An LAO Report

HOV Lanes in California: Are They Achieving Their Goals?

Background

High occupancy vehicle (HOV) lanes are one of the primary tools used to reduce traffic congestion on the state highway system and improve air quality. However, in recent years, HOV lanes' effectiveness in achieving these goals has come into question.

LAO Findings

Based on our review of available data, we conclude that the performance of HOV lanes is mixed:

- On average, California's HOV lanes carry 2,518 persons per hour during peak hours—substantially more people than a congested mixed-flow lane and roughly the same number of people as a typical mixed-flow lane operating at *maximum* capacity.
- In terms of vehicles carried, however, California's HOV lanes are operating at only two-thirds of their capacity.
- Regional data indicate that HOV lanes do induce people to carpool, but the statewide impact on carpooling is unknown due to lack of data.
- The exact impact of HOV lanes on air quality is unknown.

LAO Recommendations

- Caltrans should improve its HOV data collection efforts, conduct periodic statewide surveys to determine the impact of HOV lanes on carpooling, and report on lanes that fail Caltrans' minimum criteria of carrying 800 vehicles per hour.
- Caltrans and regional transportation planning agencies (RTPAs) should be more flexible in adjusting the hours of operation of HOV lanes.
- The Legislature should create more High Occupancy Toll lanes on HOV lanes that have unused capacity and are adjacent to congested mixed-flow lanes.
- Caltrans should work with RTPAs to:
  - Develop a statewide plan to promote carpool lane usage.
  - Compile a set of performance measures and most cost-effective practices to increase carpool lane usage.
  - Consider converting underutilized HOV lanes to mixed flow where congestion *is not* present in mixed-flow lanes.

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January 7, 2000

INTRODUCTION

High occupancy vehicle (HOV) lanes have been a central part of California's strategy for alleviating congestion. Today, HOV lanes cover 925 lane miles of the state highway system and plans are underway to double this system over the next 20 years. Given population projections for the state (expected to grow by over 30 percent by 2020) and the limited amount of capacity on the state highway system, the Legislature, the Department of Transportation (Caltrans), and regional transportation planning agencies (RTPAs) ought to take a closer look at the degree to which HOV lanes are achieving the goals of congestion relief and improved air quality. (For an index of acronyms, see page 24.)

This report examines the performance of the state's HOV lanes. It provides options to modify their use in order to ensure that the existing HOV lane infrastructure is used most efficiently and any future investments in HOV lanes will further the goal of congestion relief and improved air quality.

Congestion in California

California residents consistently rank congestion among their top concerns. Available data support this view. For example, three of the ten worst commutes in the country are located in California, according to a 1999 report on urban roadway congestion from the Texas Transportation Institute. Additionally, a 1998 congestion study by Caltrans found that:

- Vehicle hours of delay on California's urban freeways more than doubled, from about 186,800 to 418,000 between 1987 and 1998.
- Congestion on the state highway system has increased at an annual rate of 10 percent since 1995. (Congestion was defined as 15 minute intervals during peak commute periods in which vehicles travel at speeds of 35 mph or lower.)
- Approximately 40 percent of the state's urban freeways are congested. This statewide average obscures even worse congestion in parts of the state such as Los Angeles and Orange County where between 60 percent to 84 percent of freeway lane miles are congested.

A number of factors contribute to worsening congestion. First, the total number of miles driven, measured in vehicle miles traveled (VMT), consistently outpaces population growth. From 1967 to 1997, the state's population grew by 70 percent, while VMT grew by 184 percent. The rapid growth in VMT is a function of a number of factors other than population growth, including economic growth resulting in increased auto ownership and mobility per household, and the growing gap between where people live versus where they work.

In addition, as auto ownership has increased, average vehicle occupancy (AVO) has decreased, resulting in an even higher number of cars on the road relative to population. While statewide data are not available, nationwide statistics indicate that AVO for home to work trips declined from 1.3 in 1977 to about 1.14 in 1995. In Southern California, AVO in 1995 was approximately 1.13. Declining AVO is a result of various factors which make carpooling inconvenient, including less centralized employment centers, less regular work hours, and increased affluence which makes commuters less sensitive to the cost of driving.

Congestion Relief Efforts

The state makes use of a variety of strategies to relieve congestion on state highways. These strategies can be divided into those that target recurrent delay—resulting from the number of cars on the road—and those that target nonrecurrent delay—resulting from unique events, such as special events or accidents. Approximately 50 percent of congestion is due to nonrecurrent delay. Such delays are best addressed by clearing accidents as soon as possible through the use of roaming tow trucks to respond promptly to accidents and by providing the public with timely traffic information (through changeable message signs, for example) to encourage motorists to take alternate routes.

To date, the majority of the state's resources to relieve congestion have been directed towards *recurrent* delay. Construction of HOV lanes, designed to reduce the number of cars on the road by providing a time-savings incentive to carpool, has been one of the primary strategies for relieving congestion in California. To date, Caltrans has spent almost $2.3 billion in state and federal transportation funds on the construction of HOV lanes.

OVERVIEW OF CALIFORNIA'S HOV LANES

Goal of HOV Lanes: Reduce Congestion and Improve Air Quality

According to state law, the goal of HOV lanes is twofold: reduce congestion and improve air quality. State law declares that HOV lanes are "to stimulate and encourage the development of ways and means of relieving traffic congestion on California highways and, at the same time, to encourage individual citizens to pool their vehicular resources and thereby conserve fuel and lessen emission of air pollutants." State and federal law also encourage the usage of buses on HOV lanes as a way to carry more people.

Caltrans has defined the goal of HOV lanes more specifically as follows:

- Increase the people-moving capacity of the freeway system.
- Reduce overall vehicular congestion and motorist delay by encouraging greater HOV use through carpooling.

- Provide time and commute cost savings to the users of HOV lanes.
- Increase overall efficiency of the system by allowing HOVs to bypass congestion on lanes designed for their use.
- Improve air quality by decreasing vehicular emissions.

With respect to the last goal, it is worth noting that strategies to reduce congestion are generally consistent with the goal of reducing vehicular emissions since vehicles emit less pollutants when traveling at faster speeds. However, air quality can also be addressed through technological advances, such as low- or zero-emission vehicles, which have the potential to significantly reduce the negative environmental impact of vehicular travel.

Geographic Distribution of Current HOV Lane System

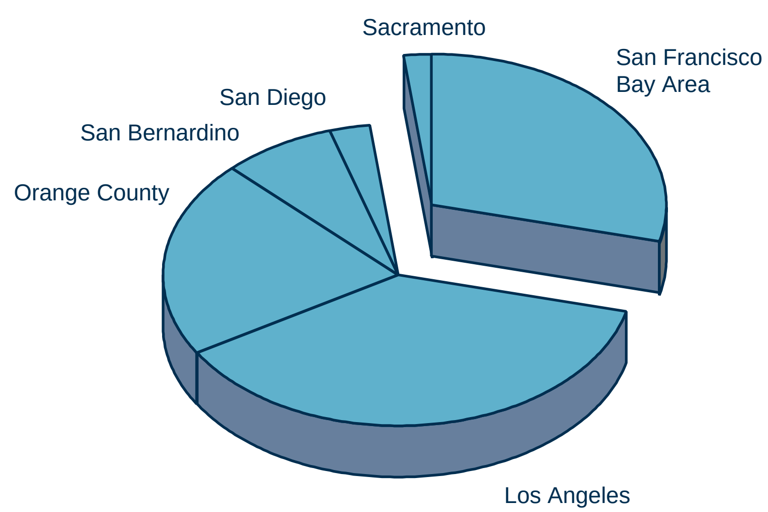
California currently has 925 HOV lane miles, approximately 1.9 percent of the state highway system's total lane miles. As indicated in Figure 1, about 70 percent of the existing HOV lanes are in Southern California (in the Caltrans district areas of Los Angeles, San Diego, San Bernardino and Orange County) while the remaining 30 percent are located in the Bay Area and the Sacramento region. In addition to the existing HOV lanes, 110 miles of HOV lanes are currently under construction, while another 809 miles have been proposed. Of the proposed HOV miles, approximately 70 percent are scheduled in the 1998 State Transportation Improvement Program (STIP) for construction between 2000 and 2003. Figure 2 shows the number of HOV lane miles in operation, under construction, and proposed in the different regions.

In Southern California, HOV lanes are operational 24 hours a day, seven days a week. According to Caltrans, this is because traffic peak periods are so long in Southern California that part-time operation would be impractical. Full-time operation of HOV lanes in Southern California has also

Figure 1

Statewide Distribution of HOV Lane Miles

by Caltrans District Area

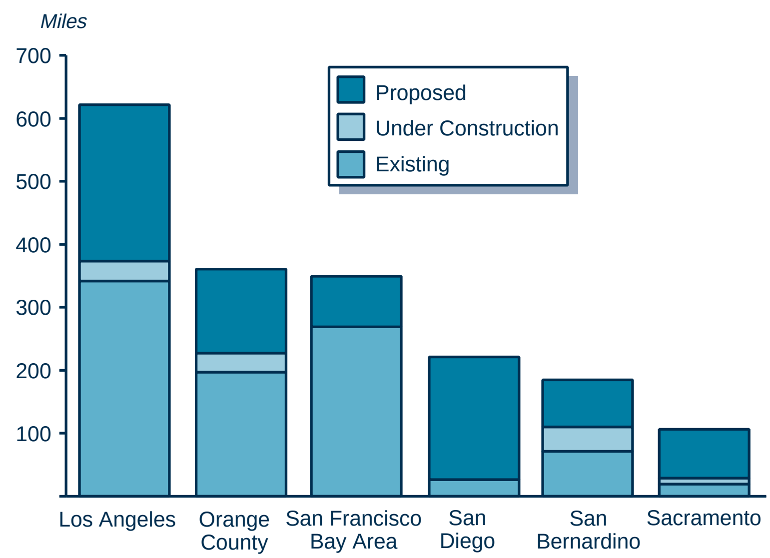


become the norm in order to minimize motorist confusion. These full-time HOV lanes are separated from the mixed-flow lanes by physical barriers or double-yellow lines.

In Northern California, HOV lanes are operational only during peak traffic hours due to shorter periods of congestion. Hours of operation are determined by Caltrans, in coordination with the relevant RTPA and are designed to match the traffic peak periods. Caltrans and RTPAs have occasionally adjusted (both lengthened and shortened) the hours of operation of several HOV lane segments from their original hours to better reflect demand for the lanes. Finally, all of the state's HOV lanes require two or more occupants, with the exception of some of the state's toll bridges and the I-80 approach to the Bay Bridge, which require three or more occupants.

Figure 2

HOV Miles by Region



Criteria for Constructing and Operating HOV Lanes

Current state law requires that prior to the construction of HOV lanes, Caltrans and local authorities conduct "competent engineering estimates of the anticipated impact of the lanes on safety, congestion and highway capacity." With respect to congestion, Caltrans guidelines recommend that a new HOV lane be constructed if the department projects that the new lane will carry a minimum of 800 vehicle per hour (vph) (or about 1,800 persons per hour, assuming an AVO of 2.2) during the peak hour one year after the lane is opened. This is not a statutory requirement, however, and once constructed, there is no review or action required if lanes do not meet this standard.

State Sets HOV Lane Capacity at 75 Percent of Mixed-Flow Lane Maximum Capacity. According to the federal highway design standards, the maximum capacity of the average mixed-flow lane is approximately 2,200 vph, under ideal conditions, including good weather, good pavement conditions, and standard freeway configuration. However, according to Caltrans, traffic tends to flow safely and smoothly at 55 mph up to about 1,800 vph, after which it becomes more dangerous and begins to slow down.

In order to ensure that HOV lanes continue to offer a time-savings incentive to carpool, the California Air Resources Board (CARB) and Caltrans have set 1,650 vph as the maximum capacity of HOV lanes—75 percent of the maximum capacity of mixed-flow lanes. Thus, even when an HOV lane has reached its operating capacity, it would always *appear* to have room for additional vehicles as compared to the adjacent mixed-flow lanes. The HOV lanes that carry more than 1,650 vph are eligible for operational changes, such as increases to the vehicle-occupancy requirements or expansion of the hours of operation.

Decisions About HOV Lanes Require Approval From Multiple Agencies. Decisions about constructing HOV lanes are subject to review by a number of agencies in addition to Caltrans. Under current state law, Caltrans cannot construct an HOV lane without the approval of the relevant RTPA. In addition, significant changes to HOV lanes, such as changes to the hours of operation or conversion to mixed flow, may be subject to review by the relevant RTPA, regional/local Congestion Management Agency (CMA), CARB, Federal Highway Administration (FHWA), and the U.S. Environmental Protection Agency (EPA).

In 1989, the Director of Caltrans assumed the authority to approve any change to vehicle occupancy requirements on existing or proposed HOV lanes. The Director also has veto power over decisions regarding the types of noncarpool vehicles that are authorized to utilize HOV lanes, such as motorcycles.

Caltrans Required to Consider HOV Lanes in All Proposals to Add Capacity to Urban Freeways. The California Transportation Commission (CTC) and FHWA require that whenever Caltrans and RTPAs consider adding capacity (that is, adding a new lane) to an urban freeway, they consider an HOV lane as an option. The CTC also requires consideration of the HOV lane alternative prior to constructing any *new* urban freeway. Finally, CTC requires that Caltrans work with RTPAs to develop region-wide HOV lane systems to be included in the regional transportation plan (RTP), which forms the basis for all future transportation investment in the region. Thus, federal and state policies ensure that HOV lanes play a central role in all transportation decisions related to freeway capacity enhancements.

HOV Lanes Used by Urban Areas to Comply With Air Quality Regulations. Due to state and federal air quality regulations, the state is severely limited in its ability to add capacity to the state highway system. This is because adding capacity to the state highway system is likely to result in additional VMT, thereby adding to vehicular emissions which in turn might put a region out of compliance with air quality regulations.

The federal Clean Air Act Amendments (CAAA) of 1990 require that areas that are designated as severe or extreme ozone nonattainment areas—most urban areas—enact transportation control measures (TCMs) to reduce mobile source emissions. The HOV lanes are among 16 TCMs which can be used to bring an area into compliance. Other TCMs include programs to improve public transit, pedestrian and bicycling facilities, trip reduction ordinances, and employer-based programs to permit flexible work schedules. Failure to comply with CAAA can result in sanctions against the state, including the withholding of federal highway funding.

A region could add mixed-flow lanes if it is able to offset the additional emissions through other control or emission mitigation measures. In practice, however, this would be very difficult since vehicular emissions account for such a large share (as much as 50 percent of ozone and 90 percent of carbon monoxide) of overall emissions. As a result, the majority of the new capacity added to the state highway system over the last 15 years has been through the construction of HOV lanes. (According to Caltrans, mixed-flow lanes have increased by about 1 percent in the last 15 years—between 300 to 500 lane-miles.)

CRITICISM OF HOV LANES

In recent years, the performance of HOV lanes has come into question. Various states have taken actions to reexamine the effectiveness of HOV lanes in reducing congestion and improving air quality.

Empty Lane Syndrome

Some argue that, far from relieving congestion, HOV lanes make congestion worse by forcing single occupant vehicles (SOVs) to crowd together in the mixed-flow lanes, while the adjacent carpool lane appears to remain largely underutilized. This so-called "empty lane syndrome" has led some to conclude that conversion of HOV lanes to mixed flow would alleviate congestion by making better use of the excess capacity. The potential consequences of this proposal have been the subject of much debate. In particular, there are concerns that eliminating the carpool lane would:

- Cause many carpoolers to revert to SOVs.
- Attract new vehicles to the corridor as a result of the additional capacity.
- Cause all freeway lanes to be congested, while eliminating a free-flowing lane available as an alternative to those who choose to carpool.

HOV Lane Conversion— The New Jersey Experience

In November 1998, the New Jersey Department of Transportation (NJDOT) converted two of its HOV facilities (one on I-80 and one on I-287) to mixed-flow lanes. In determining whether or not to convert the lanes to mixed flow, the NJDOT identified three objectives that HOV facilities must meet. Specifically, a successful HOV lane should:

- Induce people to carpool.
- Carry 700 vph, or at least the same number of people as the average of the mixed-flow lanes.
- Reduce or at least not worsen the overall level of congestion in the corridor.

The NJDOT found that neither the I-80 nor I-287 HOV lanes met all three objectives. The review further concluded that due to underutilization, the HOV lanes actually had a *negative* impact on traffic congestion and air quality by increasing traffic volume in the mixed-flow lanes thereby leading to slower travel speed, greater congestion, and higher emissions.

In the case of I-287, which failed all three objectives, the HOV facility carried about 300 vph and, in some sections, as few as 32 vph. Although I-80 met the threshold of 700 vph, it did not meet the requirements of inducing people to carpool or reducing congestion. As a result, the department concluded that converting the HOV lanes on these two highways to mixed flow would provide short-term (two to four years) congestion relief. In addition, by improving the overall traffic flow, NJDOT concluded that air quality for the corridor would also be improved. Although NJDOT is not conducting a formal evaluation of the impact of conversion, preliminary observations suggest that conversion of the I-80 HOV lane to mixed flow has resulted in a growth in the number of vehicles in the corridor above the historic-growth level. This is likely due to a combination of carpools disbanding and new vehicles drawn to the freeway to take advantage of the additional capacity.

New Jersey is not the only state reconsidering its approach to HOV lanes. Legislation has been proposed in Minnesota to convert all HOV lanes to mixed flow. In Tennessee, legislation was proposed in 1999 to reduce the fine for SOVs traveling in HOV lanes to $1 and allow the lane to be used as a passing lane for all vehicles.

Recent Legislation in California

Seven bills related to HOV lanes were introduced by the state Legislature during 1999. These bills took two general forms, as Figure 3 shows, and generally reflected a dissatisfaction with (1) the information available to assess the performance of the HOV lanes and (2) the current performance of HOV lanes. The first group of measures recommended increased study of HOV lanes in order to measure their performance and develop criteria for determining when and where to construct HOV lanes in the future. The second group sought to increase utilization of the lanes by expanding access to more vehicles through various approaches.

This latter group of bills offer a wide range of approaches to reforming HOV lanes—from operational changes in the hours of operation and vehicle occupancy requirements to wholesale conversion of the HOV system to mixed flow. Assembly Bill 44 (McClintock), for example, would require Caltrans and local authorities to convert all existing HOV lanes to mixed flow and would prohibit them from creating any new HOV lanes unless specified conditions are met.

More incremental changes to HOV lane policy focused on expanding access to the lanes to more vehicles. For instance, Chapter 330, Statutes of 1999 (AB 71, Cunneen) allows Inherently Low Emission Vehicles (ILEVs) to utilize HOV lanes from July 1, 2000 through 2003, regardless of the number of occupants. (An ILEV is a vehicle which has been certified under federal law to meet certain low-emission and ultra low-emission standards.) Under current federal standards,

Figure 3

HOV Lane Legislation in California

1999

Bill	Key Provisions
Measuring HOV Lane Performance/Criteria for Construction	
AB 199 (Pescetti)	• States the intent of the Legislature to evaluate the effectiveness of HOV lanes that are currently in this state.
AB 1647 (Torlakson)	• Requires the state to complete a study for measuring the effectiveness of HOV lanes and, in the event of underutilization, to propose remedies for increasing utilization, including conversion to mixed flow.
SB 14 (Rainey)	• Requires Regional Transportation Planning Agencies to create an HOV Master Plan.
Expanding HOV Lane Access and Use	
AB 44 (McClintock)	Requires all HOV lanes be converted to mixed flow unless: • A traffic model study has been conducted and certified by the Institute of Transportation Studies at the University of California, Berkeley establishing that an HOV lane is the most efficient alternative relative to establishing a high-occupancy toll lane (HOT lane), establishing a mixed-flow lane, or not establishing an additional lane. • Six months have elapsed from the date the analysis was submitted to the Governor and the Legislature.
AB 71 (Cunneen)—Chapter 330	• Requires Caltrans to extend access to HOV lanes to Inherently Low Emission Vehicles (ILEVs), Ultra Low Emission Vehicles (ULEVs), and Super Ultra Low Emission Vehicles (SULEVs) regardless of the number of occupants.
SB 63 (Solis)—Chapter 168	• Lowers the minimum occupancy requirement on Route 10 (El Monte busway) from three to two. Sunsets in 2001.
SB 252 (Kelley)—Chapter 481	• Lowers the traffic flow standard on the I-15 HOT lanes in San Diego to allow more vehicles to use the lanes. • Extends sunset date of the I-15 HOT lane project to January 1, 2002 and requires the San Diego Association of Governments to submit a report on the project by January 2000.

natural gas vehicles and electric vehicles are the only type of vehicles that are classified as ILEVs. There are an estimated 2,000 ILEVs currently in the state and thus the addition of these vehicles statewide is not expected to hamper the free flow of HOV lanes. From 2004 through 2007, Ultra Low Emission Vehicles (ULEVs) and Super Ultra Low Emission Vehicles (SULEVs), which meet even more stringent emission standards than ILEVs, will be granted access to HOV lanes.

MEASURING PERFORMANCE OF HOV LANES

There are several ways to measure the extent to which HOV lanes are achieving the goals of reducing congestion and improving air quality. With respect to reducing congestion, HOV lane performance can be evaluated based on (1) usage of the lanes and (2) their impact on carpooling. *Usage* can be measured in two primary ways: the number of persons per hour moving through the HOV lane and the number of vehicles per hour moving through the HOV lane. The impact of HOV lanes on *carpooling* is most accurately measured through surveys of motorists' commuting choices. With respect to improving air quality, the impact of HOV lanes has not been measured empirically, but rather estimated using mathematical models.

Usage Based on People Throughput

On Average, HOV Lanes Carry More People Than a Congested Mixed-Flow Lane. One measure of the performance of HOV lanes is to compare the number of persons they carry per hour with the number of persons transported through mixed-flow lanes. Caltrans, however, has no statewide estimate of the average number of persons carried by HOV lanes or mixed-flow lanes. Based on AVO data from Caltrans, we have developed such an estimate. Our calculations assume that AVO on HOV lanes is 2.3 persons and on mixed-flow lanes is 1.14 persons.

We estimate that the state's HOV lanes carry an average of about 2,518 persons per hour during peak hours. This is substantially more than the number of people carried by a *congested* mixed-flow lane—between 1,368 and 1,938 persons per hour—and roughly equivalent to the number of people carried by a mixed-flow lane operating at *maximum* capacity (2,508 persons per hour).

The next section examines two HOV lanes that have achieved high vehicle occupancy and can be considered successful from the perspective of person throughput.

El Monte Busway and the San Francisco-Oakland Bay Bridge. Because of the potential for very high occupancy, HOV lanes can be very efficient from the perspective of person throughput when combined with bus service. An example is the HOV lane on Route 10 (the San Bernardino freeway). This lane, known as the El Monte busway, was originally constructed in 1973 for buses only. Due to a bus strike in 1976, access was expanded to include vehicles with three or more occupants.

According to a traffic count conducted by Caltrans in 1997, the westbound HOV lane carried 49 percent of people in the freeway corridor during peak hours, while the remaining 51 percent were carried by the *four* mixed-flow lanes combined. By contrast, the HOV lane carried only 15 percent of the vehicles in the corridor, 5 percent less than its share of roadway capacity. Approximately 48 percent of the people traveling in the carpool lane were bus passengers, while the remaining 52 percent rode in carpools, vanpools, or by motorcycle.

Another example of the substantial people throughput potential of HOV lanes, even without substantial transit usage, is the Bay Bridge toll plaza. In 1998, the four HOV lanes on the toll plaza carried approximately 63 percent of all people crossing the bridge westbound (almost 16 percent each) during the morning commute, compared to 18 mixed-flow lanes which carried the remaining 36 percent of the people (an average of only 2 percent each lane). According to a 1995-96 survey of Bay Area commuters conducted for Caltrans, among drivers traveling westbound on the San Francisco-Oakland Bay Bridge, 48 percent of carpoolers formed their carpool by picking up riders at transit stops in the East Bay. These carpoolers not only save time when crossing the bridge, but also avoid toll costs since carpools travel free. Although this "casual" carpooling results in higher HOV lane usage, it has been criticized for taking away potential transit patrons.

The relative success of the El Monte busway and HOV lanes on the San Francisco-Oakland Bay Bridge is due in part to some unique features. The El Monte busway is unique in terms of its bus patronage, while the Bay Bridge is unique in terms of the existence of a system of casual carpooling. To the extent that other HOV facilities can replicate these types of features, they will be more successful.

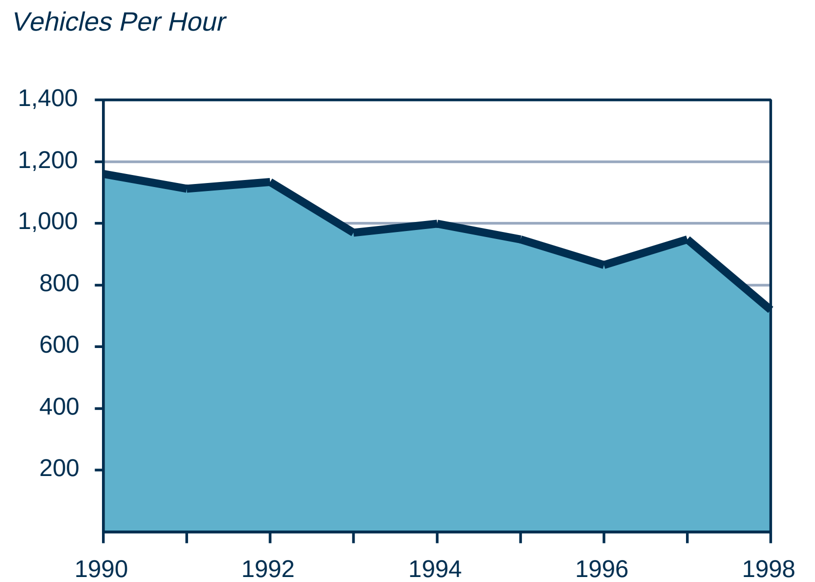
Usage Based on Vehicle Throughput

While person throughput is an important measure, HOV lanes should also be evaluated based on the number of *vehicles* they carry. This is because excess vehicular capacity in an HOV lane means that the lane is not fully utilized. For instance, while the El Monte busway carried about 49 percent of the people on the entire corridor in 1997, vehicular volume on this busway has been steadily declining over the last decade, as indicated in Figure 4 (see page 12). To the extent there is excess vehicle capacity on an HOV lane, both *vehicle* and *person* throughput of the lane can be improved. Given the limited capacity available on the state highway system, it is essential that the existing vehicle capacity of HOV lanes be used most efficiently.

Approximately 24 Percent of State HOV Lane Segments Fail Minimum Vehicle Throughput Criteria. According to vehicle counts conducted by Caltrans in 1998, about 76 percent of the state's HOV lane miles experienced volumes above 800 vph during peak hours in the peak commute direction. Thus, even during *peak* demand, 24 percent of the state's HOV lane miles fall short of Caltrans' minimum vehicle throughput criteria used to justify the original construction of HOV lanes.

Figure 4

Traffic Volume on El Monte Busway



On Average, Only Two-Thirds of HOV Lanes' Total Capacity Is Used. We estimate that in 1998, HOV lanes in California carried an average of about 1,095 vph during peak hours. This is approximately two-thirds of an HOV lane's maximum capacity (as set by Caltrans and CARB), or about half of a mixed-flow lane's capacity. These estimates are based upon annual traffic counts conducted by Caltrans, and are adjusted to reflect the differences in the length of HOV lane segments. (For instance, a 20-mile HOV lane segment would receive twice as much weight as a 10-mile HOV lane segment.) They are also adjusted for extreme low utilization in the noncommute direction in the San Francisco Bay Area and the San Bernardino regions. As a result, these figures are the most optimistic representation of HOV lane usage.

HOV Lane Usage Varies by Region and by Route. Our review indicates that usage of California's HOV lanes varies significantly, both by region and by route. For example, as indicated in Figure 5, in 1998 HOV lanes in the San Francisco Bay Area carried an average of about 930 vph during peak hours, while in Sacramento County, they carried an average of 1,240 vph, and in Orange County as many as 1,568 vph.

In addition to significant variation in usage across regions, there is also substantial variation in HOV lane usage *within* regions. Figure 6 shows the maximum and minimum HOV lane usage observed in regions with more than one HOV segment. In Los Angeles, where HOV lanes carried an average of 1,013 vph during peak hours in 1998, one segment carried over 1,457 vph, while another carried as few as 453 vph. Variations are even greater in the Bay Area, where one

Figure 5

Peak HOV Lane Volume by Region

1998

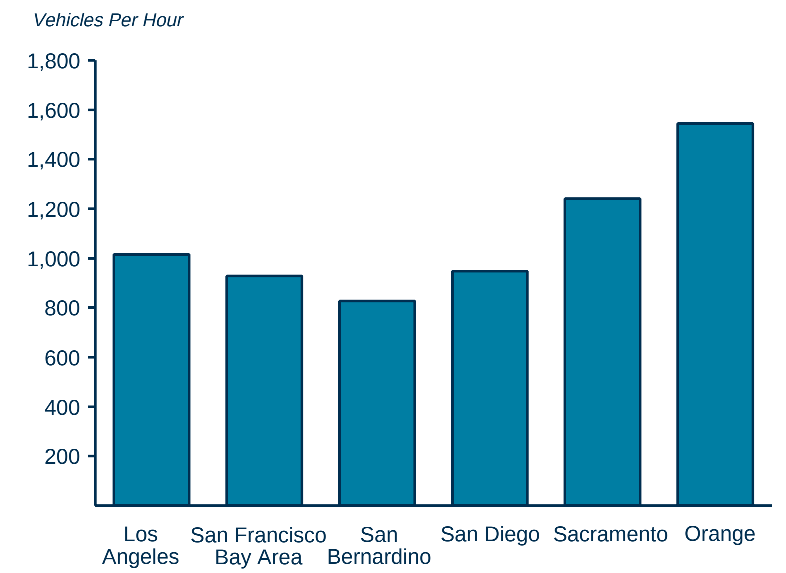
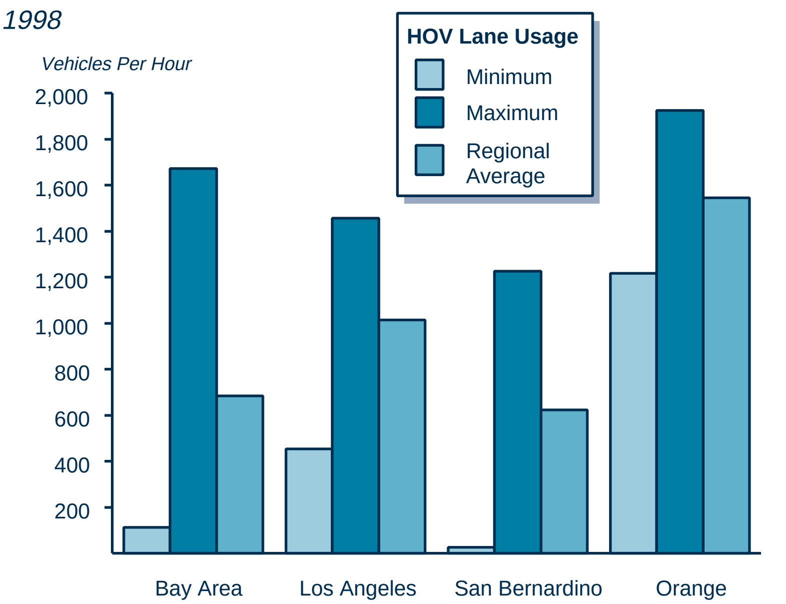


Figure 6

Variation in HOV Lane Usage Within Region

1998



segment carried as few as 112 vph, while another carried as many as 1,672 vph.

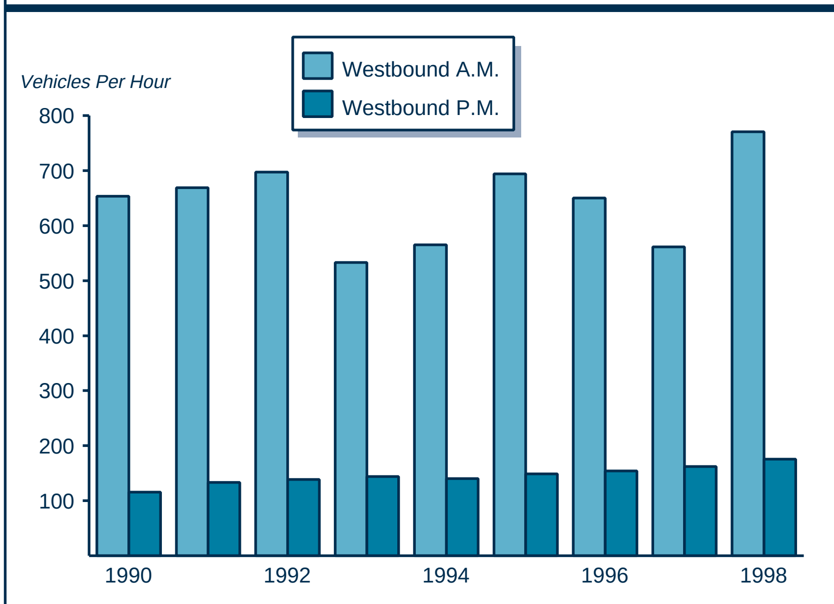
Differences in usage are driven by a number of factors. These include primarily the following:

- ***Direction and Hours.*** The HOV lanes are often highly underutilized in the off-peak direction or during off-peak hours. This is because, by definition, there is little time savings incentive to carpool when traffic is flowing smoothly in the mixed-flow lanes. For instance, Figure 7 (see page 14) illustrates the significant differences in vehicle counts during the morning versus the evening westbound commute on the San Francisco-Oakland Bay Bridge.

- ***Location.*** Studies have shown that HOV lanes are most effective when they provide time savings for commuting to and from work. Some HOV lanes may be located in areas where congestion is not yet "bad enough" to provide a sufficient time savings incentive to carpool. Some may be located in areas that are simply inconvenient for

Figure 7

Variation in HOV Lane Usage
San Francisco Bay Bridge



commuters in that particular corridor. Others may have been built in areas that are currently under development and are expected to receive higher utilization in future years.

- ***Commute Distance.*** Surveys have found a strong correlation between carpool lane usage and commute distance. To the extent that HOV lanes are located in areas where the average commute distance is relatively short (under 20 miles, for example), HOV lane usage can be expected to be lower than in areas where the average commute is longer.

HOV Lane Usage Does Not Necessarily Increase Over Time. One of the theories used to justify expanding the HOV system is that demand for HOV lanes increases over time as the system becomes more mature and integrated. The reasoning behind this theory is twofold: (1) people become accustomed to HOV lanes and make arrangements to form carpools; and (2) as the HOV system becomes more extensive, its convenience and time saving advantages increase, creating a greater incentive for motorists to use HOV lanes. Our review of vehicle throughput data in the San Francisco Bay Area, the Sacramento region, and the Los Angeles region, however, found that while *total* usage of HOV lanes has increased over time as the system has grown, the average number of vehicles using *specific* segments does not necessarily increase over time.

Figure 8 shows the average vehicle throughput of HOV lanes during peak hours in these areas from 1990 to 1998. The fluctuation in average volume (weighted by lane miles) that occurred in Los Angeles is the result of both a decline in volume on certain segments, as well as the addition of new HOV lanes which tend to have lower volumes in the first few years of operation. In the Sacramento and San Francisco regions volume has increased each year. Overall, the historical data suggest that Caltrans and RTPAs should not assume that demand for HOV lanes will simply grow over time. Instead, expansions to the HOV system should be based on consideration of the factors that influence demand for HOV lanes, such as proximity to business locations, time savings, length of commute, demand for (and availability of) transit service on the corridor, and overall willingness of commuters in the area to form carpools.

Incentives to Carpool

Statewide Impact of HOV Lanes on Ridesharing Is Difficult to Determine. In order to reduce congestion and improve air quality, HOV lanes must not simply divert existing carpoolers to the HOV lane, but must also generate *new* carpoolers. By providing travel time savings, HOV lanes are designed to give people an incentive to carpool. However, surveys have found that many carpoolers would ride together regardless of whether or not the HOV lane existed. The presence of the carpool lane simply causes them to drive in the HOV lane, as opposed to the congested mixed-flow lane. Evaluations based on throughput (person or vehicle) only measure the overall demand for HOVs versus SOVs, but not the *impact* of HOV lanes on carpooling.

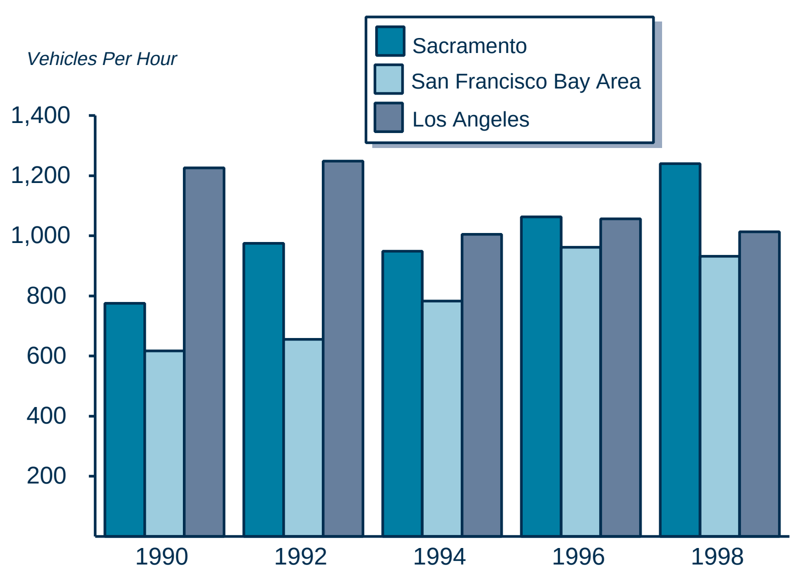
One way to measure the impact of HOV lanes on carpooling is to conduct surveys of drivers on a particular corridor over time. Although Caltrans does not conduct such surveys statewide, some regional surveys are conducted by various local agencies. For example, surveys of commuters in the San Francisco Bay Area provide some interesting findings on the factors that influence carpooling.

RIDES for Bay Area Commuters, Inc., which operates the Bay Area's Transportation Demand Management Program, conducts annual surveys of Bay Area commuters. In 1999, the survey found that 60 percent of carpoolers said that the existence of a carpool lane influenced their decision to carpool. Additionally, 64 percent said that they would discontinue carpooling if the lanes were eliminated, while another 26 percent were not sure what impact the elimination of carpool lanes would have on their behav-

Figure 8

Average HOV Lane Usage By Region

1990 Through 1998



ior. These findings suggest that HOV lanes play an important role in encouraging carpooling in the Bay Area.

Another survey conducted in 1995-96 for Caltrans, *also* focusing on the Bay Area, found that 31 percent of carpoolers in corridors with HOV lanes cited the existence of the lanes as the primary carpool incentive. The survey also found that about 22 percent of westbound San Francisco-Oakland Bay Bridge carpoolers reported that the availability of HOV lanes induced them to carpool regularly, while another 15 percent carpooled occasionally. In Santa Clara County, the survey found that about 27 percent of carpoolers formed a carpool as a direct result of the HOV lanes. Although we cannot project this regional data across the state as a whole, these findings indicate that carpool lanes at least in the Bay Area have a significant impact on the formation of carpools.

Decisions about carpooling are also affected by concerns about the cost of driving. According to the 1999 RIDES survey, the most important factor influencing commuters' decisions to carpool (cited by 18 percent of respondents) was not time savings, but rather cost savings (such as free toll, shared fuel, and parking costs). Traffic observations on the SR 91 toll lanes in Orange County also suggest that cost savings can be a strong incentive in inducing people to carpool. During the first three months of operation, HOVs carrying three or more occupants paid zero toll. Traffic observations for this period showed a greater than 40 percent increase in the number of HOVs carrying three or more people. These findings suggest that efforts to increase HOV lane usage through increased marketing should emphasize the cost savings, in addition to the time savings, of carpooling relative to driving alone.

Carpooling Has Increased on Freeways With Carpool Lanes, but Decreased or Remained Constant on Those Without. Caltrans has attempted to assess the impact of HOV lanes on ridesharing behavior by comparing the number of carpools on similar freeways with and without HOV lanes. According to Caltrans, freeways that have added HOV lanes, such as SR 210 and SR 110 in Los Angeles County, have experienced a significant growth (about 25 percent during the morning peak and 35 percent during the evening peak) in carpools from 1992 through 1997, whereas those that have no HOV lanes or have added only mixed-flow lanes or no lanes, such as SR 101 in Los Angeles County, have experienced either *no change* or a *decrease* in the number of carpools. Given the downward trend of AVO nationwide, it seems likely that the existence of carpool lanes on those corridors is an important reason for the increase in carpools.

Impact on Air Quality Unclear

Although generally believed to be beneficial, the impact of HOV lanes on air quality is unclear. While the mobile source reduction potential of HOV facilities must be documented as part of the State (air quality) Implementation Plan (SIP), this documentation is based entirely on models and projections, rather than actual emission data. This is due generally to an inability to measure emissions from specific vehicles driven in actual traffic conditions. Moreover, many of the variables critical to such models, such as the percentage of vehicles that shifted from SOVs to HOVs, are estimated based on very limited data.

There are other difficulties in estimating the impact of HOV lanes on air quality, depending on the baseline for comparison. For example, a new HOV lane may result in *higher* emissions compared to a no-build scenario, but lower emissions than a new mixed-flow lane. This is because HOV lanes that are *added* to the existing freeway capacity can be expected to increase demand for driving, albeit less so than construction of a new mixed-flow lane. On the other hand, increases in driving (or in VMT) do not necessarily result in higher emissions since emissions are a function of speed, as well as VMT. Finally, there is a potential negative air quality impact resulting from the congestion caused during the construction of the HOV lanes. Given these difficulties, more research is needed in order to determine the impact of HOV lanes on air quality.

Summary of Findings

Our review found that the *average* HOV lane in California carries 1,095 vph and approximately 2,518 persons per hour, during peak hours. These findings indicate that, on average, California's HOV lanes:

- Carry substantially more people than a *congested* mixed-flow lane and about the same number of people as a mixed-flow lane operating at *maximum* capacity.
- In terms of vehicles carried, however, California's HOV lanes are operating at only two-thirds of their capacity—a level that is equivalent to half of a mixed-flow lane's capacity under ideal conditions.

While our findings indicate that the common perception of HOV lanes as "empty" is not accurate, it also reveals that many HOV lanes in California have substantial unused capacity. This capacity could potentially be used by other vehicles (HOVs or SOVs) while still ensuring that vehicles in the lane are able to travel smoothly at 55 mph, providing a time savings incentive for motorists to carpool. Additionally, we find that about 24 percent of the state's HOV lanes do not meet Caltrans' minimum vehicle volume standard during peak hours.

In addition, our review found that HOV lanes do appear to have a positive impact on carpooling, although the statewide impact is unknown due to a lack of data. Finally, we found that the exact impact of HOV lanes on air quality, though widely believed to be positive, is unknown due to lack of actual emission data.

Evaluation of HOV Lanes Inadequate

Despite current law's clear articulation of goals, Caltrans does not adequately evaluate HOV lanes to determine how successful they are at achieving these goals. While Caltrans requires that each of its district offices operating HOV lanes publish an annual report on the usage of the lanes, our review found that not all districts comply with this requirement. For example, District 4 in the Bay Area has published a detailed HOV annual report since 1990 whereas District 8 (San Bernardino County), District 11 (San Diego County), and District 12 (Orange County) had little if any data available prior to 1998 despite each having operated HOV lanes for the last five years.

In order for the state to determine how to make better use of HOV lanes, Caltrans should:

- Establish uniform data collection methodologies and reporting requirements.
- Conduct before and after vehicle and occupancy studies on new HOV facilities to determine the impact of the lanes on carpooling. Such data should be included in the department's annual reports on HOV lanes.
- Report on lanes that do not meet the 800 vph requirement and recommend steps to increase utilization or convert to mixed flow.

In addition, Caltrans should conduct periodic statewide surveys of commuters to determine the factors influencing the public's decisions to drive, carpool, use transit, or other modes of transportation. Such surveys are the most appropriate way to assess how effective HOV lanes are in encouraging carpooling and the factors that influence HOV lane usage.

OPTIONS FOR CALIFORNIA'S HOV LANES

Although many of California's HOV lanes can be considered successful from the perspective of vehicle and person throughput, others are substantially underutilized. This section discusses the various options available to make better use of the state's HOV lanes.

One option currently used by Caltrans which may warrant greater application is to adjust the hours of operation to better reflect demand. In this connection, Caltrans and RTPAs should take a flexible, experimental approach to optimize HOV lane usage. Modifications to HOV lane operations should be based not only on consideration of the long-term impact on congestion and air quality, but should also give adequate attention to short-term benefits. For example, a temporary reduction in the hours of operation today may be worthwhile even if longer hours will be needed in several years when demand for the HOV lane increases.

As part of the effort to increase people throughput on HOV lanes, Caltrans and RTPAs should take an active interest in promoting bus service on HOV lanes where demand for such service can be demonstrated. The example of the El Monte busway, discussed previously, demonstrates the potential of HOV lanes to carry significant numbers of people, when coupled with frequent bus service. Since HOV lanes virtually guarantee a congestion-free ride, they play a very important role in the reliability of bus service, known to be a critical factor in influencing a person's decision to use transit.

Other options, discussed below, include increased outreach and marketing of HOV lanes, high occupancy toll (HOT) lanes, and conversion to mixed-flow lanes.

Promote Ridesharing and Park and Ride Facilities

Until 1996, the state provided grants to regional agencies to promote carpooling as part of the Transportation Demand Management program. The grant funds were used to provide motorists access to and information about carpools and vanpools as an alternative to driving alone. State funding for the rideshare program, which ranged from about $14 million to $40 million annually was eliminated in 1996-97. This was due to two factors: (1) Chapter 607, Statutes of 1995 (SB 437, Lewis) removed the state requirement that California employers adopt trip reduction programs; and (2) a survey found that only 2 percent of rideshare applicants actually changed their transportation choices to utilize rideshare services. As a result, funding for ridesharing promotion is now the responsibility of the RTPAs.

While a variety of funds (state and federal) may be used to promote ridesharing, RTPAs must now choose between funding rideshare programs and other transportation priorities, including highway construction projects and any projects related to air quality improvements such as transit capital enhancements. Our review shows that since becoming a regional discretionary program, overall funding for rideshare promotion has declined substantially—by over 50 percent. This decrease in funding may have resulted in less awareness of commuter services. For instance, according to the 1999 RIDES survey, awareness of the RIDES program and commuter information services peaked in 1992 when funding was twice the existing level, and reached a low in 1999.

In addition to rideshare programs, HOV lane performance is also affected by the availability and condition of facilities that support HOV lane usage such as transit service and park and ride lots. According to Caltrans, there are approximately 450 park and ride lots statewide. Of these, 210 are owned by Caltrans, 120 by local government or transit agencies, and the remaining 120 are owned privately. Caltrans is planning to expend over $1 million for additional park and ride lots over the next several years. According to Caltrans, about 62 percent of available park and ride spaces were used in 1994 (the last year for which data are available), and the extent of use appears to be declining. It is not clear what accounts for this decline, but Caltrans cited the lack of promotion as one possibility. Other possible explanations may be inconvenient location or inaccessibility by transit. In order to better manage these facilities, Caltrans should conduct annual reviews of their usage.

As long as HOV lanes continue to be state policy, Caltrans should pursue efforts to encourage carpooling and otherwise increase HOV lane usage. We recommend that Caltrans work with RTPAs and rideshare program managers to develop a statewide plan for carpool lane promotion. Additionally, the group should compile a set of performance measures and most cost-effective practices for carpool promotion and HOV lane usage. This information could be used in the future to evaluate funding proposals if the state were to establish a statewide grant program.

MAKING USE OF EXCESS CAPACITY: HOT LANES

In our 1998 report *After the Transportation Blueprint: Developing and Funding an Efficient Transportation System*, we recommended that legislation be enacted to authorize the construction (or conversion) of HOT lanes as a pilot program. HOT lanes provide an option to maximize usage of HOV lanes, while also relieving congestion in the mixed-flow lanes. Specifically, where HOV lanes have excess capacity, one option is to "sell" (by charging a toll) the additional capacity to noncarpool vehicles—SOVs or vehicles with two occupants, in the case of HOV lanes that require a minimum of three occupants.

These HOT lanes benefit users and nonusers alike. Specifically, HOT lanes:

- Offer motorists the option of paying to drive in a "congestion free" lane.
- Generate revenue which can be used to finance other transportation projects.

In order to maintain a free flow of traffic at all times, tolls on HOT lanes can be structured to vary according to the level of traffic in the HOT lane. As traffic volume approaches capacity, the

HOT LANE CASE STUDY: INTERSTATE 15 IN SAN DIEGO

The Interstate 15 (I-15) HOT lane is a federally funded, $9.95 million, demonstration project. The project began in 1991 when the San Diego Association of Governments (SANDAG) was developing air quality transportation control measures, in accordance with state and federal air quality regulations. At the time, the I-15 HOV lanes were underutilized, while the mixed-flow lanes on the corridor experienced severe congestion during peak traffic hours. There was also relatively little transit service operating on the corridor. In response, SANDAG proposed to implement a HOT lane with the following goals:

- Maximize the use of the existing capacity on the HOV lanes.
- Improve transit and HOV services along I-15.
- Relieve congestion along I-15.

California state law allows only vehicles of two or more occupants or motorcycles to use HOV lanes. In order to allow SOVs to use the I-15 HOV facility as a HOT lane, Chapter 962, Statutes of 1993 (AB 713, Goldsmith), authorized a four-year demonstration project from 1994 through 1998. This legislation also

HOT Lane Case Study: Interstate 15 in San Diego *(continued)*

required that the lanes maintain a particular traffic flow. Beginning in 2000, Chapter 481, Statutes of 1999 (SB 252, Kelley) will allow Caltrans and SANDAG to lower the traffic flow standard moderately and extends the project's sunset date though 2001.

Characteristics of the I-15 HOT Lane. The I-15 HOT lane facility consists of an eight-mile stretch of two lanes located in the freeway median. The lanes operate only during peak hours in the direction of the commute. From 5:45 A.M to 9 A.M., all vehicles in the two HOT lanes travel southbound, while from 3 P.M. to 7 P.M. they travel northbound. Entry and exit are restricted to the two endpoints of the facility. Use of the facility is free to carpools of two or more occupants, buses, and motorcycles, while a fee is charged to SOVs. Fees charged to SOVs are deducted from electronic transponders which are attached to a vehicle's windshield and allow for direct payment from a customer's account.

Congestion Pricing Enables Control of Traffic. The goal of the variable fees is to keep the lanes free-flowing while maximizing their use. Fees are set to maintain a specified traffic flow at all times. The fee, which ranges from 50 cents to $4, varies every six minutes according to the level of congestion in the lanes, as monitored by loop detectors in the pavement. The fee is displayed on electronic signs before the entry to the lanes and typically changes at 25 cent intervals. However, if traffic exceeds the specified traffic flow, such as after a severe accident, the fee may be raised to $8. If this fee is not sufficient to deter additional SOVs and maintain the traffic flow, the lanes are closed to SOVs. Revenues from tolls average about $5,000 per month and are used to finance transit service on the corridor.

Large Increase in Usage of Lanes. Currently, the I-15 project has issued over 6,700 accounts for SOVs with approximately 11,000 transponders in circulation. (Because each transponder is assigned to a specific *vehicle,* some customers, particularly private businesses, have more than one transponder.)

The SOVs currently represent about 20 percent of the total vehicles using the I-15 HOT lanes. Since their opening, daily traffic on the HOT lanes has increased by 53 percent, from 9,215 vehicles per day in October 1996, to 14,096 in July 1999. Interestingly, the additional vehicles on the lanes are primarily carpools and *not* SOVs. From fall 1996 to fall 1997, the average daily traffic volume on the mixed-flow lanes decreased by 2 percent in the morning peak period and 3 percent in the evening peak period.

Public Response Has Been Favorable. A 1997 survey by SANDAG of 1,500 commuters in the San Diego region, including 500 registered HOT lane customers, found that 89 percent viewed the program as a success. Additionally, over 70 percent of commuters felt that the program was fair to both travelers on the I-15 mixed-flow lanes and on the I-15 HOV lanes. Finally, no complaints have been received regarding the dynamic pricing structure.

tolls can be adjusted to deter entry by additional SOVs into the lane. This method of structuring the tolls, known as congestion pricing, ensures that the lane offers a faster and more reliable trip than the mixed-flow lanes. This is necessary in order for the lanes to preserve a time savings incentive to carpool and attract paying customers. Additionally, it provides an incentive for vehicles to use the lanes during off-peak hours. The HOT lane concept could also be restricted to certain types of vehicles, such as trucks or low emission vehicles. California's experience with congestion pricing and HOT lanes in San Diego (see box page 20), suggests that HOT lanes warrant further application on congested corridors that have substantial excess capacity on HOV lanes.

Are HOT Lanes Unfair? The most common objection raised against HOT lanes is that they unfairly discriminate against the poor, by restricting access to those who can afford to pay for them. Recent surveys support the view that HOT lane users are likely to have higher incomes than non-HOT lane users. A 1997 SANDAG survey found that SOV users of the I-15 HOT lanes typically have higher incomes, more years of education, and are more likely to be homeowners than drivers in the I-15 mixed-flow lanes.

A survey of the users of the SR 91 Express lanes in Orange County (where all users, including HOVs are charged a toll) had similar findings. The 1997 SR 91 survey found that high-income commuters were twice as likely as low-income commuters to be frequent users of the toll lanes—23 percent compared to 10 percent. Although this clearly indicates a relationship between income and frequency of toll lane use, the survey also found that 25 percent of the lowest income travelers (with a household income of less than $25,000) make frequent (defined as 40 percent or more of their trips on the corridor) use of the toll lanes, while 50 percent of the highest income travelers (with a household annual income of over $100,000) never or infrequently use the toll lanes.

In addressing the question of fairness, subsidies or reduced toll rates could be provided to low-income drivers to ensure that they have equal access to congestion-free lanes. However, providing a subsidy or reducing tolls for low-income drivers could undermine the cost-saving incentive to carpool. It is important to note that although HOT lanes only grant access to SOVs that are willing or able to pay, they remain free for carpoolers. Additionally, HOT lanes benefit both their users as well as other vehicles in the mixed-flow lanes. This is because vehicles using the HOT lane free up room in the mixed-flow lanes for other motorists.

Conversion to Mixed-Flow Lanes

Where HOV lanes are greatly underutilized, one option is to convert them to mixed flow. This option should be considered when congestion is not present in the mixed-flow lanes and traffic projections indicate that neither demand for the HOV lane nor congestion is likely to increase in the near term. This was the case in a recent decision by the Metropolitan Transportation Commission to decommission an HOV lane on I-580 which typically carries fewer than 300 vph.

In this case, the HOV lane offered no substantial time savings since there is no significant congestion in the mixed-flow lanes. Moreover, traffic forecasts indicate that congestion in this location is not expected over the next 20 years. Although the HOV lane did not impede traffic flow in the mixed-flow lanes, high violation rates and low HOV volumes in the lanes led the commission to conclude that conversion to mixed-flow lanes was the best solution to underutilization.

Congestion Relief From Conversion Is Probably Short-Lived. The impact of conversion is more problematic in areas where HOV lanes are underutilized *and* the mixed-flow lanes are congested. While conversion would likely result in some immediate congestion relief by allowing all vehicles to use the lane, evidence suggests that this relief would be only temporary. This is because conversion to mixed flow would induce a net gain in traffic volume on the corridor, resulting from a combination of carpools disbanding and reverting to SOVs, and additional drivers using the corridor who want to take advantage of the new capacity.

This conclusion is based on the theory of induced travel demand which holds that in the long run (five years or more), expansion of the transportation system rarely alleviates congestion because increases in the system's capacity are subsequently consumed by drivers' demand for better mobility. Recent studies have found evidence to support this view. A 1995 study at UC Berkeley, based on annual data from 30 California urban counties from 1973 to 1990, found that a 1 percent increase in lane miles induces a 0.9 percent increase in VMT in metropolitan areas within five years. Another study conducted by the EPA in 1999 found that about 25 percent of new VMT can be attributed to induced demand. Taken together, these findings suggest that conversion of the state's HOV lanes to mixed-flow may provide short-term congestion relief, but would be unlikely to provide long-term benefits.

State Does Not Have Authority to Unilaterally Convert HOV Lanes to Mixed-Flow. HOV lanes are often approved as specific transportation control measures in the SIP. As a result, conversion of HOV lanes to mixed flow would require that the impact on regional air quality of such a conversion be assessed, in order to ensure the continued viability of the SIP. Any reevaluation of air quality conformity of the SIP would require input and review by multiple agencies, including Caltrans, RTPAs, air quality management districts, CARB, FHWA, and the EPA. Additionally, where exceptions to design standards have been granted by FHWA for HOV lanes, conversion to mixed-flow lanes would require reassessment by FHWA of the design standards. As a result, the state does not have the authority to unilaterally convert existing HOV lanes to mixed-flow lanes.

Similarly, on projects where federal funds were used, the state cannot convert HOV lanes to mixed-flow lanes without FHWA approval. Because many HOV lane segments have been constructed using federal funds for congestion mitigation and air quality improvement, conversion to mixed-flow lanes would disqualify the project from using these funds. The amount of any payback of federal funds would be determined by FHWA on a case-by-case basis. Caltrans estimated that the amount could be over $2 billion if all HOV lanes were converted to mixed flow. The FHWA agreed to waive repayment of the federal funds used to construct the HOV lanes in New Jersey. However, this was a one-time waiver and does not indicate a general policy with respect to HOV lane conversion. Thus far, it appears that exceptions would be granted by FHWA for HOV lanes which, after operating for five years, carry fewer person-trips than a typical mixed-flow lane.

CONCLUSION

HOV lanes are currently one of the primary tools that the state uses to relieve congestion and improve air quality. Given annual increases in congestion and plans to double the number of HOV lanes over the next 20 years, we recommend that the Legislature, Caltrans, and RTPAs consider the options outlined above. This should help to ensure that the freeway capacity utilized by HOV lanes is managed most efficiently and that any expansion to the HOV lane system be closely tied to evidence that the lanes are achieving their goals.

Index to Acronyms

AVO	Average Vehicle Occupancy
CAAA	Clean Air Act Amendments
CARB	California Air Resources Board
CMA	Congestion Management Agency
EPA	United States Environmental Protection Agency
FHWA	United States Federal Highway Administration
HOT	High Occupancy Toll
HOV	High Occupancy Vehicle
ILEV	Inherently Low Emission Vehicle
MTC	Metropolitan Transportation Commission
NJDOT	New Jersey Department of Transportation
RTPA	Regional Transportation Planning Agency
SANDAG	San Diego Association of Governments
SIP	State Implementation Plan
SOV	Single Occupancy Vehicle
TCM	Transportation Control Measure
TDM	Transportation Demand Management
ULEV	Ultra Low Emission Vehicle
VMT	Vehicle Miles Traveled

Acknowledgments

This report was prepared by Rebecca Long, under the supervision of Dana Curry. The Legislative Analyst's Office (LAO) is a nonpartisan office which provides fiscal and policy information and advice to the Legislature.

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