Determinants of Per Capita Vehicle Miles Traveled (VMT): The Case of California
Author(s): Mintesnot Woldeamanuel and Andrew Kent
Source: *Journal of the Transportation Research Forum*, Vol. 53, No. 3 (Fall 2014), pp. 35-46
Published by: Transportation Research Forum
Stable URL: http://www.trforum.org/journal

Determinants of Per Capita Vehicle Miles Traveled (VMT): The Case of California

by Mintesnot Woldeamanuel and Andrew Kent

This study uses multivariate regression to isolate determinants of per capita VMT in California from the National Household Travel Survey (NHTS), as well as a Chow Test to identify structural change between the 2001 and 2009 NHTS. Results across the 2001 and 2009 NHTS data sets indicate certain determinant variables have emerged over time and others have changed in strength of impact. Our findings support mixed methods VMT reduction strategies to achieve near- and long-term GHG targets.

INTRODUCTION

Automobile travel is credited as the major contributor of greenhouse gas (GHG) emissions, accounting for about 28% of GHG emissions in the United States and 36% in California (Rodier 2009). The State of California has been a leader in climate change legislation with the passage of the Global Warming Solutions Act of 2006, AB 32, which sets GHG reduction targets to 1990 levels by the year 2020. Reducing per capita vehicle miles traveled (VMT) is one of the most effective methods for reducing GHG emissions. The relationship between GHG and per capita VMT has prompted further legislative actions and policies in California, such as SB 375, the Sustainable Communities and Climate Protection Act of 2008, which seek to reduce per capita VMT through sustainable development strategies at the regional planning level. SB 375 complements California's ambitious climate change legislation through transportation planning and sustainable development as a per capita VMT reduction strategy. As such, the relationship between GHG, per capita VMT and associated externalities requires an integrated transportation planning and environmental policy front. SB 375 directs metropolitan planning organizations (MPOs) to develop sustainable community plans which reduce GHG and links transportation funding to those strategies. The law also requires regional affordable housing shares to be developed based on local sustainable community strategies, exempts certain transit projects from environmental review, and grants the California Air Resources Board the authority to set regional GHG reduction targets.

To achieve the significant per capita VMT reduction required to meet regional and state GHG targets, sustainable community plans and state policies need to be grounded in a comprehensive understanding of California per capita VMT determinants. Previous research has made important contributions to the understanding of per capita VMT and toward crafting policy solutions. Increased access to active transportation, integrating land use with transport decisions and pricing strategies are three broad policy options for reducing automobile dependency and GHG (Bedsworth et al. 2011). Specific to California, there is a need to expand this understanding to include recent trends in per capita VMT determinants and the relative impact of determinants so state and regional planning organizations can develop effective strategies for near and long term per capita VMT and GHG reduction.

This research intends to derive a comprehensive understanding of California specific per capita VMT determinants by isolating significant VMT variables from the National Household Travel Survey for the years 2001 and 2009. Comparing significant variables between both years will grant an understanding of how determinants have changed or remained constant. Through the analysis we will also determine what kinds of variables have the greatest relative impacts on annual per capita VMT in California.

Our primary research questions include: (1) what are per capita VMT determinants in California? (2) how do per capita VMT determinants rank relatively? (3) how have per capita VMT determinants changed over the past decade? Through answering these question we hope to recommend which per capita VMT determinants the State of California and local MPOs should concentrate on to best reduce per capita VMT and achieve California's ambitious greenhouse gas reduction targets.

LITERATURE REVIEW

Recent VMT trends indicate a moderating of national VMT growth. VMT forecasts predict a continuation of low VMT growth in the near and long term. California annual VMT growth is estimated at 1.6%, whereas, national growth is at approximately 2% (Lave 1996, Polizin et al. 2004). Some research has attributed this moderation of VMT growth to road and highway capacity reaching critical congestion levels. Research has also pointed out that while auto travel inefficiency may limit per capita VMT growth, congestion can increase GHG emissions (Barth and Boriboonsomsin 2008).

There are three basic methods of reducing vehicle emissions: (1) reduce the amount of fossil fuel consumed, (2) reduce the carbon content or output of fuel, and (3) reduce vehicle activity. Unfortunately, fuel efficiency and air quality regulation will not adequately reduce GHG emissions to achieve California's ambitious environmental objectives (Burwell 2009, Rodier 2009). Greater fuel efficiency lowers per-mile cost of driving, encouraging longer commute distances and driving more frequently (Small and Van Dender 2005). Reducing the carbon content of fuel potentially results in higher fuel prices, curbing per capita VMT; however, previous studies have found the demand for gasoline is relatively inelastic to price increases (Greene 2012). The only method which aligns state environmental and transportation planning goals are policies that directly target vehicle activity, meaning reducing vehicle driving (Litman 2013).

Related to vehicle activity, there are three components of an individual's per capita VMT contribution: (1) trip frequency, (2) trip length, and (3) mode choice (Ewing and Cervero 2007). The determinants of per capita VMT act separately on each of these components. Polizin et al. (2004) analysis showed that between 1977 and 2001, household vehicle trips increased by 115% and person miles of travel increased about 114%, demonstrating a massive climb in vehicle activity over the past few decades (Polizin et al. 2004).

Several studies have demonstrated the built environment, specifically built structures and land uses, is a major determinant of per capita VMT. For instance, one study found that highway and road lane expansion accounts for 15% of per capita VMT growth (Noland and Cowart 2000). As well, there exists strong empirical evidence that per capita VMT is negatively related to subdivision compactness and dwelling unit density (Lui 2007, Ewing and Cervero 2007, Akar and Guldmann 2012). Such research findings have prompted transit-oriented development (TOD) and smart growth policy, such as strategies supported by SB 375. The components of TOD, such as high residential density, mixed use development, traditional community design, walkability, and greater transit access, are inversely related to per capita VMT, making TODs and sustainable land use strategies a promising long-term solution.

Demographic variables have also been identified as significant determinants of per capita VMT. Variables such as population growth, age, ethnicity, immigration, income, female labor force participation, and household size all affect aggregate VMT. One study estimated up to 65% of VMT growth was potentially driven by population growth (Choi and Hu 2008). The age group with the highest VMT contribution includes young to middle age adults; therefore, the aging baby boom population is expected to have a moderating VMT growth effect as senior citizens and retired persons tend to drive less (Polizin et al. 2004). According to a Emrath and Liu (2008), households which are larger, less educated, younger, have higher incomes, have a white householder, or have a Hispanic householder are positively correlated with greater household gasoline consumption (Liu 2007). A research paper on per capita VMT determinants found that per capita VMT increases with household income, hybrid car ownership, and the number of household vehicles (Akar and Guldmann 2012).

A few California specific studies have provided valuable information on VMT determinants needed to craft policy solutions. A study comparing per capita VMT determinants across metro regions found areas with longer commute times, younger populations, a greater number of rural inhabitants, and a greater concentration of new cars have higher rates of per capita VMT in California (Cook et al. 2012). The study also found that job density and income did not have a significant effect on per capita VMT in California, which is contrary to other research findings but may point to locational uniqueness. Another study used NPTS data from 1995 and 2001 to examine the effects of demographic composition on per capita VMT in California. The study found that demographic variables including population, age, sex, ethnicity, and immigration, significantly impact per capita VMT (Choi and Hu 2008). The statistical influence of these demographic per capita VMT determinants varied between the local and national scale. Thus, efforts to reduce per capita VMT and GHG in California will likely need to account for demographic composition over time and across space.

A principal GHG reduction strategy utilized by SB 375 and the California Air Resources Board is targeting per capita VMT through denser residential development. Alterations to land use patterns are a promising long-term strategy to promoting walking and public transit modes; however, it does not appear that increased density will be sufficient to meet California's near-term goals. Heres-Del-Valle and Niemeier (2011) found that a 10% increase in residential density would result in about a 2% decrease in per capita VMT. In the near and long term, a wide array of strategies will likely need to be implemented in California based on a larger understanding of per capita VMT determinants.

Per capita VMT reduction has been established as a necessity to resolving climate change and auto dependency (Burwell 2009, Rodier 2009). Proposed methods include land use policies, TOD, traffic calming, pricing mechanisms, transit investment, and ride-share programs. Further research on how built environment, demographics, and markets act on per capita VMT is needed to develop effective policies that serve California's climate change goals and state transportation needs.

DATA AND DESCRIPTIVE ANALYSIS

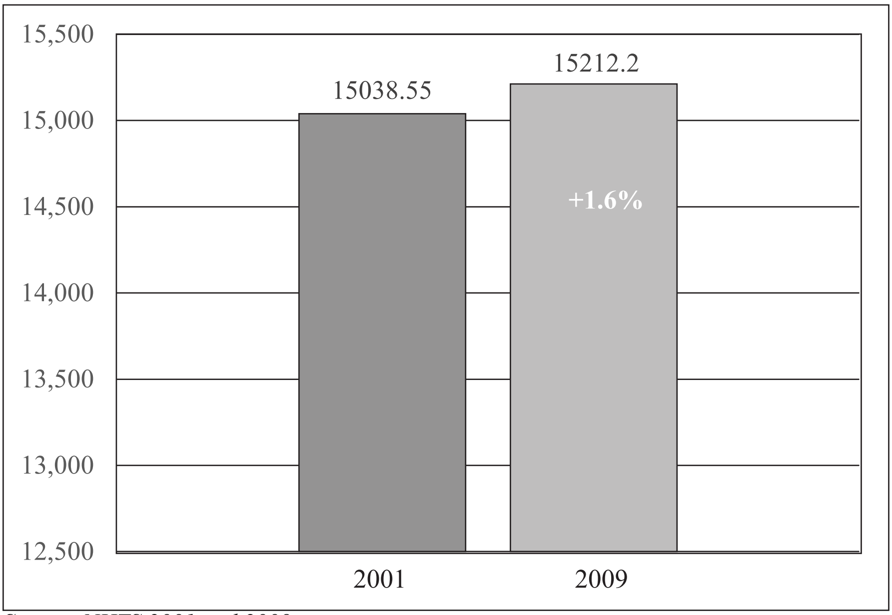
Data for isolating California per capita VMT determinants were obtained from the National Household Travel Survey (NHTS). The NHTS is a comprehensive nationwide transportation survey conducted every five to eight years by the Federal Highway Administration with the specific purpose of providing transportation researchers with data. The data were collected by the NHTS through a telephone survey using a random digit dialing system. The survey taker provided both respondent level and household level data. The NHTS data sets contain detailed information about household demographics and travel behavior. For our analysis of per capita VMT determinants and trends we used the 2001 and 2009 NHTS data sets.

Data from both years in California were systematically refined by removing households and individuals with missing and incomplete responses from the data sets. Also, numerous variables from the NHTS were initially eliminated due to an inability to compare them across the 2001 and 2009 data sets due to definition changes and uncorrectable issues. Correlation analysis was used to eliminate collinear variables.

Table 1 presents descriptive statistics of tested independent variables for the 2001 and 2009 NHTS. Figure 1 indicates California annual average per capita VMT per sampled individuals. Based on the NHTS, net VMT change in California from 2001 to 2009 is +1.6%, which is consistent with prior estimates (e.g., Lave 1996).

The descriptive statistics in Table 1 show several percent changes between the 2001 and 2009 NHTS (the last column of Table 1). For instance, the percent of families at all income levels has decreased with the exception of the highest income level, which has increased by 23%. Between 2001 and 2009, family size has decreased by 19%, from 3.05 to 2.85. The percent of homeowners has increased by 12% while the percent of renters has decreased by 13%, which seemingly indicates people converting from renting to owning a home. There is also a 7% decrease in the number of households that live in an MSA with access to rail.

Figure 1: California Average Annual VMT



Source: NHTS 2001 and 2009

For further descriptive analysis of possible per capita VMT determinants, annual per capita VMT was sorted into quartiles and graphed against variable averages within each quartile. Selected quartile graphs for the 2001 and 2009 NHTS are presented below in Figures 2 and 3. Table 2 presents the per capita VMT quartile ranges for 2001 and 2009 used in the descriptive analysis.

Table 2: Quartile Ranges for Per Capita VMT in California

Quartile	2001		2009	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Q1	0	8000	0	10000
Q2	8001	12000	10001	12000
Q3	12001	18000	12001	18000
Q4	18001	172000	18001	137000

Source: NHTS 2001 and 2009

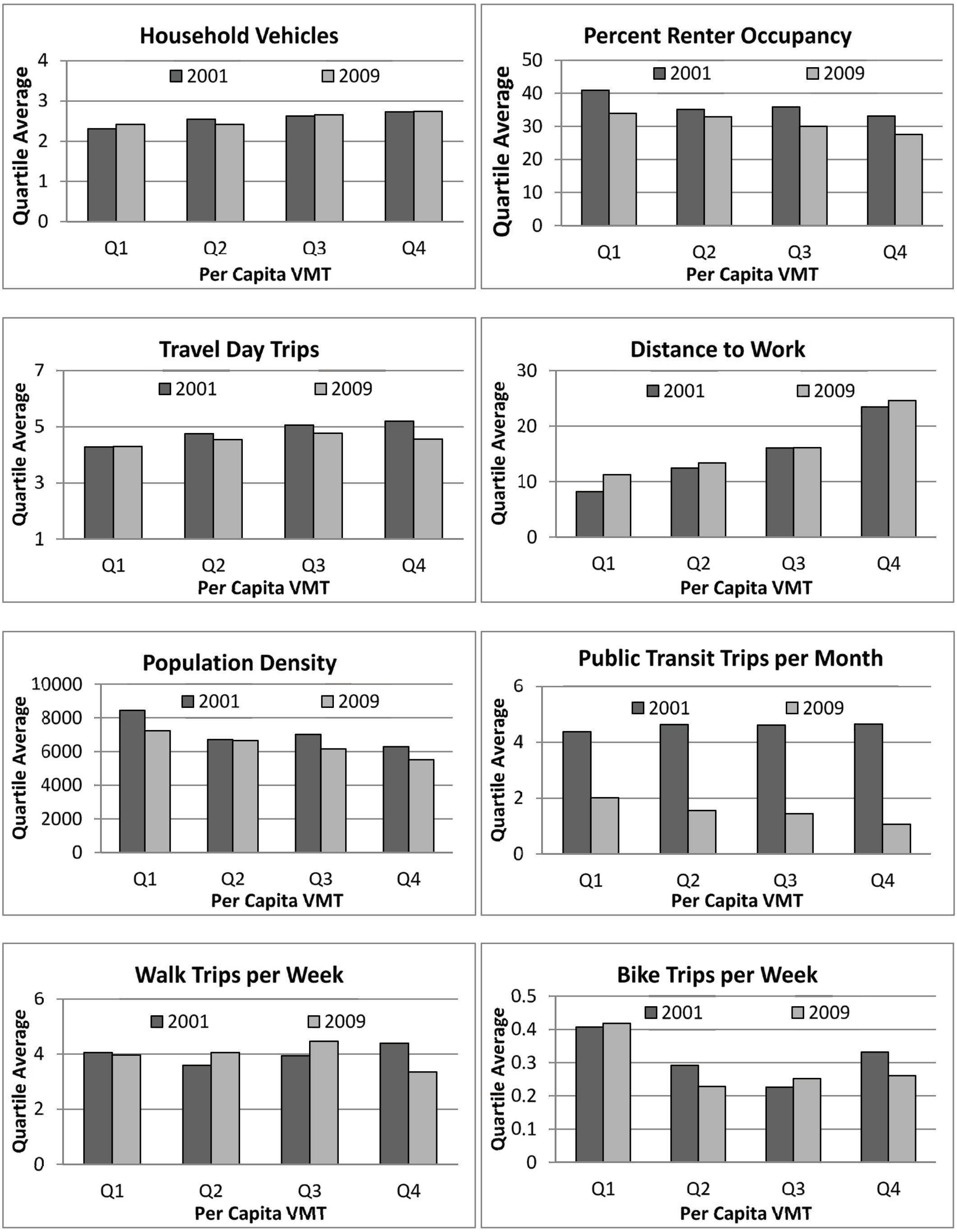
The quartile graph for the number of household vehicles by per capita VMT indicates a slight positive trend for both 2001 and 2009. The variable Percent Renter Occupancy vs. per capita VMT is distinctly a negative relationship, indicating that as renter density increases per capita VMT decreases. The opposite of Percent Renter Occupancy is Percent Owner Occupancy; therefore, homeownership and per capita VMT are positively related. Naturally, Travel Day Trips and per capita VMT are positively related. Likewise, Distance to Work and per capita VMT are positively related. Across the graphs in Figure 2 there is no visual change in per capita VMT determinants between 2001 and 2009, which indicates that for those variables, no distinct trend exists over time and there is likely stability between years.

Table 1: Descriptive Statistics of VMT Determinant Variables

Variables	Measures	2001- Tested Sample Size = 1690						2009- Tested Sample Size = 2441						
		Min	Max	Mean	S.D.	Count	Percent	Min	Max	Mean	S.D.	Count	Percent	Percent Change
% Renter Occupied- respondent's census tract	Continuous	0.00	95.00	36.00	23.00	-	-	0.00	95.00	31.00	22.00	-	-	-
Born in the U.S.	Binary	-	-	-	-	1370	81	-	-	-	-	2010	82	1
Commute Mode - Personal Vehicle	Dummy	-	-	-	-	1567	93	-	-	-	-	2303	94	2
Commute Mode - Public Transit	Dummy	-	-	-	-	50	3	-	-	-	-	59	2	-1
Distance to Work (miles)	Continuous	0.00	700.00	15.00	23.00	-	-	0.00	365.00	16.00	17.00	-	-	-
Education- Less than high school (1)	Ordinal 1-5	-	-	-	-	85	5	-	-	-	-	60	2	-3
Education- 2 - High school or GED (2)	Ordinal 1-5	-	-	-	-	350	21	-	-	-	-	295	12	-9
Education- Some college or AA (3)	Ordinal 1-5	-	-	-	-	534	32	-	-	-	-	659	27	-5
Education- Bachelor's degree (4)	Ordinal 1-5	-	-	-	-	426	25	-	-	-	-	745	31	6
Education- Graduate or Professional (5)	Ordinal 1-5	-	-	-	-	295	17	-	-	-	-	682	28	11
Family Income: 1 to 3 (< $15,000)	Ordinal 1-18	-	-	-	-	50	3	-	-	-	-	41	2	-1
Family Income: 4 to 6 (< $30,000)	Ordinal 1-18	-	-	-	-	157	9	-	-	-	-	92	4	-5
Family Income: 7 to 9 (< $45,000)	Ordinal 1-18	-	-	-	-	224	13	-	-	-	-	156	6	-7
Family Income: 10 to 12 (< $60,000)	Ordinal 1-18	-	-	-	-	245	14	-	-	-	-	226	9	-5
Family Income: 13 to 15 (< $75,000)	Ordinal 1-18	-	-	-	-	224	13	-	-	-	-	215	9	-4
Family Income: 16 to 18 (> $ 75,000)	Ordinal 1-18	-	-	-	-	790	47	-	-	-	-	1711	70	23
# of Vehicles in the Household	Continuous	0.00	9.00	3.00	1.00	-	-	0.00	11.00	3.00	1.00	-	-	-
Household Race: Asian	Dummy	-	-	-	-	141	8	-	-	-	-	195	8	-
Household Race: Black	Dummy	-	-	-	-	63	4	-	-	-	-	64	3	-1
Household Race: Multiple/Other	Dummy	-	-	-	-	192	11	-	-	-	-	84	3	-8
Household Race: Hispanic	Dummy	-	-	-	-	140	8	-	-	-	-	130	5	-3
Household Size	Continuous	1.00	10.00	3.00	1.00	-	-	1.00	11.00	3.00	1.00	-	-	-
Bike Trips (Week)	Continuous	0.00	28.00	0.00	2.00	-	-	0.00	14.00	0.00	1.00	-	-	-
Travel Day Trips	Continuous	0.00	20.00	5.00	3.00	-	-	0.00	19.00	5.00	3.00	-	-	-
Walking Trips (Week)	Continuous	0.00	75.00	4.00	6.00	-	-	0.00	99.00	4.00	6.00	-	-	-
Own a Home or Rent Apartment: Own	Dummy	-	-	-	-	1273	75	-	-	-	-	2112	87	12
Own a Home or Rent Apartment: Rent	Dummy	-	-	-	-	437	26	-	-	-	-	329	13	-13
Population Density	Continuous	50.00	30000.00	7133.00	6686.00	-	-	50.00	30000.00	6471.00	5601.00	-	-	
Public Transit Trips per Month	Ordinal 1-4	-	-	-	-	-		0.00	99.00	2.00	7.00	3868	-	-
1: 0 times	-	-	-	-	-	1456	86	-	-	-	-	-	-	-
2: 1- 4 Times	-	-	-	-	-	93	6	-	-	-	-	-	-	-
3: 5 - 10 Times	-	-	-	-	-	53	3	-	-	-	-	-	-	-
4: 11+ Times	-	-	-	-	-	88	5	-	-	-	-	-	-	-
Respondent's Age	Continuous	16.00	84.00	42.00	12.00	-	-	18.00	88.00	49.00	12.00	-	-	-
Respondent's Sex: Female	Dummy	-	-	-	-	742	44	-	-	-	-	971	40	-4
Respondent's Sex: Male	Dummy	-	-	-	-	948	56	-	-	-	-	1470	60	4
Rail (MSA has rail)	Binary	-	-	-	-	1097	65	-	-	-	-	1421	58	-7
Work: Part Time	Dummy	-	-	-	-	257	15	-	-	-	-	348	14	-1
Work: Full Time	Dummy	-	-	-	-	1426	84	-	-	-	-	2081	85	1
Work: Multiple Jobs	Dummy	-	-	-	-	7	0.00	-	-	-	-	12	0.00	-

Source: NHTS 2001 and 2009.

Figure 2: Quartile Graphs, Data from the NHTS



The quartile graph for Population Density and per capita VMT clearly indicates a negative relationship for both years. Public Transit Trips per Month versus per capita VMT indicates a slight positive relationship in 2001 and a negative relationship in 2009. This is the first graph which suggests that time has had an impact on the independent and dependent variable relationship. The graph seemingly indicates that public transit has increasing significance in reducing per capita VMT or that something over the past decade has made people more inclined to use transit over driving. Walk Trips per Week versus per capita VMT does not present a distinct relationship for 2001 or 2009. Based on the descriptive analysis, Walk Trips per Week does not seem to have any effect on per capita VMT. The graph for Bike Trips per Week presents a trend similar to an inverted bell curve, where the first two quartiles show a decreasing trend and the third and fourth quartiles seem to present an increasing trend; however, the graph is suggestive of an overall negative trend.

METHODOLOGY

Our purpose for analyzing the data sets is two-fold: isolate per capita VMT determinants from the 2001 and 2009 NHTS data sets and identify potential past trends in determinants to make policy recommendations for the future.

To identify per capita VMT determinants from the two data sets, we use multivariate regression. Regression analysis expresses an independent variable, per capita VMT, as a function of several explanatory variables. Of the possible explanatory variables in the NHTS data sets, those which are statistically significant at least at 90% confidence explain per capita VMT. To compare the relative impact of each significant variable we use the Standardized Beta Coefficient. Standardized Beta Coefficients are normalized for units so that the relative weight of each variable can be compared on a one-to-one basis. Through a direct comparison of statistically significant variables we can determine which have the greatest impact on per capita VMT.

To determine if any trends in per capita VMT determinants exist over the past decade we must first determine if regressions for 2001 and 2009 NHTS data sets differ statistically. If the regression coefficients do not differ between 2001 and 2009, then a regression model with pooled data from both years would provide per VMT determinants. To objectively determine if change has occurred in per capita VMT determinants between 2001 and 2009, we used a Chow Test.

Chow Test

The purpose of a Chow Test is to test for structural change between two regressions. A result of structural change in the regression models between 2001 and 2009 would indicate that the coefficients are significantly different. The Chow Test tests the hypothesis that the regression coefficients are different between subsets of data. In our application, we are testing if the coefficients are the same between regressions of two different years. The null hypothesis is no structural change and the alternative is structural change between subsets of data. The Chow Test requires three regressions: regressions for each data subset, and a regression with a pooled data set. The Chow Test is based on the F-distribution:

$$F = \frac{(a-b)/p}{b/(n-2p)}$$

a = Residual Sum of Squares for Pooled Model (2001 + 2009)
b = Residual Sum of Squares (2001) + Residual Sum of Squares Residuals (2009)
n = number of observations
p = number of parameters (independent variables + constant)

We use the F-distribution table to reference the critical value to determine if we reject the null hypothesis, which indicates no structural change. If structural change exists, then we can analyze separate regressions for 2001 and 2009 for trends in per capita VMT determinants using the standardized beta coefficients. If the coefficients differ between years, then we default to 2009 determinants of per capita VMT for policy recommendations. If we do not reject the null hypothesis, we can objectively say that no trends exist between years, in which case we can use regressions for either year or the regression that uses the pooled data for deriving per capita VMT determinants since there is no difference across regressions.

RESULTS

Chow Test

The F-value is F (23, 4083) = 2.75 and the critical value at .05 is equal to 1.61. Since the F-value is greater than the critical value from the F-distribution table, we rejected the null hypothesis and accepted the alternative hypothesis, which indicates structural change exists between the 2001 and 2009 data sets. Since structural change exists, the pooled data regression is not appropriate for deriving per capita VMT determinants and we must refer to the two separate regressions for 2001 and 2009. Structural change indicates that the beta coefficients are different between the 2001 and 2009 regressions. Therefore, we can analyze trends between 2001 and 2009.

Per VMT Determinant Analysis. The Chow Test revealed that the coefficients between the 2001 and 2009 data sets significantly differ. We can now use p-value and standardized beta coefficients from regression results for both years to isolate and analyze per capita VMT determinants. Table 4 presents the regression outcomes from 2001 and 2009.

Referring to Table 3, it is notable that more variables are significant in 2009 than in 2001. This indicates the emergence of a more diverse group of variables that impacts per capita VMT, and which must be accounted for when crafting strategies for reducing per capita VMT. For instance, Bike Trips per Week has emerged as a statistically significant variable in 2009. Relative to the other standardized beta coefficients, Bike Trips per Week has a moderate impact on the regression equation, indicating that the variable is an important per capita VMT determinant, although having a relatively low impact at a standardized beta of 0.05. Born in the U.S. is significant in 2009. Commute Mode – Personal Vehicle is statistically significant in both 2001 and 2009; however, there is a distinct difference in the standardized beta coefficients. In 2001, Commute Mode – Personal Vehicle has a standard beta of 0.09 and in 2009 the coefficient is at -0.05. What is notable is that the coefficient sign switches from positive to negative, indicating that commuting by personal vehicle used to have a greater impact on increasing per capita VMT than in 2009. Commute Mode – Public Transit has emerged as significant in 2009 at a standard beta at -0.08, which indicates a relatively large impact on reducing per capita VMT compared with the other variables. The emergence of commuting by public transit in recent years indicates that public transit is more relevant as a method of reducing per capita VMT.

Distance to Work is statistically significant in both years and is the most impactful explanatory variable for both years. With the greatest standardized beta coefficient of 0.22 in 2001 and 0.31 in 2009, Distance to Work must be given heavy weight by policy makers in crafting policy for reducing per capita VMT. Education emerged as a significant explanatory variable in 2009, although it has a relatively minimal impact on per capita VMT. It is interesting that Education has a negative sign, indicating that as education increases per capita VMT decreases; therefore, the least educated people tend to drive the most.

Another interesting finding is that Family Income is not statistically significant in either year, which is counter to the findings of other studies on the topic of per capita VMT. Number of Household Vehicles is significant and stable over both 2001 and 2009, with a slight change in standardized beta, falling from 0.08 to 0.06. Interestingly, Household Race-Black has emerged in 2009 as negatively related to per capita VMT. While the impact is minimal at -0.03, this may indicate a trend toward African Americans being increasingly deprived of transportation means or even higher unemployment. Household Race – Multiple/Other has emerged in 2009 as positively related to per capita VMT at standard beta of 0.04, which is also on the low end. This category tends to contain a large portion of Hispanics and mixed race, which are both increasing in population in the United States.

Table 3: Regressions Outcomes for 2001 and 2009

Variables	2001		2009	
	Stdz. Beta	P-value	Stdz. Beta	P-value
(Constant)	-	0.09	-	0.00
Percent Renter Occupied	0.00	0.93	0.01	0.75
Bike Trips per Week	0.00	0.92	-0.07	0.00*
Born in the U.S.	0.02	0.52	0.05	0.01*
Commute Mode - Personal Vehicle	0.09	0.01*	-0.05	0.08**
Commute Mode - Public Transit	-0.05	0.18	-0.08	0.00*
Distance to Work	0.22	0.00*	0.31	0.00*
Education	-0.03	0.20	-0.03	0.10**
Household Family Income	0.00	0.99	-0.02	0.37
Household Number of Vehicles	0.08	0.00*	0.06	0.00*
Household Race- Asian	-0.04	0.14	-0.01	0.66
Household Race- Black	0.02	0.33	-0.03	0.09**
Household Race-Multiple/Other	-0.02	0.42	0.04	0.06**
Household Race- Hispanic	-0.03	0.32	0.00	0.97
Household Size	0.00	0.90	-0.02	0.51
Population Density	-0.05	0.08**	-0.09	0.00*
Public Transit Used per Month	0.01	0.65	-0.05	0.02*
Access to Rail	-0.01	0.77	-0.02	0.39
Respondents Age	-0.03	0.19	-0.09	0.00*
Respondents Sex – Male	0.17	0.00*	0.14	0.00*
Travel Day Trips	0.09	0.00*	0.04	0.05*
Walk Trips per Week	0.04	0.15	-0.02	0.35
Respondent Works Part Time	-0.07	0.01*	-0.07	0.00*
Dependent Variable : Per Capita Vehicle Miles Traveled * 95% confidence level ** 90% confidence level	R Square = 0.133 Adjusted R Square = 0.121		R Square = 0.172 Adjusted R Square = 0.165	

Our regressions support past research, which has shown population density to be a significant determinant of per capita VMT. Between 2001 and 2009, standardized beta for population density has become increasingly significant in reducing per capita VMT, with an increase from -0.05 to -0.09. Public Transit Trips per Month has become statistically significant in 2009. With a -0.05 standardized beta, trips made by public transit are moderately impactful on reducing per capita VMT. This finding is mutually supportive with Commute Mode-Public Transit, highlighting the importance of public transit as a per capita VMT determinant. Respondent's age is a VMT determinant in 2009, and based on the beta coefficient of -0.09, the variable greatly negatively impacts per capita VMT.

The second most impactful variable in both years is Respondents Sex – Male, which is both positively related to per capita VMT. The variable Travel Day Trips are significant in both years and positively related to per capita VMT. Interestingly, standardized beta for Travel Day Trips fell from 0.09 in 2001, a strong impact, to 0.04 in 2009, which is a relatively weak impact. Finally, Respondents Part Time Worker is negatively related to per capita VMT at -0.07 in both years.

DISCUSSION AND CONCLUSION

This analysis has shown a shift toward a more diverse group of significant variables that explain and impact per capita VMT. There is also a group of variables that have remained constant over the past decade, which provides insight to which methods California and metropolitan planning organizations should concentrate their efforts toward. Particularly, variables that reduce the distance one needs to travel and the number of car trips necessary. Even across two regressions, which were proven to be statistically different, the variables Distance to work, Population Density, Travel Day Trips, and Number of Vehicles in Household proved to be consistent. Several studies have provided support for these variables as per capita VMT determinants (Lui 2007, Ewing and Cervero 2007, Akar and Guldmann 2012). This provides a measure of assurance that variables such as economic turmoil are not susceptible to change and should be a central focus of government action. These findings support the methods SB 375 used to reduce per capita VMT, which focuses on the built environment through increasing compact and mixed use development.

Over the past decade, the variables which have become relevant as VMT determinants are commuting by public transit and increasing public transit trips. The shift toward public transportation as a commute mode, as well as the relative weight of the variable, indicates a growing importance of increasing transit as a method of reducing per capita VMT. Number of bike trips has also emerged in 2009 as a per capita VMT determinant. With cycling becoming increasingly relevant, it is also an important consideration in reducing per capita VMT. These per capita VMT determinants were not particularly supported by older studies in the literature review and have been shown to have emerged here in recent years. This points to a growing importance of public transportation as part of the statewide conversation on reducing per capita VMT and by extension GHG.

Other interesting findings include the demographic variables found to be determinants of per capita VMT. The regression results for 2009 indicate that as black population increases per capita VMT decreases. This may point to a transportation equity issue and should be considered by policy makers but is outside the scope of this study. Male respondents were found to be negatively related to per capita VMT and is supported by the findings of Choi and Hu 2008. Age emerged as a statistically significant variable, negatively related to per capita VMT, in 2009, which might point to the aging of the baby boom population as supported by Polizin et al. 2004. The finding that income plays no role in determining per capita VMT was also found by Cook et al. (2012). The finding of less educated people driving more is supported by Liu (2007).

The outcomes of this study suggest to policy makers a mixed methods approach to reducing per capita VMT. This study supports efforts such as SB 375, which focuses on compact development to reduce per capita VMT and greenhouse gas emissions. This study also supports local government efforts that go further than SB 375. Reducing vehicle travel requires focusing on determinants of per capita VMT, such as increasing bike trips and public transit trips, while also decreasing distance from work to home, the number of driving trips, and the number of household cars. California's per capita VMT reduction targets can be met in the long term by focusing on these California specific per capita VMT determinants, through crafting incentives and promoting sustainable development that favors non-motorized modes.

Acknowledgements

The authors would like to acknowledge research support from Faculty Development and College of Social and Behavioral Sciences of California State University, Northridge.

References

Akar, G. and J.M. Guldmann. "Another Look at Vehicle Miles Traveled, Determinants of Vehicle Use in Two-Vehicle Households." *Transportation Research Record* 2322, (2012): 110-118.

Barth, M. and K. Boriboonsomsin. "Real-World CO2 Impacts of Traffic Congestion." Presentation at the Transportation Research Board 87th Annual Meeting, Washington, DC, January, 13-17, 2008.

Bedsworth, L., E. Hanak, and J. Kolko. "Driving Change: Reducing Vehicle Miles Traveled in California." Public Policy Institute of California, 2011.

Burwell, D. "Beyond Congestion: Transportation's Role in Managing VMT for Climate Outcomes." *Reducing Climate Impacts in the Transportation Sector,* Springer Netherlands, (2009): 117-137.

Choi, S. and H. Hu. "Measuring the Effects of Changing Demographic Composition on Vehicle Mile Traveled Growth Using the Standardization and Decomposition Techniques." Southern California Association of Governments, 2008.

Cook, J., D. Salon, J. Sanchirico, and J. Williams. "Driving Intensity in California: Exploring Spatial Variation in VMT and its Relationship to Fuel Prices, Fuel Economy, and the Built Environment." UC Davis, 2012.

Heres-Del-Valle, D. and D. Niemeier. "CO2 Emissions: Are Land-Use Changes Enough for California to Reduce VMT? Specification of a Two-Part Model with Instrumental Variables." *Transportation Research Part B* 45(1), (2011): 150-161.

Emrath, P. and F. Liu. "Vehicle CO2 Emissions and the Compactness of Residential Development." *Cityscape* 10(3), (2008): 185-202.

Ewing, R. and C. Cervero. "Travel and the Built Environment, a Synthesis." *Transportation Research Record* 1780, (2007): 87-114.

Greene, D. "Rebound 2007 Analysis of U.S. Light-Duty Vehicle Travel Statistics." *Energy Policy* 41, (2012): 14-28.

Lave, C.A. "What Really is the Growth of Vehicle Usage?" *Transportation Research Record* 1520, (1996): 117-121.

Liu, F. H. *Vehicle CO2 Emissions and the Compactness of Residential Development*. National Association of Home Builders, Special Studies, 2007.

Litman, T. *Are Vehicle Travel Reduction Targets Justified? Evaluating Mobility Management Policy Objectives Such As Targets to Reduce VMT and Increase Use of Alternatives*. Victoria Policy Institute, 2013.

Noland, R. and W. Cowart. "Analysis of Metropolitan Highway Capacity and the Growth in Vehicle Miles of Travel." *Transportation* 27(4), (2000) 363-390.

Polizin, S., X. Chu, and L. Toole-Holt. "Forecasts of Future Vehicle Miles of Travel in the United States." *Transportation Research Record* 1895, (2004) 147-155.

Rodier, C. "Review of the International Modeling Literature, Transit, Land Use and Auto Pricing Strategies to Reduce Vehicle Miles Traveled and Greenhouse Gas Emissions." *Transportation Research Board* 2132, (2009) 1-12.

Small K. and K. Van Dender. *A Study to Evaluate the Effects of Reduced Greenhouse Gas Emissions on Vehicle Miles Traveled*. California Air Resources Board, 2005-107586, 2005.

***Mintesnot Woldeamanuel**, PhD, is an associate professor at the department of Urban Studies and Planning at California State University, Northridge. Prior to joining Cal State, Northridge, he worked as an assistant professor at the Planning and Community Development Program of Saint Cloud State University and as a research fellow at the Transportation Research Institute of German Aerospace Center (DLR). Woldeamanuel has a PhD in urban and environmental planning/engineering. He has conducted extensive research and written on the relationship between travel behavior, the environment, and urban form, focusing on transportation mode choice and spatial analysis.*

***Andrew Kent** is a graduate student at University of California Irvine, Department of Policy, Planning and Design. He holds a bachelor's degree in Urban Studies and Planning from California State University, Northridge. He has been working as a research assistant at Cal State, Northridge, and his research interest includes transportation economics, urban planning, and sustainable communities.*