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Technical Report

Inherently Low-Emission Vehicle Program, Estimated Emission Benefits and Impact on High-Occupancy Vehicle Lanes

by

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I. Executive Summary

The Clean Air Act Amendments of 1990 (the Act) require states to implement Clean Fuel Fleet Programs in certain ozone and carbon monoxide nonattainment areas starting in 1998. One of EPA's responsibilities under the Act is to exempt the vehicles qualifying for the program from certain transportation control measures (TCMs) which will provide the fleets an incentive for their participation. EPA has proposed regulations to meet this statutory mandate. As a part of EPA's proposal, an important new concept in motor vehicle emission control was introduced. With this concept, EPA would grant expanded TCM exemptions to inherently low-emission vehicles (ILEVs). The first of these exemptions is access to high-occupancy vehicle (HOV or carpool) lanes.

ILEVs are clean fuel vehicles (LEVs, ULEVs, and ZEVs) with "inherently" low evaporative emissions, such that the evaporative emissions would remain low even if the emission control hardware were to malfunction. ILEVs must operate solely on inherently low-emitting fuels, which in many cases are expected to be alternative fuels; this is in contrast with the other clean fuel vehicles qualifying for the fleet program which are generally expected to be low-emission vehicles (LEVs) operated on reformulated gasoline. Thus, in proposing the ILEV concept, EPA anticipated that significant air quality benefits would result from the use of ILEVs.

Comments on EPA's proposed ILEV program questioned the extent of environmental benefits that would result from the ILEV program. Other comments also expressed concern that ILEVs could reduce the effectiveness of HOV lanes by contributing to traffic congestion. This report explores these two concerns in detail.

According to the detailed analysis in this report, ILEVs would provide substantial emission reductions compared to LEVs and other conventional vehicles. The evaporative and refueling emissions (vapor emissions) from ILEVs are estimated to be near zero. With the near-elimination of vapor emissions, ILEVs are expected to emit about one-half the volatile organic compound emissions as other LEVs. ILEVs are also expected to emit lower exhaust emissions based on their performance compared to today's vehicles. However, these expected additional reductions from the use of ILEVs were not included in this analysis because these lower exhaust emission levels are not an absolute requirement of the program.

This report also concludes that ILEVs are expected to result in little or no detrimental effect on traffic flow in HOV lanes. This conclusion was derived from studying the HOV lanes in Los Angeles, Houston, the District of Columbia, and Seattle. In almost all cases, even widespread use of ILEVs would have marginal impact on HOV lane flow. For Los Angeles, however, where the HOV lanes are already heavily used, the most widespread ILEV usage currently anticipated could impact HOV lane flow, but only in the out years well after the year 2000. Even here, the report identifies several ways in which Los Angeles, and any other areas with heavy HOV lane use, could modify their HOV operations to accommodate ILEVs.

Finally, this report identifies two important reasons for granting expanded TCM exemptions to ILEVs. First, the positive environmental impact of any increase in ILEV usage could be substantial while as demonstrated by this analysis of HOV lane traffic flow, the impact on the effectiveness of HOV lanes is expected to be insignificant. Thus, expanded TCM exemptions offered to ILEVs would appear to be beneficial. Second, some fleets cannot take advantage of the HOV exemption incentive either because they do not operate during rush hour, or because HOV lanes may not be available where they do business. Granting additional incentives beyond HOV lane exemptions could encourage the purchase of ILEVs. Such additional incentives could also help fleets overcome obstacles to the purchase of alternative-fueled ILEVs, such as the initial capital cost for fueling points.

Overall, this report concludes that widespread and rapid introduction of ILEVs would generally offer significant air quality benefits to society wherever they are used, and that the prudent use of TCM exemptions and incentives could encourage these purchases without significant impact on the effectiveness of the other programs.

List of Abbreviations

CFFV	Clean Fuel Fleet Vehicle
CNG	Compressed Natural Gas
CO	Carbon Monoxide (pollutant)
EPA	Environmental Protection Agency
E100	Neat Ethanol Fuel
GVWR	Gross Vehicle Weight Rating
HDGV	Heavy Duty Gasoline Vehicle
HOV	High Occupancy Vehicle
ILEV	Inherently Low-Emission Vehicle
LEV	Low-Emission Vehicle
LDV	Light-Duty Vehicle
LDT1	Light-Duty Truck
LDT2	Light-Duty Truck (6000 - 8500 lbs. GVWR
LNG	Liquid Natural Gas
LPG	Liquid Petroleum Gas
M100	Neat Methanol Fuel
NMHC	Nonmethane Hydrocarbon
NOx	Oxide of Nitrogen (pollutant)
SIP	State Implementation Plan
TCM	Transportation Control Measure
ULEV	Ultra Low-Emission Vehicle
ZEV	Zero Emission Vehicle

II. Introduction

The Clean Air Act (the Act) requires states comprising certain areas exceeding the National Ambient Air Quality Standards for ozone and carbon monoxide to implement clean fuel vehicle fleet programs. These fleet programs are to begin in 1998 and will require fleets to purchase clean fuel vehicles which emit less exhaust emissions than conventional vehicles. To further define the fleet program for the states, the Act requires EPA to promulgate specific regulations. Among the regulations which must be promulgated, is the exemption of clean fuel fleet vehicles (CFFVs) from transportation control measures (TCMs), encouraging purchase of these vehicles.

EPA proposed a two-tiered approach to TCM exemptions. All CFFVs would be exempt from temporal (time-related) TCMs instituted in whole or in part for air quality reasons, while a cleaner group of CFFVs, termed ILEVs, would receive expanded TCM exemptions. EPA proposed to exempt ILEVs owned by eligible fleets from high occupancy vehicle (HOV) lane restrictions and to pursue additional select exemptions by regulation in the future.

In terms of an overview, Section III discusses the policy basis for the ILEV program and describes the requirements and provisions of the program. The report then analyzes the projected vapor emissions of ILEVs and presents a comparison of those emissions with base case vehicles expected to be purchased as CFFVs. Section V of the report then presents a study of the impact of the ILEV HOV lane restriction exemption. And finally, Section VI concludes with a discussion of several additional incentives which could further encourage the use of ILEVs.

III. Background

a. Policy Basis for ILEV Program

The Clean Air Act directed EPA to develop regulations which provide CFFVs exemptions from "time of day, day of week, and similar transportation control measures." The language of the statute was problematic because it did not explicitly state which of the TCMs should be included in the exemptions. In discussions with EPA, fleet owners indicated a strong preference for a broad interpretation of the provisions because they viewed these exemptions as a direct recompense and incentive for their participation in the fleet program. Some fleet owners listed TCMs for which they wanted to receive exemptions, while others requested specific exemptions from only certain TCMs. The TCMs exemptions they requested ranged from temporal TCMs (i.e., time of day, day of week), to such nontemporal TCMs such as traffic flow measures, urban vehicle management, road pricing and trip reduction ordinances.

EPA and several of the states suggested that a more limited interpretation was appropriate since most CFFVs will have exhaust emission levels similar to vehicles being developed for public sale as part of the California Low Emission Vehicle program. Concern was expressed that broad exemptions may tend to undermine the environmental effectiveness of current and future TCMs and may lead to an adverse public reaction from those who purchase the California vehicles in California, and potentially in other states as well, but would not get such exemptions.

As a balance between these two views EPA developed (and will soon finalize) a two-tiered approach to implementing the TCM exemption provisions. The first tier provides CFFVs exemptions from temporal-based TCMs instituted wholly or partly for air quality reasons. This provides CFFVs with the TCM exemptions explicitly stated in the Act without allowing exemptions for non-air quality related TCMs or those not temporally based.

The second tier balances fleet owners desires for broader TCM exemptions against concerns about undermining the effectiveness of TCMs, the lack of environmental benefits, and public reaction concerns relative to California low-emission vehicles. This tier establishes a Federal program known as the inherently low emission vehicle (ILEV) program. As proposed, the ILEV program provides both temporal and expanded TCM exemptions to CFFVs with near zero evaporative emissions and decreased NOx emissions. This requirement for inherently low evaporative emissions is the heart of the program since in-use vapor emissions (evaporative and refueling) approach and often surpass exhaust hydrocarbon emission rates and yet are not controlled more stringently than conventional vehicles by the clean fuel vehicle emission requirements.

For the second tier of TCM exemptions, EPA proposed that ILEVs receive HOV lane exemptions. With this exemption, ILEVs would have access to use freeway lanes now limited to high occupancy vehicles. In the past, fleet vehicles have effectively been excluded from using HOV lanes due to their operating characteristics. To provide more incentive for the purchase of these vehicles, EPA intends to study and promulgate additional select TCM exemptions for ILEVs in future rulemakings.

The ILEV program is potentially a positive for all parties. The vehicle will generate substantial emission reductions, states will be able to claim these reductions in their state implementation plans (SIPs), and fleet owners can qualify for expanded TCM exemptions. Even looking beyond the benefits of this program, low emission technology will be developed and employed on in-use vehicles and the public will receive important exposure to these extra clean vehicles in preparation for possible expansion of the program by the state.

b. Program Provisions and Requirements

One key goal of the clean fuel fleet program is a reduction in ozone precursor emissions and air toxics. The fleet program effectively addresses reductions in ozone precursors NMOG and NOx emissions, but contains no additional provisions regarding vapor emissions from CFFVs. The ILEV program continues this emphasis on reducing ozone precursor emissions.

In order to qualify as ILEVs, vehicles would have to meet the following requirements:

1) In addition to qualifying as CFFVs, ILEVs must pass additional evaporative emission control requirements.

   ILEVs have inherently low vapor emissions because even if their evaporative emission controls were to fail, these vehicles would still emit very low amounts of vapor emissions. In order for vehicles to be certified as ILEVs, they must pass a stringent evaporative emissions test with any evaporative emission control hardware disconnected. The ILEV evaporative emissions requirement was proposed at a level which would be more than an order of magnitude less than the emissions from an uncontrolled gasoline vehicle. Of course, the existing evaporative standard would also have to be met, using a control system if necessary.

   In the case of electric and gaseous-fuel vehicles, the nature of their fuels and fuel storage reduces concern about evaporative emissions from these vehicles. Dedicated electric vehicles are not considered to make any direct contribution to urban emissions. Gaseous fuels (CNG and LPG) are stored in enclosed fuel systems under pressure and are characterized as having zero evaporative emissions. If the pressurized fuel system were to be breached, the vehicle would generally be rendered inoperative through the quick loss of fuel; the owner would then need to repair the vehicle before any future use. EPA proposed that for these vehicles to qualify as ILEVs, the manufacture would need to show through an engineering evaluation, that the vehicles would meet the evaporative emission requirement.

2) ILEVs must meet the exhaust emission requirements of CFFVs.

Light-duty ILEVs must meet the LEV exhaust standards for carbon monoxide and nonmethane organic gas (NMOG). Maintaining the focus on further reducing ozone precursor emissions from that of conventional vehicles, light-duty ILEVs must meet the ULEV NOx standards for that vehicle class. Heavy-duty ILEVs must meet the combined nonmethane hydrocarbon (NMHC) + NOx ultra low-emission standard for clean fuel heavy-duty vehicles.

3) ILEVs must be dedicated fuel vehicles.

ILEVs can only operate on the fuel(s) on which the vehicle was certified to meet the ILEV evaporative and exhaust emission standards. Any fuel is eligible provided that the ILEV requirements are met.

4) **ILEVs must** fall within the covered vehicle weight classes and be operated by covered fleets.

Vehicles which may qualify as ILEVs must fall within the weight classes covered by the fleet program, which are light-duty vehicles, light-duty trucks, and heavy-duty trucks up to 26,000 lbs. GVWR. Furthermore, ILEVs may only be operated by fleets covered by the fleet program. The states, however, may expand the ILEV program to vehicle classes and fleets not initially covered by the fleet program.

IV. ILEV Emission Reductions

a. Background

Motor vehicle emissions are composed of hydrocarbons, oxides of nitrogen (NOx), carbon monoxide, and other pollutants. Hydrocarbons and NOx react together at ground level in the presence of sunlight to form ozone. The chemical nature or reactivity of the hydrocarbon emissions from the vehicle determines to a large degree the extent that ozone will be formed from those emissions. The reactivity of the fuels in use, or those being considered for use, varies over two orders of magnitude, from electricity and methane at the low end of the range, to gasoline at the high end of the range.

For each class of clean fuel vehicles certified for the fleet program, the hydrocarbon exhaust emissions must be adjusted for reactivity. This reactivity adjustment requirement is described in the Act under the definition of nonmethane organic gas (NMOG). As required under that definition, the mass of hydrocarbon exhaust emissions of vehicles using fuels other than gasoline must be measured and speciated, and the mass of each specie adjusted for reactivity. The aggregate reactivity-adjusted mass is then compared against the applicable NMOG standard.

The ozone-forming emissions from motor vehicles generally fall into three different categories: evaporative, refueling, and exhaust. Evaporative emissions, which are hydrocarbon fuel vapors emitted from the fuel storage and distribution system on the vehicle, can be further subdivided into a number of different sources generally called diurnal, hot soak, running loss, and resting loss emissions. Each of these sources is described below in more detail:

- Diurnal emissions result from fuel vapors generated in the fuel tank from daily ambient temperature and pressure increases while the vehicle is parked.

- Hot soak emissions result from fuel vapors generated by residual vehicle heat following vehicle operation.

- Running loss emissions result from fuel vapors generated by the heating of the fuel in the fuel system while the vehicle is in operation.

- Resting loss emissions result from fuel vapors continuously emitted from the vehicle as the result of permeation through rubber and plastic components of the fuel system or migration from charcoal evaporative control canisters.

Similar to evaporative emissions, refueling emissions are fuel vapors released directly into the ambient air from the fuel storage system. The difference is that these emissions occur while the vehicle is being refueled. In the case of a liquid-fueled vehicle, the liquid entering the fuel tank displaces the air and fuel vapor in the partially empty fuel tank, forcing them out of the tank. The more volatile the fuel, the greater the refueling emissions. Refueling and evaporative emissions, when both are being considered together, will be referred to as vapor emissions for the remainder of this document.

Exhaust emissions are generated by the combustion of fuel and are discharged from the vehicle's tailpipe, usually after passing through a catalytic converter. The primary components of exhaust emissions are carbon dioxide, water vapor, carbon monoxide, NOx, and hydrocarbons. For some fuel types, particulate matter and formaldehyde are also important. To place clean fuel vehicles into production, manufacturers must certify that their vehicles emit less NOx, carbon monoxide, hydrocarbons and other pollutants than their respective standards. For hydrocarbon emissions from CFFVs, the Act requires the emissions be measured as NMOG.

Evaporative and exhaust emissions from motor vehicles usually increase (deteriorate) as the vehicles age. This deterioration occurs for a number of reasons. These include the effects of the aging of the vehicle's engine and the emission control hardware, as well as malmaintenance, defects, and deliberate tampering. This deterioration is responsible for a significant portion of the ozone forming emissions emitted from motor vehicles.

The estimation of the deterioration is a key component of an analysis to project emissions in the future. Because of the nature of the evaporative control systems on motor vehicles and the fuel vapors they control, vapor emissions do not change significantly with age until a physical or mechanical failure occurs. Most vehicle evaporative control system designs are similar and the frequency and severity of these failures are fairly well understood. Thus, future vapor emissions can be estimated with a fairly high degree of confidence.

This is not true for exhaust emissions. Exhaust emissions are dependent on the engine configurations and emission control approach used and can vary drastically with simple changes in the operational setpoints of the engine controls. This is further complicated by the fact that the full range of types of vehicles likely to qualify as ILEVs have not yet been manufactured and tested for their exhaust emissions. This lack of exhaust emission data precludes EPA from projecting the exhaust emission performance of ILEVs relative to LEVs at this time. Therefore, exhaust emissions will not be considered in this analysis, even though it is likely that some reductions are possible.

b. Base Case Vehicle Vapor Emissions

1. Emission Control Programs

CFFVs, which would be the vehicles purchased by fleets in lieu of ILEVs, form the baseline of comparison to estimate ILEV vapor emission reductions. These base case vehicles are expected to be low-emission vehicles (LEVs) running on federal reformulated gasoline.

In addition to the reformulated gasoline program, a number of other vehicle emission reduction programs are expected to be implemented which will further reduce vapor emissions compared to that from today's vehicles. These emission reduction programs include Phase II Gasoline Reid Vapor Pressure Control, Improved Evaporative Emissions Control, Onboard Diagnostics, and Enhanced Inspection/Maintenance. These programs and their initiation dates are summarized in Table 1.

Table 1 - Summary of Future Emission Control Programs

Emission Control Program	Planned or Anticipated Program Start Date
Phase II Gasoline RVP Control	May 1992
Improved Evaporative Emissions Control	Proposed Phase-in 1995 - 1998
Onboard Diagnostics	Model Year 1994
Enhanced I/M	Proposed Phase-in 1994 - 1996
Reformulated Gasoline required for most areas covered by fleet program	Assumed to be used by all base case fleet vehicles starting in 1998.

Stage II refueling emission control, which is called for in the Act, is expected not to apply to most of the fleets covered by the fleet program. Stage II refueling emission control is a state implemented program requiring most fuel dispensing facilities located within moderate or worse ozone nonattainment areas to install controls to reduce refueling emissions. In this case, fleets are generally centrally fueled from their own facilities and would only be covered if they dispense more than 10,000 gallons per month. According to past EPA analysis, most fleets do not dispense monthly volumes greater than this level; thus, they would not be covered by the stage II requirements and their refueling emissions would be uncontrolled. For this analysis, two approaches will be taken concerning this issue: 1) that no fleet vehicles would be covered by Stage II, and 2) 10 percent of fleet vehicles would be covered by Stage II.

2. Calculation Methodology

EPA assessed the benefits of the emission control programs listed above to project the vapor emissions of base case vehicles. Since the benefits of each of these programs on vehicle emissions can diminish when the parallel effects of other programs are also considered, it was necessary to use MOBILE 5.0 to account for the synergistic effect of all the future programs implemented together.

The MOBILE emission modeling computer program was developed to estimate the exhaust and vapor emissions from all classes and ages of operating vehicles. The model incorporates a number of factors that affect the level of emissions, including ambient temperature, average vehicle speed, mileage accrual rates, emission control hardware failure rates, and vehicle tampering. The benefits of mobile source emission control programs implemented prior to the CAA amendments, and projections of the benefits of programs required in the Clean Air Act amendments, are incorporated into this version of the MOBILE computer program.

Some of these MOBILE 5.0 input parameters and data output were modified in the special version of the model to account for two specific operating characteristics of fleet vehicles and the fleet program. The high urban use of covered fleet vehicles was accounted for by using an urban average driving speed. Because the fleet program is primarily concerned with reducing ozone precursor emissions, the analysis was modeled at 90.5 °F which considered high summertime temperatures associated with ozone exceedances.

The MOBILE 5.0 model reports vapor emissions for each of the separate sources discussed above for each vehicle class. The various vapor emission sources are totaled for each class to derive total vapor emissions for that class. After the emission control programs in Table 3 are fully phased-in, the vapor emission factor for each vehicle class is stable. This should occur in about 1998 when the mandatory portion of the clean fuel fleet program begins, so only one emission factor is necessary for each vehicle class (see Table 12 in Appendix).

These separate vehicle class emission figures are then combined into a composite value using weighting factors. Unlike the emission factors, the weighting factors do change as the fleet program phases in and the mix of vehicle classes changes over time. To provide sample figures for one year, the weighting factors for the year 2000 class mix of fleet vehicles including the mileages and number of vehicles are summarized in Table 2. The year 2000 was chosen because it falls in the middle of the early years of the fleet program phase-in and would tend serve as an average for the weighting factors for those years. Weighting factors for other years can be calculated using the projected sales figures in reference 1. A weighting factor for heavy-duty diesel vehicles is not included in this table because diesel is low in volatility; consequently, ILEV replacements of conventional diesels or diesels qualifying as ILEVs replacing the existing fleet are not expected to yield any reductions in vapor emissions.

Table 2 - Weighting Factors and their Base Data for Year 2000 Fleet Vehicles

Category	LDV*	LDT1*	LDT2*	HDGV*
Number of Operating Fleet Vehicles[1]	302,000	118,000	24,000	50,000
Average Annual Mileage[1]	17,600	15,700	15,700	31,700
Weighting Factors	0.58	0.21	0.04	0.17

* LDV is light-duty vehicle; LDT1 is light-duty truck under 6000 lbs. gross vehicle weight rating (GVWR); LDT2 is light-duty truck between 6000 and 8500 lbs. GVWR; and HDGV is heavy-duty gasoline vehicle.

Applying the weighting factors for any one year to the base case emission factors yields composite emission factors for the base case vehicles in that year. Emission factors for years prior to 1998 were not analyzed for two reasons. First, base case vehicle and ILEV purchases by fleets prior to 1998 are expected to be less significant and the numbers more difficult to predict than when the fleet program begins in 1998. And second, the inputs for the MOBILE computer model were difficult to determine because the final provisions and phase-in dates for some of the emission control programs mandated by the Act have not been established. Therefore, this analysis focused only toward the end of this decade when the vehicle emission control and fleet programs are certain to be implemented.

3. Modeling Results

Using the analysis and weighting scheme described above, the composite base case fleet vehicle emission factor for the year 2000 is calculated and summarized below in Table 3. The value of 0.50 grams/mile is based on the emission factor data summarized in detail in Table 12 in the Appendix and the weighting factors listed in Table 2 above. Composite emission factors for other select years are summarized below in Table 5 for the purpose of projecting the emission benefits of the ILEV program.

Table 3 - Projected Vapor Emissions from Low-Emission Vehicles in grams/mile/vehicle (parentheses includes effects of Stage II reductions)

Year	LDV*	LDT1*	LDT2*	HDGV*	Weighted Total
2000	0.33	0.38	0.39	1.23	0.50 (0.48)

* LDV is light-duty vehicle; LDT1 is light-duty truck under 6000 lbs. gross vehicle weight rating (GVWR); LDT2 is light-duty truck between 6000 and 8500 lbs. GVWR; and HDGV is heavy-duty gasoline vehicle.

c. ILEV Vapor Emissions

1. ILEV Vehicles/Fuels

Projections of the in-use emissions from ILEVs are based on vehicle technology/fuel combinations that are expected to meet an evaporative emissions requirement of 5 grams/test with any control system disconnected. The assumed vehicle technology/fuel combinations are dedicated alternative-fuel and diesel vehicles running on the proven low-emitting vehicle technology/fuels. There is no limit or specification on the fuel or technology which can be used provided that the performance standard can be met. Possible technologies/fuels include compressed natural gas, liquid petroleum gas, electricity, neat alcohols such as methanol and ethanol, and clean conventional fuel technologies.

Reformulated gasoline and alcohol blended fuels are also eligible, however, they may have greater difficulty qualifying because of their relatively high reid vapor pressure of over 8 pounds per square inch (psi). If vehicles using these fuels are subjected to the ILEV evaporative emissions test, which requires that the evaporative emissions control hardware be disconnected, they could emit several times over the ILEV evaporative limit. However, it would not be infeasible for these fuels to qualify as ILEVs, if a fuel storage system can be designed which ensures that evaporative emissions remain below the ILEV evaporative emissions requirement.

Vapor emissions from ILEVs are not expected to increase or deteriorate over time. This is based on the concept of vehicle expected to meet the requirements to qualify as an ILEV. While the vapor emissions from conventional vehicles are certified with the use of vapor emission control hardware when required, and this hardware can later fail in-use resulting in significant amounts of in-use vapor emissions. The ILEV test procedure does not allow the use of such hardware. Thus, the ILEV test procedure ensures that the in-use vapor emissions will remain very, very low because only inherently low emitting fuels and fuel storage configurations would be permitted. ILEV fuels would either be naturally low in vapor pressure, or totally enclosed in storage systems that would preclude vapor emissions. Further descriptions of the inherently low emitting qualities of the fuels expected to qualify as ILEV fuels are included separate sections on each of the ILEV fuel categories below.

For this analysis, the alternative fuels expected to qualify as ILEV fuels are categorized into four groups and evaluated in the context of several parameters. The four groups are: 1) gaseous fuels, which includes compressed natural gas and liquid petroleum gas; 2) alcohol fuels, which includes neat methanol and neat ethanol; 3) electricity; and 4) clean conventional fuel technologies. These groupings were chosen because of the similarities in the technologies and the ozone forming potential of the fuel vapors. Each of these groups will next be evaluated for their vapor emissions, their ozone forming potential, and their expected penetration of the ILEV market.

A. Gaseous-Fuel ILEVs

Gaseous-fuel vehicles do not emit diurnal, running loss, or hot soak emissions because the storage systems are completely enclosed.[2,3] The refueling emissions are also expected to be essentially zero because quick disconnect fittings are expected to be required hardware for future refueling installations. It is unknown whether gaseous fueled vehicles emit resting losses because they have never been measured. Because the fuel system is under pressure, the walls of the fuel lines are thicker than today's vehicles which would tend to eliminate the bleeding through the fuel line walls seen in today's vehicles. Thus, resting loss emissions are projected to be essentially zero as well.

Gaseous fuels are much less reactive than gasoline vapor. This is because the components of the fuels are much more inert. Compressed natural gas is composed primarily of methane and ethane (a typical fuel would contain about 95 and 2 percent, respectively, plus minor amounts of other hydrocarbons and inerts) which are much lower in reactivity.[4,5,6] Liquid petroleum gas for automotive fuel is composed primarily of propane and butane (a typical fuel will contain about 95 percent and 5 percent, respectively, plus trace amounts of other constituents), which is also relatively low in reactivity.[4,5,6] Thus, the ozone-forming potential of both these vehicle/fuel combinations is substantially lower than that for gasoline-type vehicles.

Compared to the other fuels considered, gaseous fuels are projected to capture the largest share of the ILEV market early on. Gaseous fuels are now available as conversions, and OEM models are planned. This positions gaseous fueled ILEVs to take advantage of the large benefits such as the much lower fuel price and the already widespread accessibility of the fuels.[7]

B. Alcohol-Fuel ILEVs

The alcohol fuel emissions used in this analysis are those estimated for neat methanol (M100),[8] and are assumed to apply to neat ethanol (E100) as well which has about the same ozone-producing potential. Although ethanol's vapor pressure is about one half of methanol's (2.5 psi versus 4.6 psi. at 100 °F)[9], its reactivity is about two times higher (1.34 versus 0.56);[5] therefore, reactivity adjusted emissions for ethanol would be about the same. Since alcohols and gasoline are both liquid fuels and would use similar fuel system designs, alcohol fuels are assumed to emit the same amount of resting losses as gasoline-powered vehicles. The vapor emissions from alcohol fuel-vehicles are summarized below in Table 4. To relate the ozone forming potential of these emissions to those of base case vehicles, a reactivity adjustment factor was applied. California's reactivity adjustment factor of 0.29, adjusted to that of gasoline, is used here.[5,6]

Neat alcohol fuels are estimated to comprise another large segment of the ILEV market. The cold start drawbacks related to neat alcohol fuels have shown some promise of being resolved. A direct injected methanol engine has been developed which cold starts at temperatures previously obtainable only through glow plug technology or with methanol blended with gasoline. This technology is assumed in this report to be further developed for both methanol and ethanol to allow the alcohols to make inroads into the ILEV market.

Table 4 - Projected Emissions from Alcohol-Fuel Inherently Low-Emission Vehicles (Grams/Mile)

Emission Category	Alcohol Fuels (M100 and E100)
Hot Soak and Diurnal	.030
Running Loss	.025
Resting Loss	.01
Refueling Loss	.017
Total Vapor Emissions	.077
Reactivity Adjusted Vapor Emissions (g/mi)	.022

C. Electric ILEVs

Electric vehicles are expected to emit no measurable amounts of any pollutants. The basis for this is that emissions related to power generation are not considered. Also, electric ILEVs would need to be dedicated electric vehicles, or if hybrid, the vehicles will use a secondary fuel which is also essentially zero emitting, such as another alternative fuel meeting the ILEV qualification procedures. When hybrids are developed, test procedures and other requirements will need to be developed to assess more fully their evaporative and exhaust emission characteristics.

Electric vehicles are projected to comprise a relatively small fraction of the operating ILEVs. This assumption is based on their much greater purchase cost, shorter operating range, and more time consuming "refueling" (recharging) requirement, as compared to other alternative-fuel vehicles.

D. Clean Conventional Fuel Technologies

Diesel vehicles emit very low amounts of evaporative emissions and would thus easily meet the ILEV evaporative emission requirement. This conclusion is based on data which establishes diesel's reid vapor pressure to be about 0.4 pounds per square inch,[10] which is over one order of magnitude lower than that of methanol. This difference in vapor pressure indicates that diesel vapor emissions would also be about one order of magnitude lower than that of methanol,[11] which would put the total emissions value at about 0.008 grams per mile. Because clean diesel is a petroleum-based fuel which includes many reactive compounds, the little fuel which does evaporate is considered to be very reactive.

Diesel vehicles may not qualify early on as ILEVs. This projection is based on the current difficulty diesels have in trying to meet more stringent NOx standards. As diesel emission control technology advances, which is expected to occur as the sulfur content is reduced, then new catalyst technology can then be used allowing diesels to meet more stringent NOx standards, and potentially qualify as ILEVs. Also helping clean diesel's chances for being adopted as an ILEV fuel are its current advantages as being fuel efficient and widely available. However, in the aggregate the overall number of diesel ILEVs is expected to be relatively small.

Low vapor pressure grades of reformulated gasoline, or that type fuel coupled with new fuel storage technologies, could conceivably be invented to permit gasolines to meet the ILEV evaporative emission requirements. If this technology can be developed and implemented, the amount of vapor emissions would still need to be lower than the ILEV evaporative emission standard. Therefore, any such technology would emit evaporative emissions similar to that expected for methanol, which would probably just qualify for the ILEV evaporative emission requirement without any new technology.

2. Composite Vapor Emissions

For this analysis, the first step in projecting the vapor emissions from ILEVs was to estimate the aggregate emissions from each technology/group. This aggregate figure was determined by totaling the estimated vapor emissions emitted from each emission source (i.e., refueling, diurnal, hot soak etc.). As described above, gaseous-fuel, and electric ILEVs are considered to emit zero evaporative emissions, and the nonblended alcohol and diesel vehicle vapor emissions are estimated to be 0.022 and 0.008 grams per mile, respectively. Finally, the emission figures were next weighted together using an assumed in-use mix of alternative fuels projected to be used by ILEVs. This assumed mix is 50 percent gaseous fueled, 5 percent of electric, and 40 percent composed of pure alcohol (neat alcohol) and clean conventional fuel technologies with less than 5 percent of this expected to be diesel.

This assumed mix of fuels/technology results in a vapor emission factor of 0.01 grams per vehicle-mile and will be used in the following comparison between ILEVs and base case vehicles. Even assuming that all the ILEVs are alcohol fueled or used a technology which just met the ILEV standard, the vapor emissions would only rise to 0.022 grams per mile. Conversely, if all ILEVs were zero emitting such as electric or the gaseous-fuel type, the vapor emissions would be zero. From this data it is clear that the use of ILEVs in place of base case vehicles would essentially eliminate vapor emissions.

d. ILEV Emission Benefit

1. Individual Vehicle Benefit

The projected, per vehicle hydrocarbon vapor emission benefit from the use of ILEVs is simply the difference between the ILEV composite emission factor and the base case vehicle composite emission factor. As summarized in Table 5 for several years starting in 1998, ILEVs are expected to realize vapor emission reductions in the range of 0.47 - 0.57 grams/mile/vehicle. Considering the total hydrocarbon emission inventory (vapor and exhaust emissions) as currently estimated for base case vehicles and assuming no reduction in ILEV NMOG exhaust emissions over other CFFVs, ILEVs would be expected to be about 50 percent lower emitting in NMOG emissions than base case vehicles. If ILEVs are indeed lower in exhaust emissions as expected, then the emissions reduction would be even greater.

If some of the fleets are required to implement Stage II refueling emission controls at their refueling facilities (coverage may extend to 10 percent of fleet vehicles), the vapor emission benefit would be somewhat reduced. The above stated emission benefit figures for year 2000 base case vehicles would be reduced about 4 percent to 0.47 g/mi/vehicle. The relative significance of the ILEV vapor emission benefit remains essentially the same.

2. Aggregate Benefit

The annual emission benefit from all operating ILEVs is the product of the emission benefit per ILEV, the projected number of operating ILEVs, and the average annual mileage of ILEVs. This calculation is shown in the following equation:

$$EB_{ILEV} = (e_{Base\ Case} - e_{ILEV}) \times n_{ILEV} \times VMT_{Fleet}$$

EB_{ILEV}	=	Total ILEV Emission Benefit
$e_{Base\ Case}$	=	Emission Factor for Base Case Vehicle
e_{ILEV}	=	Emission Factor for ILEV
n_{ILEV}	=	Number of ILEVs
VMT_{Fleet}	=	Annual Miles Travelled by Fleet Vehicles

The future number of operating ILEVs is difficult to predict. The reasons for this difficulty stem from the uncertainty surrounding the future cost and availability of ILEVs and their fuels, the public acceptance of such vehicles, and the effectiveness of expanded TCM exemptions and other incentives to encourage their purchase. Because of the difficulty in assessing these issues, a wide range of in-use ILEVs population will be assumed to be operating, to encompass the various possible ILEV purchase scenarios that could unfold. Certain points within this range are computed as fractions of the total CFFVs which EPA estimates will be purchased for the fleet program.[1] The middle value in this range is based on the fraction of fleet vehicles in wholesale and retail delivery fleets, which is about 1/15 of the total number of fleet vehicles.[12] These fleets would most likely want to take advantage of the HOV lane incentives. The range of operating ILEVs encompassing the 1/15 value starts at 1/50 of operating CFFVs at the low end, and extends to 1/5 at the high end.

The weighted average annual mileage of fleet vehicles was calculated to be 19,500 miles per year based on the figures in Table 2 for the average fleet mileage and projected number of vehicles for the four vehicle classes involved. The projected number of ILEVs, the vapor emission reduction of ILEVs, and the composite average annual mileage figure combine together in Table 5 to project the hydrocarbon vapor reduction benefit of the ILEV program. The gram/mile emission reduction benefit for ILEVs varies over the years because of the change in the vehicle mix in the fleet.

Table 5 - Calculation of Total Vapor Emission Benefits from the ILEV Program

Year	Projected Number of Operating CFFVs	Fraction of CFFVs as ILEVs	Projected Number of Operating ILEVs	Emission Reduction of ILEVs (g/mi)	Composite Mileage of Fleet Vehicles (mi/year)	Total Emission Benefit from ILEVs (tons/year)
1998	106,000	1/50 1/15 1/5	2,100 7,100 21,200	0.57	20,800	28 93 280
1999	270,000	1/50 1/15 1/5	5,400 18,000 54,000	0.52	20,100	62 210 620
2000	498,000	1/50 1/15 1/5	10,000 33,200 100,000	0.49	19,500	105 350 1050
2005	996,000	1/50 1/15 1/5	20,000 66,400 199,000	0.47	20,100	210 690 2100
2010	1,130,000	1/50 1/15 1/5	22,600 75,300 226,000	0.47	19,000	230 750 2300

The figures indicate a range of vapor reductions from 105 to 1050 tons per year in the year 2000, and 230 to 2300 tons per year in the year 2010. Since the projected number of ILEVs operating is linked to the number of operating CFFVs, the increase in emission reductions associated with the phase-in of the program plateaus by the year 2005. After that point, smaller increases in emission benefits which are expected would result from the growth of the fleet industry, although there could be additional expansions of the program through state initiatives.

The projected aggregate emission benefit of the ILEV program would be smaller if Stage II refueling emission controls affected a portion of the fleet vehicles. Considering that 10 percent of the vehicles could be affected, the projected aggregate emission reduction would be reduced by about 4 percent.

Conversely, the emissions benefit would be much larger if fleets resell their ILEVs to the general public. Up to this point, ILEVs were assumed to be held by the fleet to the end of the vehicle's useful life. This approach was chosen because the fuels projected to be used by ILEVs may not be available to the general public. However, if the fuels are made widely available, (which is likely where local alternative fuel programs or the National Energy Strategy is implemented), if fleets continue their current practices of reselling their vehicles prior to reaching their useful life, and if states offer incentives to noncovered fleets and the public, then ILEV resale prior to full useful life is probable.

Such ILEV sales to the public would increase the number of ILEV purchases and also yield associated emission benefits. In the most optimistic scenario, all ILEVs would be sold off to the public at the same rate currently seen by the fleet industry, which is about 3 years for LDVs, 4 years for LDTs and 5 years for HDVs.[1] At these turnover rates and using average fleet mileage, LDVs, LDTs and HDTs would be sold with about 45,000 miles, 60,000 miles and 75,000 miles on the vehicle, respectively. Comparing these mileage figures with those of useful life would give a sense for the potential increase in the number of operating ILEVs and associated emission reductions which could be realized. The useful lives of LDVs, LDTs and HDTs are 100,000 miles, 120,000 miles, and 120,000 miles, (the weighted average for light and medium heavy-duty vehicles), respectively.[13]

The ratio of mileage to useful life indicates that fleets typically sell their fleet vehicles with about half of the useful life left for those vehicles. Since half of accrued mileage would occur outside of fleets, the effective ILEV fleet size would double as a result. The total impact of the increased ILEV fleet would be observed when the entire fleet turns over. After the start of the fleet program in 1998 when the number of ILEVs sold is expected to increase, and if current fleet resale practices apply, then the resale of light-duty ILEVs would begin as soon as three years later in 2001. The number of ILEVs operated in the public sector would catch up to the sales to fleets 10 years after 1998 when the heavy-duty fleet vehicles would have completely turned over. The emissions impact of ILEVs depends on the increased number of ILEVs which would begin immediately and would increase until the fleet size stabilizes in 2008.

Based on the scenario laid out above, the ILEV emission benefit figures determined above would be adjusted upwards to include the potential additional ILEV sales and associated air benefits. Thus, the above projected year 2010 ILEV VOC emission benefits of 230 - 2300 tons per year would increase to 460 - 4600 tons per year.

e. Conclusion

The projected composite hydrocarbon vapor emission factor (0.01 g/mi/vehicle) for ILEVs is very low compared to the projected composite emission factor for base case CFFVs (0.50 grams/mile/vehicle). The purchase of ILEVs by fleets would essentially eliminate vapor emissions relative to base case vehicle purchases. Preliminary exhaust emission calculations shows base case vehicles to emit about equal quantities of hydrocarbon exhaust emissions as evaporative emissions. Even assuming equal exhaust hydrocarbon emissions from ILEVs (which would seem to be a conservative assumption), the purchase of ILEVs is projected to cut NMOG emissions by over one half. Thus, ILEVs would be much cleaner vehicles than base case vehicles, and are justified in receiving the additional TCM exemptions and other incentives extended to them.

Compared to other emission control programs, the per vehicle benefit of ILEVs is significant. Reformulated gasoline and enhanced inspection/maintenance programs are two emission control programs currently being considered for implementation, and EPA estimated either to reduce exhaust and evaporative nonmethane emissions by about one quarter. Based only on evaporative emissions, the ILEV program would be incrementally twice as effective as these other programs.

If ILEVs are resold by fleets to noncovered fleets and to the private sector before the vehicles reach their full useful life, the aggregate number of ILEV sales and related emission benefits would increase. The extent of the increase would seem to depend on the availability of ILEV fuels and the degree to which states make incentives available to noncovered fleets and the public. This analysis demonstrates how this effect could potentially double ILEV sales and emission benefits.

The aggregate emission benefits of the ILEV program would increase following promulgation of additional transportation control measure exemptions for ILEVs. EPA proposed in the rulemaking process to study other incentive programs and promulgate additional TCM exemptions that make good policy sense. These additional exemptions would be expected to result in more ILEV purchases and, as more conventional vehicle or LEV purchases are supplanted by ILEVs, the total emission benefit will rise.

V. Affects of ILEV Use of HOV Lanes

a. Background

Now that the ILEVs have been shown to be much lower emitting than the base case vehicles, the next task is to compare that benefit with any implications of ILEVs using HOV lanes.

1. What are HOV Lanes?

High-occupancy vehicle (HOV) lanes are special lanes of the road restricted for use by vehicles carrying multiple occupants, such as carpools, vanpools, and buses. Several different types of HOV lanes have been implemented and each of these types could be affected by the ILEV program. These include freeway HOV lanes, arterial HOV lanes, and bus-only lanes. Other HOV lane lanes are really variations of the above, and include freeway ramps and bridge and toll road HOV lanes. Because bus-only lanes are generally not open to vehicles other than buses, they would not be available for use by ILEVs under the federal program. The state and local governments, however, could choose to open up such lanes to ILEVs on a case-by-case basis. This report will focus on freeway HOV lanes because of their relative high usage and widespread implementation, and because data are much more available on their operation. It is reasonable to assume that the impact on other types of HOV lanes would be similar to that expected for freeway HOV lanes, since they are all used in essentially the same ways.

Two conditions must be present for HOV lanes to be successful as transportation control measures. First, the volume of traffic in the general purpose lanes (non-HOV lanes) must be great enough to cause frequent congestion problems during the heavy traffic or peak periods. Second, the volume of HOV lane traffic flow must be sufficiently low to avoid congestion even during the rush period. This difference in traffic flow would then provide a twofold incentive for single occupancy drivers to join a carpool and use the HOV facility. The first incentive is that the daily commute takes less time, and second is the greater reliability of arriving at one's destination on time (i.e., fewer or no traffic jams).

2. HOV Lane Benefits

HOV lanes can produce a range of benefits. One benefit is motor vehicle emission reductions, which can be separated into primary and secondary reductions. The primary emission reduction is the elimination of emissions from vehicles the drivers of which become passengers in other vehicles. These reductions are significant, since potentially each additional rider eliminates a vehicle trip. The secondary emission reduction results from the reduced congestion brought about by the reduced number of vehicles on the road. More efficient traffic flow decreases total vehicle emissions because vehicles are spending less time in inefficient stop-and-go operation. For several reasons the emission reductions from HOV lane use have not been perhaps as large as originally anticipated by those studying the effectiveness of HOV lanes.[14] However, the use of HOV lanes is positive from an environmental prospective.

Other benefits of HOV lanes which result from congestion relief include decreased energy consumption, increased economic efficiencies related to transport of people and goods, and reduced need to expand freeway capacity. When realized, these benefits increase economic efficiency by reducing the cost or time it takes to do business. In addition, to the extent that congestion is reduced, HOV lanes may also lower public frustration from traffic jams.

3. HOV Lane Utilization

HOV lane traffic flow is considered undesirable if it is either too high or too low. In the case of freeways, a rule of thumb which has been established is that the flow is considered too high if it increases above 1500 vehicles per hour.[15] Above this level, the lane begins to appear full and the HOV lane incentive that lures potential carpoolers to participate begins to be less inviting. The maximum of any lane carrying a normal mix of vehicles under normal weather conditions is accepted to be about 2000 vehicles per hour. At this point unstable flow or stop-and-go traffic usually begins.[16] The second issue occurs when the HOV lane drops to about 800 vehicles per hour or lower. At these lower traffic flows, the HOV lane appears practically empty and objections by the general public to the lane can arise. The most optimum flow would seem to occur around 1500 vehicles per hour at which point all lanes of the freeway are carrying the maximum numbers of persons and vehicles.

b. Method of Analysis

The HOV lane analysis presented here projects the increase in HOV lane traffic flow arising from the use of ILEVs and assesses whether current vehicle volume would be increased above the 1500 vehicles per hour threshold thought to be the indicator of optimum flow for HOV lanes. The analysis further quantifies the impact of allowing ILEVs access to HOV lanes by assessing how the increased flow may decrease HOV lane speed. To best predict the actual impact of ILEVs, the analysis used lane-use data collected from existing HOV lanes.

The analysis of the impact of ILEVs on HOV lanes was made in three steps, and each step often involved several substeps. First, several urban areas with HOV lanes were chosen for study. Then, to project the number of operating ILEVs in each of those areas, the number of operating CFFVs in each area was projected and, the same broad range used in the ILEV emission reduction section above (1/50, 1/15, 1/5) was applied here. In addition, however, the ILEV range was adjusted by the fraction of urban freeways in each area projected to have HOV lanes. This adjustment brings the projected number of ILEVs more in line with the estimated amount of available incentives. Finally, the third step was to assess the impact of ILEVs on the traffic flow in HOV lanes during the peak traffic period. Each of these steps is detailed below.

To project the impact of ILEVs on HOV lanes, several urban areas with HOV lanes were chosen for study. Houston, Texas; District of Columbia; Los Angeles, California, and Seattle, Washington were chosen because HOV lanes are already functioning in these areas, and data on their use patterns have been collected and were readily available. The entire urban area was studied because each HOV lane and associated freeway lanes are part of a traffic management strategy for the urban area where they are located. Furthermore, these areas, except for Seattle, are all covered by the clean-fuel fleet program. Although Seattle is not a covered area, it was chosen because it is similar in population and highway characteristics to Atlanta and Baltimore, which do not currently have HOV lanes to analyze. Like Baltimore and Atlanta, Seattle has about 2 million inhabitants, and about 10 freeways entering and encircling the urban area.

The next step was to project the number of operating CFFVs in each of the chosen areas. This number was found by adjusting the projected nationwide number of CFFVs in all areas covered by the fleet program by the area fuel use fraction of the area being studied.[1] Table 6 below summarizes these steps and resulting numbers.

Table 6 - The Number of CFFVs in Particular Urban Areas for the Years 2000 and 2010.

Area Being Studied	Area Fuel Fraction	Year	Number of CFFVs*
Houston Texas	0.059	2000	30,500
		2010	69,400
District of Columbia	0.050	2000	25,800
		2010	58,800
Seattle Washington	0.033	2000	16,900
		2010	38,300
Los Angeles California	0.193	2000	99,800
		2010	227,000

* **Number of CFFVs for entire U.S. was estimated to be 516,900 cars and trucks in the year 2000, and 1,176,000 in 2010.[1]**

Next, the number of operating ILEVs was determined for each area studied. Consistent with Section IV above, the number of ILEVs is projected to fall within a relatively broad range based on fractions of the projected number of operating CFFVs. The same range of fractions (1/50, 1/15, 1/5) is used as a starting point; however, in this case the range is adjusted lower by the fraction of freeways in that particular urban area expected to have operating HOV lanes by the year 2000. This fraction was established with the HOV lane information summarized in Table 13 in the Appendix,[17] and the use of a recent road atlas. In effect, this approach reasonably supposes that only fleet operators near HOV lanes will purchase and use ILEVs.

The third step was to determine the extent that ILEVs might increase HOV traffic flow during the heaviest traffic periods of the day. To conduct this analysis, information was needed on how the ILEV population would be dispersed throughout the heavy traffic period and to determine the duration of that period. The dispersion of ILEVs was determined from the operating characteristics of fleets in general. Based on the operating characteristics, it is reasonable to believe that fleet vehicle use of HOV lanes would be equally dispersed throughout the commute period. These vehicles are used for various delivery purposes such as raw and finished material deliveries; mail, package and administrative paperwork deliveries and each application would tend to demand a different vehicle use schedule. Furthermore, fleets try to minimize their costs by accomplishing multiple tasks in the immediate area of their destination prior to returning to their central location. This requires additional time in the destination area. Based on these characteristics, fleet use of HOV lanes would be limited to perhaps one trip per vehicle during each commute period, and the tendency is that the trips would be dispersed.

The heaviest traffic period was identified by studying the characteristics of urban highways and current HOV lanes. Urban highway traffic flows tend to be highest during the commute periods, and the absolute highest during the peak-hour of those periods. For the HOV lanes analyzed, the peak-hour flow during the morning commute, was generally found to be the maximum flow period of the entire day.[18] The morning commute period is usually reported to occur from 6:00 a.m. to 10:00 a.m.[18]

Based on the discussion above, it was then possible to estimate HOV lane use by ILEVs during the heavy traffic periods. Fleet vehicles would be expected to make only one trip during the heavy traffic period and based on the variety of fleet applications, these trips would be spread out over the entire heavy traffic period. Information suggests that the heavy traffic period is about 4 hours. Therefore, the ILEV population using HOV lanes is divided by 4 to estimate the number of ILEVs which would be added to an HOV lane during the peak-hour traffic period.

The impact of ILEVs on HOV lane traffic flow in each studied area was analyzed with the use of a commonly used highway design diagram. This diagram, reproduced in Figure 1 in the appendix, was developed by transportation engineers to relate the traffic speed in any one lane to the traffic flow.[14] For this analysis, the diagram was used to determine the change in average vehicle speed which might occur from a given increase in the flow of traffic. The far right point of the diagram's curve indicates the "maximum flow point" of about 2000 vehicles per hour. When the "maximum flow point" is reached, further traffic demand begins to result in a drastic decrease in lane flow and speed. This resulting condition is termed unstable flow.[16]

This analysis methodology was applied to each of the four urban areas studied. This next section summarizes the specific information used in making the analysis for each urban area, and the results of the individual analyses.

c. Case-by-Case Analyses

1. Houston, Texas

The Houston area provides an especially good case to evaluate for this analysis because several HOV lanes are already implemented and designs are complete to add more HOV lanes. Figure 2 in the Appendix shows the existing and planned HOV lanes for the Houston urban area.[19] The future highway HOV lane system serves almost every quadrant surrounding the city center, except for I-10 to the east and SH 288 to the south.

As described in the subsection above, the previously used broad range of fractions (1/50, 1/15, 1/5) was adjusted by the fraction of freeways with HOV lanes and applied to the number of CFFVs in Table 6 to project a range of operating ILEVs. The Houston area has 10 total highways and 6 of these are expected to have HOV lanes;[17,19] the previously used fractions are therefore adjusted downward by 6/10 to 1/80, 1/25, and 1/8. The range of ILEVs operating in each HOV lane is determined by dividing the projected range of ILEVs for the entire area by the number of HOV lanes. Finally, the number of ILEVs operating during the morning peak hour was determined by multiplying the calculated range of ILEVs expected to be operating in each HOV lane by the 1/4 adjustment factor discussed in the previous section. The results of these calculations are summarized below in Table 7.

Table 7 - Projected Number of ILEVs Operating in Houston HOV Lanes During Peak Hour

Area Being Studied	Year	Adjusted Range of Fractions	Number of Operating ILEVs	ILEVs Operating in Each HOV Lane	ILEVs Operating During Peak Hour
Houston Texas	2000	1/80	380	60	15
		1/25	1,220	200	50
		1/8	3,810	635	160
	2010	1/80	870	140	36
		1/25	2,800	460	120
		1/8	8,700	1,400	360

The impact on HOV lane volume caused by the use of ILEVs was projected by adding the estimated ILEV peak-hour operating volume to that recently recorded for an existing HOV lane. The Houston highway labeled I-10, which is also called the Katy Highway, has been studied extensively and that available data was used for study in this analysis and reasonably assumed to apply to the other Houston HOV lanes as well. The data reveal that the Katy highway peak-hour flow is about 1050 vehicles per hour.[19] Adding the range of ILEVs projected to be operating during the peak hour in an HOV lane in the year 2000 to the current volume of 1050 vehicles per hour yields a range of 1065 - 1200 vehicles per hour. The same calculation performed for the year 2010 yields a range of 1085 - 1400 vehicles per hour.

The impact of this projected increased volume in HOV lanes during peak hour can be estimated by using the vehicle speed versus traffic flow diagram (see Figure 1 in the Appendix). By dividing the initial flow of 1050 vehicles per hour by the potential maximum flow of 2000 vehicles per hour, a volume/capacity ratio of 0.53

results. This value forms the baseline of comparison for the projected increased traffic flows after the introduction of ILEVs. Using the potential maximum HOV and ILEV traffic volume in the year 2000 of 1200 vehicles per hour and dividing by 2000 vehicles per hour, a volume/capacity value of 0.60 is produced. The 0.53 value corresponds with 57 miles per hour, while the 0.60 value corresponds with the value of about 56 miles per hour (using the non-California curve in the diagram), or a 1 mile per hour decrease in speed. The impact on traffic speed determined from the other value for the year 2000, and the upper and lower values of the range for the year 2010 were calculated in the same fashion. These calculations show that the projected increase in traffic volume would cause average vehicle speed to be reduced by 0 - 1 miles per hour in the year 2000, and 0 - 2 miles per hour in the year 2010. These projected changes in flow are essentially insignificant, especially considering the hourly and daily variations in traffic flow typically seen on these roads.

2. District of Columbia

The District of Columbia currently has three operating HOV lanes and tentatively plans to implement one more as indicated in Figure 3 in the Appendix.[19] The HOV lane which has been studied and documented extensively is called the Shirley Highway, or I-395; the others are I-66, I-95 (which is an extension of I-395), and the Dulles tollroad.[15,19] There are a total of ten major highways entering and connecting the D.C. urban area. Using these figures, the previously used fractions are adjusted downward by 4/10 to 1/125, 1/40, and 1/12. The peak hour volume is reported to be 2460 vehicles per hour for two HOV lanes of traffic, or 1230 vehicles per hour in each lane.[19] These figures and assumptions as they apply to the D.C. HOV lanes are summarized below in Table 8.

Table 8 - Projected Number of ILEVs Operating in District of Columbia HOV Lanes

Area Being Studied	Year	Adjusted Range of Fractions	Projected Number of Operating ILEVs	ILEVs Operating in Each HOV Lane	ILEVs Operating During Peak Hour
District of Columbia	2000	1/125 1/40 1/13	210 650 1,980	50 160 500	13 40 125
	2010	1/125 1/40 1/13	470 1,470 4,520	120 370 1,130	30 90 280

Using the methodology used for Houston above, the HOV lane traffic for Washington DC is expected to increase from 1230 vehicles per hour to 1243 - 1355 vehicles per hour in the year 2000, and to 1260 - 1510 vehicles per hour in 2010. Using the lane speed versus flow diagram, these flow increases correspond to average vehicle speed reductions of 0 - 1 mile per hour in the year 2000, and 0 - 3 miles per hour in 2010. Once again, this effect is essentially insignificant.

3. Seattle, Washington

The HOV lane in Seattle which has been adequately studied is I-5 North. Other existing and planned HOV lane lanes are: I-90, I-5 South, I-405, SR 167, SR 522, and SR 520. There are a total of 10 major highways entering and connecting the Seattle urban area. The highways with and without HOV lanes are shown in Figure 4 in the Appendix.[19] Using these figures, the initial range of fractions was adjusted by 7/10 to 1/70, 1/20, and 1/7. The peak hour volume for I-5 was reported to be 500 vehicles per hour, which is below the undercapacity point for freeway HOV lanes. Since the data was collected, the HOV lane occupancy was modified from 3 to 2 minimum occupants per vehicle, and the lane volume has very likely increased. However, this report will evaluate the data available at this point in time. These figures and assumptions as they apply to the Seattle HOV lanes are summarized below in Table 9.

Table 9 - Projected Number of ILEVs Operating in Seattle HOV Lanes During Peak Hour

Area Being Studied	Year	Adjusted Range of Fractions	Number of Operating ILEVs	ILEVs Operating in Each HOV Lane	ILEVs Operating During Peak Hour
Seattle Washington	2000	1/70	240	34	10
		1/20	800	110	30
		1/7	2,400	340	80
	2010	1/70	550	80	20
		1/20	1,920	270	70
		1/7	5,470	780	200

The effect of ILEVs using I-5 and the other HOV lanes, based on the higher occupancy threshold, can be evaluated by the same methodology used earlier. The HOV lane traffic would be expected to increase from 500 vehicles per hour to 510 - 580 vehicles per hour in the year 2000, and to 520 - 700 vehicles per hour in 2010. Using the speed versus flow diagram, these volume increases correspond to no vehicle speed reduction in the year 2000 and a 0 - 1 mile per hour reduction in 2010. Obviously, even if the number of current vehicles using HOV lanes doubled as a result of the recent change in the occupancy requirement, the effect of ILEVs would still be insignificant.

4. Los Angeles, California

Los Angeles has three HOV lanes operating at this time: the San Bernardino freeway (I-10); the Newport/Costa Mesa freeway (Route 55); and the Artesia freeway (Route 91). Another 18 HOV lanes are planned which would increase the total number of freeways with HOV lanes to 21 out of a total of 24 freeways.[17,19]] These freeways are shown in Figure 5 in the Appendix.[19] Using the numbers of highways with and without HOV lanes, the initial range of fractions is adjusted by 21/24 to 1/60, 1/17, and 1/6. Because of the severity and complexity of the traffic problem in Los Angeles, HOV lanes are used extensively. The highest flow can be in afternoon or morning or near equal for both; therefore, the entire data set of morning and afternoon peak hour flow will be used in lieu of just one data set for all lanes.[19] The averaging of the HOV lane peak hour traffic flows is 1370 vehicles per hour, and this data is summarized in Table 10 below.

Table 10 - Average Peak Hour Flow for HOV Lanes in Los Angeles[19]

HOV Lane	Morning Peak Hour Flow	Afternoon Peak Hour Flow	Average Peak Hour Flow
San Bernardino	1,445	1,267	
Route 55	1,298	1,578	
I-405	1,294	1,082	
Route 91	-	1,629	
Average Peak Hour Flow			1,370

The result of the HOV lane calculations are summarized in Table 11 below.

Table 11 - Projected Number of ILEVs Operating in Los Angeles HOV Lanes During Peak Hour

Area Being Studied	Year	Adjusted Range of Fractions	Number of Operating ILEVs	ILEVs Operating in Each HOV Lane	ILEVs Operating During Peak Hour
Los Angeles California	2000	1/60	1,660	80	20
		1/17	5,900	280	70
		1/6	16,600	790	200
	2010	1/60	3,780	180	45
		1/17	13,400	640	160
		1/6	37,800	1,800	450

The analysis shows that HOV lane traffic is expected to increase from the current average of 1370 vehicles per hour to 1390 - 1570 vehicles per hour in the year 2000, and to 1415 - 1820 vehicles per hour in 2010. Using the California-specific curve of the speed versus diagram, these flow increases correspond to average speed decreases of 0 - 2 miles per hour in the year 2000, and 0 - 3 miles per hour in 2010.

This analysis of the Los Angeles area, based on the average of HOV lane data available, indicates that for the high end estimate (1/6) in the out years (2010) ILEVs may increase the HOV traffic flow beyond the range which transportation engineers would consider optimal. As already stated, engineers generally design HOV lanes to maintain the volume of traffic in those lanes at or under 1500 vehicles per hour, and absolutely keep the flow in HOV lanes under the maximum flow of 2000 vehicles per hour. At the high end of the estimated range of operating ILEVs, traffic volume would increase to values beyond the optimal range. This impact on HOV lane flow would be offset, however, by the commensurate decrease in flow in the general purpose lanes.

The 1500 vehicle per hour design optimum, however, does not appear to be a hard and fast rule. According to the data available on HOV lanes, there are 8 cases where the average peak-hour flow exceeds the 1500 vehicle per hour value, and four of those are greater than 1600 vehicles per hour.[19] If HOV lane traffic flow above the recommended threshold was indeed a significant problem in those cases, then steps to correct those situations would have already been taken.

d. Conclusion

The city-specific HOV lane analysis presented in this report shows that ILEV use of HOV lanes would not cause a significant vehicle volume increase for three of the four cases analyzed. Estimates of ILEV use in Houston, District of Columbia, and Seattle (representing Baltimore and Atlanta) suggests that the probable traffic flow increase in HOV lanes is well below the desired optimal flow of 1500 vehicles per hour. The HOV traffic flow was so low in Seattle's situation at the time the data was being collected that the addition of ILEVs might actually improve any public perception of underutilization. Further analysis shows that such increases in flow for these three areas would decrease average vehicle speed only two miles per hour or less. Data collected from most other HOV lanes currently operating appear to be similar to these three cases analyzed here.[19] The increase in HOV lane flow would be offset by the commensurate decrease in flow in the general purpose lanes.

The analysis of the HOV lanes in Los Angeles demonstrates that there could be some instances where ILEV use of a highly-used HOV lane could increase the flow to a level somewhat beyond the design optimum for a HOV lane. Several important points need to be made concerning this case. First, this analysis conservatively assumed that the 18 lanes to be added would all receive use at the same level as the 3 current lanes. And even using this assumption, potential impacts were projected only at the high end estimate in the out years.

Second, the modifications currently employed by transportation authorities to relieve increasing HOV demand could also be implemented for any similar case created in part by ILEVs. One option for accommodating increased demand for HOV lanes is to increase the minimum number of occupants that will qualify a vehicle to use a particular lane. This method was employed by Houston for the Katy freeway. The facility was opened as a four-person-per-vehicle HOV facility and then was eventually reduced to a two-person facility to encourage participation.[18] When the participation increased to extreme levels, the minimum vehicle occupancy was increased to a three-person HOV lane during the peak period.[19] The Seattle HOV lane analyzed was only recently changed from a three-person facility to a two-person facility to increase its usage and carrying capacity.

Another way to accommodate increased demand for HOV lanes is to increase the number of lanes available. The Shirley freeway is an example of a two lane HOV facility. This obviously allows for twice the capacity as a single lane facility. Another possibility is to convert an existing general purpose lane to another HOV lane. Also, increased enforcement of HOV lane requirements could help to reduce use by eliminating ineligible vehicles. This would have salutary effects on lane use and in public perception regarding HOV lanes.

If ILEV overuse of HOV lanes were to be widespread, there could be other ways in which the use of ILEVs could be curtailed. One method would be to require that ILEVs be designed to operate even cleaner than currently proposed. For example, more stringent inspection and maintenance testing requirements for exhaust emissions could be required for ILEVs. This more stringent requirement would guarantee cleaner vehicles, with the subsequent result of increasing the owner's responsibility of operating these vehicles. Added future requirements such as these, if found to make good economic sense, could help to limit the ILEV program to a truly advanced technology program.

Third, even though there are many potential remedies, EPA is allowing **any** state to seek a waiver from EPA to allow them to discontinue the HOV exemption for part or all of a particular HOV lane where ILEVs are the direct cause of extreme HOV lane congestion. EPA would carefully consider waiver requests in which requesting states demonstrate that other solutions are either too costly or too unreasonable to pursue.

V. Additional TCM Exemptions for ILEVs

During the course of this analysis, two reasons made it apparent that the HOV lane exemption proposed for ILEVs may not offer an incentive sufficient enough to encourage widespread purchases of ILEVs. First, not all nonattainment areas covered by the fleet program have such lanes or firm plans to implement them. As summarized in Table 14 in the Appendix, of the 22 nonattainment areas covered by the fleet program, only 11 have committed plans to have HOV lanes by the end of this decade.[17,19] And of these 11 areas, only three have committed plans to implement HOV lanes for more than half of the major highways in the urban area. More HOV lanes are expected to be implemented, however, as states finalize plans on how to meet the urban airshed improvement goals specified in the Act. Second, during the rulemaking process, the fleet industry expressed some concern that the HOV lane exemption does not offer an equal incentive to each fleet. Apparently, fleets use highways to varying degrees and the HOV lane exemption would tend to favor those fleets which use highways more. Based on these two reasons, many fleets may not be encouraged to purchase ILEVs.

To offer all fleets an equal playing field to participate in the ILEV program, EPA intends to propose to exempt ILEVs from additional TCMs. EPA will study the effectiveness of each potential TCM exemption to determine which of the additional exemptions would provide the broadest possible incentive while minimizing any related negative repercussions. After such evaluations, EPA would promulgate those select TCM exemptions in rulemakings giving the public the opportunity to comment on the proposed exemptions. EPA intends to consider all TCM exemptions including those suggested by the fleet industry during the rulemaking process which established the ILEV program.

As additional TCM exemptions are promulgated and phased in, the number of ILEV purchases are expected to increase resulting in associated air quality benefits. EPA intends to estimate and summarize these benefits during the rulemaking process.

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Appendix

Table 12 - Emission Factors for Base Case Vehicles Operating in 1998 and Thereafter (figures in parentheses includes effects of Stage II reductions)

Vehicle Class	Hot Soak and Diurnal Emissions	Running Loss	Resting Loss	Refueling Emissions	Total Vapor Emissions
LDV	0.04	0.08	0.04	0.17 (0.16)	0.33 (0.32)
LDT1	0.05	0.07	0.04	0.22 (0.20)	0.38 (0.36)
LDT2	0.05	0.07	0.04	0.23 (0.21)	0.39 (0.37)
HDGV	0.51	0.32	0.04	0.36 (0.33)	1.23 (1.20)
Weighted Average					0.50 (0.48)

Table - 13

Operational Characteristics of
Freeway/Highway HOV Facilities in Areas
Covered by the Fleet Program and Seattle, Washington

Area/HOV Facility	Number of Lanes	Project Length (Miles)	Eligibility Requirements	Facility Type
Houston				
Existing:				
I-10 (Katy)	1 (Reversible)	13	3 + Peak Hours 2 + Other Times	Barrier-Separated; Reversible-Flow
I-45 (Gulf)	1 (Reversible)	6.5	2 + HOVs	Barrier-Separated; Reversible-Flow
US-290 (Northwest)	1 (Reversible)	13.5	2 + HOVs	Barrier-Separated; Reversible-Flow
I-45 (North)	1 (Reversible)	13.5	2 + HOVs	Barrier-Separated; Reversible-Flow
Planned				

US 59 (SouthWest)	1 (Reversible)	13.8		Flow Lane and Ramps
US-59 (Eastex)	1 (Reversible)	20		Flow Lane and Ramps
I-45 (North)	Extension to Reversible	6.2		Flow Lane
I-45 (Gulf)	Extension to Reversible	9		Flow Lane
District of Columbia				
Existing:				
I-86 (Northern Virginia)	2-3 each direction	9.6	3 + HOVs	Barrier-Separated; Reversible-Flow
I-395 (Shirley)	2 (Reversible)	11	3 + HOVs	Barrier-Separated; Reversible-Flow
I-95 (Interim)	1 each direction		3 + HOVs	Concurrent-Flow; Buffer-Separated/Non-Separated

Planned:				
I-95	Extension to Reversible	19		Flow Lanes
I-66	Concurrent	7.5		Flow Lanes
Dulles Toll Road	Concurrent	10		Flow Lanes
Seattle				
Existing:				
I-5 (North)	1 each direction	5.9 SB 6.2 NB	2 + HOVs	Concurrent-Flow; Buffer-Separated/Non-Separated
I-5 (North Express Lanes)	1 (Reversible w/mixed Flow)	6	2 + HOVs	Concurrent-Flow; Buffer-Separated/Non-Separated
I-90 (Interim)	1 (WB only)	5	2 + HOVs	Concurrent-Flow; Buffer-Separated/Non-Separated

I-5 (South)	1 each direction	6.7 NB 5.0 SB	3 + HOVs	Concurrent-Flow; Buffer-Separated/Non-Separated
I-405	1 each direction	8.5	2 + HOVs	Concurrent-Flow; Buffer-Separated/Non-Separated
SR-167	1 (WB only)	1.1	2 + HOVs	Concurrent-Flow; Buffer-Separated/Non-Separated
SR-509	1 (NB only)	0.8	2 + HOVs	Queue Bypasses
SR-15 (Gig Harbor)	1	0.7	3 + HOVs	Queue Bypasses
Various Entry Ramps	1	0.1	Mostly 3 + HOVs	Queue Bypasses
Ferry terminal docks	1	0.1	2 + HOVs	Queue Bypasses
<u>Planned</u>:				

I-405	Extensions to Concurrent	31		Flow Lanes
I-5 (South)	Extensions to Concurrent	39		Flow Lanes
I-90	Reversible and Concurrent	14		Flow Lanes
SR-520	Concurrent	6		Flow Lanes
SR-522	Extensions to Concurrent	2.1		Flow Lanes
SR-167	Extensions to Concurrent	12.5		Flow Lanes
Los Angeles				
<u>Existing</u>:				
Los Angeles, CA, I-10 (El Monte)	1 each direction	12	3 + HOVs	Barrier-Separated: Two-Way
Los Angeles, CA, Rte. 91	1 (EB only)	8	2 + HOVs	Concurrent-Flow; Buffer-Separated/Non-Separated

Rte. 55	1 each direction	11	2 + HOVs	Concurrent-Flow; Buffer-Separated/Non-Separated
I-405	1 each direction	24	2 + HOVs	Concurrent-Flow; Buffer-Separated/Non-Separated
Over 250 Entry Ramps	1	0.1	2 + HOVs	Queue Bypasses
Planned:				
I-210	Concurrent	45		Flow Lanes
Rte. 91	Westbound Concurrent	13		Flow Lanes
I-10 (San Bernardino)	Extension to Concurrent	10		Flow Lanes
I-10 (Santa Monica)	Concurrent	12		Flow Lanes
I-710 (Harbor)	Transitway and Ramps	14.5		

I-105 (Century)	Concurrent	18		Flow Lanes
Rte. 118	Concurrent	44		Flow Lanes
I-405	Concurrent	25		Flow Lanes
I-605	Concurrent	20		Flow Lanes
I-5	Concurrent	34		Flow Lanes
Route 2	Concurrent	7.5		Flow Lanes
Route 14	Concurrent	10		Flow Lanes
Route 57	Concurrent	11		Flow Lanes
Route 60	Concurrent	32		Flow Lanes
Route 101	Concurrent	30		Flow Lanes
Route 134	Concurrent	13		Flow Lanes
Route 170	Concurrent	5.5		Flow Lanes
Route I-5	Concurrent	46		Flow Lanes
Route I-5	Barrier	3.3		Separated Lanes
Routes 55/405, 57/91, 55/91		6		HOV Interchanges
Route 57	Concurrent	10		Flow Lanes

Route 91	Concurrent	19		Flow Lanes
Route 91	Concurrent	10		Flow Lanes
Route 215	Concurrent	14		Flow Lanes
Baltimore				
Existing:				
NONE				
Planned:				
I-270	Concurrent	Not Available		Flow Lanes
Boston				
Existing:				
NONE				
Planned:				
I-90	Concurrent	1		Flow Lanes
I-93 (South)	Barrier	1.5		Separated Lanes
I-93 (North)	Concurrent	0.5		Flow Lanes

Denver				
Existing:				
U.S. 35 (Boulder Turnpike)	1 (EB Only)	4.1	Buses Only	Queue Bypasses
Planned:				
I-25	Reversible	12		Flow Lanes and Ramps
Greater Connecticut				
Existing:				
Hartford, CT, I-84	1 each direction	10	3 + HOVs	Concurrent-Flow; Buffer-Separated/Non-Separated

Hartford, CT, I-91	1 each direction	10	3 + HOVs	Concurrent-Flow; Buffer-Separated/Non-Separated
Planned:				
I-91	Concurrent	9		Flow Lanes
New York				
Existing:				
Rte. 495 (Lincoln Tunnel)	1	2.5	Buses Only	Contraflow
Long Island Expy.	1	4	Buses, vanpools, taxis	Contraflow
Gowanus Expy.	1	2	Buses, vanpools, taxis	Contraflow
Ft. Lee, NJ (New York City) I-95	1 (EB Only)	1	3 + HOVs	Queue Bypasses

Rte. 495 (Lincoln Tunnel)	1	0.3	Buses Only	Queue Bypasses
Planned:				
I-495 (Long Island Expy.)	Concurrent	23		Flow Lanes
Sacramento				
Existing:				
NONE				
Planned:				
Route 99	Concurrent	11		Flow Lanes
San Diego				
Existing:				
San Diego, CA	2 (Reversible)	8	2 + HOVs	Barrier-Separated; Reversible-Flow

Various Entry Ramps	1	0.1	2 + HOVs	Queue Bypasses
<u>Planned</u>:				
I-5	Concurrent	21		Flow Lanes
I-15	Concurrent	12		Flow Lanes

Fleet program covered areas currently without HOV facilities or plans for such facilities:

Atlanta, GA
Beaumont - Port Arthur, TX
El Paso, TX
Philadelphia, PA
San Joaquin Valley, CA
Springfield, MA
Baton Rouge, LA
Chicago, IL
Milwaukee, WI
Providence, RI
Southeast Desert, CA

Figure 1

SPEED-FLOW RELATIONSHIP

From 1985 Highway Capacity Manual (70 mph design speed, 8-lane curve)

With Typical California Operation Shown

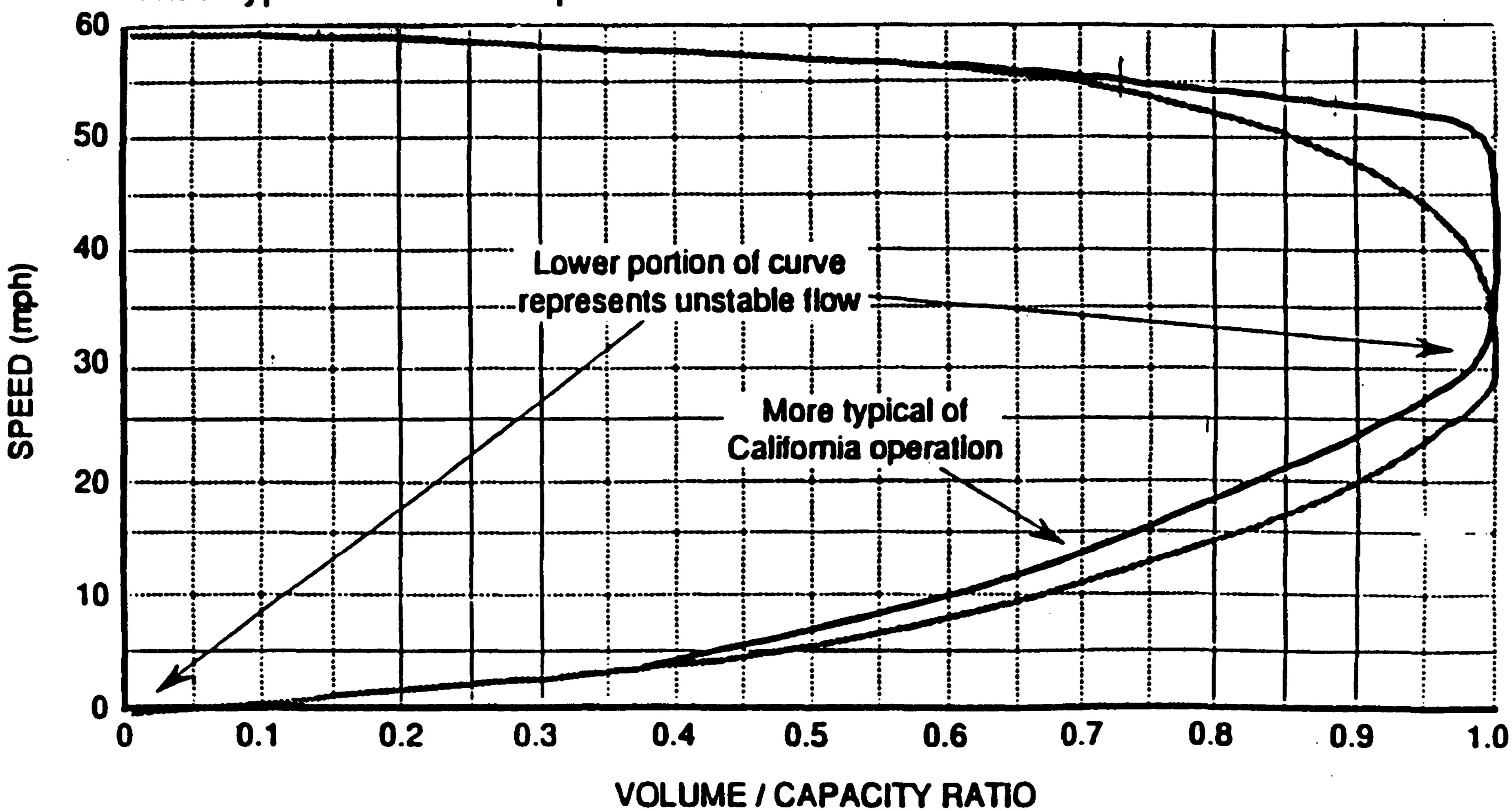

Figure 2

Houston Transitways

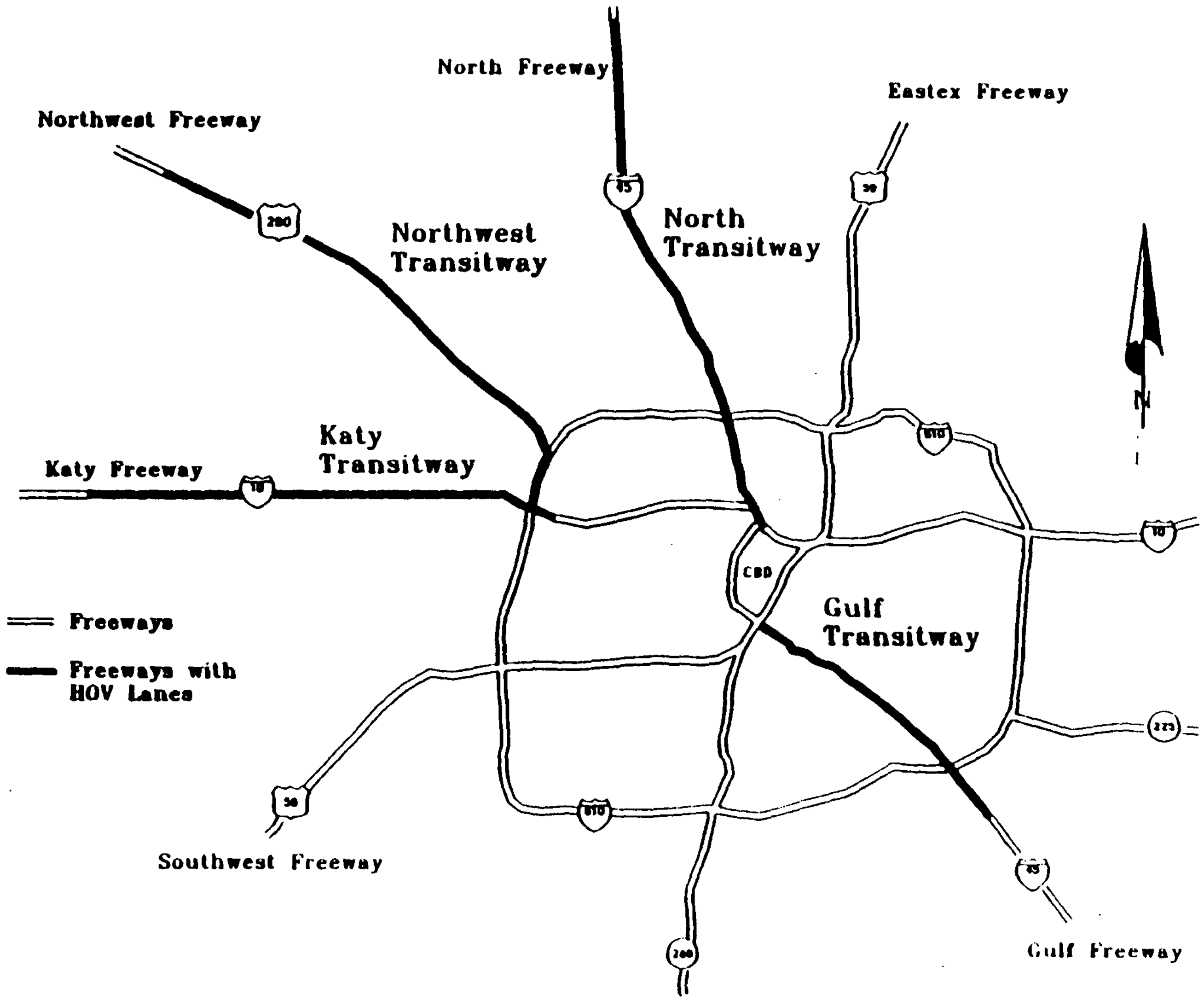

Figure 3

Washington D.C./Northern Virginia HOV Lanes

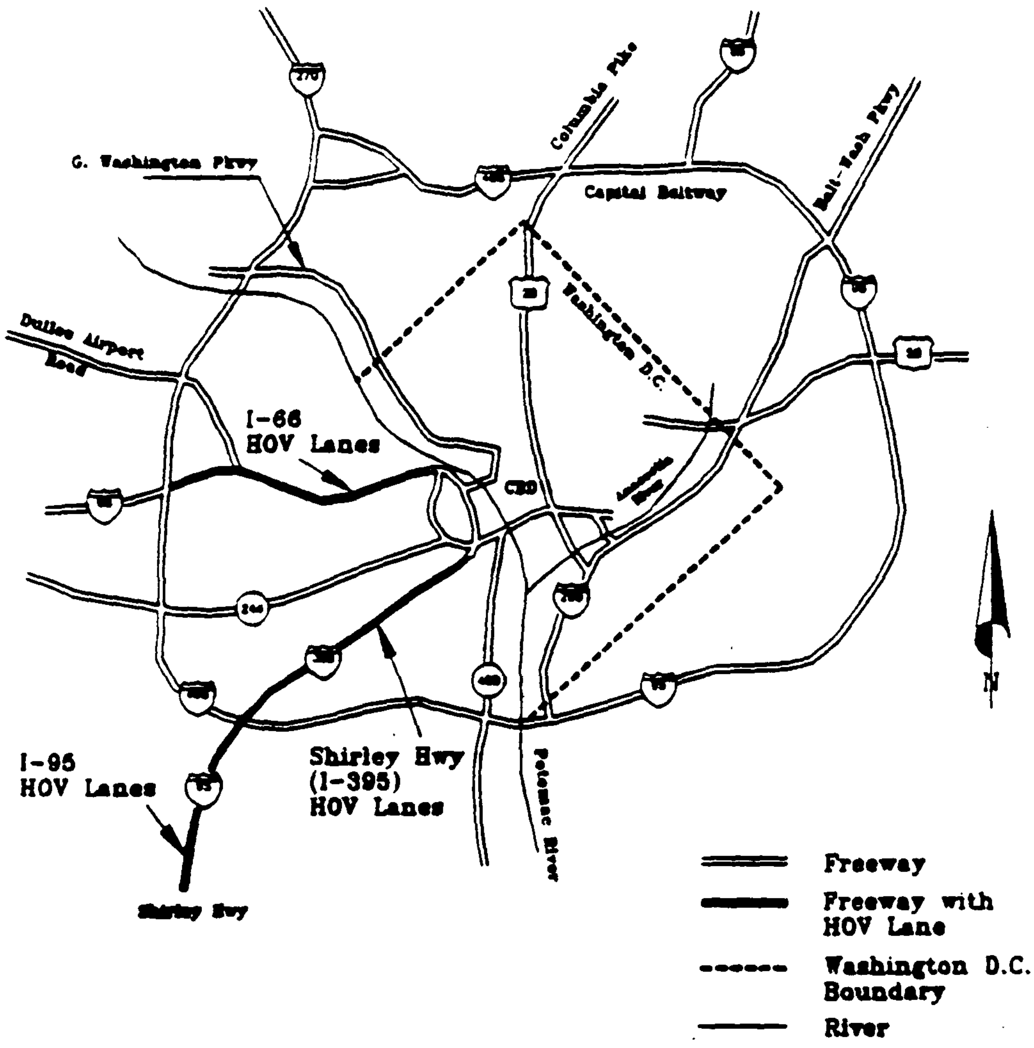

Figure 4

Seattle HOV Lanes

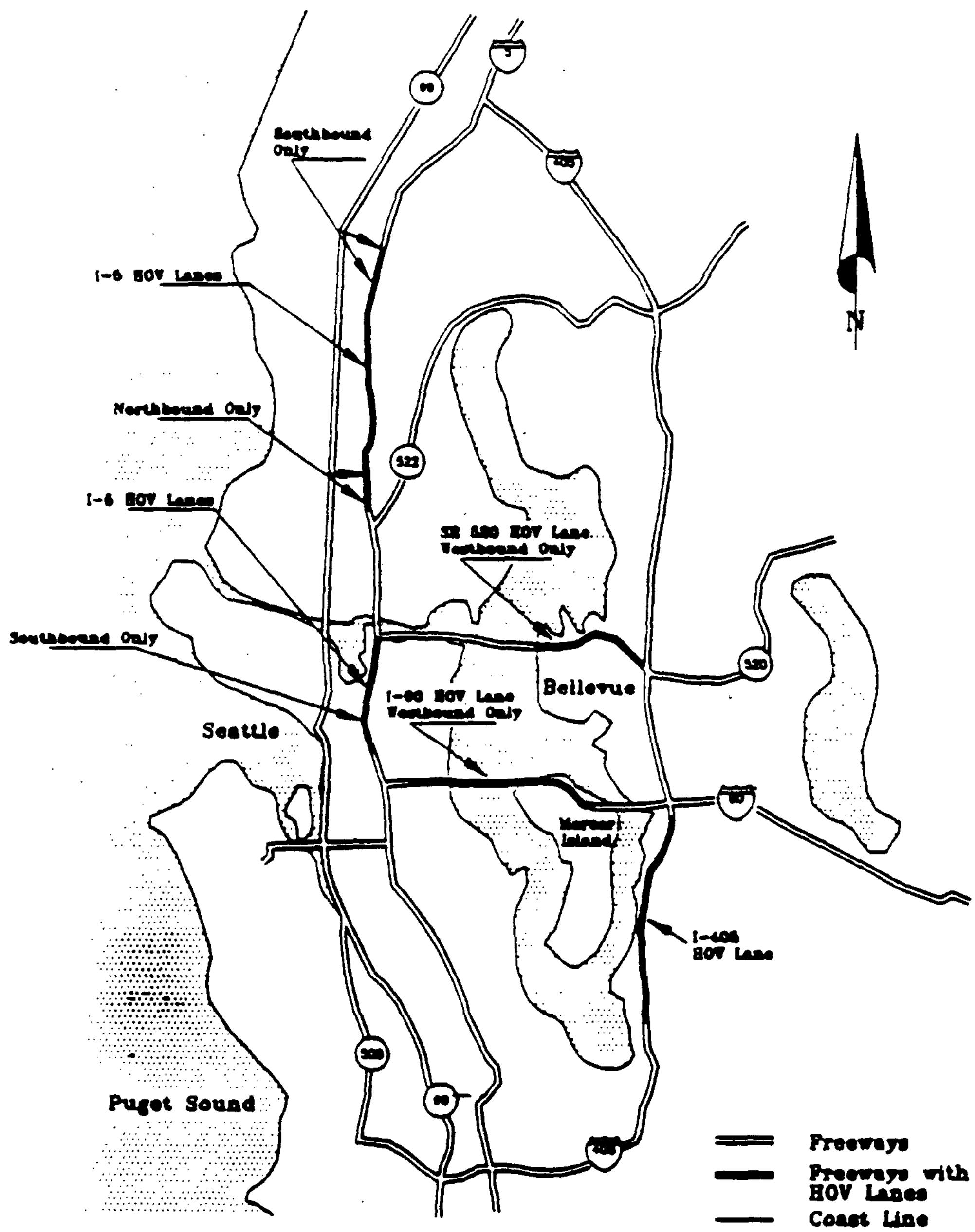

Figure 5

Los Angeles/Orange County
HOV Lanes