Priority Based High Occupancy Vehicle Lanes Operation

Lianyu Chu
California Center for Innovative Transportation (CCIT)
University of California Berkeley
522 Social Science Tower
Irvine, CA 92697-3600
Tel: 949-824-1876
Fax: 949-824-8385
E-mail: lchu@berkeley.edu

K S Nesamani
Institute of Transportation Studies
University of California
522 Social Science Tower
Irvine, CA 92697-3600
Tel: 949-824-5623
Fax: 949-824-8385
E-mail: nesamani@uci.edu

Hamed Benouar*
California Center for Innovative Transportation (CCIT)
University of California – Berkeley
2105 Bancroft Way, Suite 300
Berkeley, CA 94720-383
Phone: 510-642-5224
Fax: 510-642-0910
Email: benouar@calccit.org

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* Corresponding author

Abstract

Federal and State governments are investing billions of dollars and promoting usage of High Occupancy Vehicle (HOV) lanes through various programs. Many states, including California have demonstrated the effectiveness of HOV lanes and are in the process of completing the HOV lane network. However, HOV lane operations continue to be criticized for its underutilization of roadway capacity and limited ability to shift Single Occupancy Vehicle (SOV) drivers to transit and carpools. Hence, many states are considering the conversion of HOV lanes to other type of operation. Ten states in the US have considered allowing single occupant hybrid vehicles (SOHV) into HOV lanes to encourage the purchase of hybrids and reduce the fuel consumption and congestion in both HOV lanes and general purpose lanes. In addition, High Occupancy Toll (HOT) operation is being considered as a good alternative to make better use of HOV lane capacity and at the same time generate revenue that can be used to improve transit and other transportation facilities within the corridor. All the proposed strategies are aimed at better utilization of the roadways and to better manage the multi-modal transportation system. For HOV Operations to be managed in an efficient way, a usage priority system must be developed. To improve the current HOV lane operation, this paper proposes a priority based HOV operation strategy, which manages the productivity of the HOV lanes by controlling the access to HOV lanes based on dynamic traffic condition and priorities of vehicle types. The strategy is then evaluated in a microscopic simulation environment based on a freeway network in the City of Irvine, California. Simulation results show that the proposed strategy improves 10.3% of total passenger travel time and 6.78% of travel speed. It is also shown that the proposed strategy also has the capability to maintain good traveling conditions along the HOV lanes and at the same time improves the condition along general purpose lanes.

Introduction

Federal and State governments are investing billions of dollars in building and promoting usage of High Occupancy Vehicle (HOV) lanes through various programs (1). The main motive behind this policy is to better manage the transportation system, moving more people by buses and carpools, saving travel time, reducing congestion, and improving air quality. Currently, there are about 1285.3 miles of HOV lanes in the US and there are about 525.7 HOV lane miles in California alone (2). HOV lane construction has become a major freeway improvement strategy. Many states, including California have demonstrated the effectiveness of HOV lanes and are in the process of completing the HOV lane network.

HOV lane concept was originally perceived as dedicated bus lane, which later allowed vanpools and carpools. There are many studies on whether HOV lanes improve the efficiency and safety of transportation. Kim et al. analyzed the impact of adding HOV lanes to the existing freeway (I-680) in the Bay area using micro simulation models. They concluded that adding HOV lane has significantly improved the travel time and provided other benefits (3). However, some studies do not support HOV lanes or the current HOV lane operation. A study conducted by Kwon and Varaiya using Performance Measurement System (PeMS) data found that HOV lanes increase rather than reduce congestion (underutilizes the capacity of the lane by about 400 vph) in the Bay area HOV network (4). Further studies in the Bay Area by Benouar and Gomes using PeMS Data found that the HOV Lane carrying capacity is not reduced in some areas and that in many cases the underutilized capacity could be more than compensated by the increase in people carrying capacity (5). In southern California, legislators have passed a bill to change the number of occupants from 3+ to 2+ in 1999 on the El Monte HOV facility. The before and after data from Caltrans and other agencies showed that this policy has considerably reduced the speed of El Monte bus way from 65mph to 20 mph. In addition, the new HOV Operations policy did not increase the speed in the general purpose lanes. As a result, the bill was revoked back in July 2000 (6).

While many people agree that HOV lanes carry more people than SOV lanes during peak hours, one of the main reasons that HOV Lanes are criticized is the perception that they underutilize roadway capacity and they have a limited ability to shift Single Occupancy Vehicle (SOV) drivers to transit and carpools. New operational strategies including High-Occupancy Toll (HOT) operation and allowing low emission vehicles SOV are proposed to make better use of the HOV lanes throughout the day (1).

Over the past few years, a number of government-sponsored initiatives promoting hybrid vehicles have emerged. Ten states have considered allowing single occupant hybrid vehicles (SOHV) into high occupancy vehicle (HOV) lanes to encourage the purchase of hybrids and reduce the fuel consumption and congestion in both HOV lanes and general purpose lanes. Based on Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), HOV lane should not be degraded and the speeds in one or both of the peak hours should not be less than 45 MPH for more than 18 out of 180 days (7). Breiland et al. studied the potential impacts of the policy using a microscopic simulation model based on freeway networks in City of Irvine California. They found evident change in volume, travel time and flow rate when the hybrid demand increased to 19% of HOV demand, but within the acceptable range (8). Based on the second evaluation of HOV task force conducted by Virginia, both I-95 and I-395 are clogged by 19 percent and 7 percent of Single Occupancy Hybrid Vehicles (SOHV) respectively (9).

HOT concept was first proposed by Gordon J Fielding and Daniel B Klein in 1993, which was designed to be a freeway facility that can be used by HOV drivers and those SOV drivers who are willing to pay toll (10). HOT has been considered as a good alternative that would improve HOV lane operations and generate funding that can be used to improve the transportation system in the area. Currently, there are four HOT projects in US, among that two are in California (SR-91 in Orange County and CA I-15 in San Diego) and two are in Texas (Kathy Freeway-I-10 and Northwest Freeway – US290). Based on the success of these corridors, other states are considering HOT lanes and Bus Rapid Transit (BRT) as viable options. The main reason behind these proposals is that BRT can move more people and relieve congestion on the freeway and HOT lanes make better use of the freeway facility and can generate revenue to improve transit including BRT. These concepts need to be integrated in a corridor management scheme with overall system management in mind.

In Texas, (QuickRide) HOT facilities are restricted to HOV 2+ occupants with a charge of $ 2.00 per trip during peak period and free during off-peak period; free for HOV 3+ occupants (11). Appiah and Burris analyzed the survey of travelers data collected in Texas and found that many respondents prefer to pay high toll and drive as SOV, mainly because it is difficult to arrange carpools, when the potential passengers have different origin and destination or different choice of time of travel. In California, SOV drivers can use HOT lanes by paying toll; Both SR-91 and I-15 created positive impact in both HOT lanes and general purpose lanes. After few years of implementation the demand on the system increased but the congestion was kept below the previous congestion level. The use of variable pricing based on the time of the day and volume has shifted the demand significantly and influenced travel behavior. The San Diego I-15 demonstration project uses dynamic pricing based on volume to control the congestion level and keep the HOV lane operations at an acceptable level of service. Revenues generated from these toll roads are used to improve alternative mode of transport (12).

The benefits of HOT have been further analyzed using simulation models. Safirova et al. developed a simulation model to understand the impact of HOT lane policy in Northern Virginia using the Washington-START model. They converted the existing HOV lanes to HOT lanes. They found that many SOV drivers have used the HOT lanes by paying 20 cents per mile toll and some of the carpool drivers have moved to SOV drivers (13). This policy has increased the number of trips since it has reduced the congestion level. Rodier and Johnston compared HOV, HOT and truck only lanes in terms of travel demand, emissions, economic benefits and equity in the Sacramento region. They found that HOT lane reduced the congestion level to a certain extent, but the significant amounts of reduction were seen in combination of HOT and truck lane. In all the scenarios vehicle trips, emissions and VMT increased compared to the base case. From the economic benefits perspective, the combination of HOT and truck lanes scenario ranked better than other scenarios (14).

In this paper, the authors propose a new operation strategy called "priority based HOV" with the purpose to optimally utilize the current HOV lane facility. The proposed strategy allows vehicles with a certain priority level to use HOV lane based on instantaneous or predicted HOV lane traffic condition. Buses and carpools receive the highest priority level, down to HOV 3+ and 2+, then Hybrid/low emission vehicles and SOV vehicles willing to pay toll. A microscopic simulation method will be presented to examine the possible effects of the proposed priority based HOV lane operation strategy.

The paper is organized as follows. The next section presents the methodology for the proposed priority-based HOV operation strategy. The succeeding section evaluates the proposed strategy using microscopic simulation. The last section concludes the paper and discusses future research directions.

Methodology

This paper proposes a priority based HOV lane access based on vehicle occupancy, vehicle type and dynamic tolling of single occupant vehicles in order to improve the efficiency of the HOV lanes and the corridor in general. The priority access will be dependent on dynamic traffic conditions and on maintaining the operations of the HOV lanes and the freeway facility at a desired level of service. The proposed HOV operation uses dynamic traffic conditions to set the toll for SOV to control demand first, then when necessary to keep a desired level of service will not allow the toll paying SOV in the facility, then may not allow Hybrid, then may not even allow HOV 2 and only maintain HOV3+ operations. As is the case on the El Monte bus way in Southern California, some HOV facilities may have to be operated at HOV3+ for a period of time to keep the lane operations at an acceptable level of service. Many HOV lanes throughout California and the nation experience some level of congestion during peak hours but may also operate under capacity for long periods of time. That is the reason that HOV lanes need to be operated in a dynamic way to keep up with changing traffic conditions and allow various types of vehicles and occupancy including SOV willing to pay toll to make better use of the available capacity. The proposed strategy will allow the lanes to be operated more efficiently. However, it is important to note that implementation of such strategy would require a good detection system as well as variable message signs and additional communication and technology that will measure and predict traffic conditions and inform the drivers of the vehicle occupancy requirements and the toll.

In order to implement the strategy, vehicles need to be categorized based on occupancy, emission level, and whether driver is willing to pay toll. Each category of vehicles will be assigned a certain level of priority. Priority levels can be varied to simplify operations and to meet policy needs. The priority levels suggested by the authors are as shown in Table 1. Except level 0's SOV vehicles, all other priority levels of vehicles may be qualified for driving on HOV lanes. "Bus" has the highest priority level since it carries more number of people and uses less space than other types of vehicles. Along with bus allowing “HOV 4 plus” and “HOV 3” would make better sense to optimally utilize the HOV lane capacity. “HOV 2” would be the next priority level of vehicles. Due to the low energy consumption and emissions features of hybrids and LEVs, they are also allowed to use HOV lane and their priority level is the second lowest. Due to increasing congestion level in general purpose lanes, many SOV drivers are willing to pay toll to use less congested lanes. Thus, the lowest priority will be given to them.

<Insert Table 1>

The proposed HOV operation strategy needs to determine which priority levels of vehicles are allowed to use HOV lanes based on the HOV lane traffic condition, which can be measured by Level of Service (LOS), speed or throughput. The strategy could be expanded to consider the traffic conditions of the adjacent general purpose lanes. This study focuses on HOV lane operations. We propose to use the same performance measure mandated by the current transportation act in effect i.e. SAFETEA-LU. This US Congressional bill uses 45 mph as the threshold to determine if HOV lane operation is degraded. The objective function of HOV lane operation is to maintain the traveling speed higher than 45 mph on HOV lanes.

The control logic for the proposed strategy is as shown in Figure 1. For each HOV section, priority level starts from level 1, which means priority 1 and all priorities higher than 1 can use HOV lanes. Each section has at least one detector that is used to collect aggregated speed with a certain time period, typically 30 sec in California. A prediction algorithm can then predict the future speed of the section. If speed data are the only data used for prediction, the predicted speed can be a function of either local data (historical speed data of the study section) or system-level data (including data of the study section and its adjacent sections).

<Insert Figure 1>

The predicted speed is then compared with the target speed, i.e. 45 mph. If the predicted speed is slower than the target speed, the priority level will be increased for the study section. Otherwise, the section will keep the same priority level or be given a lower priority level (i.e. only if the current priority is higher than 1).

The implementation of this strategy will need a good coverage with reliable vehicle detector systems, Changeable Message Signs (CMS) to inform the users, a capable communication system, and a user identification and automatic payment system, etc. Although all technologies needed for this kind of system exist, its deployment will need to consider various factors and solve various technical details. User acceptance/interface and enforcement are among the issues to be considered. In addition, some of the operational strategies have to take into account the type of facilities. For example, in Northern California, there is no separation between HOV lanes and general purpose lanes. Drivers can move in and out of the HOV lane anytime, while in Southern California, the lanes are separated and are accessed only at limited locations.

Evaluation

Evaluation Methodology

The implementation of the proposed HOV lane operation depends on the support of transportation infrastructure. However, policy makers may need to know the potential benefits of this kind of system first. The traditional method to evaluate the possible impacts of a new policy or strategy is to use a transportation planning model. However, the proposed strategy is actually an Intelligent Transportation Systems (ITS) strategy and cannot be evaluated in a static model.

This paper presents a microscopic simulation based evaluation method as shown in Figure 2. The evaluation study starts from building the micro-simulation model of the study site, which needs to be calibrated. Based on the proposed HOV lane operation, a corresponding model needs to be developed as a plugin that works with the simulation model during simulation. Then, multiple simulation runs need to be conducted and performance measures from simulation can then be used to compare different scenarios.

<Insert Figure 2>

The micro-simulation model selected for the study is Paramics. PARAMICS is a scalable, ITS-capable, high-performance microscopic traffic simulation package developed in Scotland (15). It has been widely used to model the movement and behavior of individual vehicles on urban and highway road networks. PARAMICS provides users with Application Programming Interfaces (API) through which users can access its core models, and customize and extend many features of the underlying simulation model without having to deal with the underlying proprietary source codes.

Study site

The study site for this research is located in Southern California. Figure 3 shows the map of Orange County, California. The freeways around the 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 is about 12 miles from north to south and 15 miles from east to west. The lengths of I-5, I-405 and SR-55 are 18 miles, 12 miles and 10 miles respectively. The area is well covered by loop detectors, has several busy freeways with HOV lanes. HOV lanes are operated 24 hours a day, 7 days a week. There is a separation between the HOV lane and general purpose lanes and lane changing can only be made at a limited number ingress/egress areas. The implementation of the proposed priority based HOV operation strategy in the study network will also keep the same lane changing rule.

Simulation model

As shown in Figure 4, the study network was coded into Paramics based on aerial photos and geometric data from Caltrans. Based on a previous study, the simulation model was well calibrated and could represent the target network's real-world traffic condition (8).

<Insert Figure 4>

In order to suit for this study, we further improved the simulation model by updating SOV and HOV demands and its vehicle composition. The reason to update SOV and HOV OD demands is that OD demands from the previous study were estimated based on:

(1) Average flow of morning peak three-hour flows
(2) Data observed in 2004 and old Caltrans District 12 HOV report in 2002. In both years, hybrid vehicles were not allowed into HOV lanes.

The demands in this study were estimated based on:

(1) Peak-hour (i.e. 7-8 AM) flow data of 2005 because peak hour shows highest flow on HOV lanes and some parts of HOV lanes have shown traffic congestion.
(2) The latest Caltrans District 12 HOV report in 2005 includes operation of hybrid vehicles in HOV lanes.

This study needs to have a better estimation of the composition of vehicle types defined in Table 2. The distribution of different types of vehicles was derived from the OCTAM (Orange County Transportation Analysis Model) model version 3.1 obtained from Orange County Transportation Authority (OCTA) and then adjusted against base year data (16). In Orange County, there are about 1,876,500 daily auto trips and 89,100 transit trips. Based on the home based trips and daily model choice model share of different types of vehicles were estimated. The share of demand for SOV willing to pay toll was assumed to be the same as that of the SR-91 express lane site, which was estimated based on the average daily traffic data of SR-91 obtained from PeMS. The shares of LEV and hybrid vehicles were estimated based on data from automotive industry information data in January 2005 and the 2001 National Household Travel Survey (17, 18). The remaining share of vehicles is SOV.

<Insert Table 2>

Evaluation scenarios

There are two scenarios to be evaluated. The base scenario represents the existing scenario, corresponding to Year 2005, when HOV 2 plus and single occupant hybrid vehicles are allowed on HOV lanes. The other scenario sets the current HOV lane to be under a priority based HOT lane operation. In this case, different types of vehicles will be allowed into HOV lanes based on HOV lane traffic condition.

Priority based HOV operation plugin

A plugin was developed in order to emulate the proposed HOV lane operation explained in the second section of the paper in the study network, which has separation between

HOV lanes and general purpose lanes and vehicles can only change lanes within egress/ingress areas. The implementation also has the following assumptions:

(1) A HOV section is defined as the segment of HOV lane from a HOV entry point to HOV exit point. The speed on the section is measured by at least one detector within the section. Number of detectors depend on how long the HOV section is and how many detectors that have been installed in the field. The weighted average speed is used as the measured speed of the section, which will then be used for speed prediction;

(2) Since we do not have a value of time assignment model for trips, SOV toll is a fixed dollar amount. All SOV vehicles willing to pay toll can use HOV lanes if the priority level allows them to.

(3) Since how to better predict travel speed is beyond the scope of this paper, a simple prediction method is used (i.e. the predicted speed is equal to the measured speed of last time interval):

$$s^{p}(i,t+1) = s(i,t) \tag{1}$$

Performance measures

The performance measures of the study include two levels of measure. The first level is overall system performance and the second is HOV lane performance. The overall system performance measures include:

(1) Vehicle Hours Traveled (VHT)
(2) Vehicle Miles Traveled (VMT)
(3) Total passenger travel time
(4) Average travel speed

The HOV lane performance measures include:

(1) Average lane speed
(2) LOS
(3) Average lane flow

Paramics simulation runs

The simulation time period for two scenarios is the morning peak period from 6:00 to 8:00. Because traffic takes some time to build up in the network, the first hour of simulation was considered warm-up time and only the last one hour of the simulation data were analyzed. Due to the rigid rules in simulation, it is assumed that there is no violation of HOV lanes, although it is impossible in the field.

Some of performance measurement data were collected using Paramics' measurement function and others were collected using one plugin we developed. Multiple simulation runs were conducted to ensure the simulation results were statistically meaningful (19). 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 performance measure 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 for the 5% allowable error and 95% significance level was calculated based on VHT of each run. Finally, the authors settled on performing five runs to ensure a statistically significant number of observations across both scenarios. For both scenarios, the simulation results of the medium run with respect to VHT was used for further analysis.

Results and Analysis

Table 3 shows the comparison of four system performance measures, i.e. the total passenger travel time, average travel speed, VMT and VHT. The priority-based scenario performs better. It provides 10.3% total passenger travel time saving and 5.12% VHT saving. The average vehicle travel speed is also increased by 6.78% and the two scenarios have comparable VMT.

<Insert Table 3>

In table 4, average mainline and HOV speed and HOV flow on different freeways are compared. It is found that HOV lane speeds on most freeways have decreased and mainline speeds on all freeways have increased. The speed changes on mainline and HOV lanes lead to 2.66% increase on overall travel speed, as illustrated in Table 3. The reason for the increase of mainline speeds is the SOV demand shifting from mainline to HOV lanes, as illustrated in the HOV flow data part of Table 4. Although number of vehicles shifted from mainline to HOV is small in proportion to overall flow that relieves the overall congestion in the mainline.

<Insert Table 4>

Table 5 provides the comparison of LOS along HOV lanes of all freeways based on density values obtained every 2 minutes from simulation. It is found that 51% of the sections are operated in LOS A and B condition in the base case while only 36% in the priority scenario. It implies that the priority based HOV operation moves more vehicles to the HOV lanes, which decreases the LOS of some sections of HOV lanes. For the base scenario, 47.5% of sections are operated under LOS C and 1.5% under LOS D. However, 64% of sections of the priority based scenario are operated under LOS C and no section under LOS D. The above data from simulation verifies that the priority based HOV operation has the capability to maintain the traveling condition along HOV lanes. When the travel speed drops on a HOV section, the priority based HOV operation increases priority level and thus limits allowed vehicle types to access HOV lanes, as a way to avoid the HOV section to breakdown.

<Insert Table 5>

Table 6 provides evidences of successful HOV operation under the policy and details on the percentage of time of HOV lane operation on each priority level during simulation. In all the HOV sections, about 80% of time these HOV sections are operated under priority level 1, which indicates that by and large HOV lanes have more roadway capacity to accommodate SOV vehicles who are willing to pay toll apart from current share of 0.3% hybrid vehicles. The percentage of time for HOV lanes to be operated under priority levels from 2 to 5 are 9.2%, 5.3%, 3.3%, and 2.2% respectively. HOV lanes are never operated under priority 6. From the distribution of the percentage of priority level shown in Table 6, it is found that the HOV lanes on I-5 NB and I-405 SB are more congested than HOV lanes on other routes and SR-55 NB almost has free-flow condition on HOV lanes.

<Insert Table 6>

Considering all sections during the peak one-hour simulation, it is found that the HOV section’s speed is higher than 45 mph for 87% of chances. Since the control variable is HOV lane speed, when it is lower than 45 mph, the corresponding section’s priority level is changed from a lower level to a higher level.

The above results imply that the implemented priority based HOV lane operation strategy successfully switches between different priority levels. It has the capability to allow more vehicles to use HOV lanes when they are operated under good condition and prohibit vehicles with lower priority from using HOV lanes when HOV lanes traffic condition gets worse.

Discussion and Future Work

This paper presents a new HOV operational strategy, which integrates the HOT lane concept into a priority based HOV operation. It improves the current HOV lane operation by controlling the access to HOV lanes based on dynamic traffic condition and priorities of vehicle types. The strategy was evaluated in a microscopic simulation environment based on a freeway networks in City of Irvine, California. Simulation results show that HOV lane operations as well as overall traffic conditions can be improved further. Based on the analysis using simulation data, it is found that the strategy could also avoid the breakdown of HOV lanes since the priority based HOV operation has the capability to maintain the desired traveling condition along HOV lanes by controlling the access to HOV lanes.

It uses a different model than the HOT lane operation and it has higher operation complexity, but it has the potential to reduce freeway congestion by optimally utilizing the existing roadway capacity. This in fact improves the current HOT lane operations concept by introducing a priority level that further controls demand on the HOV lanes going beyond driver's decision to pay a higher level of tool. This priority concept, when necessary to keep the HOV lanes and the transportation system more efficient, may not allow SOV with any level of Toll or even HOV2 in the HOV lane facility.

Although the simulation study showed that the proposed strategy can yield many benefits and has the potential to be implemented in the real world, its deployment will be much harder than HOT lane operation. Further investigations on the feasibility of the implementation of the system and explorations of the available technologies and deployment details will be needed. Properly designed enforcement strategies will be required and motorists should be educated well before implementing this policy through advertisements and sign postings. Although this paper implements the strategy in the southern California HOV system using simulation in a straightforward manner, it will be even harder if implementing it in a HOV system that features non-24 hour operations and constant access HOV without separation from the general purpose lanes as is the case in Northern California and many other parts of the nation.

One potential limitation of the strategy could be that the system may lead to drivers' confusion and more vehicles weaving in the egress/ingress area. As a result, a better way to define HOV section is needed based on the homogeneous network concept. In addition, the priority level for adjacent sections may need to keep as stable as possible between time periods for the same section, and for adjacent sections at the same time.

The current system developed and evaluated is based on a simple speed control concept. How to implement the system may need to be further studied since the existing and/or potential vehicle detection system provide more types of data that can be used for the operation strategy. Also, either local data (historical data of the study section) or system-level data (including data of the study section and its adjacent sections) can be considered. With the advancement of prediction algorithms and traffic flow spatial analysis, a reliable HOV lane traffic condition prediction algorithm can be developed and used by the system. Since the data communication cost could be one major issue for a complicated system, the implementation of the system based on the legacy system will be more cost-effective.

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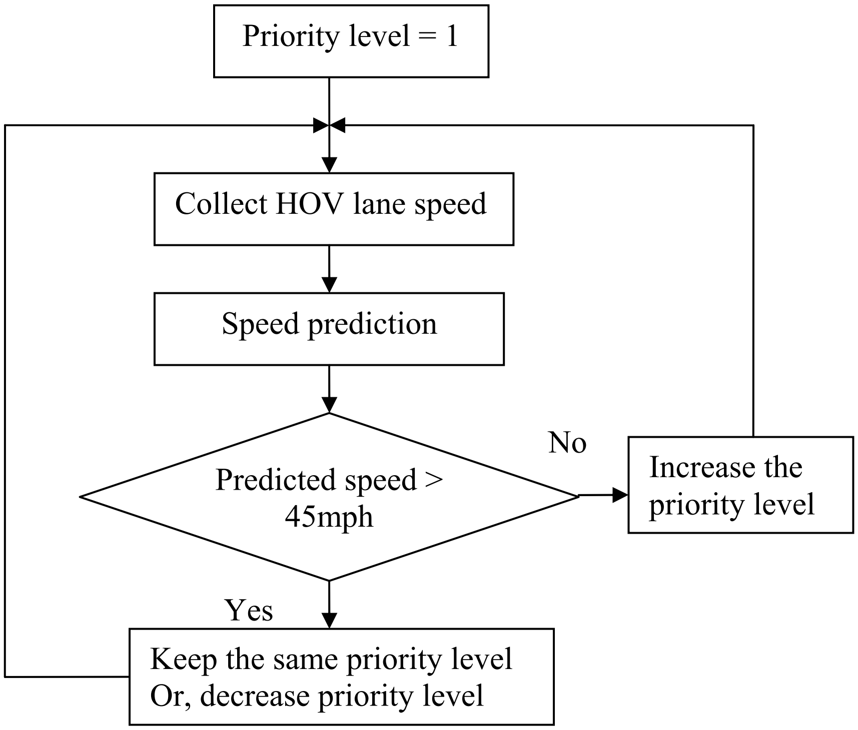

Figure 1 Schematic diagram of decision model

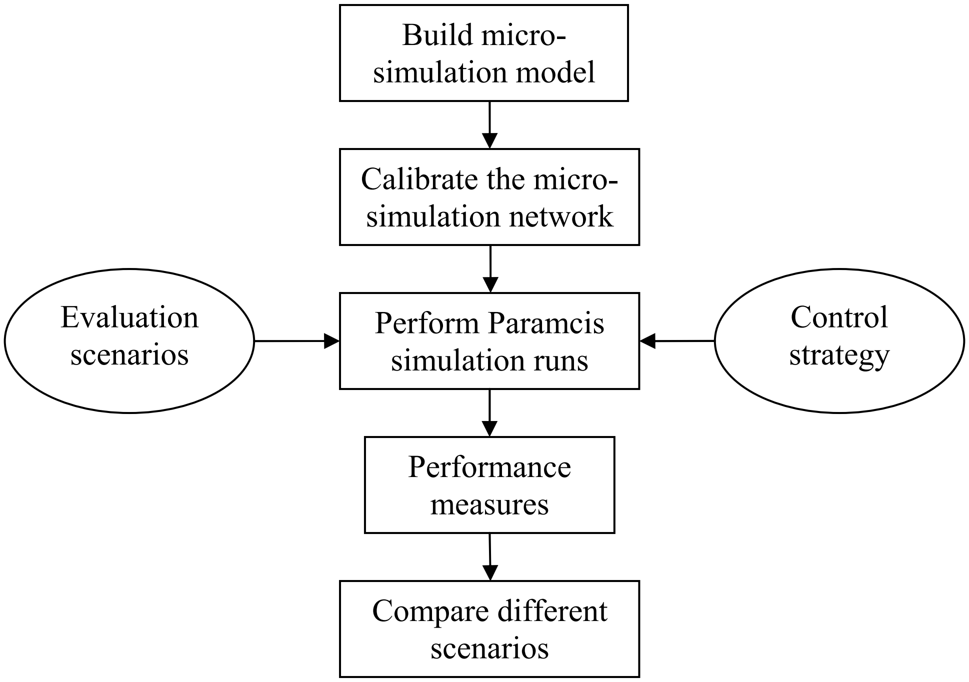

Figure 2 Evaluation of proposed methodology

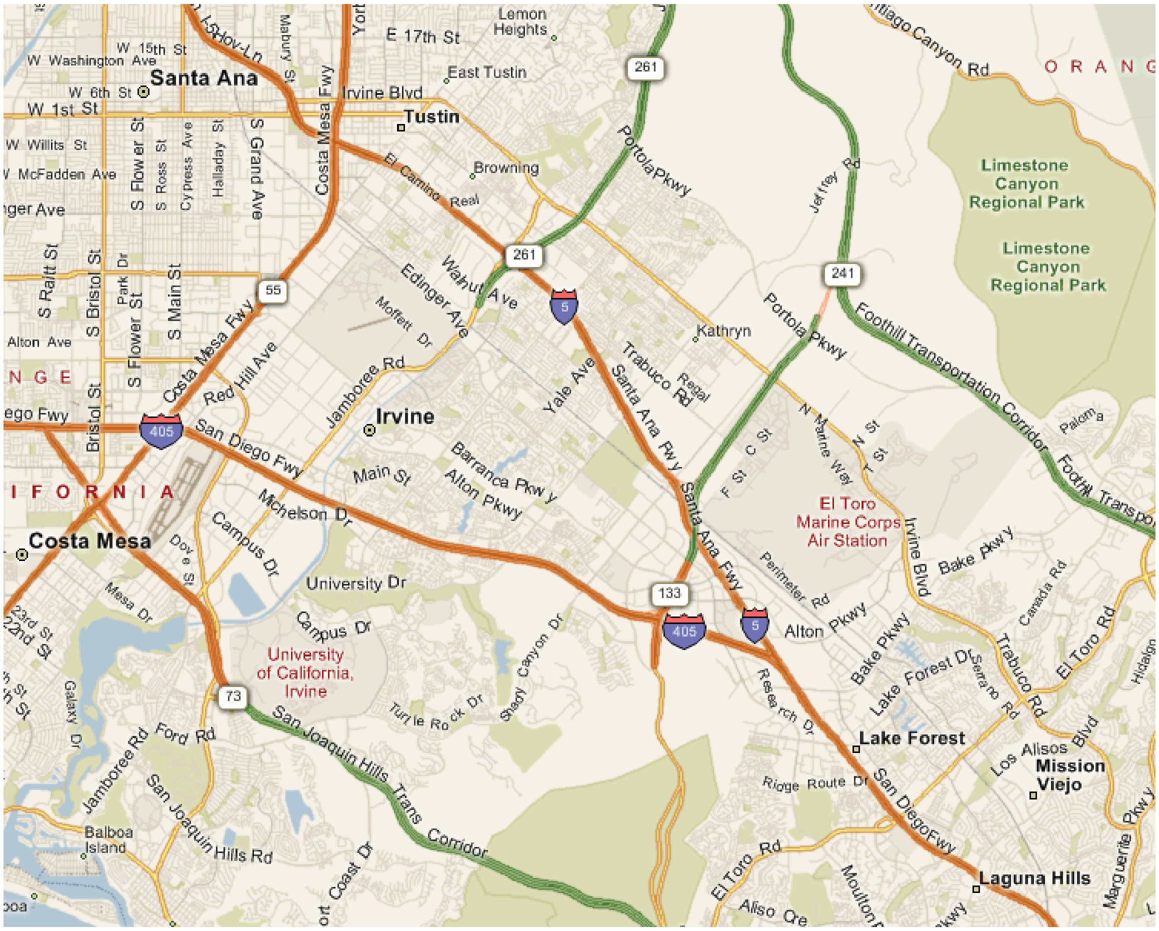

Figure 3 Study Site (Source: Window Live Local)

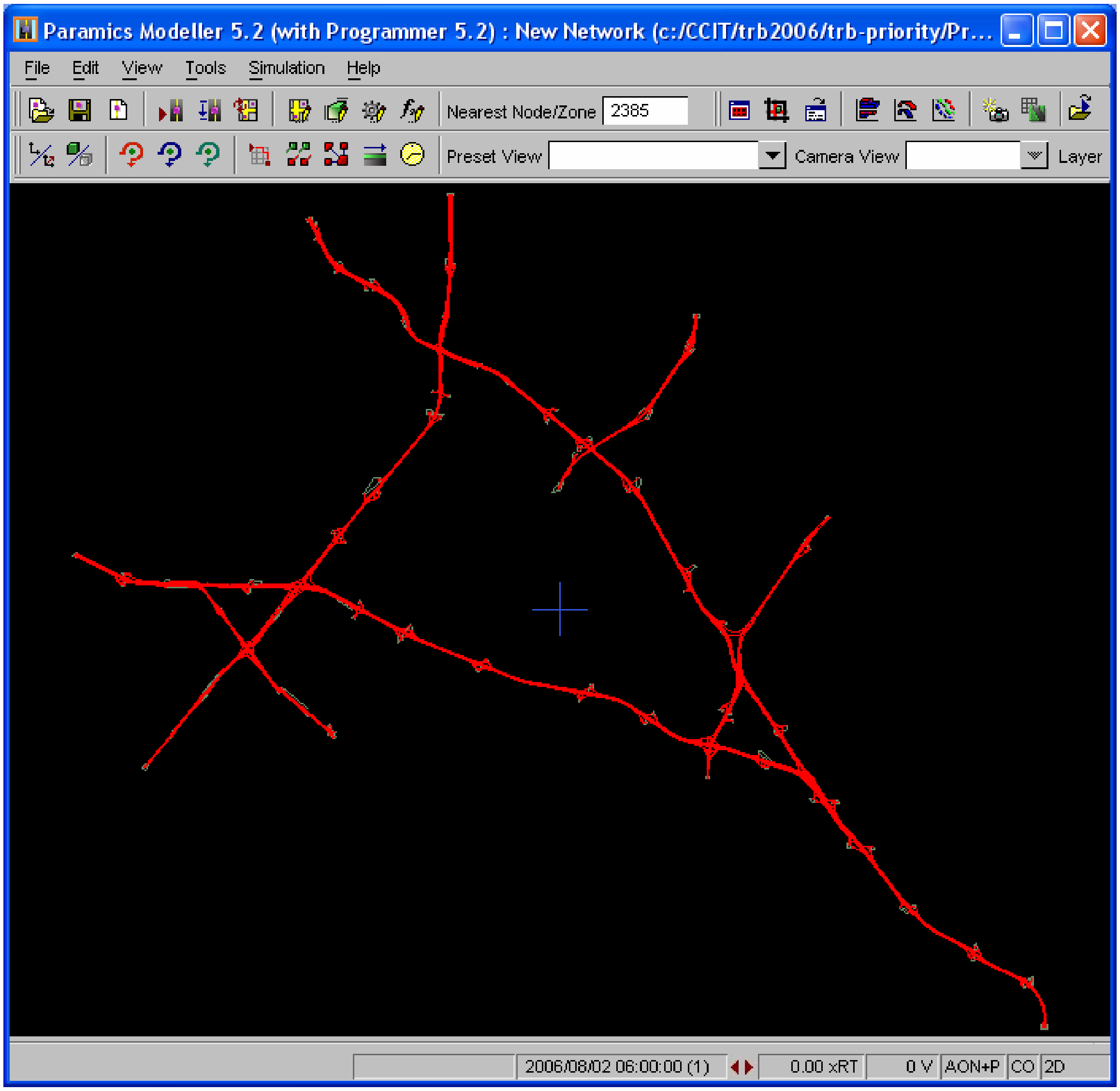

Figure 4 Simulation model of the study network

List of Tables

Table 1 Suggested priority levels

Priority level	Vehicle types
6	Bus
5	HOV 4 plus (includes van pools)
4	HOV 3
3	HOV 2
2	Hybrids, Low Emission Vehicles (LEV)
1	SOV willing to pay toll
0	SOV

Table 2 Share of different types of vehicles in priority based Scenario

Vehicle Type	Share of vehicles (%)
Bus	0.5
HOV 4+ (including vanpool)	1.0
HOV 3	3.5
HOV 2	11.2
Hybrid (0.3%) and LEV (0.5%)	0.8
SOV willing to pay toll	3.6
SOV	79.4

Table 3 Comparison of passenger travel time, speed, VMT and VHT

	Base Scenario	Priority-based Scenario	Difference (%)
Total Passenger travel time (hrs)	54049.2	48482.3	-10.30
Average Travel Speed (mph)	45.0	48.1	6.78
Vehicle-miles traveled (VMT)	689609.0	690024.2	0.06
Vehicle-hours traveled (VHT)	15025.3	14255.9	-5.12

Table 4 Compares speed and flow at different freeways

	HOV Speed		Mainline Speed		HOV Flow	
Freeway	Base Scenario	Priority-based Scenario	Base Scenario	Priority-based Scenario	Base Scenario	Priority-based Scenario
I-405N	53.1	52.25	47.1	48.38	1137	1196
I-405S	53.42	52.7	41.64	44.76	1138	1243
I-5N	55.16	53.28	45.9	49.3	1245	1330
I-5S	52.32	55.04	42.16	45.21	1306	1436
I-55N	62.4	61.06	60.45	60.7	652	823
I-55S	54.12	53.37	47.64	51.31	1245	1343
Overall Average	52.4	51.4	47.48	49.94	1196	1300

Table 5 Comparison of LOS

	Base Scenario (%)	Priority-based Scenario (%)
Section with LOS A	22	17
Section with LOS B	29	19
Section with LOS C	47.5	64
Section with LOS D	1.5	0

Table 6 Percentage of time of HOV lanes to be operated in different priority level

	Priority level 1 (%)	Priority level 2 (%)	Priority level 3 (%)	Priority level 4 (%)	Priority level 5 (%)	Priority level 6 (%)
I-405N	79	11	7	2	1	0
I-405S	74	13	5	5	3	0
I-5N	74	12	8	4	2	0
I-5S	78	9	6	4	3	0
SR-55N	99	1	0	0	0	0
SR-55S	76	9	6	5	4	0
Total	80.0	9.2	5.3	3.3	2.2	0.0