# High Occupancy Vehicle Lanes

# High Occupancy Vehicle Lanes

## ■ Introduction

High occupancy vehicle (HOV) Lanes give priority to buses, carpools and vanpools, providing two important incentives for people to travel by HOV:

- Travel time savings; and
- Trip time reliability.

Well-designed, appropriately-sited HOV lanes have been shown to significantly increase transit use and car occupancy for the journey to work in congested urban travel corridors. This, in turn, results in reduced vehicle trips and vehicle-miles traveled. HOV lane improvements are most effective when implemented as a regional network of linked lanes , with a system of supporting facilities and services.

## ■ Definition of Measures

High Occupancy Vehicle Lanes can be divided into <u>freeway</u> and <u>arterial</u> facilities, and include the following types:

**Freeway HOV Facilities**
(1) Exclusive, in a separate right of way
(2) Barrier or buffer-separated
(3) Concurrent-flow (no physical separation)
(4) Contra-flow
(5) Queue bypass

**Arterial HOV Facilities**
(1) Concurrent-flow
(2) Contra-flow
(3) Median
(4) Bus street
(5) Bus tunnel

High occupancy vehicle lanes, designed to documented standards (1), typically are planned, designed and constructed in a 3 to 8-year time frame. The potential need to acquire land to implement the HOV lanes often determines the facility's feasibility and the time required to implement the project.

The primary purpose of HOV facilities is to increase the people-moving versus the vehicle-moving capacity of a highway. The HOV lane is typically opened to buses and other vehicles with 2 or 3 plus occupants, although some are exclusive to buses. HOV facilities have been implemented throughout the United States and represent an established method for improving the efficiency of an existing roadway corridor or system by offering reduced travel times for commuters. In 1989, there were 38 freeway HOV facilities operating in 18 U.S. metropolitan areas (18). HOV facilities such as the Shirley Highway in Northern Virginia, Oakland Bay Bridge in California and the I-495 Contraflow Lane in New York carry more people per HOV lane than in all the remaining general purpose lanes of the highway facility.

Many planned and operating HOV facilities are oriented to serve the major downtown core of a metropolitan area along radial corridors. These facilities usually are in operation during the peak morning and afternoon periods and primarily serve the downtown oriented work trip. In several regions, the scope of HOV facilities is being expanded to address regional problems of suburban mobility, congestion, and air quality. In Portland, Seattle and San Francisco, analyses suggest that other transportation management measures such as park-and-ride lots, employer-based transportation (vanpool and carpool) programs and commuter parking subsidies can have an important role in supporting the level of HOV lane usage.

## ■ Examples

### San Francisco Bay Area HOV Lane Plan

The Metropolitan Transportation Commission (MTC) adopted a "2005 HOV Lane Master Plan" in May 1990 (13). The Master Plan is intended as a first step in the development of a comprehensive plan to promote high occupancy vehicles (HOV) in the Bay area. The plan's primary objectives are to reduce single occupant vehicles (SOV) and to provide an effective method to improve air quality. The Bay Area currently has seventy-seven miles of HOV lanes in operation. The plan proposes two additional phases that include 140 miles of HOV lane by 1995 and 190 miles more by 2005.

A follow-on planning effort involved the prioritization of the identified regional HOV lanes and provided a substantial amount of research and analytical work concerning the applicability and effectiveness of HOV lanes (4). Included in this work are draft implementation standards; and guidelines for prioritizing specific HOV lanes and various facilities such as park-and-ride lots, vanpool and carpool programs and other employer based transportation programs.

The project investigated several germane issues including:

- How usage of an HOV lane is affected by the amount of travel time savings;
- How travel time savings vary by the type of HOV lane implemented;
- How such support facilities as park-and-ride lots, employer-based transportation programs and commuter parking subsidies may further increase use of the HOV lane facility; and
- How HOV lanes and nearby transit services may interact to affect the overall effectiveness of both services.

The project determined that an overall trip travel time savings of less than five minutes would not generate much HOV formation. It was determined that HOV formation increases very significantly when the HOV lane facility reduces trip times by fifteen minutes. Additional research determined that different types of existing HOV lanes provide varying amounts of time savings with unseparated, concurrent flow facilities generating the least at about 0.5 minutes per mile and exclusive HOV right of way lane facilities the most with about 1.5 to 2.0 minutes saved per mile.

The analyses indicated that several types of support facilities and programs would further enhance the usage of a system of HOV lanes. Particularly useful are park-and-ride lots, employer-based transportation programs (ridematching, vanpool and carpool programs) and reducing commuter parking subsidies. The data indicated that park-and-ride lots should be larger (greater than 300 spaces), located near the HOV lane interchange and not charge a parking fee. Under these circumstances, the data indicated that a park-and-ride facility could reduce travel times by about 8 minutes and would boost HOV lane peak hour ridership by as much as 50%.

Surveys indicated that there is a strong relationship between HOV lane usage and employer programs to reduce use of single-occupant vehicles (SOV). In the Bay Area, such programs resulted in up to 24% of all first year employees changing to non-drive alone commuting (4). The research shows that the most sensitive variable influencing HOV lane usage is the availability and level of subsidy provided to employees for a parking space. Elimination of employee parking subsidies in San Francisco (so that the employee would have to pay market rates for the space) could reduce peak period vehicle trips to the downtown by 10% to 15%, with the majority of these trips using an HOV lane facility. In surveys in Los Angeles, Boston, Hartford and Ottawa, companies providing a substantial parking subsidy (65% to 100%) experienced drive alone commuting exceeding 65%. Companies that dropped employee parking subsidies worth more than $50 experienced drops in drive alone commuting to below 40%.

One other interesting feature of the San Francisco Bay Area analysis involved the application of 2 plus versus 3 plus occupants per vehicle as the requirements for HOV lane usage. The analysis indicated that 3 plus occupants per vehicle should be applied in (radial) corridors that include rail transit lines within several miles of the HOV lane facility. In other cases, 2 plus occupants per vehicle could be applied if capacity of the

HOV lane allows. Analysis in San Francisco (substantiated by similar research in Boston) indicated that an HOV lane used by 2 plus occupants per vehicle can lead to a substantial number of diversions from nearby (rail) transit services, at least in the short term. (This would also be true for local and express bus services that do not use the lane facility and provide competing origin to destination service.) The data indicate that overall vehicle trips might actually increase under these conditions since formation of a two person carpool is considerably easier than formation of a three person carpool. Under these conditions, transit could be particularly susceptible to losing ridership to two person carpools.

## The Houston HOV Facility System

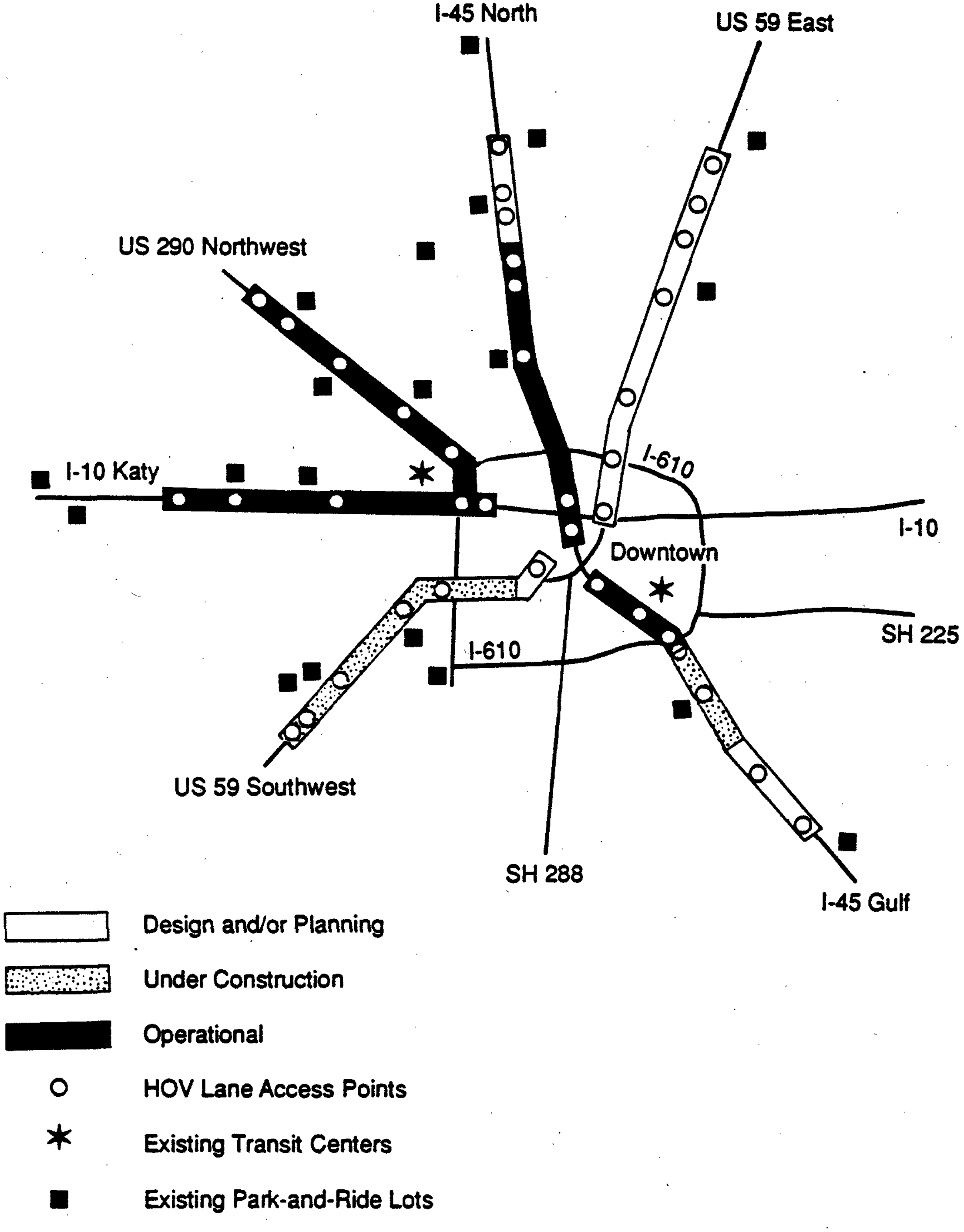
The Houston, Texas high occupancy vehicle lanes represent the most extensive network of barrier-separated HOV lanes in the country (17). As of 1990, almost 47 miles of a planned 95.5 mile system were in operation (Figure 1). Designed and operated to provide preferential treatment for buses, vanpools and carpools, the HOV lane system is an important approach to managing traffic congestion and mobility problems. While air quality was a secondary motivation for constructing the Houston HOV lanes, passage of the 1990 Clean Air Act Amendments and Houston's classification as a "severe" non-attainment area for violation of National Ambient Air Quality Standards for ozone has brought a new interest in the potential of the HOV lanes to reduce automotive emissions.

HOV lanes currently are in operation in four major freeway corridors in metropolitan Houston, and an HOV lane is under construction in a fifth corridor and in the design stage in a sixth. The development and operation of this HOV priority system have been the result of a joint effort between the Metropolitan Transit Authority of Harris County (METRO) and the Texas State Department of Highways and Public Transportation. These two agencies have used a variety of funding sources and have established a coordinated and flexible working relationship to develop and operate the system.

In each corridor of the Houston system, there are several large park-and-ride lots, most having more than 1,000 spaces. Some of these lots are located at access points to the HOV lanes, with elevated ramps providing a direct connection from the park-and-ride lot to the HOV lane. Transit centers, as well, are located at access points, and these are served by multiple bus routes with short headways. On the I-45 North facility, for example, there are 128 scheduled buses in the peak period, and 75 in the peak hour. Access to this bus service is primarily through park-and-ride. Experiments in local "feeder bus" service have resulted in low patronage.

The types of vehicles allowed to use the HOV lanes, as well as the required number of persons per vehicle, have changed on several occasions. As of 1990, with one exception, vehicles with 2 or more persons are allowed to use all of the HOV lanes during the operating hours, which on weekdays are 4 a.m. to 1 p.m inbound and 2 p.m. to 10 p.m

**Figure 1. Status of Houston Transitway Development, September 1990**



outbound. The exception to this rule is the Katy Freeway HOV lane, where usage is restricted to vehicles with 3 or more persons during the morning peak hour. The occupancy requirement was increased from 2+ to 3+ in October 1988 to reduce the a.m. peak hour congestion that was occurring on this facility as a result of increased carpool volumes. This increase in the occupancy requirement restored the high speeds and reliable trip times that are important to HOV lane success.

The estimated capital cost of the entire 95.5-mile HOV facility system in Houston is $830 million, or approximately $8.7 million per mile. Included in this total is the cost of most of the major support facilities, including transit centers and park-and-ride lots. In general, costs are reduced by locating the HOV lanes in available highway rights-of-way, and constructing the lanes in conjunction with major highway projects.

A primary goal of the Houston HOV system is to increase person movement in congested travel corridors by providing incentives for people to travel by bus, vanpool or carpool. With about half of the planned system operational, it has been possible to measure whether this goal is being achieved. In 1990, the HOV system served about 63,000 daily person trips, of which 40% were bus transit riders, and 60% were in carpools and vanpools. On the two facilities that are substantially complete, the Katy and Northwest, bus ridership has increased by 345% and 135%, respectively, from the pre-HOV to the post-HOV 1990 condition. In the same period, bus ridership declined by 6% in the Southwest freeway corridor, which has no HOV lane. Car occupancies have increased as well, growing by 20% in the peak hour on freeways with HOV lanes. In sum, during the a.m peak hour, about 14,000 people travel in 3,400 vehicles on the four lanes of the Houston HOV facilities. During the same peak hour, on the 13 parallel unrestricted freeway lanes, about 27,000 people travel in 24,000 vehicles. The 14,000 people using the HOV lanes have free-flow, 55 MPH travel conditions, while the 27,000 people on the unrestricted lanes experience typical peak hour urban freeway congestion.

## New York City Bus Lane Program

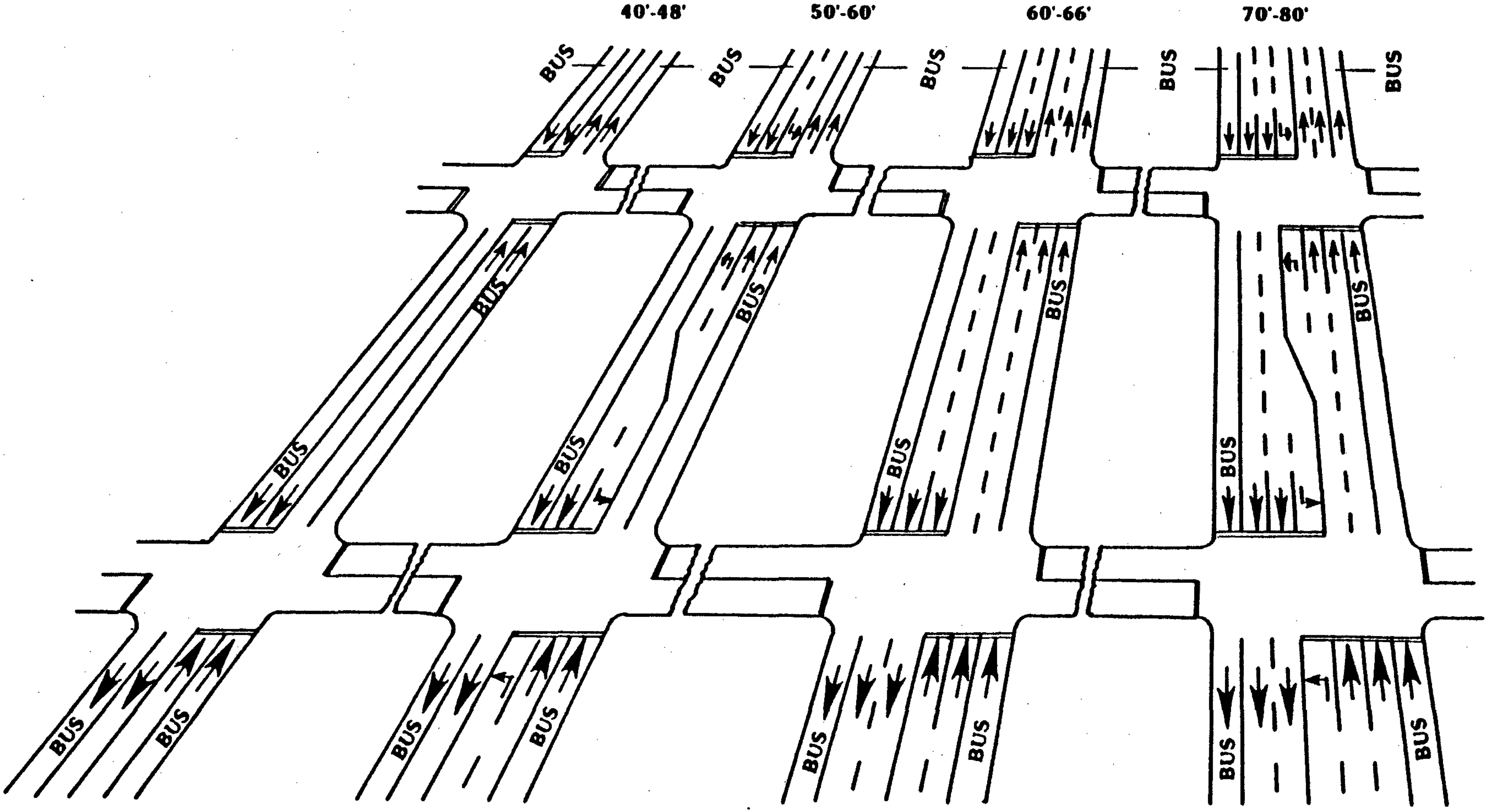
The New York City Department of Transportation has developed and implemented an extensive bus lane program throughout the city (14,16). The concept is to give priority to the bus as the most efficient mover of people on city streets (Figure 2). The concept is implemented through a variety of techniques, assigning priority to buses as follows:

- **Red Zone Bus Lanes**: The right hand lane is devoted to buses and right-turning vehicles, and is marked with a red line along the curb. Violators are subject to large fines and towing charges.

- **Curbside Bus Lanes**: Only buses and right-turning vehicles are allowed in the right lane.

- **Exclusive Lanes**: One or two lanes are devoted exclusively to buses, and separated physically from other traffic by cones, stanchions or heavy markings. These include contra-flow lanes.

Figure 2. Normal Flow Curb Bus Lane Designs for Two Way Streets



*Notes: Prohibit right turns from bus lane whenever possible. Left turns may be permitted where traffic conditions warrant. Reference 10.*

- **Transit Streets**: An entire street is devoted to transit operations, with some access maintained for goods movements and garage entries.

- **Queue Bypass Traffic Signals**: These allow buses to bypass waiting traffic at certain high-use intersections, providing substantial time-savings.

The New York City bus lane program increases the people-moving capacity of the city street system by reducing travel time and increasing transit use. By separating buses from other traffic, the bus lanes also have the effect of improving traffic flow in general. Since they increase transit use and reduce traffic congestion, bus lanes contribute to the improvement of air quality in New York City. The Red Zone Bus Lane program, in fact, was first implemented in 1982 as part of New York State's SIP, and in response to U.S. Court of Appeals orders that New York State and City comply with the Clean Air Act. At that time, the city also implemented other related actions to improve air quality, including elimination of the ability for public parking lots to be built in downtown and mid-town Manhattan without city review or permission, and elimination of required accessory parking for new residential developments.

Currently, there are 30 miles of street within New York City that have bus lanes. They operate from several hours a day to 24 hours a day. In total, these lanes carry 10,700 daily bus trips, and 415,000 daily passenger trips. Following are capsule summaries of some of the individual facilities:

- **2nd Avenue Contraflow Bus Lane**: Established in 1978, it extends approximately one mile from E. 57th Street to the Queensboro Bridge, servicing 17 bus routes during the weekday evening rush period. Up to 10 minutes are saved each day for 210 buses carrying 8,000 passengers.

- **Madison Avenue Dual Bus Lanes**: Established in 1981 as the city's first dual bus lane, it operates from E. 42nd St. to E. 46th St. on weekdays from 2-7 p.m. 35 bus routes, 700 buses, and 27,000 riders experience travel savings of up to 20 minutes daily. Local buses using the facility increased ridership 7% while citywide patronage was declining.

- **49th-50th Street Transit Corridor**: This transit street improvement was introduced in 1979 and upgraded in 1986 on two city streets that are historically slower than almost any other crosstown street. 410 buses carrying 14,000 passengers have daily time savings of over 30%, and bus on-time performance has been substantially improved.

- **Long Island Expressway Contraflow Bus Lane**: This was implemented in 1971, and operates westbound between 7 and 10 a.m. from the Brooklyn-Queens Expressway for about 2.2 miles into the Queens-Midtown Tunnel. 400 buses carrying 19,000 passengers save about 20 minutes each by using this bus lane.

- **Fulton Street Pedestrian/Transit Mall**: Completed in 1984, this transit mall runs for approximately 1/2 mile from Flatbush Ave. to Boerum Pl. Use of the facility is exclusively for pedestrians, buses, taxis and local deliveries, 24 hours a day. Daily, 1,430 buses carrying 37,200 passengers travel along the mall and benefit from reliable travel times.

## Travel Impacts

High occupancy vehicle lanes usually have been implemented to increase person movements in congested travel corridors. When they are properly planned and situated, they do this effectively, producing increased car occupancies and transit use, and fewer vehicle trips and miles of travel (VMT) than the addition of conventional highway capacity. Table 1 is taken from the "Description of High-Occupancy Vehicle Facilities in North America" (18) and shows the important results that HOV lanes can have on person carrying capacity and on vehicle occupancy. The facilities cited in the table have been well documented and represent corridors exhibiting very high and worsening levels of congestion and delay. Case studies for these facilities and others indicate that, in congested travel corridors, implementation of HOV lanes results in increased person volumes without corresponding increases in VMT.

### Congestion and Travel Time Delay

The amount of congestion and travel time delay are critical factors in determining HOV lane usage. Recent studies in Seattle, Washington indicated that the cost savings per commuter using a newly constructed HOV lane compared with no new construction resulted in a benefit-to-cost ratio greater than six to one, derived primarily in the form of travel time savings. A recent paper published by the Institute of Transportation Studies at the University of California suggests that "the single most important predictor of success of an HOV lane is its ability to generate travel time savings to HOV users." In a 1984 survey of the El Monte busway in California, travel time savings of 5 minutes or less were shown to have little or no affect on HOV formation. Following-up on this survey, data were developed as part of a 1988 Institute of Transportation Engineers (ITE) study that determined that different types of HOV lane facilities vary in the amount of travel time savings that they provide and therefore have different levels of effectiveness (Table 2).

The analysis undertaken for the San Francisco Bay Area HOV Lane Master Plan study confirmed that different types of HOV facilities achieve different amounts of time savings. Analysis of the list of the candidate new HOV lane facilities identified in the Master Plan estimated a range of time savings from only 1 minute to nearly 20 minutes. The prioritization study developed a rating system to prioritize these projects and included such other criteria as cost and environmental factors. The results of this prioritization, however, showed that all HOV lane facilities having a forecast travel time savings of less than 10 minutes were listed in the bottom priority category.

# Table 1. Impact of HOV Facilities on Person Movement and Vehicle Occupancy

| | HOV Facility | | | | Gen. Purpose Lanes | | |
|---|---|---|---|---|---|---|---|
| | Buses | Cars/ Vans | People | Avg. Occup. | Veh. | People | Avg. Occup. |
| Shirley Highway (No. VA) | | | | | | | |
| (peak period) | 441 | 4,800 | 34,200 | 6.5 | 23,500 | 28,200 | 1.2 |
| (peak hour) | 161 | 2,300 | 15,100 | 6.1 | 8,700 | 10,400 | 1.2 |
| I-495 Contraflow Lane (NYC) | | | | | | | |
| (peak period) | 1,640 | - | 65,600 | 40.0 | 17,400 | 29,100 | 1.7 |
| (peak hour) | 725 | - | 34,700 | 47.9 | 4,500 | 7,400 | 1.6 |
| I-10 Katy Transit Way (Houston) | | | | | | | |
| (peak period) | 92 | 2,600 | 9,100 | 3.4 | 16,500 | 18,200 | 1.1 |
| (peak hour) | 46 | 1,000 | 4,400 | 4.2 | 5,300 | 5,700 | 1.1 |
| I-5 Flow System (Seattle) | | | | | | | |
| (peak period) | 146 | 800 | 7,900 | 8.4 | 20,700 | 25,400 | 1.2 |
| (peak hour) | 64 | 500 | 3,700 | 6.6 | 7,700 | 9,500 | 1.2 |
| San Bernadino Fwy (LA) | | | | | | | |
| (peak period) | 132 | 2,500 | 13,200 | 5.0 | 16,500 | 19,300 | 1.2 |
| (peak hour) | 71 | 1,400 | 7,100 | 4.8 | 8,400 | 9,500 | 1.1 |

Source: A Description of High-Occupancy Vehicle Facilities in North America (18).

## Table 2. HOV Lane Effectiveness by Type of Facility

| Type of Facility | Time Saved per Mile |
|---|---|
| 1. Concurrent Flow, Unseparated Shoulder Lane | 0.5 minutes |
| 2. Concurrent Flow, Unseparated Median Lane | 0.4 to 1.1 minutes |
| 3. Exclusive, Separated Lane in Freeway | 1.3 to 2.1 minutes |
| 4. Tunnel and Bridge Lane Approach | 8.9 to 11.2 minutes |

Reference (9).

### Interaction with Existing Transit Service

Studies for new HOV lanes should carefully consider the potential impacts on existing transit service in the corridor, especially if that service is fixed rail or express bus that could not use the new HOV facility. Work in Boston for the Southeast Expressway HOV Lane study and in the San Francisco Bay Area for the HOV Lane Master Plan study showed that HOV lanes located along radial corridors within 2 or 3 miles of a major line haul transit service have the potential, at least in the short term, to divert existing transit users in sufficient numbers so as to off-set any reduction in vehicle trips or miles. Both studies showed that transit users are much more likely to form carpools if the HOV lane facility will allow carpools of 2 or more persons rather than 3 or more persons.

The experience in Houston, on the other hand, shows that the introduction of HOV lanes can lead to increases in both transit use and carpooling, under both HOV-2 and HOV-3 rules. In the Houston case, the HOV lanes function as transitways used by corridor express bus service.

There also is evidence that long-term effects may be different than the short-term impacts, reflecting the synergistic effects of different program elements, the results of marketing and promotional programs, and evidence indicating that the effects of a HOV facility as psychologically perceived by a user may be larger than the actual changes. Experience with the San Bernardino Freeway Express Bus (I-10) in Los Angeles provides an example. When the lane was first opened to 3+ HOV vehicles, there was initially no shift of bus riders, but a 10% drop occurred when bus fares increased from $.50 to $.80 in mid-1977. However, most of the lost ridership was regained by February 1978. During the first year of joint use, the efficiency of the busway doubled with total person-trips increasing from 5,000 to 10,000 trips per day by November 1977. Each mode averaged 1,200 person-trips per hour during peak periods. After 15 years of operation, the "El Monte Busway" continues to have a high level of transit ridership, although 2+ carpools are also allowed to use the bus/HOV lane.

## ■ Air Quality Impacts

The impacts of HOV lanes on air quality are more complex and less studied than are HOV travel impacts. There are a number of key factors to be considered in evaluating how effective HOV lanes may be in reducing emissions. These are discussed below, followed by estimates of emission reductions from each of the prior examples of HOV facilities, and, finally, discussion of guidance produced by the California Air Resources Board.

Travel demand assessments of how well HOV lane facilities reduce system-wide emissions have indicated that reductions would amount to less than 1%. For example, work in Sacramento by the Sacramento Area Council of Governments, in Los Angeles by the Southern California Association of Governments and in Phoenix by the U.S.

Environmental Protection Agency all indicate that the regional effects on emissions of any one HOV lane facility may be of this order of magnitude. Corridor emission reductions of a single HOV lane, however, may be much greater, and more recent research has shown that larger systems of HOV facilities may have correspondingly more significant impacts on regional emissions.

Use of HOV lanes can result in lessened air pollution emissions in two ways: reduction in running emissions, and reduction in trip end emissions. HOV lanes achieve reductions in running emissions because of increased use of buses, vanpools and carpools, resulting in fewer vehicle miles traveled, and because of higher speeds associated with uncongested operations in the HOV lane. HOV lanes also reduce trip end emissions; however, it is necessary to take into account that many users of HOV lanes meet their pool or bus through a park-and-ride arrangement.

Trip-end emissions result from the initial inefficient engine operation when the trip begins (cold start) and evaporation of fuel from a hot engine at the end of the trip (hot soak). Both cold starts and hot soaks occur for even a short auto trip between home and a park-and-ride lot. Trip-end emissions are a significant component of all automotive emissions, comprising 75% of a 5 mile auto trip, 61% of a 10 mile trip and 45% of a 20 mile trip. HOV lanes are most effective in reducing emissions, therefore, when carpool and bus riders are picked up within walking distance of their homes. It is important, when calculating the effectiveness of HOV lanes in reducing emissions, to account for trip-end emissions resulting from the use of park-and-ride for the linkage with a high-occupancy mode access.

## San Francisco Bay Area HOV Lane Plan

For the San Francisco Bay Area HOV Lane Plan, HOV lanes were assessed as a regional system of facilities that would be an integral part of the region's primary roadway network. The analysis results indicate that regional peak period VMT in the year 2005 would be reduced by less than 1% compared to the do-nothing alternative. Vehicle hours of travel during the a.m. peak hour, however, are decreased by 5%. Work trip CO emissions are reduced 3% and HC emissions decrease 2.3% on a regional basis.

## The Houston High Occupancy Vehicle System

Preliminary analysis of the impact of the Houston HOV system on emissions is documented in "An Evaluation of the Houston High-Occupancy Vehicle Lane System" (5). The authors note that HOV facilities may reduce vehicle volumes from the base situation, and may even result in increased vehicle-miles-traveled in the future, due to new carpools and buses. The key question to be asked, however, is "What is the most effective means of serving the travel demand that is expected to occur?" To address this question, analysis was performed assuming a given increase in the level of demand, and three alternatives in the Katy Freeway corridor:

1) Do Nothing (3 directional freeway lanes with no HOV lane).

2) Add a general purpose freeway lane.

3) Add an HOV lane.

The emissions analysis of these alternatives was conducted using the FREQ simulation model. Demand for a future year (1990) was expressed as passenger-miles, and held constant for each alternative. Average vehicle occupancy was adjusted between alternatives as necessary to reflect the observed impacts of the HOV facility on vehicle occupancy. The results of this analysis are shown on Figure 3. It can be seen that the HOV alternative produces substantially less corridor emissions than the other alternatives. Since demand is projected to continue to increase in the future, the HOV lane should, over time, continue to serve additional growth in person movement. The other alternatives are at capacity in 1990, and will accommodate increased volumes only with greater congestion.

### New York City Bus Lane Program

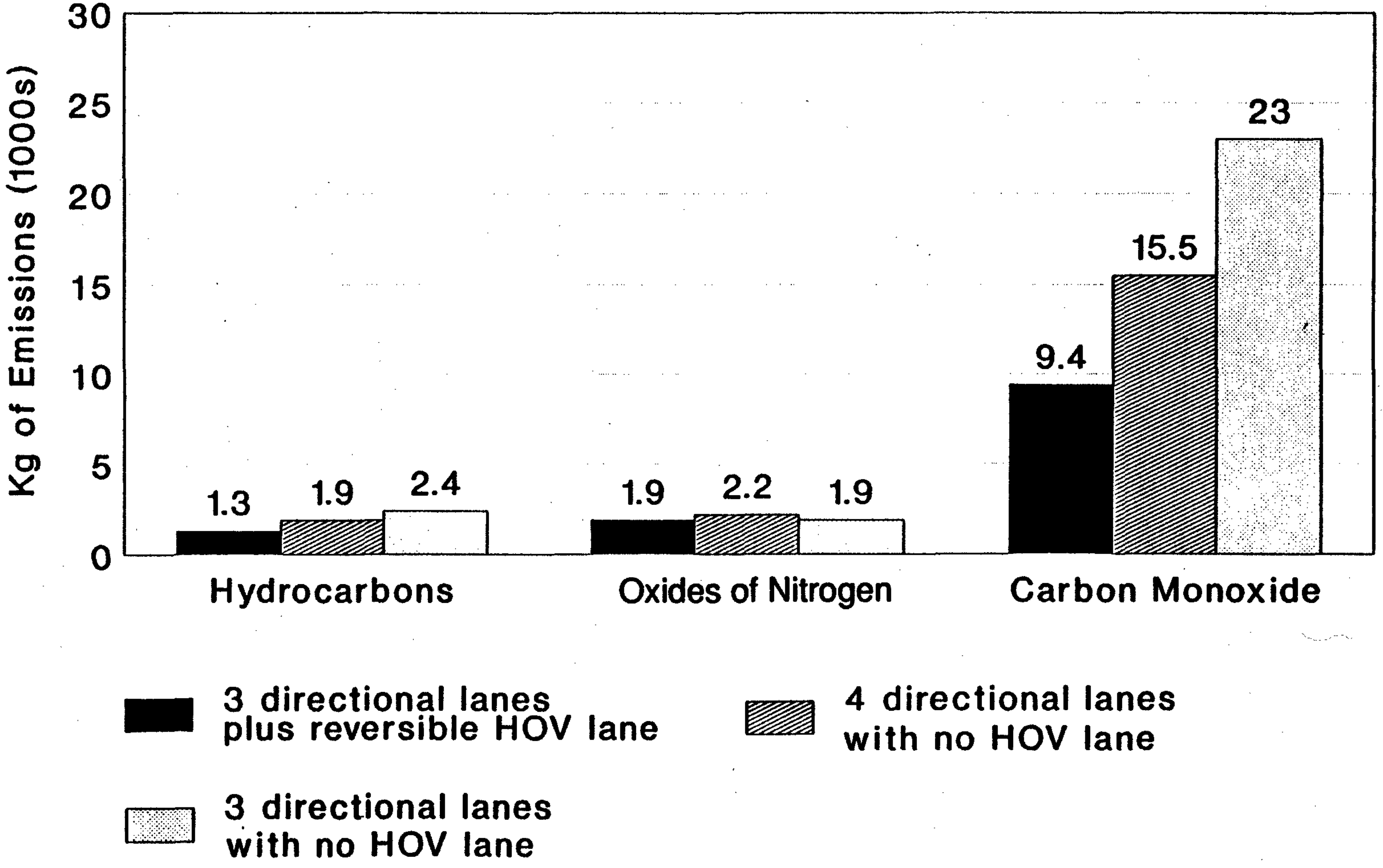
The bus lane program in New York City was implemented as a response to the requirements of the Clean Air Act, and, in particular, to address the issue of carbon monoxide hot spots in the city. An air quality analysis was performed for the 2nd Avenue Contraflow Bus Lane, and it was found that CO emissions dropped 90% in the vicinity following implementation of the bus lane. Another finding of the program is that separation of buses and taxis from other classes of vehicles improves traffic operations and raises overall speeds. For example, speeds for all traffic on Madison Avenue increased by 10% following implementation of the Madison Avenue dual width bus lane.

### California Air Resources Board Guidance

The California Air Resources Board (CARB) has issued a guidance document, "High Occupancy Vehicle System Plans as Air Pollution Control Measures" (3). The CARB guidance estimates that if sound planning principles are observed, regional emission reductions of 5-10% can be achieved from an HOV system. This assumes that average vehicle occupancy will increase from the current 1.3 in urban areas to 1.5 by 1999; that HOV lanes are developed as a regional, linked network; and that development includes other demand management strategies: park-and-ride lots, rideshare marketing, employer trip reduction regulations, and enhanced bus service.

Average vehicle occupancy (AVO) for commuting in major urban areas of California is currently about 1.3 persons per passenger vehicle (automobile, bus, commuter rail). California AVO targets of 1.5 persons will be achieved through a 10-15% reduction in automobile trips, which, in turn, would reduce emissions by 5-10%. Based on

**Figure 3. Estimated Impacts of HOV Improvements on Air Quality, Katy Freeway**



experience, CARB finds it reasonable that changes of this scale can be achieved through implementation of HOV facilities. For example, in the I-10 corridor of the South Coast Air Basin, Caltrans counts show that inbound morning traffic using mixed flow lanes has an AVO of 1.20 persons per vehicle. Adding the three-and-more person carpools to the El Monte Busway increases the AVO to 1.38. Adding the express bus ridership from the Busway brings the AVO for the corridor to 1.67, in excess of the 1.5 target.

## ■ Program Costs

High occupancy vehicle (HOV) lane costs vary greatly by the type of facility to be implemented. A review of data available from the Institute of Transportation Engineers for 19 existing and 11 proposed projects shows costs range from $4,000 to $24.5 million per lane mile. Table 3 shows these costs summarized by facility type. A concurrent flow priority lane that is located within the existing highway right-of-way may cost between $30,000 and $2,000,000 per lane mile to implement. A contraflow lane may cost up to $400,000 per mile for the construction of access lanes and for the placement of signs and barriers. A physically separate HOV facility within a freeway right-of-way would cost $5,000,000 per mile, while an exclusive right-of-way might easily exceed $8,000,000 per mile.

Many factors can have a considerable effect on actual costs. A further review of HOV lane cost data available from the California Department of Transportation (Caltrans) shows that costs can vary significantly based on several design assumptions. For example, Expressway HOV lanes typically are located along the shoulder lane and cost from $0.4 to $1.43 million per lane. Freeway HOV lanes typically are located along the median and cost from $1.8 to $25.2 million per mile. Factors shown to significantly affect the cost of any HOV project include right-of-way acquisition or the cost of land, bridge and overpass modifications, and interchange and ramp modifications.

## ■ Implementation Considerations

Development of a regional HOV facility plan should be based on a set of guiding principles. The following design guidelines are suggested by the California Air Resources Board (3):

- Freeway and expressway segments that are expected to experience congestion by 2010 should form the backbone of a connected HOV lane system.

- New limited access roadways should include HOV lanes, and, where feasible, adequate rights-of-way for rail, express bus and bikeway facilities.

# Table 3. High Occupancy Vehicle (HOV) Lane Costs

| | Capital Costs |
|---|---|
| Physically separate HOV facility in a separate ROW | $8,000,000/Mile |
| Physically separate facility within a freeway ROW | $5,000,000/Mile |
| Concurrent flow lane not physically separated | $30,000 to 2,000,000/Mile |
| Contraflow lane in the "off-peak direction" | $400,000/Mile |

- Bypass lanes for HOV use should be provided at bottlenecks, wherever they will carry more persons at ramps, bridges, tunnels or interchanges.

- Private toll roads and bridges should be required to operate under the same carpool definition and vehicle occupancy standards as public facilities.

- Arterial HOV/bus lanes to improve transit travel times should operate during peak periods as links between transit hubs and the freeway HOV system.

- HOV system plans should be created to encompass the above recommendations, and create a network that is continuous in time and space.

High occupancy vehicle lanes typically are implemented by a State department of transportation (DOT). Because of their substantial physical and financial requirements, several basic factors should be taken into consideration when developing either individual HOV facilities or entire system plans.

- HOV project planning and design should include the participation of various agencies and interest groups to facilitate project acceptance and consensus. Participation by political leaders, business groups and citizen groups is necessary to ensure that all views and concerns are addressed and incorporated in the project design.

- The effects of an HOV lane project on non-users also should be considered. The implementation of a concurrent or contraflow lane that converts an existing freeway travel lane into an HOV lane will result in adverse effects on non-HOV traffic if the project is not well designed. The Southeast Expressway HOV lane project in Boston removed a lane from mixed traffic and resulted in such an adverse effect on the non-HOV traffic that public opinion compelled that the project be terminated. The standard rule of thumb is that service conditions for mixed-traffic should not be degraded.

- Public education or marketing should begin before the project is implemented to gain public acceptance for the project. For the Shirley Highway in Northern Virginia, public resistance to the standard of 4 occupants or more was based on the perception that the facility was underutilized, despite data showing that the HOV lanes were carrying more people than mixed-use lanes.

- Enforcement is critical for the successful operation of an HOV lane facility. Surveys show that early and substantial enforcement of HOV rules on a new facility is the best determinant of long-term public compliance. An adequate enforcement program must be planned prior to, and implemented concurrent with the opening of the facility. The design of the project should facilitate enforcement. Physical barriers, for example, deter casual violations, and all projects should be designed so that police can pull over violators safely without impeding the flow of the HOV lanes. A successful enforcement program includes a suitably structured system of fines. Relatively low fines do little to support other elements of the enforcement program. In 1989, fines for HOV violations ranged nationally from $40 to $246 for the first offense. In California, the third offense costs $800, plus court costs. Public education is a key part of any enforcement program, as the public needs to be aware of HOV rules and understand the reasons for the rules to support them. Seattle Metro's HERO program is exceptional in that it both educates the public in the reasons for the HOV facilities and how to use them, and directly involves the public in enforcement activities.

- Projects with unsolvable or debatable safety or operational problems should be avoided. The contraflow lane experiment on the Southeast Expressway in Boston included a cumbersome and hazardous method of using traffic cones to delineate the lane during peak periods; turn-out lanes were short and did not provide adequate visibility for merging traffic. The project led to a number of accidents and a fatality of one of the work crew while placing the cones in the road, which contributed to the project's termination and the public's disfavor for the strategy.
- An HOV lane project should be planned and implemented along with support facilities such as park-and-ride lots, preferential parking at employment sites, carpool and vanpool programs and other projects to reduce drive alone commuting. The Bay Area HOV study by the Metropolitan Transportation Commission identified a number of support facilities that clearly promoted additional use of an HOV lane facility.

## Bibliography

1. American Association of State Highway and Transportation Officials, "Guide for the Design of High Occupancy Vehicle Facilities," Washington DC, 1991.
2. Billheimer, John W., "HOV Violation Study," U.S. Department of Transportation, Washington DC, 1990.
3. California Air Resources Board, "High Occupancy Vehicle System Plans as Air Pollution Control Measures," 1991.
4. Cambridge Systematics, Inc., "2005 HOV Lane and Support Facility Program Prioritization Project," prepared for the Metropolitan Transportation Commission, 1990.
5. Christiansen, Dennis L., and Daniel E. Morris, "An Evaluation of the Houston High-Occupancy Lane System," Texas Transportation Institute, College Station, Texas, 1991.
6. Christiansen, Dennis L., "High-Occupancy Vehicle System Development in the United States," Texas Transportation Institute, College Station, Texas, 1990.

7. Fuhs, Charles A., "High-Occupancy Vehicle Facilities: A Planning, Design, and Operation Manual," Parsons, Brinckerhoff Quade and Douglas, Inc., New York, New York, 1990.

8. Fuhs, Charles A., "High-Occupancy Vehicle Facilities: Current Planning, Operation, and Design Practices," 1990; William Barclay Parsons Fellowship, Monogram 5), Parsons Brinckerhoff Inc., 1990.

9. Institute of Transportation Engineers. "The Effectiveness of High Occupancy Vehicle Facilities," Washington DC, 1988.

10. Institute of Transportation Engineers, "Guidelines for High-Occupancy Vehicle (HOV) Lanes, A Recommended Practice," Publication No. RP 017, Washington DC, 1986.

11. Institute of Transportation Engineers, "Toolbox for Alleviating Traffic Congestion," Washington, D.C., 1989.

12. Levinson, Herbert S., "HOV Lanes on Arterial Streets" "Proceedings, Second National Conference On High-Occupancy Vehicle Lanes and Transitways," Texas Transportation Institute, College Station, Texas, 1987.

13. Metropolitan Transportation Commission, "2005 HOV Lane Master Plan," Oakland, CA, April 1990.

14. New York City Department of Transportation, "Priority Bus Treatments," undated.

15. Purvis, Charles L., "Air Quality Impacts of a Regional HOV System," paper presented at the Third National Planning Applications Conference, Metropolitan Transportation Commission, Oakland, CA, April 1991.

16. Schwartz, Samuel I., and Linda Corcoran, "Cleaning up the Air – A Hidden Opportunity For Transportation Improvements" "Compendium of Technical Papers," Institute of Transportation Engineers, 54th Annual Meeting, 1984.

17. Texas Transportation Institute, "The High-Occupancy Vehicle Facility System Houston, Texas," undated.

18. Turnbull, Katherine F., and James Hanks, Jr., "A Description of High-Occupancy Vehicle Facilities in North America," Technical Report 925-1, Texas Transportation Institute, College Station, Texas, 1990.

19. Turnbull, Katherine F., and Russell Henk, "Suggested Procedures for Evaluating the Effectiveness of Freeway HOV Facilities," Texas Transportation Institute for the Texas State Department of Highways and Public Transportation, College Station, Texas, 1990.