Exploring the Methods of Estimating Vehicle Miles of Travel

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1 INTRODUCTION

California's Sustainable Communities and Climate Protection Act or Senate Bill No. 375 (SB 375) is the nation's first law to control greenhouse gas emissions (GHG) through coordination between land use planning and transportation planning. SB 375 requires California's Air Resources Board (ARB) to develop regional reduction targets for greenhouse gas emissions (GHG) for California's Metropolitan Planning Organizations (MPOs). MPOs are required to develop "Sustainable Community Strategies" (SCS) through integrated land use and transportation planning, and demonstrate an ability to attain the proposed reduction targets by 2020 and 2035. The target of emission reduction focuses on both passenger vehicles and light-duty trucks. A common approach to measure the effectiveness of various SCS is to examine the associated vehicle miles travelled (VMT) of each strategy.

1.1 SCAG Year 2012 RTP/SCS

Southern California Association of Governments (SCAG) is tasked with developing a SCS as an element of the agency's new long-term Regional Transportation Plan (2012 RTP/SCS). ARB issued a target of per capita GHG emission reduction from year 2005: 8% reductions for 2020, and a conditional target of 13% for 2035. To estimate emission reductions from different land use and transportation strategies developed by SCS, a regional travel demand model is used to estimate vehicle flows and speed data as input to an emission model.

Variables that represent characteristics of local or neighborhood-level land use such as density, diversity, and design should be included in the travel demand model to estimates their effects on vehicle use. SCAG's travel demand model has incorporated a mixed density variable that is a composite measure of household, employment, and intersection density. In order to meet the emission reduction target, it is important that the SCAG model is sensitive to the SCS land use scenario so that GHG emission reductions won't be underestimated.

In general, the size of transportation analysis zones (TAZs) used for most of the travel demand models provide a too generalized expression of local land use and built environment are too varied to represent variations among residential neighborhoods. As a result, those models may not accurately estimate land use impact or not with sufficient sensitivity to land use characteristics. Since TAZs of SCAG's travel demand model is developed based on Census

Block geography, the model may not be able to reflect the impact of land use scenarios from SCS strategies to accurately capture the percentage GHG reductions required under SB 375.

Since GHG emission is directly linked to travel distance of a vehicle, VMT can be used to estimate overall emission levels. Even without running an emission model, the difference of GHG emission can be estimated through the comparison of VMT estimated by different scenarios. An alternative modeling approach can be used for examining land use – GHG emission if VMT can be estimated. In order to accurately estimate the effect of SCS on GHG emission reduction, an alternative model that can show land use – VMT is developed in this research.

1.2 Research Purpose

The purpose of this research is to develop a statistical model to estimate total household VMT. This model should be sensitive and accurately reflect land use characteristics, so it can be a supplemental tool which augments SCAG's trip-based regional model. This model, termed the NHTS Model, is estimated by statistical modeling using the 2009 National Household Travel Survey (NHTS). The model will use parcel-level input data to estimate VMT for different scenarios.

1.3 Structure of this Paper

This paper has six sections. The next section describes past literature on land use- travel behavior relationships. Section 3 describes the research methodology and data sources. Section 4 summarizes model results. Section 5 shows model validation and sensitivity tests and provides a comparison to the trip-based model. Section 6 summarizes conclusions and further analysis. The model results show that land use factors are sensitive to VMT. Compared to the model output of SCAG's trip-based model, this statistical model has shown an additional 2% reduction in per capita VMT.

2. REVIEW OF PAST LAND USE – TRAVEL BEHAVIOR RESEARCH

The analysis of travel behavior is based on the concept that travel is a derived demand for activity participation. People travel to a place where they want to engage in an activity in order to satisfy their physical and psychological needs. Chapin (1974) argued that an individual's desire for human needs creates the motivation to engage in an activity, and an individual travels to a place where supports such an activity. Accordingly, travel is explained as the outcome of the interaction between demand for and supply of an activity. The demand for an activity is viewed as an individual's propensity or motivation to engage in the activity (e.g., shopping for food), while supply of an activity refers to opportunities or spatial distribution of the activity (e.g., supermarket, grocery stores). Chapin's research suggested that travel demand is linked to an individual's propensity to travel that is linked to his or her socioeconomic status, such as age, gender and income, and the role in family or society.

In his work published in 1970, Hägerstrand introduced the concept of time-space interaction of human activity. It was based on the idea that a person would travel to access activities by moving through both space and time. By considering the engagement of human activity from the angle of constraints, his study on activity constraints has provided a comprehensive foundation to analyze travel behavior in a time-space context. The integration of the concept developed by Chapin and Hägerstrand provides a reasonable approach to analyze travel behavior as an interaction among propensity to an activity (demand), opportunities or activity distribution (supply), and activity constraints in time and space. Once an individual decides the need for an activity, the travel decision to an activity place is made based on the consideration of estimated travel time by available transportation modes, available time for activity participation, and their interaction with an activity that comes next.

The analysis of land use-transportation relationships is traced back to the research by Pushkarev and Zupan (1977). They concluded that transit use increases with higher population density based on data of urbanized areas in the U.S. According to research by Newman and Kenworthy (1989a, 1989b), it was found that as residential density increases, automobile use, trip length, and gasoline consumption decline. Many studies in this field have appeared in the literature since 1990s, but these works have been criticized by using average values to measure land use characteristics (e.g. average density) and the causality issue between land use and travel behavior (Handy, 2005).

It is generally assumed that land use characteristics of residential neighborhoods will influence one's choice on vehicle ownership and daily travel decisions. Past research has identified that some land use factors are linked to travel characteristics. They include density, variety and accessibility of activity, and neighborhood design. The proximity to a transit center or living in a transit-oriented development (TOD) type of community is also shown to influence different travel characteristics.

Density is commonly used as a simple measure of built form for metropolitan areas or neighborhoods. Because activity places are more concentrated in high-density areas, travel distances tend to be shorter in those areas. Higher density is also associated with more use of transit service due to better service quality. As the demand for transit service increases with higher density, more services will be provided. Furthermore, using a car is difficult in high-density neighborhoods because parking spaces are scarce and expensive, and local streets are congested. Consequently, travel patterns in higher residential density areas exhibit shorter travel distances, less automobile use, and more use of transit compared to areas with lower residential density.

The different types of land uses within close proximity to one's residence is also found to be associated with reduced vehicle trips, lower rates of auto ownership, and increased use of alternative modes such as walking or public transit (Frank & Pivo, 1995; Cervero, 1996; Cervero & Kockelman, 1997; Hess & Ong, 2002). In addition, design factors such as site design, street connectivity, and presence or completeness of pedestrian facilities (i.e., block size, street pattern, and sidewalk length) are found to affect the propensity to use non-motorized travel (Handy, 1996; Moudon, Hess, Snyder, & Stanilov, 1997). Accessibility to destinations, defined as the number of opportunities available within a certain distance or travel time (Hanson, 1995), is also an important land use factor affecting trip length, trip frequency, and mode choice. Cervero and Duncan (2006) found that enhanced accessibility to jobs was associated with reduced vehicular travel length and time.

By analyzing 2009 NHTS data, SCAG staff found that the effect of residential density on travel patterns is larger for those residing in TOD communities than outside TOD communities. The result shows the land use – travel behavior relationship is more profound for TOD residents. Though there is a concern about the self-selection issue, it is believed that this influence will be reduced in the future due to a larger housing supply in TOD areas and more investment on transit services.

3. RESEARCH APPROACH AND METHODS

The review of travel behavior theory in Section 2 has laid out a foundation to establish a conceptual model for this research. A travel decision is made by the interaction of activity demand, supply of opportunities, and activity constraints (Giuliano, 2000). Activity demand, which results from an individual's needs and propensity to engage in an activity, is related to one's socioeconomic status. Land use characteristics that affect the spatial distribution of activity places are linked to the supply side of activities. Because travel patterns are directly related to the types of transportation mode used by a traveler, travel capability that refers to the ease or difficulty for people to use a certain mode need to be included in the analysis. Finally, residential location within a TOD community is found to have a more profound association with travel behavior.

3.1 Modeling Approach

According to choice hierarchy theory (Ben-Akiva, 1977; Salomon, 1982), a travel decision is described as a sequential process from long-term life style choice, to mid-term mobility choice, and to short-term travel choice. Thus, a short-term travel decision on daily activities, destinations and travel modes is dependent on the earlier (mid-term) decision on residential location, housing type and car ownership. An individual's travel is the "outcome of a short-term decision given household car ownership and residential location (Giuliano and Dragay, 2005, p.7)."

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/trip 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:

3.1.1 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.

3.1.2 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.

3.1.3 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.

3.1.4 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.

3.1.5 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 in Section 3.1.2.

3.2 Data Source and Variable Description

The 2009 National Household Travel Survey (NHTS) is used as the primary data for the model estimate. The NHTS is a household-based travel survey conducted periodically by the Federal Highway Administration (FHWA). California Department of Transportation (Caltrans) purchased an add-on sample, and provided the confidential data to SCAG. The 2009 NHTS data includes approximately 6,700 households and 15,000 persons, and the travel diary data includes a total of 55,000 trips. This survey was completed in 2008 and represents the most current travel survey data for the SCAG region. Information extracted from the NHTS for use in this evaluation includes household VMT, trips by mode, auto ownership, and household socioeconomic characteristics including the number of household members by working status and age cohorts, and median household income. NHTS confidential data includes latitude and longitude information for each sampled household. Variables such as neighborhood land use or regional accessibility that are processed by other data sources can be linked to each NHTS household for model estimation. The model developed in this research is named as the NHTS Model. The data sources and variables used in this research are described below (also shown in Table 3-1).

3.2.1 Dependent Variables

The number of household vehicles and mode use of each trip is directly extracted from the NHTS household file and trip file. Total household daily trips, the number of vehicle trips, and household VMT are computed by aggregating from trip data to each sampled household. Household VMT that is greater than 250 miles is excluded to avoid extremely large numbers.

3.2.2 Independent Variables

Three groups of independent variables include 1) socioeconomic characteristics, 2) travel capability, and 3) land use characteristics.

3.2.2.1 Household Socioeconomic Characteristics

Socioeconomic characteristics refer to individual and household attributes that influence travel demand. Socioeconomic variables used in this study include the number of workers in a household, the number of non-workers by three age cohorts (below 16, 16-64, and 65 or older), and median household income. All household socioeconomic data is from 2009 NHTS data.

It is reasonable to expect that a household with more household members will have a higher demand on vehicle use. However, different household structures or household member compositions will have different demand on using a car. For example, workers usually have higher demand on using a car than non-workers because of their needs for commuting. Among non-workers, adults between 16 and 64 years old are more likely to use a car than the elderly because of their family responsibilities. In addition, a household with school-age children will have additional demand for pick-up/drop off to school activities. Household income is one of the most influential factors in explaining the capability of activity engagement because higher income reflects more resources available or expenditure capability to engage in activities. Higher income also implies more resources for owning and using a car. Therefore, households with higher incomes are expected to have a higher demand for travel and use more cars than those with lower incomes.

3.2.2.2 Travel Capability

Travel capability refers to the availability of a transportation mode, such as one's ability to use a mode (i.e., car availability) in a household, or the nearness of one's residence to a transit stop. The number of household vehicles is from NHTS data. Bus stop density for high-quality local bus service is created from a ¼ mile buffer of each NHTS household. Using SCAG's 2008 transit network data, high-quality local bus is defined as a less than 20 minute headway for local bus service.

The use of non-motorized modes has important implications on regional planning. There is not enough detailed data to represent the easiness to use non-motorized modes, such as walking and biking. However, the output of the mode choice model for non-motorized modes can be used as an approximate measure about the easiness to walk. If a household has higher share of non-motorized travel, their reliance on driving will be lower as will be their VMT.

3.2.3 Land Use Characteristics

Land use characteristics are related to residential and activity distributions which directly affects travel costs and accessibility. Land use at the regional level is largely related to job opportunities, the specialization and variety of goods, and services that are not available locally. Neighborhood land use is related to the proximity to local opportunities, such as personal services, local retail and shopping, and social networks. Past research has identified several primary land use and built environment characteristics known as the "D" variables that are associated with travel behavior: residential/employment density (Density), employment or land use diversity (Diversity), local network connection (Design), distance of transit (Distance), and employment/opportunities accessibility (Destination). This research defines distance to transit as one of the travel capability variables.

3.2.3.1 Regional Land Use Characteristics

Using SCAG regional model output for the 2012 RTP, two gravity-model types of accessibility indicators, with travel time as an impedance value, are calculated: auto accessibility is used as an independent variable in the VMT model, and local bus accessibility is used in the mode choice model. Zone-to-zone travel time used in the accessibility calculation reflects the traffic condition of the transportation network, which is very useful to this production-based modeling analysis.

A job-household ratio within 5 miles of each TAZ is also measured. A low ratio implies a higher possibility for workers to commute outside of a 5 miles boundary from their home, and regional services or shopping centers are also less available. They are more likely to use a car and drive a longer distance, compared to those who live in high regional accessibility areas.

3.2.3.2 Local Land Use Characteristics

A set of land use data was developed for a ¼ mile buffer of each NHTS household. Population density, employment density and job diversity were developed based on SCAG 2008 parcel database and 2008 InfoUSA employment data. Local street connectivity was calculated by the sum of 3-leg nodes (weighted by 0.5) and 4-leg nodes (weighted by 1) based on the SCAG street network.

It is hypothesized that a higher population density with a greater concentration of residences could reduce the distance to access local activities and transit services. It is expected that as population density increases, both household trips and VMT will decrease accordingly. Employment density and job diversity are a measure of the concentration and variety of local services and activities. Higher local employment density and diversity means that more opportunities for daily needs are available in the neighborhood area. Residents can travel a shorter distance or use non-motorized modes if they decide to shop locally. As a result, less vehicle use and shorter vehicle travel distances are expected with a higher value of local employment density and diversity. Finally, higher street connectivity also implies better walkability because it is easier for pedestrians cross streets. In addition, walking distance will be shorter with higher local street connectivity.

In order to avoid a skewed distribution problem that will affect the validity of statistical model estimates, some variables such as household density, employment density, and bus stop density are transformed to log form.

3.2.4 TOD Residency and Interactive Variables

TOD is an important planning element 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 analysis, people living in TOD areas tend to own fewer vehicles, use more transit and walking/bicycling, drive less frequently and have lowerVMT then those living outside of TOD areas.

A model approach that uses TOD residency as an interaction variable provides a direct way to analyze travel behavior for TOD residency. If the travel behavior of the TOD households is more sensitive to land use than non-TOD households, the coefficients of the interaction terms to the TOD will be significant, meaning that land use could have different effects on travel behavior. As a result, land use may have a beneficial effect to the TOD residents who want to take advantage of better transit services and other TOD characteristics.

Two types of TOD communities are defined: within a ½ mile buffer of major bus services, and within a ½ mile buffer of a rail station. A simple way to identify the TOD effect is to create a dummy variable in the model analysis. In order to have a better understanding about how TOD influences travel behavior, we tested an interaction effect between TOD residency and all other variables used in the analysis. Test results show that TOD residency has a significant interaction with household density and bus accessibility. It is assumed that high household density and bus accessibility have a more profound association with travel behavior for TOD households than non-TOD households.

4. MODEL RESULTS

Statistical analysis in this research is used to estimate the value and significance of model coefficients. Tables 4-1 to 4-5 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.

A number of tests are conducted to avoid biased estimates. Correlation analysis of all models is tested among all variables. The results show no high correlation among the variables used. The variance inflation factor (VIF) is calculated to quantify the severity of multicollinearity in an ordinary least squares regression analysis. Model results do not show serious multicollinearity in the model estimate.

The number of household vehicles estimated by the vehicle ownership model is used as an independent variable by other sub-models. Since the vehicle ownership model contains variables that are used by other sub-models, it might cause a multicollinearity issue. A correlation test shows that the predicted vehicle ownership has low to moderate correlation with other variables.

The following sections summarize the model results by major independent variables.

4.1 Socioeconomic Variables

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. On average, each additional worker will add 19 VMT. Among non-working household members, the younger (below 16) members have no significant association with vehicle ownership and vehicle trips. The elderly have shown a reliance on using a car and are less likely to use transit services or non-motorized modes. This is reasonable due to the overall physical condition of the elderly. In addition, the household daily trip model has shown that the coefficient of non-working elderly variable (2.53) is marginally lower than non-working adults (2.99), which implies that the elderly are still actively involved in daily life. 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.

4.2 Travel Capability Variables

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 of 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 a TAZ without high-quality transit services tend to drive 3.2 miles longer than those living in areas with frequent bus services.

4.3 Land Use Variables

As described in 3.2.3.2, three accessibility indicators are created for the model estimate. The 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 bus accessibility show a higher share of transit trips and non-motorized modes.

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 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.

4.4 Interactive Variables

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 (Table 4.1) shows that the coefficient value of household density is -0.122, and the coefficients for the TOD-density interactive variables are -0.227 for bus TOD, and -0.318 for rail TOD. Therefore, the coefficient of household density for bus-TOD households is calculated as -0.349 (the summation of -0.122 and -0.227). For rail-TOD households, the coefficient is calculated as -0.44.

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.

5 MODEL TEST AND ANALYSIS

This section presents the model validity test, sensitivity tests on VMT, and a comparison with 2012 RTP/SCS model output from SCAG regional model.

5.1 Model Validity Test

To test model quality, we apply the estimated equation back to the NHTS data to calculate the predicted value for each sampled household. Mean predicted values are compared to mean observed values by 1) household size, 2) SCAG counties 3) neighborhood density, and

4) inside/outside TOD areas. Tables 5-1 to 5-6 show the comparison of the observed value and predicted value for each of the models. For the mode choice model, transit share and non-motorized share are presented in Tables 5-4 and 5-5. Charts 5-1 to 5-6 show the validity comparison by household density. The results show that the predicted values calculated by the models are consistent with the observed values from NHTS households. However, transit share and non-motorized share tend to be under-estimated by the mode choice model for households in high-density neighborhoods. This is probably due to the lack of detailed transit service data and infrastructure information for walking and bicycling for those high-density areas.

The validation test for VMT shows that the predicted household VMT tends to be lower than the observed VMT for higher-density areas. The difference will be adjusted in the model validation procedure, which will be described in Section 5-3. Overall, predicted household VMT is very close to observed values.

5.2 VMT Sensitivity Test

Since the purpose of this research is to develop a modeling procedure that is VMT sensitive to land use factors, the model sensitivity test on VMT involved a comparison between the elasticities estimated from the NHTS Model as compared to the values from several sources including research from the California ARB and a national analysis of the D's effects. The purpose of this test is to verify that the relationships identified in the household VMT model are within the range of values observed elsewhere in a variety of sources.

The statewide values were extracted from research compiled for the ARB by researchers at UC Irvine and UC Davis. The national elasticities are taken from a meta-analysis compiled by Robert Cervero and Reid Ewing and reflect a summary of the D's based on a wide cross-section of studies. Table 5-7 documents this comparison and indicates that a majority of the elasticities calculated from the NHTS Model are within the range of observed values from these two sources.

5.3 Model Comparison

In order to compare the results between the NHTS model estimated from this research and a regional travel demand model currently used by SCAG, we tested both models with the same set of input data that was developed as model input data for the 2012 RTP/SCS. Two tests were conducted: 1.) a comparison ofhousehold VMT for year of 2008 and 2.) a test of the VMT difference for the year 2035.

5.3.1 Comparison for Year 2008

Since the NHTS Model is designed for using disaggregated data, SCAG staff developed a parcel-level socioeconomic database that is well controlled by the TAZ-level data. The parcel data includes the number of household members by working status, three age cohorts, and median household income. A ¼ mile buffer is created to calculate household density and employment for each parcel. TOD location is also identified by each parcel. For some data that currently cannot be created at the parcel level, TAZ-level data is used. Accessibility is calculated based on the output data of the trip-based model.

SCAG's forecasting staff developed a set of socioeconomic data by SCAG's 11,267 TAZs for the 2008 base year and all of the forecasted years with different land use scenarios. The data is used as input for SCAG's trip-based model which is the model that is used for the RTP/SCS analysis. Since VMT calculated from the trip-based model is network based, a residents-based VMT that is consistent with household-based VMT estimated from NHTS Model was developed for this analysis. VMT estimated for each parcel from the NHTS Model was aggregated to the TAZ or larger geography in order to be compared to the trip-based model.

5.3.1.1 Correlation Analysis

The high correlation in VMT between the NHTS Model and the trip-based model implies the consistency of the two models. The correlation is tested by SCAG's 11,267 TAZs (tier 2), 4109 TAZs (tier 1), and by two aggregated zonal systems used for sketch planning purpose - 302 Community Statistical Areas (CSAs), and 56 Regional Statistical Areas (RSAs). Table 5-8 shows the result of the correlation analysis. The correlation coefficient ranges from 0.91 for 11267 tier-2 TAZs to 0.98 for 56 RSAs.   A value of correlation above 0.9 is considered high, which implies that the NHTS model is consistent with the trip-based model.

5.3.1.2 Model Validation to HPMS VMT

The regional VMT for year 2008 estimated from NHTS Model is about 20 percent lower than a regional VMT control that is calculated based on the Highway Performance Monitoring

System (HPMS) program. The HPMS VMT for year 2008 is used for SCAG's model validation. Since residents-based VMT used for this research has been controlled to HPMS VMT, a conversion factor was created for the NHTS Model. Because the correlation is high at the RSA level between the both models, we decided to create conversion factors for 56 RSAs so that both models are more closely linked than using only one conversion factor calculated from total regional VMT. In this case, both models are controlled to the same VMT for the 2008 base year. The conversion factors will be applied to forecasting years so that the NHTS Model can be compared to the regional model for future years.

5.3.2 Comparison for Year 2035

We tested a 2035 Plan scenario for SCAG's 2012 RTP/SCS. The Plan scenario was developed by SCAG's SCS program, reflecting high-density, mixed use, and TOD type of development. Both the NHTS Model and trip-based model use the same socioeconomic data that is controlled at the TAZ level. This test is to compare the results of the trip-based model and the NHTS Model for the same scenarios. This allows us to estimate the level of land use variable sensitivity that is not captured in the trip model. Tale 5-9 shows this comparison. Both sets of results exclude the effects of other strategies such as TDM and active transportation. As indicated in the table, when both the trip-based model and the NHTS Model are applied to the same database, the additional reduction in VMT associated with the NHTS Model is about 2.4%.

Table 5-10 presents output of other sub-models for both the 2008 and 2035 SCS. The table shows, between 2008 and 2035, a reduction in household vehicles and share of vehicle use, and an increase in the transit and non-motorized share, which is consistent with the declining pattern of VMT per household.

There are several factors contributing to the lower VMT estimated by NHTS Model: 1) the NHTS model is sensitive to land use and built environment factors while the trip-based model has limited land use variables to provide the sensitivity, 2) the NHTS Model uses parcel level data that is a more accurate measure of neighborhood household density and employment density while the trip-based model calculate gross density by TAZ data, 3) the NHTS Model is able to show the difference in people's travel behavior inside and outside of TOD areas, 4) the NHTS Model is estimated based on2008 travel survey data, which is the most current data. The trip-based model is estimated by SCAG's 2001 household survey. Due to several new urban rail services that became available after 2000, people's travel behavior might be affected by TOD and transit use, 5) the NHTS Model is estimated based on 1/4 mile buffer land use data, which can better reflect the land use-transportation relationship.

6. SUMMARY & CONCLUSION

The relationship between land use and transportation is becoming an important concern for planners when dealing with worsening congestion and air pollution. One major challenge for planners is that there is no appropriate tool for them to fully quantify the impact of different land use patterns. This research attempts to develop a model that can analyze the impact of lane land use on vehicle use.

By analyzing travel behavior data from 2009 NHTS data, a sequential modeling approach with five sub-models, called the SCAG NHTS Model, was developed to estimate the land use – travel behavior relationship, particularly for household VMT. The test for model validity and sensitivity has shown that the NHTS Model produces reasonable and accountable results and is sensitive to land use characteristics. The NHTS Model also can produce similar model results to SCAG's trip-based model. After running the model with SCAG 2012 Plan scenario data, it is shown that household VMT estimated from NHTS Model is about 2.4 % lower than that of the trip-based model.

Although the model 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, commuting travel is less likely to be affected by land use planning. As a result, additional analysis on the home-based work and non-work purpose is needed. Third, it is necessary to improve and enhance the parcel-level database in terms of socioeconomic data or land used characteristics. Fourth, a gentrification effect or self-selection should be considered. Finally, a calibration procedure may be needed, especially for household vehicle ownership as well as transit share and non-motorized mode share.

This model can be modified or expanded to analyze different transportation planning topic. Our future plan is to enhance the model for analyzing other planning topics that are related to land use, such as health impact and water demand. Since it takes a lot of effort to prepare parcel data, this model can be easily converted to a sketch model that can use TAZ data. The sketch model can quickly estimate travel impact by difference land use scenario.

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.

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Table 3-1 Variable Description

Variable	Description
Socioeconomic Characteristics	
WKER	Number of Household Workers
NW0015	Number of Household Members (< 16 yr old)
NW1664	Number of Household Members (16-64 yr old)
NW6500	Number of Household Members (> 64 yr old)
INC10K	Median Household income in $10,000 (in $1999)
Travel Capability	
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 millions
LBTIME08	Local Bus Accessibility based on Time - in millions
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	
BUS TOD	Households within ½ Buffer of Major Bus Stops
RAIL TOD	Households within ½ Buffer of Rail Stations

Table 4-1 Household Vehicle Ownership Model

Variable	Description	Coeff.	Standard Error	z	Prob. |z|>Z*
Intercept		0.643	0.086	7.460	0.000
WKER	Number of Household Workers	0.785	0.02	38.6	0.00
NW0015	Number of Household Members (< 16 yr old)	-0.010	0.021	-0.47	0.00
NW1664	Number of Household Members (16-64 yr old)	0.575	0.023	25.44	0.64
NW6500	Number of Household Members (> 64 yr old)	0.480	0.026	18.32	0.00
INC10K	Median Household Income in $10,000 (in $1999)	0.130	0.005	25.73	0.00
LGRSHH	Log (Household Density) within 1/4 mile buffer of residents	-0.122	0.018	-6.66	0.00
LGRSEMP	Log (Job Density) within 1/4 mile buffer of residents	-0.021	0.007	-2.88	0.00
JOBMIX2	Diversity by (Tier2 TAZ)	-0.147	0.078	-1.9	0.00
WALKAINX	Walkability/Street connect (Density of 3-leg and 4-leg intersections	-0.005	0.001	-3.21	0.06
LDLBUSHQ	Log of Frequent Bus Stop density (Tier 2 TAZ - headway <= 20 minutes)	-0.040	0.014	-2.89	0.00
JH5MI08	Job/HH Ratio in 5 miles	-0.047	0.024	-1.98	0.00
BS_LGRSH	Bus TOD * LGRSHH	-0.105	0.02	-5.22	0.05
RL_LGRSH	Rail TOD * LGRSHH	-0.196	0.037	-5.26	0.00
Mu(1)		1.560	0.021	75.59	
Mu(2)		3.028	0.019	157.35	0.00
Mu(3)		3.937	0.025	155.99	0.00
Model	Ordered Probit Model				
Dep Var	HHCAR1 (0, 1, 2, 3, 4+)				
N		6,663			
Chi squared		3,597.25			
Significance level		0.000			
McFadden Pseudo R-squared		0.192			

Table 4-2 Probability of Vehicle Trips

Variable	Description	Coeff.	Standard Error	Wald Chi-Sqr.	Prob. > ChiSq
INTERCEPT		-1.158	0.217	28.57	<.0001
WKER	Number of Household Workers	1.211	0.099	148.66	<.0001
NW0015	Number of Household Members (< 16 yr old)	0.113	0.087	1.68	0.20
NW1664	Number of Household Members (16-64 yr old)	0.320	0.088	13.27	0.00
NW6500	Number of Household Members (> 64 yr old)	0.511	0.091	31.57	<.0001
INC10K	Median Household Income in $10,000 (in $1999)	0.109	0.02	30.00	<.0001
HHCAR	Household Cars	0.723	0.064	127.78	<.0001
WALKAINX1	Walkability/Street connect (Density of 3-leg and 4-leg intersections	-0.013	0.004	8.66	0.00
LDLBUSHQ	Log of Frequent Bus Stop density (Tier 2 TAZ - headway <= 20 minutes)	-0.073	0.044	2.76	0.10
BS_LGRSHH	Bus TOD * LGRSHH	-0.134	0.055	5.98	0.02
RL_LGRSHH	Rail TOD * LGRSHH	-0.341	0.093	13.55	0.00
Model	Binary Logit Model				
Dep Var	1 = Household makes at least 1 vehicle trip				
N		4,787			
Somers'D		0.662			
C value		0.831			

Table 4-3 Household Daily Trips Model

Variable	Description	Coeff.	Standard Error	t	Prob. > [t]
INTERCEPT		-0.158	0.200	-0.79	0.431
WKER	Number of Household Workers	3.303	0.107	30.96	<.0001
NW0015	Number of Household Members (< 16 yr old)	4.273	0.105	40.83	<.0001
NW1664	Number of Household Members (16-64 yr old)	2.986	0.116	25.7	<.0001
NW6500	Number of Household Members (> 64 yr old)	2.532	0.132	19.22	<.0001
INC10K	Median Household Income in $10,000 (in $1999)	0.214	0.026	8.32	<.0001
LGRSEMP	Log (Job Density) with 1/4 mile buffer of residents	0.093	0.032	2.92	0.00
HHCAR	Household Cars	0.274	0.077	3.55	0.00
Model	Ordinary Least Square				
Dep Var	Household Trips				
N		4,786			
F value		685.14			
Pr>F		<0.0001			
Adj. R square		0.50			

Table 4-4 Mode Choice Model

1. Auto Passenger Component

Variable	Description	Coeff.	Standard Error	z	Prob. |z|>Z*
Intercept		-1.371	0.080	-17.110	0.000
WKER	Number of Household Workers	0.116	0.019	6	0.000
NW0015	Number of Household Members (< 16 yr old)	0.635	0.015	43.46	0.000
NW1664	Number of Household Members (16-64 yr old)	0.362	0.02	18.16	0.000
NW6500	Number of Household Members (> 64 yr old)	0.430	0.026	16.52	0.000
INC10K	Median Household Income in $10,000 (in $1999)	0.002	0.005	0.45	0.649
LGRSHH	Log (Household Density) within 1/4 mile buffer of residents	-0.006	0.018	-0.36	0.716
LGRSEMP	Log (Job Density) within 1/4 mile buffer of residents	-0.002	0.007	-0.29	0.769
WALKAINX	Walkability/Street connect (Density of 3-leg and 4-leg intersections	0.002	0.001	1.44	0.149
LDLBUSHQ	Log of Frequent Bus Stop density (Tier 2 TAZ - headway <= 20 minutes)	0.004	0.014	0.26	0.797
HHCAR	Household cars	-0.225	0.018	-12.83	0.000
JH5MI08	Job/HH Ratio in 5 miles	-0.116	0.026	-4.53	0.000
LBTIME08	Local Bus Accessibility based on Time - in million	-1.537	0.617	-2.49	0.013
BS_LBTIM	Bus TOD * LBTIME08M	0.961	0.465	2.06	0.039
RL_LBTIM	Rail TOD * LBTIME08M	4.144	0.86	4.82	0.000

2. Transit Component

Variable	Description	Coeff.	Standard Error	z	Prob. |z|>Z*
Intercept		-3.264	0.283	-11.550	0.000
WKER	Number of Household Workers	0.720	0.058	12.34	0.000
NW0015	Number of Household Members (< 16 yr old)	0.222	0.048	4.67	0.000
NW1664	Number of Household Members (16-64 yr old)	0.548	0.058	9.51	0.000
NW6500	Number of Household Members (> 64 yr old)	0.191	0.089	2.14	0.032
INC10K	Median Household Income in $10,000 (in $1999)	-0.234	0.021	-11.12	0.000
LGRSHH	Log (Household Density) within 1/4 mile buffer of residents	0.136	0.073	1.86	0.063
LGRSEMP	Log (Job Density) within 1/4 mile buffer of residents	0.000	0.029	0	0.999
WALKAINX	Walkability/Street connect (Density of 3-leg and 4-leg intersections	0.004	0.004	0.82	0.411
LDLBUSHQ	Log of Frequent Bus Stop density (Tier 2 TAZ - headway <= 20 minutes)	0.070	0.04	1.77	0.076
HHCAR	Household cars	-1.334	0.061	-21.9	0.000

JH5MI08	Job/HH Ratio in 5 miles	0.206	0.083	2.48	0.013
LBTIME08	Local Bus Accessibility based on Time - in million	14.306	2.66	5.38	0.000
BS_LBTIM	Bus TOD * LBTIME08M	3.047	1.354	2.25	0.024
RL_LBTIM	Rail TOD * LBTIME08M	4.593	1.766	2.6	0.009

3. Non-Motorized Component

Variable	Description	Coeff.	Standard Error	z	Prob. |z|>Z*
Intercept		-1.591	0.101	-15.790	0.000
WKER	Number of Household Workers	0.128	0.024	5.43	0.000
NW0015	Number of Household Members (< 16 yr old)	0.356	0.018	19.48	0.000
NW1664	Number of Household Members (16-64 yr old)	0.244	0.024	10.09	0.000
NW6500	Number of Household Members (> 64 yr old)	0.059	0.033	1.8	0.072
INC10K	Median Household Income in $10,000 (in $1999)	-0.022	0.006	-3.67	0.000
LGRSHH	Log (Household Density) within 1/4 mile buffer of residents	0.169	0.025	6.65	0.000
LGRSEMP	Log (Job Density) within 1/4 mile buffer of residents	0.013	0.009	1.39	0.164
WALKAINX	Walkability/Street connect (Density of 3-leg and 4-leg intersections	0.007	0.002	4.07	0.000
LDLBUSHQ	Log of Frequent Bus Stop density (Tier 2 TAZ - headway <= 20 minutes)	0.046	0.016	2.79	0.005
HHCAR	Household cars	-0.459	0.021	-21.34	0.000
JH5MI08	Job/HH Ratio in 5 miles	-0.014	0.031	-0.45	0.649
LBTIME08	Local Bus Accessibility based on Time - in million	5.918	0.816	7.25	0.000
BS_LBTIM	Bus TOD * LBTIME08M	1.062	0.506	2.1	0.036
RL_LBTIM	Rail TOD * LBTIME08M	1.439	0.883	1.63	0.103

4. Other Modes Component

Variable	Description	Coeff.	Standard Error	z	Prob. |z|>Z*
Intercept		-2.973	0.209	-14.230	0.000
WKER	Number of Household Workers	0.168	0.05	3.39	0.001
NW0015	Number of Household Members (< 16 yr old)	0.452	0.036	12.58	0.000
NW1664	Number of Household Members (16-64 yr old)	0.257	0.051	5.02	0.000
NW6500	Number of Household Members (> 64 yr old)	0.044	0.074	0.6	0.551
INC10K	Median Household Income in $10,000 (in $1999)	-0.034	0.013	-2.54	0.011
LGRSHH	Log (Household Density) within 1/4 mile buffer of residents	-0.040	0.044	-0.9	0.370
LGRSEMP	Log (Job Density) within 1/4 mile buffer of residents	-0.007	0.019	-0.38	0.700
WALKAINX	Walkability/Street connect (Density of 3-leg and 4-leg intersections	0.004	0.004	0.99	0.324

LDLBUSHQ	Log of Frequent Bus Stop density (Tier 2 TAZ - headway <= 20 minutes)	0.116	0.038	3	0.003
HHCAR	Household cars	-0.242	0.046	-5.28	0.000
JH5MI08	Job/HH Ratio in 5 miles	0.061	0.063	0.97	0.334
LBTIME08	Local Bus Accessibility based on Time - in million	-0.921	1.614	-0.57	0.568
BS_LBTIM	Bus TOD * LBTIME08M	-0.482	1.209	-0.4	0.690
RL_LBTIM	Rail TOD * LBTIME08M	-0.383	2.327	-0.16	0.869

Model	Logit Model	
N	Weekday Trips	40163
Chi squared		5969.8
Significance level		0.000
McFadden Pseudo R-squared		0.072

Table 4-5 Household VMT Model

Variable	Description	Coeff.	Standard Error	t	Prob. > [t]
INTERCEPT		21.619	3.499	6.18	<.0001
WKER	Number of Household Workers	18.785	1.104	17.01	<.0001
NW0015	Number of Household Members (< 16 yr old)	3.587	1.056	3.4	0.00
NW1664	Number of Household Members (16-64 yr old)	9.368	1.19	7.87	<.0001
NW6500	Number of Household Members (> 64 yr old)	3.603	1.365	2.64	0.01
INC10K	Median Household Income in $10,000 (in $1999)	1.944	0.264	7.36	<.0001
TR_SHARE	Transit Share of Household Trips	-43.425	15.233	-2.85	0.00
NM_SHARE	NM Share of Household Trips	-28.837	4.269	-6.75	<.0001
HHCAR	Number of Household Vehicles	5.337	0.843	6.33	<.0001
LGRSHH	Log (Household Density) within 1/4 mile buffer of residents	-1.747	0.902	-1.94	0.053
T2AUTOTIME08M	Auto Accessibility based on Time (T2 TAZ) - in million	-97.176	20.098	-4.84	<.0001
JH5MI08	J/H ratio in 5 miles	-2.33	1.385	-1.68	0.093
NOHQBUS	Household TAZ has no HQ Bus stop	3.218	1.492	2.16	0.031

Model	Ordinary Least Square	
Dep Var	Household VMT	
N		3,973
F value		104.03
Pr>F		<0.0001
Adj. R square		0.24

Table 5-1. Test for Household Vehicle Ownership

	Sample	Observed	Predicted
Total	6663	2.04	1.95
Household Size			
1	1450	1.10	1.23
2	2584	2.04	1.92
3	1031	2.51	2.31
4	1598	2.59	2.42
County			
Imperial	48	1.90	1.92
Los Angeles	3381	1.93	1.83
Orange	1282	2.13	2.07
Riverside	802	2.15	2.07
San Bernardino	764	2.13	2.07
Ventura	386	2.30	2.17
Household Density in 1/4 mile (per acre)			
<=2	1250	2.34	2.26
2-6	3914	2.12	2.00
6-10	1018	1.70	1.63
10-20	385	1.43	1.45
>20	96	1.06	1.17
TOD-Bus (within 1/2 mile from Major Bus Stops)			
Outside TOD-Bus	5123	2.13	2.05
Inside TOD-Bus	1540	1.73	1.61
TOD-Rail (within 1/2 milefrom Rail Stations)			
Outside TOD-Rail	6428	2.06	1.97
Inside TOD-Rail	235	1.49	1.37

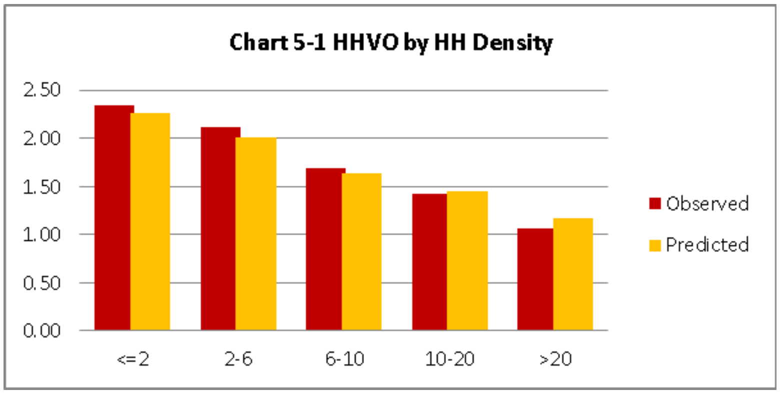

Table 5-2 Test for Vehicle Trips Making

	Sample	Observed	Predicted
Total	4787	82.7%	82.8%
Household Size			
1	1045	66.2%	63.9%
2	1884	83.9%	85.2%
3	726	91.7%	91.3%
4	1132	90.3%	90.8%
County			
Imperial	36	88.9%	83.1%
Los Angeles	2436	79.9%	79.6%
Orange	918	88.0%	86.7%
Riverside	581	84.3%	85.2%
San Bernardino	538	82.0%	85.9%
Ventura	278	87.4%	87.8%
Household Density in 1/4 mile (per acre)			
<=2	926	86.0%	88.9%
2-6	2761	85.4%	84.7%
6-10	746	76.7%	76.0%
10-20	281	70.5%	69.8%
>20	73	50.7%	56.7%
TOD-Bus within (1/2 mile fromn Major Bus Stops)			
Outside TOD-Bus	3678	85.0%	85.4%
Inside TOD-Bus	1109	75.1%	74.5%
TOD-Rail within (1/2 mile from Rail Stations)			
Outside TOD-Rail	4605	83.4%	83.6%
Inside TOD-Rail	182	65.9%	63.8%

Chart 5-2 %HHVT by HH Density

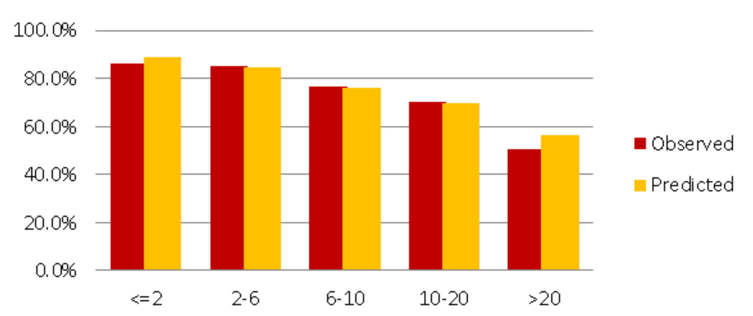

Table 5-3 Daily Person Trips Per Household

	Sample	Observed	Predicted
Total	4787	8.40	8.54
Household Size			
1	1045	3.68	3.95
2	1884	6.87	7.04
3	726	10.10	10.24
4	1132	14.22	14.18
County			
Imperial	36	9.44	8.75
Los Angeles	2436	8.09	8.32
Orange	918	9.03	9.00
Riverside	581	8.03	8.26
San Bernardino	538	8.56	8.71
Ventura	278	9.43	9.17
Household Density in 1/4 mile (per acre)			
<=2	926	8.49	8.70
2-6	2761	8.71	8.78
6-10	746	7.87	8.05
10-20	281	6.99	7.51
>20	73	6.62	6.27
TOD-Bus (within 1/2 mile from Major Bus Stops)			
Outside TOD-Bus	3678	8.60	8.69
Inside TOD-Bus	1109	7.76	8.04
TOD-Rail (within 1/2 mile from Rail Stations)			
Outside TOD-Rail	4605	8.45	8.58
Inside TOD-Rail	182	7.23	7.42

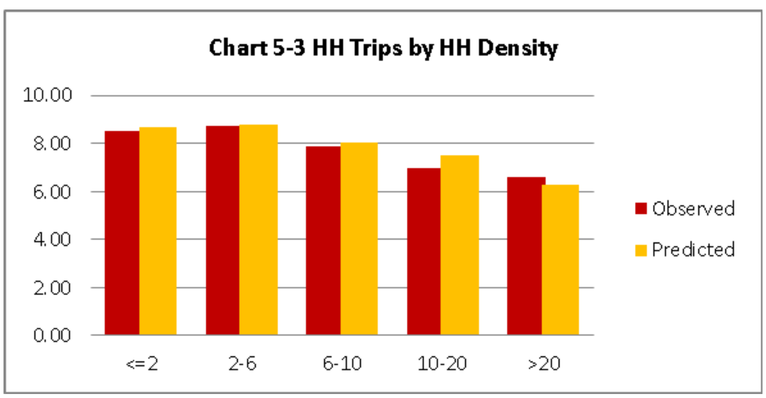

Table 5-4 Test for Household Share of Transit Trips

	Sample	Observed	Predicted
Total	40216	1.8%	1.4%
Household Size			
1	3843	2.3%	2.2%
2	12947	1.2%	1.0%
3	7332	1.4%	1.2%
4	16094	2.2%	1.5%
County			
Imperial	340	0.0%	0.4%
Los Angeles	19701	2.7%	2.1%
Orange	8286	1.2%	0.7%
Riverside	4663	0.5%	0.5%
San Bernardino	4605	0.8%	0.6%
Ventura	2621	0.4%	0.6%
Household Density in 1/4 mile (per acre)			
<=2	926	0.5%	0.4%
2-6	2761	1.1%	0.9%
6-10	746	3.7%	2.6%
10-20	281	5.7%	4.8%
>20	73	14.3%	9.2%
TOD-Bus (within 1/2 mile from Major Bus Stops)			
Outside TOD-Bus	31614	1.2%	0.9%
Inside TOD-Bus	8602	4.0%	3.0%
TOD-Rail (within 1/2 mile from Rail Stations)			
Outside TOD-Rail	38900	1.6%	1.2%
Inside TOD-Rail	1316	8.0%	6.3%

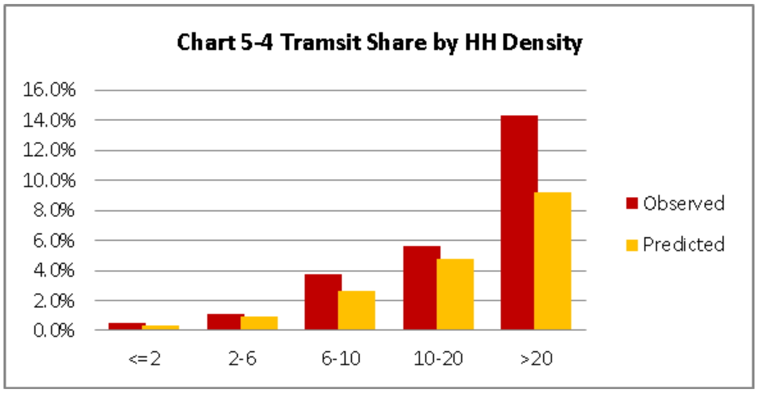

Table 5-5 Test for Household Share of Non-motorized Mode Trips

	Sample	Observed	Predicted
Total	40216	13.03%	13.39%
Household Size			
1	3843	13.61%	16.2%
2	12947	12.36%	12.0%
3	7332	12.88%	12.6%
4	16094	13.50%	14.2%
County			
Imperial	340	4.71%	8.89%
Los Angeles	19701	15.95%	16.11%
Orange	8286	11.09%	11.98%
Riverside	4663	9.89%	9.16%
San Bernardino	4605	8.86%	10.00%
Ventura	2621	11.22%	11.00%
Household Density in 1/4 mile (per acre)			
<=2	926	9.08%	8.04%
2-6	2761	11.67%	12.78%
6-10	746	18.84%	18.58%
10-20	281	22.82%	23.08%
>20	73	34.37%	26.63%
TOD-Bus (within 1/2 mile from Major Bus Stops)			
Outside TOD-Bus	31614	11.64%	11.64%
Inside TOD-Bus	8602	18.15%	19.66%
TOD-Rail (within 1/2 mile from Rail Stations)			
Outside TOD-Rail	38900	12.80%	13.20%
Inside TOD-Rail	1316	19.68%	18.83%

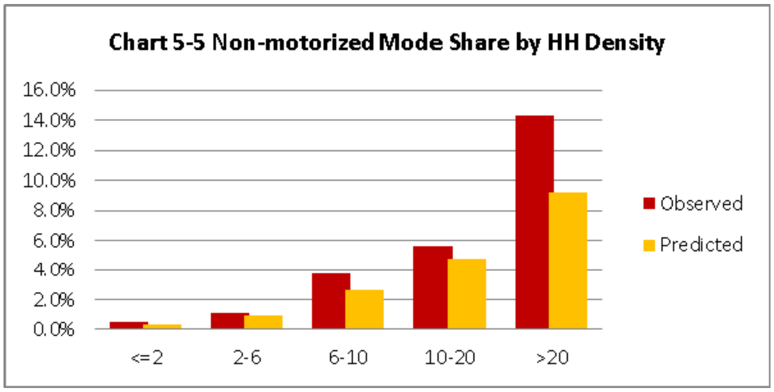

Table 5-6 Test for Household VMT

	Sample	Observed	Predicted
Total	4787	42.70	41.14
Household Size			
1	1045	18.21	15.25
2	1884	38.85	38.32
3	726	56.78	54.72
4	1132	62.70	60.84
County			
Imperial	36	39.55	52.02
Los Angeles	2436	37.83	35.75
Orange	918	44.65	42.86
Riverside	581	48.59	47.70
San Bernardino	538	52.65	48.41
Ventura	278	47.85	53.69
Household Density in 1/4 mile (per acre)			
<=2	926	52.30	53.25
2-6	2761	44.61	42.98
6-10	746	32.74	29.18
10-20	281	26.02	22.52
>20	73	14.80	12.52
TOD-Bus (within 1/2 mile from Major Bus Stops)			
Outside TOD-Bus	3678	46.02	45.06
Inside TOD-Bus	1109	31.69	28.16
TOD-Rail (within 1/2 mile from Rail Stations)			
Outside TOD-Rail	4605	43.25	41.87
Inside TOD-Rail	182	28.84	22.81

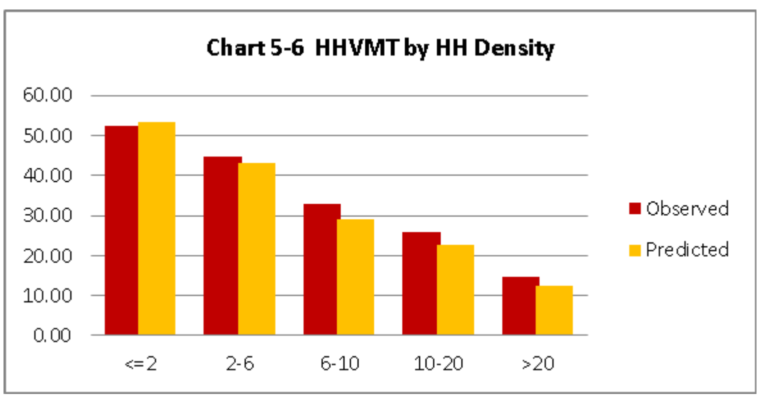

Table 5-7 Comparison of NHTS Model Elasticities vs. Other Studies

	Elasticity Range of NHTS Model	**CARB Study[1]**	**Meta Analysis[2]**
Residential Density	-0.068 to -0.072	-0.05 to -0.12	-0.04
Employment Density	-0.004 to -0.005	N/A	0
Job Mix	-0.016 to -0.017	-0.02 to -0.11	-0.09
Walkability/Connectivity	-0.035 to -0.036	-0.06 to -0.12	-0.12
Jobs/Housing Balance	-0.079 to -0.083	-0.02	-0.02
Auto Accessibility	-0.27	-0.05 to -0.25	-0.20
Regional Local Bus Accessibility	-0.042 to -0.044	N/A	-0.05
High Quality Local Bus Density	-0.007 to -0.009	N/A	-0.05

Note

1. Summarized from research compiled by Susan Handy and Marlon Boarnet for California Air Resources Board (http://arb.ca.gov/cc/sb375/policies/policies.htm)
2. Reid Ewing & Robert Cervero (2010): Travel and the Built Environment, Journal of the American Planning Association, 76:3, 265-29 (http://www.tandfonline.com/doi/abs/10.1080/01944361003766766)

Table 5-8 Correlation Analysis on VMT

Zone	Number	Correlation
Tier2 TAZ	11267	0.910
Tier1 TAZ	4109	0.912
CSA	302	0.960
RSA	56	0.984
Sub Air Basin	13	0.997
County	6	0.997

Table 5-9 Comparison of 2035 Model Output

	2008	**2035 Proposed Plan (Trip-Based Model)**	**2035 Proposed Plan (NHTS Model)**
VMT	374,033,557	435,661,031	425,286,388
VMT/Household	64.35	59.51	58.09
Percentage Reduction in VMT/HH from 2008	--	7.50%	9.70%
Percentage Reduction in VMT/HH from 2035 Trip-Based Model	--	--	2.40%

Table 5-10 NHTS Model Output

	2008	2035 Plan
HH Vehicles	2.19	2.13
% V Trips	80.40%	80.54%
Total Trips	11.96	11.65
Model Share		
Auto_driver	55.8%	55.0%
Auto_passenger	26.7%	25.1%
Transit	1.3%	2.0%
Non-Motorized	13.8%	15.7%
Other	2.4%	2.2%