TRANSPORTATION FUEL DEMAND FORECAST HOUSEHOLD AND COMMERCIAL FLEET SURVEY

Task 8 Report: Logistic Regression Analysis and Results

CONSULTANT REPORT

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Abstract

This report summarizes the model estimation results conducted as part of the Energy Commission's California Vehicle Survey (CVS) of households and commercial fleets.

The Energy Commission's CVS is designed to collect revealed and stated preference data from automobile drivers and commercial fleet managers. Choice models estimated with this data will be used as inputs to update the Energy Commission's transportation fuel demand model, known as the CALCARS model.

The CALCARS forecasting model provides the State of California an essential tool for evaluating potential policies and initiatives designed to influence the vehicle choice and fuel choice behavior of residential and commercial motor vehicle users. This report summarizes 1) the estimation of a system of six models describing vehicle ownership and use for residential households and 2) a single model describing vehicle choice for commercial vehicle fleets.

Introduction

The California Energy Commission (CEC) is required by state law to analyze strategies for reducing petroleum dependency in the state. To comply with this mandate, CEC developed the California (light duty) Conventional and Alternative Fuel Response Simulator (CALCARS) model to predict the vehicle fleet composition and fuel consumption of the California vehicle fleet. RSG used data from the 2008–2009 California Vehicle Survey (CVS) to statistically estimate coefficients of vehicle choice models, which will be used as inputs to the CALCARS model.

The 2008-2009 CVS consisted of a Residential Vehicle Survey and a Light-Duty Commercial Vehicle Survey. Both surveys included stated preference (SP) questions that were designed to support development of vehicle choice models. Survey data were collected using a two-phase, multi-method approach. The first phase involved a revealed preference (RP) recruitment survey that was conducted over the telephone. The second phase included the stated preference survey with eight vehicle choice experiments. Respondents had the option of completing the second phase of the survey by mail or over the Internet. A total of 6,577 respondents completed the RP survey; of those, 3,274 went on to complete the SP survey.

The CALCARS forecasting model provides the State of California an essential tool for evaluating potential policies and initiatives designed to influence the vehicle choice and fuel choice behavior of residential and commercial motor vehicle users. This report summarizes 1) the estimation of a system of six models describing vehicle ownership and use for residential households and 2) a single model describing vehicle choice for commercial vehicle fleets.

Residential Models

A set of six interrelated models were estimated using the residential CVS data to support CALCARS forecasting:

1. Vehicle choice model
2. Vehicle transaction and replacement choice model
3. New-used vehicle choice model
4. Fuel choice model
5. Vehicle quantity choice model
6. Vehicle miles traveled (VMT) model

The six interrelated models are described in more detail below.

Residential Vehicle Choice Model

The residential vehicle choice model is based on the stated preference data from the 2008–2009 CVS. Residential household information from the RP survey was merged with the stated preference responses, forming a vehicle choice dataset of 26,192 observations from 3,274 respondents. The vehicle choice model was estimated first, as the vehicle choice coefficients are used to calculate 1) logsum parameters that are carried into the vehicle transaction and replacement model as well as the vehicle quantity model and 2) the expected value of the fuel cost per mile variable used in the VMT model.

More information about the alternatives, attributes, levels, and experimental design used in the SP survey can be found in Appendix B.

Description of Alternatives

In the SP survey, respondents answered eight vehicle choice questions, each of which is considered an experiment. Each experiment presented respondents with four hypothetical vehicle alternatives labeled Vehicle A, Vehicle B, Vehicle C, and Vehicle D. These four vehicles were described by a set of ten to twelve attributes, depending on the fuel type that was presented. The new or used vehicle the respondent planned to purchase next for their household, based on their responses in the RP survey, was always presented as Vehicle A, or the reference vehicle. The vehicle attributes presented for vehicles B, C, and D varied according to the experimental design. Respondents were asked to select the vehicle they would most likely purchase based on the attribute levels presented for each of the four alternatives.

Figure 1: Sample Stated Preference Experiment

2008 California Vehicle Survey

If the following vehicle options were available to you, which would you choose?
Please carefully examine all the attributes of each vehicle and then select the one you will most likely purchase by filling in the circle below your choice.

Vehicle Choice 1	Vehicle A	Vehicle B	Vehicle C	Vehicle D
Vehicle type	Midsize car	Compact SUV	Midsize car	Compact van
Fuel type	Gasoline	Natural Gas (NGV)	Plug-in Hybrid (PHEV)	Clean Diesel
Age of vehicle	New (2009)	New (2009)	New (2009)	New (2009)
Purchase price	$29,400	$36,600	$31,100	$20,900
Incentive	--	--	$1,000 tax credit	--
MPG or equivalent	29 MPG	15 MPG	60 MPG	31 MPG
Fuel cost per year	$1,090	$1,950	$780	$1,170
Fuel availability		1 in 50 stations		
Refueling time		10 Minutes at station, 4 hours at home		
Driving range		300 Miles		
Maintenance cost per year	$460	$370	$350	$550
Acceleration (0-60 mpg)	10.2 seconds	11 seconds	8 seconds	11.8 seconds
Select One:	○	○	○	○

Residential Vehicle Choice Model Segmentation

The CALCARS model segments the residential population by the number of vehicles owned by the household, and this segmentation scheme was found to result in statistically significant differences in models among the segments. The current version of CALCARS supports two vehicle ownership segments, 1) one vehicle and 2) two or more vehicles. However, future versions of the model are expected to support a third vehicle ownership segment for three or more household vehicles. To support both segmentation schemes, separate vehicle choice models were estimated for one-vehicle, two or more-vehicle, two-vehicle, and three or more-vehicle households. Results for the two-class segmentation are presented in this report, while the three-class results are documented in Appendix A. Table 1 shows the number of respondents in each vehicle ownership category for the two-segment model.

Table 1: Vehicle Ownership Distribution of the Sample

Number of Vehicles	Number of Households	Number of Observations
1 vehicle	944	7552
2 or more vehicles	2330	18640
Total	3274	26192

Residential Vehicle Choice Model Specification

The choice among the four vehicle alternatives was modeled using a multinomial logit model form. Coefficients of this logit model form were estimated for a large number of utility function specifications. All of the specifications included the vehicle attributes that were varied in the SP experiments, household characteristics, and constants for different vehicle types, vehicle sizes, and fuel options. Interpretation and discussion of each set of parameters follows below.

Inertia and Alternative Specific Constants

To remove potential bias from the coefficient estimates, several alternative specific and inertia constants were included in the vehicle choice utility specification. Vehicle type and fuel type inertia dummy variables were included on all four vehicle alternatives. These variables assumed a value of one for any alternative that presented the same vehicle type or fuel type that the respondent indicated they would purchase for their next vehicle in the RP survey. The positive values of these coefficients represent "inertia", or the tendency of a respondent to choose a vehicle in the stated preference experiments that has the same vehicle type or fuel type as the vehicle they said they expect to purchase next.

Alternative specific constants were included on the first three of the four alternatives presented, labeled as vehicles A, B and C in Figure 1 above. The alternative specific constant on Vehicle A, the reference vehicle, captures any tendency to select the reference vehicle independent of vehicle type and fuel type. The constants on vehicles B and C capture any bias related to the order of the alternatives.

Both the inertia constants and the alternative specific constants are included to remove potential bias from the coefficient estimates, and are not intended to be used in forecasting.

Vehicle Type

Coefficients were estimated for 14 of the 15 vehicle types presented in the stated preference experiments. The coefficient for subcompact car was constrained to zero, and the remaining vehicle type coefficient values are relative to the subcompact coefficient. A positive value for a given vehicle type indicates that, all else equal, the vehicle type is preferred to subcompact, while a negative value indicates that subcompact is preferred to that vehicle. Several interactions were tested with the vehicle type variables; these are discussed in more detail below.

Fuel Type

The gasoline fuel type coefficient was constrained to zero, and the six remaining fuel type coefficients were estimated relative to gasoline. In general, ethanol, hybrid electric, plug-in hybrid electric, and diesel fuel types were preferred to gasoline, while compressed natural gas and full electric fuel types were viewed less favorably than gasoline. These relationships held across both household vehicle segments.

Vehicle Type – Fuel Type Interactions

Interactions between vehicle type and fuel type variables were tested to determine if the combined effects of vehicle type and fuel type significantly influence vehicle choice. For example, one might expect that certain vehicle type – fuel type combinations might be viewed less favorably than others. Many different combinations of vehicle size groups and alternative fuel groups were tested. The groups with the best model fit, as described in Table 2 below, included three vehicle size categories and a dummy variable for all non-gasoline alternative fuels (including diesel).

Table 2: Vehicle Size Groups

Vehicle Group	Vehicle Types Included
Vehicle Group 1: Small Vehicles	Subcompact car Compact car Midsize car Sports car Small cross utility car Compact pickup
Vehicle Group 2: Medium Vehicles	Large car Small cross utility SUV Midsize cross utility SUV Compact SUV Midsize SUV Standard pickup
Vehicle Group 3: Large Vehicles	Large SUV Compact van Large van

Negative and significant coefficients were found on the large vehicle size interactions with fuel type, implying that alternative fuels are less desirable for large vehicles.

Household Size and Vehicle Type

Household size was also interacted for the same vehicle size groupings that are described above in Table 2. Dummy variables for each of the three vehicle groups were interacted with a large household dummy variable, which was defined as a household with four or more household members. The group 1 (small) vehicle coefficient was constrained to zero. The positive values for the group 2 and group 3 coefficients indicate that respondents with large households are more likely to choose vehicles in these groups.

Incentives

Coefficients were estimated for each of the six incentives, with the coefficient for the no incentive level constrained to zero. The coefficients for the remaining five incentives, including HOV lane use, free parking, $1,000 tax credit, 50 percent reduced tolls, and $1,000 reduced vehicle purchase price, are relative to the base level. The majority of incentives were viewed favorably, but only one ($1,000 tax credit) significantly and consistently influenced consumer behavior across both household vehicle segments. The reduced toll incentive for one-vehicle households was removed from the final estimation as the coefficient had a counterintuitive sign and was not statistically significant.

Vehicle Age

Vehicle age was presented as a continuous variable in the experiments; that is, values ranged from new to 20 years old. Several specifications were tested for vehicle age, including:

- A continuous age variable,
- A new vehicle dummy variable in conjunction with the log of vehicle age, and
- Categorical age variables.

Ultimately, using three age categories for 1) new vehicles, 2) used vehicles one or two years old, and 3) used vehicles three or more years old provided the best model fit.

The coefficient for new vehicles was constrained to zero, and the two used vehicle coefficient values are relative to new vehicles. The negative values for both used vehicle categories indicate that, all else equal, new vehicles are preferred to used vehicles.

Vehicle Purchase Price

Vehicle purchase price was interacted with annual household income to identify how sensitivity to price varies with income. After estimating different price coefficients for the seven household income categories from the RP survey, a clear linear relationship was identified between price and income. Several non-linear income transformations were also tested, but the linear income interaction provided the best model fit. In the final specification, a price coefficient was estimated along with a linear price-income interaction coefficient. These two parameters can be used to calculate a price coefficient for any household income category. The negative value of the price coefficient indicates that vehicle utility decreases with increasing price; the positive value of the price-income interaction coefficient indicates that vehicle purchase price becomes less onerous as household income increases from one category to the next. These coefficients are estimated in units of thousands of dollars.

Maintenance Cost and Fuel Cost

Maintenance and fuel cost were presented in the experiments in units of thousands of dollars per year, but the coefficients are estimated in units of cents per mile by dividing the annual dollar amount by the respondent's annual VMT. The annual VMT is obtained from the RP survey, where respondents indicated how many miles per year they expect to drive the vehicle they will purchase next for their household. The negative values of both of these coefficients indicate the disutility of increasing operating costs. Several linear and non-linear interactions with income were tested for maintenance and fuel costs alone, as well as with both combined into a single operating cost. No clear statistically significant relationship with income was identified.

Miles per Gallon

The miles per gallon coefficient represents the value of a vehicle's fuel efficiency. The units are in miles per gallon equivalent (MPGE). The positive value indicates that vehicle utility increases as MPGE increases. Non-linear transformations of MPGE were tested, including logarithmic and quadratic specifications; however, both resulted in a decrease in model performance when compared to the linear specification. The linear model provides the best fit.

Acceleration

This coefficient represents the value of vehicle acceleration from zero to 60 miles per hour and has units of seconds. Lower acceleration times (closer to zero) are viewed more favorably by respondents, resulting in a negative value for this coefficient. As with miles per gallon, several non-linear transformations of acceleration were tested, including logarithmic and quadratic forms. These transformations resulted in negligible changes in log likelihood (less than one-tenth of a percent) and were not included in the final specification.

Fuel Availability and Refueling Time

The fuel availability and refueling time attributes were presented only for compressed natural gas (CNG) and full electric fuel types. Therefore, these coefficients apply only to vehicles with those fuel types. Two levels were presented for each of these attributes for CNG and full electric vehicles. In both cases, the lower-level, or the level expected to be perceived as the worst, was constrained to zero. The value of the upper level represents the impact of the difference between the two levels on consumer preference.

Range

As with fuel availability and refueling time, the range attribute applies only to CNG and full electric vehicles. Different range levels were presented for each of the fuel types, although all values were presented in miles. This coefficient represents the perceived benefit of extending the operating range between refueling stops for CNG and electric vehicles. Using the natural log of range was found to slightly improve the model fit. This transformation indicates that additional range provides more benefit at lower range values. For example, an increase in vehicle range from 50 to 100 miles provides more utility than an increase in range from 250 to 300 miles.

As a final test, range was interacted with vehicle type to see if there are any differences in sensitivity to range among different vehicle types. No statistically significant differences were found.

Cell Phone-only Households

Additional specification testing was conducted using a variable to distinguish cell phone-only households from landline households. Two hundred of these households were included in the residential RP survey, and 61 households went on to complete the SP survey. Tests were conducted to determine if these respondents had significantly different preferences from the rest of the sample.

A dummy variable for cell phone-only households was interacted with the same three vehicle size groups described above in Table 2. These coefficients were found to be not statistically different from zero.

The cell phone-only variable was also interacted with fuel type. First, it was interacted with three alternative fuel groups. A second specification included a hybrid vehicle dummy variable for cell phone-only households. In both specifications, the coefficient estimates were not statistically different from zero. The statistical insignificance may be a result of the relatively small sample size of cell phone-only households; of the 200 responses collected in the RP survey, only 61 went on to complete the stated preference survey. As a result of the statistical insignificance, the cell phone-only variables were not included in the final model specification.

Regional Coefficients

The vehicle choice model was segmented by region to identify significant differences in coefficient estimates. The regions include the four major metropolitan areas of San Francisco, Los Angeles, San Diego, and Sacramento. A fifth region includes the rest of the State outside of these urban areas. The regions consist of one or more counties as described below in Table 3.

Table 3: Region Definitions

Region	Counties Included in Region		
San Francisco	Alameda	Napa	Santa Clara
	Contra Costa	San Francisco	Solano
	Marin	San Mateo	Sonoma
Los Angeles	Imperial	Orange	San Bernardino
	Los Angeles	Riverside	Ventura
San Diego	San Diego		
Sacramento	El Dorado	Sacramento	Yolo
	Placer	Sutter	Yuba
Rest of State	Alpine	Lake	San Joaquin
	Amador	Lassen	San Luis Obispo
	Butte	Madera	Santa Barbara
	Calaveras	Mariposa	Santa Cruz
	Colusa	Mendocino	Shasta
	Del Norte	Merced	Sierra
	Fresno	Modoc	Siskiyou
	Glenn	Mono	Stanislaus
	Humboldt	Monterey	Tehama
	Inyo	Nevada	Trinity
	Kern	Plumas	Tulare
	Kings	San Benito	Tuolumne

Variables specific to San Francisco include hybrid and plug-in hybrid coefficients. These were found to be more significantly positive than other regions in the state, indicating that these fuel types are more likely to be chosen in the San Francisco region. Variables with Los Angeles specific estimates include sports car and large SUV vehicle types, the HOV lane use incentive, and acceleration. All of the variables are larger in magnitude than their non-LA counterparts. No other significant regional interactions were identified.

Because the CALCARS model cannot currently incorporate region-specific parameters, the vehicle choice models were estimated both with and with out the regional variables. Results for the regional specification are presented in Appendix A.

Residential Vehicle Choice Model Coefficient Estimates

Table 4 presents the coefficient values and t-stats for the model specification described above. Fit statistics, including the log likelihood at zero, the log-likelihood at convergence, and rho-squared values, are provided at the end of the table.

Table 4: Residential Vehicle Choice Coefficients

Type	Coef.	Description	Units	1 Vehicle Estimate	1 Vehicle T-stat	2+ Vehicles Estimate	2+ Vehicles T-stat
Constants*	α_1	Vehicle type inertia	--	0.993	22.4	0.896	34.7
	α_2	Fuel type inertia	--	0.217	2.91	0.295	6.31
	α_3	Vehicle A constant	--	0.848	13.3	0.809	20.7
	α_4	Vehicle B constant	--	0.157	3.49	0.136	5.06
	α_5	Vehicle C constant	--	0.0357	0.778	0.0698	2.57
Vehicle Type	$\beta_{1,1}$	Subcompact car	(0,1)	0.00	0.00	0.00	0.00
	$\beta_{1,2}$	Compact car	(0,1)	-0.131	-1.55	0.0121	0.226
	$\beta_{1,3}$	Midsize car	(0,1)	0.284	3.18	0.237	4.21
	$\beta_{1,4}$	Large car	(0,1)	0.0186	0.143	0.52	6.78
	$\beta_{1,5}$	Sports car	(0,1)	0.0749	0.655	0.445	6.54
	$\beta_{1,6}$	Small cross car	(0,1)	0.449	4.46	0.485	7.55
	$\beta_{1,7}$	Small cross utility SUV	(0,1)	0.44	3.68	0.634	8.61
	$\beta_{1,8}$	Midsize cross utility SUV	(0,1)	0.29	2.22	0.802	10.2
	$\beta_{1,9}$	Compact SUV	(0,1)	0.64	4.78	0.662	8.08
	$\beta_{1,10}$	Midsize SUV	(0,1)	0.588	4.34	0.765	9.37
	$\beta_{1,11}$	Large SUV	(0,1)	0.825	4.7	0.981	9.23
	$\beta_{1,12}$	Compact van	(0,1)	0.212	1.47	0.54	6.1
	$\beta_{1,13}$	Large van	(0,1)	-0.264	-1.4	0.129	1.15
	$\beta_{1,14}$	Compact truck	(0,1)	0.144	1.15	0.224	3.12
	$\beta_{1,15}$	Standard truck	(0,1)	0.227	1.63	0.613	7.68
Fuel Type	$\beta_{2,1}$	Gasoline	(0,1)	0.00	0.00	0.00	0.00
	$\beta_{2,2}$	E-85	(0,1)	0.132	1.48	0.281	4.72
	$\beta_{2,3}$	Plug-in hybrid	(0,1)	0.178	1.38	0.546	6.7
	$\beta_{2,4}$	Compressed natural gas	(0,1)	-2.25	-2.22	-2.24	-3.68
	$\beta_{2,5}$	Diesel	(0,1)	0.0881	0.982	0.481	8.09
	$\beta_{2,6}$	Hybrid	(0,1)	0.419	5.75	0.615	11.8
	$\beta_{2,7}$	Full electric	(0,1)	-2.78	-3.74	-2.54	-5.69
Age	$\beta_{3,1}$	New	(0,1)	0.00	0.00	0.00	0.00
	$\beta_{3,2}$	Used vehicle 1 or 2 years old	(0,1)	-0.193	-3.01	-0.178	-4.64
	$\beta_{3,3}$	Used vehicle 3 or more years old	(0,1)	-0.406	-7.55	-0.409	-12.2
Incentive	$\beta_{4,1}$	No incentive	(0,1)	0.00	0.00	0.00	0.00
	$\beta_{4,2}$	HOV lane use	(0,1)	0.0611	1.03	0.142	3.39
	$\beta_{4,3}$	Free parking	(0,1)	0.041	0.687	0.169	4.06
	$\beta_{4,4}$	$1,000 tax credit	(0,1)	0.186	3.12	0.193	4.61
	$\beta_{4,5}$	50% reduced tolls	(0,1)	--	--	0.04	0.948
	$\beta_{4,6}$	$1,000 reduced purchase price	(0,1)	0.0644	1.08	0.114	2.73
Price		Price	$000	-0.0746	-15.4	-0.0785	-20.6
		Price * income category	$000	0.00675	6.74	0.0068	10.8
	$\beta_{5,1}$	Price for income less than $20,000	$000	-0.0678	--	-0.0717	--
	$\beta_{5,2}$	Price for income $20,000 to $39,999	$000	-0.0611	--	-0.0649	--
	$\beta_{5,3}$	Price for income $40,000 to $59,999	$000	-0.0543	--	-0.0581	--
	$\beta_{5,4}$	Price for income $60,000 to $79,999	$000	-0.0476	--	-0.0513	--
	$\beta_{5,5}$	Price for income $80,000 to $99,999	$000	-0.0408	--	-0.0445	--
	$\beta_{5,6}$	Price for income $100,000 to $119,999	$000	-0.0341	--	-0.0377	--
	$\beta_{5,7}$	Price for income $120,000 or more	$000	-0.0273	--	-0.0309	--

Type	Coef.	Description	Units	1 Vehicle Estimate	1 Vehicle T-stat	2+ Vehicles Estimate	2+ Vehicles T-stat
Maintenance	β_6	Maintenance cost	c/mi	-0.0584	-3.09	-0.0696	-6.01
Fuel Cost	β_7	Fuel cost	c/mi	-0.0788	-8.9	-0.0699	-13.6
MPGE	β_8	MPGE	MPGE	0.0169	5.91	0.0143	8.43
Acceleration	β_9	Acceleration	secs	-0.04	-5.25	-0.0332	-7.13
Range	β_{10}	Natural log of range	miles	0.279	1.5	0.336	3.02
Fuel Availability	$\beta_{11,1}$	1 in 50 stations (CNG)	(0,1)	0.00	0.00	0.00	0.00
	$\beta_{11,2}$	1 in 20 Stations (CNG)	(0,1)	0.327	2.21	0.0458	0.519
	$\beta_{11,3}$	Plug-in at home only (EV)	(0,1)	0.00	0.00	0.00	0.00
	$\beta_{11,4}$	Plug-in at work and other locations (EV)	(0,1)	0.133	1.05	0.183	2.46
Refueling Time	$\beta_{12,1}$	Refuel in 10 min (station); 8 hrs (home) (CNG)	(0,1)	0.00	0.00	0.00	0.00
	$\beta_{12,2}$	Refuel in 10 min (station); 4 hrs (home) (CNG)	(0,1)	--	--	--	--
	$\beta_{12,3}$	Recharge in 8hrs (EV)	(0,1)	0.00	0.00	0.00	0.00
	$\beta_{12,4}$	Recharge in 3 hrs (EV)	(0,1)	--	--	0.0616	0.829
Household Size-Vehicle Type Interaction	$\beta_{13,1}$	Large HH - Small vehicles	(0,1)	0.00	0.00	0.00	0.00
	$\beta_{13,2}$	Large HH - Medium vehicles	(0,1)	0.397	2.84	0.21	3.98
	$\beta_{13,3}$	Large HH - Large vehicles	(0,1)	0.718	4.1	0.366	4.43
Alt Fuels-Vehicle Type Interaction	$\beta_{14,1}$	Alt Fuel - Small vehicles	(0,1)	0.00	0.00	0.00	0.00
	$\beta_{14,2}$	Alt Fuel - Medium vehicles	(0,1)	-0.0154	-0.207	-0.0675	-1.55
	$\beta_{14,3}$	Alt Fuel - Large vehicles	(0,1)	-0.277	-2.48	-0.422	-6.27

* *Not used in forecasting*

Fit Statistics	1 Vehicle	2+ Vehicles
Number of observations	7552	18640
Number of individuals	944	2330
Number of parameters	44	46
Log Likelihood at Zero	-10469.30	-25840.53
Constants only log likelihood	-8943.85	-23427.02
Log likelihood at convergence	-7654.51	-20388.30
Rho-squared	0.269	0.211
Adjusted Rho-squared	0.265	0.209

Based on the model specification and coefficient values outlined above, the probability of a household selecting vehicle *i,* with vehicle type *v*, fuel type *f*, age *a,* and purchase incentive *c* for a household with income category *d* is given by the following formula:

$$P(i) = \frac{e^{U_i}}{\sum_j e^{U_j}}$$

Where U_i is the modeled utility of vehicle *i* given by the following equation:

$$U_i = \sum_{k=1}^{15} \beta_{1,k} X_{1,k} + \sum_{m=1}^{7} \beta_{2,m} X_{2,m} + \sum_{n=1}^{3} \beta_{3,n} X_{3,n} + \sum_{p=1}^{6} \beta_{4,p} X_{4,p} + \sum_{q=1}^{7} \beta_{5,q} X_{5,q}$$

$$+ \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10}$$

$$+ \beta_{11,1} X_{11,1} + \beta_{11,2} X_{11,2} + \beta_{11,3} X_{11,3} + \beta_{11,4} X_{11,4} + \beta_{12,1} X_{12,1} + \beta_{12,2} X_{12,2} + \beta_{12,3} X_{12,3} + \beta_{12,4} X_{12,4}$$

$$+ \beta_{13,1} X_{13,1} + \beta_{13,2} X_{13,2} + \beta_{13,3} X_{13,3} + \beta_{14,1} X_{14,1} + \beta_{14,2} X_{14,2} + \beta_{14,3} X_{14,3}$$

Where:

$X_{1,k}$ = Array of dummy variables equal to 1 when vehicle type = *v*, else 0
$X_{2,m}$ = Array of dummy variable equal to 1 when fuel type = *f*, else 0
$X_{3,n}$ = Array of dummy variable equal to 1 when vehicle age category = *a*, else 0
$X_{4,p}$ = Array of dummy variable equal to 1 when incentive = *c*, else 0
$X_{5,q}$ = Array of: vehicle price in thousands of dollars * (dummy variable equal to 1 when income category = *d*, else 0)
X_6 = Vehicle maintenance cost in cents per mile
X_7 = Vehicle fuel cost in cents per mile
X_8 = Vehicle efficiency in miles per gallon equivalents (MPGE)
X_9 = Vehicle acceleration from 0 to 60 mph in seconds
X_{10} = $\log_e$(vehicle range in miles) * (dummy variable equal to 1 if fuel type = CNG or EV, else 0)
$X_{11,1}$ = Dummy variable equal to 1 when fuel type is CNG and fuel availability is 1 in 50 stations, else 0
$X_{11,2}$ = Dummy variable equal to 1 when fuel type is CNG and fuel availability is 1 in 20 stations, else 0
$X_{11,3}$ = Dummy variable equal to 1 when fuel type is EV and fuel availability is plug-in at home only, else 0
$X_{11,3}$ = Dummy variable equal to 1 when fuel type is EV and fuel availability is plug-in at work and other locations, else 0
$X_{12,1}$ = Dummy variable equal to 1 when fuel type is CNG and refueling time is 10 mins. at station and 8 hrs at home, else 0
$X_{12,2}$ = Dummy variable equal to 1 when fuel type is CNG and refueling time is 10 mins. at station and 4 hrs at home, else 0
$X_{12,3}$ = Dummy variable equal to 1 when fuel type is EV and refueling time is 8 hrs, else 0
$X_{12,4}$ = Dummy variable equal to 1 when fuel type is EV and refueling time is 3 hrs, else 0
$X_{13,1}$ = Dummy variable equal to 1 when household size >=4 and vehicle is small, else 0
$X_{13,2}$ = Dummy variable equal to 1 when household size >=4 and vehicle is medium, else 0
$X_{13,3}$ = Dummy variable equal to 1 when household size >=4 and vehicle is large, else 0
$X_{14,1}$ = Dummy variable equal to 1 when fuel type is non-gasoline and vehicle is small, else 0
$X_{14,2}$ = Dummy variable equal to 1 when fuel type is non-gasoline and vehicle is medium, else 0
$X_{14,3}$ = Dummy variable equal to 1 when fuel type is non-gasoline and vehicle is large, else 0

The denominator term is the sum of exponentiated utilities for all vehicles in the respondents' choice set, which includes all vehicle types and fuel types available for each model year.

Vehicle Transaction and Replacement Model

The vehicle transaction and replacement model was estimated with data from the RP survey. In the RP survey, respondents described the existing vehicles in their household and reported their expected replacement timeframe for each vehicle. The replacement timeframe, along with various household and vehicle characteristics, form the data for this model.

Only transactions within the next year were considered, and multiple transactions within the next year were not included. That is, if a household expected to replace more than one vehicle within the next year, only the first vehicle reported was coded as replaced. A maximum of three vehicles were considered for each household. If a household reported more than three vehicles, the soonest three vehicles reported to be replaced were selected.

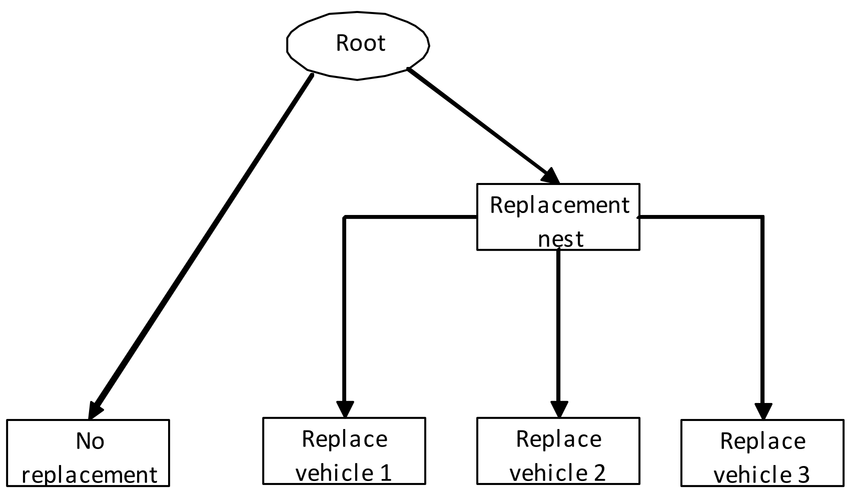
Vehicle Transaction and Replacement Model Specification

The vehicle transaction and replacement model was estimated as a nested logit model with four alternatives:

1. No replacement
2. Replacement of vehicle 1
3. Replacement of vehicle 2 (if applicable)
4. Replacement of vehicle 3 (if applicable)

Alternatives two through four were grouped into a single replacement nest, while the no-replacement alternative stood alone in a separate branch. It is important to note that the structure of the nested logit model does not imply a sequential decision making process; rather, it implies that the vehicle replacement alternatives are closer substitutes for each other than the no replacement alternative.

Figure 2: Vehicle Transaction and Replacement Nested Logit Model Structure



Two variables apply to the no-replacement alternative, 1) an alternative specific constant and 2) the vehicle ownership category. This categorical variable for the number of household vehicles has value of (1) and (2) for one-vehicle and two or more-vehicle households, respectively.

All other variables apply to the three vehicle replacement alternatives. Household-specific variables include household size, number of full-time equivalent workers, and annual household income. These variables were tested in both linear and non-linear forms, including the natural log of household size, income, and workers. The best model fit was obtained by using linear forms of these variables.

A categorical population density variable was obtained form the Random Digit Dial (RDD) sample provider. This variable was recoded into an urban dummy variable, where an urban household is defined as being located in the central city of a Census Metropolitan Statistical Area (MSA). The central city of an MSA is defined as one or more cities named in the MSA's title. For example, Santa Ana is one of the title cities of the Los Angeles-Long Beach-Santa Ana MSA. This variable was found to be statistically significant; however, because of potential difficulties in applying this variable in the CALCARS forecasting model, the vehicle transaction and replacement model was estimated both with and without this variable. Results for the estimation without the urban variable are presented below; those with the urban variable are presented in Appendix A.

Vehicle-specific variables include vehicle age and the difference between the utility of the vehicle considered for replacement and the expected value of the maximum utility of all available vehicles based on vehicle type, fuel type, and vehicle age back to and including the 1989 model year.

The expected value of the maximum vehicle utility for each household, or logsum value, was calculated from the vehicle choice coefficients presented above and vehicle data provided by CEC for vehicle class, fuel type and model year. The vehicle choice parameters were multiplied by the corresponding vehicle attributes to obtain the utility for each vehicle. These vehicle utilities were exponentiated, summed, and the natural log of the sum was calculated. Because the vehicle choice model coefficients varied according to vehicle ownership category, income, household size, and, in the case where regional variables were included, region, the logsum values varied across these same dimensions. For the two vehicle ownership segmentations, two-class (1, 2+) and three-class (1, 2, 3+), logsum values were calculated using the vehicle choice coefficients both including and excluding regional variables, resulting in a total of four different sets of logsum values.

After calculating the logsum values, utilities were also calculated for each household vehicle in the model. These utilities were then subtracted from the logsum value, which represents the difference between the maximum potential vehicle utility for a given household and the utility of the vehicle considered for replacement for the same household.

Vehicle Transaction and Replacement Model Segmentation

As with the vehicle choice model, the vehicle transaction and replacement model was estimated for two separate vehicle ownership classification schemes. The first included two vehicle ownership categories, 1) one vehicle and two or more vehicles, and 2) one, two, and three or more vehicles. Results from the two-class model are presented here, while the three-class model results are presented in Appendix A.

Vehicle Transaction and Replacement Model Coefficient Estimates

The variables included in the model are presented below in Table 5. The models are estimated using the RU2, or top-down, normalization in Limdep, where the upper-level scale parameters are set to unity.

Table 5: Vehicle Transaction and Replacement Nested Logit Model Coefficients

Alternative	Coef.	Description	Units	Estimate	T-stat
No Replacement Alternative	α_1	No replacement constant	--	3.89	7.1
	β_1	Vehicle ownership category	--	0.15	1.52
Vehicle Replacement Alternatives	β_2	Large HH dummy (>=4)	(0,1)	0.274	3.58
	β_3	Full-time equivalent workers	persons	0.138	3.03
	β_4	Income	$000	0.00367	3.64
	β_5	Vehicle age	years	0.185	7.32
	β_6	Vehicle age squared	years^2	-0.00573	-6.37
	β_7	Logsum minus vehicle utility	--	0.118	1.69
Nest Coefficient	θ_{rep}	Replacement nest	--	0.375	7.66

Number of observations	6364
Number of individuals	6364
Number of parameters	9
Log likelihood at zero	-6622.77
Constants only log likelihood	-5677.89
Log likelihood at convergence	-3550.02
Rho-squared	0.464
Adjusted Rho-squared	0.463

The dependent variable in this model is the choice between the four alternatives described above. In a nested logit model, the probability of choosing a particular alternative is given by a product of the individual choice probabilities for each level in the nest structure. In this case, the probability of a household replacing one of their existing vehicles, say vehicle *i,* within the next year is given by the probability that the household replaces any vehicle multiplied by the probability that the vehicle replaced is vehicle *i*.

$$P(i) = P(replacement) * P(vehicle_i)$$

Within-nest probabilities are given by:

$$P(vehicle_i) = \frac{e^{\frac{U_i}{\theta_{rep}}}}{\sum_j e^{\frac{U_j}{\theta_{rep}}}}$$

Where:

$$U_i = \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7$$

X_2 = Dummy variable equal to 1 when household size >= 4, else 0
X_3 = Number of full-time workers + 0.4 * number of part-time workers
X_4 = Annual household income in thousands of dollars
X_5 = Age of vehicle considered for replacement in years
X_6 = Square of age of vehicle considered for replacement in years
X_7 = Logsum minus utility of vehicle considered for replacement

The nest probability is given by:

$$P(replacement) = \frac{e^{\theta_{rep} * IV_{rep}}}{e^{\theta_{rep} * IV_{rep}} + e^{U_{norep}}}$$

Where:

$U_{norep} = \alpha_1 + \beta_1 X_1$

X_1 = Vehicle ownership category (1,2)

The term IV_{rep} is the inclusive value term, also referred to as the logsum, of the vehicle replacement nest, and is given by:

$$IV_{rep} = LN\left(\sum_i e^{\frac{U_i}{\theta_{rep}}} \right)$$

The inclusive value term represents the expected gain from choosing an alternative in the replacement nest.

Looking at the magnitude and signs of the coefficients, the combined effects of the large household dummy and full-time equivalent worker coefficients imply that increasing household size and the number of household workers increases the likelihood of vehicle replacement.

As expected, income has a positive and significant coefficient, indicating that households with higher income are more likely to make vehicle transactions or replacements.

Vehicle age is specified with two coefficients; vehicle age and vehicle age squared. The positive value of the vehicle age coefficient and the negative value of the vehicle age squared imply that vehicles are more likely to be replaced as they get older, but the likelihood increases more slowly as vehicle age increases.

New-Used Vehicle Choice Model

The CALCARS model addresses vehicle choice in two stages. When a vehicle transaction or replacement decision is made, it is assumed that a household first chooses between purchasing a new vehicle or a used vehicle and then chooses from within the set of available new or used vehicles.

New-Used Vehicle Model Specification

To support this model structure, a binomial logit model was estimated to predict whether the next vehicle purchased by a household will be new or used. Data from the stated preference exercises with eight choice observations per respondent were used to estimate this model. As with the vehicle choice model, separate new-used models were estimated for one-vehicle, two or more-vehicle, two-vehicle, and three or more-vehicle households, as well as with and without the urban and regional dummy variables. The models without urban and regional variables for the one-vehicle and two or more-vehicle segments are presented below, while the remaining model results are documented in Appendix A.

Factors such as income, household size, and population density were found to significantly affect the new-used decision. Income and household size provided the best model fit when entered into the equation in logarithmic form. All coefficients apply to the new vehicle alternative.

New-Used Model Coefficient Estimates

Table 6: New-Used Vehicle Choice Model Coefficients

			1 Vehicle		2+ Vehicles	
Coef.	**Description**	**Units**	**Estimate**	**T-Stat**	**Estimate**	**T-Stat**
α_1	New vehicle constant	--	-7.92	-18.4	-6.66	-18.9
β_1	Natural log of income	dollars	0.806	19.9	0.688	21.8
β_2	Natural log of household size	persons	-0.448	-9.31	-0.494	-12.8

Fit Statistics	1 Vehicle	2+ Vehicles
Number of observations	7552	18640
Number of individuals	944	2330
Number of parameters	3	3
Log likelihood at zero	-5234.65	-12920.26
Constants only log likelihood	-4962.27	-12093.59
Log likelihood at convergence	-4734.93	-11802.79
Rho-squared	0.0955	0.0865
Adjusted Rho-squared	0.0949	0.0863

The dependent variable was the choice among a new or used vehicle. The probability of selecting a new vehicle is given by the following equations:

$$P(new) = \frac{e^{U_{new}}}{e^{U_{new}} + 1}$$

Where:

$$U_{new} = \alpha_1 + \beta_1 X_1 + \beta_2 X_2$$

$X_1 = \log_e$(annual household income in dollars)
$X_2 = \log_e$(household size)

The income coefficient is positive and strongly significant, suggesting that higher income households are more likely to purchase new vehicles. The negative coefficient for household size indicates that, accounting for income, larger households are less likely to purchase new vehicles, reflecting the lower value of income per household member.

Fuel Choice Model

After completing the eight vehicle choice questions in the stated preference survey, respondents were presented with a set of three follow-up questions asking which type of fuel, E-85 or gasoline, they would typically use if they purchased a flex-fuel vehicle. Respondents were asked to make their selection over three different price conditions, 1) if the annual fuel cost was about the same for E-85 and gasoline, 2) if the annual fuel cost was 15% higher for E-85 than gasoline, and 3) if the annual fuel cost was 30% higher for E-85 than gasoline.

While all respondents were presented with these questions after the SP experiments, only the 1,306 respondents (40%) who indicated they would purchase a flex-fuel vehicle in at least one of their eight SP experiments were included in this fuel choice analysis.

Fuel Choice Model Specification

Data from these three questions were used to estimate a binomial logit fuel choice model with alternatives for gasoline and ethanol. To account for the fact that households would most likely not purchase only one type of fuel all of the time, the choice variables were specified as a proportion of 0.25 or 0.75 for each fuel type instead of 0 and 1. For example, if a respondent selected ethanol, the ethanol alternative was assigned a choice value of 0.75, while the gasoline alternative was assigned a choice value of 0.25.

All variables in the fuel choice model are applied to the ethanol alternative, while the gasoline alternative is assigned a utility of zero. The only variable found to significantly affect fuel choice was the ratio of the ethanol cost to gasoline cost. As with the other model specifications discussed above, regional variables and the urban variable were tested. Some of the regional variables were found to be marginally significant and are included in Appendix A. The urban variable had no statistical significance and is therefore not included in any of the fuel choice models.

Fuel Choice Model Coefficient Estimates

Table 7: Fuel Choice Model Coefficients

Coef.	Description	Units	Estimate	T-Stat
α_1	Ethanol constant	--	5.03	15.7
β_1	E-85:gasoline price ratio for income < $40,000	--	-4.6	-16.1
β_2	E-85:gasoline price ratio for income $40,000 to $79,999	--	-4.55	-16.3
β_3	E-85:gasoline price ratio for income >= $80,000	--	-4.49	-16

Fit Statistics	
Number of observations	3903
Number of individuals	1301
Number of parameters	4
Log likelihood at zero	-2705.35
Log likelihood at convergence	-2548.84
Rho-squared	0.058
Adjusted Rho-squared	0.056

The very large and statistically significant ethanol constant implies that, all things equal, respondents exhibit a strong preference for ethanol over gasoline. However, the price ratio coefficients indicate a very large change in ethanol use when the price of ethanol changes in comparison to the price of gasoline.

$$P(ethanol) = \frac{e^{U_{ethanol}}}{e^{U_{ethanol}} + 1}$$

$$U_{ethanol} = \alpha_1 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3$$

X_1 = (Ethanol price/gasoline price) * (dummy variable equal to 1 when income < $40,000, else 0)
X_2 = (Ethanol price/gasoline price) * (dummy variable equal to 1 when income >= $40,000 AND < $80,000, else 0)
X_3 = (Ethanol price/gasoline price) * (dummy variable equal to 1 when income >= $80,000, else 0)

Vehicle Quantity Model

The probability of owning zero, one, or two vehicles is estimated by the vehicle quantity model. This model uses vehicle ownership data from the RP survey.

Vehicle Quantity Model Specification

The vehicle quantity model is a function of household income and household size, which both enter the equation in log form, and the number of full-time equivalent workers, transit availability, and the expected value of the maximum utility of all available vehicles. The number of full-time equivalent workers is calculated as the number of full-time workers plus 40% of the number of part-time workers, while per capita transit ridership values by county are used as a proxy for transit availability. The expected value of the maximum utility of all vehicles, or the logsum, is calculated by multiplying the coefficients from the vehicle choice model by the corresponding vehicle attribute variables for all available vehicles by vehicle type, fuel type, and model year. The resulting utilities are exponentiated, summed, and the natural log is taken of the resulting sums. The logsum values vary among households according to annual household income, household size, the number of household vehicles, and region in the instances where the regional vehicle choice coefficients are used.

Vehicle ownership alternatives are specified for 1) zero, 2) one, and 3) two or more household vehicles. The utility for the zero-vehicle alternative was always fixed to zero. Because household characteristics remain constant for all alternatives, separate coefficients were estimated for each alternative.

To provide flexibility for implementation in CALCARS, the vehicle quantity model was estimated using a multinomial logit form with several different specifications, including four vehicle ownership alternatives for 1) zero, 2) one, 3) two, and 4) three or more household vehicles, and with and without an urban dummy variable. Regional coefficients were tested, but not found to be significant in any model specification. Results from the additional specifications are presented in Appendix A.

Vehicle Quantity Model Coefficient Estimates

Table 8: Vehicle Quantity Model Coefficients

Alternative	Coeff.	Description	Units	Estimate	T-stat
1 Vehicle Alternative	α_1	Constant - 1 Vehicle	--	-5.77	-3.68
	β_1	Natural log of income - 1 Vehicle	dollars	0.781	5.62
	β_2	Full-time equivalent workers - 1 Vehicle	persons	-0.355	-2.98
	β_3	Natural log of household size - 1 Vehicle	persons	-0.996	-5.57
	β_4	Per capita transit ridership - 1 Vehicle	trips/person	-0.00294	-2.01
2 + Vehicle Alternative	α_2	Constant - 2 Vehicle	--	-18.8	-9.55
	β_5	Natural log of income - 2 Vehicle	dollars	1.83	10.5
	β_6	Full-time equivalent workers - 2 Vehicle	persons	-0.0678	-0.585
	β_7	Natural log of household size - 2 Vehicle	persons	0.883	4.97
	β_8	Per capita transit ridership - 2 Vehicle	trips/person	-0.00888	-6.01
Logsum (applied to all alternatives)	β_9	Logsum	--	0.201	0.617

Fit Statistics	
Number of observations	6577
Number of individuals	6577
Number of parameters	11
Log likelihood at zero	-7291.67
Constants only log likelihood	-4706.46
Log likelihood at convergence	-3620.04
Rho-squared	0.504
Adjusted rho-squared	0.502

The probability of owning zero, one, and two or more vehicles is assigned using the utility for each ownership level.

$$P(n) = \frac{e^{U_n}}{1 + e^{U_1} + e^{U_{2+}}}$$

Where:

$$U_1 = \alpha_1 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_9 X_9$$

$$U_{2+} = \alpha_2 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9$$

X_1 = Log_e(annual household income in dollars for one-vehicle households)
X_2 = Full-time workers + 0.4 * part-time workers for one-vehicle households
X_3 = Log_e(household size for one-vehicle households)
X_4 = Per capita transit ridership for household county of residence for one-vehicle households
X_5 = Log_e(annual household income in dollars for two or more-vehicle households)
X_6 = Full-time workers + 0.4 * part-time workers for two or more-vehicle households
X_7 = Log_e(household size for two or more-vehicle households)
X_8 = Per capita transit ridership for household county of residence for two or more-vehicle households
X_9 = Expected maximum vehicle utility (logsum)

Vehicle Miles Traveled Model

The vehicle miles traveled (VMT) model was estimated at an individual vehicle level based on respondents' reported VMT from the previous year. All vehicles reported by each respondent were included in the model except vehicles for which the annual VMT was not known. VMT values reported in the RP survey were limited to a minimum of 1,000 miles and a maximum of 100,000 miles.

VMT Model Specification

The VMT model was estimated as a log-linear regression with the dependent variable specified as the natural log of VMT. Using this specification results in a better model fit than regressing against linear VMT.

The model is a function of 1) the vehicle characteristics of fuel cost per mile and vehicle age, and 2) the household characteristics of household income, household size, full-time equivalent workers, transit availability (as per capita transit ridership), and the average distance to work for working household members. The number of full-time equivalent workers is calculated as the number of full-time workers in the household plus 40% of the number of part-time workers. The per capita transit ridership in the household's county of residence was used as a proxy for transit availability. Both of these variables have been used in their respective forms in previous versions of the CALCARS model. The average distance to work for working household members is simply the reported one-way distance between home and work for each working household member, averaged over all working household members.

Both linear and logarithmic forms of all variables were tested in the model. Using the natural log of most variables resulted in an improvement in model fit.

Because households are able to choose both vehicle utilization amounts and vehicle attributes, the vehicle attribute of fuel cost per mile is endogenous in the VMT equation. That is, if a household anticipates a high amount of driving, they may decide to purchase a vehicle with a low fuel cost per mile. In that case, fuel cost per mile may appear to have a significant causal effect on VMT, when, in actuality, it has little or no effect.

To correct for this potential bias, the vehicle fuel cost per mile attribute was replaced with the expected value of this attribute. The expected value is calculated as the vehicle choice probability for a given household multiplied by the vehicle characteristic and summed over all possible vehicle choices. Coefficients from the vehicle choice model were used to calculate household-specific vehicle choice probabilities for all vehicles by vehicle type, fuel type, and model year back to and including 1989. These probabilities were then multiplied by the fuel cost per mile attribute for each vehicle.

Table 9 presents the estimation results of the VMT model for the two-class vehicle ownership segmentation scheme. As with the other models, the VMT model was also estimated using three classes, as well as with the urban and regional variables. Results for these models are presented in Appendix A.

VMT Model Coefficient Estimates

Table 9: VMT Model Coefficients

Coef.	Description	Units	1 Vehicle Estimate	1 Vehicle T-stat	2+ Vehicles Estimate	2+ Vehicles T-stat
α_1	(Constant)	--	14.7	3.06	17.3	5.32
β_1	Natural log of household size	persons	0.114	2.27	0.256	7.77
β_2	Natural log of full-time equivalent workers	persons	0.0549	1.08	0.162	8.84
β_3	Natural log of average household miles to work	miles	0.135	8.87	0.104	15
β_4	Per capita transit ridership	trips/person	-0.00127	-3.14	-0.00057	-2.56
β_5	Number of vehicles more than 2	vehicles	--	--	-0.173	-20.4
β_6	Natural log of income	dollars	0.105	3.15	0.0798	4.48
β_7	Natural log of fuel cost per mile*	cents/mile	-2.74	-1.45	-3.7	-2.92
β_8	Vehicle age	years	-0.00926	-2.07	-0.0292	-19.9

** Expected value of attribute*

Fit Statistics	1 Vehicle	2+ Vehicles
Number of observations (vehicles)	1735	10338
Number of parameters	8	9
Standard error of the estimate	0.784	0.785
R-squared	0.0866	0.135
Adjusted R-squared	0.0829	0.135

The dependent variable for this model is the natural log of VMT, and the full equation of the model is given by:

$$\log_e(VMT) = \alpha_1 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8$$

X_1 = $\log_e$(household size)
X_2 = $\log_e$(Number of full-time workers + 0.4 * number of part-time workers)
X_3 = $\log_e$(distance between home and work for each working household member, averaged across all working household members)
X_4 = Per capita transit ridership in household county of residence
X_5 = Household vehicles minus two (two or more vehicle segment only)
X_6 = $\log_e$(annual household income in dollars)
X_7 = $\log_e$(expected value of vehicle fuel cost in cents per mile)
X_8 = Vehicle age in years (2009 model year = 0)

Price Elasticity of VMT

The average price elasticity of VMT with respect to per mile fuel cost can be determined using the fuel cost per mile coefficient. Since fuel cost per mile takes a log form in the regression equation, the constant price elasticity of VMT is simply the value of this coefficient. Therefore, the elasticity is -2.74 for one-vehicle households, and -3.70 for two-or-more-vehicle households, implying that a 10% increase in the per mile cost of fuel will result in a 27% and 37% decrease in VMT, respectively.

Commercial Models

Commercial Vehicle Choice Model

Data from the commercial fleet SP survey were combined with fleet information from the RP survey to form a dataset with 14,240 observations from 1,780 respondents.

Description of Alternatives

In the stated preference portion of the survey, respondents completed eight vehicle choice experiments. In a similar fashion to the residential survey, each stated preference experiment presented respondents with four hypothetical vehicles described by a set of ten to twelve attributes, depending on the fuel type. The first vehicle, or the reference vehicle, was always presented as the new or used vehicle the respondent planned to purchase next for their commercial vehicle fleet based on their responses in the RP survey. The vehicle attributes presented in the next three alternatives varied according to the experimental design. Respondents were asked to select the vehicle they would most likely purchase for their fleet, based on the attributes presented in each alternative.

Commercial Vehicle Choice Model Specification

Coefficients were estimated for each attribute presented in the stated preference survey. These attributes are identical to those presented in the residential stated preference survey, and are discussed above in the residential vehicle choice description. Many of the same specification tests for vehicle age, range, acceleration, and vehicle type – fuel type interactions that were conducted for the residential vehicle choice model were also conducted here. Interpretation and discussion of each set of parameters follows below.

Inertia

The inertia variable captures the effect of the reference vehicle on vehicle choice to remove potential bias from the other coefficient estimates. This variable should not be used in forecasting.

Vehicle Type and Fuel Type by Industry

The primary commercial demographic variable examined was industry type. There are, in many cases, strong differences in preferences among industry types for attributes such as vehicle type and fuel type. Several different specifications were tested to account for this taste heterogeneity among industries, including using industry interaction terms with various stated preference variables and estimating separate model segments for several different groups of industries. Ultimately, the vehicle type and fuel type attributes were found to have the most important differences.

The final specification used a pooled model approach to account for these differences in vehicle type and fuel type preference. Separate vehicle type and fuel type coefficients were estimated for three different groups of industries, while the remaining vehicle attribute coefficients were constrained to be equal among the industry groups. The industry classifications used in the model estimation are described in Table 10 and Table 11 presents the number of commercial respondents in each classification.

Table 10: Industry Classifications

Industry Group	Industries Included
Industry Group 1	Agriculture, Forestry, Fishing, And Hunting Mining, Quarrying, and Oil and Gas Extraction Utilities (I.E. Electric, Gas, Water) Construction Manufacturing
Industry Group 2	Wholesale Trade Retail Trade Transportation and Warehousing
Industry Group 3	Information (I.E., Communications, Information Services, Publishers, Telecommunications) Finance and Insurance Real Estate and Rental And Leasing Professional, Scientific, and Technical Services (I.E., Lawyers, Engineering, Marketing) Management Of Companies and Enterprises Administrative and Support and Waste Management and Remediation Services Educational Services (I.E., Schools, Colleges, Universities) Health Care and Social Assistance Arts, Entertainment, and Recreation Accommodations and Food Services Public Administration Repair Service A/O Professional, Scientific, and Technical Services Mentions

Table 11: Industry Distribution of the Sample

Industry Group	Number of Companies	Number of Observations
Group 1	805	6,440
Group 2	402	3,216
Group 3	573	4,584
Total	1,780	14,240

Companies in the group 1 industry segment, consisting of heavy industries such as construction, mining, and manufacturing, have stronger preferences for large vehicles. In particular, the difference in utility between pickup trucks (both compact and standard) and subcompact cars is at least 40% larger in magnitude than the difference in the other two industry groups. Other large vehicles, such as large vans, compact vans, and large SUVs also have coefficients that are larger in magnitude than those for the other industries.

Differences in fuel type preference among industry groups are largely found in the stronger preference for diesel over gasoline in the group 1 segment. Group 3 industries, primarily consisting of professional and service industries, have a less negative perception of alternative fuels when compared to the other industry groups.

Vehicle Age

Vehicle age was specified using three age categories for 1) new vehicles, 2) used vehicles one or two years old, and 3) used vehicles three or more years old. The negative and statistically significant values for the used vehicle categories indicate that, all else equal, new vehicles are preferred to used vehicles.

Incentives

Coefficients were specified for all six incentive levels that were tested. Of the incentives, only HOV lane use was statistically different than no incentive. The remaining incentives had both positive and negative coefficients, but were not statistically significant.

Costs

Vehicle purchase price was specified in thousands of dollars, and maintenance and fuel costs were specified in cents per mile. The negative and significant coefficient estimates indicate decreasing utility with increasing purchase and operating costs.

Miles per Gallon

The miles per gallon coefficient represents the value of a vehicle's fuel efficiency. The units are in miles per gallon equivalent (MPGE). The positive value indicates that vehicle utility increases as MPGE increases. Non-linear transformations of MPGE were tested, including logarithmic and quadratic specifications; however, both resulted in a decrease in model performance when compared to the linear specification. The linear model provides the best fit.

Acceleration

This coefficient represents the value of vehicle acceleration from zero to 60 miles per hour and has units of seconds. Lower acceleration times (closer to zero) are viewed more favorably by respondents, resulting in a negative value for this coefficient.

Fuel Availability, Refueling Time and Range

These three attributes were presented only for compressed natural gas (CNG) and full electric fuel types. Therefore, these coefficients apply only to vehicles with those fuel types. The range coefficient estimate represents the perceived benefit of extending the operating range between refueling stops for CNG and electric vehicles. Using the natural log of range was found to slightly improve the model fit.

Two levels were presented for fuel availability and refueling time. In both cases, the lower-level, or the level expected to be perceived as the worst, was constrained to zero. The value of the upper level represents the impact of the difference between the two levels on consumer preference. Fuel availability was found to be important for CNG vehicles, but for the remaining attributes the differences in levels were not statistically significant.

Vehicle Type – Fuel Type Interactions by Industry

Interactions between vehicle type and fuel type variables were tested to determine if the combined effects of vehicle type and fuel type significantly influence vehicle choice. Many different combinations of vehicle size groups and alternative fuel groups were tested. The groups with the best model fit, as described in Table 12 below, included three vehicle size categories and a dummy variable for all non-gasoline alternative fuels (including diesel).

Table 12: Vehicle Size Groups

Vehicle Group	Vehicle Types Included
Vehicle Group 1: Small Vehicles	Subcompact car Compact car Midsize car Sports car Small cross utility car Compact pickup
Vehicle Group 2: Medium Vehicles	Large car Small cross utility SUV Midsize cross utility SUV Compact SUV Midsize SUV Standard pickup
Vehicle Group 3: Large Vehicles	Large SUV Compact van Large van

These interactions were segmented by industry. In contrast with the automobile results, positive and, in some cases, statistically significant coefficients were identified on the medium and large vehicle size interactions with fuel type. This implies that, alternative fuels are more desirable for medium and large vehicles than small vehicles in some industry groups.

Number of Vehicles in Fleet

The final set of variables capture the likelihood of a respondent to choose vehicles of a similar body type to the vehicles in his or her existing fleet. Vehicles were grouped into four types: cars, SUVs, vans, and pickup trucks. The number of fleet vehicles in each of these groups was included as a variable in the model. The interpretation of this is that respondents with a large number of one type of vehicle in their existing fleets are more likely to replace or add a vehicle of the same type in the future.

Commercial Vehicle Choice Model Coefficient Estimates

The commercial vehicle choice model coefficient estimates are presented as three separate industry-group segments. The vehicle type, fuel type, and vehicle type-fuel type interaction coefficients vary across industry groups, but all other coefficients are constrained to be equal. Because this was estimated as a single pooled model, only one set of fit statistics is produced.

Table 13: Commercial Vehicle Choice Model Coefficients

Type	Coef.	Description	Units	Industry Grp 1		Industry Grp 2		Industry Grp 3	
				Est.	T-stat	Est.	T-stat	Est.	T-stat
Constants*	α_1	Inertia	--	1.39	43.1	1.39	43.1	1.39	43.1
Vehicle Type	$\beta_{1,1}$	Subcompact car	(0,1)	--	--	--	--	--	--
	$\beta_{1,2}$	Compact car	(0,1)	0.324	1.69	0.193	0.962	0.411	2.76
	$\beta_{1,3}$	Midsize car	(0,1)	0.57	3.06	0.45	2.29	0.64	4.36
	$\beta_{1,4}$	Large car	(0,1)	0.452	2.16	0.215	0.954	0.867	4.99
	$\beta_{1,5}$	Sport car	(0,1)	0.196	0.842	0.019	0.075	-0.0117	-0.058
	$\beta_{1,6}$	Small cross car	(0,1)	0.23	1.12	0.235	1.07	0.0924	0.517
	$\beta_{1,7}$	Small cross utility SUV	(0,1)	0.448	2.2	0.321	1.33	0.492	2.7
	$\beta_{1,8}$	Midsize cross utility SUV	(0,1)	0.818	4.02	0.365	1.5	0.645	3.3
	$\beta_{1,9}$	Compact SUV	(0,1)	0.429	2.07	0.229	0.898	0.561	2.85
	$\beta_{1,10}$	Midsize SUV	(0,1)	0.731	3.66	0.657	2.78	0.981	5.47
	$\beta_{1,11}$	Large SUV	(0,1)	1.47	7.02	0.0867	0.337	0.906	4.54
	$\beta_{1,12}$	Compact van	(0,1)	0.926	4.85	0.505	2.51	0.885	5.52
	$\beta_{1,13}$	Large van	(0,1)	1.64	8.82	1.01	5.02	1.57	9.68
	$\beta_{1,14}$	Compact truck	(0,1)	1.37	8.12	0.774	4.09	0.923	6.15
	$\beta_{1,15}$	Standard truck	(0,1)	2.04	11.7	1.46	7.38	1.43	8.92
Fuel Type	$\beta_{2,1}$	Gasoline	(0,1)	--	--	--	--	--	--
	$\beta_{2,2}$	E-85	(0,1)	-0.146	-1.36	-0.122	-1.01	0.00833	0.083
	$\beta_{2,3}$	Plug-in hybrid	(0,1)	-0.136	-1.02	-0.238	-1.64	0.0112	0.088
	$\beta_{2,4}$	Compressed natural gas	(0,1)	-2.83	-3.4	-2.86	-3.41	-2.59	-3.11
	$\beta_{2,5}$	Diesel	(0,1)	0.226	2.18	0.0963	0.817	0.166	1.68
	$\beta_{2,6}$	Hybrid	(0,1)	0.0993	0.922	-0.00789	-0.065	0.104	1.06
	$\beta_{2,7}$	Full electric	(0,1)	-2.86	-4.67	-2.81	-4.54	-2.59	-4.22
Age	$\beta_{3,1}$	New vehicle	(0,1)	--	--	--	--	--	--
	$\beta_{3,2}$	Used vehicle 1 or 2 years old	(0,1)	-0.111	-2.26	-0.111	-2.26	-0.111	-2.26
	$\beta_{3,3}$	Used vehicle 3 or more years old	(0,1)	-0.439	-10.3	-0.439	-10.3	-0.439	-10.3
Incentive	$\beta_{4,1}$	No incentive	(0,1)	--	--	--	--	--	--
	$\beta_{4,2}$	HOV lane use	(0,1)	0.112	2.1	0.112	2.1	0.112	2.1
	$\beta_{4,3}$	Free parking	(0,1)	-0.0407	-0.747	-0.0407	-0.747	-0.0407	-0.747
	$\beta_{4,4}$	$1,000 tax credit	(0,1)	0.0658	1.23	0.0658	1.23	0.0658	1.23
	$\beta_{4,5}$	50% reduced tolls	(0,1)	-0.0151	-0.28	-0.0151	-0.28	-0.0151	-0.28
	$\beta_{4,6}$	$1,000 reduced purchase price	(0,1)	0.0515	0.961	0.0515	0.961	0.0515	0.961
Price	β_5	Price	$000	-0.0372	-17.1	-0.0372	-17.1	-0.0372	-17.1
Maintenance	β_6	Maintenance cost	c/mi	-0.0695	-4.52	-0.0695	-4.52	-0.0695	-4.52
Fuel Cost	β_7	Fuel cost	c/mi	-0.0664	-12.1	-0.0664	-12.1	-0.0664	-12.1
MPGE	β_8	MPGE	MPGE	0.00866	3.38	0.00866	3.38	0.00866	3.38
Acceleration	β_9	Acceleration (0 to 60 mph)	secs	-0.0127	-2.15	-0.0127	-2.15	-0.0127	-2.15
Range	β_{10}	Natural log of range (CNG and EV)	miles	0.334	2.2	0.334	2.2	0.334	2.2
Fuel Availability	$\beta_{11,1}$	1 in 50 stations (CNG)	(0,1)	--	--	--	--	--	--
	$\beta_{11,2}$	1 in 20 stations (CNG)	(0,1)	0.294	2.63	0.294	2.63	0.294	2.63
	$\beta_{11,3}$	Plug-in at home only (EV)	(0,1)	--	--	--	--	--	--
	$\beta_{11,4}$	Plug-in at work and other locations (EV)	(0,1)	0.18	1.65	0.18	1.65	0.18	1.65

Type	Coef.	Description	Units	Industry Grp 1		Industry Grp 2		Industry Grp 3	
				Est.	T-stat	Est.	T-stat	Est.	T-stat
Refueling Time	$\beta_{12,1}$	Refuel in 10 min (station); 8 hrs (home) (CNG)	(0,1)	--	--	--	--	--	--
	$\beta_{12,2}$	Refuel in 10 min (station); 4 hrs (home) (CNG)	(0,1)	-0.123	-1.1	-0.123	-1.1	-0.123	-1.1
	$\beta_{12,3}$	Recharge in 8hrs (EV)	(0,1)	--	--	--	--	--	--
	$\beta_{12,4}$	Recharge in 3 hrs (EV)	(0,1)	-0.133	-1.22	-0.133	-1.22	-0.133	-1.22
Veh. type - fuel type interactions	$\beta_{13,1}$	Alt fuel - Small vehicles	(0,1)	--	--	--	--	--	--
	$\beta_{13,2}$	Alt fuel - Medium vehicles	(0,1)	0.376	3.93	0.174	1.44	0.00428	0.044
	$\beta_{13,3}$	Alt fuel - Large vehicles	(0,1)	0.08	0.683	0.404	3.29	0.067	0.686
Number of Vehicles in Fleet	$\beta_{14,1}$	Cars	(0,1)	0.0311	5.33	0.0311	5.33	0.0311	5.33
	$\beta_{14,2}$	SUVs	(0,1)	0.0443	5.23	0.0443	5.23	0.0443	5.23
	$\beta_{14,3}$	Vans	(0,1)	0.0668	7.88	0.0668	7.88	0.0668	7.88
	$\beta_{14,4}$	Trucks	(0,1)	0.0553	9.54	0.0553	9.54	0.0553	9.54

* *Not used in forecasting*

Fit Statistics	Pooled Model
Number of observations	14240
Number of individuals	1780
Number of parameters	88
Log Likelihood at Zero	-19740.83
Log Likelihood Constants Only	-15067.22
Log Likelihood at Convergence	-13030.73
Rho squared	0.3399
Adjusted Rho squared	0.3355

Based on the model specification and coefficient values outlined above, the probability of selecting vehicle *i,* with vehicle type *v*, fuel type *f*, age *a*, and purchase incentive *c* is given by:

$$P(i) = \frac{e^{U_i}}{\sum_j e^{U_j}}$$

Where U_i is the modeled utility of vehicle *i* given by the following equation:

$$U_i = \sum_{k=1}^{15} \beta_{1,k} X_{1,k} + \sum_{m=1}^{7} \beta_{2,k} X_{2,k} + \sum_{n=1}^{3} \beta_{3,k} X_{3,k} + \sum_{p=1}^{6} \beta_{4,k} X_{4,k}$$

$$+ \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10}$$

$$+ \beta_{11,1} X_{11,1} + \beta_{11,2} X_{11,2} + \beta_{11,3} X_{11,3} + \beta_{11,4} X_{11,4} + \beta_{12,1} X_{12,1} + \beta_{12,2} X_{12,2} + \beta_{12,3} X_{12,3} + \beta_{12,4} X_{12,4}$$

$$+ \beta_{13,1} X_{13,1} + \beta_{13,2} X_{13,2} + \beta_{13,3} X_{13,3} + \beta_{14,1} X_{14,1} + \beta_{14,2} X_{14,2} + \beta_{14,3} X_{14,3} + \beta_{14,4} X_{14,4}$$

Where:

$X_{1,k}$ = Array of dummy variables equal to 1 when vehicle type = *v*, else 0
$X_{2,m}$ = Array of dummy variable equal to 1 when fuel type = *f*, else 0

$X_{3,n}$ = Array of dummy variable equal to 1 when vehicle age category = *a*, else 0
$X_{4,p}$ = Array of dummy variable equal to 1 when incentive = *c*, else 0
X_5 = Vehicle price in thousands of dollars
X_6 = Vehicle maintenance cost in cents per mile
X_7 = Vehicle fuel cost in cents per mile
X_8 = Vehicle efficiency in miles per gallon equivalents (MPGE)
X_9 = Vehicle acceleration from 0 to 60 mph in seconds
X_{10} = $\log_e$(vehicle range in miles) * (dummy variable equal to 1 if fuel type = CNG or EV, else 0)
$X_{11,1}$ = Dummy variable equal to 1 when fuel type is CNG and fuel availability is 1 in 50 stations, else 0
$X_{11,2}$ = Dummy variable equal to 1 when fuel type is CNG and fuel availability is 1 in 20 stations, else 0
$X_{11,3}$ = Dummy variable equal to 1 when fuel type is EV and fuel availability is plug-in at home only, else 0
$X_{11,3}$ = Dummy variable equal to 1 when fuel type is EV and fuel availability is plug-in at work and other locations, else 0
$X_{12,1}$ = Dummy variable equal to 1 when fuel type is CNG and refueling time is 10 mins. at station and 8 hrs at home, else 0
$X_{12,2}$ = Dummy variable equal to 1 when fuel type is CNG and refueling time is 10 mins. at station and 4 hrs at home, else 0
$X_{12,3}$ = Dummy variable equal to 1 when fuel type is EV and refueling time is 8 hrs, else 0
$X_{12,4}$ = Dummy variable equal to 1 when fuel type is EV and refueling time is 3 hrs, else 0
$X_{13,1}$ = Dummy variable equal to 1 when fuel type is non-gasoline and vehicle is small, else 0
$X_{13,2}$ = Dummy variable equal to 1 when fuel type is non-gasoline and vehicle is medium, else 0
$X_{13,3}$ = Dummy variable equal to 1 when fuel type is non-gasoline and vehicle is large, else 0
$X_{14,1}$ = Number of cars in fleet * (dummy variable equal to 1 when vehicle type is a car, else 0)
$X_{14,2}$ = Number of cars in fleet * (dummy variable equal to 1 when vehicle type is a SUV, else 0)
$X_{14,3}$ = Number of cars in fleet * (dummy variable equal to 1 when vehicle type is a van, else 0)
$X_{14,4}$ = Number of cars in fleet * (dummy variable equal to 1 when vehicle is a truck, else 0)

Conclusions

Estimations were successfully conducted for all six models in the residential chain and the single commercial vehicle choice model. The coefficient estimates were generally found to be statistically significant and intuitively correct in terms of sign and magnitude. Numerous specifications tests were conducted in each analysis to find the number and form of variables with the most explanatory power.

The application of these coefficient estimates in the CALCARS model will allow the CEC to forecast vehicle fleet composition, VMT, and fuel consumption in the State of California and to analyze strategies for reducing petroleum dependency in the state.

APPENDIX A

2009 California Vehicle Survey Model Estimation Results

Introduction

This appendix presents the results of several different specification tests that were conducted for each model described in the 2008-2009 California Vehicle Survey (CVS) Task 8 Report. The specification tests included the following:

1. Segmentation by three vehicle ownership classes for one, two, and three or more household vehicles
2. Estimating region-specific variables
3. Estimating a proxy for population density, coded as an urban dummy variable

Vehicle Class Segmentation

At present, CALCARS supports two vehicle ownership classes for one and two or more household vehicles. It is anticipated that future versions of the model will support further segmentation of the two or more vehicle segment into 1) two and 2) three or more household vehicles. Each of the residential models, with the exception of the fuel choice model, which was not segmented by vehicle ownership class, was estimated using both the two-class and three-class segmentation schemes. Table 1 shows the number of respondents in each vehicle ownership category.

Table 1: Vehicle Ownership Distribution of the Sample

Number of Vehicles	Number of Households	Number of Observations
1 vehicle	944	7552
2 vehicles	1514	12112
3 or more vehicles	816	6528
Total	3274	26192

Regional Variables

Five major regions of interest were identified by CEC at the onset of the CVS. The regions include the four major metropolitan areas of San Francisco, Los Angeles, San Diego, and Sacramento. The fifth region includes the rest of the State outside of these urban areas. The regions consist of one or more counties as described below in Table 2.

Table 2: Region Definitions

Region	Counties Included in Region		
San Francisco	Alameda	Napa	Santa Clara
	Contra Costa	San Francisco	Solano
	Marin	San Mateo	Sonoma
Los Angeles	Imperial	Orange	San Bernardino
	Los Angeles	Riverside	Ventura
San Diego	San Diego		
Sacramento	El Dorado	Sacramento	Yolo
	Placer	Sutter	Yuba
Rest of State	Alpine	Lake	San Joaquin
	Amador	Lassen	San Luis Obispo
	Butte	Madera	Santa Barbara
	Calaveras	Mariposa	Santa Cruz
	Colusa	Mendocino	Shasta
	Del Norte	Merced	Sierra
	Fresno	Modoc	Siskiyou
	Glenn	Mono	Stanislaus
	Humboldt	Monterey	Tehama
	Inyo	Nevada	Trinity
	Kern	Plumas	Tulare
	Kings	San Benito	Tuolumne

In the residential vehicle choice model, certain coefficients were estimated separately by region. For example, if the sports car coefficient was found to have a larger magnitude in the Los Angeles region than other regions, two sports car coefficients were estimated, one for Los Angeles and one for all other regions.

In the remaining residential models, the effect of region was tested by including dummy variables for the five regions. Generally, the San Francisco regional dummy coefficient was constrained to zero, and the remaining four regional coefficients are estimated in relation to San Francisco.

No significant regional differences were identified in the commercial vehicle choice model.

Urban Variable

A categorical population density variable was obtained form the Random Digit Dial (RDD) sample provider for the RP survey. This variable was recoded into an urban dummy variable, where an urban household is defined as being located in the central city of a Census Metropolitan Statistical Area (MSA). The central city of an MSA is defined as one or more cities named in the MSA's title. For example, Santa Ana is one of the title cities of the Los Angeles-Long Beach-Santa Ana MSA. Table 3 lists all of the MSA central cities in the State of California, along with the corresponding county.

Table 3: List of California MSA Central Cities

MSA Central City	County	MSA Central City	County
Arden-Arcade	Sacramento	Riverside	Riverside
Bakersfield	Kern	Roseville	Placer
Carlsbad	San Diego	Sacramento	Sacramento
Chico	Butte	Salinas	Monterey
Corcoran	Kings	San Bernardino	San Bernardino
El Centro	Imperial	San Diego	San Diego
Fairfield	Solano	San Francisco	San Francisco
Fremont	Alameda	San Jose	Santa Clara
Fresno	Fresno	San Luis Obispo	San Luis Obispo
Goleta	Santa Barbara	San Marcos	San Diego
Hanford	Kings	Santa Ana	Orange
Long Beach	Los Angeles	Santa Barbara	Santa Barbara
Los Angeles	Los Angeles	Santa Clara	Santa Clara
Madera	Madera	Santa Cruz	Santa Cruz
Merced	Merced	Santa Maria	Santa Barbara
Modesto	Stanislaus	Santa Rosa	Sonoma
Napa	Napa	Stockton	San Joaquin
Oakland	Alameda	Sunnyvale	Santa Clara
Ontario	San Bernardino	Thousand Oaks	Ventura
Oxnard	Ventura	Vallejo	Solano
Paso Robles	San Luis Obispo	Ventura	Ventura
Petaluma	Sonoma	Visalia	Tulare
Porterville	Tulare	Watsonville	Santa Cruz
Redding	Shasta	Yuba City	Sutter

Specification Summary

While the specifications described above present unique forecasting challenges in the current version of CALCARS, it is expected that future versions of the CALCARS model implementation will be able to support these variables and segmentations.

To provide flexibility for future forecasting efforts, several combinations of these specifications were run as presented below in Table 4. Results are not included in cases were the regional or dummy variables had a negligible or negative impact on model fit.

Table 4: Model Specification Summary

Model	Vehicle Ownership Class	Regional Variables	Urban Variable	Table Number
Residential Vehicle Choice	Two-class (1,2+)		N/A	Table 5
		X	N/A	Table 6
	Three-class (1,2,3+)		N/A	Table 5
		X	N/A	Table 6
Vehicle Transaction	Two-class (1,2+)			Table 7
			X	Table 8
		X		Table 9
			X	Table 10
	Three-class (1,2,3+)			Table 7
			X	Table 8
		X		Table 9
			X	Table 10
New-Used	Two-class (1,2+)			Table 11
			X	Table 12
		X		Table 13
			X	Table 14
	Three-class (1,2,3+)			Table 11
			X	Table 12
		X		Table 13
			X	Table 14
VMT	Two-class (1,2+)			Table 15
			X	Table 16
		X		Table 17
			X	Table 18
	Three-class (1,2,3+)			Table 15
			X	Table 16
		X		Table 17
			X	Table 18
Fuel Choice	N/A		N/A	Table 19
			N/A	Table 20
Vehicle Quantity	Two-class (1,2+)	N/A		Table 21
			X	Table 22
	Three-class (1,2,3+)	N/A		Table 23
			X	Table 24
Commercial Vehicle Choice	N/A	N/A	N/A	Table 25

The final results for each specification are presented below in Table 5 through Table 25.

Residential Vehicle Choice Model

Table 5: Residential Vehicle Choice Coefficients – Statewide

Type	Coef.	Description	Units	1 Vehicle Est.	1 Vehicle T-stat	2+ Vehicles Est.	2+ Vehicles T-stat	2 Vehicles Est.	2 Vehicles T-stat	3+ Vehicles Est.	3+ Vehicles T-stat
Constants	α_1	Vehicle type inertia	--	0.993	22.4	0.896	34.7	0.924	28.7	0.838	19.2
	α_2	Fuel type inertia	--	0.217	2.91	0.295	6.31	0.298	5.11	0.282	3.58
	α_3	Vehicle A constant	--	0.848	13.3	0.809	20.7	0.814	16.6	0.803	12.3
	α_4	Vehicle B constant	--	0.157	3.49	0.136	5.06	0.138	4.1	0.129	2.9
	α_5	Vehicle C constant	--	0.0357	0.778	0.0698	2.57	0.0697	2.05	0.0689	1.52
Vehicle Type	$\beta_{1,1}$	Subcompact car	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{1,2}$	Compact car	(0,1)	-0.131	-1.55	0.0121	0.226	0.0988	1.47	-0.123	-1.38
	$\beta_{1,3}$	Midsize car	(0,1)	0.284	3.18	0.237	4.21	0.257	3.62	0.221	2.38
	$\beta_{1,4}$	Large car	(0,1)	0.0186	0.143	0.52	6.78	0.443	4.62	0.684	5.5
	$\beta_{1,5}$	Sports car	(0,1)	0.0749	0.655	0.445	6.54	0.441	5.11	0.455	4.12
	$\beta_{1,6}$	Small cross car	(0,1)	0.449	4.46	0.485	7.55	0.461	5.62	0.526	5.06
	$\beta_{1,7}$	Small cross utility SUV	(0,1)	0.44	3.68	0.634	8.61	0.579	6.25	0.76	6.46
	$\beta_{1,8}$	Midsize cross utility SUV	(0,1)	0.29	2.22	0.802	10.2	0.876	8.93	0.707	5.54
	$\beta_{1,9}$	Compact SUV	(0,1)	0.64	4.78	0.662	8.08	0.664	6.4	0.694	5.34
	$\beta_{1,10}$	Midsize SUV	(0,1)	0.588	4.34	0.765	9.37	0.858	8.49	0.609	4.49
	$\beta_{1,11}$	Large SUV	(0,1)	0.825	4.7	0.981	9.23	0.754	5.5	1.35	8.36
	$\beta_{1,12}$	Compact can	(0,1)	0.212	1.47	0.54	6.1	0.484	4.36	0.655	4.68
	$\beta_{1,13}$	Large can	(0,1)	-0.264	-1.4	0.129	1.15	0.0715	0.528	0.258	1.32
	$\beta_{1,14}$	Compact truck	(0,1)	0.144	1.15	0.224	3.12	0.204	2.25	0.261	2.21
	$\beta_{1,15}$	Standard truck	(0,1)	0.227	1.63	0.613	7.68	0.612	6.16	0.647	4.94
Fuel Type	$\beta_{2,1}$	Gasoline	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{2,2}$	E-85	(0,1)	0.132	1.48	0.281	4.72	0.29	3.91	0.249	2.66
	$\beta_{2,3}$	Plug-in hybrid	(0,1)	0.178	1.38	0.546	6.7	0.633	6.25	0.385	2.87
	$\beta_{2,4}$	Compressed natural gas	(0,1)	-2.25	-2.22	-2.24	-3.68	-2.04	-2.73	-2.67	-2.55
	$\beta_{2,5}$	Diesel	(0,1)	0.0881	0.982	0.481	8.09	0.514	6.9	0.407	4.39
	$\beta_{2,6}$	Hybrid	(0,1)	0.419	5.75	0.615	11.8	0.69	10.7	0.47	5.75
	$\beta_{2,7}$	Full electric	(0,1)	-2.78	-3.74	-2.54	-5.69	-2.27	-4.12	-3.1	-4.03
Age	$\beta_{3,1}$	New	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{3,2}$	Used vehicle 1 or 2 years old	(0,1)	-0.193	-3.01	-0.178	-4.64	-0.189	-4.01	-0.154	-2.32
	$\beta_{3,3}$	Used vehicle 3 or more years old	(0,1)	-0.406	-7.55	-0.409	-12.2	-0.451	-10.7	-0.343	-6.14
Incentive	$\beta_{4,1}$	No incentive	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{4,2}$	HOV lane use	(0,1)	0.0611	1.03	0.142	3.39	0.119	2.27	0.195	3.2
	$\beta_{4,3}$	Free parking	(0,1)	0.041	0.687	0.169	4.06	0.172	3.29	0.183	3.06
	$\beta_{4,4}$	$1,000 tax credit	(0,1)	0.186	3.12	0.193	4.61	0.184	3.53	0.221	3.61
	$\beta_{4,5}$	50% reduced tolls	(0,1)	--	--	0.04	0.948	0.0767	1.47	--	--
	$\beta_{4,6}$	$1,000 reduced purchase price	(0,1)	0.0644	1.08	0.114	2.73	0.104	1.98	0.151	2.49

Type	Coef.	Description	Units	1 Vehicle Est.	1 Vehicle T-stat	2+ Vehicles Est.	2+ Vehicles T-stat	2 Vehicles Est.	2 Vehicles T-stat	3+ Vehicles Est.	3+ Vehicles T-stat
Price		Price	$000	-0.0746	-15.4	-0.0785	-20.6	-0.0805	-17.1	-0.0774	-11.6
		Price * income category	$000	0.00675	6.74	0.0068	10.8	0.00721	9.17	0.00656	6.11
	$\beta_{5,1}$	Price for income less than $20,000	$000	-0.0678	--	-0.0717	--	-0.0733		-0.0709	--
	$\beta_{5,2}$	Price for income $20,000 to $39,999	$000	-0.0611	--	-0.0649	--	-0.0661		-0.0643	--
	$\beta_{5,3}$	Price for income $40,000 to $59,999	$000	-0.0543	--	-0.0581	--	-0.0589		-0.0577	--
	$\beta_{5,4}$	Price for income $60,000 to $79,999	$000	-0.0476	--	-0.0513	--	-0.0517		-0.0512	--
	$\beta_{5,5}$	Price for income $80,000 to $99,999	$000	-0.0408	--	-0.0445	--	-0.0444		-0.0446	--
	$\beta_{5,6}$	Price for income $100,000 to $119,999	$000	-0.0341	--	-0.0377	--	-0.0372		-0.0381	--
	$\beta_{5,7}$	Price for income $120,000 or more	$000	-0.0273	--	-0.0309	--	-0.03		-0.0315	--
Maint.	β_6	Maintenance cost	c/mi	-0.0584	-3.09	-0.0696	-6.01	-0.0663	-4.61	-0.078	-3.99
Fuel Cost	β_7	Fuel cost	c/mi	-0.0788	-8.9	-0.0699	-13.6	-0.0737	-11.5	-0.0637	-7.32
MPGE	β_8	MPGE	MPGE	0.0169	5.91	0.0143	8.43	0.0123	5.86	0.018	6.18
Accel.	β_9	Acceleration	secs	-0.04	-5.25	-0.0332	-7.13	-0.0279	-4.8	-0.0427	-5.45
Range	β_{10}	Natural log of range	miles	0.279	1.5	0.336	3.02	0.309	2.26	0.39	2.03
Fuel Availability	$\beta_{11,1}$	1 in 50 stations (CNG)	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{11,2}$	1 in 20 Stations (CNG)	(0,1)	0.327	2.21	0.0458	0.519	0.101	0.931	--	--
	$\beta_{11,3}$	Plug-in at home only (EV)	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{11,4}$	Plug-in at work and other locations (EV)	(0,1)	0.133	1.05	0.183	2.46	0.162	1.77	0.227	1.76
Refueling Time	$\beta_{12,1}$	Refuel in 10 min (station); 8 hrs (home) (CNG)	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{12,2}$	Refuel in 10 min (station); 4 hrs (home) (CNG)	(0,1)	--	--	--	--	--	--	--	--
	$\beta_{12,3}$	Recharge in 8hrs (EV)	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{12,4}$	Recharge in 3 hrs (EV)	(0,1)	--	--	0.0616	0.829	0.0611	0.668	0.0726	0.566
HH Size-Veh. Type Interaction	$\beta_{13,1}$	Large HH - Small vehicles	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{13,2}$	Large HH - Medium vehicles	(0,1)	0.397	2.84	0.21	3.98	0.369	5.2	--	--
	$\beta_{13,3}$	Large HH - Large vehicles	(0,1)	0.718	4.1	0.366	4.43	0.602	5.66	--	--
Alt Fuels-Veh. Type Interaction	$\beta_{14,1}$	Alt Fuel - Small vehicles	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{14,2}$	Alt Fuel - Medium vehicles	(0,1)	-0.0154	-0.207	-0.0675	-1.55	-0.127	-2.33	0.0289	0.398
	$\beta_{14,3}$	Alt Fuel - Large vehicles	(0,1)	-0.277	-2.48	-0.422	-6.27	-0.343	-4.06	-0.551	-4.88

Fit Statistics	1 Vehicle	2+ Vehicles	2 Vehicles	3+ Vehicles
Number of observations	7552	18640	12112	6528
Number of individuals	944	2330	1514	816
Number of parameters	44	46	46	42
Log Likelihood at Zero	-10469.30	-25840.53	-16790.80	-9049.73
Constants only log likelihood	-8943.85	-23427.02	-15131.15	-8292.14
Log likelihood at convergence	-7654.51	-20388.30	-13095.31	-7241.14
Rho-squared	0.269	0.211	0.220	0.200
Adjusted Rho-squared	0.265	0.209	0.217	0.195

Table 6: Residential Vehicle Choice Coefficients – Regional

				1 Vehicle		2+ Vehicles		2 Vehicles		3+ Vehicles	
Type	Coef.	Description	Units	Est.	T-stat	Est.	T-stat	Est.	T-stat	Est.	T-stat
Constants	α_1	Vehicle type inertia	--	0.991	22.3	0.896	34.7	0.925	28.7	0.838	19.2
	α_2	Fuel type inertia	--	0.213	2.85	0.29	6.2	0.293	5.02	0.278	3.52
	α_3	Vehicle A constant	--	0.847	13.3	0.812	20.7	0.816	16.7	0.809	12.4
	α_4	Vehicle B constant	--	0.158	3.5	0.138	5.13	0.139	4.13	0.134	3
	α_5	Vehicle C constant	--	0.0362	0.788	0.0715	2.63	0.0716	2.1	0.0717	1.58
Vehicle Type	$\beta_{1,1}$	Subcompact car	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{1,2}$	Compact car	(0,1)	-0.13	-1.54	0.011	0.206	0.0982	1.46	-0.126	-1.41
	$\beta_{1,3}$	Midsize car	(0,1)	0.288	3.23	0.237	4.21	0.257	3.62	0.219	2.36
	$\beta_{1,4}$	Large car	(0,1)	0.02	0.154	0.521	6.79	0.44	4.59	0.689	5.53
	$\beta_{1,5}$	Sports car	(0,1)	-0.0117	-0.086	0.363	4.58	0.4	3.97	0.311	2.41
	$\beta_{1,5\text{-}LA}$	LA Sports car	(0,1)	0.213	1.35	0.571	6.16	0.503	4.24	0.677	4.52
	$\beta_{1,6}$	Small cross car	(0,1)	0.448	4.45	0.484	7.52	0.461	5.62	0.524	5.04
	$\beta_{1,7}$	Small cross utility SUV	(0,1)	0.441	3.69	0.637	8.64	0.58	6.25	0.764	6.49
	$\beta_{1,8}$	Midsize cross utility SUV	(0,1)	0.293	2.23	0.799	10.2	0.871	8.87	0.705	5.52
	$\beta_{1,9}$	Compact SUV	(0,1)	0.643	4.8	0.662	8.08	0.665	6.4	0.692	5.32
	$\beta_{1,10}$	Midsize SUV	(0,1)	0.59	4.35	0.762	9.33	0.854	8.44	0.606	4.47
	$\beta_{1,11}$	Large SUV	(0,1)	0.492	2.32	0.927	7.8	0.668	4.35	1.36	7.45
	$\beta_{1,11\text{-}LA}$	LA Large SUV	(0,1)	1.18	5.68	1.05	8.06	0.869	5.09	1.35	6.79
	$\beta_{1,12}$	Compact van	(0,1)	0.195	1.35	0.534	6.02	0.479	4.31	0.647	4.62
	$\beta_{1,13}$	Large van	(0,1)	-0.271	-1.43	0.124	1.11	0.0713	0.526	0.246	1.26
	$\beta_{1,14}$	Compact truck	(0,1)	0.148	1.18	0.221	3.09	0.202	2.23	0.257	2.17
	$\beta_{1,15}$	Standard truck	(0,1)	0.223	1.6	0.609	7.63	0.606	6.09	0.647	4.93
Fuel Type	$\beta_{2,1}$	Gasoline	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{2,2}$	E-85	(0,1)	0.123	1.38	0.276	4.63	0.285	3.84	0.246	2.62
	$\beta_{2,3}$	Plug-in hybrid	(0,1)	0.146	1.12	0.479	5.79	0.556	5.4	0.337	2.47
	$\beta_{2,3\text{-}SF}$	SF Plug-in hybrid	(0,1)	0.274	1.79	0.756	8.02	0.88	7.52	0.536	3.43
	$\beta_{2,4}$	Compressed natural gas	(0,1)	-2.28	-2.24	-2.23	-3.67	-2.04	-2.72	-2.64	-2.53
	$\beta_{2,5}$	Diesel	(0,1)	0.0826	0.92	0.478	8.03	0.511	6.85	0.404	4.37
	$\beta_{2,6}$	Hybrid	(0,1)	0.369	4.78	0.571	10.4	0.655	9.59	0.409	4.75
	$\beta_{2,6\text{-}SF}$	SF Hybrid	(0,1)	0.568	5.52	0.746	11	0.798	9.49	0.657	5.91
	$\beta_{2,7}$	Full electric	(0,1)	-2.8	-3.76	-2.53	-5.67	-2.25	-4.1	-3.09	-4.01

Type	Coef.	Description	Units	1 Vehicle Est.	1 Vehicle T-stat	2+ Vehicles Est.	2+ Vehicles T-stat	2 Vehicles Est.	2 Vehicles T-stat	3+ Vehicles Est.	3+ Vehicles T-stat
Age	$β_{3,1}$	New	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	$β_{3,2}$	Used vehicle 1 or 2 years old	(0,1)	-0.186	-2.9	-0.178	-4.66	-0.192	-4.08	-0.151	-2.28
	$β_{3,3}$	Used vehicle 3 or more years old	(0,1)	-0.403	-7.48	-0.409	-12.2	-0.453	-10.7	-0.341	-6.1
Incentive	$β_{4,1}$	No incentive	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	$β_{4,2}$	HOV lane use	(0,1)	0.0769	1.08	0.0934	1.92	0.0711	1.17	0.146	1.96
	$β_{4,2\text{-}LA}$	LA HOV lane use	(0,1)	0.0299	0.34	0.225	3.94	0.2	2.79	0.279	3.19
	$β_{4,3}$	Free parking	(0,1)	0.0416	0.697	0.168	4.04	0.171	3.28	0.182	3.04
	$β_{4,4}$	$1,000 tax credit	(0,1)	0.187	3.15	0.192	4.59	0.183	3.5	0.224	3.66
	$β_{4,5}$	50% reduced tolls	(0,1)	--	--	0.0393	0.932	0.0763	1.46	--	--
	$β_{4,6}$	$1,000 reduced purchase price	(0,1)	0.0652	1.09	0.115	2.75	0.104	1.99	0.153	2.52
Price		Price	$000	-0.074	-15.3	-0.078	-20.4	-0.08	-17	-0.077	-11.5
		Price * income category	$000	0.00665	6.63	0.00669	10.7	0.00709	9.01	0.00647	6.01
	$β_{5,1}$	Price for income less than $20,000	$000	-0.0674	--	-0.0714	--	-0.0729		-0.0706	--
	$β_{5,2}$	Price for income $20,000 to $39,999	$000	-0.0607	--	-0.0647	--	-0.0658		-0.0641	--
	$β_{5,3}$	Price for income $40,000 to $59,999	$000	-0.0541	--	-0.058	--	-0.0587		-0.0576	--
	$β_{5,4}$	Price for income $60,000 to $79,999	$000	-0.0474	--	-0.0513	--	-0.0516		-0.0512	--
	$β_{5,5}$	Price for income $80,000 to $99,999	$000	-0.0408	--	-0.0446	--	-0.0445		-0.0447	--
	$β_{5,6}$	Price for income $100,000 to $119,999	$000	-0.0341	--	-0.0379	--	-0.0374		-0.0382	--
	$β_{5,7}$	Price for income $120,000 or more	$000	-0.0275	--	-0.0312	--	-0.0304		-0.0318	--
Maint.	$β_6$	Maintenance cost	c/mi	-0.0595	-3.15	-0.0695	-6.01	-0.0659	-4.57	-0.0781	-3.99
Fuel Cost	$β_7$	Fuel cost	c/mi	-0.0791	-8.93	-0.0705	-13.7	-0.0743	-11.6	-0.0642	-7.38
MPGE	$β_8$	MPGE	MPGE	0.0169	5.9	0.0142	8.36	0.0121	5.75	0.018	6.18
Accel.	$β_9$	Acceleration	secs	-0.0306	-3.19	-0.0271	-4.68	-0.0229	-3.18	-0.0347	-3.55
	$β_{9\text{-}LA}$	Acceleration	secs	-0.055	-4.66	-0.043	-5.81	-0.0362	-3.9	-0.0551	-4.46
Range	$β_{10}$	Natural log of range	miles	0.283	1.52	0.334	3	0.308	2.25	0.385	2
Fuel Availability	$β_{11,1}$	1 in 50 stations (CNG)	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	$β_{11,2}$	1 in 20 Stations (CNG)	(0,1)	0.328	2.22	0.0458	0.519	0.0997	0.915	--	--
	$β_{11,3}$	Plug-in at home only (EV)	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	$β_{11,4}$	Plug-in at work and other locations (EV)	(0,1)	0.132	1.05	0.184	2.47	0.162	1.78	0.227	1.76

Type	Coef.	Description	Units	1 Vehicle Est.	1 Vehicle T-stat	2+ Vehicles Est.	2+ Vehicles T-stat	2 Vehicles Est.	2 Vehicles T-stat	3+ Vehicles Est.	3+ Vehicles T-stat
Refueling Time	$\beta_{12,1}$	Refuel in 10 min (station); 8 hrs (home) (CNG)	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{12,2}$	Refuel in 10 min (station); 4 hrs (home) (CNG)	(0,1)	--	--	--	--	--	--	--	--
	$\beta_{12,3}$	Recharge in 8hrs (EV)	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{12,4}$	Recharge in 3 hrs (EV)	(0,1)	--	--	0.0629	0.847	0.0621	0.68	0.0734	0.573
HH Size-Veh. Type Interaction	$\beta_{13,1}$	Large HH - Small vehicles	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{13,2}$	Large HH - Medium vehicles	(0,1)	0.407	2.91	0.209	3.97	0.369	5.2	--	--
	$\beta_{13,3}$	Large HH - Large vehicles	(0,1)	0.731	4.15	0.368	4.44	0.604	5.68	--	--
Alt Fuels-Veh. Type Interaction	$\beta_{14,1}$	Alt Fuel - Small vehicles	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{14,2}$	Alt Fuel - Medium vehicles	(0,1)	-0.0145	-0.194	-0.0679	-1.56	-0.127	-2.33	0.0265	0.365
	$\beta_{14,3}$	Alt Fuel - Large vehicles	(0,1)	-0.264	-2.35	-0.418	-6.21	-0.343	-4.05	-0.547	-4.83

Fit Statistics	1 Vehicle	2+ Vehicles	2 Vehicles	3+ Vehicles
Number of observations	7552	18640	12112	6528
Number of individuals	944	2330	1514	816
Number of parameters	50	52	52	48
Log Likelihood at Zero	-10469.30	-25840.53	-16790.80	-9049.73
Constants only log likelihood	-8943.85	-23427.02	-15131.15	-8292.14
Log likelihood at convergence	-7644.84	-20369.95	-13083.05	-7232.68
Rho-squared	0.270	0.212	0.221	0.201
Adjusted Rho-squared	0.265	0.210	0.218	0.195

Vehicle Transaction and Replacement Model

Table 7: Vehicle Transaction and Replacement Nested Logit Model Coefficients – Statewide

Alternative	Coef.	Description	Units	Two-class Vehicle Ownership (1,2+) Estimate	Two-class Vehicle Ownership (1,2+) T-stat	Three-class Vehicle Ownership (1,2,3+) Estimate	Three-class Vehicle Ownership (1,2,3+) T-stat
No Replacement Alternative	α_1	No replacement constant	--	3.89	7.1	4.11	7.49
	β_1	Vehicle ownership category	--	0.15	1.52	0.117	1.87
Vehicle Replacement Alternatives	β_2	Large HH dummy (>=4)	(0,1)	0.274	3.58	0.286	3.71
	β_3	Full-time equiv. workers	persons	0.138	3.03	0.146	3.16
	β_4	Income	$000	0.00367	3.64	0.00378	3.75
	β_5	Vehicle age	years	0.185	7.32	0.194	7.37
	β_6	Vehicle age squared	years^2	-0.00573	-6.37	-0.00598	-6.41
	β_7	Logsum - vehicle utility	--	0.118	1.69	0.134	1.96
Nest Coefficient	θ_{rep}	Replacement nest	--	0.375	7.66	0.397	7.37

Fit Statistics	Two-class	Three-class
Number of observations	18617	18617
Number of individuals	6364	6364
Number of parameters	9	9
Log likelihood at zero	-6622.77	-6622.77
Constants only log likelihood	-5677.89	-5677.89
Log likelihood at convergence	-3550.02	-3549.02
Rho-squared	0.464	0.464
Adjusted Rho-squared	0.463	0.463

Table 8: Vehicle Transaction and Replacement Nested Logit Model Coefficients – Statewide with Urban Variable

				Two-class Vehicle Ownership (1,2+)		Three-class Vehicle Ownership (1,2,3+)	
Alternative	Coef.	Description	Units	Estimate	T-stat	Estimate	T-stat
No Replacement Alternative	α_1	No replacement constant	--	3.97	7.21	4.17	7.6
	β_1	Vehicle ownership category	--	0.139	1.41	0.106	1.7
Vehicle Replacement Alternatives	β_2	Large HH dummy (>=4)	(0,1)	0.281	3.66	0.291	3.77
	β_3	Full-time equiv. workers	persons	0.136	2.98	0.143	3.09
	β_4	Urban dummy	(0,1)	0.149	2.25	0.145	2.18
	β_5	Income	$000	0.00355	3.51	0.00363	3.6
	β_6	Vehicle age	years	0.184	7.3	0.192	7.32
	β_7	Vehicle age squared	years^2	-0.00572	-6.36	-0.00594	-6.37
	β_8	Logsum - vehicle utility	--	0.119	1.7	0.133	1.95
Nest Coefficient	θ_{rep}	Replacement nest	--	0.375	7.64	0.394	7.32

Fit Statistics	Two-class	Three-class
Number of observations	18617	18617
Number of individuals	6364	6364
Number of parameters	10	10
Log likelihood at zero	-6622.77	-6622.77
Constants only log likelihood	-5677.89	-5677.89
Log likelihood at convergence	-3547.49	-3546.66
Rho-squared	0.464	0.464
Adjusted Rho-squared	0.463	0.463

Table 9: Vehicle Transaction and Replacement Nested Logit Model Coefficients – Regional

Alternative	Coef.	Description	Units	Two-class Vehicle Ownership (1,2+)		Three-class Vehicle Ownership (1,2,3+)	
				Estimate	T-stat	Estimate	T-stat
No Replacement Alternative	α_1	No replacement constant	--	3.92	7.07	4.13	7.46
	β_1	Vehicle ownership category	--	0.148	1.5	0.118	1.87
Vehicle Replacement Alternatives	β_2	Large HH dummy (>=4)	(0,1)	0.269	3.51	0.28	3.64
	β_3	LA region dummy	(0,1)	0.208	3.08	0.209	3.09
	β_4	Full-time equiv. workers	persons	0.134	2.95	0.142	3.08
	β_5	Income	$000	0.00368	3.64	0.00379	3.76
	β_6	Vehicle age	years	0.187	7.33	0.196	7.36
	β_7	Vehicle age squared	years^2	-0.00579	-6.36	-0.00604	-6.39
	β_8	Logsum - vehicle utility	--	0.108	1.54	0.122	1.78
Nest Coefficient	θ_{rep}	Replacement nest	--	0.383	7.7	0.406	7.39

Fit Statistics	Two-class	Three-class
Number of observations	18617	18617
Number of individuals	6364	6364
Number of parameters	10	10
Log likelihood at zero	-6622.77	-6622.77
Constants only log likelihood	-5677.89	-5677.89
Log likelihood at convergence	-3545.47	-3544.56
Rho-squared	0.465	0.465
Adjusted Rho-squared	0.463	0.463

Table 10: Vehicle Transaction and Replacement Nested Logit Model Coefficients – Regional with Urban Variable

Alternative	Coef.	Description	Units	Two-class Vehicle Ownership (1,2+)		Three-class Vehicle Ownership (1,2,3+)	
				Estimate	T-stat	Estimate	T-stat
No Replacement Alternative	α_1	No replacement constant	--	4	7.18	4.18	7.57
	β_1	Vehicle ownership category	--	0.138	1.39	0.107	1.7
Vehicle Replacement Alternatives	β_2	Large HH dummy (>=4)	(0,1)	0.276	3.59	0.286	3.7
	β_3	LA region dummy	(0,1)	0.208	3.08	0.209	3.09
	β_4	Full-time equiv. workers	persons	0.132	2.9	0.139	3.02
	β_5	Urban dummy	(0,1)	0.148	2.23	0.144	2.17
	β_6	Income	$000	0.00356	3.52	0.00366	3.62
	β_7	Vehicle age	years	0.187	7.31	0.194	7.31
	β_8	Vehicle age squared	years^2	-0.00578	-6.35	-0.006	-6.35
	β_9	Logsum - vehicle utility	--	0.108	1.54	0.121	1.77
Nest Coefficient	θ_{rep}	Replacement nest	--	0.382	7.68	0.403	7.34

Fit Statistics	Two-class	Three-class
Number of observations	18617	18617
Number of individuals	6364	6364
Number of parameters	11	11
Log likelihood at zero	-6622.77	-6622.77
Constants only log likelihood	-5677.89	-5677.89
Log likelihood at convergence	-3542.98	-3542.22
Rho-squared	0.465	0.465
Adjusted Rho-squared	0.463	0.463

New-Used Vehicle Choice Model

Table 11: New-Used Vehicle Choice Model Coefficients – Statewide

			1 Vehicle		2 + Vehicles		2 Vehicles		3 + Vehicles	
Coef.	Description	Units	Estimate	T-Stat	Estimate	T-Stat	Estimate	T-Stat	Estimate	T-Stat
α_1	New vehicle constant	--	-7.92	-18.4	-6.66	-18.9	-6.43	-15.2	-8.13	-12.3
β_1	Natural log of income	dollars	0.806	19.9	0.688	21.8	0.668	17.6	0.804	13.7
β_2	Natural log of household size	persons	-0.448	-9.31	-0.494	-12.8	-0.434	-8.82	-0.469	-7.08

Fit Statistics	1 Vehicle	2+ Vehicles	2 Vehicles	3+ Vehicles
Number of observations	7552	18640	12112	6528
Number of individuals	944	2330	1514	816
Number of parameters	3	3	3	3
Log likelihood at zero	-5234.65	-12920.26	-8395.40	-4524.86
Constants only log likelihood	-4962.27	-12093.59	-7747.47	-4330.76
Log likelihood at convergence	-4734.93	-11802.79	-7565.78	-4219.03
Rho-squared	0.0955	0.0865	0.0988	0.0676
Adjusted Rho-squared	0.0949	0.0863	0.0985	0.0669

Table 12: New-Used Vehicle Choice Model Coefficients – Statewide with Urban Variable

			1 Vehicle		2 + Vehicles		2 Vehicles		3 + Vehicles	
Coef.	Description	Units	Estimate	T-Stat	Estimate	T-Stat	Estimate	T-Stat	Estimate	T-Stat
α_1	New vehicle constant	--	-7.96	-18.4	-6.67	-19	-6.44	-15.2	-8.12	-12.3
β_1	Natural log of income	dollars	0.821	20.2	0.69	21.8	0.67	17.6	0.807	13.7
β_2	Natural log of household size	persons	-0.458	-9.5	-0.494	-12.8	-0.432	-8.78	-0.471	-7.11
β_3	Urban dummy	(0,1)	-0.23	-4.65	-0.037	-1.19	-0.027	-0.687	-0.075	-1.43

Fit Statistics	1 Vehicle	2+ Vehicles	2 Vehicles	3+ Vehicles
Number of observations	7552	18640	12112	6528
Number of individuals	944	2330	1514	816
Number of parameters	4	4	4	4
Log likelihood at zero	-5234.65	-12920.26	-8395.40	-4524.86
Constants only log likelihood	-4962.27	-12093.59	-7747.47	-4330.76
Log likelihood at convergence	-4724.10	-11802.08	-7565.54	-4218.01
Rho-squared	0.0975	0.0865	0.0988	0.0678
Adjusted Rho-squared	0.0968	0.0862	0.0984	0.0669

Table 13: New-Used Vehicle Choice Model Coefficients – Regional

			1 Vehicle		2 + Vehicles		2 Vehicles		3 + Vehicles	
Coef.	Description	Units	Estimate	T-Stat	Estimate	T-Stat	Estimate	T-Stat	Estimate	T-Stat
α_1	New vehicle constant	--	-8.17	-18.1	-6.54	-18	-6.17	-14	-8.16	-12
β_1	Natural log of income	dollars	0.809	19.5	0.674	21	0.649	16.7	0.795	13.3
β_2	Natural log of household size	persons	-0.448	-9.26	-0.498	-12.9	-0.42	-8.51	-0.536	-7.99
β_3	LA dummy	(0,1)	0.422	6.26	0.21	5.01	0.0486	0.916	0.5	7.21
β_4	San Diego dummy	(0,1)	0.322	3.21	0.0039	0.067	-0.245	-3.47	0.509	4.69
β_5	Sacramento dummy	(0,1)	0.0506	0.535	-0.256	-4.09	-0.348	-4.41	-0.097	-0.943
β_6	Other Region dummy	(0,1)	0.0952	1.27	-0.072	-1.54	-0.098	-1.63	-0.013	-0.174

Fit Statistics	1 Vehicle	2+ Vehicles	2 Vehicles	3+ Vehicles
Number of observations	7552	18640	12112	6528
Number of individuals	944	2330	1514	816
Number of parameters	7	7	7	7
Log likelihood at zero	-5234.65	-12920.26	-8395.40	-4524.86
Constants only log likelihood	-4962.27	-12093.59	-7747.47	-4330.76
Log likelihood at convergence	-4708.08	-11759.59	-7544.59	-4169.64
Rho-squared	0.101	0.0898	0.101	0.0785
Adjusted Rho-squared	0.0993	0.0893	0.101	0.0770

Table 14: New-Used Vehicle Choice Model Coefficients – Regional with Urban Variable

			1 Vehicle		2 + Vehicles		2 Vehicles		3 + Vehicles	
Coef.	Description	Units	Estimate	T-Stat	Estimate	T-Stat	Estimate	T-Stat	Estimate	T-Stat
α_1	New vehicle constant	--	-8.13	-18	-6.52	-17.9	-6.16	-14	-8.12	-12
β_1	Natural log of income	dollars	0.82	19.7	0.675	21	0.65	16.7	0.796	13.3
β_2	Natural log of household size	persons	-0.456	-9.41	-0.497	-12.9	-0.418	-8.46	-0.538	-8.01
β_3	Urban dummy	(0,1)	-0.253	-5.02	-0.047	-1.48	-0.035	-0.875	-0.076	-1.42
β_4	LA Dummy	(0,1)	0.41	6.06	0.205	4.87	0.045	0.846	0.492	7.06
β_5	San Diego Dummy	(0,1)	0.31	3.09	-0.002	-0.026	-0.248	-3.5	0.491	4.5
β_6	Sacramento Dummy	(0,1)	0.0048	0.051	-0.262	-4.18	-0.352	-4.46	-0.108	-1.05
β_7	Other Region Dummy	(0,1)	0.044	0.578	-0.082	-1.74	-0.105	-1.73	-0.032	-0.417

Fit Statistics	1 Vehicle	2+ Vehicles	2 Vehicles	3+ Vehicles
Number of observations	7552	18640	12112	6528
Number of individuals	944	2330	1514	816
Number of parameters	8	8	8	8
Log likelihood at zero	-5234.65	-12920.26	-8395.40	-4524.86
Constants only log likelihood	-4962.27	-12093.59	-7747.47	-4330.76
Log likelihood at convergence	-4695.44	-11758.50	-7544.21	-4168.64
Rho-squared	0.103	0.0899	0.101	0.0787
Adjusted Rho-squared	0.102	0.0893	0.100	0.0770

Vehicle Miles Traveled Model

Table 15: VMT Model Coefficients – Statewide

			1 Vehicle		2 + Vehicles		2 Vehicles		3 + Vehicles	
Coef.	Description	Units	Estimate	T-stat	Estimate	T-stat	Estimate	T-stat	Estimate	T-stat
α_1	(Constant)	--	14.7	3.06	17.3	5.32	16	6.02	17.7	0.458
β_1	Natural log of household size	persons	0.114	2.27	0.256	7.77	0.257	6.26	0.214	6.39
β_2	Natural log of full-time equivalent workers	persons	0.0549	1.08	0.162	8.84	0.129	5.29	0.184	6.57
β_3	Natural log of average household miles to work	miles	0.135	8.87	0.104	15	0.101	12	0.113	9.88
β_4	Per capita transit ridership	trips/ person	-0.0013	-3.14	-0.0006	-2.56	-0.00074	-2.75	-0.00043	-1.15
β_5	Number of vehicles more than 2/3	vehicles	--	--	-0.173	-20.4	--	--	-0.161	-11
β_6	Natural log of income	dollars	0.105	3.15	0.0798	4.48	0.112	5.35	0.045	0.54
β_7	Natural log of fuel cost per mile*	cents/ mile	-2.74	-1.45	-3.7	-2.92	-3.35	-3.22	-3.73	-0.251
β_8	Vehicle age	years	-0.0093	-2.07	-0.0292	-19.9	-0.0243	-11.6	-0.0323	-15.5

Fit Statistics	1 Vehicle	2 + Vehicles	2 Vehicles	3 + Vehicles
Number of observations	1735	10338	5418	4920
Number of parameters	8	9	8	9
Standard error of the estimate	0.784	0.785	0.721	0.849
R-squared	0.0866	0.135	0.117	0.137
Adjusted R-squared	0.0829	0.135	0.116	0.135

Table 16: VMT Model Coefficients – Statewide with Urban Variable

Coef.	Description	Units	1 Vehicle		2 + Vehicles		2 Vehicles		3 + Vehicles	
			Estimate	T-stat	Estimate	T-stat	Estimate	T-stat	Estimate	T-stat
α_1	(Constant)	--	14.8	3.06	17.4	5.35	16.1	6.05	18.2	0.472
β_1	Natural log of household size	persons	0.112	2.22	0.257	7.81	0.261	6.35	0.213	6.36
β_2	Natural log of full-time equivalent workers	persons	0.0551	1.08	0.164	8.91	0.131	5.41	0.184	6.59
β_3	Natural log of average household miles to work	miles	0.135	8.87	0.102	14.7	0.0991	11.7	0.112	9.76
β_4	Per capita transit ridership	trips/ person	-0.0011	-2.71	-0.0004	-1.84	-0.00051	-1.87	-0.00037	-0.983
β_5	Urban dummy	(0,1)	-0.0516	-1.32	-0.0623	-3.91	-0.095	-4.74	-0.0227	-0.9
β_6	Number of vehicles more than 2/3	vehicles			-0.175	-20.6			-0.161	-11
β_7	Natural log of income	dollars	0.107	3.2	0.0841	4.72	0.118	5.64	0.0458	0.55
β_8	Natural log of fuel cost per mile*	cents/ mile	-2.75	-1.45	-3.75	-2.95	-3.38	-3.26	-3.94	-0.264
β_9	Vehicle age	years	-0.0091	-2.03	-0.0291	-19.8	-0.024	-11.5	-0.0322	-15.5

Fit Statistics	1 Vehicle	2 + Vehicles	2 Vehicles	3 + Vehicles
Number of observations	1735	10338	5418	4920
Number of parameters	9	10	9	10
Standard error of the estimate	0.784	0.784	0.719	0.849
R-squared	0.0876	0.137	0.120	0.137
Adjusted R-squared	0.0833	0.136	0.119	0.135

Table 17: VMT Model Coefficients – Regional

Coef.	Description	Units	1 Vehicle		2 + Vehicles		2 Vehicles		3 + Vehicles	
			Estimate	T-stat	Estimate	T-stat	Estimate	T-stat	Estimate	T-stat
α_1	(Constant)	--	15.3	3.24	17.5	5.38	16	6.04	15.6	0.404
β_1	Natural log of household size	persons	0.119	2.37	0.259	7.87	0.259	6.29	0.217	6.48
β_2	Natural log of full-time equivalent workers	persons	0.053	1.04	0.162	8.82	0.127	5.2	0.185	6.62
β_3	Natural log of average household miles to work	miles	0.136	8.88	0.104	15	0.101	12	0.112	9.83
β_4	Per capita transit ridership	trips/ person	-0.001	-2.23	-0.0005	-1.94	-0.00065	-2.26	-0.00027	-0.673
β_6	Number of vehicles more than 2/3	vehicles	--	--	-0.174	-20.5	--	--	-0.164	-11.1
β_7	Natural log of income	dollars	0.111	3.28	0.0829	4.63	0.116	5.46	0.0533	0.652
β_8	Natural log of fuel cost per mile*	cents/ mile	-3.04	-1.63	-3.8	-2.99	-3.38	-3.25	-2.96	-0.198
β_9	Vehicle age	years	-0.0093	-2.06	-0.0291	-19.8	-0.0242	-11.5	-0.0322	-15.4
β_{10}	LA region dummy	(0,1)	0.0949	1.39	0.0279	1.22	0.0215	0.762	0.0185	0.411
β_{11}	San Diego region dummy	(0,1)	0.0965	1.23	0.085	2.78	0.0773	2.03	0.0903	0.903
β_{12}	Sacramento region dummy	(0,1)	0.0506	0.626	-0.0046	-0.135	0.00281	0.066	-0.00756	-0.074
β_{13}	Other region dummy	(0,1)	0.103	1.54	0.0534	2.02	0.0392	1.19	0.0714	0.74

Fit Statistics	1 Vehicle	2 + Vehicles	2 Vehicles	3 + Vehicles
Number of observations	1735	10338	5418	4920
Number of parameters	12	13	12	13
Standard error of the estimate	0.785	0.785	0.721	0.849
R-squared	0.0882	0.136	0.118	0.138
Adjusted R-squared	0.0823	0.135	0.116	0.136

Table 18: VMT Model Coefficients – Regional with Urban Variable

Coef.	Description	Units	1 Vehicle		2 + Vehicles		2 Vehicles		3 + Vehicles	
			Estimate	T-stat	Estimate	T-stat	Estimate	T-stat	Estimate	T-stat
α_1	(Constant)	--	15.3	3.24	17.5	5.4	16.1	6.06	15.7	0.409
β_1	Natural log of household size	persons	0.116	2.32	0.26	7.89	0.262	6.38	0.217	6.45
β_2	Natural log of full-time equivalent workers	persons	0.053	1.04	0.164	8.9	0.129	5.33	0.186	6.64
β_3	Natural log of average household miles to work	miles	0.136	8.88	0.102	14.7	0.099	11.7	0.112	9.73
β_4	Per capita transit ridership	trips/ person	-0.0009	-1.89	-0.0003	-1.4	-0.00045	-1.56	-0.00023	-0.568
β_6	Number of vehicles more than 2/3	vehicles	--	--	-0.0602	-3.77	--	--	-0.0186	-0.732
β_7	Urban dummy	(0,1)	-0.05	-1.28	-0.175	-20.6	-0.0952	-4.74	-0.164	-11.1
β_8	Natural log of income	dollars	0.112	3.32	0.0866	4.83	0.121	5.69	0.0543	0.663
β_9	Natural log of fuel cost per mile*	cents/ mile	-3.04	-1.63	-3.82	-3.01	-3.4	-3.27	-3.03	-0.203
β_{10}	Vehicle age	years	-0.0091	-2.02	-0.029	-19.7	-0.024	-11.5	-0.0321	-15.4
β_{11}	LA region dummy	(0,1)	0.097	1.42	0.0238	1.04	0.0145	0.516	0.0174	0.386
β_{12}	San Diego region dummy	(0,1)	0.0962	1.23	0.0798	2.61	0.0747	1.96	0.0878	0.877
β_{13}	Sacramento region dummy	(0,1)	0.0522	0.645	-0.0066	-0.195	0.00266	0.062	-0.00845	-0.082
β_{14}	Other region dummy	(0,1)	0.102	1.53	0.047	1.77	0.0285	0.864	0.0698	0.723

Fit Statistics	1 Vehicle	2 + Vehicles	2 Vehicles	3 + Vehicles
Number of observations	1735	10338	5418	4920
Number of parameters	13	14	13	14
Standard error of the estimate	0.784	0.784	0.719	0.849
R-squared	0.0890	0.137	0.121	0.138
Adjusted R-squared	0.0827	0.136	0.119	0.136

Fuel Choice Model

Table 19: Fuel Choice Model Coefficients – Statewide

Coef.	Description	Units	Estimate	T-Stat
α_1	Ethanol constant	--	5.03	15.7
β_1	E-85:gasoline price ratio for income < $40,000	--	-4.6	-16.1
β_2	E-85:gasoline price ratio for income $40,000 to $79,999	--	-4.55	-16.3
β_3	E-85:gasoline price ratio for income >= $80,000	--	-4.49	-16

Fit Statistics	
Number of observations	3903
Number of individuals	1301
Number of parameters	4
Log likelihood at zero	-2705.35
Log likelihood at convergence	-2548.84
Rho-squared	0.0579
Adjusted Rho-squared	0.0564

Table 20: Fuel Choice Model Coefficients – Regional

Coef.	Description	Units	Estimate	T-Stat
α_1	Ethanol constant	--	5.14	15.8
β_1	E-85:gasoline price ratio for income < $40,000	--	-4.6	-16.1
β_2	E-85:gasoline price ratio for income $40,000 to $79,999	--	-4.55	-16.3
β_3	E-85:gasoline price ratio for income >= $80,000	--	-4.5	-16
β_4	LA dummy	(0,1)	-0.147	-1.67
β_5	San Diego dummy	(0,1)	-0.143	-1.11
β_6	Sacramento dummy	(0,1)	-0.127	-0.923
β_7	Other dummy	(0,1)	-0.127	-1.24

Fit Statistics	
Number of observations	3903
Number of individuals	1301
Number of parameters	8
Log likelihood at zero	-2705.35
Log likelihood at convergence	-2547.29
Rho-squared	0.0584
Adjusted Rho-squared	0.0555

Vehicle Quantity Model

Table 21: Vehicle Quantity Model Coefficients – Alternatives for 0, 1, 2+ Vehicles

Alternative	Coeff.	Description	Units	Estimate	T-stat
1 Vehicle Alternative	α_1	Constant - 1 Vehicle	--	-5.77	-3.68
	β_1	Natural log of income - 1 Vehicle	dollars	0.781	5.62
	β_2	Full-time equivalent workers - 1 Vehicle	persons	-0.355	-2.98
	β_3	Natural log of household size - 1 Vehicle	persons	-0.996	-5.57
	β_4	Per capita transit ridership - 1 Vehicle	trips/person	-0.00294	-2.01
2 + Vehicle Alternative	α_2	Constant - 2 Vehicle	--	-18.8	-9.55
	β_5	Natural log of income - 2 Vehicle	dollars	1.83	10.5
	β_6	Full-time equivalent workers - 2 Vehicle	persons	-0.0678	-0.585
	β_7	Natural log of household size - 2 Vehicle	persons	0.883	4.97
	β_8	Per capita transit ridership - 2 Vehicle	trips/person	-0.00888	-6.01
Logsum (applied to all alternatives)	β_9	Logsum	--	0.201	0.617

Fit Statistics	
Number of observations	6577
Number of individuals	6577
Number of parameters	11
Log likelihood at zero	-7291.67
Constants only log likelihood	-4706.46
Log likelihood at convergence	-3620.04
Rho-squared	0.504
Adjusted rho-squared	0.502

Table 22: Vehicle Quantity Model Coefficients – Alternatives for 0, 1, 2+ Vehicles with Urban Variable

Alternative	Coef.	Description	Units	Estimate	T-stat
1 Vehicle Alternative	α_1	Constant - 1 Vehicle	--	-5.77	-3.66
	β_1	Natural log of income - 1 Vehicle	dollars	0.8	5.73
	β_2	Full-time equivalent workers - 1 Vehicle	persons	-0.354	-2.96
	β_3	Natural log of household size - 1 Vehicle	persons	-1.01	-5.62
	β_4	Per capita transit ridership - 1 Vehicle	trips/person	-0.00223	-1.47
	β_5	Urban dummy - 1 Vehicle	trips/person	-0.33	-2
2 + Vehicle Alternative	α_2	Constant - 2 Vehicle	--	-18.7	-9.51
	β_6	Natural log of income - 2 Vehicle	dollars	1.85	10.6
	β_7	Full-time equivalent workers - 2 Vehicle	persons	-0.0636	-0.547
	β_8	Natural log of household size - 2 Vehicle	persons	0.866	4.86
	β_9	Per capita transit ridership - 2 Vehicle	trips/person	-0.00784	-5.13
	β_{10}	Urban dummy - 2 Vehicle	trips/person	-0.457	-2.81
Logsum (applied to all alternatives)	β_{11}	Logsum	--	0.187	0.575

Fit Statistics	
Number of observations	6577
Number of individuals	6577
Number of parameters	13
Log likelihood at zero	-7291.67
Constants only log likelihood	-4706.46
Log likelihood at convergence	-3615.11
Rho-squared	0.504
Adjusted rho-squared	0.502

Table 23: Vehicle Quantity Model Coefficients – Alternatives for 0, 1, 2, 3+ Vehicles

Alternative	Coef.	Description	Units	Estimate	T-stat
1 Vehicle Alternative	α_1	Constant - 1 Vehicle	--	-5.47	-3.92
	β_1	Natural log of income - 1 Vehicle	dollars	0.794	6.02
	β_2	Full-time equivalent workers - 1 Vehicle	persons	-0.368	-3.06
	β_3	Natural log of household size - 1 Vehicle	persons	-0.989	-5.69
	β_4	Per capita transit ridership - 1 Vehicle	trips/person	-0.00286	-1.97
2 Vehicle Alternative	α_2	Constant - 2 Vehicle	--	-17.7	-11.9
	β_5	Natural log of income - 2 Vehicle	dollars	1.8	12.7
	β_6	Full-time equivalent workers - 2 Vehicle	persons	-0.202	-1.71
	β_7	Natural log of household size - 2 Vehicle	persons	0.679	3.83
	β_8	Per capita transit ridership - 2 Vehicle	trips/person	-0.00812	-5.45
3 + Vehicle Alternative	α_3	Constant - 3 Vehicle	--	-22.8	-13.3
	β_9	Natural log of income - 3 Vehicle	dollars	2.05	12.9
	β_{10}	Full-time equivalent workers - 3 Vehicle	persons	0.226	1.86
	β_{11}	Natural log of household size - 3 Vehicle	persons	1.55	8.49
	β_{12}	Per capita transit ridership - 3 Vehicle	trips/person	-0.0107	-6.6
Logsum (applied to all alternatives)	β_{13}	Logsum	--	0.0935	0.656

Fit Statistics	
Number of observations	6577
Number of individuals	6577
Number of parameters	16
Log likelihood at zero	-9117.66
Constants only log likelihood	-7633.58
Log likelihood at convergence	-6354.21
Rho-squared	0.303
Adjusted rho-squared	0.301

Table 24: Vehicle Quantity Model Coefficients – Alternatives for 0, 1, 2, 3+ Vehicles with Urban Variable

Alternative	Coef.	Description	Units	Estimate	T-stat
1 Vehicle Alternative	α_1	Constant - 1 Vehicle	--	-5.51	-3.94
	β_1	Natural log of income - 1 Vehicle	dollars	0.811	6.11
	β_2	Full-time equivalent workers - 1 Vehicle	persons	-0.366	-3.04
	β_3	Natural log of household size - 1 Vehicle	persons	-1	-5.76
	β_4	Per capita transit ridership - 1 Vehicle	trips/person	-0.00218	-1.44
	β_5	Urban dummy – 1 vehicle		-0.324	-1.97
2 Vehicle Alternative	α_2	Constant - 2 Vehicle	--	-17.7	-11.9
	β_6	Natural log of income - 2 Vehicle	dollars	1.82	12.7
	β_7	Full-time equivalent workers - 2 Vehicle	persons	-0.198	-1.67
	β_8	Natural log of household size - 2 Vehicle	persons	0.662	3.73
	β_9	Per capita transit ridership - 2 Vehicle	trips/person	-0.00725	-4.7
	β_{10}	Urban dummy – 2vehicle		-0.395	-2.41
3 + Vehicle Alternative	α_3	Constant - 3 Vehicle	--	-22.8	-13.3
	β_{11}	Natural log of income - 3 Vehicle	dollars	2.07	13
	β_{12}	Full-time equivalent workers - 3 Vehicle	persons	0.234	1.92
	β_{13}	Natural log of household size - 3 Vehicle	persons	1.53	8.34
	β_{14}	Per capita transit ridership - 3 Vehicle	trips/person	-0.00932	-5.56
	β_{15}	Urban dummy – 3vehicle		-0.618	-3.63
Logsum (applied to all alternatives)	β_{16}	Logsum	--	0.0974	0.683

Fit Statistics	
Number of observations	6577
Number of individuals	6577
Number of parameters	19
Log likelihood at zero	-9117.66
Constants only log likelihood	-7633.58
Log likelihood at convergence	-6343.71
Rho-squared	0.304
Adjusted rho-squared	0.302

Commercial Vehicle Choice Model

Table 25: Commercial Vehicle Choice Model Coefficients

Type	Coef.	Description	Units	Industry Group 1		Industry Group 2		Industry Group 3	
				Estimate	T-stat	Estimate	T-stat	Estimate	T-stat
Constants	α_1	Inertia	--	1.39	43.1	1.39	43.1	1.39	43.1
Vehicle Type	$\beta_{1,1}$	Subcompact car	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{1,2}$	Compact car	(0,1)	0.324	1.69	0.193	0.962	0.411	2.76
	$\beta_{1,3}$	Midsize car	(0,1)	0.57	3.06	0.45	2.29	0.64	4.36
	$\beta_{1,4}$	Large car	(0,1)	0.452	2.16	0.215	0.954	0.867	4.99
	$\beta_{1,5}$	Sport car	(0,1)	0.196	0.842	0.019	0.075	-0.0117	-0.058
	$\beta_{1,6}$	Small cross car	(0,1)	0.23	1.12	0.235	1.07	0.0924	0.517
	$\beta_{1,7}$	Small cross utility SUV	(0,1)	0.448	2.2	0.321	1.33	0.492	2.7
	$\beta_{1,8}$	Midsize cross utility SUV	(0,1)	0.818	4.02	0.365	1.5	0.645	3.3
	$\beta_{1,9}$	Compact SUV	(0,1)	0.429	2.07	0.229	0.898	0.561	2.85
	$\beta_{1,10}$	Midsize SUV	(0,1)	0.731	3.66	0.657	2.78	0.981	5.47
	$\beta_{1,11}$	Large SUV	(0,1)	1.47	7.02	0.0867	0.337	0.906	4.54
	$\beta_{1,12}$	Compact van	(0,1)	0.926	4.85	0.505	2.51	0.885	5.52
	$\beta_{1,13}$	Large van	(0,1)	1.64	8.82	1.01	5.02	1.57	9.68
	$\beta_{1,14}$	Compact truck	(0,1)	1.37	8.12	0.774	4.09	0.923	6.15
	$\beta_{1,15}$	Standard truck	(0,1)	2.04	11.7	1.46	7.38	1.43	8.92
Fuel Type	$\beta_{2,1}$	Gasoline	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{2,2}$	E-85	(0,1)	-0.146	-1.36	-0.122	-1.01	0.00833	0.083
	$\beta_{2,3}$	Plug-in hybrid	(0,1)	-0.136	-1.02	-0.238	-1.64	0.0112	0.088
	$\beta_{2,4}$	Compressed natural gas	(0,1)	-2.83	-3.4	-2.86	-3.41	-2.59	-3.11
	$\beta_{2,5}$	Diesel	(0,1)	0.226	2.18	0.0963	0.817	0.166	1.68
	$\beta_{2,6}$	Hybrid	(0,1)	0.0993	0.922	-0.00789	-0.065	0.104	1.06
	$\beta_{2,7}$	Full electric	(0,1)	-2.86	-4.67	-2.81	-4.54	-2.59	-4.22
Age	$\beta_{3,1}$	New vehicle	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{3,2}$	Used vehicle 1 or 2 years old	(0,1)	-0.111	-2.26	-0.111	-2.26	-0.111	-2.26
	$\beta_{3,3}$	Used vehicle 3 or more years old	(0,1)	-0.439	-10.3	-0.439	-10.3	-0.439	-10.3
Incentive	$\beta_{4,1}$	No incentive	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{4,2}$	HOV lane use	(0,1)	0.112	2.1	0.112	2.1	0.112	2.1
	$\beta_{4,3}$	Free parking	(0,1)	-0.0407	-0.747	-0.0407	-0.747	-0.0407	-0.747
	$\beta_{4,4}$	$1,000 tax credit	(0,1)	0.0658	1.23	0.0658	1.23	0.0658	1.23
	$\beta_{4,5}$	50% reduced tolls	(0,1)	-0.0151	-0.28	-0.0151	-0.28	-0.0151	-0.28
	$\beta_{4,6}$	$1,000 reduced purchase price	(0,1)	0.0515	0.961	0.0515	0.961	0.0515	0.961
Price	β_5	Price	$000	-0.0372	-17.1	-0.0372	-17.1	-0.0372	-17.1
Maintenance	β_6	Maintenance cost	c/mi	-0.0695	-4.52	-0.0695	-4.52	-0.0695	-4.52
Fuel Cost	β_7	Fuel cost	c/mi	-0.0664	-12.1	-0.0664	-12.1	-0.0664	-12.1
MPGE	β_8	MPGE	MPGE	0.00866	3.38	0.00866	3.38	0.00866	3.38
Acceleration	β_9	Acceleration (0 to 60 mph)	secs	-0.0127	-2.15	-0.0127	-2.15	-0.0127	-2.15
Range	β_{10}	Natural log of range (CNG and EV)	miles	0.334	2.2	0.334	2.2	0.334	2.2

Type	Coef.	Description	Units	Industry Group 1		Industry Group 2		Industry Group 3	
				Estimate	T-stat	Estimate	T-stat	Estimate	T-stat
Fuel Availability	$\beta_{11,1}$	1 in 50 stations (CNG)	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{11,2}$	1 in 20 stations (CNG)	(0,1)	0.294	2.63	0.294	2.63	0.294	2.63
	$\beta_{11,3}$	Plug-in at home only (EV)	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{11,4}$	Plug-in at work and other locations (EV)	(0,1)	0.18	1.65	0.18	1.65	0.18	1.65
Refueling Time	$\beta_{12,1}$	Refuel in 10 min (station); 8 hrs (home) (CNG)	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{12,2}$	Refuel in 10 min (station); 4 hrs (home) (CNG)	(0,1)	-0.123	-1.1	-0.123	-1.1	-0.123	-1.1
	$\beta_{12,3}$	Recharge in 8hrs (EV)	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{12,4}$	Recharge in 3 hrs (EV)	(0,1)	-0.133	-1.22	-0.133	-1.22	-0.133	-1.22
Vehicle type - fuel type interactions	$\beta_{13,1}$	Alt fuel - Small vehicles	(0,1)	0.0	0.0	0.0	0.0	0.0	0.0
	$\beta_{13,2}$	Alt fuel - Medium vehicles	(0,1)	0.376	3.93	0.174	1.44	0.00428	0.044
	$\beta_{13,3}$	Alt fuel - Large vehicles	(0,1)	0.08	0.683	0.404	3.29	0.067	0.686
Number of Vehicles in Fleet	$\beta_{14,1}$	Cars	(0,1)	0.0311	5.33	0.0311	5.33	0.0311	5.33
	$\beta_{14,2}$	SUVs	(0,1)	0.0443	5.23	0.0443	5.23	0.0443	5.23
	$\beta_{14,3}$	Vans	(0,1)	0.0668	7.88	0.0668	7.88	0.0668	7.88
	$\beta_{14,4}$	Trucks	(0,1)	0.0553	9.54	0.0553	9.54	0.0553	9.54

Fit Statistics	
Number of observations	14240
Number of individuals	1780
Number of parameters	88
Log Likelihood at Zero	-19740.83
Log Likelihood Constants Only	-15067.22
Log Likelihood at Convergence	-13030.73
Rho squared	0.340
Adjusted Rho squared	0.335

APPENDIX B

2009 California Vehicle Survey Stated Preference Questionnaire Design

Introduction

The California Energy Commission (CEC) is required by state law to analyze strategies for reducing petroleum dependency in the state. To comply with this mandate, CEC developed the California (light duty) Conventional and Alternative Fuel Response Simulator (CALCARS) model that predicts vehicle fleet composition and fuel consumption of the California vehicle fleet. RSG used data from the 2008–2009 California Vehicle Survey (CVS) to statistically estimate coefficients of vehicle choice models, which will be used as inputs to the CALCARS model.

The 2008-2009 CVS consisted of a Residential Vehicle Survey and a Light-Duty Commercial Vehicle Survey. Both surveys included stated preference (SP) questions that were designed to support development of vehicle choice models. Survey data were collected using a two-phase, multi-method approach. The first phase involved a revealed preference (RP) recruitment survey that was conducted over the telephone. The second phase included the stated preference survey with eight vehicle choice exercises.

The CALCARS forecasting model is an essential tool for the State of California to evaluate potential policies and initiatives designed to influence the vehicle choice and fuel choice behavior of residential and commercial motor vehicle users. This appendix summarizes 1) the attributes and levels used to create the alternatives presented in the eight stated preference exercises and 2) a description of the underlying experimental design.

Stated Preference Questionnaire Design

After completing the revealed preference (RP) survey over the telephone, respondents were given two options for completing the stated preference (SP) survey:

- By mail: Respondents selecting this option were mailed a paper version of the SP survey and a postage paid business reply envelope.
- By Internet: Respondents selecting this option were emailed a URL to the online survey with an embedded unique password. In addition, all mail respondents were provided with a URL and unique password on the first page of the paper survey so that they could complete the survey online, if desired.

Data from the RP survey was used to construct a set of eight stated preference exercises for the SP survey. In the RP survey, respondents were asked to indicate the type of vehicle they are most likely to purchase next for their household; including information about the vehicle type, fuel type, expected fuel efficiency, purchase price, vehicle age, and estimated number of miles the vehicle would be driven annually.

Each stated preference exercise presented respondents with four hypothetical vehicles as alternatives. The first vehicle, or the reference vehicle, was presented as the new or used vehicle the respondent planned to purchase next for their household. The attributes that describe the reference vehicle were consistent with what the respondent reported in the RP survey. The next three alternatives were presented as vehicles of different sizes, fuel types and ages. The four vehicles in each exercise were described by a set of ten to twelve attributes, depending on the fuel type presented. Respondents were asked to select the vehicle they would most prefer to purchase based on the attributes presented in each alternative. The values of each attribute varied according to an experimental design, requiring respondents to tradeoff attributes against each other. Figure 1 presents an example of one of the eight stated preference exercises of a hypothetical respondent.

Figure 1: Example Stated Preference Exercise

2008 California Vehicle Survey

If the following vehicle options were available to you, which would you choose?
Please carefully examine all the attributes of each vehicle and then select the one you will most likely purchase by filling in the circle below your choice.

Vehicle Choice 1	Vehicle A	Vehicle B	Vehicle C	Vehicle D
Vehicle type	Midsize car	Compact SUV	Midsize car	Compact van
Fuel type	Gasoline	Natural Gas (NGV)	Plug-in Hybrid (PHEV)	Clean Diesel
Age of vehicle	New (2009)	New (2009)	New (2009)	New (2009)
Purchase price	$29,400	$36,600	$31,100	$20,900
Incentive	--	--	$1,000 tax credit	--
MPG or equivalent	29 MPG	15 MPG	60 MPG	31 MPG
Fuel cost per year	$1,090	$1,950	$780	$1,170
Fuel availability		1 in 50 stations		
Refueling time		10 Minutes at station, 4 hours at home		
Driving range		300 Miles		
Maintenance cost per year	$460	$370	$350	$550
Acceleration (0-60 mpg)	10.2 seconds	11 seconds	8 seconds	11.8 seconds
Select One:	○	○	○	○

RSG worked closely with the Energy Commission to finalize the attributes and levels used to describe each alternative. The attributes and levels for the SP survey were evaluated in a set of six focus groups. Input from the focus group participants was used to refine the attributes and instructions. Effort was also made to present only the most important attributes that have the greatest influence on vehicle choice behavior. If too many attributes are presented, respondents can become overwhelmed by the amount of information shown in each choice exercise.

Stated Preference Attributes and Levels

Vehicle Type and Fuel Type

The first two attributes for each alternative were vehicle type and fuel type. A total of fifteen vehicle types and seven fuel types were selected for the exercises.

Vehicle Type

The vehicle type was fixed to the response given in the RP survey for the reference vehicle. For the remaining three alternatives, vehicle type was drawn from one of the following fifteen types:

1. Subcompact car
2. Compact car
3. Mid-size car
4. Large car
5. Sport car or "two door high performance subcompact car"
6. Small cross-utility car or "small wagons with flexible seating"
7. Small cross-utility SUV
8. Mid-size cross-utility SUV
9. Compact SUV
10. Mid-size SUV
11. Large SUV
12. Compact van
13. Large van
14. Compact pick-up truck
15. Standard pick-up truck

While it was possible any vehicle could be selected for the three alternate vehicles, the selection of those vehicles was done using weighted draws based on the respondent's reference vehicle type. Weighted draws were used because it is expected that respondents will have relatively strong preferences for at least a broad category of vehicle (e.g. small or large), and as a result presenting a respondent with a choice between a reference subcompact car and a large van makes little sense. In that situation, vehicle type would dominate the choice process and little or no information could be gained for the sensitivities to other attributes. On the other hand, it was also not seen as appropriate to completely restrict the different combinations of vehicle types presented to a respondent.

As a result, a set of weights were developed for each reference vehicle type. Table 1 presents the weights that were used for the vehicle type selection for the three alternate vehicles, with the reference vehicle types running across the top of the table.

Table 1: Vehicle Type Weights

	Reference Vehicle Type															
Alternate Vehicle	**Sub-compact car**	**Compact car**	**Mid-size car**	**Large car**	**Sports car**	**Small x-utility car**	**Small x-utility SUV**	**Mid-size x-utility SUV**	**Compact SUV**	**Mid-size SUV**	**Large SUV**	**Compact van**	**Large van**	**Compact pick-up**	**Standard pick-up**	**Total**
Subcompact car	0.52	0.05	0.03	0.02	0.05	0.05	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.91
Compact car	0.05	0.52	0.05	0.03	0.05	0.05	0.05	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.96
Mid-size car	0.05	0.05	0.52	0.05	0.05	0.03	0.05	0.03	0.03	0.03	0.02	0.03	0.02	0.02	0.02	1.00
Large car	0.03	0.03	0.05	0.52	0.03	0.02	0.03	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.97
Sports car	0.05	0.05	0.03	0.02	0.52	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.89
Small x-utility car	0.05	0.05	0.03	0.03	0.05	0.52	0.05	0.05	0.03	0.02	0.03	0.02	0.03	0.02	0.03	1.01
Small x-utility SUV	0.05	0.05	0.05	0.03	0.05	0.05	0.52	0.05	0.05	0.03	0.03	0.03	0.03	0.03	0.03	1.08
Mid-size x-utility SUV	0.03	0.03	0.05	0.05	0.03	0.05	0.05	0.52	0.05	0.05	0.03	0.03	0.03	0.03	0.03	1.06
Compact SUV	0.03	0.03	0.05	0.03	0.03	0.05	0.05	0.05	0.52	0.05	0.03	0.03	0.03	0.05	0.03	1.06
Mid-size SUV	0.03	0.03	0.03	0.05	0.03	0.03	0.03	0.05	0.05	0.52	0.05	0.05	0.05	0.05	0.05	1.10
Large SUV	0.02	0.02	0.02	0.05	0.03	0.02	0.02	0.03	0.05	0.05	0.52	0.05	0.05	0.05	0.05	1.03
Compact van	0.03	0.03	0.03	0.05	0.02	0.03	0.03	0.03	0.03	0.03	0.05	0.52	0.05	0.05	0.05	1.03
Large van	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.05	0.05	0.52	0.03	0.05	0.91
Compact pick-up	0.02	0.02	0.02	0.03	0.02	0.03	0.03	0.03	0.05	0.05	0.05	0.05	0.05	0.52	0.05	1.02
Standard pick-up	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.05	0.05	0.05	0.05	0.05	0.52	0.97
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	15.00

With these weights, all vehicle types have a non-zero probability of being included in an exercise, but the probability is higher for those vehicles that are more similar to the reference vehicle type. An especially high weight of approximately 50 percent was used for the reference vehicle type, which ensured that, at least for one pair of alternatives, the relative preference was not influenced by vehicle type. The reference vehicle was allowed to repeat in one other alternative, allowing respondents to trade-off attributes other than vehicle type. No other vehicle types were allowed to repeat across alternatives within a single exercise.

Fuel Type

For the reference vehicle, fuel type was fixed to the respondent's RP response. The remaining fuel types were draw from the following list:

1. Standard Gasoline
2. Flex Fuel/E85
3. Clean Diesel
4. Compressed Natural Gas
5. Hybrid-electric
6. Plug-in Hybrid-electric
7. Full Electric

The selection of which fuel type to show for the three alternate vehicles was done entirely randomly, i.e. not using any weights, thus guaranteeing that all possible combinations were represented roughly evenly. The reference vehicle fuel type was allowed to repeat in one of the three alternate vehicles, allowing respondents to tradeoff attributes other than fuel type. No other fuel types were allowed to repeat across alternatives within a single exercise.

Other Vehicle Attributes

The remaining vehicle attributes were dependent on the vehicle and fuel type. While values for vehicle type and fuel type were selected using weighted and random draws as described above, the values for the remaining attributes varied according to an orthogonal experimental design. The orthogonal design is described in more detail later in this appendix.

Many of the vehicle attributes vary around a base value. In the case of purchase price, maintenance cost, miles per gallon equivalent, fuel cost per gallon equivalent, and acceleration, the Energy Commission provided tables of base values. These base values represent average values for all vehicles of a particular vehicle type, fuel type and vintage.

Vehicle age

The age of the vehicle was dependent on the respondent's response from the RP survey. The reference vehicle age was fixed using the response from the RP survey. Plug-in hybrid electric and full electric vehicles were fixed as new vehicles only. Vehicles with other fuel types were presented at the following levels:

1. 3 years older than the reference vehicle
2. Same age as the reference vehicle
3. 3 years younger than the reference vehicle (max of current year)

Purchase price

The purchase price of the vehicle varied around a base value. For the reference vehicle, the base value is the response given in the RP survey. For the three remaining alternatives, the base value was dependent on a "list price" determined from the combination of vehicle type, fuel type, and vintage. Because the list price represents an average price for all vehicles of a particular vehicle type, fuel type, and vintage, the base price value was adjusted by the ratio between the indicated price of the reference vehicle in the RP survey and the list price for that vehicle, thus accounting for the possibility that a respondent was considering a higher than average or lower than average price for the reference vehicle.

The base price values were varied using the following levels:

1. Base purchase price + 20%
2. Base purchase price + 7%
3. Base purchase price - 7%
4. Base purchase price - 20%

Purchase incentive

There were six purchase incentive levels shown in the survey. Gasoline-powered vehicles were always presented with no purchase incentive, while the remaining alternative fuel vehicles saw one of the following levels:

1. No purchase incentive
2. SOV carpool lane access
3. Free parking
4. $1,000 tax credit
5. 50% reduced tolls
6. $1,000 reduced vehicle purchase price

Annual maintenance cost

A base maintenance cost per mile for each vehicle was assumed based on the vehicle type, fuel type, and vehicle age. The maintenance cost per mile was multiplied by the reported annual VMT to calculate an annual maintenance cost. These annual maintenance costs varied according to the following levels:

1. Base annual maintenance cost + 25%
2. Base annual maintenance cost + 10%
3. Base annual maintenance cost - 10%
4. Base annual maintenance cost - 25%

Miles per gallon equivalent

A base value for miles per gallon equivalent was assumed based on the vehicle type, vehicle age, and fuel type. This value varied for according to the following levels:

1. Base miles per gallon equivalent + 15%
2. Base miles per gallon equivalent + 5%
3. Base miles per gallon equivalent - 5%
4. Base miles per gallon equivalent - 15%

Fuel cost per gallon equivalent

Fuel cost per gallon equivalent was not shown to respondents, but was used to calculate the annual fuel cost. A base fuel cost in gasoline gallon equivalents was assumed for each type of fuel using current fuel prices. These values were varied according to the following levels:

1. Base fuel cost per gallon equivalent + 15%
2. Base fuel cost per gallon equivalent + 5%
3. Base fuel cost per gallon equivalent - 5%
4. Base fuel cost per gallon equivalent - 15%

Annual fuel cost

The annual fuel cost was calculated using the fuel cost in gasoline gallon equivalents, the vehicle efficiency in miles per gallon equivalent, and the annual miles reported in the RP survey. Note that this attribute did not vary independently; rather, it was a calculated value based on the independently varying fuel cost and vehicle efficiency attributes.

Fuel availability

The fuel availability attribute only applied to full electric or compressed natural gas vehicles. For all other fuel types (gasoline, flex fuel, diesel, hybrid, and plug-in hybrid), the fuel distribution network was assumed to be the same as gasoline. For example, even though E85 is not currently available at many fuel stations, and outlets for plug-in hybrids are not readily available, flex fuel vehicles and plug-in hybrids can still operate using unleaded gasoline. Two levels were shown for each fuel type. For full electric vehicles, the levels were:

1. Plug-in at home only
2. Plug-in at work and other locations

For compressed natural gas vehicles, the levels were:

1. 1 in 50 stations
2. 1 in 20 stations

Refueling time

The refueling time attribute only applied to full electric and compressed natural gas vehicles. The attributes varied according to the following levels for full electric vehicles:

1. 8 hour charging time
2. 3 hour charging time

The attributes varied according to the following levels for compressed natural gas vehicles:

1. 10 minutes at station; 8 hours at home
2. 10 minutes at station; 4 hours at home

Vehicle range

The vehicle range attribute only applied to full electric and compressed natural gas vehicles. Four levels were shown for each fuel type. For full electric vehicles, the levels were:

1. 30 miles
2. 40 miles
3. 50 miles
4. 60 miles

For compressed natural gas vehicles, the levels were:

1. 150 miles
2. 200 miles
3. 250 miles
4. 300 miles

Acceleration

The acceleration attribute was presented as the time it takes to accelerate from zero to 60 miles per hour in seconds. The acceleration of each vehicle was assumed based on the vehicle type, fuel type and vehicle age, and varied according to the following two levels:

1. Two seconds slower than the base acceleration value
2. Two seconds faster than the base acceleration value

Figure 2 summarizes the attributes and levels described above.

Figure 2: Attributes and Levels

Attribute	Notes	Vehicle A Reference Vehicle		Vehicle B SP Alternative 1		Vehicle C SP Alternative 2		Vehicle D SP Alternative 3	
Vehicle Type	*Reference vehicle fixed to RP vehicle type. Other vehicle types weighted based on reference vehicle*	RP Vehicle Type [fixed]		*RP is only repeated in 1 alternative* Subcompact car Compact car Mid-size car Large car Sport car Small cross-utility car Small cross-utility SUV Mid-size cross-utility SUV Compact SUV Mid-size SUV Large SUV Compact van Large van Compact pick-up Standard pick-up		*RP is only repeated in 1 alternative* Subcompact car Compact car Mid-size car Large car Sport car Small cross-utility car Small cross-utility SUV Mid-size cross-utility SUV Compact SUV Mid-size SUV Large SUV Compact van Large van Compact pick-up Standard pick-up		*RP is only repeated in 1 alternative* Subcompact car Compact car Mid-size car Large car Sport car Small cross-utility car Small cross-utility SUV Mid-size cross-utility SUV Compact SUV Mid-size SUV Large SUV Compact van Large van Compact pick-up Standard pick-up	
Fuel type	*Vehicle A fixed to RP fuel type. RP may be repeated once in vehicles B, C, or D*	RP Fuel Type [fixed]		*RP is only repeated in 1 alternative* Gasoline E85 Diesel CNG HEV PHEV Full EV		*RP is only repeated in 1 alternative* Gasoline E85 Diesel CNG HEV PHEV Full EV		*RP is only repeated in 1 alternative* Gasoline E85 Diesel CNG HEV PHEV Full EV	
Age of Vehicle	*Reference vehicle fixed to RP age*	RP Vehicle Age [fixed]		*PHEV or Full EV* New [fixed]	*All other fuel types* RP age - 3 RP age RP age + 3 *(max 2009)*	*PHEV or Full EV* New [fixed]	*All other fuel types* RP age - 3 RP age RP age + 3 *(max 2009)*	*PHEV or Full EV* New [fixed]	*All other fuel types* RP age - 3 RP age RP age + 3 *(max 2009)*
Base Price (MSRP)	*Base price dependent on vehicle type, age, and fuel type premium*	RP Vehicle Price - 20% RP Vehicle Price - 7% RP Vehicle Price + 7% RP Vehicle Price + 20%		Base price - 20% Base price - 7% Base price + 7% Base price + 20%		Base price - 20% Base price - 7% Base price + 7% Base price + 20%		Base price - 20% Base price - 7% Base price + 7% Base price + 20%	
Purchase Incentive	*Gasoline always sees "none"*	*Gasoline* None [fixed]	*All other fuel types* None HOV access Free parking $1,000 tax credit 50% reduced toll $1000 reduced purch. price	*Gasoline* None [fixed]	*All other fuel types* None HOV access Free parking $1,000 tax credit 50% reduced toll $1000 reduced purch. price	*Gasoline* None [fixed]	*All other fuel types* None HOV access Free parking $1,000 tax credit 50% reduced toll $1000 reduced purch. price	*Gasoline* None [fixed]	*All other fuel types* None HOV access Free parking $1,000 tax credit 50% reduced toll $1000 reduced purch. price
Fuel Cost per Gallon Equivalent *(Not shown)*	*Base cost dependent on fuel type*	Base cost - 15% Base cost - 5% Base cost + 5% Base cost + 15%		Base cost + 15% Base cost + 5% Base cost - 5% Base cost - 15%		Base cost + 15% Base cost + 5% Base cost - 5% Base cost - 15%		Base cost + 15% Base cost + 5% Base cost - 5% Base cost - 15%	
MPG Equivalent	*Base MPGE dependent on vehicle type and fuel type*	Base MPGE + 15% Base MPGE + 5% Base MPGE - 5% Base MPGE - 15%		Base MPGE - 15% Base MPGE - 5% Base MPGE + 5% Base MPGE + 15%		Base MPGE - 15% Base MPGE - 5% Base MPGE + 5% Base MPGE + 15%		Base MPGE - 15% Base MPGE - 5% Base MPGE + 5% Base MPGE + 15%	
Annual Fuel Costs		(Fuel cost per gallon) x (RP VMT) / (MGPE)		(Fuel cost per gallon) x (RP VMT) / (MGPE)		(Fuel cost per gallon) x (RP VMT) / (MGPE)		(Fuel cost per gallon) x (RP VMT) / (MGPE)	
Fuel Availability *(if fuel type is full EV or CNG)*	*Only shown if fuel type is full EV or CNG*	*Full EV* Plug-in only at home Plug-in at work and other loc.	*CNG* 1 in 50 stations 1 in 20 stations	*Full EV* Plug-in only at home Plug-in at work and other loc.	*CNG* 1 in 50 stations 1 in 20 stations	*Full EV* Plug-in only at home Plug-in at work and other loc.	*CNG* 1 in 50 stations 1 in 20 stations	*Full EV* Plug-in only at home Plug-in at work and other loc.	*CNG* 1 in 50 stations 1 in 20 stations
Refueling Time *(if fuel type is full EV or CNG)*	*Only shown if fuel type is full EV or CNG*	*Full EV* 8 Hrs 3 Hrs	*CNG* 10 min (station), 4 hrs (home) 10 min (station), 8 hrs (home)	*Full EV* 8 Hrs 3 Hrs	*CNG* 10 min (station), 4 hrs (home) 10 min (station), 8 hrs (home)	*Full EV* 8 Hrs 3 Hrs	*CNG* 10 min (station), 4 hrs (home) 10 min (station), 8 hrs (home)	*Full EV* 8 Hrs 3 Hrs	*CNG* 10 min (station), 4 hrs (home) 10 min (station), 8 hrs (home)
Range *(if fuel type is full EV or CNG)*	*Only shown if fuel type is full EV or CNG*	*Full EV* 30 miles 40 miles 50 miles 60 miles	*CNG* 150 miles 200 miles 250 miles 300 miles	*Full EV* 30 miles 40 miles 50 miles 60 miles	*CNG* 150 miles 200 miles 250 miles 300 miles	*Full EV* 30 miles 40 miles 50 miles 60 miles	*CNG* 150 miles 200 miles 250 miles 300 miles	*Full EV* 30 miles 40 miles 50 miles 60 miles	*CNG* 150 miles 200 miles 250 miles 300 miles
Maintenance Costs	*Base cost dependent on vehicle type and age*	Base cost - 25% Base cost - 10% Base cost + 10% Base cost + 25%		Base cost - 25% Base cost - 10% Base cost + 10% Base cost + 25%		Base cost - 25% Base cost - 10% Base cost + 10% Base cost + 25%		Base cost - 25% Base cost - 10% Base cost + 10% Base cost + 25%	
Acceleration	*Acceleration dependent on vehicle type and age*	Base acceleration - 2 Base acceleration + 2		Base acceleration - 2 Base acceleration + 2		Base acceleration - 2 Base acceleration + 2		Base acceleration - 2 Base acceleration + 2	

Experimental Design

The experimental design used for this SP survey was based on an underlying orthogonal design. While several types of designs were considered at the onset, including arguably more advanced efficient designs, it was concluded that, given the complexity of the SP scenarios, an orthogonal design was the most appropriate for this particular application.

While efficient designs can be preferable in some situations, the generation of an efficient design requires prior parameter values for all coefficients, as well as a priori decisions in relation to model structure and utility specification, including interactions with socio-demographic variables. While this already causes significant problems in the case of studies looking at the choice between hypothetical options, further problems arise in the California Vehicle Survey which looks at the choice of vehicle types and fuel types. Here, the preferences can be expected to vary across respondents to such an extent – some respondents will strongly prefer compact cars, while others will strongly prefer large SUVs – that it becomes difficult to obtain reliable prior parameter estimates.

Additionally, vehicle type and fuel type would have to be included directly in the design, leading to the requirement to generate a very large number of different designs for different combinations of vehicle types and fuel types. This was not necessary with the approach used in this study, where vehicle type and fuel type were added to the design in a second stage, after the generation of the base design.

Base Orthogonal Design

This base design is an orthogonal design of 144 rows, split into 18 blocks of eight choices. Orthogonal blocking was used to avoid any correlation between the attributes and the blocks (e.g. avoiding the situation where one respondent gets all the high price options). The design contains the levels for ten attributes (the attributes other than vehicle type and fuel type) and four alternatives. The vehicle types and fuel types drawn according to the approach described above were used as inputs for calculating the base values for the levels in this underlying design.

In the actual survey, each respondent was presented with one block of eight choice situations. Care was taken to ensure that the 18 different blocks were presented the same number of times and that there was no correlation between sample subgroups and blocks. The choice situations presented to the respondent were constructed on the basis of the set of vehicle type/fuel type combinations drawn for that respondent, and the block of eight choice situations used from the experimental design for that respondent. The order in which the eight choice situations from a given block were presented to a respondent was randomized across respondents.

Ordering of Alternatives

Several steps were taken to eliminate any potential ordering effects in the design. In each choice set, a respondent is faced with four alternatives, the reference alternative (Vehicle A), and three remaining alternatives (Vehicles B, C, and D). While the reference vehicle was always presented as vehicle A in each of the eight choice situations, vehicles B, C, and D varied according to the weighted vehicle type draws and the random fuel type draws. However, given the way in which the vehicle types are drawn, there would have been a high probability (roughly 50%) of Vehicle B being of the same vehicle type as the adjacent alternative A. To address this situation, the three vehicle types drawn for a given respondent were assigned in random order to B, C, and D for each choice situation. In this way, each vehicle B, C, and D had an equal probability of being assigned the reference vehicle type. No such precaution was required for fuel type as equal weights for used for all fuel types.

APPENDIX C

2009 California Vehicle Survey Example Stated Preference Survey

February 2, 2011

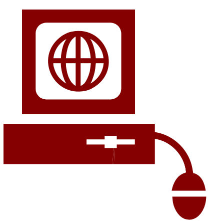
<<Respondent Name>>
<<Respondent Address>>

Dear <<Respondent Name>>,

Thank you again for agreeing to participate in the California Vehicle Survey we recently discussed with you over the telephone. Completing this survey will only take a few minutes of your time. This survey is being conducted on behalf of the California Energy Commission. Results from this survey will be used to help the Energy Commission forecast vehicle fleet composition and fuel consumption in the State of California.

For convenience, you have the following two options to complete the survey:

Mail: Complete the enclosed survey forms and return them in the business reply envelope provided – no postage necessary.



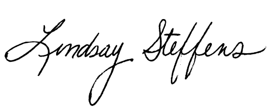
Internet: You can complete the survey online by logging on to: http://www.surveycafe.com/cavehicle and entering your password.

Your password is: <<Password>>

Your responses will remain strictly confidential and will only be used for this study. Once we receive your vehicle choice survey answers, we will send you a check for <<Amount>> as a thank-you gift for your participation.

If you have any questions or want to verify the legitimacy of this survey, please call the survey helpline at 1-800-631-0702 or email cacars@surveycafe.com. We look forward to your response and once again, thank you for your participation.

Sincerely,



Lindsay Steffens
Project Manager
The California Vehicle Survey

California Vehicle Survey: Instructions

It may be helpful to review the enclosed attribute definitions before answering any questions. These definitions can be found starting on page 13 of this survey packet.

Over the telephone, you indicated that the next vehicle your <<Respondent Type>> is likely to buy would be a Midsize car and the fuel type will most likely be Gasoline. Based on that information, we developed eight hypothetical vehicle choice scenarios for you starting on the next page.

In each scenario, Vehicle A is always the vehicle you indicated that you are likely to buy. The attributes of Vehicles B, C and D may be different than those of Vehicle A. Please carefully examine all the attributes of each vehicle and then select the one vehicle you will most likely buy.

We understand that some of the combinations of attributes and fuel types may not currently exist. For these hypothetical scenarios, please assume the combinations of attributes do exist and you could buy any of the vehicles presented to you.

We also understand that the vehicles offered may not completely suit your needs. For the purpose of this study, please assume the four vehicles on each page are the only four available and you must buy one.

You must choose one vehicle on each page for ALL EIGHT questions.

If the following vehicle options were available to you, which would you choose?
Please carefully examine all the attributes of each vehicle and then select the one you will most likely purchase by filling in the circle below your choice.

Vehicle Choice 1	Vehicle A	Vehicle B	Vehicle C	Vehicle D
Vehicle type	Midsize car	Compact SUV	Midsize car	Compact van
Fuel type	Gasoline	Natural Gas (NGV)	Plug-in Hybrid (PHEV)	Clean Diesel
Age of vehicle	New (2009)	New (2009)	New (2009)	New (2009)
Purchase price	$29,400	$36,600	$31,100	$20,900
Incentive	--	--	$1,000 tax credit	--
MPG or equivalent	29 MPG	15 MPG	60 MPG	31 MPG
Fuel cost per year	$1,090	$1,950	$780	$1,170
Fuel availability		1 in 50 stations		
Refueling time		10 Minutes at station, 4 hours at home		
Driving range		300 Miles		
Maintenance cost per year	$460	$370	$350	$550
Acceleration (0-60 mpg)	10.2 seconds	11 seconds	8 seconds	11.8 seconds
Select One:	○	○	○	○

CONTINUE TO NEXT PAGE

If the following vehicle options were available to you, which would you choose?
Please carefully examine all the attributes of each vehicle and then select the one you will most likely purchase by filling in the circle below your choice.

Vehicle Choice 2	Vehicle A	Vehicle B	Vehicle C	Vehicle D
Vehicle type	Midsize car	Midsize car	Large SUV	Midsize cross-utility SUV
Fuel type	Gasoline	Clean Diesel	Plug-in Hybrid (PHEV)	Flex Fuel (FFV)
Age of vehicle	New (2009)	New (2009)	New (2009)	3 years old (2006)
Purchase price	$33,000	$32,300	$47,600	$21,300
Incentive	--	$1,000 reduced vehicle price	Carpool lane access	50% reduced tolls
MPG or equivalent	29 MPG	30 MPG	31 MPG	17 MPG
Fuel cost per year	$1,220	$1,370	$1,640	$1,490
Fuel availability				
Refueling time				
Driving range				
Maintenance cost per year	$640	$670	$440	$600
Acceleration (0-60 mpg)	6.2 seconds	6.2 seconds	7.7 seconds	7.4 seconds
Select One:	○	○	○	○

If the following vehicle options were available to you, which would you choose?
Please carefully examine all the attributes of each vehicle and then select the one you will most likely purchase by filling in the circle below your choice.

Vehicle Choice 3	Vehicle A	Vehicle B	Vehicle C	Vehicle D
Vehicle type	Midsize car	Subcompact car	Small cross-utility SUV	Midsize car
Fuel type	Gasoline	Full Electric	Hybrid-Electric (HEV)	Natural Gas (NGV)
Age of vehicle	New (2009)	New (2009)	New (2009)	New (2009)
Purchase price	$25,600	$24,800	$21,900	$39,000
Incentive	--	--	$1,000 tax credit	--
MPG or equivalent	21 MPG	135 MPG	25 MPG	22 MPG
Fuel cost per year	$2,000	$350	$1,680	$1,310
Fuel availability		Plug-in only at home		1 in 50 stations
Refueling time		8 Hours		10 Minutes at station, 4 hours at home
Driving range		30 Miles		150 Miles
Maintenance cost per year	$570	$480	$440	$390
Acceleration (0-60 mpg)	6.2 seconds	5.2 seconds	11.1 seconds	6.2 seconds
Select One:	○	○	○	○

If the following vehicle options were available to you, which would you choose?
Please carefully examine all the attributes of each vehicle and then select the one you will most likely purchase by filling in the circle below your choice.

Vehicle Choice 4	Vehicle A	Vehicle B	Vehicle C	Vehicle D
Vehicle type	Midsize car	Compact car	Midsize car	Small cross-utility car
Fuel type	Gasoline	Natural Gas (NGV)	Flex Fuel (FFV)	Full Electric
Age of vehicle	New (2009)	3 years old (2006)	3 years old (2006)	New (2009)
Purchase price	$33,000	$13,600	$14,400	$39,000
Incentive	--	--	$1,000 reduced vehicle price	Carpool lane access
MPG or equivalent	21 MPG	27 MPG	27 MPG	92 MPG
Fuel cost per year	$1,660	$1,070	$850	$470
Fuel availability		1 in 50 stations		Plug-in only at home
Refueling time		10 Minutes at station, 8 hours at home		8 Hours
Driving range		200 Miles		60 Miles
Maintenance cost per year	$570	$370	$390	$450
Acceleration (0-60 mpg)	6.2 seconds	6.9 seconds	10.6 seconds	6.2 seconds
Select One:	○	○	○	○

If the following vehicle options were available to you, which would you choose?
Please carefully examine all the attributes of each vehicle and then select the one you will most likely purchase by filling in the circle below your choice.

Vehicle Choice 5	Vehicle A	Vehicle B	Vehicle C	Vehicle D
Vehicle type	Midsize car	Midsize cross-utility SUV	Sports car	Midsize car
Fuel type	Gasoline	Flex Fuel (FFV)	Clean Diesel	Natural Gas (NGV)
Age of vehicle	New (2009)	3 years old (2006)	New (2009)	New (2009)
Purchase price	$22,000	$27,400	$38,100	$26,000
Incentive	--	$1,000 reduced vehicle price	$1,000 reduced vehicle price	$1,000 reduced vehicle price
MPG or equivalent	24 MPG	23 MPG	36 MPG	22 MPG
Fuel cost per year	$1,330	$1,220	$1,120	$1,060
Fuel availability				1 in 50 stations
Refueling time				10 Minutes at station, 4 hours at home
Driving range				300 Miles
Maintenance cost per year	$570	$690	$620	$460
Acceleration (0-60 mpg)	10.2 seconds	7.4 seconds	9 seconds	6.2 seconds
Select One:	○	○	○	○

Password: <<Password>>
ID: <<ID>>

CONTINUE TO NEXT PAGE

If the following vehicle options were available to you, which would you choose?
Please carefully examine all the attributes of each vehicle and then select the one you will most likely purchase by filling in the circle below your choice.

Vehicle Choice 6	Vehicle A	Vehicle B	Vehicle C	Vehicle D
Vehicle type	Midsize car	Compact SUV	Compact pickup truck	Small cross-utility SUV
Fuel type	Gasoline	Hybrid-Electric (HEV)	Plug-in Hybrid (PHEV)	Flex Fuel (FFV)
Age of vehicle	New (2009)	1 year old (2008)	New (2009)	New (2009)
Purchase price	$33,000	$22,000	$25,400	$28,600
Incentive	--	$1,000 reduced vehicle price	$1,000 reduced vehicle price	$1,000 reduced vehicle price
MPG or equivalent	26 MPG	22 MPG	52 MPG	24 MPG
Fuel cost per year	$1,620	$1,570	$980	$1,280
Fuel availability				
Refueling time				
Driving range				
Maintenance cost per year	$460	$360	$560	$510
Acceleration (0-60 mpg)	6.2 seconds	11.6 seconds	8.2 seconds	11 seconds
Select One:	○	○	○	○

CONTINUE TO NEXT PAGE

If the following vehicle options were available to you, which would you choose?
Please carefully examine all the attributes of each vehicle and then select the one you will most likely purchase by filling in the circle below your choice.

Vehicle Choice 7	Vehicle A	Vehicle B	Vehicle C	Vehicle D
Vehicle type	Midsize car	Small cross-utility car	Small cross-utility SUV	Midsize car
Fuel type	Gasoline	Natural Gas (NGV)	Flex Fuel (FFV)	Full Electric
Age of vehicle	New (2009)	New (2009)	New (2009)	New (2009)
Purchase price	$22,000	$22,200	$25,500	$43,200
Incentive	--	$1,000 reduced vehicle price	Carpool lane access	50% reduced tolls
MPG or equivalent	21 MPG	28 MPG	22 MPG	115 MPG
Fuel cost per year	$1,830	$900	$1,300	$460
Fuel availability		1 in 50 stations		Plug-in only at home
Refueling time		10 Minutes at station, 8 hours at home		3 Hours
Driving range		250 Miles		60 Miles
Maintenance cost per year	$390	$280	$410	$440
Acceleration (0-60 mpg)	10.2 seconds	11.6 seconds	11 seconds	9 seconds
Select One:	○	○	○	○

If the following vehicle options were available to you, which would you choose?
Please carefully examine all the attributes of each vehicle and then select the one you will most likely purchase by filling in the circle below your choice.

Vehicle Choice 8	Vehicle A	Vehicle B	Vehicle C	Vehicle D
Vehicle type	Midsize car	Large car	Compact van	Midsize car
Fuel type	Gasoline	Flex Fuel (FFV)	Plug-in Hybrid (PHEV)	Full Electric
Age of vehicle	New (2009)	3 years old (2006)	New (2009)	New (2009)
Purchase price	$22,000	$23,800	$22,000	$32,300
Incentive	--	--	$1,000 reduced vehicle price	Carpool lane access
MPG or equivalent	29 MPG	18 MPG	59 MPG	115 MPG
Fuel cost per year	$1,350	$1,430	$710	$500
Fuel availability				Plug-in only at home
Refueling time				3 Hours
Driving range				50 Miles
Maintenance cost per year	$460	$830	$400	$370
Acceleration (0-60 mpg)	10.2 seconds	10.1 seconds	8.3 seconds	9 seconds
Select One:	○	○	○	○

Follow-up Question 1		
A vehicle with Flex Fuel capability can either run on unleaded gasoline or on E-85, a fuel mixture consisting of 15% gasoline and 85% ethanol*. Assuming you purchased a vehicle with Flex Fuel capability and both types of fuel were readily available, which fuel would you typically use? Please respond to each of the following scenarios:		
If the annual fuel cost is about the same for either fuel?	○ Unleaded Gasoline	○ E-85
If the annual fuel cost is 15% higher for E-85 than for standard gasoline?	○ Unleaded Gasoline	○ E-85
If the annual fuel cost is 30% higher for E-85 than for standard gasoline?	○ Unleaded Gasoline	○ E-85
** Ethanol is a renewable fuel made from various plant materials, or "biomass."*		

Follow-up Question 2		
Assuming the only two vehicles available to you were those outlined below, which would you buy? Please select the vehicle you would be most likely to purchase by filling in the circle below your choice.		
Fuel type:	**Propane***	**Hydrogen Fuel Cell***
Vehicle cost:	$31,500	$36,000
Fuel cost per year:	$1,550	$1550
Refueling availability:	2 in 100 stations	4 in 100 stations plus home refueling option
Fuel efficiency:	24 MPG	52 MPG
Emissions:	Low air emissions	Zero Air Emissions
Select one:	○	○
** For additional information about these fuels, please see the list of attribute definitions starting on page 13 of this survey packet.*		

Follow-up Question 3

For each of the following pairs of vehicles, please select the option that you feel is safer.

Vehicle Pair #1: Which do you feel is safer?	○	Electric powered vehicle	OR	○ Hydrogen powered vehicle
Vehicle Pair #2: Which do you feel is safer?	○	Compressed Natural Gas powered vehicle	OR	○ Hydrogen powered vehicle
Vehicle Pair #3: Which do you feel is safer?	○	Diesel powered vehicle	OR	○ Hydrogen powered vehicle
Vehicle Pair #4: Which do you feel is safer?	○	Gasoline powered vehicle	OR	○ Hydrogen powered vehicle

Contact Information

Please confirm your name and contact information so that we can send you your <<Amount>> incentive check.

Your information will remain confidential and will only be used for communication regarding this survey. Your information will not be shared with any other organization. Fields marked with an asterisk (*) are required.

Full Name:*					
Mailing Address:*					
City:*		State:*		Zip:*	
Email:					
Phone:					

Thank You!

This concludes the survey. Your input is very important to this research. Please return this survey to us in the postage-paid envelope provided within the next few days.

California Vehicle Survey: Definitions

Below are some brief definitions of the attributes, or features, of the vehicle choices that may appear in your survey.

Vehicle Type

There are 15 possible vehicle types in the survey. Possible vehicle types & examples include:

Vehicle Type	Example Vehicles
Subcompact car	Toyota Yaris, Chevy Aveo, VW Golf
Compact car	Honda Civic, Chevy Cobalt, Ford Focus
Midsize car	Honda Accord, Ford Taurus, Toyota Camry
Large car	Buick LeSabre, Ford Five Hundred, Chevy Impala
Sports car	Ford Mustang, Mitsubishi Eclipse, Toyota Celica
Small cross-utility car	Chrysler PT Cruiser, Toyota Matrix, Pontiac Vibe
Small cross-utility SUV	Toyota RAV4, Honda CR-V, Ford Escape
Midsize cross-utility SUV	Toyota Highlander, Honda Pilot, GMC Acadia
Compact SUV	Jeep Cherokee, Nissan Xterra, Toyota 4 Runner
Midsize SUV	GMC Envoy, Ford Explorer, Dodge Durango
Large SUV	Chevy Tahoe, Toyota Sequoia, Ford Expedition
Compact van	Dodge Caravan, Honda Odyssey, Toyota Sienna
Large van	Ford Econoline, Chevy Express, Dodge Ram Van
Compact pickup truck	Chevy Colorado, Ford Ranger, Nissan Frontier
Standard pickup truck	Ford F150, GMC Sierra, Toyota Tundra

Fuel Type

There are seven possible fuel types in the survey. Possible fuel types and examples include:

Fuel Type:	Description
Hybrid Electric Vehicles (HEV)	A hybrid electric vehicle (HEV) is powered by a standard gasoline engine, as well as an electric motor with a battery. The combination offers low emissions, with the power, range, and convenient fueling of conventional (gasoline and diesel) vehicles—and HEVs never need to be plugged in.
Plug-In Hybrid Electric Vehicles (PHEV)	A plug-in hybrid electric vehicle (PHEV) operates exactly like the hybrid electric vehicle (HEV) above. However, in addition to the one battery that a HEV contains, the PHEV has a second battery that can be charged by plugging it into an electrical outlet. The vehicle can operate the solely on electricity for short trips. As a result, PHEV vehicles use less gasoline and produce fewer direct emissions than a standard hybrid electric vehicle.

Full Electric Vehicles	A full electric vehicle is powered solely by an electric motor. The battery is charged by plugging into an electrical outlet. There is no gasoline engine and the vehicle produces no direct emissions.
Flex Fuel Vehicles (FFV)	A flexible fuel vehicle (FFV) is a vehicle that can operate on a blend of ethanol and gas. The blend containing 85% ethanol and 15% gasoline is called E85. If E85 is not available, the vehicle can operate on regular gasoline, or on any percentage of ethanol blends containing up to 85% of ethanol. Ethanol is a renewable fuel made from various plant materials, which collectively are called "biomass."
Clean Diesel Vehicles	Clean diesel vehicles use low sulfur diesel fuel instead of gasoline. Today's clean diesels offer high performance, high fuel economy, and low emissions compared to past gasoline and diesel engines. These new advanced diesels can provide up to 45% better fuel economy compared to the equivalent gasoline powered car. Clean diesels can also use renewable diesel fuels known as biofuels.
Light-Duty Natural Gas Vehicles (NGV)	Light-duty natural gas vehicles are powered on compressed natural gas (CNG) or liquefied natural gas (LNG). Compared with vehicles fueled with conventional diesel and gasoline, natural gas vehicles can produce significantly lower amounts of harmful emissions. Natural gas vehicles can be refueled at certain stations that carry the fuel, or at home using home-fueling system installed in your garage.
Standard Gasoline Vehicles	A standard gasoline vehicle is powered by regular unleaded gasoline that can contain up to 10% ethanol.

Additional Fuel Types Seen in Follow-up Question 2:

Fuel Type:	Description
Propane	Propane vehicles are similar to light duty natural gas vehicles, but are powered by liquefied propane gas (LPG) instead of natural gas.
Hydrogen Fuel Cell	Hydrogen fuel cell vehicles are powered by an electric motor. However, instead of using batteries, these vehicles produce their electricity using a fuel cell. The fuel cell is powered by hydrogen stored in an onboard fuel tank. Fuel cell vehicles fueled with pure hydrogen emit no pollutants, only water and heat.

Vehicle Age

The age of the vehicle at the time of purchase.

Purchase Price

The price the vehicle would cost if you were to buy it outright and pay for it in one single payment (and not lease).

 CONTINUE TO NEXT PAGE

Purchase Incentive

There are six possible incentives in the survey for purchasing alternative fuel vehicles:

Incentive	Description
None	No incentive offered
Carpool lane access	You will be allowed to use the carpool lane while driving alone.
Free parking	You will have access to free parking in certain spots designated for this type of alternative fuel vehicle
$1,000 tax credit	You will be offered a $1,000 tax credit, which would directly reduce the amount of your annual income tax owed.
50% reduced tolls	You will be offered a 50% discount on toll bridges and toll roads in the State of California.
$1,000 Reduced vehicle price	You will receive $1,000 off of the price of the vehicle through a dealer incentive, cash back, or a purchase rebate.

Fuel Cost per Year

The total amount you would pay in fuel costs over the course of a year. This amount is based on the number of miles you estimated you would drive this vehicle in the telephone survey.

MPG or Equivalent

The fuel efficiency of the vehicle in miles per gallon. If the vehicle does not use gasoline, this is presented as miles per gallon of gasoline equivalent. Using miles per gallon of gasoline equivalent allows a direct comparison of the efficiency of vehicles that use different types of fuel.

Fuel Availability

The number of fuel stations that sell this type of fuel. This attribute only applies to compressed natural gas and full electric vehicles.

Refueling Time

The amount of time it takes to fill the tank (for compressed natural gas vehicles) or recharge the battery (for full electric vehicles). This attribute only applies to compressed natural gas and full electric vehicles.

Driving Range

The estimated driving range of the vehicle with a full tank of gas or a fully charged battery. This attribute only applies to compressed natural gas and full electric vehicles.

Maintenance Cost per Year

The total amount you would pay in maintenance over the course of a year, including the cost for oil changes and routine vehicle maintenance. This amount is based on the number of miles you estimated you would drive this vehicle in the telephone survey.

Acceleration (0-60 mpg)

The amount of time (in seconds) it takes the vehicle to speed up from 0 mph to 60 mph