FACTORS AFFECTING PASSENGER TRAVEL DEMAND IN THE UNITED STATES

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A White Paper from the National Center for Sustainable Transportation

Giovanni Circella, University of California, Davis
Kate Tiedeman, University of California, Davis
Susan Handy, University of California, Davis
Patricia Mokhtarian, Georgia Institute of Technology

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National Center for Sustainable Transportation

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Factors Affecting Passenger Travel Demand in the United States

Key Findings

Vehicle Miles Traveled (VMT) per capita has declined in the United States since the early 2000s.

Passenger travel demand seems to have *decoupled* from economic activity.

Sociodemographic trends in the U.S. society include smaller household sizes, delayed childbearing and increased presence of immigrants.

Baby boomers are starting to retire (e.g. they make fewer commuting trips), and new generations (e.g. *millennials*) tend to own fewer vehicles and have increased multimodality.

There is a resurgence of the central parts of cities, and increased availability of travel options also in non-central areas.

The impact of new transportation technologies, e.g. *shared mobility* services today, and *autonomous vehicles* in the future, is uncertain.

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Factors Affecting Passenger Travel Demand in the United States

EXECUTIVE SUMMARY

During recent years, the use of private vehicles in the United States has gone through a period of stagnation. In particular, starting in the mid 2000s, the average per-capita vehicle miles traveled (VMT) have declined, after a long period of steady growth in the previous decades. In addition, an increased portion of Americans live without a car, and while the total amount of person-trips in the country continues to rise, this has not translated into increased car use. Instead, the use of alternative modes, including public transportation and active means of travel, has increased.

The image of U.S. passenger travel demand at the beginning of the 21st centuries is one of a country that is increasingly diverse, multimodal, and (slightly) less reliant on the use of private cars. Travelers modify their behaviors due to an increased number of alternatives that are available to them, changes in the characteristics of the available alternatives, and in the way they evaluate and perceive the characteristics of these alternatives. The economic crisis from 2007-2009 has certainly contributed to reducing total VMT in the country. However, it is not believed to be the main cause of the observed changes in travel behavior, and other factors seem to play an important role. In particular, the observed reduction in the amount of travel by car predates the economic crisis by at least a few years.

In this white paper we discuss the forces behind the trends, the relative permanence of which is often unclear: we explore travel demand's relationship with explanatory factors such as the impact of economic activity, gas prices, urban form, changes in socio-demographic traits and generational effects, and the expanding availability of travel options (including electronic alternatives to travel). We discuss how these factors affect trip generation and characteristics, modify the *choice set* (i.e. the alternatives that are available to travelers), as well as the characteristics of each alternative, and the way travelers perceive and evaluate the characteristics of these alternatives.

Trends in passenger travel demand no longer seem to track trends in economic activity. A number of factors may affect this, including the complex changes happening in society and work organization, also due to the impact of the adoption of technology, as well as the differential growth of the various economic sectors, with stronger growth observed in the technological, financial and service industry, and the growing disparity in personal wealth. These trends are expected to continue, and thus economic activity may no longer be the strong driver of VMT it has been in the past.

The urban form of American cities is an important predictor of car travel; the literature has demonstrated that individuals that live in more dense, compact, diverse neighborhood tend to drive less than those in suburban areas. Recent data show some evidence of a return to the central parts of cities, though on average suburban growth continues to dominate land use density patterns. American cities are changing, though, and the increased opportunities associated with the investments in public transportation and the other interventions to promote pedestrian and bicycle mobility provide increased multimodal accessibility and travel options to

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many travelers. This turns, in the short run, into increased choice options for traveling and less dependence on car travel; it may allow lower levels of auto ownership among those individuals that benefit from, or are more interested in, such choice options, over the longer term; it also encourages changes in the awareness and perception of travel alternatives among various individuals, further contributing to changes in travel behavior, and eventually supporting the use of non-auto travel modes.

Large shifts in sociodemographic trends have characterized U.S. households, and they are potentially lasting influential factors on travel demand. These factors include lifecycle effects, period effects and cohort (generational) effects. The observed trends include smaller average household size, delayed marriage, childbearing and other life events, and an increased prevalence of immigrants. Further, baby boomers are starting to transition into retirement. This reduces the number of their commuting trips, and VMT, but increases the space for discretionary travel. Among the *generational* effects, younger generations are found to have different travel patterns from older cohorts. Both members of Generation X and Generation Y (i.e. *millennials*) are found to drive less than their older peers at the same stage of life, and exhibit different urban preferences. Millennials, in particular, tend to delay having children, and often live in smaller housing units. They were hit hard by the economic recession, and still have a higher rate of unemployment than previous generations. Millennials are also credited to have stronger preferences for urban lifestyles, although it is not clear whether this represents a long lasting trait, or only a temporary preference associated with the specific stage in life. All of these generations include frequent users of communication technologies: more than half of Americans own a smartphone, which allows increased opportunities for micro-coordination of travel, and for the adoption of travel alternatives that may decrease car use. How these transformations affect travel demand is still not clear, though. Technology is associated with a complex pattern of effects which may eventually lead to substitution of, complementarity or neutrality with car travel. Changes in gas prices have also certainly had a role in affecting travel behavior, but their impact on VMT, on average, is found to be rather weak. Changes in gas prices affect vehicle choice, though, which in turns somehow affect the relationships of Americans with their cars, though not necessarily the amount of travel per se.

It is unclear if per-capita VMT will continue to decline, or if it will resume growth after the temporary "peak" observed in the past few years. In other words, it is unclear if *peak car* is a temporary or lasting phenomenon, i.e. whether if after removing some of the causes (e.g. the recent economic crisis), the growth in travel demand and the use of private vehicles will resume as before. There are reasons to believe, though, that some of the observed trends will extend in the future. Several of the factors that are discussed in this white paper are expected to continue to have an effect in future years: the underlying regime of growth of travel demand that powered the previous decades has lost strength, with the effects of factors like the expansion of cities into the suburbs, the gender gap and the role of age on drivers' licensing losing strength after they had been important reasons for growth in car travel in previous years. With an auto ownership ratio of approximately one vehicle per licensed driver, and almost all adults of driving age that desire to obtain a license already having one, growth in passenger travel demand in the 21st century is now driven by other factors, such economic growth, urban form, and personal preferences of individuals.

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Thus, it is unlikely that passenger travel demand will resume the rapid growth observed in the past. Instead, more limited adjustments will likely be associated with the factors affecting demand, or the combination of factors that will prevail. In such a future, important leverage is left to policy intervention, in particular at the urban level. Most Americans live in environments which necessitate cars for private mobility, but more options for multimodal travel are becoming available. Further, the adoption of new technology solutions already provides access to alternatives to car use. Additional challenges will confront planners in future years. Disrupting technologies, including shared mobility services, which are already available in many regions, and connected and autonomous vehicles (in the future) can potentially revolutionize the way Americans travel. These technologies may cannibalize other means of travel, at least under some circumstances. The final impacts of these emerging transportation technologies will effectively depend on the way they are deployed, and how they are integrated with the existing means of travel.

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Introduction

The characteristics of passenger travel demand in the United States are changing. Most notably, during recent years, the use of private vehicles, commonly measured in vehicle miles traveled (VMT), has gone through a period of stagnation. In particular, the average per-capita VMT has recently declined, after many decades of steady growth. A growing body of empirical research suggests that the United States, similar to several other developed countries, might have passed the peak of per-capita automobile use (Kuhnimhof et al. 2013; Sivak 2013; Sivak 2014b; Zmud et al. 2013).

The reasons for this apparent peaking in the use of personal vehicles, and its relationships with the use of other travel modes, are not entirely clear. Several possible explanations have been proposed to explain this trend in travel demand. They include the impact of the recent economic recession, changes in gas prices, demographic trends, changes in the urban form of American cities, and emerging changes in personal preferences and lifestyles (Puentes 2013; Goodwin 2012; Wachs 2013). Little evidence exists, to date, as to whether these trends will continue in future years, and therefore represent a deeper and more structural change in travel demand, or if they are only temporary as it would be the case if they are largely the result of temporary economic conditions. In other words, it is unclear if *peak car* is a temporary or lasting phenomenon, i.e. whether if after removing some of the causes, such as fuel price increases, the growth in the use of private vehicles will resume as before, or not.

The observed changes in travel demand have important implications for urban and transportation planning owing to the large financial investments and considerable time required to provide new transportation infrastructure and services. Accordingly, understanding the factors affecting current passenger travel demand, and their potential relevance in affecting future trends in the use of cars relative to the other means of travel, is of outmost importance to planning processes.

This white paper aims to serve as a useful reference for transportation researchers and practitioners in understanding the factors behind the recent changes in passenger travel demand in the U.S., particularly the observed decline in per-capita VMT, and the potential impact that these factors will have on travel demand in future years. In the white paper, we review the findings from scientific studies and recent technical reports, and discuss the contribution of each factor to the use of private vehicles rather than other means of travel, the direction and magnitude of the dominant effects of each factor, their potential future effects, and the degree of certainty with which these factors may affect travel demand in future years.

General Trends in Travel Demand

The use of motor vehicles - in the remainder of the document we refer to “cars” to include all light-duty vehicles such as passenger vehicles, pickup trucks, sport-utility vehicles (SUVs), and

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vans, unless otherwise specified – grew steadily in the United States in the second half of the 20th and the first few years of the 21st Century. This trend mirrored the positive trends in economic growth and the expansion of cities towards a model of lower-density residential development with separated land uses that were observed in the same years.

Figure 1 summarizes the observed trends in *total VMT* and *VMT per capita* in the United States between 1970 and 2015, using data from the Federal Highway Administration (FHWA). The figure highlights the apparent *VMT peak* that was recorded in the first years of the 21st century. Recent preliminary FHWA data from 2015, however, seem to suggest a resurgence of VMT growth at the national level, with total VMT expected to reach a record-high value at the end of the year (according to the monthly-adjusted annual VMT estimates from FHWA), and an upswing in per-capita VMT as well (although the latter still remains below its 2005 peak).

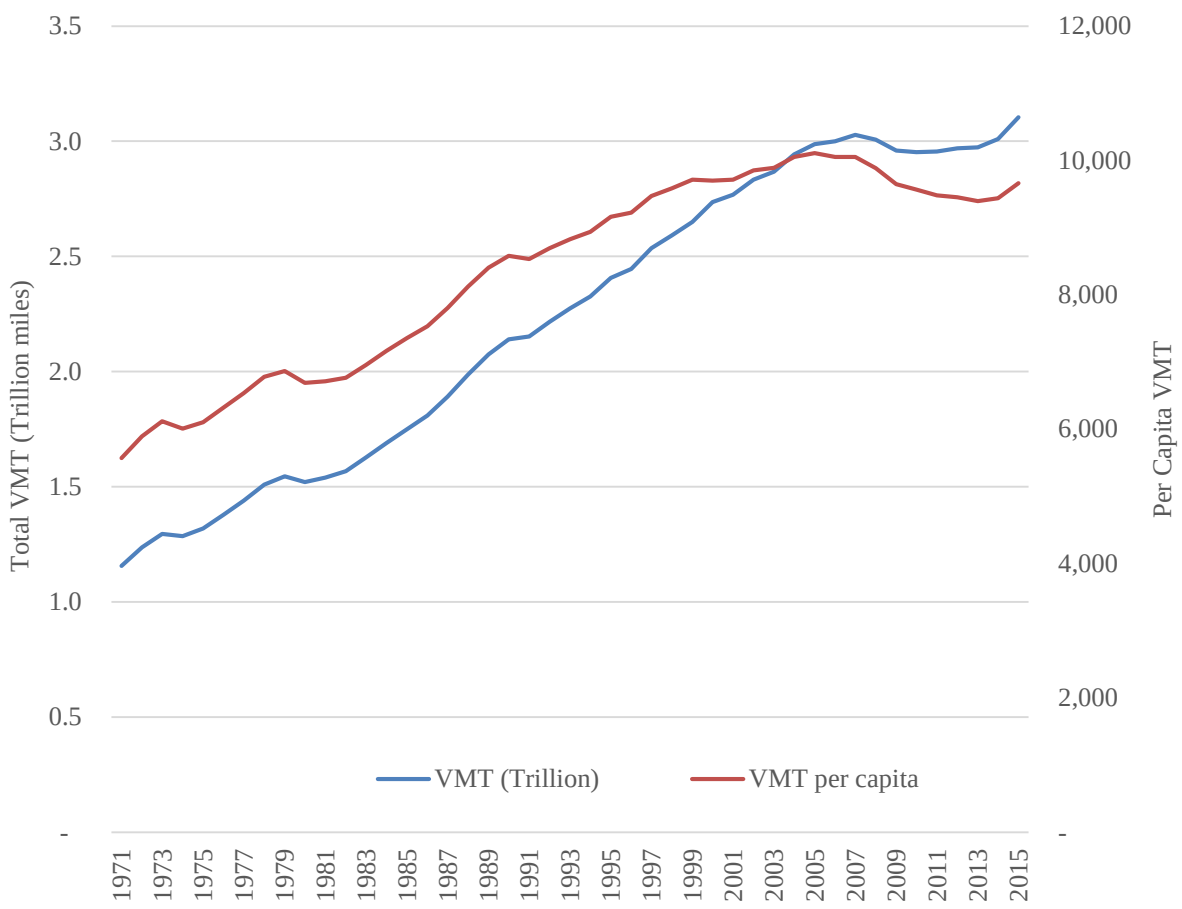

Figure 1: Trends in Total and Per-capita VMT 1970-2015 (created by the authors using FHWA and Census data for 1970-2015; forecast data for 2015 were added using information obtained from the moving annual-average VMT data from FHWA, last updated in July 2015).

Similarly, the total number of privately owned and commercial light duty vehicles[1] within the United States reached a (at least temporary) maximum of 242.9 million in 2008, and decreased nearly four million vehicles by 2011, but has rebounded to 241.0 million in 2013 (FHWA, 2015). In addition, an increasingly large number of households have been found to own fewer or no cars in many U.S. metropolitan areas (Sivak 2014a). Nationwide, 9.2% of U.S. households were found not to own a car in 2012, compared to 8.7% in 2007 (Sivak 2014a).

The observed decreases in total and per-capita VMT have been accompanied by other changes in U.S. travel patterns. Analysis of National Household Travel Survey (NHTS) data shows that the total number of person-trips continued to increase between 1995 and 2009. However, the mode distribution shifted. In particular, the percentage of person-trips made by car fell from 87.8% in 1990 to 83.4% in 2009 (after reaching a maximum of 89.3% in 1995), while the percent of person-trips made by transit rose from 1.8% to 1.9% and walking rose from 7.2% to 10.4% over the same period[2] (Santos et al. 2011). In addition, commuting data from the American Community Survey show that the number of commuters who traveled to work by bicycle increased from about 488,000 in 2000 to about 786,000 in 2008–2012, with an increase in commute mode share of 0.2 percentage points, from 0.4% to 0.6% (McKenzie 2014).

The VMT peak phenomenon has also been examined with greater precision at the state level. Garceau et al. (2014) summarized the trends in VMT per capita for each state in the U.S. from 1980 to 2011.[3] The results indicate that, in 1992, Washington was the first state to reach a peak in its per-capita use of cars, e.g. the time in which a state average measure of per capita annual VMT started to decline after years in which it had been increasing. Six other states followed by 1999. By 2004, a total of 26 states had reached a peak in their VMT per capita, with a majority of those states continuing to decline since their respective peaks. By the final year included in their analysis (2011), 48 out of 50 states had reached an apparent peak, with Alabama and North Dakota being the only exceptions of U.S. States where the per-capita use of cars continuously grew during the analyzed period. It is interesting to note that in 40 of the 48 states that reached at least a temporary peak, per-capita-VMT continued to decline in the remaining years included in the study (Garceau et al. 2014)[4].

[1] This measure includes the number of privately owned and commercial cars, motorcycles, pickups, vans, sport utility vehicles (SUVs), and other light trucks. It does not include buses, heavy trucks and government-owned vehicles.

[2] Caution should be used when comparing results from different NHTS datasets, as different methods in collecting the data were used. In particular, travel survey data were collected in the U.S. until 1995 with the Nationwide Personal Transportation Survey, and with the NHTS starting in 2001. Additional modifications were made in the language used to collect information for specific transportation modes, e.g. walking trips, which may explain part of the differences in mode share observed over time.

[3] This study also compared the observed trends in VMT per capita, by state, to the correspondening measures of gross domestic product (GDP) per capita. We will discuss the relationship between travel demand and economic activity (and GDP in particular), in the following section.

[4] As national trends have shown an upswing in the amount of total VMT and per-capita VMT since 2011, it is possible that the state-level findings may also be changing in that direction as well.

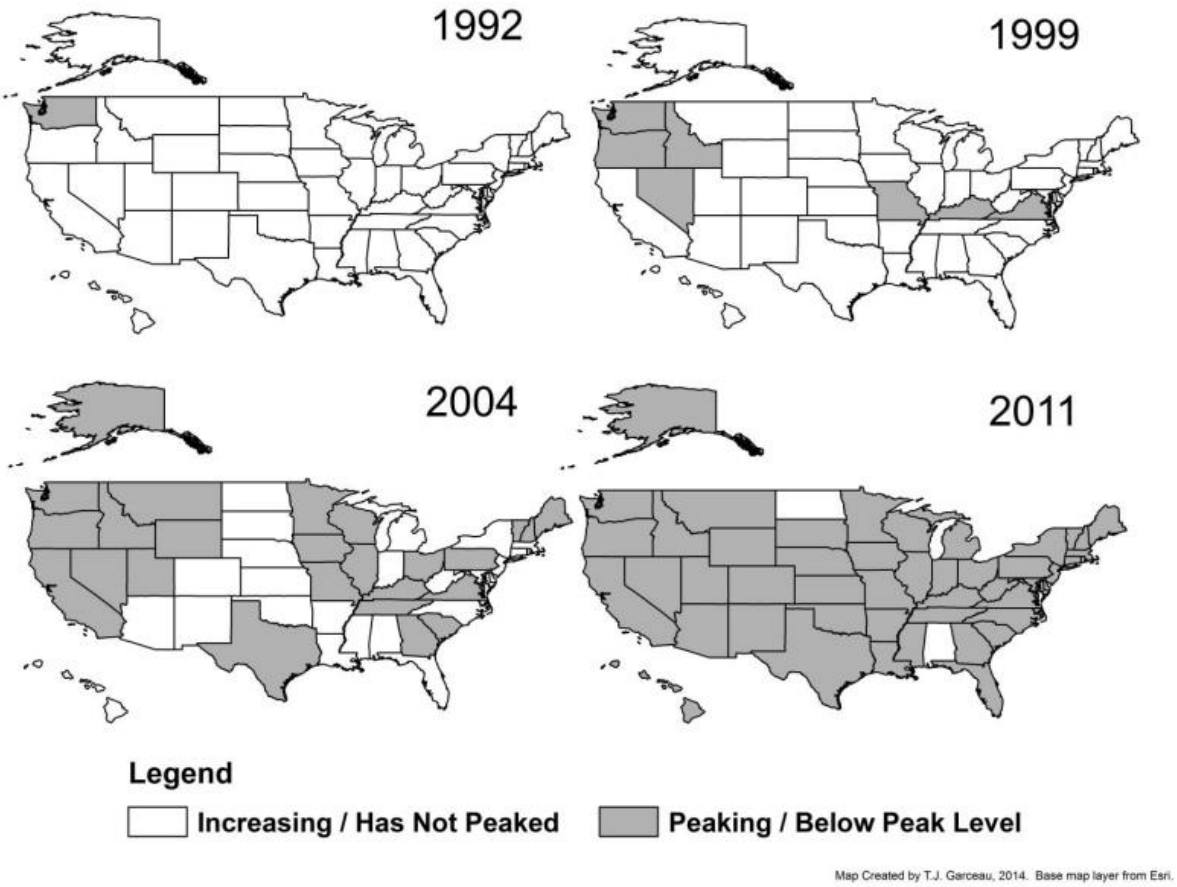

Figure 2. VMT peak by state, 1992-2011 (Garceau et al. 2014)

The observed trends in car use in the United States mirror the trends documented in other developed countries. For example, a decline in automobile usage has been observed in several European countries as far back as the early 1990s, thus preceding the apparent peak in car use in the U.S. by several years. Kuhnimhof et al. (2013) compared data from the national travel surveys from the United States, France, the United Kingdom, and Germany, and examined trends in travel behavior and mode choice over approximately 20 years (with the exact years included in the analysis varying by country, due to the availability of national data for each country). They found that during the first study period (1990 to 2000) every country included in the study experienced an increase in automobile travel per capita[5]. All four countries experienced an overall decrease in automobile travel per capita during the second study period, from approximately 2000 to 2010. The majority of study regions saw an increase in multi-modality and multi-modal behavior, especially within Germany (Kuhnimhof et al. 2013).

[5] The increase in automobile travel per capita was attributed to an overall increase in general travel in the United States and France, and mainly to an increase in automobile availability in the United Kingdom and Germany.

Factors Affecting Passenger Travel Demand

Several possible explanations have been proposed for the recent changes in driving patterns and the apparent peak observed in the use of cars (Puentes 2013). The 2008 economic recession has been offered as a possible, at least partial explanation for these trends. However, it has been noted that the VMT per capita, as well as the rates of vehicle ownership, including the number of vehicles per person, vehicles per licensed driver, and vehicles per household, reached their respective peaks between 2004 and 2006, which means approximately two years before the economic recession (Van Dender & Clever 2013; Sivak 2015). This lends supporting evidence to the importance of non-economic factors contributing to decline in VMT per capita. The economic recession seems to have reinforced a pre-existing trend, and increased its magnitude, without being its primary cause.

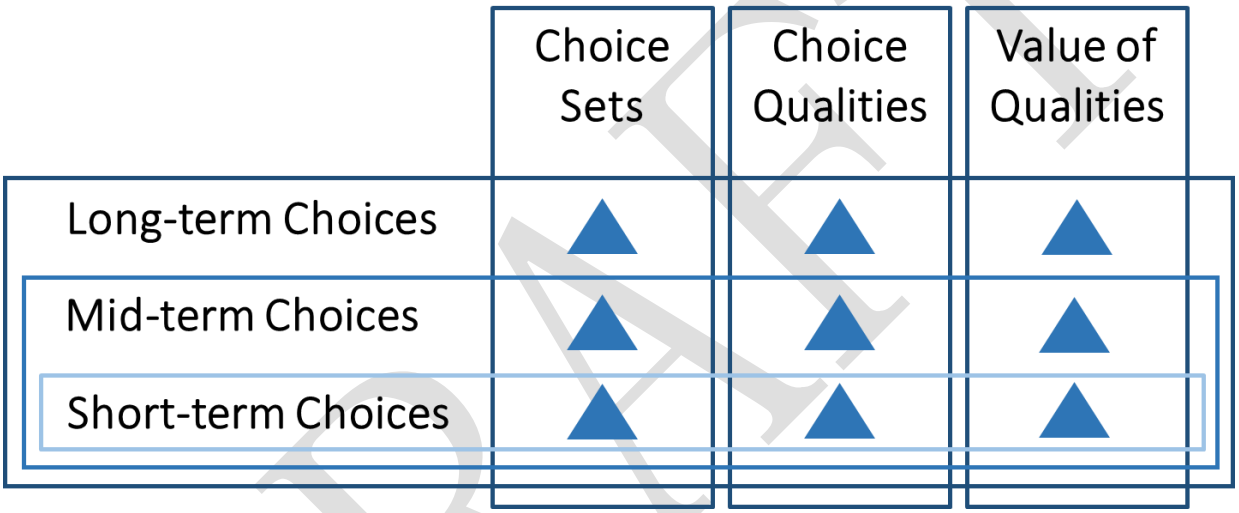

Figure 3. Potential points of impact of different factors: on the availability of travel choice options (choice sets), the characteristics (qualities) of the available options, and the way users evaluate the alternative characteristics (over different time scales)

Possible factors affecting passenger travel demand include the changes in fuel prices observed during the past few years, the high levels of traffic congestion in large metropolitan areas, changes in household composition and demography, eventual shifts in personal preferences and lifestyles of the U.S. population, and the impacts of emerging transportation services and new technological solutions – e.g. the eventual substitution of physical trips with electronic alternatives to travel (Newman & Kenworthy 2011; Wachs 2013).

America is changing. The decline in the growth rate of passenger travel demand in the U.S. observed in recent years, apart from some temporary effects associated with economic cycles and other short-term factors, certainly mirrors several modifications happening in the society during recent years. In terms of some factors, car travel has probably reached a "saturation" level (Metz 2012; Van Dender and Clever, 2013). The underlying regime of growth of travel demand that powered the previous decades has lost strength, with the effects of factors like the *gender gap* (both in drivers' licensing and in employment) and the role of *age* on drivers' licensing almost vanishing. On the contrary, these factors had been an important reasons

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for growth in travel demand in previous years.[6] With an auto ownership ratio of approximately one vehicle per licensed driver, and almost all adults of driving age that desire to obtain a license already having one, growth in passenger travel demand in the 21st century is now left to other factors, such economic growth, urban form, and personal preferences of individuals.

On the other hand, a number of additional factors contribute, in the short-term as well as in the long-term, to affecting several components of the individual's decision processes related to travel demand. American cities are changing, with the resurgence of downtowns and more central areas, and an increase in the mix of land uses in many neighborhoods. These changes, in the short term, increase the availability of choice options for travelers, including the use of means of travel other than cars, e.g. walking and biking, for short-distance trips. In the medium-term, they may impact the decisions on whether to own a car/vary the level of vehicle ownership in a household.

In addition, the literature has suggested that changes in personal lifestyles, trends in household formation and composition, and potential substitution of physical trips with electronic substitutes may also affect travel demand. In particular, the way individuals evaluate travel options is affected by their personal attitudes and preferences: recent trends reportedly show an increased preference towards urban lifestyles at least among specific segments of the population (e.g. urban populations of young adults, or "millennials"). This, in the short term, is believed to be responsible for part of the observed changes in travel demand for these individuals. Similarly, electronic alternatives expand the range of solutions that allow individuals to interact, work and shop remotely, and potentially substitute physical trips with alternatives (such as *telecommuting*, *teleconferencing* and *e-shopping*) based on the use of information and communication technologies (ICT). The availability of new *shared mobility* options, such as car-sharing and on-demand ride services (e.g. Uber) may also impact the current trends in the use of private cars. However, new mobility options are a recent phenomenon: most of their impacts on travel demand and mode choice are expected to happen in future years.

The following sections discuss the role of the major groups of factors that, according to the literature, are affecting recent trends in travel demand. For each group of factors, we discuss the main drivers of the effects and the expected impact on travel demand, as well as the peculiar characteristics with which these factors are affecting individuals' choices related to passenger travel.

Economic Growth

- **Drivers:** income growth only for higher income groups; economic growth in the financial and service sector.

[6] The *gender* gap (in terms of total amount of miles driven) was drastically reduced in the U.S. during the past 40 years. For example, according to NPTS/NHTS data, women drove only 5,400 miles per year, on average, in 1969, which was equivalent to 48% of the average miles driven by men in the same year (11,352). By 2009, this ratio had increased to 67% (10,244 miles driven per year for women, vs. 15,139 for men) (Sivak, 2015b).

- **Impact on travel demand:** non-linear relationship with income; growth in service sector does not increase VMT as much as growth in other sectors; if current trends in income growth continue, a rather slow growth in per-capita travel is expected.

Economic activity and personal income have been recognized as exogenous drivers of personal travel, and VMT in particular, for many years. As per-capita income increases, people tend to travel more by private vehicle (Greene et al. 1995; Brownstone & Golob 2009; Litman 2005; Rentziou et al. 2012). The direct effect of per-capita income on per-capita VMT has been positive and statistically significant over several decades (Ewing et al. 2014). Income has an indirect effect on VMT as well, through its effect on auto ownership (i.e. increasing auto availability and reducing the competition for the use of vehicles in a household), on the purchase of new homes (often located further away from the urban core), and through the availability of larger amounts of discretionary funds for leisure trips. According to some studies, income may also have a positive effect on the use of some types of public transportation in urban areas, and in those circumstances have a negative effect on VMT (Ewing et al. 2014).

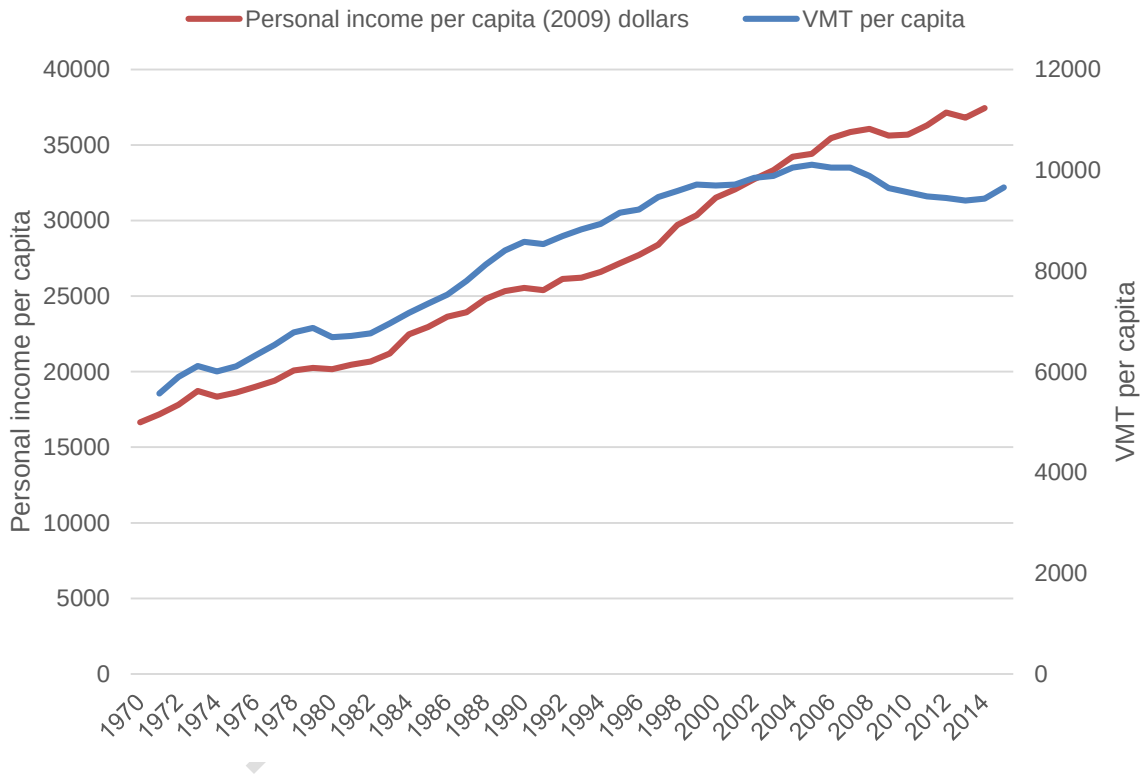

Figure 4. VMT per capita and personal income per capita in the U.S., 1970-2014 (created by the authors using data from the U.S. Bureau of Economic Analysis and FHWA).

Not surprisingly, VMT and economic growth appear in the aggregate to be positively correlated: the two measures have grown largely in parallel (e.g. proportionally). Except during World War II, when many national resources were devoted to the war effort, the two indicators have largely followed the same path until the mid-1990s (Figure 4). Even the recent travel trends seem to

show an uptick as the economy improves, after the plateau in travel demand in the years 2005-2009.

However, beginning around 1996, the two trajectories began diverging, with the growth in VMT growing at a much lower rate than the U.S. gross domestic product (GDP). According to many studies, travel demand seems to have *decoupled* from economic growth: in the first two decades of the 21st Century, a robust increase in economic activities is not necessarily associated with an increase in travel of a similar size, and the growth in VMT appears to be more limited. Accordingly, in the U.S. as well as other developed countries, future growth in economic activity may not generate the same increase in car travel observed in past years, due to the sum of a number of factors, including the saturation of the driving forces behind total travel growth, the stagnation in travel per capita, and some shifts to non-car modes of transportation (Metz 2012; Millard-Ball & Schipper 2011).

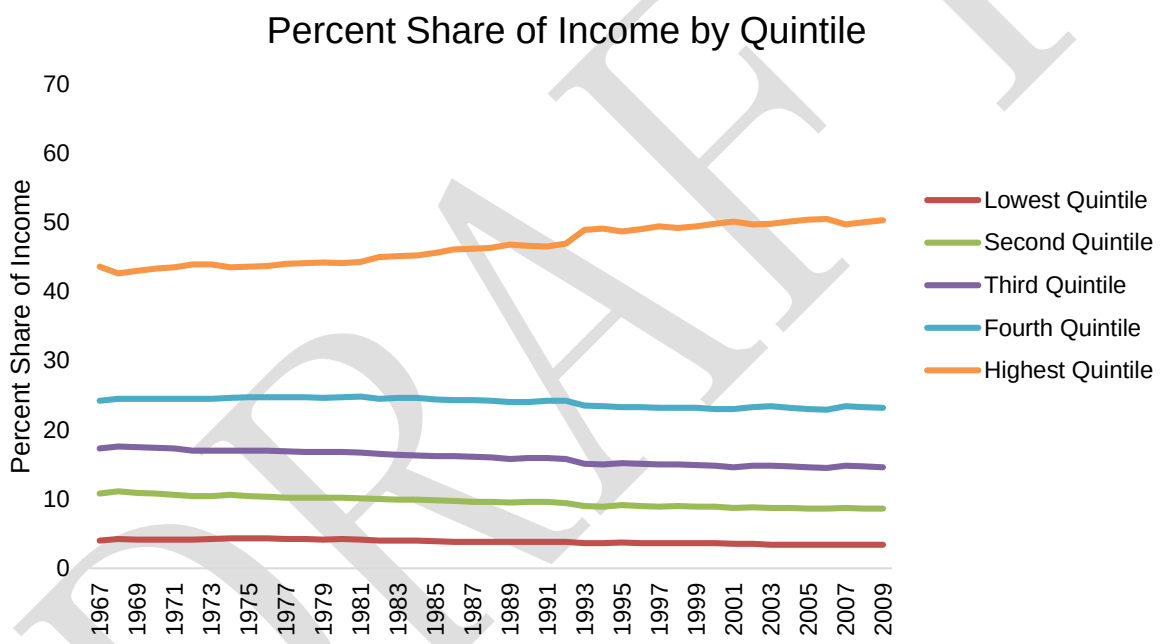

Figure 5. Percent share of income by quintile (1967-2009) (created by the authors using US Census data)

In addition to the contemporaneous modifications in society and work organization, also due to impact of the adoption of technology, whose effects are not easy to separate, two additional factors affecting this trend seem to emerge. One relates to the *income* distribution, i.e. the tendency with which some social groups - usually, the higher income groups - benefit from the economic recovery more than others; the other one relates to differential growth in various sectors of the economy, in particular with the financial and service sectors growing at a faster rate than the rest of the economy during the last two decades. On a state level, several states

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even exhibited a negative correlation between GDP per capita and VMT per capita, especially those that were the first states to reach peak VMT per capita (Garceau et al. 2014).[7]

Several authors have suggested that the relationship between income and VMT is not necessarily linear: VMT rises quickly at low income levels before tapering off (or even declining) at higher income levels (Holtzclaw et al. 2002; Salon 2013; Bento et al. 2005; Boarnet et al. 2011). Salon et al. (2013) suggested that a quadratic relationships might explain the effect of income more appropriately. VMT rises with income only up to some level (with a threshold level identified at $170,000 to $179,000 in that study). Non-linear patterns were also identified by Boarnet et al. (2011), who found that VMT rises in lower income brackets (until households earn $50,000 a year, roughly the median income of their study area), then stagnates until households earn more than $150,000, at which point it rises again.

These findings suggest that at lower income levels, VMT increases as incomes rise, but once households have reached the area's median income, VMT tends to level out.[8] This effect may partially explain the apparent decoupling of income and VMT during recent years, due to the increasing wage gap observed in the U.S. economy. While the economy has been recently increasing, according to US census data from 2011, the top quintile now encompasses nearly 50% of the income share in the U.S., with a growing trend compared to previous years (see Figure 5). The real income growth for the bottom three quintiles has remained relatively stagnant (with an average annual growth rate of 0.09% for the bottom quintile since 1980), while the income of the top quintile has grown robustly during the same years. Median income declined 7% from 2000 to 2010 in the US, after adjusting for inflation (US Census 2011). In addition, income distribution has certainly impacted in a different way certain segments of the population. For example, the recent economic slowdown has impacted younger generations (e.g. millennials) harder than older cohorts, through higher unemployment rates and stronger reductions in available income. The effects of such impacts are expected to have longer-term consequences, as members of this generation are often found to continue to have weaker economic conditions, also after they (re)-gain employment.

The decoupling of economic growth and transportation demand may also be influenced by the disproportionate growth experienced in the financial, technological and service sectors of the U.S. economy. During the past 50 years, the share of total U.S. GDP associated with the goods-producing industries has fallen by roughly half. During the same years, advances in information and communication technology (ICT) and increased globalization of economic processes have accelerated the shift within the U.S. economy towards the service industries. These shifts have been attributed a dampening impact on passenger travel and VMT, as well as a

[7] The apparent decoupling of VMT per capita from GDP from capita in these states may be a sign of the prevalence of non-economic factors, e.g. changes in sociodemographics and urban form, over economic factors, with the first group of factors causing a reduction in VMT per capita *also* at times in which the economy grew, rather than a relation of causality among these variables.

[8] At the disaggregate level, this is probably due in part to the substitution of air travel for car travel. At the aggregate level, the apparent decoupling may partly reflect the same principle (marginal increases in income may generate more air travel and less car travel), as well as the broader economic climate (both air and car travel tend to decrease during an economic recession).

modification in freight tonnage growth: a dollar of added value in the computer or financial sectors generates fewer trips for commuting or other purposes than an equivalent amount in manufacturing. The relationships between the growth of the economy by various sectors of the industry and travel patterns may be rather difficult to fully disentangle, though, as they are the product of multiple effects often working in counteracting directions. For example, the overall effect of technological innovation has been generally cited as one of the factors contributing to a growth in overall travel (see later section on the *impact of technology*). At the same time, the impacts of economic growth on total employment vary by sector, and so does the spatial distribution of the workers in different industry sectors[9]. These effects may partially explain the decreased elasticity of VMT with respect to the growth in the U.S. economic activity (and GDP) during recent years.

The changes in economic activity and the recent crisis, are often cited as the cause of a large portion of the decline in car travel registered in several countries (Bastian & Börjesson 2015). Still, as the economy improves, there are reasons to believe that the economic activity will not have the same strong role it has had in the past in pushing car travel growth.

Put in other words, economic factors will probably continue to play a role in the generation of travel, but this effect will be downsized by the current mutated conditions. Reasonably, when economic factors operate in the same direction as the impacts of the demographic and other trends on travel, as it has been the case for most of the 20th Century in the United States, the effects are amplified. Nowadays, with a recovering economy, the economic effects may be operating somewhat *against* the impact of the dominant demographic trends, with the resulting effects of these factors on VMT largely canceling out.

Forecasting the future impact of economic activity on travel demand is not easy, and it depends on a number of additional exogenous variables. According to most forecasts, economic activity is expected to continue to grow, as the economy continues to recover after the recent recession in the United States. This is expected to contribute to an increase in travel demand, even if with a slower growth rate than what has been observed in previous decades, due to the correlates with the other economic and non-economic conditions. In addition, unless major modifications in the composition of the economy and the political agenda alter the current trends, the median income will probably remain stagnant. If the income gap in the United States continues to increase, it is possible that future VMT will remain flat or will grow at a much lower rate than economic growth.

Gas Price

- **Drivers:** historically travel demand considered inelastic with respect to gas price; larger impacts in times of larger fluctuations in prices

[9] For example, white collar workers (and, more generally, the workers of the service industry) often live farther away from work, and commute longer distances, than blue collars. However, they can also rely more easily on solutions for telecommuting, which are generally less available to workers employed in goods-production and manufacturing.

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- **Impact on travel demand:** modest effect on VMT and mode choices (in the short term); impact on vehicle ownership and vehicle choice (in the medium term)

Gas price is a well-established driver of VMT, and its relationship with travel demand has been studied extensively in previous years. Most studies that investigate the impact of gas prices on travel behavior report the elasticity of VMT (and/or gasoline consumption) with respect to gas price: this measure is the ratio of the observed percentage change in VMT (and/or gasoline consumption) to the corresponding percentage change observed in gas price. For many years, the elasticity of VMT with respect to gas price has been considered rather low, i.e. travel demand was considered quite inelastic, and an increase in the fuel cost was not believed to determine a sizable change in the amount of travel (Noland 2000). Recent scientific findings have found that the reality is more complex, and the magnitude of the impact of gasoline price on VMT varies with the timeframe that is considered. In fact, changes (increases, in particular) in gas prices can affect VMT in several ways. In the short run, travelers can adapt their driving style to improve fuel efficiency (e.g. eco-driving), reduce their VMT by making fewer trips or switching to other modes, or rely more heavily on a more efficient vehicle if the household has more than one. In the medium and long run, travelers have more options: they can buy a more efficient car, switch to an alternative fuel, or even change household location to optimize housing vs. travel expenditures.

Short-run fluctuations in gas prices may lead to temporary changes in driving behavior, whereas long-run changes in gas prices have lasting effects on VMT (and even larger effects on gasoline consumption, due to the additional impact of vehicle fuel efficiency). Further, recent research shows that some effects might be associated when gas prices exceed some levels (Knittel 2012). Various studies have estimated the short term elasticity – with findings from -0.02 (Small & Van Dender 2007; Lin & Prince 2013)to -0.17 (Brand 2009). Hughes, Knittel, and Sperling (2008) found that the one-month elasticity in the 1970s was roughly -0.3, while it was -0.07 in the 2000s. However, others indicate that the elasticity has increased in recent years; Brand (2009) estimates a short run elasticity of -0.12 to -0.17 in the US from 2007-2008, compared to -0.05 from 1966-2001 (Small & Van Dender 2007) or -0.03 from 1966-2004 (Hymel et al. 2010). Long term elasticity is more difficult to quantify, though it is typically larger than short term. Small and Dender (2007) estimate a long-term elasticity of vehicle-miles travelled with respect to price of -0.11 from 1997 to 2001 and -0.22 across their entire sample from 1966 to 2001. Lin and Prince estimate -0.26 to -0.29 from 2001-2006 and Brand estimates -0.21 to -0.3 from 2007-2008. Price volatility plays a role in elasticity: demand is less elastic when price volatility is high (Lin & Prince 2013).

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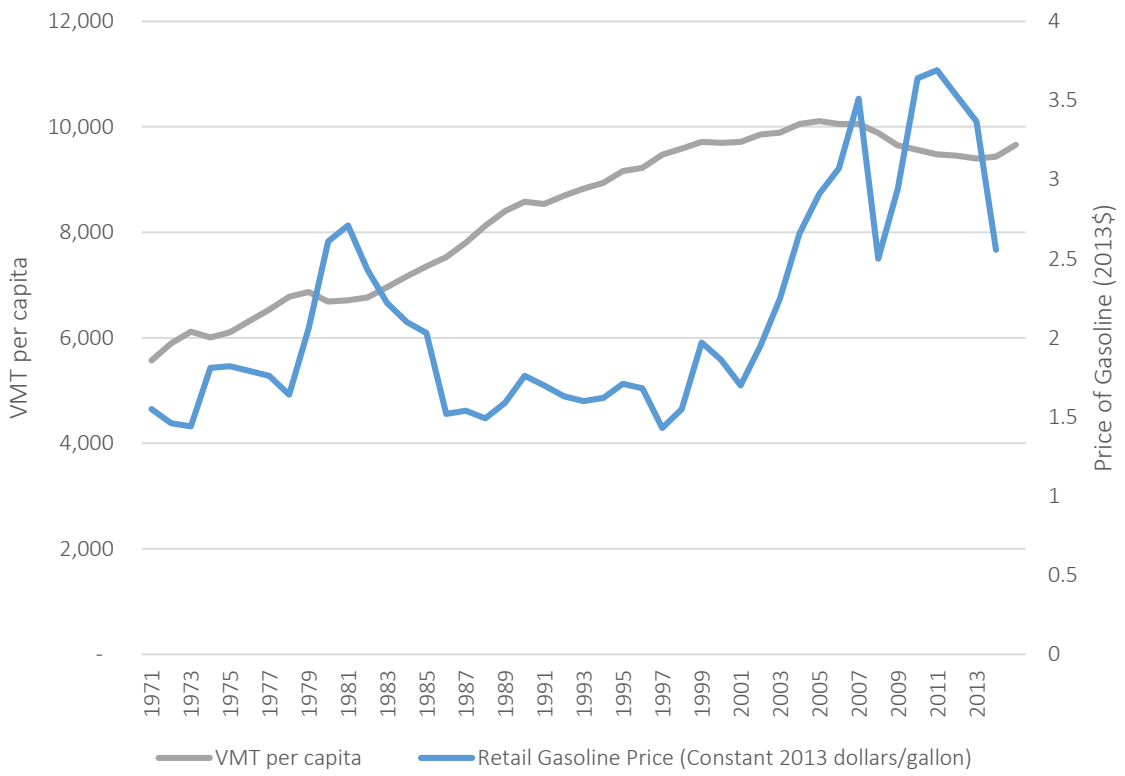

Figure 6: Real price of gas (in 2013 $) and VMT per capita (Source: EIA AEO 2014)

Even if it does not reduce VMT and the use of cars to a great extent, fuel price has a potential effect on consumer vehicle choice (Gallagher & Muehlegger 2011; van Bree et al. 2010). More fuel efficient vehicles were sold during the years of high gas prices, while the ratio of trucks/cars that are sold in the US seems to have increased again during 2014 and 2015, as a result of lower gas prices. According to the 2015 Energy Information Agency's (EIA) Annual Energy Outlook (AEO), motor gasoline prices are expected to increase only at an estimated average rate of 0.3% per year in real dollars (adjusted for inflation). The slower growth in the demand for oil, paired with the increased U.S. domestic production and increased availability of alternative energy sources at the international level, give reasons to believe that new peaks in gasoline prices are not expected in the short or medium term. This relatively flat (compared to the average annual increase during 1984-2011 – 2.1%) increase in gas prices could mean rather neutral effects on VMT. Further, increased fuel efficiency of modern vehicles, also as the effect of the Corporate Average Fuel Economy (CAFE) standards, are expected to further weaken the relationship between gas price and VMT (Anas & Hiramatsu 2012). Still, foreign politics, unexpected internationally crises, and/or other factors may impact gas prices in rather unknown ways.

Urban Form and Transportation Supply

- **Drivers:** increase in population in denser areas; access to alternative modes of travel; mixed land use and transit oriented development; policies for smart growth (e.g. Sustainable Community Strategies in California); self-selection of residents that prefer urban lifestyles.

- **Impact on travel demand:** urban residents travel less by car; increased availability of public transportation and walk/cycle options (in the short term); lower auto ownership rates (in the medium term); if current trends in real estate continue, decrease in per-capita travel.

Various studies have attempted to quantify the effect of land use on transportation outcomes, particularly with respect to the effect of *density* and mixed land use on VMT. Most studies agree that increased urban density and mixed land use can lower regional VMT by reducing the average trip distance and by increasing the proportion of trips made by means of travel alternative to the use of cars, in particular by walking or bicycling. Specifically, high accessibility, and by extension balanced, mixed-use growth, reduces total travel time and distance (Cervero & Duncan 2006), while housing-job proximity decreases commute time and regional VMT (Sarzynski et al. 2006). Ewing and Cervero (2010) provide a detailed discussion of the scientific findings related to the relationships among travel and the built environment.

The integration of land-use and transportation policies that aim to reduce the dependence on car travel and to increase environmental sustainability is central to the development of policies that promote mixed land use and support the use of public transportation, as in the case of the policies inspired by the principles of *smart growth*, *new urbanism*, and *transit-oriented development*. In many regions, progressive regulations and planning policies are promoting changes in travel patterns as a strategy to achieve reduced GHG emissions from transportation: this is the case, for example, of the Sustainable Community Strategies mandated in California by the Senate Bill 375 (2008) which require metropolitan planning organizations to identify strategies that meet the transportation and housing needs of a region while ensuring an appropriate reduction in the environmental impact from transportation and an increase in the livability of California's communities, identifying, among other things, the location of land uses, densities, areas to house future population, and the transportation network investments needed to serve these areas. Similar policy approaches are developed in other regions of the country and abroad, with the stated goal of reducing the dependence on car travel and the environmental disruptions caused by public transportation, and improving the health effects of transportation. Transit oriented developments (TODs) and other concerted efforts to develop housing units near transit are becoming increasingly popular in many US cities: experimental findings indicate that TOD residents drive about 20% fewer miles annually than non-TOD residents, and rely more on walking, cycling, and public transport (Jeihani et al. 2013). Similar conclusions were found in the analysis of other measures of the land use and transportation connection: for example, a 5% increase in neighborhood walkability is associated with 6.5% fewer vehicle miles traveled (VMT) per capita (Frank et al. 2006). Similarly, a 10% reduction in average distance between homes and rail transit stations is credited, on average, to reduce VMT about 1% (Bento et al. 2003). The characteristics of the built environment also influence transportation mode choices: Salon (2006) concluded that the built environment accounted for one half to two thirds of the difference in walking levels among different neighborhoods. Neighborhood type impacts both utilitarian and recreational walking frequency.

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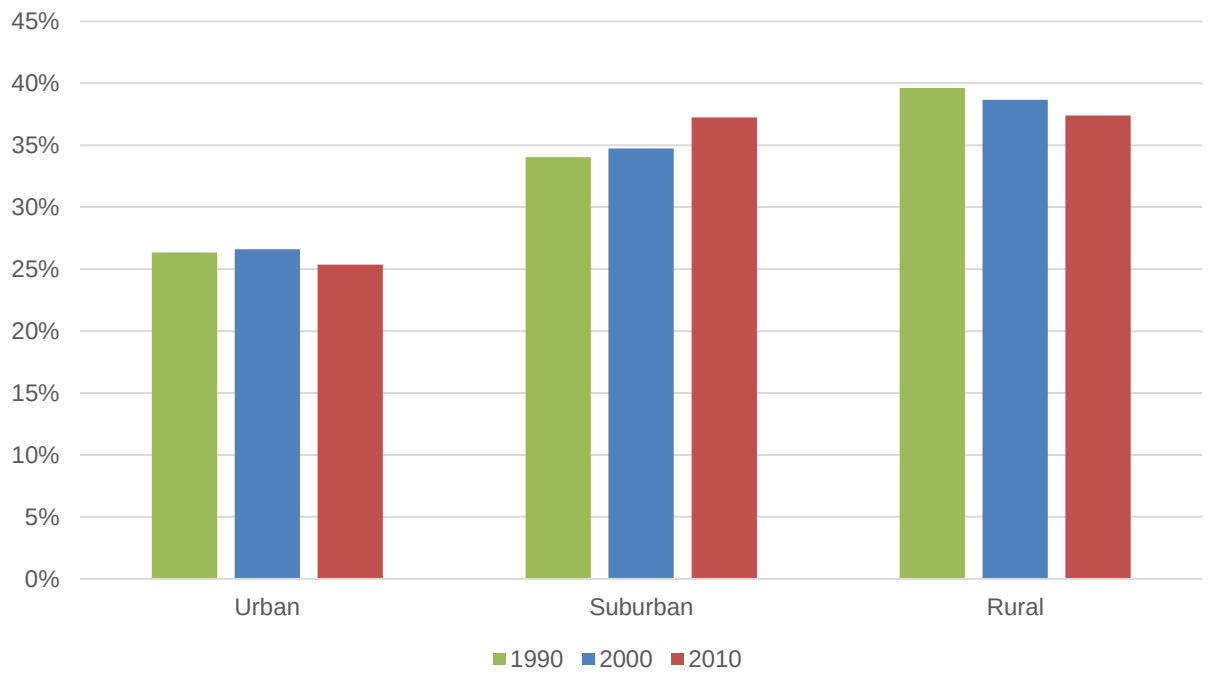

Figure 7. Distribution of U.S. population by urban, suburban and rural land use types (according to the definition of urban areas defined by the U.S. Census as the tracts with population density higher than 5,000 people per square mile; Source: Created by the Authors using Data from the US Decennial Census)

Analysis of NHTS data shows that the likelihood of a household not to have a car increases with the density of the neighborhood where the household lives: almost 29% of households living in areas with population density higher than 10,000 persons per square mile do not own a car. However, a very small percentage of the U.S. population lives in these high density areas (Santos et al. 2011). Similarly, the amount of car travel seems to be affected by the characteristics of the urban form (and density in particular) in a more prevalent way in dense areas. The very dense historical districts well served by public transportation account for most of the reductions in VMT associated with the impact of urban areas, and they are conducive to much higher use of public transportation and walking. However, these districts account for a very limited portion of the U.S. population (approx. 7%), and are clustered in very specific areas of the country (Voulgaris et al. 2015).

Differences in travel patterns among residents that live in different neighborhood types may not be entirely attributable to the impact of land use and urban form on travel patterns though. Such an effect is not homogenous across all individuals, and some segments of the population (e.g. young cohort, and immigrants) seem to show larger impacts on their amount of car travel: Wang (2015) demonstrated that the elasticity of residential density on personal VMT of the native-born respondents born in the 1950s is around 20% lower than those born in the 1980s and around 60% lower than the foreign born respondents staying in the US for less than 10 years. Further, individuals may choose to live in high density settings with varied land uses because they seek to drive less and enjoy an increased variety of travel mode options for their trips. If this is true, they do not adopt these travel patterns as a direct effect of the built

environment, but as a consequence of their personal attitudes and preferences. The *residential self-selection* effect may significantly reduce the effects of policies designed to reduce the use of private vehicles and incentivize alternative transportation modes: if residential self-selection is in place, these policies would reduce VMT by providing living places for persons who already seek to drive less. If there is a shortage of such places, building higher density neighborhoods would reduce VMT to the extent that it would modify the travel patterns of the persons choosing to live in these areas. Many studies have attempted to quantify the effects of residential self-selection, highlighting how it often accounts for a large portion of the impact that could be otherwise attributed to the built environment (Cao et al. 2009).

Urban development patterns in the 20th century have been increasingly typified by urban sprawl (Barrington-Leigh & Millard-Ball 2015; Bruegmann 2006) (Barrington-Leigh & Millard-Ball 2015, Hayden 2003, Bruegmann 2005) . The growth of population in low density tracts fell from the 1970s to the 2000s. The overall population in dense census tracts in metropolitan America also increased over this time in every decade. However, despite the growth in dense areas, sprawl increased with the population living in low density suburban census tracts that increased at a faster rate than the population in higher density urban tracts (Figure 7). In addition, for individual cities density patterns, it appears that sprawl patterns were basically set in place by 1970 (Lopez 2014). Despite efforts to revitalize neighborhoods and provide better alternatives for transportation, neighborhoods that were built with a low-connectivity street network tend to stay that way, even as the network expands (Barrington-Leigh & Millard-Ball 2015).

Still, recent years have seen a resurgence of more central areas with an increase of the urban population in all major urban areas of the U.S. Census data indicate that many city centers grew faster than their suburbs between 2010 and 2012 for the first time in decades (U.S. Census 2012). As of 2014, the highest growth rates were again found in suburban areas, though most new development is multi-unit (Trulia 2015). Further, the division between city and suburb is blurring (Zmud et al. 2014): both suburbs and urban areas are increasingly home to residences and businesses, and this contributes to reducing the average trip distances among origin and destinations (in addition to offering more opportunities for the adoption of non-motorized means of transportation). Most recent trends in real estate development show that there is not necessarily a clear delineation between an urban center where people work and suburbs where people live. The type of suburbs also matters: inner-ring suburbs have experienced population changes more similar to those in center cities than to outer-ring suburbs (Zmud et al. 2014). Data from the 2010 Census also show that many suburbs linked to a city with public transit or well-developed roadways are benefiting from strong city growth.

Much of the effect of city growth on future VMT will certainly depend on future transportation investments and availability of options. Both road and transit infrastructure improvements are thought to have distinct short-term and long-term impacts on VMT. In the short run, increased highway capacity releases some latent demand; some travelers switch modes, routes, and times of travel (Cervero 2010). Lessening traffic might make it attractive for travelers to switch from transit to driving. Households are assumed to choose their VMT and

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mode of transit so as to maximize their utility and minimize total cost of travel (service frequency, speed, and wait time) (Parry & Small 2007). The majority of empirical evidence to date suggests that the effects of induced demand are substantial. A widely cited study by Hansen and Huang (1997) found that every 10% increase in lane miles was associated with a 9% increase in vehicle miles traveled (VMT). Handy et al. (2014) summarize elasticity estimates of the short-run effect of increased highway capacity in the range of 0.3 to 0.6, with long run elasticity values from 0.6 to 1.0 (Handy & Boarnet 2014). Other studies have concluded that investments in road capacity increase average economic growth while simultaneously inducing additional growth in VMT (Melo et al. 2012). A similar finding is true of transit infrastructure investments and transit use, resulting in lower VMT. Improvements in public transit induce modal shifts. Improving the public transit system by making it faster and more convenient has a small but significant impact on mode choice (Spiller et al. 2014). However, Duranton and Turner (2011) found no evidence that public transit service affects VMT. Rail supply has a large effect on VMT; a 10% increase in a city's rail transit service reduces 40 annual vehicle-miles per capita (70 VMT including New York City), compared with just a one mile reduction from a 10% increase in bus service (Bento et al. 2003). Investments in bicycle infrastructure investments have not been explicitly tied to VMT. Investment in sidewalk length has been found to decrease VMT (Fan 2007; Salon et al. 2012).

Future effects on transportation will largely depend on the difficult equilibrium between market forces (e.g. demand for housing, and market supply) and policies developed at the federal, state and local level. It is difficult to forecast future transportation investments in transit and highway infrastructure. For example, the recent infrastructure investments included in the proposed Grow America Act may provide increased stimulus to highway infrastructure, possibly contributing to an increase of total travel by car. At the same time, large investments in public transit services are occurring in several U.S. regions and cities, which may contribute to rebalancing mode share, and may have an additional calming effect on the amount of car travel. Cities that have been once associated with images of car-dependence such as Los Angeles are currently undergoing massive efforts to expand public transportation services, while at the same time promoting investments in improved pedestrian and bicycling infrastructures, also at the expenses of the reduction of the number of road car lanes. In addition of the direct impacts of such investments on mode share and VMT, they also believed to have indirect effects on promoting the awareness and perceived utility of non-car travel alternative modes. Quantifying the effects of such impacts, however, is often not easy, also due to the expected time-lag between the time investments and policies are implemented, and the time in which changes in travel behavior are observed.

Sociodemographic Trends

- **Drivers:** slow population growth; smaller household size and changes in family structure; aging baby boomers; impact of immigration on population growth; increased urban lifestyles among some population segments; women saturating workforce

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- **Impact on travel demand:** households without children travel less by car; first generation immigrants travel differently from U.S. born individuals; current trends point to a decrease in per-capita VMT.

Sociodemographic trends will likely have dampening effects on U.S. VMT. In a recent report for the Transportation Research Board, Zmud et al. (2014) summarize several sociodemographic trends of the past and future that impact U.S. travel demand, including: (1) slow population growth, (2) increasing aging population (over 65), (3) structural changes in population distribution by race/ethnicity, (4) changing work force makeup, (5) slow household growth. The authors predict that all but one of these trends (structural changes in population distribution) will result in lower VMT per capita (Zmud et al. 2014).

Sociodemographic trends affect travel demand through a combination of *lifecycle, period*, and *cohort* effects. Lifecycle effects are associated with the changes and events that happen during a person's life, and that cause changes in their lifestyles and travel behavior. Period effects are associated with changes observed as the result of specific events and modified conditions occurring in a specific period (e.g. changes in work organization and social habits that affect individuals of all ages and stages in life during a specific period, although effects may vary among different segments of the population). Finally, cohort effects are associated with specific trends affecting individuals that were born in a specific cohort (or generation). The total impacts of these effects may be amplified, for example if some lifecycle effects such as the ageing of the members of an older generation (e.g. baby boomers) who tend to transition into retirement and begin to travel less, are reinforced by other period (e.g. all individuals tend to travel less, due to changes in the urban form and increased accessibility by other modes) or cohort effects, as in the case of younger generations such as millennials who tend to exhibit travel patterns that differ from those of the previous cohorts.

Age and household composition may affect transportation demand and VMT through both the number of people living in a household and their ages and relationships. In particular, households with children have higher VMT than households without children. According to the 2009 NHTS, households with children averaged 30,400 VMT per year, while households without children averaged only 14,400 VMT per year (FHWA 2012). Census data from 2010 indicate that households with children under 18 years have grown at the slowest rate over the period from 1960 to 2010, and increased by only 0.5 percent between 2000 and 2010 (Brownstone & Golob 2009). Vehicle travel tends to increase as adolescents become adults, peaks at 30-60-years when employment and childrearing responsibilities are greatest, and then declines as individuals retire and age (Le Vine & Jones 2012).

As average household size decreased from 4.6 people per household in 1900 to 3.3 in 1960 to a low of 2.59 in 2000, the proportion of households raising young children - about 50% in 1950 - has decreased to about 30% now and is projected to decrease to 25% by 2030 (Nelson 2006). This long trend in falling household size has five main drivers: lower fecundity, aging baby boomers, longer life spans, entrance of women in the labor force (though this is unlikely to drive future household size due to saturation), and rising incomes (Zmud et al. 2014).

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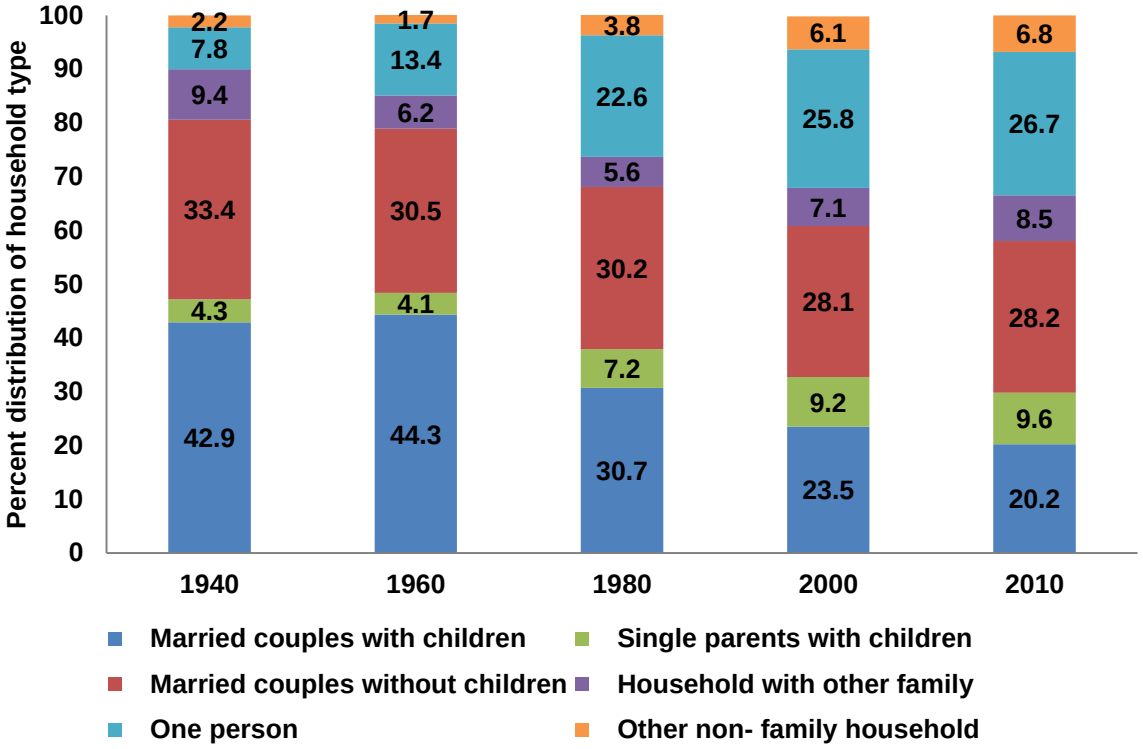

Figure 8. Percent distribution of household type (1940-2010) (Created by the authors using US Decennial Census data)

The demography of America is expected to change substantially in the future. According to the U.S. Census Bureau, the U.S. population is anticipated to increase to 438 million by 2050, which constitutes more than a 40% increase from the 2008 population of 304 million. A significant percentage of the projected increase is due to immigration, meaning the population will be more ethnically diverse. New immigrants tend to have different travel patterns, mainly because of previous habits: they often continue to have similar travel patterns to those they used to have in their country of origin also after they move to the U.S. However, immigrants tend to assimilate into the society over time, and the behavior of second-generation immigrants tend to differ from that of their parents, converging towards the general trends in the population. U.S.-born Hispanics also tend to have more vehicles per household and own newer vehicles compared with foreign-born Hispanics (Liu & Painter 2012). Overall, as Hispanics become a larger portion of the total U.S. population and if current trends among Hispanic households continue, they are expected to contribute to increasing public transit use and aging of the vehicle fleet, at least until the groups of immigrants integrate more into the U.S. society. The population will also be older in 2050; more than 20% of the U.S. population will be 65 years or older by 2050, compared to 12.6% currently. Only 25% of households will be raising young children by 2030, as opposed to roughly 30% in 2005 (Nelson 2006), contributing to reshaping trip patterns in future years, reducing the impact of household with children on trip generation and trip chaining: members of the households with children usually make more trips, and are more likely to use a car for these trips.

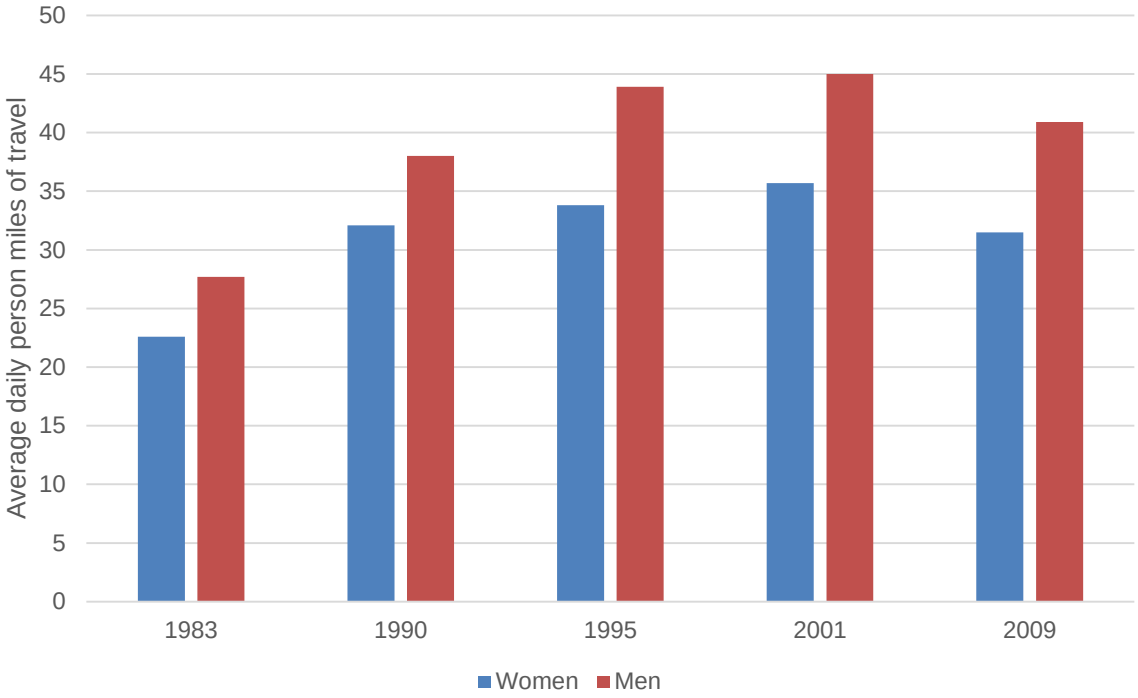

Figure 9 Average daily person miles of travel, by gender (created by the authors using NHTS data)

Additional effects relate to other sociodemographic features of the population, including gender. Historically, men and women have demonstrated different travel patterns. Women tended to make shorter work trips, make greater use of public transit, make more trips for the purpose of serving another person's travel needs, and drive far fewer miles per year than men (Gordon et al. 1988). However, women's increasing participation in the labor force in addition to familial obligations has resulted in an increase in VMT (Sivak 2015). Transportation planners and policy-makers expect women's VMT to further increase in the future (Sloboda & Yao 2006), although women's VMT may have plateaued (Figure 9). Overall, the difference in car use between men and women is declining, and the gender gap is expected to have less of a role as an engine for VMT growth in the future.

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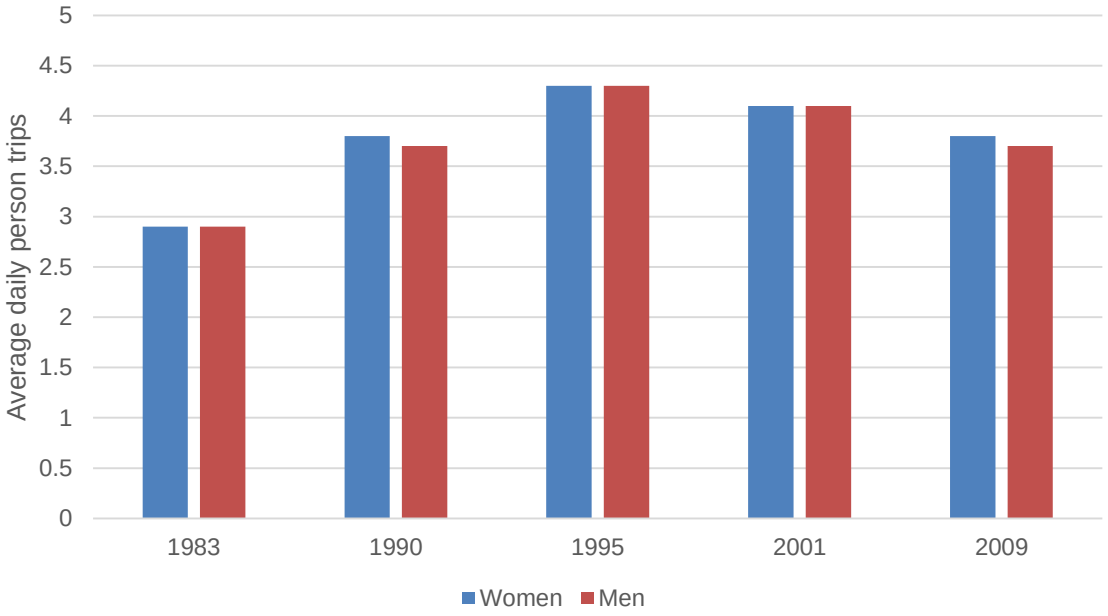

Figure 10. Average daily person trips, by gender (created by the authors using NHTS data)

Generational changes are also observed in the lifestyles and dynamics associated with the travel behavior of the members of different cohorts. The following subsections specifically discuss travel patterns observed among the four main generational groups: *baby boomers*, *Generation X*, *Generation Y* (also known as "*millennials*") and *Generation Z*.

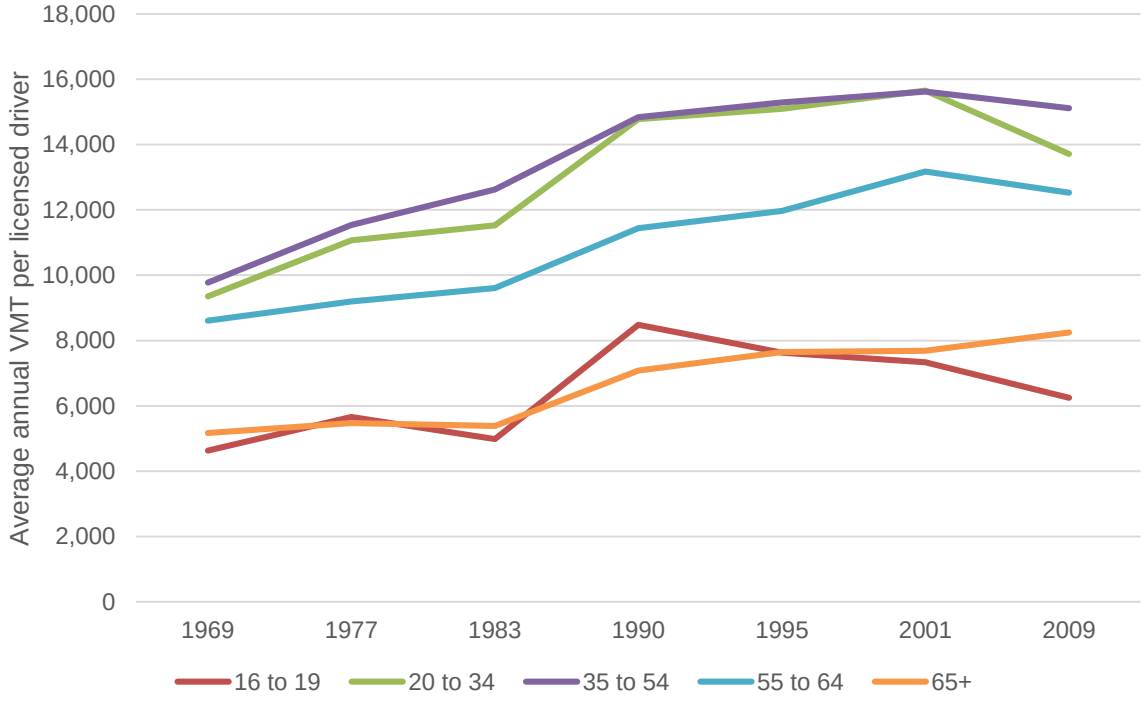

Figure 11. Average Annual Miles per Licensed Driver by Age Group (created by the authors using FHWA data).

Baby Boomers

- **Drivers:** baby boomers transitioning into retirement; higher income generation; increased amount of discretionary funds for leisure trips; less need for space in residential location
- **Impact on travel demand:** fewer commuting trips; potential replacements of short-distance trips with infrequent long-distance trips; unlikely to leave suburbs as they age

The baby boomers, individuals born between 1946 and 1964, represent a major wave of aging adults. In 2010, 13% of the population were aged 65 and over in the United States, but by 2030, all of the baby boomers will be aged over 65, pushing the United States' share of 65+ to 19% of the population (Vincent & Velkoff 2010). The Baby boomer generation has driven many trends in travel over the past 40 years, both in the number of travelers and in the amount of travel per person. Still, nowadays, baby boomers are a very influential group in terms of car purchasing behavior, as an effect of both the large number of purchased vehicles and the high average price of the vehicles purchased by the members of this cohort. Those in the Baby Boomer age cohort have traditionally traveled more than their counterparts from other generations at the same stages in life. Although baby boomer seniors tend to drive more than seniors of previous generations (and this is particularly true for women, given the large gender gap in driver licensing and travel demand observed among the members of the previous *silent* generation), as part of their life cycle they now drive much less than they used to during their peak driving years, when they were employed and raising children. They are also found to use public transit more often (Litman 2015).

As trends in society and the economy continuously change, also as an effect of the increased adoption of technology, a majority of baby boomers are expected to choose a "soft retirement" and continue to work part-time beyond retirement age. The past decade provided some evidence that baby boomers became more urban and less automobile dependent (across residential settings) and walked for a greater share of all trips in both suburban and urban settings (Lee et al. 2014). However, massive relocation of non-urban boomers to urban areas remains to be seen. An AARP analysis of 2010 Census data showed that 9 of 10 older adults nationally were living in the same communities where they raised their children (Farber et al. 2011). Suburban baby boomers may express concerns regarding their current neighborhoods becoming unsuitable for them as they age, but they are unlikely to move away in large numbers from the privacy, amenity, and their existing social networks that suburbia provides (Lee et al. 2014).

Generation X

- **Drivers:** Active workers with children; telecommute more often; increased adoption of e-commerce
- **Impact on travel demand:** increased multimodality; probable decrease in future VMT as an effect of lifecycle effects

Generation X includes those individuals that were born from 1965 to 1980 (35 to 50 years old as of 2015). This cohort is relatively small, being an "echo" of the Depression era generation. This

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group is less well studied than the following generation (millennials), as is often described as a generation of transition between the bolder characteristics of baby boomers and millennials. Research findings suggest that members of Generation X drive less than their parents did at the same age (Kamga 2015). Part of the different behaviors observed among the members of the Generation X during the recent years is associated with the drop in travel caused by the recent recession (McDonald 2015). In 2009, 31-42 year olds drove 33-35.6 daily auto miles per day, as opposed to 38.5-39.2 auto miles per day driven by the same age group in 1995. Generation Xers make fewer automobile trips than the same age group did in 1995, and make more biking and walking trips than the previous generation(McDonald 2015).

This reduction in driving is likely to be related to a number of factors, one of which may be the adoption of information and communication technologies (ICTs) by Generation X (Mans et al. 2012). Generation X is the first generation that has more widely adopted telecommuting as potential trip replacement[10] (Mans et al. 2012). This generation is also more likely to shop online – the Pew center found that 80% of Generation X Internet users engage in e-commerce compared to 71% of Millennial Internet users and 38% of online teens. These behaviors are generally found to decrease VMT (Mans et al. 2012; Choo et al. 2005). In contrast to the members of Generation Y, as of 2009, Generation X has formed households and is in the mid phase of their careers; roughly 70-72 percent of Generation X were a parent (McDonald 2015). Typically, having children in the household contributes to increase VMT (Le Vine & Jones 2012), but this effect tend to disappear as part of one's life cycle leading to potential reduction in VMT per capita for the members of this generation in future years.

Generation Y

- **Drivers:** delay in childbearing and other life events; high adoption of technologies; preference for urban areas
- **Impact on travel demand:** reduced use of private cars, increased multimodality, unclear long-lasting trends of millennials travel

"Generation Y" or "Millennials" includes individuals born from 1981 to 1997 (18-34 as of 2015). Millennials make up approximately 25% of the U.S. population and represent a very influential demographic due to their stage in lifecycle, and differences in travel behavior from the previous generations. Among the observed trends, millennials tend to own fewer cars (and often do not own a car), drive less if they do own a car, and use alternative non-motorized means of transportation more often (Blumenberg et al. 2012; Kuhnimhof et al. 2012; Polzin et al., 2014; Frändberg & Vilhelmson 2011). Millennials are credited to drive less than previous cohorts at the same age for two possible reasons: their lifestyle-related demographic changes, including shifts in employment rates, delays in marriage and childbearing (Pew Research Center 2014), and shifts in attitudes and use of virtual mobility, which are believed to be more specific of their cohort (McDonald 2015). Additional period effects reinforce the differences observed between

[10] The overall impact of telecommuting on VMT is unclear though, and most evidences seem to indicate that it does not lead to a *net* reduction in VMT. This topic is better discussed in the later section on the *impact of technology*.

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the behavior of the members of this generation and that of the members of previous generations at the same stage of life: thanks to technological development and other evolution of society, a number of additional travel (and non-travel) options have become available during recent years.

Millennials are less likely to be employed, to be married, and to have children than cohorts at similar ages (McDonald 2015). Blumenberg et al. (2012) suggest that there are very few, if any, differences between the factors that influence middle-aged adult travel and young adult travel. Economic factors seem to have a predominant influence on travel for both groups. Of note are the generational changes suggested by the quasi-cohort model: the youngest cohorts make about 4% fewer trips and they travel about 18% fewer miles than the previous generation at the same stage in their lives, though no clear motivations are identified.

Millennials have been proven more likely to adopt virtual mobility options, such as online shopping, telecommuting, ride-sharing, and other real-time transportation services (Blumenberg et al. 2012). The Millennial generation is characterized by, among other things, the widespread adoption of the internet, cell phones, and social networks, which have been hypothesized as "game-changers" in terms of young adult mobility (Blumenberg et al. 2012). Further, this group faces hurdles to obtain driving licenses such as graduated driver licensure programs (GDLPs) (Raimond & Milthorpe 2010; Blumenberg et al. 2012).

Millennials are credited for being more likely than older Americans to prefer living in a big city, and they showed the strongest preference for communities with mixed uses and different types of housing (BRS 2013). 2010 Census data indicate that 20–34-year-olds who are delaying marriage much longer form a disproportionate share of new city residents since 2008 (Zmud et al. 2014). This may account for some of the decrease in VMT, as urban residents are more likely to use other modes.

Understanding the reasons behind millennials' behaviors is fundamental in order to predict future impacts of this cohort on travel demand. If the decrease in millennial driving can be explained by lifestyle-related changes, millennials may begin to drive more as they become employed, get married and have children (even if this happens at a later stage in life, compared to their parents). However, if an attitudinal shift is the cause of the decline, the decline in VMT may be more permanent. Some studies have attempted to quantify the relative prevalence of these groups of factors: McDonald (2015) suggested that "millennials' specific factors such as changing attitudes and use of virtual mobility explain 35% to 50% of the drop in driving" of this generation. However, the NHTS data available for that study do not seem to support such results with certainty, as specific information about personal attitudes is not available, and the effect of these factors are largely inferred in an indirect way. Further, despite the trends observed among millennials who reside in large cities throughout the country, there is evidence that large masses of millennials continue to live in suburban settings, and exhibit more traditional behaviors. Accordingly, further research is needed to assess how Millennials will travel in the future, and the relative permanence of their preferences if and when they form households and engage in more stable employment after the recent economic downturn (Circella et al., 2015).

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Generation Z

- **Drivers:** young teenagers get into driving age; delay in driver's licensing; high-use of technologies and social media
- **Impact on travel demand:** largely unknown effects; Generation Z has more options than previous generations; expected to adopt technological solutions sooner

Generation Z (also *Post-Millennials* or *Pluralists*) are the cohort born after the millennial generation. This includes individuals born from either the late 1990s or early 2000s to today. There are approximately 60 million members of this generation as of 2015, outnumbering the Millennials by about one million. Little is known about this new generation, which was mainly born and raised in the new millennium. The oldest members of this generation are currently reaching driving age, and they will enter the workforce soon.

Generation Z is the first generation born after the invention of the internet (they are "digital natives"), and they are expected to be very open, and used, to the adoption of a wide range of technologies, as they represent the environment in which they have been raised and with which they familiarized in the early stages of life. There is reason to believe that several of the trends of the millennial generation will extend also among the members of the Generation Z, including many consolidated trends of society, such the modified household structures, and tendency to delay important life events (e.g. marriage, childbearing). The Generation Z is more ethnically and culturally diverse than the previous generations, and its members reasonably have more diverse groups of friends.

It is currently too early to advance speculations about the potential travel behavior patterns of the members of this generation. However, it is not unreasonable to assume that at least the behavior of the older members of this cohort will largely resemble that of younger millennials. Other speculations suggest, instead, that the members of this generation, who were largely born and raised at a time of economic crisis, and international, cultural and social tensions, will more likely resemble the characteristics of another generation that was raised at a time of financial hardship and social crisis, the *silent* generation.

Impact of Technology

- **Drivers:** increase in ICT users; wider adoption of telecommuting and e-commerce; emerging technologies in transportation and shared mobility services
- **Impact on travel demand:** unclear impact of many technologies; increased alternatives for mode choice; probable slight increase in per-capita VMT.

For many years, Information Communication Technology (ICT) has been seen as a trip replacement strategy and thus a solution for many societal problems, including urban congestion, dependence on non-renewable energy sources, air pollution, and greenhouse gas emissions, as well as rural underdevelopment, reduced economic opportunity for the mobility-limited, and the struggle to balance job and family responsibilities. Certainly, technological

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solutions such as telecommuting can function as a substitute for commute trips (Zhu 2012) and can replace *some* travel, but at the same time, they can generate additional travel as well. Mokhtarian (2009) discusses a number of reasons for which ICTs can respectively have no relevant effect on travel (*neutrality*), generate new travel (*complementarity*, or stimulation), alter travel that would have occurred anyway (*modification*), or reduce travel (*substitution*) (Mokhtarian, 2009; Salomon and Mokhtarian, 2008). The rapid increase in the use of technological solutions, and communication devices and services in particular, means that increased opportunity to work, study, access news and information, and communicate with others are nowadays accessible to a vast majority of the U.S. population (figure 12). However, most findings, to date, show that high frequency of internet use and mobile phone use are both positively correlated with VMT, suggesting a complementary effect between e.g. mobile phone and internet usage and travel, rather than a substitution effect (Zhang et al. 2007). At least early studies in this field show that the individuals that engage more often in ICT and online activities are also more likely to travel by car more, although more research is needed in this field, e.g. to better understand the direct relationships between these variables (e.g. eventual causality of ICT use on car travel) vs. the effect of other factors (e.g. impact of socioeconomic status, lifestyles, or personal attitudes, which affect both ICT use and travel). In the remainder of this section, we discuss the impacts on travel demand of four groups of technological solutions associated respectively with the adoption of telecommuting, e-commerce, online social media, and new *shared mobility* services.

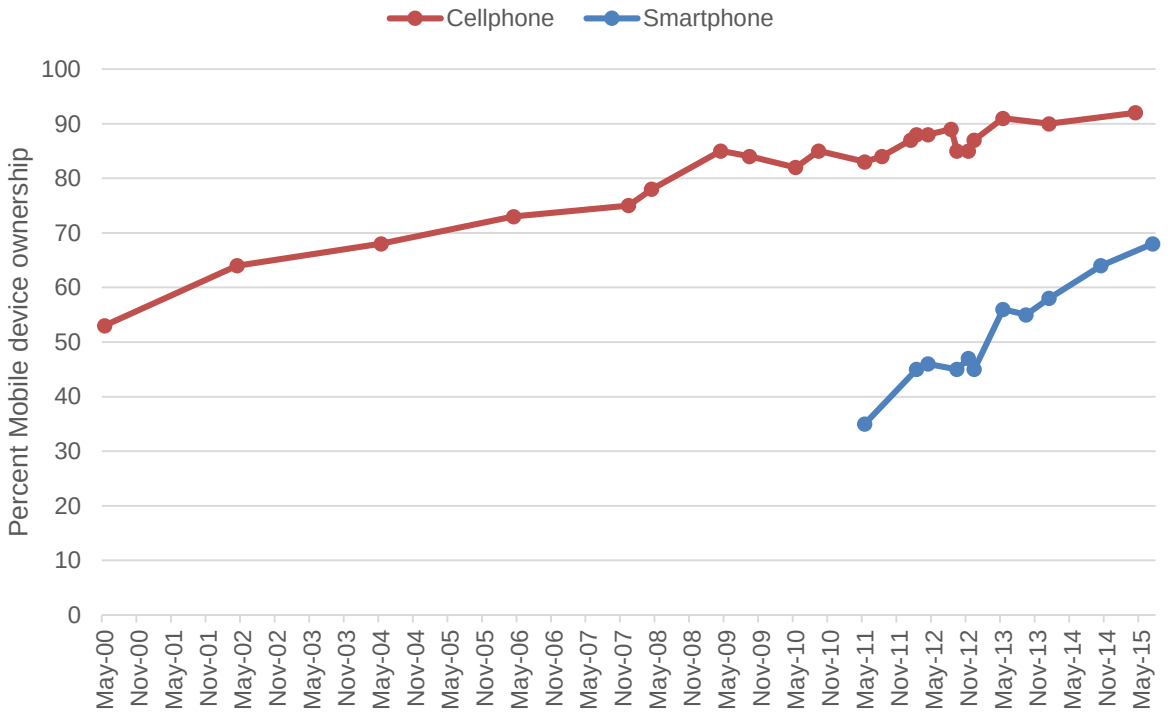

Figure 12. Percent mobile device ownership (Pew Center 2015)

Many early studies found a positive correlation between telecommuting and travel. However, more recent studies have found that telecommuting tends to either reduce or modify the nature of work-related travel (Mans et al. 2012). Choo et al. (2005) found that, from 1988 to 1998, all

telecommuters in the United States reduced annual national VMT approximately 0.8 % (Choo et al. 2005). Telecommuting may decrease individual VMT, but there are questions about the number of individuals that will opt in, the type of travel that is most affected by the adoption of telecommuting, and the eventual saturation point. The number of individuals working from home as the usual "means of transportation to work" has grown from 3.3% in 2000 to a 4.3% average for 2009-2013 in the U.S. according to the data from the U.S. Census and the American Community Survey. A 2009 study found that the number of Americans working at least 1 day a month from home or remotely increased by 74%, from about 9.9 million in 2005 to 17.2 million in 2008 (Dieringer Research Group 2009). The growth in telecommuting between 2006 and 2008 appears to have been driven mainly by the younger population, with the median age of telecommuters decreasing from 40 to 38 years old (Mans et al. 2012). The age of telecommuting workers is important in considering the permanence of the trend. About 80% of the roughly 80 million baby boomers will retire over the next decade. A recent poll of millennial workers found that 14% listed the ability to work from home as one of the top three actions an employer could take to retain them (Deloitte 2009). Similarly, a further increase in the adoption of telecommuting is expected in future years. Accordingly, more research is needed to better understand the impact of such trend on total travel demand and mode choice among the entire population, and among specific subgroups in particular. For example, a reduction in the number of commute trips might generate other kind of travel as the commuting trips that are eliminated by telecommuting free up time for making more non-commuting trips, which might be made more easily by car instead of transit and therefore use more energy than the commuting trips they replace (Circella and Mokhtarian, forthcoming). Additional impacts relate to the trip distances and the time of the day when these trips are made.

Online shopping has also dramatically increased in the past ten years, although the impact of increased online shopping on travel behavior remains ambiguous. Similarly to what said for ICT in general, e-shopping can also generate a number of partial impacts, including effects of substitution (replacing trips to a store with e-shopping), complementarity (generating additional trips to stores, e.g., to touch, try, and/or buy items seen online), modification (adjusting the patterns of pre-existing trips), and neutrality (no significant impact) (Mokhtarian, 2004; Weltevreden, 2007). Most studies on the topic have found mixed results: in some cases, making online purchases replaced a shopping trip, and in other cases, e-commerce resulted in new shopping trips, possibly due to product information obtained online (Wilson et al. 2015). Certainly, the delivery of merchandise purchased online may increase the miles traveled associated with freight distribution.[11] But the larger adoption of e-shopping may also have relevant effects on reshaping retail organization and thus impact the urban form, with the disappearance of some types of shops more directly affected by the competition of online shopping, with the transformation of other retail stores into entertainment center, which are less subject to online competition (Circella and Mokhtarian, forthcoming). The future effects of e-shopping on passenger transportation demand will also depend on the online shopping behavior of specific groups, e.g. younger generations. Several studies have found that younger

[11] We will not further discuss the impacts of modern ICT solutions on freight transportation, as goods movements are not part of the focus of this white paper

generations are more likely to shop online, as a result of their comfort with technology (Sulaiman et al. 2008). However, to date, the members of Generation X still dominate online shopping by volume of sales and frequency of use: 80% of Generation X Internet users engage in e-commerce, in comparison with 71% of Millennial Internet users (18 to 32 years old) and 38% of online teens (Jones & Fox 2009). The impact of the latter is expected to increase strongly during the next few years: understanding the relationships between adoption of e-shopping and travel (e.g. frequency of physical trips to stores) among the members of these segments of the population, and in different geographic areas, will be fundamental to understand future impacts on car travel.

Online social media are a relatively new phenomenon, and the effects of this expansion in social networking on transportation behavior and VMT are still unclear. It is possible that the increase in online social activities has resulted in an increase in trips for social purposes. It is equally possible that in some cases social networking replaces some types of social trips. Overall, social networking has ambiguous effects on travel (Contrino & McGuckin 2006): in some cases, online interactions might replace social interactions. Alternatively, by widening an individual's social network and increasing the ease of connecting with others, social media usage may indicate increased travel. The analysis of the 2001 National Household Travel Survey provides some preliminary evidence that Internet users may be reducing their time traveling for social and recreational reasons (Contrino & McGuckin 2006). Across each age group, internet users traveled fewer minutes for social and recreational trips than the average for the same age group. However more robust evidence is needed in this area, in particular considering the continuously changing landscape of available online services, and the evolving effects that they might have on travel.

In general, the use of ICT devices has largely expanded in the last few years among large segments of the population. These technological solutions have offered increased options for communications, as well as for the micro-coordination of trips and access to news and information, which can increase the opportunity to travel, as well as the awareness about options available for a trip, e.g. information about the available destinations for a trip (e.g. restaurants or cafes for a leisure trip), the travel time needed to reach a specific destination, and/or the modes available for (and related characteristics of) a trip.

Further, the massive adoption of ICT solutions, tablet and smartphones, and online services is at the basis of the rise of an entire group of new services in transportation. The recent developments in the field of emerging transportation and *shared mobility* services have largely contributed to expanding the set of available options for a trip, as well as to providing alternatives to traditional models of ownership (i.e. of a car), inspired by the new models of the *shared economy*. Shared mobility services include a variety of options, ranging from *car-sharing* services, including *fleet-based* services such as Zipcar or *peer-to-peer* services such as Turo, to *ridesharing* services, including dynamic carpooling such as Carma, *on-demand ride services* such as Uber/Lyft, or bike-sharing services. From a review of the availability of 11 groundbreaking technology-enabled transportation solutions in 70 U.S. cities, in 2015 there are already 19 cities that have access to nearly all new mobility options. In addition, 35 cities have access to most

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new options (but not all of them), and only 16 cities have access to fewer than half of the new mobility options (Hallock et al., 2015).

However, the impact of these services on travel demand are not clear yet. There are expectations that these new transportation alternatives contribute to reducing vehicle ownership, providing an alternative to owning a car, without the fixed costs associated with it. Traditional ridesharing has been touted as desirable means of reducing VMT (Anderson 2014), by encouraging drivers to ride together. Carsharing programs such as Zipcar have been found to decrease VMT among both vehicle owning and non-vehicle owning users (Martin & Shaheen 2011; Cervero et al. 2007). The new shared mobility services can also provide an alternative to driving through the availability of more flexible and resilient alternatives, eventually decreasing the total vehicle miles driven (depending on the means of travel they substitute): they may boost transit ridership by well serving the first and last miles and by improving the experience of riding transit services (Hallock et al., 2015; Shaheen et al., 2015), or providing the availability of a ride home outside the hours of operation of public transit (or at a time in which traveling by transit and/or walking to/from the transit stops may be considered unsafe).

The universe of the technology-enabled transportation services is continuously evolving, and new services (and Apps) become available almost on a daily basis. In an overall review study developed by Caltrans (Caltrans, 2015), car-sharing is suggested as an efficient tool to achieve the reductions in VMT and greenhouse gas (GHG) emissions that have been targeted in the State for 2040. Caltrans forecasts that statewide VMT could be reduced by 1.1% with a 5% increase in the adoption of car-sharing. In another study, Cervero and Tsai (2004) found that 30% of the members of car-sharing programs want to sell one or more of their vehicles, and others postpone purchasing an additional vehicle after using car-sharing services for about 2 years. It is worth noting, though, that early adopters of car-sharing services (as well as other technology-based services) tend to be higher-income individuals, who often report car disposal or postponement or complete avoidance of a car purchase to fulfill their mobility needs (Shaheen 2012). However, the behavior of such early adopters may not be typical of later entrants to the car-sharing market. In another study, Martin and Shaheen (2011) surveyed members of car-sharing program in United States and Canada, and concluded that adding another vehicle to the fleet of shared car would replace 9 to 13 vehicles among the members of car-sharing services, which might contribute to a 27-43 percent reduction in VMT (Martin & Shaheen 2011). On the other hand, bikesharing programs have been found to reduce driving and taxi use in almost every city in which they are available (Shaheen 2012). In addition, while in small cities bike-sharing tends to increase transit use through better serving the first and last mile access, conversely in large cities bike-sharing may reduce transit ridership through providing a faster and cheaper travel option for many trips (Shaheen et al., 2012; 2014). Similarly, bike sharing programs may increase transit use for those living in the urban periphery, and decrease transit use for individuals in the urban core (Martin & Shaheen 2014).

On demand ride services, also referred to as ridesourcing, or transportation network company (TNC), such as Uber and Lyft primarily resemble taxi services, which are typically considered additive to VMT (Cooper et al. 2010). The rapid growth of these services seems to

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have disrupted the use of classic taxi services as well as the activity and travel scheduling of many users by providing extended options for short-distance trips (Rayle et al. 2014). Overall, on-demand ride services may reduce the overall amount of driving (Rayle et al., 2014), as well as the use of shuttle services (e.g. to and from an airport). However, the overall effects of these services on travel demand and mode choice have not been quantified yet, and it is reasonable to expect them to vary depending on the local context, the characteristics of the users, the land use features and the transportation alternatives that are available.

More research is needed to quantify the magnitude of changes in travel patterns and behavior associated with these emerging transportation services. Not surprisingly, millennials are reported as the most frequent users of these emerging transportation options. For example, according to a 2013 study commissioned by Zipcar, millennials are more willing to use technology-enabled transportation options than older users (Zipcar, 2013). Similarly, in a survey of bike-sharing users in Washington D.C., Buck et al. (2013) show that more than half of the annual members are in the age group between 25 and 34. This is also true for the users of on-demand ridesharing services: interviewing 380 users of on-demand ride services in San Francisco, Rayle et al. (2014) show that the majority of these users are composed of young and highly educated people. One of the potential reasons for which millennials are found to be heavy users of these services, apart from the familiarity with technological solutions in general, may relate to the residential location of millennials, and the availability of the new mobility options. As discussed earlier, Millennials seem to be more interested in living in central, urban areas and more open to try means of transportation alternative to the use of a private car. If confirmed, the two factors combined would mean that not only millennials have higher accessibility to the new mobility options, but when exposed to them they would be also more inclined to adopt them. However, the user base of these services seems to be continuously increasing among many different age groups, and is not only limited anymore to the tech-savvy and early adopters, e.g. millennials living in dense urban areas (ITS America 2015).

Connected and Autonomous Vehicles

- **Drivers:** possibly provide mobility for those who cannot drive; change in value of travel time; increased road network capacity; increased ability to perform activities while traveling
- **Impact on travel demand:** releasing latent demand; increase in VMT if widely implemented

In a not-very far future, the future of passenger transportation will be potentially revolutionized by the advent of connected and (in particular) fully autonomous vehicles. The automobile industry has already made significant strides in automating driving: many current car models include features like cruise control, parking assist and other assistive technology, and companies have already produced autonomous vehicles (AVs) that can drive themselves on existing roads and navigate many types of roadways and environmental contexts with almost no direct human input. Assuming that these technologies are successful and available to the mass market (subject to regulatory approval, and federal, state and local regulations), AVs have the potential to

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dramatically change future travel demand. If widely adopted autonomous vehicles may lead to safer roads, less congestion, and reduced parking.

Among the expected impacts on transportation, AVs are expected to bring increased road network capacity (in particular under high adoption rate scenarios), increased road safety, improved comfort and lower fuel consumption. AVs may provide mobility for those too young to drive, the elderly and the disabled. Further, among the effects of AVs on individual's travel behavior is the reduced fatigue associated with driving and the ability to perform activities while traveling, which may contribute to lower the value of travel time for car users, and affect mode choice (Malokin et al., 2015). The adoption of AVs will likely result in higher per-capita VMT due to latent demand. Explorative research suggests that with increased mobility among the elderly and others, as well as lowered travel effort and congestion delays, the U.S. will almost certainly experience VMT increases, unless demand-management strategies are thoughtfully implemented (Fagnant & Kockelman 2015; Litman 2014). Brown et al. (2014) estimate that VMT could approximately double and overall energy use increase threefold (Brown et al. 2014). To date, it is unclear when AVs will become commercially available. Some studies predict that AVs will be an accepted technology by 2030s (or even earlier) and dominate personal transportation by 2050 (Greenblatt & Shaheen 2015).

The impact of AVs on travel demand is the topic of another White Paper being developed by the National Center for Sustainable Transportation, and is not further discussed in this report.

Impact on Future Travel Demand

Several factors have been suggested in the literature to explain the recent changes in passenger travel demand and the reduction in per-capita VMT observed in the U.S. over the course of the past few years. The literature has provided many evidences for some of these effects, often with conflicting results. Overall, all the presented effects are expected to partially influence travel demand, in a complex pattern of relationships and causality behind the formation of individuals' travel behavior choices.

Little evidence exists, to date, whether these trends will continue in future years, and therefore represent a deeper and more structural modification in travel demand, or if they are only temporary (e.g. they are largely the result of temporary economic conditions). As Goodwin and Van Dender (2013) say, "*The aggregate trends […] do not allow us to forecast with any certainty the car use that we can expect in the future.*" (Goodwin and Van Dender, 2013). It is unclear if car-peak is a temporary or lasting phenomenon, i.e. if after removing some of the causes, the growth in travel demand and the use of private vehicles will resume as before, or not. Accordingly, future trends in car use might differ significantly: car use might keep growing in the long term, with the current temporary peak being mainly an interruption dominated by economic circumstances; it might no longer grow, having it reached a physiological saturation level (or "plateau") in which contrasting factors cancel out their effects on VMT. Finally, if the forces driving the modifications in travel demand (e.g. changes in urban form, multimodal

accessibility and individuals' lifestyles) continue and become more dominant in the future, car use might continue to decline in the longer-term, despite the economic recovery or any expansion of economic activities (Sivak 2014b).

Table 1 summarizes the main findings reported in the literature, to date. We report the impact of each specific factors on car use, as well as the other expected impacts the factor will have on other components of travel behavior, and the use of other means of travel.

There are reasons to believe that several influence that had shaped travel demand in previous decades are vanishing, and this effect has been largely responsible, together with any economic effects, of the flattening of car travel observed in the recent years. The underlying regime of growth of travel demand that powered the previous decades has lost strength, e.g. the effects of factors like the gender gap (both in drivers' licensing and in employment) and the role of age on drivers' licensing, after they had been important reasons for growth in travel demand in previous years. With an auto ownership ratio of approximately one vehicle per licensed driver, and almost all adults of driving age that desire to obtain a license already having one, it is unlikely that passenger travel demand will resume the rapid growth rate observed in the past. Instead, more limited adjustments will likely be associated with factors affecting demand, or combination of factors, will prevail.

A combination of factors are found to explain the aggregate trends but some are more likely to be persistent than others. In addition, the impact of some factors (e.g. lifecycle and cohort effects) have been better understood than others (e.g. impact of innovative technology), which remain largely uncertain. Further, local trends in specific region might differ significantly from national trends, due to a combination of policy environments, specific characteristics and local conditions. Overall, there are reasons to believe that future patterns of travel demand will feature increased *heterogeneity* among individuals and among regions, also as an effect of the increased availability of new travel options, and increased *uncertainty*, due to the number of unknown effects and the impact of emerging drivers of travel demand. In such a scenario, an important role is associated with the development of policies that can affect car use, with specific interest that should be focused on identifying those policies that are more robust to uncertainty i.e. that can be successful under a wider set of eventual future conditions and outcomes (Van Dender and Clever, 2013).

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Table 1. Dominant impact of various groups of factors on vehicle miles traveled according to a review of the literature

Type of factor	Main effect on VMT per capita	Additional impacts on travel demand	*Direct or indirect* effect	Strength	Time Horizon of effects	Permanent vs. Temporary	Degree of certainty
Economic Activity							
- Increasing income gap	*Reduction in VMT per capita*	*Substitution with other modes*	*Indirect*	*Weak*	*Short-term*	*Temporary or Permanent*	*Unsure*
- Growth in financial and service sector	*Slower growth in VMT per capita*	*Changes to travel patterns (distances and frequencies)*	*Indirect*	*Probably weak*	*Short-term*	*Permanent*	*Unsure*
Gas Price							
- Changes in gas prices	*Reduction/ Increase in VMT per capita*	*Changes in driving pattern and use of other modes*	*Direct*	*Weak*	*Short-term*	*Temporary*	*Rather certain*
	Neutral effect on VMT per capita	*Changes in vehicle fleet*	*Indirect*	*Medium*	*Medium-/Long-term*	*Permanent*	*Certain*
Urban Form and Transportation Supply							
- Resurgence of urban areas	*Reduction in VMT per capita*	*Increase in active modes*	*Direct*	*Medium/ Strong*	*Short-term*	*Temporary or Permanent*	*Uncertain*
- Better accessibility in all NH types	*Reduction in VMT per capita*	*Increased travel options for short-distance trips*	*Direct*	*Medium*	*Short-/Medium-term*	*Permanent*	*Certain*
		Reduced auto ownership	*Indirect*	*Medium*	*Medium-/Long-term*	*Permanent*	

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Type of factor	Main effect on VMT per capita	Additional impacts on travel demand	*Direct or indirect* effect	Strength	Time Horizon of effects	Permanent vs. Temporary	Degree of certainty
(Urban Form and Transportation Supply - *continued)*							
- Investment in highway infrastructure	*Increase in VMT per capita*	*Increased "automotivity" (latent demand)*	*Direct*	*Medium/ Strong*	*Medium Term*	*Temporary or Permanent*	*Certain*
- Investment in transit and multimodal accessibility	*Reduction in VMT per capita*	*Increase in transit ridership*	*Direct*	*Weak/ Medium*	*Short-/Medium-term*	*Permanent*	*Rather certain*
		Increase in walking/bicycling	*Direct*	*Weak/ Medium*	*Short-/Medium-term*	*Permanent*	*Rather certain*
Socio-Demographic Traits and Generational Effects							
- Reduced HH size and delayed childbearing	*Reduction in VMT per capita*	*Reduction in trip generation*	*Direct*	*Strong*	*Short-term*	*Permanent*	*Rather certain*
	Reduction in VMT per capita	*Change in mode share and auto ownership*	*Direct/ Indirect*	*Medium*	*Short-/Medium-term*	*Temporary or permanent*	*Rather certain*
- Urban lifestyles	*Reduction in VMT per capita*	*Increase in use of non-auto modes*	*Indirect*	*Weak/ Medium*	*Short-/ Medium-term*	*Permanent*	*Uncertain*
	Reduction in VMT per capita	*Change in residential location*	*Indirect*	*Weak/ Medium*	*Medium-/Long-term*	*Permanent*	*Uncertain*
		Reduction in auto ownership	*Indirect*	*Weak/ Medium*	*Medium-term*	*Temporary or permanent*	*Rather certain*
- Baby Boomers	*Reduction on/ Neutrality with VMT per capita*	*Reduction in commuting trips, more discretionary travel*	*Direct and indirect*	*Weak/ Medium*	*Short-/ Medium-term*	*Permanent*	*Rather certain*

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Type of factor	Main effect on VMT per capita	Additional impacts on travel demand	*Direct or indirect* effect	Strength	Time Horizon of effects	Permanent vs. Temporary	Degree of certainty
(Socio-Demographic Traits and Generational Effects - *continued)*							
- Generation X	*Reduction in VMT per capita*	*Adoption of other modes*	*Direct and Indirect*	*Weak*	*Short-term*	*Still unknown*	*Uncertain*
- Millennials (Generation Y)	*Reduction in VMT per capita*	*Changes in lifestyles, residential location and mode choice*	*Direct and indirect*	*Medium*	*Short-/Medium-term*	*Still unknown*	*Rather certain*
- Generation Z	*Unknown (probable reduction)*	*Adoption of technology, unknown behaviors*	*Still unknown*	*Still unknown*	*Still unknown*	*Still unknown*	*Still unknown*
Impact of Technology							
- Telecommuting	*Neutrality with VMT per capita*	*Reduction of commuting trips*	*Direct*	*Weak/ medium*	*Short-term*	*Permanent*	*Uncertain*
		Complementarity with other trips	*Indirect*	*Weak*	*Short-term*	*Temporary or permanent*	*Rather certain*
		Impact on mode choices	*Indirect*	*Weak/ medium*	*Short-/Medium-term*	*Temporary or permanent*	*Rather certain*
- E-shopping	*Neutrality with/increase in VMT per capita*	*Change in trip patterns*	*Direct*	*Weak/ medium*	*Short-term*	*Permanent*	*Uncertain*
- Online social media	*Neutrality with/increase in VMT per capita*	*Impact on leisure trip patterns*	*Indirect*	*Weak*	*Short-term*	*Temporary*	*Uncertain*

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Type of factor	Main effect on VMT per capita	Additional impacts on travel demand	*Direct or indirect* effect	Strength	Time Horizon of effects	Permanent vs. Temporary	Degree of certainty
(Impact of Technology - *continued)*							
- Shared mobility services	*Increase in VMT per capita*	*Reduction in use of other modes*	*Direct*	*Weak/ medium*	*Short-term*	*Temporary or Permanent*	*Uncertain*
	Decrease in VMT per capita	*Decrease in auto ownership*	*Indirect*	*Weak/ medium*	*Medium-term*	*Permanent*	*Uncertain*
Connected and Autonomous Vehicles							
- Availability of C/AV	*Increase in VMT per capita*	*Latent Demand*	*Direct/ Indirect*	*Probably Strong*	*Medium-/Long-term*	*Probably permanent*	*Uncertain*
		Reduction of use of other modes	*Direct/ Indirect*	*Probably Strong*	*Medium-/Long-term*	*Probably permanent*	*Uncertain*

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