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Operational Effect of Allowing Single Occupant Hybrid Vehicles into High Occupancy Vehicle Lanes

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ABSTRACT

In an effort to reduce the environmental impacts of automobile travel, legislatures across the country are considering laws that would allow single occupant hybrid vehicles to use high-occupancy vehicle (HOV) lanes. Over time, single occupant hybrid vehicles could increase congestion in HOV lanes to such a degree that the travel time incentive would be lost. This paper presents a microscopic simulation method to examine the possible effects of a proposed California state hybrid-HOV law that would allow single occupant hybrid vehicles into the state's HOV network. The results from simulating a 12-mile by 16-mile freeway network around Irvine, California under several travel demand scenarios show that the policy would not have a significant impact on HOV lane operations in the study area. While the addition of single occupant hybrids might only have a modest impact on short-run HOV lane operations, policy implementation opens the door to more difficult long-term policy questions.

INTRODUCTION

Over the past several decades, lawmakers have introduced policies aimed at reducing automotive fuel consumption and emissions. Some legislation, like the federal Corporate Average Fuel Economy (CAFE) standards and state inspection/maintenance programs, demands that all vehicles meet a set of fuel economy and emissions standards [1]. Other programs, like California's Zero Emission Vehicle (ZEV) mandate, seek to reduce the environmental impact of automobiles by encouraging the manufacture and sale of a particular type of vehicle [2]. Recently, state policies have targeted hybrid vehicle technologies in hopes that this new innovation will make transportation less burdensome on the environment.

Hybrid vehicles have taken the automotive world by storm. According to a report from Bloomberg News, Toyota plans to double the number of models sporting hybrid powerplants by 2006 and Honda plans to sell 300,000 hybrid vehicles that year alone [3]. ABI Research predicts worldwide sales of hybrid vehicles will reach nearly 1.1 million units in 2010 as the number of hybrid models increase and the technology makes its way into more popular midsize sedans and SUVs [4].

With all the hype surrounding hybrids, lawmakers and government officials have taken notice. In recent years, a number of government-sponsored initiatives promoting hybrid vehicles have emerged. These initiatives range from free hybrid parking and hybrid vehicle purchase rebates in some areas to more controversial state laws allowing single occupant hybrid vehicles (SOHV) into high occupancy vehicle (HOV) lanes. Ten states have considered the latter policy to encourage the purchase of hybrids. For example, California Assemblywoman Fran Pavley lauded California's proposed bill (AB 2628), stating "This bill is great for Californians. It eases our commutes, saves us money at the pump, reduces our dependency on foreign oil, and cleans our air all at the same time."[5] Meanwhile, Virginia has already implemented a "hybrid-HOV" law despite objection from the Federal Highway Administration.

Given that hybrids are a growing segment of the auto market, it is uncertain whether such a law might congest the state's HOV lanes. This paper presents a microscopic simulation method to examine the possible effects of a proposed California state law that would allow single occupant hybrid vehicles into the state's HOV network. The paper is organized as follows. The next section designs several testing scenarios, describes the study site, and explains the microscopic simulation methodology. The succeeding sections provide the details of simulation modeling and evaluation studies. Conclusions and policy implications are given in the final section.

STUDY DESIGN

Scenarios

While several states are considering hybrid-HOV bills and Virginia has passed one, California's proposed version of the law is interesting as the state has the busiest and most extensive HOV lane network in the country and the proposed law includes many safety checks to try and minimize the negative operational impacts of single occupant hybrid vehicles. The safety checks incorporated into California's hybrid-HOV law lead to scenarios that can be tested and also suggest measures of effectiveness by which to compare scenarios.

A baseline scenario was established to determine how HOV lanes operate under current conditions where single occupant hybrid vehicles are not allowed into HOV lanes.

Scenario one assumes that the proposed hybrid-HOV policy has no influence on hybrid sales, but California's existing stock of eligible single occupant hybrid vehicles gain access to HOV lanes upon policy implementation.

One of the provisions of California's hybrid-HOV law requires that California Department of Transportation (Caltrans) must determine whether or not HOV lane breakdown has occurred on any of the state's HOV lanes after 50,000 "HOV lane access" permits are issued to hybrid vehicles. Using the same logic that was used to develop the first scenario, scenario two is created by increasing the state's population of hybrids to 50,000.

The third scenario simulates the conditions when California issues 75,000 HOV lane access permits, the maximum allowed under the state's hybrid-HOV law; these conditions are compared against the baseline scenario.

California's proposed hybrid-HOV law is fairly conservative when compared to other states' laws. Two additional scenarios are created based on observations of Virginia's HOV lanes. With no restrictions on the number or type of hybrid vehicles that are allowed into Virginia's HOV lanes, hybrids constitute a surprisingly large share of traffic found in some Washington D.C. area HOV lanes. According to the Second Annual HOV Task Force Report published by the Virginia DOT, seven percent of all the traffic in the I-395 HOV lanes and nineteen percent of all the HOV lane traffic in the northbound I-95 HOV lanes are hybrids [6]. Two additional scenarios based on the proportion of hybrids found in the I-395 and I-95 HOV lanes, respectively, are also included in the study to examine how California's HOV lanes would operate under more relaxed rules.

Study Site

There are two types of HOV lanes in California. In Northern California, HOV lanes work during peak periods and vehicles in general purpose lanes (or the HOV lane) can change to the HOV lane (or general purpose lanes) without restriction. In Southern California, HOV lanes work 24 hours a day, 7 days a week and there is a separation between the HOV lane and general purpose lanes that allows for lane changing at a limited number ingress/egress points.

The study site for this research is located in Southern California. Figure 1 shows the map of Orange County, California. The freeways around City of Irvine (within the triangle) are 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. 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. The results of this analysis may not be applicable to HOV operations in Northern California due to the different operational strategy and HOV traffic demand levels.

Study Method

The traditional method to evaluate the possible impacts of a new policy is to use a transportation planning model. Here, we introduce a microscopic simulation method to investigate California's proposed hybrid-HOV policy. A microscopic simulation approach is appropriate as HOV lanes can be modeled as an Intelligent Transportation System (ITS) strategy and whether a driver chooses to use an HOV lane is a route choice decision largely influenced by traffic conditions. 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 [7]. Paramics is well suited to study Intelligent Transportations Systems due to its ability to model emerging ITS infrastructures, such as loop detectors, adaptive ramp meters, and variable message signs (VMS). In addition, PARAMICS provides users with Application Programming Interfaces (API) through which users can access the core models to customize and extend many features of the underlying simulation model without having to deal with the underlying proprietary source codes.

The study method is illustrated in Figure 2. The corresponding microscopic simulation model for the study site needs to be built and then calibrated against the baseline traffic conditions. Next, the calibrated simulation model will be simulated under different travel demand scenarios and simulation results will be analyzed and compared in order to show the operational effects of the policy.

SIMULATION MODELING

Network Coding

As shown in Figure 3, 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. As a result, HOV lanes and mixed-flow lanes were coded 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. While coding the network, particular attention was paid to the location and length of HOV lane ingress/egress points as it was felt that congestion would most likely occur in these areas. 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 of a simulation network typically come from planning models. Corresponding to the study site, the planning model that was used is the OCTAM (Orange County Transportation Analysis Model) model obtained from Orange County Transportation Authority (OCTA) [8].

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 "multi-modal, 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 Choices

The stochastic route choice model was selected for the simulation model and Paramics' HOV plugin 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.

In order for HOV vehicles to have a greater propensity to select HOV lanes as their path during simulation, the costs for HOV lanes were set to a lower value than that of mixed-flow lanes. 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

The simulation model of a network needs to represent the network's real-world traffic condition, which is the objective of model calibration. In the model calibration process, model parameters were adjusted until 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.

This paper takes the following procedure to calibrate the simulation model. Calibration is an iterative process and sometimes steps have to be repeated.

(1) Correcting geometric coding errors - Most network coding errors were fixed by loading the OD table obtained from the planning model and observing the simulation for obvious problems (blocked links, underutilization of links, low throughput, etc.).

(2) Initial OD matrix estimation - Using Paramics OD estimator, an OD estimation tool provided by Paramics, the planning OD table was modified in order to achieve more realistic traffic flows on the links in the simulation network . By performing an initial OD matrix calibration, subsequent steps in model calibration are simplified as modeled link flows are closer field observations. The performance measure used in OD estimation was GEH statistic [9].

$$GEH = \sqrt{\frac{(obs - sim)^2}{(obs + sim)/2}} \tag{1}$$

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 [10].

(3) Capacity calibration - This stage involves the calibration of global parameters and the fine-tuning the link specific parameters in order 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 signrange, headway factor, reaction time factor of a link, and lane choice parameters. The capacity calibration usually starts at the beginning of a freeway segment and moves downstream to uncover otherwise hidden bottlenecks.

(4) Final OD estimation - Paramcis OD estimator is again used to fine-tune the OD table.

(5) Performance calibration - This stage fine-tunes additional model parameters in order to reflect network level traffic congestion pattern. Model parameters include global and local route choice parameters and the global and local parameters used in capacity calibration.

OD estimation is only one step of the study. Due to the difficulty to estimate both single occupancy vehicle (SOV) and HOV demand tables together, only the SOV demand table was estimated 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.

The final model calibration results are shown in Tables 1 and 2. There are two calibration targets:

(1) HOV Lane Usage Rates at four locations - Using data from Caltrans that identified the percentage of HOVs using HOV lanes at various points in the Los Angeles/Orange County area, the authors calibrated the global cost factor for HOV lanes and the global perturbation parameter for the stochastic route choice model. It was found that the simulated HOV lane use rate was reasonably close to that of the Caltrans observations when the cost factor for HOV lanes was 0.93 (compared to the cost factor of 1.0 for mixed-flow lanes) and the perturbation is 2 for 80 percent of the HOVs [11]. Table 1 shows how the perturbation factor affects HOV lane usage at four measurement locations when the cost factor for HOV lanes was 0.93.
(2) Volumes at various mainline and ramp locations and travel time data along six routes - According to Table 2, both simulated link flow and travel time data have been well matched with the corresponding observed data. Compared to the FHWA criteria, the calibrated model performs satisfactorily [12].

EVALUATION

Hybrid Demand Estimation

There are three assumptions 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. This assumption is valid in a rather small, socio-economically homogeneous area like Irvine, California, but a more elegant solution would be needed for larger or more complex areas.
(2) Another assumption is 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. This assumption may be an oversimplification, but in the absence of a model that relates hybrid ownership to income, geographic location, or congestion levels, the authors did not have a better estimate of the distribution.
(3) It is 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 [11].

The procedure for the hybrid demand estimation for the current year is shown in Figure 4. Data from automotive industry information websites [13, 14] 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) [15], 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.

It is assumed that the total demands across all scenarios are the same. Using the same method, the total qualified hybrid vehicles for scenarios 2 and 3 were calculated as 396 and 592, which are 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.

Performance Measures

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 study. California's hybrid-HOV law also recognizes that HOV lane travel time is an important measure of whether or not performance in an HOV lane has broken down. However, the bill is not specific as to how much change in travel time should be considered significant, noting only that a consistent increase is grounds for suspending the program. As travel time is the incentive offered by hybrid-HOV bills, changes in HOV lane travel time are important, and HOV lane travel times in excess of twenty percent are considered significant in this study. HOV lane flows are included as a final measure of effectiveness. 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 plug-in had to be developed. The plug-in gathered data about HOV lane travel times and densities between a pair of loop detectors that were spaced one-to-two miles apart. Relatively small gaps between successive loop detectors were chosen as HOV lane congestion can be highly localized, and if the detectors were too far apart, much of the detail could be lost. After all the detector stations were established, 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.

Results and Analysis

The simulation time period for all scenarios is the morning peak period from 6:00 to 9:00 A.M. Because traffic takes some time to build up in the network, the first hour of simulation time was considered warm-up time and only the last two hours of the simulation data were analyzed.

Multiple simulation runs were conducted to ensure the simulation results were statistically meaningful [16]. The method to calculate the number of required runs is as follows:

$$N = (t_{\alpha/2} \bullet \frac{\delta}{\mu \bullet \varepsilon})^2 \qquad (2)$$

where μ and δ are the mean and standard deviation of a MOE based on the already conducted simulation runs; ε is the allowable error specified as a fraction of the mean μ; $t_{\alpha/2}$ is the critical value of the t-distribution at the significance level α. This calculation needs to be done for all performance measures of interest. The highest value is the required number of runs. If the current number of runs is larger than the required number of runs, the simulation of this scenario is ended. Otherwise, one additional run is performed and then the required number of runs needs to be recalculated. Given the constraints on computing power and time available, this study conducted three simulation runs first and the number of required runs was calculated based on Vehicle Hour Traveled (VHT) of each run. Finally, the authors settled on performing four runs to ensure a statistically significant number of observations across all scenarios.

As can be seen in the Tables 3 and 4, 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 one, 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 one; however, the similarity is expected as the hybrid population did not increase very much between the two scenarios.

Recall that scenario three 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 3 and 4 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 benchmarks established by the authors 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. But what would happen if all restrictions as to the number and type of hybrids allowed in the lanes were removed? Scenarios four and five test this latter case by using data based on the Virginia experience. In scenario four, 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 four, the impact of the additional hybrids is noticeable in the network, but the changes remain modest. Table 4 shows that a substantial number of HOV lane sections have had their

LOS go from A to B, and Table 3 shows that mean flow, density, and travel times have also increased slightly when compared to the baseline scenario.

In scenario five, where the proportion of hybrid vehicles using the HOV lanes has increased dramatically to nineteen percent, the Irvine area HOV lanes 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.

CONCLUSION AND POLICY IMPLICATIONS

This paper introduces a microscopic simulation method to investigate the operational effects of the proposed California hybrid-HOV law that allows single occupant hybrid vehicles into the HOV lane. The 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 key findings from this study are summarized below:

- Scenario one 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 if California’s proposed hybrid-HOV law were passed, 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. Also, these 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 state-wide level. In order to fully discover the operational effects of the hybrid-HOV policy, further investigation using a sufficiently large network (for example, the entire Orange County network) may be required, which in turn would require a significantly more modeling and computing efforts. 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.

While this initial research indicates that California's hybrid-HOV law would probably not have a detrimental impact on local HOV lane operations, the uncertainties involved in the projections would argue for caution in enacting the legislation, primarily as it relates to the "take away" problem. A prime example of the "take away" problem was observed in the Santa Monica Freeway diamond lane experiment.

In the mid 1970s, Caltrans decided to convert one of the four general-purpose lanes to an HOV (or diamond) lane on each direction of the I-10 Santa Monica Freeway between Santa Monica and downtown Los Angeles. Even though the HOV lanes were successful in increasing carpooling and bus ridership, the high occupancy requirement of the new HOV lane (3+) excluded the vast majority of drivers from using the lane they had previously driven on. The resulting increased congestion in the remaining general purpose lanes thus precipitated understandably negative public reaction. Under intense pressure from the public and the court system, the Santa Monica Freeway diamond lanes were converted back to general-purpose lanes five months after they opened. Since the decommissioning of the Santa Monica Freeway diamond lanes, California has built over one thousand HOV lane miles. However, the primary difference between the Santa Monica Freeway diamond lanes and all subsequent HOV projects is that when a new HOV project comes online, the HOV lane is a new lane that is added to a facility rather than a general-purpose lane that is "taken away."

The Santa Monica Freeway diamond lane failure demonstrates that people are loath to give up a privilege that they have enjoyed, even if it is to support of a policy with which they agree. The concern is that once single occupant hybrid owners are given access to HOV lanes, hybrid owners might feel that they have been granted an inalienable right to use the HOV lanes. With buyers of hybrid vehicles paying a premium of about $3,000 for vehicles that will give them solo access to HOV lanes, they may feel that they have an even greater right to use HOV lanes since they have "paid their dues" to get in.

Should hybrid sales and population increase substantially, measures may have to be taken to ensure that HOV lanes continue to provide travel time benefits. While California's hybrid-HOV bill is carefully designed to avoid impairing HOV lane operations, the mitigation strategies in the bill are heavily slanted toward continued hybrid usage. If it is found that single occupant hybrid vehicles cause congestion in HOV lanes, one likely response would be to eliminate single occupant hybrids from the lanes, as they do nothing to forward the policy objective of moving more people in fewer vehicles. In examining the provisions in the bill, the legislature requires Caltrans to eliminate single occupant hybrid vehicle access to HOV lanes only if it can be shown that it is infeasible to reduce congestion by any other means, including increasing occupancy requirements [5]. In order to address the "take-away" problem and promote better use of the HOV lanes, the bill should require the development of an HOV lane operational policy that is clear to the public. Such policy would allow access to the HOV lanes by a wide range of vehicles, including SOVs on a priority basis. This can only be done with dynamic management of the lanes. The policy should be based on letting the maximum number of vehicles use the HOV lanes without allowing the lanes to become congested. This may facilitate the use of HOV lanes in some areas as High Occupancy Toll (HOT) lanes when the HOV capacity is underutilized. Dynamic management of the lanes will require fully instrumented HOV facilities including vehicle sensors, electronic message signs and ability for the users to pay tolls through transponders. The HOV lane managers must have the ability to monitor the traffic and communicate to the users via the signs the type of vehicles that are allowed to use the facility at any given time. For example, buses could have the highest priority and SOVs who are paying toll would have the lowest priority. In congested peak hours, only “3 plus” or “4 plus” HOV may be allowed.

Although the analysis of the five scenarios suggests that California’s proposed law will not have a significant impact on HOV lane operations in the study area, the need for such a bill solely for hybrids use of HOV lanes is questionable. Across the country, where most places do not even have HOV lanes, not to mention a hybrid-HOV law, hybrid vehicles are being bought faster than they can be manufactured. If hybrids are allowed into HOV lanes, it may be very hard to remove them at a later date if and when they do begin to cause congestion in the lanes. The HOV Lane Task Force in Virginia recommended that the state allow its hybrid-HOV law to expire because of concerns over HOV lane congestion caused by single occupant hybrid vehicles; the Virginia experience may offer cogent lessons for others considering implementing similar laws. The authors recommend that HOV facilities should be well instrumented with intelligent infrastructure such as vehicle detector systems in order to monitor their performance, improve their operations and better predict the effect of additional vehicles such as hybrids. Further, it is recommended that the efficient operation of HOV lanes need to be addressed by policies that are developed by the operating agencies, not through legislation.

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List of Figures

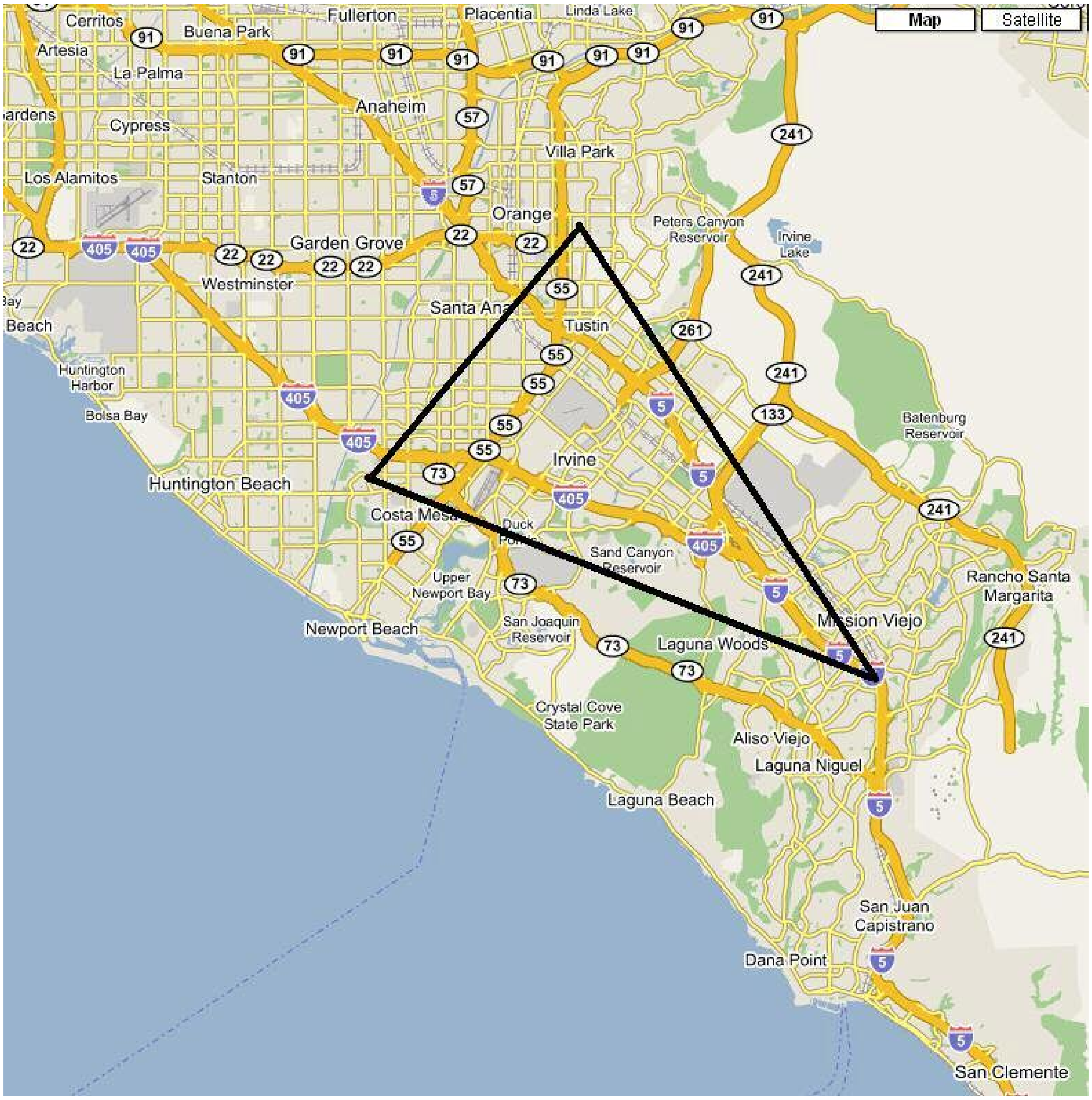

Figure 1 Study Site (Source: Google Maps)

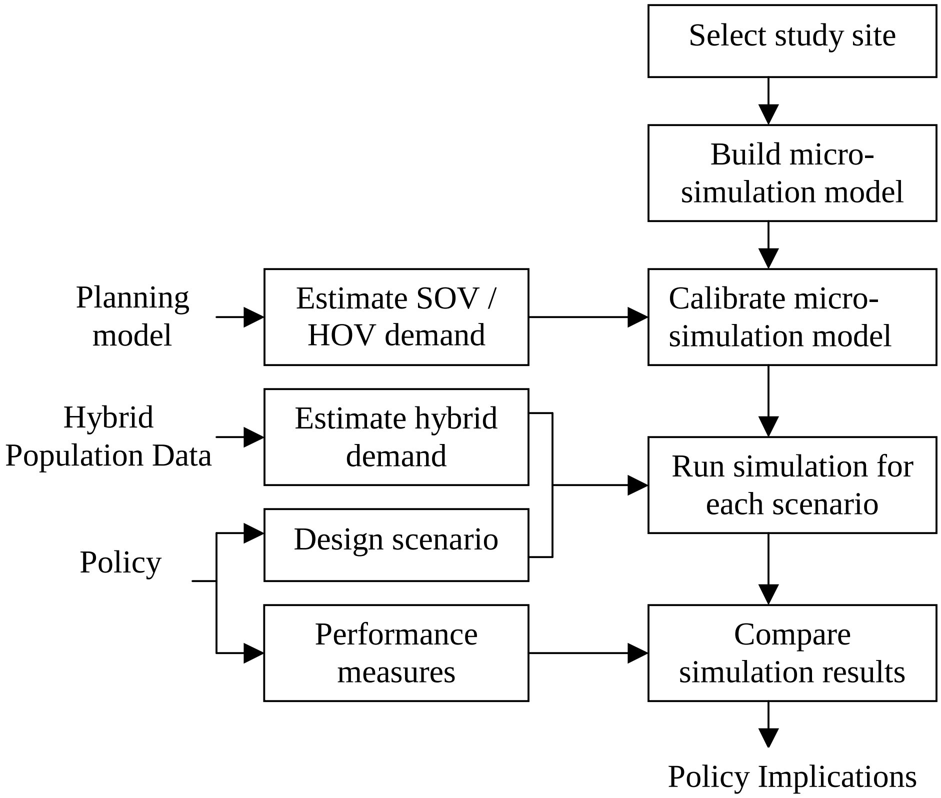

Figure 2 Study Procedure

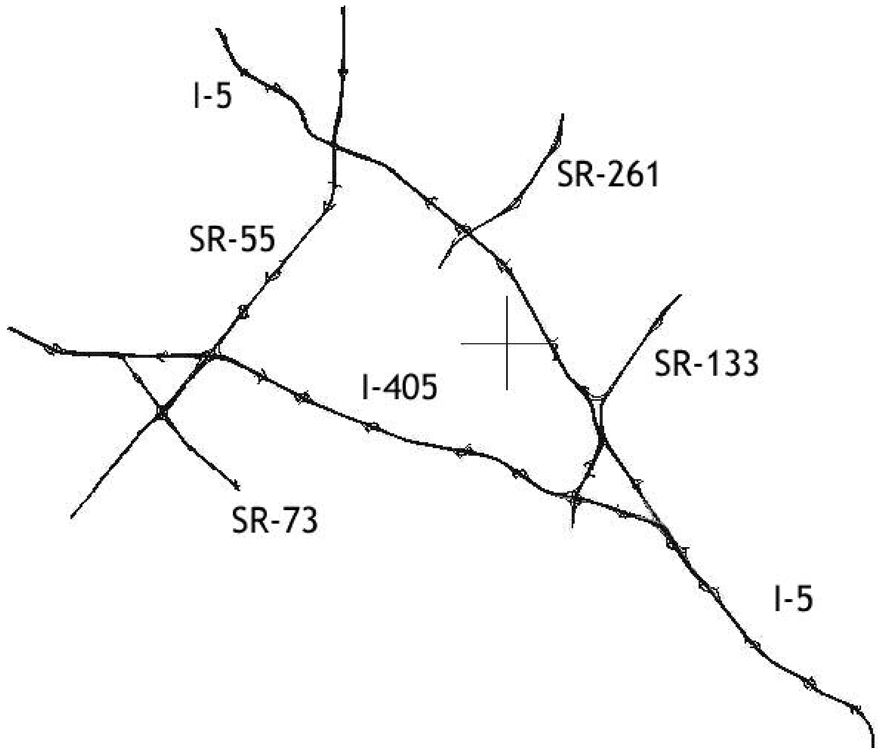

Figure 3: Paramics Simulation Network

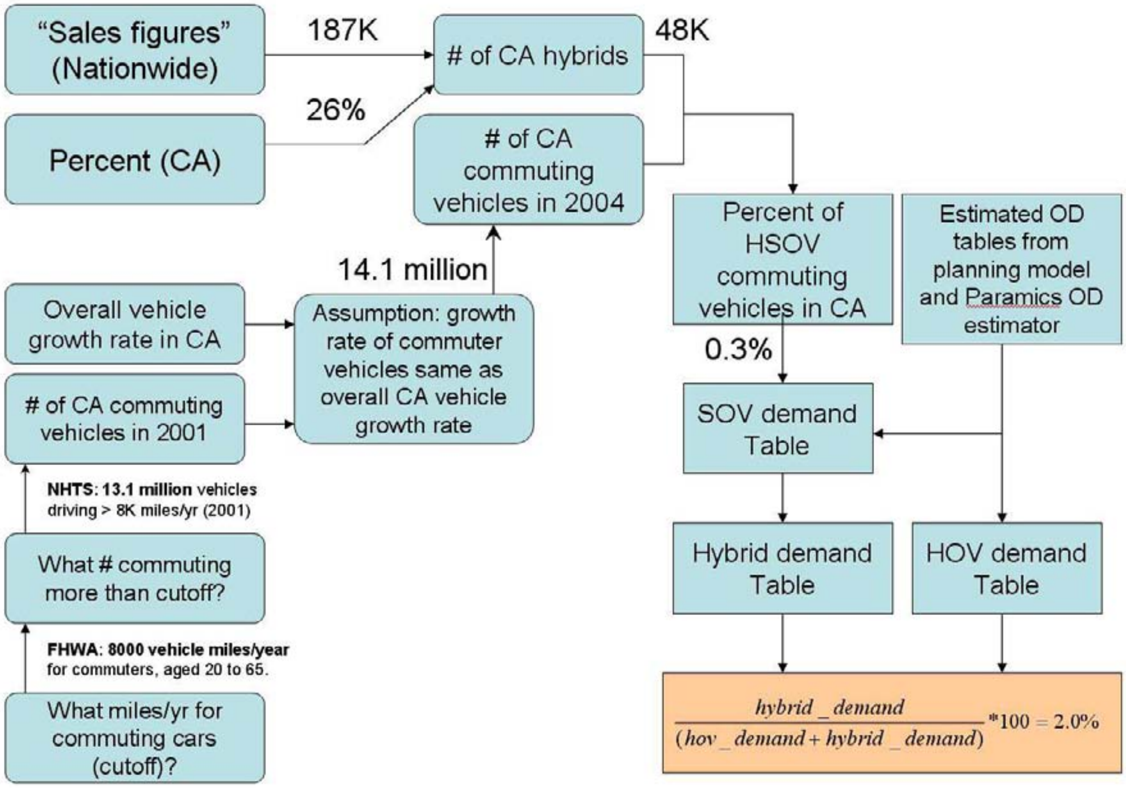

Figure 4 Estimate of base year hybrid demand

List of Tables

Table 1 HOV Lane Usage Rates and Perturbation Parameter Settings

	Percent of Eligible Traffic in HOV Lanes at the Four Survey Points			
HOV Perturbation Setting	I-405 South at Von Karman	I-5 South at Tustin Ranch	I-405 North near Sand Canyon	I-5 North at Culver
100% 0 (All-or-nothing)	77	81	88	89
100% 1.0	67	47	79	88
100% 1.5	67	46	80	88
100% 1.7	67	47	79	87
100% 2.0	57	45	68	79
100% 3.5	53	42	60	76
20% 1, 80% 2	61	45	74	82
20% 0, 80% 2	61	52	70	82
TARGET	**57**	**52**	**70-85**	**70-85**

*The numbers above are averages of several simulation runs, rounded to the nearest percent

Table 2 Calibration results

Criteria and Measures	Acceptability Targets	Golden Triangle Performance
Hourly flows: modeled versus observed		TOTAL: 153 mainline and ramp links
Individual Link Flows Within 400 vph for flow > 2700 vph	> 85% of all cases	75%*
Total (summed) Link Flows Within 5%	All links	Yes – Average error 3.61%
GEH Statistic – Individual Link Flows GEH < 5	> 85% of all cases	92%
GEH Statistic – Total (summed) Link Flows GEH < 4	All links	Yes – Average GEH 3.17
Travel Time: modeled versus observed		TOTAL: 6 trips
Point-to-point Travel Times Within 15% or one minute, whichever is higher	> 85% of all cases	83%**
Visual Audits		
Individual Link Speeds Visually acceptable speed-flow relationship	To analyst's satisfaction	Good
Bottlenecks Visually acceptable queuing	To analyst's satisfaction	Good

* If criteria were expanded to allow flows of 408 or less, then 92% of cases would have been acceptable
** Due to a limited number of Caltrans travel time measurements, only six travel time comparisons can be made with 5 of the 6 trips within one minute of the measured time.

Table 3 Density, Travel Time, and Flow Comparisons

HOV Lane Segment MOE		Baseline	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Density (vpm)	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 HOV Lane Travel 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 (vph)	Mean	1064	1065	1061	1077	1206	1225

* Due to the presence of unreasonable outliers in the travel time data, the minimum value above represents the data point at which 95 percent of all observations lie above, and the maximum value represents the data point at which 95 percent of all observations lie below. The authors suspect that extreme travel time outliers are artifacts of the simulation and would not be expected under real-world conditions.

Table 4 LOS and Flow Comparisons

MOE	Baseline	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 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 LOS D or Above	0	0	0	0	0	0
Number of Periods where Flow > 1800 vph	0	0	0	0	0	0