

## **The Impacts of Allowing Hybrid Vehicles and Solo Toll-Paying Vehicles in Existing High-Occupancy Vehicle Lanes**

David Brownstone  
Department of Economics  
University of California, Irvine  
USA  
Phone: +1-949-824-6231  
Fax: +1-949-824-2182  
E-mail: dbrownst@uci.edu

Will Recker  
Department of Civil Engineering and Institute of Transportation Studies  
University of California, Irvine  
USA

Christopher Breiland  
Fehr and Peers Associates Inc., Sacramento  
USA

### **Abstract**

This paper introduces a microscopic simulation method to investigate the operational effects of allowing single occupant hybrid vehicles and or toll-paying single occupant vehicles into HOV lanes. The demand methodology is based on disaggregate stated and revealed preference vehicle purchase models, and includes a flexible aggregation method for converting the household level predictions to aggregate traffic analysis zone predictions conditioned on available sociodemographic data for these zones. The demand model can be generalized to include predictions of the distribution of value of travel time savings, and these can be incorporated into the microscopic simulation method to investigate the possibility of allowing single occupancy vehicles to pay a toll to use the HOV lanes. An initial study was conducted within a 12-mile by 16-mile freeway network surrounding Irvine, California. Each scenario was analyzed based on changes in HOV lane travel times, density, and flow rates. The results suggests that allowing the current stock of single occupant hybrid vehicles into the HOV lanes will not have a substantial negative impact on lane operations.

### **Keywords:**

Hybrid Vehicles, HOT Lanes, HOV Lanes, Microsimulation, Demand

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## **1. Introduction:**

The objective of this study is to evaluate the impacts of allowing use of High Occupancy Vehicle (HOV) lanes by single-occupant gasoline-electric hybrid vehicles as well as by single-occupant vehicles paying a possibly time dependent toll. Allowing hybrid vehicles to use HOV lanes ostensibly would promote the ownership and usage of hybrid vehicles by providing savings in travel time and reliability. How such benefits affect the hybrid vehicle market are key components in predicting impacts. Policy makers are also interested in evaluating the impact of these policies on fuel use, air pollution, and congestion. Although these policies are motivated by the observation that most HOV lanes in the United States are currently under-utilized, a careful evaluation of extending the use of such facilities must be sensitive to the possibility that allowing hybrid vehicles and/or toll-paying vehicles might congest the HOV lanes during peak periods. Policy makers also want to measure the costs and benefits of these policies on different geographic and sociodemographic groups since access to HOV facilities varies widely depending on location.

This study employs a microscopic traffic simulation model (using the Paramics modeling system) incorporating a behavioral model that captures HOV/hybrid lane choice behavior. Demand for hybrid vehicles is forecast using modified existing models of consumers' automobile choice behavior and vehicle allocation, which in turn feed origin-destination (O-D) matrices. The model is calibrated to accurately represent the freeway network in Orange County—a large metropolitan area south of Los Angeles—that has an extensive network of limited-access HOV lanes. The limited access feature makes tolling these lanes a practical option.

Impacts can be measured in terms of the overall levels of fuel consumption and traffic congestion. The model system also tracks toll revenue, and iterated application of the model can be used to predict the minimum toll level required to avoid congestion on the HOV lanes.

The demand models are derived from individual stated and revealed choice data. Stated choice experiments are used to estimate the household demand for hybrid vehicles in the next vehicle transaction, and revealed preference data are used to model the timing and vehicle type of the household's next vehicle transaction. The toll facility demand model uses the same value of time saved as the model used to allocate hybrid vehicles so that the results are consistent across different scenarios. The value of time saved is estimated from previous studies of congestion pricing experiments in Southern California (Brownstone and Small, 2005).

The individual demand models are converted to aggregate zonal demand by using census data to create artificial aggregate zones. The demand for each household is predicted from the disaggregate demand model, and these demands are then aggregated to the zone level. We then fit a flexible econometric model relating the aggregate demand in each artificial zone to aggregate socioeconomic characteristics that are available for the actual Orange County traffic analysis zones. This model is then used to predict demand for hybrid vehicles as a function of purchase price and fuel economy for each traffic analysis zone, and this predicted demand generates the hybrid vehicles that enter the microscopic traffic simulation model.

Finally, we illustrate the model results by computing how many hybrid vehicles can be

allowed into the network before the HOV lanes experience peak congestion. We find that the current level of hybrids allowed in HOV lanes does not greatly impact the congestion levels in these lanes. The modeling system described here also can be used to compute the minimum toll necessary to keep HOV lanes congestion-free and the resulting toll revenue as well as the reduced vehicle emissions resulting from more efficient utilization of the freeway network. We can also predict the increase in hybrid vehicle demand caused by allowing them to drive solo in the HOV lanes, but these calculations are not yet complete.

## **2. HOT Lanes and Study Area:**

The area we are modeling is the Orange County, California freeway network shown in Figure 2.1. Orange County is a densely populated portion of the Greater Los Angeles metropolitan area, with 3 million inhabitants in 800 square miles. As can be seen from the map in Figure 2.1, the freeway network is quite dense and serves both internal and through traffic. This network also contains a well-developed set of access-controlled HOV lanes on the 405, 5, 55, and 57 freeways. The HOV lanes have separate connectors at the junctions of the 5 and 55, 5 and 57, 5 and 405, and 405 and 55 freeways. This infrastructure makes Orange County a relatively easy place to convert HOV to HOT lanes, and the relatively high income (\$75,000 median household income) suggest that there is strong latent demand for both hybrid vehicles and HOT lanes.

In October, 2005 California began issuing stickers to owners of high-mileage gas-electric hybrid vehicles allowing them to drive solo in the HOV lanes. By April 2006 approximately 50,000 of these stickers had been issued, including 5200 to hybrids registered in Orange County and 26,000 to hybrids registered in the Greater Los Angeles metropolitan area. Of course, this is a tiny fraction of the approximately 10 million cars registered in the Greater Los Angeles Area (1.8 million in Orange County). Observations from HOV lanes after hybrids were allowed to use the HOV lanes will allow us to test the predictions of our model for hybrid HOV use against observed behavior.

Modeling the Orange County freeway network is complicated by the size of the network and the fact that there are many trips on the network with origins and/or destinations outside of Orange County. Although we have been able to implement the demand model described in Section 3 for the entire Greater Los Angeles Metropolitan area, we are still working on calibrating the microsimulation model described in Section 4 for the entire Orange County freeway network. Therefore we will only give simulation results for a subset of the entire network in Section 5.



stated preference studies where survey respondents indicate their choices among a set of hypothetical vehicles that include gasoline-electric hybrids. We used data from the 2002 California Vehicle Survey (CVS) conducted for the California Energy Commission (CEC) by Morpace International.

The focus of the survey was on vehicle choice from among hypothetical gasoline, hybrid electric, and diesel fuel/technology types. The choice tasks were relatively simple. Three-alternative choice sets using one each of the three fuel/technology types were constructed using the following attributes: purchase price, fuel cost, annual maintenance cost, acceleration, gradability, and purchase incentive. Fuel cost was expressed in terms of annual fuel cost, assuming that the vehicle is driven 10,000 miles. Acceleration is 0-60 time in seconds. “Gradability” is defined as the maximum sustainable speed on an upgrade. Purchase incentive is a categorical variable with four levels: none, use of diamond (HOV) lane, no sales tax on purchase, and free public and metered parking. The incentive attribute was varied only for hybrid and diesel fuel types. Each survey respondent received eight choice tasks.

When the approximately 1000 responses to this survey from Southern California are used to fit a multinomial logit model including all design attributes we found that all cost variables had the expected negative sign. Respondents with annual household income greater than \$40,000 are less sensitive to purchase price and operating cost, but more sensitive to acceleration. Respondents strongly prefer gasoline to either hybrid or diesel fuel, and the only “no sales tax on purchase” showed a significant positive effect. Note that sales tax in California averages 7 per cent of the purchase price, so this incentive is typically larger than the rebates frequently used by U.S. automobile makers to get consumers to buy their cars.

Unfortunately the model described in the previous paragraph is cannot be used for forecasting since it requires information on the body types of all of the vehicles held by the household, and these data are not available in the U.S. Census data we are using for our forecast base. We therefore simplified the model to the one given in Table 3.1. This model contains attributes for diesel vehicles because they were part of the choice experiment. We do not predict shares for diesel vehicles since currently no such vehicles meet California’s strict emission standards and are therefore not available in the California market.

Since the coefficient on fuel cost for high income households is zero in this model, the model predicts that only low income households will purchase hybrid vehicles. This problem is due to the design of the stated preference experiment – respondents were simply asked to choose one of the listed vehicles for their next vehicle transaction. They were not given the option of purchasing a used vehicle, which is in fact what most low-income households choose in real life. Therefore the model in Table 3.1 needs to be interpreted as explaining choice given that the household has decided to purchase a new vehicle.

Table 3.1: Multinomial Logit Estimates for Stated Preference Choice Model

| Variable  | Coefficien<br>t | t-statistic |
|---|-----------------|-------------|
| Price(/\$10000) * (Income less than or equal to \$40K)        | -0.5936         | -4.22       |
| Price(/\$10000) * ( Income greater than \$40K)                | -0.1534         | -2.38       |
| Fuel Cost <sup>a</sup> * (Income less than or equal to \$40K) | -1.0423         | -2.52       |
| Fuel Cost <sup>a</sup> * (Income greater than \$40K)          | 0.0025          | 0.01        |
| Hybrid  | -1.1602         | -14.90      |
| Diesel  | -2.0594         | -21.06      |
| Hybrid * Household with 2 or more members                     | -0.1876         | -2.67       |
| Diesel * Household with 2 or more members                     | 0.1109          | 1.21        |
| Gas * Household with 1 or more workers                        | -0.3789         | -5.03       |
| Gas * Household with 2 or more workers                        | -0.1660         | -2.94       |

Notes:

a. Annual fuel cost assuming 10,000 miles (\$/10000)

The model in Table 3.1 therefore needs to be supplemented with a model to predict the probability that a household chooses to purchase a new vehicle, since the only hybrid vehicles currently available are new. We used the 2001 National Household Transportation Survey (NHTS) to fit a model of new car purchases. The NHTS is a household-based travel survey conducted every five years by the U.S. Department of Transportation. Prior to 2001, the portion of the NHTS focusing on local trips was known as the National Personal Transportation Survey (NPTS) and the long-distance travel portion of the survey was called the American Travel Survey. There are 2,583 California (CA) households in the 2001 NHTS sample, representing 9.9% of the total base sample of 26,038. (The 2001 NHTS survey also contains nine add-on samples for specific geographical regions, all of which are outside of California.) The survey was conducted over a period of fourteen months ending in May 2002, and it contains data on all household vehicles and their utilization. The 2001 NHTS is described in detail in exhibits, reports, and codebooks maintained on .the NHTS website (ORNL, 2004).

Table 3.2 gives the results of fitting a binomial logit model for whether a household purchased a new car in the last year. This model is fit using all 24,615 NHTS households with vehicles, and only 5.3% of this sample purchased a new car. There are not enough observed purchases in the California subsample to fit a reliable model, but there are no indications that the California estimates are significantly different from those in Table 3.2. As expected, higher income households and those with more workers are more likely to purchase new vehicles.

For the purposes of this study we are only interested in predicting the demand for high-mileage hybrid vehicles that qualify for a sticker to use the HOV lanes. These vehicles are primarily the Toyota Prius and the Honda Civic Hybrid, but the new hybrid SUVs from Ford and Toyota do not qualify. We therefore apply the model in Table 3.1 to predict the probability that a household will purchase a qualifying hybrid given that they purchase a new car. It is difficult to get reliable data on purchase prices of the Prius and Honda Civic Hybrid since these cars typically are in short supply and sell above list price. Based on personal

experience purchasing a Prius for Brownstone’s mother in October 2005, we set the price of the hybrids at \$22,000 and the price of the competing gas vehicles at \$18,000. Based on tests conducted by Popular Mechanics (2006), we set the fuel cost of the hybrid at 20% below the gasoline model.

Table 3.2: Binomial Logit Estimates for New Car Purchase Model

| Variable                                 | Coefficient | t-statistic |
|--|-------------|-------------|
| Household Income between \$40K and \$79K | 0.318       | 4.32        |
| Household income greater than \$80k      | 0.950       | 13.36       |
| Exactly one vehicle in household         | -0.277      | -3.66       |
| 3 or more workers in household           | 0.338       | 3.83        |
| Exactly 2 children in household          | 0.382       | 4.31        |
| 3 or more children in household          | -0.506      | -5.51       |
| Constant                                 | -0.868      | -5.82       |

Given the above assumptions about the relative costs of hybrid vehicles, our prediction for the probability that a household will purchase a qualifying hybrid is just the product of the choice probabilities from the logit models given in Tables 3.1 and 3.2. Of course, this model is specified at the individual household level, but we need to produce forecasts for the approximately 2900 traffic analysis zones in our study area. One approach is to create synthetic households in each traffic analysis zone so that the joint distribution of the exogenous variables in our choice models match the joint distributions of these variables in each zone. Unfortunately the demographic variables easily available at the zonal level are not identical to those used in estimating the choice models, and no distributional information is available for these variables within a zone.

We therefore used the California sub-sample of the public use microsample from the 2000 Census (PUMS) as our forecast base population. These approximately 600,000 households include data on all of the required exogenous variables, so we could easily compute the probability of each household purchasing a hybrid vehicle. We then aggregated into 62 different geographic regions (the smallest geographic breakdown available in these data), and computed the same aggregate sociodemographic variables that are available at the traffic analysis zone level. We then used these 62 “synthetic” zones to fit a linear regression model shown in Table 3.3 predicting the share of hybrid vehicles in each zone. Note that this relatively simple aggregation procedure captures the qualitative trends from the underlying disaggregate models. In particular hybrid share is predicted to be higher when average income and household size are larger.

The same methodology used to produce zonal predictions for hybrid vehicle shares can also be used to predict other important zonal characteristics. In future work we will assign value of travel time savings to each PUMS household using results from Brownstone and Small (2005), and we will then generate the distribution of these value of travel time savings across the 62 synthetic zones. We will then use a bivariate regression system to predict the mean and variance of value of travel time savings at the traffic analysis zone level. Draws from these predicted distributions can then be assigned to vehicles in the microsimulation system which

will then influence their behavior in choosing to take HOT lanes during the simulation runs.

Table 3.3: Regression Model for Share of Hybrid Vehicles

| Variable                                  | Coefficient | t-statistic |
|---|-------------|-------------|
| Median Household Income /\$10k            | 0.012364    | 11.25       |
| Average Household Size                    | 0.002286    | 1.46        |
| Average Workers per Household             | 0.018347    | 2.96        |
| Average Workers / Median Household Income | -0.06142    | -2.90       |
| Constant                                  | 0.186429    | 26.72       |
|   |             |             |
| Number of observations                    | 62          |             |
| R-squared                                 | 0.9866      |             |
| Root MSE                                  | 0.00248     |             |

#### 4. Microsimulation Model Structure:

Prior to incorporation of the demand models described in Section 3 into the modeling framework for the complete network, a simulation study was conducted on a subsection of the network to help determine potential systemwide operational impacts of allowing Hybrids in the HOV lanes, based on scenarios that parallel: 1) current California restrictions, and 2) experience on similar operations in the State of Virginia. For this study, a subarea within Orange County, California, that includes freeways within the City of Irvine was chosen as the study site. The study area, which is called The Golden Triangle network, includes sections of three of Orange County’s principle freeways, I-5, I-405, and SR-55 and is about 12 miles from north to south and 15 miles from east to west (see Figure 4.1). The area is well covered by loop detectors, has several busy freeways, and also contains a variety of HOV lane configurations, including freeway-to-freeway HOV lane connectors, exclusive HOV lane ramps, and limited ingress/egress points.

We used microscopic simulation to investigate California’s proposed hybrid-HOV policy. Since microscopic simulation is designed to model the movement and behavior of individual vehicles on urban and highway road networks, it is well suited to study the impacts of a hybrid-HOV policy. The microscopic simulation model to be used is Paramics, a scalable, ITS-capable, high-performance microscopic traffic simulation package developed in Scotland (Smith, 1994). The microscopic simulation model for the study site was built and then calibrated against the baseline traffic conditions. The calibrated simulation model was then simulated under different travel demand scenarios and simulation results analyzed and compared in order to show the operational effects of the policy.



Figure 4.1: Map of “Golden Triangle” Network area

### **Network Coding**

The study network was coded into Paramics based on aerial photos and geometric data from Caltrans. The HOV system in southern California allows HOVs to change lanes from and to HOV lanes only between ingress and egress points. This facet of operation was modeled by coding HOV lanes and mixed-flow lanes as two separate links at points where there is a hard barrier between HOV and mixed-flow lanes and as a same link between ingress and egress points. Ramp meters were added to all applicable on-ramps and set to the field metering rate, and loop detectors were placed to run the ramp meters and collect data across the network.

### **Zone Structure and Demands**

The zone structure and the corresponding origin-destination matrix were determined according to the OCTAM (Orange County Transportation Analysis Model) model of the Orange County Transportation Authority (OCTA) (OCTA, 2001). The study network is a “freeway-only” network and thus the commonly used sub-area analysis method cannot be applied. A special type of sub-area extraction called “multimodal, multi-class assignment (MMA)” was employed using TransCAD, a transportation planning software package. In MMA, the analyst defines the links that are of interest and TransCAD keeps track of the number of vehicles that enter and leave the links; in a freeway only network, zones are thus created at each on- and off-ramp. After selecting links that are freeway, toll road, HOV lane,

or freeway exits, the MMA procedure was executed and TransCAD produced an OD matrix with 106 zones. Two OD matrices were generated; one for single occupancy vehicles and another for high occupancy vehicles.

### **Route Choice**

A stochastic route choice model was selected for the simulation model and the HOV plugin in Paramics was used to replicate the behavioral aspects of HOV lane usage. The stochastic route choice model in Paramics assumes that different drivers perceive different costs from a decision node to the destination. The perceived cost is calculated based on a given perturbation factor, which is a global parameter that needs to be calibrated, and a random number assigned to the vehicle. The shortest perceived route is chosen at the decision node. Paramics has a global/local cost factor parameter that can be used to set link costs. In this study, the global cost factor of HOV links was calibrated to match HOV lane use factors observed in the field.

### **Model Calibration**

In the model calibration process, model parameters were adjusted until a reasonable (qualitative and quantitative) correspondence between the model and field-observed data was achieved. Loop detector data and floating car based travel time data collected on October 18th, 2001 were used as observed data.

Using the built-in Paramics OD estimator, the planning OD table was modified in order to achieve more realistic traffic flows on the links in the simulation network. The performance measure used in OD estimation was GEH statistic (UK Highways Agency, 1996). The objective function is to minimize the average GEH among all measurement locations. If the average GEH is less than 5.0, the estimated OD table is considered well calibrated (Gardes, et al., 2003). Global parameters and link specific parameters were fine-tuned to best reproduce observed traffic capacities in the field. Global parameters include mean target headway and mean driver's reaction time. Local parameters include signposting and sign range, headway factor, reaction time factor of a link, and lane choice parameters.

A final stage of calibration was used to fine-tune additional model parameters to reflect observed network level traffic congestion patterns. Model parameters include global and local route choice parameters and the global and local parameters used in capacity calibration. Due to the difficulty in estimating both single occupancy vehicle (SOV) and HOV demand tables together, only the SOV demand table was estimated; the estimation was based on real-world loop counts at 153 mainline and ramp locations. The final demand matrix produced by Estimator converged very well, with a GEH error statistic of 0.73.

## **5. Scenario Analysis:**

In evaluating the limits imposed by operational considerations, the demand model described in Section 3 above was not used. Rather, the simplified procedure used for the hybrid demand estimation for these initial tests is shown in Figure 5.1 below. For the base year, data from automotive industry information websites (R.L. Polk and Company, 2004; Green Car Congress, 2004) were used to estimate the number of hybrids present in the state of California as of January 2005. Using data from the 2001 National Household Travel Survey (scaling the data to account for population growth) (Bureau of Transportation Statistics, 2005), an estimate of the ratio of hybrid vehicles to in-use vehicles was made to find the share of

hybrids on the road during the commute hour. The data revealed that there are approximately 48,000 hybrid vehicles in the state, which made up about 0.3 percent of the vehicles that are on the road in the AM peak period, which translates to 335 hybrid vehicles per hour. Since the estimated HOV OD table showed that there are about 16522 HOV vehicles per hour in the study area, the 335 hybrid vehicles is equivalent to 2.0% of all vehicles that could travel on the HOV lanes. It should be noted that the percentage of hybrid vehicles in Orange County might be slightly higher than the state's average since the presence of a more extensive network of HOV lanes in the area could be an incentive for the purchase of such vehicles. However, it is not expected that the slightly higher percentage will significantly change the results of this analysis.

In this initial simulation analysis, three assumptions were employed relating to the estimation of hybrid demand. (1) Since there is no existing information about the travel patterns of hybrid vehicle owners, it was assumed that hybrids would have the same origin destination patterns as all other vehicles in the network. Although this assumption is probably valid in a rather small, socio-economically homogeneous area like Irvine, California, a more elegant solution, based on the demand modeling procedure described in previous sections, will be applied for full study. (2) Pending the incorporation of the demand model that relates hybrid ownership to income, geographic location, and congestion levels, it was further assumed that hybrid vehicles are evenly distributed in California. In other words, the ratio of hybrid cars to in-use passenger cars is assumed to be the same in both Orange County and less congested areas of the state like Fresno. (3) It was assumed that the HOV lane violation rate for ineligible hybrid vehicles zero, which is not unreasonable given that the violation rate of SOVs is about one to two percent in Orange County (Caltrans District 12, 2003).

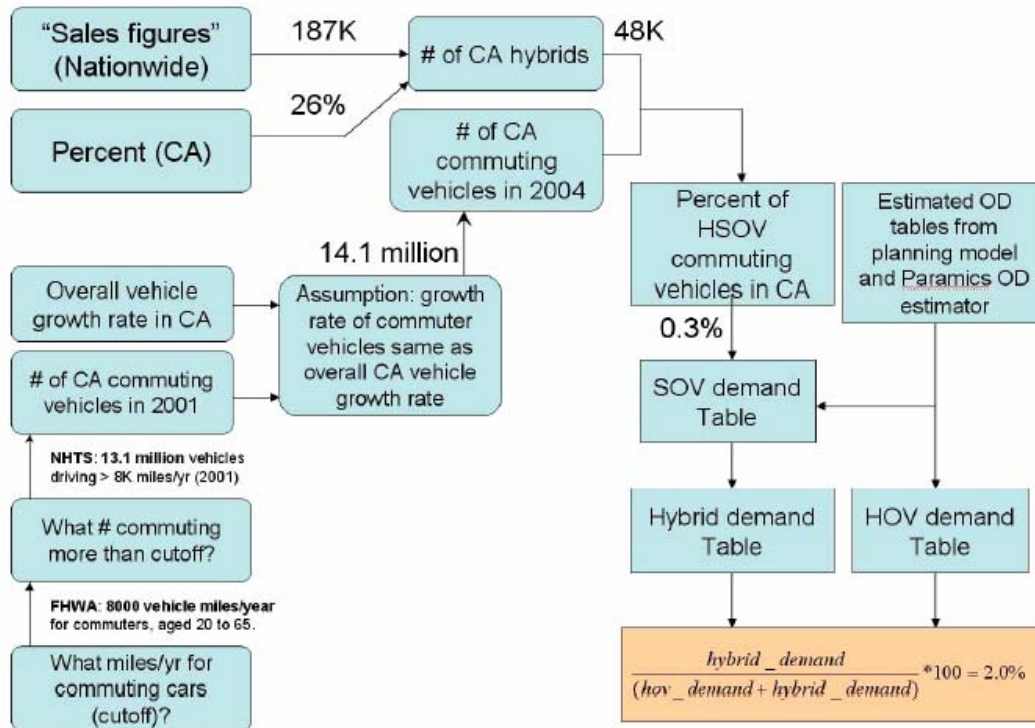


Figure 5.1: Simplified Demand Model Schematic

In addition to these baseline conditions, five different scenarios were considered, as shown in the table below:

**Table 5.1: Scenarios**

| Scenario | Description                          |
|----------|--------------------------------------|
| Baseline | Current: Only HOV                    |
| 1        | Current: HOV + Existing Hybrids      |
| 2        | HOV + Limit of 50,000 Hybrid Permits |
| 3        | HOV + Limit of 75,000 Hybrid Permits |
| 4        | HOV + Virginia I-395 Experience (7%) |
| 5        | HOV + Virginia I-95 Experience (19%) |

Scenarios 2 and 3 represent the maximum number of HOV permits currently available for issuance from California DMV and the limiting number prescribed under current legislation, respectively. Scenarios 4 and 5 represent actual experience (in terms of percent of traffic on HOV lanes that are Hybrid) from two interstate routes in Virginia.

Using the method described for determining the existing “base year” number of Hybrid vehicles in Orange County, the total qualified hybrid vehicles for scenarios 2 and 3 are 396

and 592, which is equivalent to 2.3% and 3.5% of all vehicles that could travel on the HOV lanes. For Scenarios 4 and 5, the percentages of SOHVs on HOV were set based on Virginia DOT observations, at 8% (corresponding to 1244 hybrid vehicles) and 19% (corresponding to 3875 hybrid vehicles), respectively.

According to California’s proposed hybrid-HOV law, Caltrans has the authority to remove “individual HOV lanes, or portions of those lanes” if traffic conditions exceed a level of service (LOS) C, which corresponds to a traffic stream density greater than 26 vehicles per mile per lane. This benchmark of operational degradation provides a convenient measure to test whether any of the HOV lanes breakdown with the addition of single occupant hybrid vehicles and is used as the primary measure of effectiveness in this preliminary study.

HOV lane travel times in excess of twenty percent of current are considered significant in this study. Flows in excess of 1,800 vehicles per hour per HOV lane are considered to represent breakdown conditions. In order to gather the data relating to the measures of effectiveness, a Paramics API plugin was developed to gather data about HOV lane travel times and densities between a pair of loop detectors that were spaced one-to-two miles apart; there were 41 analysis segments in the Paramics network. A second plug-in was used to estimate HOV lane flow at four busy locations in the network.

The simulation time period for all scenarios is the morning peak period from 6:00 to 9:00 A.M. Multiple simulation runs were conducted to ensure the simulation results were statistically meaningful (Chu, L., et al., 2004). The results of these simulations are summarized in Tables 5.2 and 5.3.

Table 5.2: HOV Lane Segment Measures Of Effectiveness

| HOV lane segment<br>Measures Of Effectiveness |      | Scenario |       |       |       |       |       |
|---|------|----------|-------|-------|-------|-------|-------|
|   |      | Baseline | 1     | 2     | 3     | 4     | 5     |
| Density (vehicles<br>per mile)                | Min  | 4.7      | 4.7   | 4.7   | 4.6   | 5.0   | 5.6   |
|   | Mean | 12.0     | 12.1  | 12.5  | 12.4  | 13.2  | 14.5  |
|   | Max  | 19.8     | 19.9  | 20.0  | 20.7  | 21.9  | 23.7  |
| % change in<br>HOV lane travel<br>time        | Min  | N.A.     | -2.2% | -2.3% | -1.8% | -0.5% | -0.4% |
|   | Mean | N.A.     | 0.85% | 0.76% | 0.94% | 1.24% | 1.78% |
|   | Max  | N.A.     | 5.3%  | 7.3%  | 4.7%  | 8.1%  | 8.0%  |
| Flow (vehicles<br>per hour)                   | Mean | 1064     | 1065  | 1061  | 1077  | 1206  | 1225  |

Table 5.3: Changes between Scenarios 1, 2, 3, 4, and 5

| Measures Of Effectiveness            | Scenario |    |    |    |    |    |
|--------------------------------------|----------|----|----|----|----|----|
|                                      | Baseline | 1  | 2  | 3  | 4  | 5  |
| Number of sections with LOS A        | 25       | 23 | 24 | 25 | 19 | 13 |
| Number of sections with LOS B        | 15       | 17 | 14 | 13 | 20 | 23 |
| Number of sections with LOS C        | 1        | 1  | 3  | 3  | 2  | 5  |
| Number of sections with $\geq$ LOS D | 0        | 0  | 0  | 0  | 0  | 0  |
| Periods with flow > 1800 VPH         | 0        | 0  | 0  | 0  | 0  | 0  |

As can be seen in the Tables 5.2 and 5.3, under the baseline scenario the Irvine area HOV lanes perform quite well with densities and flow rates at reasonable levels, well below the thresholds specified in California’s proposed hybrid-HOV bill. Under Scenario 1 where the state’s existing single occupant hybrids have access to HOV lanes, lane operations are not significantly impacted when compared to the baseline scenario. The results for scenario two, where the state’s population of hybrids is 50,000 are almost identical to the results for Scenario 1; however, the similarity is expected as the hybrid population did not increase very much between the two scenarios.

Scenario 3 represents the case where the state has issued its full complement of 75,000 permits that allow single occupant hybrid vehicles to drive in the HOV lanes. While the number of permitted hybrids has increased by fifty percent over the previous scenario, Tables 5.2 and 5.3 show that the Irvine HOV lane system is accommodating the additional vehicles with little difficulty. Again, flow and density values for the HOV lane segments are well below the established benchmarks and average HOV lane travel times are still within one percent of the baseline scenario. Based on the findings to this point, it appears that California could implement its hybrid-HOV bill without crippling the state’s HOV lane system.

What would happen if all restrictions as to the number and type of hybrids allowed in the lanes were removed? Scenarios 4 and 5 test this latter case by using data based on the Virginia experience. In Scenario 4, conditions found on I-395 where hybrids constitute about eight percent of all HOV lane traffic are simulated in the Irvine area network. In Scenario 4, the impact of the additional hybrids is noticeable in the network, but the changes remain modest. Table 5.3 shows that a substantial number of HOV lane sections have had their LOS go from A to B, and Table 5.2 shows that mean flow, density, and travel times have also increased slightly when compared to the baseline scenario.

In Scenario 5, where the proportion of hybrid vehicles using the HOV lanes has increased dramatically to nineteen percent, the Irvine area HOV lanes continue to fair remarkably well. While there are considerably more HOV lane segments operating at LOS B or C when compared to the baseline scenario, none of the segments operate at LOS D, which would constitute breakdown. Similarly, HOV lane flows and travel times have also increased over the baseline, but neither of these statistics point to widespread HOV lane congestion.

## 6. Conclusions:

This paper introduces a microscopic simulation method to investigate the operational effects of the new California hybrid-HOV law that allows single occupant hybrid vehicles into the HOV lane. The demand methodology is based on disaggregate stated and revealed preference vehicle purchase models, and includes a flexible aggregation method for converting the household level predictions to aggregate traffic analysis zone predictions conditioned on available sociodemographic data for these zones. The demand model can be generalized to include predictions of the distribution of value of travel time savings, and these can be incorporated into the microscopic simulation method to investigate the possibility of allowing single occupancy vehicles to pay a toll to use the HOV lanes.

An initial study was conducted under several hybrid purchase scenarios within a 12-mile by 16-mile freeway network surrounding Irvine, California. Each scenario was analyzed based on changes in HOV lane travel times, density, and flow rates. The results suggests that the initial wave of single occupant hybrid vehicles that will enter the HOV lanes will not have a substantial negative impact on lane operations. When single occupant hybrid vehicles make up 19 percent of the vehicles in the HOV lanes, as in scenario five, the volume of traffic in the HOV lanes increases noticeably, but LOS, flow rates, and travel time changes remain within the ranges of acceptability established by the authors. In analyzing the five scenarios, it was shown that California's current hybrid-HOV law limits it is unlikely that the study network would become significantly more congested as there is sufficient capacity in the HOV lanes to absorb the additional demand. Further, the findings suggest that even if California's law was modified and the 75,000 hybrid vehicle cap were removed, it is unlikely that HOV lane operations in the study area would be adversely impacted for some time to come. Note that these results do not preclude the possibility that isolated stretches of HOV lanes could become congested during the peak periods, particularly if there is an incident.

These preliminary results are obtained based on the simulation of the 12-mile by 16-mile freeway network around Irvine, California. As such, the result may or may not apply on a statewide level. In order to fully discover the operational effects of the hybrid-HOV policy, we are currently expanding the model to cover entire Orange County network. In addition, the next work to be done is to study the environmental effects of the policy, which requires Paramics to interface with a good emission model and emission data for each type of vehicle.

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