely to use carpool, public transit, and bicycling. The share of these modes decline as age increases across the American population. In addition, according to the National Household Travel Survey millennials are traveling considerably less than other generations were at the same age (Martin et al., 2016). Millennials are travelling less partly due to economics, overall decreases in mobility in the U.S., and partly due to increased "virtual mobility" like social networks, remote working, and delivery services (McDonald, 2015).

Many point to changing lifestyle and preferences amongst millennials to explain their reduced travel and car use. Younger generations do not see car ownership as important as older generations do. Millennials and those in the younger cohort of Gen Z are more than twice as likely than Gen X (1964-81) and Boomers to question whether they need to own a vehicle going forward and are less willing to buy a car than other generations (Vitale et al., 2019). Only 64% of Millennials said that their preferred mode of transport was the car they own, in comparison to 81% of consumers from other generations (Giffi et al., 2014).

Some of this disinterest in car ownership may arise from the fact that millennials prefer to live in cities and feel "happiest" in urban environments. This could be due to the fact that in general across time periods, young people have enjoyed living in cities, but it also could be due to the changes that have happened in American cities and in American culture. Cities are now safer than they used to be and they offer more and better economic opportunities (Florida, 2018). Millennials value convenience more and 47% are willing to relocate closer to work to reduce their commute compared to only 22% of other generations.

They also prefer living in neighborhoods where everything they need is within walking distance, which could explain their preference for urban living (Giffi et al., 2014). Higher density also allows for more opportunities to make friends and find partners in cities. Culturally, the idea of "making it" in America is increasingly focused on finding success in an urban environment, rather than suburban home-ownership. Millennials also value diversity more than other generations, which cities offer more of (Florida, 2018). Car ownership is more expensive, less convenient in urban environments and there are usually other transport options, meaning that millennials' urban preference could in part explain why they are less interested in cars and car travel than other generations.

The changes in millennial mobility may be in part due to changes in preferences and cultural shifts, but a large portion of millennials came of age and entered the workforce at the height of an economic recession. This has and continues to shape millennials' earnings and life choices, impacting particularly millennial car ownership and mobility. As a result of the continued impacts of the recession and slow recovery, millennials are more likely to live at home than other generations and are getting married and having children later all of which mean less consumption, including travel-related consumption. The millennial generation in the United States also has a high level of student indebtedness which also limits their ability to buy expensive items like cars (Tilford, 2018).

As the millennial economic situation changes, their car ownership and use may also increase. Whereas some studies point towards changing millennial mobility preferences, other studies note that preferences towards cars have not changed so much as millennials' ability to afford them has (Kurz, Li, & Vine, 2018). According to one study, 80% of millennials were planning to purchase a vehicle in the next five years and the top reasons for not owning a car were affordability and maintenance costs (Giffi et al., 2014). Millennials want cars, but are still concerned about affording them. In another study of travel behavior in the Twin Cities from 2000-2010, millennials were traveling less than other generations. However, once they controlled for employment, millennials were travelling more. The reduction in travel was more due to lack of employment than any innate preference, and millennials were more likely to be unemployed (Levinson et al., 2015). Whether the changes in millennial travel behavior are a result of changing preferences or will recover if millennials recover economically still remains to be seen. Likely both processes are at work with changing preferences happening more in and near urban centers.

Urban and Rural Travel Behaviors

Travel behaviors in urban and rural areas differ significantly from one another and new technologies and policies will have to take into account those differences. In the United States, the number of people in rural areas has remained about the same since 1980, but all of population growth has gone to urban areas, thus increasing the share of people living in urban areas in the U.S. to around 80% (McGuckin, 2018).

The U.S. Census Bureau definition for a rural area is town or village with fewer than 2,500 residents. While rural areas can differ substantially from one another, rural populations in the U.S. tend to be older with a median age of 43, compared to 36 in urban areas, with 17% aged 65 and older (only 14% are in urban areas). Rural areas also tend to have a higher percentage of military veterans and people with disabilities. They are historically less diverse than urban areas, but in recent years rural areas have seen a rapid growth of the Hispanic population living there. Urban areas have a higher percentage of people with college degrees than rural areas, though both have similar levels of high-school education. The median income is also higher in urban areas, but there is also higher percentage of people living below the poverty line, since the cost of living is more expensive (Hough & Taleqani, 2018).

In urban areas public transit is more available, safer, and more widely used than it is in less dense areas. Walking and biking are active transportation options that can be used for a commute in urban areas, whereas in suburban and rural areas distances are too far to enable commutes to school, work, and elsewhere to be carried out by walking and bicycling alone (Mundorf et al., 2018). In addition to availability of public transit, the built environment of dense urban areas encourages transport by modes other than private vehicle. Compact development has an anti-car influence on business trips. Those living in neighborhoods with grid-iron street design and limited commercial parking average significantly fewer vehicle miles (Cervero & Kockelman, 1997). Those living in urban areas take more trips per capita than those in rural areas. However, urban VMT per capita is lower, since journeys, though frequent, are over shorter distances. Public transit use is higher for lower income populations and decreases as income rises, except among high-income households. This is not the case in rural areas as there is a lack of access to public transit (Martin et al., 2016).

In rural areas, the main challenge to mobility is lack of access, rather than congestion as it is in urban areas. Regardless of age, income, and race, everyone in rural areas relies on a private car for almost all travel needs—around 91% of all trips are made by car. Many rural residents do not have access to viable public transit or other modes of transport other than private vehicle (Joseph, 2018). Even though over 97% of rural households own at least one car (Pucher & Renne, 2004), there is increased demand for transit services for low-income, elderly, and handicapped drivers. Almost 40% of American transit-dependent population resides in rural areas (Lockwood, 2004). More people in rural areas think that access to public transit is a problem in their community—43%, compared to only 19% in urban areas and 25% in suburban areas who feel the same (“Millennials in Adulthood,” 2014). How the United States adopts new mobility trends will be impacted by its unique urban-rural divides and generational trends.

Behavioral Trends in Europe

Trends in Transport Mode Usage

Europe is car dependent, but not to the same extent as the United States. It has only 507 cars for every 1000 persons, compared to the U.S.'s 766 (McGuckin, 2018). The modal share of private vehicles is 81.3% of all passenger kilometers, whereas in the U.S. private vehicles account for over 90%. Buses and coaches have a 9.3% share, railways 7.6%, and tram and metro 1.8% (Bormans, 2018). Like in the U.S., public transit trips have increased slightly, both absolutely and as a modal share (Goodwin, 2019). Walking and cycling rates are also pretty high, accounting for 20-40% of all journeys taken in the EU ("Walking and cycling as transport modes," 2016).

From 2000 to 2015 Europe saw an overall decrease in distance travelled by car, but with a slight recovery in more recent years. There is a large discrepancy in car usage between countries in Europe with the average person in Austria and Germany travelling around 14,000 kilometers per year by car and people in less developed nations, such as Latvia, Poland, Czech Republic, Romania, Slovakia, and Slovenia, traveling only around 8000 km per year (Odyssee-Mure, n.d.).

Car Ownership

Although Europe is not known for its love of automobiles the way the U.S. is, two-thirds of Europeans take pride in owning a car according to one study (ING Economics Department, 2018). Just like in the U.S., drivers in Germany expect to maintain the status quo in terms of the number of cars they own (Vitale et al., 2019). In addition, from 2013 to 2018 Europe's passenger car fleet has grown by 5.7% from 243 to 257 million cars (ACEA, 2018).

The story of car ownership in Europe is really one of two different Europes. In less developed countries starting with lower levels of car ownership, rates have been rising rapidly, with the number of cars per capita growing above 5% each year in Bulgaria, Latvia, Lithuania, Poland, and Romania. In countries such as Italy, Sweden, France, and Belgium there is much lower growth of car ownership due to market saturation (Odyssee-Mure, n.d.). As a result of these opposing forces, EU car registrations have remained stable from 2017 to 2018 (ACEA, 2019).

Demographic Changes

Europe's (specifically the EU-28) population is projected to peak around 2045, reaching 529 million people. Like the U.S. population, the European population is expected to age. The median age of the EU population is likely to increase by 4.2 years by 2080, and by that time there will be 66.1 million people 80 years old and over. However, with lower fertility rates and less immigration than the U.S., Europe could face demographic and economic challenges as the number and share of the elderly population increases. The travel behaviors of current younger generations as well as those that accompany their aging population will have a large impact on future European travel behaviors (eurostat, 2017b).

Similar to their counterparts in the United States, the baby boomer generation in Europe has been considered as highly car oriented. Acquiring a car to them is a rite of passage into adulthood (Goodwin, 2019). Their car buying habits were fueled by the car's role as a status symbol, but younger generations place much higher value on electronic devices. Younger generations achieve a sense of freedom and identity through communication devices and the profiles they create online, not cars (Siren & Haustein, 2013).

The millennial generation does not make up as large a share of the European population (24%) as they do in the U.S. (27%). Also, whereas millennials in the U.S. are expected to become the largest generation in 2019, in a survey of seven EU countries, the millennial generation remains a significantly smaller population group than those 50 and older (Stokes, 2015). Despite differences in the size of the generational cohort, European and American millennial travel behavior trends are largely similar. European millennials are less likely to use cars than older generations. They make fewer trips by car both as driver and as passenger. Studies by Stokes (2013), Van der Waard, and Kuhnimhof, Zumkeller, and Chlond (2013) and (2014) show that the changing mentalities of young Europeans towards car use has significantly contributed to the to the recent stagnation of car use in Europe. Also similar to Americans, young Europeans are getting fewer licenses than past generations. The proportion of young people with a license has fallen from 48% to 29% at the initial entry age and from 75% to 63% for people in their 20's. This decrease is proportionate to the decrease in those with access to a private car (Goodwin, 2019).

European millennials have also lived with the economic crisis, but the economy and their fortunes have not improved as much as they have for American millennials (Stokes, 2015). Trends such as the rise of lower paid and less secure jobs and decline in disposable income lead to changes in travel behavior like reduced car use (Goodwin, 2019). Similar to their American counterparts, they are also living in urban areas, having children later and consuming less than previous generations at the same age (Tilford, 2018). The decline of private car use by millennials is likely influenced by the economic situation though not solely caused by it. According to a study from the UK, peak car use happened in 2005 before the economic crisis, indicating a change in preferences as well (Goodwin, 2019). The question about young Europeans and Americans and car use is whether their preferences will be permanent or if they are simply delaying car purchases until economic circumstances improve or until they start families and move to more rural areas.

According to the most in depth study on this issue in Europe, by the Social Research Association (2015), most young people in their survey of those under 30 in the United Kingdom say that cost is the primary reason why they drive less. However, even those who do own cars often prefer to travel by walking, cycling or public transit. The number of young people who say they don't ever want a car is growing and this preference increases with age. Thus 15% of non-car owners aged 17-29 don't want a car in the future compared to twice as many (32%) of non-car owners aged 30-42," showing that there could be permanent preference changes happening amongst young Europeans.

Any permanent change in travel preferences away from cars may be in part due to recent changes to social interactions favoring digital to face-to-face interactions. "Connecting to the social network, either physically or telecommunication based, seems to have replaced the car ownership dream observed in previous generations." "The possession of a car tends to be replaced by the idea of connecting to the social network" (Chalkia, De La Cruz, Keseru, L'Hostis, & Muller, 2018).

Urban and Rural Travel Behaviors

Despite already having high levels of urbanization in Europe, they are expected to increase from 73% in 2014 to 84% in 2050 (Chalkia et al., 2018). In 2015, 28% of the EU-28 population was living in rural areas, whereas 31.6% were living in towns or suburbs, and the biggest share of the population (40.4%) lives in cities. While there are long-term urbanization trends, from 2010-2015 there was a gradual increase in those living in rural areas, a more pronounced increase in those living in towns, and a decrease in those living in cities. This may be due to Europeans leaving inner city areas in search of more affordable space in towns or the countryside.

Like in the United States, those with higher education are more concentrated in urban areas. Among people aged 30 to 34, a little more than a quarter (27.9%) of those living in rural areas had a university degree or higher. In towns and suburbs that percentage is around 33.4% and in cities is almost half at 48.1%. A higher proportion of those living in rural areas face the risk of poverty or social exclusion than those in urban areas, in contrast with the U.S. measures (although this could be caused by different measures of poverty and the inclusion of social exclusion as a measure) (eurostat, 2017a). Like in the U.S. access to public transit is more available in urban areas than it is in rural areas. This enables people in urban areas to choose their mode of transport based on their values, like environmental sustainability (Lind et al., 2015). Europe's adoption of new mobility trends will be defined by the urban-rural divide, but also particularly the divide between more and less developed nations.

Behavioral Trends in China

Trends in Transport Mode Usage

The story of Chinese travel behavior differs substantially from that of the United States and Europe. Paralleling the story of its growing economy and population, mobility and car ownership in China has been expanding at impressive rates. Currently, total passenger kilometers in private car are only one-fifth of U.S. totals (OECD, 2019). However, by 2030 personal mileage for China could overtake that of the U.S. (Kuhnert, Strurmer, & Koster, 2018). However, China faces its own challenges with high levels of air pollution in cities and street congestion caused by the use of private vehicles.

Although car use, congestion, and air pollution make the news more often, walking and bicycling make up a little over 70% of the modal share in a typical Chinese city. Another 20% goes to bus use, with about only 2% of trips being performed with a private car. Indeed, only around 20% of the Chinese population has a driver's licence and the cost of a vehicle is a much higher portion of the average Chinese income than it is in the U.S. or Europe (Keeney, 2017). People with higher incomes (>$12,500 U.S.D equivalent) use motorized forms of transport far more frequently than the general population: over 50% of all trips. Private cars account for over 20% of trips and motorcycles another 10%. The majority of the urban poor rely on non-motorized modes (walking and cycling) for daily travel since they bear almost no monetary cost (Song, Peng, & Zhu, 2008).

Car Ownership

Due to its continually increasing overall wealth, China's car ownership is projected to grow at higher rates than the rest of the world through 2050. However, the number of cars per person in 2050 will still be below that of the United States and Europe (European Environment Agency, 2012). The growth in car sales will be fueled by its growing population, rising motorization, and increasing urbanization (Kuhnert et al., 2018).

Increasing urbanization both encourages and limits the adoption of personal vehicles. On the one hand, commuting in urban sprawl common to eastern China often necessitates a private vehicle, or at least some form of motorized transport. On the other hand, congestion and tightened regulations are making driving in megacities more expensive, and less convenient and safe. Unavailability of parking is another challenge to owning a car in China's megacities. Beijing has 4.4 million private vehicles, but only 1.93 million parking spaces and Shanghai is even worse with 3.22 million cars competing for only 600,000 spaces. As a result some cities are taking measures to limit the number of vehicles purchased and registered (Zixiong, 2017).

Car owners in China's megacities like Shanghai, Guangzhou, and Beijing are therefore rethinking the value of owning a car. In 2018 car sales fell by 3.5% in China (ACEA, 2019). According to a survey of car owners from six of China's largest cities, some would consider giving up their car if conditions continue to decline. If traffic conditions deteriorate significantly or if gas prices increase sharply, 10% to 30% of current car owners would consider giving up their cars. They would also more strongly consider abandoning their cars if there was improved public transportation, taxi availability, car rental accessibility, and new mobility solutions (Boutot, 2015).

Similar to the United States and Europe, owning a car is a status symbol in China. Car ownership and income level are highly correlated in China. In the city of Hefei, two-thirds of households in the highest-income group own cars with ownership rates decreasing in the lower income levels. In the lowest income level only 0.82% of the households own cars, but around 70% own a bicycle (Song et al., 2008). However, due to the expensive and inconvenient situation in megacities, the car is losing its power as a symbol in China's largest cities. China's most urban residents value safe, on-time, flexible, and reliable mobility more than the cultural meaning of car ownership. Indeed, according to one survey, 19% of consumers in China are "very willing" and 51% are "slightly willing" to consider alternative solutions to owning a car (Wei & George, 2017). In a similar study in the U.S., 69% of people still want to own their vehicles (Ibold, 2018). The majority of prospective car buyers also think that cars will lose their power as a status symbol over time (Boutot, 2015).

Demographic Changes

As the main drivers of the surge in consumption in China, Chinese millennials are known to be big spenders, which is one of their main differences from their Western peers. Born during China's one-child policy many Chinese millennials have their financial needs taken care of by their parents (Kidwai, 2019). In contrast, millennials in the U.S. and Europe often face roadblocks to wealth such as the repercussions of the global financial crisis, student debt, tighter credit, and rising income inequality. Beneficiaries of China's economic rise and funded education, Chinese millennials have fewer financial burdens and more disposable income to spend on luxury products (Pan, 2019).

Their financial freedom allows Chinese millennials to buy more personal vehicles. In a 2014 study, approximately 90% of Chinese millennials expected to buy a vehicle in the next five years, which was higher than the number of U.S. millennials who felt the same way (80%) (Giffi et al., 2014). Many ask their parents to buy them a luxury car. However, Chinese millennials are not completely without financial constraint. Increasing property values make buying an apartment very difficult. Also many Chinese millennials do have debt but only about half as much as American millennials. Instead of the higher education debt that Americans have, Chinese millennials go into consumer debt often to pre-own high-profile luxury items (Pan, 2019).

Also similar to their Western peers, Chinese millennials are less interested in marriage than previous generations, though not to the same extent as their American peers. They are also having children later, which might damper their consumption levels over their lifetime (Tilford, 2018). Despite their relative financial freedom, affordability is the number one reason for not owning a car for Chinese millennials just as it is for American ones. This differs from past generations whose primary reason for not owning a car was that their mobility needs were met by public transit. The availability of less expensive vehicles would enable Chinese millennials to buy more cars (Giffi et al., 2014).

Chinese millennials, like millennials elsewhere, will be significant drivers for new sustainable and convenient forms of mobility. Chinese millennials would prefer living in neighborhoods where everything they need is within walking distance (Giffi et al., 2014). Tech-savvy millennials are also more willing to participate in peer-to-peer carsharing than older generations (Baan, Gao, Wang, & Zipser, 2017). Perhaps to an even greater extent than in the U.S. and Europe, Chinese millennials define their identity through online activity. The inability to text and drive may be a deterrent for Chinese millennials, despite their relative wealth, from owning a car (Sender, 2019).

Urban and Rural Travel Behaviors

China has been undergoing a rapid urbanization process. About 60% of the Chinese population lives in urban areas and this is expected to continue to grow (Ritchie & Roser, 2018). Urban form and travel patterns are regionalized in China. Eastern cities are characterized by disperse urban development with long commute times. Western and central cities have smaller and more condensed built-up area with more paved-road per person, which decreases commute time compared to eastern cities.

The sprawl in the East started with the start of China's rapid urbanization in the 1970's and the fragmentation that was brought about by the establishment of satellite cities and tech centers. The disperse nature of this development has led to higher driving demand, inefficient land use, traffic jams, increased emissions, and related social costs. There is much migration from rural areas to eastern cities which further puts pressure on public infrastructure. However, there is also a high rate of construction of roads and public transportation infrastructure, indicating continued economic growth (Song et al., 2008). Forces such as overall growth in wealth, migration to Eastern urban cities, and changing preferences of Chinese millennials will likely cause the number of private vehicles and the availability of alternative mobility solutions to rise together in China.

New Mobility Trends

This section will examine the emerging mobility trends of shared mobility, autonomous vehicles, and mobility as a service and how regional behaviors and preferences could affect their adoption and sustainability.

Shared Mobility

Shared mobility is defined as transportation services and resources that are shared by users, either concurrently or one after another. While shared mobility can include public transport as well as taxis and limos ("What Is Shared Mobility?"), this report will look more specifically at newer forms such as carsharing, ride-hailing and ridesharing, and micromobility such as bikesharing and upright electric scooter programs. This report will focus specifically on these forms since they are the most well developed and are having the largest impacts on travel behavior. All forms of shared mobility reflect a shift away from using vehicles as a product to vehicles as a mobility service, a concept that will be discussed even more in following sections. Shared mobility is perhaps the oldest and most developed of the mobility trends but with handheld communications technology it has become very dynamic as experiments with various programs are happening in cities all around the world.

Carsharing

Carsharing is the short-term rental of shared automobiles. There are many different models of carsharing. The most popular model involves a company owning a fleet of cars that members can share. The benefits of this model are that users can avoid the maintenance, parking, and other costs of owning a car, but still have access to a private vehicle when necessary. Some programs require that drivers return the car to the location they picked it up (stationary), while others allow them to drop the car off at an approved spot at their destination (one-way), and others allow leaving the car anywhere within a predetermined area (free-floating). A different model is peer-to-peer (P2P) carsharing where vehicles are owned by individuals instead of a company, but are rented out to other members of the program, in a kind of AirBnB-styled model. To those who rent out their car, the benefits are not the avoided ownership costs but the personal revenue made (Shaheen, Martin, & Bansal, 2018).

Ride-Hailing and Ride-Sharing

Ride-hailing is an arrangement where a passenger travels in a private vehicle driven by its owner for a fee. The fee is supposed to be enough for both the company and the driver to make a small profit off of each ride. The booking of and paying for rides is done through a smartphone app with a transportation network company (TNC) such as Uber, Lyft, or Didi Chuxing. In ride-hailing, there is only one passenger or group who is being driven by the driver.

Ride-sharing is similar to ride-hailing with the exception that the driver may pick up additional passengers along the route requiring passengers to share their ride with strangers. The fees per passenger for ride-sharing tend to be lower to account for the reduced convenience and comfort. One study finds that the top

reasons for switching to ride-hailing or sharing from driving a private vehicle include avoiding driving after drinking and expensive parking (Clelow & Mishra, 2017).

Micromobility

Micromobility includes the modes of transport such as shared bicycles, electric pedal assisted bicycles, and electric scooters. It is usually used to travel short distances, often the first or last mile of a journey and with connections to public transit. This report will address the use of shared micromobility, that is where the bicycles or scooters are not owned by the users, but rented for a small fee from either a company or city (in the case of some bike-sharing programs). Shared bicycles can either be stationed-based, meaning they have to be returned to a designated station at the end of the ride or free-floating, where they can be left anywhere streetside, often within a certain geographical area. Electric scooter programs are usually free-floating. The combined micromobility market of China, Europe, and the United States could reach as large as $300 billion to $500 billion by 2030 (Heineke, Kloss, Scurtu, & Weig, 2019).

According to a McKinsey report, micromobility could be used for all passenger trips less than 8 kilometers (5 miles), which would account for 50-60% of all passenger miles traveled in the U.S., EU, and China (Heineke et al., 2019). Electrified modes of micromobility have an important role to play in encouraging the adoption of micromobility. Electric bicycles, or e-bikes have an important role to play in encouraging bike-sharing adoption as well as replacing miles driven by cars. E-bikes are used when they are available, and more than regular bicycles, they help replace car rides. Those who try e-bikes are likely to continue to be users of a bike-sharing program (S. Cairns, Behrendt, Raffo, Beaumont, & Kiefer, 2017).

Shared Mobility in the U.S.

Shared mobility is becoming more and more popular in the United States, especially among young urban-dwellers, but it still lags far behind shared mobility in Europe and China due to how cheap it is to drive in the U.S. Ride-hailing dominates U.S. shared mobility (Santos, 2018), but like other forms of shared mobility, it has not spread much beyond urban centers. Typical users of shared mobility in the U.S. tend to be younger, urban, male, highly-educated, and middle-upper income. For example, 42% of millennials are willing to try carsharing, carpooling and other modes of shared mobility, compared to 28% in other generations (Giffi et al., 2014).

Carsharing

Carsharing succeeds where it does in the U.S. because it can provide consumers with enhanced mobility or sufficient mobility at reduced costs. Carsharing inherently changes the cost-structure of driving. Car ownership involves a mixture of fixed (purchase of the vehicle) and variable (fuel and maintenance) costs. Driving with carsharing only involves variable costs—you pay for the vehicle based on how much you use it. This allows some people to drive more than they have in the past because now they have access when they did not before, but also encourages others to drive less and only when it is a necessity to help reduce costs (Cohen & Shaheen, 2018).

According to one study, each carsharing vehicle results in on average 9 to 13 vehicles taken off the road, which includes sold and postponed car purchases. Those who have access to carsharing are more likely to reduce their car ownership—go from two to one cars, though not necessarily eliminate it (Cohen & Shaheen, 2018) (Santos, 2018). Carsharing can help increase the use of public transportation in the U.S. in places that need more first and last mile connectivity.

By 2021, there will be 6 million Americans registered for carsharing services and around 600,000 users making multiple trips per month (Haydin, 2018). Users of carsharing in the U.S. tend to be younger, white, liberal, upper-middle class men. Age and gender are most strongly correlated to carsharing behavior. These demographics are also similar to the demographics of the cities where carsharing is the most popular: San Francisco, Boston, Washington D.C., and others. Those who use P2P carsharing are even younger than the carsharing population at large. This reflects younger populations' greater willingness to participate in the sharing economy (Shaheen, Martin, & Bansal, 2018).

Ride-hailing and ridesharing

Ride-hailing is the most well-known form of shared mobility in the U.S., and perhaps the most widely used. Since 2015, the share of the U.S. population that has used ride-hailing services has more than doubled (Jiang, 2019). Uber and Lyft are the largest ride-hailing and ridesharing companies in the United States. Despite ride-hailings's relative popularity with respect to other modes of shared mobility, 42% of respondents in a Deloitte study reported that they had never used a ride-hailing service. This is down, however, from 2017 when 55% of respondents had not used ride-hailing. Ride-hailing has been spreading in the U.S., but the share or people who use it at least once a week is down from a couple of years ago. In 2017, 23% used a ride-hailing service once or more per week, but in 2019 this number has almost halved and is now only 12% (Vitale et al., 2019). Ride-hailing has become more popular across all demographic groups, but the largest shares of users are amongst 18-29 year old, college graduates, and those with an income of $75,000 a year or more (Jiang, 2019).

Not all Americans are enthusiastic about using ride-hailing. A majority of respondents to a survey (67%) preferred "driving their own cars over using ride-hailing apps" and 63% would not give up their vehicles for ride-hailing even if it were free (Santos, 2018). The desire for autonomy and the American cultural draw of the car are still strong, but this could be slowly changing. Amongst American ride-hail users, 46% of millennials and younger question whether they need to own a vehicle going forward. This is significantly higher than it is amongst Gen X (20%) and boomers and older (17%) and points to significant differences in culture between the younger generations and their older counterparts (Vitale et al., 2019).

Ride-hailing and sharing use in the U.S. is largely concentrated in urban centers. Only 19% of Americans living in rural areas use ride-hailing apps, whereas in urban and suburban areas, those numbers are 45% and 40% respectively (Jiang, 2019). Rural areas use ride-hailing much less for many reasons. The coverage of ride-hailing service in rural areas is likely not as good as the main providers (Uber and Lyft) say they are. Mobile phone service, which is usually necessary for hailing a ride, can also be less reliable in smaller towns. Payment for ride-hailing usually requires a credit or debit card, which could deter people who only use cash, which is more common in rural areas. Rural areas are much less lucrative money-making opportunities for potential drivers and the ride-hailing companies themselves, since there are fewer and

typically longer rides. Indeed, ride-hailing is most economical for all where the distance is short and the parking is expensive, which is not usually the case in rural areas (Shrikant, 2019).

Micromobility

Micromobility use in the United States has been growing. In 2018 Americans took 84 million trips by shared micromobility, which is more than double the number of trips taken in 2017 (NACTO, 2018). By 2030, the micromobility market in the U.S. is predicted to be worth $200-300 billion (Heineke et al., 2019). Stationed bikeshare has the longest history in the U.S., but in the past year electric scooter use has emerged as extremely popular and has surpassed the number of rides taken on station-based bikes. Dockless bicycle programs in the U.S. are expected to become less popular in the U.S. as more dockless trips are taken on e-scooters. Station-based bikeshare use also increased from 2017-2018 though largely due to the expansion of existing bikeshare programs rather than the inauguration of new programs in new cities (NACTO, 2018).

Micromobility could potentially help Americans reduce their car dependence or at least support those who do not have a car. According to a study by Lime, a dockless scooter and bike sharing company, Lime riders' households own on average 1.67 cars, compared to the national average of 1.88. Lime users are also 40% more likely to live in zero-car households than the average person in a comparably-sized city (Lime, 2019).

The adoption of micromobility in the U.S. will also be somewhat slowed by the fact that the use of micromobility is concentrated in urban areas, where distances between points of interest are closer. The six cities with the highest levels of station-based bikeshare usership account for 84% of all station-based bike trips in the country. E-scooter use is similarly concentrated with only three metropolitan areas making up 40% of trips (NACTO, 2018).

Shared Mobility in Europe

The shared mobility market is also growing in Europe. Sectors like micromobility are expected to grow even more in the coming years. Users of shared mobility and their preferences tend to be the same as in the U.S. Less than one percent of all journeys in Europe are currently made using shared mobility services, but with its strong growth rate it could reach more than 10% of miles travelled by the second half of the 2020s (Kuhnert et al., 2018).

Carsharing

Car sharers in Europe have distinct socio-demographic profiles that are similar to car sharers in the U.S. Being male, highly educated, and living in the city center significantly increase the probability of adopting carsharing according to a study of car owners in London, Madrid, Paris and Tokyo. City centers are also the best locations to recruit new users of carsharing. Being younger also increases the likelihood of participating in carsharing, which is in line with the trends of younger generations putting less importance on car ownership (Prieto, Baltas, & Stan, 2017).

European cities have been a site where there has been much interesting research done on what encourages or discourages carsharing. A study done by Durand, Harms, Hoogendoorn-Lanser & Zijlstra (2018) overviews factors that encourage carsharing use using the Netherlands as a case study. Those factors that

have the strongest effect on people's decisions to join a carsharing network include vehicle proximity to point of departure, pricing schemes, other competing options, satisfaction with current travel pattern, non-availability of shared cars, and decisions of their social network. Convenience is a very important factor for carsharing as time constraints, lack of spontaneity, and larger variation in travel times all have significant negative impacts on people's intentions to use a shared car. The likelihood for someone to use a shared vehicle increase as waiting times decrease. Cheaper parking for shared vehicles and more available parking for shared vehicles increases the use of carsharing. A study by Paundra, Rook, Van Dalen & Ketter (2017) also identifies price and parking convenience as influencing people's intention to select a shared car.

Psychological ownership is also important in the decision whether to have a private car or participate in a carsharing program. Those who place high value on psychological ownership were much less likely opt for a shared car (Paundra, Rook, Van Dalen, & Ketter, 2017).The symbolic value of owning a car still holds sway for many people, but marketers could convince more people to car share if they build up the symbolic value of sharing a car. Another psychological preference that influences carsharing is environmental consciousness. Carsharing is seen as an environmentally friendly option, though not as environmentally friendly as public transport, which can encourage some use by those who want their behaviors to reflect their environmental consciousness (Durand, Harms, Hoogendoorn-Lanser, & Zijlstra, 2018).

Ride-hailing and ridesharing

Carsharing is not as widely accepted in Europe as ride-hailing. One study found that 75% of respondents consider ride-hailing to be at least somewhat accessible, compared to 38% for carsharing (Lekach, 2018). That said, not many people have tried ride-hailing in Europe. Looking at Germany, 80% surveyed had never used a ride-hailing service (Vitale et al., 2019). Looking at the region as a whole, only 11.3% of the European population has an account on a ride-hailing service platform (Statista, 2019).

While ride-hailing in Europe is only modestly popular, there is a very popular carpooling service, BlaBla Car, which substitutes for private vehicle use and public transport on longer journeys between cities. BlaBla Car links passengers and drivers who are going to the same destination or in the same direction together. Drivers charge each passenger up to reimbursement rate for the ride, but no more, to discourage drivers to using the service for a profit. Since the service is not getting commercialized and at the encouragement of the organization itself, more people are having conversations in their rides (hence the name "BlaBla") than they would in a more typical ride-hailing service. This and the writing of reviews of drivers and passengers helps new users feel more comfortable and trusting of the idea of carpooling and sharing a ride with strangers—an important part of encouraging more carpooling and ride-sharing (Morris, 2015).

Micromobility

Regulations in European cities such as congestion pricing and banning the sale of gasoline and diesel powered vehicles in some countries encourage the use of micromobility for urban transportation. The micromobility market in Europe could grow to $150 billion by 2030. The only reason that this is smaller than the prediction for the U.S. is because Europe prices its micromobility solutions at about half of the price charged in the U.S. (Heineke et al., 2019).

Europe has a robust history of bikesharing, even more developed and involved than in the U.S. Chinese dockless bikes from companies like Ofo and Mobike have begun to penetrate the market in Europe as well (European Bicycle Manufacturers Association, n.d.). Their model contrasts with the older European systems, such as Paris's Velib, which require users return the bike to one of the predesignated stations at the end of their ride. Dockless bikes can struggle to compete in European cities, since bicycle penetration is already very high (Bathke, 2018).

Dockless scooter programs have been increasingly popular in Europe starting in 2018 (CBInsights, 2019). European-based startups, Tier Mobility, Wind Mobility, Voi Technology, Dott, and Flash have recently raised more than $150 million over the last several months alone. Part of the reason they have been able to raise such large amounts of capital is due to the success of the American scooter-share companies Lime and Bird in cities like Paris, Madrid, London, and Vienna (Ajao, 2019).

Shared Mobility in China

China has been a trailblazer in the shared mobility sector. It is spurred on in part by air pollution in cities, street congestion, and expensive vehicle registration in some cities that makes people want to look for alternatives to car ownership. The need for shared mobility is amplified by the fact that the car ownership in China rate is still very low when compared to Europe or the U.S. (only 74 cars per 1,000 people compared to 507 in Europe and 766 in the U.S.), but expected to grow quickly through 2050. Although ownership in China is currently relatively low, many roads are jammed—10 of the 25 most congested cities in the world are in mainland China. If car ownership rates rise, many cities will become even more congested and polluted. The Chinese government is promoting CASE (Connected-Autonomous-Shared-Electric) transport in hopes to curb pollution, congestion, and private vehicle uptake (Ibold, 2018).

Carsharing

Willingness to try carsharing is higher in China than in the U.S. with nearly three out of five consumers willing to use carsharing (Giffi et al., 2014). Many Chinese consumers are also ready to give up car ownership for an alternative—51% were slightly willing and 19% were very willing to consider alternative mobility options to owning a car, including carsharing. Carsharing can help with issues of congestion and pollution while still allowing personal-mobility demand from the middle class to grow.

As of 2018, there were more than 40 car-sharing operators with more than 40,000 vehicles in China, mainly in Tier 1 and 2 cities. More than 90 percent of them are Chinese-owned entities, which are more likely to get governmental support such as subsidies or license plate acquisition, which helps encourage adoption. The growth of carsharing in China is largely driven by the government through promotion and subsidy policies (Ibold, 2018).

Like their European counterparts, Chinese consumers prioritize convenience and have little tolerance for non-availability of carsharing. Since parking in large Chinese cities is limited, consumers do not want to waste time looking for a parking spot. This will perhaps deter commuters in large cities from choosing a free-floating car share. Despite public willingness to try carsharing, utilization rates of carsharing operators

averages around 12%, which is below the typical breakeven level for the companies. As a result, carsharing is still a relatively niche market in China compared to ride-hailing (Ibold, 2018).

Ride-hailing and ridesharing

Shared mobility in China is dominated by ride-hailing (Santos, 2018). China has perhaps the most extensive ride-hailing services compared to Europe and the U.S. Didi Chuxing, China's version of Uber has about six times more users than Uber (Ibold, 2018). In 2017, only 25% of respondents had never tried ride-hailing in China (compared to U.S. 55% and Germany 73%). Today, only 17% of respondents say that they have never tried ride-hailing. As in the U.S., there was also a drop, however, in how many people use ride-hailing at least once a week. In China, this drop was more pronounced, falling from 43% in 2017 to 14% in 2019. The number of ride-hailing rides has also decrease from 2017 to 2019, but China still has higher usage than in the U.S. or in Europe. More young Chinese who use ride-hailing question the need for a car than older generations, but the difference is not as stark as is the contrast between young Americans and older generations (Vitale et al., 2019).

Micromobility

Micromobility faces fewer regulatory challenges in Asia than it does in Europe and North America, which allows startups to have quick implementation. Investors focus on micromobility in China, with 85% stakeholder investment targeting China, since the sector is expected to grow quicker there compared to other regions and compared to other forms of shared mobility (Heineke et al., 2019). The lack of regulation also allows for oversaturation of the market and millions of bicycles to pile up around city streets. For example, China was the first country in the world to implement a dockless bike-sharing platform in 2015 (CBInsights, 2019). Competition between the two giant bikesharing platforms, Ofo and Mobike, led to stranded bicycles in areas of oversaturation.

Growth in dockless bikesharing in China has slowed, but in its wake electric micromobility may help to fill mobility gaps in Chinese cities. According to data collected by Hellobike, nearly 300 million rides are completed on analog bikes every day in China. Accounting for pedal-assist electric bikes and e-scooters together more than double that number, generating 700 million rides per day (Liao, 2019). There are currently 200 million e-bikes and electric scooters on Chinese roads (Frazer, 2019). There are benefits to renting rather than buying in China due to lack of packing infrastructure and no need to worry about theft. Driven by necessity, China has been and will continue to be an early adopter of new mobility trends.

Impacts and Challenges of Shared Mobility

Strong growth of shared mobility is expected around the world. By optimistic projections, where consumers and cities demand shared self-driving taxis and shuttles, shared mobility could grow by 28% per year until 2030. In less optimistic projections, shared mobility is still expected to grow by 15% per year. How well shared mobility will grow depends on how the industry addresses behavioral aspects, such as potentially uncomfortable dynamics between passengers who are strangers sharing a space. Shared mobility is expected to grow in part because its availability is still limited to dense urban areas and has the potential to spread to all different kinds of communities. According to one report, shared mobility makes up about one percentage point of the thirty percent of annual vehicle miles traveled that it could address. As it grows,

shared mobility will likely dampen global vehicle sales. About one-third of the potential growth in vehicles by 2030 will be prevented by shared mobility. However, there will still be overall growth in car sales as developing countries demand more vehicles (Grosse-Ophoff, Hausler, Heineke, & Moller, 2017).

Another report warns that studies of shared mobility are vulnerable to self-selection bias. All forms of shared mobility, but particularly shared cars, bicycles, and scooters tend to be located in densely populated areas, near public transportation hubs, or near major employment centers. The location could be determining the profiles of the users rather than the other way around. The decision to use shared mobility is often coupled with a decision to live in a densely populated area. Those that decide to live in densely populated areas may have specific values, like a desire to live a car-free life, that are not shared by the general population. That means projections about the continued uptake of shared mobility may be based on an unconscious assumption that users outside of urban areas have the same values as shared mobility users in urban areas, which could lead to an overestimation of the impact of shared mobility if they do not (Franckx, 2017).

The ability of shared mobility to help with congestion and air pollution problems is mixed and dependent on the technology. Of carsharing, ride-hailing, ridesharing, and carpooling, only those that involve sharing the same vehicle at the same time (ridesharing and carpooling) would actually be able to reduce congestion and emissions. However, these modes might be less attractive since sharing a vehicle at the same time can increase waiting time and travel time and decrease convenience and comfort by sharing with at least one other passenger (Santos, 2018).

Carsharing

While an attractive option for many, carsharing faces certain challenges to increased adoption, and therefore car ownership reduction. Carsharing is not an attractive substitute for private vehicle ownership, since with its current prices and availability, it is not convenient for a daily commute. Even young people who express enthusiasm for the concept are reluctant to actually use carsharing and most plan to buy a car (Santos, 2018). Also for companies with carsharing fleets, their programs are rarely economically viable in cities with fewer than half a million inhabitants (Grosse-Ophoff et al., 2017). Indeed, the number of the urban population that are licensed drivers determines carsharing services popularity (Haydin, 2018). Since carsharing in its current forms is unlikely to eliminate car ownership, it is also not likely to reduce congestion or greenhouse gas emissions (Santos, 2018).

Ride-hailing and ridesharing

Ride-hailing (single passenger) can have negative impacts on the environment and traffic as its lower-than-taxi prices encourage more trips. Ridesharing is more effective than single-rider ride-hailing at reducing congestion and emissions. However, increasing ridesharing's popularity may be difficult as riders prefer to sit in relatively empty vehicles and have complete control over pick-up and arrival times, which with ridesharing they have less of as the driver picks up and drops off other passengers. Longer waiting times for ridesharing can also deter potential users (Santos, 2018).

Micromobility

Micromobility can help with traffic congestion and urban air pollution if it takes people out of personal vehicles. In a study by the micromobility company, Lime, operating in the U.S. and Europe, 30% of Lime riders surveyed replaced a trip by automobile during their most recent trip. There is also some evidence supporting that micromobility can help reduce car ownership and dependence (Lime, 2019). Micromobility services can also increase access to public transportation by providing transportation for the first and last mile of a journey (CBInsights, 2019). Micromobility can also help significantly with emissions reduction. Bicycles are emission free and e-scooters are extremely efficient. An e-scooter could go 82.8 miles on 1 kWh of energy, whereas an electric vehicle would only be able to go 4.1 miles and a gas vehicle only 0.8 miles on the same amount of energy (CBInsights, 2019).

How people use micromobility largely depends on what kind of membership program they have. People who have monthly or annual memberships to bikeshare programs are more likely to travel during rush hours, implying that they are more likely to cycle for their commute than those with day passes or single-ride passes. Those who only have a day pass or single ride are more likely to ride in the middle of the day or on the weekends with longer trips, implying they are using micromobility more for social and recreational purposes. E-scooter use also mirrors more recreational use patterns, and indeed most companies have single-ride rates (NACTO, 2018). If cities want to increase micromobility use to not just recreational use, they should make sure that companies offer longer-term membership plans.

One of the challenges to increased micromobility use is weather: people bicycle less and use scooters less in the rain, snow, and cold temperatures, so it will not be able to be a significant form of mobility in all cities at all times of the year. Micromobility, especially dockless forms are also rather new in most cities. As a result of cities addressing safety concerns over how to best absorb large volumes of two-wheel traffic, there have been regulatory clashes about whether the scooters and dockless bicycles should be allowed in the city if there are not clear rules about where they can be ridden and parked (Ajao, 2019).

Autonomous Vehicles

A fully autonomous vehicle (AV) is one that can guide itself without human direction. There are five levels of autonomous driving and this report will primarily deal with the highest levels (4 and 5) or high and full automation. Levels 1-3 range from driver assistance to conditional automation, but all require a driver to be in the car (NHTSA, 2017). There are many fully autonomous models that are being tested by companies—both automaker and software—around the world, but there are none yet in commercial markets. While some have promised that the first fully self-driving cars will hit the markets in 2020, it is more likely that it will take many more years before an AV is tested and approved that can drive safely at any speed on any road in any weather (Litman, 2019). Autonomous driving will likely initially increase in narrowly defined and geographically restricted areas, such as inner cities and on highways (Kuhnert et al., 2018).

Consumer Perceptions

Consumers are drawn to potential AV use because of convenience. Many cited an AV's ability to drop someone off, find a parking spot, and park on its own as their top reason for wanting to try a self-driving vehicle. Other selling-points for AVs are the ability to multitask and let the car drive itself in heavy traffic (BCG, 2019).

The impact of AVs will be will largely be determined by how they are used once they are released. So far there have been some studies about intended use of AVs, but information about actual AV usage patterns will not be available until AVs are commercially available. In a survey of consumers in the U.S. and Germany, only 19% stated with certainty that they would like to use an AV. Technologically savvy people are more likely to say that they intend to use AVs and they also tend to be younger (HERE Technologies, 2017). Indeed, other studies confirm that millennials are more comfortable with automation than other generations. However, this comfort with automation is stronger at the lower levels, such as driver assistance to prevent skidding. The desire for automation decreases as the level of automation increases for all age groups. While millennials prefer some features that offer lower levels of automation, they are not willing to pay significantly more for vehicles with those features, which could slow the overall adoption of higher levels of automation (Giffi et al., 2014).

Another roadblock to eventual AV adoption is the level of trust or lack thereof that people have for a computer to drive a car. Reports of accidents during self-driving tests, such as a pedestrian killed in Arizona (Hawkins, 2018), reduce the amount of trust potential consumers have in AVs. Over fifty percent of consumers feel that media reports of accidents involving AVs have made them more cautious of the technology in the U.S., China, and Germany. As a result, consumer perception on whether AVs will be safe dropped everywhere in from 2017 to 2018 and has not improved much in 2019. Around 50% of respondents in the U.S. and Germany think that AVs will not be safe, but only 25% of respondents feel the same way in China (Vitale et al., 2019). One way that trust in AVs could be rebuilt and by boosted is through the promotion of lower levels of automated driving that are already popular, such as Advanced Driver Assistance Systems (ADAS). People with ADAS features in their vehicles are more willing to use AVs (HERE Technologies, 2017). Also, the more the public interacts with AVs, the more likely their views of the technology will be positive (Penmetsa, Adanu, Wood, Wang, & Jones, 2019).

Ownership Models

The impact of the eventual adoption of AVs will also depend on which model of ownership is dominant. An AV can be a product—something that is purchased and used by a consumer, the way a traditional automobile is—or AVs can be seen as a service. AVs as a service would likely involve fleets of AVs owned by a company and dispatched to customers to bring them to a destination for a fee, very similar to ride-hailing and ridesharing, but without the driver. In a study by HERE Technologies, about 57% of respondents found the AV ownership model appealing and only slightly less, 52%, found the service model appealing. One might expect that current car owners and driving aficionados would prefer an AV ownership model over a service model, but there was no correlation between current car ownership and the enjoyment of driving on the preference for owning an AV over using an AV mobility service (HERE Technologies, 2017). Now we will examine the preliminary impressions of AV's in the U.S., Europe, and China.

U.S.

Willingness to try using a self-driving car is moderately strong in the United States, with 52% of respondents to a BCG survey saying they are likely or very likely to take a ride (BCG, 2019). A PwC report predicts that by 2030 almost 36% of personal mileage could be covered by AVs in the U.S. (Kuhnert et al., 2018). Many companies in the U.S. are trying to make the automated future a reality with the likes of Google, Uber, Lyft, Tesla and others currently testing AVs on the roads.

EU

Mobility habits for Europe are expected to change at the same pace as for the U.S. AVs of at least Level 4 automation could enter the European market as early as 2022. By 2030, 40% of the mileage in Europe could be covered by autonomous vehicles according to a PwC forecast (Kuhnert et al., 2018). Willingness to take a ride in a self-driving vehicle in Europe varies depending on the country. For example, 58% of French respondents were likely or very likely to take a ride in a fully self-driving car whereas only 41% of Dutch responded the same (BCG, 2019).

China

As noted above Chinese respondents were more likely to think of AVs as safe than their peers in Europe or the United States. In a BCG survey 75% of Chinese respondents stated that they would likely take a ride in a self-driving vehicle (BCG, 2019). As a result, penetration of autonomous mobility is expected to happen faster in China than in the Western world (Kuhnert et al., 2018). Interest in AVs is about double that in EU or the U.S. and the willingness to pay for automated driving features is higher as well (Giffi et al., 2014). The percentage of AVs that will be shared in China is also higher due to a higher demand for shared vehicles as a result of limits on the number of new vehicle registrations in some cities (Kuhnert et al., 2018).

Impacts of Autonomous Vehicles

The more that AVs are shared, the more cars will be taken off the road and the more likely the overall impact of AVs will be environmentally friendly. Shared AVs may save up to ten times the number of cars needed for self-owned AVs, as they can perform trips for many other people while a self-owned AV might not be in use (Fagnant & Kockelman, 2014). It is good news then that respondents preferred a shared service model about as much as they did private AV ownership. However, AVs will capture not just current car use, but also rides from all different modes of transport. There is a real risk that AV adoption will increase congestion as people move to AVs from public transport, walking, biking, and not travelling at all (HERE Technologies, 2017).

AVs would not necessarily need to be parked on city streets or always near the user, which could change the urban landscape and narrow streets (Goulding & Butler, 2018) as cities get rid of parking spaces. However, AVs driving to homes or parking lots outside of city centers would require them them to drive further using more energy, causing more congestion, and potentially even creating more urban sprawl. To avoid these potential negative consequences of AV adoption there needs to be electrification of AV fleets, the widespread adoption of ridesharing of AVs, along with the continued maintenance and development of

high capacity public transit. Depending on the predominant ownership mode, the net effects of AVs on energy use could range from more than 90% fuel savings with a predominant shared service model to 150% increase in energy use with personal AV ownership dominating (Konings, 2017).

Mobility as a Service

Mobility as a service (MaaS) is the integration of multiple forms of transport, both public and private, to bring planning, booking, and payments onto one platform to create a seamless mobility system. Instead of owning individual modes of transportation, e.g. a car, bicycle, monthly metro card, customers would purchase mobility service packages (Durand et al., 2018). The focus of MaaS is on the service of mobility, rather than owning any one mode of mobility. MaaS can also help integrate mobility trends such as shared mobility and AVs into the larger mobility system. For example, with just one payment, riders could use a carshare, bike-share or ride-hailing system to get to and from a commuter rail system (Axsen & Sovacool, 2019). Adoption of MaaS systems is positively correlated to their levels of integration and convenience (Durand et al., 2018).

Existing MaaS schemes can be categorized into different levels of integration. The lowest level of integration is the integration of information. A Level 1 MaaS scheme would function like a multimodal travel planner that may provide price information, but would not offer any way to buy tickets. Many Level 1 Maas schemes currently exist such as Google Maps, City Mapper, and many regional transit-planning apps. Level 2 schemes integrate booking and payments. A user of a Level 2 scheme could plan their trip then buy the necessary tickets or rides to make it happen, though the booking and payment of the individual tickets would be booked and paid for separately. Level 3 integration involves bundling or subscriptions and contracts. The user would not have to book individual trips but could have a monthly pass to use public transit as well as a certain number of miles of ride-sharing or uses of bikesharing all for a monthly rate paid to the MaaS provider. Only three Level 3 schemes have been designed to date. Level 4 integration would be the integration of societal goals through policies and incentives that would impact MaaS schemes. So far, there are no Level 4 MaaS schemes. This report will primarily focus on Levels 2 and 3 of MaaS integration which are in early phases in many locations and provide more functionality than simple trip planning (Durand et al., 2018).

Consumer Perceptions

The users of MaaS share many of the same demographic traits with users of other mobility trends. Indeed, users of shared mobility are most likely to be early adopters of MaaS. Like users of shared mobility, users of MaaS tend to be young adults, well-educated, middle or upper income, urban, carless or single car, and already heavy users of modes of transport that are not private vehicles. Trials of MaaS have primarily been done on these users, who represent a small, specific subset of the population at large, therefore the trials are not representative of what could be achievable with MaaS with the entire population (Konings, 2017).

By integrating fares, ticketing, and payment, MaaS increases the amount of convenience, freedom of choice, and occasionally reduces travel costs in public transit systems. By improving these factors MaaS schemes have increased public transit usage in multiple European cities (Durand et al., 2018).

MaaS in the U.S.

The U.S. has some emerging MaaS schemes. The ones with the greatest potential are being developed by ride-hailing companies. Currently Lyft has started to incorporate public transit routes and times into their app, giving it only Level 1 MaaS integration, but the potential to eventually integrate payments as well (Dickey, 2018). It also recently bought up North America's largest bike-sharing provider in hopes of eventually becoming the go-to app for city transportation. Uber has similar aspirations and also bought up a bikesharing company (Marshall, 2018). In the U.S. there is a high likelihood that a more integrated form of MaaS will come out of one of these companies.

That said, there have been experiments with more integrated MaaS in the U.S. The first Level 3 MaaS scheme, SHIFT, was developed in Los Angeles but was never operational. It would have integrated bikesharing, carsharing, taxi, demand responsive transport, and would have owned the bus, car, and bike fleets (Durand et al., 2018). The relative limited development of MaaS in the U.S. can be explained in part by the fact that personal mobility is dominated by private vehicles to a higher extent than it is in Europe or China (Schweiger, 2017).

MaaS in Europe

Europe is the region with the most development of MaaS systems. The development and deployment of MaaS schemes has been increasing at a rapid rate in recent years, much faster than in the U.S. Some examples of Level 2 MaaS schemes in Europe include moovel in Germany, myCicero in Italy, Tuup in Finland, NaviGoGo in Scotland, WienMobil Lab in Austria, and iDPASS in France. Hannovermobilin Germany and EMMA in France both offer partial payment integration (Durand et al., 2018).

Europe is also home to some of the most advanced MaaS schemes. For example, Whim is a Level 3 MaaS scheme available in Finland. Users can choose between two types of bundles: one where for 49 euros a month users get unlimited public transport and discounted taxi prices and another where for 499 euros a month users get unlimited access to public transport, taxi, and shared vehicles according to their needs (Durand et al., 2018).

MaaS in China

China is poised to become a leading market for MaaS, since traffic and congestion in its largest cities make hailing a ride much easier than driving a car. In addition, ride-hailing and ridesharing have grown rapidly in China, as has the urban population. ARK Invest estimates that the market for MaaS in China could rise to $2.5 trillion by 2030. China is particularly positioned to embrace MaaS due to: a majority population unlicensed to drive (80%); low average income relative to vehicle prices; and the difficulty of obtaining a car in China (Keeney, 2017).

MaaS programs have recently started in China with the platforms of Meituan-Dianping and AutoNavi offering the ability on their apps to book to rides from competing ride-hailing companies and taxi dispatchers. The ride-hailing giant DiDi Chuxing has also started a pilot program in Chengdu where users there may also hail rides through the company Tongcheng on the DiDi app (Dai, 2019). DiDi started as a taxi-hailing app but now, like Uber in the U.S., is also incorporating other forms of mobility into their platform including ridesharing and bikesharing (DiDi, 2019).

Impacts of MaaS

MaaS could play a large role in moving users away from private vehicles and instigating different travel patterns (Durand et al., 2018). While private vehicles are typically seen as the mode of transport that grants the most freedom and flexibility, good MaaS systems can help make shared mobility and public transit more convenient by making booking and payment easy and by showing which options are closest and would get the user to their destination fastest. For these reasons MaaS is also likely an integral element in encouraging the development and use of autonomous vehicles as a service and the shared use of AVs.

MaaS helps maximize the private-functional benefits of shared mobility and public transit by integrating them. In one study, 39% of respondents said they drove less or much less because of mobility apps on their smartphone (Goulding & Butler, 2018). MaaS can also help bring down the operating costs for public transit by taking over much of the ticketing. Lower public transit costs can help continue to encourage less personal vehicle usage (Axsen & Sovacool, 2019). However, habits are difficult to change and MaaS might be more likely to change behavior on incidental trips before it is used for daily commutes. The size and timeline of these potential impacts is unknown since quantitative studies and trials of MaaS are still relatively limited (Durand et al., 2018).

Policy Recommendations for More Sustainable Transport

Personal mileage around the world is expected to increase: in Europe it could rise by 23% by 2030, in the U.S. by 24%, and by 183% in China (Kuhnert et al., 2018). If these increases are going to be sustainable for cities and for the planet, then they cannot be met with more personal vehicles. Mobility trends such as shared mobility, autonomous vehicles, and mobility as a service can help people increase their mobility without increasing the number of vehicles on the road. However, how these trends are adopted will determine how sustainable mobility becomes. There need to be more shared autonomous vehicles than privately owned ones. Modes of shared mobility that more effectively reduce the number of vehicles needed should be prioritized, such as ridesharing, carpooling, and micromobility. MaaS schemes can be implemented to help increase usage of shared mobility, public transit, and active mobility, by making them more convenient to use.

With the private car use dominating in the U.S., to a lesser extent in Europe, and growing rapidly in China, more sustainable forms of transport must be able to compete in terms of comfort, convenience, freedom, and perceived status, in addition to speed and cost. To encourage the use of shared forms of transport from shared autonomous vehicles to public transport local governments and companies should think about how

to make the experience of sharing a space with strangers more comfortable. In addition, convincing solo-drivers to share rides may be challenging and will require strong financial incentives to compensate for the disutility caused by the reduction in comfort by sharing space and soundscapes whether in a shared taxi or bus. Compensation for increased waiting times and less reliable arrival times when sharing rides should also be considered (Santos, 2018).

Efforts should also be made to bring versions of these new forms of mobility and public transit to less densely populated areas so private car ownership is not the only way to have mobility in those places. One example from the United States was a rural-friendly ride-hailing company called Liberty Mobility Now that operated in Ohio, Texas, and Nebraska. Instead of a smartphone app platform that could not be used by rural residents with poor mobile phone service, Liberty Mobility Now had a call center to dispatch cars so it could be used without a smartphone. Ride-hailing with a set up more similar to a taxi company made more sense in these rural areas where there is is not a saturation of network (Shultze, 2017). Since car culture is not homogenous between the U.S., Europe, and China, and even within these places, sustainable transport solutions will also have to not be homogenous.

Since the net impacts of shared mobility and AVs are uncertain and since cost is still an important factor in modal choice, the correct pricing of transport, including new mobility trends will be an important aspect of policy to reduce transport emissions and congestion. Litman (2019) argues that driving is underpriced, especially in North America. Every dollar spent on private car use imposes a $2.55 cost on society. As long as driving remains underpriced initiatives for more sustainable transport will not be fully effective. Without accounting for the costs to society, policy measures are taken and infrastructure is built that may save the motorist 5 cents per mile, but cost society 10 cents per mile. This is inequitable since people must bear the costs that others create. Drivers have almost no incentive to limit trips where the benefits exceed the costs of making the trip, which results in economically excessive travel. He argues for more efficient pricing of transportation, especially private vehicles, as well as changes in planning, land use, and infrastructure investments.

Changing Travel Behavior

For more sustainable transport to take hold, travel behavior will have to change. Some of that can be achieved with more efficient pricing as mentioned above. Travel behavior can also be changed through behavioral nudges. In one example from Durham, NC in the U.S., the city worked with companies to provide personalized maps of transit, walking, and cycling routes from home to work for participants who opted in. The maps also included a list of the advantages of not driving like savings on gas, potential weight loss, and reclaimed time from not sitting in traffic. The materials also included the slogan, “Driving downtown is so 2017.” Another method involved entering people who used public transit in a contest each month for a cash prize. The informational intervention brought the share of commuters who reported driving to work alone down 12% compared to those who had not received the maps and the solo-driving share dropped by 16% among those who received the maps and took transit for prizes (Webber, 2018). Initiatives such as these could help encourage more shared rides and active transport.

Habits, such as a daily commute can be hard to change, especially within the context where they develop. Research has shown that travel habits are easiest to change when the context is changed: for example, after a move or getting a new job. After these changes is the best time to inform about alternative modes of transportation (Unal, 2017). Policies that use these moments to encourage more sustainable transport could include: a city sending out informational packets about or even discounts to local transport options or companies providing similar information and discounts to new employees.

The younger generations around the world can help bring about sustainable travel behavior changes. They are opting to build identity online instead of through car ownership. They prefer to live in urban areas and are often the first to use new mobility options. This is important for transport planners to keep in mind since investments are made with a long-term perspective and the preferences of today's young generations will be more prevalent in the future. However, to really have sustainable and congestion free transportation systems policy makers will also have to make new mobility solutions accessible to older, more rural, and less technologically savvy populations as well.

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