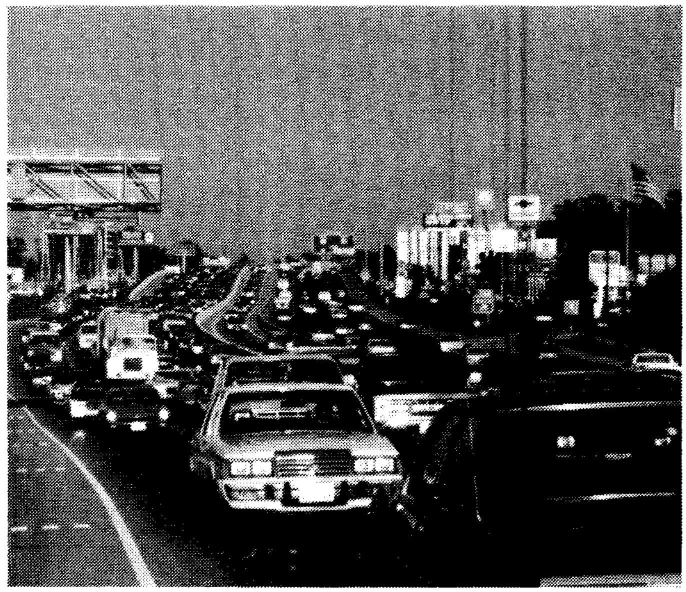
U.S. Department of Transportation

High Occupancy Vehicle Project Case Studies

Historical Trends and Project Experiences

August 1992



High-Occupancy Vehicle Project Case Studies

Historical Trends and Project Experiences

Final Report
February 1991

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METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	2.54	centimeters	cm
ft	feet	0.3048	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	6.452	centimeters squared	cm^2
ft^2	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.395	hectares	ha
		MASS (weight)		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		VOLUME		
fl oz	fluid ounces	29.57	millimeters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0328	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

Note: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

These factors conform to the requirement of FHWA Order 5190.1A

*SI is the symbol for the International System of Measurements

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
yd	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
yd^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.53	acres	ac
		MASS (weight)		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME		
mL	millimeters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
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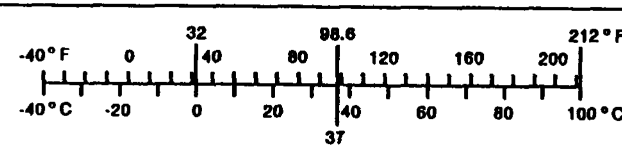

Abstract

High-occupancy vehicle (HOV) facilities represent one approach being used in many metropolitan areas today to respond to increasing traffic congestion, declining mobility levels, air quality and environmental concerns, and limited resources. HOV facilities, which can offer priority treatments to buses, vanpools, and carpools, focus on increasing the person-movement—rather than vehicle-movement—efficiency of a roadway or travel corridor. This document represents the fourth report prepared as part of a three-year assessment of HOV lane projects located either on freeways or in separate rights-of-way in North America. It provides an examination of the historical trends in use and impacts of six HOV project case studies and other HOV facilities in North America.

High-occupancy vehicle facilities in Houston, Texas; Minneapolis, Minnesota; Orange County, California; Pittsburgh, Pennsylvania; Seattle, Washington; and Washington, D.C./Northern Virginia represent the selected case study sites. The historical development and utilization trends for the HOV projects in these locations are examined. Further, based on available data, the case study HOV projects and other HOV facilities are analyzed using the nine evaluation measures developed as part of the overall study. The evaluation measures examined included the following:

- Person movement capacity of the freeway facility
- Bus service operating efficiencies
- Travel time savings and trip time reliability
- Air quality and energy impacts
- Per-lane efficiency of the freeway facility
- Impacts on the operation of the freeway general-purpose lanes
- Safety
- Public support
- Cost-effectiveness

The results of this analysis indicate that—although differing in the exact impacts—the HOV project case studies and other HOV facilities do provide significant benefits and are effective transportation improvements. The information in this report should be of use to transportation professionals interested in ensuring that existing and planned HOV projects are developed and operated in a cost-effective and efficient manner. Further, the report adds to the growing body of knowledge on the use of HOV facilities and supports the development of a national data base on HOV projects.

Implementation Statement

This report was funded by the Federal Transit Administration (FTA) through the Texas Department of Transportation (TxDOT). It represents the fourth report prepared as part of a three-year assessment of high-occupancy vehicle lane projects located either on freeways or in separate rights-of-way in North America. High-occupancy vehicle (HOV) facilities represent one approach being used in many metropolitan areas to respond to increasing traffic congestion, declining mobility levels, air quality and environmental concerns, and limited resources. High-occupancy vehicle facilities, which can offer priority treatments to buses, vanpools, and carpools, focus on increasing the person-movement—rather than vehicle-movement—efficiency of a roadway or travel corridor.

The three-year research study was undertaken to provide an assessment of HOV lanes on freeways and in separate rights-of-way in North America. The assessment included an examination of the design treatments, operating scenarios, enforcement techniques, utilization levels, and general experiences with the different HOV facilities. A suggested approach and procedure for evaluating freeway HOV lanes was developed to provide a national model for areas interested in conducting before-and-after evaluations and ongoing monitoring activities. A more detailed analysis of selected HOV project case studies was conducted. This report examines the historical trends and experiences of the six HOV project case studies. The suggested evaluation measures developed as part of the assessment form the basis for this analysis. In addition to the six case study HOV projects, other HOV facilities are examined using available data.

Disclaimer

Acknowledgements

A number of individuals assisted with the data collection and other activities associated with the preparation of this report. The following individuals were especially helpful in providing the information on utilization trends and impacts of the different HOV case studies.

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I.

Introduction

The Texas Transportation Institute (TTI), a part of The Texas A&M University System, has completed an assessment of high-occupancy vehicle (HOV) projects located either on freeways or in separate rights-of-way in North America. The three-year research study was funded by the Federal Transit Administration (FTA) through the Texas Department of Transportation (TxDOT). A variety of activities were conducted as part of this assessment. The research study included an overall assessment of the status of HOV projects on freeways and in separate rights-of-way in North America, the development of suggested procedures for conducting before-and-after evaluations of operating HOV facilities, and the examination of specific case study HOV projects.[1]

A major element of the assessment was the examination of selected HOV facilities in six case study sites. High-occupancy vehicle facilities in Houston, Texas; Minneapolis, Minnesota; Orange County, California; Pittsburgh, Pennsylvania; Seattle, Washington; and Washington, D.C./ Northern Virginia represent the selected case study sites. An intent of the case study analysis was to provide an examination of the history, institutional arrangements, operating characteristics, utilization rates, and impacts of various types of HOV projects in different parts of the country.

This report examines a variety of information associated with the use of the six HOV case study projects. In addition, available historical information on other operating HOV facilities is reviewed. The analysis is based on the evaluation measures identified in *Suggested Procedures for Evaluating the Effectiveness of Freeway HOV Facilities* and the approach used in conducting the ongoing monitoring of the Houston HOV lanes.

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[1]Three reports completed as part of the assessment are currently available through the Technology Sharing Program of the U.S. Department of Transportation. The reports are: *A Description of High-Occupancy Vehicle Facilities in North America; Suggested Procedures for Evaluating the Effectiveness of Freeway HOV Facilities*; and *High-Occupancy Vehicle Project Case Studies: History and Institutional Arrangements.*

Background and Purpose

Since the opening of the Shirley Highway exclusive bus lane in the Washington, D.C./Northern Virginia area in 1969, numerous metropolitan areas have developed priority facilities on freeways for high-occupancy vehicles. As of the fall of 1992, there were some 49 HOV facilities in operation on either freeways or in separate rights-of-way in 22 North American metropolitan areas. These facilities, while sometimes differing in design and operation, have similar purposes. In general, HOV facilities are intended to help maximize the person-carrying capacity of a roadway or corridor. This is accomplished by altering the design and/or operation of the facility in order to provide priority treatments, such as shorter travel times and improved travel time reliability, for high-occupancy vehicles. High-occupancy vehicles are usually defined as buses, vanpools, and carpools.

In order to obtain a more comprehensive understanding of the variety of factors associated with the planning, implementation, operation, and evaluation of HOV facilities, several case studies were conducted of selected HOV projects as a major element of the assessment. The case study sites were selected to provide a mix of old and new projects, HOV design treatments, and geographic coverage. The first aspect of the case study analysis examined the history and institutional arrangements associated with the development and ongoing operation of the HOV projects. The results of that analysis were presented in the report *High Occupancy Vehicle Project Case Studies: History and Institutional Arrangements.*

The second aspect of the case study analysis focused on examining historical information on operating characteristics, utilization levels, and impacts of the HOV projects. The results of that analysis, which are based on the evaluation measures developed as part of the assessment, are presented in this report. In addition to the HOV projects at the six case study sites, available information is examined on other HOV facilities in North America.

The results of this analysis provide an enhanced understanding of the use, benefits, and issues associated with the different HOV projects. This information should be of value to transportation professionals and policy makers interested in ensuring that existing and planned HOV facilities are developed and operated in the most cost-effective and efficient manner. Thus, this element of the assessment provides valuable insight into the use of existing HOV facilities.

Organization of this Report

Following this introduction, the remainder of this report is divided into three chapters. The next chapter briefly examines the historical development and utilization trends for the HOV projects at the six case study sites. Chapter III provides a more detailed examination of the case study HOV projects. The nine evaluation measures developed in the assessment, and presented in the report *Suggested Procedures for Evaluating the Effectiveness of Freeway HOV Facilities*, form the basis for the analysis in the chapter. Those nine evaluation measures include:

- Person movement capacity of the freeway facility
- Bus service operating efficiencies
- Travel time savings and trip time reliability
- Air quality and energy impacts
- Per-lane efficiency of the freeway facility
- Impacts on the operation of the freeway general-purpose lanes
- Safety
- Public support
- Cost-effectiveness

The report concludes with a summary of the major points covered in this element of the assessment and the identification of areas where additional research may be warranted.

II.

Project Case Studies: Historical Development & Utilization

This chapter examines the development of the HOV projects at the six case study sites and provides a summary of historical utilization trends. A brief description of each facility is provided first. Information is presented on the general nature and operating characteristics of the facility. This is followed by a summary of the trends in utilization over the life of the project. The information in this chapter is intended to provide an overview of each facility; a more detailed examination of the HOV projects based on the evaluation measures developed as part of this assessment is contained in the next chapter. The specific HOV facility examined at each of the case study sites is noted below.

- Katy Freeway (I-10 West) — Houston, Texas
- I-394 — Minneapolis, Minnesota
- Route 55 — Orange County, California
- I-279 — Pittsburgh, Pennsylvania
- I-5 North — Seattle, Washington
- Shirley Highway (I-395) — Washington D.C./Northern Virginia

Katy Freeway (I-10 West) — Houston, Texas

The Katy Freeway HOV lane is located on I-10 West in Houston, Texas. The location of this facility, which serves as the major travel corridor on the west side of the city, is shown in Figure 1. The 13-mile HOV lane was opened in stages between 1984 and 1990. It is a one-lane, barrier-separated, reversible HOV lane located in the freeway median. Three park-and-ride lots and three park-and-pool lots are located in the corridor. Access and egress is provided by both slip ramps and direct access ramps. The Katy Freeway HOV lane is one of four operational HOV lanes in the Houston area and is part of a planned 96-mile HOV network.

The HOV lane is open in the inbound direction from 4:00 a.m. to 1:00 p.m. It is then closed from 1:00–2:00 p.m. to reverse the flow of HOV traffic. The lane reopens at 2:00 p.m. and operates in the outbound direction until 10:00 p.m. The vehicle occupancy requirement on the facility has changed a number of times over the life of the project. Only buses and authorized vanpools were allowed to use the facility when it opened in 1984. Due to low utilization, it was opened to authorized carpools with four or more persons in April 1985. The occupancy requirement was lowered to 3+ in December 1985, and in August 1986 it was changed to 2+ and the authorization requirement was dropped.

The 2+ occupancy requirement remained in effect until the fall of 1988. In response to the high volumes occurring in the morning peak hour, and the corresponding decline in travel speeds and travel time reliability, a 3+ vehicle occupancy requirement from 6:45–8:15 a.m. was reinstated in October 1988. The 3+ hours were slightly revised to 6:45–8:00 a.m. in May 1990, and in the fall of 1991, the 3+ requirement was applied to the afternoon peak hour from 5:00–6:00 p.m.

The historical trends in vehicle volumes and person movement during the morning peak hour are shown in Figure 2. The figure illustrates the change in utilization levels over an eight-year period. The vehicle volumes grew steadily after the lane was opened to 2+ carpools, reaching a high of almost 1,500 peak-hour vehicles in 1986. The vehicle and person volumes dropped initially after implementation of the 3+ occupancy requirement, but have been increasing since that time.[2] As of December 1991, approximately 840 vehicles and 4,000 persons were using the HOV lane during the morning peak hour. In the peak period (6:00–9:30 a.m.) approximately 2,350 vehicles and 8,760 persons were using the lane (*1*).

[2]For more information, see D.L. Christiansen and D.E. Morris. *The Status and Effectiveness of the Houston Transitway System, 1989*. Texas Transportation Institute, College Station, Texas, 1990.

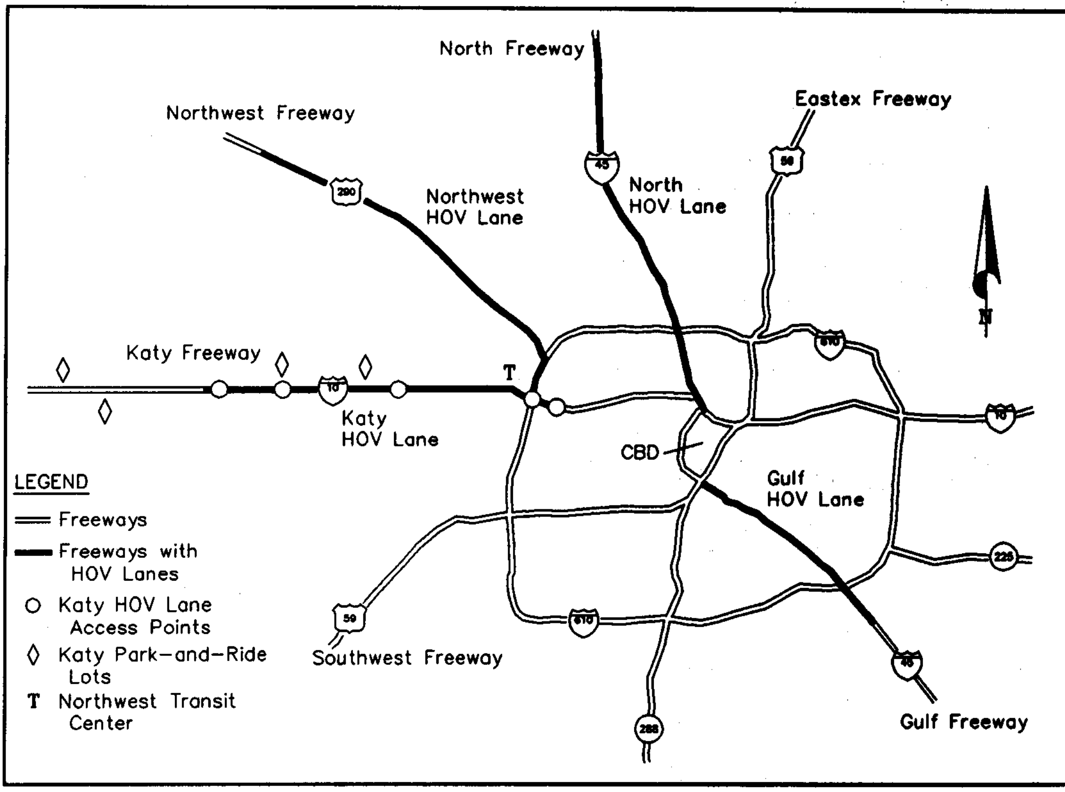


Figure 1 **Katy Freeway HOV Lane, Houston, Texas**

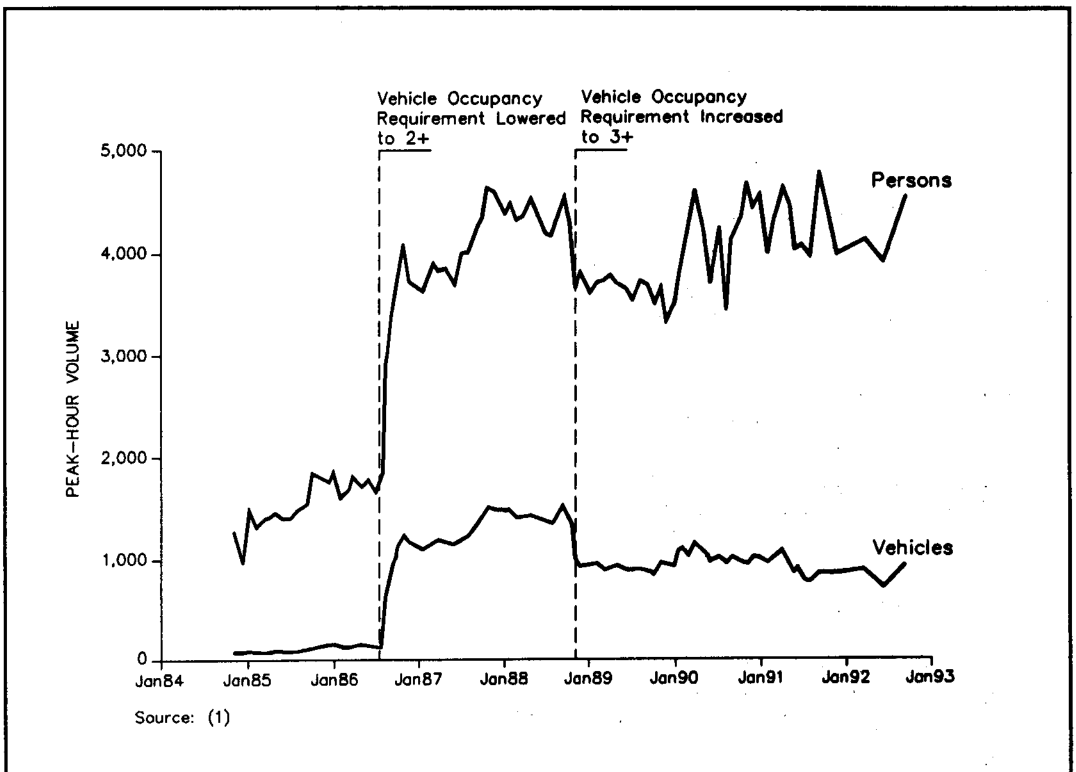


Figure 2 **Katy Freeway HOV Lane, A.M. Peak-Hour Utilization**

I-394 — Minneapolis, Minnesota

The I-394 freeway and HOV lanes are located on the western side of the Minneapolis-St. Paul metropolitan area. As shown in Figure 3, the facility extends 11 miles from downtown Minneapolis to the city of Wayzata. I-394, which represents the final segment of the interstate system to be completed in the area, was constructed on the alignment of an existing arterial, US 12. Completed in the fall of 1992, the final freeway and HOV design includes two general-purpose traffic lanes in each direction and two different HOV treatments. East of Highway 100, a three-mile, two-lane, barrier-separated, reversible HOV facility is located in the median of the freeway. Those HOV lanes provide direct access into the downtown parking garages built as part of the overall project. West of Highway 100, eight miles of concurrent flow HOV lanes are in operation.

An interim HOV lane was used during construction of the I-394 facility. The interim facility was marketed as the "Sane Lane," and was implemented to help manage traffic during construction and to introduce the HOV concept in the area. The interim HOV lane was approximately three miles long, and was located in the median of US 12. Opened in November 1985, the interim HOV lane operated in the inbound direction during the morning peak period (6:00–9:00 a.m.) and in the outbound direction in the afternoon (2:00–7:00 p.m.). The operating hours changed slightly during the interim period in response to construction needs. A 2+ vehicle occupancy requirement has been in effect over the life of the project, and buses, vanpools, and carpools are allowed to use the facility.

Figure 4 illustrates the morning peak-hour vehicle and person volumes for the I-394 HOV lanes. The interim HOV lane was in operation for approximately five years. During this time, an average of some 500 vehicles carrying 1,400 persons used the facility during the morning peak hour (2). In the fall of 1992, approximately 1,100 vehicles carrying 3,580 persons were using the peak-direction concurrent flow HOV lane west of Highway 100 during the morning peak hour (3).

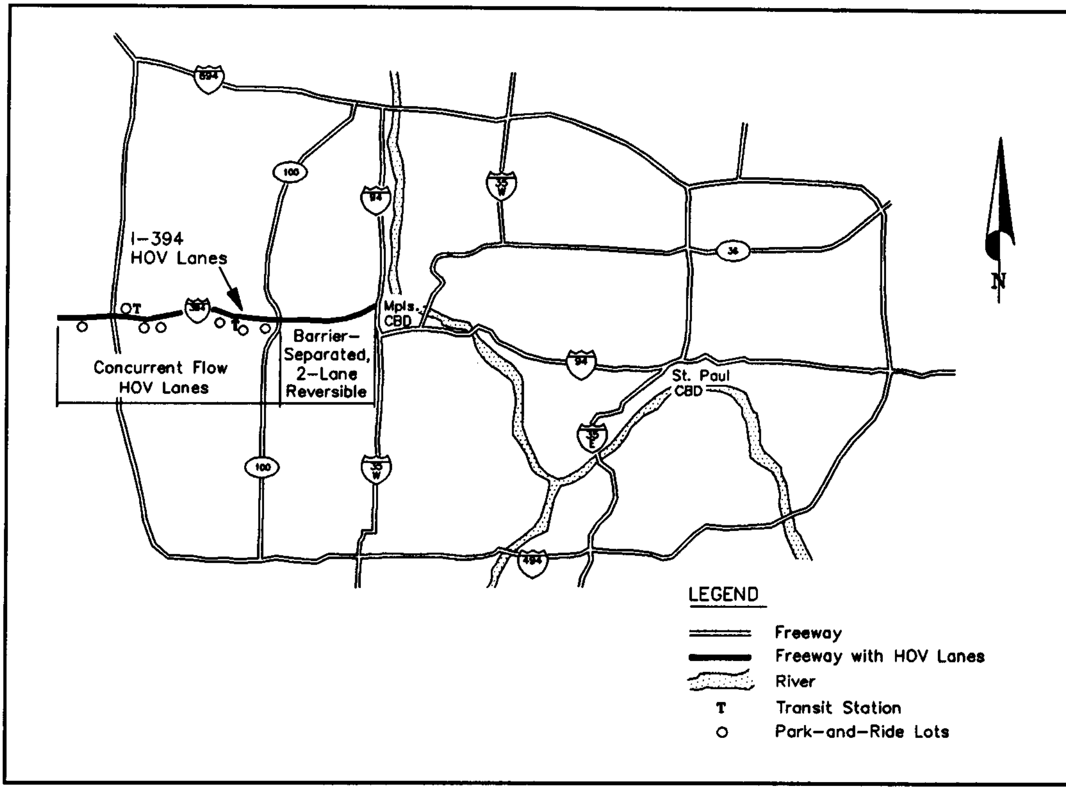


Figure 3 I-394 HOV Lanes, Minneapolis, Minnesota

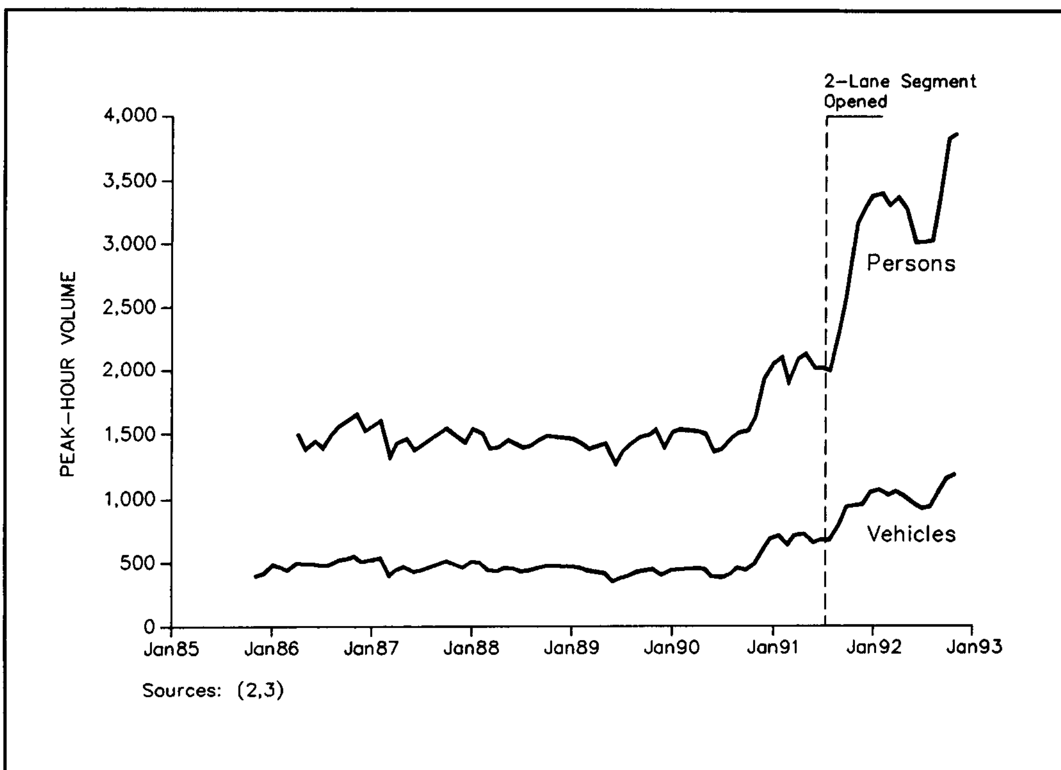


Figure 4 I-394 HOV Lanes, A.M. Peak-Hour Utilization

Route 55 — Orange County, California

The location of the Route 55 HOV lanes in Southern California is shown in Figure 5. Route 55 (the Newport-Costa Mesa Freeway) serves as a heavily-traveled link between the residential areas in eastern Orange and Riverside Counties and the employment centers in central Orange County. Eleven miles of HOV lanes—or commuter lanes as they are called locally—were opened on Route 55 in 1985.

The Route 55 HOV facility consists of a pair of concurrent flow commuter lanes (one in each direction), and is open to buses, vanpools, and carpools on a 24-hour basis. A 2+ vehicle occupancy requirement is in effect on the Route 55 HOV lanes.

The historical morning peak-hour, peak-direction vehicle volumes and person movement on the Route 55 HOV lanes are shown in Figure 6. The vehicle volumes have been relatively consistent over the eight-year period, averaging between 1,100 and 1,500 vehicles during the morning peak hour in the peak direction. However, morning peak-hour vehicle volumes as high as 1,600 have been recorded on the Route 55 HOV lane. The corresponding person movements have also remained relatively constant over this period, averaging between 2,300 and 3,200 persons during the morning peak hour in the peak direction. Since very little bus service is provided in the Route 55 corridor, the vehicle volumes and person movements for the HOV lanes primarily reflect carpools (*2, 4, 5*).

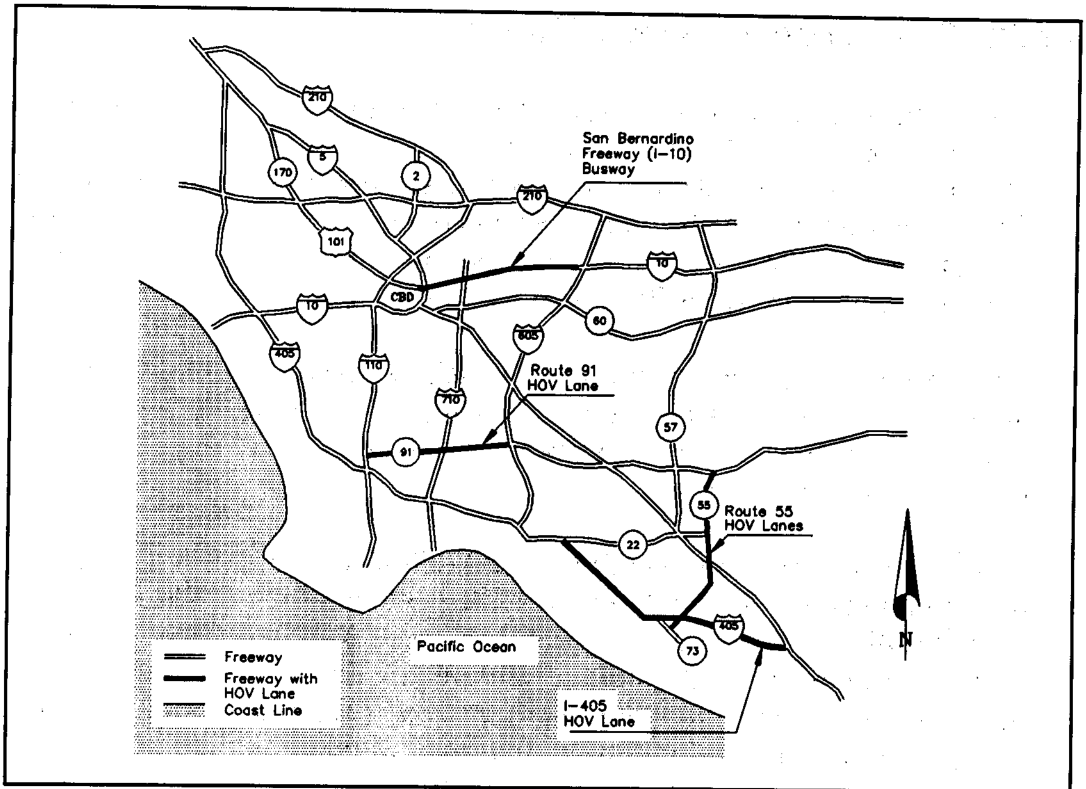


Figure 5 **Route 55 HOV Lanes, Orange County, California**

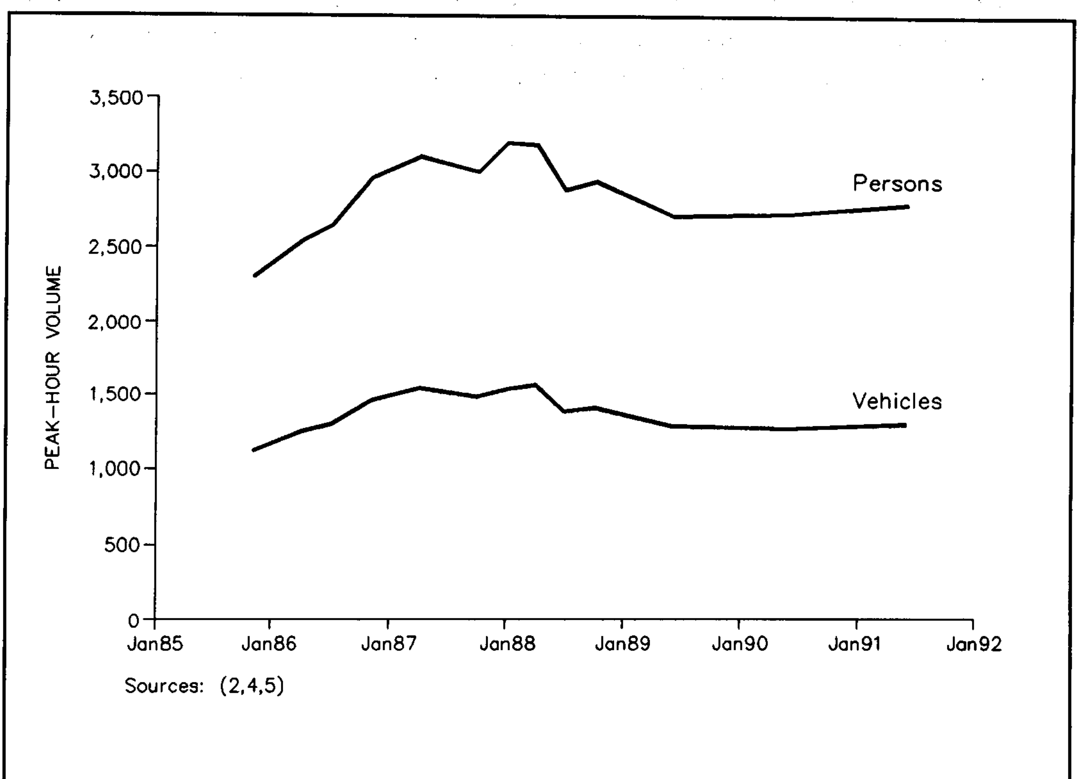


Figure 6 **Route 55 HOV Lanes, A.M. Peak-Hour Utilization**

I-279 — Pittsburgh, Pennsylvania

The location of the I-279 HOV lanes in the Pittsburgh area is shown in Figure 7. The project is a four-mile, two-lane, reversible, barrier-separated HOV facility located in the median of I-279. Two short one-lane segments are located at the southern end of the facility, providing access to Three Rivers Stadium via I-579 and the downtown area via I-279. The freeway and HOV lanes were first opened in August of 1989. The HOV lanes were open to buses, vanpools, and 3+ carpools during the first three years of operation. In August 1992, a demonstration project was implemented in which the vehicle occupancy requirement on the HOV facility was lowered to two or more persons per vehicle.

The I-279 HOV lanes operate in the inbound direction from 5:00 a.m. to noon. From noon to 2:00 p.m. the lanes are closed to reverse the flow of HOV traffic. From 2:00–8:00 p.m. the lanes operate in the outbound direction with the HOV restrictions. Finally, from 8:00 p.m. to 3:00 a.m. the lanes operate in the outbound direction with no vehicle occupancy restrictions. This is done in part to accommodate traffic leaving events at Three Rivers Stadium.

Information on the morning peak-hour vehicle and person volumes for the I-279 HOV lanes is shown in Figure 8. With the 3+ occupancy requirement, the morning peak-hour vehicle volumes had increased from approximately 164 vehicles in November 1989 to 345 vehicles in November 1991. The corresponding peak-hour person volumes had increased from some 1,100 persons to 2,200 persons. After the vehicle occupancy requirement was lowered to 2+ for a demonstration project in August 1992, the morning peak-hour volume increased to 868 vehicles and the corresponding person movement rose to 2,600 (2, 6).

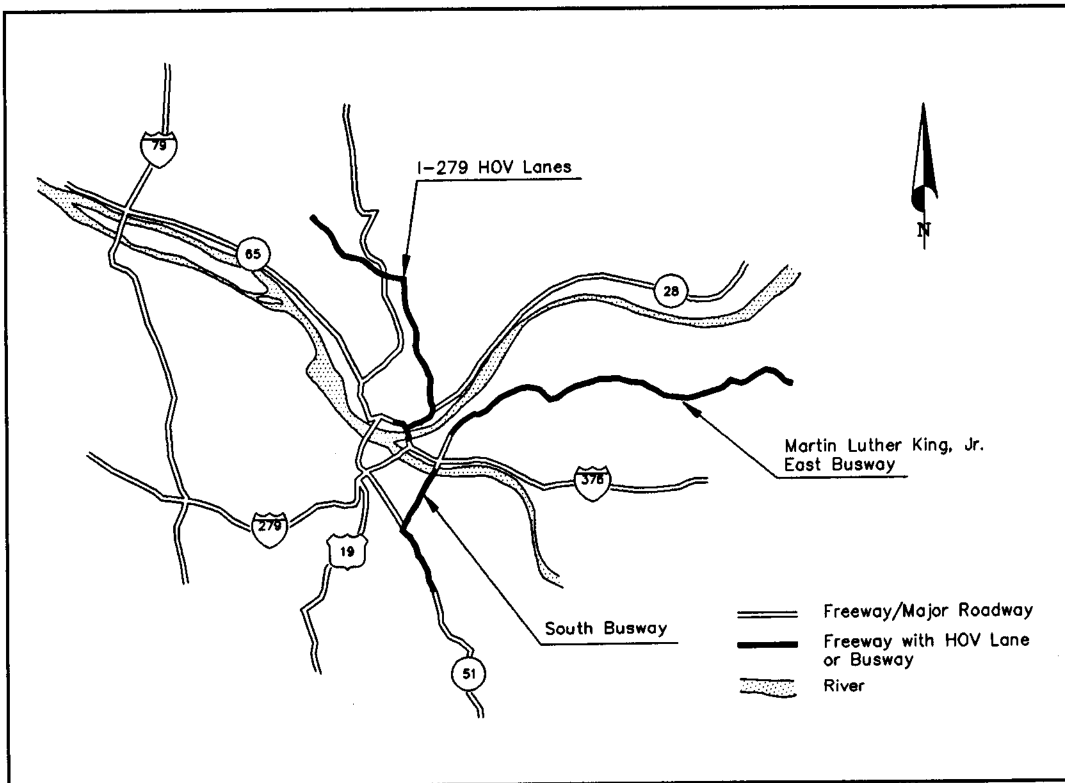


Figure 7 I-279 HOV Lanes, Pittsburgh, Pennsylvania

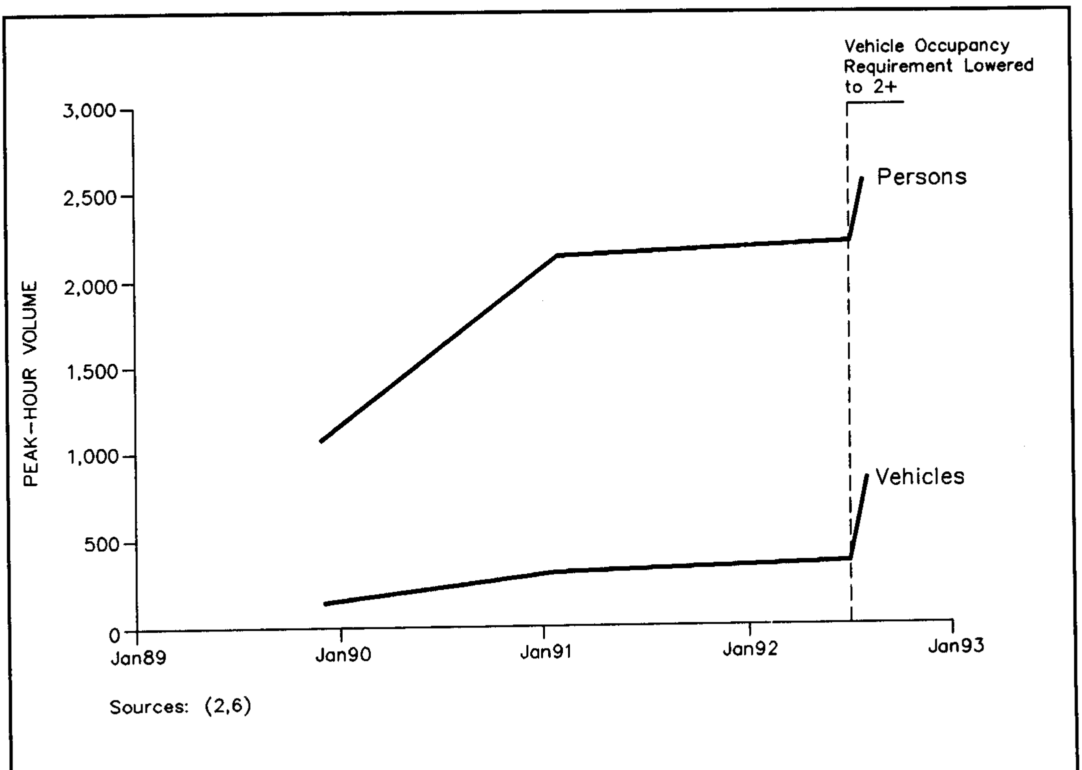


Figure 8 I-279 HOV Lanes, A.M. Peak-Hour Utilization

I-5 North — Seattle, Washington

The location of the I-5 North HOV lanes selected as a case study project is shown in Figure 9. The concurrent flow HOV lanes are located to the north of both downtown Seattle and the University of Washington. The southbound HOV lane is 7.7 miles in length and the northbound HOV lane is 6.2 miles in length. The I-5 North HOV lanes were opened in 1983 and are operated on a 24-hour basis. From 1983 until July 1991, a 3+ vehicle occupancy requirement was in effect. On July 29, 1991, the occupancy requirement was lowered to two or more persons per vehicle as part of a demonstration project.

The historical trends in morning peak-hour, peak-direction vehicle volumes and person movement on the I-5 HOV lanes are shown in Figure 10. An average of about 280 vehicles used the facility during the morning peak hour in the first few weeks following the opening of the facility. That volume had grown to 410 vehicles after the first three months of operation and 460 vehicles after the first 20 months (*7, 8*). Between 1985 and August 1991, an average of 460 to 550 vehicles used the HOV lane during the morning peak hour in the peak travel direction (*2, 9*). After initiation of the demonstration project lowering the vehicle occupancy requirement to 2+, the morning peak-hour, peak-direction volumes averaged between 1,200 and 1,400 vehicles (*10*).

Figure 10 also shows the change in person volumes over the life of the project. Between 1985 and 1991, an average of 3,710 persons used the facility during the morning peak hour in the peak travel direction. Approximately 70 percent, or 2,605 persons, rode buses on the HOV lane, while 30 percent, or 1,105 persons, were in 3+ carpools. After the vehicle occupancy requirement was changed to 2+, the person volumes increased to an average of 5,644 during the morning peak hour in the peak travel direction. Bus ridership remained relatively constant with the reduced occupancy requirement, but the number of persons carried in carpools increased to 3,039—approximately 54 percent of the total morning peak-hour, peak-direction person volume on the facility (*10*).

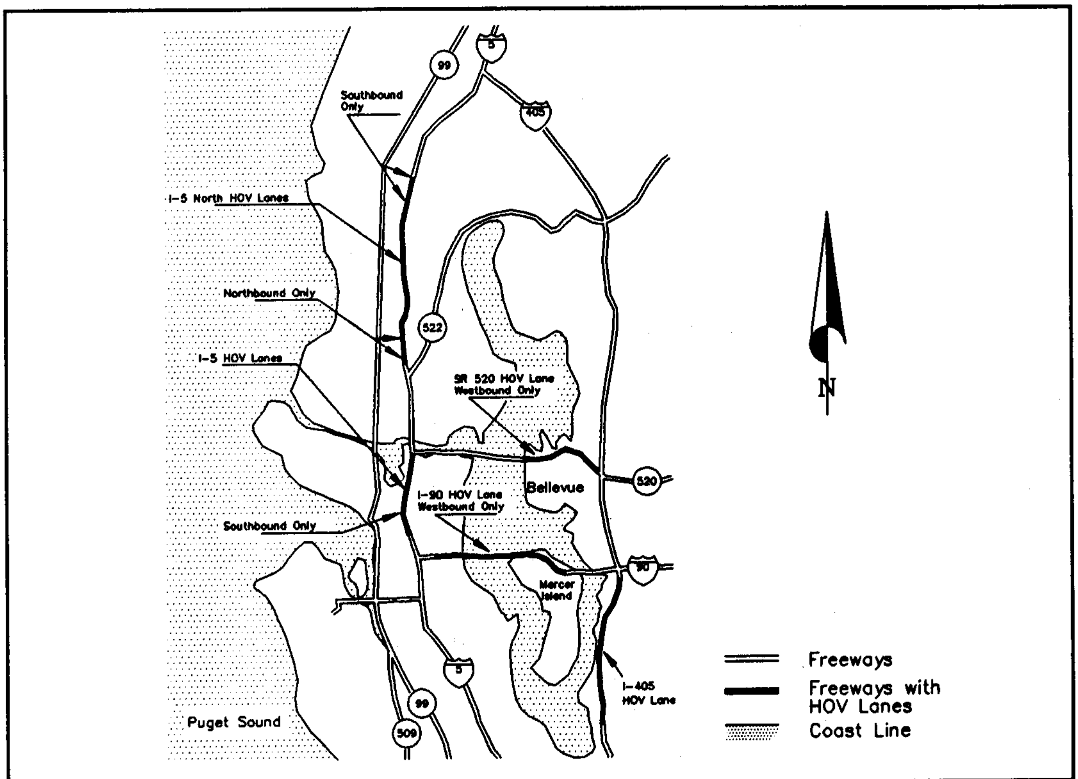


Figure 9 I-5 North HOV Lanes, Seattle, Washington

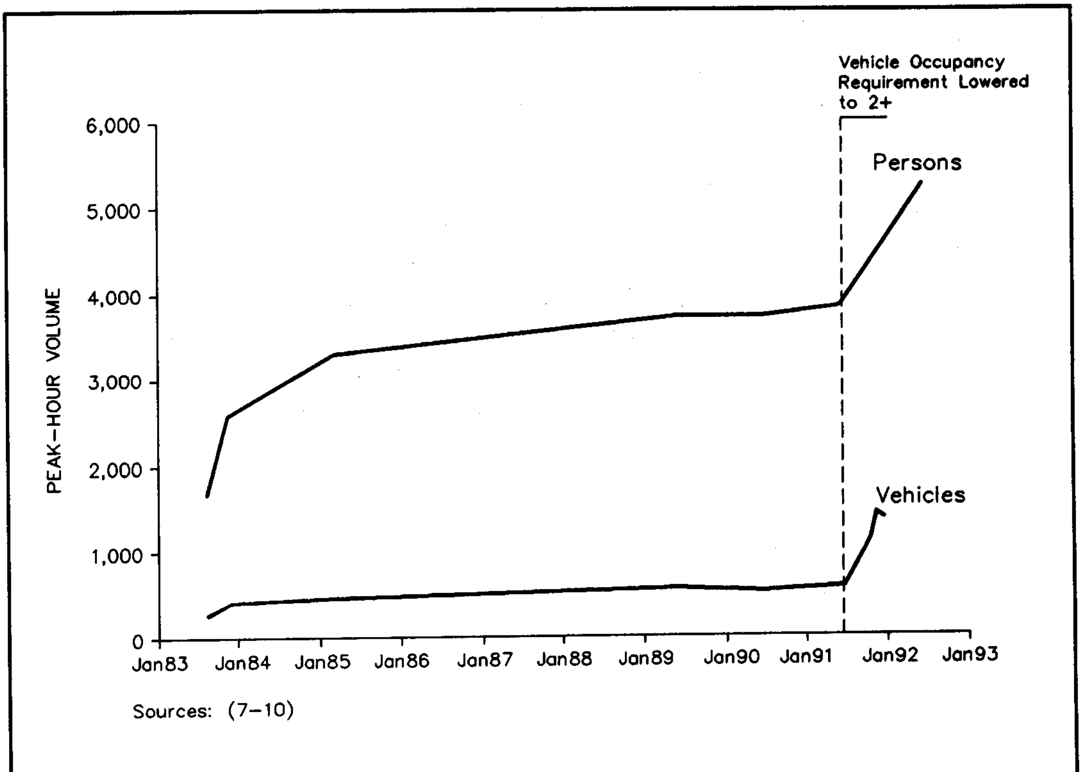


Figure 10 I-5 North HOV Lanes, A.M. Peak-Hour Utilization

Shirley Highway (I-395) — Washington, D.C./Northern Virginia

The opening of the initial five miles of bus-only lanes on the Shirley Highway (I-395) in 1969 represented the first use of an HOV facility on a freeway in the United States. The location of the Shirley Highway HOV lanes is shown in Figure 11. The project, which was opened in several stages between 1969 and 1975, is now approximately 11 miles in length. The two-lane, reversible HOV facility is located in the median of the freeway and is separated from the general-purpose traffic lanes by concrete barriers. Park-and-ride lots and direct access ramps are provided at strategic points along the corridor.

A number of changes have been made in the occupancy requirements and operating hours for the Shirley Highway HOV lanes. Only buses were allowed to use the facility during the first four years of operation. In December 1973, the HOV lanes were opened to vanpools and carpools with four or more persons. In January 1989, a 3+ carpool definition was implemented for the facility. Until 1985, the lanes operated in the inbound direction from 11:00 p.m. to 11:00 a.m. and in the outbound direction from 1:00–8:00 p.m. The lanes were closed for maintenance and reversing the flow of HOV traffic during other hours. As a result of a Congressionally-mandated demonstration project in the spring of 1985, the operating hours of the HOV lanes were changed to 6:00–9:00 a.m. in the inbound direction and 3:30–6:00 p.m. in the outbound direction. The lanes are open to general-purpose traffic during the remainder of the day, except when they are closed to reverse the flow of traffic. Bus service levels and service orientation were changed in 1983 with the opening of the Metrorail Yellow Line, resulting in a slight decline in vehicle and person volumes on the HOV lanes.

The historical morning peak-hour vehicle and person volumes for the Shirley Highway HOV lanes are shown in Figure 12. Approximately 39 peak-hour buses, carrying some 1,920 persons, used the HOV lanes during the first year of the project (*11*). By 1974, that number had increased to 279 buses and 11,340 passengers (*11*). The slight decline resulting from the opening of the Metrorail Yellow Line in 1983 is also illustrated in Figure 12. As of 1991, the morning peak-hour volume for buses, vanpools, and carpools was approximately 2,773 vehicles, carrying some 18,406 persons (*12*).

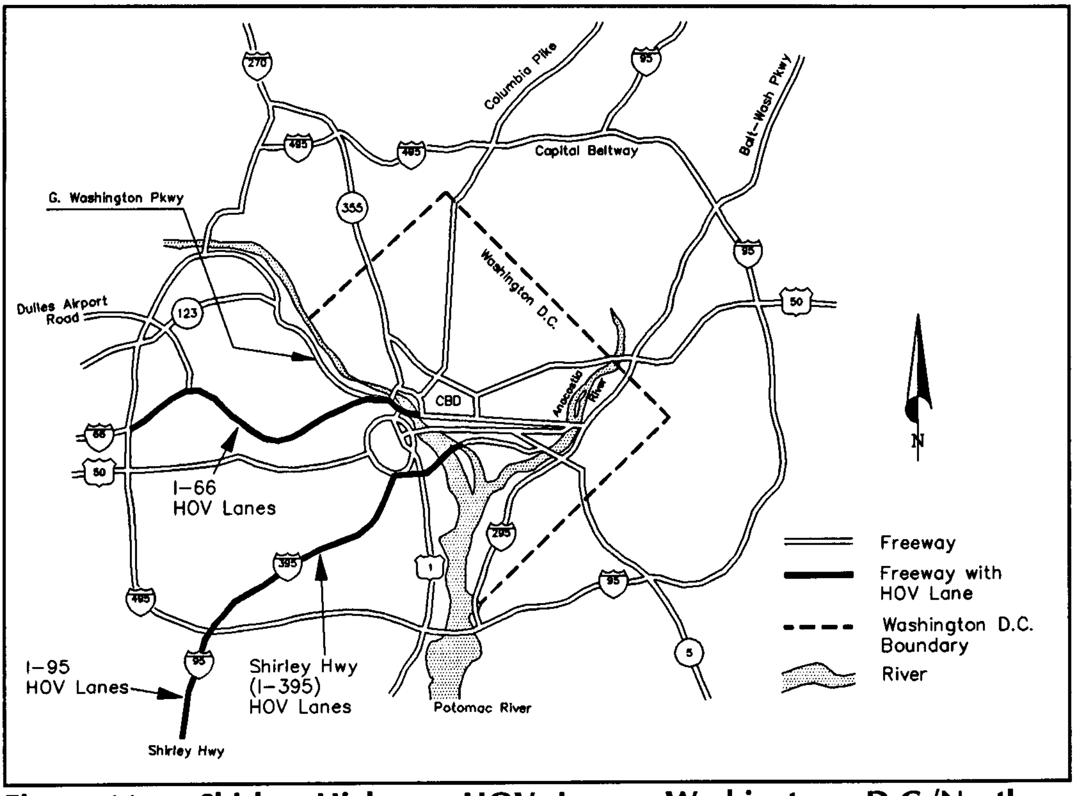


Figure 11 **Shirley Highway HOV Lanes, Washington, D.C./Northern Virginia**

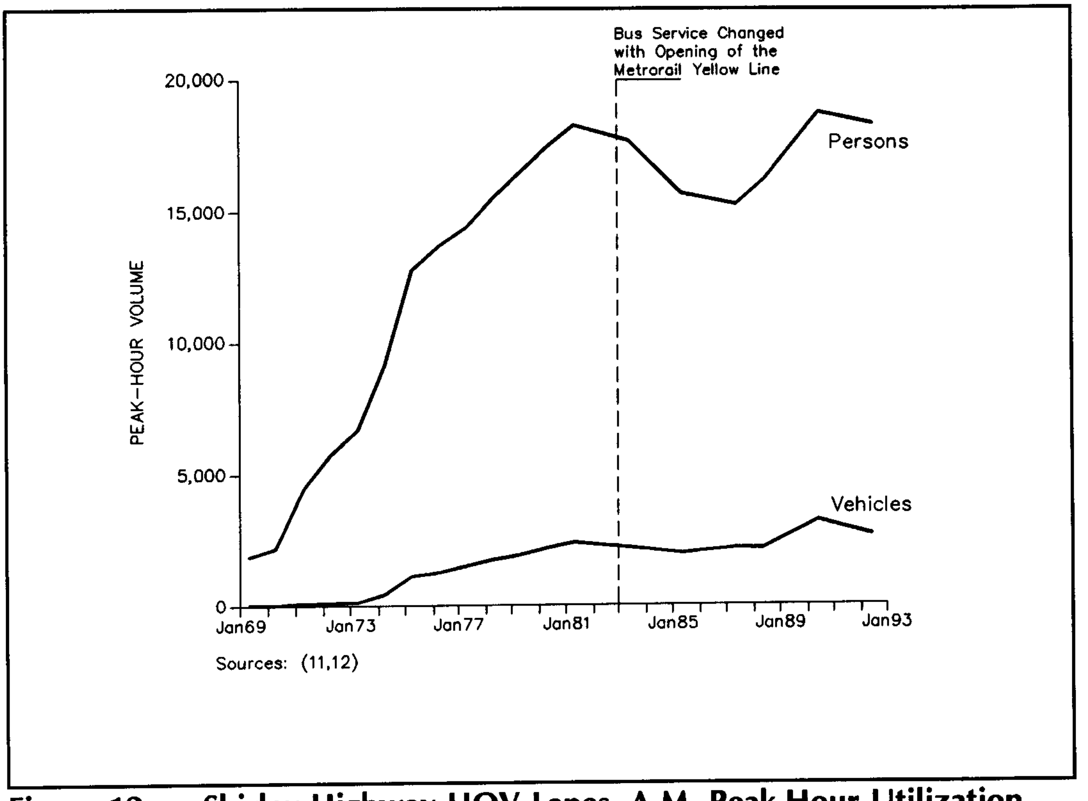


Figure 12 **Shirley Highway HOV Lanes, A.M. Peak-Hour Utilization**

III.

Project Case Studies: Evaluation Measures

This chapter provides a more detailed examination of the experience with HOV projects at the six case study sites. In addition, information on other HOV facilities in North America is also included. The level of analysis varies among the different projects based upon the availability of information. In many cases, little data are available on conditions before the HOV lanes were implemented, limiting before-and-after comparisons. Further, some projects—such as I-279 in Pittsburgh—represent completely new facilities. Thus, before data are not relevant for that project because there previously was no facility in the corridor. The I-394 project in Minneapolis presents a similar problem for before-and-after analysis. The corridor consisted of a two-lane signalized arterial before the HOV lane was implemented, whereas the current facility is a new interstate freeway. Thus, before-and-after comparisons for this project need to consider the significant changes in the underlying facility—in addition to the existence of the HOV lanes.

The nine evaluation measures developed as part of the overall assessment provided the framework for the analysis in this chapter. The nine evaluation measures, which relate to the general objectives HOV facilities are typically designed to meet, include the following:

- Person movement capacity of the freeway facility
- Bus service operating efficiencies
- Travel time savings and trip time reliability
- Air quality and energy impacts
- Per-lane efficiency of the freeway facility
- Impacts on the operation of the freeway general-purpose lanes
- Safety
- Public support
- Cost-effectiveness

In this chapter, a consistent approach is used to examine relevant HOV project experience related to each of these measures. First, the objective associated with each of the nine evaluation measures is briefly described.

The measures of effectiveness identified for use with each objective are then presented. Next, information from the HOV projects at the case study sites and other areas is analyzed and discussed. The intent of this analysis, which forms the major focus of the chapter, is to provide examples of how various HOV projects relate to the different measures. Given the lack of available data on many of the HOV facilities, it is not possible to examine every case study project by all the evaluation measures. Rather, the attempt is made to provide a sample of the experiences with different HOV projects within the constraints of available information.

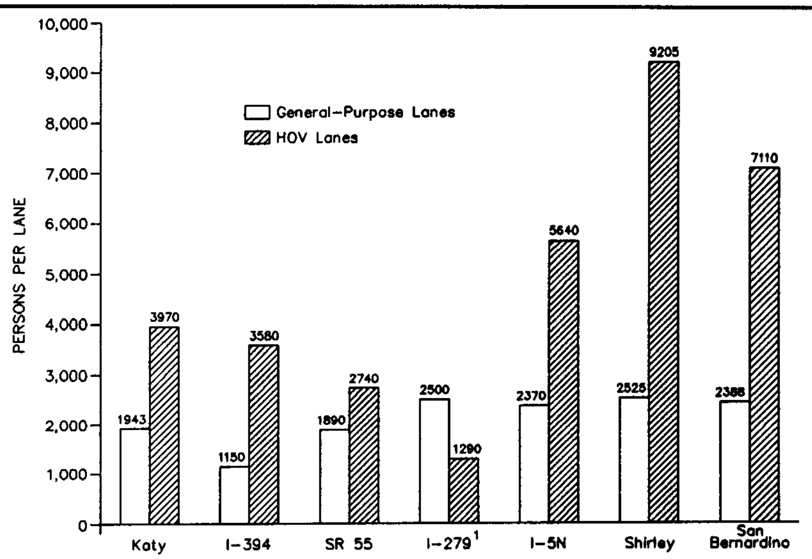
Person Movement Capacity of the Freeway Facility

Objective: *The HOV facility should improve the capacity of a congested freeway corridor to move more people by increasing the number of persons per vehicle.*

This objective recognizes the important role HOV facilities play in increasing the person-movement capacity, rather than vehicle-movement capacity, of a congested travel corridor. In general, the relative increase in the peak-hour, peak-direction person volume resulting from the HOV facility should be at least greater than the percentage increase in directional lanes added to the roadway. This will be accomplished by increasing the average vehicle occupancy level (persons per vehicle) on the roadway. A significant portion of this increase should be the result of creating new carpools and attracting new bus riders, rather than just diverting buses, vanpools, and carpools from the adjacent freeway lanes or parallel routes to the HOV facility. The following measures of effectiveness were identified as appropriate for use with this objective.

- Actual and percent increase in the person-movement efficiency on the total freeway facility (general-purpose plus HOV)
- Actual and percent increase in the average vehicle occupancy of the total freeway facility (general-purpose plus HOV)
- Actual and percent increase in carpools and vanpools for the total freeway facility (general-purpose plus HOV)
- Actual and percent increase in bus riders for the total freeway facility (general-purpose plus HOV)

Figure 13 provides a comparison of the peak-hour, peak-direction person volumes per lane for the case study HOV projects and the adjacent freeway lanes. For almost all of the case study projects, a single HOV lane does move a greater volume of people than an adjacent general-purpose lane. During the peak hour, the HOV lanes in the case study sites are moving approximately 60 percent to 350 percent more persons per lane than are the freeway general-purpose lanes. The Shirley Highway, I-5 North, and Katy Freeway HOV lanes carry the largest number of people. These represent the oldest of the case study HOV lanes, and all three have relatively high levels of bus service. Approximately 64 buses use the I-5 North HOV lane during the peak hour, while 72 buses use the Katy HOV lane, and 200 buses operate on the Shirley Highway HOV lanes during that period. The Route 55, I-394, and I-279 HOV lanes represent facilities that have been open for shorter periods of time. Further, all three have lower levels of bus service, averaging between three and 23 buses during the morning peak hour in the peak direction of travel.



[1] Data for the I-279 HOV and freeway lanes are from August 1992, immediately after the occupancy requirement was lowered from 3+ to 2+. HOV volumes are expected to increase as a result of this change.

Sources: (1-3,5,6,10)

Figure 13 A.M. Peak-Hour, Peak-Direction Person Volumes per Lane for HOV and Freeway Lanes

The greater number of persons in the HOV lane is to be expected, however, since most of the high-occupancy vehicles on the roadway would be in the HOV lane. Therefore, to be effective, the HOV lane should at least increase the person movement by an amount greater than the increase in lanes added to the roadway due to implementing the HOV lane. As shown in Figure 14, for those facilities with information available, the increase in person movement exceeds the increase in lanes provided.

As noted by the second measure of effectiveness, for HOV lanes to generate the disproportionate increase in person movement reflected in Figure 14, it is necessary to increase the average vehicle occupancy levels on the total roadway facility. Figure 15 illustrates the change in the average vehicle occupancy level for the total roadway facility for those case study projects with data available for this comparison. As can be seen by the results, the HOV lanes have resulted in an increase in the average vehicle occupancy level for the total freeway facility. The percentage increase in the average vehicle occupancy level is shown in Figure 16.

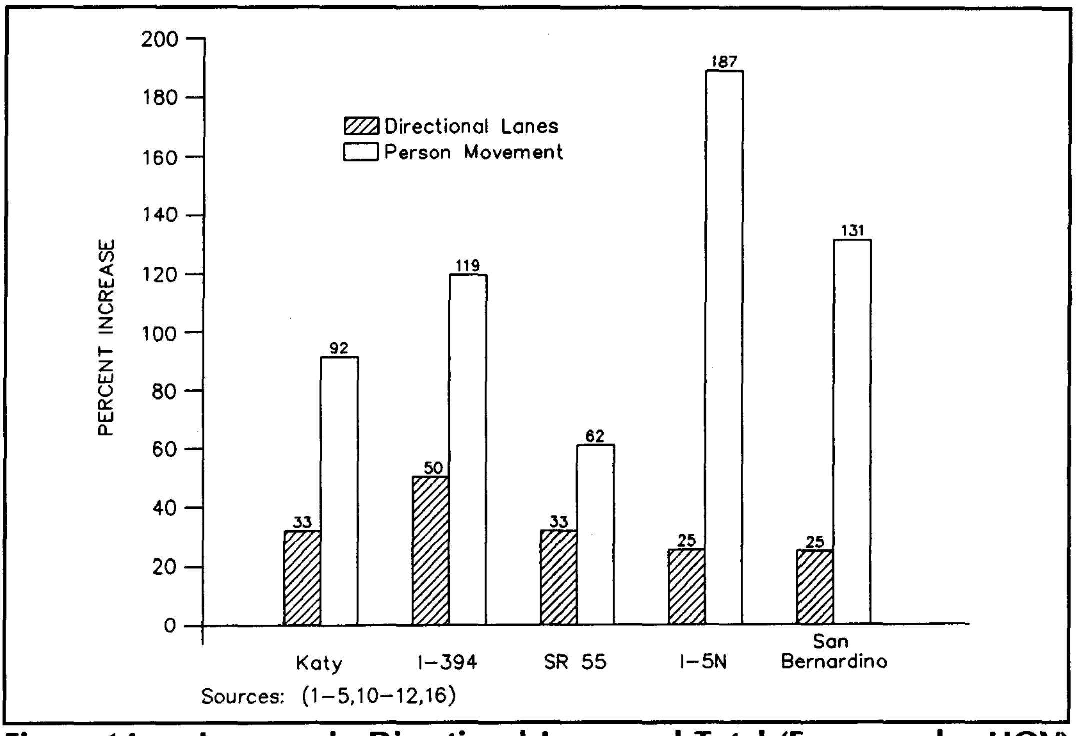


Figure 14 Increase in Directional Lanes and Total (Freeway plus HOV) A.M. Peak-Hour, Peak-Direction Person Movement

The increase in average vehicle occupancy levels experienced in these corridors is contrary to the national trends of declining overall vehicle occupancy levels (*13*). This indicates that HOV lanes in the case study sites appear to have been successful in attracting new bus riders, vanpoolers, and carpoolers. The ongoing analysis of the Houston HOV lanes, which includes a comparison of freeway corridors with and without HOV lanes, further supports this finding. In Houston, the average vehicle occupancy levels tend to be higher in those corridors with HOV facilities than those without (*1*).

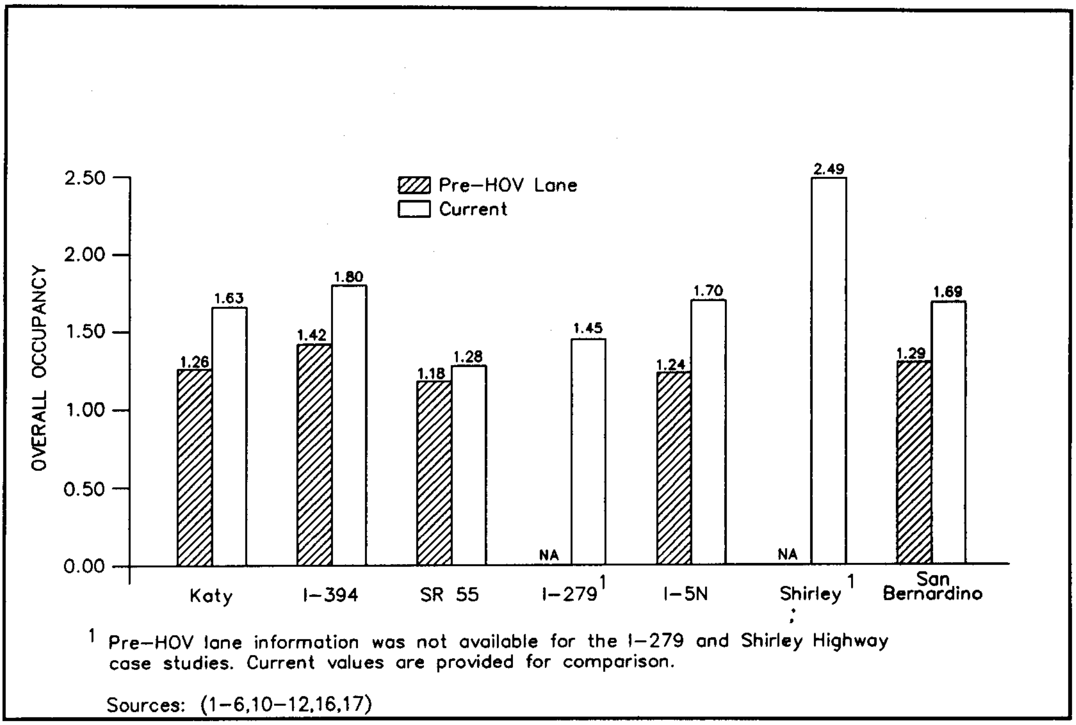


Figure 15 **A.M. Peak-Hour, Peak-Direction Average Vehicle Occupancy (Freeway plus HOV)**

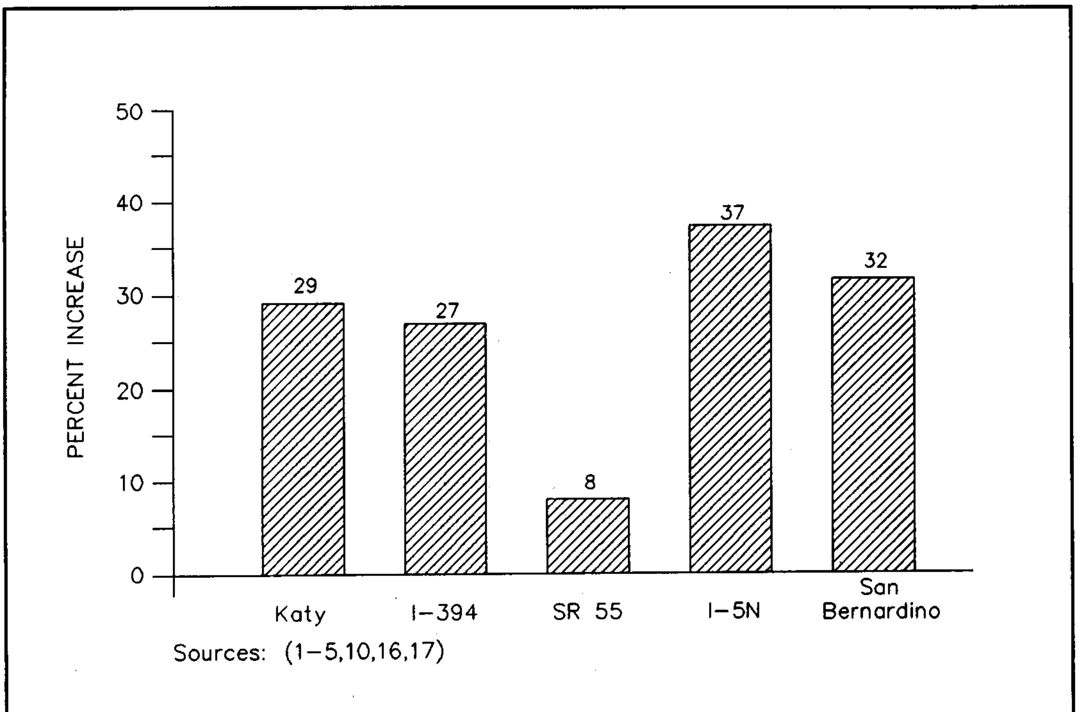
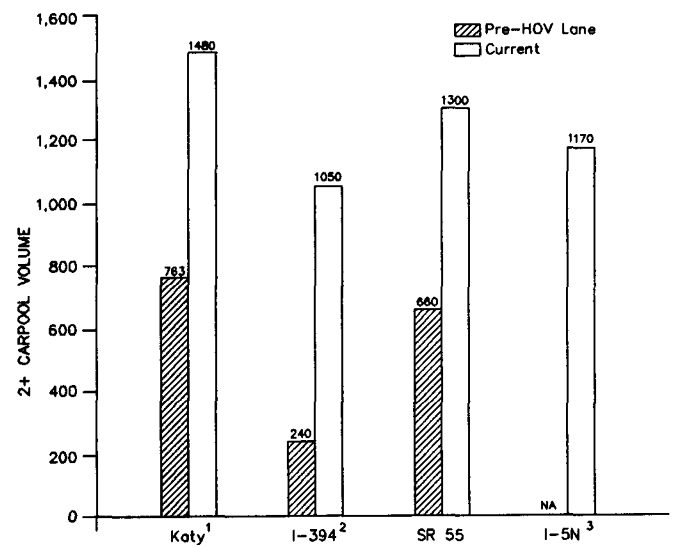


Figure 16 **Increase in A.M. Peak-Hour, Peak-Direction Average Vehicle Occupancy, Pre-HOV Lane to Present**

The increases in the actual number and the percentage of carpoolers, vanpoolers, and bus riders also serve as measures of effectiveness for this objective. As noted previously, the HOV lane should attract new carpoolers, vanpoolers, and bus riders, rather than just diverting existing HOVs from the freeway lanes or parallel roadways. In addition to examining changes in the number of HOVs, surveys of bus riders, vanpoolers, and carpoolers can be used to provide additional information on the influence the HOV facility has had on encouraging a change in commute mode. Information on changes in the number of carpools is examined next, followed by changes in bus ridership. Given the low number of vanpools using most of the case study HOV lanes, changes in vanpool levels are not examined in detail in this analysis.

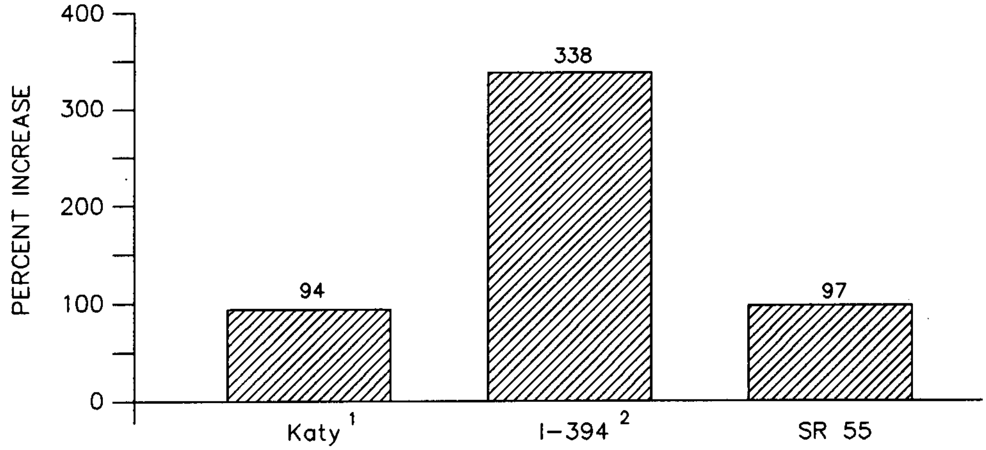
Figure 17 provides a before-and-after comparison of the total peak-hour, peak-direction volume of 2+ carpools for each of the case study sites, within the limitations of available data. As shown in the figure, the number of 2+ carpools has increased in all locations where pre-HOV lane data were available. As further illustrated in Figure 18, the relative increases at those locations range from 94 percent to 338 percent.



[1] Katy Freeway data for p.m. peak hour due to 3+ requirement in a.m.
[2] Pre-HOV lane data for I-394 represents a signalized arterial highway.
[3] Pre-HOV lane data not available for the I-5N case study.

Sources: (1-5,7,10,16)

Figure 17 A.M. Peak-Hour, Peak-Direction 2+ Carpool Volume (Freeway plus HOV)



[1] Katy Freeway data for p.m. peak hour due to 3+ requirement in a.m.
[2] Pre-HOV lane data for I-394 represents a signalized arterial highway.
Sources: (1-5,16)

Figure 18 Increase in A.M. Peak-Hour, Peak-Direction 2+ Carpool Volume (Freeway plus HOV), Pre-HOV Lane to Present

Information obtained through surveys of carpoolers can be used to help identify the number of new carpools that were formed primarily due to the benefits offered by the HOV facility. Table 1 provides a summary of available survey data from the case study HOV facilities and other HOV projects identifying the percentage of carpoolers who previously drove alone. On average, between 23 percent and 56 percent of the survey respondents indicated they had previously driven alone. This information indicates that a significant number of carpools using the different HOV facilities are new carpools.

Additional information was obtained in many of these surveys on the importance carpoolers placed on the benefits provided by HOV facilities and how they influenced changes in commuting modes. For example, the surveys conducted of carpoolers on the Houston HOV lanes asked if the respondents would have been carpooling if the HOV lanes had not been present. The results from the surveys conducted in 1989 and 1990 of carpoolers on the four Houston HOV lanes indicated that between 20 percent and 43 percent of the respondents would not have been carpooling if the HOV lanes had not been in operation (*14*). A 1988 survey of carpoolers on the Route 237 HOV lane in Santa Clara County, California found that 48 percent of the respondents rated the travel time savings offered by the facility as one of the main reasons they started carpooling (*15*).

Table 1 **Percentage of HOV Lane Carpoolers Who Previously Drove Alone[1]**

HOV Facility[2]	Percentage
Case Study HOV Lanes	
Katy Freeway (1990)	36%
I-394 (1986)	43%
Shirley Highway (1974)[3]	23%[3]
Other HOV Lanes	
I-45 North, Houston (1990)	39%
US 290, Houston (1990)	46%
I-45 South, Houston (1989)	38%
San Bernardino Freeway, Los Angeles (1977)	46%
SR 237, Santa Clara County (1988)	56%

[1]Based on surveys of carpoolers using the listed HOV facilities.
[2]Year in parentheses indicates the survey date.
[3]The 1974 survey on the Shirley Highway was conducted when the vehicle occupancy requirement was 4+. This may partially explain the lower percentage of carpoolers who previously drove alone.

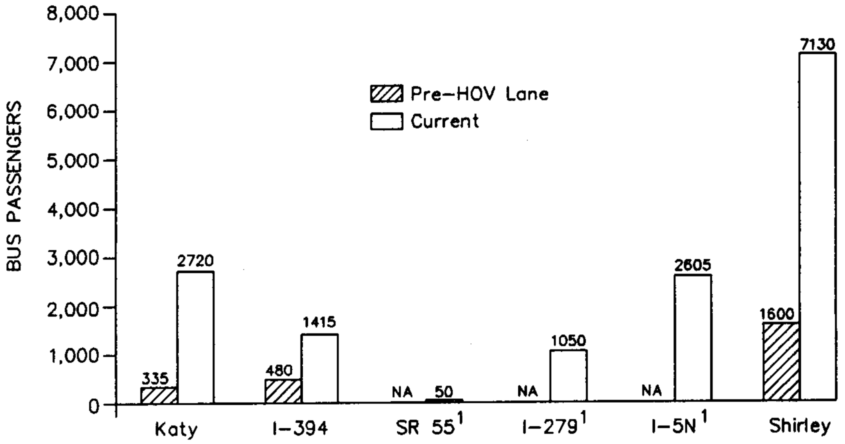
Sources: (*11*, *14–17*).

Analysis conducted in Houston further indicates that HOV lanes have a positive influence on the duration or life of carpools. A comparison of surveys results of carpoolers on freeways with HOV lanes and on freeways without HOV lanes indicates that the median age of carpools is two times greater on the freeways with HOV lanes (*1*). Thus, it appears that the presence of an HOV lane both creates incentives supporting new carpool formations and causes carpools to remain in existence longer.

The last measure of effectiveness under this objective examines the actual and percentage increase in bus riders for the total freeway facility. Similar to the discussion of new carpool formations, to be considered effective, an HOV facility should encourage an increase in bus ridership. Thus, the HOV lane should attract new passengers, not just divert existing bus services and riders from the freeway lanes or parallel roadways. The available information on historical trends and current levels of bus ridership on the different HOV lanes in North America is examined next. In addition to the HOV project case studies, information from the bus-only facilities in Ottawa and Pittsburgh is examined along with trends on other HOV lanes.

The development of an HOV facility is often accompanied by the implementation of new or expanded bus service. Park-and-ride lots are often constructed as part of an HOV project, with new or improved express or park-and-ride bus service provided from these facilities. In most cases, this service is oriented toward the downtown area, but service is also provided to other major employment centers in some areas. HOV lanes located primarily in suburban areas, such as Route 55 and other HOV lanes in Orange County, are oriented primarily toward serving carpool demand and little bus service has been implemented.

Figure 19 shows the number of morning peak-hour, peak-direction bus riders before the HOV facility opened and the most recent available passenger counts for the case study HOV lanes and other projects. As noted by the increase in bus ridership levels on many of the facilities, it appears that the HOV lanes have been an important factor in generating increased transit use in many corridors.



[1] Pre–HOV lane data not available for SR 55, I–279, and I–5N case studies.

Sources: (1–3,5,6,10,12,16)

Figure 19 A.M. Peak-Hour, Peak-Direction Bus Passengers, Pre-HOV Lane and Present

Information on the previous mode of bus riders, obtained through on-board ridership surveys conducted in the different areas, also provides an indication of the important role HOV lanes play in encouraging new bus riders. Table 2 provides a summary of the percentage of bus riders in different areas who indicated they previously drove alone. As can be see from the information in this table, a significant number (between 36 and 50 percent) of the bus riders indicated they had previously driven alone.

Table 2 Percentage of HOV Lane Bus Riders Who Previously Drove Alone[1]

HOV Facility[2]	Percentage
Case Study HOV Lanes	
Katy Freeway (1990)	36%
Shirley Highway (1974)	49%
Other HOV Lanes	
I-45 North, Houston (1990)	39%
US 290, Houston (1990)	46%
I-45 South, Houston (1989)	38%
San Bernardino Freeway, Los Angeles (1977)	50%

[1]Based on surveys of bus riders using the listed HOV facilities.
[2]Year in parentheses indicates the survey date.

Sources: (11, 14, 16, 17).

A number of the on-board ridership surveys asked additional questions to help determine the importance of the HOV lane in an individual's decision to ride a bus. Responses to these questions indicate that the HOV lanes have played a significant part in encouraging individuals to change from driving alone to using the bus. For example, in surveys conducted in 1988, 1989, and 1990, between 54 and 76 percent of the bus riders using the Houston HOV lanes responded that the opening of the HOV lanes was very important in their decision to ride a bus (*1*). Further, between 22 and 39 percent of the respondents in those surveys indicated that they would not be riding the bus if the HOV lane had not been opened (*1*). In 1971 and 1974, surveys of bus riders on the Shirley Highway HOV lanes identified the shorter bus travel times and the reduced congestion in the HOV lane as important factors (*11*). Bus riders on the San Bernardino Freeway Busway responding to a 1977 on-board survey also identified the ability to avoid congestion and the travel time savings offered by the HOV lanes as important factors in their decision to use the bus (*17*).

Bus Service Operating Efficiencies

Objective: *The HOV facility should increase the operating efficiency of bus service in the freeway corridor.*

This objective focuses on the benefits HOV lanes offer to transit operators. By increasing bus operating speeds and improving service reliability, HOV facilities can increase the vehicle operating efficiency of bus service in the corridor. The following three measures of effectiveness have been identified for use with this objective.

- Improvement in vehicle productivity, measured by operating cost per vehicle-mile, operating cost per passenger, and operating cost per passenger mile
- Improved schedule adherence, measured by on-time performance
- Improved safety, measured by a reduction in vehicle accident rates

To date, little analysis has been conducted on the impact HOV facilities have had on bus service productivity, schedule adherence, and safety. The best available information on these impacts is from studies of the Shirley Highway HOV lanes, the Houston HOV lanes, the Pittsburgh Busways, and the Ottawa Transitway system. Some of these studies, such as the one on the Shirley Highway HOV lanes, were conducted as part of the initial before-and-after evaluation and have not been updated. Further, in most cases only a very cursory examination has been made of any bus-related impacts. The limited information available from these studies is briefly examined in this section.

The before-and-after evaluation of the Shirley Highway Express-Bus-on-Freeway Demonstration Project, conducted in the early 1970s, attempted to examine the impact the opening of the HOV lanes had on bus on-time performance, bus service productivity, and the financial status of the operator. On-time performance was analyzed by comparing the actual arrival times of buses at the first downtown stop with the times listed in the printed schedule. The results of this analysis indicated that bus on-time performance improved as a result of the opening of the HOV lanes (*11*). As discussed in more detail under the next measure, the improvement in on-time performance resulted from increased bus operating speeds and more reliable travel times.

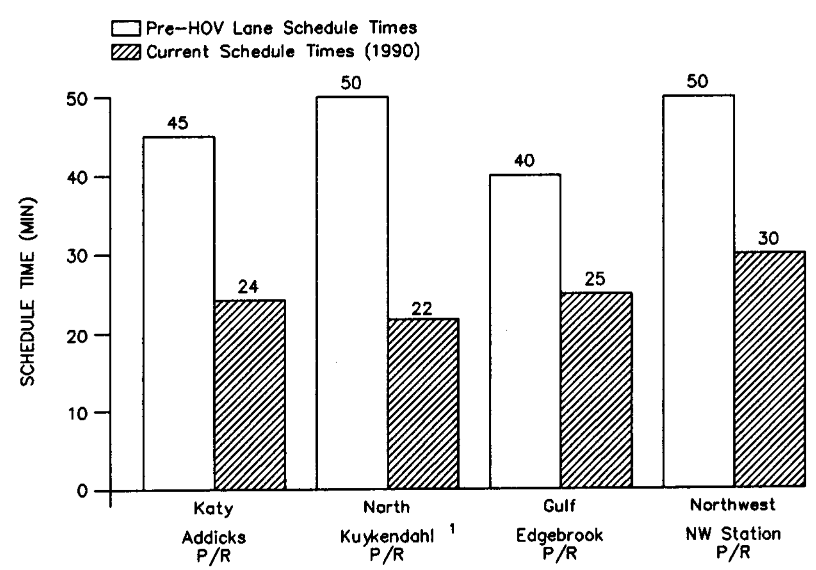
Unfortunately, the evaluation of the demonstration was unable to measure the direct impact of the HOV lanes on bus operator productivity, due to a lack of route-level data on operating hours, vehicle miles, required vehicles, and frequency of service. However, an estimate was made based on the bus requirements that would be needed if buses were operating at slower speeds in the general-purpose lanes. The study estimated that 17 additional buses would be needed, equivalent to a monthly capital and operating cost of $26,600 in 1973 dollars. The analysis also indicated that peak-period operating costs had been reduced slightly with the opening of the HOV facility (*11*).

A preliminary analysis of the impact the Houston HOV lanes have had on bus service enhancements and bus operating costs has been conducted. As Table 3 shows, the morning peak-hour bus operating speeds increased significantly when HOV lanes were introduced on each of the four freeways listed (*1*). On average, the peak-hour operating speeds have almost doubled, increasing from 26 mph to 54 mph. This increase in bus operating speeds has resulted in significant reductions in bus schedule times. Figure 20 illustrates the improvements that have been made in schedule times as a results of the opening of the Houston HOV lanes.

Table 3 Increase in Average A.M. Peak-Hour Bus Operating Speeds on the Houston HOV Lanes

HOV Facility	Bus Operating Speed (mph)		Increase
	Before HOV	Current	
Katy (I-10W)	23	56	143%
North (I-45N)	20	56	180%
Gulf (I-45S)	31	53	71%
Northwest (US 290)	29	50	72%
Unweighted Average	26	54	107%

Source: (*1*).



[1] Kuykendahl opened after the HOV lane existed. The pre-HOV schedule time is an estimate based on freeway operating speeds.

Source: (1)

Figure 20 Bus Schedule Time, A.M. Peak-Hour Service to Downtown Houston, Pre-HOV Lane and Present

The Metropolitan Transit Authority of Harris County (METRO) has also conducted a preliminary operational analysis of recent enhancements to the Houston HOV system. METRO examined the impacts of the opening of a direct access ramp from the Northwest Station Park-and-Ride lot to the Northwest (US 290) HOV lane, the temporary closing of an almost four-mile segment of the North (I-45N) HOV lane due to construction, and the 1½-mile eastern extension to the Katy (I-10W) HOV lanes. Table 4 summarizes some of the benefits realized from these improvements. Further, during 1990, TTI estimated that the HOV lanes reduced the revenue bus-hours needed to provide service by 31,000 hours. At an average cost of $152 per revenue bus-hour, the HOV lanes reduced METRO's 1992 bus operating costs by approximately $4.8 million (*1*).

Table 4 Bus Operations Impacts of Improvements to the Houston HOV Lane System

HOV Facility & Bus Route	Schedule Time (min.)		Bus Operations Impacts		
	Before	After	Bus-Hours Saved	Equivalent Buses Saved	Annual Cost Savings
Northwest (US 290)[1]					
Route 214	44	30	14.9	4	$85,000[4]
North (I-45N)[2]					
Route 204	40	28	—	—	—
Route 207	31	23	—	—	—
Combined	—	—	20.0	5	$115,000
Katy (I-10W)[3]					
Route 228	30	24	6.4	2	$117,000

[1]The improvement is a ramp from a park-and-ride lot to the HOV lane.
[2]The improvement is the re-opening a 3.8-mile section of the HOV lane.
[3]The improvement is a 1.5 mile extension to the HOV lane.
[4]Partially due to more efficient allocation of routes to operating facilities.

Source: (*1*).

The opening of the East Busway in Pittsburgh also resulted in reduced bus travel times and improved bus on-time performance. Two types of services are operated on the East Busway. First, routes that existed prior to the opening of the busway were diverted off the local street system and onto the Busway. Second, a new route, called the East Busway All Stops (EBA) route, was implemented. This route operates exclusively on the busway with high frequency service, in much the same manner as a light rail transit (LRT) system. Individuals can access the EBA route by transferring from connecting buses, walking to the stations, or being dropped off. Travel time savings of 20 to 24 minutes, equating to a reduction of 40 to 50 percent in bus travel times, have been realized on many of these routes. Passengers who now have to transfer to the EBA route still realize travel time savings. Improvements have also recorded in travel time reliability and bus on-time performance (*17*).

The Ottawa-Carleton Regional Transit Authority (OC Transpo) examined the operational cost savings of the Ottawa Transitway in 1986. The analysis was based on two years of operating experience and took a relatively simple approach of comparing the existing experience to an alternative without the Transitway. The analysis indicated that some 220 fewer standard buses and 40 fewer articulated buses were needed because of the Transitway. The analysis further identified a cumulative operating and capital cost savings—exclusive of the Transitway construction costs—for the first 31 kilometers of Transitway of $209 million by 1994 (*18*).

Travel Time Savings and Trip Time Reliability

Objective: *The HOV facility should provide travel time savings and a more reliable trip time to high-occupancy vehicles utilizing the HOV facility.*

This objective addresses the incentives offered by HOV facilities for individuals to change from driving alone to taking a bus, vanpooling, or carpooling. The two major incentives provided by HOV lanes are travel time savings and travel time reliability. Experience indicates that some commuters find these benefits attractive enough to change from driving alone to using a high-occupancy commute mode. The following two measures of effectiveness have been identified for use with this objective.

- The peak period, peak-direction travel time in the HOV lane should be less than the travel time in the adjacent freeway lanes
- Increased travel time reliability for vehicles using the HOV lane

Figure 21 illustrates the average travel time savings realized by peak-hour commuters using the HOV facility over the general-purpose traffic lanes for the project case studies and other HOV projects. As can be seen by the figure, the peak hour travel time savings provided by the different HOV lanes vary, but in all cases represents an important improvement over the travel times in the general-purpose lanes.

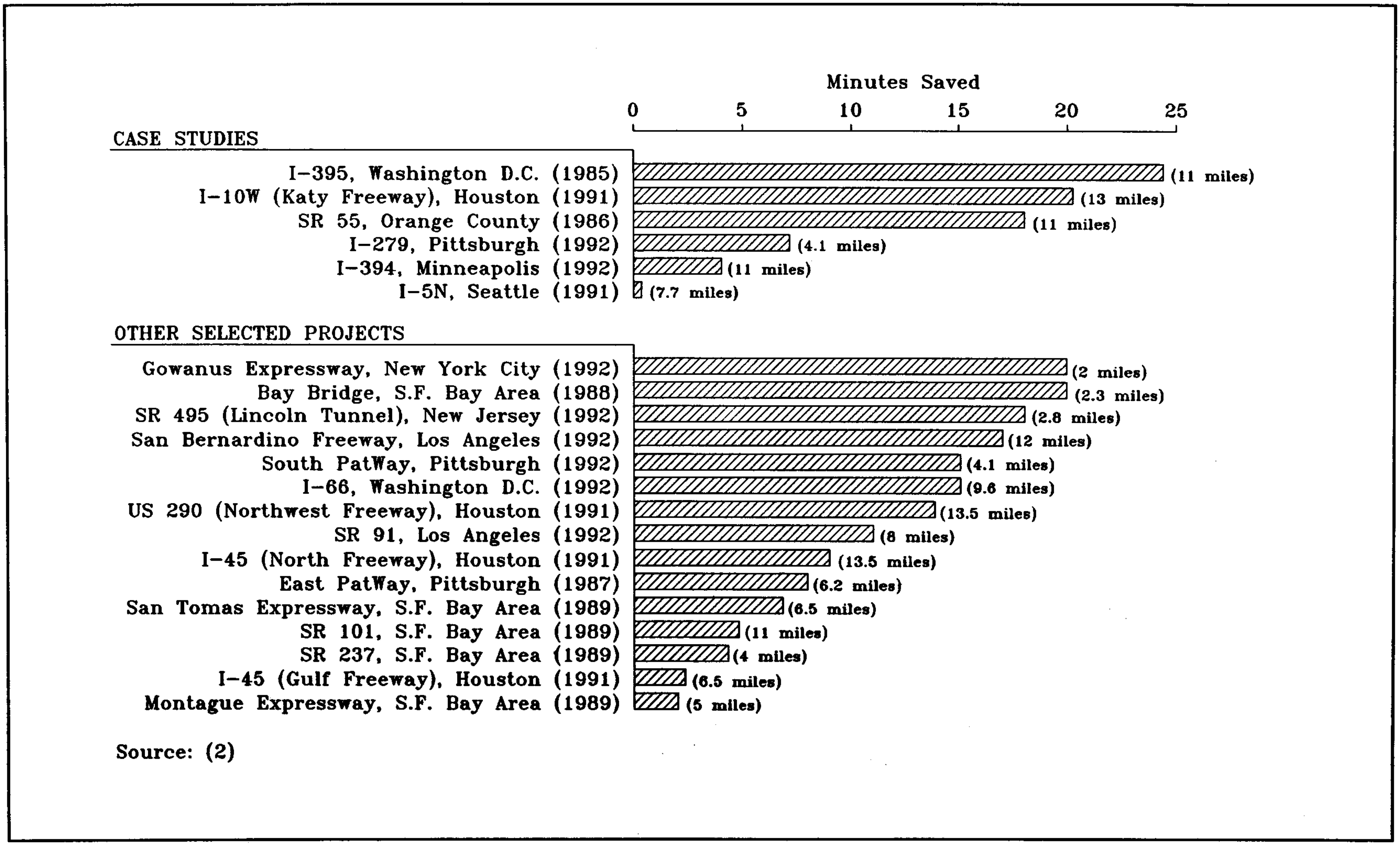


Figure 21 **Average A.M. Peak-Hour Travel Time Savings of HOV Lanes over Freeway Lanes**

A number of studies have also examined changes in travel time reliability in addition to travel time savings. Improvements in travel time reliability were noted with most HOV projects (*1*). For example, an analysis of the Houston HOV lanes, which was based on a comparison of standard deviations, found that travel times in the HOV lanes are much more reliable and consistent than are travel times on the freeway general-purpose lanes (*1*).

Air Quality and Energy Impacts

Objective: *The HOV facility should have favorable impacts on air quality and energy consumption.*

This objective focuses on the environmental benefits of HOV facilities, specifically those benefits associated with air quality and energy consumption. These are important concerns in many metropolitan areas today, especially those areas currently in violation of the Environmental Protection Agency (EPA) standards for ozone and carbon dioxide. The following three measures of effectiveness were identified for use with this objective.

- Reduction in emissions
- Reduction in total fuel consumption
- Reduction in the growth of vehicle miles of travel (VMT)

Very little analysis has been done on the air quality and energy impacts of HOV facilities. Further, most of the analyses that have been conducted have taken relatively simplistic approaches that have not considered the more complex issues associated with cold starts and hot soaks. This includes both general analyses of potential benefits and evaluations of project specific impacts. To date, most of the work that has been done focuses either on the use of computer simulation models to estimate the impacts of an HOV facility compared to other alternatives or estimates the impact of operating HOV projects based on the number of people using high-occupancy commute modes. No comprehensive evaluations have been conducted addressing the three suggested measures of effectiveness. The analyses that have been conducted on the case study HOV projects and on other HOV facilities are relatively simplistic and are reviewed in this section.

The analysis of the air quality and energy impacts of the Houston HOV lanes provides the best example of the use of computer simulation models to estimate the impact of different transportation improvement alternatives. The analysis was conducted by the Texas Transportation Institute for the

Texas Department of Transportation. The approach used in this analysis was undertaken based on the realization that implementing an HOV lane does not necessarily reduce vehicular volumes on the freeway, but rather allows more persons to use the total facility without increasing congestion in the freeway general-purpose lanes. As a result, the HOV lane traffic may increase the vehicle-miles of travel compared to the condition before the opening of the facility. Thus, an increase in total vehicle-miles of travel may result, which may also increase the amount of energy consumed and pollutants emitted.

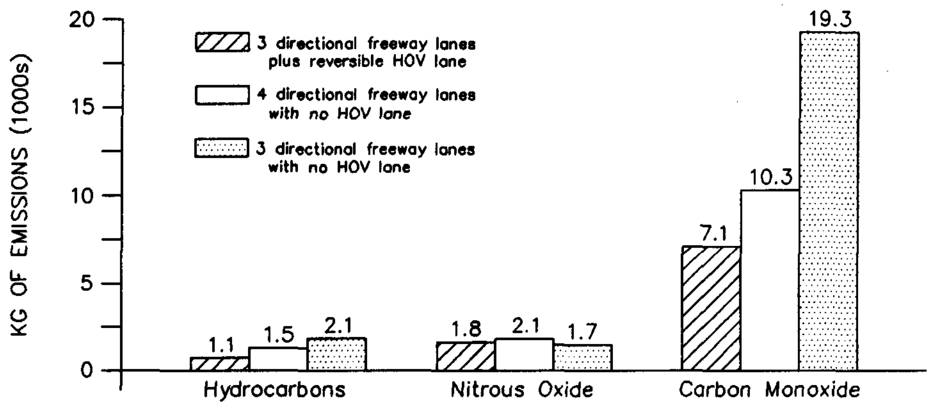
However, as noted by the measure of effectiveness that focuses on reducing the growth in VMT, this is too simplistic an approach. To address this issue, the analysis in Houston has focused on asking the question, What is the most effective means of serving the travel demand that is expected to occur and what are the air quality and energy impacts of the different alternatives (*1*)? This analysis, which utilizes a freeway simulation computer model (FREQ), has focused on the following three alternatives for the Katy Freeway.

Do Nothing — This alternative has three general-purpose traffic lanes in each direction and no HOV facility in the corridor. It represents the conditions that existed prior to implementation of the HOV lane.

Add a General-Purpose Traffic Lane — This alternative would provide a total of four general-purpose traffic lanes in each direction with no HOV lanes.

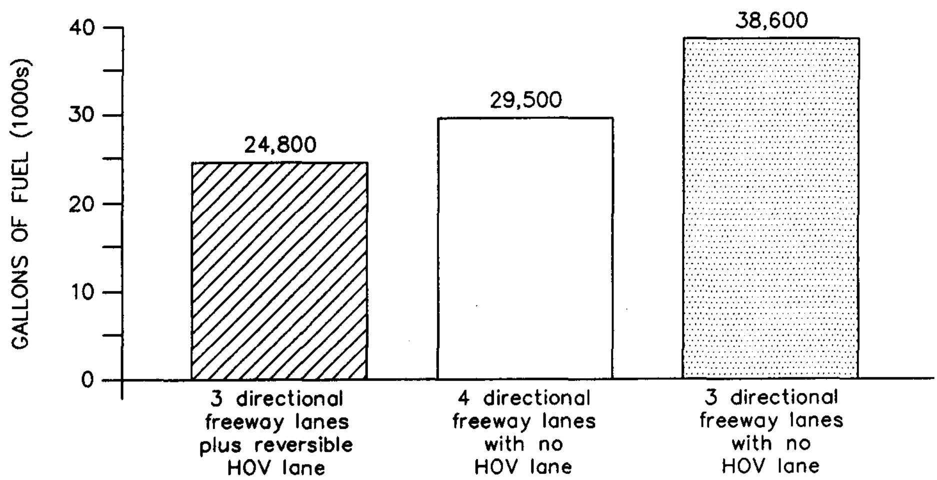
Add an HOV Lane — This alternative has three general-purpose traffic lanes in each direction and a reversible HOV lane. This alternative represents the scenario that was implemented.

To date, this analysis has been completed for the Katy Freeway and HOV lane. Similar analyses are also planned for other HOV lanes in the Houston area. The results of the analysis for the Katy Freeway and HOV lane, based on 1991 travel volumes, are shown in Figures 22 and 23. Using the FREQ model, the operation on both the freeway general-purpose lanes and the HOV lane was simulated. The 1991 demand, expressed in passenger-miles, was held constant across the alternatives, and the average vehicle occupancy was adjusted between alternatives as necessary to reflect the observed impacts of the HOV facility on vehicle occupancy (*1*).



Source: Texas Transportation Institute simulation analyses, 6 a.m. to noon, peak direction, 1991 demand levels.

Figure 22 Estimated Impacts of HOV Alternatives on Air Quality, Katy Freeway, Houston, Texas



Source: Texas Transportation Institute simulation analyses, 6 a.m. to noon, peak direction, 1991 demand levels.

Figure 23 Estimated Impacts of HOV Alternatives on Energy Consumption, Katy Freeway, Houston, Texas

As illustrated in Figures 22 and 23, the alternative with the HOV lane provides the greatest air quality and energy benefits. Figure 22 shows the hydrocarbon, nitrogen oxide, and carbon monoxide emissions generated by each of the three alternatives in the simulation. The HOV lane alternative generates the lowest levels of emissions for two of the three pollutants. As illustrated in Figure 23, the HOV lane option also results in the lowest levels of gasoline consumption among the alternatives. The Houston analysis also points out that since increases in demand are expected to continue in the future, the HOV lane alternative may provide even greater benefits because it provides capacity to serve additional growth while the other alternatives do not (*1*).

The initial evaluation of the Shirley Highway Express-Bus-on-Freeway Demonstration included an examination of the environmental impacts of the project. The final evaluation report indicated that the project had positive environmental impacts in the corridor (*11*). This analysis was based on an estimate of the number of automobiles that would use the freeway if motorists were not diverted to the express bus services or carpools using the HOV lanes. The number of motorists who changed from driving alone to using the bus or carpooling was estimated based on the results of surveys of these two groups. This provided an estimate of the reduction in peak period automobile volumes, which was used to calculate changes in automobile-generated air pollution and gasoline consumption. The analysis indicated that, in 1974, the Shirley Highway HOV lanes had influenced a reduction of approximately 21 percent in the carbon monoxide, hydrocarbon, and nitrogen oxide emissions in the corridor (*11*). Further, in 1974 the HOV lanes were estimated to save approximately 17,200 gallons of gasoline daily, or about a 23-percent reduction in the level of consumption without the facility (*11*).

Additional analysis of the potential air quality and energy impacts of HOV facilities in the Washington, D.C. metropolitan area is currently being conducted by the Metropolitan Washington Council of Governments (WASHCOG). A quick-response modeling procedure has been developed to analyze two future transportation network alternatives. One network contains only the existing HOV facilities, while the other contains a full program of additional HOV lanes. The quick-response model estimates the HOV travel times by subtracting the zone-to-zone network travel times from the base case network travel times. A pivot-point model is then used to estimate mode shifts and changes in VMT and vehicle trips. Based on a very preliminary analysis for the year 2010, it appears that the complete HOV network alternative results in a 3-percent reduction in home-based-work vehicle trips, a 6-percent reduction in VMT for work travel, and the lowest level of fuel consumption among the alternatives.

The evaluation covering the first five years of operation on the San Bernardino Freeway Busway also examined the air quality and energy impacts of the facility. An approach similar to the one used with the Shirley Highway Express-Bus-on-Freeway Demonstration evaluation was used in this analysis. The reductions in vehicles on the freeway and VMT resulting from the operation of the HOV facility were estimated based on surveys of bus riders and carpoolers. This analysis identified a 10- to 20-percent reduction in air pollution emissions over the peak period in the peak direction of travel resulting from the HOV lane improvement. Energy savings were estimated at 7 percent to 10 percent during the same time period (*17*).

Per-Lane Efficiency of the Freeway Facility

Objective: *The HOV facility should increase the per lane efficiency of the total freeway facility.*

This objective focuses on the overall impact the HOV lane should have on the freeway. HOV facilities are intended to move substantial volumes of commuters at relatively high speeds. Thus, the HOV lane should improve the overall efficiency of the freeway facility. The measure of effectiveness identified for use with this objective was a comparison of the peak-hour per-lane efficiency of the freeway lanes prior to implementation of the HOV project and the combined peak-hour per-lane efficiency of the freeway lanes and HOV lane(s) after implementation. The peak-hour efficiency is expressed as the multiple of the peak-hour person volume and the speed at which that volume is moved, and the result is expressed on a per-lane basis.

The first measure—before the HOV lane—is calculated by multiplying the person volume on the freeway and the average freeway operating speed. The second measure—with the HOV lane in operation—is calculated by multiplying the person volume on the freeway and the average freeway operating speed, and adding the product of the HOV lane person volume and the average HOV lane operating speed. A hypothetical example is provided below.

Before HOV Project Measure: The freeway (comprised of three general-purpose lanes in the peak direction of travel) had an average morning peak-hour, peak-direction volume of 1,750 persons per lane and a corresponding travel speed of 22 mph before the HOV lane was open.

$$\textit{Peak-hour, per-lane efficiency} = \frac{1{,}750 \times 22}{1{,}000} = 38.5$$

After HOV Project Measure: After the opening of the HOV lane, the average morning peak-hour, peak-direction volume changed to 1,650 persons per lane for the general-purpose lanes and was 4,100 for the HOV lane. Travel speeds were 25 mph for the general-purpose lanes and 45 mph for the HOV lane.

$$\textit{Per-lane efficiency of the HOV lane} = \frac{4{,}100 \times 45}{1{,}000} = 184.5$$

$$\textit{Per-lane efficiency of the general-purpose lanes} = \frac{1{,}650 \times 25}{1{,}000} = 41.3$$

$$\textit{Per-lane efficiency of the total facility} = \frac{(184.5)(1) + (41.3)(3)}{4} = 77.0$$

Table 5 provides a comparison of the changes in the morning peak-hour per-lane efficiency for three of the case study HOV lanes where the data needed for this analysis were available. Experience in Houston indicates that on a facility with a mature HOV lane, the peak-hour per-lane efficiency should increase by an absolute value of at least 20 from the conditions before the HOV lane was implemented (*1*). The three HOV projects listed in Table 5 all meet this general guideline.

Caution must be noted with the use of this measure, however. The average speeds in the general-purpose and HOV lanes are major components in the per-lane efficiency calculation. Representative speed data are often difficult to obtain and may not always be reliable.

Table 5 A.M. Peak-Hour, Per-Lane Efficiency for Case Study HOV Lanes

Facility	Person Volume			Average Speed (mph)			Number of Directional Lanes		Per-Lane Efficiency[1]				Absolute Increase[3]	Percent Increase[4]
	General Purpose		HOV	General Purpose		HOV	General Purpose	HOV	Before	After				
	Before	After		Before	After					General Purpose	HOV	Total[2]		
Katy (I-10)	5,300	6,190	4,810	23	23	47	3	1	41	47	226	92	51	124
I-394[5]	2,680	4,200	3,630	33	41	52	2	1	44	86	189	120	76	173
Route 55	5,200	5,670	2,740	20	20	43	3	1	35	38	118	58	23	66

[1]Peak-hour, per-lane efficiency is defined as the person volume per lane multiplied by the average speed and divided by 1,000. Thus, it is a measure of both the person volume moved and the speed at which that volume is moved.

[2]The peak-hour, per-lane efficiency of the entire facility (general-purpose and HOV lanes) in the peak travel direction.

[3]The absolute difference between the peak-hour, per-lane efficiencies of the entire facility (combined general-purpose and HOV lanes) and the general-purpose lanes prior to HOV facility implementation.

[4]The percentage difference between the peak-hour, per-lane efficiencies of the entire facility (combined general-purpose and HOV lanes) and the general-purpose lanes prior to HOV facility implementation.

[5]The data used for this analysis are from a section of the I-394 HOV facility located west of State Highway 100. In that section there are two general-purpose lanes and one concurrent-flow HOV lane in the peak direction.

Impacts on the Operation of the Freeway General-Purpose Lanes

Objective: *The HOV facility should not unduly impact the operation of the freeway general-purpose lanes.*

This objective addresses the need to ensure that the implementation of an HOV facility does not have a negative impact on the capacity and operating speeds of the adjacent general-purpose freeway lanes. The suggested measure of effectiveness for this objective is a comparison of the level-of-service on the freeway general-purpose lanes before and after implementation of the HOV project.

To date, no before-and-after comparisons have been made of HOV projects using level-of-service as a measure. Comparisons have been made of the different elements used to calculate level-of-service, such as speed and vehicle volumes, on some facilities. There are a number of difficulties with the use of these measures, however. First, vehicle volumes continue to increase on freeways nationwide in response to increasing demand. Vehicle volumes on the freeways with HOV lanes are following this trend, resulting in increasing congestion levels and potentially slower travel speeds. Freeway travel speeds also reflect a great deal of variability. Weather conditions and incidents can have significant impacts on travel speeds and congestion levels. Thus, using level-of-service or other related measures to estimate the impact of an HOV facility on the general-purpose lanes should be done with care.

A number of the HOV project case studies have examined the influence of the HOV lanes on the general-purpose lanes. Analysis conducted in Houston has indicated that the implementation of HOV facilities with the design being used in Houston does not greatly effect the operation of the freeway general-purpose lanes (*1*). Similar results have been noted on I-5 North (*10*), I-394 (*11*), the Shirley Highway, and the San Bernardino Freeway Busway (*17*). It is important to note, however, that some conflicts have been observed on some of these projects as a result of the merging of HOV lane traffic back into the general-purpose lanes at the HOV lane terminus. Thus, consideration should be given in the design phase to minimize the potential for these types of conflicts.

Safety

Objective: *The HOV facility should be safe and should not unduly impact the safety of the freeway general-purpose lanes.*

This objective supports the previous one related to the impact of the HOV facility on the general-purpose freeway lanes, but specifically addresses safety concerns. It recognizes that the HOV lane itself should be safe to operate and that the addition of the HOV lane should not negatively impact the safety of the freeway general-purpose lanes. The following two measures of effectiveness have been suggested for use with this objective.

- Number and severity of accidents for the HOV and freeway general-purpose lanes
- Accident rate per million vehicle-miles or million passenger-miles of travel for the HOV and freeway general-purpose lanes

Available information from the case study HOV projects and other HOV facilities indicates that the implementation and operation of HOV lanes have not caused a noticeable increase in accidents, nor have the facilities degraded the safety of the overall freeway. However, complete information on accidents is not available for many areas. This is often due to different reporting procedures by local and state enforcement agencies, incomplete accident records, and difficulties in determining the cause of a specific accident. Even with these limitations, the experience reported on different HOV projects indicates that they are operated safely and have not adversely impacted the safety of the freeway general-purpose lanes.

A few examples illustrate this point. The ongoing monitoring and evaluation of the I-394 interim HOV lane in the Minneapolis area indicated that there were no unique accident problems associated with the project (*16*). As part of the evaluation of the change in the vehicle occupancy level from 3+ to 2+ on the Seattle I-5 North HOV lane, accident records for the four-year period from 1988 to 1991 were examined. The analysis did not identify any specific trends or variations that could be associated with the reduction in vehicle occupancy requirement (*10*). The initial evaluations on both the Shirley Highway HOV lanes and the San Bernardino Freeway Busway found no apparent effects on safety on either the HOV lanes or the general-purpose freeway lanes (*11*). The ongoing monitoring of the four Houston freeways with HOV lanes has indicated that there has not been a noticeable change in the aggregate accident data for the four freeways with HOV lanes (*1*).

In response to specific local concerns, special studies focusing on safety issues were conducted on the Route 55 and Route 91 HOV lanes in the Los Angeles/Orange County area. The Institute of Transportation Studies at the University of California, Irvine conducted a study in 1986 and 1987 examining the safety impacts of those facilities. The study was conducted for the Orange County Transportation Commission, the Los Angeles County Transportation Commission, the California Department of Transportation, and the Southern California Association of Governments.

The objective of the study was to determine whether or not the operation of the HOV lanes on these routes contributed to a decline in safety levels (*20*). Based on an examination of accident data, the study provided three general conclusions. First, the analysis indicated that the traffic congestion experienced on the freeway overwhelmed all other factors in determining safety. Thus, identifying the impact of the HOV lanes was difficult due to increasing congestion patterns. Second, the study indicated that little change in safety would result if the lanes were general-purpose lanes rather than HOV lanes. Finally, the lack of good accident data from the period before the HOV lanes were implemented was cited as a limiting factor in the analysis. Thus, the recommendation was made that future HOV projects should include a detailed analysis of accident data prior to the implementation of the HOV project (*20*).

A 1989 study by SYSTAN, Inc., which was conducted for the Santa Clara County Transportation Agency, examined accident data on Route 101 and Route 237 in Santa Clara County. Accident data for a six-year period prior to the implementation of the HOV lanes were examined, along with current data. The study found that statistically significant increases in accident levels occurred during the morning commute period following the installation of the HOV lanes. However, after an initial increase, the accident rates on both facilities had begun to decline (*20*). The report suggested that additional examination and ongoing monitoring should be conducted on the facilities (*20*).

Public Support

Objective: *The HOV facility should have public support.*

This objective recognizes the important role public acceptance and support plays in the successful implementation and operation of any type of transportation project, including HOV lanes. Experience has shown that public support is an important factor in helping ensure a successful project. Thus, support should exist for the HOV facility among users, non-users, the general pubic, and policy makers. In addition, the general perception should exist that the facility is adequately utilized.

Two measures of effectiveness were identified to help gauge public acceptance and the attitudes of HOV lane users and non-users toward the HOV facilities. First, opinion surveys and other market research techniques—as well as monitoring calls, letters, and the media—can be used to measure public opinions and reactions. Second, public perceptions may be reflected in the HOV lane violation rate, which is the fraction of vehicles in the HOV lane that do not meet the required occupancy level.

Public opinion surveys and surveys of HOV lane users and non-users have been conducted in many areas to help identify public reactions to the facilities. The ongoing surveys of bus riders, carpoolers, vanpoolers, and motorists in the Houston area represent one of the longest and most comprehensive programs. Surveys were first conducted in 1980 as part of the initial contraflow demonstration project on the North Freeway (*21*). Additional surveys have been undertaken on the different HOV and freeway facilities between 1985 and 1990. Although not every HOV and freeway facility has been surveyed every year, each was surveyed frequently enough to provide a very rich data base on the perceptions of the HOV lane users and non-users. Table 6 provides a summary of the responses to the survey questions asking if the HOV lanes are good transportation improvements. As can be seen by the results, even motorists not using the HOV lanes feel they are good improvements.

Houston is not the only area to use different survey techniques to help identify public reaction to the HOV projects and to build public support. Mail surveys, telephone surveys, focus groups, and other approaches have all been used in many areas to obtain information from users of the HOV lanes and motorists in the general-purpose lanes. Results of surveys from Seattle, Minneapolis, Orange County, Los Angeles, and Santa Clara County indicated support for the HOV projects among both users and non-users (*10, 15–17, 22*).

The second measure of effectiveness addresses the violation rates associated with an HOV facility. Violation rates measure the number of vehicles using an HOV facility that do not meet the minimum occupancy requirement. Theoretically, areas that exhibit a high level of public support for the HOV project should also have low violation rates. It is important to note that other factors, such as design, enforcement levels, and supporting programs may also influence violation rates.

Available information from the case study HOV projects indicates that the violation rates for all the facilities are relatively low. The reported violation rates for the Shirley Highway, I-394, and Route 55 HOV lanes all average below 6 percent (*2*). The rates for the Katy HOV lanes fall within this range, except during the peak hours when the 3+ requirement is in effect (*1, 2*). The rates for the I-5 North facility before the 1991 demonstration lowering the occupancy requirement to 2+ were approximately 15 percent (*2*). No information on violation rates is available for the I-279 facility.

Table 6 Non-HOV User Responses to the Question, Do You Feel the Transitways Being Developed in Houston Are Good Transportation Improvements?[1]

Survey Responses by Location	Year of Survey					
	1985	1986	1987	1988	1989	1990
Freeways with Transitways						
North Freeway[2]						
Yes	—	62%	—	—	—	81%
No	—	20%	—	—	—	9%
Not Sure	—	28%	—	—	—	10%
Katy Freeway[3]						
Yes	41%	36%	60%[4]	64%	67%	71%
No	35%	43%	24%	22%	19%	16%
Not Sure	24%	21%	16%	14%	14%	13%
Northwest Freeway[5]						
Yes	—	—	—	—	71%	75%
No	—	—	—	—	13%	11%
Not Sure	—	—	—	—	16%	14%
Gulf Freeway[6]						
Yes	—	—	—	—	63%	—
No	—	—	—	—	21%	—
Not Sure	—	—	—	—	16%	—
Freeway without Transitway						
Eastex Freeway						
Yes	—	—	—	58%	—	—
No	—	—	—	15%	—	—
Not Sure	—	—	—	27%	—	—

[1]The question, "Do you feel the transitways being developed in Houston are good transportation improvements?," was asked of motorists in the freeway general-purpose lanes on each facility listed.

[2]The original North Freeway contraflow lane opened in 1979; the North Transitway opened in 1984.

[3]The Katy Transitway opened in October 1984.

[4]Average results from two surveys conducted in 1987.

[5]The Northwest Transitway opened in August 1988.

[6]The Gulf Transitway opened in May 1988.

Source: (*1*).

Cost-Effectiveness

Objective: *The HOV facility should be a cost-effective transportation improvement.*

This objective recognizes that an HOV facility should provide a cost-effective improvement to the transportation system. The suggested measure for use with this objective is the benefit-cost ratio. A number of different elements, such as travel time savings, operating cost savings, and savings in the cost of congestion can be included as benefits to calculate the benefit-cost ratio of an HOV facility. For simplicity, the suggested method focuses only on the value of travel time savings by persons using the HOV facility. Thus, the suggested guideline is that if an HOV facility has a benefit-cost ratio greater than 1.0—based only on the value of travel time savings to persons using the facility—the project can reasonably be considered cost-effective. Clearly this is an extremely conservative approach, since the HOV lane should also generate other benefits.

Using this approach, the benefit-cost ratios have been calculated for three HOV projects. The Katy Freeway, I-5 North, and I-394 case study HOV projects are used to provide examples of how this approach can be applied. All three provide examples of HOV projects that appear to be cost-effective using this conservative approach. The information needed to calculate the cost-benefit ratio for an HOV project and the steps in the process are briefly summarized next.

There are five basic assumptions used with this approach. These assumptions are noted below.

- A constant stream of benefits is assumed over the life of the project. The only benefit included in the calculation is the time savings realized by users of the HOV lane. This is a conservative assumption. Travel time savings should continue to increase over time as congestion levels increase in the general-purpose lanes. Also, the HOV lane should generate other benefits—such as operating cost savings, fuel savings, and reductions in the cost of congestion—in addition to the travel time savings.
- A 20-year life with no salvage value is assumed for the HOV lane. Again, this is a conservative assumption, since no salvage value is included for the facility.
- A 4-percent discount rate is used in the calculation.
- A $9 per hour value of time is used in the calculation.
- A figure of 250 working days a year is used in the calculation.

Using these assumptions, and available information from the three HOV project case studies on construction costs, HOV person volumes, and travel time savings, the cost-benefit ratios can be calculated. The results of this analysis, which are presented in Table 7, indicate that all three of the selected HOV case study projects can be viewed as cost-effective transportation improvements. The conservative nature of this approach needs to be stressed as other benefits could be used in the calculations. However, this does represent one approach that can be used to estimate the cost-benefit ratio of an HOV project for evaluation purposes.

Table 7 Examples of Cost/Benefit Ratios for Selected Case Study HOV Projects

Facility	HOV Person Volume		Travel Time Savings (min.)[1]		Value of Time Saved ($ million/year)[3]	Construction Costs ($ million)[4]	Ratio of Annual Time Savings to Construction Costs[5]
	Peak Hour	Peak Period (duration)	Peak Hour	Balance of Peak Period[2]			
Katy (I-10)	4,810	10,060 (3.5)	13.8	5.5	7.2	32.0	23%
I-394	3,630	7,260 (4.0)	4.0	1.5	1.5	14.0	11%
I-5 North	5,640	12,240 (3.0)	2.5	1.0	1.6	10.1	16%

[1]The travel time savings experienced by HOV lane users relative to the general-purpose freeway lanes.

[2]The average time savings experienced by HOV lane users during the portions of the peak period that are before the beginning and after the end of the peak hour.

[3]The annual value of time saved by HOV lane users was computed by assuming that the value of time was $9 per hour and that there were 250 working days in a year.

[4]The construction costs associated with the HOV facility and any support facilities (e.g., park-and-ride lots).

[5]The annual value of time saved divided by construction costs, expressed as a percentage.

IV.

Conclusion

This report has provided an overview of the experience with HOV projects in the six case study locations. Information on the historical trends and current utilization levels has been examined for HOV facilities in Houston, Texas; Minneapolis, Minnesota; Orange County, California; Pittsburgh, Pennsylvania; Seattle, Washington; and Washington, D.C./Northern Virginia. Further, a more detailed analysis has been conducted of the case study HOV projects and other HOV facilities based on the evaluation measures identified in the earlier report *Suggested Procedures for Evaluating the Effectiveness of Freeway HOV Facilities.*

The results of this analysis serve a number of different purposes. First, the report provides a summary of the experience to date with a variety of HOV projects in North America. This information begins to develop a common national data base on HOV facilities. Building a common body of knowledge on the use and effectiveness of HOV facilities will assist in keeping transportation professionals informed on the latest developments in the field and the merits and potential problems associated with the different approaches. Second, the report provides examples of how the evaluation measures developed as part of the three-year assessment can be used to examine the impacts of HOV projects. This should be of benefit to transportation professionals interested in evaluating existing and planned HOV projects.

Finally, the report reemphasizes the need for data collection and monitoring activities to provide the information necessary to conduct the evaluations. As noted throughout the report, the evaluation of many HOV projects has been limited by the lack of available data, especially on conditions before the HOV facility was implemented. Ensuring that comprehensive before-and-after data collection activities and ongoing monitoring is conducted will help support future efforts of this nature.

The results of the analysis indicate that many HOV facilities do provide significant benefits. Further, as outlined in the previous chapter, many HOV facilities meet the objectives commonly associated with projects of this nature. For example, based on the available data, the HOV projects included in the analysis have increased the person movement capacity of the total freeway facility, enhanced bus service efficiencies, provided travel time savings and more reliable trip times for HOVs, and improved the per-lane efficiency of the total freeway. At the same time, the analysis indicated that these benefits have been realized without degrading the operation and safety of the freeway general-purpose lanes. Further, support for the HOV facilities appears to be strong in many areas among users, non-users, and the general public. Finally, the analysis indicated positive air quality and energy benefits from the HOV projects and the cost-effectiveness of the projects as transportation improvements.

The analysis also indicates areas where more research is needed to provide a more accurate and complete picture of the impacts of many HOV projects. As noted previously, the analysis of many projects has been limited by the lack of available data. Thus, the results of this study reemphasize the need for comprehensive before-and-after assessments of HOV projects and ongoing monitoring activities. Further research into the air quality and energy impacts, the safety issues associated with different design treatments and operating scenarios, changes in bus service operation efficiencies, and the overall operation of the total freeway or corridor are needed.

The analysis in this report indicates that many HOV facilities do provide numerous benefits. However, it is important to remember that HOV facilities may not be appropriate in all situations and may not preclude the need for other transportation improvements. Thus, HOV projects should be viewed as just one of many approaches that may be appropriate for addressing traffic congestion and mobility concerns in metropolitan areas today.

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