National Energy & Transportation Sustainability, Cost, & Resiliency
NETSCORE21
Research Project

VMT, energy consumption and greenhouse gas emissions forecasting for passenger transportation (#11-0372)

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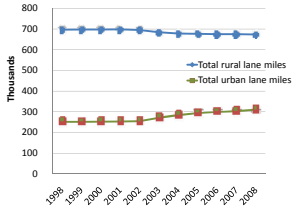
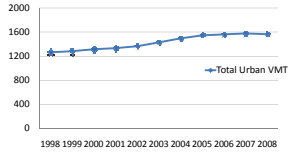
Globalization, greenhouse gas (GHG) emissions and energy concerns, and emerging vehicle technologies make the present moment an opportune time to revisit aggregate vehicle miles traveled (VMT), energy consumption, and GHG forecasting for passenger transportation. Using panel data for the 48 continental states during the period 1998–2008, the authors develop simultaneous equation models for predicting VMT on different road functional classes and examine how different technological solutions and changes in fuel prices can affect passenger VMT. Moreover, a random coefficient panel data model is developed to estimate the influence of various factors (such as demographics, socioeconomic variables, fuel cost, and capacity) on the total amount of passenger VMT in the United States. To assess the influence of each significant factor on VMT, elasticities are estimated. Further, the authors investigate the effect of different policies governing fuel tax and population density on future energy consumption and GHG emissions. The presented methodology and estimation results can assist transportation planners and policy-makers in determining future energy and transportation infrastructure investment needs.

Table 1: Summary Statistics of Select Variables

Variables	Mean or percentage (standard deviation)*
Vehicle Miles Traveled in Rural Areas (billions)	
Interstate	4.07 (2.87)
Principal arterial	4.26 (3.31)
Minor arterial	3.08 (2.47)
Collector	3.79 (3.10)
Total	15.2 (11.05)
Vehicle Miles Traveled in Urban Areas (billions)	
Interstate	7.89 (10.08)
Freeways	3.79 (7.69)
Other principal arterials	8.28 (9.75)
Minor arterials	6.82 (7.95)
Major collector	3.00(3.71)
Total	29.78 (38.00)
Population (millions)	5.99 (6.41)
Percentage of urban population	67.03 (15.51)
Percentage of White population	79.09 (10.19)
Percentage of Black and African-American population	10.11 (9.53)
Percentage of Hispanic or Latino population	8.47 (9.41)
Percentage of Asian population	2.33 (2.04)
Population under 18 years old (millions)	1.51 (1.66)
Population 65 years old and over	746,516 (768,776)
Percentage of male/female population	49.18 / 50.82
Income per capita (real dollars)	31,021 (5,859)
Percentage of population working at home (telecommuting)	17.25 (11.41)
Fuel cost (cents/gallon)	192.69 (68.47)
Fuel tax-State (cents/gallon)	20.85 (4.85)
Total fuel tax	39.25 (4.85)
Density (population per square mile)	189.05 (253.84)
Vehicle registrations (millions)	2.80 (3.16)
Vehicles per capita	0.46 (0.07)
Percentage of alternative fuel vehicles	0.23 (0.15)
Percentage of congested miles on rural roads	1.42 (1.96)
Percentage of congested miles on urban roads	10.05 (4.99)

* represent the averages over the data sample used in this study (i.e., 48 states over 11 years, or a total of 528 observations)





Data for the 48 continental states in the U.S. from 1998-2008 obtained from FHWA Highway Statistics, HPMS, U.S. Census, U.S. DOE and EIA were used in this study. Seemingly Unrelated Regression Equation (SURE) models were developed to estimate VMT on different functional classes for urban and rural roads. The SURE model was selected due to the high correlation among VMT on different functional classes. A dummy variable for each state was included in the models so that a fixed-effects or dummy-variable SURE model could be estimated and the unmeasured factors that affect VMT and are associated with each state could be accounted for. Dynamic adjustment of VMT over time was not considered and as such, the estimated effects are intended to be interpreted as short-term effects. In addition, the authors estimated an aggregate model (panel data regression model with random parameters) for total passenger VMT for forecasting future energy consumption and GHG emissions.

I. Estimation of VMT on Rural and Urban roads

Table 2: SURE Model Estimation Results for log-VMT on Rural Roads

Independent Variables	Interstate	Principal arterial	Minor arterial	Collector
Constant	2.137	3.863	1.481	13.049
Percentage of White population	0.024**	0.013**	0.024**	
Percentage of African American or Black population	0.025**	0.01**	0.019**	
Percentage of Hispanic or Latino population	0.003**			
Percentage of male population	0.025**			-0.220**
Natural logarithm of income per capita				0.853**
Percentage of population working at home (telecommuting)				-0.003**
Natural logarithm of fuel cost	-0.035**			
Density		-0.001**		
Natural logarithm of Interstate lane miles	0.244**			
Natural logarithm of minor arterial lane miles			0.336**	0.432**
Natural logarithm of collector lane miles				0.376**
Natural logarithm of vehicle registrations	0.479**	0.669**	0.648**	
Percentage of congested miles on Interstates		0.0004**		
Percentage of congested miles on minor arterials				0.005**

*: Variables significant at the 90% confidence interval.
**: Variables significant at the 95% confidence interval.
State specific constants are omitted for brevity.

Table 3: SURE Model Estimation Results for log-VMT on Urban Roads

Independent Variables	Interstate	Freeway	Principal arterial	Minor arterial	Collector
Constant	9.857	7.021	12.678	9.622	7.499
Percentage of urban population	0.005**	0.010**	0.009**	0.009**	0.008**
Percentage of White population		-0.065**		-0.011**	-0.012**
Percentage of Black of African American population	0.005**	-0.076**			
Percentage of Hispanic or Latino population		-0.063**	0.018**		
Percentage of Asian population	0.072**		-0.043**	0.036**	
Percentage of male population	-0.050**		-0.115**		
Percentage of population working at home (telecommuting)		-0.004**	-0.002**		-0.002**
Natural logarithm of fuel cost	-0.042**	0.466**	0.132**		0.167**
Natural logarithm of fuel tax-State					0.182**
Density				-0.0002**	-0.0002**
Natural logarithm of Interstate lane miles	0.628**				
Natural logarithm of freeway lane miles	0.068**	0.149**			
Natural logarithm of principal arterial lane miles			0.482**		
Natural logarithm of minor arterial lane miles				0.056**	
Natural logarithm of collector lane miles					0.422**
Natural logarithm of vehicle registrations		0.920**			
Percentage of alternative fuel vehicles	-0.044**	0.377**			
Vehicles per capita			0.202**	0.138**	
Percentage of congested miles on collector roads				0.0008*a	

*: Variables significant at the 90% confidence interval.
**: Variables significant at the 95% confidence interval.
State specific constants are omitted for brevity.

The number of vehicle registrations and the amount of lane miles were exogenously estimated as a function of income, race, gender, percentage of people telecommuting, density, fuel cost, fuel tax, and percentage of alternative fuel vehicles.

II. Random Coefficients-Panel Data Model for Total log-VMT

Table 4: Variables with Constant Coefficients

Variable	Coefficient
Natural logarithm of fuel cost	-0.014
Natural logarithm of fuel tax-State	-0.037
Natural logarithm of vehicle registrations	0.052
Percentage of alternative fuel vehicles	0.016
Natural logarithm of total rural lane miles	0.068
Natural logarithm of total urban lane miles	0.256

Table 5: Variables with Normally-distributed Coefficients

Variable	Mean (St. deviation)
Constant	4.616 (0.015)
Natural logarithm of population	0.647 (0.004)
Percentage of urban population	0.0003 (0.0002)
Percentage of White population	-0.002 (0.0001)
Percentage of Hispanic or Latino population	-0.005 (0.005)
Percentage of Asian population	0.004 (0.003)
Natural logarithm of income per capita	0.067 (0.004)
Natural logarithm of density	-0.009 (0.002)

III. Energy consumption and GHG emissions

The VISION model, developed by Argonne National Laboratory, estimated the energy consumption in the horizon year (2040) based on the amount of VMT in the base year (2008), predictions regarding the amount of VMT for the years between the base and the horizon years, and assumptions about advanced vehicle and alternative fuel market penetration.

Table 6: The Potential Impact of Increasing Fuel Tax and Density on Energy Consumption and GHG Emissions

Policy 1: Indexing state fuel tax to inflation (31.5% increase)		
Estimated elasticity of demand (VMT)	-0.037	
Estimated annual VMT growth factor	0.997	
	Light duty vehicles	*Passenger cars*
Estimated energy consumption (% reduction)	40.6	10.9
Estimated GHG emissions (% reduction)	41.1	10.9
Policy 2: Doubling the density (100% increase)		
Estimated elasticity of demand (VMT)	-0.009	
Estimated annual VMT growth factor	1.0006	
	Light duty vehicles	*Passenger cars*
Estimated energy consumption (% reduction)	36.5	4.8
Estimated GHG emissions (% reduction)	37.1	4.8

Conclusions:

- Confirmed the effect of well-established contributing factors on VMT, such as population, race, gender, urban population, income per capita, number of vehicles per capita, and density.
- Found differences in the magnitude and direction of the effect of these factors on total passenger VMT ; for certain groups (urban populations, Hispanic or Latino and Asian populations) the effect can be either positive or negative.
- Examined the impact of technological solutions, such as telecommuting and alternative fuel vehicles, on travel demand and the impact of one road type's lane miles or capacity on the VMT of another road type (cross-elasticities).
- Increasing the percentage of people telecommuting would decrease short-distance trips traveled on collector roads in both urban and rural areas, as well as some longer trips on urban freeways and principal arterials.
- Found higher elasticity values of VMT with respect to lane miles on most classes of urban roads compared to rural roads.
- Found non-uniform effect of fuel cost, fuel tax, and alternative fuel vehicles on VMT across the various functional road classes.
- Presented a methodology for estimating future energy consumption and GHG emissions from passenger transportation.

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