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Understanding the Effects of Demographic and Socio-Economic Factors on Public Transit Ridership Trends

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Understanding the Effects of Demographic and Socio-Economic Factors on Public Transit Ridership Trends

by

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the requirements for the degree of
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DEDICATION

I dedicate this thesis to my brother, Karl, with whom I have had countless conversations about my ideas regarding transportation issues, and whose intelligence has always challenged me to strive for academic excellence. Karl has shown me that any adversity can be overcome with a cheerful outlook, a lesson that has helped me often throughout my education. I also dedicate this thesis to my parents, who gave their time, their effort, and their livelihood for so many years to ensure that I had the ability to pursue my passion through education. Nothing has taught me the value of dedication to a goal more than having two parents who have devoted themselves to each other for as long as mine have.

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ABSTRACT

Public transit, an important mobility service for many, has incurred ridership decline in the U.S. for the past three years. In 2014, U.S. transit ridership was 10.74 billion unlinked passenger trips. In 2015, total ridership was 1.0 percent fewer, and the 2016 decrease was 2.2 percent from 2015. The consistent abandonment of transit in the U.S. does not seem to be ending. In 2017, ridership predicted from year-to-date data is 2.4 percent less than 2016. Furthermore, per capita ridership has decreased 17 percent since 1980. Both the short-term ridership trend and long-term per capita ridership trend is concerning given the increased spending and service provision during the same periods.

In seeking to understand the many factors that influence transit ridership trends, it is important to analyze each so that policymakers and practitioners can respond and position transit accordingly. Numerous demographic and economic phenomena help explain this decline in transit use. This research focuses on five of these considerations – age, vehicle availability, telecommuting, fuel price, and geographical distribution of the population.

CHAPTER 1: INTRODUCTION

1.1 Background

In 2016, public transit services provided 10.4 billion unlinked person trips in the U.S [1]. This mobility option serves many people across the U.S. and benefits society in many ways. Public transit, including bus, paratransit, vanpool, and rail modes help people get to work and school, go shopping, and receive medical care. In 2007, 59.2 percent of transit trips were for commuting to work, 10.6 percent were for trips to school, 8.5 percent were for shopping and dining, 6.8 percent for social purposes, 6.3 percent for personal business, and 3.0 percent for medical trips according to the American Public Transportation Association (APTA) [2]. Agencies routinely plan fixed route transit, non-paratransit, which constitutes over 90 percent of total transit cost and ridership [3]. Besides serving as a mobility option for people who are not able to own their own car, these services alleviate congestion from single-occupant vehicles on roadways by attracting choice riders. Benefits of transit range from economic, to environmental, to social.

However, fewer and fewer people are using transit for mobility. According to APTA, 2014 was the latest in a series of transit ridership peaks in the last few decades, marking the highest ridership level since 1957 at 10.74 billion unlinked passenger trips. Since 2014, though, ridership has seen multi-consecutive year declines – 1.0 percent in 2015, 2.2 percent in 2016 and 2.4 percent in 2017 [3]. Likewise, per capita transit ridership has decreased from 37.7 annual trips to 31.2 annual trips, or 17 percent, since 1980. [1].

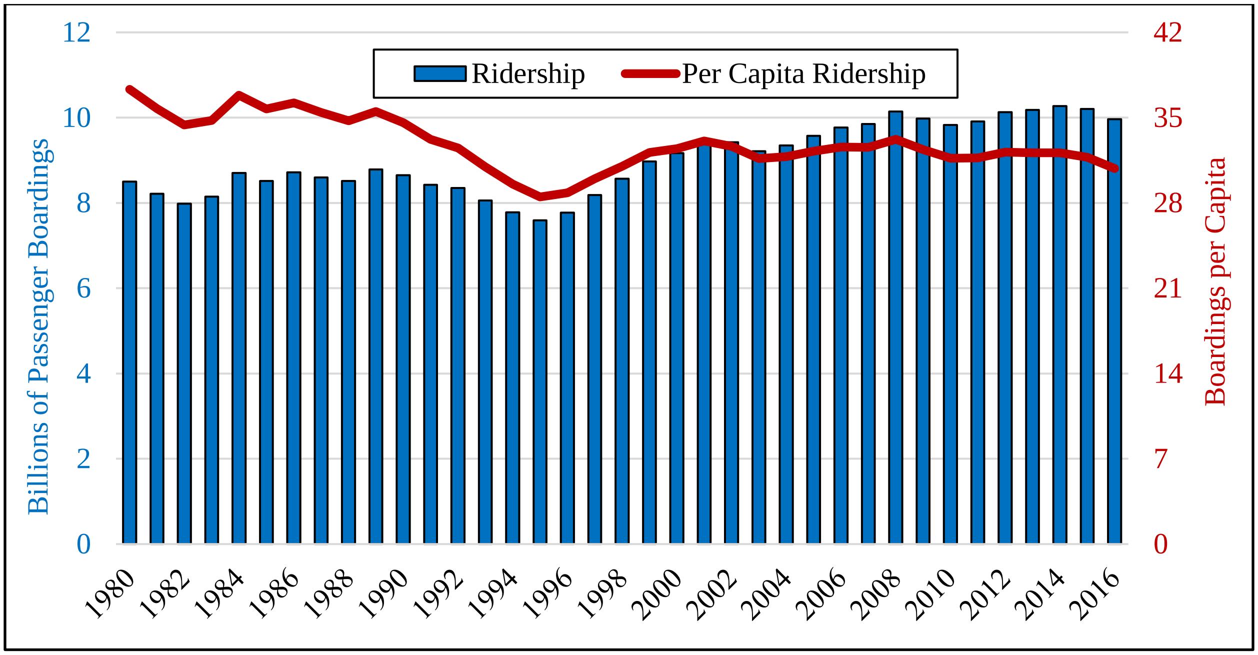

Figure 1.1 National bus and rail transit ridership and per capita ridership.

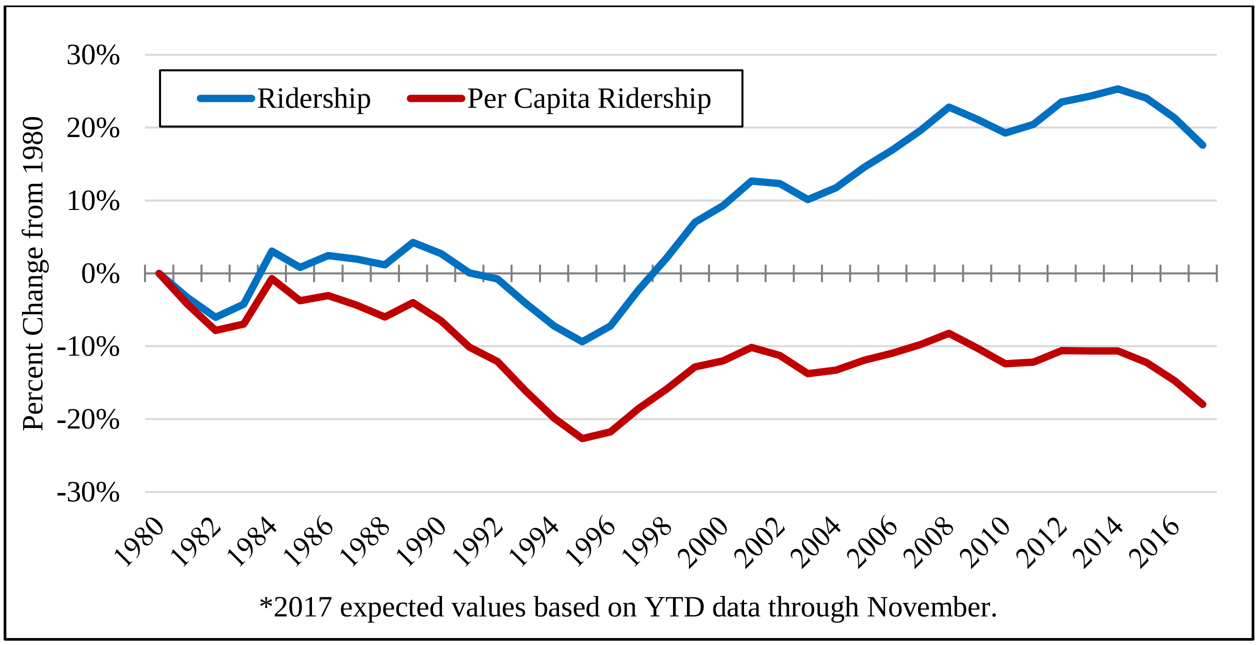

Figure 1.2 U.S. transit ridership and per capita ridership percent change from 1980.

Meanwhile, spending for public transit has never been higher and operations have not slowed down. According to APTA, transit vehicle revenue miles increased by 53 percent between 1995 and 2014. Because of the service expansion between 1992 and 2014, inflation-adjusted capital and operating investment (2017 dollars) in U.S. transit has grown from 39.8 billion to 66.0 billion, or 39.8 percent. That is also equivalent to an additional 1.2 billion dollars per year increase, which has resulted in a disappointing per capita ridership increase of 0.025 trips per person per year. According to the National Transit Database, from 2014 to 2017 service has grown by 4.3 percent while ridership has decreased by 5.5 percent [3]. Investment and service are increasing despite decreasing demand, as shown in Figure 1.3. Service cuts are, at least nationwide, not the reason for the ridership decline.

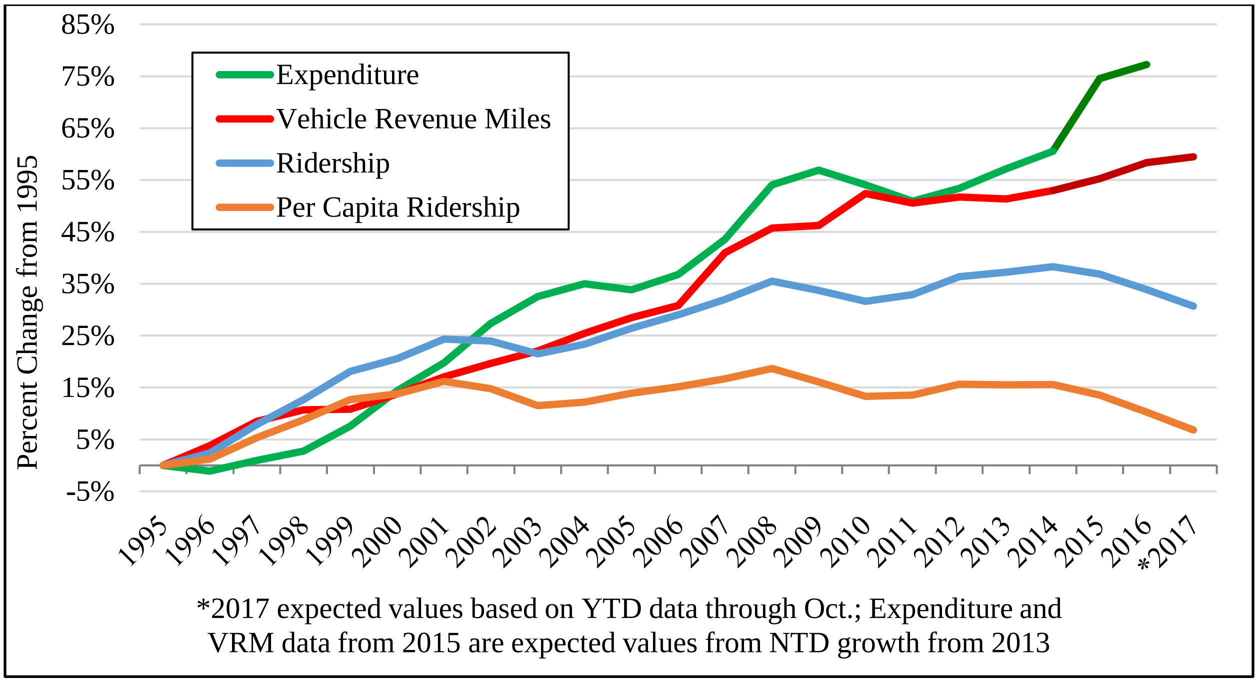

Figure 1.3 APTA U.S. ridership, per capita ridership, expenditure in 2017 dollars, and service.

Additionally, transit ridership is declining across the entire country. Very few agencies have experienced ridership growth from 2014 to 2016. Of the top 40 urbanized areas in the U.S. by 2016 ridership, ridership decreased in 34 during that time. The six urban areas in which transit ridership increased from 2014 to 2016 were Buffalo, Detroit, Hartford, Houston, Las Vegas, and Seattle. Ridership decline was prevalent across the West, Midwest, Central, Northeast, and

Southern U.S. Those top 40 urban areas consist of 84 percent of the national ridership decline from 2014 to 2016.

In conclusion, there are some other factors besides investment and service contributing to widespread ridership decline from 2014 to 2017, ridership per capita decline from 1980 to 2017, and ridership per service provided decline since the early 2000s. What are some of the outside factors, such as demographic make-up, economic conditions, and technology disruption that could be influencing this downward trend in transit ridership?

1.2 APTA and NTD

The public transit ridership data used for this analysis comes from two primary sources – the American Public Transportation Association (APTA) and the National Transit Database (NTD). APTA calls itself the "leading force in advancing public transportation." APTA members include transit operators that are engaged in the areas of bus, paratransit, light rail, commuter rail, subways, ferries, and high-speed rail. Members also include other stakeholders who plan, design, construct, finance, supply, and operate bus and rail services worldwide. Lastly, members can include government agencies, metropolitan planning organizations, state departments of transportation, academic institutions, and trade publications involved in public transportation planning and research. APTA publishes many reports and collections of data helpful in tracking the state of public transportation. Included in those reports is the Public Transportation Fact Book containing public transit usage data from as early as 1890. In addition to ridership data, APTA keeps record of capital and operating spending, service mileage, and many other metrics with varying dates of availability. Variance in timelines for analyzing data in this paper is due in part to the differentiation in availability of data in APTA reports [4].

APTA also partially uses NTD data. NTD is an initiative of the Federal Transit Administration (FTA) under the U.S. Department of Transportation (USDOT). In 1974, Congress required new levels of data reporting for transit agencies, which caused the NTD to be the nation's primary collection of financial information for public transit operators. Today, transit agencies must comply with prescribed requirements for data reporting to receive federal funding. NTD releases annual fiscal year reports and monthly reports on many performance metrics. NTD's Monthly Module Raw Data Series informed any reference to 2017 ridership or service in this paper [5].

1.3 Internal versus External Factors

The 2003 working paper "The Factors Influencing Transit Ridership: A Review and Analysis of the Ridership Literature" outlined the terminology of "internal" and "external" factors. External factors are those affecting ridership that take place regardless of the actions and policies of transit systems and managers. Transit operators do not directly influence these factors but operators may react to these factors, amending their deployment of service to curb their effects. Internal factors, conversely, are those affecting ridership and over which transit operators exercise some control.

Examples of external factors include demographic and economic changes, such as population and employment. Examples of internal factors include service provision and fare level. While transit operators can only directly influence internal factors, understanding external factors may aid them in adapting service to avoid their effects on decreasing ridership. This paper mostly discusses external factors.

1.4 Heterogeneity between Factors

Because this paper includes univariate approaches to understanding factors related to transit ridership, it is important to note that each factor is most certainly heterogeneous with other discussed and undiscussed factors. For instance, when travel behavior informs transit propensity for people of different ages, income may be an unobserved heterogeneous factor. Younger people are generally lower income, so the difference in income partially causes difference in transit use between age groups. There may be any number of unmentioned factors that influence transit ridership but also relate with the discussed factors. Moreover, the factors discussed in this paper may relate with each other. For example, age and vehicle availability may be correlative, so travel behavior analysis of the two may observe overlapping effects.

1.5 Outline

This thesis performs an overall review of literature on traditional and recent findings relating to factors affecting transit ridership. Following the literature review, this thesis reviews different factors affecting transit ridership including age profile, household vehicle availability, geographical distribution, telecommuting, and gasoline price. The thesis uses a different methodology for each factor, but some are very similar. The methods used for analysis in this paper attempt to quantify the effects of each factor discussed. Methods in Chapter 3 and 4 include assuming constant travel behavior and applying its data to changing demographics profiles. Methods in Chapter 5 and 6 include assuming a constant demographic state and travel behavior, then comparing its transit ridership implication to that of the actual demographic state. Chapter 7 includes statistical analysis using third-order polynomial regression. Finally, the thesis concludes with a summary of findings and suggestions for future research.

CHAPTER 2: LITERATURE REVIEW

The following literature review covers traditional and more modern research pertaining to both internal and external factors affecting transit ridership.

2.1 Traditional Factors Affecting Transit Use

The 2003 working paper "The Factors Influencing Transit Ridership: A Review and Analysis of the Ridership Literature" by Brian Taylor and Camille Fink provides a broad view of some of the traditional research relevant to factors of transit ridership [6]. Taylor and Fink did well to distinguish between internal and external factors.

2.1.1 Traditional External Factors

Taylor and Fink referred to those factors exogenous to the transit system and its managers as "external factors." One of these factors is employment. In San Diego and Houston, employment growth between 1980 and 1990 accounted for 15 and 10 percent, respectively, of the transit ridership increase [7]. Employment levels were a statistically significant factor for the Massachusetts Bay Transportation Authority (MBTA) ridership change from 1969-1990. The *t*-statistic for the effect of employment level on transit ridership of 7.51 was higher, for instance, than that of income, vehicle-miles of service, and fare level [8].

Another external factor influencing transit ridership is per capita income. Lower income earners are overrepresented among public transit users. APTA's 2007 "A Profile of Public Transportation Passenger Demographics and Travel Characteristics Reported in On-Board Surveys" shows that persons from households earning under $50,000 (nearly the median household income in 2007) make up 65.7 percent of transit passengers in the U.S. [2]. Additionally, persons from households earning under $25,000 make up 34.9 percent of transit riders but make up less than 13 percent of total population [9]. Gomez-Ibanez found real per capita income to have a more significant effect than fares and service provision on transit ridership in the Boston area between 1969 and 1990 [8]. Populations that are more affluent demand public transportation less, since higher income allows for provision of private transportation.

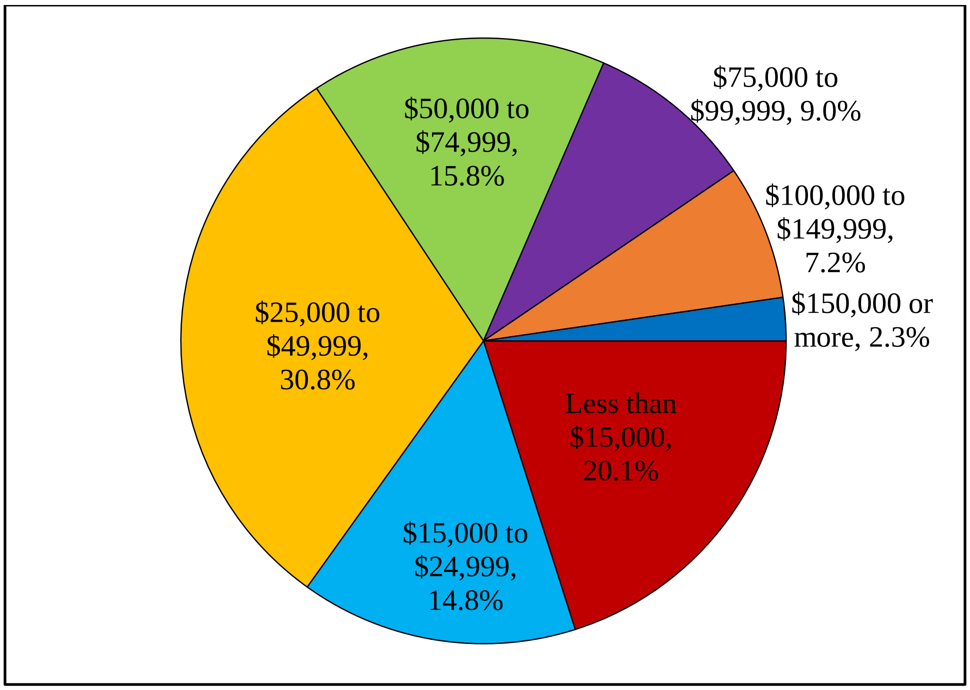

Figure 2.1 Transit riders by household income in 2007.

Gasoline price is another factor outside the control of transit operators. Gasoline price elasticities are difficult to predict – especially their timing. According to "Effects of Rising Gas Prices on Bus Ridership for Small Urban and Rural Transit Systems," large and medium-large cities have a short-term delay of up to one month for responses to gas prices. In medium-small cities, reaction to gas price changes are immediate, but less significant, and may linger for several months. In small cities, there is no effect for several months, and then a delayed reaction takes multiple months to see full effect. Elasticities range from 0.08 to 0.16, usually on the lower side in less populated cities and higher in more populated cities. Therefore, a 1 percent increase in gas price would lead to an increase in transit ridership of about 0.08-0.16 percent [10].

Another external factor is weather. In Kuby, Barranda, and Upchurch's multiple regression study on light rail station boardings, weather extremity was a statistically significant measure affecting boarding rate. Kuby et al. used monthly degree-days, which accounts for the number of days and degrees below a certain level for a metro area. According to the paper, San Diego, which had the most "temperate" climate in the sample, can expect up to 300 more boardings per station per week than the average. Cities like Buffalo, Cleveland, and Salt Lake City, which experience more "extreme" temperatures, would see a reduced boarding rate [11]. Further in-depth analysis of specific weather impacts on transit ridership, including time of day affects, in "Impact of Weather on Urban Transit Ridership" shows differing levels of significance for impact of the following weather conditions: rain, snow, heavy rain, heavy snow, wind speed, strong wind, temperature deviation, fog, last 24 hours of snow, and season of the year. The level of significance of ridership impact for these conditions depends on daily vs. hourly ridership, weekend or weekday ridership, and AM, Midday, or PM ridership [12].

2.1.2 Traditional Internal Factors

On the other hand, Taylor and Fink introduced those factors under the managing entity's control as "internal factors." An example of an internal factor is fare level. James Sale studied seven different transit properties in 1976, all of which had shown annual increases in ridership above 5 percent from 1971 to 1975. His analysis showed that stable or decreasing fare levels were significant for increasing ridership, but that service expansion was more significant [13]. Kain and Liu's analysis also shows that transit fare elasticities for the agencies and years they studied range from 0.34 to 0.44. These are lower than those elasticities of service provision [7]. From 1990 to

2016, APTA and NTD data shows that real fares have increased 0.76 percent annually, a slight increase. When controlled for trip length, however, per mile fares have stayed virtually constant. According to Manville et al., however, fare changes may be a leading factor in ridership changes for isolated operators. He noted how inflation-adjusted fares per boarding for Orange County's operator and the Big Blue Bus operator have increased by about 50 percent between 2002 and 2016 [14].

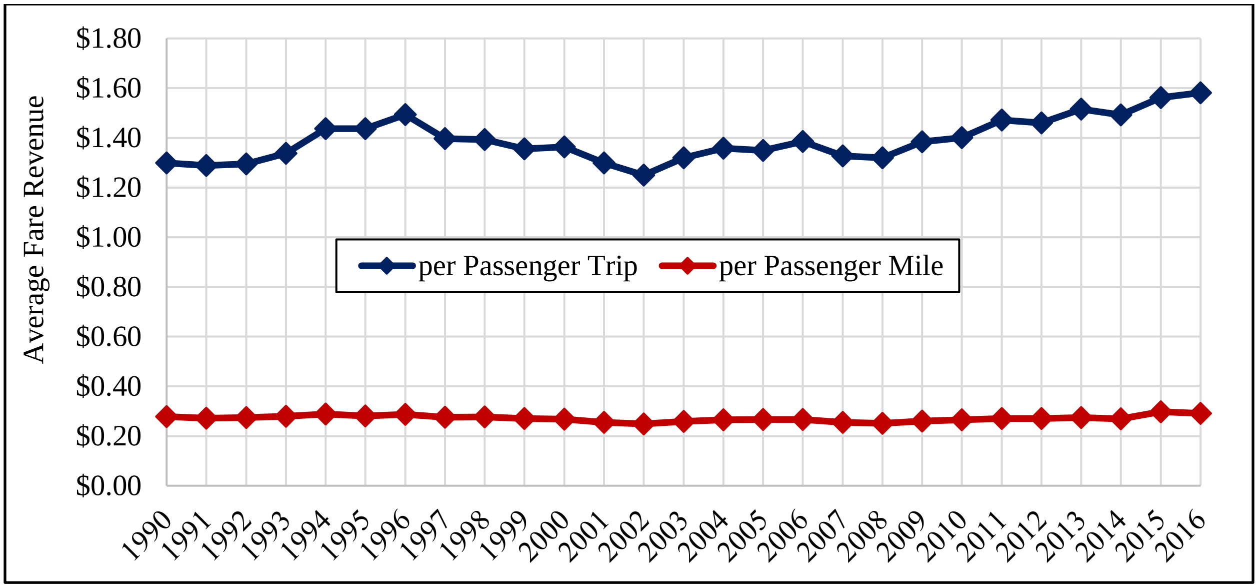

Figure 2.2 Fare revenue (2017 dollars) per passenger trip and passenger mile in the U.S.

The other internal factors are service quality and service quantity. McLeod et al. found a significant correlation between numbers of buses operating and ridership in Honolulu [15]. Gomez-Ibanez found vehicle miles of service to be significant to Boston-area ridership between 1969 and 1990 [8]. Kain and Liu's study showed that number of bus and rail miles of service between 1980 and 1990 contributed to 57 percent of the total 85 percent change in Houston's ridership and 18 percent of the total 49 percent change in San Diego's ridership. These were the highest contributing factors to ridership change in their study [7]. Harold M. Kohn found major significance in the effect of revenue vehicle hours on Canadian transit ridership. His model with vehicle revenue hours and average fare as independent variables shows that for every additional hour of service, ridership should increase by about 50 passengers [16]. However, despite improvement in provision of service mileage and hours since 2014, U.S. ridership has significantly decreased.

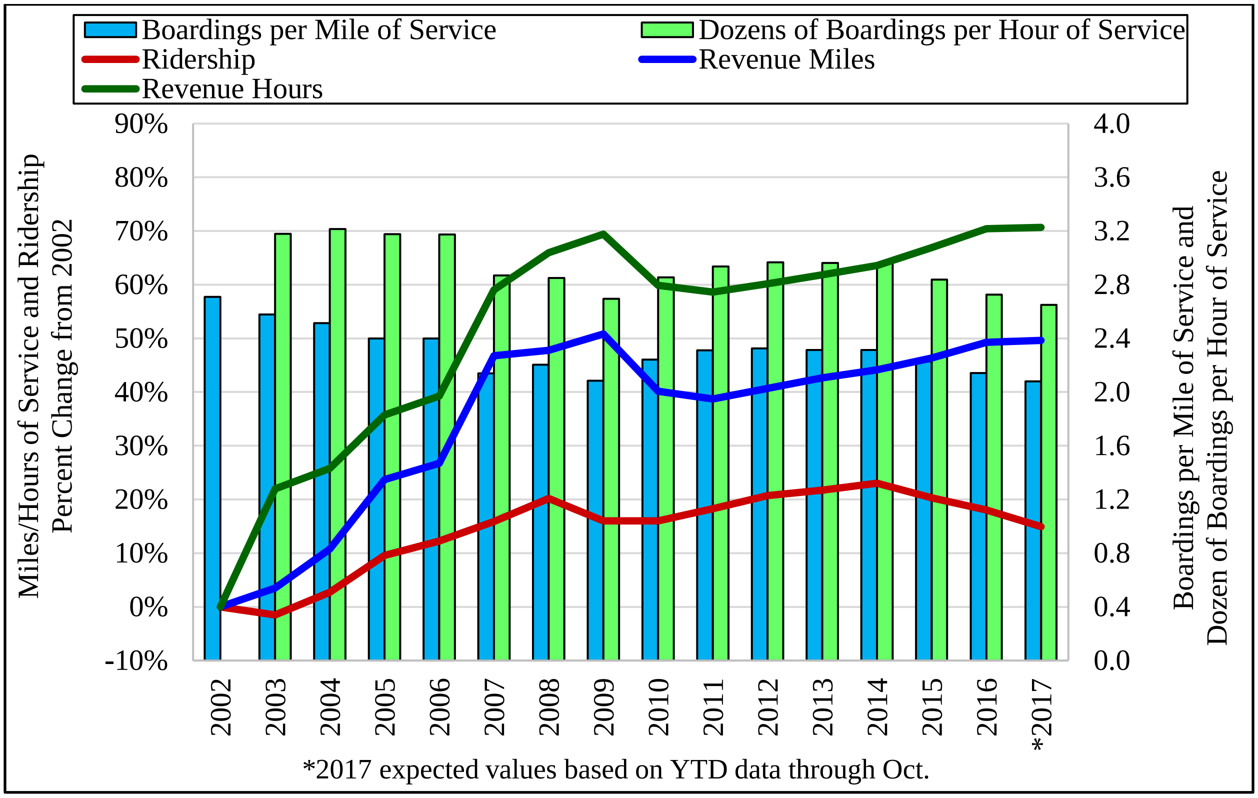

Figure 2.3 NTD U.S. transit percent change ridership and service since 2002 and ridership/service relationship.

A logistic regression model by Syed and Khan found major significance of bus information availability and on-street service as effects on ridership and minor significance of customer service and station safety as effects on ridership. As a percentage of variance explained by the various factors, results showed 22.1 percent for bus information, 10.9 percent for on-street service, 5.6 percent for customer service, and 4.3 percent for cleanliness. Syed and Khan's work shows the significance of service quality included with quantity [17]. Passenger comfort, safety, and perceptions have a measurable effect on likelihood of use of transit.

Transit operators may not directly control parking cost and availability but public policy and local decision-makers can be a major influence. During the Remix conference in October 2017, Yonah Freemark called for parking requirement reduction as a way to reduce demand for auto use in order to increase demand for transit [18]. A 1996 study by John Morrall and Dan Bolger shows that the number downtown parking spots per CBD employee explained 59 percent of variation of modal share in select Canadian and U.S. cities [19].

2.2 Recently Studied Factors Affecting Transit Use

Since 2003, however, much has changed. New technologies and changing travel behavior combined with recent ridership declines has inspired more research in the last few years on factors contributing to transit ridership. Almost all of these factors are external in nature, and therefore their effects require much more effort and maneuvering to curb.

2.2.1 Growth in Telecommuting

The rise of telecommuting is one of those factors. The Washington Metropolitan Area Transit Authority (WMATA) Finance Committee presented to its Board on October 12 of 2017 on "Understanding Rail and Bus Ridership" in response to recent declines in ridership. Telecommuting was one of the six reasons to which they attributed their ridership decline. Average trip frequency across their system (for users taking more than five rail-trips per card per month) has fallen from 20 to 18 rail-trips per card per month since 2013. According to the Finance Committee, telecommuting and/or alternative work schedules are helping to push down ridership by 15% on Fridays [20]. APTA's November 2017 Report on "Understanding Recent Ridership Changes" suggests that "teleworking, alternative work schedules, and increase in online commerce" have reduced trip rates among the transit faithful. The report states that in 2016 "66 percent of employers allow some employees to occasionally work regular paid hours from home, up 20 percentage points from 2006" [21].

2.2.2 Transportation Network Companies

Transportation Network Company (TNC) availability is also a factor out of the operators' control. TNCs such as Uber and Lyft have proven disruptive in the transportation industry, and that includes public transit. Much of the recently published literature is usually inconclusive and in many cases contradictory. Having said that, Hall, Palsson, and Price from the University of Toronto released work in July 2017 indicating that Uber presence in smaller metropolitan areas tends to have a negative effect on transit usage but in larger metropolitan areas has a positive effect. On average, they say, an Uber penetration increase of one standard deviation lowers public transit ridership in smaller cities by 0.5 percent while increasing ridership in larger cities by 1.8 percent. On the other hand, they found that Uber had significant impacts for places where transit ridership had less ridership at the time of Uber's introduction. For transit agencies with below median ridership, the introduction of Uber was met with an increase in transit ridership of 5.8 percent, while for transit agencies with above median ridership Uber's presence brought a decrease in transit ridership of 2 percent. They found that Uber most strongly complemented smaller transit agencies in larger cities [22]. Clewlow and Mishra's work on the effect of TNCs on transit ridership showed that "after using ride-hailing, the average net change in transit use was a 6 percent reduction among Americans in major cities." More specifically, they found that ride hailing attracts Americans away from bus and light rail but serves as a complementary mode for commuter rail [23]. The disruption of TNCs was alluded to in the November 2017 APTA report as well, theorizing that traditionally transit-dependent people may drive for TNCs as a pathway to car ownership through the various companies' car-rental assistance programs. The report also attributes erosion of transit customer loyalty to TNC presence and the ability for travelers to choose the mode that fits each individual trip [21]. Manville et al. concluded that TNC users do not resemble typical transit users and therefore TNC trips are probably not replacing large numbers of transit trips [14].

2.2.3 Low-Income Gentrification

Urban residential displacement of low-income residents is an external factor. More research is showing evidence that such displacement is leading to ridership loss in select cities. For example, an article by Tom Mills and Madeline Steel mentions Portland's TriMet survey that shows since 2003 the share of customers earning a low income has decreased, while the share of customers earning a high income has increased substantially. In those surveys, they add, "riders often cited a change in home or work address as the primary reason they rode less today than in the past." Many residential lots near downtown Portland increased in value more than 125 percent from 2001 to 2016. Their analysis shows a large area near the downtown core, which saw high home value increase and high ridership decline during that period [24]. This suggests that low-income residents, the largest share of transit users, are being "priced out," so to speak, from areas with good quality transit. In Atlanta, between 2000 and 2009, public transit commute share decreased in the downtown and inner city, but increased in the outer-ring suburbs. Shares of "less than high school" educated people in the downtown, inner city, and inner-ring suburbs decreased in the same period, but increased in the outer-ring suburbs. Additionally, it was in the eastern outer-ring suburb where median household income fell from 2000 to 2009, while downtown residents had a median income increase of 61 percent [25]. Yonah Freemark discussed that rising investment into urban cores has driven up cost of living close to transit service. He applauded Indianapolis' regional transit operator for investing in increased service to exurban office parks and manufacturing districts to account for changing settlement patterns [18].

2.2.4 Immigrant Travel Behavior

Immigrant behavior is also an external factor. Foreign-born people have traditionally been an over-represented group of transit users. In 2005, foreign-born people comprised 15.1 percent of the working population but 34.2 percent of transit commuters. Immigrants have been some of the most loyal transit users because of the barriers they face in licensure, socio-economic constraints, and settlement patterns. However, the trend has shown shifting tendencies among the immigrant population relating to transit use. Although the trend is still strong – foreign-born people made up 17 percent of the workers in 2016 but 33 percent of transit users – immigrants have been gravitating away from public transit as their main mode of commuting [9]. From 1980 to 2014, the transit commute share among foreign-born people in the U.S. decreased from 16 percent to 10 percent. In the same period, the overall transit commute share has dropped from 6 percent to 5 percent, transit commute share for people 20-29 has stayed constant at 7 percent, and the transit commute share for the poor has dropped from 9 percent to 8 percent. According to Tanvi Mishra, "more and more immigrants are bypassing the traditional gateways like New York City, San Francisco, and Chicago and heading straight to new destinations like Dallas, Atlanta, and Charlotte" which could be driving some of the transit exodus [26].

2.2.5 Tax and Benefit Structure

Tax and benefit structure is another recently studied factor affecting transit ridership. Darnell Grisby conducted a special APTA report on the implications of potential tax code changes. The report outlines the effect of transit-commute tax benefit programs on transit ridership by estimating a total annual tax savings of 1,130 dollars per year for employees and 235 dollars per year per employee for employers. Grisby concluded that if the current transit benefit were eliminated, it “would result in roughly a 40 percent effective fare increase for a large number of commuters, as fares would be paid using post-tax earnings which are subject to state and local taxation.” [27]. A study on the impacts of transit benefit programs in 2008 states that beneficiaries of employer programs comprised between 5 and 25 percent of total transit riders among the agencies interviewed. In the study, Denver’s transit operator saw 6,000 new riders per day from their Eco Pass program, explaining up to 42 percent of their overall ridership growth from 1997 to 2001. Overall, estimates for the agencies used in their study suggested that transit benefit programs contributed to between 30 and 40 percent of ridership growth from 1997 to 2001 [28]. This research lays out the importance of these programs for generating a faithful customer base. Recently, some are blaming federal and local tax benefit reductions for some of the recent ridership declines. The WMATA Finance Committee Report named a federal benefit drop in 2014 as a reason for reduction in high use SmartBenefits customers in 2015 and therefore part of their observed ridership decline [20].

CHAPTER 3: AGE DISTRIBUTION IMPACTS

One major factor influencing a person's travel behavior is age. People of different ages have different life priorities, work different amounts, and use different means of transportation. A person's stage of life such as youth, working age, or retirement correlates not only with how much they travel, but also by what mode they travel. People aged 36-55 take more trips than other age groups, especially older cohorts, for example. Additionally, younger people tend to use transit at a higher rate than do their older counterparts [29].

3.1 Trip Rates and Mode Shares

The National Household Survey (NHTS) is a "list-assigned random digit dialing (RDD) computer assisted telephone interviewing (CATI) survey conducted over an entire year. Travel data were collected from the civilian, non-institutional, non-institutionalized population of the United States. People living in medical institutions, prisons, and in barracks on military bases were excluded from the sample." Survey results from the NHTS, which is an initiative of the USDOT, provide information on travel behavior of the U.S [30].

3.1.1 NHTS 2009 Results

The 2009 NHTS results, the most current data available, indicate that people between 36 and 45 years old take more trips than do any other age cohort, at 4.3 trips per day. In comparison, people between 66 and 75 take 3.6 trips per day as shown in Figure 3.1. Over the course of a full year, and with population in the hundreds of millions, this seemingly small difference in travel results in a significant displacement of trip potential between younger-middle-aged people and the elder populous [30].

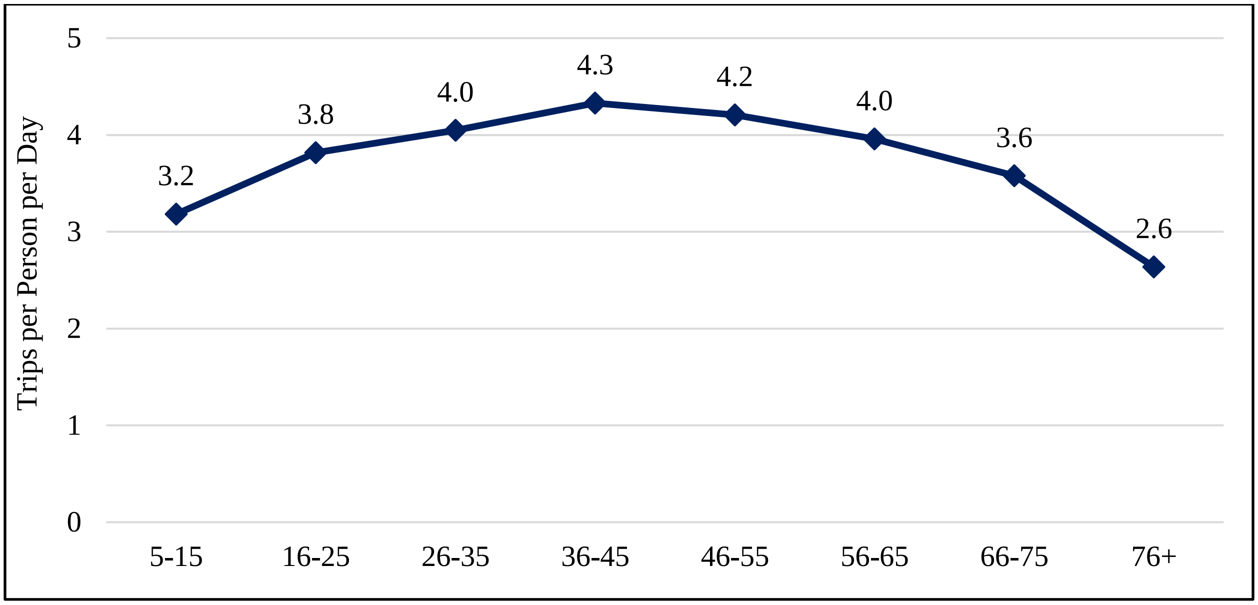

Figure 3.1 NHTS trips per person per day by age group, 2009.

According to 2009 NHTS results, people between the ages 16 and 25 have the highest propensity toward transit use. As Figure 3.2 shows, this young age group takes an average of 3.3 percent of all their trips using transit, and the next youngest group (26-36) takes an average of 2.6 percent. In contrast, older age cohorts' transit trip share ranges between 1.7 percent and 2.0 percent. It makes practical sense that teenagers, college students, and young professionals are more likely to use transit than are older individuals. Young people may be less able to afford private transportation, and more able to move afoot – a requirement for most transit use – than those that are older and more financially established.

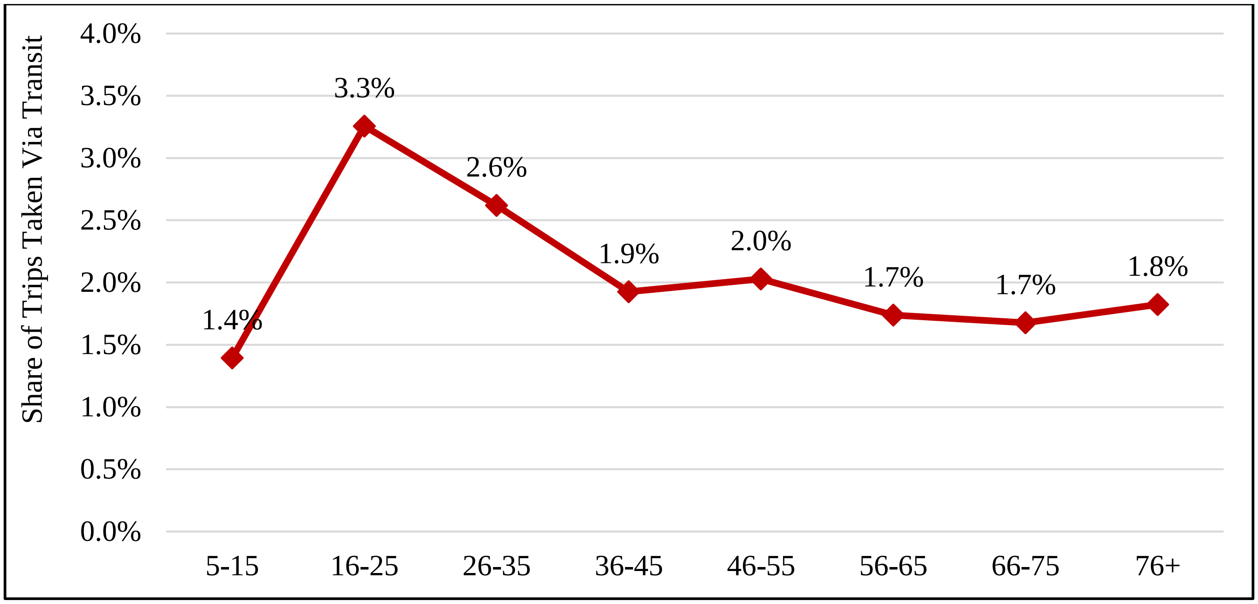

Figure 3.2 NHTS shares of trips via transit by age group, 2009.

3.1.2 NHTS 1995, 2001, and 2009

USDOT conducted the NHTS for the years 1995, 2001, and 2009. This temporal data can show trends in travel behavior. Different years' data will yield different travel behavior results. However, though some behavior characteristics change with demographics, others stay more constant over time. For instance, all three NHTS results show that 36-45 year olds take the most trips of any age group. Likewise, 16-25 year olds consistently use transit more than any other age group. The magnitude of the difference, though, does vary. In 1995, 16-25 year olds used transit for 2.5 percent of trips while 36-45 year olds used transit for 1.6 percent of trips. NHTS 2009 results are discernably comparable. 16-25 year olds used transit for 3.3 percent of trips, while 35-44 year olds used transit for 1.9 percent of trips. It was a difference of 0.9 percent in 1995 and a difference of 1.4 percent in 2009.

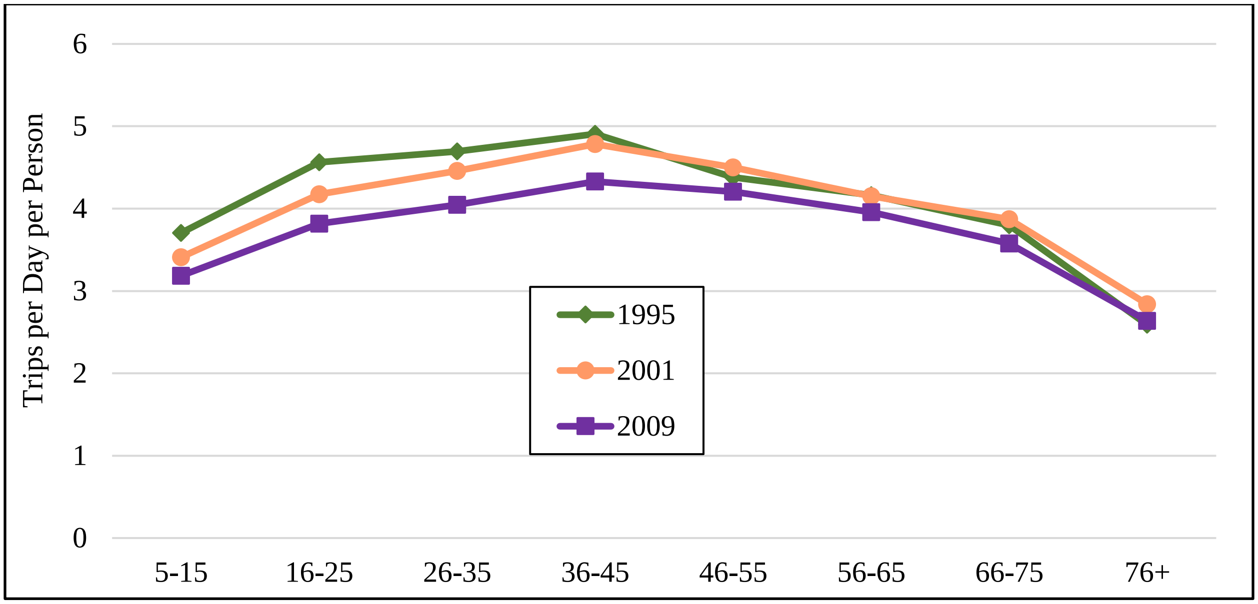

Figure 3.3 NHTS trips per person per day by age group and survey year.

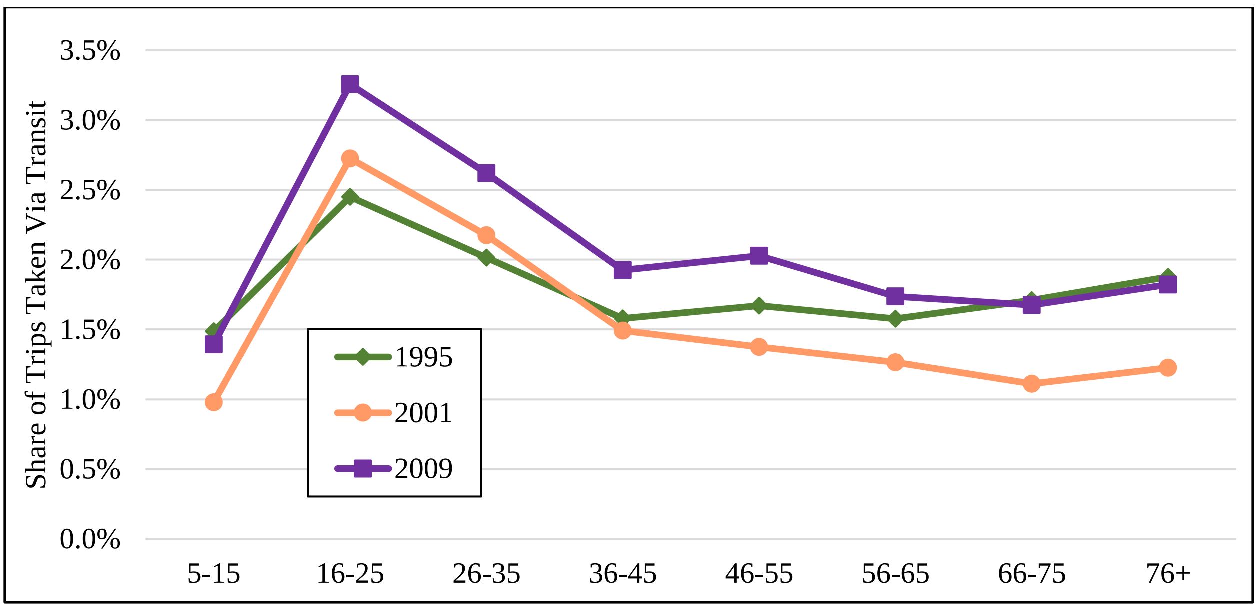

Figure 3.4 NHTS shares of trips via transit by age group and survey year.

One notable change among NHTS years is the older population's tendency to use transit. In 1995, people gradually used transit more after 56-65 resulting in a transit trip share of 1.7 percent for 66-75 year olds, and 1.9 percent for 76+ year olds. In 2001, however, transit use declined consistently after 36-45, resulting in a transit trip share of 1.1 percent for 66-75 year olds, and then increased for 76+ year olds to 1.2 percent. Finally, in 2009, transit use likewise declined for people older than 55 years old, resulting in a transit trip share of 1.7 percent for 66-75 year olds, and then ticked up slightly for 76+ year olds to 1.8 percent. Older people use transit less relative to their middle age counterparts than they did in 1995.

3.2 Age Profile and Methods

Because of the difference in travel behavior between age groups, a changing national age profile has resulted in shifts to overall travel tendencies over the last thirty-five years. The “baby boomer” population bubble shows up in a national age profile, and it has moved with time, as the baby boomers have grown older, as seen in Figure 3.5.

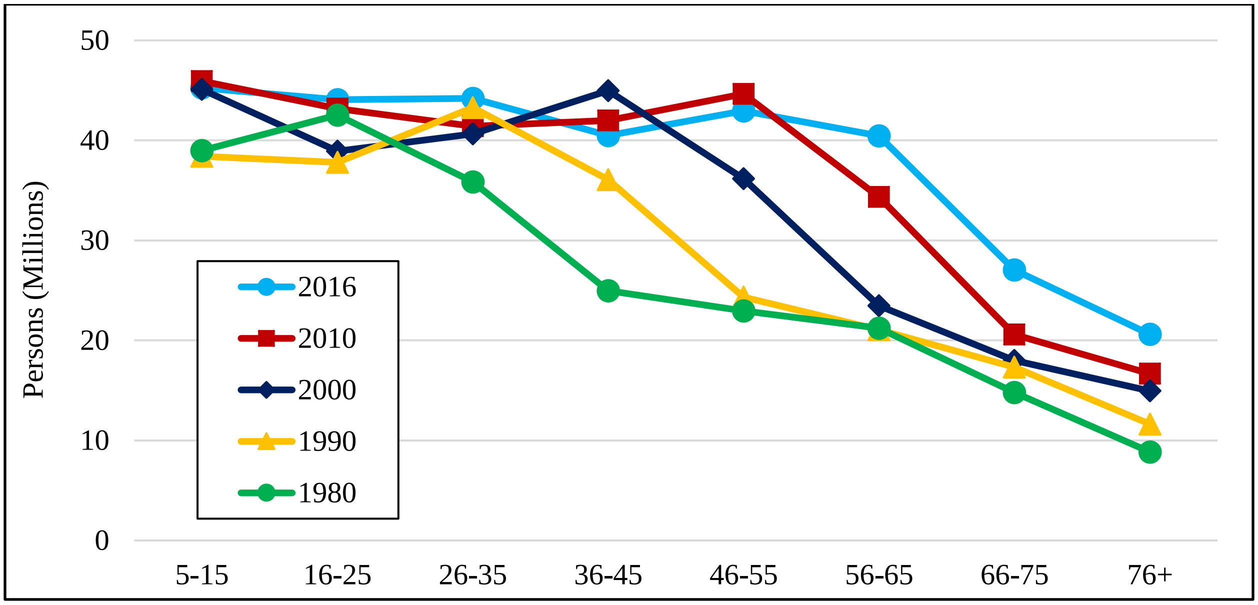

Figure 3.5 Select U.S. Census population age distributions, 1980-2016

In 1980, the bulge of the populous was under age 36. Although the people represented by this bulge were taking fewer trips than those over 35, they took over 3 percent of those trips using transit. Although that share may not sound impressive, it is much higher than older age cohorts’ transit share. However, by 2010, that same bulge was into the 46-55 and 56-65 age groups [31] [32] [33]. At that point, the baby boomers were taking more trips than they were in the 1980s, but using transit much less. Could this age distribution shift lead to a shrinking propensity for the populous to use transit?

To test this theory, a numerical model can estimate the number of theoretical transit trips that should occur under any given age distribution, using the NHTS trip rates and transit usages by age group. The robustness of this theory can be tested by applying trip rate and transit mode share data from additional NHTS survey years, 2001 and 1995 [30]. Travel behaviors are ever changing, thus it is not certain that today's 36-45 year olds will behave identically to today's 46-55 year olds when they reach that age. However, understanding past cohort travel behaviors provides a comparative baseline. The Equations 3.1, 3.2, and 3.3 outline the steps of the model for estimating potential transit trips [2]:

$$\begin{array}{c}\textit{Total}\\ \textit{theoretical trips}\\ \textit{in year y for}\\ \textit{age group g}\end{array} = \frac{\text{total trips}}{\text{person} * \text{day}} \begin{array}{c}\textit{for age}\\ \textit{group g}\\ \textit{(NHTS)}\end{array} * \frac{365\ \text{days}}{\text{year}} * \begin{array}{c}\textit{persons in age}\\ \textit{group g in year y}\\ \textit{(Census)}\end{array} \quad (3.1)$$

$$\begin{array}{c}\textit{Total}\\ \textit{theoretical}\\ \textit{transit trips in}\\ \textit{year y for age}\\ \textit{group g}\end{array} = \begin{array}{c}\textit{Total}\\ \textit{theoretical trips}\\ \textit{in year y for}\\ \textit{age group g}\end{array} * \frac{\text{transit trips}}{\text{total trips}} \begin{array}{c}\textit{for age group g}\\ \textit{(NHTS)}\end{array} \quad (3.2)$$

$$\begin{array}{c}\textit{Total}\\ \textit{theoretical}\\ \textit{unlinked}\\ \textit{transit trips in}\\ \textit{year y,}\\ \textit{adjusted for}\\ \textit{population}\\ \textit{growth}\\ \textit{(2015), for}\\ \textit{age group g}\end{array} = \begin{array}{c}\textit{Total}\\ \textit{theoretic}\\ \textit{al transit}\\ \textit{trips in}\\ \textit{year y for}\\ \textit{age}\\ \textit{group g}\end{array} * \frac{\text{total population}, 2015}{\text{total population}, \text{year } y} * \frac{1.53\ \text{unlinked trip}}{\text{linked trips}} \quad (3.3)$$

3.3 Implications

In theory, transit ridership per capita has had the propensity to decrease each decade since 1980 simply due to the shifting age distribution and a gradually aging populous. Thus, the age distribution effect creates the expectation of dampened overall transit ridership due to trip rate and mode share changes associated with aging. Superimposing the 1980 age distribution on the 2016 total population, there is a theoretical expectation for 14.29 billion unlinked transit trips. However, the same expectation using the 2016 age distribution is 13.74 billion unlinked transit trips, 3.9 percent fewer. The aging of the populous does not have enough power to produce decreased total transit ridership, but it does carry a suppressing effect. Therefore, the theoretical results explain part of the shrinking transit ridership per capita trend, as shown in Figure 3.6 and Figure 3.7.

Since 1980, per capita ridership has decreased from 37.7 to 32.2 trips per year. That is a decrease of 5.6 trips per year from 1980 to 2016. A 3.9 percent reduction would have resulted in a 2016 per capita ridership 1.5 fewer than in 1980. Therefore, the changing age demographic explains about 20 percent of the total per capita ridership decline since 1980 [1].

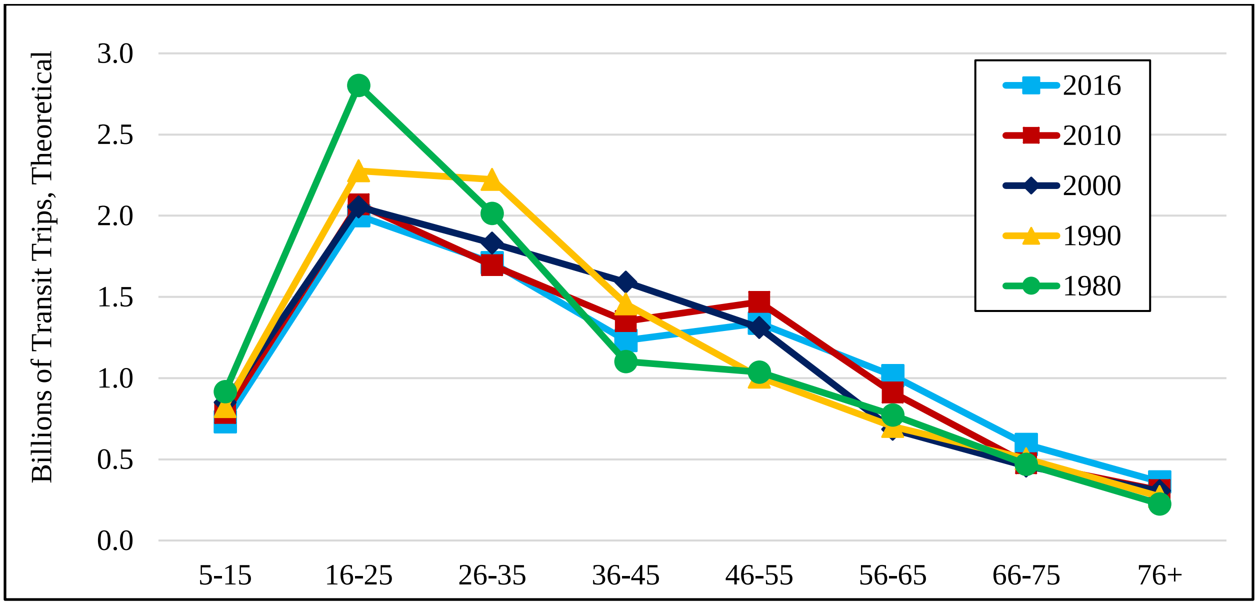

Figure 3.6 Theoretical transit trips by age group and year, adjusted to 2016 total population.

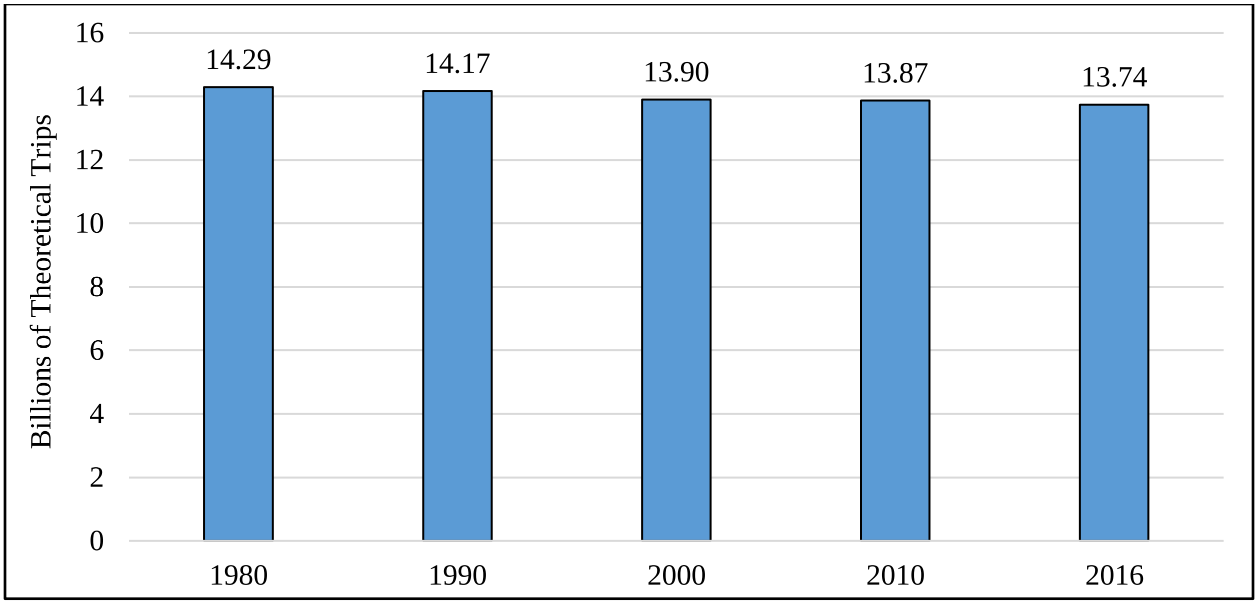

Figure 3.7 Total theoretical transit trips by year, adjusted to 2016 total population.

These estimations are higher than actual nationally reported transit ridership, which was 10.6 billion in 2015, for example [1]. This could be due to sampling error on the part of the NHTS, or a disconnect between the definitions of transit as used by the APTA and NHTS respondents. Perhaps APTA data does not capture all transit use referred to in the NHTS survey responses. The results of this model using the 2009 NHTS are very similar to those using inputs from different NHTS years.

3.4 Forecasting Future Growth

In another 15 years, the bubble in the age distribution will have grown even older, and, as shown in Figure 3.8, will have moved in to the 66+ age groups. As per the 2009 NHTS, people make fewer trips as they grow older, decreasing from 4.0 to 3.6 to 2.6 trips per day at 56-65, 66-75, and 76+, respectively. Compared to 2016, U.S. Census Bureau predicts a population profile in 2030 with 42 percent more people aged 66-75, and 69 percent more people aged 76 and older [34]. The nature of travel, and thus of transit ridership, will surely evolve as the population moves into older age cohorts.

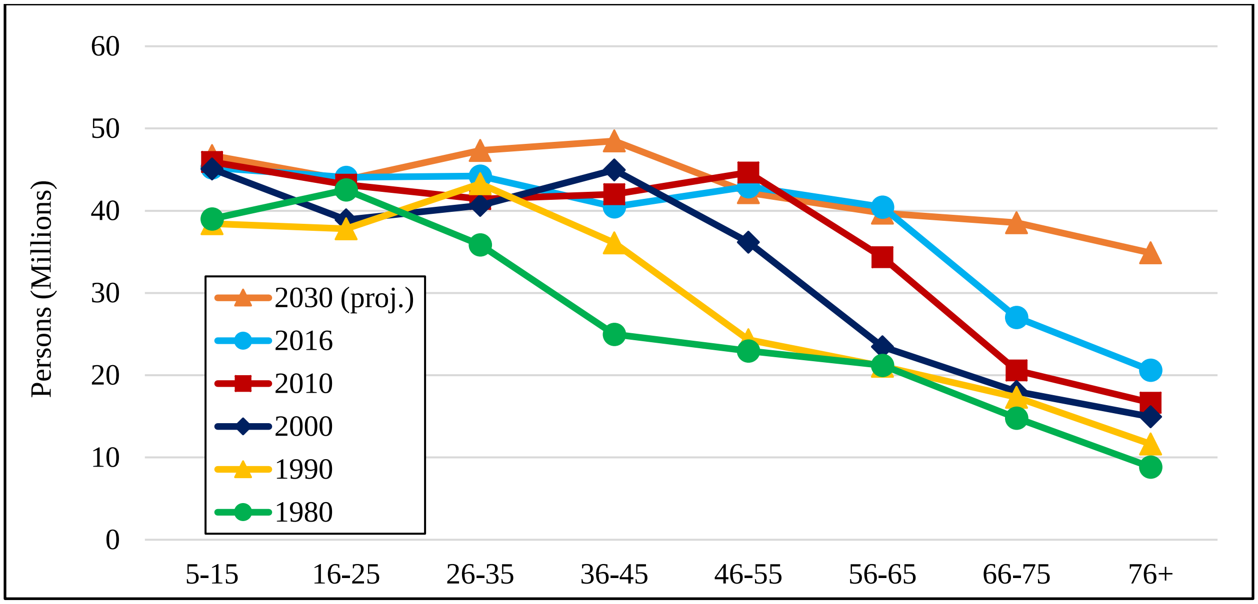

Figure 3.8 Select population age distributions, 1980-2015, and 2030 projection.

The 2015-equivalent number of transit trips expected using the 2030 age profile is 13.41 billion, a decrease twice as steep as the previous 15 years. This highlights the impending need for transit agencies to evolve their service with changing demographics. To keep ridership per capita from falling further, the transit industry could use its resources to appeal more to the older age cohorts that are on the verge of growing by unprecedented volumes.

In essence, as more people have grown out of the transit-faithful age groups, the transit industry has struggled to maintain even modest ridership growth and has failed to produce growth in transit ridership per capita. While this effect is minimal, under one tenth of one percent per year, it is nonetheless providing downward pressure on transit use. Changes in immigration or other factors could exacerbate this trend.

CHAPTER 4: VEHICLE AVAILABILITY IMPACTS

One of the most impactful demographic factors on transit ridership is vehicle availability. Manville et al. built a series of statistical models to estimate annual transit ridership for California – one model accounted for socioeconomic changes but not vehicle access while the other model accounted for both. Their model not accounting for vehicle access estimated relatively identical per capita ridership in 2015 and 2000 while their model accounting for vehicle access estimated a decline in that period of greater than 15 trips per capita [14]. According to APTA, only 45.4 percent of public transportation users have a vehicle available when making a transit trip. In addition, 30.7 percent of public transit rider households have no vehicles, and another 29.1 percent have only one vehicle [2]. When trip-makers have no vehicle available in their household, they are captive to alternative modes of transportation, such as walking, bicycling, and – for longer trips – transit. When trip-makers have one household vehicle, they often must share the vehicle and tend to take transit for recurring, pre-planned trips. This analysis will be very similar to that used in the previous chapter, applying NHTS travel behavior data to changing demographics reported in the U.S. Census.

4.1 NHTS 2009 Results

According to the 2009 NHTS, people living in zero-vehicle households take significantly fewer trips than those with a vehicle in the household, 2.73 per day. Zero-vehicle household members probably take fewer recreational trips and mostly only necessary ones because trips are generally difficult for them to make. One-vehicle household members take 3.70 trips per day, two-vehicle household members take 3.95 trips per day (the most), three-vehicle household members take 3.91 trips per day, and members of four-or-more-vehicle households take 3.81 trips per day. Perhaps people with 3+ household vehicles, although more affluent, have more constrained life schedules, and therefore do not make as many extraneous trips as those with two vehicles [30].

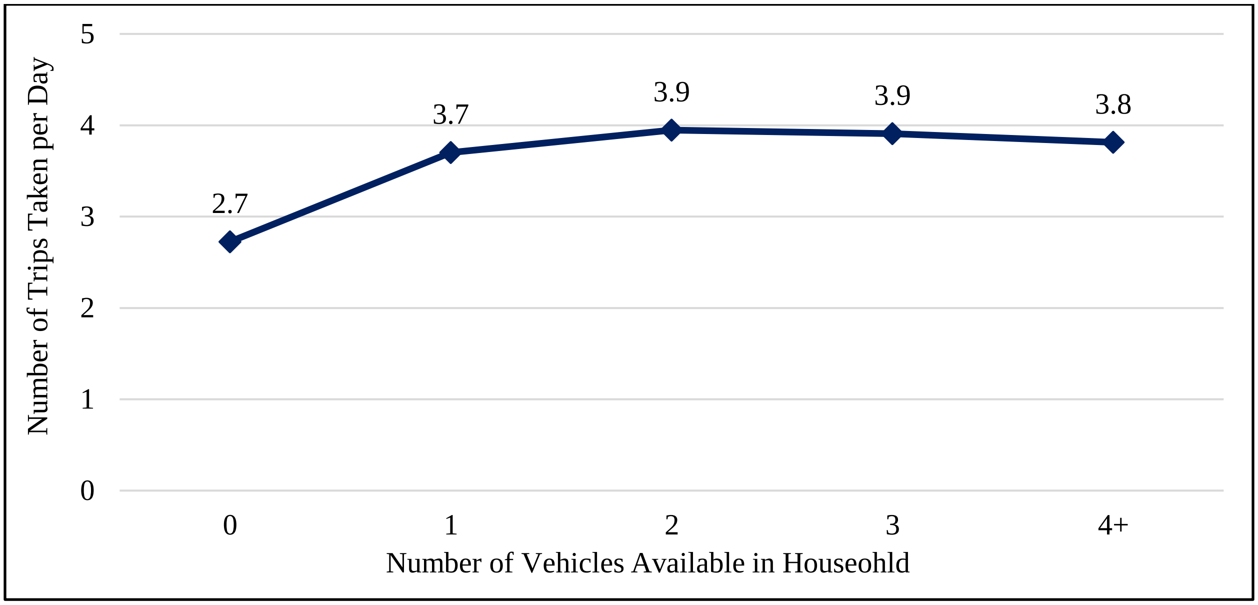

Figure 4.1 NHTS trips per person per day by household vehicle availability, 2009.

Although members of zero-vehicle households take fewer trips than those of other households, they tend to take transit much more frequently. Zero-vehicle household members use transit for over 50 percent of work trips and 23.9 percent of all trips, according to the NHTS. That is contrasted with one-vehicle households, whose members take 2.9 percent of trips using transit, two vehicle households, whose members take 0.9 percent of their trips using transit, three-vehicle households, whose members take 0.6 percent of their trips using transit, and four-or-more-vehicle households, whose members take 0.3 percent of trips using transit. With increased household vehicle availability, people generally use transit less. The difference in transit trip rate between zero-vehicle household members and one-vehicle household members is almost seven times greater than that between one and two-or-more-vehicle household members [30]. The share of the population living in zero-vehicle households will greatly influence propensity for transit use. During the economic recovery period since 2011, household vehicle availability has generally grown, with fewer zero-and-one-vehicle household members and many more three-and-four-vehicle household members. Maybe vehicle availability change, therefore, can partially explain some of the transit ridership decline in recent years. This analysis will assume that travel behavior by household vehicle availability does not change.

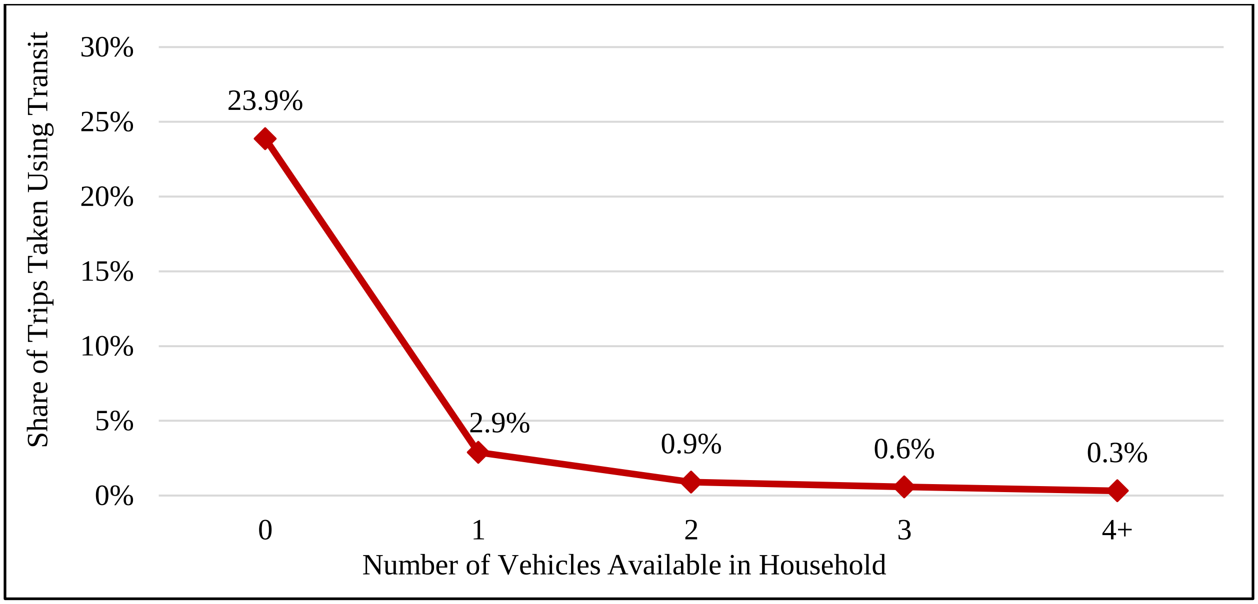

Figure 4.2 NHTS shares of trips via transit by household vehicle availability, 2009.

4.2 Household Vehicle Availability Population Profile

Any change in the profile of population by household vehicle availability may explain significant amounts of the transit ridership change. One resident switching from a household with zero to one car results in 199 fewer annual transit trips. One resident switching from a household with one car to two results in 28 fewer annual transit trips. The household vehicle availability profile has made some significant changes since 2005, according to the U.S. Census [30]. Because NHTS data does not include persons under the age of five, the analysis requires a scale factor applying to the resident populations to account for only five and older populations. In summary, the share of people 5 and older in households with two vehicles is by far the greatest – over 40 percent. The next most popular household vehicle availability is one – over 20 percent of the population 5 and over – mostly from one-person households. Not far behind is three-vehicle households with just under 20 percent of the population 5 and older belong to such households. Finally, four-or-more-vehicle household members and zero-vehicle household members each make up less than 10 percent of the population [9].

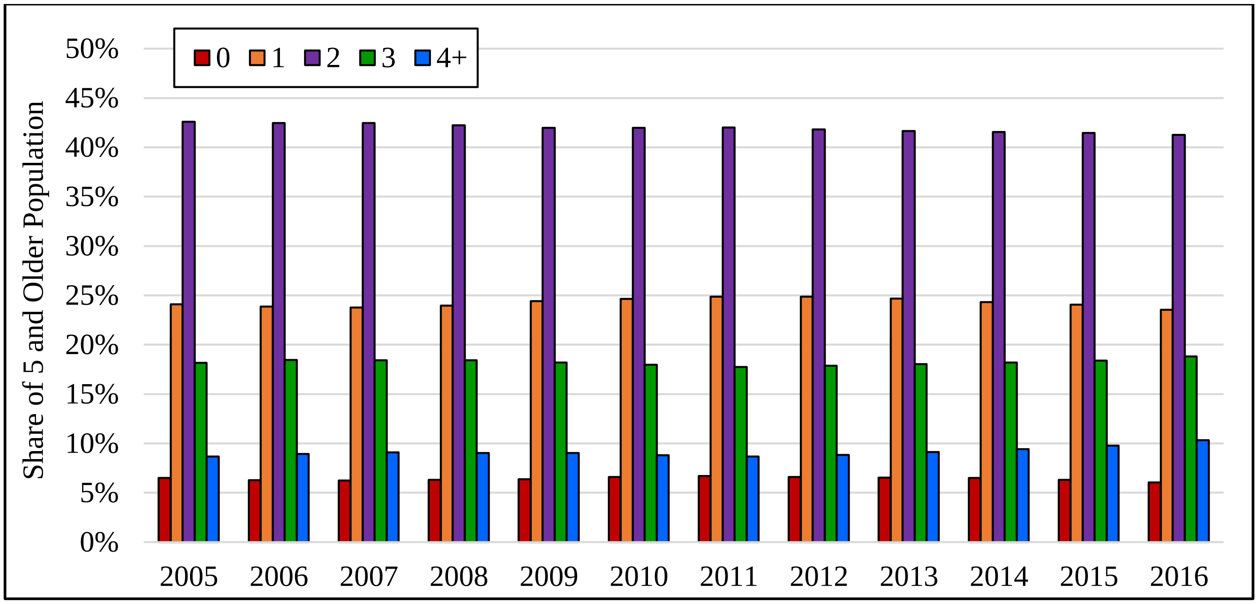

Figure 4.3 Share of persons 5 and older by number of vehicles available in household.

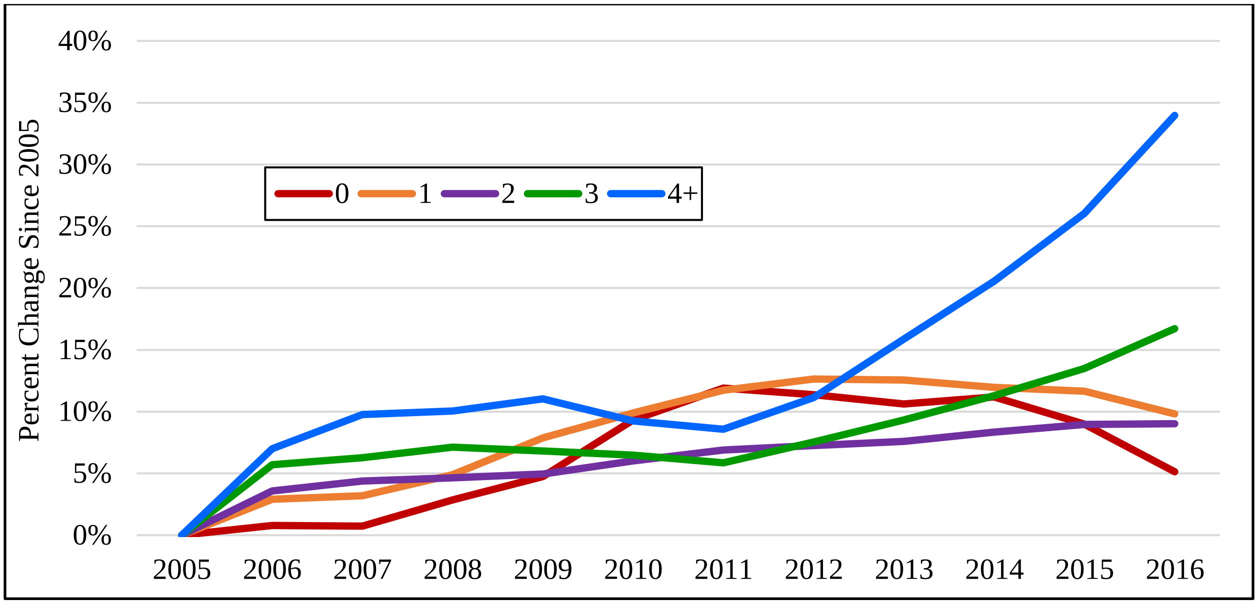

Figure 4.4 Percent change in persons 5 and older by vehicles available in household from 2005.

4.2.1 Zero-Vehicle Households

During the economic recession of 2009, zero-vehicle resident population grew substantially. By 2011, there were over two million more zero-vehicle household residents than five years earlier. Through the recovery period of 2011-2014, the number of zero-vehicle household residents remained high – above 20 million – and transit ridership increased as employment grew without meaningful change in zero-vehicle household makeup. Since 2014, however, the number of zero-vehicle household residents has decreased by over one million. After the recovery, more households were able to save up enough with newfound income to purchase a vehicle and the effects of economic growth started to show through vehicle availability. Zero-vehicle household members comprised 6.1 percent of the total five-and-over population in 2016, the lowest share on record (since ACS started tracking in 2005) [9]. Using the NHTS estimate of 238 transit trips taken per year, this decline represents 260 million fewer transit trips from 2014 to 2016 [30].

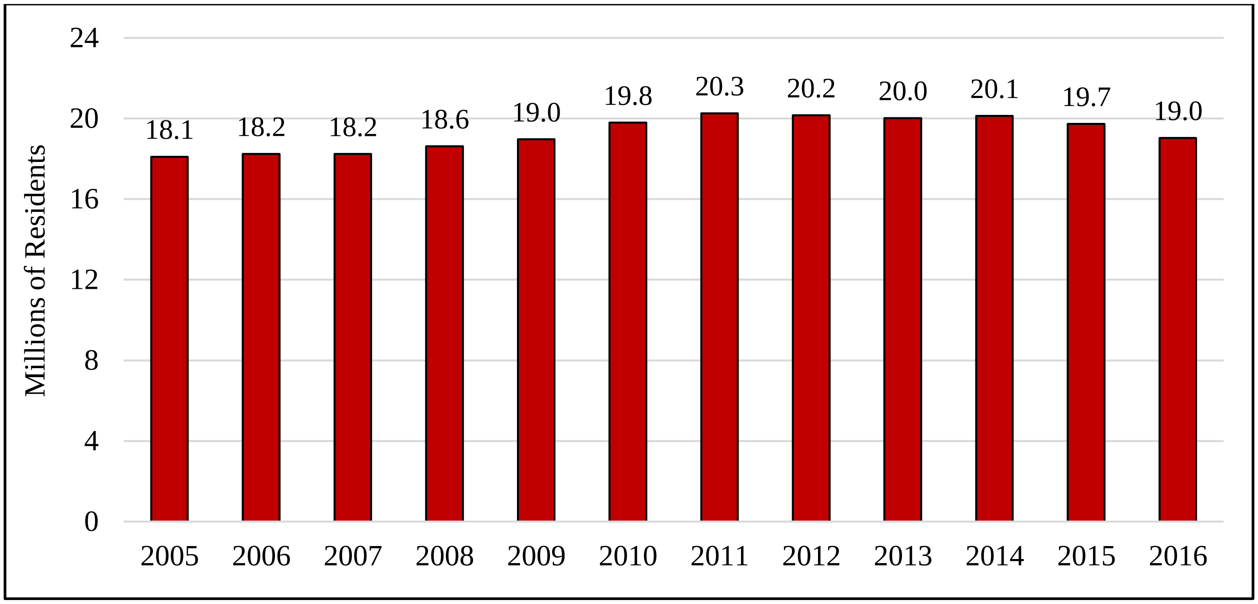

Figure 4.5 Population 5 and older in households with zero vehicles available.

4.2.2 One-Vehicle Households

Population in one-vehicle households grew more steadily from 2005 to 2012. During the recession, many one-vehicle households probably became zero-vehicle households, but many two-plus-vehicle households probably also became one-vehicle households. Therefore, the recession did not make a meaningful net influence on one-vehicle household population change. By 2012, 75.8 million Americans 5 and older lived in a one-vehicle household. Since 2012, that number has declined by nearly 2 million (despite additions from those leaving the zero-vehicle household pool). As the economy has recovered, more households have added a second vehicle to increase flexibility – especially those with more than one household member. One-person households, however, constitute 54 percent of one-vehicle households, and are less likely to add a second vehicle [9]. Using an NHTS estimate of 39 transit trips taken per year, the decline between 2014 and 2016 of 1.4 million one-vehicle household residents represents 56 million fewer transit trips in that period.

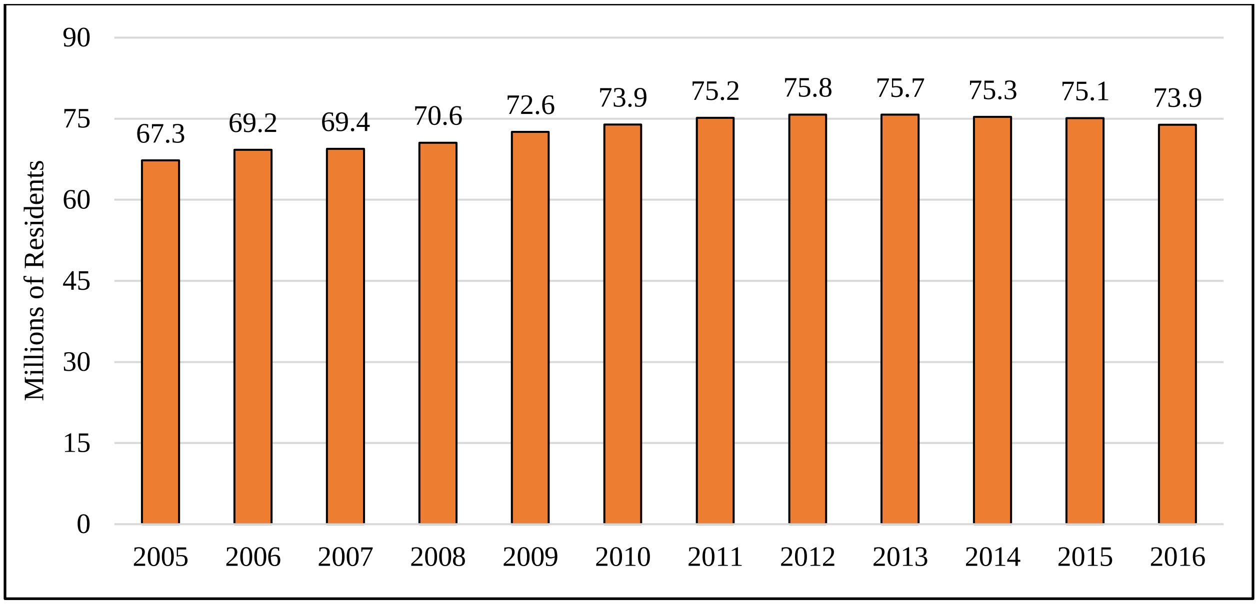

Figure 4.6 Population 5 and older in households in households with one vehicle available.

4.2.3 Two-Vehicle Households

Since 2005, the number of residents living in two-vehicle households has never decreased. Two-vehicle householders make up the highest as a share of the five and older population, of over 41.3 percent, down from 42.6 percent in 2005. The share of two-vehicle household members living in two-person households is 48.4 percent. The number of two-vehicle household members 5 and older has increased 9.0 percent since 2005. Growth in two-vehicle household members has not been robust, and in 2016 increased by only one hundred thousand, or less than one-tenth of a percent. Using the NHTS estimate of 13 transit trips taken per day, the increase between 2014 and 2016 of eight hundred thousand two-vehicle household residents represents 10 million additional transit trips in that period.

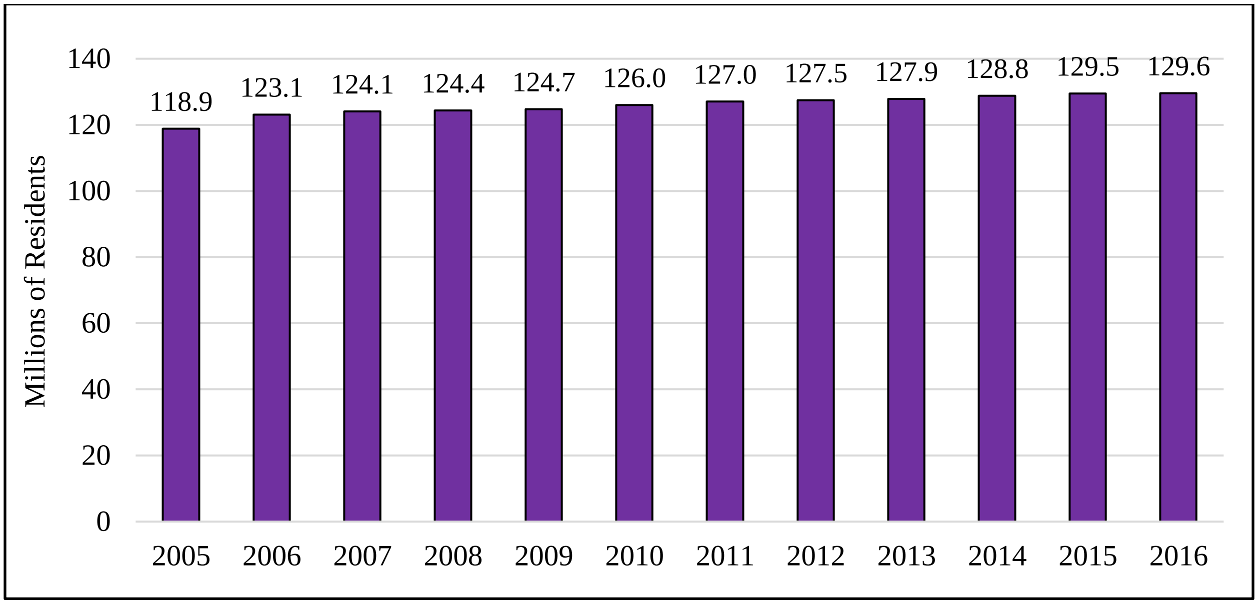

Figure 4.7 Population 5 and older in households with two vehicles available.

4.2.4 Three-Vehicle Households

Three-vehicle household population has seen much more change, especially recently. 2005-2008 was a growth period for population in three-vehicle households, increasing from 50.7 million to 54.3 million. Then, during the economic recession, such population flat-lined. Since 2011 – the same period over which zero-vehicle household population has been decreasing – number of three-vehicle household members has increased from 53.6 to 59.1 million. Overall, since 2005, three-vehicle household population 5 and older grew 16.7 percent. The share of the population living in three-vehicle households increased from 18.2 to 18.8 percent, the highest on record. During the economic recovery, many one-and-two-vehicle households probably became three-vehicle households. Using an NHTS estimate of 8 transit trips taken per year, the increase between 2014 and 2016 of 2.8 million three-vehicle household residents represents 22 million additional transit trips in that time.

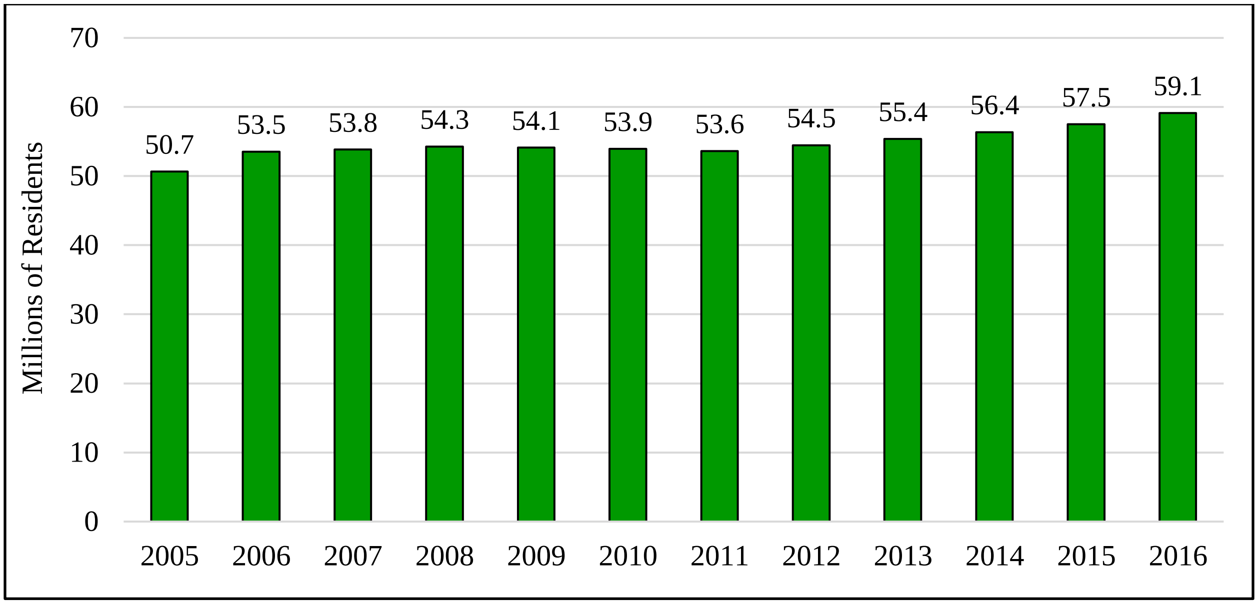

Figure 4.8 Population 5 and older in households with three vehicles available.

4.2.5 Four-or-More-Vehicle Households

The household vehicle classification that had the highest population growth since 2005 was four-or-more vehicle households, increasing 34 percent. Similar to three-vehicle household population, four-or-more vehicle household population declined slightly during the recession from 2009-2011. Since then, however, growth has been extreme. From 2011 to 2016, four-or-more-vehicle household population has grown from 26.3 million to 32.4 million, or 23 percent. The share of the population in four-or-more vehicle households has increased from 8.7 to 10.3 percent in the same period. Using an NHTS estimate of 4 transit trips taken per year, the increase between 2014 and 2016 of 3.2 million four-or-more-vehicle household residents represents 14 million additional transit trips in that time.

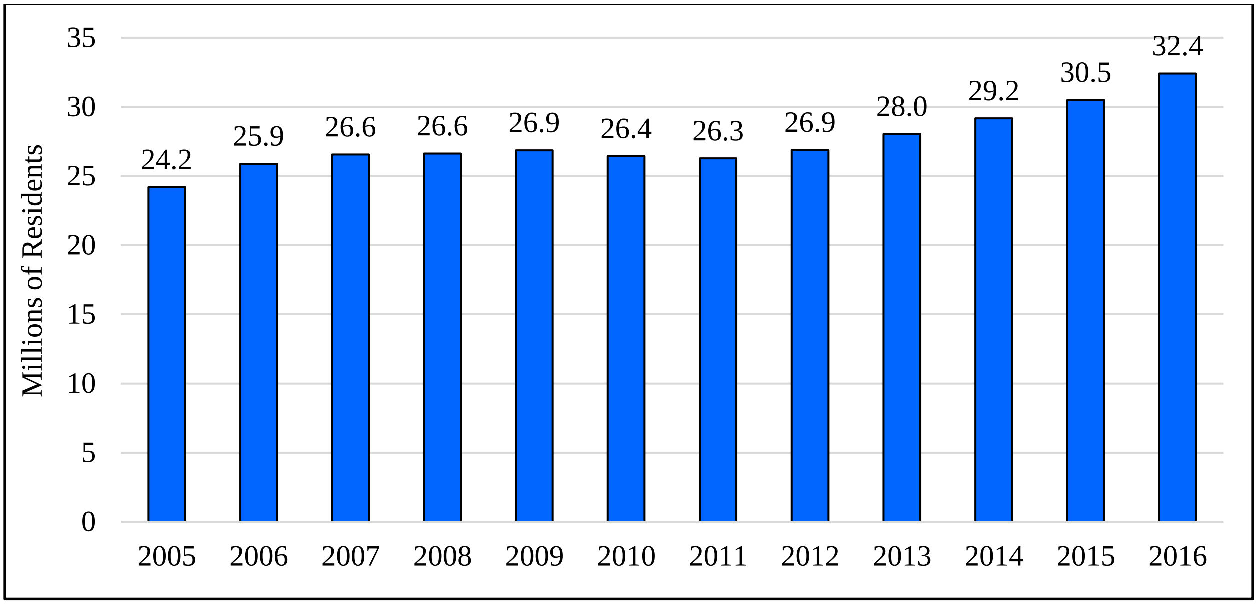

Figure 4.9 Population 5 and older in households with four or more cars available.

The high growth of four-or-more vehicle household population may be partially explained by the average household size increasing, especially the four-or-more-person household size. The average size of households with more than three people increased from 5.0 persons in 2005 to 5.7 in 2016. Since 56 percent of four-or-more vehicle households are also four-or-more person households, the growth in household size has contributed to the increase in population with access to many vehicles.

4.3 Results

Assume that travel behavior relating to transit use by household vehicle availability does not change over time. To estimate the effect of vehicle availability on transit ridership, apply the difference in number of people in each household vehicle category between two years to the number of estimated trips a person from that category takes per year using transit, as shown in Equation 5.1. Table 4.1 shows an analysis from 2014 to 2016 using this method. In total, the changing vehicle availability profile explains 269 million trips of the observed 340 million (APTA) decline from 2014 to 2016 [1]. This is a very powerful result, as it explains 79 percent of transit ridership decline. Using NTD ridership estimate, the observed decline in ridership between 2014 and 2016 is greater, 432 million trips. Yet still, using NTD data, these results explain 62 percent of the ridership decline.

$$\text{Estimated Trip Change for Household Vehicle Category } w\text{, 2014-2016} = \text{Change in Population in Household Vehicle Category } w\text{, 2014-2016} * \text{Annual Transit Trips per Person for Household Vehicle Category } w \text{ (2009 NHTS)} \quad (5.1)$$

Table 4.1 Transit Use, Population Change, and Estimated Ridership Effect by Household Vehicle Availability

Vehicles in household	**0**	**1**	**2**	**3**	**4+**	**Total**
Resident Population (5 and up) in millions, 2016	19.04	73.89	129.58	59.12	32.42	309.77
Change in Population (5 and up) in millions, 2014-2016	-1.09	-1.44	0.80	2.75	3.25	4.27
Annual Transit Trips per Person	238	39	13	8	4	-
Estimated Transit Trip Change in millions, 2014-2016	-259.94	-56.01	10.48	22.38	14.16	**-268.93**

4.4 Implications

The results from this analysis show the importance of vehicle availability as it relates to the propensity for transit use. Travel behavior-demographic analysis is not a perfect method by any means – travel behavior changes, however slightly, with changes in demographics. Moreover, there remains possible endogeneity, as vehicle availability may be changing because of transit abandonment, and not the other way around. However, the relationship between zero-vehicle household share and transit use is so strong that these major changes explain a significant part of observed transit ridership trends. Since 2014, zero-vehicle and one-vehicle household populations has decreased and three-or-more vehicle household population has increased. As more families have been able to purchase private transportation, dependence on public transportation has conversely decreased.

As is turns out, private vehicle transportation is much more convenient for most U.S. residents than public transit as a means of travel. Public transportation with continue to lose ridership as household vehicle availability continues to improve unless the landscape of the transportation system changes dramatically. If travel time using transit substantially improves, perhaps vehicle availability will not be such a strong factor in transit ridership. However, as it stands, transit operators cannot realistically compete with the growth of vehicle availability in the face of a growing and thriving economy.

The transit-dependent market is shrinking and therefore transit operators must attempt to increase choice ridership. This is becoming more difficult as choice riders now have more options for trip-specific mobility than ever before. If it is good news that there are fewer economically challenged people in an improving employment market, attracting choice ridership, despite the challenges, will be increasingly important to the transit industry for avoiding future ridership loss.

CHAPTER 5: GEOGRAPHICAL DISTRIBUTION IMPACTS

One potential reason for transit ridership change is a change in overall proximity of the population to transit service. If urbanization is occurring nationwide, and more of the population lives close to transit operators, then transit ridership per capita might increase. However, if population is increasing in the peripheries of urban areas, or in select urban areas with less quality transit service, then transit ridership might decline.

One level for analyzing geographic distribution's effect on transit ridership is on the county-by-county level for the entire nation. Census data includes population and transit commuting use for every county in the U.S. using 5-year estimates. This analysis originates from the hypothesis that population is not growing as fast in counties with quality transit as in counties with poor quality transit.

5.1 Background

Certain areas of the country like the Northeast, Seattle, Chicago, and Los Angeles, have huge transit networks that stretch over hundreds of miles collectively, while other areas have far more modest transit networks. Strong transit networks are primarily a function of population density, explaining why large cities and downtown areas have such vast transit networks and are so dependent on transit for transportation.

5.2 Geographies of Interest

The American Community Survey (ACS) provides yearly data for various commuting travel and population demographics. According to the ACS, transit is the choice mode for over 18 percent of commuters in Cook County, Illinois and well over half of commuters in several New York counties. The national average is 4.9 percent [9]. These heavily populated cities require a transit system capable of supporting peak hour demands to relieve roadway congestion and provide for the basic travel necessities of the residents.

There are a number of counties across the country without a transit intensive transportation system that are experiencing increasing population. Of the ten counties that gained the most population between 2013 and 2016, eight had lower than national average 2015 commuting share using transit, shown in Table 5.1. Even more surprising, of the ten counties that lost the most population in the same period, six had a transit commute share higher than national average in 2015, shown in Figure 5.2 [9].

Table 5.1 ACS Transit Commuting Share by Largest Population Increase, 2013-2016

County	Population 2016	Population Change (Percent Change) 2013-2016	2015 Commuting, Share Using Transit
Harris County, Texas	4,589,928	243,045 (5.6%)	2.9%
Maricopa County, Arizona	4,242,997	231,778 (5.8%)	2.4%
Clark County, Nevada	2,155,664	130,568 (6.4%)	4.0%
Los Angeles County, California	10,137,915	122,479 (1.2%)	6.8%
Bexar County, Texas	1,928,680	106,624 (5.9%)	2.8%
Tarrant County, Texas	2,016,872	104,371 (5.5%)	0.6%
King County, Washington	2,149,970	104,096 (5.1%)	12.1%
San Diego County, California	3,317,749	99,330 (3.1%)	3.0%
Riverside County, California	2,387,741	96,289 (4.2%)	1.4%
Dallas County, Texas	2,574,984	95,174 (3.8%)	2.9%
Weighted Average:	-	-	4.4%

Table 5.2 ACS Transit Commuting Share by Largest Population Decrease, 2013-2016

County	Population 2016	Population Change (Percent Change) 2013-2016	2015 Commuting, Share Using Transit
Cook County, Illinois	5,203,499	-36,784 (-0.7%)	18.4%
Wayne County, Michigan	1,749,366	-25,257 (-1.4%)	3.2%
Cuyahoga County, Ohio	1,249,352	-13,982 (-1.1%)	4.9%
San Juan County, New Mexico	115,079	-11,439 (-9.0%)	0.3%
Allegheny County, Pennsylvania	1,225,365	-8,266 (-0.7%)	9.1%
Baltimore city, Maryland	614,664	-8,194 (-1.3%)	18.6%
Suffolk County, New York	1,492,583	-8,193 (-0.5%)	6.5%
Genesee County, Michigan	408,615	-6,938 (-1.7%)	1.2%
St. Louis city, Missouri	311,404	-6,543 (-2.1%)	9.4%
Caddo Parish, Louisiana	248,851	-6,373 (-2.5%)	1.8%
Weighted Average:	-	-	11.4%

The movement of individuals out of more transit-intensive counties and into lower transit-intensive counties is evident not only in the last 3 years, but also from 2000 to 2016. Population growth has prevailed in and around counties that have less than 3.0 percent share of commuters using transit, well below the 4.9 percent national average [9]. U.S. residents are electing to live in areas traditionally characterized by lower population density. In low-density settlement, supplying access to quality transit is difficult, and such settlement has inevitably contributed to declining U.S. transit ridership per capita since 2000.

When examining areas where transit commuters constitute a large share of total commuters and population has decreased, it is possible to explore the reason why the per capita transit ridership in the U.S. is falling. Some areas of the Northeast corridor, including Baltimore and several counties just outside of New York City, have had population decreases since 2000 thereby reducing the number of commuters utilizing transit. Similarly, the rust belt has had noted population declines in the Detroit, Cleveland and Pittsburgh areas, all of which are characterized by heavier transit use. The Chicago area has seen some of the highest population declines in the country where tens and hundreds of thousands of people have left its counties, some of which have as much as a fifth of commuters taking transit. This is not to say that every agency in these locations are losing ridership, but rather ridership per person in the U.S. is going down as a result, at least partially, of slower growth or decline in population in transit oriented areas.

Those areas where population is increasing and transit commuters are a smaller portion of all commuters, the per capita ridership story is the same. In Texas, the area formed by the interstates connecting San Antonio, Dallas, and Houston has seen tremendous population growth since 2000, but most counties have transit commuter shares much lower than the national average. Similarly, Florida counties in the Tampa, Orlando, and Jacksonville areas constitute a large share of population growth in the state, yet very few compete with the national average share of transit commuters. The South region as a whole has had significant population growth across many counties with notable increases in and around Nashville, Atlanta, and Charlotte, North Carolina particularly along the interstate roads connecting these cities, all of which have limited transit use. These counties may actually have some or most of their agencies increasing ridership, but since the share of commuters riding transit is lower than that of the national average, the per capita ridership decreases.

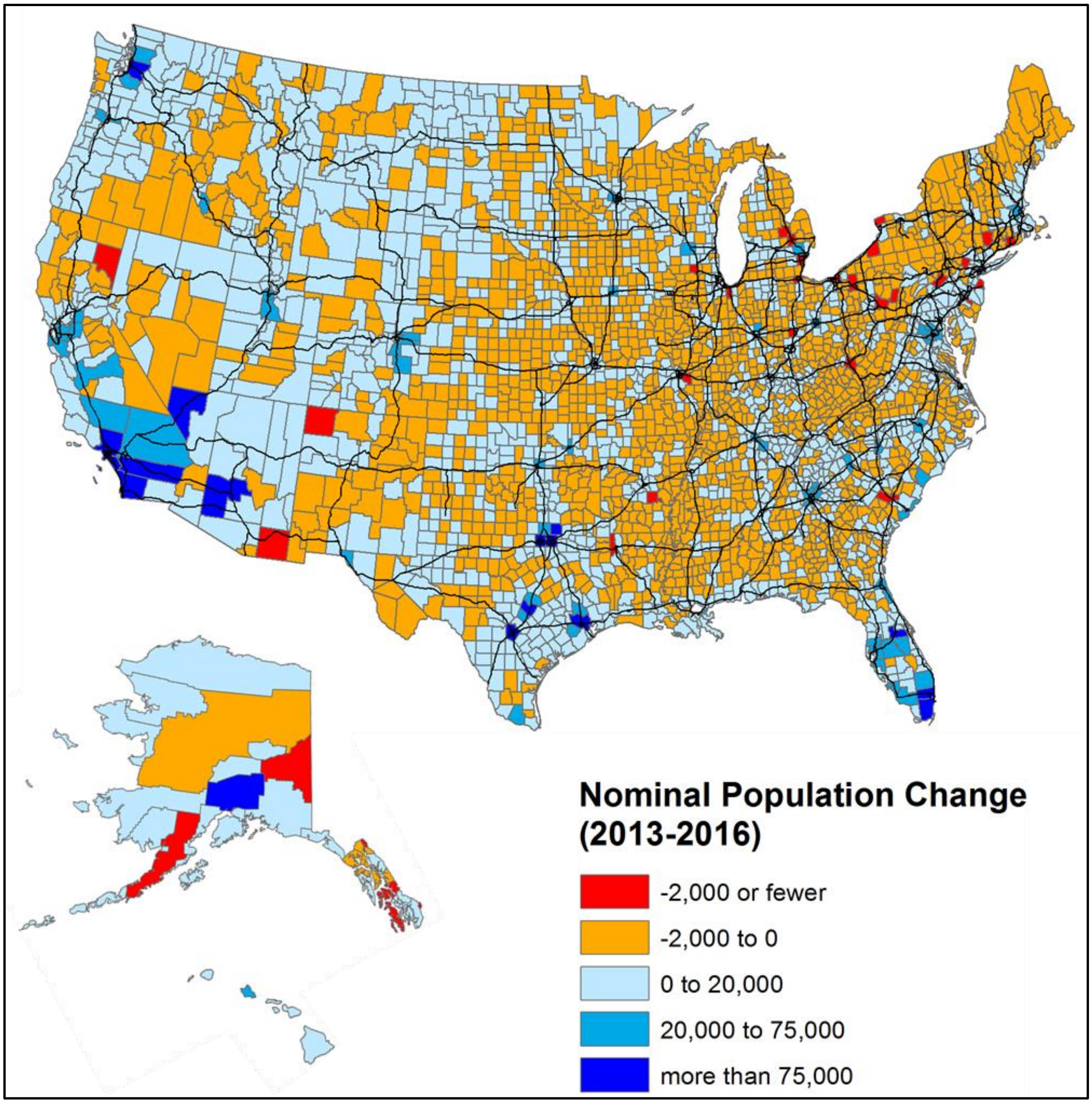

Figure 5.1 U.S. counties by nominal population change 2013-2016.

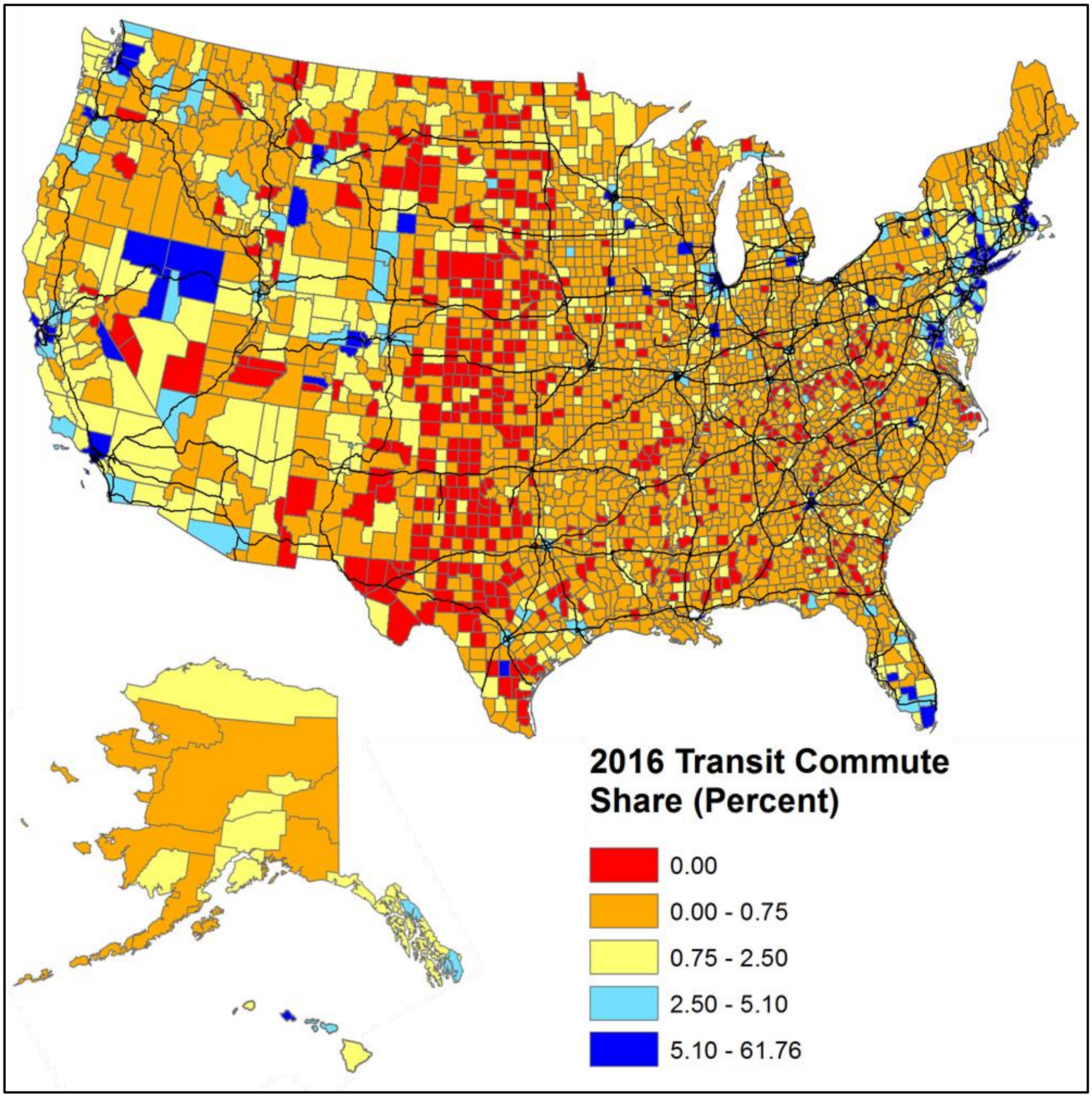

Figure 5.2 U.S. counties by 2016 transit commute share.

5.3 Commute Trips Method

An estimate of potential 2016 unlinked commute trips (had population grown uniformly) was compared to an estimate of actual 2016 unlinked commute trips (given actual population growth) to quantify the impact of population growth in areas with differing transit use. The comparison used the following assumptions:

- same workforce participation rates in each county's population in 2016 as 2013,
- 2015 transit commuter share assumed for both years,
- transit commuters took two linked trips per day,
- 1.53 unlinked trips per linked trip [2], and
- 235 working days per year.

Resulting is the development of Equation 4. The equation estimates commute ridership using 2013 and 2016 data:

$$\begin{array}{c}\text{Annual}\\ \text{Unlinked}\\ \text{Commute}\\ \text{Trips}\end{array} = \text{Workers} * \begin{array}{c}\text{2015}\\ \text{transit}\\ \text{commute}\\ \text{share}\end{array} * 2 * 1.53 * 235 \qquad (5.1)$$

After estimating the 2013 unlinked commute trips, a growth rate of 0.7% applied to each county to simulate uniform annual population increase for the 3 years to 2016 [9]. The national figure is the sum of the products from every county in the U.S. This potential 2016 unlinked commute trips estimate was 5,334 million compared to the actual 2016 unlinked commute trips of 5,314 million. This indicates that transit ridership for commuting would have been 20 million greater had the population distribution remained constant.

5.4 Implications

Certainly not all transit ridership is commute based, but a significant portion is and is therefore telling of overall transit use. Potential 2016 unlinked commuter trips outperforming actual 2016 unlinked commuter trips shows that transit commute trips missed an additional 0.4% of commute ridership. This comes to nearly 20 million additional unlinked trips, which is synonymous with a 20 million increase in total ridership. Again, this analysis only accounts for commute trips on transit, but this shows that ridership is a function of population growth in transit-limited areas rather than a function of decreasing share of commuters using transit. More recent estimates suggest that commute trips on transit constitute about 30 percent of all ridership, so an estimated total ridership lost to population growth outside transit oriented areas is expected to be over 66 million from 2013 to 2016 [35]. This is the equivalent of 20.5 percent of the actual observed ridership decline from 2013 to 2016. There may need to be a shift in the allocation of federal funding for transit to better match where population is growing fastest in the U.S., although it might come at the cost of decreasing funding for those cities historically known as transit-intensive.

CHAPTER 6: THE GROWTH OF TELECOMMUTING

The work at home "commuting mode" share has grown steadily since 2005. Technology has been replacing travel for many different trip purposes, but since work commuting is the most common purpose for transit users, increased telecommuting is of particular concern. This chapter discusses general trends in telecommuting, and constructs a numerical argument for the negative effect of increased telecommuting on public transit ridership.

6.1 Background

The American Community Survey ascertains a worker's usual commute mode through the question, "How did you usually get to work last week?" In 2005, the work-at-home share was 3.6 percent according to the U.S. Census. That share has increased in every year except 2013. In 2016, the pseudo-commute mode made its largest share increase on record, rising from 4.6 percent to 5.0 percent. More and more people are working primarily from home, as technology is allowing high-quality communication in increasingly more professions. For some types of work, commute trips will not be as susceptible to the telecommuting phenomenon – like service, manual labor, or medical care jobs. However, travel is now unnecessary for many types of professions. In 2005, there were 4.791 million telecommuters. In 2014, there were 6.543 million telecommuters and in 2016, there were 7.592 telecommuters, an additional 1-plus million. This accelerating telecommute rate suggests a dampening of work trip potential. As telecommuting replaces would-be work trips, transit ridership may experience some downward pressure [9].

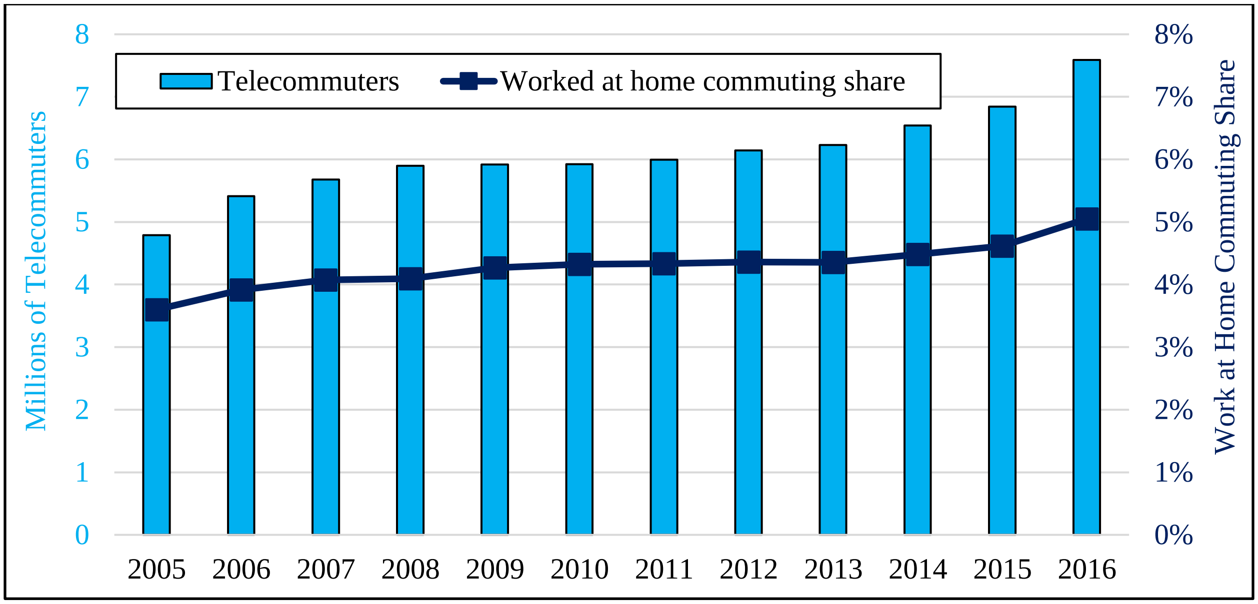

Figure 6.1 Work at home trend in the U.S.

6.2 Effect on Transit Commute Ridership

Assume that the share of overall telecommuting workers remained constant from 2005 forward, at 3.6 percent. The number of additional transit commuters for a given year would be determined by multiplying that year's share of *physical* commuters using transit by the assumed additional physical commuters. The number of those additional physical commuters is determined by multiplying the differential in that year's work-at-home commute share from the 2005 level by that year's number of total workers. Equation 5.1 shows the formula for this determination. Figure 6.2 shows the resulting number of estimated would-be transit commuters along with number of observed actual transit commuters.

$$\text{Number of additional would-be transit commuters in 2016} = \text{2016 Workers} * \text{Difference in work at home commute share, 2005-2016} * \text{2016 transit commute share of physical commuters} \qquad (5.1)$$

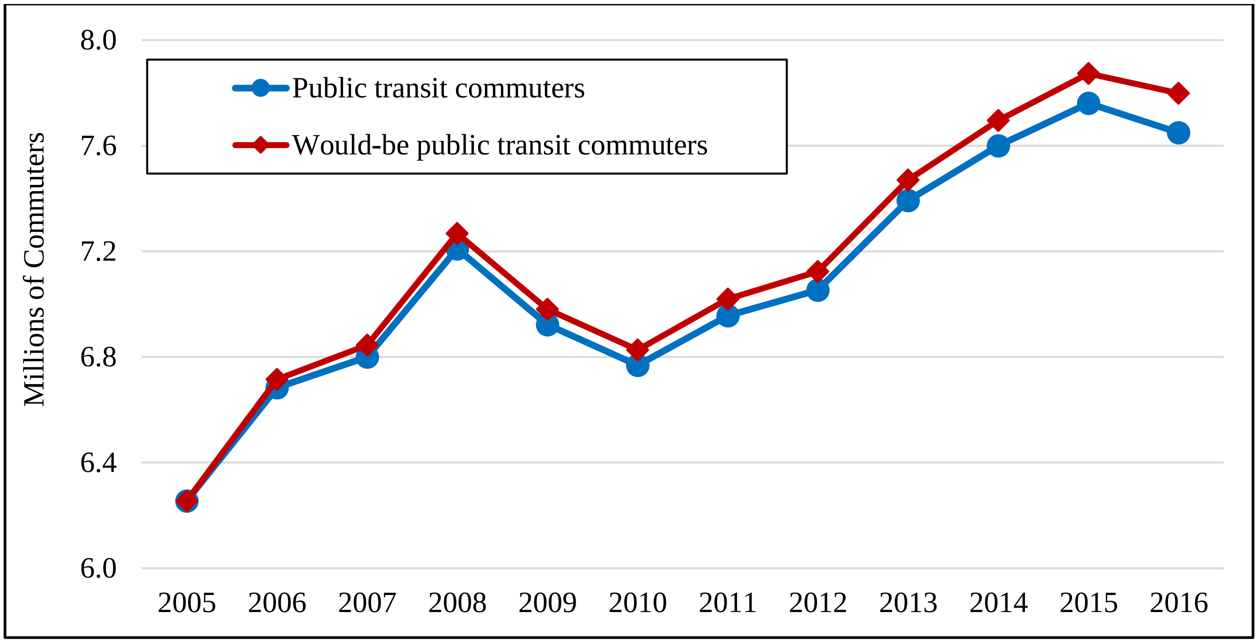

Figure 6.2 Commuters using public transit, actual versus prevailing 2005 work at home share.

To estimate the trips that these commuters would have taken, imagine a similar method to that used in the national county-level analysis in Chapter 5. Assume these potential additional transit commuters would have worked 235 days per year, that they would have taken two commute trips per day, and that they would have transferred at a rate of 1.53 unlinked trips per linked trip [2]. Equation 5.2 shows the determination of total estimated additional transit trips in 2016, which would have equaled 83.9 million.

$$\text{Total additional transit commute trips in 2016} = \text{Number of additional would-be transit commuters in 2016} * 2 * 1.53 * 235 \quad (5.2)$$

This would have increased the national per capita transit ridership by 0.26. Between 2005 and 2016, per capita ridership decreased by 1.07. This means work at home increase explains 24.3 percent of the per capita transit ridership decline since 2005. Evaluation using the same technique but for 2014 as the base year shows that growth in telecommuters since then has made an even greater impact. If the 2014 work at home share of commuters stayed constant, there would have been an additional 847 thousand physical commuters in 2016. Using the same assumptions, the increase in unlinked transit commute trips would have been 32.6 million. That equates to 16.3 million additional transit trips per year. The total observed ridership change from 2014 to 2016 was 170.0 million fewer unlinked transit trips, so the work at home increase explains 9.6 percent of the *nominal* ridership loss between 2014 and 2016.

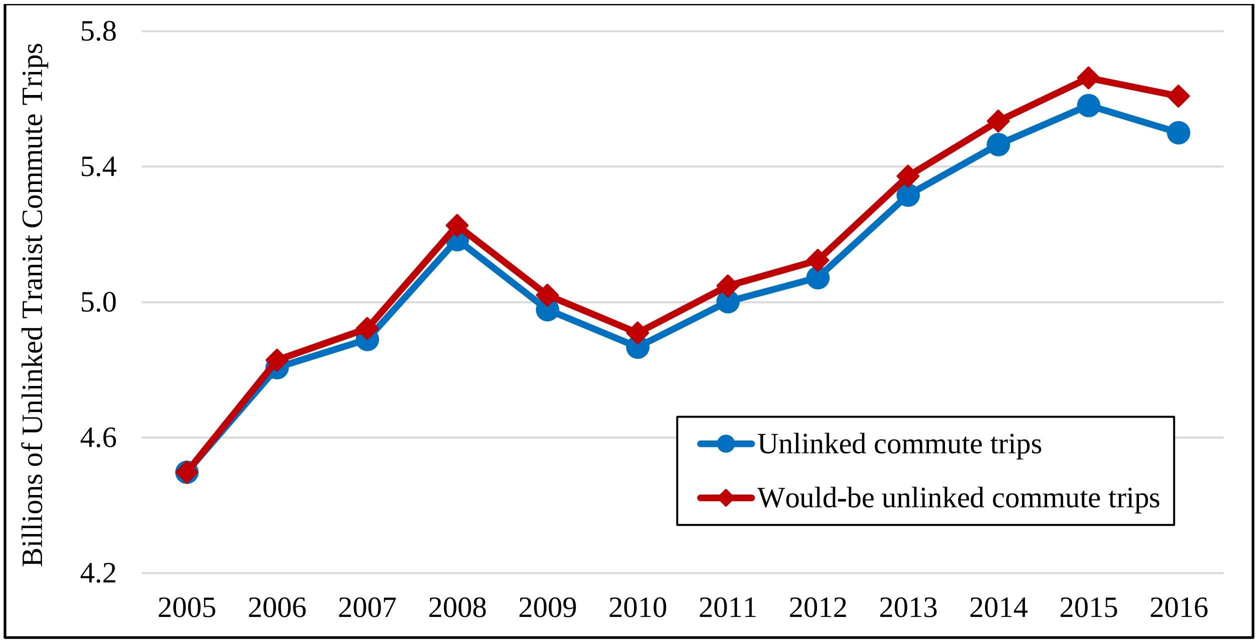

Figure 6.3 Unlinked public transit commute trips, actual versus prevailing 2005 work at home share.

6.3 Inaccuracy of Usual Trips versus Actual Trips

Research using the NHTS suggests that privately owned vehicle (POV) travel is the only commute mode with near-perfect loyalty. In other words, people who report "usually" using POVs for work trips "actually" use POVs for 99.1 percent of such trips, while those reporting "usually" using transit for work "actually" use transit for 69.5 percent of work trips. Reported transit commuters actually resort to POVs for 18.5 percent of work trips, perhaps sharing or borrowing vehicles with family/friends, and walk for 8.5 percent of work trips, maybe when the weather is pleasant enough. For those reporting "other" means of travel to work, they "actually" used "other" means for 50.4 percent of work trips, used POVs for 30.0 percent of such trips, and used transit for 11.5 percent of trips [36]. This mode disloyalty shows that the estimated effect from work at home increase using 325 working days per year for each potential transit commuter could be exaggerated.

6.4 Other Telecommuting

The American Community Survey does not capture all of work trip replacement, either. This analysis only highlights the growing share of workers who *primarily* work at home. Many workers – although primarily still physically commuting to work – are taking fewer trips per year by teleworking some of the time. According to APTA, 66 percent of employers allow employees to “occasionally work regular paid hours from home.” This is up 20 percentage points from 2006 [21]. According to a report by Global Workplace Analytics, 40 percent more U.S. employers offered flexible workplace options in 2016 than they did in 2010 [37]. A worker who telecommutes once every two weeks, for example, takes four fewer trips per month. A worker who telecommutes once per week takes 8 fewer trips per month and 47 fewer trips per year. This trend in partial telecommuting has increased in some areas that have high transit use, such as Washington, D.C. According to the WMATA Finance Committee, average trip frequency among riders with greater than five rail-trips/card/month has fallen from 20 rail-trips/card/month in June 2013 to 18 rail-trips/card/month in August 2016. Now, four-day-a-week commuters outnumber five-day-a-week commuters, and Friday peak ridership is 15 percent lower than the average for the other weekdays.

This factor may seem subtle, but while this analysis measures the effect of commute trip replacement, technology is replacing trips of all kinds. Technology will not substitute dining, grocery, or medical trips as much, but new applications of technology are replacing schooling, social, and financial business trips through distance learning, social media, and online banking.

Such replacement may explain even more of the declining ridership, although public transit users may not fairly represent the share of the population with best access to newer trip-replacing technology.

6.5 Implications

Technology should continue to make an impact on travel behavior in general going forward. For niche purposes, online interaction and business is replacing travel. Transit operators cannot fight this trend, and since work trips seem to be a measurable target of this technology trip replacement, it may disproportionately affect transit ridership. At the end of the day, transit's dependent riders will be overwhelmingly unaffected by the telecommuting phenomenon. Either they will be unemployed, or they will have jobs that require physical presence. It may be in the best interest of transit operators to start planning less for users with professional, consulting, or online-only jobs and more for users with service or labor jobs. Demographic data and knowledge will be more important as technology changes travel for some parts of the population.

Non-dependent transit users will become less loyal as technology allows them to forego some trips and therefore diversify their mode choice for trip-specific convenience. Monthly pass options will become less attractive to those workers who are able to telecommute for two or more days per month. Transit operators must start focusing on purpose-specific and trip-specific service provision or they will lose a significant amount of ridership in the face of the new technological era.

CHAPTER 7: GASOLINE PRICE

Many cite fuel price changes as a meaningful factor affecting transit ridership. The literature has observed delays in the effect of changing gasoline prices on transit ridership. There is, however, some strength of relationship between raw gas prices and transit ridership. It is difficult to ascertain whether the relationship is causal or if other economic condition factors create correlation between both variables. This analysis does not adjust for inflation because of gas price month-by-month volatility, although such adjustment is arguably necessary.

7.1 Background

12-month rolling average gasoline price has had four extended periods of growth since December 2002. The first extended across 2002-2006. In October 2006, the 12-month average gas price paused its growth but did not see serious decline. Gas price resumed growth again one year later in October 2007. Leading up to the onset of the 2008-2009 economic recession, gas prices eclipsed 4 dollars per gallon in July 2008. By October 2008, the 12-month rolling average gas price peaked. A sharp period of gas price decline lasted from November 2008 to October 2009, followed by a growth period from November 2009 through April 2012. From May 2012 through October 2014, gas price rolling average stayed relatively constant. Another strong decline period took place between November 2014 and October 2016. More recently, December 2016 through the present has seen increasing gasoline price [38].

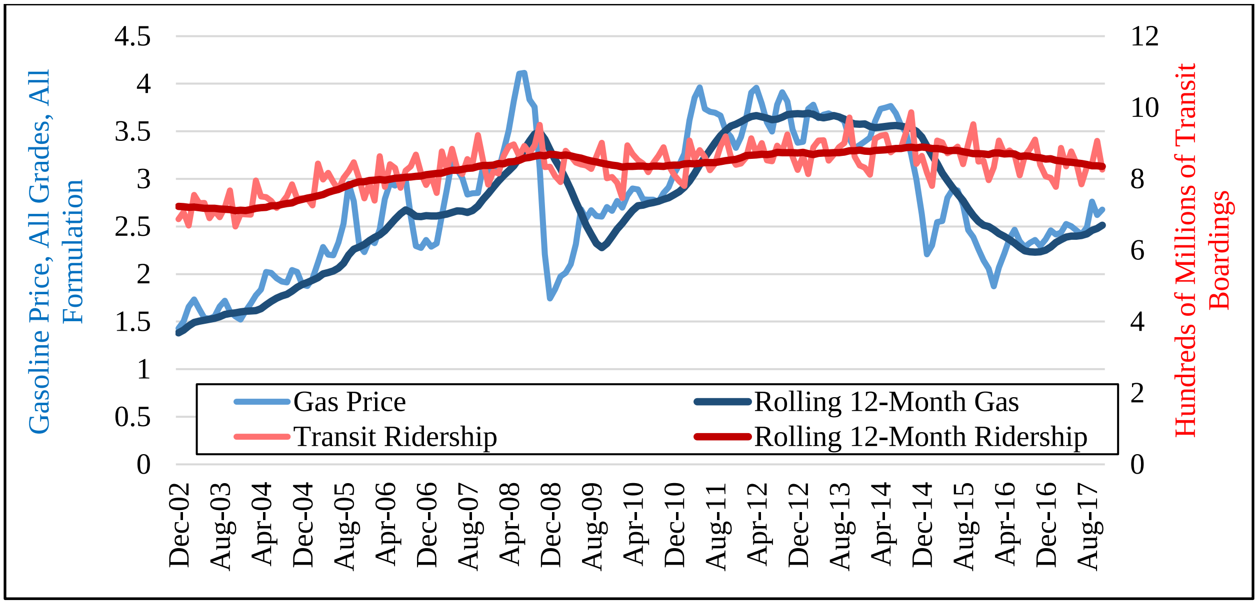

Figure 7.1 U.S. NTD transit ridership and average gasoline price with 12-month rolling averages.

7.2 Relationship between Gas Price and Ridership

There is a somewhat weak relationship between monthly gas price and transit ridership using a third order polynomial best-fit line with an intercept at zero. The zero-intercept is necessary because it is impossible to have negative transit ridership. The R-squared fitness measure is 0.53 (1.0 would indicate perfect fit). Mostly, when transit ridership was below 800 thousand trips for a month, the gas price was below 3 dollars per gallon, with a few exceptions. Without exception, ridership was never lower than 800 thousand for a month in which the gas price was greater than 3.50 dollars per gallon. Meanwhile, in only three months since 2002 when gas price was under 2 dollars per gallon was transit ridership greater than 800 thousand. Between 2 and 3.5 dollars per gallon, transit ridership varied and price-ridership relationship was not well-defined [38] [3].

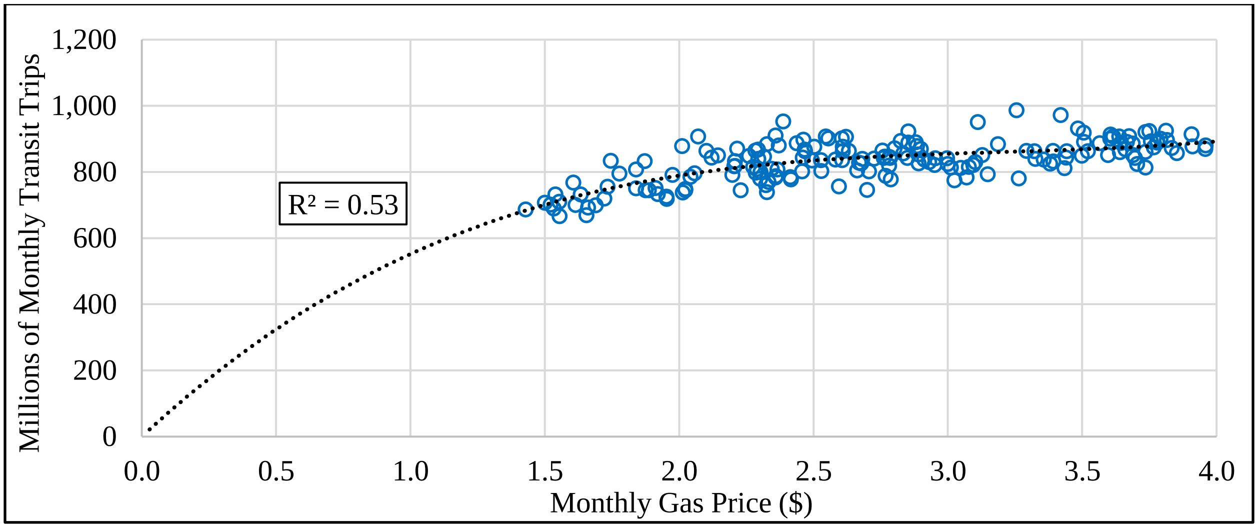

Figure 7.2 Monthly U.S. transit ridership by national gasoline price, from January 2002.

Perhaps a better way to analyze the relationship of gasoline price and transit ridership is through 12-month rolling averages of both. This method solves the issue of month-to-month volatility in gasoline prices. Travelers, being habitual, may not respond at one-month intervals to a change in gas price. However, year over year changes in gas prices generate significant impact on household annual disposable income, and therefore auto ownership choice, and therefore transit ridership propensity. A third order polynomial best-fit regression between annual average monthly gas price and transit ridership has a better fit than the monthly model, with an R-squared of 0.83. Out of the four years in which transit ridership averaged below 800 thousand monthly trips, three of them occurred when average gasoline price was under 2 dollars per gallon and the other year had the fifth lowest average gasoline price in the dataset. Of the seven years in which transit ridership averaged above 850 thousand monthly trips, five of them occurred when gasoline price was above 3.25 dollars per gallon and were the five highest annual gas prices [38] [3].

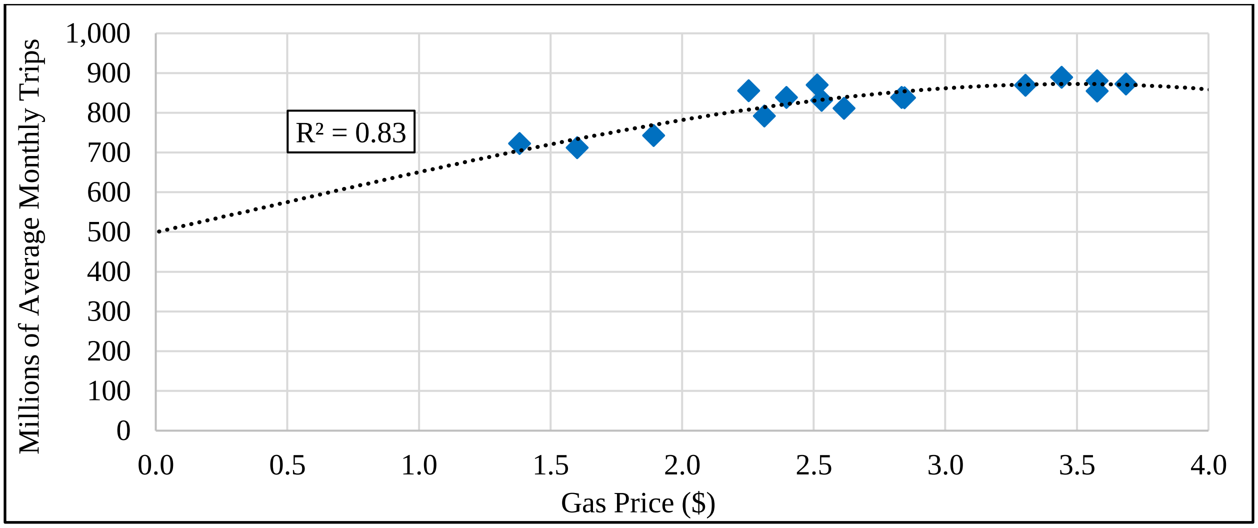

Figure 7.3 December 12-month rolling average transit ridership by gas price, from 2002.

Furthermore, matching previous year gasoline price with transit ridership data at an annual rolling average interval better shows how travelers respond to gasoline price change. The immediate effect of operating a vehicle with higher gas prices is quite low relative to the overall cost of operating that vehicle. However, prolonged periods of higher gas prices begin to hinder a household's ability to afford a new vehicle. For instance, a household with one vehicle driving 15,000 miles a year, at an average of 25 miles per gallon spends $1,200 on gasoline in that year if gas price is 2.00 dollars per gallon. The same family might spend $1,500 per year on car insurance, $4,500 per year on loan payments, and $750 per year on car maintenance. Therefore, month-to-month changes in gas price will not affect travel behavior since gas cost is a relatively modest share of the total cost of operating a vehicle. However, if gas price increased to 4.00 dollars per gallon, the same family would spend $2,400 a year on gasoline, a difference of $1,200. The forfeited $1,200 might have been enough to fund a down payment on a second vehicle, in which case the family would be far less dependent on transit. Figure 7.4 shows a third order polynomial best-fit regression between gas prices and the following year's December 12-month rolling average transit ridership, with an R-squared of 0.96 and 0.86 when inflation-adjusted. The fitness of this regression shows that the effect of prolonged gasoline price differences is significant and its effects on transit manifest in a delayed fashion.

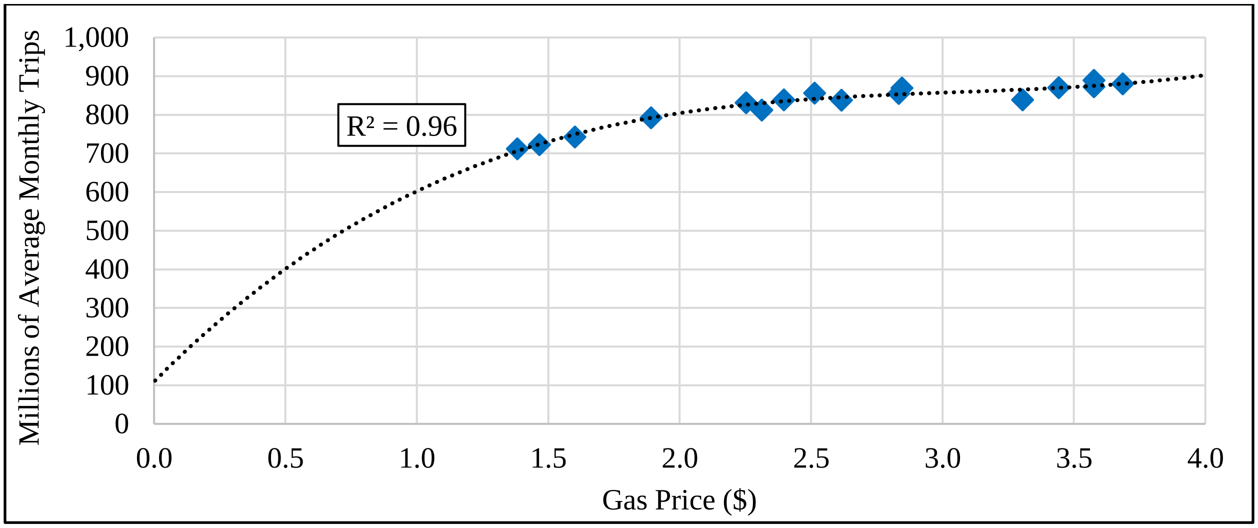

Figure 7.4 December 12-month rolling average transit ridership by previous year's gas price, from 2003.

Other lag periods show similar results of third-order polynomial regression fitness. Six months prior 12-month average gas prices matched with 12-month average transit ridership at an R-squared of 0.92. 18 months prior 12-month average gas prices matched with 12-month average transit ridership at an R-squared of 0.96. Finally, 24 months prior 12-month average gas prices matched with 12-month average transit ridership at an R-squared of 0.90.

7.3 Estimated Ridership from Regression

Figure 7.5 shows annual estimates of transit ridership based on the regression shown in Figure 7.3 as well as the corresponding actual observed transit ridership. Figure 7.6 shows annual estimates of transit ridership based on the regression shown in Figure 7.4. The current ridership and gas price regression correctly predicts the 2009 drop in transit ridership, but estimates an unobserved 2017 increase in ridership. Conversely, the ridership and previous-year gas price regression estimates an incorrect ridership increase in 2009 and decrease in 2010, but correctly predicts the 2017 decline in transit ridership. The modest increase of gas price in 2017 suggests stabilization/growth of transit ridership in 2018 via the delayed effect model. Assuming no heterogeneity between gas price and other factors, the delayed model predicts a decline 61 percent more than the observed decline from 2013 to 2016, and a decline 10 percent more than the observed decline from 2013 to 2017.

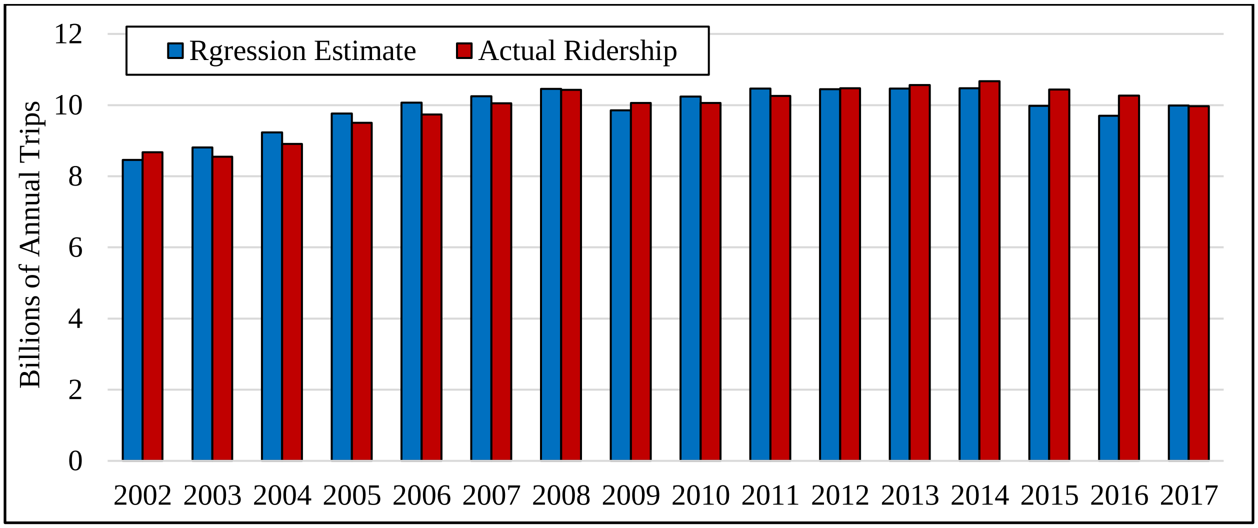

Figure 7.5 12-month December-based rolling average best-fit regression estimate of annual transit ridership by same-year gas price and actual annual transit ridership.

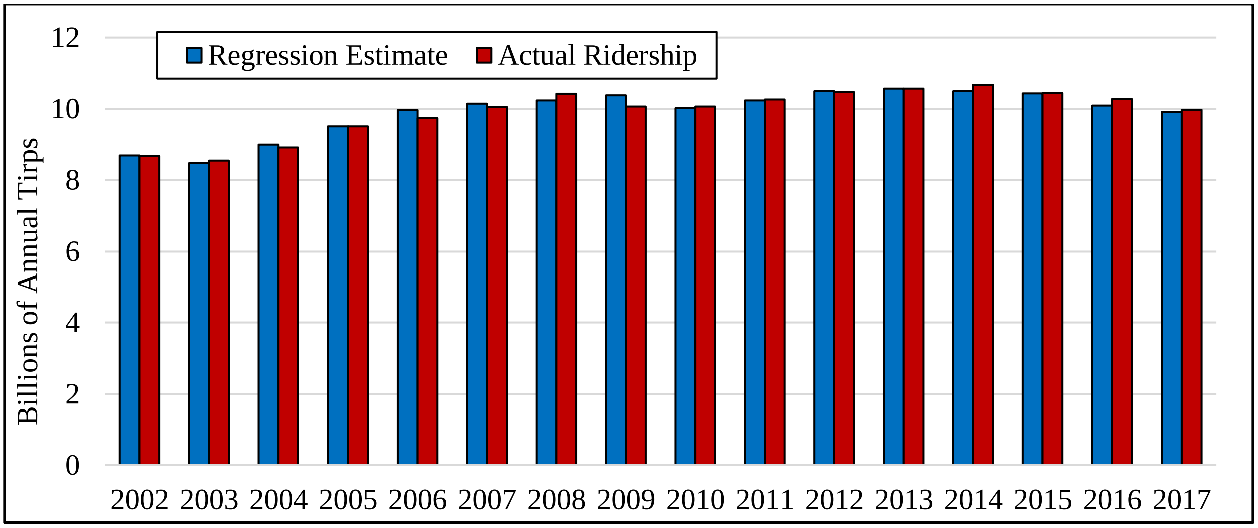

Figure 7.6 12-month December-based rolling average best-fit regression estimate of annual transit ridership by previous-year gas price and actual annual transit ridership.

7.4 Implications

Gasoline price change is volatile, making it difficult to predict, and transit operators have no control over the price of gas in their communities. However, it is helpful to know that some of the transit ridership decline is due to prolonged lower gas price. Transit agencies must not react to random monthly changes in gas price but must pay attention to longer-term gas price precedents. Since gas prices have increased in 2017, for instance, transit operators may be prepared to observe somewhat higher demand in 2018. However, as technology improves and vehicles become more fuel-efficient, the effect of gas price change on transit ridership will diminish. Out-of-pocket cost of private transportation will approach a constant value, but using public transportation is usually less costly than private transportation anyway. The public transit industry must be able to compete with private vehicle ownership with respect to user-experienced travel time and convenience and must rely less on gas price volatility to attract ridership.

CHAPTER 8: CONCLUSIONS AND FUTURE WORK SUGGESTIONS

8.1 Conclusions

Transit ridership has decreased since 2014 and per capita transit ridership has decreased from 1980 and the early 2000s. There are many reasons for these trends, but investment change, service provision change, population change, or fare price does not explain them. As demographics have changed over time, so has propensity of transit use. There may be a multitude of underlying causes, of which this research identifies a few – though they are only the tip of the iceberg. Age, vehicle availability, geographical distribution, trip behavior, and gas prices all affect transit ridership, as reported in Table 8.1. Many of the factors contributing to transit ridership decline are demographic, economic, and behavioral. Though these are external factors, and therefore not easily addressed by transit operators, agencies and decision-makers must respond to these changes. In some cases, changing demographics warrant general service cuts, but there are alternative policy changes that could position transit operators for successful adaptation.

Table 8.1 Summary of Findings

Factor Affecting Transit Ridership	Extent of Effect	On Ridership or Per Capita Ridership?	Time Frame of Effect
Age Distribution	20%	Per Capita	1980-2016
Vehicle Availability	55%	Ridership	2014-2016
Geographical Distribution	8%	Ridership	2013-2016
Telecommuting	10%, 24%	Ridership, Per Capita	2014-2016, 2005-2016
Gas Price	-	-	2002-2017

The general aging of the U.S. population, especially the position of the "baby boom" age cohort explains up to 20 percent of the per capita transit ridership decline since 1980. This has been an effective drag on transit ridership in the last few decades. What is more concerning is that population estimates predict even faster aging in the future. The per capita ridership effect from 2015 to 2030 will be twice as powerful as that between 2000 and 2015. Transit agencies must either make service more attractive to older people or be prepared to lose more ridership potential. Because older people are less able to use conventional transit, demand response programs might serve them better than fixed route transit. People 76 years and older use paratransit services three times more often than younger people (0.21 and 0.07 percent of all trips, respectively), according to the 2009 NHTS [30]. With newer ride-hailing technologies available, provision of demand-response service to older people may be an increasingly more cost effective method to maintain ridership.

Household vehicle availability change in the U.S. explains up to 62 percent of transit ridership decline from 2014 to 2016. In one way, this is an indicator of economic growth and improved quality of life for many previously transit-dependent families, but on the other hand, it spells trouble for transit ridership. After all, those members of households that have acquired new vehicles are only freer until they are stuck in traffic congestion, until their air quality diminishes from increased emissions, or until they are involved in a serious crash. The core benefits of transit remain, but it has lost and will continue to lose the fight against quick, cheap, and unimpeded private vehicle options when available. Perhaps the TNC revolution, in which masses of people forgo vehicle ownership because of the convenience of on-demand mobility, is yet to come (or perhaps it will never come). Certainly, lower-cost driverless vehicle technology would help induce such a revolution. In the meantime, transit operators must either work with their localities and states to impede the availability of private transportation, improve their service to better compete with private transportation, or accept the reality of lower ridership in an improved economy.

U.S. county settlement patterns explain up to 21 percent of transit ridership decline from 2013 to 2016. Some major historically transit-intensive area, such as Chicago, Cleveland, St. Louis, and Pittsburgh have declined in population during the same period of nationwide declining ridership. Meanwhile, some of the fastest-growing counties in the U.S. such as those in Texas, New Mexico, and Arizona are historically transit-deprived. National spending on transit may need to shift, as there is some major room for capital expansion in those areas of the nation growing rapidly. The paradox of this issue is that many of the fastest-growing areas also have political climates unsupportive of local transit adoption, so they are far less likely to receive federal assistance for transit. Transit agencies must always study settlement patterns within their jurisdiction and deploy service within close proximity to their constituents, or micro levels of accessibility decline will decrease ridership potential further.

Telecommuting increase explains up to 24 percent of per capita transit ridership decline from 2005 to 2016 and up to 10 percent of nominal ridership decline from 2014 to 2016. This effect is from those who usually work at home, but the additional effect of those who sometimes work from home is unknown. As technology continues to improve, the implications of internet-based business will increase. This is hardly negative news for overall quality of life and efficiency, but has negative implications for transit use. Although most transit users may not be among those to benefit from trip-replacing technology early on, there are some large transit markets with higher shares of middle to high-income earners, and trip substitution will eventually affect even the transit-dependent users as well. Transit agencies may not be able to avoid ridership loss from trip potential reduction, but they may yet benefit from changing technology through real-time customer updates, app-based services, and collaborating with TNCs if they adapt quickly enough.

Gasoline prices estimation through polynomial regression overestimated transit ridership decline from 2013 to 2016 and from 2013 to 2017. However, such statistical analysis showed that gasoline prices are more accurate predictors of the following year's transit ridership than current year transit ridership. Transit agencies usually have an advantage over private vehicle transportation in overall user fee per mile of travel, but transit benefits particularly when prolonged increased gas prices prevent lower to middle-income households from saving money to purchase an additional vehicle. As vehicle fuel efficiency improves, changes in gas price will have a lesser effect on public transit ridership.

8.2 Future Work Suggestions

This thesis should be one among a series of research efforts to identify the effects causing transit ridership change. Further work may enhance the depth of the analyses within this thesis. Many of such analyses, given fewer restrictions, could be more accurate and refined. Additional work may analyze other factors including parking cost and supply, real income, real employment, auto occupancy, and other travel behavior considerations.

Future researchers must continue to monitor changing demographics and economic status in the U.S. The Census releases annual population data through the American Community Survey. Every year, population age, geographical distribution, and commuting behavior change. Future work on this topic should consist of analyzing these factors with the most recently available Census data on a yearly basis. Constant analysis of demographic data may yield discoveries of new relationships.

The NHTS 2016 data release will occur sometime in early 2018. This travel behavior data is an important aspect in determining the effect of both the age distribution and vehicle availability on transit ridership. In Chapters 3 and 4, assumptions included unchanging travel behavior from 2009. This assumption is certainly limited and the new NHTS data will allow researchers to determine how travel behavior is changing and how that affects the results of this paper.

More work is necessary in understanding the specifics of mode loyalty and the real volume of telecommuting trip replacement taking place today. American Community Survey results provide a sort of litmus test for the growth in telecommuting, but how often do usual POV or transit commuters actually travel to work fewer than five days a week? In addition, what is the specific effect of reduced monthly trips on monthly pass subscribers and therefore discretionary transit use? Moreover, how is technology replacing other trips, such as retail shopping, banking, and schooling trips? Telecommuting may be the tip of the iceberg when it comes to the reduction of physical travel rate and therefore transit use.

Gasoline prices are always changing due to market demands and world events. It seems as though there is a noticeable correlation between gasoline prices and transit ridership, but only when averaging over a longer period. How much of this relationship is causal and how much is correlative based on unobserved heterogeneity? If there is a delay in reaction to gas price change, it suggests that transit ridership will start rising in 2018 to match 2017 gas price increases. More researchers must study the effects of gas price on transit ridership, delay effects, and the difference in this case between correlative and causal relationship.

Individual agencies may apply these analyses to their particular markets to understand local demographic change effects on their ridership. Transit ridership has decreased in 34 of the top 40 urban areas (by 2016 ridership) since 2014. Each area has its own challenges based on the effect of technology, travel behavior, and demographic change. This research, applied locally, may help transit operators and stakeholders make better decisions while planning. Perhaps through improved decision-making, the public transportation industry will enter a new era defined by efficiency. Through the changing profile of demographics and economic conditions, perhaps the industry will lead the way in making transportation safer, cheaper and faster in the U.S.

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