Aging Population and Greenhouse Gas (GHG) Emissions In the Southern California Region

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ABSTRACT: The objective of this research is to examine how the elderly population and their residential location and land uses affect the greenhouse gas (GHG) emissions in the SCAG region. This research estimates the impact of aging trends and geographical distribution of the elderly on regional transportation and Greenhouse Gas (GHG) emissions for the Southern California Association of Governments (SCAG) region by using the SCAG Household Travel Demand Analysis (HTDA) model. The SCAG HTDA model is a statistical model measuring the household vehicle miles of travel (VMT) by using socioeconomic, land use, and travel characteristics from 2009 National Household Travel Survey (NHTS) data. The results and findings of this research will identify the land use - transportation characteristics of the elderly population, and will help planners and policy makers to explore land use/transportation strategies to reduce the GHG emissions. Using SCAG's growth forecast data as input, the model results from this research can be used for estimating the impacts of land use strategies or demographic changes on travel demand, VMT, and GHG emissions. The research will contribute to further understanding of 1) the travel needs of the elderly population, 2) the implications on the gentrification and aging in place of the elderly population and the access to daily activities, and 3) the impact of the elderly population on regional VMT and GHG.

Keywords: Elderly Population, Greenhouse Gas, SCAG, Southern California, Household Travel Demand Analysis (HTDA) Model

1. INTRODUCTION

California Senate Bill 375 (SB 375) is a California state law that became effective January, 2009. This law requires California's Air Resources Board to develop regional reduction targets for greenhouse gas (GHG) emissions, and prompts the creation of regional plans to reduce emissions from vehicle use. The law is the nation's first law to control GHG emissions through coordination between land use planning and transportation planning. California's eighteen Metropolitan Planning Organizations (MPOs) are asked to develop a land use policy called "Sustainable Communities Strategy." The concept of the SCS is based on the idea of "compact" residential development, such as higher density, mixed-use development, walkability, and better transit access. Residents living in compact communities are expected to reduce their reliance on automobiles, while using more transit and non-motorized travel modes. Therefore, the goal to reduce GHG emissions can be achieved.

Southern California Association of Governments (SCAG), the MPO for six counties in Southern California, is tasked with developing a Sustainable Communities Strategy as an element of the agency's long-term Regional Transportation Plan. A regional travel demand model is used to estimate vehicle flows and speed as input to an emission model. Because GHG emissions are generally proportioned to the travel distance of vehicles, vehicle miles of travel (VMT) is used as an approximate indicator of GHG emissions for comparative analysis among different policy scenarios.

To test the sensitivity of VMT to land use policies, a transportation model needs to be built with land use input variables that can represent neighborhood land use characteristics such as density, diversity, and design. SCAG developed a parcel-based sketch planning model that uses a quarter-mile radius of each parcel as the neighborhood boundary to estimate the land use-transportation relationship. Since the model input includes socioeconomic characteristics, neighborhood land use, and built environment, the model can analyze both land use impact and demographic impact on travel patterns.

Demographic characteristic is one of the major factors for the analysis of travel behavior. While estimating the impact of land use policy on GHG emission reduction for a region, it is important to understand whether there will be a dramatic change in the demographic or economic composition of the region. Age is known as an important factor to analyze an individual's travel activities. People in different age groups will have different demand in their daily activities and travel choices. Thus, the change in age composition of a region may have important planning implications on regional transportation. Due to the aging of baby boomers, the proportion of the elderly in Southern California will increase from current 10% of the total population to about 17% in 2035. It is interesting to know how travel behavior will be different between the elderly and the younger population, and how the drastic growth of the aging population will influence regional transportation, particularly VMT and GHG emissions.

The purpose of this research is to 1) analyze the travel behavior of the elderly based on the 2009 National Household Travel Survey (NHTS), and 2) to estimate the impact of aging trends on VMT for the SCAG region. Using 2008 and 2035 input data, the SCAG parcel-based model was modified to calculate VMT and other travel indicators. Due to the increase of the elderly in future years, it is expected that regional VMT will be further reduced. The model result has confirmed the assumption.

This paper has five sections. The next section describes travel behavior of the elderly. The section also describes travel patterns by age cohorts based on the analysis of 2009 NHTS data. Section 3 describes the parcel-based model. Section 4 summarizes results of VMT estimation from SCAG's parcel-based model. Section 5 contains the summary and conclusion.

2. TRAVEL BEHAVIOR OF THE ELDERLY

People travel to access activities in order to meet their needs for living or life satisfaction. Three types of human activities have been identified based on Reichman's (1976) activity typology. First, subsistence activities refer to work or work-related activities, which generate income for supporting living. Travel associated with this type of activity is most commonly commuting. Second, maintenance activities pertain to the purchase and consumption of goods or services needed by individuals or households. Finally, leisure or discretionary activities refer to voluntary activities, such as socializing or recreational activities. In general, subsistence and maintenance activities serve basic human needs for surviving and living, while discretionary activities satisfy the quality of life.

Most elderly, who are 65 years old or older, are retired. As a result, they no longer need to travel to work. Therefore, the primary activity needs for most of the elderly is to acquire goods and services, and to participate in social activities. It is found that the elderly have stronger preference for social and entertainment activities than other types of activities (Coughlin, 2001). However, one should be aware that the future labor force participation rate of the elderly may be much higher than the current level. Due to future population growth, the labor force is expected to grow accordingly. However, due to the drop of the fertility rate and the increase in elderly dependency, labor force participation of the elderly may need to drastically increase (Bloom et al, 2011). This implies that there will be more senior commuters traveling on streets.

Social segregation has been a major concern to the older population. One key problem of the elderly is not health care or economic well-being, but lack of social integration (Rosow, 1967). To avoid social segregation, it is imperative for the elderly to participate in social activities, such as volunteer and religious service, or to interact with social networks, such as visiting friends, neighbors and relatives. Past research has shown that participating in social activities is positively associated with health, longevity and life satisfaction (Havighurst and Albrecht 1953; Moen et al., 1989; Young & Glasgow, 1998). According to a time use survey analyzed by Gauthier & Smeeding (2001), the elderly spend more time on social-related activities during a day than other activities. Since the elderly have more flexibility than the younger population to decide when to travel, they are more like to travel at off-peak hours to avoid busy traffic and congestion during peak hours.

Many studies have analyzed the travel patterns of the elderly (TRB, 1988, 2004; Rosenbloom, 1995; ECMT, 2000; OECD, 2001; Hu, 2006). Those studies have concluded that older people are active since their travel demand for non-work activities is not lower than younger adults. However, it is found that the mobility level drops dramatically for those who are very old. Remarkably declining health or physical conditions are known as one of the major reasons causing mobility reduction. Similar to the general population, most elderly rely on automobiles to keep them mobile even though many of them do not drive a car. The share of automobile use for the elderly is 90 percent of total trips, which is almost the same as the non-elderly (Rosenbloom, 2004; Collia 2003). Walking and transit trips for the elderly account for only 6 percent and 2 percent of total trips, respectively. For those very old (75 or older) who do not drive a car, most of them travel as a car passenger, followed by walking and transit use. Transit share does not increase with older age.

Analysis of 2009 NHTS

Using 2009 NHTS data, we compare travel patterns by different age cohorts, including 16-24 (the younger), 25-49 (adults), 50-64 (pre-elderly), 65-74 (younger elderly), and 75-84 (older elderly). Table 1 summarizes statistics of average daily travel per person, driving status and vehicle ownership, and vehicle use. The analysis of this section is based on the data presented in this table.

Table 1. Travel Patterns by Age Cohort

Age Cohort	16-24	25-49	50-64	65-74	75-84
Daily Travel					
Mean Trips	3.6	4.2	4.1	3.6	2.9
Mean Travel Distance	26.8	33.3	31.3	24.3	17.7
Mean Travel Time	64.2	73.3	71.2	61.1	49.2
% of Person not Travel	12.0%	9.6%	11.9%	19.7%	28.4%
Driving Status & Vehicle Ownership					
% of Persons with Driver's License	79%	93%	93%	88%	76%
Average Number of Household Vehicles	2.81	2.19	2.21	1.83	1.45
% of Persons without Car	4.8%	5.4%	5.2%	8.6%	12.7%
Vehicle Use					
Person VMT	16.3	26.3	24.6	17.7	11.4
Mode Share as Auto Driver	54.5	71.2	72.4	69.0	64.0
Mode Share as Auto Passenger	28.2	13.7	13.4	18.2	23.6
For Those Who Travel					
Mean Trips	4.1	4.7	4.6	4.5	4.1
Mean Travel Distance	32.7	39.4	37.5	32.1	26.5
Mean Travel Time	75.1	83.9	83.8	78.7	71.4
Non-Work Trips	3.3	3.5	3.5	4.1	3.9
NHTS Person Sample	19364	77016	88268	46744	30601

Source: 2009 NHTS

The trend of decreasing daily travel, including daily trips, travel distance and travel time, with age is evident. There is a particularly significant drop between the younger elderly and the older elderly. The result is consistent with past findings that the elderly have a lower travel demand than the non-elderly, and the older elderly have shown a significant drop in travel demand.

Not all people traveling outside of the home every day. According to 2009 NHTS data, 20% of younger elderly and 30% of older elderly do not travel out of the home during the survey day, compared to 10%-12% of the non-elderly. There are several factors to explain the lower travel demand: most of the elderly do not need to commute due to retiring from work, and some have less responsibility to family and grown-up children. Medical condition may change the travel patterns of the elderly. According to 2009 NHTS data, 16% of younger elderly and 24% of older elderly are reported the need to reduce daily travel due to medical conditions, compared to 5% for those whose age is between 25 and 49.

Generally speaking, most of the elderly still hold their driver’s license. In addition, they still can access a car. Compared to the 1995 NPTS, the elderly now have a higher percentage that hold a driver’s license (data not shown). NHTS data shows that a car is still the favorite transportation mode of the elderly. Mode share for car use is slightly higher for the elderly than the younger population. The older elderly are more likely to use a car as passengers rather than drivers. Mode share for transit and non-motorized modes is significantly lower for the elderly than the younger population. It takes more physical effort to use transit and non-motorized modes than using a car. It might be an issue to future elderly if they cannot drive a car, but still have a need to access daily activities. Though the elderly are still using a car to access daily activities, they tend to travel shorter distances. Average VMT is much lower for the elderly than non-elderly. This is consistent with the earlier discussion that the elderly have less demand on daily travel, including vehicle driving distance.

As discussed above, about 20% of younger elderly and 30% of older elderly do not travel out of the home on the survey day due to medical conditions or changes in family responsibility. More elderly may travel out of the home to engage in activities if the health condition of the future elderly is much improved, vehicle technology makes driving a car much easier, or the future elderly have better retirement plans. For those who traveled on the survey day, the data in Table 1 shows that the difference in daily travel is becoming narrower. Even without work, the elderly are still very active. For those who traveled, average daily trips for non-work purposes are higher for the elderly than non-elderly.

3. MODEL DESCRIPTION

This analysis uses SCAG's parcel-based sketch planning model to estimate the impact of land use on VMT and other travel indicators. For this research, we modify the structure of the model, so it can quantify the influence on travel patterns by the elderly.

3-1 Introduction of SCAG HTDA Model

SCAG developed the SCAG HTDA model, which is a statistical model measuring the household vehicle miles of travel (VMT) by using socioeconomic, land use, and travel characteristics from 2009 National Household Travel Survey (NHTS) data. The SCAG HDTA model is the parcel-based transportation model designed to calculate the impact of land use scenarios on regional VMT. Since the model is estimated based on 1/4 mile buffer land use data, it can better reflect the land use-transportation relationship. The parcel-based model is estimated based on the 2009 NHTS. The 2009 NHTS for the SCAG region contains approximately 6,700 households, 15,000 persons, and 55,000 trips.

Based on the choice theory described above, this research uses a sequential modeling approach that includes five household-based sub-models to estimate household VMT. The sequential modeling approach starts with a household vehicle ownership model that reflects mid-term decisions. The number of household vehicles estimated from the vehicle ownership model is then input into short-term decision models. Four short-term daily travel models are estimated: the probability of making at least one vehicle trip, total household trips, mode share, and household VMT. Both vehicle ownership and mode share that are estimated from previous steps are input to the household VMT model. Independent variables of each sub-model include household-level socioeconomic characteristics, travel capability, and land use characteristics. The modeling approach of each sub-model is summarized below:

1) Household Vehicle Ownership (sample = total households): The number of household autos is estimated using an ordered probit model that predicts the number of autos owned by the household. The estimated household vehicles are used as input variables to other sub-models for estimating short-term choice.
2) Probability of Vehicle Trip (sample = weekday households): A binary logit model was used to determine the probability of a household to make at least one vehicle trip during a day. The estimated probability was multiplied by the estimated VMT from the household VMT model to estimate average household VMT.
3) Household Daily Trip Model (sample = weekday households): A linear regression model was used to determine the number of person trips made by a household on a daily basis.
4) Mode Choice Model (sample = weekday households): A multinomial logit model was used to determine the mode share of household trips, including as an automotive driver, an auto passenger, a transit passenger, non-motorized modes for both walking and bicycling, or other modes. Both estimated transit share and non-motorized mode share are then used as an input variable to the household VMT model.
5) Household VMT Model (sample = weekday households, vehicle trip > 0): A linear regression model was used to determine VMT, using the results of the auto ownership model and the mode share model as an input. Since NHTS data shows that approximately 20 percent of households do not make any vehicle trips during the surveyed day, it is difficult to model this serious zero-inflated distribution, especially with a linear regression

model. An approach to solve this issue is to estimate household VMT by excluding those households with zero VMT, which makes the dependent variable, VMT, normally distributed.

Since the household VMT model does not estimate zero VMT, the average household VMT is calculated by multiplying the estimated VMT with the probability of the household making a vehicle trip as described above. Figure 1 shows the relationship among those sub-models.

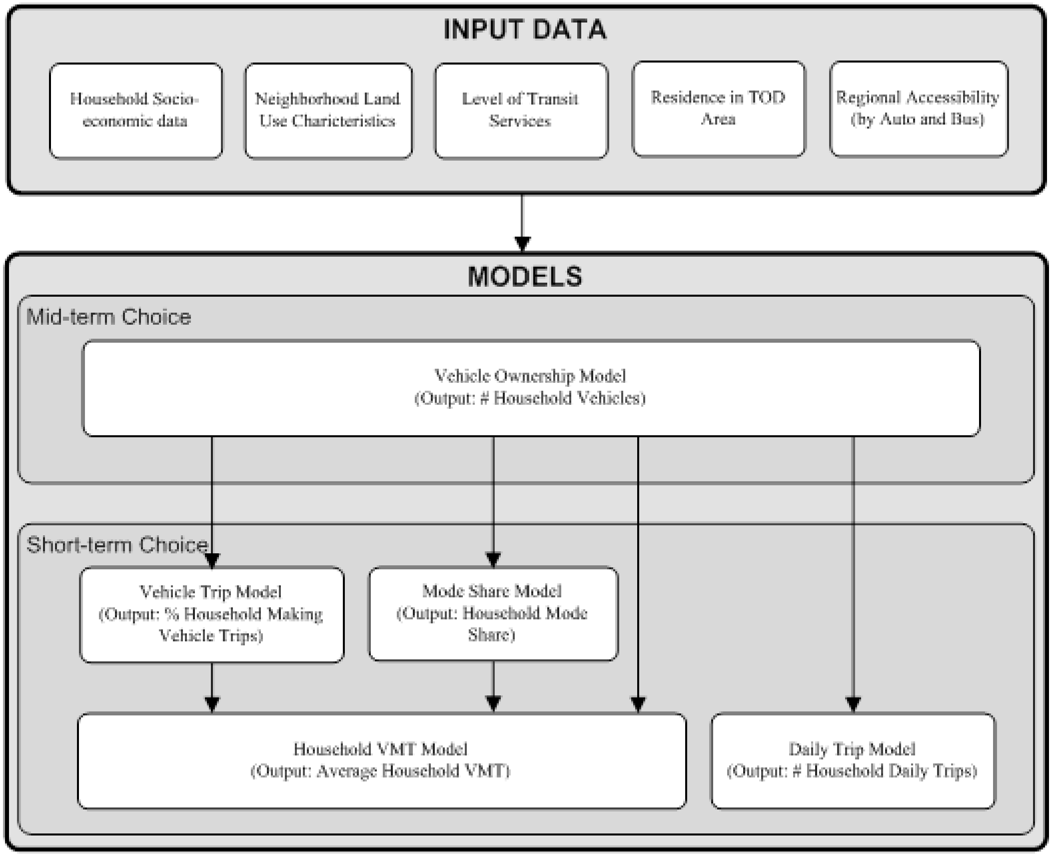

Figure 1. Flow Chart of SCAG Parcel-based Travel Demand Model

The model contains comprehensive input variables to estimate travel behavior. Key independent variables used in the model include 1) household socioeconomic characteristics, 2) neighborhood land use characteristics, 3) level of transit services, 4) residence in transit-oriented development (TOD) communities, and 5) regional accessibility by automobile and transit. Variables for household socioeconomic characteristics including median household income and the number of household members by their working status and age cohort, such as number of household workers, number of non-working children (younger than 16 years old), number of non-working adults (age 16-64), and number of non-working elderly (65 or older). Neighborhood land use variables include household density, employment density, street connectivity, and mixed use (diversity). Neighborhood boundary is defined as a quarter-mile buffer from each parcel.

In order to estimate how future growth of the elderly population will affect the travel pattern of a region, the parcel-based model needs to be modified. We modify socioeconomic variables by adding more detailed age categories for elderly members of a household. Five variables that represent the number of elderly members of a household are created – they are 1) the number of household workers, age 65-74, 2) the number of household workers, age 75-84, 3) the number of household non-workers, age 65-74, 4) the number of household non-workers, age 75-85, and 5) the number of the oldest elderly, 85 or older. The data sources and variables used in this research are described below (see Table 2). Table 2 shows the description of input and output variables of the model.

It is known that the relationship between land use and travel behavior might be different for people in different age cohorts. That land use strategies promote more use of transit and non-motorized transportation models may be less effective for the elderly because it is more difficult for the elderly to use transit or walk to access activities than the younger. This research does not discuss this issue. Our approach is straightforward: we test whether older age plays a significant role on different travel behavior, while controlling all variables that will influence travel behaviors. We will continue to research the land use-travel behavior relationship by different age groups in the future research.

Table 2. Variable Description

Variable	Description
Socioeconomic Characteristics	
WK1664	Number of Household Workers (16-64 years old)
WK6574	Number of Household Workers (65-74 years old)
WK7584	Number of Household Workers (75-84 years old)
NW0015	Number of Household Members (< 16 years old)
NW1664	Number of Household Members, non workers (16-64 years old)
NW6574	Number of Household Members, non workers (65-74 years old)
NW7584	Number of Household Members, non workers (75-84 years old)
P8500	Number of Household Members (> 84 years old)
IN10K	Median Household income in $10,000 (in $1999)
Transportation Capabilities	
HHcar	Number of household cars
LDlbushq	Log of Frequent Bus Stop density (bus stops with headways less than 20 minutes)
NoHQBus	Household TAZ has no HQ Bus stop
Regional Accessibility	
T2autotime08M	Auto Accessibility based on Time (T2 TAZ) - in million
LBTIME08	Local Bus Accessibility based on Time - in million
JH05mi08	J/H ratio in 5 miles
Local Accessibility	
LGRSHH	Log (Household Density) within 1/4 mile buffer of residents
LGRSEMP	Log (Job Density) within 1/4 mile buffer of residents
Jobmix2	Diversity (mix of jobs by 13 industries)
WalkaInx1	Street Connectivity: Density of 3-leg and 4-leg intersections, with 3-leg intersections weighted at 0.5 to account for lower level of connectivity offered
TOD	
BS_LBtime	Household within ½ Buffer of Major Bus Stops
RL_LBtime	Household within ½ Buffer of Rail Stations

3-2 Model Estimation

Statistical analysis in this research is used to estimate the value and significance of model coefficients. Tables 2 and 3 present the estimated results of each sub-model. NHTS data used for the model test includes 6,633 households. Each variable is tested to assess whether the coefficient of each variable is significantly different from zero. The P-value associated with the coefficient test is given in the table. The model as a whole is all significant. The following sections summarize the model results by major variables.

<u>Household Socioeconomic Characteristics</u>

Model results present a reasonable association between the composition of household members and each dependent variable estimated. Households with more workers are likely to own more vehicles and make more vehicle trips and VMT. By analyzing workers by age, household VMT is much lower for households with older workers than for younger workers. Model results show that household VMT will be increased by 19.2 miles for each additional worker in the younger age group (16-64), 12.6 miles for younger elderly (65-74), and 10.5 miles for older elderly (75-84).

Similar to workers, household VMT is also much lower for households with each additional non-working older person than younger person. It is reasonable that due to their overall physical condition, the elderly tend to drive shorter distances. However, the household daily trip model shows that the coefficients of non-working elderly variable are marginally lower than the younger, which implies that the elderly are still actively involved in daily life.

Young household members of 15 years old or less have no significant association with vehicle ownership and vehicle trips. They are more likely to be auto passengers and use non-motorized modes - probably for school trips. For those older than 15 years old, the mode choice results in Table 3 show that older people are less likely to use transit and non-motorized modes than the younger, while the mode share for auto passengers is higher with older age.

Median household income is positively associated with the number of vehicles and travel demand. Higher-income households are less likely to use transit and non-motorized modes than lower-income households.

Neighborhood Land Use

Overall, neighborhood land use has a significant and reasonable association with each model. Household density is the most important land use variable. Households in a neighborhood with higher density tend to own fewer cars, have higher shares of using transit trips and non-motorized modes, and drive for shorter VMT than households in a lower-density neighborhood. Households in areas with higher employment density also tend to own fewer vehicles, but they tend to make more daily trips than those in areas with lower employment density. Those excessive trips are probably caused by induced travel that is triggered by better access for local services. The job diversity variable also shows a negative association with vehicle ownership models. Street connectivity is shown to be positive and with a strong association with mode share for the non-motorized mode, and a negative association with vehicle trip making.

Auto Ownership and Transit Access

Both household vehicles and bus stop density show a reasonable relationship with the models estimated. Households with more vehicles tend to use more cars and drive for longer distances. Households in neighborhoods with higher bus stop density show less vehicle use. Transit share and non-motorized modes from the mode choice model have shown a significant and negative relationship with household VMT. Since some areas in the SCAG region do not have frequent transit services, a "no high-quality bus service" dummy is created for analyzing the VMT effect for those areas. Households living in a TAZ without high-quality transit services tend to drive 3.2 miles longer than those living in areas with frequent bus services.

Regional Accessibility

Model results show that accessibility indicators do not have a significant association with the probability to drive a vehicle and daily household trips, but they are significant to other models. Households located in a neighborhood with a higher job-household ratio tend to own fewer cars and are more likely to drive for a shorter VMT. Households in areas with better auto accessibility show lower VMT. Households in areas with better bus accessibility show a higher share of transit trips and non-motorized modes.

Travel Behavior in TOD Area

TOD is an important planning tool in SCAG's RTP/SCS. In terms of the land use and housing plan, there will be more multiple-dwelling housing growth in the TOD areas. It is important to identify the difference in travel behavior between residing inside and outside a TOD community and to include it into the model analysis. According to our past analysis, people living in TOD areas tend to own fewer vehicles, use more transit and walking/bicycling, drive less frequently and have lower VMT than those living outside of TOD areas.

The coefficients of interactive variables with TOD residency and household density are significant in the vehicle ownership model and the vehicle trip model. The result of the household vehicle ownership model shows that the coefficient value of household density is -0.119, and the coefficients for the TOD-density interactive variables are -0.109 for bus TOD, and -0.199 for rail TOD (see Table 2). Therefore, the coefficient of household density for bus-TOD households is calculated as -0.228 (the summation of -0.119 and -0.109). For rail-TOD households, the coefficient is calculated as -0.318.

The coefficients of interactive variables with TOD residency and bus accessibility are significant in the mode choice model for both transit and non-motorized modes. This means that bus accessibility has a larger influence on transit share for TOD residents than non-TOD residents. With all else equal, residents in TOD communities will tend to use more transit and non-motorized modes than residents outside of TOD communities.

The result is consistent with our observation from analyzing NHTS data. For the influence of local household density and bus accessibility on vehicle ownership and travel behavior, TODs around rail stations have a larger influence than TODs around main bus stops; and TODs have a larger influence than non TODs.

Table 2. Model Results of Four Sub-Models

Variable	Description	Household Vehicle Model	Vehicle Trips Model	Daily Total Trip Model	Household VMT Model
Intercept		0.682***	-1.132***	NS	21.880***
WK1664	Worker 16-64	0.791***	1.190***	3.324***	19.199***
WK6574	Worker 65-74	0.744***	1.460***	3.226***	12.600***
WK7584	Worker 75-84	0.675***	1.564***	4.045***	10.468**
NW0015	Non-Worker <= 15	NS	NS	4.270***	3.224***
NW1664	Non-Worker 16-64	0.571***	0.330***	3.000***	9.091***
NW6574	Non-Worker 65-74	0.632***	0.641***	2.857***	5.721***
NW7584	Non-Worker 75-84	0.415***	0.520***	2.857***	NS
P8500	Person 85+	NS	NS	1.600***	NS
INC10K	Median Household Income	0.128***	0.108***	0.210***	1.882***
LGRSHH	Household Density	-0.119***			-1.845***
LGRSEMP	Employment Density	-0.023***		0.091***	
JOBMIX2	Job Diversity	-0.168**			
WALKAINX	Walkability/Street connectivity	-.004***	-0.013***		
HHCAR	Number of household cars		0.702***	0.244***	5.116***
LDLBUSHQ	Frequent Bus Stop density	-0.039***	-0.071*		
NoHQBus	No Bus Stop				3.151***
TR_SHARE	Transit Share of Household Trips				-44.856***
NM_SHARE	NM Share of Household Trips				-29.659***
T2AUTOTIME08M	Auto Accessibility				-96.408***
LBTIME08	Local Bus Accessibility				
JH5MI08	Job/Household Ratio in 5 miles	-0.044*			-2.242*
BS_LGRSH	Bus TOD * LGRSHH	-0.109***	-0.138***		
RL_LGRSH	Rail TOD * LGRSHH	-0.199***	-0.345***		
BS_LBTIME	Bus TOD * LBTIME08				
RL_LBTIME	Rail TOD * LBTIME08				
Mu(1)		1.581***			
Mu(2)		3.060***			
Mu(3)		3.971***			
N		6663	4787	4787	3975
Chi squared		3681			
C value			0.83		
Adj. R square	(McFadden Pseudo R-squared)	0.197		0.502	0.239

Note: ***, **, * ==> Significance at 1%, 5%, 10% level.   NS: Not Significant

Table 3. Model Results of Mode Choice Model

Variable	Description	Auto Passenger	Transit Passenger	Walking or Bicycling	Other Modes
Intercept		-1.336***	-3.273***	-1.574***	-2.928***
WK1664	Worker 16-64	0.116***	0.730***	0.136***	0.166***
WK6574	Worker 65-74	-0.226***	0.537***	NS	-0.340*
WK7584	Worker 75-84	NS	NS	-0.291*	NS
NW0015	Non-Worker <= 15	0.623***	0.209***	0.345***	0.435***
NW1664	Non-Worker 16-64	0.347***	0.520***	0.234***	0.235***
NW6574	Non-Worker 65-74	0.374***	0.434***	0.104**	NS
NW7584	Non-Worker 75-84	0.441***	NS	NS	NS
P8500	Person 85+	0.553***	-0.827***	-0.213**	0.332**
INC10K	Median Household Income	NS	-0.237***	-0.023***	-0.034***
LGRSHH	Household Density	NS	0.127*	0.164***	NS
LGRSEMP	Employment Density	NS	NS	NS	NS
WALKAINX	Walkability/Street connectivity	NS	NS	0.007***	NS
LDLBUSHQ	Frequent Bus Stop density	NS	NS	0.044***	0.114***
HHCAR	Number of household cars	-0.221***	-1.340***	-0.463***	-0.234***
JH5MI08	Job/Household Ratio in 5 miles	-0.118***	0.213**	NS	NS
LBTIME08	Local Bus Accessibility	-1.497**	14.338***	5.967***	NS
BS_LBTIME	Bus TOD * LBTIME08	0.931**	3.168**	1.088**	NS
RL_LBTIME	Rail TOD * LBTIME08	4.104***	4.860***	1.532*	NS
N	40163				
Chi squared	6093.02				
Significance level	0.00				

Note: ***, **, * ==> Significance at 1%, 5%, 10% level. NS: Not Significant

4. ANALYSIS OF REGIONAL VMT BY AGING TREND

SCAG staff allocated socioeconomic data to each parcel for SCAG's 2012 RTP analysis. The dataset include four demographic characteristics that are composed of household size (or the number of household members): total household workers, household non-workers with age younger than 16, age between 16-64 and older than 64. Table 4 shows that the share of non-working elderly is increased from 8.2% in 2008 to 12.9% in 2035. The total population for the non-working elderly of the SCAG region is projected to double between 2008 and 2035.

Table 4. 2008 and 2035 Population Distribution by Working Status and Age

	2008	% 2008	2035	% 2035	08-35	% 08-35
Workers	7,566,870	42.2%	9,201,282	41.5%	1,634,412	-0.7%
Non-worker 16-64	4,202,698	23.4%	4,815,573	21.7%	612,875	-1.7%
Non-worker <16	4,691,659	26.2%	5,310,772	23.9%	619,114	-2.2%
Non-worker >64	1,469,206	8.2%	2,852,794	12.9%	1,383,588	4.7%
Total	17,930,434	100.0%	22,180,422	100.0%	4,249,989	0.0%

Assumption of Test Scenarios

To test how the change of age composition and labor force participation rate of the elderly affects regional VMT, we conducted two year 2035 test scenarios with detailed assumptions on age composition and work participation rate (worker to population ratio) for the elderly. To develop a parcel database for scenario tests, SCAG demographers created allocation factors for both 2008 and 2035 to allocate household workers of each parcel by four age categories: 16-64, 65-74, 75-84, and 85 or older; and allocate non-working household elderly by 65-74, 75-84, and 85 or older. The factors are developed based on the data from U.S. Census and Bureau of Labor Statistics (BLS). Due to the small population proportion, we use total population for the oldest elderly (85+), not by their working status. Table 5 shows the assumptions of both workers and non-workers allocation for 2008 and two 2035 scenarios: Scenario 1 (2035S1) uses the same allocation factor as 2008, and Scenario 2 (2035S2) is based on Census and BLS assumptions. The two 2035 scenarios have the same number of total workers and non-working household members by age, but not by detailed age category for the elderly population. Of the total 9 million workers in the SCAG region in 2035, Scenario 2 shows about a half million more elderly workers than Scenario 1; and has more non-working older elderly (75+) as well as fewer non-working younger elderly (65-74) than Scenario 1.

The overall worker participation rate, measured by the worker to population ratio, is expected to be decreasing between 2008 and 2035 due to a higher proportion of the aging population which has a much lower labor force participation rate than the working age population. However, as discussed in Chapter 2, the future labor force participation rate of the elderly is expected to be higher than the current figure. Table 6 shows data for work participation rate for 2008 and two 2035 scenarios. Overall work participation is shown to be decreasing from 55.1% to 53.0 % between 2008 and 2035.

Both 2035 scenarios share the same overall work participation rate. Scenario 2 has a higher participation rate for the elderly than the 2008 figure, which is a reasonable assumption and consistent with BLS projections. Scenario 1 data is developed based on the 2008 proportion, which is similar to most transportation modeling assumptions – aging status is not considered.

Table 5. Assumption of Worker and Non-Worker Allocation

	2008	2035S1	2035S2	2008	2035S1	2035S2	S2-S1
Worker 16-64	96.7%	96.7%	90.7%	7,314,493	8,894,393	8,346,994	-547,399
Worker 65-74	2.7%	2.7%	6.4%	202,257	245,943	591,301	345,357
Worker 75-84	0.6%	0.6%	2.4%	41,922	50,976	221,351	170,375
Worker >84	0.1%	0.1%	0.5%	8,199	9,970	41,637	31,667
Total Worker	100.0%	100.0%	100.0%	7,566,870	9,201,282	9,201,282	0
Non-worker 65-74	50.0%	50.0%	45.7%	733,906	1,425,044	1,303,315	-121,729
Non-worker 75-84	34.8%	34.8%	37.8%	510,757	991,749	1,078,384	86,635
Non-worker > 84	15.3%	15.3%	16.5%	224,543	436,001	471,095	35,095
Non-worker >64	100.0%	100.0%	100.0%	1,469,206	2,852,794	2,852,794	0
Persons >84	1.3%	2.0%	2.3%	232,742	445,970	512,732	66,762

Table 6 Work Participation Rate by Scenario

	2008	2035S1	2035S2
Total	55.1%	53.0%	53.0%
16-64	60.9%	62.6%	61.1%
> 64	14.6%	9.7%	23.0%
65-74	21.6%	14.7%	31.2%
75-84	7.6%	4.9%	17.0%
> 84	3.5%	2.2%	8.1%

Model Results

Table 7 shows the model results for 2008, 2035 Plan, and 2035 Scenarios 1 and 2. The Plan model output was developed by SCAG’s 2012 RTP/SCS program, reflecting high-density, mixed use, and TOD type of development. Model results for 2008 and 2035 Plan were estimated by the parcel-based model used for SCAG's 2012 RTP/SCS. The model results have shown a marginal reduction in average household vehicle ownership and daily household trips, but a more significant increase in mode share for transit and non-motorized modes, which is generally reflective of SCS land use patterns. The most important factor to examine the potential impact of SCS land use policy on GHG emissions is VMT per household. Table 4-5 shows that 2035 Plan VMT per household has shown a 9.7% reduction from the 2008 figure. SCAG model results have shown that the SCS plan met GHG emissions targets.

The scenario test has shown interesting results. Scenario 1 that reflects the same number of workers and non-working elderly as the Plan, but has detailed age category for the elderly based on 2008 proportion does not show much difference from the Plan result. Scenario 2, with the same number of total workers and non-working elderly as Plan and Scenario 1 but with reasonable assumptions on future population growth and labor force participation rate to elderly for each major age category, has shown very different results. With detailed and reasonable elderly projections and assumptions, the results of Scenario 2 do not show a reduction in vehicle use and total trips during a day. Compared to the Plan result, Scenario 2 shows a reduction in mode share for transit and non-motorized modes. Though the reduction is marginal, it reasonably reflects the fact that transit and non-motorized modes are not favorite modes of the elderly. Table 8 also shows a significant reduction in regional VMT as well as VMT per household. An additional 6 million VMT will be reduced due to aging trends, and an additional 1.3% reduction in VMT per household.

Table 7. Model Results of Scenario Tests

	2008	2035Plan	2035S1	2035S2
Household Vehicles	2.19	2.13	2.14	2.13
% Vehicle Trip Making	80.40%	80.54%	80.52%	80.48%
Daily Total Trips	11.96	11.65	11.68	11.67
Model Share				
Auto Driver	55.80%	55.00%	54.98%	55.50%
Auto Passenger	26.70%	25.10%	25.14%	24.87%
Transit Rider	1.30%	2.00%	1.93%	1.89%
Non-Motorized Mode	13.80%	15.70%	15.75%	15.58%
Other Modes	2.40%	2.20%	2.21%	2.16%
Total VMT	374,033,557	425,286,388	424,765,835	419,200,286
Households	5,812,319	7,321,030	7,321,030	7,321,030
VMT per Household	64.35	58.09	58.02	57.26

Table 8. Comparison of 2035 Model Output

	2008	2035 Plan	2035 Scenario 1	2035 Scenario 2
VMT	374,033,557	425,286,388	424,765,835	419,200,286
VMT/Household	64.35	58.09	58.02	57.26
Percentage Reduction in VMT/HH from 2008	--	-9.73%	-9.84%	-11.02%
Reduction in VMT from 2035 Plan	--	--	-520,553	-6,086,102

5. SUMMARY & CONCLUSION

A regional transportation model is used to estimate future travel demand and analyze travel patterns from different plans or policies. Since travel is made by people, a transportation model needs input on the future growth and distribution of population and jobs. The change in demographic characteristics, such as the increasing share of aging population, is becoming an important factor for estimating future travel demand. Based on the analysis of 2009 NHTS data, we understand that future increase of elderly population will reduce travel distance by vehicles. But the question is how we quantify the impact.

Another factor that has important implication on future transportation planning is land use policy. The relationship between land use and transportation is becoming an important concern for planners when dealing with worsening congestion and air pollution. SCAG has developed a parcel-based model that can quantify the impact of land use patterns on travel patterns and VMT, an indirect measurement of GHG emissions. This research attempts to modify the parcel-based model so it can analyze the impact of aging trends in Southern California on vehicle use and VMT, while land use characteristics and other factors are controlled.

Data for testing the aging growth scenario for year 2035 was developed, based on assumptions of the detailed age composition and work participation rate. VMT estimated by the model with the reasonable aging assumption is about 6 million miles lower the VMT estimated by the model without considering future aging trend. Furthermore, the model result shows that VMT per household is about 11% lower than 2008, which is 1.3% lower than the model without aging assumptions. The implication is important: regional planners or transportation modelers need to understand the dynamics of demographic characteristics of their region, and should consider the interaction between demographic change and travel behavior. If the change in demographic composition is large in the future, it might have significant impacts on the transportation plan. Our analysis to estimate the impact of future increases in Hispanic households as well as their assimilation influence on travel patterns in Southern California has similar findings (presented at the TRB Modeling conference).

SCAG is developing an activity-based travel demand model. Compared to the existing four-step trip-based model, an activity-based model can simulate travel behavior because ABM is input with detailed demographic and economic characteristics for each household and person of the region. Age is one of the person variables in the SCAG ABM. Therefore, the result of this research can provide justification to explain the difference of model results between ABM and TBM.

Although the model used in this research can perform reasonable estimates of VMT, further analysis, testing, and improvement are needed. First, since the model is household or production based, it cannot estimate travel impact generated by non-residential land use or from the trip-attraction side, such as a new shopping center development. Second, this model does not consider the interaction between land use characteristics and travel behavior by different age groups. We should further analyze topics such as residential choice of the elderly, aging in place, gentrification, and the land use-transportation travel behavior relationship of the elderly. Third, it is necessary to improve and enhance the parcel-level database on socioeconomic data or land use characteristics. Finally, a calibration procedure may be needed. We can examine the model with SCAG's 2011-12 household travel survey.

The model has also been an important part of SCAG's assessment of the full potential of its Sustainable Communities Strategy to accomplish the GHG reductions required under SB 375. If future projections and assumptions of aging trends are refined, the model can estimate GHG emission reductions, with the consideration of both demographic composition and land use characteristics.

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