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16. Abstract

This report evaluates the operation of freeway high-occupancy vehicle (HOV) lanes in Texas through calendar year 1995. As of the end of 1995, HOV lanes were in operation on the five following Houston freeways: 1) Katy Freeway (I-10W); 2) North Freeway (I-45N); 3) Northwest Freeway (U.S. 290); 4) Gulf Freeway (I-45S); and 5) Southwest Freeway (U.S. 59S). The only HOV facility in operation in Dallas as of the end of 1994 was on the East R. L. Thornton Freeway (I-30E).

This research report provides an analysis of data related to the 1) operation of the HOV lanes; 2) operation of the freeway mainlanes; 3) combined HOV lane and freeway data; and 4) data relating to transit usage and operations. Both a "before" and "after" trendline analysis (where applicable) and a comparison to control freeways are used as a means of assessing the impacts of the HOV facilities.

As of December 1995, 102.4 kilometers (63.6 miles) of barrier-separated HOV facilities were in operation in Houston, while 8.4 kilometers (5.2 miles) were in operation in Dallas. Approximately 77,027 daily person trips are served on the Houston HOV lane system. Sixty-five percent of total person trips on the Houston HOV lanes are being served by carpools and vanpools, with the remaining 35 percent being served by buses. The East R. L. Thornton HOV lane in Dallas serves 13,572 daily person trips. Sixty-six percent of these trips are being served by carpools and vanpools, with the remaining 34 percent being served by buses.

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AN EVALUATION OF HIGH-OCCUPANCY VEHICLE LANES IN TEXAS, 1995

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IMPLEMENTATION STATEMENT

The Texas Department of Transportation sponsored this report as part of an overall effort entitled *"An Evaluation of High-Occupancy Vehicle Lanes in Texas."* The principal objectives of this effort are to collect, analyze, and interpret data to assess the performance and effectiveness of the committed freeway HOV lanes now being implemented in Texas.

The first permanent HOV facility in Texas opened in Houston on the Katy Freeway (I-10W) in October 1984. In November 1984, the contraflow lane (which was implemented in 1979) on the North Freeway (I-45N) was converted to a barrier-separated HOV lane, and in 1988, priority facilities were opened on both the Northwest Freeway (U.S. 290) and the Gulf Freeway (I-45S). In 1990, extensions of the Katy, North, and Northwest HOV lanes were completed, carpool use of the North HOV lane began, and construction of the Eastex (U.S. 59N) facility was initiated. The Southwest Freeway (U.S. 59S) HOV lane opened for use to vehicles with two or more occupants (2+) in January 1993. High-occupancy vehicle lane construction continues in the Gulf (I-45S), North (I-45N), Southwest (U.S. 59S), and Eastex (U.S. 59N) Freeway corridors.

The first completed HOV facility in Dallas opened on the East R.L. Thornton (East RLT) Freeway (I-30E) in September 1991. This facility is currently operating as a barrier-separated contraflow lane. An extension of the contraflow lane is planned within the next two years.

This report presents data relating to the six operating HOV lanes in Texas and focuses on data collected during calendar year 1995. The results of this research have helped the implementing agencies learn from the early experience with HOV lanes in order to allow future projects to be developed more effectively.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation, nor is it meant for construction, bidding, or permit purposes. This report was prepared by Russell H. Henk (Texas certification number 74460) and Dennis L. Christiansen (Texas certification number 37961).

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SUMMARY

Texas urban areas are the targets of a variety of transportation actions initiated in response to congestion and related concerns. One of these actions involves the implementation of priority lanes for high-occupancy vehicles (HOV) on freeways in Houston and Dallas. In Houston, the Texas Department of Transportation (TxDOT) and the Metropolitan Transit Authority of Harris County are jointly developing these facilities; TxDOT and Dallas Area Rapid Transit (DART) are developing these projects in Dallas. This report presents and evaluates data relative to HOV lane and freeway performance in Houston and Dallas through calendar year 1995, future expansion plans for the HOV systems in these areas, and plans for HOV facility development in other major Texas urban areas.

A commitment is in place to develop 166 kilometers (103.2 miles) of barrier-separated high-occupancy vehicle (HOV) lanes in Houston. The cost of the entire HOV lane system, including all support facilities, will be approximately $900 million.[1] As of the end of 1995, 102.4 kilometers (63.6 miles) of barrier-separated HOV lanes were in place and operational in five corridors, implemented at a cost of approximately $540 million.[1] While some sections of two-direction HOV lanes have been developed, the typical Houston HOV lane is located in the freeway median, is approximately 6 meters (20 feet) wide, is reversible, and is separated from the freeway general-purpose mainlanes by concrete median barriers. Grade-separated ramps provide access/egress to most HOV lanes.

In December 1995, the Houston HOV lane system served 77,027 daily person trips, a one percent increase compared to December 1994. At the end of 1995, 9,387 cars were parked in Houston HOV lane corridor park-and-ride lots on a typical day. Surveys conducted in Houston

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[1]These costs include the HOV lanes, HOV lane access and egress ramps, all park-and-ride lots, park-and-pool lots and bus transfer centers, and the HOV surveillance, communication, and control system. The costs are in 1995 dollars.

indicate that the HOV lanes have been successful in attracting young, educated, professional, white-collar patrons. These individuals are choosing to use the high-occupancy vehicle lanes primarily to 1) save time; 2) avoid having to drive in congested traffic; 3) have a reliable trip time; 4) have time to relax; and 5) save money.

The Dallas HOV system is in the early stages of development. A plan is currently in place, however, to construct approximately 60 kilometers (37 miles) of HOV lanes. This "plan" consists of the components which are common to both the DART system plan and the North Central Texas Council of Government's (NCTCOG) current plan for the year 2010. The cost of this system is yet to be determined. As of December 1995, an 8.4-kilometer (5.2-mile) barrier-separated contraflow lane on the East R.L. Thornton (East RLT) Freeway was the only component of this HOV system in operation. The cost to construct this contraflow lane (in 1995 dollars) was $15.4 million.

In December 1995, the East RLT HOV lane served 13,572 daily person trips. By the end of 1995, 908 cars parked in East RLT corridor park-and-ride lots on a typical day.

MEASURES OF HIGH-OCCUPANCY VEHICLE LANE EFFECTIVENESS

In order to assess the effectiveness of the HOV lanes, it is necessary to identify the impetus behind the development of these facilities. To a large extent, the decision to consider building HOV lanes came through the realization that it was simply not possible, either physically or economically, to provide enough street and highway lanes to indefinitely serve peak-period travel demands at 1.2 persons per auto.

Accordingly, it is assumed that the primary goal of HOV lanes in Texas is to cost-effectively increase the person-movement capacity of the freeways. Achieving this should also 1) enhance bus operations; 2) improve air quality; and 3) reduce fuel consumption. Implementation of the HOV lanes should not unduly impact the operation of the freeway general-purpose lanes. That implementation should have public support.

This report presents data and analyses to determine whether these objectives and implementation strategies are being attained. Researchers used two principal evaluation approaches. First, researchers collected "before" and "after" trendline data for each freeway where an HOV lane is being developed. Second, researchers collected similar data in control corridors that do not have high-occupancy vehicle lanes. These procedures help to identify and isolate the impacts of the freeway HOV lanes.

The priority lanes move a relatively high percentage of the total roadway person movement in a relatively low percentage of total vehicles. This is, however, to be expected when most of the higher-occupancy vehicles operate in a single lane, and it does not, by itself, imply that the HOV lanes are effective.

On a typical non-incident day, the HOV lanes in Houston and Dallas offer a travel time savings to users during the peak hour. In Houston, these savings range from five minutes on the Gulf HOV lane to 18 minutes on the Katy HOV lane. The East RLT HOV lane in Dallas saves its users approximately five minutes. In an average, non-incident morning peak hour, the 102.4-kilometer (63.6-mile) system in Houston offers 41 minutes of time savings, or an average of about 0.4 minutes per kilometer (0.6 minutes per mile). The 8.4-kilometer (5.2-mile) East RLT HOV lane in Dallas offers a time savings of approximately 0.6 minutes per kilometer (1.0 minute per mile). It is of interest to note, however, that the time savings perceived by the users (as determined in surveys of HOV lane users) are much greater than the actual time savings.

Factors Influencing High-Occupancy Vehicle Lane Utilization

This research has shown that the following three factors significantly impact the level of utilization of an HOV lane: 1) the length of time the priority lane has been operating; 2) the vehicle groups allowed to use the HOV lane; and 3) the travel time savings and trip time reliability provided by the HOV lane. This third factor is, perhaps, the most important single factor influencing transitway use. The data suggest that, unless the HOV lane offers (on a recurring basis) a peak-hour travel time savings relative to the general-purpose lanes of at least five minutes, utilization of the priority facility will be marginal.

Changes in Roadway Person Movement

A major reason for implementing HOV lane improvements is to increase the effective person-movement capacity of a roadway. Since implementation of the HOV lane increases the number of directional roadway lanes, the high-occupancy vehicle lane should *at least* increase person movement by an amount greater than the increase in lanes added to the roadway. The data show that the HOV lanes in Texas are helping to bring about an increase in person movement (Table S-1).

Changes in Average Vehicle Occupancy

For the priority HOV lanes to generate increases in person movement, it is necessary to increase the average vehicle occupancy; this has happened. On the two freeways with the more mature HOV lanes, peak-hour average vehicle occupancies are approximately 1.5 persons per vehicle (Tables S-1 and S-2). Compared to pre-HOV lane conditions, average vehicle occupancy on the North, Katy, and Northwest Freeways has increased by approximately 15 percent. This type of increase has not been experienced on freeways without HOV lanes.

For average occupancy to increase, there needs to be an increase in transit use and carpooling. The HOV lanes have resulted in the formation of new carpoolers and transit riders. These increases in ridesharing have not been experienced on freeways not having HOV lanes (Tables S-1 and S-2). *Estimates indicate that about half the people currently ridesharing on the HOV lanes have chosen to carpool or ride a bus because of the presence of the high-occupancy vehicle lane.*

HOV LANE IMPACTS ON BUS OPERATIONS

The HOV lanes have generated a large increase in transit use and have attracted a new type of transit rider. Young, educated, white-collar Texans are making extensive use of transit. Also, in comparing pre-HOV conditions to the present, average bus operating speeds during the peak hour have nearly doubled, increasing from 42 kph (26 mph) to 81 kph (50 mph). The result has been a reduction in schedule times.

HOV LANE IMPACTS ON FREEWAY GENERAL-PURPOSE LANE OPERATIONS

Although the HOV facilities move several thousand persons in the peak hour, there has been virtually no adverse impact on the operation of the freeway general-purpose lanes that can be attributed to implementation of these HOV lanes (Table S-1). Per-lane volumes on the general-purpose lanes are often higher today than they were prior to HOV implementation. Peak-hour travel speeds on the general-purpose lanes have also increased (in most cases) after HOV lane implementation. In reviewing accident data for the six freeways with HOV lanes, accident rates have typically declined (in some cases substantially) on the mainlanes.

The implementation of a high-occupancy vehicle lane should increase the overall efficiency of a freeway. For purposes of this study, the peak-hour per lane efficiency of a freeway is expressed as the multiple of peak-hour person volume and the speed at which that volume is moved (a weighted average for the freeway and the HOV lane). In all cases, this efficiency has increased (Table S-1) since the HOV lanes have been implemented. Data indicate that a significant part of that increase is the result of HOV lane implementation.

Table S-1. Summary of Measures Used to Assess the Effectiveness of the High-Occupancy Vehicle Lanes

Measure of Effectiveness	HOV Facility					
	Katy	North	Gulf	Northwest	Southwest	East RLT
Change in Roadway Person Movement						
% Increase in directional lanes due to HOV lane	33%	25%	25%	33%	20%	25%
% Increase in a.m. person volume[1]	70%	91%	28%	55%	105%	40%
Change in Average Vehicle Occupancy (persons/vehicle)[1]						
Occupancy before HOV lane	1.26	1.28	1.29	1.14	1.16	1.35
Occupancy in December 1995	1.47	1.45	1.24	1.45	1.32	1.32
% Change, Pre-HOV lane to current	+17%	+13%	-4%	+27%	+14%	-2%
% Change in 2+ Carpool Volume[1]	+59%	+162%	+70%	+267%	+212%	+172%
% of carpools formed due to HOV lane[2]	50%[3]	46%	26%	47%	---	217%
% Change in Bus Passengers (peak hour)[1]	+350%	---	---	+275%	-5%	-19%
% New bus riders due to HOV lane[2]	66%	52%	33%	55%	---	17%
% Change, Freeway Mainlane Vehicle Volume per Lane[1,4]	+25%	+6%	+18%	-4%	-1%	+22%
% Change, Freeway Mainlane Speed (Peak Hour)[1,4]	-8%	+63%	+4%	+11%	+11%	+26%
% Change, Freeway Mainlane Accident Rate[5]	-3%	-15%	-32%	-7%	-35%	+24%
% Change, Per Lane Efficiency[1,6]	+82%	+132%	+9%	+51%	+37%	+78%
Comparison, HOV Lane vs. Freeway Lane[7] (HOV lane improvement as a % of freeway improvement)						
Fuel consumption (liters)	91%	---	---	---	---	---
Air quality (kg of CO)	56%	---	---	---	---	---
Annual Value of Travel Time Saved on HOV Lane[8] ($ millions)	$10.2	$5.4	$2.5	$3.8	$4.0	$3.1
Travel time saved as a % of construction cost[9]	25%	6%	5%	5%	5%	20%
Are HOV Lanes Good Improvements[10]						
Yes	66%	81%	63%	64%	---	66%
No	20%	9%	21%	14%	---	20%
Not Sure	14%	10%	16%	22%	---	14%

[1]A.M. peak-hour, peak-direction. Percentage change from pre-HOV lane conditions to current conditions (mixed lanes).
[2]Estimated percent of total carpools or bus passengers using the HOV lane that have been created because of the HOV lane.
[3]The percentage change in 3+ carpool volume during the peak hour has been +351%.
[4]Data for the freeway general-purpose mainlanes.
[5]Percentage change in accident rate (injury accidents per 100 million vehicle-kilometers) from pre-HOV to current.
[6]Freeway per lane efficiency is expressed as the multiple of persons moved and average speed. Analysis combines freeway general-purpose lane performance with HOV lane performance.
[7]Simulation was used on the Katy Freeway to estimate what conditions would have been had an extra general-purpose lane been provided instead of the HOV lane. The values of fuel consumption and air quality (CO emissions) are those characteristic of the HOV alternative as a % of those estimated to be characteristic of the all-mainlane alternative. Both alternatives serve essentially the same demand, expressed in passenger-miles.
[8]This is an estimate of the annual value of time saved by users of the HOV lane.
[9]This is the estimated annual value of travel time savings for HOV lane users expressed as a percent of the cost of constructing the operating segment of the HOV lane (not including support facilities). A simplistic analysis suggests that, if this value exceeds 10%, the project is cost effective.
[10]Responses from motorists in the general-purpose freeway lanes to the question "Do you feel the HOV lanes being developed in Houston are good transportation improvements?"

Table S-2. Comparison of Experience on Freeways With and Without High-Occupancy Vehicle Lanes

Measure of Effectiveness	Representative Pre-HOV Lane Value	Representative Current Value	% Change
A.M. Peak-Hour, Peak-Direction Avg. Vehicle Occupancy			
Freeways With HOV Lanes			
Katy	1.26	1.47	+17%
North	1.28	1.45	+13%
Northwest	1.14	1.45	+27%
Southwest	1.16	1.32	+14%
Freeway Without HOV Lane	1.23	1.18	-4%
Peak-Hour, Peak-Direction 2+ Carpool Volume			
Freeways With HOV Lanes			
North	700	1,834	+162%
Northwest	490	1,800	+267%
Southwest	531	1,656	+212%
Freeway Without HOV Lane	600	571	-5%
Peak-Hour, Peak-Direction 3+ Carpool Volume			
Freeway With HOV Lane			
Katy	76	343	+351%
Freeway Without HOV Lane	123	93	-24%
A.M. Peak-Period Bus Ridership (3.5 hours)			
Freeways With HOV Lanes			
Katy	900	2,750	+206%
North	0	4,590	---
Northwest	605	1,930	+219%
Freeways Without HOV Lane	1,188	762	-36%
Cars Parked at Park-and-Ride Lots			
Freeways With HOV Lanes			
Katy	575	1,877	+226%
North	---	3,237	---
Gulf	1,115	1,226	+ 10%
Northwest	430	1,591	+270%
Freeway Without HOV Lane	1,236	1,035	-16%

Note: The freeway data without an HOV lane are from the Eastex (U.S. 59N) Freeway in Houston.

AIR QUALITY AND ENERGY CONSIDERATIONS

Researchers undertook a simulation analysis (a.m. inbound, 6 a.m. to noon) to compare the "add an HOV lane" alternative to both the "do nothing" alternative and the "add a general-purpose freeway lane" alternative. If all alternatives serve the same demand (expressed as the combined passenger-miles using the HOV lane and the freeway in 1995), the HOV lane is more favorable in terms of a reduction in both energy consumption and pollution emissions (Table S-1). The HOV alternative, compared to the add a general-purpose lane alternative, resulted in an eight percent reduction in fuel consumed and a five percent reduction in carbon monoxide emissions. Additional analyses addressing the impacts of HOV lanes on air quality (i.e., vehicle emissions) have been summarized in a previous report entitled "Mobile Source Emission Impacts of High Occupancy Vehicle Facilities," Texas Transportation Institute Research Report 1353-02, William Knowles, November 1994.

HOV PROJECT COST EFFECTIVENESS

The cost effectiveness analyses conducted in this report consider only one benefit -- the value of the time saved by users of the HOV facility. Successful HOV projects generate many other benefits, some of which can be significant. For example, in the North Freeway corridor, it would be necessary to construct three to four additional general-purpose lanes to provide the peak-period capacity needed to serve the demand now using the HOV lane. Also, by serving large travel volumes in the HOV lane, congestion levels in the general-purpose lanes are less, resulting in potentially significant travel time savings on the mainlanes as well.

However, if an HOV project is even marginally cost effective based on the travel time savings experienced by HOV lane users, that project would simply be even more cost effective if all benefits were quantified. Based on this analysis (using 1995 data), the Katy and East RLT HOV lanes are cost effective, while the Gulf, North, Northwest, and Southwest facilities are less than cost effective (when only considering travel time savings benefits).

If some of the additional benefits referred to previously are considered, the benefit-cost ratio can increase markedly. For example, with this type of analysis, in 1995 the benefit-cost ratio for the Katy HOV project was approximately 4.0 (see Table 35, p. 94). For that facility, the value of all quantified benefits was approximately five times greater than the value of user time saved. For the entire Houston area, estimates are that HOV lanes presently reduce areawide congestion levels by about four percent. This equates to a reduction in the areawide cost of congestion of approximately $125 million per year.

PUBLIC SUPPORT FOR THE HIGH-OCCUPANCY VEHICLE LANE PROGRAM

Acceptance of HOV lanes in Texas by the public is high and has been increasing over time. Based on 1994 surveys in Houston, over 65 percent of the motorists in the freeway general-purpose lanes (not HOV lane users) viewed these projects as being good transportation improvements. On average, fewer than 20 percent stated the projects were not good improvements.

CONCLUSIONS

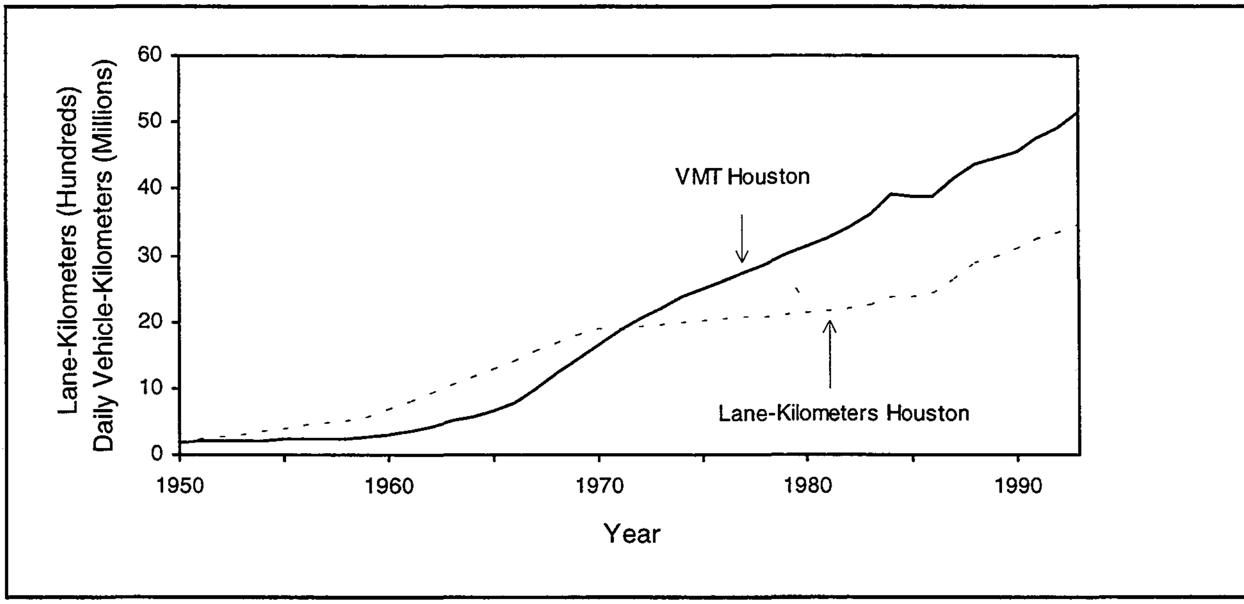
This report identified the objectives associated with developing high-occupancy vehicle lanes in Texas. The report reviews and analyzes data collected through calendar year 1995 to assess the performance of the priority lanes in meeting their objectives.

Tables S-1 and S-2 show some of the relevant data associated with these analyses. A review of these performance measures leads to several general observations. The performance measures suggest that the Katy and East RLT HOV lanes are fulfilling their intended purpose. The performances of the Gulf, North, Northwest, and Southwest HOV lanes are marginal at this time.

Continued monitoring of all the committed high-occupancy vehicle lane projects in Texas will take place as part of this research project.

I. INTRODUCTION

Beginning in the early 1970s, increases in travel demand, expressed as freeway vehicle-kilometers of travel (VKT), in Houston began to exceed increases in roadway supply, expressed as lane-kilometers of freeway (Figure 1). Between 1970 and 1985, VKT per freeway lane-kilometer in the City of Houston increased by 95 percent.[2] During that period, congestion increased noticeably; in fact, a 1984 Federal Highway Administration study indicated that Houston had some of the most, if not the most, congested freeway facilities in the nation.[3]



Source: "Regional Mobility Plan for the Houston Area, 1989" and TTI Research.

Figure 1. Relationship Between Freeway Vehicle-Kilometers of Travel and Lane-Kilometers of Freeway, Houston

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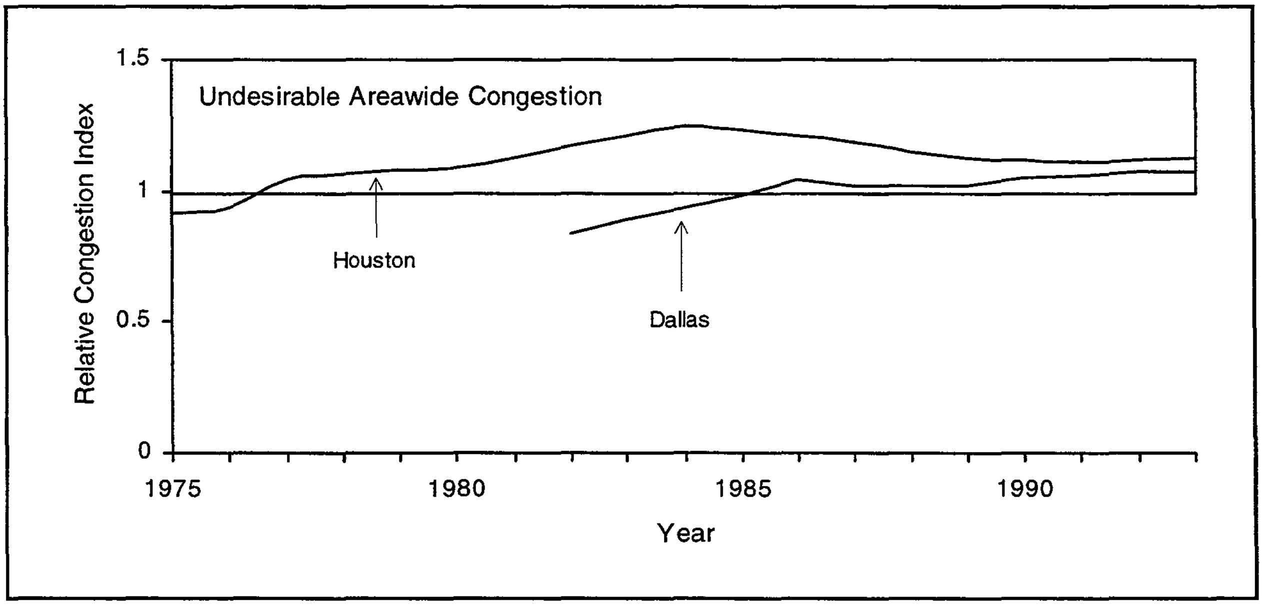
[2]"Impact of Declining Mobility in Major Texas and Other U.S. Cities." Texas Transportation Institute Research Report 431-1F. Timothy J. Lomax, Diane L. Bullard, James W. Hanks, Jr., 1988.

[3]"Quantification of Urban Freeway Congestion and Analysis of Remedial Measures." Federal Highway Administration, October 1986.

Monitoring of overall urban congestion in major cities clearly indicated that mobility in both Houston and Dallas deteriorated significantly during the late 1970s and early 1980s. Areawide congestion levels increased by 39 percent between 1975 and 1984 in Houston and by 24 percent between 1982 and 1986 in Dallas.[4] However, as the result of an aggressive multimodal effort to restore mobility in these urban areas, congestion has been moderating in recent years (Figure 2). Between 1984 and 1993, the congestion index in Houston actually declined by approximately ten percent, even though vehicle-kilometers of travel increased by about twelve percent during that time period. The congestion index for Dallas increased slightly between 1986 and 1993. Nevertheless, Houston and Dallas remain relatively congested cities (Table 1).



Note: An index of greater than 1.0 is assumed undesirable areawide congestion in an urban area. This index is based on vehicle-kilometers of travel and lane-kilometers of roadway for both freeways and principal arterials.

Figure 2. Relative Mobility Levels for Houston and Dallas, 1975-1993

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[4]"Relative Mobility in Texas Cities." Texas Transportation Institute Research Report 339-8. Timothy J. Lomax, 1975-1984; 1986.

Table 1. Relative Mobility Levels in Major United States Cities, 1993

Urban Area	Relative Mobility Index[1]	Urban Area	Relative Mobility Index[1]
1. Los Angeles	1.54	7. Sea-Everett	1.23
2. Washington, D.C.	1.41	8. San Bernardino-Riverside	1.21
3. San Francisco-Oakland	1.33	9. San Diego	1.21
4. Miami	1.32	10. Atlanta	1.16
5. Chicago	1.26	13. HOUSTON	1.13
6. Detroit	1.23	17. DALLAS	1.07

[1]An index of greater than 1.0 is assumed to represent undesirable areawide congestion in an urban area. This index is based on vehicle-kilometers of travel and lane-kilometers of roadway for both freeways and principal arterials.

Source: Texas Transportation Institute Research Report No. 1131-7.

In response to the congestion problem, a variety of actions are being taken. One of these actions involves the implementation of a system of priority lanes for high-occupancy vehicles on the urban freeways. These facilities are being jointly developed by the Texas Department of Transportation (TxDOT) and the Metropolitan Transit Authority of Harris County (Metro) in Houston, and by TxDOT and Dallas Area Rapid Transit (DART) in Dallas.

Through this research effort, a comprehensive evaluation of the HOV lanes is being performed. An objective of this research is to use the experience to date as a means for developing improved guidelines for planning, designing, and operating the freeway HOV lanes. Researchers conducted the evaluations using two approaches. First, researchers collected "before" and "after" trendline data for each freeway on which an HOV lane is being developed; this provides a means for identifying changes that occur in those corridors. Second, researchers collected similar data for freeways that do not have an HOV lane. These "control" corridors help isolate the specific impacts of the HOV facilities.

This report presents and evaluates data relative to high-occupancy vehicle facility and freeway operations in Houston and Dallas through December 1995. Data are presented for all six of the operational HOV lanes in these urban areas. Preliminary planning of HOV facilities is also taking place in Austin, Fort Worth, and San Antonio. This report also presents the varying stages of planning for these facilities.

ORGANIZATION OF THE REPORT

Section II of this report provides an overview of the entire high-occupancy vehicle facility systems in Houston and Dallas. Sections III through VIII review the available data to help determine the current effectiveness of the HOV lanes. Section IX presents the conclusions. A series of appendices provides a listing of milestone dates in the development of these HOV lanes as well as more detailed data on each of the HOV lane projects.

II. OVERVIEW OF HIGH-OCCUPANCY VEHICLE FACILITIES IN TEXAS

HOUSTON

By the early 1970s, it was evident that serious congestion problems were developing in the Houston area. At the same time, experiences with HOV lanes on the Shirley Highway in northern Virginia and the San Bernardino Freeway in Los Angeles were highly successful. As a result, the city of Houston and the Texas Department of Transportation (then the Texas Highway Department) made a joint decision in the mid 1970s to test the high-occupancy vehicle lane concept in Houston. Accordingly, these two agencies developed and operated a 14.5 kilometer (9-mile) contraflow lane on the North Freeway (I-45). This contraflow lane, which opened in August 1979, reserved the inside freeway lane in the off-peak direction for exclusive use by buses and vans traveling in the peak direction during both peak periods.

This contraflow lane was successful beyond all expectations. Although it operated for only 2.5 hours during each peak period and was used by only authorized buses and vans, the contraflow lane moved over 8,000 persons during each peak period. The facility attracted transit riders who had autos available for the trip. Large vanpool programs also developed.

It became evident that, under certain conditions, a significant unserved demand for high-speed, high-quality transit existed in at least some Houston travel corridors. The success of the relatively modest contraflow project and the emergence of Metro as a well-financed transit agency with a long-range plan dependent upon HOV lanes brought about a large-scale commitment in Houston to the HOV concept. As a result, since 1979, the Houston area has seen continuous development of barrier-separated, high-occupancy vehicle projects. The appendices include a listing of milestone dates in the development of the Houston HOV system.

DALLAS

Dallas began experiencing significant traffic congestion in the late 1980s. Influenced by the success of HOV lanes in Houston and other areas of the nation, TxDOT and DART made a decision to test the high-occupancy vehicle lane concept in Dallas. An 8.4-kilometer (5.2-mile) barrier-separated contraflow lane was consequently developed and opened for operation on East R.L Thornton (East RLT) Freeway (I-30E). This contraflow lane (which opened in September 1991) reserves the inside freeway lane in the off-peak direction for use by carpools, vanpools, and buses.

Similar to the I-45 contraflow lane project in Houston, the East RLT contraflow lane in Dallas has enjoyed some success. Less than one year after opening, the contraflow lane was serving 16,000 daily person trips and saving its users approximately 0.6 minutes per kilometer (one minute per mile) in travel time during the morning peak hour. The early success of the East RLT contraflow lane has helped give rise to a plan for constructing additional HOV lanes in the Dallas urban area.

THE PLANNED SYSTEMS

Houston

A commitment is in place in the Houston area to develop approximately 166 kilometers (103 miles) of high-occupancy vehicle lanes (Figure 3). As of December 1995, five separate HOV facilities were in operation (Table 2). A total of 102.4 kilometers (63.6 miles) of barrier-separated, high-occupancy vehicle lanes were operating. Recent changes in the system include the opening of the first phase of the Southwest HOV lane in January 1993 and the extension of the Gulf HOV lane south to Almeda-Genoa (an extension of 8.2 kilometers, 5.1 miles). Construction is continuing in the Southwest, Gulf, Eastex, North, and Katy corridors. The final segments of the Gulf and Southwest HOV lanes should be completed in 1996.

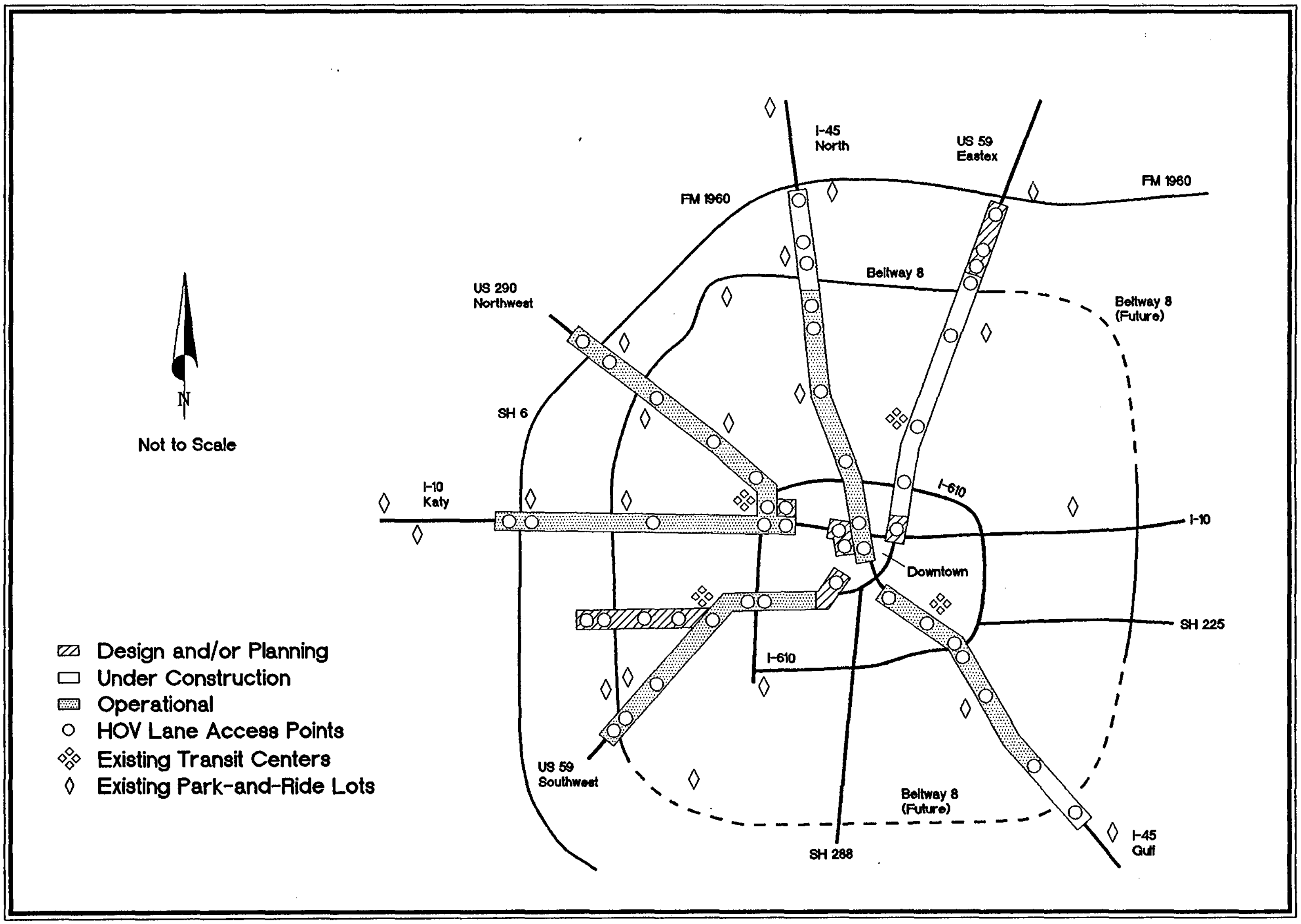


Figure 3. Status of Houston HOV Lane System, December 1995

Table 2. Status of the Houston High-Occupancy Vehicle Lane System, December 1995

HOV Facility	Date First Phase Opened	Kilometers (Miles) in Operation	Ultimate System Kilometers (Miles)	Vehicles Allowed to Use HOV Lane	Hours of Weekday Operation[1]
Katy (I-10W)	October 1984	20.9 (13.0)	24.6 (15.3)	3+ vehicles from 6:45 to 8:00 a.m. 5:00 to 6:00 p.m. 2+ during other operating hours	5 a.m. to noon inbound 2 p.m. to 9 p.m. outbound
North (I-45N)	November 1984[2]	21.7 (13.5)	32.0 (19.9)[3]	2+ vehicles	5 a.m. to noon inbound 2 p.m. to 9 p.m. outbound
Gulf (I-45S)	May 1988	19.5 (12.1)	25.0 (15.5)[3]	2+ vehicles	5 a.m. to noon inbound 2 p.m. to 9 p.m. outbound
Northwest (U.S. 290)	August 1988	21.7 (13.5)	21.7 (13.5)	2+ vehicles	5 a.m. to noon inbound 2 p.m. to 9 p.m. outbound
Southwest (U.S. 59S)	January 1993	18.5 (11.5)	23.0 (14.3)[3]	2+ vehicles	5 a.m. to noon inbound 2 p.m. to 9 p.m. outbound
Eastex (U.S. 59N)	Not open in 1994	---	32.5 (20.2)	---	---
Westpark Corridor	Not open in 1994	---	7.2 (4.5)	---	---
Total		102.4 (63.6)	166.0 (103.2)		

[1]Beginning in October 1989, the Katy and Gulf HOV lanes were opened to 2+ carpools on weekends; those facilities operate outbound on Saturday (4 a.m. to 10 p.m.) and inbound on Sundays (4 a.m. to 10 p.m.). In June 1990, the North HOV lane opened on weekends, and in October 1990 the Northwest HOV lane opened on weekends. Weekend use of all HOV lanes except the Katy was discontinued in October 1991 due to low usage.
[2]A contraflow lane was implemented on the North Freeway in August 1979. It was replaced with a barrier-separated, reversible lane in November 1984.
[3]Scheduled for completion in 1996.

Dallas

Compared to Houston, the Dallas HOV lane system is relatively new. A plan is, however, currently in place to construct approximately 60 kilometers (37 miles) of HOV lanes (Figure 4). This "plan," although not formally adopted, consists of the HOV components which are common to both the DART system plan and the North Central Texas Council of Government's (NCTCOG) current plan for the year 2010. As of December 1995, the East RLT HOV lane was the only operational component of this system (Table 3). An extension of the East RLT HOV lane is scheduled for completion in 1995, while additional HOV facilities are in the planning and design stage for five other Dallas freeways.

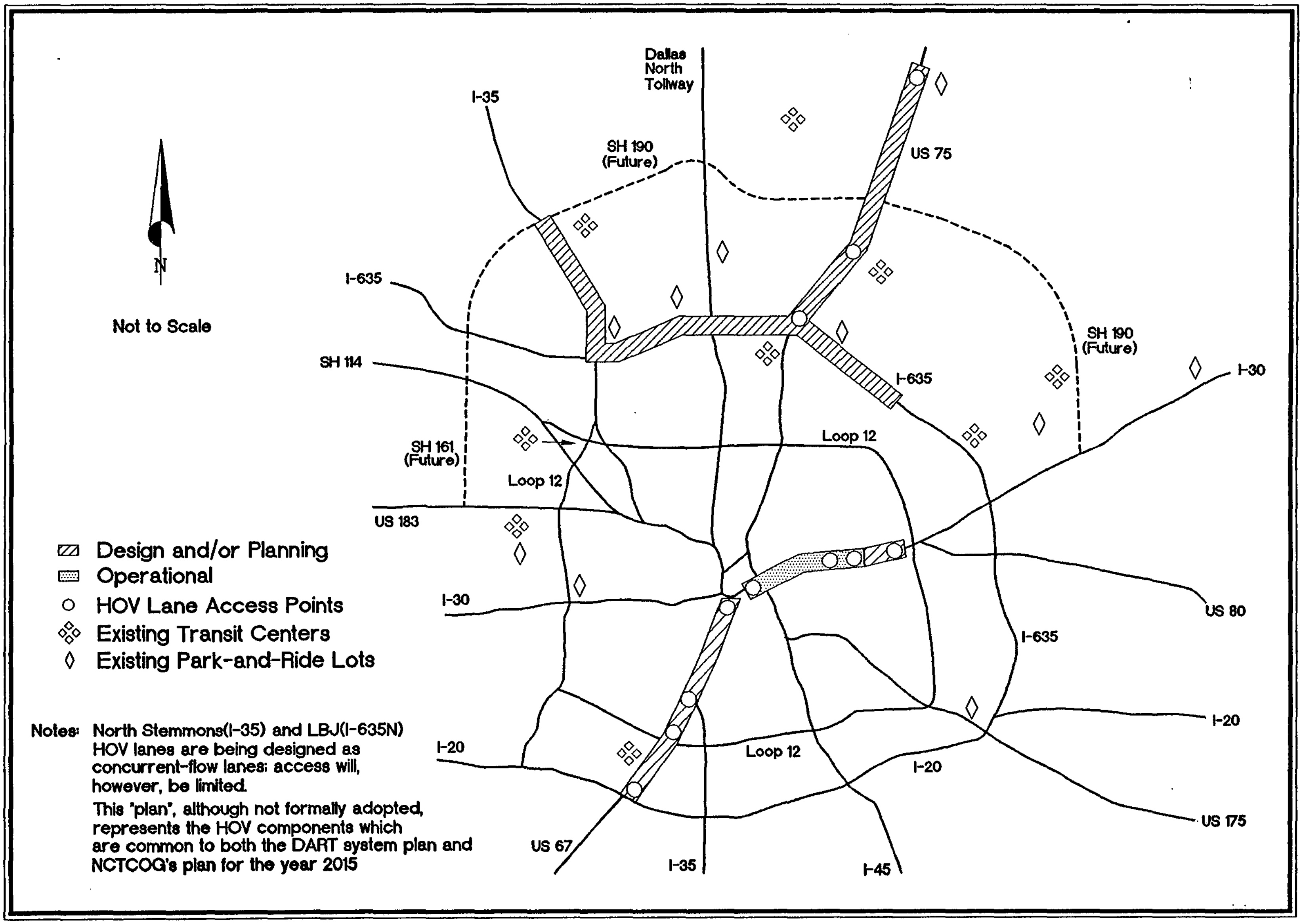


Figure 4. Status of Dallas HOV Lane System, December 1995

Table 3. Status of the Dallas High-Occupancy Vehicle Lane System, December 1995

HOV Facility	Date First Phase Opened	Kilometers (Miles) in Operation	Ultimate Kilometers (Miles)	Vehicles Allowed to Use HOV Lane	Hours of Weekday Operation
East R.L. Thornton (I-30)	September 1991[1]	8.4 (5.2) IB 5.3 (3.3) OB	8.4 (5.2) IB 8.4 (5.2) OB[2]	2+ vehicles	6 a.m. to 9 a.m. IB 4 p.m. to 7 p.m. OB
North Stemmons (I-35E)	Not open in 1994	---	10.9 (6.8)IB 8.8 (5.5)OB[3]	---	---
LBJ (I-635)	Not open in 1994	---	10.5 (6.5)EB 10.0 (6.2)WB[3]	---	--- ---
South R.L. Thornton (I-35E)	Not open in 1994	---	8.8 (5.5)IB 8.8 (5.5)OB[4]	---	---
Marvin D. Love (U.S. 67)	Not open in 1994	---	3.2 (2.0)IB 6.4 (4.0)OB5[5]	---	---
North Central Expwy. (U.S. 75)	Not open in 1994	---	---[5]	---	---

NOTE: IB = inbound, OB = outbound

[1]Beginning in September 1991, the movable barrier contraflow lane was opened to buses and vanpools for 2 weeks; buses, vanpools, and 3+ carpools for 2 weeks; and in October 1991 opened to 2+ carpools.

[2]Movable barrier contraflow lane extension scheduled for completion in 1995; the current outbound length is 5.3 kilometers (3.3 miles).

[3]Concurrent flow lane scheduled for completion in 1996.

[4]Movable barrier contraflow lane scheduled for completion in 1998.

[5]An HOV lane is currently being planned in this corridor north of I-635. An exact date and length has not been determined at this time.

OTHER MAJOR TEXAS URBAN AREAS

While there are no HOV lanes which are currently in operation outside of those in Dallas and Houston, the following urban areas are examining such facilities at varying degrees of planning and/or design.

Austin. A recently completed urban area-wide study addresses HOV facility feasibility on Austin's freeway system and major arterials. Advanced planning and design for I-35 currently includes HOV applications from Parmer Lane on the north to Slaughter Lane on the south for most long-range alternatives. Major investment studies (MISs) are either in progress or soon to be initiated in most of the major freeway and arterial street corridors. A more detailed assessment of HOV facility feasibility for Austin's major thoroughfares will be a product of these efforts.

Fort Worth. A feasibility study for HOV facility implementation on Fort Worth's freeways has also recently been completed. As a result of this study, plans for a reversible, barrier-separated HOV facility on U.S. 183 have reached the engineering design stage. This proposed facility will stretch from I-35W to the Dallas County Line (a distance of approximately 27.3 kilometers, 17.0 miles). Right-of-way (R.O.W.) and/or envelopes of space are also being purchased and/or preserved for future HOV lanes on West Freeway (I-30W) and South Freeway (I-35S).

San Antonio. A long-range plan assessing HOV lane feasibility has recently been completed for San Antonio as well. This analysis addressed both freeways and major arterials. The results of the study have contributed to an emphasis of HOV alternatives analysis in MISs currently being conducted for North Loop 410 (from Bandera Road east to I-35N) and I-35N from FM 3009 to downtown.

PHYSICAL DESCRIPTIONS OF EXISTING HIGH-OCCUPANCY VEHICLE LANES

Houston

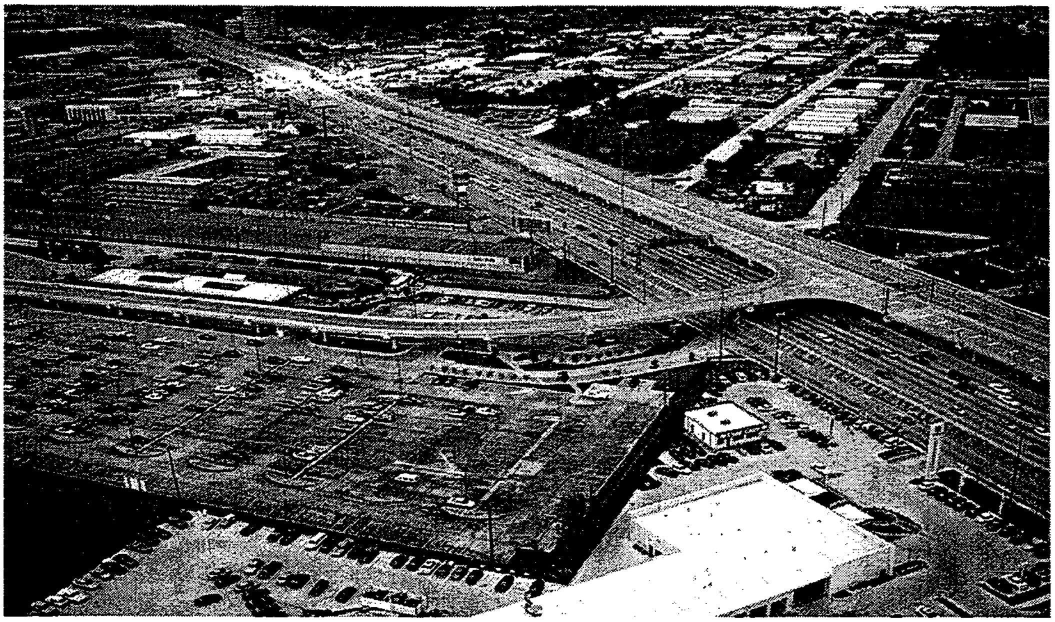
While some sections of two-direction HOV facilities are being developed, the typical Houston HOV lane is located in the freeway median, is approximately 6 meters (20 feet) wide, is reversible, and is separated from the general-purpose freeway mainlanes by concrete median barriers (Figure 5).

Access to the median HOV facilities is provided in a variety of manners. At some locations, "slip ramps" provide access and egress to/from the inside freeway lane (Figure 6). While these are relatively inexpensive, depending on their location, they may create a variety of operational problems. As a consequence, grade-separated interchanges of various designs provide most access to the median HOV lanes (Figure 7). The HOV lanes become elevated in the median, and ramps go over the freeway lanes to connect with streets, park-and-ride lots, or bus transfer centers. These grade-separated interchanges are typically constructed at a cost in the range of $2 to $7 million each; access to the HOV lanes is typically provided at 5- to 8-kilometer (3- to 5-mile) intervals.

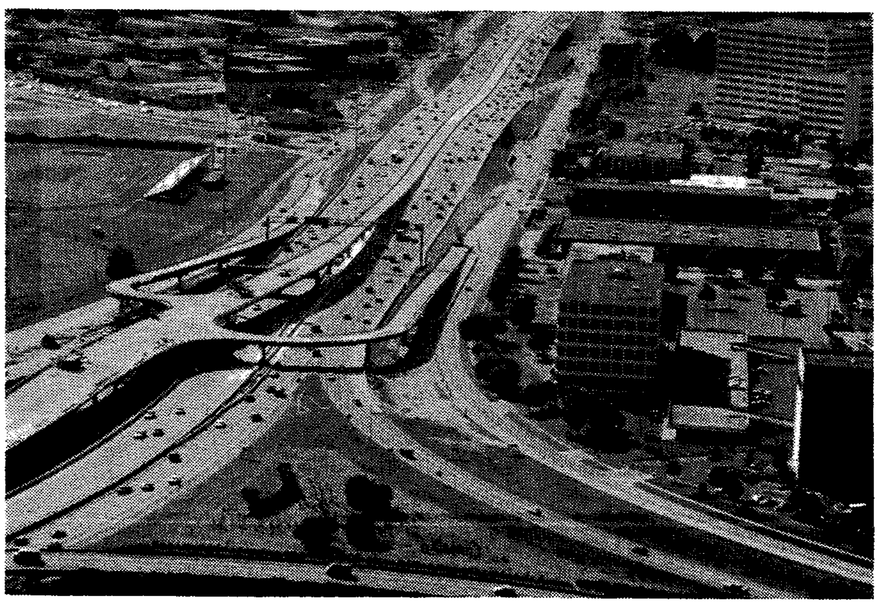
In some locations, implementation of the Houston HOV lanes was accomplished by narrowing freeway lanes to 3.4 meters (11 feet) and reducing inside shoulder widths. A typical section is shown in Figure 8.

Figure 5. HOV Lane in Median of Katy Freeway

Figure 6. Slip Ramp for HOV Lane Access/Egress on Katy Freeway



Direct Ramp to Park-And-Ride Lot



Ramps to Frontage Roads, Northwest HOV Lane

Figure 7. Examples of Grade-Separated HOV Lane Interchanges

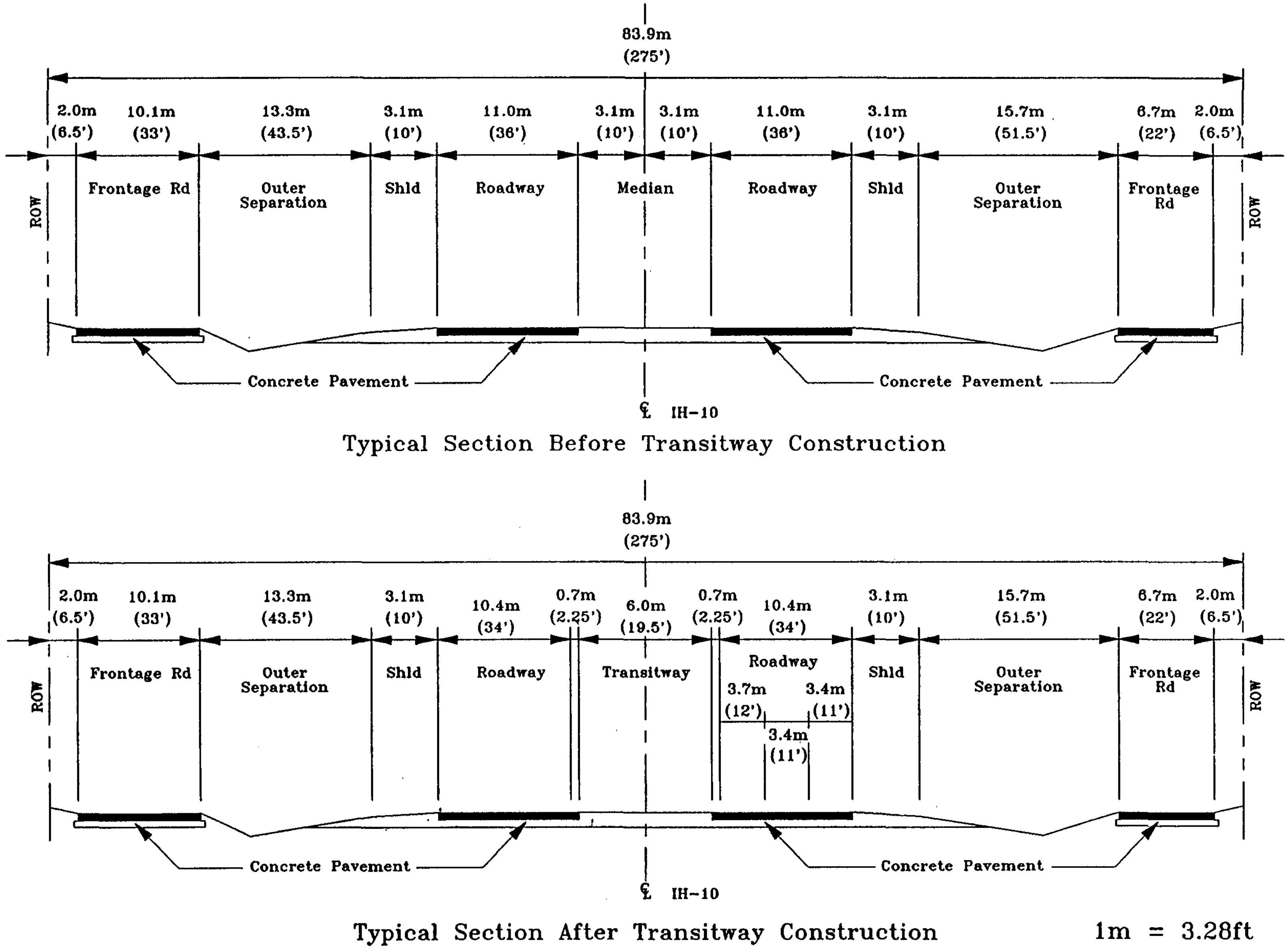


Figure 8. Typical Sections, Before and After Katy HOV Lane Construction

Dallas

The East RLT HOV lane in Dallas is a movable barrier contraflow lane (Figure 9). The movable barrier, which is used to create the 6-meter (20-foot) wide HOV lane, consists of one-meter (three-feet) concrete segments joined together by pins. The flexibility created by these pins allows the barrier machine (Figure 9) to shift the barrier approximately 7 meters (22 feet) laterally to create an extra travel lane for the peak direction of flow. The implementation of this HOV lane was accomplished by narrowing freeway lane widths to 3.4 meters (11 feet) and reducing the inside shoulder of the freeway in some locations (Figure 10). Slip ramps such as the one shown in Figure 11 provide access to, and egress from, the East RLT HOV lane.

Figure 9. Machine Used to Shift the Moveable Concrete Barrier on East R.L. Thornton

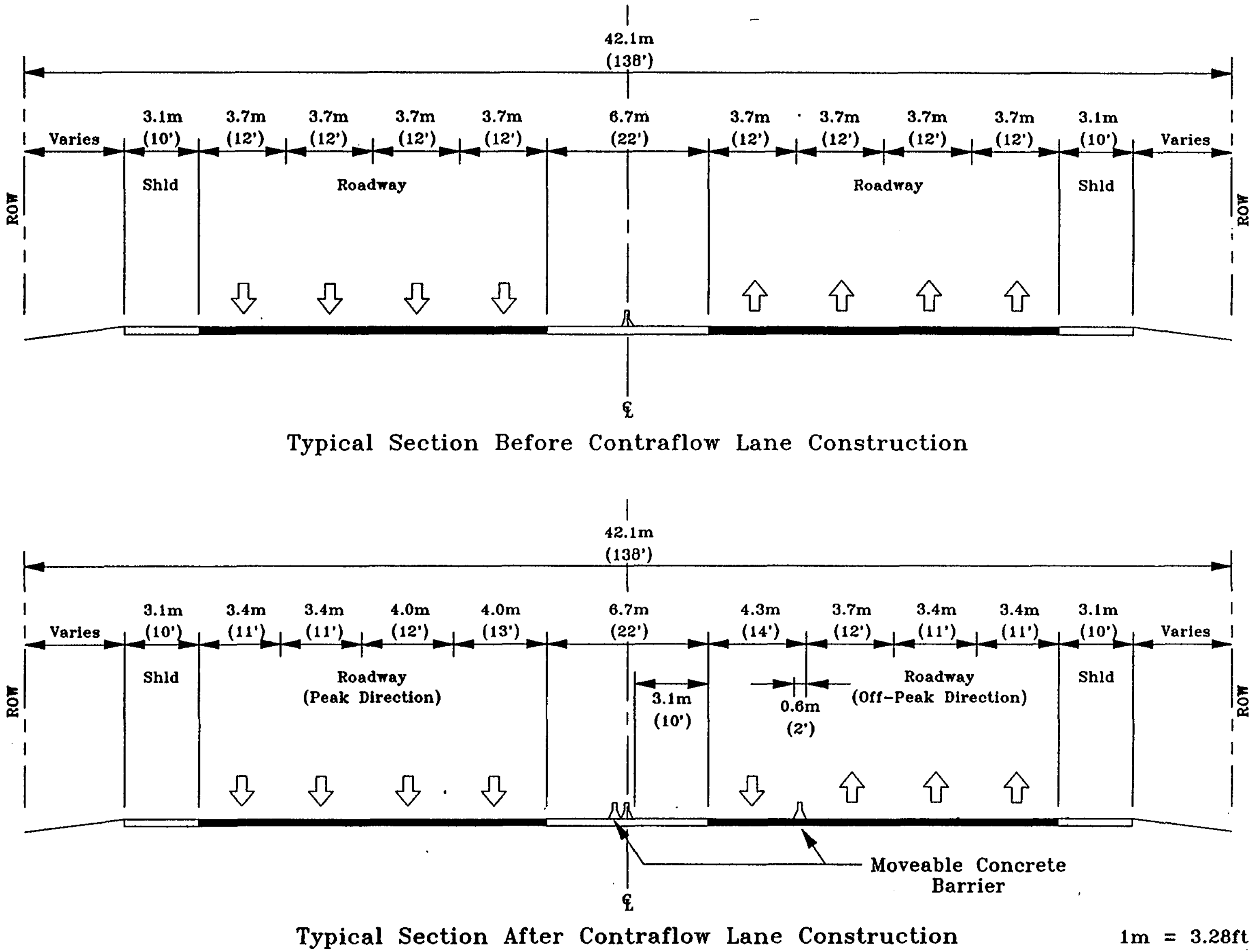


Figure 10. Typical Sections, Before and After East RLT Contraflow Lane Construction

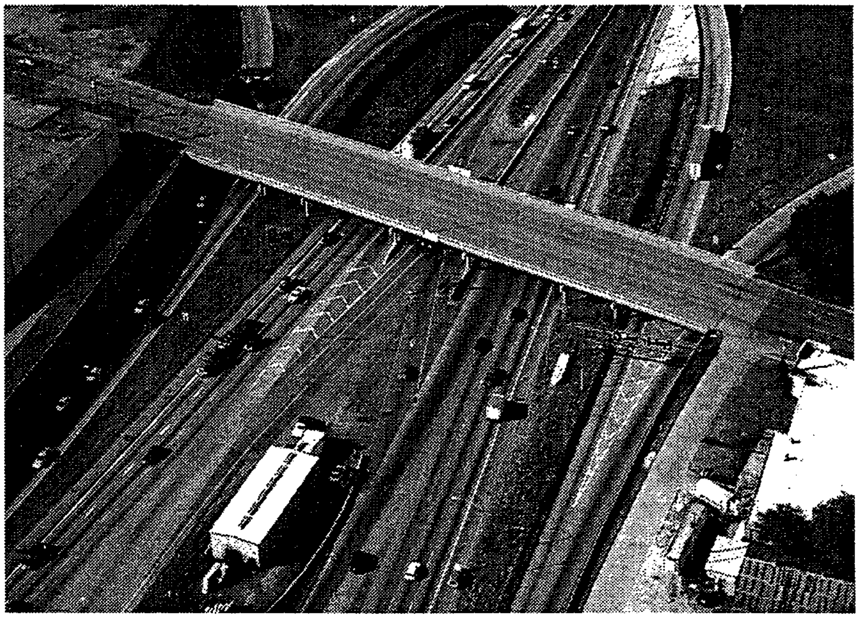


Figure 11. Example of Access Point on East R.L. Thornton HOV Lane

ESTIMATED CAPITAL COST

Houston

Since the Houston HOV lanes have generally been constructed as part of freeway reconstruction projects, it is difficult to precisely determine the capital cost of the priority lanes. Information provided by both Metro and TxDOT is used in developing the costs shown in this section. The appendices include a more detailed cost breakdown.

The HOV lanes in operation today, including all access ramps, have typically been built at an average cost of $3.4 million per kilometer in 1995 dollars ($5.4 million per mile) (Table 4). An extensive system of support facilities (i.e., park-and-ride lots, park-and-pool lots, and bus transfer facilities) also has been provided in each corridor. Some of these facilities would have been provided even if there were no HOV lanes. In total, a substantial investment (typically about $1.7 million per kilometer [$2.8 million per mile]) exists in these support facilities. A surveillance, communication, and control system is being installed on the Houston HOV lanes at an average cost of approximately $200,000 per kilometer ($300,000 per mile). The total cost for all project elements is in the range of $5.3 million per kilometer ($8.5 million per mile). Total capital expenditures (1995 dollars) for the operating segments have been approximately $540 million. Figure 12 summarizes current capital expenditures on the Houston HOV system.

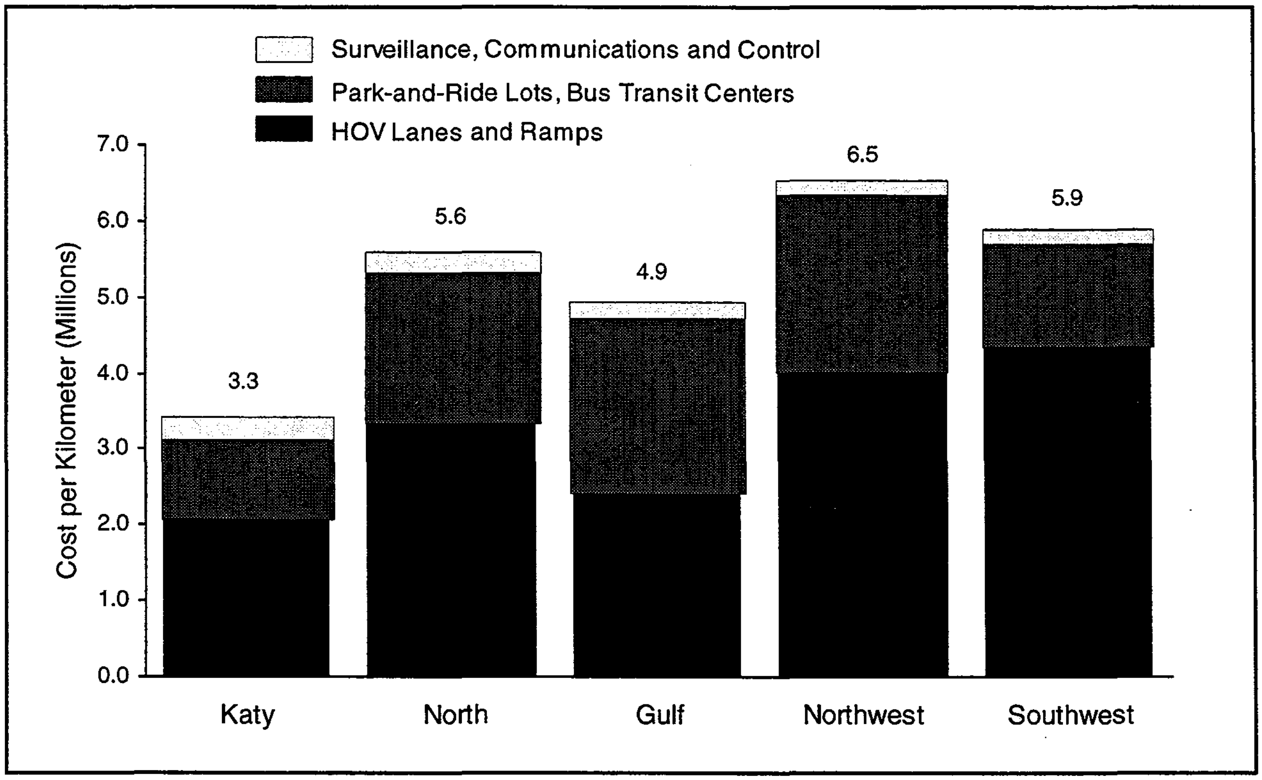
Table 4. Estimated Capital Cost[1] of the Operational Houston HOV Lane System, 1995

HOV Lane	Kilometers (Miles) in Operation	Estimated Capital Cost, Millions[1,2]							
		HOV Lane Plus Ramps[3]		Support Facilities[4]		Surveillance, Communication and Control[5]		Total	
		Total	Per Kilometer (Mile)	Total	Per Kilometer (Mile)	Total	Per Kilometer (Mile)	Total	Per Kilometer (Mile)
Katy (I-10W)	20.9 (13.0)	$41.0	$2.0 ($3.7)	$22.7	$1.1 ($1.7)	$4.7	$0.2 ($0.4)	$68.4	$3.3 ($5.3)
North (I-45N)	21.7 (13.5)	$96.9	$4.5 ($7.2)	$22.3	$1.0 ($1.7)	$2.9	$0.1 ($0.2)	$122.1	$5.6 ($9.0)
Gulf (I-45S)[6]	19.5 (12.1)	$54.1	$2.7 ($4.3)	$40.0	$2.0 ($3.2)	$4.2	$0.2 ($0.3)	$98.3	$4.9 ($7.9)
Northwest (U.S. 290)	21.7 (13.5)	$79.0	$3.6 ($5.8)	$57.9	$2.7 ($4.3)	$3.5	$0.2 ($0.3)	$140.4	$6.5 ($10.4)
Southwest (U.S. 59S)	18.5 (11.5)	$74.3	$4.0 ($6.4)	$32.5	$1.7 ($2.8)	$4.2	$0.2 ($0.4)	$111.0	$5.9 ($9.6)
	—	—	—	—	—	—	—	—	—
Total	102.4 (63.6)	$345.3	$3.4 ($5.4)	$175.4	$1.7 ($2.8)	$19.5	$0.2 ($0.3)	$540.2	$5.3 ($8.5)

[1]Estimated capital costs are in 1995 dollars.
[2]Costs do not include the value of the existing freeway rights-of-way in which HOV lanes have been located. The costs do not include additional buses required to provide the HOV service and the bus maintenance facilities needed to serve those buses.
[3]Includes the cost of the median HOV lane and the access/egress ramps serving that lane.
[4]Includes the cost of all existing park-and-ride lots, park-and-pool lots, and bus transfer centers.
[5]The cost of the surveillance, communication, and control system serving the HOV lanes.
[6]Phase 3 of the Gulf HOV lane was partially completed during 1994. Accurate breakdowns are, however, not available and are, therefore, included as estimated future costs in Table 5.
Source: Developed from information provided to TTI by Metro and TxDOT. An additional cost breakdown is included in the appendices.

Approximately 60 percent of the ultimate HOV lane system in Houston was operating in 1995. Table 5 provides an estimate of the cost of the completed system. The ultimate capital cost for the HOV lanes and ramps will be approximately $3.9 million per kilometer ($6.3 million per mile). The HOV support facilities will cost an additional $1.3 million per kilometer ($2.2 million per mile). The entire completed system will cost approximately $900 million, or about $5.5 million per kilometer ($8.8 million per mile).

The HOV facilities have been funded in a variety of manners, with funding coming from a combination of federal and state highway funds and federal and local transit monies. About 80 percent of the total capital cost is from transit funds. With the exception of some ramps and support facilities, the HOV facility system has been constructed in state-owned rights-of-way.



Source: Developed from data provided by TxDOT and Metro, see appendices.

Figure 12. Capital Cost Per Kilometer (1995 Dollars) of the Operating Houston HOV Facilities

Table 5. Estimated Cost[1] of the Planned Houston HOV Lane System

HOV Lane	Ultimate System Kilometers (Miles)	Estimated Capital Cost, Millions[1,2]							
		HOV Lane Plus Ramps[3]		Support Facilities[4]		Surveillance, Communication and Control[5]		Total	
		Total	Per Kilometer (Mile)	Total	Per Kilometer (Mile)	Total	Per Kilometer (Mile)	Total	Per Kilometer (Mile)
Katy (I-10W)	24.6 (15.3)	$91.3	3.7 (6.0)	$22.7	0.9 (1.5)	$4.7	0.2 (0.3)	$118.7	4.8 (7.8)
North (I-45N)	32.0 (19.9)	$141.6	4.7 (7.5)	$33.7	1.1 (1.7)	$5.3	0.2 (0.3)	$180.6	5.6 (9.1)
Gulf (I-45S)	25.0 (15.5)	$71.9	2.9 (4.6)	$40.0	1.6 (2.6)	$4.2	0.1 (0.2)	$116.1	4.7 (7.5)
Northwest (U.S. 290)	21.7 (13.5)	$79.0	3.6 (5.9)	$57.9	2.7 (4.3)	$3.5	0.1 (0.2)	$140.4	6.5 (10.4)
Southwest (U.S. 59S)	23.0 (14.3)	$103.8	4.5 (7.3)	$32.5	1.4 (2.3)	$4.2	0.2 (0.3)	$140.5	6.1 (9.8)
Eastex (U.S. 59N)	32.5 (20.2)	$117.5	3.6 (5.8)	$21.5	0.7 (1.1)	$7.8	0.3 (0.4)	$146.8	4.5 (7.3)
Westpark	7.2 (4.5)	$50.0	6.6 (10.6)	$13.8	1.8 (2.9)	0.0	0.0 (0.0)	$63.8	8.4 (13.6)
Total	166.0 (103.2)	655.1	3.9 (6.3)	222.1	1.3 (2.2)	29.7	0.2 (0.3)	906.9	5.5 (8.8)

[1]Capital costs which have already been incurred are in 1995 dollars.
[2]Costs do not include the value of the existing freeway rights-of-way in which HOV lanes have been located. The costs do not include additional buses required to provide the HOV service and the bus maintenance facilities needed to serve those buses.
[3]Includes the cost of the median HOV lane and the access/egress ramps serving that lane.
[4]Includes the cost of all park-and-ride lots, park-and-pool lots, and bus transfer centers.
[5]The cost of the surveillance, communication, and control system serving the HOV lanes.

Source: Developed from information provided to TTI by Metro and TxDOT. The appendices include an additional cost breakdown.

Dallas

Total capital costs for the operating portion of the East RLT HOV lane have amounted to approximately $15.4 million (Table 6). The movable concrete barriers and barrier machines account for $8.4 million of this cost. The majority of the remaining cost has been associated with upgrading the structural integrity of the shoulders next to the freeway median.

Table 6. Estimated Cost of the Operating East R.L. Thornton HOV Lane

Kilometers (Miles) in Operation	Estimated Capital Cost, Millions[1,2]					
	HOV Lane Plus Ramps[3]		Barrier Machines and Barrier[4]		Total[5]	
	Total	Per Kilometer (Mile)	Total	Per Kilometer (Mile)	Total	Per Kilometer (Mile)
8.4 (5.2)[6]	$7.0	$0.8 ($1.3)	$8.4	$1.0 ($1.6)	$15.4	$1.8 ($3.0)

[1]Estimated costs are in 1995 dollars.
[2]Costs do not include the value of the existing freeway rights-of-way in which the HOV lane is located. The costs of any additional buses required to provide HOV service and any associated increases in bus maintenance costs are not included.
[3]Includes the cost of any structural upgrades of pavement for the HOV lane and the access/egress ramps serving the lane.
[4]Includes the cost of the movable concrete barriers and the machines required to move those barriers.
[5]No new support facilities (e.g., park-and-ride lots and bus transfer centers) have been provided as part of this project.
[6]The East RLT HOV lane operates 8.4 kilometers (5.2 miles) inbound and 5.3 kilometers (3.3 miles) outbound. The HOV lane will eventually operate 8.4 kilometers (5.2 miles) in each direction.

The funding for the East RLT HOV lane has come from a combination of federal and state highway funds and federal and local transit monies. Approximately 50 percent of the total capital cost has come from each of these (highway and transit) sources. The East RLT HOV lane has been constructed completely within state-owned right-of-way.

FACILITY OPERATING AND ENFORCEMENT COST

Houston

The daily operation and enforcement of the Houston HOV lanes is the responsibility of the Metropolitan Transit Authority. On average, this is costing approximately $260,000 per HOV lane per year (Table 7). This is equivalent to 0.4 cents per passenger-kilometer (0.6 cents per passenger-mile).[5]

Table 7. Estimated Annual Cost of Operating and Enforcing the Operating Houston HOV Lanes, 1995

Type of Cost	Annual Budget
Daily Operations	$ 675,000
Enforcement[1]	$ 625,000
Total	$1,300,000
Average Per HOV Lane (unweighted)	$ 260,000

[1]Includes costs associated with materials, supplies, and training.

Source: Metropolitan Transit Authority.

This report will present additional discussion of the operating costs associated with providing bus transit service on the HOV lanes in later sections. Those analyses indicate that an operating subsidy of approximately $2.91 (excluding depreciation costs) is required for each bus passenger using the HOV facilities. This equates to an annual subsidy of approximately $21 million to provide the bus service on the HOV facilities.

[5]In 1995, approximately 341 million passenger-kilometers (211 million passenger-miles) were served on the Houston HOV facilities. At $1,300,000 per year for operations and enforcement, this equates to 0.4 cents per passenger-kilometer (0.6 cents per passenger-mile).

Thus, the total annual public operating cost for the HOV lanes is approximately $22 million; $1.3 million is for operations and enforcement, and $21 million is for bus operating subsidies. Figure 13 provides a summary of operating cost data. This report will provide more detail on these costs in later sections.

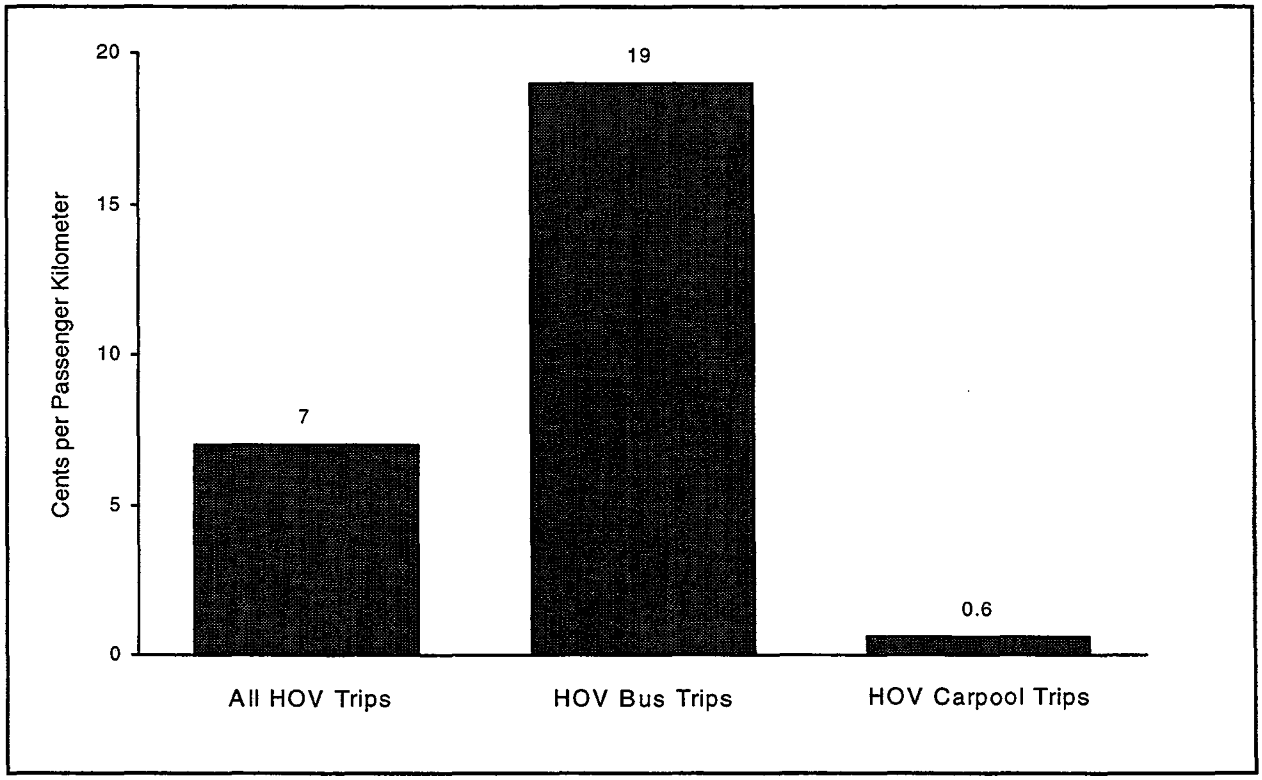


Figure 13. Operating Cost Per Passenger-Kilometer for the Operating Houston HOV Facilities, 1995

Dallas

Operation and enforcement of the East RLT HOV lane is the responsibility of DART. The cost of operating and enforcing this HOV lane amounted to approximately $645,000 per year in 1995 (Table 8). The majority of this cost relates to the daily transfer of the movable concrete barriers used in conjunction with the contraflow lane. The data required to calculate the operating cost per passenger-kilometer are unavailable at this time.

Table 8. Estimated Annual Cost of Operating and Enforcing the East R.L. Thornton HOV Lane, 1995

Type of Cost	Annual Budget
Daily Operations	$ 600,000
Enforcement	$ 45,000
Total	$ 645,000

Source: Dallas Area Rapid Transit.

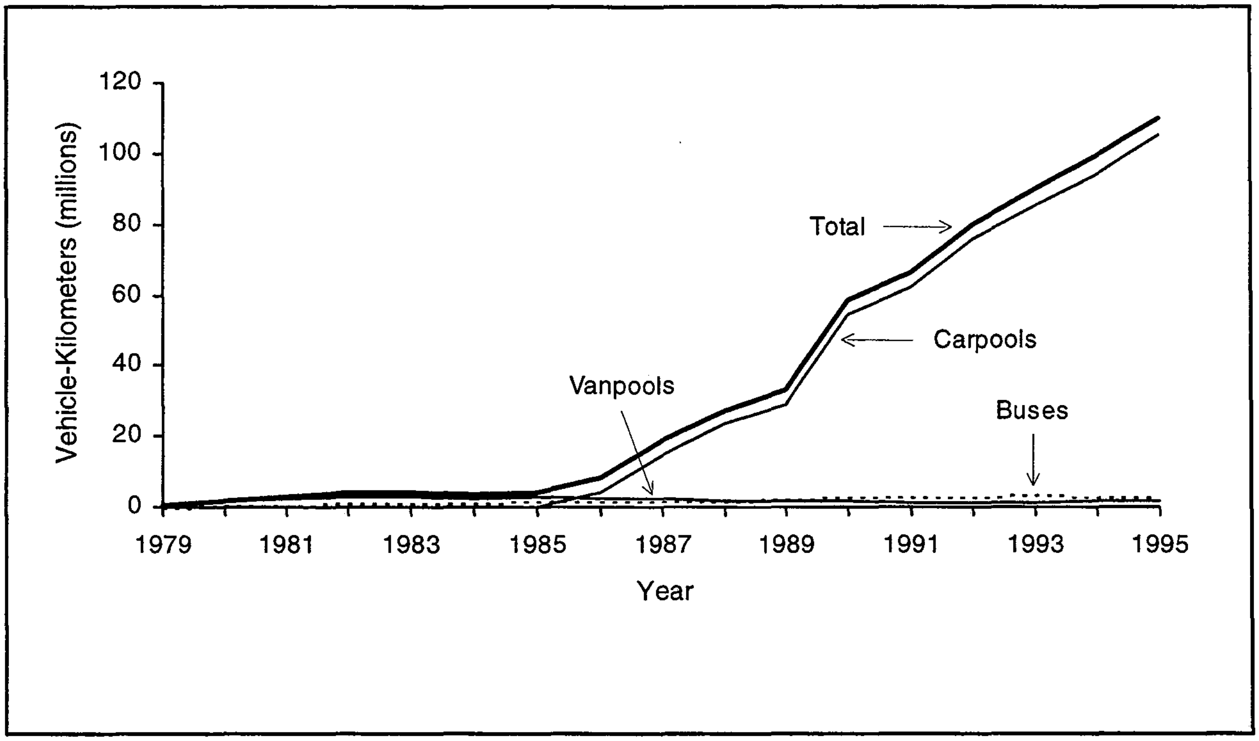
GENERAL TRENDS IN HOUSTON HOV SYSTEM UTILIZATION

This section briefly reviews system-wide data that help describe the usage of the Houston HOV lanes over time. This report includes a more detailed evaluation of these data in a subsequent section. The appendices include additional data for both the Houston and Dallas HOV lanes.

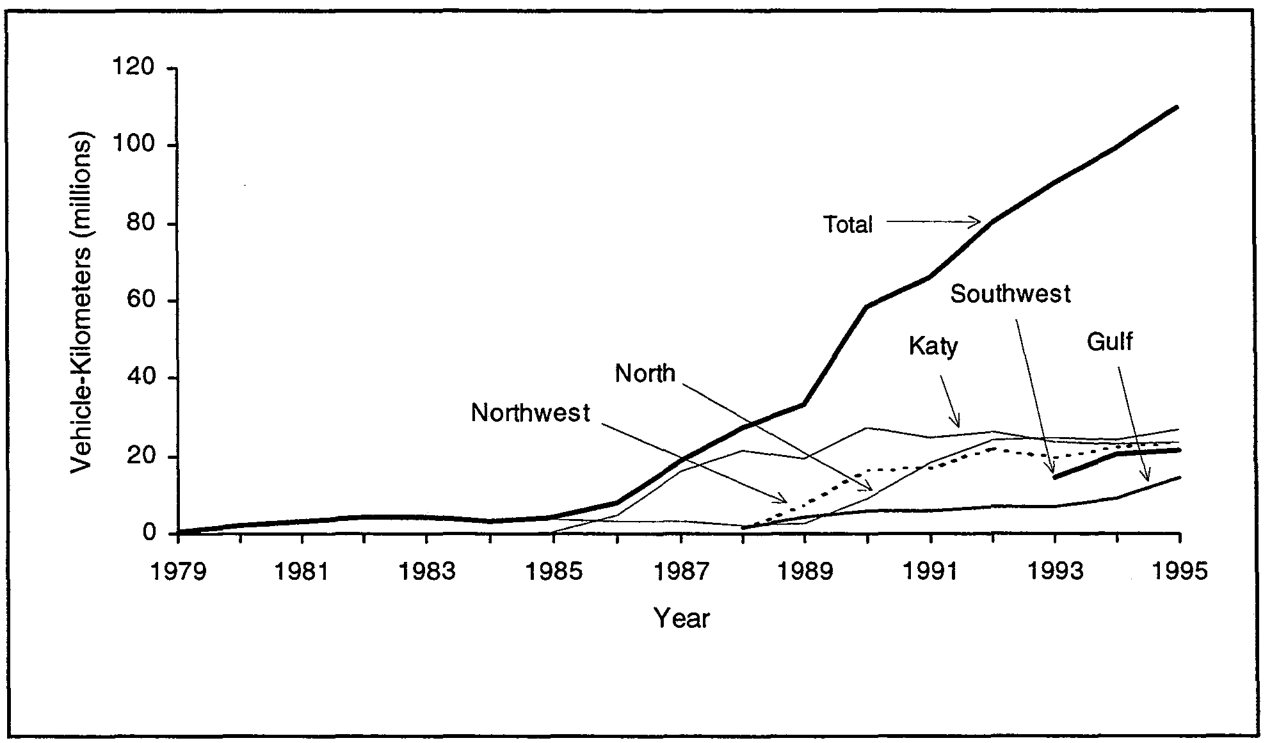
Trends in System-Wide HOV Usage

Figures 14 and 15 depict annual vehicle-kilometers of travel and annual passenger-kilometers of travel on the HOV lanes. Since carpools were first allowed to use the HOV lanes in 1985, vehicle-kilometers of HOV lane usage have increased rapidly. With this carpool use and the continued opening of HOV lanes and HOV lane extensions, annual passenger-kilometers on the HOV system have also been increasing. While not affecting system-wide utilization levels, ridership on the Katy HOV lane has decreased slightly between 1990 and 1995. This slight decrease is attributable to the opening of the Southwest HOV lane (in the same general travel corridor), to which some HOV ridership has diverted.

Figure 16 depicts total daily system-wide HOV usage in Houston. Daily person trips in December 1995 totaled 77,027, a slight (one percent) increase in the ridership level relative to December 1994. Historically, the annual increase in HOV lane usage has been much greater than the increase in overall travel on the freeways and principal arterials in the Houston area (Figure 17). Between 1985 and 1995, daily person trips on the HOV lanes have increased in almost direct proportion to increases in kilometers of operational HOV facilities.

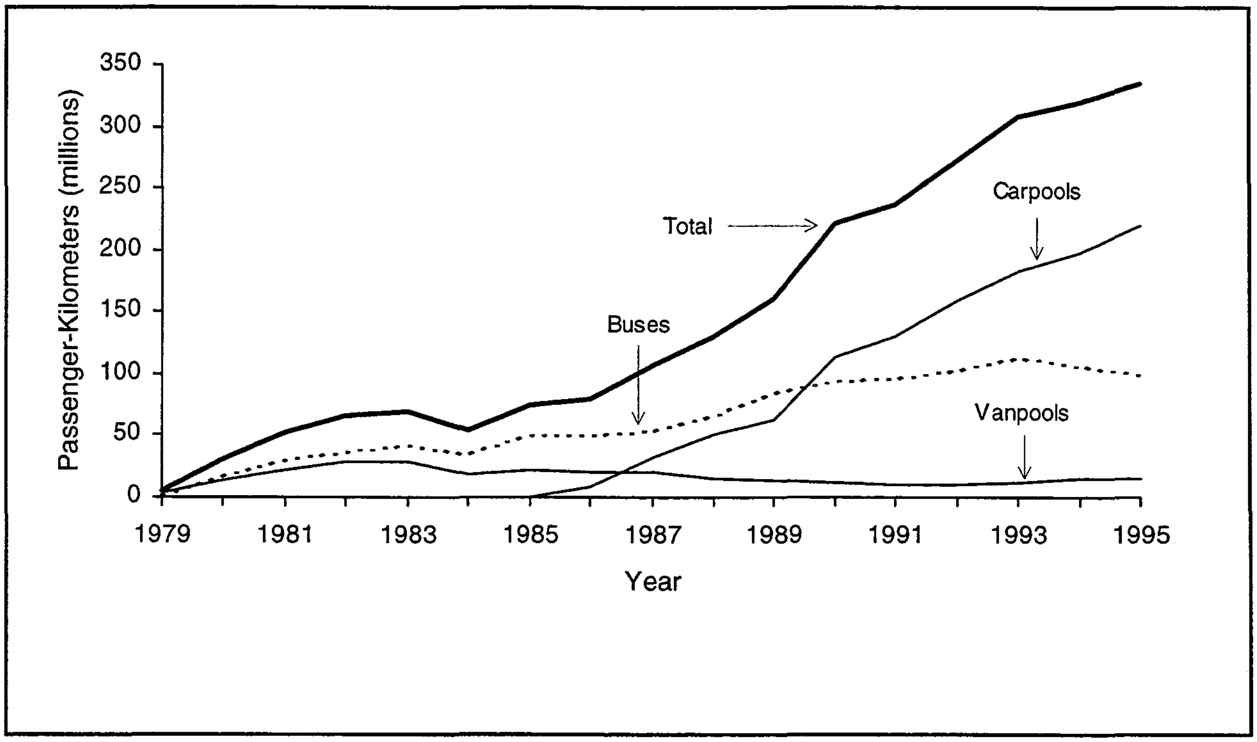


Source: See data in appendices.

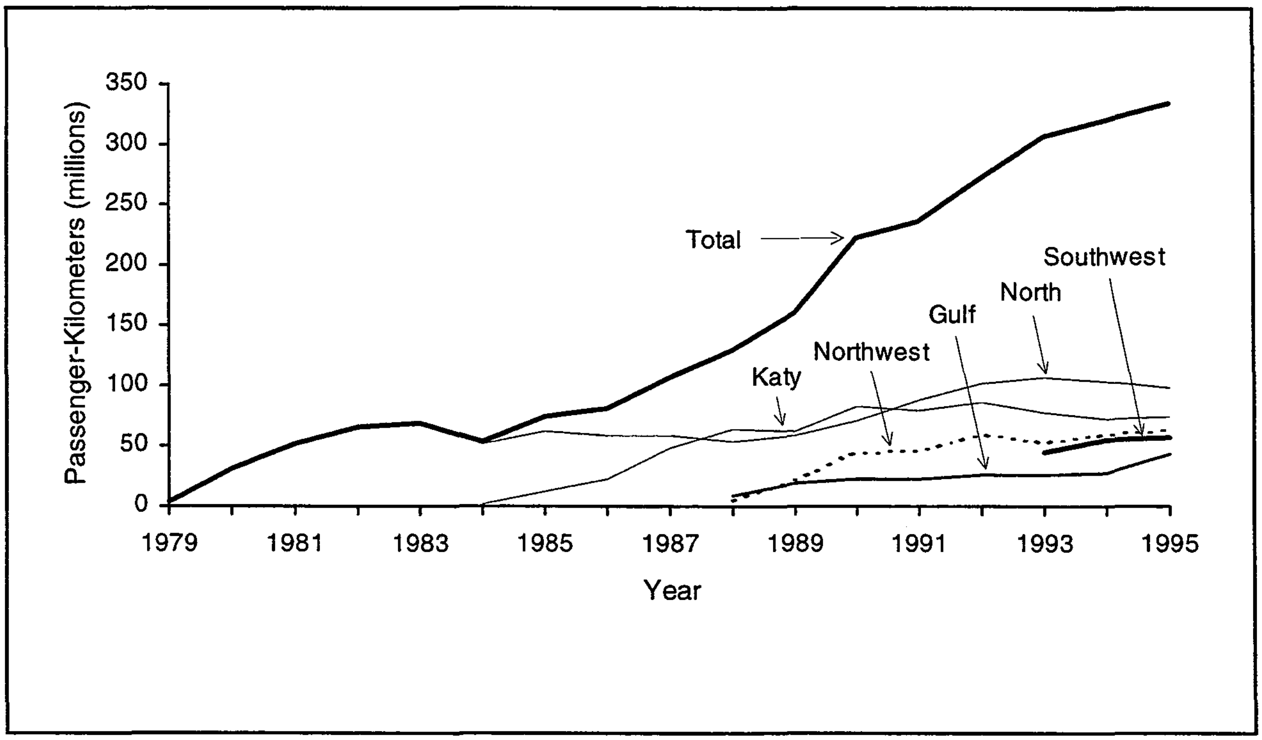


Source: See data in appendices.

Figure 14. Trends in Annual Vehicle-Kilometers of Travel on Houston HOV Lanes

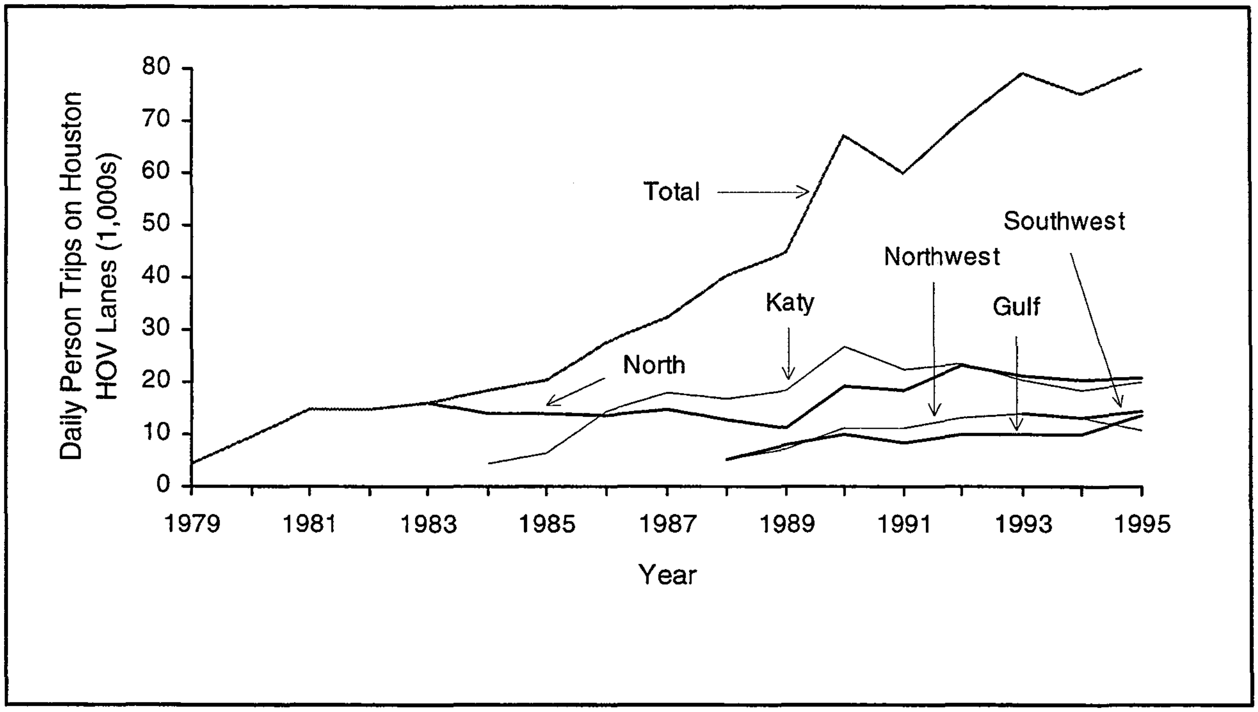


Source: See data in appendices.



Source: See data in appendices.

Figure 15. Trends in Annual Passenger-Kilometers of Travel on Houston HOV Lanes



Source: See data in appendices.

Figure 16. Trends in Daily Person Trips on Houston HOV Lanes

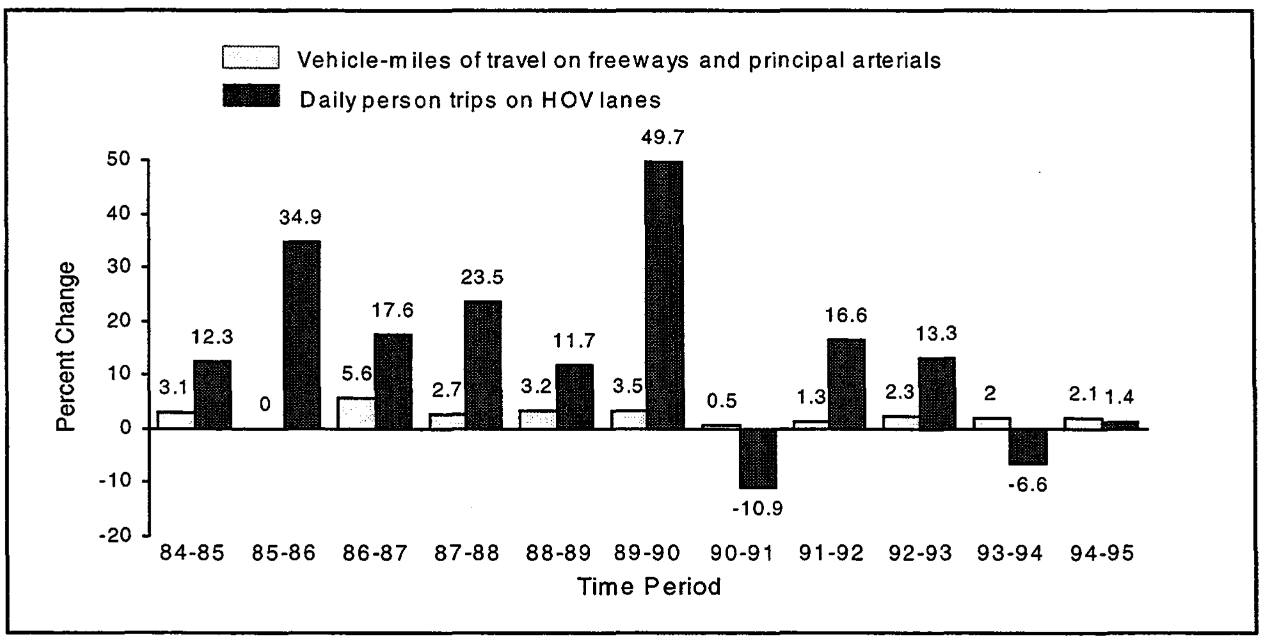
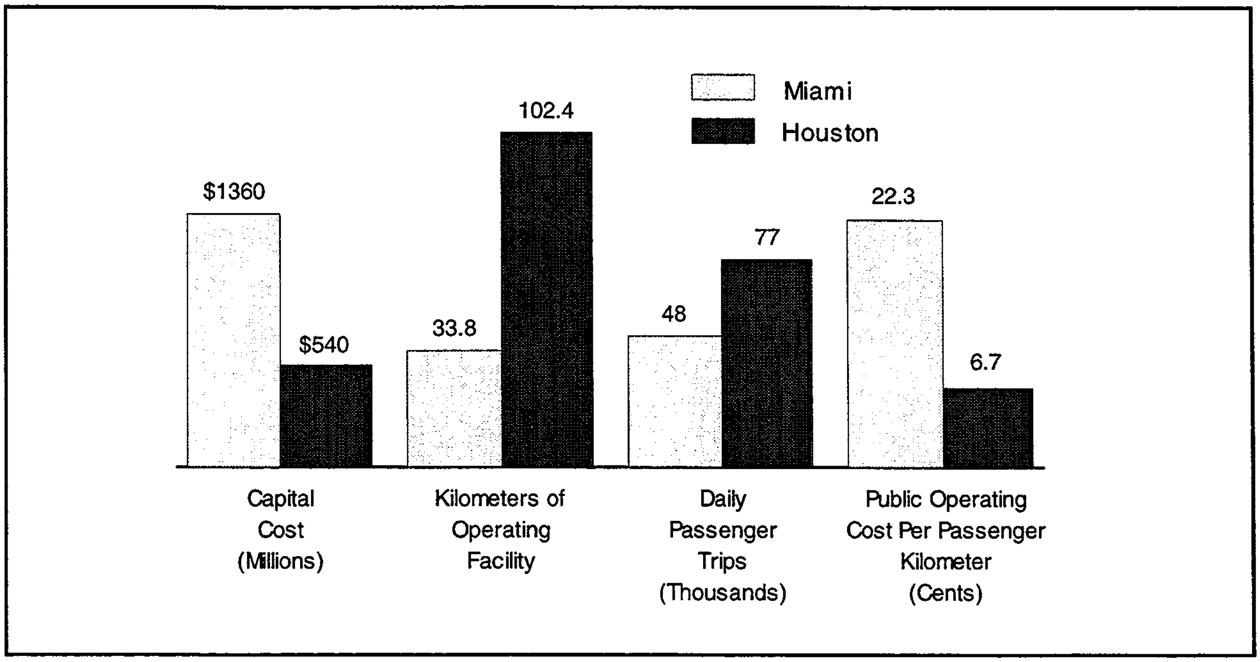


Figure 17. Annual Percentage Increase in HOV Person Trips and in Vehicle-Kilometers of Travel on Freeways and Principal Arterials

Comparison to Other Fixed-Guideway Projects

Simply as a basis of comparison, the operating Houston HOV lane system (102.4 kilometers [63.6 miles]), constructed for a capital cost (in 1995 dollars) of approximately $540 million, serves approximately 77,000 person trips per day. The public operating cost per passenger-kilometer is roughly 7 cents (11 cents per passenger-mile). The Miami heavy rail system (34 kilometers [21 miles]), constructed at a cost of approximately $1.36 billion (in 1995 dollars), is serving about 48,000 daily person trips. The public operating cost per passenger-kilometer on that system is 22 cents (36 cents per passenger-mile). This simplistic comparison (Figure 18) is not intended to lead to a conclusion that either of the projects is necessarily good or bad, but it helps to demonstrate the relative significance of the HOV investment in Houston.



Source: Texas Transportation Institute and respective transit agencies.

Figure 18. Comparative Data for the Operating Houston HOV Lanes and the Miami Rail Transit System

Table 9 compares cost and ridership data for selected light rail projects with the Houston HOV lanes. The Houston HOV lanes are, in general, less expensive than the rail projects and move more persons during the peak hour in the peak direction. In comparison, the rail projects are generally moving more total daily passengers, and the facilities are greater in physical length.

Table 9. Houston HOV Facilities Compared to Other Fixed-Guideway Projects

City and Transit Improvement	Length in Kilometers (Miles)	Capital Cost Per Kilometer (Mile) (millions)	Average Weekday Person Trips[2]	Maximum Ridership, Peak-Hour, Peak-Direction
Houston HOV Lanes				
Katy (I-10W)	20.9 (13.0)	$3.3 ($5.3)[1]	20,057	3,497
North (I-45N)	21.7 (13.5)	$5.6 ($9.0)[1]	20,918	4,775
Gulf (I-45S)	19.5 (12.5)	$4.9 ($7.9)[1]	7,233	1,974
Northwest (U.S. 290)	21.7 (13.5)	$6.5 ($10.4)[1]	13,946	3,920
Southwest (U.S. 59S)	18.7 (11.6)	$5.9 ($9.6)[1]	14,873	3,222
Average	20.5 (12.7)	$5.3 ($8.5)	15,405	3,478
U.S. Light Rail Lines				
Los Angeles	35.4 (22.0)	$25.1 ($40.5)	36,900	N/A
Portland	24.3 (15.1)	$ 8.8 ($14.1)	26,100	2,150
Sacramento[3]	29.5 (18.3)	$ 7.3 ($11.8)	22,400	2,800
San Diego (San Ysidro)				
Route 510	26.4 (16.4)	$ 5.0 ($ 8.0)	46,000	1,900
Route 520	34.8 (21.6)	$ 5.2 ($ 8.3)	20,000	1,300
San Jose	32.0 (19.9)	$12.9 ($20.8)	18,250	1,400
Average	30.4 (18.9)	$10.7 ($17.3)	28,300	1,590

N/A - Not available
[1]HOV capital costs from Table 4. All costs are in 1995 dollars.
[2]Houston HOV data for December 1995. LRT ridership data represent average annual operations during 1994.
[3]1993 Data.
Source: Texas Transportation Institute and respective transit agencies.

Table 10 compares public operating cost per passenger-kilometer for the Houston HOV lanes with operating cost data for selected rail transit projects. As would be expected, because of the large carpool use of the Houston HOV lanes and the low marginal cost associated with that use, the public operating costs are relatively low.

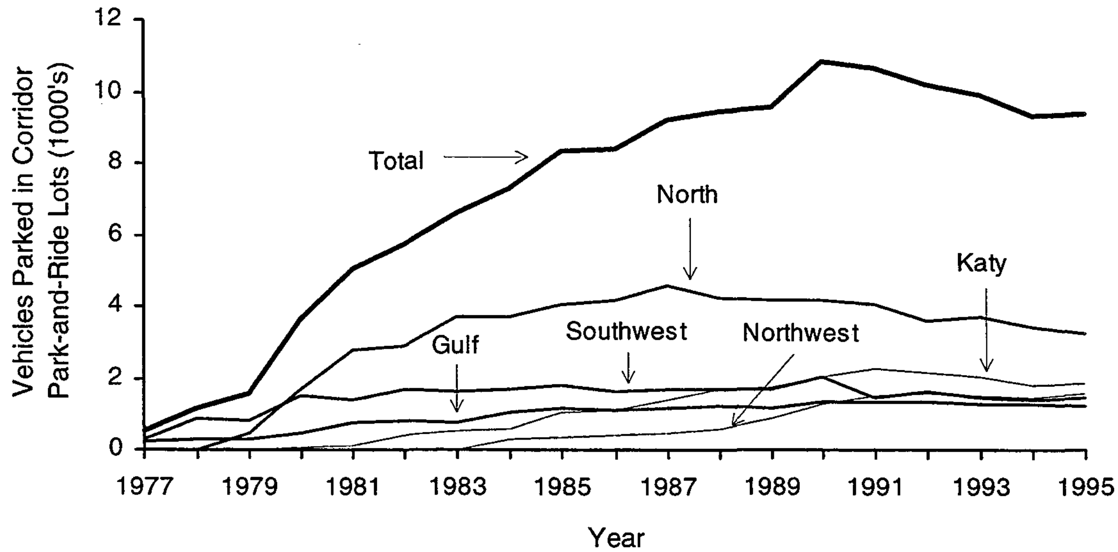
Table 10. Estimated Public Operating Cost Per Passenger-Kilometer for Selected Fixed-Guideway Facilities

Fixed Guideway	Operating Cost Per Passenger-Kilometer (Passenger-Mile), cents	
Houston HOV System[1], 1994	7 (11)	
Rail Transit Systems, 1994		
Unweighted Average	21 (33)	
Atlanta		11 (17)
Miami		24 (38)
Portland		17 (27)
Sacramento[2]		30 (49)
San Diego		15 (24)
San Jose		30 (48)
Washington, D.C.		17 (28)

[1]Operating costs include 1) daily costs to operate lanes; 2) daily costs to enforce lanes; and 3) bus operating subsidy. The bus operating subsidy was approximately $23 million, and the cost of operating and enforcing the priority lanes was about $1.1 million.
[2]1993 Data
Source: Respective transit agencies.

Park-and-Ride Usage

Between December 1994 and December 1995, there has been an increase of one percent in the use of park-and-ride lots in the corridors served by HOV lanes (Figure 19). In December 1995, approximately 9,387 cars were parked at park-and-ride lots; in December 1994 that number was 9,331. By comparison, reductions over the past several years have been significant in corridors without HOV lanes. For instance, the average park-and-ride patronage in the freeway corridors without HOV lanes has decreased approximately 15 percent over the past five years.



Source: See data in appendices.

Figure 19. Trends in Usage of Park-and-Ride Lots in HOV Facility Corridors

Summary of HOV Usage Data

Table 11 presents selected HOV operating data. Except for the Katy HOV lane during the period when carpool usage is restricted to 3+, violations have not been a problem and have been less than five percent. The accident rates on the HOV lanes have generally been comparable to, or less than, the rates on the freeway general-purpose lanes. While several HOV lanes have opened for weekend use in the past, only the Katy HOV lane has remained in use on Saturdays and Sundays. Weekend volumes on the Katy HOV lane have decreased slightly due to weekend installation of surveillance, communication and control (SC&C) equipment.

Table 11. Selected HOV Lane Operating Statistics, December 1995

Time Period and Operating Data	HOV Lane				
	Katy	North	Gulf	Northwest	Southwest
Weekday Operations					
HOV Lane Person Volume					
A.M. Peak Hour	3,497	4,775	1,974	3,920	3,222
Daily	20,057	20,918	7,233	13,946	14,873
HOV Lane Vehicle Volume					
A.M. Peak Hour	835[1]	1,302	787	1,434	1,181
Daily	6,454	5,737	3,215	5,159	5,518
Percent of Total A.M. Peak-Hour, Peak-Direction Person Volume on HOV Lane[2]	40%	40%	24%	41%	26%
Vehicles Parked in Corridor Park-and-Ride Lots	1,877	3,237	1,226	1,591	1,456
Weekend Operations[3]					
Daily Saturday Vehicles	1,539	---	---	---	---
Daily Sunday Vehicles	2,926	---	---	---	---

[1]Carpool vehicle occupancy restricted to 3+ during the peak hour.
[2]Data collected at HOV lane maximum load point. The remaining percentage is in the freeway general-purpose lanes.
[3]Scheduled bus service does not use the HOV lanes on weekends. Weekend operations for North, Gulf, and Northwest HOV lanes ended October 1991.
Source: Texas Transportation Institute data collection, see appendices.

CHARACTERISTICS OF HIGH-OCCUPANCY VEHICLE LANE USERS

On several occasions, TTI has surveyed both bus patrons and carpoolers using the HOV facilities. Those surveys, which are thoroughly documented elsewhere,[6] are highlighted herein. The most recent surveys were completed in 1994 and include Dallas East R.L. Thornton HOV facility.

[6]Refer to TTI Research Reports 484-8, 484-10, 484-12, 484-14F and 1361-F.

Transit Surveys

Table 12 summarizes selected data. The HOV facilities have attracted young, educated, white-collar professionals to ride transit. The bus is being used to serve long-distance commute trips, primarily to downtown. These individuals are using the HOV lanes primarily to save time, avoid driving in congested traffic, have time to relax, and have a reliable trip time. The bus patrons are transit users by choice, with over 85 percent having an auto available for the trip in Houston and approximately 70 percent having an auto available in the East R.L. Thornton corridor in Dallas. Over 60 percent of the bus passengers have all or part of their bus fare paid by their employer. Interestingly, on the two Houston HOV facilities surveyed in 1994 that have been open to carpool use for at least five years (Katy and Northwest), about half of the bus riders have at some time carpooled or vanpooled on the HOV lane. By comparison, approximately 25 percent of East R.L. Thornton HOV lane bus riders have carpooled on the HOV lane. This Dallas HOV lane has now been in operation for three years.

Carpool and Vanpool Surveys

Carpoolers also tend to be young, educated, white-collar professionals (Table 13). They are using the HOV lane for a long-distance commute trip. The carpools are more effective at serving dispersed trip patterns; compared to bus patrons, fewer destinations are in the downtown. Over 60 percent of the carpools are made up of family members. Approximately 20 percent of the carpools on Houston HOV lanes form at either a park-and-ride or a park-and-pool lot, which compares to only 6 percent for East R.L. Thornton in Dallas.

Freeway Motorist Surveys

As indicated in Table 14, motorists using the general-purpose lanes in HOV lane corridors tend to be slightly older and a greater percentage are men (compared to HOV lane transit users and carpoolers). Trip destinations for freeway motorists are extremely dispersed with a comparatively small percentage commuting to downtown. Compared to transit users and carpoolers, a smaller percentage of freeway motorists commuting during the peak periods of travel indicate their occupations as professionals.

Table 12. Selected Characteristics of HOV Lane Bus Patrons, 1994

Characteristic	HOV Lane				
	Katy	North[1]	Northwest	Gulf[2]	East R.L. Thornton
A.M. Trip Destination (Houston/Dallas)					
Downtown	93%	91%	95%	86%	88%
Galleria, Post Oak/Las Colinas	2%	0%	1%	1%	1%
Greenway Plaza/Market Center	0%	1%	1%	0%	1%
Texas Medical Center/Park Central	2%	6%	1%	5%	1%
Other	3%		2%		9%
Trip Purpose (% Work)	99%	98%	99%	96%	88%
Age, Years (50th Percentile)	38	38	38	34	37
Sex (% Male)	43%	40%	49%	30%	29%
Education, Years (50th Percentile)	15	15	15	14	14
Occupation					
Professional	61%	43%	56%	41%	42%
Managerial	13%	17%	13%	16%	6%
Clerical	19%	30%	25%	32%	29%
Sales	3%	3%	4%	2%	3%
Service	2%		1%		5%
Auto Available for Trip (% Yes)	95%	95%	96%	87%	69%
Does Employer Pay for Transit[1]					
Yes, All	17%	16%	17%	14%	---
Yes, Part	44%	48%	54%	48%	---
No	39%	36%	29%	38%	---
Why Use HOV Lane[1]					
Freeway Too Congested	20%	23%	---	---	---
Saves Time	16%	20%	---	---	---
Time to Relax	18%	15%	---	---	---
Reliable Trip Time	14%	15%	---	---	---
Costs Less	14%	12%	---	---	---
Dislike Driving	11%	10%	---	---	---
Have You Carpooled on HOV Lane (% Yes)	56%	32%	58%	---	25%

[1]Data from 1990 transit user survey.
[2]Data from 1989 transit user survey.

Source: Texas Transportation Institute surveys.

Table 13. Selected Characteristics of Carpoolers Using the HOV Facilities, 1994

Characteristic	HOV Lane				
	Katy	North[1]	Northwest	Gulf[2]	East R.L. Thornton
A.M. Trip Destination (Houston/Dallas)					
Downtown	66%	76%	42%	78%	71%
Galleria, Post Oak/Las Colinas	3%	3%	32%	6%	3%
Greenway Plaza/Market Center	2%	2%	6%	2%	4%
Texas Medical Center/DFW Airport	5%	7%	6%	4%	1%
Other	24%	12%	14%	10%	21%
Trip Purpose					
% Work	88%	95%	95%	98%	92%
% School	8%	5%	4%	2%	5%
Age, Years (50th Percentile)	38	37	39	38	41
Sex (% Male)	48%	53%	53%	41%	45%
Education, Years (50th Percentile)	15	15	15	14	14
Occupation					
Professional	53%	38%	57%	46%	54%
Managerial	19%	21%	18%	15%	16%
Clerical	11%	21%	13%	26%	17%
Sales	2%	11%	6%	4%	4%
Service	3%	---	2%	---	5%
Why Use HOV Lanes[2]					
Freeway Too Congested	19%	20%	---	---	---
Saves Time	20%	20%	---	---	---
Time to Relax	14%	13%	---	---	---
Reliable Trip Time	12%	13%	---	---	---
Costs Less	14%	15%	---	---	---
Who Makes up Carpool					
Family Members	64%	61%	68%	---	60%
Neighbors	6%	13%	8%	---	8%
Co-workers	30%	25%	32%	---	32%
Does Carpool Stage at Park/Pool Lot (% Yes)	23%	11%	19%	---	6%

[1]Data from 1990 survey.
[2]Data from 1986 survey.

Source: Texas Transportation Institute surveys.

Table 14. Selected Characteristics of Freeway Motorists, 1994

Characteristic	Freeway		
	Katy	Northwest	East R.L. Thornton
A.M. Trip Destination (Houston/Dallas)			
Downtown	13%	15%	27%
Galleria, Post Oak/Las Colinas	13%	17%	9%
Greenway Plaza/Market Center	2%	6%	7%
Texas Medical Center/DFW Airport	3%	6%	3%
Other	69%	56%	54%
Trip Purpose			
% Work	91%	94%	92%
% School	2%	2%	2%
Age, Years (50th Percentile)	42	42	42
Sex (% Male)	60%	57%	54%
Education, Years (50th Percentile)	15	14	14
Occupation			
Professional	48%	45%	46%
Managerial	18%	18%	15%
Clerical	11%	13%	13%
Sales	11%	11%	6%
Service	4%	4%	8%

Source: Texas Transportation Institute Surveys.

III. MEASURES OF HIGH-OCCUPANCY VEHICLE LANE EFFECTIVENESS

A major intent of this research project is to evaluate the effectiveness of the high-occupancy vehicle lanes being implemented in Texas. The commitment to developing these priority lanes is extensive in Houston and Dallas, and the projects are unlike anything previously implemented. As a result, a high level of interest exists in assessing the effectiveness of the HOV lane projects. In response to this interest, the Texas Department of Transportation has chosen to pursue a long-range evaluation of the high-occupancy vehicle lanes.

To a large extent, the decision to consider building HOV lanes came through the realization that it was simply not possible, either physically or economically, to provide enough street and highway lanes to indefinitely continue to serve peak-period travel demands at 1.2 persons per auto. The current round of freeway expansion being pursued in Houston and Dallas, which will be largely complete by the end of the 1990s, represents, to a significant extent, the last major capacity expansion that can be added to existing freeway corridors. However, expectations are that demand will continue to increase into the foreseeable future at rates of around two to three percent per year.

In concept, if the HOV lanes perform as intended, provision of the priority lanes offers a means to help accommodate some of this future growth. If design year volumes of 7,000 to 10,000 persons per hour per lane are achieved on these lanes, the person-movement capacity of the freeway will effectively have been doubled at a cost of $3 to $6 million per kilometer ($5 to $9 million per mile), and future volumes can be served acceptably. However, this will be the case only if the HOV lanes perform as expected. As a result, their performance is being closely monitored to assess the effectiveness of the improvements.

POTENTIAL MEASURES OF EFFECTIVENESS

Prior to establishing measures of effectiveness by which to evaluate the performance of the high-occupancy vehicle lanes, it is necessary to identify the primary reason(s) for building those facilities. Effectiveness measures can then be determined to help establish whether the project goals are being met. Numerous potential HOV project objectives exist, some qualitative in nature and some that can be quantified. A survey[7] of North American high-occupancy vehicle lane projects determined that increasing roadway capacity and reducing vehicle-kilometers of travel were the primary reasons for implementing HOV lanes.

In Houston and Dallas, it appears that the primary reason for high-occupancy vehicle lane development has been to increase the effective roadway capacity to move people. In the face of increasing congestion and projected freeway average daily traffic volumes in the range of 300,000 vehicles or more, transportation planners realized that travel demand simply could not be served just by building more additional mixed-flow traffic lanes. At the same time, a desire existed to enhance the role of transit in the area, and air quality issues needed to be addressed.

Thus, it is assumed that the primary goal of HOV lanes in Texas is to cost effectively increase the person-movement capacity of the freeways. Achieving this should 1) enhance bus transit operations; 2) improve air quality; and 3) reduce fuel consumption. Implementation of the HOV lanes should not unduly impact the operation of the freeway general-purpose lanes and should have general public support.

If these are accepted as major reasons for implementing high-occupancy vehicle lane projects, the next issue becomes the identification of the data and analyses required to assess whether the project objectives are being realized. This section presents a discussion of these issues; subsequent sections of this report present actual data collection and analyses.

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[7]Texas Transportation Institute Technical Report 0925-1.

Objective. Increase the effective person-movement capacity of the freeway.

Measure. *The percentage increase in the peak-hour, peak-direction person volume resulting from HOV lane implementation should at least be greater than the percentage increase in directional lanes added to the roadway.* This will be accomplished by increasing the average number of persons per vehicle on a roadway; the increase in average vehicle occupancy should be the result of creating *new* carpoolers and *new* bus transit riders. Unless an HOV lane creates a significant volume of new rideshare patrons, it is difficult to argue why that lane should be an HOV lane as opposed to a general-purpose lane.

Objective. Improve the efficiency of bus transit operations.

Measure. *Schedule times should decrease.* The HOV lane should result in a faster schedule speed. It provides a more reliable travel time which should increase schedule adherence (i.e., bus on-time performance).

Objective. HOV lane implementation should not unduly impact freeway mainlane operation, and its implementation should increase overall roadway efficiency.

Measure. *Operation on the mainlanes should not be degraded as a result of the HOV lane, and the per lane efficiency of the roadway should increase because of the HOV lane.* Capacity, operating speed, and safety on the general-purpose freeway mainlanes should not be unduly impacted. Also, the per lane efficiency of the roadway, defined in this report as the multiple of person volume moved times speed of movement, should increase due to the implementation of the HOV lanes.

Objective. The HOV lane project should be cost effective.

Measure. *If the project has a benefit-cost ratio greater than one, based on the only benefit being the value of the time saved by persons using the HOV lane, it is clear that the project is cost effective.* This is a conservative estimate, since an effective HOV lane should also generate other benefits. However, if the project is cost effective based on this single benefit, it is apparent that the project would simply be more cost effective if all benefits were considered. This highly conservative approach suggests that the annual value of time saved by users of the HOV lane should be at least 10 percent of the total HOV lane construction cost.

Objective. Development of the HOV facility system should have public support.

Measure. *Opinion surveys should show that public support exists for developing freeway high-occupancy vehicle lanes.* Experience has shown that major transportation projects—whether freeway or transit—that generate significant public opposition will sometimes either not proceed forward or not proceed forward on schedule. The on-going debate over rail transit development in Houston, which has now lasted well over 10 years without yet being resolved, is an example of the difficulty that can be encountered in developing major transportation projects without having clear public support. Monitoring of public attitudes regarding HOV facilities should, desirably, show that support for these improvements exists.

Objective. High-occupancy vehicle facilities should have favorable impacts on air quality and energy consumption.

Measure. *For the total demand being served, the HOV lane should have more favorable air quality and energy impacts than would the addition of a general-purpose lane.* If a lane is to be added to the facility and if it is designated as an HOV lane, that HOV designation should bring about more favorable impacts than would designating the lane as a general-purpose lane. It should also be favorable when compared to the "do nothing" alternative.

Subsequent sections of the report analyze the data from the Houston and Dallas research efforts to assess the effectiveness of the high-occupancy vehicle facilities at this point in time in regard to the objectives set forth above.

THE TIME FACTOR

As of the end of 1995, the oldest HOV lanes in Texas (the Katy and North HOV lanes in Houston) have been in operation for just over 10 years. The average length of time HOV facilities in Texas have been in operation is approximately five years. Until 1990, none of the high-occupancy vehicle facilities had been completed in their final forms. In assessing the worth of these improvements, it should be recognized that these facilities are being looked to as a means of helping to serve long-term growth. Design year demand estimates are two to three times greater than the current demand on some of the HOV lanes.

It is not expected that the HOV lanes will be as effective in their early years of operation as they are expected to be in future years. Consequently, in reviewing the data in this report, more emphasis should be given to the evaluations that relate to the more mature HOV facilities, the Katy and the North HOV lanes. Even then, it should be realized that there is reason to expect that the current level of effectiveness associated with those facilities will increase over time; this will be the case if usage and congestion on the freeway mainlanes increase as is anticipated.

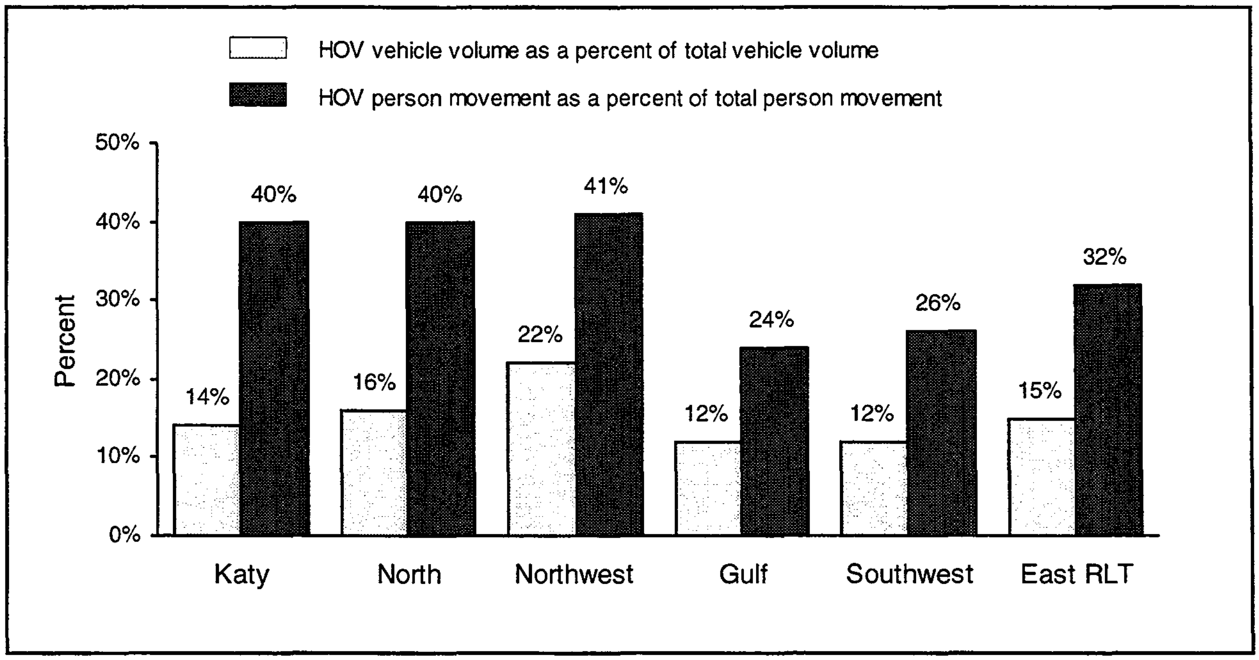
IV. PERSON MOVEMENT, OCCUPANCY, AND TRANSIT EFFICIENCY

A primary objective of high-occupancy vehicle lane implementation is to significantly increase person-movement on a roadway. This will be accomplished if average vehicle occupancy (persons per vehicle) is increased, and if that increase is largely the result of increases in ridesharing (both carpooling and transit). This section of the report presents data that address these issues. Also, this section documents transit operating data.

HIGH-OCCUPANCY VEHICLE LANE UTILIZATION

In December 1995, 77,027 daily person trips were counted on the Houston HOV lane system. This level of ridership represents a slight (one percent) increase in comparison to 1994. The East RLT HOV lane in Dallas served 13,572 daily person trips in December 1995. By comparison, this facility served 12,879 daily person trips in December 1994.

As would be expected, the HOV lanes in both Houston and Dallas move a relatively high percentage of total roadway person volume in a relatively low percentage of total vehicles (Figure 20). However, this is the result that should occur if nearly all of the higher-occupancy vehicles operate in a single lane; as a consequence, by itself, this is not necessarily a measure of effectiveness.



Source: See data in appendices.

Figure 20. HOV Vehicle and Person Volumes as a Percent of Total (HOV plus Freeway) Volumes, A.M. Peak-Hour, Peak-Direction

FACTORS INFLUENCING HIGH-OCCUPANCY VEHICLE LANE UTILIZATION

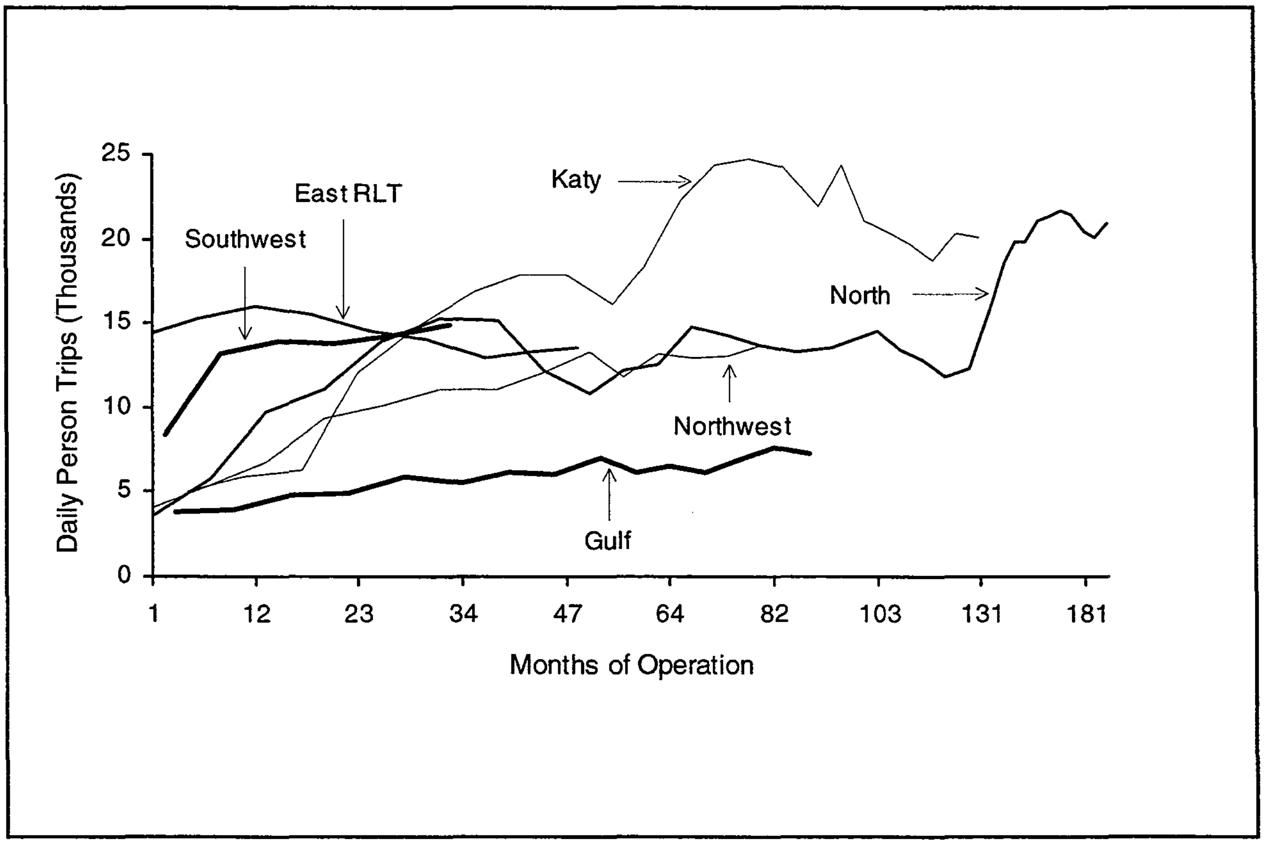
It is evident that a number of factors influence both bus ridership and carpooling on an HOV lane. Some of those factors, such as parking cost, are the ones used in traditional mode split models. A review of the Houston data suggests that at least three factors appear to be significant in helping to explain current HOV lane ridership levels.

Length of Time HOV Lane Has Operated

Most successful HOV projects experience rapid growth over the first three to four years of operation.[8] This reflects the fact that mode choice changes continue to occur over a period of several years.

[8]See data in Texas Transportation Institute Research Report 1146-2.

This occurrence of rapid growth in usage during the early years of operation has been observed on the Houston HOV facilities (Figure 21). Both the North and Katy HOV lanes have been in operation long enough to have experienced this early-year growth surge. The same is now beginning to be true for the Gulf and Northwest HOV lanes, which opened in 1988. The Southwest HOV lane has experienced significant growth since opening in January 1993, but has still been open only a short period of time. The East RLT HOV lane has not followed this general trend; ridership has declined slightly in recent years due partly to operational problems associated with the evening merge point between the HOV lane and freeway general-purpose lanes. Extension of the evening operations to Jim Miller Road in 1996 will alleviate this problem. It is important to note that no additional park-and-ride or bus service has been offered since the implementation of the East RLT HOV lane.



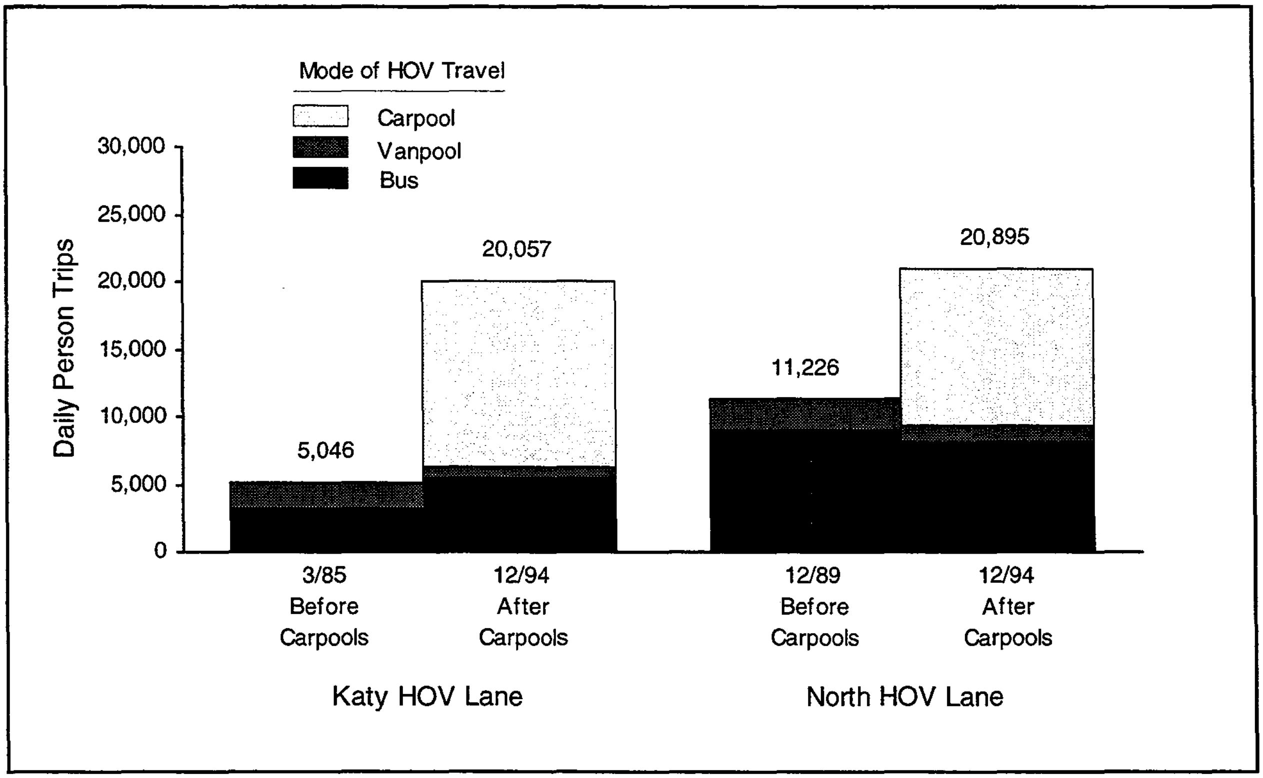
Source: See data in appendices.

Figure 21. Daily Ridership by Months of Operation, Houston and Dallas HOV Lanes

Vehicle Groups Allowed to Use the HOV Lane

As would be expected, either allowing carpools to use an HOV lane or reducing carpool occupancy requirements will result in an increase in HOV lane usage (as long as the vehicular capacity of the priority lane is not exceeded). The fact that 65 percent of total HOV person trips on the Houston HOV lanes and 66 percent of HOV person trips on the East RLT HOV lane are in carpools or vanpools reflects this expected result.

Figure 22 shows carpool impacts on HOV usage. The North HOV lane had been experiencing a slow decline in total usage for over four years until carpools were allowed onto the facility in 1990. Carpool use of HOV lanes offers numerous benefits; one of these is that the total capacity of the lane to move people is better utilized.



Source: Texas Transportation Institute data collection.

Figure 22. Impacts of Carpool Usage on Daily HOV Lane Person Trips, Katy and North HOV Facilities

Travel Time Savings and Reliability Offered by the HOV Lane

Provision of meaningful travel time savings is, perhaps, the most important single factor influencing HOV lane use. Quite simply, unless severe freeway congestion exists on a recurring basis, usage of HOV lanes will not be high. It has been postulated for many years that a priority high-occupancy vehicle lane must provide at least 40 seconds of travel time savings per kilometer (one minute of travel time savings per mile) of lane to be successful.[9]

As part of this research project, researchers collect travel time data on at least a semi-annual basis for each freeway and HOV lane and continuously in several corridors (Katy, North, and Northwest Freeway and HOV lanes). These data are averaged to estimate the representative travel time savings offered by the HOV lanes. Figure 23 shows a plot of the morning peak period travel times.

Table 15 presents selected usage and time savings data related to the Houston HOV facilities for 1994 and 1995. Statistics indicate a slight increase in the average usage of the HOV facilities during 1995.

The lack of travel time savings for the Gulf HOV lane is caused by freeway construction south of the outer limit of the HOV lane which has created a bottleneck and is metering inbound traffic during the morning peak period. This temporary operational situation for the Gulf Freeway has eliminated any possibility for HOV lane travel time savings during the morning peak period. This same condition is present in the evening and causes queueing problems for both the general-purpose lanes and HOV lane.

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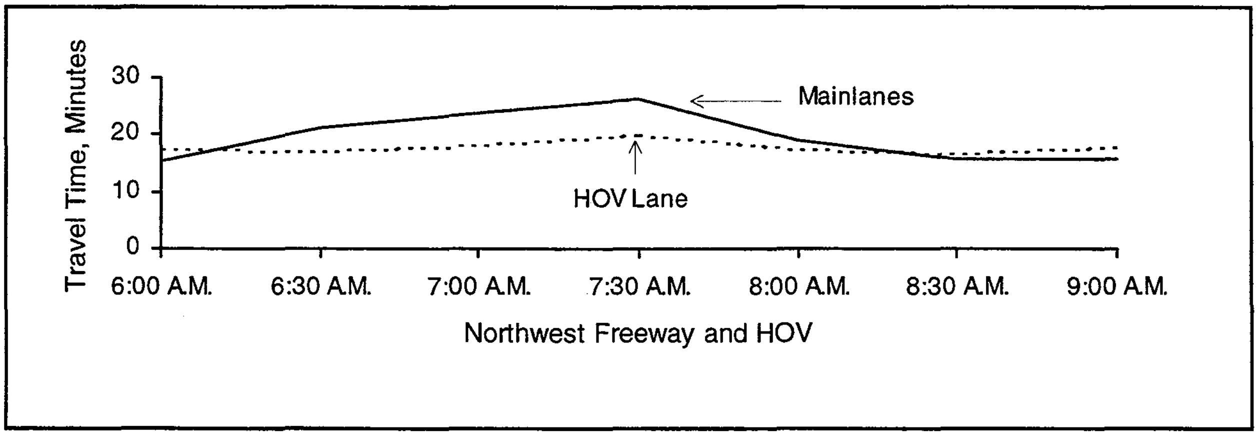
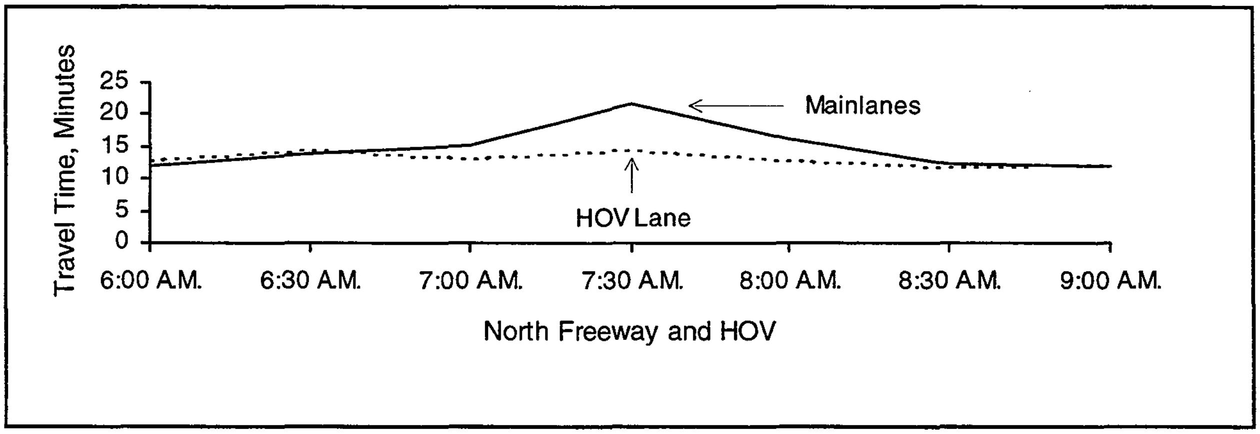
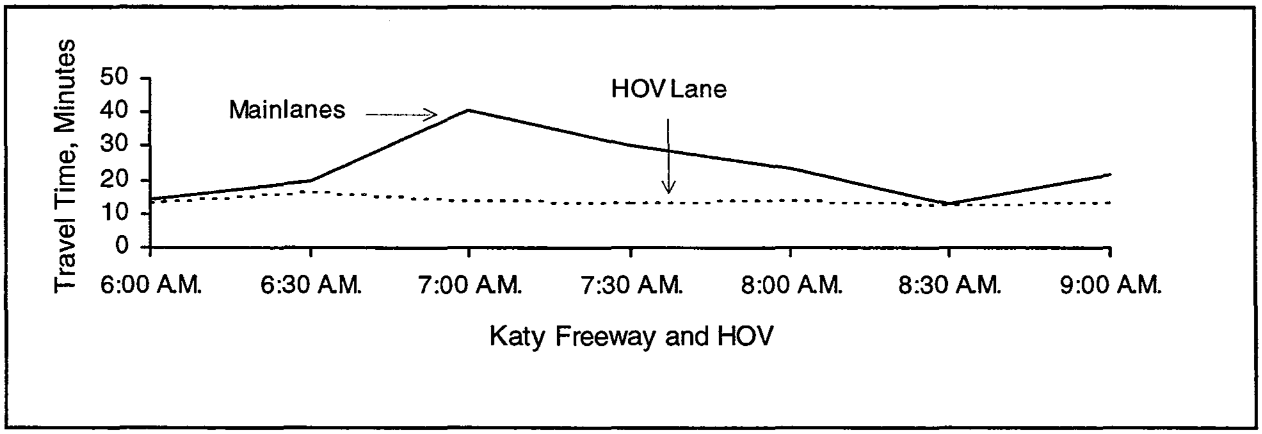
[9]D. Baugh and Associates. "Freeway High-Occupancy Vehicle Lanes and Ramp Metering Evaluation Study." Prepared for U.S. Department of Transportation, 1979.



Note: Travel times are from Senate to the S.P. Railroad.

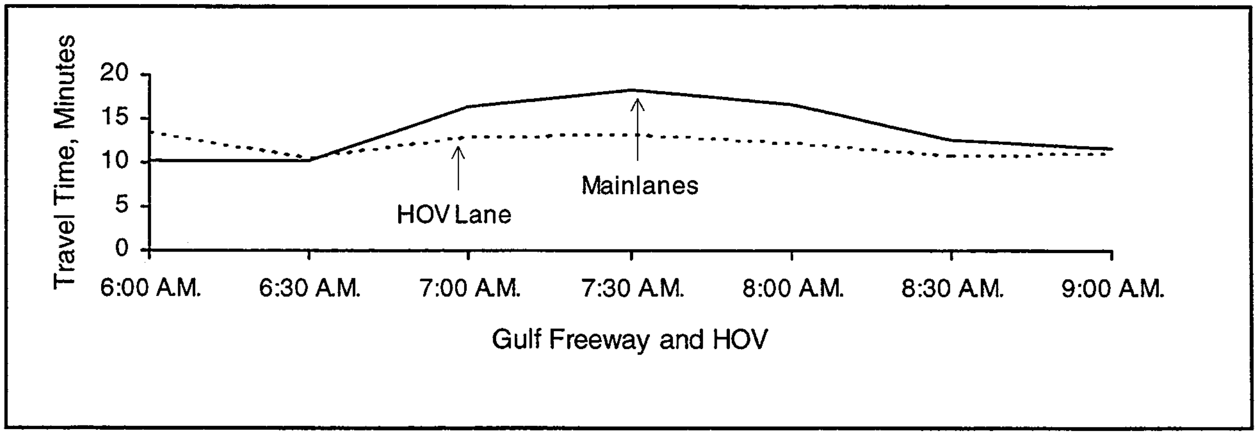


Note: Travel times are from Beltway 8 to Hogan.

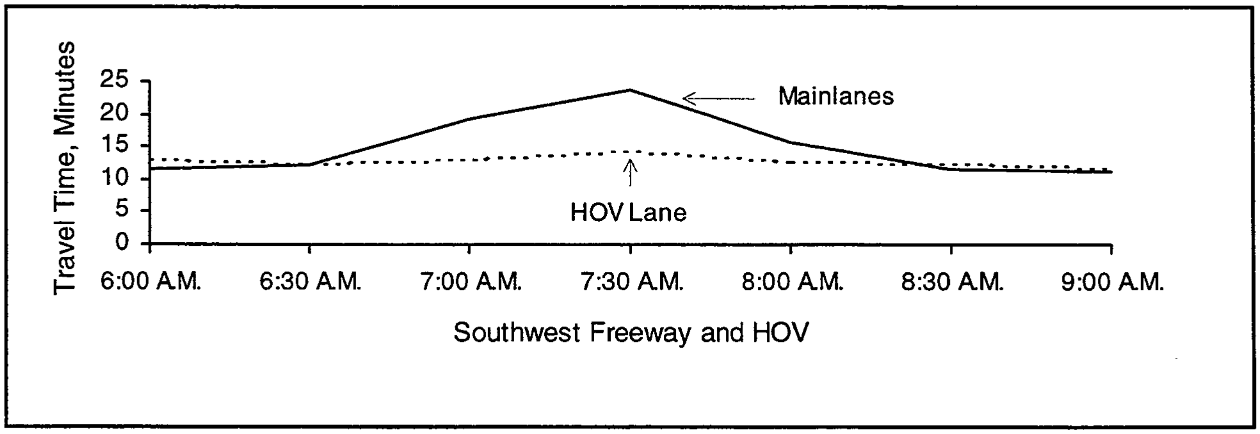


Note: Travel times are from SH 6 to the S.P. Railroad.

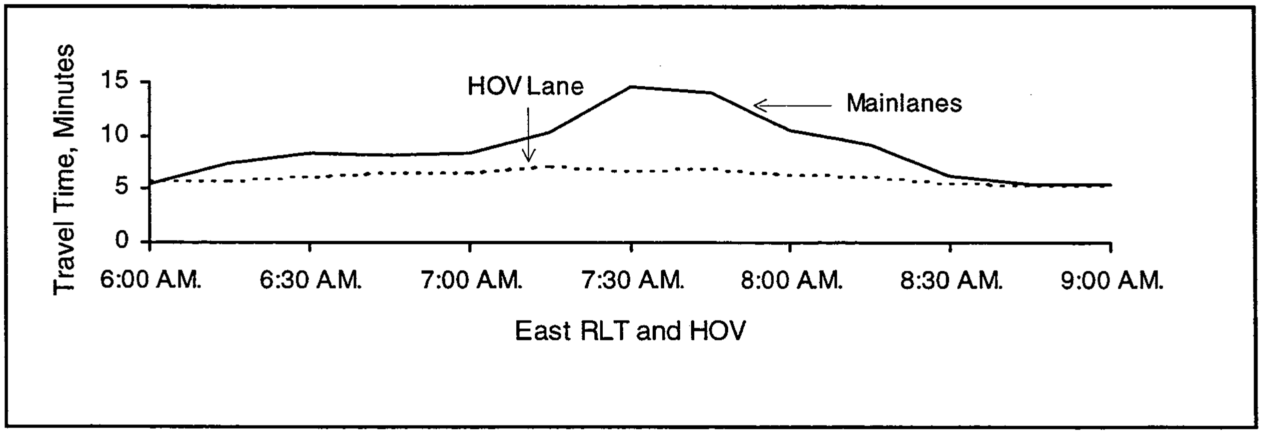
Figure 23. A.M. Peak Period Travel Time, Houston and Dallas Freeway HOV Lanes



Note: Travel times are from Park Place to Dowling.



Note: Travel times are from Bellfort to S. Shepherd.



Note: Travel times are from Central Expressway to Jim Miller.

Figure 23. (Con't) A.M. Peak Period Travel Time, Houston and Dallas Freeway HOV Lanes

Table 15. Summary of Selected Data Relating to Usage and Travel Time Savings on the Houston HOV Lanes

Data	Katy		North		Northwest		Gulf		Southwest		Total, 5 HOV Lanes	
	12/95	% Change[1]	12/95	% Change[1]	12/95	% Change[1]	12/95	% Change[1]	12/95	% Change[1]	12/95	% Change[1]
Kilometers of HOV Lane	20.9	0	21.7	0	21.7	0	19.5	0	18.5	0	102.3	0
HOV Lane Person Volume												
Daily	20,057	+7.0	20,918	+2.2	13,946	+6.9	7,233	-29.1	14,873	+8.1	77,027	+1.1
A.M. Peak Hour	3,497	+1.0	4,775	-12.2	3,920	-5.4	1,974	-34.8	3,222	-8.6	17,388	-6.6
A.M. Peak Period	8,348	+3.8	10,858	+7.9	7,446	+4.9	3,897	-22.8	6,638	-1.2	37,187	+0.6
P.M. Peak Hour	3,666	+13.3	3,913	-22.2	3,043	+48.9	2,360	-2.9	3,219	+6.5	16,201	+4.2
P.M. Peak Period	9,110	+14.3	9,164	-5.1	6,166	+7.3	4,533	-2.9	7,012	+13.3	35,985	+14.1
HOV Lane Vehicle Volume												
Daily	6,454	+5.9	5,737	+16.8	5,159	+7.5	3,215	-7.2	5,518	+10.4	26,083	+32.6
A.M. Peak Hour	835	+1.3	1,302	-1.5	1,434	-8.4	787	-21.4	1,181	-10.3	5,539	-4.2
A. M. Peak Period	2,457	+5.2	2,816	+16.0	2,729	+2.8	1,520	-10.7	2,384	-2.1	11,906	+6.6
P.M. Peak Hour	957	+20.4	1,100	+2.6	1,108	-3.3	787	+2.2	1,132	+7.4	5,084	+32.7
P.M. Peak Period	2,697	+12.6	2,472	+17.0	2,262	-28.1	1,520	-0.2	2,539	+19.0	11,490	+1.6
Avg. HOV Lane Vehicle Occupancy, A.M. Peak Hour	4.19	-0.2	3.67	-10.7	2.74	+3.4	2.51	-16.9	2.73	+1.9	2.95	-17.0
HOV Lane Travel Time Savings Avg. Peak Hour (min)[2]	15.5	+6.2	5.8	-19.4	6.5	+10.2	2.9	N/A	7.8	+30.0	38.5	+14.2

Notes: Peak hour is defined as the hour in which person movement is the highest. As a result, it is not always the same hour. The peak period is a 3.5 hour time period. See Appendices A through E for more detail.
N/A Not applicable.

[1]Percent change relative to 1994.
[2]Travel time data can vary significantly due to normal variations in traffic flow. Time shown is the average of a.m. and p.m. peak hours. It is also the average of data collected on a semi-annual basis. Due to these variations and the error associated with measuring these values, changes or differences in the range of 2 minutes or less have little significance.

Source: Texas Transportation Institute.

Table 16 includes selected usage and time savings data for the East RLT HOV facility. These statistics indicate a moderate increase in usage of the facility and a slight decrease in average peak hour time savings. As is the case on the North, Northwest, and Southwest HOV lanes in Houston (Table 15), vehicle volumes on the East RLT HOV have reached the point that free-flow conditions are not always maintained during the peak hour. Compared to the Houston HOV facilities, East R.L. Thornton has received little additional support such as increased bus service and/or new park-and-ride facilities.

Table 16. Summary of Selected Data Relating to Usage and Travel Time Savings on the East R.L. Thornton HOV Lane

Data	12/94	12/95	% Change
Miles of HOV Lane			
Morning	5.2	5.2	0
Evening	3.3	3.3	0
HOV Lane Person Volume			
Daily	12,879	13,572	+5.4
A.M. Peak Hour	3,341	3,494	+4.6
A.M. Peak Period	6,746	7,088	+5.1
P.M. Peak Hour	3,181	3,381	+6.3
P.M. Peak Period	6,025	6,484	+7.6
HOV Lane Vehicle Volume			
Daily	4,354	4,588	+5.4
A.M. Peak Hour	1,073	1,221	+13.8
A.M. Peak Period	2,289	2,500	+9.2
P.M. Peak Hour	1,043	1,012	-3.0
P.M. Peak Period	1,886	2,078	+10.2
Avg. HOV Lane Vehicle Occupancy, A.M. Peak Hour	3.11	2.86	-8.0
HOV Lane Travel Time Savings, Avg. Peak Hour (min)[1]	4.7	4.3	-8.5

Notes: Peak hour is defined as the hour in which person movement is the highest. As a result, it is not always the same hour. The peak period is a 3.0 time period. See Appendix E for more detail.

[1]Travel time data can vary significantly due to normal variations in traffic flow. Time shown is the average of a.m. and p.m. peak hours; it is also the average of data collected on a quarterly basis. Due to these variations and the error associated with measuring these values, changes in the range of 2 minutes or less have little significance.

The data in Tables 15 and 16 show the average peak-hour travel time savings measured on the Houston and Dallas HOV lanes. Variability exists in travel times on a daily basis; plus, there is some error in the measurement of travel times. As a result, differences or changes of only two to three minutes have little significance. It is interesting to note that the surveys show that the users of the HOV lanes typically perceive a much greater time savings than is actually realized (Table 17).

Table 17. Comparison of Actual and Perceived Travel Time Savings on the HOV Lanes, 1994

HOV Facility	Measured Peak-Hour Travel Time Savings (min)		Perceived HOV Travel Time Savings (min.)			
			Transit Riders		Carpoolers	
	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.
Katy	19.8	14.6	23	26	25	25
North[1]	6.9	4.5	15	19	15	19
Gulf[2]	2.1	1.5	10	15	12	15
Northwest	11.5	7.2	17	18	21	20
East R.L. Thornton	4.8	4.6	13	12	16	13

[1]Perceived travel time savings are 1990 data.
[2]Measured and Perceived travel time savings are 1989 data.

Source: Texas Transportation Institute surveys and data collection.

The historical data from the Houston and Dallas HOV evaluations provide a general relationship between HOV lane usage and travel time savings (Figure 24). These data suggest that HOV usage does not start to increase rapidly until travel time savings begin to exceed five minutes. While the relationship depicted in Figure 24 exhibits considerable data scatter, an explanation exists for most of the outlying data points.

The relationship illustrated in Figure 24 is critical in planning and justifying HOV improvements. The high-occupancy vehicle lane can be an appropriate improvement in freeway corridors that routinely experience intense congestion so that the HOV lane can offer, as a minimum, a five- to ten-minute travel time savings compared to driving in the freeway general-purpose lanes.

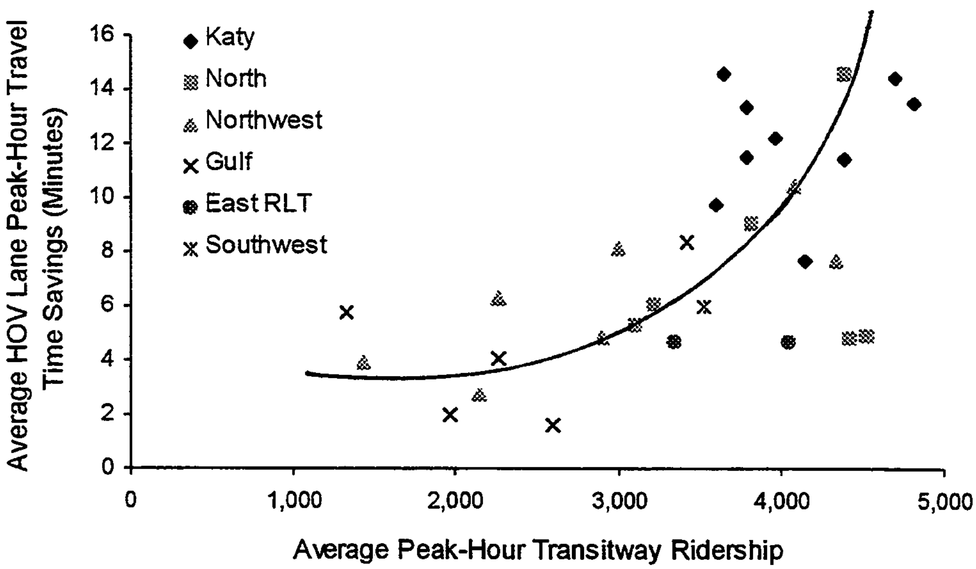


Figure 24. Relationship Between Peak-Hour HOV Lane Ridership and Peak-Hour HOV Lane Travel Time Savings

Travel time reliability is an additional characteristic of HOV lanes which appears to have a positive influence on the utilization of these priority facilities. Table 18 includes average speed and speed variability data for the Katy and East RLT Freeways. Examination of Table 18 shows that the speed variability (as illustrated by the standard deviation) for each of the HOV lanes is considerably less than that of the adjacent general-purpose lanes. The standard deviations in speed range from 1.8 kph (1.1 mph) to 3.7 kph (2.3 mph) for the HOV lanes, while the general-purpose lane standard deviations range from 9.3 kph (5.8 mph) to 14.8 kph (9.2 mph). Data collection for the Houston HOV facilities utilized automatic vehicle identification (AVI) equipment, while data collected for East R.L. Thornton utilized the floating car technique.

Table 18. Summary of Travel Time Reliability Data for Selected HOV Facilities, 1995

Facility	Peak Hour[1]	Standard Deviation, kph (mph)[2]	
		General-Purpose Lanes	HOV Lane
Katy	Morning	11.6 (7.2)	1.8 (1.1)
	Evening	9.3 (5.8)	2.7 (1.7)
North	Morning	11.8 (7.3)	3.7 (2.3)
	Evening	11.1 (6.9)	3.1 (1.9)
Northwest	Morning	14.8 (9.2)	3.7 (2.3)
	Evening	9.5 (5.9)	2.9 (1.8)

[1]Morning and evening peak hours defined as 7:00 to 8:00 a.m. and 5:00 to 6:00 p.m., respectively.
[2]Data from 1994.

Source: Texas Transportation Institute data collection.

Statistical analyses of the data included in Table 18 indicate a significant difference (at a 99% confidence level, $\alpha = 0.01$) between the travel time reliability offered by the HOV lanes versus general-purpose freeway lanes. Figure 25 includes a speed profile illustrating this significant difference during a typical peak period. Illustrated in Figure 26 are average peak-hour travel speeds for the Northwest Freeway and HOV lane during a typical month. As can be noted in Figure 26, there is a greater variation (i.e., less reliability) in general-purpose lane speeds relative to HOV lane speeds.

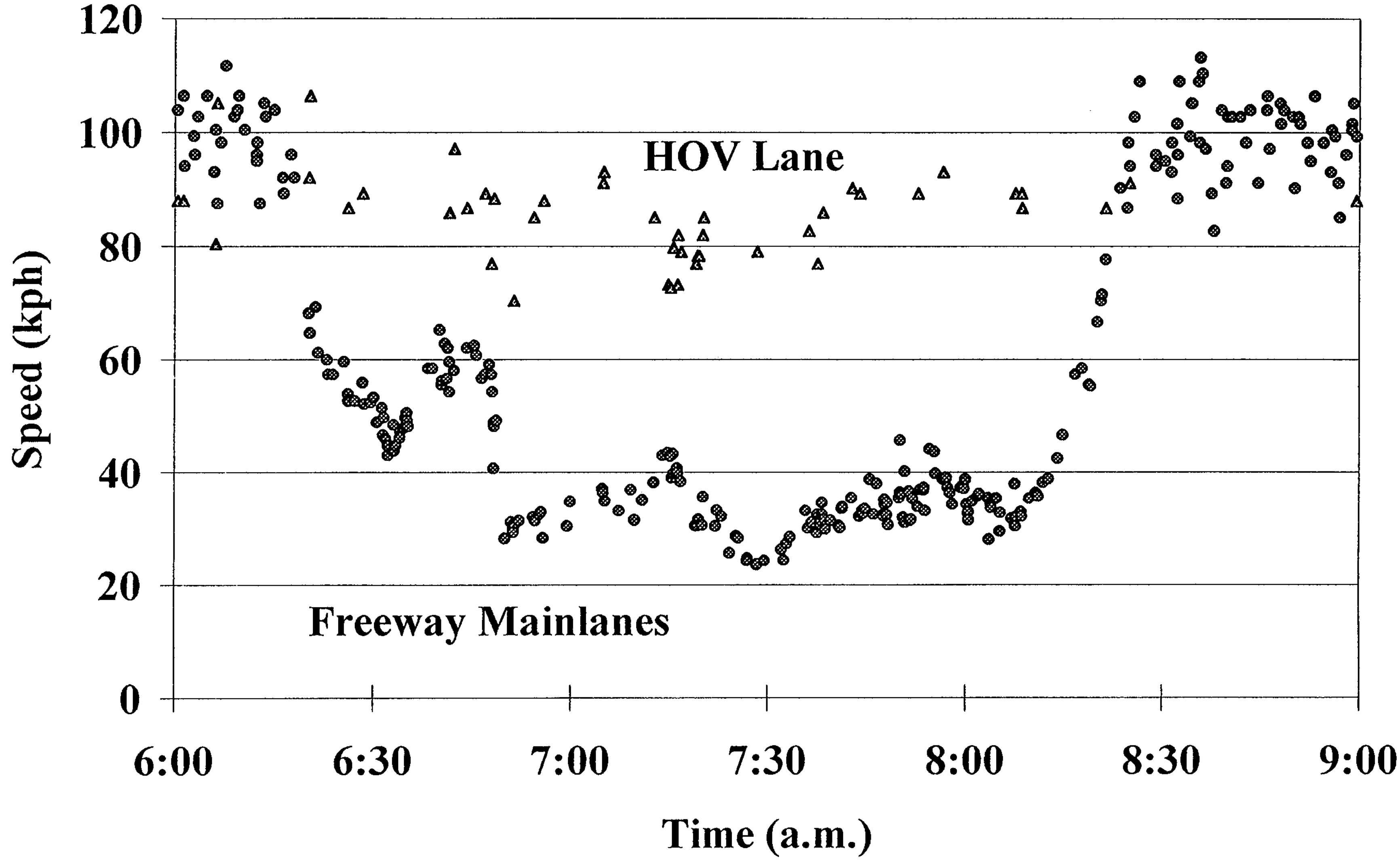


Figure 25. Morning Peak Period Speed Profile, Northwest Freeway and HOV Lane (1994)

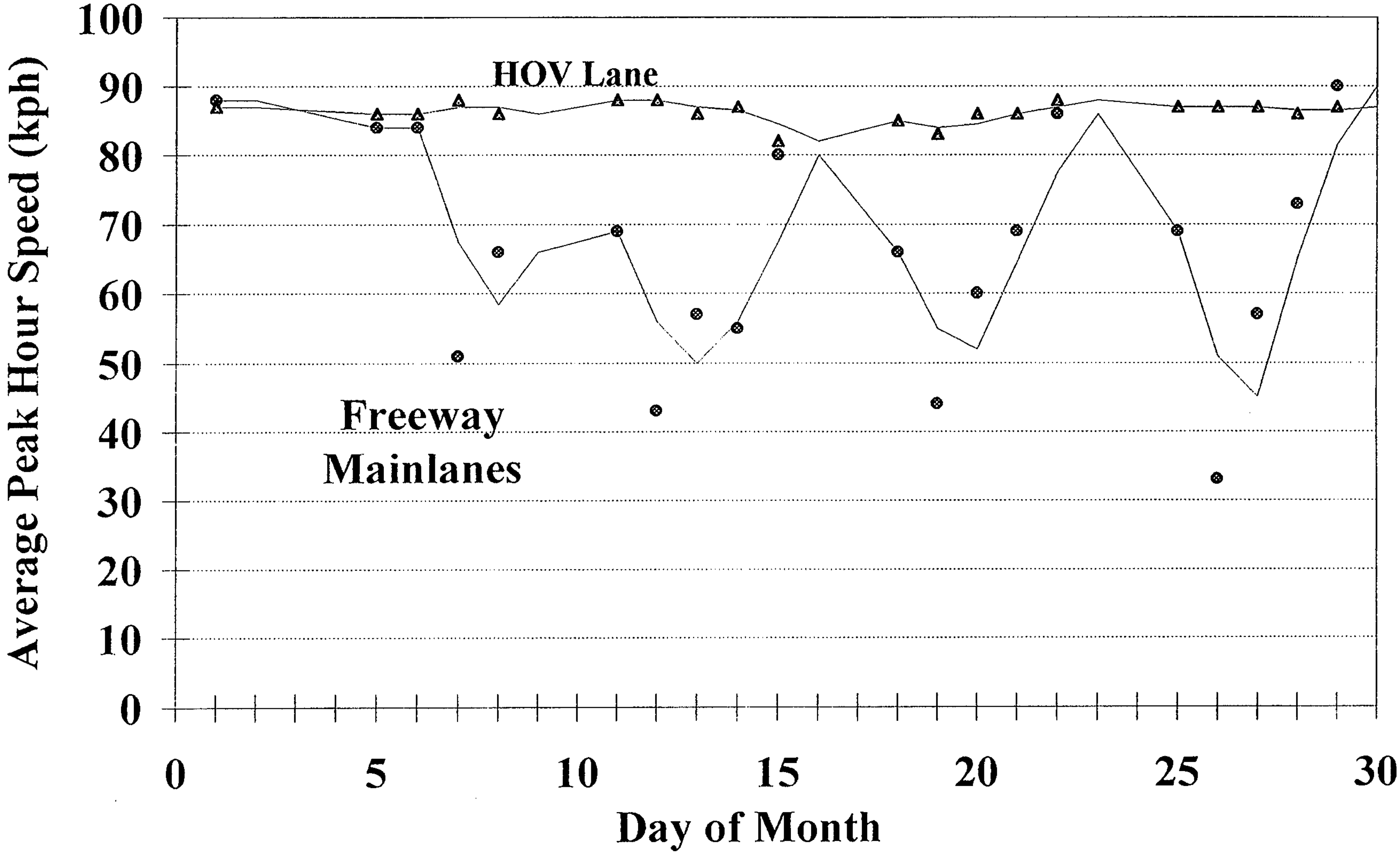
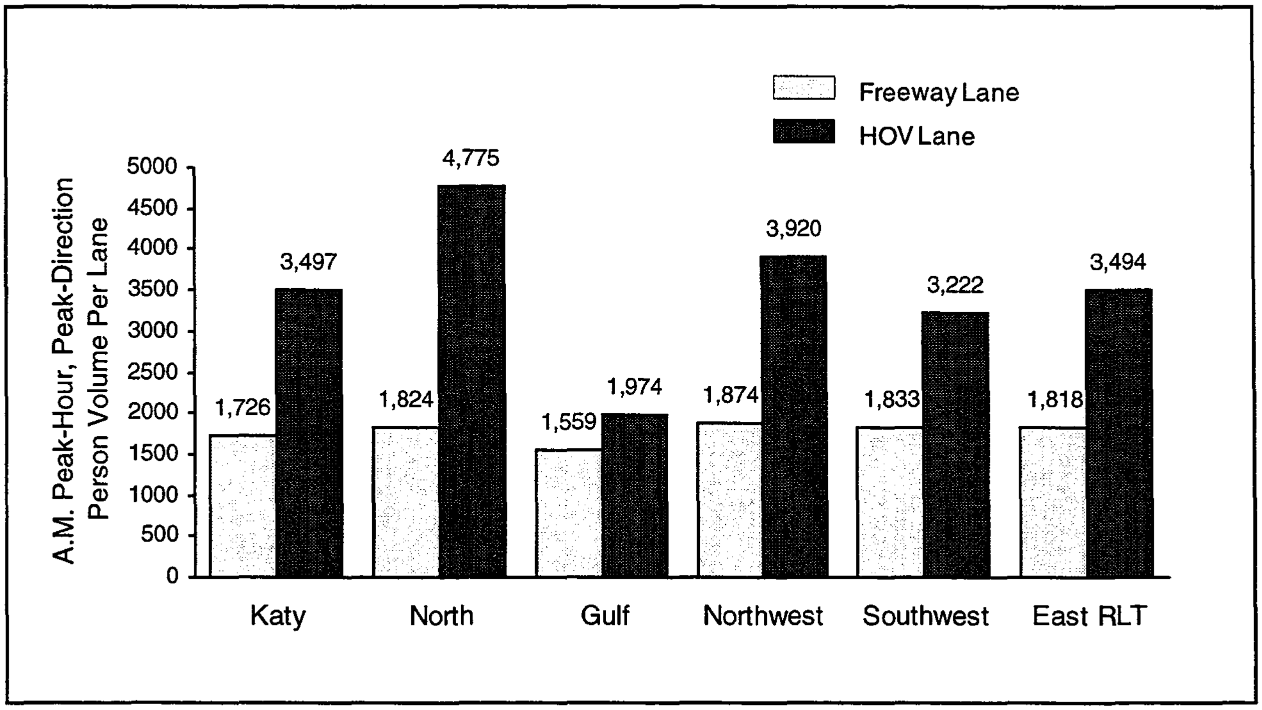


Figure 26. Average Peak-Hour Speeds for Northwest Freeway and HOV Lane, 1994

CHANGES IN ROADWAY PERSON MOVEMENT

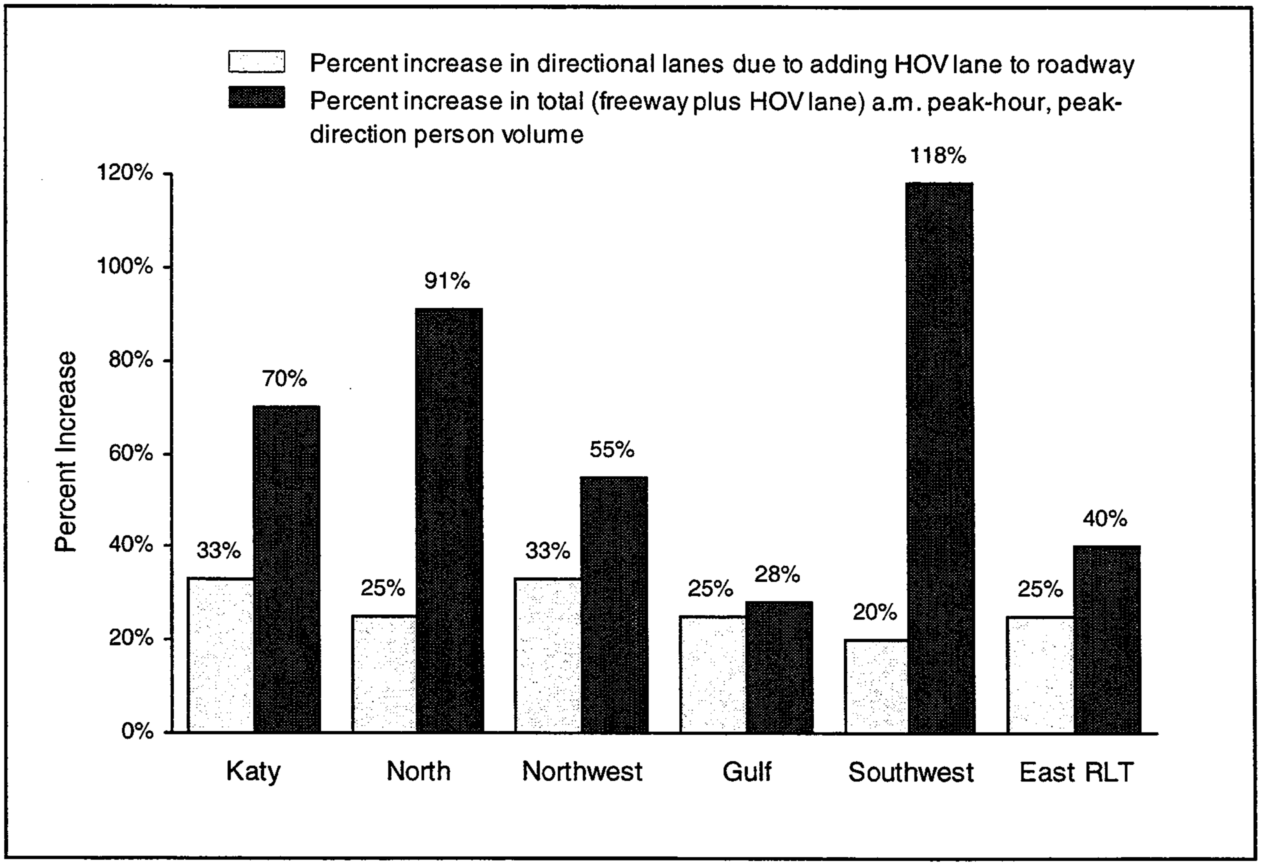
A major reason for implementing high-occupancy vehicle lanes is to increase the effective person-movement capacity of a roadway. There is increasing recognition that emphasis needs to begin to be focused on moving people rather than vehicles. The HOV facilities are incentives to help bring about this increase in person movement. The HOV lanes do typically move a greater volume of persons than do the freeway lanes (Figure 27). With the exception of the Gulf HOV lane, Texas HOV facilities are moving 75 percent to 190 percent more persons per lane than are the freeway mainlanes during the peak hour. To an extent, however, this would be expected since nearly all of the higher-occupancy vehicles are utilizing the HOV lane.



Source: See data in appendices.

Figure 27. Peak-Hour, Peak-Direction Person Volumes Per Lane on Houston Freeways and HOV Lanes

Since implementation of the HOV lane does increase the number of directional lanes, for the priority lane to be effective it should at least increase person movement by an amount greater than the increase in lanes added to the roadway due to implementing an HOV lane. If this is not the case, the effectiveness of the HOV lane is questionable. The data show that the HOV lanes in Texas are producing an increase in person movement (Figure 28). In all instances where data are available, the increase in person movement exceeds the increase in lanes provided.



Source: See data in appendices.

Figure 28. Increase in Total (Freeway plus HOV Lane) A.M. Peak-Hour, Peak-Direction Person Movement, Comparison of Pre-HOV Lane Conditions to Present

CHANGES IN AVERAGE VEHICLE OCCUPANCY

For the HOV lanes to generate the disproportionate increases in person movement reflected in Figure 28, it is necessary to increase the average vehicle occupancy (persons per vehicle) characteristic of the roadway. The high-occupancy vehicle lane is intended to offer a travel alternative that a significant percentage of commuters will find attractive and, as a result, choose to either carpool or ride a bus. If this occurs, an increase in average vehicle occupancy should result.

On the two more mature Houston HOV lanes (Katy and North), peak-hour average vehicle occupancies are unusually high for Texas (or other southwestern states) freeways, being approximately 1.5 persons per vehicle (Figure 29). These occupancies are the combined average of all freeway mainlanes plus all HOV facility traffic.

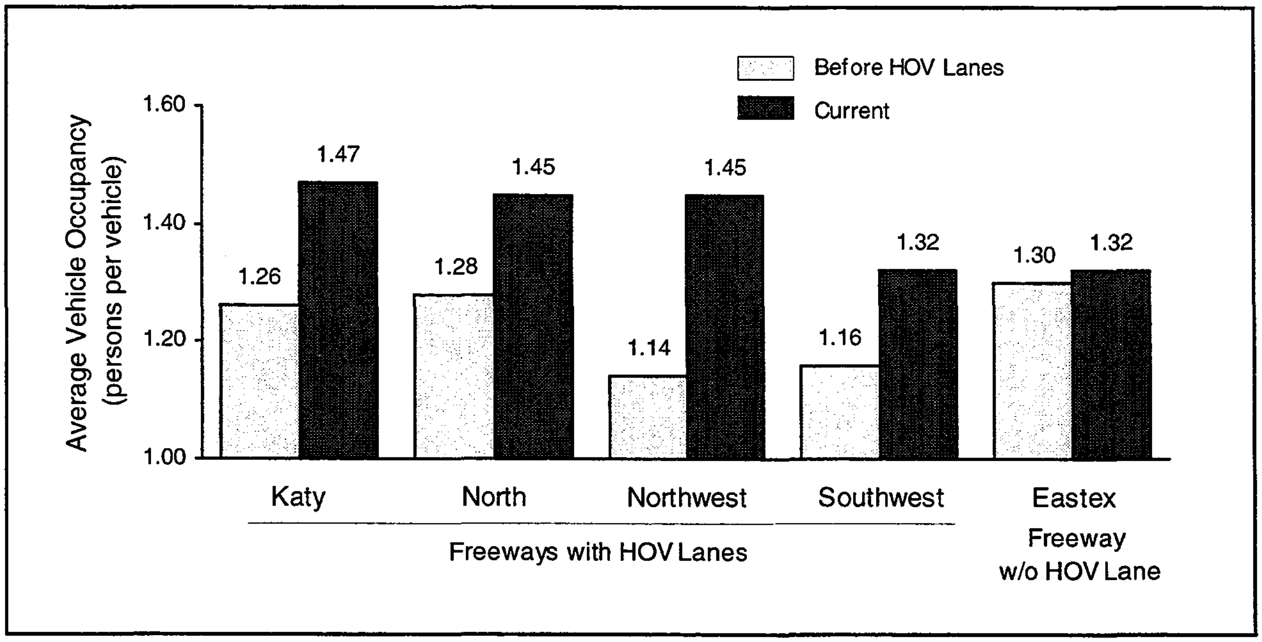


Figure 29. Change in A.M. Peak-Hour, Peak-Direction Average Vehicle Occupancy, Freeways With and Without HOV Lanes

During the time period being studied, the percentage increase in average vehicle occupancy on the freeways with HOV lanes has been significant. This has not been the case on a freeway not having an HOV facility (Figure 30).

The data clearly show that the presence of the HOV lane has resulted in a meaningful increase in average vehicle occupancy. On the freeways with HOV lanes, in comparison to pre-HOV lane conditions, the average peak-hour, peak-direction vehicle occupancy has increased by at least 20 percent in most cases. Over the same time period, occupancy on a freeway without an HOV lane has experienced an eight percent decrease in average vehicle occupancy.

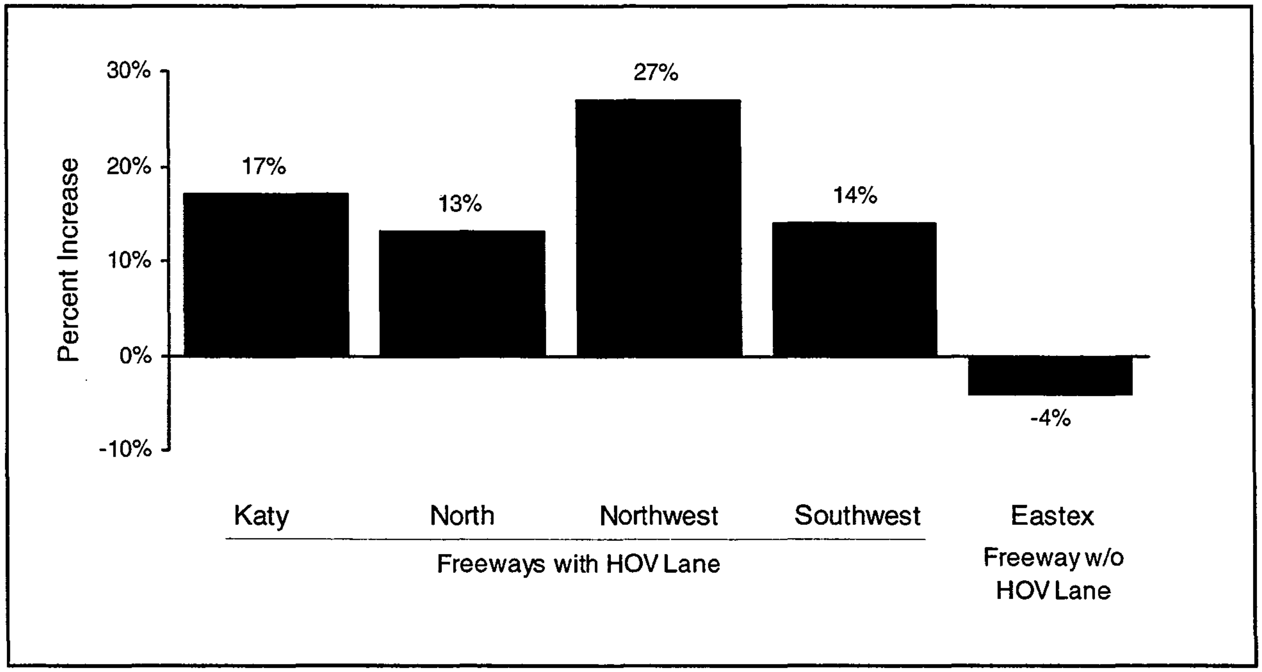


Figure 30. Percentage Change (Pre-HOV Lane to Present) in Average Vehicle Occupancy, A.M. Peak-Hour, Peak-Direction, Freeways With and Without HOV Lanes

The data from Houston suggest that the HOV lanes have increased vehicle occupancy. For the HOV facilities to be successful, it is important that they generate new rideshare patrons, not merely divert existing rideshare users to the HOV lane. The next two sections of this report review the data relative to changes in carpooling and bus ridership resulting from the HOV implementation.

CHANGES IN CARPOOLING

Survey data suggest that relatively few carpools now using the HOV lanes were existing carpools that diverted to the HOV lane from parallel routes (Table 19). This indicates that the increases that occurred in average vehicle occupancy were primarily from factors other than this diversion.

Table 19. Carpools That Diverted to the HOV Facility From Parallel Routes

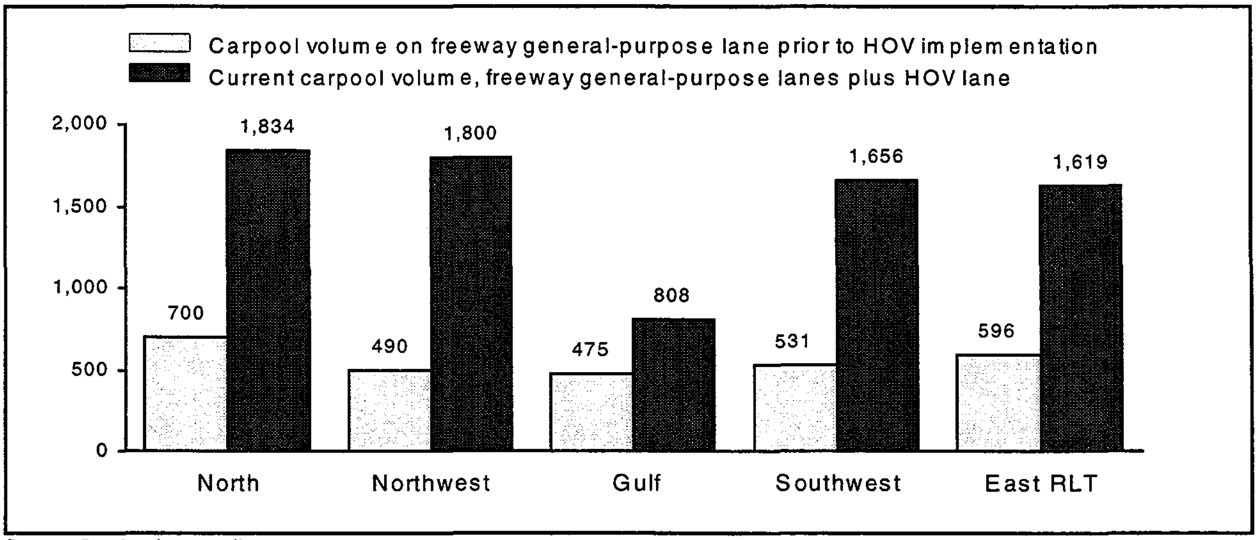
HOV Facility	Percent of HOV Carpoolers Whose Previous Mode Was Carpooling[1]			Percent of Those Carpoolers Who Previously Used a Parallel Route[2]		
	1989	1990	1994	1989	1990	1994
Katy	26%	29%	19%	15%	13%	11%
North	---	40%	---	---	19%	---
Gulf	44%	---	---	14%	---	---
Northwest	46%	33%	22%	11%	15%	9%
East R.L. Thornton	---	---	51%	---	---	19%
Unweighted Average	39%	34%	31%	13%	16%	13%

[1]The mode of travel prior to carpooling on the HOV lane.
[2]As an example, in 1990, 13% of 29%, or approximately 4%, of the total carpools using the Katy HOV lane are carpools that diverted to the HOV lane from parallel routes. This does not include carpools that previously used the freeway general-purpose lanes.

Source: Texas Transportation Institute surveys.

There have been significant increases in carpool volumes since carpools were allowed to use the HOV facilities (Figure 31). Increases of approximately 200 percent are typical. To assess the effectiveness of the high-occupancy vehicle lanes, it is necessary to develop estimates of how many of the carpools using the HOV lanes are new carpools formed largely due to the implementation of these priority lanes.

The estimate of new carpools is further complicated in that carpools naturally have relatively high turnover rates. Just to keep the carpool volumes constant, many new carpools need to be formed to replace those that discontinue. Two approaches exist to try to define this impact. First, if HOV lanes create more carpools, it might be reasonable to assume that, because of the HOV lane, those carpools would remain in existence longer than would carpools in corridors not having HOV facilities. Second, a comparison of the changes in carpool volumes over time between corridors having and not having HOV lanes helps to isolate the impacts of the HOV facilities.

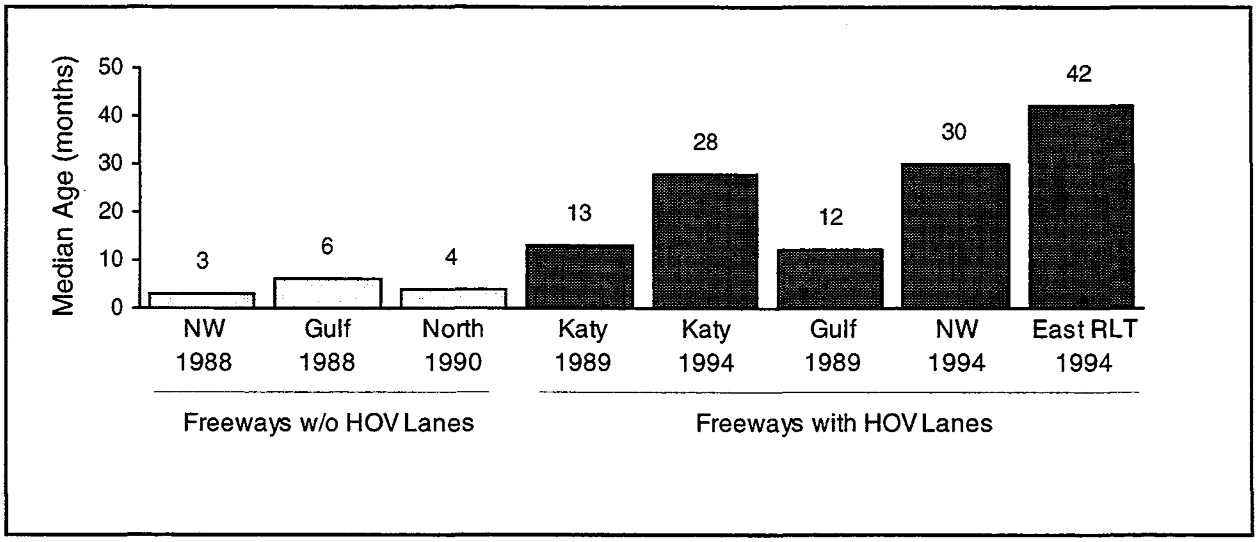


Source: See data in appendices.

Figure 31. Volume of 2+ Carpools (Freeway Plus HOV Lane), A.M. Peak-Hour, Peak-Direction, Pre-HOV Lane and Current

Available data suggest that carpools in corridors with HOV lanes do remain in existence substantially longer than carpools in corridors without HOV lanes (Figure 32). The median age of a carpool on an HOV facility varies from over two to seven times greater than the median carpool age on a non-HOV facility. It appears that the presence of an HOV lane is causing carpools to remain in existence longer.

Comparing what has occurred on freeways with HOV lanes to what has taken place over the same time period on freeways without HOV lanes helps to isolate the impacts of the HOV facilities (Figure 33). The magnitude of increase that has occurred on the freeways with priority lanes simply has not taken place in the corridor without a HOV lane. The increase in carpools on the freeways with HOV lanes has been several times greater than the increase experienced on a freeway without an HOV lane. Since the major difference in the corridors being compared is the availability of an HOV lane, a conclusion is that the priority lane is a significant factor in creating new carpools.



Source: Texas Transportation Institute surveys.

Figure 32. Median Age of a Carpool in Corridors With and Without High-Occupancy Vehicle Lanes

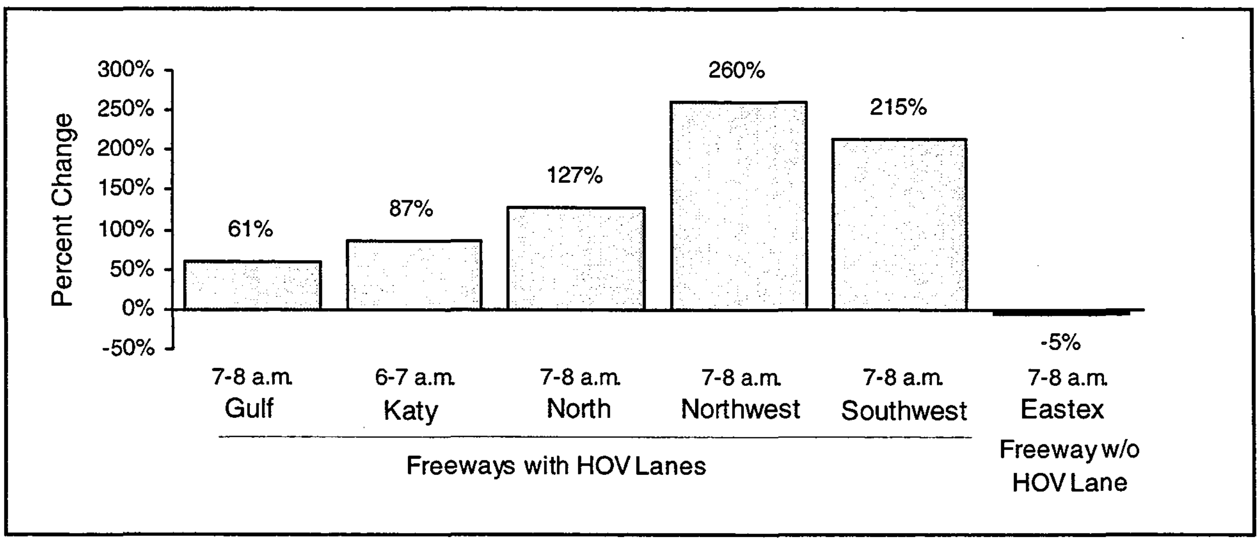
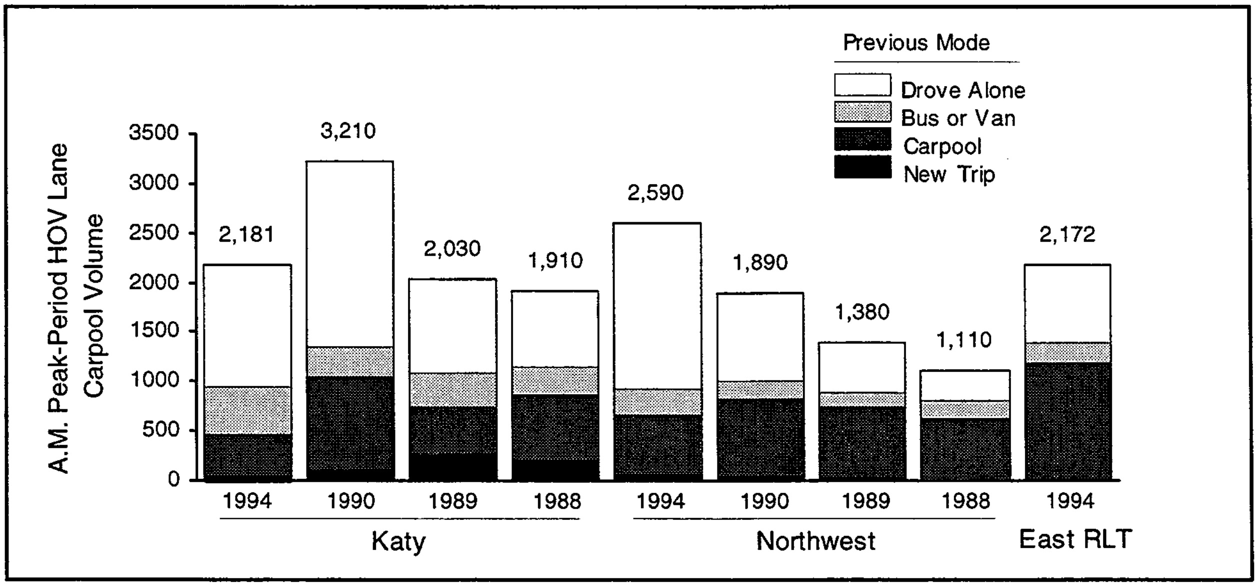


Figure 33. Percent Change (Pre-HOV Lane to Present) in 2+ Carpool Volumes, A.M. Peak-Hour, Peak-Direction, Freeway Volume Plus HOV Lane Volume

Other approaches exist for identifying that component of carpooling that has been created as a result of the HOV lane. One indicator is the "previous mode" of travel for carpoolers; that is, prior to carpooling on the HOV lane, how was the trip made (Figure 34)? Those data indicate that somewhere between 35 percent and 66 percent of carpoolers on HOV lanes were previously in "drive alone" vehicles; as the HOV lanes become more mature and carpool volumes increase, this percentage increases. The sum of "drive alone" plus "new trips," which in 1990 was in the range of 43 percent to 63 percent of total carpools on the HOV lanes, can be considered as an initial indication of the volume of new carpools created as a result of the HOV lane.



Source: TTI Surveys.

Figure 34. Previous Mode of Travel for HOV Lane Carpoolers

However, as pointed out previously, due to the relatively high turnover rate of carpools, at least some of those with a previous mode of "drive alone" would, in all likelihood, have formed carpools regardless of whether an HOV lane were present.[10] To try to identify this portion of carpool

[10]Similarly, some of the existing carpools would have changed to a drive alone mode.

demand, researchers surveyed carpoolers using the HOV lanes to assess the importance of the HOV lane in their decision to carpool.

One question asked was, "how important was the HOV lane in your decision to carpool?" The responses (Table 20) suggest that the HOV lane was "somewhat important" or "very important" in the decision to carpool to over 80 percent of the HOV carpoolers surveyed in 1994; that percentage has generally been increasing over time as more carpools form.

Table 20. Responses to Question "How Important Was the HOV Lane in Your Decision to Carpool?"

HOV Facility	Response (percent)								
	Very Important			Somewhat Important			Not Important		
	1989	1990	1994	1989	1990	1994	1989	1990	1994
Katy	73	64	82	14	20	13	13	17	5
North	---	60	---	---	21	---	---	19	---
Gulf	48	---	---	19	---	---	33	---	---
Northwest	56	74	82	20	9	12	24	17	6
East R.L. Thornton	---	---	64	---	---	19	---	---	17
Unweighted Average	59	66	76	18	17	15	23	17	9

Source: Texas Transportation Institute surveys.

A second question asked carpoolers if they would be carpooling if there were no HOV lane (Table 21). Over half of the respondents to the 1994 surveys in Houston indicated that they would not likely carpool if there were no HOV lanes.

Table 21. Responses to Question "If the HOV Lane Had Not Opened to Carpools, Would You Be Carpooling Now?"

HOV Facility	Response (percent)								
	Yes			No			Not Sure		
	1989	1990	1994	1989	1990	1994	1989	1990	1994
Katy	42	37	40	42	43	39	16	20	21
North	---	48	---	---	40	---	---	12	---
Gulf	68	---	---	20	---	---	12	---	---
Northwest	52	45	47	30	39	29	18	16	23
East R. L. Thornton	---	---	73	---	---	14	---	---	13
Unweighted Average	54	43	53	31	41	27	15	16	19

Source: Texas Transportation Institute surveys.

Implementation of the HOV lanes appears to have lengthened the median life of a carpool and increased the volume of carpools. The type of increase in carpooling experienced on freeways with HOV facilities simply has not taken place on freeways that do not have HOV facilities. The surveys indicate that the HOV lane is an important factor in the decision to carpool. It appears that on the HOV lanes surveyed, approximately 40 percent of the current HOV carpoolers previously drove alone and formed a carpool as a result of the HOV facility (Table 22).

Table 22. Estimated Impact of HOV Lanes in Forming New Carpools

HOV Facility	Apparent % New Carpools Based on Previous Mode[1]			Would You Carpool if No HOV Lane[2]									Est. % of 1994 HOV Lane Carpools Formed Due to HOV Lane[3]
				Yes			No			Not Sure			
	1989	1990	1994	1989	1990	1994	1989	1990	1994	1989	1990	1994	
Katy	61%	62%	60%	42%	37%	40%	42%	43%	39%	16%	20%	21%	50%
North	---	43%	---	---	48%	---	---	40%	---	---	12%	---	46%[4]
Gulf	45%	---	---	68%	---	---	20%	---	---	12%	---	---	26%[5]
Northwest	48%	57%	67%	52%	45%	47%	30%	39%	29%	18%	16%	23%	47%
East R.L. Thornton	---	---	35%	---	---	73%	---	---	14%	---	---	13%	21%
Unweighted Average	51%	54%	54%	54%	43%	53%	31%	41%	---	15%	16%	---	43%

[1]The sum of "drove alone" and "new trips."
[2]See Table 21.
[3]It is assumed that the sum of "no" responses plus one-half of the "not sure" responses equals the percentage of total HOV lane carpools that were formed due to implementing the HOV lane. The previous mode response provides a logic check for this conclusion.
[4]1990 data.
[5]1989 data.
Source: Texas Transportation Institute surveys.

Thus, on a freeway with an HOV facility that has operated several years and offers meaningful time savings, the presence of that HOV facility can be expected to essentially double carpooling.

HOV Carpool Benefits

Carpool use of HOV facilities increases operational and enforcement problems. However, this use also creates several benefits, including 1) an increase in the perception that the HOV lanes are adequately utilized; 2) the capability to serve travel patterns, particularly suburban-to-suburban travel, that can be difficult to serve with conventional, fixed-route bus service; and 3) a lowering of the public operating cost per passenger-kilometer on the HOV facility.

Perception of Underutilization

A common criticism of HOV lanes is that, based on the vehicular volumes using the lanes, they can appear underutilized. Previous research in Texas has shown that, unless peak-hour HOV volumes are at least 400 to 500 vph, a strong perception of underutilization is likely to exist.[11] On the Houston HOV lanes, bus volumes are generally less than 70 buses per hour, and vanpool volumes are typically below 30 vehicles per hour. Thus, carpools are the means of greatly increasing vehicular volume on the HOV facilities. Typically, 95 percent of the vehicle volume on the HOV lanes is carpools. Consequently, carpools can be an effective tool for increasing the perception that the HOV lane is adequately utilized.[12]

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[11] Texas Transportation Institute Research Report 484-10.

[12] Section VIII of this report includes additional discussion of this perception issue.

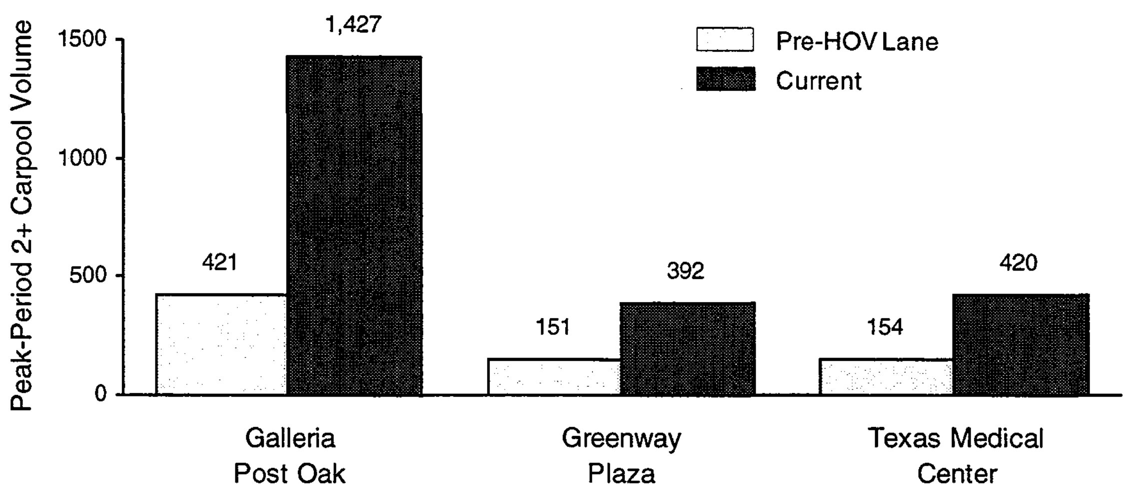
Travel to Locations Other Than Downtown

As shown previously in this report (see Table 12), orientation of the overwhelming majority of HOV bus service is to downtown. While that serves a useful purpose, it does not necessarily help in serving the growing travel to other major employment centers. A significant percentage of HOV carpool trips are not to downtown (see Table 13), and implementing the HOV lanes has greatly increased the volume of carpools traveling to the other three major activity centers (Table 23). That volume has almost tripled (Figure 35). Being able to help serve these dispersed trips contributes to the effectiveness of the HOV lanes.

Table 23. Increases in A.M. Peak-Period Carpooling to the Major Suburban Activity Centers, Pre-HOV Lane to Present

HOV Facility	Activity Center and 2+ Carpool Vehicle Volumes					
	Galleria/Post Oak		Greenway Plaza		Texas Medical Center	
	Pre-HOV Volume	1991 Volume	Pre-HOV Volume	1991 Volume	Pre-HOV Volume	1991 Volume
Katy	170	354	49	135	43	150
% increase	---	+108%	---	+176%	---	+249%
North	169	315	75	112	56	125
% increase	---	+ 86%	---	+ 49%	---	+123%
Northwest	82	826[1]	27	145[1]	55	145[1]
% increase	---	+907%	---	+437%	---	+164%
TOTAL	421	1,495	151	392	154	420
% increase	---	+367%	---	+221%	---	+179%

Note: Volumes shown in carpool vehicles per hour. 1991 volumes include both freeway general-purpose lane and HOV lane carpools.
[1]1994 data
Source: Texas Transportation Institute data collection.



Source: Texas Transportation Institute data collection.

Figure 35. Increase (Pre-HOV to Present) in Peak-Period 2+ Carpool Volumes Destined to Major Non CBD Activity Centers, All Houston HOV Lanes

Marginal Public Operating Cost

Unlike bus transit service, carpools are privately owned vehicles, and their operation does not require a direct public operating subsidy. Some additional operational and enforcement costs are incurred because carpools are allowed to use the priority facilities. If it is assumed that approximately half of the total operating and enforcement cost should be assigned to carpools (see Table 7), the public operating cost for carpools is less than one cent per passenger-kilometer, which helps make the HOV lanes attractive alternative transportation improvements. HOV lanes accommodate carpools, which are serving roughly 60 percent of total HOV person trips, at a minimal marginal cost (refer to Figure 13).

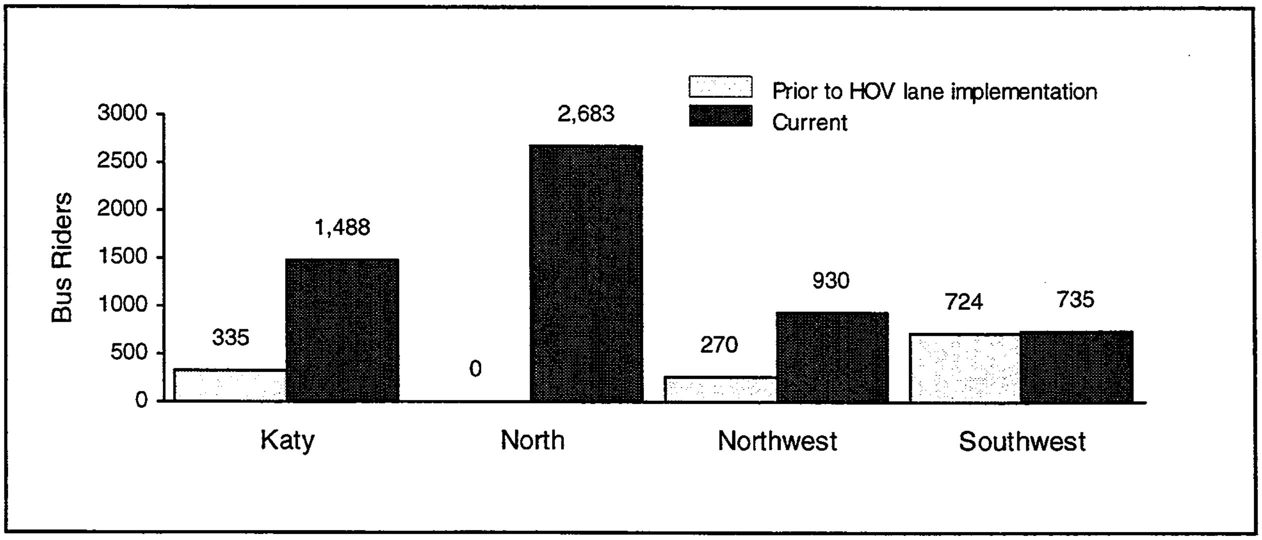
BUS TRANSIT OPERATIONS

Data shown previously (see Table 12) indicate that the HOV facilities have been successful in attracting a new type of bus rider. Young, educated, professional Texans are riding buses on the high-occupancy vehicle lanes. This section of the report presents data describing HOV impacts on bus transit.

Changes in Bus Ridership

The previous section determined that the HOV lanes have been responsible for creating a significant volume of new carpools. The available data suggest that these priority lanes have also caused increases in bus ridership.

With the opening of the HOV lanes, increases in bus ridership have been realized (Figure 36). In the North Freeway corridor, there was essentially no bus service prior to the opening of the contraflow lane in 1979. It appears that the HOV lanes have been a meaningful factor in generating the observed ridership increases.

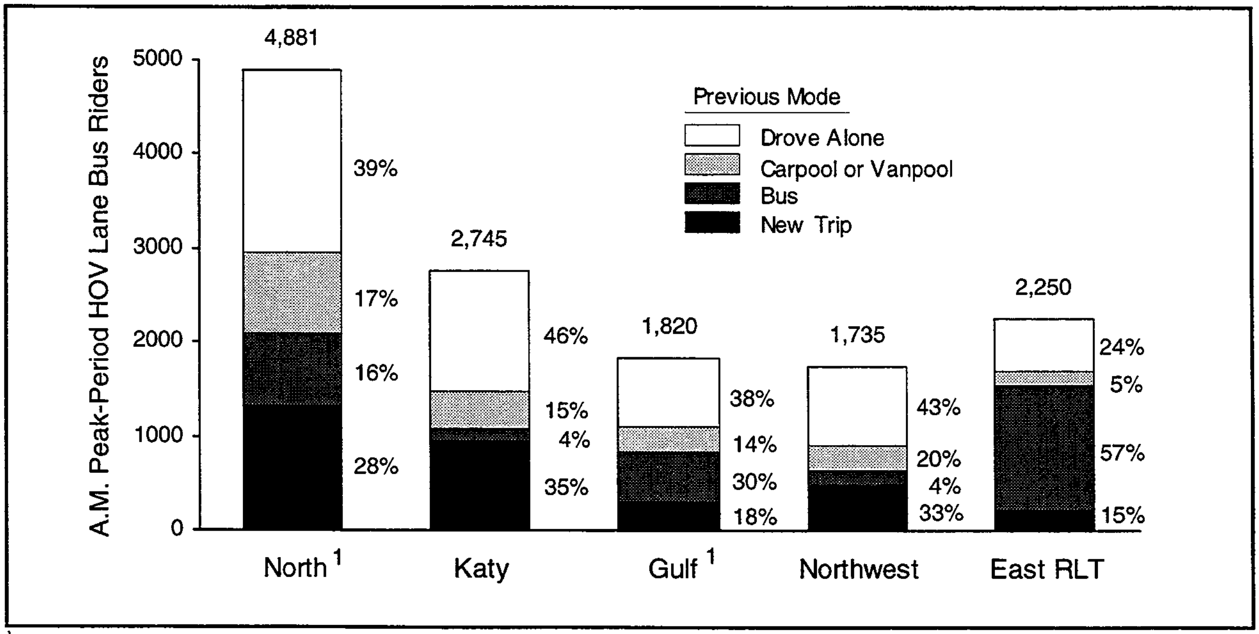


Source: See data in appendices.

Figure 36. Number of Bus Riders, A.M. Peak-Hour, Peak-Direction, Pre-HOV Lane and Current

An examination of the previous mode of travel for HOV bus riders provides an indication that the HOV lanes have created new bus riders (Figure 37). These data suggest that fewer than 30 percent of existing HOV lane bus riders rode a bus prior to using the HOV lane. In Houston, over a third of the bus riders previously drove alone, while in Dallas, this figure was approximately 24%. The unweighted average of the survey data regarding previous mode of travel indicates that 38 percent drove alone; 14 percent carpooled or vanpooled; 22 percent rode a bus; and 26 percent did not make the trip.

Researchers have surveyed the HOV lane bus riders on numerous occasions to help determine the importance of the HOV lane in their decision to ride a bus. The data suggest that the availability of an HOV lane has been a very important consideration in deciding to ride a bus (Table 24). Over time, the importance of the HOV lane in attracting riders appears to be increasing.



[1]Previous mode percentages from 1989 survey.
Source: TTI Surveys, 1994.

Figure 37. Previous Mode of Travel for HOV Lane Bus Riders, 1994

Table 24. Responses to Question "How Important Was the Opening of the HOV Lane in Your Decision to Ride a Bus?"

HOV Facility	Response to Question (percent)											
	Very Important				Somewhat Important				Not Important			
	1988	1989	1990	1994	1988	1989	1990	1994	1988	1989	1990	1994
Katy	68	72	72	93	18	17	19	5	14	11	9	2
North	---	---	73	---	---	---	17	---	---	---	10	---
Gulf	---	54	---	---	---	22	---	---	---	24	---	---
Northwest	---	71	76	89	---	21	15	10	---	8	9	2
East R.L. Thornton	---	---	---	65	---	---	---	19	---	---	---	16
Unweighted Average	68	66	74	82	18	20	17	11	14	14	9	7

Source: Texas Transportation Institute surveys.

A second question asked bus riders if they would be riding a bus if there were no HOV lane (Table 25). The data for the facilities surveyed in 1994 suggest that about half of total bus ridership would not be riding the bus if there were no HOV facility.

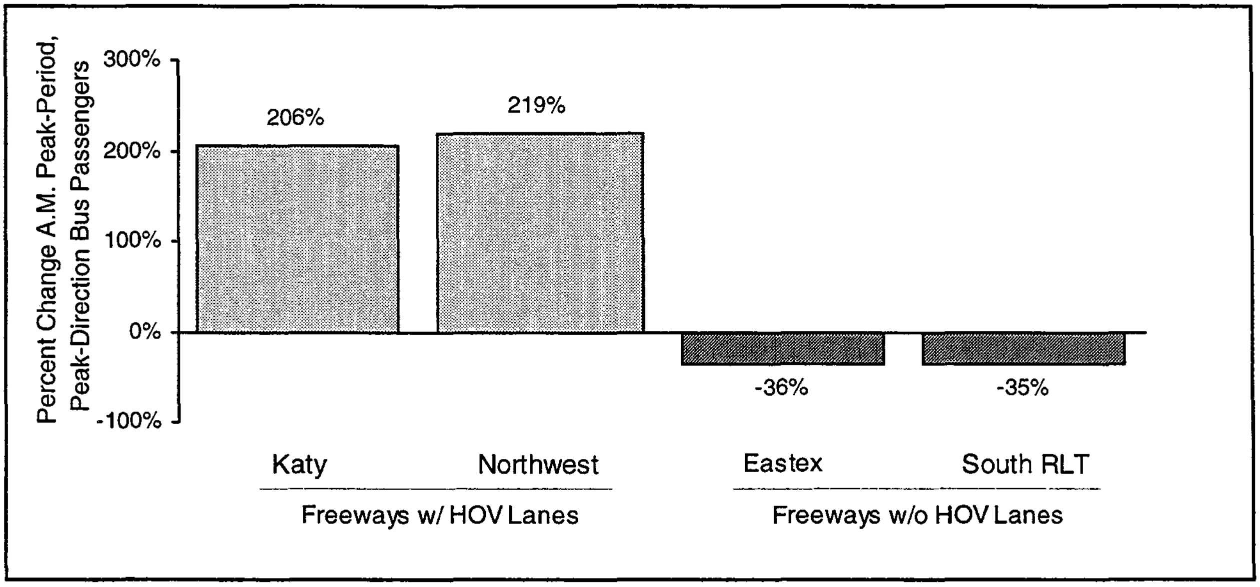
Table 25. Responses to Question "If the HOV Lane Had Not Opened, Would You be Riding a Bus Now?"

HOV Facility	Apparent % New Bus Riders Based on Previous Mode[1]	Response to Question (percent)									Est. % of Bus Ridership Formed Due to HOV Lane[2]
		Yes			No			Not Sure			
		1989	1990	1994	1989	1990	1994	1989	1990	1994	
Katy	78	32	35	18	36	31	50	32	33	32	66%
North	52[3]	---	33	---	---	37	---	---	30	---	52%[3]
Gulf	47[4]	56	---	---	22	---	---	22	---	---	33%[4]
Northwest	78	41	41	26	39	35	35	20	24	39	55%
Est R.L. Thornton	33	---	---	74	---	---	9	---	---	17	17%
Unweighted Average	62	43	36	39	32	34	31	25	29	29	46%

[1]The sum of "drove alone" and "new trips."
[2]It is assumed that the sum of "no" responses plus one-half of the "not sure" responses equals the percentage of total HOV bus riders that are riding a bus due to the presence of the HOV lane. The "previous mode" data provide a logic check for this conclusion.
[3]From 1990 survey.
[4]From 1989 survey.
Source: Texas Transportation Institute surveys.

Bus ridership has increased more rapidly in corridors having HOV lanes than it has in corridors without HOV lanes (Figure 38). Again, these data seem to confirm that the HOV lane has been a primary force in increasing bus ridership. Peak-period, peak-direction ridership has increased by 206 to 219 percent in the corridors with HOV lanes in Houston; the increases in peak-hour ridership have been even greater than the peak-period increases.

Thus, on a freeway with an HOV facility that has operated several years and offers meaningful time savings, the presence of that HOV facility can be expected to more than double transit ridership.



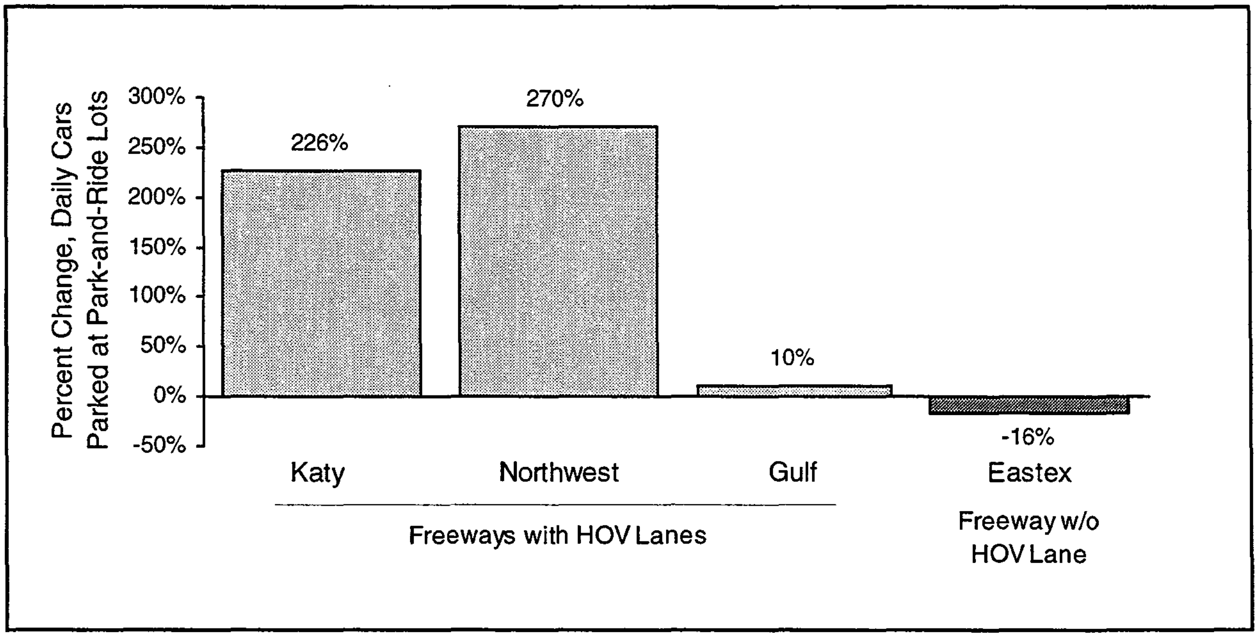
Note: North Freeway data are not shown since no bus service existed prior to implementation of the HOV contraflow lane.

Source: See data in appendices.

Figure 38. Change (Pre-HOV Lane to Present) in A.M. Peak-Period, Peak-Direction Bus Ridership, Freeways With and Without HOV Lanes

Change in Park-and-Ride Lot Utilization

As would be expected, significant increases in the use of park-and-ride lots have also occurred in the corridors with high-occupancy vehicle lanes (Figure 39). Both the Northwest and the Katy corridors have experienced an increase of over 200 percent in the use of the park-and-ride lots. In a corridor not having a high-occupancy vehicle lane, there has been a slight decrease in park-and-ride usage during the same period of time.



Source: See data in appendices.

Figure 39. Percent Change (Pre-HOV Lane to Present) in Daily Vehicles Parked in Corridor Park-and-Ride Lots

Enhancement of Bus Service

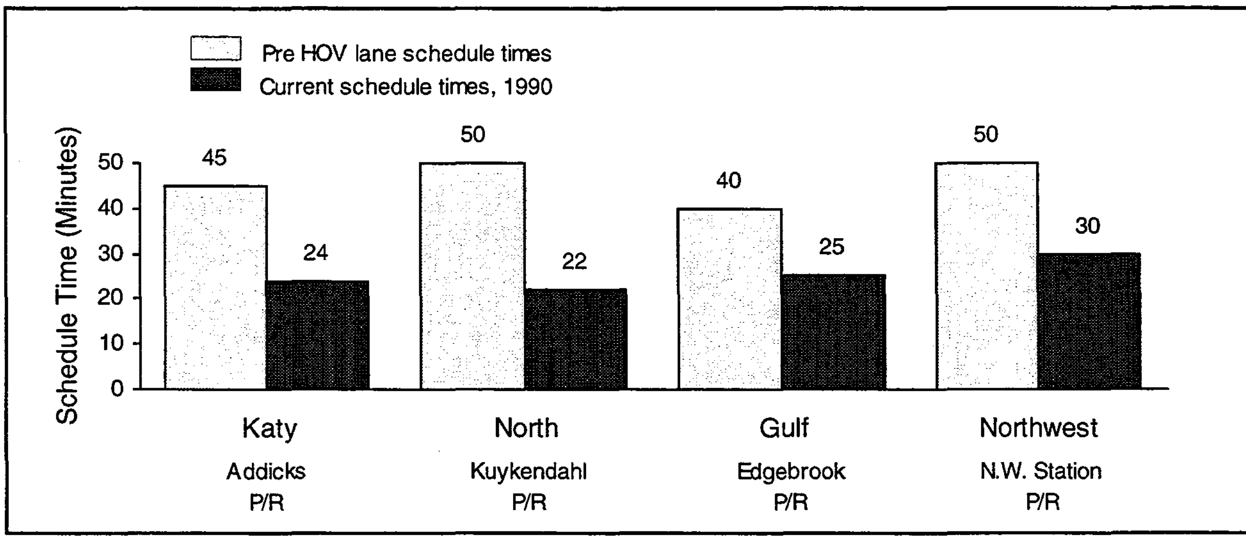
A major reason for implementing HOV lanes is to enhance bus operations. The high-occupancy vehicle lanes offer higher travel speeds and more reliable trip times. Efforts are currently underway to provide more extensive documentation of the impacts of the HOV facilities on Metro's bus operations. Preliminary data suggest these impacts are substantial.

Compared to conditions that existed prior to HOV lane implementation, average bus operating speeds have increased dramatically (Table 26). On average, peak-hour bus operating speeds have approximately doubled, increasing from 41 kph to 79 kph (26 mph to 49 mph). Also, as shown previously in this report and also documented elsewhere, research[13] has illustrated that, based on a comparison of standard deviations, travel times in the HOV lanes are much more reliable and consistent than are travel times on the freeway mainlanes. Figure 40 provides an indication of the impacts that the HOV lanes can have on bus schedules during the peak hour. Due to the increase in bus operating speeds, schedule times have been cut significantly.

Table 26. Average A.M. Peak-Hour Bus Operating Speeds, Before HOV Implementation and Current

Freeway	Bus Operating Speed kph (mph)		
	Before HOV	Current	Percent Increase
Katy	37 (23)	77 (48)	114%
North	32 (20)	82 (51)	155%
Gulf	50 (31)	84 (52)	68%
Northwest	47 (29)	82 (51)	74%
Southwest	47 (29)	82 (51)	74%
East RLT	34 (21)	77 (48)	126%
Unweighted Average	41 (26)	81 (50)	98%

Source: See data in appendices.



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

Source: Metropolitan Transit Authority bus schedules.

Figure 40. Bus Schedule Time, A.M. Peak-Hour Service to Downtown, "Before" and "After" HOV Lane Development

[13]Texas Transportation Institute Research Report 339-12.

Metro has performed operational analyses of some of the enhancements to the HOV facility system.[14] Analyses were performed for improvements to the Northwest, Katy, and North HOV lanes. Metro analyzed the following modest improvements:

- Northwest HOV Lane. In April 1990, the direct ramp from the Northwest Station park-and-ride lot to the HOV lane was opened.
- North Freeway. For construction purposes, the 6.1-kilometer (3.8-mile) section of HOV lane from North Shepherd to West Road was closed during 1988; it reopened in January 1989.
- Katy Freeway. A 2.4-kilometer (1.5-mile) eastern extension of the 18.5-kilometer (11.5-mile) Katy HOV lane opened in January 1990.

Table 27 presents a summary of the impacts of these improvements.

Table 27. Bus Operational Impacts of Enhancements to the HOV Facilities

HOV Facility	Schedule Time (min.)		Bus Operations Savings		
	Before Improvement	After Improvement	Bus Hours Saved	Equivalent Buses Saved	Annual Operating Cost Savings ($1000s)
Northwest[1]					
Route 214	44	30	14.9	4	$ 85[4]
North[2]					
Route 204	40	28	---	---	---
Route 207	31	23	---	---	---
Total	---	---	20	5	$115
Katy[3]					
Route 228	30	24	6.4	2	$117

[1]The improvement is the ramp from the park-and-ride lot to the HOV lane.
[2]The improvement is re-opening a 6.1-kilometer (3.8-mile) section of the HOV lane.
[3]The improvement is a 2.4-kilometer (1.5 mile) extension to the Katy HOV lane.
[4]A part of this savings is the result of more efficient allocation of routes to bus operating facilities.

Source: Metropolitan Transit Authority of Harris County.

While the changes in Metro service are noticeable, in comparison to the opening of the major sections of HOV lane, the impacts of these modest HOV lane enhancements are small. During 1990,

[14]Metropolitan Transit Authority, "Transitway Analysis." April 1991.

the presence of the HOV lanes reduced the revenue bus-hours required to provide the service by over 31,000. For commuter bus service in 1990, the average Metro cost was $152 per revenue hour. Thus, the HOV time savings effectively reduced Metro's 1990 bus operating costs by approximately $4.8 million.

Bus Operating Costs[15]

On a system-wide basis, Metro recovers about 25 percent of operating costs (excluding depreciation) from the fare box (Table 28). The commuter routes, which have a higher fare structure, perform somewhat better than the local routes in this regard. However, the operating subsidy per passenger is greater for the commuter system.

Table 28. Revenue-Cost Ratios and Subsidy Per Passenger, Metro Bus Service, Average Weekday, 1993

Type of Service	Passenger Boardings	Revenue/Cost[2]	Subsidy Per Passenger
Local	255,572	22%	$1.51
Commuter[1]	22,231	42%	$3.00
System-wide	277,803	25%	$1.76

[1]Commuter service includes all park-and-ride service, not just the park-and-ride that uses HOV facilities.
[2]Cost does not include depreciation.

Source: Metropolitan Transit Authority of Harris County.

Thus, providing the commuter bus service on the HOV lanes requires an operating subsidy. Table 29 provides an estimate of the annual subsidy per passenger required to operate the bus service on the high-occupancy vehicle lanes. As shown in the table, the HOV bus service operated from the park-and-ride lots recovers approximately 43 percent of operating costs from fare box revenue.

[15]From "Quarterly Ridership and Route Performance Report, June 1993." Metropolitan Transit Authority.

Table 29. Selected Characteristics of Bus Service on the High-Occupancy Vehicle Lanes, 1995

HOV Lane and Bus Route[1]	Avg. Weekday Passenger-Trips	Subsidy Per Passenger Trip[2]	Revenue/Cost[2]	Estimated Annual Subsidy[3] (1000s)
Katy				
West Belt (210)	359	$4.65	28%	$ 403
Addicks (228)	2,457	$2.11	51%	$ 339
Kingsland (221)	1,035	$3.76	44%	$ 899
Sub-Total	3,851	$2.79	46%	$ 1,641
North[4]				
N. Shepherd (201)	695	$4.50	27%	$ 718
Kuykendahl (202)	2,592	$2.67	46%	$ 499
Seton Lake (212)	1,427	$2.81	43%	$ 377
Spring (204)	1,549	$1.10	70%	$ 117
FM 1960 (207)	211	$7.92	28%	$ 387
Sub-Total	6,474	$2.69	45%	$ 2,098
Gulf				
Edgebrook (245)	1,190	$3.75	34%	$ 373
Bay Area (246)	1,585	$1.86	58%	$ 812
Sub-Total	2,775	$2.67	46%	$ 1,185
Northwest				
W. Little York (216)	243	$4.59	32%	$ 153
Pinemont (218)	337	$3.12	37%	$ 83
N.W. Station (214)	2,293	$2.21	50%	$ 390
Sub-Total	2,873	$2.52	46%	$ 626
Southwest[5]				
Westwood (262)	1,004	$4.04	32%	$ 502
Alief (263)	642	$5.99	25%	$ 915
Bellfort (265)[6]	399	$4.75	38%	$ 483
Missouri City (270)	524	$4.56	31%	$ 671
Sub-Total	2,569	$4.56	28	$ 2,571
Total HOV System	18,542	$2.91	43%	$ 7,643

[1]Only data for routes serving downtown are shown. This is virtually all of the service (17 of 23 park-and-ride routes).
[2]Cost does not include depreciation.
[3]Daily subsidy multiplied by 255.
[4]Data from Woodlands lot, which is not a Metro-operated lot, are not shown.
[5]Southwest HOV lanes opened in January 1993.
[6]Route started in January 1993--complete data not available.

Source: Metropolitan Transit Authority.

In general, each passenger trip using the HOV lanes on a bus requires an operating subsidy of $2.91. Data suggest that, in 1994, approximately 7.10 million passenger trips were made by bus on the HOV lanes; thus, the total bus operating subsidy (excluding depreciation costs) for HOV lane service was in the range of $21 million in 1994.

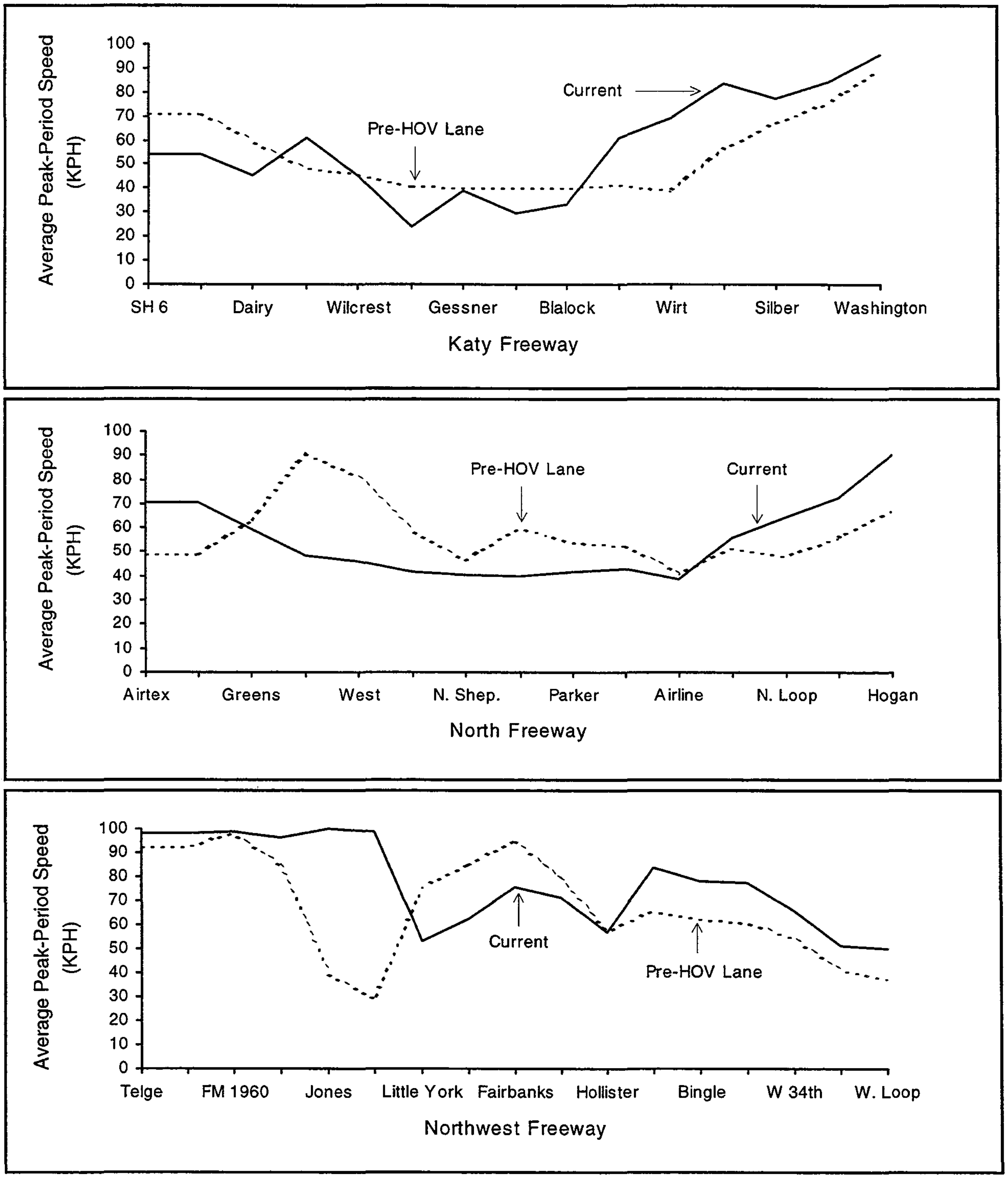
V. HOV LANE IMPACTS ON FREEWAY GENERAL-PURPOSE LANE OPERATIONS

Data presented previously have shown that the HOV lanes have increased the overall average vehicle occupancy characteristic of the roadways within which they have been implemented. Desirably, the implementation of a high-occupancy vehicle lane, regardless of how much utilization it generates, will not unduly impact the operation of the freeway mainlanes. The HOV lane should also improve the overall efficiency of the roadway.

IMPACTS ON FREEWAY GENERAL-PURPOSE LANE OPERATIONS

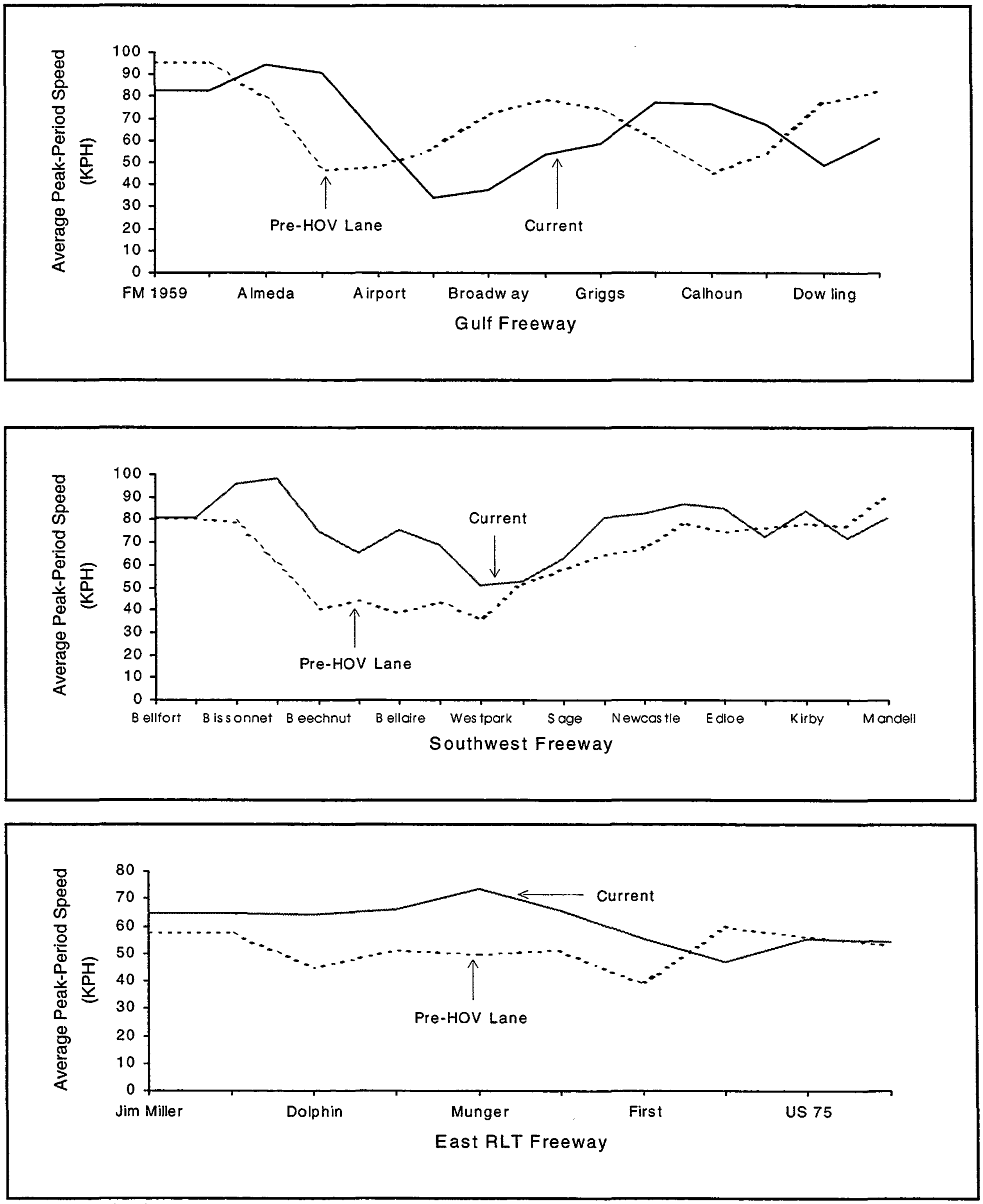
As demonstrated previously, in order to be "successful," HOV facilities must offer a significant travel time savings. As such, they are congestion-dependent improvements; that is, severe congestion must exist on the freeway mainlanes in order for the HOV lane to be able to offer a significant travel time savings.

Available data suggest that the implementation of high-occupancy vehicle lanes, with a design similar to those being used in Houston and Dallas, does not greatly affect the operation of the freeway general-purpose lanes, in spite of the fact that these priority facilities are moving several thousand persons in the peak hour (Table 30). Freeway volumes have, on average, increased 11 percent in HOV lane corridors. The increased volume on the Katy Freeway appears to be attributable to eliminating a downstream bottleneck. While speeds on some freeways have actually increased since HOV lane implementation, this is largely attributable to factors other than the priority facility implementation. Figure 41 shows plots of freeway travel speeds prior to and after HOV lane implementation.



Source: See data in appendices.

Figure 41. Freeway Peak-Period Speeds on Mainlanes, Pre-HOV and Current



Source: See data in appendices.

Figure 41. (Con't) Freeway Peak-Period Speeds on Mainlanes, Pre-HOV and Current

Table 30. Freeway General-Purpose Lane Operation, Prior to HOV and Current

Freeway General-Purpose Lane Data	HOV Facility or Freeway											
	Katy		North		Gulf		Northwest		Southwest		East RLT	
	Pre-HOV	Current	Pre-HOV	Current	Pre-HOV	Current	Pre-HOV	Current	Pre-HOV	Current	Pre-HOV	Current
Vehicle Volume per Hour per Lane[1]												
A.M. Peak Hour	1,350	1,690	1,650	1,750	1,650	1,945	1,790	1,720	1,640	1,640	1,420	1,730
A.M. Peak Period	1,220	1,465	---	1,560	1,400	1,700	1,460	1,530	1,430	1,525	1,500	1,740
Freeway Peak-Hour Speed[2], kph (mph)	37 (23)	34 (21)	32 (20)	52 (32)	50 (31)	48 (30)	45 (28)	50 (31)	47 (29)	52 (32)	34 (21)	43 (27)
Injury Accidents per 100 MVK[3] (per 100 MVM)	12.4 (20.0)	12.0 (19.3)	18.8 (30.3)	16.0 (25.7)	18.5 (29.8)	12.5 (20.1)	7.3 (11.7)	6.8 (10.9)	16.3 (26.2)	10.6 (17.0)	14.0 (22.6)	17.3 (27.9)

[1]Peak-period volumes are for a 3.5 hour period in Houston and a 3.0 hour period in Dallas (East RLT HOV lane).
[2]Many factors other than HOV implementation have had a more significant impact on freeway operating speeds.
[3]Accident rate expressed as injury accidents per 100 million vehicle-kilometers. Accidents were evaluated for the following roadway sections: Katy, Gessner to Post Oak (7.6 km [4.7 mi.]); North, N. Shepherd to Hogan (12.6 km [7.8 mi.]); Northwest, Little York to I-610 (12.4 km [7.7 mi.]); Gulf, Broadway to Almeda-Genoa (19.5 km [12.1 mi.]); and East RLT, Central Expressway to Jim Miller (8.4 km [5.2 mi.]).

Source: See data in appendices.

Implementation of some of the HOV lanes has involved narrowing traffic lanes and inside shoulders. As a result, potential accident impacts have been a concern. Table 30 presents the relevant data. Accident rates are slightly higher on the East RLT general-purpose lanes, but consistently lower on Houston freeways. The unweighted average accident rate has declined from 15 injury accidents per 100 million vehicle-kilometers (MVK) (22 injury accidents per 100 million vehicle-miles [MVM]) prior to the HOV lanes to 13 injury accidents per 100 MVK (21 accidents per 100 MVM) currently. It appears that HOV lane implementation has not significantly impacted freeway accident rates.

Parallel Route Volumes

It is commonly postulated that, as a result of implementing an HOV facility, significant rideshare volumes of travel divert from parallel routes. Thus, even though mainlane freeway volumes may not change, it is postulated that volumes on parallel routes may show decreases.

Researchers have pursued two different efforts to attempt to determine whether this has occurred. First, they asked HOV lane carpoolers which route they traveled prior to using the HOV lane. And second, they took volume counts on parallel routes in the Northwest and Gulf corridors to see if a perceptible change had occurred.

A summary of the survey data from the HOV carpool surveys is in Table 31. It appears that between 8 percent and 15 percent of HOV lane carpoolers previously traveled on a parallel roadway. Given typical carpool volumes on the HOV lanes, this would equate to roughly 80 to 150 vehicles in the peak hour.

Table 31. HOV Lane Carpooler Responses to the Question "Prior to Carpooling on the HOV Lane, How Did you Normally Make the Trip?"

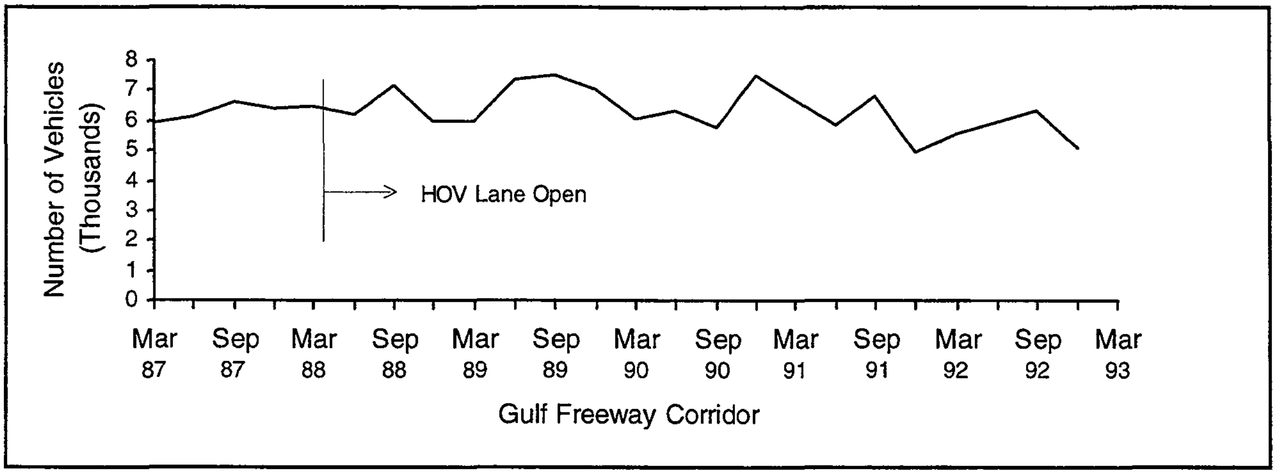
Response	HOV Lane									
	Katy			North		Gulf		Northwest		
	1989	1990	1994	1989	1990	1989	1990	1989	1990	1994
On the HOV lane (bus or van)	16%	15%	23%	---	22%	17%	---	17%	14%	13%
On the freeway general-purpose lanes	64%	68%	66%	---	58%	68%	---	68%	67%	78%
On a parallel street or highway	9%	13%	10%	---	19%	10%	---	10%	15%	8%
Did not make this trip	11%	4%	1%	---	1%	5%	---	5%	4%	1%

Source: Texas Transportation Institute surveys.

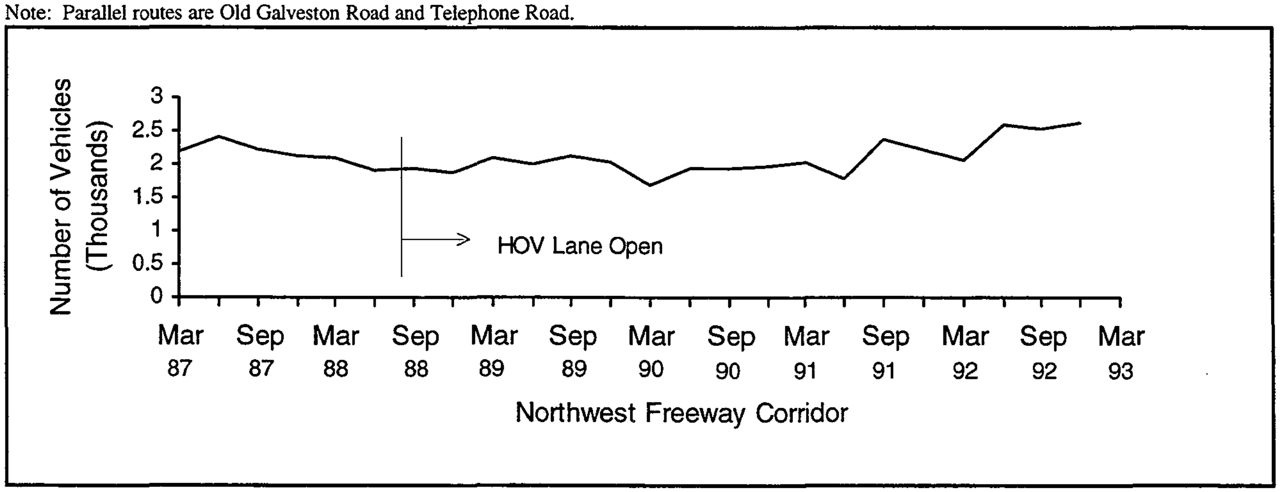
In two of the corridors, volume counts have been conducted on parallel routes. Figure 42 depicts these data. There is no reason to conclude from these data that the opening of the HOV lanes brought about a significant decrease in parallel route volumes, although a small decline may have occurred. Rather than reducing peak vehicle volumes, the HOV lanes appear to be a means of increasing person volume without a corresponding increase in vehicle volume.

IMPACTS ON OVERALL ROADWAY EFFICIENCY

The HOV facilities are intended to move substantial volumes of commuters at relatively high speeds. As such, successful HOV lane implementation should improve the overall efficiency of a freeway. For purposes of this study, the peak-hour efficiency of the freeway is expressed as the multiple of the peak-hour person volume and the speed at which that volume is moved. It is expressed on a per lane basis.



Note: Parallel routes are Old Galveston Road and Telephone Road.



Note: Parallel route is Hempstead Highway.

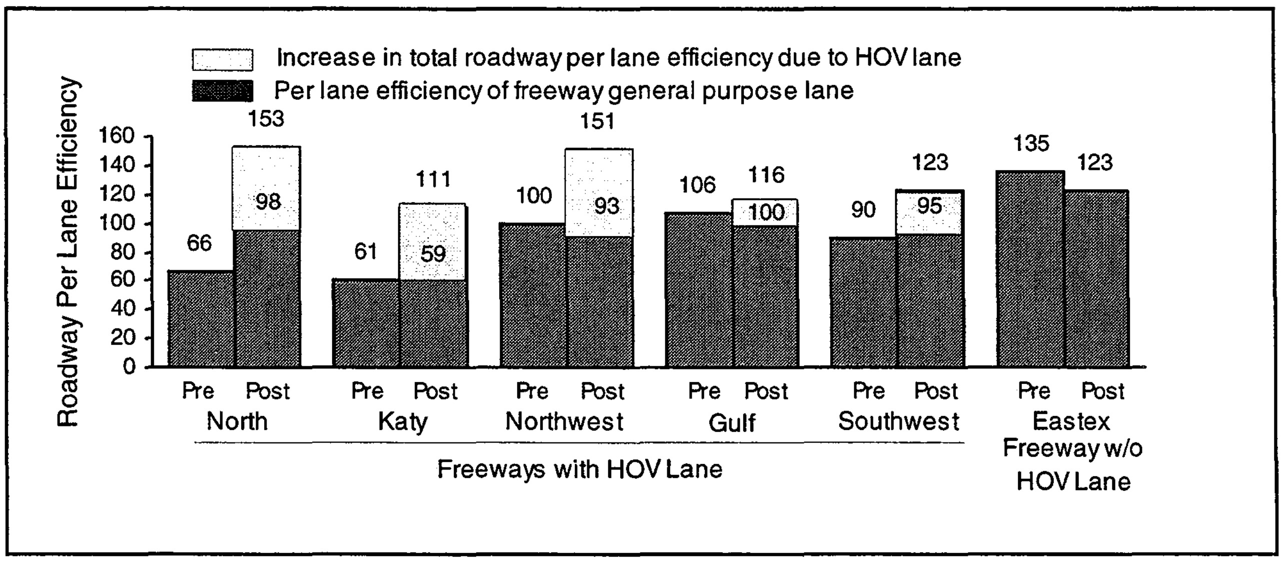
Figure 42. A.M. Peak-Period (6-9:30), Peak-Direction Vehicle Volumes on Parallel Routes in the Gulf and Northwest Freeway Corridors

In all cases for which data are available, the implementation of the HOV lane has increased the overall efficiency of the facility (Table 32). It appears that, on a facility with a mature HOV lane, the priority lane should increase the per lane efficiency, compared to pre-HOV conditions, by an absolute value of at least 30; this level of increase has been attained on the North, Katy, Northwest, Southwest, and East RLT HOV lanes. These increases in efficiency have been larger than those experienced on freeways that do not have an HOV lane (Figures 43 and 44).

Table 32. Estimated Change in A.M. Peak-Hour, Peak-Direction Per Lane Efficiency[1], "Before" and "After" HOV Lane Implementation

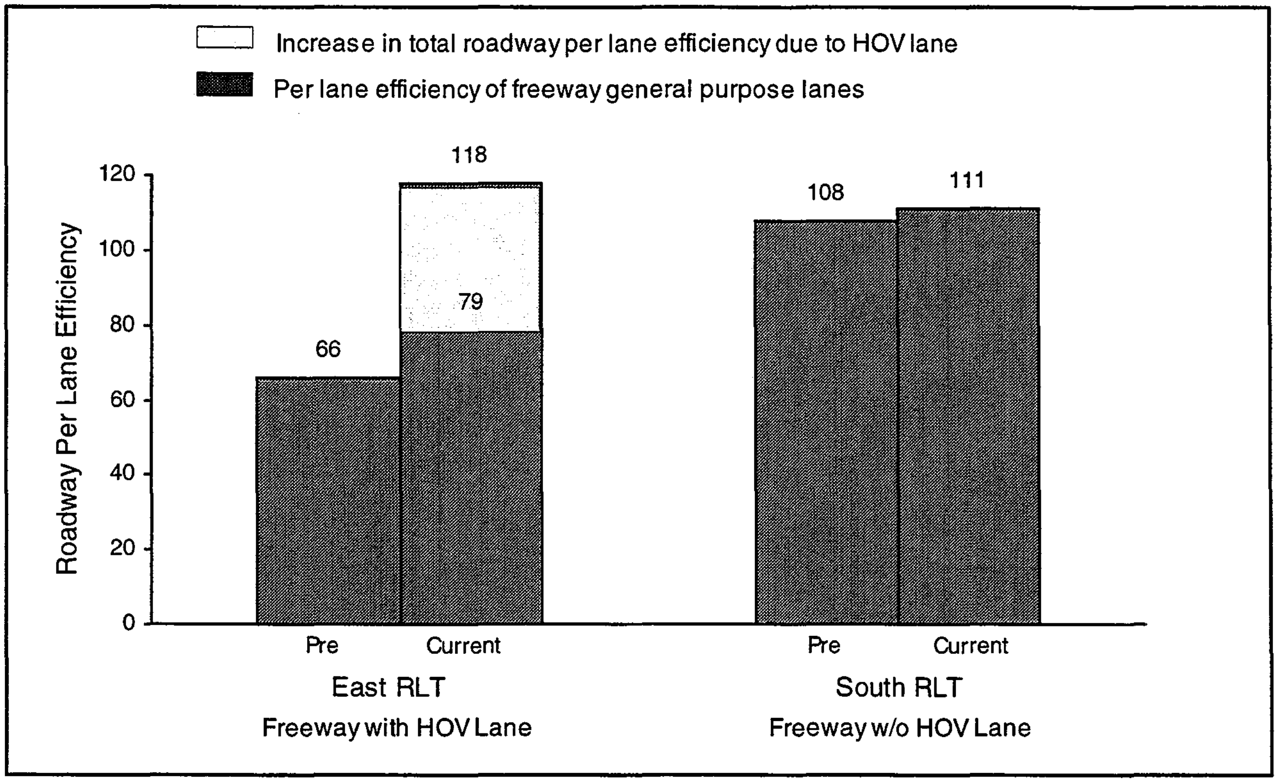
Freeway	Pre-HOV Lane Per Lane Freeway Efficiency (1)	Current Per Lane Efficiency			Absolute Increase in Per Lane Efficiency Due to HOV Lane[2] (5)
		Freeway (2)	HOV Lane (3)	Combined Freeway & HOV Lane (4)	
North	66	98	392	153	87
Katy	61	59	271	111	50
Northwest	100	93	322	151	51
Gulf	106	100	166	116	10
Southwest	90	95	265	123	33
East RLT	66	79	270	118	52
Eastex[3] (w/o HOV, Houston)	135	123	NA	123	-12
South RLT[4] (w/o HOV, Dallas)	108	111	NA	111	+3

NA - Not applicable.
[1] Peak-hour per lane efficiency is defined as the person volume per lane times the average speed divided by 1000. Thus, it is a measure both of the person volume moved and the speed at which that volume is moved.
[2] Calculated as follows: Column (4) minus Column (1).
[3] For comparison, this is a freeway without an HOV lane. The pre-HOV value is the average of conditions on the Eastex Freeway prior to implementation of the Katy, the Northwest, and the Gulf HOV lanes.
[4] For comparison to East RLT, this is a freeway without an HOV lane in Dallas.



Note: Peak-hour lane efficiency is defined as the person volume per lane times the average speed divided by 1000. Thus, it is a measure both of person volume moved and the speed at which that volume is moved.
Source: See data in appendices.

Figure 43. Change (Pre-HOV Lane to Current) in A.M. Peak-Hour, Peak-Direction Roadway Efficiency, Freeways With and Without HOV Lanes in Houston



Note: Peak-hour per lane efficiency is defined as the person volume per lane times the average speed divided by 1000. Thus, it is a measure both of person volume moved and the speed at which that volume is moved.
Source: See data in appendices.

Figure 44. Change (Pre-HOV Lane to Current) in A.M. Peak-Hour, Peak-Direction Roadway Efficiency, Freeways With and Without HOV Lanes in Dallas

In order to address the issue of what would have happened to overall roadway efficiency had the new lane been used as another mixed-flow lane, researchers conducted an analysis using automatic vehicle identification (AVI) data and the FREQ model (a microscopic freeway simulation model). Table 33 summarizes the results of this analysis. A basic assumption used in this analysis was that both alternatives (i.e., "add-an-HOV lane alternative" versus "add-a-general-purpose lane alternative") would provide service to the same number of persons. In all cases, the addition of an HOV lane appears to be the more efficient option for providing person-mobility.

Table 33. Estimated Impacts of Adding a General-Purpose Lane Versus Adding an HOV Lane on A.M. Peak-Hour Per Lane Efficiency

Freeway Corridor	Per Lane Efficiency[1]		
	Add an HOV Lane[2]	Add a General-Purpose Lane[3]	Absolute Difference
Katy	111	68	43
North	153	63	90
Northwest	151	74	77

[1]Peak-hour per lane efficiency is defined as the person volume per lane times the average speed divided by 1000. Thus, it is a measure both of the person volume moved and the speed at which that volume is moved.
[2]The per lane efficiency for existing conditions; general-purpose lanes and one reversible HOV lane.
[3]The per lane efficiency for adding a general-purpose freeway lane each direction relative to pre-HOV freeway configuration.

VI. AIR QUALITY AND ENERGY CONSIDERATIONS

Surveys[16] have indicated that, while not the primary reasons for implementing high-occupancy vehicle facilities, air quality and energy conservation are secondary reasons for developing these projects. The passage of the 1990 Clean Air Act (CAA) and the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) increases the emphasis given to the air quality and energy conservation impacts of alternative transportation improvements. Unfortunately, evaluating the effectiveness of HOV projects regarding these issues is difficult.

As shown in previous sections, implementing the high-occupancy vehicle lane does not necessarily reduce the vehicular volumes on the freeway general-purpose mainlanes; the HOV lane, in effect, is allowing more person movement to be served without increasing congestion on the freeway general-purpose lanes. As a result, the travel that takes place in the lane that serves as the HOV facility can be an increase in vehicle-kilometers of travel compared to what existed prior to constructing the priority lane. Consequently, in comparison to pre-HOV conditions, implementing an HOV lane may well increase the total vehicle-kilometers of travel, which will also increase energy consumed and pollutants emitted.

However, such a conclusion is simplistic. Recognizing that HOV lanes are developed in congested corridors and that demand is projected to increase over time, a more appropriate question might be, "what is the most effective means of serving the travel demand that is expected to occur?" Thus, the relevant analysis might be to compare, for a given level of travel demand, the "add an HOV lane" alternative to both a "do nothing" alternative and to an "add another mixed-flow traffic lane" alternative. This comparison needs to recognize that future travel demands are likely to be greater than those that currently exist.

[16]"A Description of High-Occupancy Vehicle Facilities in North America," Texas Transportation Institute Technical Report 925-1, 1990.

This analysis allows the impacts of doing nothing to be quantified. It also provides data that help to answer the question that, if one lane is to be added to a freeway, should that lane be designated as a reversible HOV lane, or should it be designated as an additional general-purpose traffic lane?[17]

The analysis presented in this section of the report utilized a freeway simulation model (FREQ) and applied that model to the Katy Freeway and HOV lane. Researchers simulated operation on both the freeway mainlanes and the HOV lane, based on 1995 travel volumes. The demand, expressed as passenger-kilometers, that existed in 1995 was held constant in comparing alternatives. Average vehicle occupancy was adjusted between alternatives as necessary to reflect the observed impacts of the HOV facility on vehicle occupancy.

Researchers evaluated the following three alternatives:

1. **Do nothing.** The freeway would have three mixed-flow freeway lanes in each direction and no HOV facility. This is the condition that existed prior to adding the HOV facility to the freeway.

2. **Add a general-purpose freeway lane.** This would result in four general-purpose freeway lanes in each direction with no HOV facility. It is the condition that would have resulted had an additional freeway general-purpose lane been added to the freeway instead of an HOV lane.

3. **Add an HOV lane.** This is the improvement that was implemented. A reversible HOV lane was added to the freeway. Three directional general-purpose freeway lanes remain.

Figures 45 and 46 show the results of this analysis. Since demand is projected to continue to increase in the future, the HOV lane should (over time) continue to look even more favorable; the HOV alternative provides capacity to serve additional growth, while the alternatives that provide only freeway mainlanes operate at capacity in 1995 and are unable to serve higher volumes. It is

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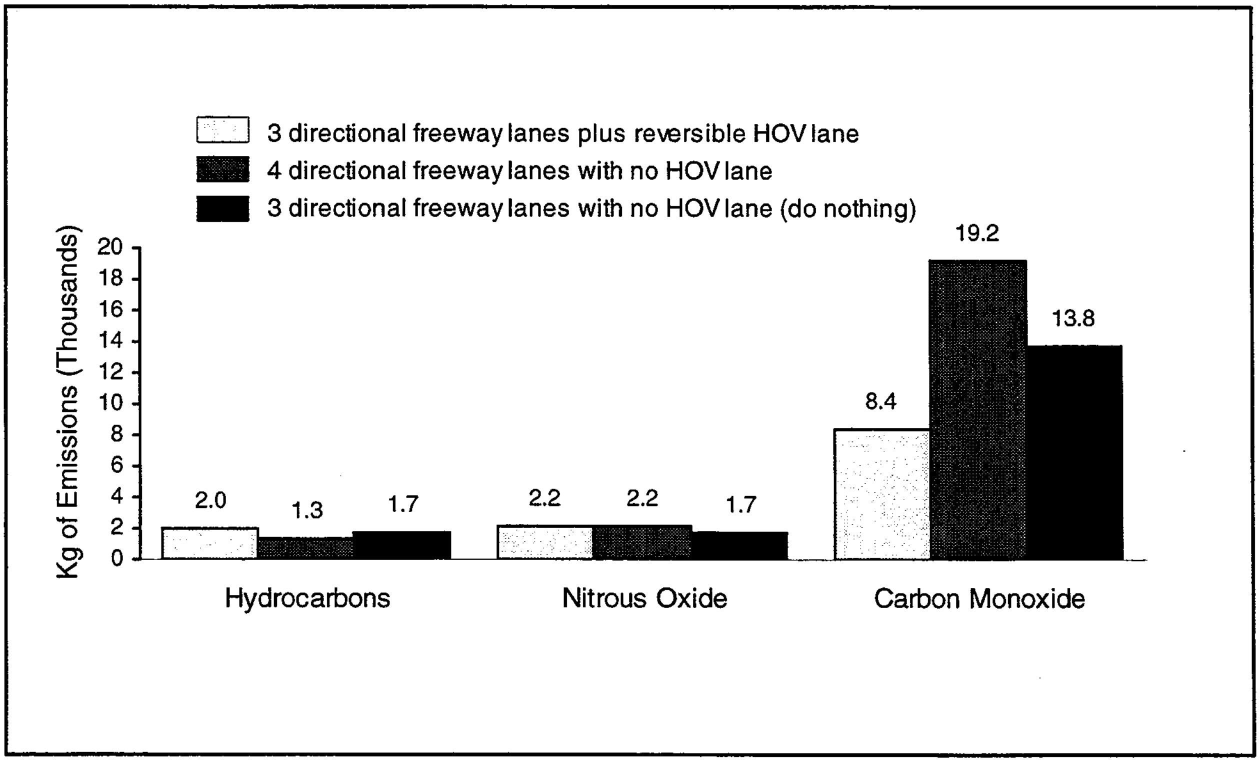
[17]The reversible HOV lane requires approximately the same pavement width as would be required to provide one additional general-purpose lane in each direction.

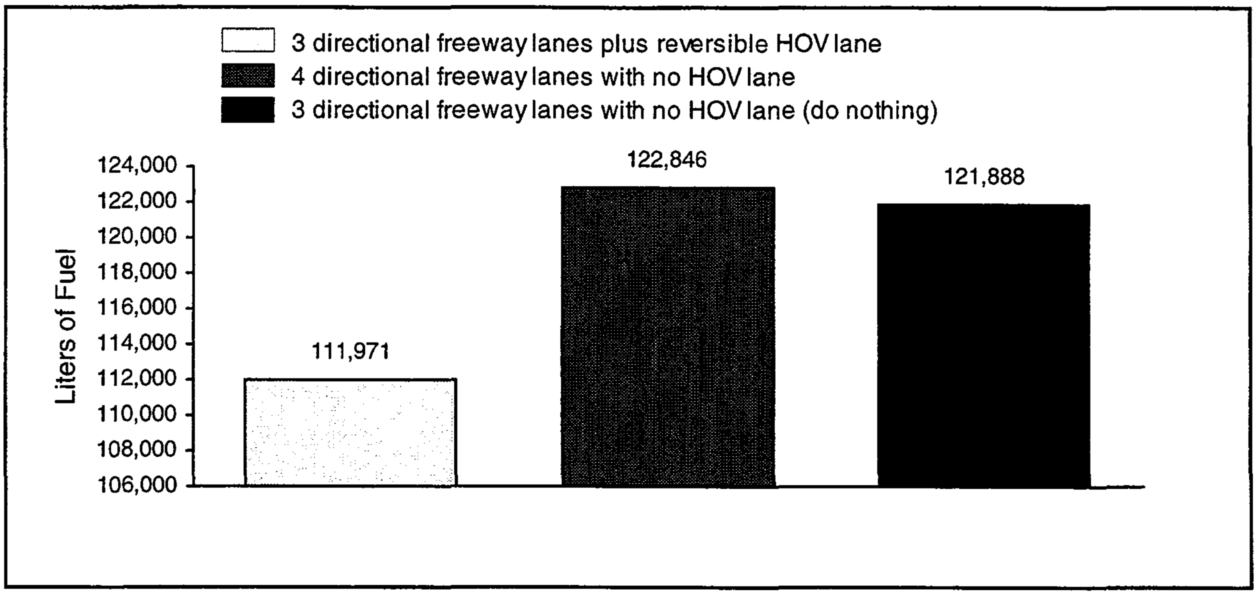
recognized that this analysis has limitations (e.g., it does not consider the benefits that would accrue from having an additional mixed-flow lane available to serve off-peak and off-peak direction travel, and it does not address cold start and hot soak issues). However, it is clear that, to serve the passenger-kilometer demand in the peak direction that is occurring today on this particular facility, the HOV lane alternative is slightly favorable in terms of air quality and energy conservation benefits.



Source: Texas Transportation Institute simulation analyses, 6 a.m. to noon, peak direction, 1995 demand levels.

Figure 45. Estimated Impacts of HOV Improvements on Air Quality, Katy Freeway and HOV Lane

Analyses of this type on additional freeway corridors are needed to better understand the trade-offs between adding freeway lanes as opposed to adding HOV lanes. However, at least in the Katy Freeway corridor, the HOV lane alternative offers the most favorable impacts on pollutants emitted and energy consumed.



Source: Texas Transportation Institute simulation analyses, 6 a.m. to noon, peak direction, 1995 demand levels.

Figure 46. Estimated Impacts of HOV Improvements on Energy Consumption, Katy Freeway and HOV Lane

VII. HIGH-OCCUPANCY VEHICLE LANE COST EFFECTIVENESS

An objective of HOV projects is that they be cost effective. If these projects are to compete for the limited available highway and transit funding, they must be viewed as being favorable from a cost effectiveness standpoint.

Data presented previously in this report (Table 33, Figures 45 and 46) provided an indication of how an HOV lane project compares to a general-purpose lane project. These analyses indicate that the HOV alternative results in a reduction in total travel time and energy consumption and exhibits greater per lane efficiency relative to the alternative of adding a general-purpose freeway lane. Since those are principal variables in determining cost effectiveness, one can argue that, in at least the Katy Freeway corridor, the HOV lane was a more effective improvement than the addition of another general-purpose mainlane. This conclusion should be viewed with caution and not generalized. The implication is that, in some highly congested corridors with appropriate travel patterns, the HOV alternative will rate highly in a benefit-cost analysis. This certainly will not be the conclusion for all (or probably even most) highway corridors. A rather specific set of conditions needs to be present in a corridor to enhance the relative attractiveness of the HOV alternative. In many instances, if an either/or decision needs to be made, general-purpose freeway improvements may be preferable to HOV lane implementation.

The analysis in this report focuses on the HOV facilities that have been built and reviews available data to assess whether those projects are cost effective. Many of the potential benefits associated with an HOV facility, while possibly significant, are difficult to quantify. Included in this potential benefit list are factors such as air quality, energy consumption, impacts on regional economic development, impacts of improved bus schedule reliability, etc. While these are not readily quantifiable, they can, nevertheless, be significant HOV project benefits.

One benefit that can be quantified relatively easily is the value of the time saved by users of the HOV lanes. It would appear that, if the project is cost effective based solely on this criterion, the project would be even more cost effective if all the other potential benefits were considered.[18] It must be realized that this approach does not consider certain benefits that can be significant. For example, in the Katy corridor, it would be necessary to provide three additional general-purpose lanes if an HOV lane was not serving the high demand it presently serves. The cost of these alternative general-purpose lane improvements, costs that are foregone by building the HOV lane, are not considered in a benefit assessment that considers only travel time savings.

Depending on the assumptions made concerning the discount rate and project life used in the economic analysis, different conclusions can be drawn concerning the level of travel time savings required to make the HOV project cost effective based solely on that criterion. However, it appears that, as a simplified "rule of thumb," if the average annual value of the HOV user travel time savings is at least ten percent of the construction cost of the project, the HOV project will be cost effective.[19]

For reasons cited in the footnote, the average annual value of time saved over the life of the project should be greater than the amount saved in the early years of the project.[19] Previous discussions in this report have identified specific reasons why time savings should be expected to

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[18]An argument that has some merit and has not yet been fully resolved is what would happen to overall travel time if the new lane added was a mixed-flow lane and not an HOV lane. Experience would suggest that expansion of freeway capacity will not, other than possibly in the very short term, significantly improve freeway operating speeds during peak periods. This does not mean that freeway projects aren't necessary and cost effective, it simply suggests they will not eliminate peak-period congestion. Also, as shown previously, moving several thousand persons per hour on the Houston HOV lanes has not resulted in significantly improved operations on the freeway mainlanes. Simulation of the Katy Freeway, also presented previously, suggests that, on that particular facility for the current level of demand, the HOV project reduced delay much more than would the addition of a general-purpose freeway lane. More simulation of this type is needed to more fully address trade-off issues between HOV lanes and general-purpose freeway lanes.

[19]Assuming a constant stream of benefits over the life of the project (which is conservative since benefits should increase over time as HOV utilization and freeway congestion both increase), a 20-year project life (again, conservative since no salvage value is included), a 4% discount rate, and a $11.37/hour value of time, the present worth factor would be 13.6. Thus, if operating and maintenance costs are not included (they are relatively small), a benefit/cost ratio of approximately 1.4 would result if the annual benefit stream equaled 10% of the initial construction cost.

increase on all of the Texas HOV lanes. However, if the project appears cost effective based on today's level of use, it should prove to be even more cost effective as HOV lane use increases.

Table 34. Annual Value of Time Saved by HOV Lane Users as a Percent of HOV Lane Construction Cost

HOV Facility	Annual Value of Time Saved[1] ($ millions)	Estimated Construction Cost For Operating Segment[2] ($ millions)		Annual Value of Time Saved as a % of Construction Costs	
		HOV Lane and Ramps	HOV Lane, Ramps and Support Facilities	HOV Lane and Ramps	HOV Lane, Ramps and Support Facilities
Katy	$10.2	$41.0	$68.4	24.9%	14.9%
North	$ 5.4	$96.9	$122.1	5.6%	4.4%
Gulf	$2.5	$54.1	$98.3	4.6%	2.5%
Northwest	$ 3.8	$79.0	$140.4	4.8%	2.7%
Southwest	$ 4.0	$74.3	$111.0	5.4%	3.6%
East RLT	$ 3.2	$15.4	$15.4	12.4%[3]	12.4%[3]
Total	$29.1	$360.7	$555.6	8.1%[3]	5.2%[3]

[1]Based on 1995 time savings for HOV lane users. Does not include any time savings by motorists in the freeway mainlanes.
[2]See Tables 4 and 6 and appendices.
[3]The 10-year life of the contraflow lane on East RLT Freeway (as opposed to the 20-year assumed life of the Houston HOV lanes) has been taken into account. This adjustment results in a present worth factor of 8.1 rather than 13.6 and is reflected in the values shown.

Based on this simplistic analysis, under 1995 operating conditions, the Katy and East RLT HOV facilities are clearly effective, and the other HOV lanes are less effective. The analysis shown in Table 34 does not include many potential benefits. In an effort to compile a more complete listing of costs and benefits associated with one of the HOV facilities, researchers prepared Table 35.

Table 35. Estimated Costs and Benefits of the Katy HOV Lane, 1994

Cost or Benefit Category	Dollars (millions)	
Cost		
Capital Cost[1]	$6.8	
Operating Cost		
Enforcement and Operations[2]	0.2	
Bus Subsidy[3]	5.0	
TOTAL COST		$12.0
Benefits		
HOV User Travel Time Savings[4]	$10.2	
Bus Operating Cost Savings[5]	1.4	
Freeway Construction Foregone[6]	21.3	
Freeway General-Purpose Travel Time Savings[7]	9.7	
Reduced Fuel Consumption[8]	5.6	
TOTAL Benefits		$48.2
Benefit/Cost Ratio		4.0

[1]10 percent of HOV capital cost, assumed to be the annualized cost.
[2]Based on $230,000 per year for operating and enforcement support.
[3]Based on a subsidy of $4.03 per bus passenger on the Katy HOV lane (see Table 28).
[4]The value of the time saved by users of the HOV facility.
[5]The reduction in bus operating costs due to the reduction of revenue hours of bus service due to the higher bus operating speeds on the HOV lane. Cost per revenue hour for Metro commuter bus service is $152.
[6]Assumes that, if the HOV lanes were not provided, at least four additional general-purpose lanes would be needed to provide the equivalent peak-hour capacity. Cost per lane-kilometer assumed to be $2.5 million. Ten percent of total cost is assumed to be the annual cost. Counting both freeway construction foregone and freeway general-purpose travel time savings could be considered as double counting benefits.
[7]Simulation analyses suggest that person-hours of travel time in the freeway mainlanes would increase significantly if the HOV lane did not exist and all person movement was handled in the general-purpose lanes. This is an estimate of the value of the increase that would result in travel time on the general-purpose lanes if there were no HOV lane.
[8]The HOV alternative, compared with an all general-purpose lane alternative, reduces fuel consumption.

Based on the costs and benefits listed in that table, and based on usage levels in 1995, the Katy HOV facility had a benefit-cost ratio of 4.0. The actual benefits quantified in that table are five times greater than the value of the time saved by HOV lane users (that value of time is the only benefit considered in Table 34).

On a regular basis, the Texas Transportation Institute has quantified the annual congestion cost in Houston. Analyses suggest that the HOV lanes presently in place are reducing the congestion index in the Houston area by approximately five percent. This translates to an annual reduction in the cost of congestion of approximately $125 million in Houston.[20]

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[20]This estimate is based on a relationship between congestion and costs due to congestion which was developed and documented in "An Assessment of Strategies for Alleviating Urban Congestion," Texas Transportation Institute Research Report 1252-1F, 1991.

VIII. DOES THE HOV LANE PROGRAM HAVE PUBLIC SUPPORT?

Since the HOV lane system being developed in Houston is unique, is viewed as a major means of serving future growth in travel, and involves the expenditure of approximately $900 million in tax monies, public attitudes pertaining to HOV facility development have been an area of continued interest. Desirably, for this program to continue to move forward, it should have public support.

Since 1985, TTI researchers have surveyed individuals that use the HOV facilities as well as individuals not using the high-occupancy vehicle lanes to identify their attitudes concerning these priority lane projects. Researchers performed surveys both on freeways that have HOV lanes (Katy, North, Northwest, Gulf, and East R.L. Thornton) and on a freeway (Eastex) that does not presently have an HOV lane. Two primary issues have been addressed: 1) are the HOV facilities transportation improvements; and 2) are the HOV lanes sufficiently utilized. The most recent of these surveys was conducted in 1994.

ARE THE HOV LANES TRANSPORTATION IMPROVEMENTS?

Acceptance of the high-occupancy vehicle facilities as effective improvements is extremely high and has been generally increasing over time. In all three of the corridors surveyed in 1994 (Table 36), over 65 percent of the motorists in the freeway mainlanes (not HOV lane users) viewed these projects favorably. Of those motorists surveyed, only about 20 percent felt the HOV lanes were not transportation improvements; this is similar to what was found in a 1988 survey on a freeway (Eastex) that does not have an HOV lane. Figure 47 reflects the trend of increasing acceptance of the HOV lanes over time.

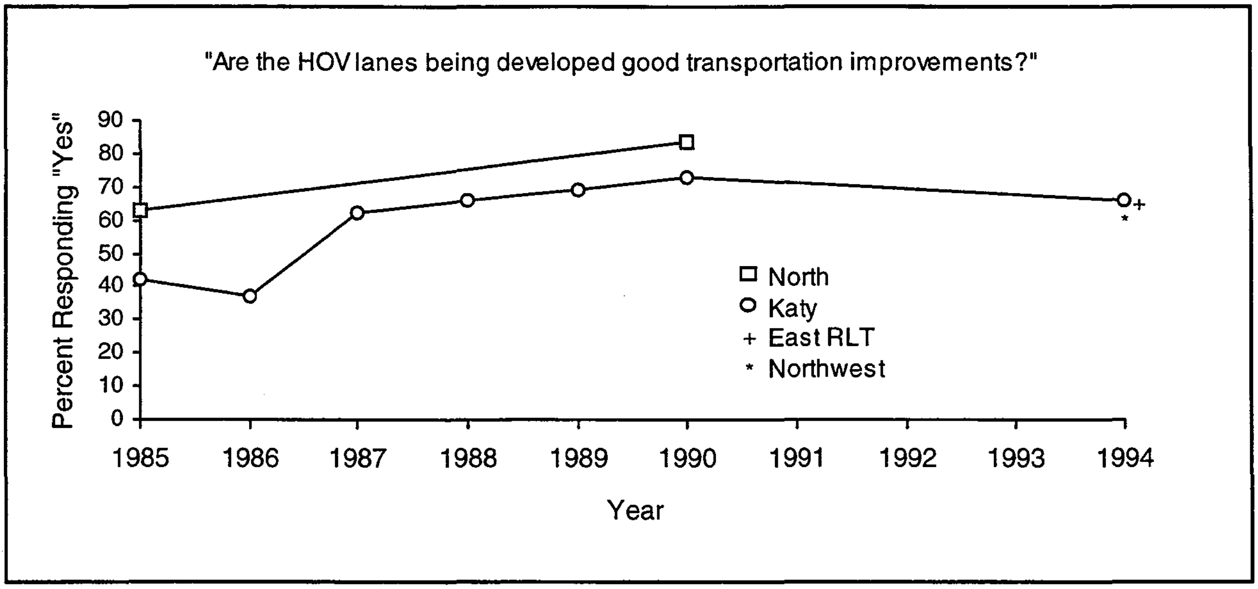


Figure 47. Trends in Public Attitudes Concerning HOV Lane Development

The responses shown in Table 36 and Figure 47 are those of the motorists using the congested freeway mainlanes during peak periods. While these individuals may perceive that they are receiving relatively few direct benefits (e.g., freeway congestion has not, in general, been noticeably reduced) from the HOV lane development, they nevertheless strongly indicate that, in their opinion, the high-occupancy vehicle lanes represent good transportation improvements.

Thus, strong public support for the HOV program exists, and that support has been increasing over time.

ARE THE HOV LANES SUFFICIENTLY UTILIZED?

While the responses in Table 36 indicate that HOV lanes are being overwhelmingly accepted as worthwhile transportation improvements, there is less agreement as to whether these priority lanes are sufficiently utilized (Tables 37 and 38). The perception that the HOV lanes do not carry enough traffic and are, therefore, underutilized is a concern that has existed since the initiation of the HOV programs in Texas.

Table 36. Responses to the Question "Do You Feel the HOV Lanes Being Developed in Houston are Good Transportation Improvements?"

Survey Location and Group Responses to Question	Year of Survey						
	1985	1986	1987	1988	1989	1990	1994
Motorists in Freeway Mainlanes Freeways With HOV Lanes							
North Freeway[1]							
Yes	---	62%	---	---	---	81%	---
No	---	20%	---	---	---	9%	---
Not Sure	---	28%	---	---	---	10%	---
Katy Freeway[2]							
Yes	41%	36%	60%[6]	64%	67%	71%	66%
No	35%	43%	24%	22%	19%	16%	20%
Not Sure	24%	21%	16%	14%	14%	13%	14%
Northwest Freeway[3]							
Yes	---	---	---	---	71%	75%	---
No	---	---	---	---	13%	11%	---
Not Sure	---	---	---	---	16%	14%	---
Gulf Freeway[4]							
Yes	---	---	---	---	63%	---	---
No	---	---	---	---	21%	---	---
Not Sure	---	---	---	---	16%	---	---
East R.L. Thornton[5]							
Yes	---	---	---	---	---	---	66%
No	---	---	---	---	---	---	20%
Not Sure	---	---	---	---	---	---	14%
Freeway Without HOV Lane							
Eastex Freeway							
Yes	---	---	---	58%	---	---	---
No	---	---	---	15%	---	---	---
Not Sure	---	---	---	27%	---	---	---

[1]The original North Freeway contraflow lane opened in 1979; the North HOV Lane opened in 1984.
[2]The Katy HOV Lane opened in October 1984.
[3]The Northwest HOV Lane opened in August 1988.
[4]The Gulf HOV Lane opened in May 1988.
[5]The East R.L. Thornton HOV Lane opened in September 1991.
[6]Average of 2 surveys conducted in 1987.
Source: Texas Transportation Institute surveys.

Over 75 percent of those who use the HOV lanes feel that those facilities are sufficiently utilized (Table 37). This percentage has generally increased significantly after the HOV lane has been in operation for several years.

Table 37. Responses from Users of the HOV Lane to the Question "Is the HOV Lane Sufficiently Utilized?"[1]

Survey Location and Group Responses to Question	Year of Survey						
	1985	1986	1987	1988	1989	1990	1994
Katy HOV Lane Users							
Bus Riders							
Yes	49%	66%	77%	72%	85%	81%	64%
No	33%	14%	7%	8%	5%	4%	17%
Not Sure	18%	20%	16%	20%	10%	9%	19%
Carpoolers & Vanpoolers[2]							
Yes	33%	43%	82%	45%	77%	75%	88%
No	46%	35%	9%	35%	14%	15%	12%
Not Sure[3]	21%	22%	9%	20%	9%	10%	---
North HOV Lane Users							
Bus Riders							
Yes	---	81%	---	---	---	88%	---
No	---	6%	---	---	---	4%	---
Not Sure	---	13%	---	---	---	8%	---
Vanpoolers and Carpoolers[4]							
Yes	---	84%	---	---	---	88%	---
No	---	7%	---	---	---	5%	---
Not Sure[3]	---	9%	---	---	---	7%	---
Northwest HOV Lane Users							
Bus Riders							
Yes	---	---	---	---	72%	88%	71%
No	---	---	---	---	6%	6%	11%
Not Sure	---	---	---	---	22%	6%	18%
Carpoolers & Vanpoolers							
Yes	---	---	---	---	75%	87%	83%
No	---	---	---	---	12%	6%	17%
Not Sure[3]	---	---	---	---	13%	7%	---
East R.L. Thornton HOV Lane Users							
Bus Riders							
Yes	---	---	---	---	---	---	62%
No	---	---	---	---	---	---	13%
Not Sure	---	---	---	---	---	---	25%
Carpoolers & Vanpoolers							
Yes	---	---	---	---	---	---	95%
No	---	---	---	---	---	---	5%
Not Sure[3]	---	---	---	---	---	---	---

[1]This question has been asked as it applies to both HOV lane vehicle and person volumes. In general, the responses were not greatly different.
[2]Unweighted average of responses from vanpoolers and carpoolers for 1985-1988. Weighted average in 1989. 1987 survey is carpoolers only. Between 1987 and 1988, a.m. occupancy requirements changed from 2+ to 3+ between 6:45 a.m. and 8:15 a.m. This helps to explain the wide variation in responses from 1987 to 1989.
[3]"Not Sure" was not a potential response on the 1994 survey.
[4]Survey of vanpoolers in 1986; survey of vanpoolers and carpoolers in 1990.
Source: Texas Transportation Institute surveys.

However, the motorists using the general-purpose mainlanes do not feel that the HOV lanes are sufficiently utilized (Tables 38 and 39). The plurality of responses in the corridors in which surveys have been conducted to date is that the HOV lanes were not sufficiently utilized. The 1994 surveys were modified to gauge the perception of utilization (by freeway motorists) relative to both vehicles and persons. Table 39 summarizes the results of this survey, and results indicate that, while the general perception is underutilization, freeway motorists feel that vehicle utilization is more sufficient than that by person. The issue of perceived lane utilization will need to continue to be addressed in the formulation of strategies for operating the HOV facilities.

Table 38. Responses from Non-Users of the HOV Lane to the Question "Is the HOV Lane Sufficiently Utilized?" 1985-1990

Survey Location and Group Responses to Question	Year of Survey					
	1985	1986	1987	1988	1989	1990
Katy Freeway Mainlane Motorists						
Yes	3%	3%	40%[1]	31%[2]	31%	37%
No	90%	92%	48%	55%	53%	45%
Not Sure	7%	5%	12%	14%	16%	18%
North Freeway Mainlane Motorists						
Yes	---	26%	---	---	---	32%
No	---	56%	---	---	---	40%
Not Sure	---	18%	---	---	---	28%
Northwest Freeway Mainlane Motorists						
Yes	---	---	---	---	22%	29%
No	---	---	---	---	58%	47%
Not Sure	---	---	---	---	20%	24%
Gulf Freeway Mainlane Motorists						
Yes	---	---	---	---	21%	---
No	---	---	---	---	55%	---
Not Sure	---	---	---	---	24%	---

[1]Average of two surveys conducted in 1987.
[2]Data collected after a.m. peak occupancy requirement for carpools on the HOV lane was changed from 2+ to 3+ between 6:45 and 8:15 a.m.

Source: Texas Transportation Institute surveys.

Table 39. Responses from Non-Users of the HOV Lane to the Question "Is The HOV Lane Sufficiently Utilized?" 1994

Survey Location and Group Responses to Questions	1994 Survey	
	Is Vehicle Utilization Sufficient?	Is Person Utilization Sufficient?
Katy Freeway Mainlane Motorists		
Yes	21%	19%
No	62%	59%
Not Sure	17%	22%
Northwest Freeway Mainlane Motorists		
Yes	31%	25%
No	41%	43%
Not Sure	28%	32%
East R.L. Thornton Freeway Mainlane Motorists		
Yes	48%	38%
No	32%	39%
Not Sure	20%	23%

Source: Texas Transportation Institute Surveys.

IX. CONCLUSIONS

A 166.0-kilometer (103.2-mile) system of freeway HOV lanes is being developed in Houston. As of the end of 1995, 102.4 kilometers (63.6 miles) of that barrier-separated system were operational, with priority facilities operating in five different freeway corridors. The Dallas HOV lane system is currently planned to consist of approximately 60 kilometers (37 miles) of HOV facilities. As of December 1995, an 8.4-kilometer (5.2-mile) barrier-separated contraflow lane was the only operational component of the Dallas system.

In this report, it is assumed that the primary goal of HOV lanes is to cost-effectively increase the person-movement capacity of the freeways. Achieving this should 1) enhance bus operations; 2) improve air quality; and 3) reduce fuel consumption. Implementation of the HOV lanes should not unduly impact the operation of the freeway general-purpose lanes. That implementation should have public support.

This report reviews and analyzes data collected through calendar year 1995 to assess the extent to which these objectives are being attained (Tables 40 and 41). In assessing the performance of the HOV lanes, the following quantitative values can be used as guides.

Objective: Increase Roadway Person Movement

1. Daily HOV lane ridership (measured in person trips) should be in the range of 10,000 to 15,000 or greater.

2. The HOV lane should increase peak-hour, peak-direction person volume by a percentage greater than the percent increase in directional lanes added to the roadway due to HOV lane implementation.

3. The HOV lane should increase the peak-hour, peak-direction average vehicle occupancy (persons per vehicle) of the roadway by at least 10 percent to 15 percent.

- More than 25 percent of the total carpools using the HOV lane should be new carpools created because of the HOV lane.

- More than 25 percent of the total bus riders using the HOV lane should be new bus riders created because of the HOV lane.

Objective: Don't Unduly Impact Freeway General-Purpose Lane Operations

1. Implementing the HOV lane should not significantly increase either freeway general-purpose lane congestion or the accident rate on those lanes.

Objective: Increase the Overall Efficiency of the Roadway

1. The absolute value of the total roadway (general-purpose lanes plus HOV lane) peak-hour per lane efficiency (defined as the multiple of person volume times speed of movement and expressed in 1,000s) should increase by at least 30 due to implementation of the HOV lane. Stated differently, the total roadway per lane efficiency should be greater than the freeway general-purpose lane efficiency by an amount of at least 30.

Objective: Create Favorable Energy and Air Quality Impacts

1. Compared to the alternative of either providing an additional general-purpose lane or doing nothing, implementation of the HOV lane should result in reductions in energy consumed and pollutants emitted.

Objective: Enhance Bus Transit Operations

1. Peak-hour bus operating speeds should be increased by at least 50 percent on the HOV lanes.

2. A safer bus operating environment should result. HOV accident rates should be equal to, or less than, freeway general-purpose lane rates.

3. Significant savings in bus operating costs should result.

Objective: HOV Projects Should be Cost Effective

1. From an extremely conservative viewpoint, the projects can be considered cost effective if the average annual value of time saved over the life of the project exceeds 10 percent of the initial construction cost.

Objective: Public Support Should Exist for HOV Development

1. Surveys should show that most people feel the HOV lanes are good transportation projects.

A review of these performance measures based on the HOV evaluations performed in Houston and Dallas leads to several general observations (Table 42). The performance measures suggest that, at today's level of usage, the Katy, North, and East RLT HOV lanes are fulfilling their intended purpose. The Northwest, Southwest, and Gulf HOV lanes are considered to be marginally effective at this time, with the Gulf HOV lane currently being adversely impacted by interim construction phasing.

Continued monitoring of all the committed high-occupancy vehicle lane projects in Texas will take place as part of this research project.

Table 40. Potential Performance Measures for the Houston HOV Lanes, A.M. Peak-Hour, Peak-Direction

Performance Measure[1]	Freeway					
	Katy[2] w/ HOV Lane	North[2] w/HOV Lane	Gulf[2] w/HOV Lane	Northwest[2] w/HOV Lane	Southwest[2] w/HOV Lane	Eastex[3] w/o HOV Lane
Daily HOV Lane Person Trips (12/95)	20,057	20,918	7,233	13,946	14,873	NA
Percent Change over 12/94	+7%	+2%	-29%	+7%	+8%	NA
% Change in Number of Lanes[4]	+33%	+25%	+25%	+33%	+20%	NA
% Change in Person Volume[5]	+70%	+91%	+28%	+55%	+118%	-5%
% Change in Average Vehicle Occupancy[5] (persons/vehicle)	+17%	+13%	-4%	+27%	+14%	-4%
% Change in 2+ Carpool Volumes[5]	+59%[11]	+162%	+70%	+267%	+212%	-5%
% New Carpools Due to HOV Lane[6] (1994)	50%	46%[12]	26%[12]	47%	NA	NA
% Change in Peak-Period Bus Riders	+206%	NA	NA	+219%	-2%	-36%
% New Bus Riders Due to HOV Lane[7]	66%	52%	33%	55%	NA	NA
% Change in Peak-Hour Bus Speeds	+114%	NA	+68%	+74%	+74%	+6%
% Change in Vehicles at Park-and-Ride Lots	+226%	NA	+10%	+270%	+1%	-16%
% Change, Freeway Vehicle Volumes Per Lane[8]	+25%	+6%	+18%	-4%	0%	+2%
% Change, Roadway Efficiency[9]	+82%	+132%	+9%	+51%	+37%	-11%
HOV Travel Time Savings as a % of Construction Cost[10]	25%	6%	5%	5%	5%	NA

NA = Either not available or not applicable.
[1]The percent change is a comparison of current values with representative pre-HOV lane values.
[2]These freeways have operating HOV lanes as of 12/95.
[3]This freeway does not have an HOV lane and represents a basis of comparison to the freeways with HOV lanes.
[4]The HOV added one lane; this is the percent increase in the number of total lanes (freeway plus HOV) resulting from implementing the HOV lane.
[5]A.M. peak-hour, peak-direction, combined mainlane and HOV data.
[6]This is an estimate of the percent of total carpools using the HOV lane that are new carpools created as a result of the HOV lane.
[7]This is an estimate of the percent of total bus riders using the HOV lane that are new bus riders created as a result of the HOV lane.
[8]Data for freeway mainlanes. A.M. peak-hour, peak-direction.
[9]Freeway per lane efficiency is expressed as the multiple of persons moved times average speed, a.m. peak-hour, peak-direction.
[10]This is the estimated annual value of 1995 travel time savings for HOV lane users expressed as a percent of the cost of constructing the segment of the HOV lane in operation in 1995.
[11]6 a.m. to 7 a.m. volume is used for this calculation due to the 3+ requirement during both the a.m. and p.m. peak hours as of 9/16/91.
[12]Based on 1990 data.

Table 41. Potential Performance Measures for the Dallas HOV Lane, A.M. Peak-Hour, Peak-Direction

Performance Measure[1]	Freeway	
	East RLT[2] w/ HOV Lane	South RLT[3] w/o HOV Lane
Daily HOV Lane Person Trips (12/95)	13,572	NA
Percent Change over 12/94	+5%	NA
% Change in Number of Lanes[4]	+25%	NA
% Change in Person Volume[5]	+43%	+6%
% Change in Average Vehicle Occupancy[5] (persons/vehicle)	-2%	-10%
% Change in 2+ Carpool Volumes	+172%	+5%
% New Carpools Due to HOV Lane	21%	NA
% Change in Peak-Period Bus Riders	-24%	-35%
% New Bus Riders Due to HOV Lane	17%	NA
% Change in Peak-Hour Bus Speeds	+126%	+12%
% Change in Vehicles at Park-and-Ride Lots	+7%	+15%
% Change, Freeway Vehicle Volumes Per Lane[6]	+22%	+8%
% Change, Roadway Efficiency[7]	+78%	+3%
HOV Travel Time Savings as a % of Construction Cost[8]	+12%	NA

NA = Either not available or not applicable.
[1]The percent change is a comparison of current values with representative pre-HOV lane values.
[2]Freeway with an operating HOV lane as of 12/95.
[3]This freeway does not have an HOV lane and represents a basis of comparison to the freeways with HOV lanes.
[4]The HOV added one lane; this is the percent increase in the number of total lanes (freeway plus HOV) resulting from implementing the HOV lane.
[5]A.M. peak-hour, peak-direction, combined mainlane and HOV data.
[6]Data for freeway mainlanes. A.M. peak-hour, peak-direction.
[7]Freeway per lane efficiency is expressed as the multiple of persons moved times average speed, a.m. peak-hour, peak-direction.
[8]This is the estimated annual value of 1995 travel time savings for HOV lane users expressed as a percent of the cost of constructing the segment of the HOV lane in operation in 1995.

Table 42. Comparison of HOV Lane Objectives and HOV Lane Performance, 1995

Objective, Measure of Effectiveness	HOV Facility					
	Katy	North	Gulf	Northwest	Southwest	East RLT
Increase Person Movement						
· Is daily ridership greater than 10,000?	Yes	Yes	No	Yes	Yes	Yes
· Is daily ridership greater than 15,000?	Yes	Yes	No	No	No	No
· Has the increase in a.m. peak-hour person volume exceeded the increase in lanes due to the HOV lane?	Yes	Yes	Yes	Yes	Yes	Yes
· Has a.m. peak-hour occupancy increased by more than 15%?	Yes	No	No	Yes	No	No
· Are more than 25% of the HOV lane carpools new due to the HOV lane?	Yes	Yes	Yes	Yes	NA	No
· Are more than 25% of the HOV lane bus riders new due to the HOV lane?	Yes	Yes	Yes	Yes	NA	No
Don't Unduly Impact Freeway General-Purpose Lane Operations						
· Has mainlane congestion increased due to the HOV lane?	No	No	No	No	No	No
· Has the mainlane accident rate increased significantly due to the HOV lane?	No	No	No	No	No	No
Increase the Overall Efficiency of the Roadway						
· Has the roadway per lane efficiency increased by more than 30 due to the HOV lane?	Yes	Yes	No	Yes	Yes	Yes
HOV Lane Should Have Favorable Air Quality & Energy Impacts						
· Has adding an HOV lane been more effective than adding a general-purpose freeway lane would have been?	Yes	NA	NA	NA	NA	NA
Enhance Bus Operations						
· Peak-hour bus speeds increase by at least 50%.	Yes	NA	Yes	Yes	Yes	Yes
· HOV lane accident rate less than or approximately the same as general-purpose lanes?	Yes	No	Yes	Yes	Yes	Yes
The HOV Lane Should be Cost Effective						
· Is the annual value of time saved by HOV lane users greater than 10% of the HOV lane capital cost?	Yes	No	No	No	No	Yes
HOV Lanes Should Have Public Support						
· Do most of the persons responding to surveys indicate support for HOV lane development?	Yes	Yes	Yes	Yes	NA	Yes
Overall Assessment, Is HOV Facility Effective?	Effective	Marginally Effective	Marginally Effective	Marginally Effective	Marginally Effective	Effective

NA = Either not available or not applicable.

APPENDIX A

KATY FREEWAY AND HOV LANE DATA

KATY FREEWAY (IH 10) AND HOV LANE, HOUSTON

Table A-1. Summary of A.M. Peak-Direction Katy Freeway and HOV Lane Data, December 1995

Type of Data Phase 1 of HOV Lane Became Operational 10/29/84	"Representative" Pre-HOV Lane	"Representative" Current Value	Percent Change
HOV Lane Data			
HOV Lane Length (kilometers [miles])		20.9 (13.0)	
HOV Lane Cost (millions)		$63.0	
Person-Movement			
Peak Hour (7-8 a.m.)	---	3,497	---
Peak Period (6-9:30 a.m.)	---	8,348	---
Total Daily	---	20,057	---
Vehicle Volumes			
Peak Hour (7-8 a.m.)	---	835	---
Peak Period	---	2,457	---
Vehicle Occupancy, Peak Hour (persons/veh)	---	4.19	---
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM]), 11/84-12/94[1]	---	12.7 (20.4)	---
Vehicle Breakdowns (VKT/Breakdown [VMT/Breakdown]), 11/84-12/94	---	70,368 (43,707)	---
Violation Rate (6-9:30 a.m.)	---	12%	---
Peak Hour Lane Efficiency (1000's)[2]	---	271 (168)	---
Annual Value of User Time Saved (millions)[3]	---	$5.1- $10.2	---
Freeway Mainlane Data			
Person Movement			
Peak Hour	5,100	5,177	+2%
Peak Period (6-9:30 a.m.)	15,655	15,971	+2%
Vehicle Volume			
Peak Hour	4,045	5,063	+25%
Peak Period	12,750	15,376	+21%
Vehicle Occupancy, Peak Hour (persons/veh)	1.26	1.02	-19%
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM])[1]	12.4 (20.0)	12.0 (19.3)	-3%
Avg. Operating Speed[4] (kph [mph])			
Peak Hour	37 (23)	34 (21)	-8%
Peak Period	53 (33)	52 (32)	-2%
Peak Hour Lane Efficiency (1000's)[2]	61 (38)	59 (37)	-3%

Source: Texas Transportation Institute. The Texas A&M University System.

[1]Due to inconsistencies in reporting accidents in Harris County, this analysis includes only injury accidents. Accidents were analyzed between Gessner and Post Oak, a distance of approximately 7.6 kilometers (4.7 miles). This corresponds to Phase 1 of the HOV lane. "Before" data are for the period 1/82 through 10/84. "After" data are for the period from 11/84 to 8/95. Only officer-reported accidents are included in current files. TTI estimated 1995 freeway volumes.

[2]This represents the multiple of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.

[3]Based on time savings for HOV lane users in 1995 and HOV lane volumes in 1995, an annual estimate of travel time savings to HOV lane users is developed. A value of time of $11.37/hour is used based on the value applied in the Highway Economic Evaluation Model.

[4]The distance from SH 6 to Washington is 19.6 kilometers (12.2 miles). The HOV lane is in place over this section.

Table A-1. Summary of A.M. Peak-Direction Katy Freeway and HOV Lane Data, December 1995 (Continued)

Type of Data Phase 1 of HOV Lane Became Operational 10/29/84	"Representative" Pre-HOV Lane	"Representative" Current Value	Percent Change
Combined Freeway Mainlane and HOV Lane Data			
Total Person Movement			
Peak Hour	5,100	8,674	+70%
Peak Period	15,655	24,318	+55%
Vehicle Volume			
Peak Hour	4,045	5,898	+46%
Peak Period	12,750	17,833	+40%
Vehicle Occupancy			
Peak Hour	1.26	1.47	+17%
Peak Period	1.23	1.36	+11%
Carpool Volumes[1]			
2+, 6 a.m. to 7 a.m.	505	802	+59%
3+, 7 a.m. to 8 a.m.	76	343	+351%
3+, 5 p.m. to 6 p.m.	104	407	+291%
Travel Time (minutes)			
Peak Hour	33.9[2]	15.3[3]	-55%
Peak Period	23.1[2]	14.1[3]	-39%
Peak Hour Lane Efficiency (1000's)[4]	61 (38)	111 (69)	+82%
Transit Data			
Bus Vehicle Trips			
Peak Hour	11	40	+264%
Peak Period	32	78	+144%
Bus Passenger Trips			
Peak Hour	335	1,508	+350%
Peak Period	900	2,750	+206%
Bus Occupancy (persons/bus)			
Peak Hour	30.5	37.7	+24%
Peak Period	28.1	35.3	+26%
Vehicles Parked in Corridor Park & Ride Lots	575	1,877	+226%
Bus Operating Speed (kph [mph])[5]			
Peak Hour	36 (23)[2]	77 (48)[3]	+114%
Peak Period	53 (33)[2]	84 (52)[3]	+59%

Source: Texas Transportation Institute. The Texas A&M University System.

[1]Carpool counts are adjusted in an effort to compensate for undercounting of occupancies in the field.

[2]Data pertain to operation in the freeway mainlanes.

[3]Data pertain to operation in the HOV lane.

[4]This represents the multiple of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.

[5]The distance from SH 6 to Washington is 19.6 kilometers (12.2 miles). The HOV lane is in place over this section.

Table A-2. Comparison of Measures of Effectiveness, Freeway With (Katy, I-10W) and Freeway Without (Eastex, U.S. 59) HOV Lane, Houston

Measure of Effectiveness	"Representative" Pre-HOV Lane Value	"Representative" Current Value	Percent Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/HOV lane	1.26	1.47	+17%
Freeway w/o HOV lane	1.23	1.18	-4%
Peak-Hour 3+ Carpool Volume			
Freeway w/HOV lane	76	343	+351%
Freeway w/o HOV lane	123	93	-24%
Bus Passengers, Peak Period			
Freeway w/HOV lane	900	2,750	+206%
Freeway w/o HOV lane	1,188	762	-36%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	575	1,877	+226%
Freeway w/o HOV lane[1]	1,236	1,035	-16%
Facility Per Lane Efficiency[2]			
Freeway w/HOV lane	61 (38)	111 (69)	+82%
Freeway w/o HOV lane	138 (86)	123 (77)	-11%

[1]Data for freeways without HOV lanes are a composite of data collected on the Gulf Freeway during the time in which no HOV lane existed on that facility (6/83 through 4/88), the Southwest Freeway (9/86 to 12/92), and on the Eastex Freeway (1/93 to present).

[2]This represents the multiple of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.

HOV LANE DATA

DESCRIPTION

- Phase 1 (7.6 kilometers [4.7 miles]) of the HOV lane opened October 29, 1984.
- The HOV lane is now complete with 20.9 kilometers (13.0 miles) in operation.
- The capital cost (including all support facilities) for the completed facility in 1990 dollars was $59.1 million. Table A-3 provides a more detailed cost breakdown (including dates) on the following page.
- Selected milestone dates are listed below. Other dates are shown in the capital cost table.
- 10/29/84 Post Oak to Gessner (7.6 kilometers [4.7 miles]) opens, used by buses and vans.
- 4/1/85 4+ authorized carpools allowed onto HOV.

- 5/2/85 HOV extended to West Belt (10.3 kilometers [6.4 miles]).
- 11/4/85 3+ authorized carpools allowed onto HOV.
- 8/11/86 2+ carpools, no authorization, hours extended.
- 6/29/87 HOV extended to SH 6 (18.5 kilometers [11.5 miles]).
- 7/25/88 Hours of operation extended.
- 10/17/88 3+ from 6:45 a.m. to 8:15 a.m.
- 10/1/89 Weekend operation begins.
- 1/9/90 Eastern extension opens (20.9 kilometers [13.0 miles]).
- 4/1/90 Northwest Transit Center opens.
- 5/23/90 3+ carpool hours changed to 6:45 to 8:00 a.m.
- 9/16/91 3+ carpool restriction, 5:00 to 6:00 p.m.
- 9/8/92 Motorcycles allowed on HOV facility (no occupancy restrictions).

Table A-3. Estimated Capital Costs (millions), Katy HOV Lane

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1995 dollars
HOV Lane and Ramps			
Eastern Extension (1990)	$7.1	1.21	$ 8.6
Phase 1, Silber to West Belt (1984) Design and Construction	10.5	1.13	11.9
Phase 2, West Belt to SH 6 (1987) Design and Construction	11.7	1.03	12.0
Addicks North Ramp (1987)	2.8	1.03	2.9
Addicks South Ramp	0.3	1.21	0.4
Misc.	4.3	1.21	5.2
SUB-TOTAL	$36.7		$41.0
Per Kilometer (Mile)	$1.8 ($2.8)		$2.0 ($3.2)
Surveillance, Communication & Control (1987)	$4.6	1.03	$4.7
SUB-TOTAL	$4.6		$4.7
Per Kilometer (Mile)	$0.2 ($0.4)		$0.2 ($0.4)
Support Facilities			
West Belt P/R (1984)	$4.8	1.13	$5.4
Addicks P/R (1981)	3.9	1.27	5.0
Addicks P/R Expansion (1988)	6.3	1.11	7.5
Kingsland P/R (1985)	3.8	1.19	4.2
Fry Road Park-and-Pool (1987)	0.2	1.03	0.2
Mason Road Park-and-Pool (1986)	0.2	0.96	0.2
Barker-Cypress Park-and-Pool (1986)	0.2	0.96	0.2
SUB-TOTAL	$19.4		$22.7
Per Kilometer (Mile)	$0.9 ($1.5)		$1.1 ($1.7)
TOTAL COST	$60.7		$68.4
COST PER KILOMETER (20.9 kilometers [13.0 miles])	$2.9 ($4.7)		$3.3 ($5.3)

Source: Compiled by TTI from data provided by Metro and TxDOT

Table A-4. Estimated Capital Cost (millions), Katy HOV Lane, Future Segments

Cost Component	Estimated Year of Construction	Estimated Cost ($Millions)
HOV Lane Ramps/Connectors		
Katy-CBD Ramp, 3.7 kilometers (2.3 Miles)	1999	40.4
Northwest Transit Center/Inner Katy Connection	1998	9.9
		50.3

PERSON MOVEMENT

- In September 1995, the HOV lane served 20,057 person trips per day.
- A.M. Peak Hour, 3,497 persons/hour.
  - 1,508 (43%) by bus, 167 (5%) by vanpool, 1,809 (52%) by carpool, and 15 by motorcycle (Figure A-1).
  - Average HOV lane vehicle occupancy = 4.19 persons/vehicle.
- A.M. Peak Period, 8,348 persons.
  - 2,750 (33%) by bus, 451 (5%) by vanpool, by carpool 5,109 (61%), and 39 by motorcycle (Figure A-2).

VEHICLE MOVEMENT

- A.M. Peak Hour, 835 vph.
  - 20 (2%) buses, 20 (2%) vans, 761 (91%) carpools, and 15 (2%) by motorcycle (Figure A-3).
- A.M. Peak Period, 2,457 vehicles.
  - 78 (3%) buses, 59 (2%) vans, 2,282 (93%) carpools, and 39 (2%) by motorcycle (Figure A-4).

ACCIDENT RATE

- For the period from November 1984 through September 1995, the HOV lane accident rate was 12.7 injury accidents per 100 million vehicle kilometers (20.4 injury accidents per 100 million vehicle miles).

VEHICLE BREAKDOWN RATES

- As measured for 11/84 to 9/95, the following rate has been observed.

  - The weighted average for all vehicle types is one breakdown per 70,368 VKT (43,707 VMT).

VIOLATION RATE

- The observed violation rate (vehicles on the HOV lane not eligible to use the HOV lane) varies by time period.

  - For the overall a.m. peak period, it is 12%.
  - For the period from 7:00 a.m. to 8:15 a.m. (the 3+ operating time), it averaged 34% for 1995 and was 35% in September.
  - For the p.m. peak hour (the 3+ operating time), the violation rate was 41% in 1995.

PEAK HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. For the HOV lane, this value (expressed in 1000's) is approximately 271 (3,497 passengers at 77 kph), or 168 (3,497 passengers at 48 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane experienced an average travel time savings of 18 minutes during the morning peak hour in 1995 (Figure A-5).

- Table A-5 indicates that, on a typical non-incident day, travel time savings of approximately 1,795 person hours (107,723 min.) are realized. Assuming 250 days of operation, annual savings would be 448,846 hours. At $11.37/hour, this equates to $5.10 million per year. This is extremely conservative since it does not consider travel time savings due to incidents on the freeway. Data from Houston suggest that increasing this value by 100% to account for incidents would be reasonable. Thus, conservatively estimated travel time savings to HOV lane users are in the range of $5.10 to $10.21 million per year.

FREEWAY DATA

NOTES

- For purposes of safety and visibility, freeway volumes are counted at Bunker Hill between an exit ramp and an entrance ramp. Thus, freeway volumes may be low in comparison to typical freeway operations.

PERSON MOVEMENT

- In the a.m. peak hour, person movement has increased by 2% relative to pre-HOV conditions (Figure A-6).

- In the a.m. peak period, person movement has increased by 2% relative to pre-HOV conditions (Figure A-7).

VEHICLE VOLUME

- In the a.m. peak hour, vehicle volume has increased by 25%, relative to pre-HOV conditions (Figure A-8).

- In the a.m. peak period, vehicle volume has increased by 21%, relative to pre-HOV conditions (Figure A-9).

VEHICLE OCCUPANCY

- In the a.m. peak hour, mainlane occupancy has decreased by 19%, relative to pre-HOV conditions (Figure A-10).

- In the a.m. peak period, mainlane occupancy has decreased by 15%, relative to pre-HOV conditions (Figure A-11).

ACCIDENT RATE

- Implementation of the HOV lane resulted in narrower freeway lanes and no inside emergency shoulder.

- The accident data shown are for the section between Gessner and Post Oak (toll road construction impacted the freeway section west of Gessner). The accident rate for the period (1/82-10/84) preceding Phase 1 of the HOV lane was 12.4 accidents per 100 million vehicle kilometers (100 MVK) (20.0 accidents per 100 million vehicle miles [100 MVM]). For the period from 11/84 to 8/95, the freeway accident rate was 12.0 accidents/100 MVK (19.3

accidents/100 MVM). These statistics do not include driver reported accidents; current accident files include only officer reported accidents.

AVERAGE OPERATING SPEED

- In comparison to pre-HOV lane conditions, mainlane operating speeds have increased by 8% in the peak hour and 2% in the peak period (Figure A-12).

PEAK HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of per lane efficiency.

- For the freeway mainlanes, there has been a slight decrease in per lane efficiency.

Table A-5. Travel Time Savings for Katy HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1995)

Eastbound A.M. Travel Time Savings for Katy HOV Lane								
Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section From SH 6 to Gessner Interchange								
6:00	7.27	6.45	0.82	417	70	240	727	594
6:30	11.00	6.98	4.02	958	68	271	1,297	5,210
7:00	21.97	6.30	15.67	446	52	441	939	14,711
7:30	19.88	6.07	13.82	321	10	495	826	11,413
8:00	9.85	6.73	3.12	707	23	300	1,030	3,210
8:30	7.70	6.00	1.70	376	23	110	509	8.65
9:00	6.00	6.37	-0.37	195	0	0	195	-72
Peak Period Total				3,420	246	1,857	5,523	35,931
Section From Gessner Interchange to Washington								
6:00	8.07	7.62	0.45	404	90	280	774	348
6:30	8.63	7.23	1.40	1,219	96	531	1,846	2,584
7:00	18.17	8.28	9.88	651	104	610	1,365	13,491
7:30	15.32	7.25	8.07	731	74	750	1,555	12,544
8:00	11.28	7.85	3.43	953	45	355	1,353	4,645
8:30	7.02	7.22	-0.20	690	37	156	883	-177
8:00	7.30	7.63	-0.33	432	11	90	533	-178
Peak Period Total				5,080	457	2,772	8,309	33,257
Westbound P.M. Travel Time Savings for Katy HOV Lane								
Section from Washington to Gessner Interchange								
3:30	9.58	7.00	2.57	259	12	121	392	1,008
4:00	9.79	7.19	2.60	395	23	176	593	1,541
4:30	12.45	7.88	4.57	740	70	234	1,044	4,765
5:00	16.27	7.27	9.01	309	22	346	676	6,090
5:30	22.44	7.70	14.74	389	29	370	788	11,616
6:00	14.34	8.03	6.31	446	34	173	653	4,116
6:30	8.14	7.03	1.11	231	4	71	305	338
Peak Period Total				2,768	193	1,489	4,449	29,474

Table A-5. Travel Time Savings for Katy HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1995) (Continued)

Eastbound A.M. Travel Time Savings for Katy HOV Lane								
Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section from Gessner Interchange to SH 6								
3:30	6.14	6.02	0.13	121	3	53	176	22
4:00	6.29	5.99	0.30	209	15	105	329	99
4:30	9.04	6.20	2.84	299	19	128	445	1,263
5:00	11.64	6.17	5.47	340	30	166	535	2,926
5:30	11.08	6.10	4.97	213	15	373	601	2,987
6:00	9.48	6.41	3.07	317	8	173	498	1,527
6:30	7.29	6.23	1.06	177	0	46	222	235
Peak Period Total				1,675	88	1,042	2,804	9,060

COMBINED FREEWAY MAINLANE AND HOV LANE DATA

TOTAL PERSON MOVEMENT

- Percent by HOV lane, a.m. peak hour.
    - At Bunker Hill, the HOV lane is responsible for 41% of peak-hour person movement (HOV lane = 3,497; freeway = 5,403) and 35% of peak-period (HOV lane = 8,348; freeway = 15,330) person movement.
- Increase in a.m. person movement at Bunker Hill relative to pre-HOV lane operations.
    - Provision of the HOV lane increased total directional lanes by 33%.
    - Total peak-hour person movement has increased by 70% from 5,100 to 8,674 (Figure A-6). Peak-period person movement has increased by 55% from 15,655 to 24,318 (Figure A-7).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.47, a 17% increase over the pre-HOV lane occupancy (Figure A-10). Occupancy in the peak period is greater than pre-HOV lane levels (Figure A-11), increasing from 1.23 to 1.36 (11%).

- While the occupancy on the Katy Freeway has increased significantly, freeways which do not have HOV lanes have decreased occupancy (Figure A-13).

CARPOOL VOLUMES

- Prior to the HOV lane, 2+ carpool volume from 6 to 7 a.m. was 505 vehicles -- now it is more than 800 vehicles (Figure A-14).

- In the a.m. peak hour, the total number of 3+ carpools (freeway plus HOV lane) has increased by 351% compared to pre-HOV lane levels (Figure A-15).

PEAK HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. The average efficiency of a lane on the freeway (3 freeway lanes plus 1 HOV lane) has increased by 82% since the implementation of the HOV lane (Figure A-16).

BUS TRANSIT DATA

BUS VEHICLE AND PASSENGER TRIPS

- In the a.m. peak hour, bus vehicle trips have been increased by 264% since the HOV lane opened, and a 350% increase in bus ridership has also resulted (Figure A-17). In the peak period, a 144% increase has occurred in bus trips and a 206% increase in bus ridership has resulted (Figure A-18).

- While bus passenger trips have increased significantly in the Katy Freeway corridor, this has not occurred in the corridors which do not have HOV lanes (Figure A-19).

PARK-AND-RIDE

- Prior to opening the HOV lane, approximately 575 vehicles were parked in corridor park-and-ride lots. This has increased 226% to a current level of 1,877 (Figure A-20).

- The same magnitude of increase in cars parked at park-and-ride lots in the Katy corridor has not been realized in the freeway corridors that do not have HOV lanes (Figure A-21).

FIGURE A-1. KATY FREEWAY (IH 10W) HOV LANE
A.M. PEAK HOUR HOV LANE PERSON MOVEMENT

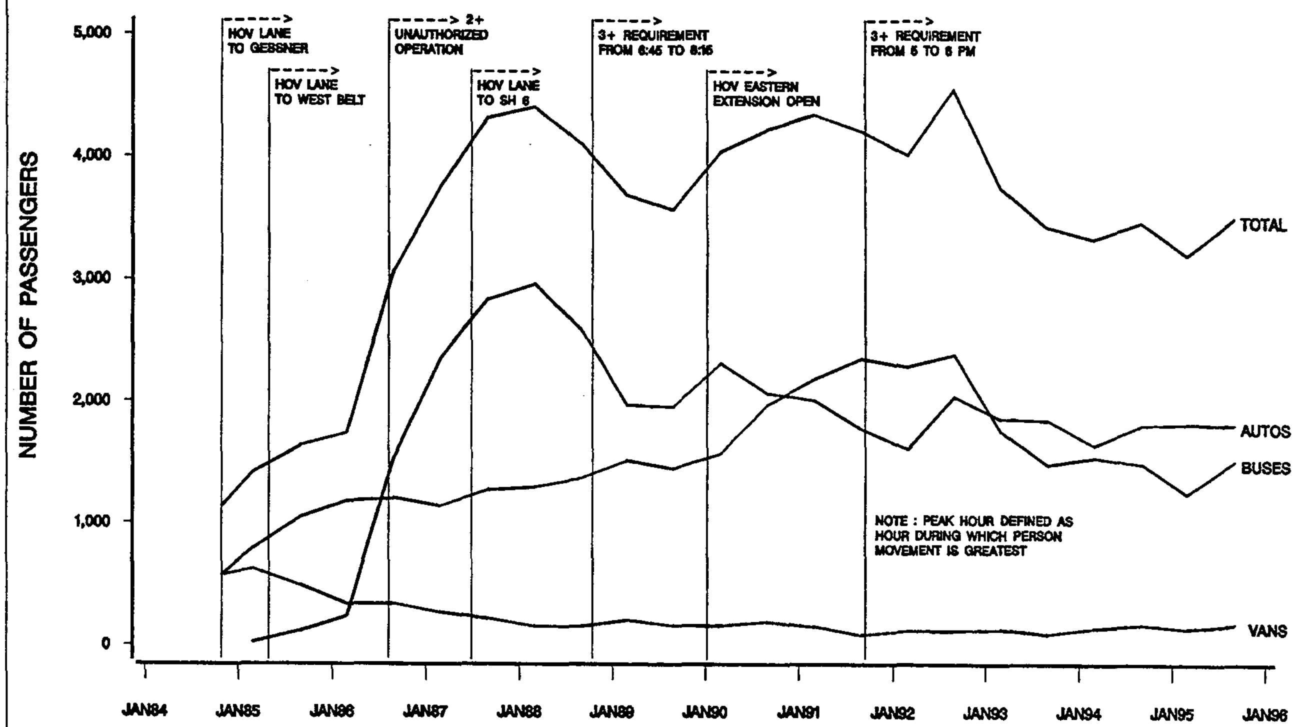


FIGURE A-2. KATY FREEWAY (IH 10W) HOV LANE
A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT

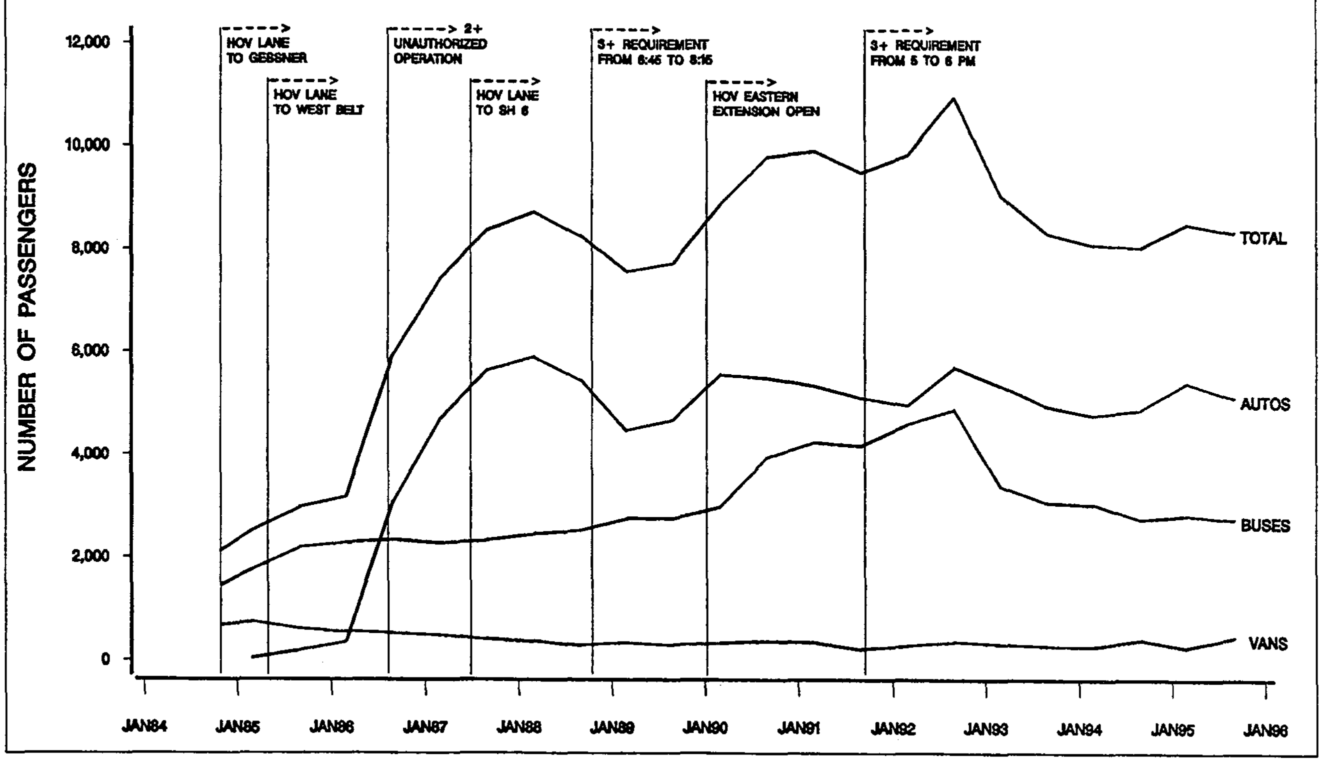


FIGURE A-3. KATY FREEWAY (IH 10W) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION

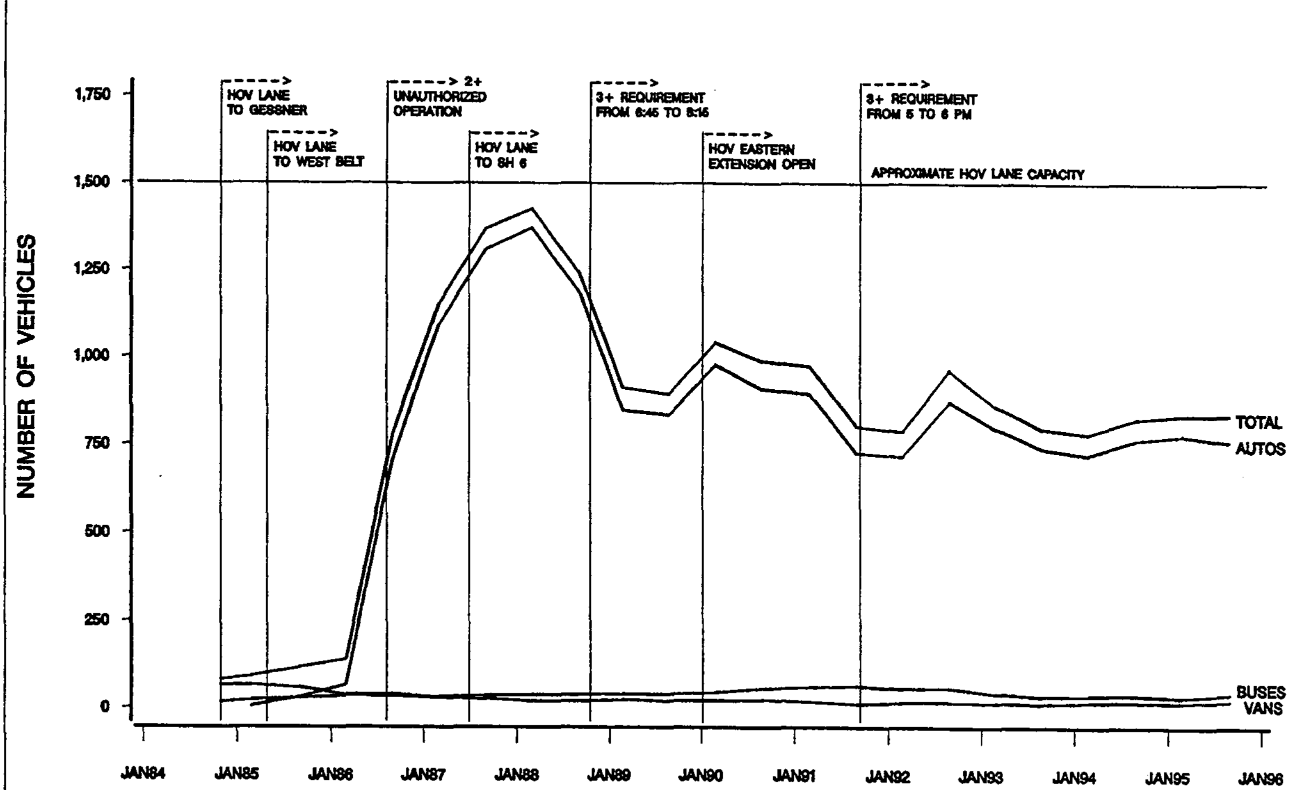


FIGURE A-4. KATY FREEWAY (IH 10W) HOV LANE
A.M. PEAK PERIOD HOV LANE VEHICLE UTILIZATION

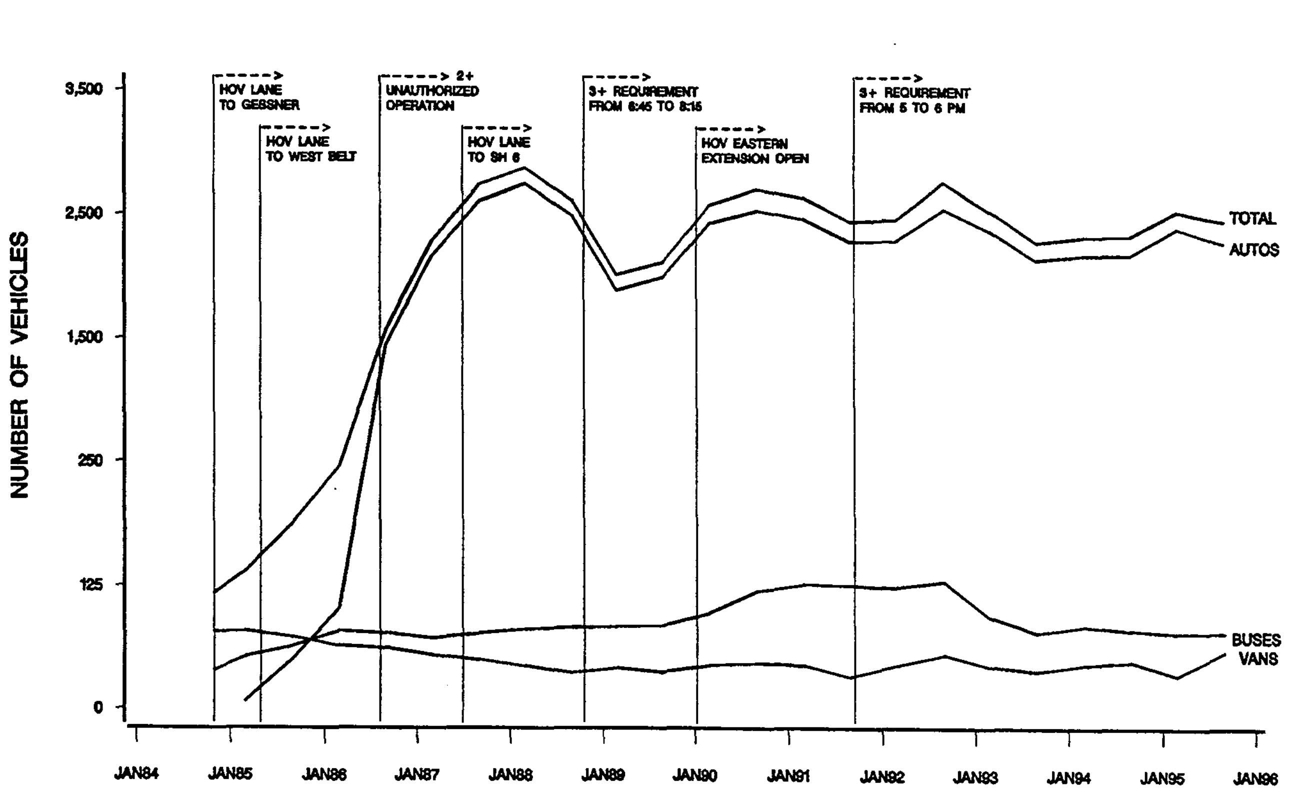


FIGURE A-5. KATY FREEWAY (IH 10W) MAINLANES AND HOV LANE A.M. TRAVEL TIME

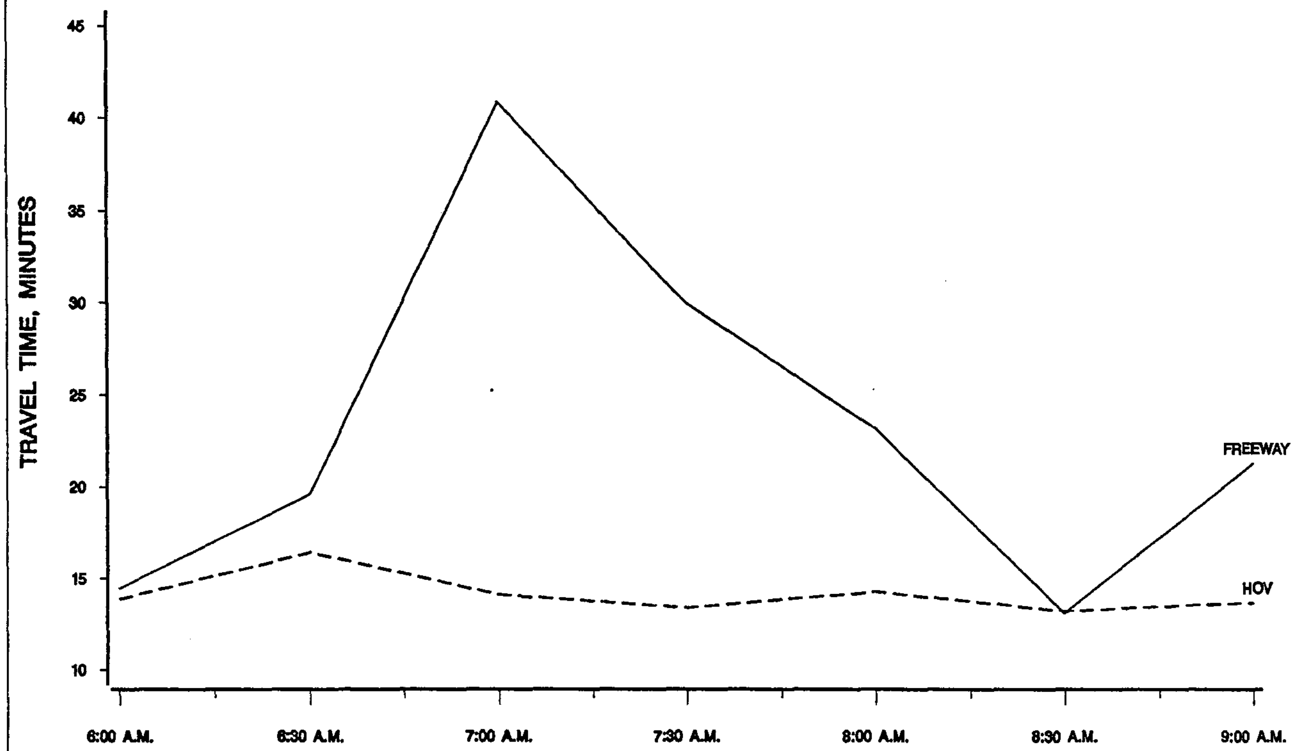


FIGURE A-6. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK HOUR PERSON TRIPS

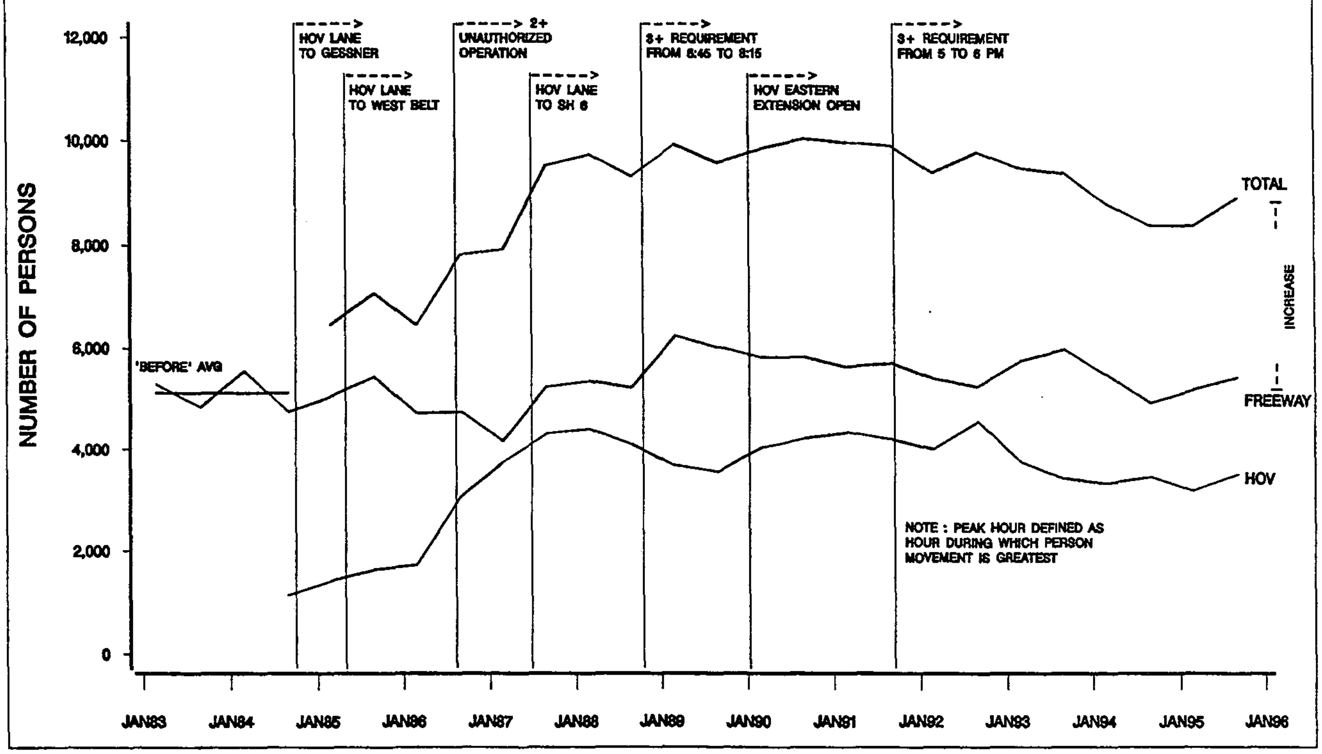


FIGURE A-7. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK PERIOD PERSON TRIPS

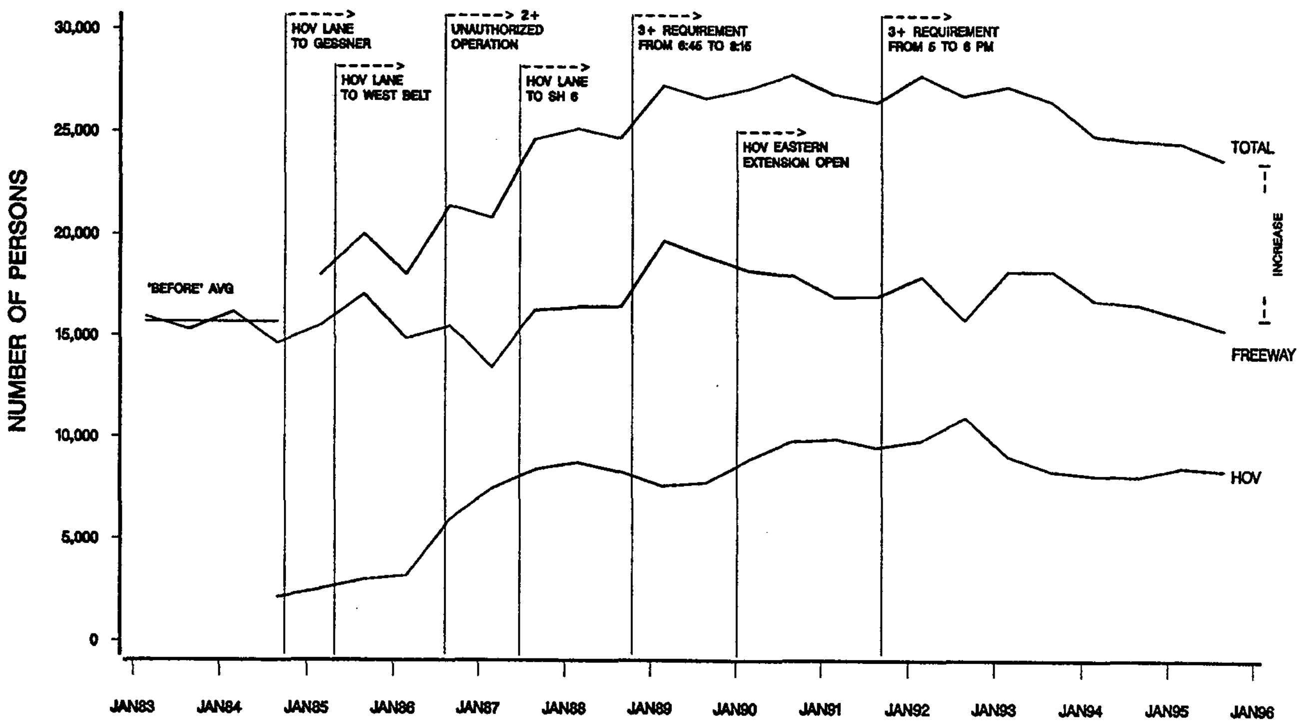


FIGURE A-8. KATY FREEWAY (IH 10W)
A.M. PEAK HOUR MAINLANE TRIPS

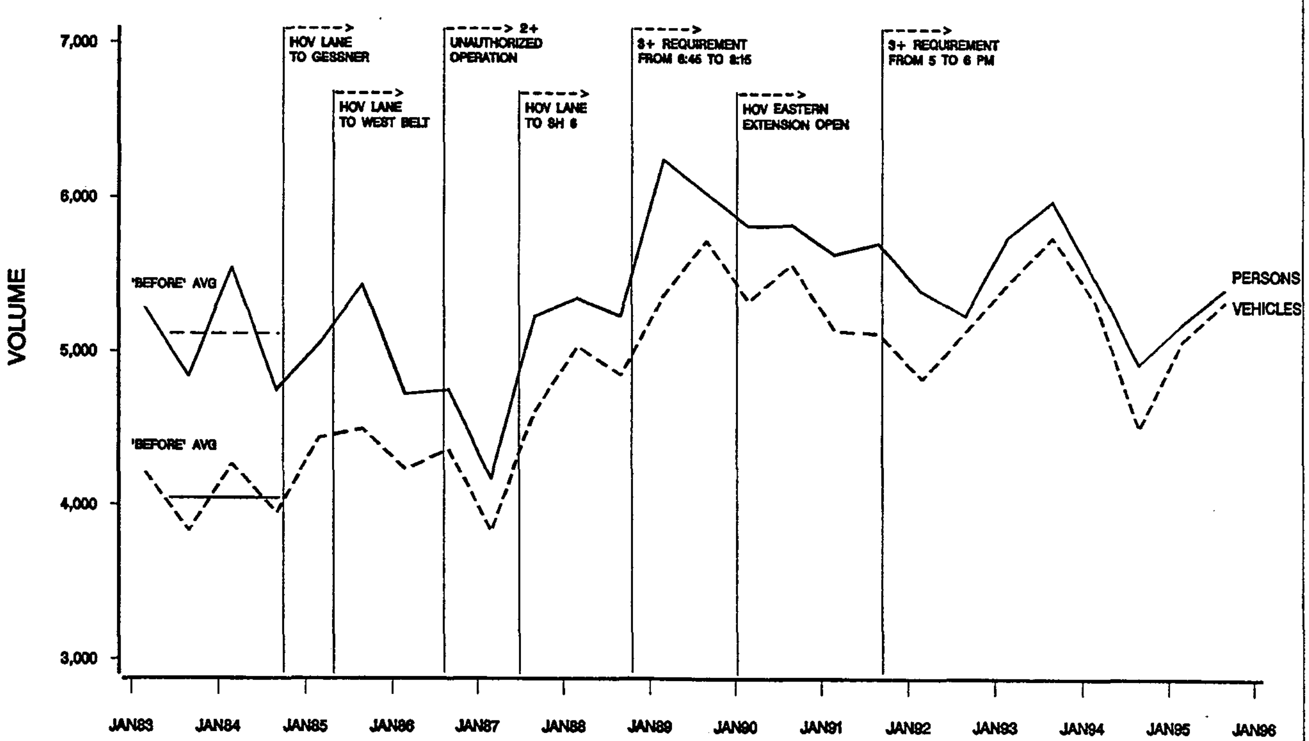


FIGURE A-9. KATY FREEWAY (IH 10W)
A.M. PEAK PERIOD MAINLANE TRIPS

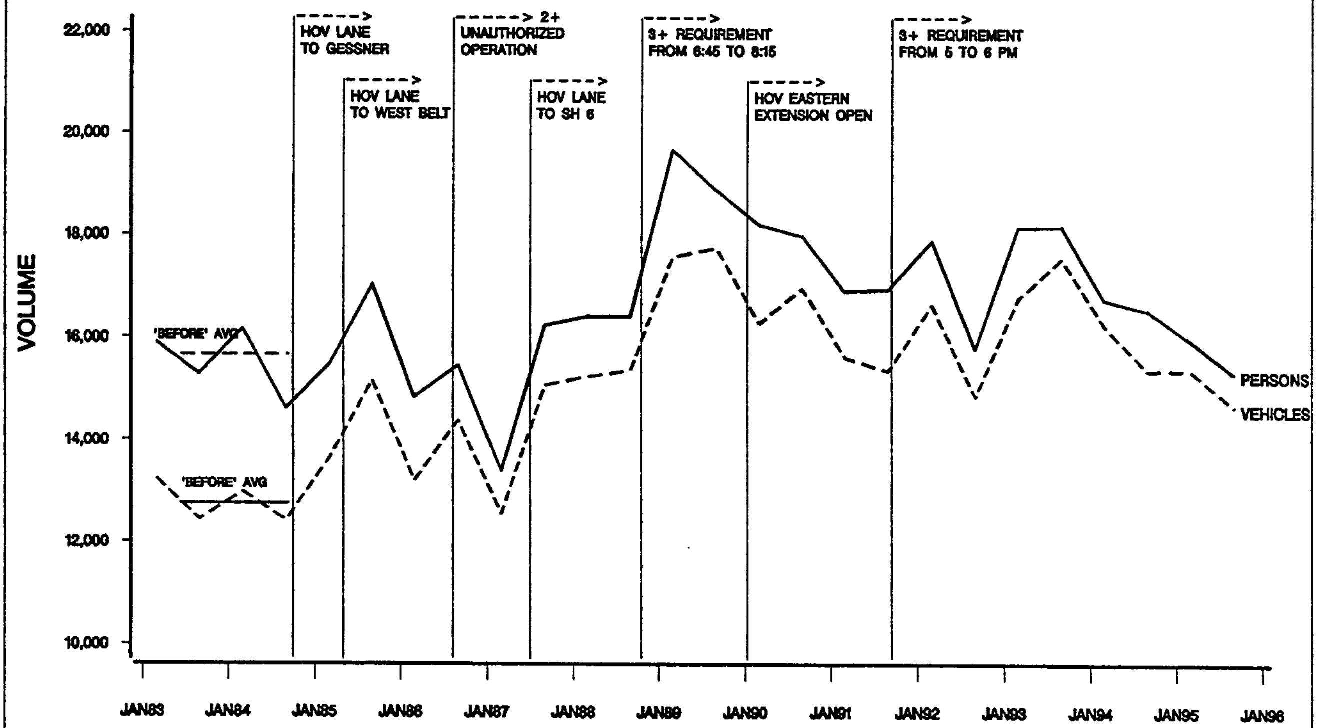


FIGURE A-10. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK HOUR AVERAGE OCCUPANCY

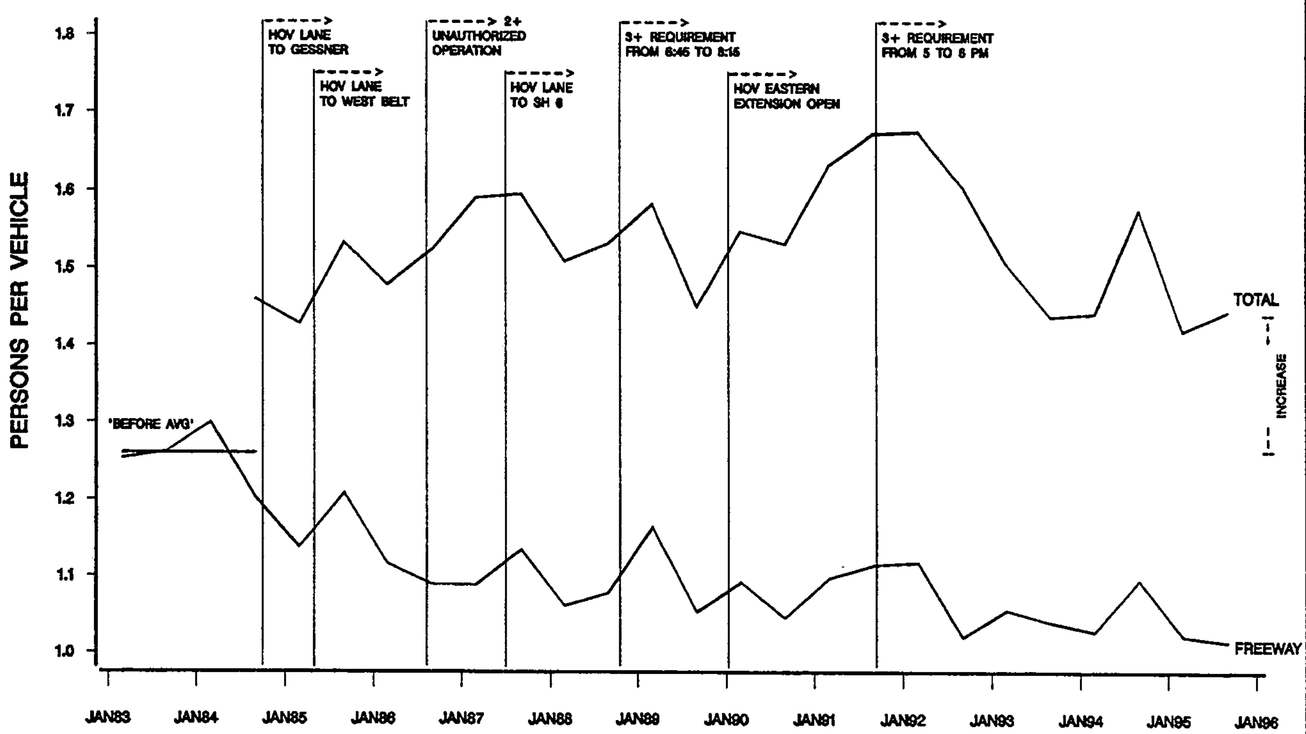


FIGURE A-11. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK PERIOD AVERAGE OCCUPANCY

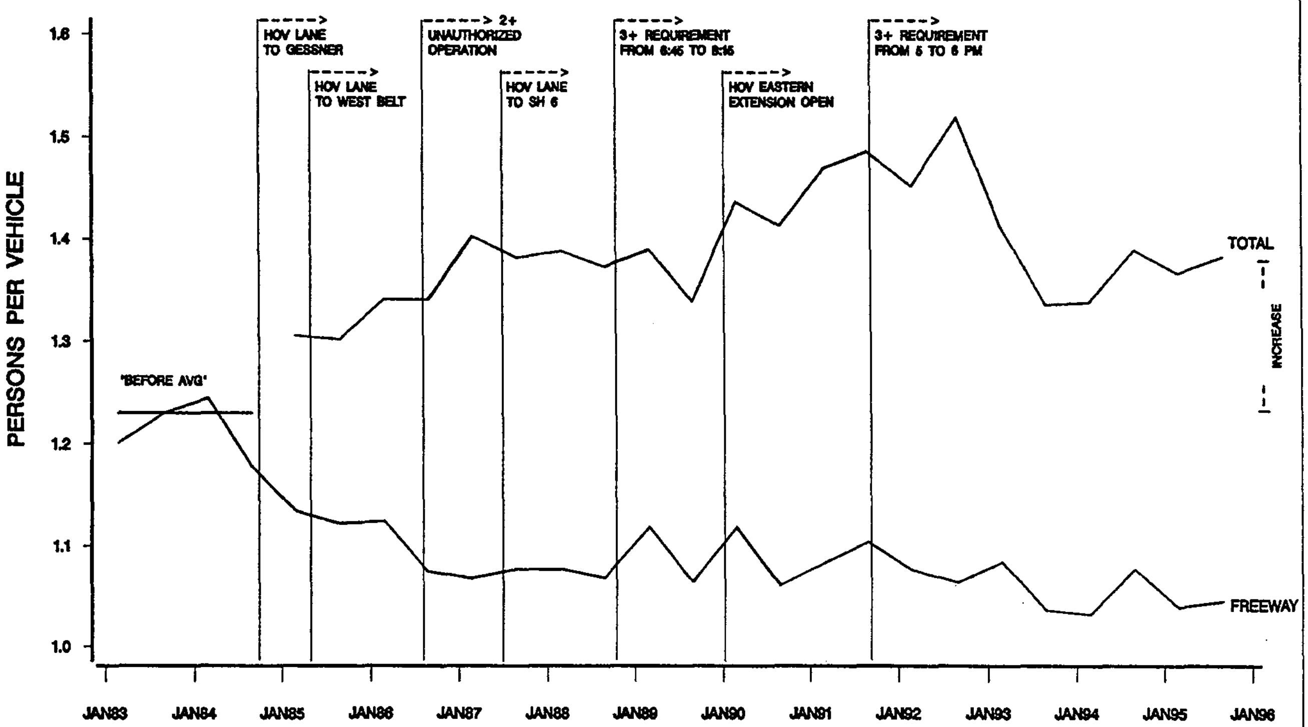


FIGURE A-12. KATY FREEWAY (IH 10W) MAINLANE TRAVEL TIME AND SPEED SURVEY
EASTBOUND, SH 6 TO WASHINGTON
A.M. PEAK PERIOD

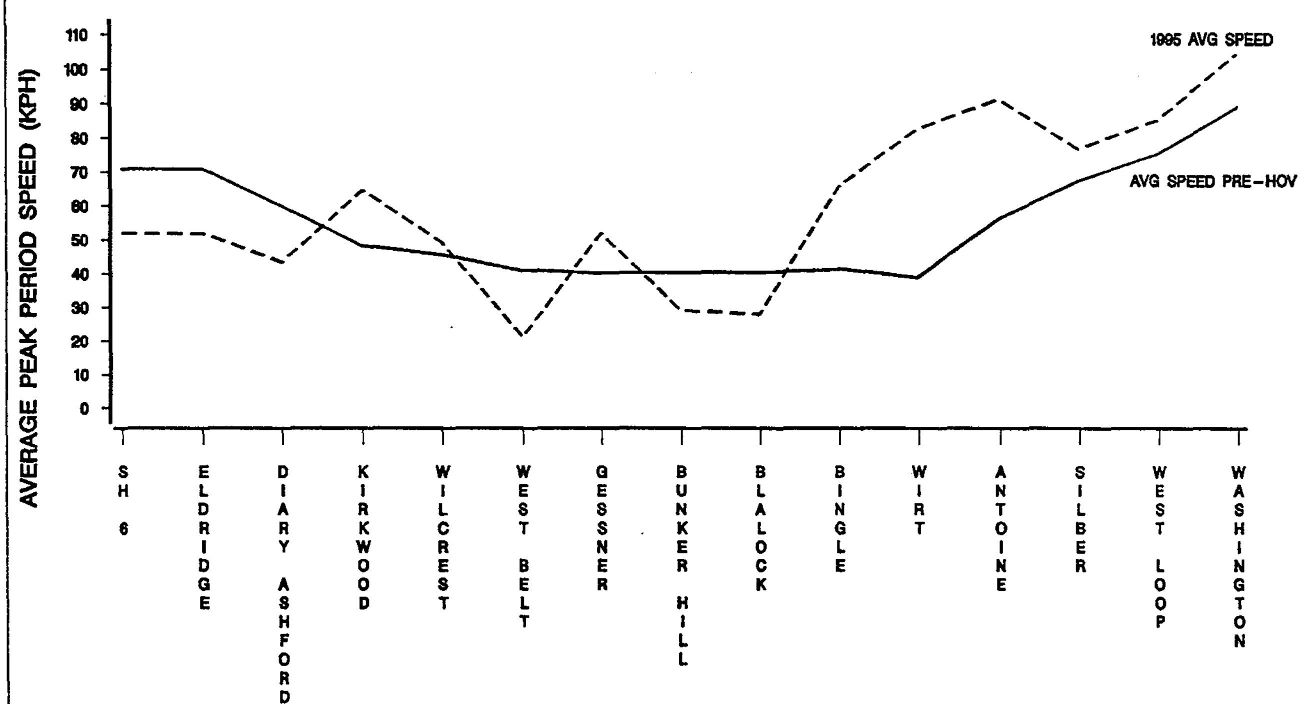


FIGURE A-13. A.M. PEAK HOUR AVERAGE OCCUPANCY
KATY FREEWAY AND FREEWAY WITHOUT HOV LANE

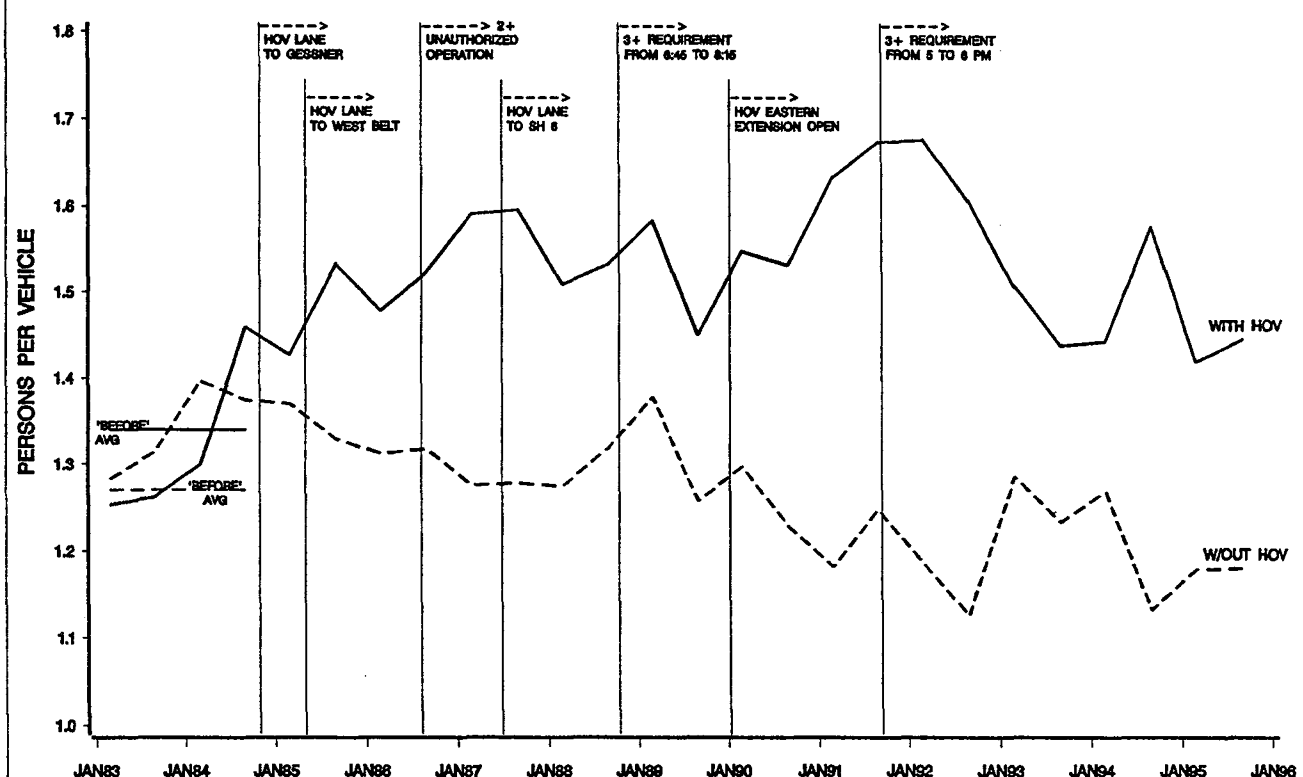


FIGURE A-14. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK HOUR 2+ CARPOOL UTILIZATION

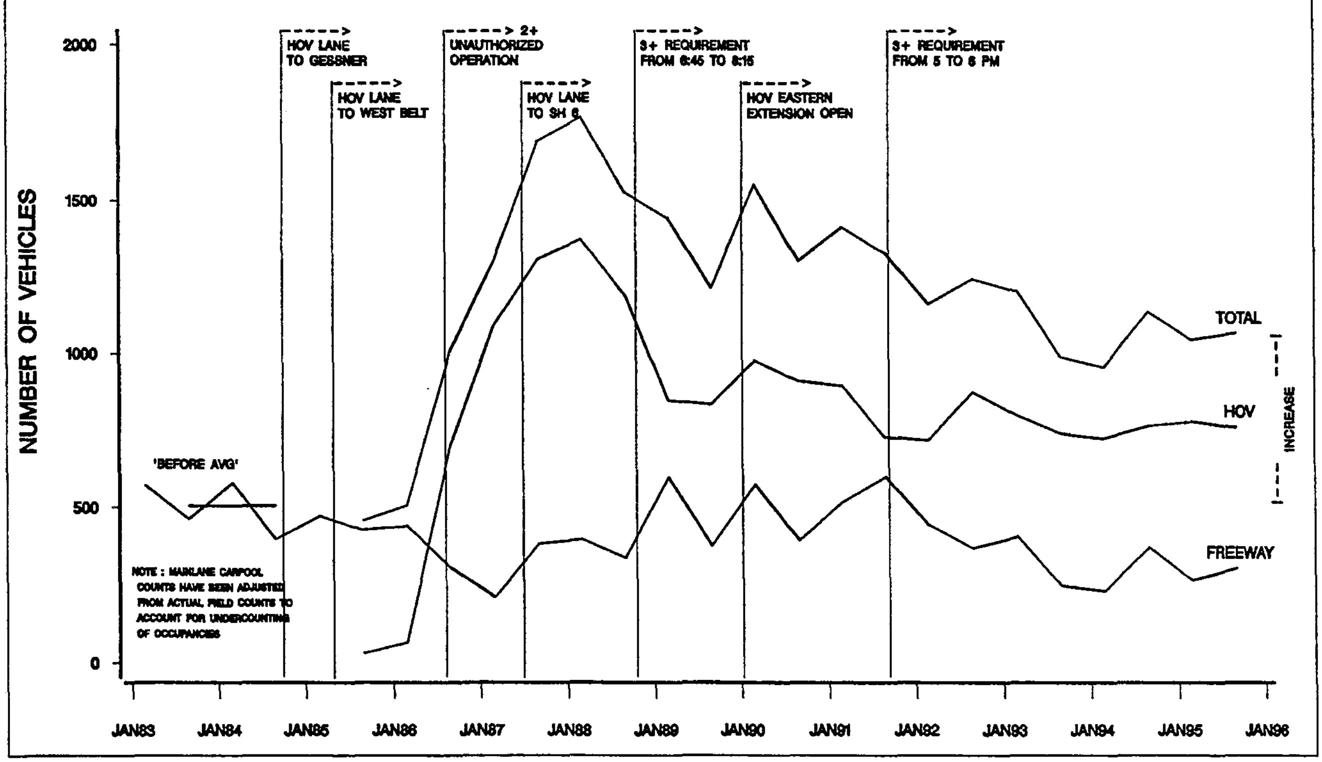


FIGURE A-15. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
7:00 A.M. TO 8:00 A.M. 3+ CARPOOL UTILIZATION

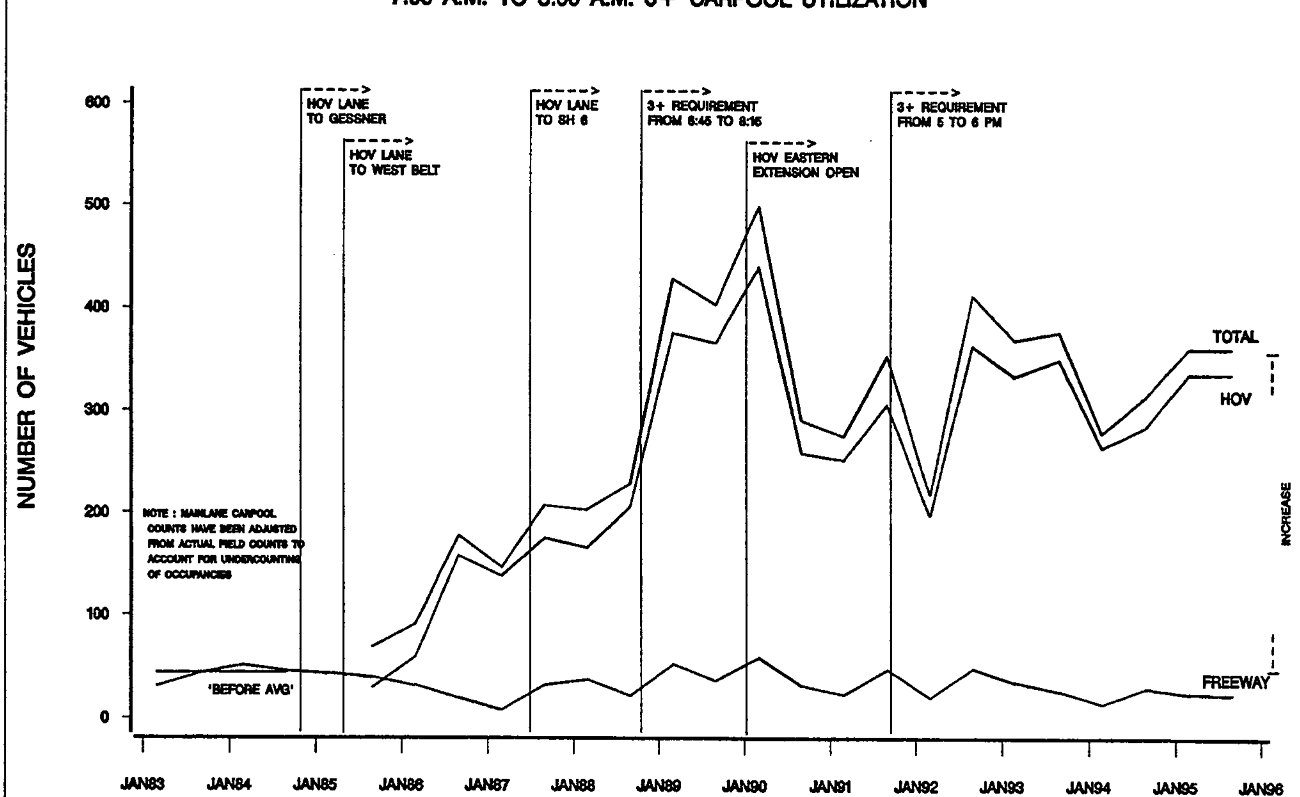


FIGURE A-16. A.M. PEAK HOUR FREEWAY PER LANE EFFICIENCY
KATY FREEWAY AND FREEWAY WITHOUT HOV LANE

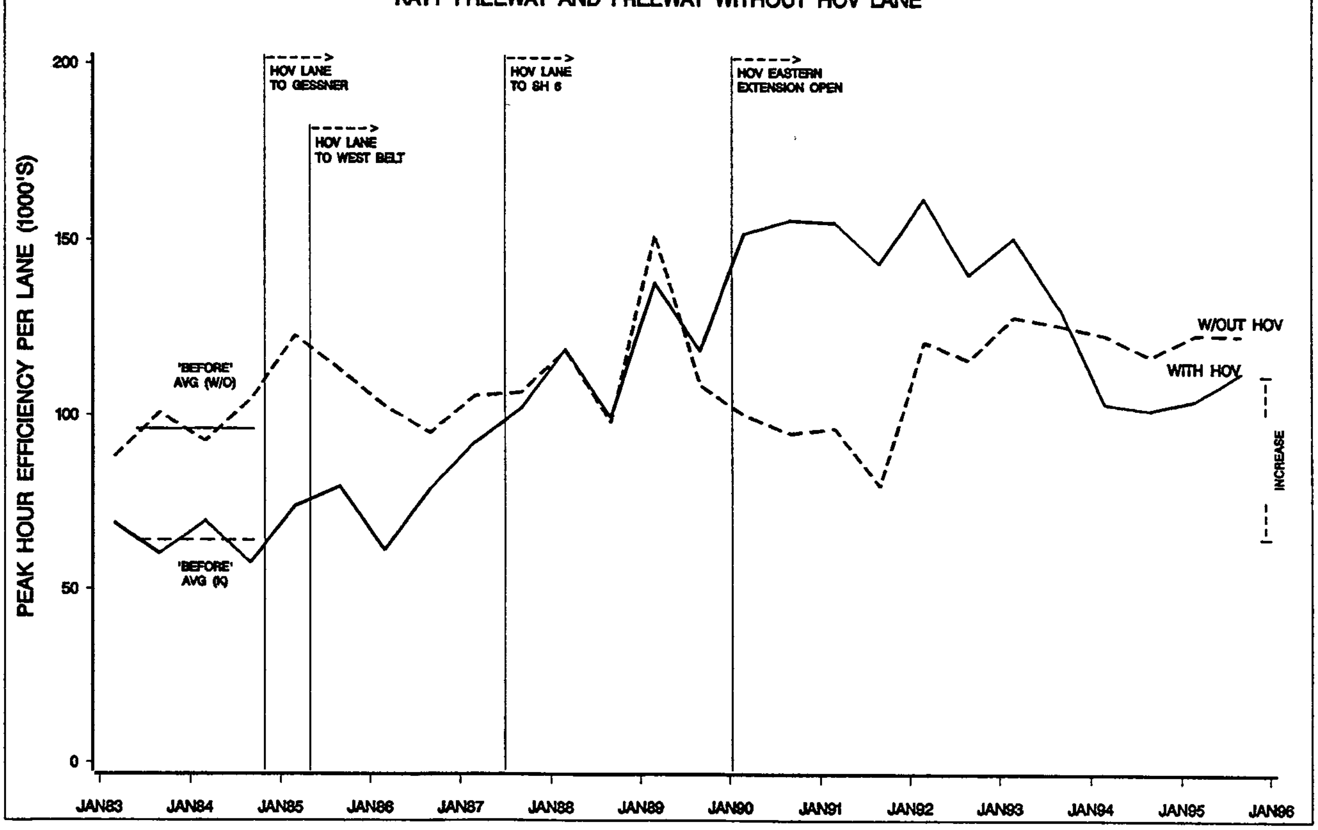


FIGURE A-17. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS

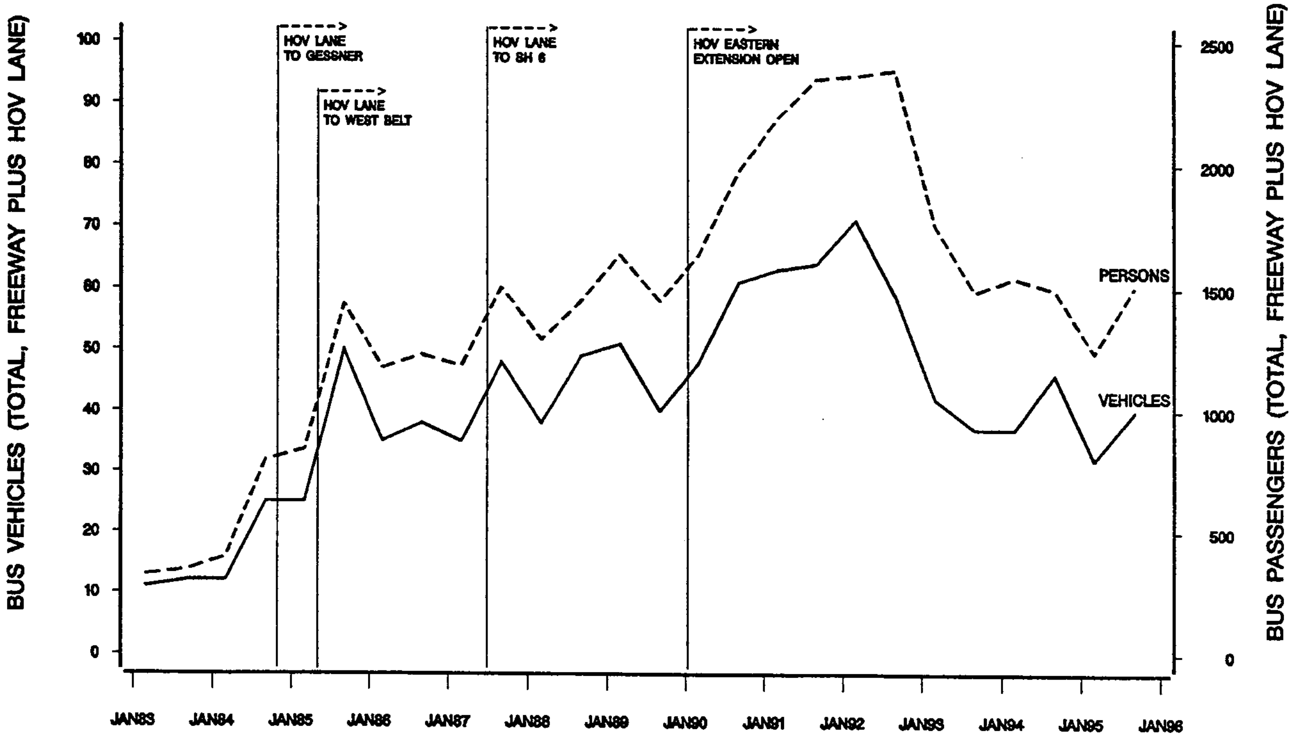
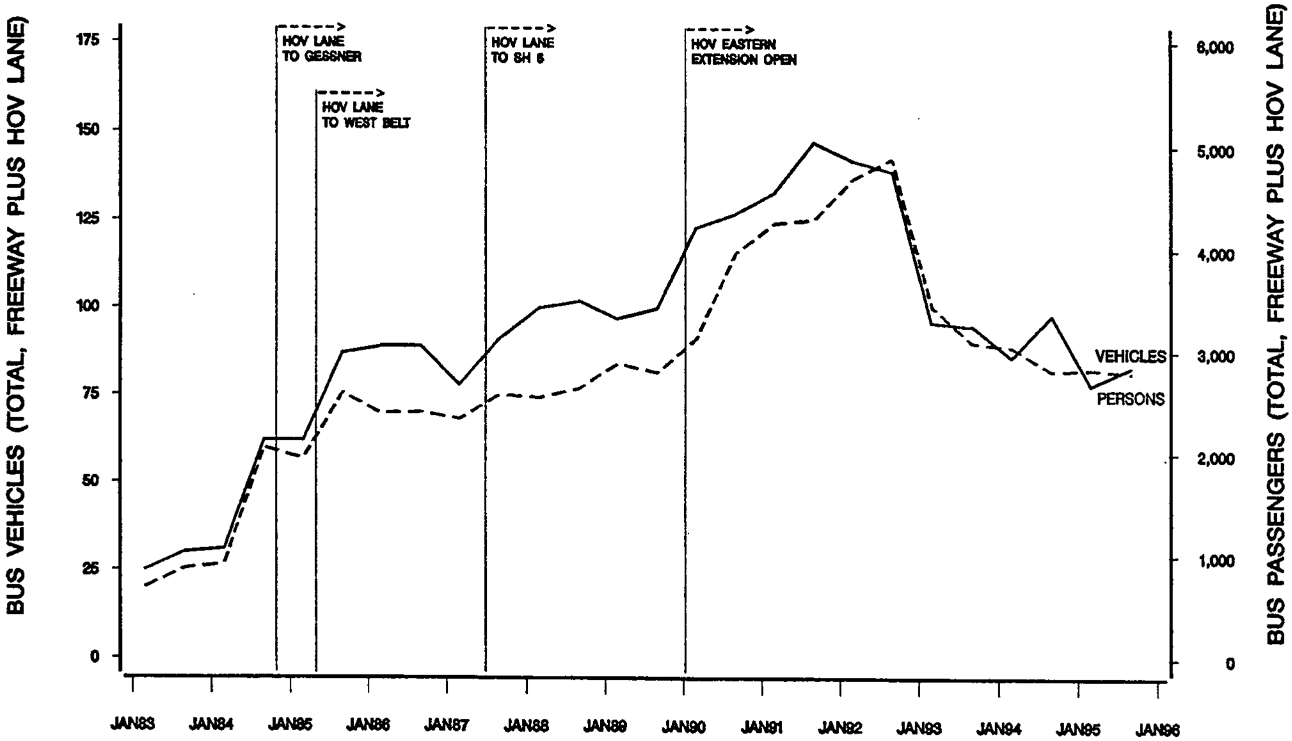


FIGURE A-18. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS



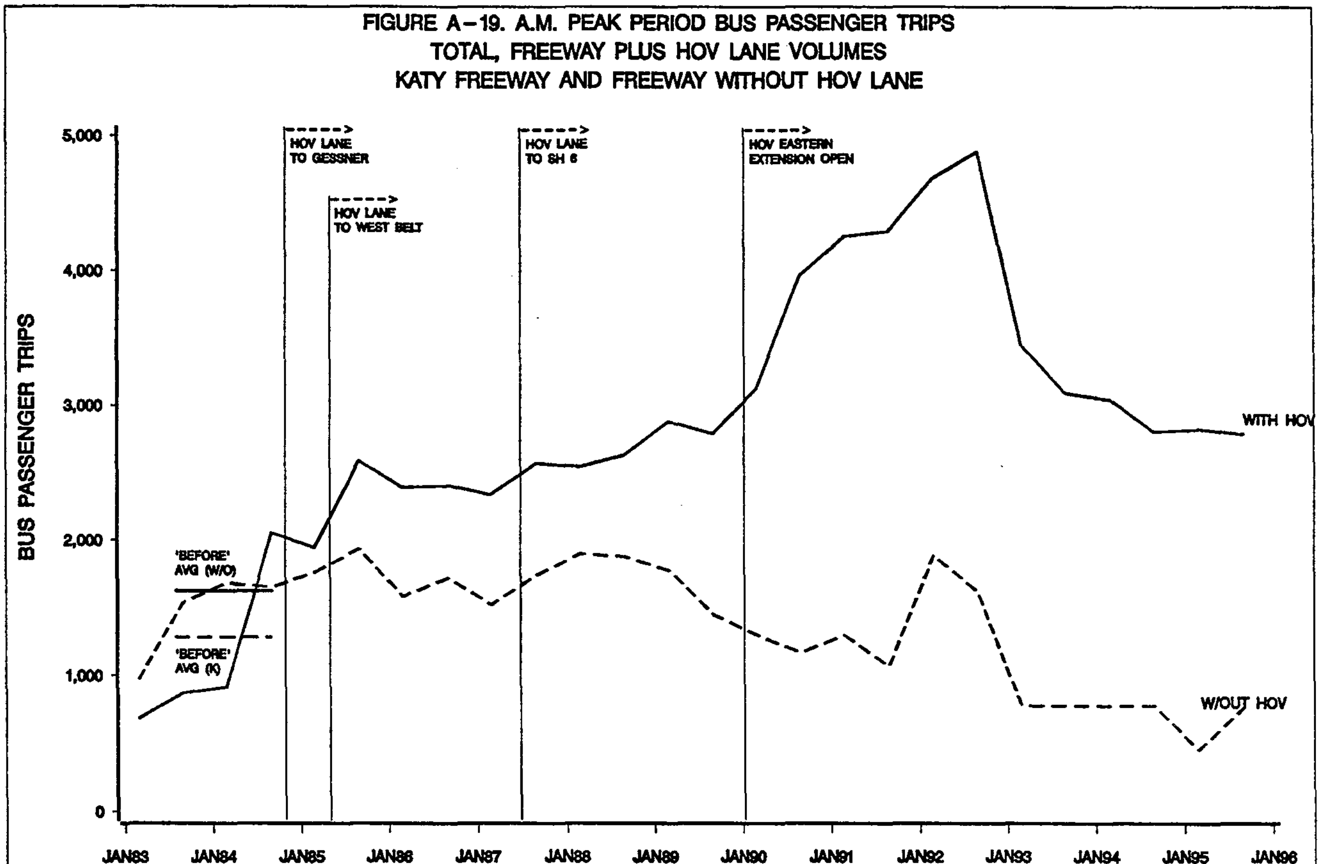


FIGURE A-19. A.M. PEAK PERIOD BUS PASSENGER TRIPS
TOTAL, FREEWAY PLUS HOV LANE VOLUMES
KATY FREEWAY AND FREEWAY WITHOUT HOV LANE
BUS PASSENGER TRIPS
5,000
4,000
3,000
2,000
1,000
0
HOV LANE TO GESSNER
HOV LANE TO WEST BELT
HOV LANE TO SH 6
HOV EASTERN EXTENSION OPEN
'BEFORE' AVG (W/O)
'BEFORE' AVG (K)
WITH HOV
W/OUT HOV
JAN83
JAN84
JAN85
JAN86
JAN87
JAN88
JAN89
JAN90
JAN91
JAN92
JAN93
JAN94
JAN95
JAN96

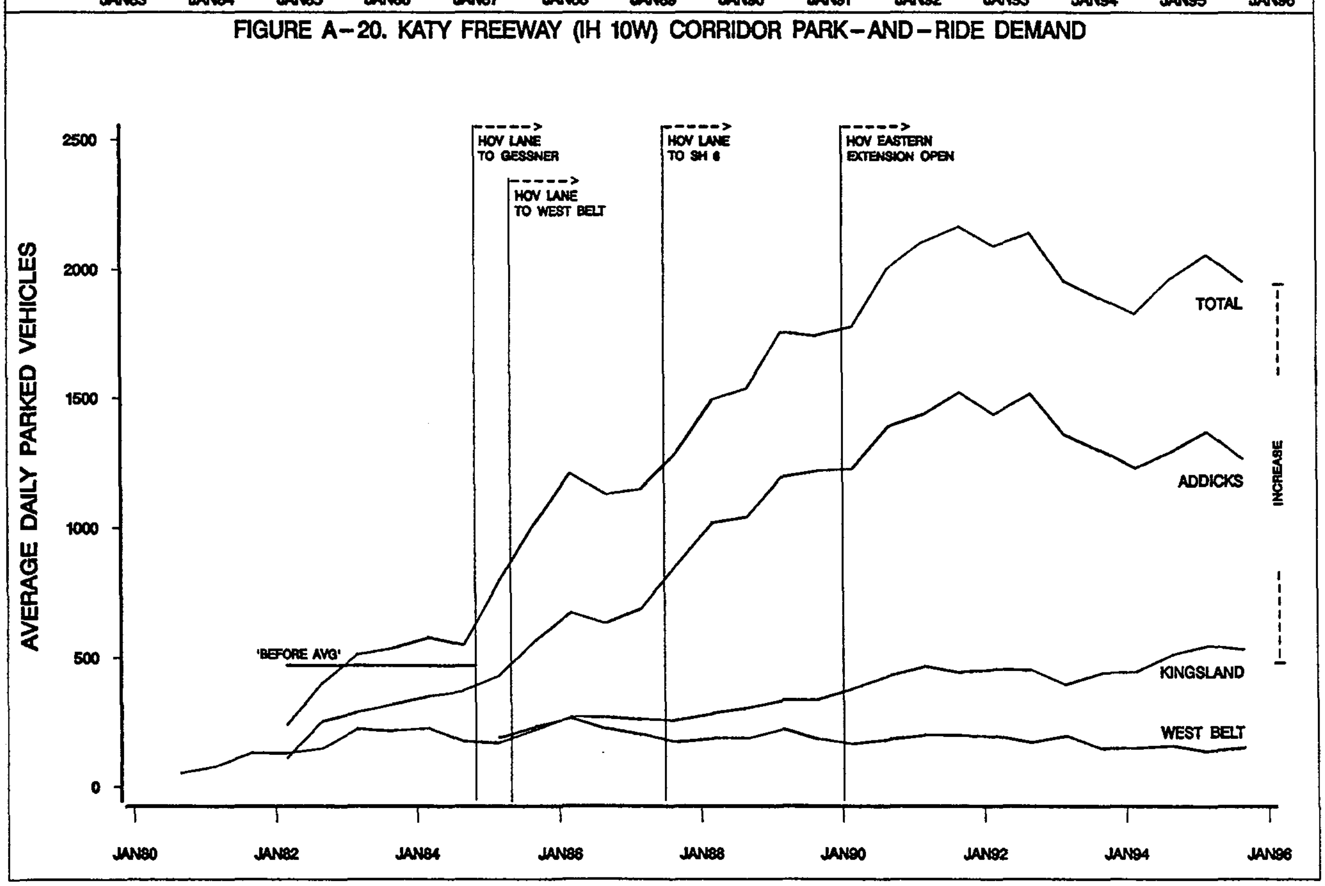
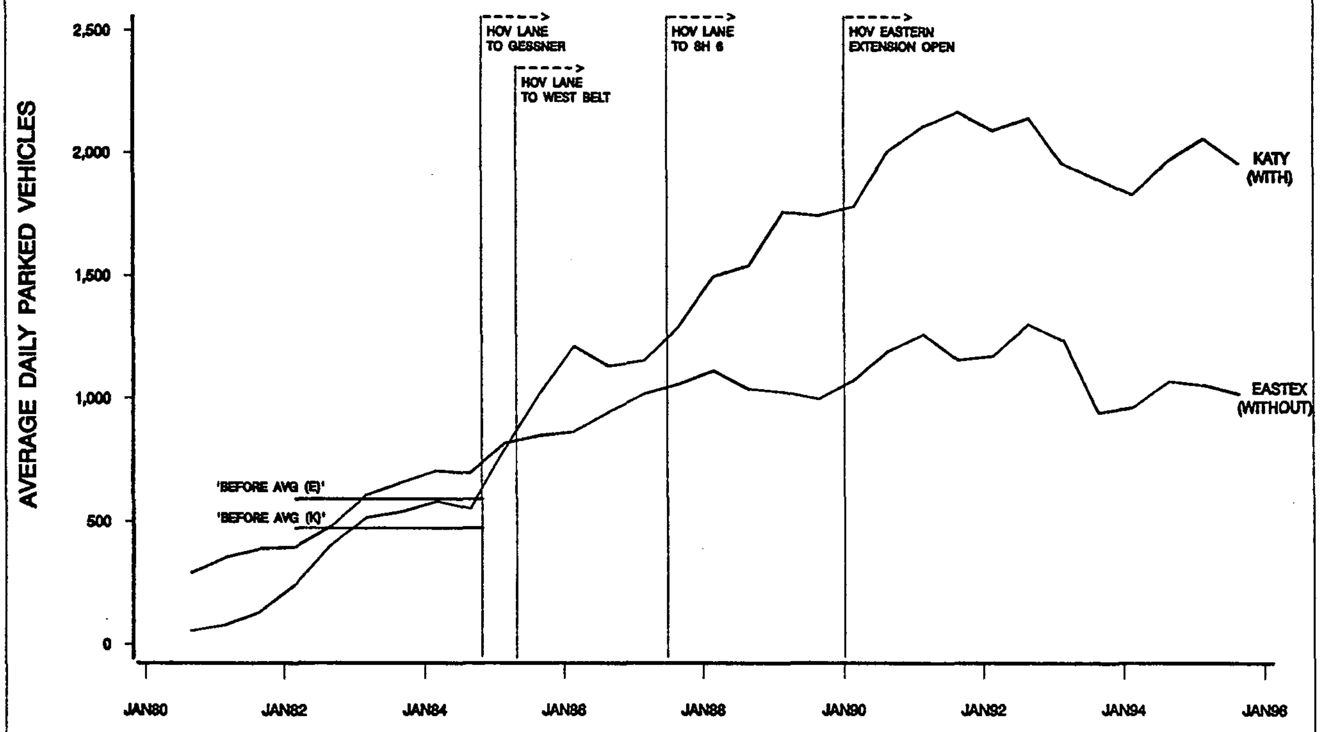


FIGURE A-20. KATY FREEWAY (IH 10W) CORRIDOR PARK-AND-RIDE DEMAND
AVERAGE DAILY PARKED VEHICLES
2500
2000
1500
1000
500
0
HOV LANE TO GESSNER
HOV LANE TO WEST BELT
HOV LANE TO SH 6
HOV EASTERN EXTENSION OPEN
'BEFORE AVG'
TOTAL
ADDICKS
KINGSLAND
WEST BELT
INCREASE
JAN80
JAN82
JAN84
JAN86
JAN88
JAN90
JAN92
JAN94
JAN96

FIGURE A-21. AVERAGE DAILY VEHICLES PARKED AT PARK-AND-RIDE LOTS KATY FREEWAY AND FREEWAY WITHOUT HOV LANE



APPENDIX B

NORTH FREEWAY AND HOV LANE DATA

NORTH FREEWAY (I-45N) AND HOV LANE, HOUSTON

Table B-1. Summary of A.M. Peak-Direction North Freeway and HOV Lane Data, December 1995

Type of Data Phase 1 of HOV Lane Became Operational 11/23/84 Contraflow Lane Became Operational 8/79	"Representative" Pre-Contraflow Value[1]	"Representative" Current Value	Percent Change
HOV Lane Data			
HOV Lane Length (kilometers [miles])		21.7 (13.5)	
HOV Lane Cost (millions)		$78.6	
Person-Movement			
Peak Hour (7-8 a.m.)	---	4,775	---
Peak Period (6-9:30 a.m.)	---	10,858	---
Total Daily	---	20,918	---
Vehicle Volumes			
Peak Hour	---	1,302	---
Peak Period	---	2,816	---
Vehicle Occupancy, Peak Hour (persons/veh)	---	3.67	---
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM]),4/84-12/94[2]	---	25.4 (40.8)	---
Vehicle Breakdowns (VKT/Breakdown [VMT/Breakdown]), 4/84-12/94	---	93,054(57,821)	---
Violation Rate (6-9:30 a.m.)		2.7%	
Peak Hour Lane Efficiency (1000's)[3]	---	392 (244)	---
Annual Value of User Time Saved (millions)[4]	---	2.7 - 5.4	---
Freeway Mainlane Data (see note)			
Person Movement			
Peak Hour	6,335	7,294	+15%
Peak Period (6-9:30 a.m.)	---	23,788	---
Vehicle Volume			
Peak Hour	4,950	6,996	+41%
Peak Period	---	21,789	---
Vehicle Occupancy, Peak Hour (persons/veh)	1.28	1.04	-19%
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM])[2]	18.8 (30.3)	16.0 (25.7)	-15%
Avg. Operating Speed[5] (kph [mph])			
Peak Hour	32 (20)	52 (32)	+63%
Peak Period	48 (30)	72 (45)	+50%
Peak Hour Lane Efficiency (1000's)[3]	66 (41)	98 (58)	+49%

Source: Texas Transportation Institute. The Texas A&M University System.

[1]Pre-HOV lane values are generally not shown since these data were not collected prior to the opening of the contraflow lane in August 1979. A barrier separated reversible HOV lane replaced the contraflow lane in November 1984. Pre-contraflow data are for 1978.

[2]Due to inconsistencies in reporting accidents in Harris County, this analysis includes only injury accidents. Accidents analyzed are between North Shepherd and Hogan, a distance of approximately 12.6 kilometers (7.8 miles). This corresponds to Phase 1 of the HOV lane. "Before" data are for the period 1/82 through 11/84. "After" accident rate shown is for the time period from 12/84 to 12/95. Only officer reported accidents are included in files. 1995 freeway volumes were estimated by TTI to compute rates.

[3]This represents the multiple of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.

[4]Based on time savings for HOV lane users in 1995, an annual estimate of travel time savings to HOV lane users is developed. A value of time of $11.37/hour is used based on the value applied in the Highway Economic Evaluation Model.

[5]The distance from North Shepherd to Hogan is 12.6 kilometers (7.8 miles).

Table B-1. Summary of A.M. Peak-Direction North Freeway and HOV Lane Data, December 1995 (Continued)

Type of Data Phase 1 of HOV Lane Became Operational 11/23/84 Contraflow Lane Became Operational 8/79	"Representative" Pre-Contraflow Value[1]	"Representative" Current Value	Percent Change
Combined Freeway Mainlane and HOV Lane Data			
Total Person Movement			
Peak Hour	6,335	12,069	+91%
Peak Period	---	34,646	---
Vehicle Volume			
Peak Hour	4,950	8,298	+68%
Peak Period	---	24,605	---
Vehicle Occupancy			
Peak Hour	1.28	1.45	+13%
Peak Period	1.28	1.41	+10%
2+ Carpool Volumes			
Peak Hour	700	1,834	+162%
Travel Time (minutes)[2]			
Peak Hour	23.2[3]	9.1[4]	-61%
Peak Period	15.5[3]	8.6[4]	+45%
Peak Hour Lane Efficiency (1000's)[5]	66 (41)	153 (95)	+132%
Transit Data[6]			
Bus Vehicle Trips			
Peak Hour	---	45	---
Peak-Period	---	115	---
Bus Passenger Trips			
Peak Hour	---	1,893	---
Peak Period	---	4,590	---
Bus Occupancy (persons/bus)			
Peak Hour	---	42.1	---
Peak Period	---	39.9	---
Vehicles Parked in Corridor Park & Ride Lots	---	3,237	---
Bus Operating Speed[2] (kph [mph])			
Peak Hour	---	82 (51)	---
Peak Period	---	89 (55)	---

Source: Texas Transportation Institute. The Texas A&M University System.

Note: Site-specific data collected at Little York. For purposes of visibility, volumes are counted between an exit and an entrance ramp. Thus, the mainlane volumes can be considered to be low.

[1]Pre-HOV lane values are generally not shown since these data were not collected prior to the opening of the contraflow lane in August 1979. A barrier separated reversible HOV lane replaced the contraflow lane in November 1984. Pre-contraflow data are for 1978.

[2]The distance from North Shepherd to Hogan is 12.6 kilometers (7.8 miles).

[3]Data pertain to operation in the freeway mainlanes.

[4]Data pertain to operation in the HOV lane.

[5]This represents the multiple of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.

[6]Prior to opening the contraflow lane in 1979, virtually no transit service was provided in this freeway corridor.

Table B-2. Comparison of Measures of Effectiveness, Freeway With (North, I-45N) and Freeway Without (Eastex U.S. 59) HOV Lane, Houston

Measure of Effectiveness	North Freeway	Eastex Freeway
Average A.M. Peak-Hour Vehicle Occupancy	1.45[1]	1.18
Bus Passengers, Peak Period	4,590	1,069
Cars Parked at Park-and-Ride Lots	3,237	1,035
Facility Per Lane Efficiency[2]	153 (95)	123 (77)

[1] 1978 pre-contraflow occupancy estimated at 1.28 persons per vehicle.
[2] This represents the multiple of peak-hour passengers and average speed for the HOV lane and freeway mainlanes combined (passengers x kilometers/hour) [passengers x miles/hour]).

HOV LANE DATA

DESCRIPTION

- The contraflow lane operation began 8/28/79.
- Phases 1 and 2 of HOV lane operation began 11/23/84.
- The capital cost for the operating segment (including all existing support facilities) in 1990 dollars was $75.9 million. The estimated total cost for the completed HOV lane (1990 dollars) is $142.1 million. Tables B-3 and B-4 provide a more detailed cost breakdown.
- Selected milestone dates are listed below. The capital costs tables show other dates.
  - 8/29/79 Contraflow lane operations begin (14.7 kilometers [9.1 miles]).
  - 3/31/81 A.M. concurrent flow lane to West Road opens (20.8 kilometers [12.9 miles]).
  - 11/23/84 HOV Lane replaces contraflow.
  - 4/2/90 HOV Lane extended to Beltway 8 (21.7 kilometers [13.5 miles]).
  - 6/26/90 Carpools allowed on HOV.
  - 6/30/90 Weekend operations begin.
  - 10/5/91 Weekend operations end.
  - 9/8/92 Motorcycles allowed on HOV facility (no occupancy restrictions).

PERSON MOVEMENT

- In September 1995, 20,918 person trips per day were served on the HOV lane.
- A.M. Peak Hour, 4,775 persons/hour.
  - 1,893 (40%) by bus, 291 (6%) by vanpool, 2,587 (54%) by carpool, and 5 by motorcycle (Figure B-1).
  - Average HOV lane vehicle occupancy = 3.67 persons/vehicle.
- A.M. Peak Period, 10,858 persons.
  - 4,590 (42%) by bus, 756 (7%) by vanpool, 5,500 (51%) by carpool, and 12 by motorcycle (Figure B-2).

Table B-3. Estimated Capital Cost (millions), North HOV Lane Operating Segment

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1995 Dollars
HOV Lane and Ramps			
Phase 1 Construction (1984)	$17.3	1.13	$19.5
Phase 2 Construction (1987)	50.6	1.03	52.1
Phase 3 Construction (1990) Incl. Aldine-Bender Interchange	5.4	1.21	6.5
Phase 4 Construction (1990)	7.6	1.21	9.2
Connection L	1.9	1.19	2.3
Miscellaneous (all phases), (1988)	6.2	1.19	7.3
SUB-TOTAL	$89.0		$96.9
Per Kilometer (Mile)	$4.1 ($6.6)		$4.5 ($7.2)
Surveillance, Communication and Control (1990)	$2.4	1.21	$2.9
SUB-TOTAL	$2.4		$2.9
Per Kilometer (Mile)	$0.1 ($0.2)		$0.1 ($0.2)
Support Facilities			
North Shepherd P/R (1980)	$2.2	1.29	$2.8
North Shepherd P/R Expansion (1982)	2.1	1.25	2.6
Kuykendahl P/R (1980)	1.7	1.29	2.2
Kuykendahl P/R Expansion (1983)	1.8	1.22	2.2
Spring P/R (1982)	3.7	1.25	4.6
Seton Lake P/R (1983)	3.3	1.22	4.0
Woodlands P/R (1985)	2.6	1.11	2.9
Woodlands P/R Expansion (1991)	0.8	1.21	1.0
SUB-TOTAL	$18.2		$22.3
Per Kilometer (Mile)	$0.8 ($1.3)		$1.0 ($1.7)
TOTAL COST	$109.6		$122.1
COST PER KILOMETER (21.7 kilometers [13.5 miles])	$5.0 ($8.1)		$5.6 ($9.0)

Source: Compiled by TTI from data provided by Metro and TxDOT.

Table B-4. Estimated Capital Cost (millions), North HOV Lane, Future Segments

Cost Component	Estimated Year of Completion	Estimated Cost $Millions)	
HOV Lane and Ramps			
Beltway 8 to Airtex	1996		$6.4
Airtex to FM 1960	1999		3.8
Kuykendahl Interchange	1996		8.4
FM 1960 Interchange	1999		5.1
Downtown Terminus Improvement	1997		7.3
HOV Lane Barrier Modification	1999		0.3
Crosstimbers Access Ramp	1997		13.4
SUB-TOTAL		$44.7	
Per Kilometer (Mile)			$4.3 ($7.0)
Surveillance, Communication and Control		$2.4	
Support Facilities			
Kuykendahl P/R Expansion			$11.4
SUB-TOTAL		$11.4	
TOTAL COST		$58.5	
COST PER KILOMETER (10.3 kilometers [6.4 miles])		$5.7 ($9.1)	

Source: Compiled by TTI from data provided by Metro and TxDOT.

VEHICLE MOVEMENT

- A.M. Peak Hour, 1,302 vph
  - 45 (3%) buses, 32 (2%) vans, 1,220 (94%) carpools, and 5 by motorcycle (Figure B-3).
- A.M. Peak Period, 2,816 vehicles.
  - 115 (4%) buses, 83 (3%) vans, 2,606 (93%) carpools, and 12 by motorcycle (Figure B-4).

ACCIDENT RATE

- For the period from November 1984 through December 1994, the HOV lane accident rate was 25.4 injury accidents per 100 million vehicle kilometers (40.8 injury accidents per 100 million vehicle miles).

VEHICLE BREAKDOWN RATES

- The following vehicle breakdown rates were observed between December 1984 and December 1995.
  - Overall weighted average: 1 breakdown per 93,054 VKT (57,821 VMT).

VIOLATION RATE

- The observed violation rate (vehicles on the HOV lane not eligible to use the HOV lane) for December 1995 was approximately 2.7%.

PEAK HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. For the HOV lane, this value (expressed in 1000's) is approximately 392 (4,775 passengers at 82 kph), or 244 (4,775 passengers at 51 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane experienced an average travel time savings of 8 minutes during the morning peak hour in 1995 (Figure B-5).
- The table on the following page indicates that, on a typical non-incident day, travel time savings of approximately 940 hours (56,405 min.) are realized. Assuming 250 days of operation, annual savings would be 235,000 hours. At $11.37/hour, this equates to $2.70 million per year. This is extremely conservative since it does not consider travel time savings due to incidents on the freeway. Data from Houston suggest increasing this value by 100% to account for incidents would be reasonable. Thus, estimated travel time savings to HOV lane users are in the range of $2.70 to $5.40 million per year.

Table B-5. Travel Time Savings for North HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1995)

Southbound A.M. Travel Time Savings for North HOV Lane								
Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section from Sam Houston Parkway to N. Shepherd								
6:00	4.67	5.07	-0.40	131	12	135	278	-111
6:30	5.37	4.97	0.40	420	141	525	1,086	434
7:00	4.77	4.93	-0.17	721	93	570	1,384	-231
7:30	4.50	4.92	-0.42	889	137	575	1,601	-667
8:00	4.30	5.10	-0.80	737	21	420	1,178	-942
8:30	4.42	4.35	0.07	542	8	210	760	51
9:00	4.25	4.77	-0.52	252	8	150	410	-212
Peak Period Total				3,692	420	2,585	6,697	-1,678
Section From N. Shepherd to the Hogan Overpass								
6:00	7.95	8.95	-1.00	201	62	485	748	-748
6:30	10.43	8.72	1.72	680	172	1,030	1,882	3,231
7:00	14.08	8.63	5.45	1,086	173	735	1,994	10,867
7:30	23.18	9.12	14.07	1,285	47	810	2,142	30,131
8:00	13.72	8.87	4.85	1,084	151	985	2,220	10,767
8:30	7.88	7.88	0.00	617	55	355	1,027	0.00
9:00	7.75	8.13	-0.38	211	43	335	589	-226
Peak Period Total				5,164	703	4,735	10,602	54,022
Northbound P.M. Travel Time Savings for North HOV Lane								
Section from Sam Houston Parkway to N. Shepherd								
3:30	4.48	4.67	-0.18	106	0	165	271	-50
4:00	4.40	5.10	-0.70	336	32	150	518	-363
4:30	4.43	4.83	-0.40	473	47	335	855	-342
5:00	4.48	5.00	-0.52	710	91	715	1,516	-783
5:30	4.63	5.67	-1.03	660	175	725	1,560	-1,612
6:00	4.53	4.87	-0.33	294	41	525	860	-287
6:30	4.45	4.92	-0.47	110	19	335	464	-217
Peak Period Total				2,689	405	2,950	6,044	-3,653

Table B-5. Travel Time Savings for North HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1995) (Continued)

Southbound A.M. Travel Time Savings for North HOV Lane								
Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section from N. Shepherd to the Hogan Overpass								
3:30	8.65	7.95	0.70	176	36	195	407	285
4:00	10.47	8.53	1.93	386	152	330	868	1,678
4:30	9.52	8.95	.057	558	90	463	1,111	630
5:00	10.08	9.43	0.65	898	180	925	2,003	1,302
5:30	11.50	10.32	1.18	1,148	167	1,350	2,665	3,153
6:00	9.75	9.07	0.68	695	62	647	1,404	959
6:30	7.92	8.25	-0.33	438	29	415	882	-294
Peak Period Total				4,229	716	4,325	9,340	7,714

FREEWAY DATA

NOTE

- For purposes of safety and visibility, freeway volumes are counted at Little York between an exit ramp and an entrance ramp. Thus, freeway volumes may be low in comparison to typical freeway operations. The cross section at the count location has been expanded from 3 to 4 lanes per direction; the southbound expansion was completed in June 1987 and the northbound expansion in 1988.

PERSON MOVEMENT

- In the a.m. peak hour, person movement has been increasing and is currently at 7,294 persons in the peak hour (Figure B-6). Prior to contraflow implementation, limited data suggest this value was 6,335.

- Figure B-7 shows a.m. peak period mainlane person trips.

VEHICLE VOLUME

- In the a.m. peak hour, an average of 6,996 vehicles used the mainlanes during 1995 (Figure B-6). Prior to contraflow implementation, limited data suggest this value was 4,950.

VEHICLE OCCUPANCY

- In the a.m. peak period, an average of 21,789 vehicles used the mainlanes (Figure B-7).
- In the a.m. peak hour, mainlane occupancy is approximately 1.04 (Figure B-8).
- In the a.m. peak period, mainlane occupancy is approximately 1.05 (Figure B-9).

ACCIDENT RATE

- Implementation of the HOV lane resulted in narrower shoulders and no inside emergency shoulder.
- Prior to opening the barrier-separated HOV lane, a contraflow lane was in operation. For this period (1/82 to 11/84), the freeway accident rate was 18.8 injury accidents per 100 million vehicle kilometers (100 MVK) (30.3 injury accidents per 100 million vehicle miles [100 MVM]). From 12/84 through 12/94, (since the barrier-separated HOV lane opened) the accident rate has been 16.0 injury accidents/100 MVK (25.7 injury accidents/100 MVM). Only officer reported accidents are included.

AVERAGE OPERATING SPEED

- Average operating speed on the mainlanes has increased since the HOV lane opened (Figure B-10).

PEAK HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of per lane efficiency.
- For the freeway mainlanes, the current peak hour per lane efficiency is 98 (1,824 passengers per lane at 52 kph) or 58 (1,824 passengers per lane at 32 mph).

COMBINED FREEWAY AND HOV LANE DATA

TOTAL PERSON MOVEMENT

- Percent by HOV lane, a.m. peak.
  - At Little York, the HOV lane is carrying 37% of the total peak-hour person movement (Figure B-11). In the peak period, the HOV lane carries 31% of the a.m. peak period person trips (Figure B-12). Compared to pre-contraflow conditions, peak-hour person movement has increased by 91%.

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.45 versus 1.04 occupants per vehicle for the mainlanes (Figure B-8). Occupancy in the peak period has also increased with the opening of the HOV lane (Figure B-9). Prior to implementing the contraflow lane in 1978, average occupancy on the North Freeway was 1.28 persons per vehicle.

- The occupancy on the North Freeway, which has had a priority HOV lane since 1979, has consistently been higher than the occupancy of freeways without HOV lanes (Figure B-13).

PEAK HOUR LANE EFFICIENCY

- Peak hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a freeway corridor. The efficiency of the North Corridor is 153 (persons x kph) or 95 (persons x mph) (Figure B-14). Prior to contraflow lane implementation in 1978, the per lane efficiency was estimated to be 66 (persons x kph) or 41 (persons x mph). Freeway corridors without HOV lanes experience lower efficiencies (Figure B-15).

BUS TRANSIT DATA

BUS VEHICLE AND PASSENGER TRIPS

- Within the a.m. peak period, bus passenger trips have decreased slightly over the past year. Currently there are about 1,893 passengers per peak hour (Figure B-16) and 4,590 passengers per peak period (Figure B-17). Likewise, the bus vehicle trips for the peak period have decreased slightly to 115 bus trips per peak period (Figure B-17).

- The North Freeway Corridor carries over four times the number of bus passenger trips as corridors which do not have HOV lanes (Figure B-18).

PARK-AND-RIDE

- Currently, 3,237 vehicles are parked in the corridor park-and-ride lots. Approximately 44% of the 7,386 parking spaces are utilized (Figure B-19).

- The Eastex Freeway corridor (which does not have a HOV lane) has 72% less park-and-ride patrons than the North Freeway corridor. Eastex Freeway park-and-ride lots are operating at only 25% capacity as opposed to 46% on North Freeway (Figure B-20).

FIGURE B-1. NORTH FREEWAY (IH 45N) HOV LANE
A.M. PEAK HOUR HOV LANE PERSON MOVEMENT

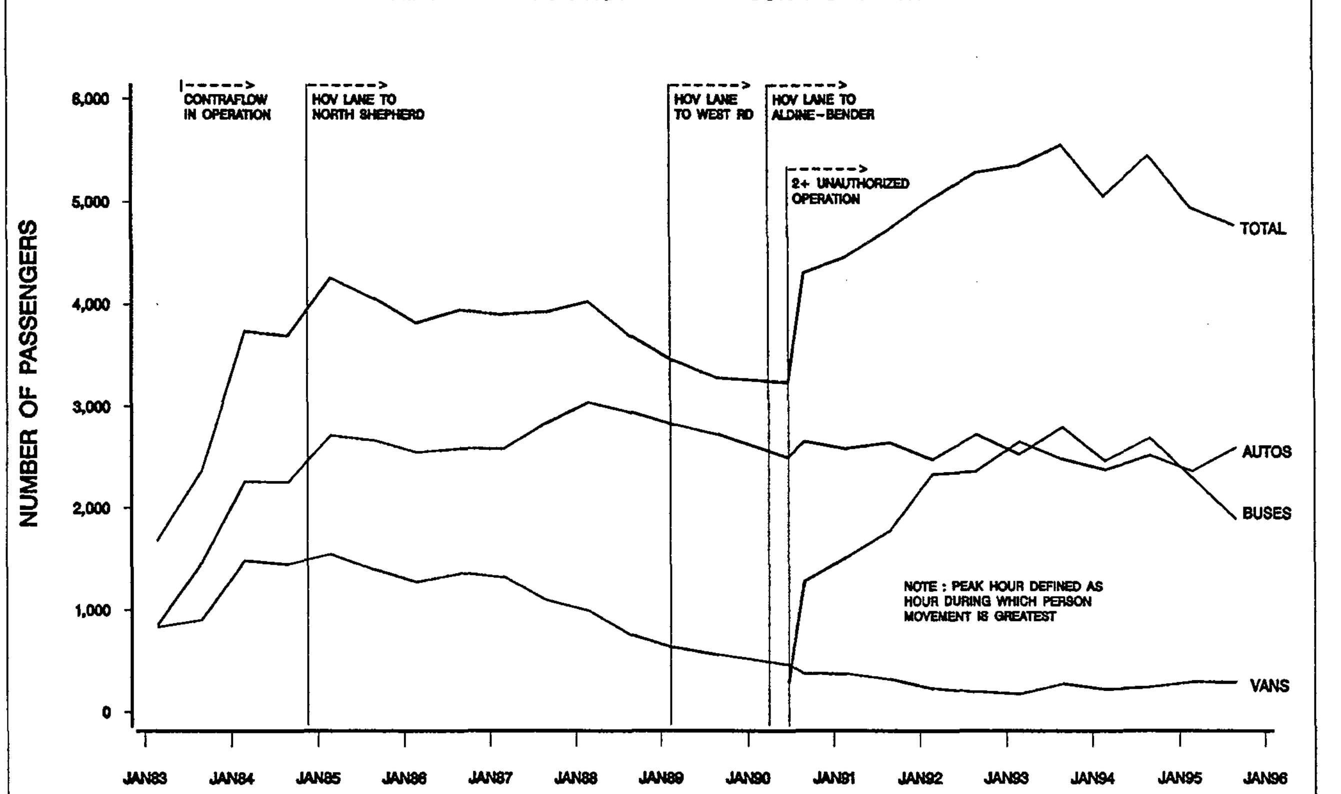


FIGURE B-2. NORTH FREEWAY (IH 45N) HOV LANE
A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT

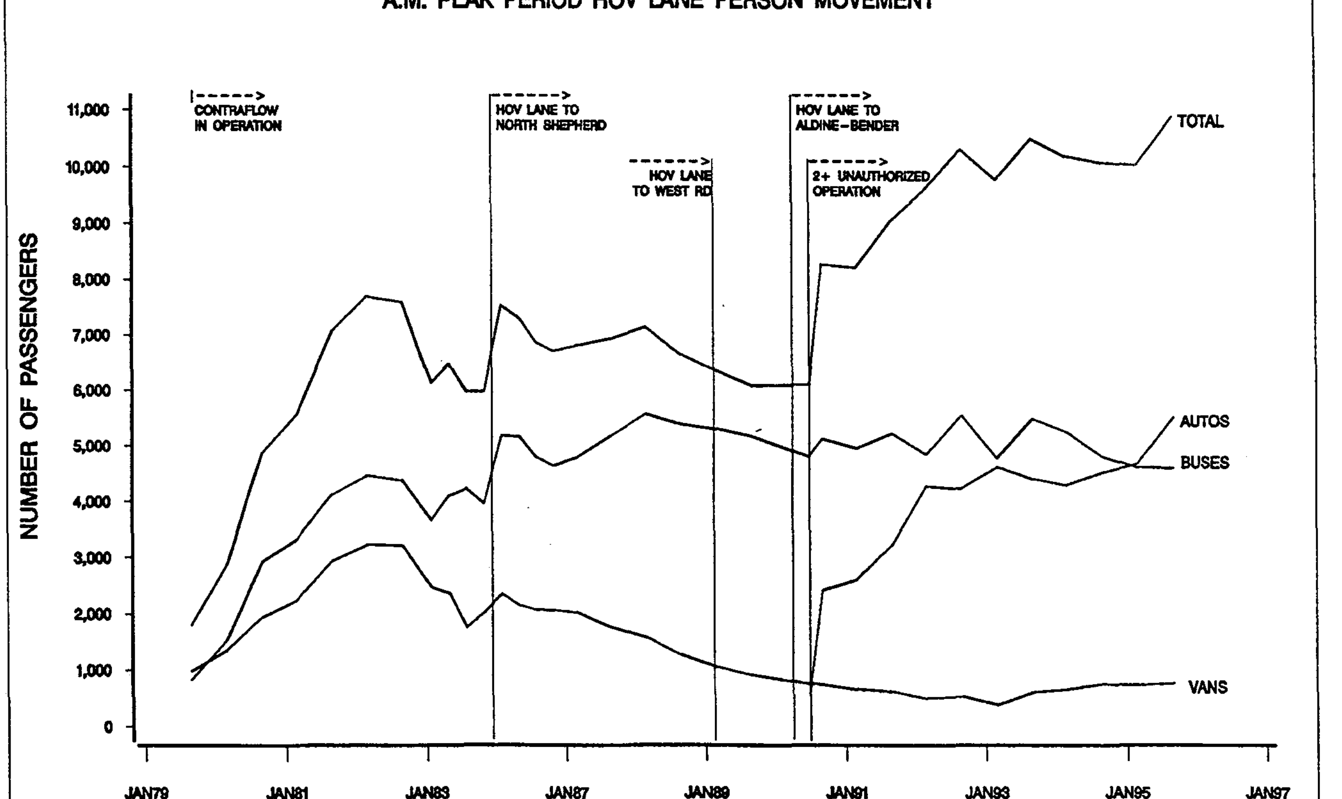


FIGURE B-3. NORTH FREEWAY (IH 45N) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION

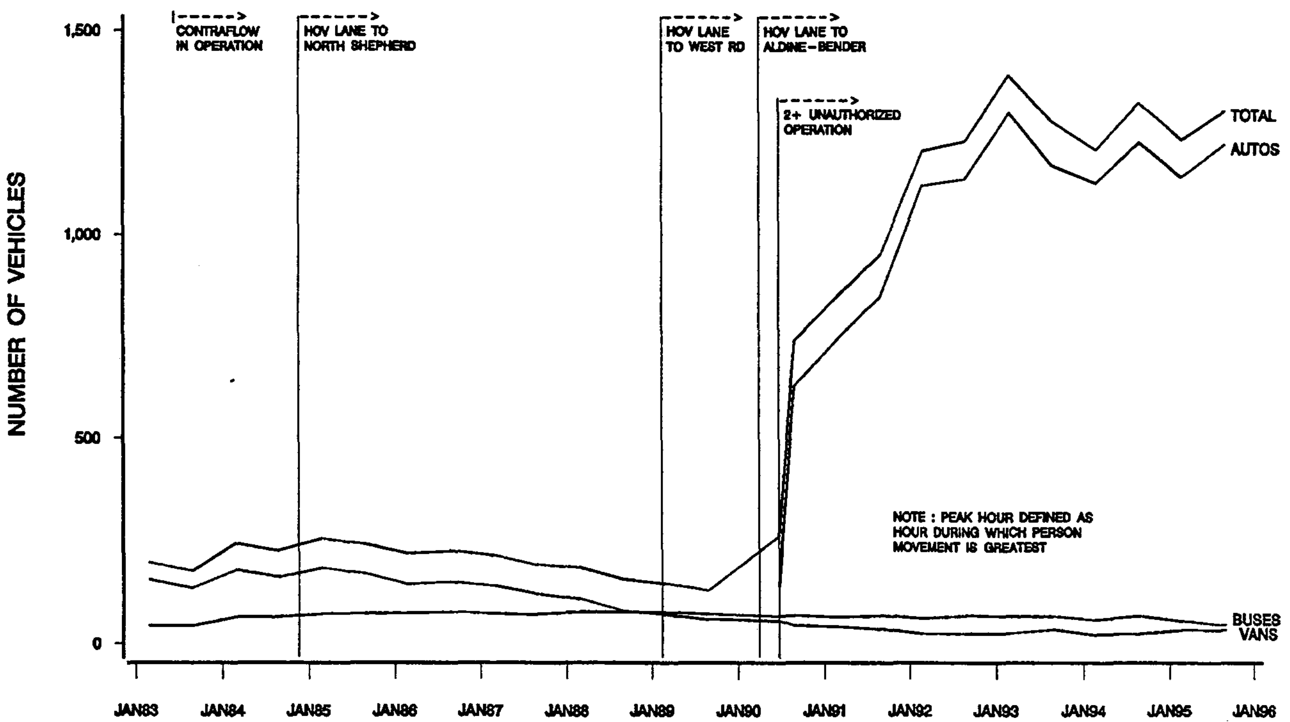


FIGURE B-4. NORTH FREEWAY (IH 45N) HOV LANE
A.M. PEAK PERIOD HOV LANE VEHICLE UTILIZATION

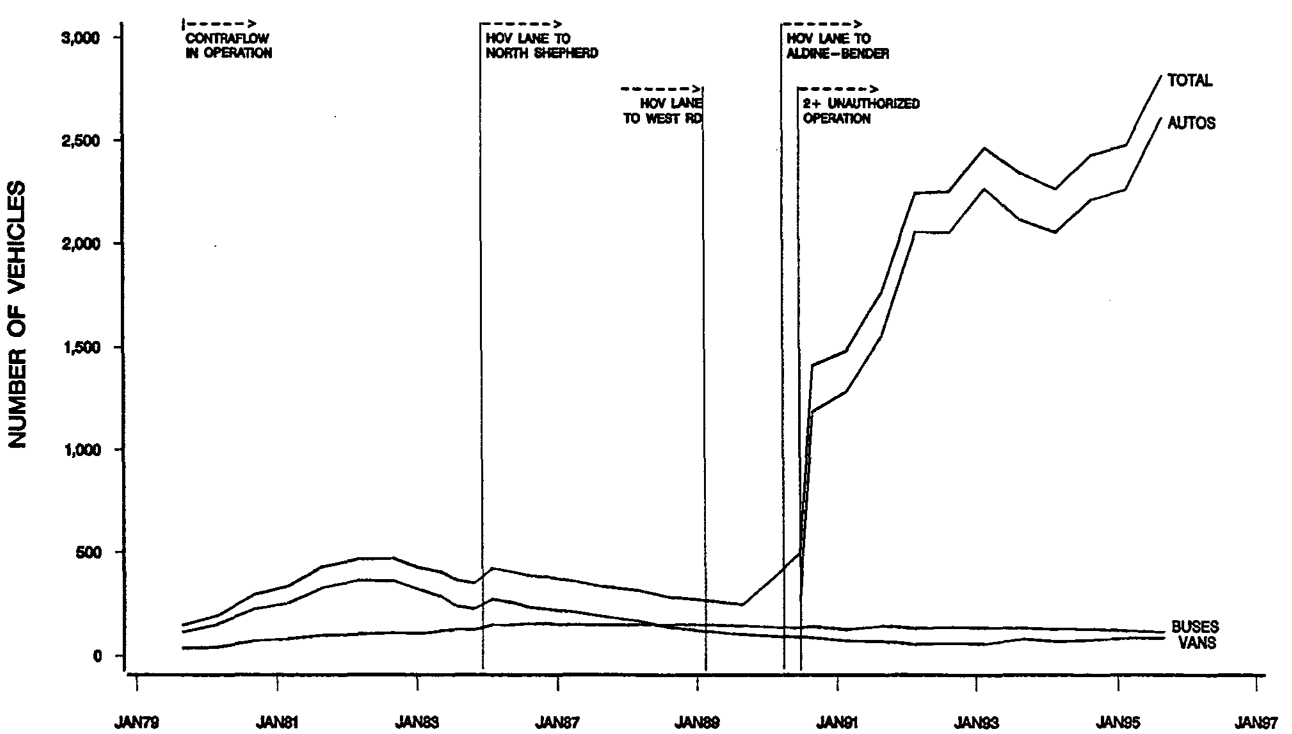


FIGURE B-5. NORTH FREEWAY (IH 45N) MAINLANES AND HOV LANE A.M. TRAVEL TIME

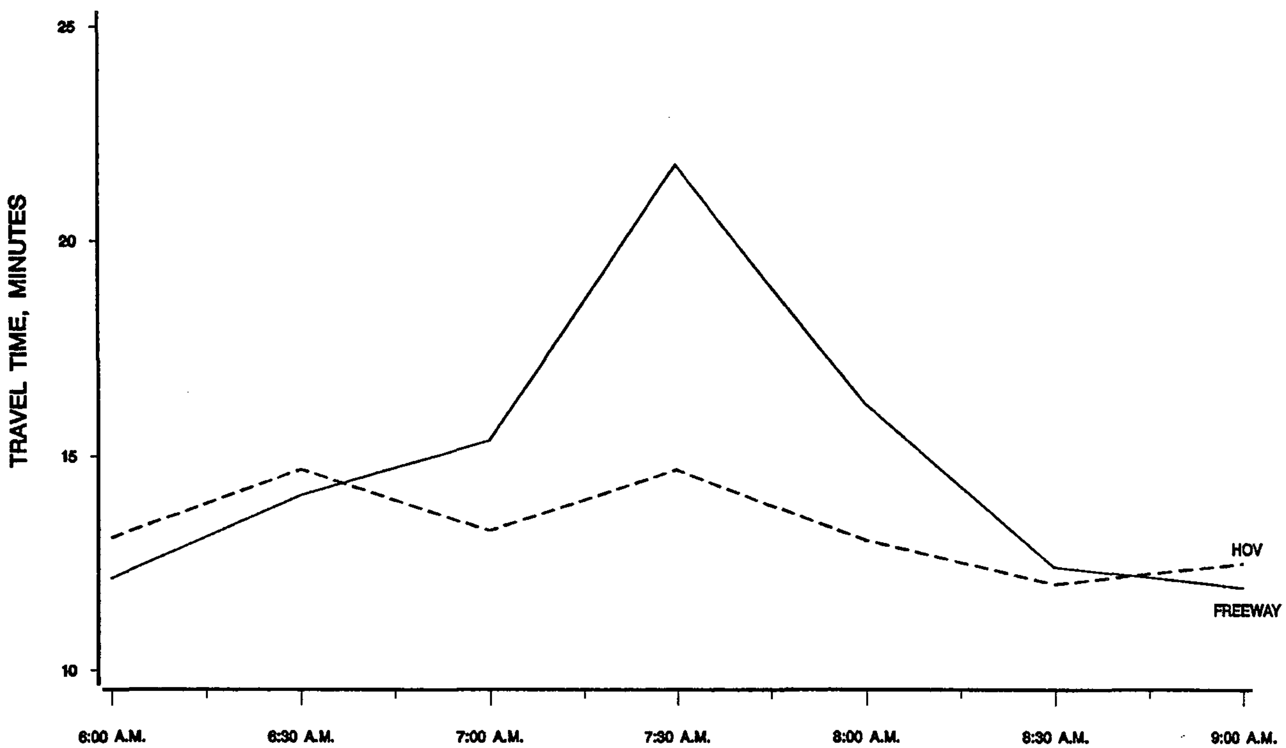


FIGURE B-6. NORTH FREEWAY (IH 45N)
A.M. PEAK HOUR MAINLANE TRIPS

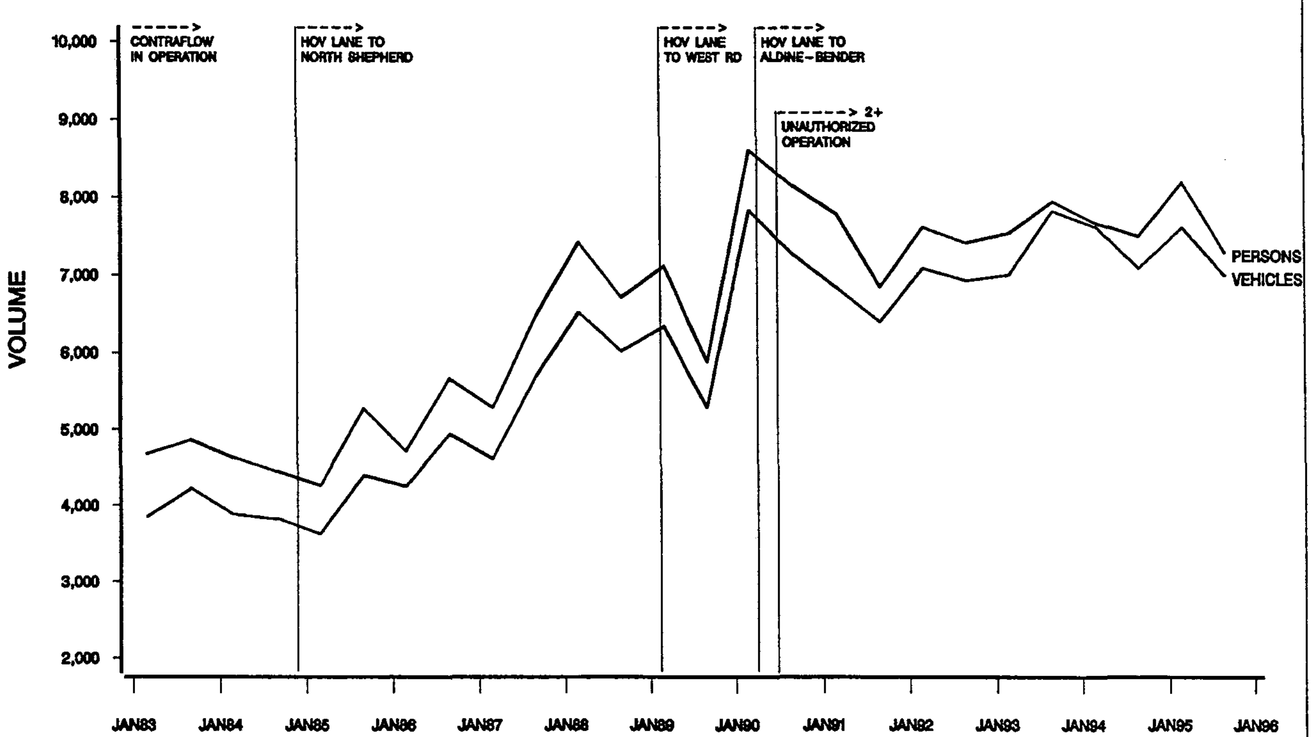


FIGURE B-7. NORTH FREEWAY (IH 45N)
A.M. PEAK PERIOD MAINLANE TRIPS

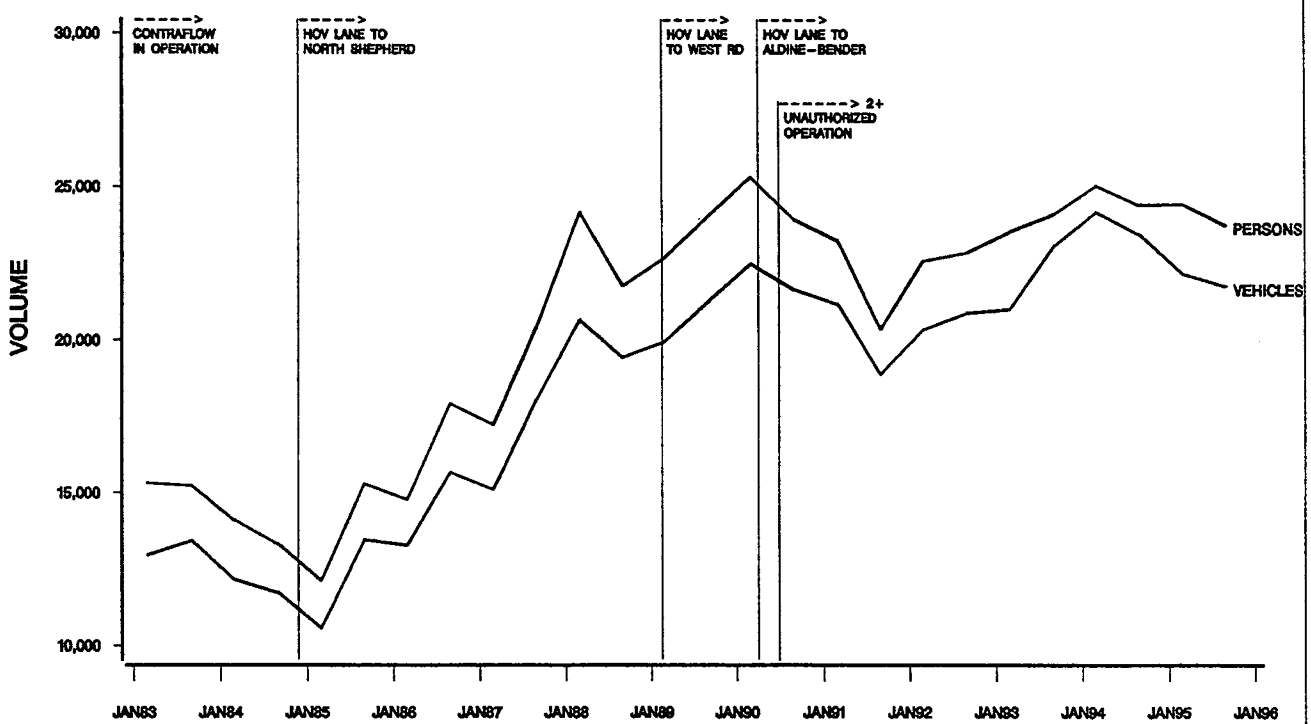


FIGURE B-8. NORTH FREEWAY (IH 45N) MAINLANE AND HOV LANE
A.M. PEAK HOUR AVERAGE OCCUPANCY

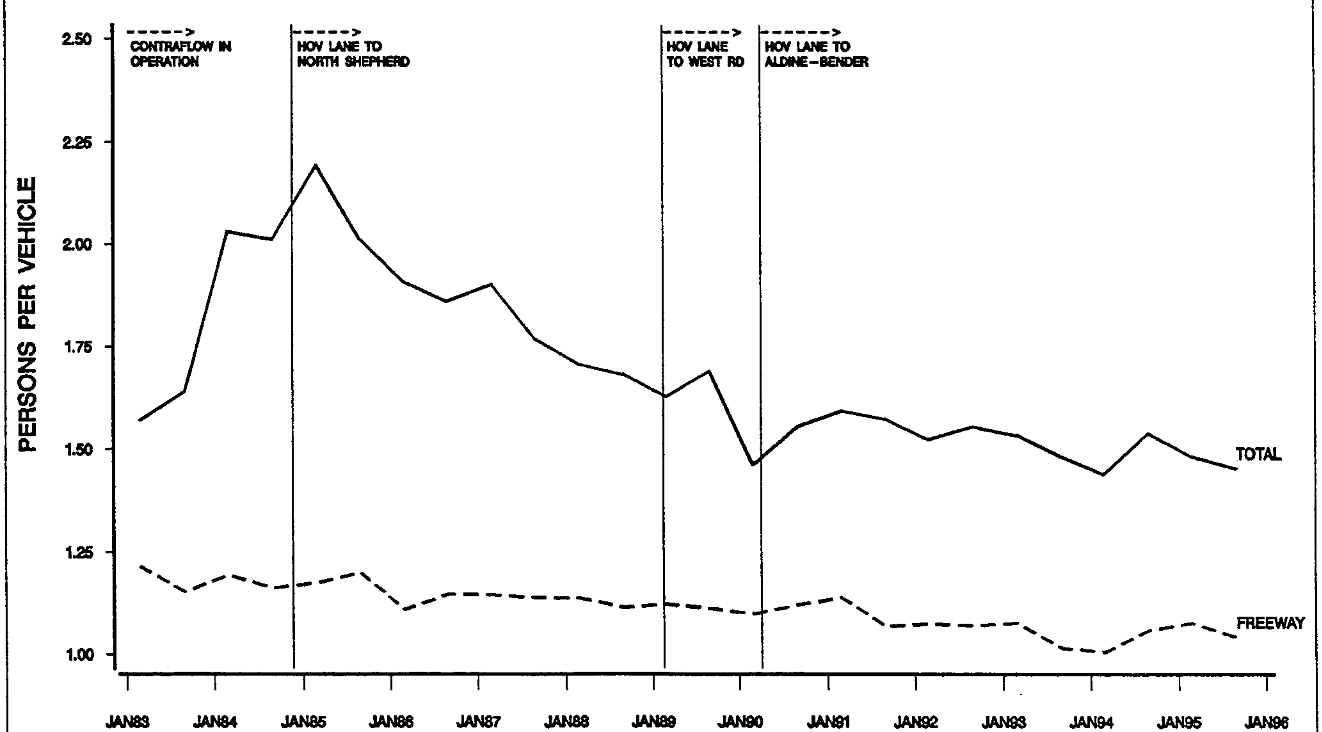


FIGURE B-9. NORTH FREEWAY (IH 45N) MAINLANE AND HOV LANE
A.M. PEAK PERIOD AVERAGE OCCUPANCY

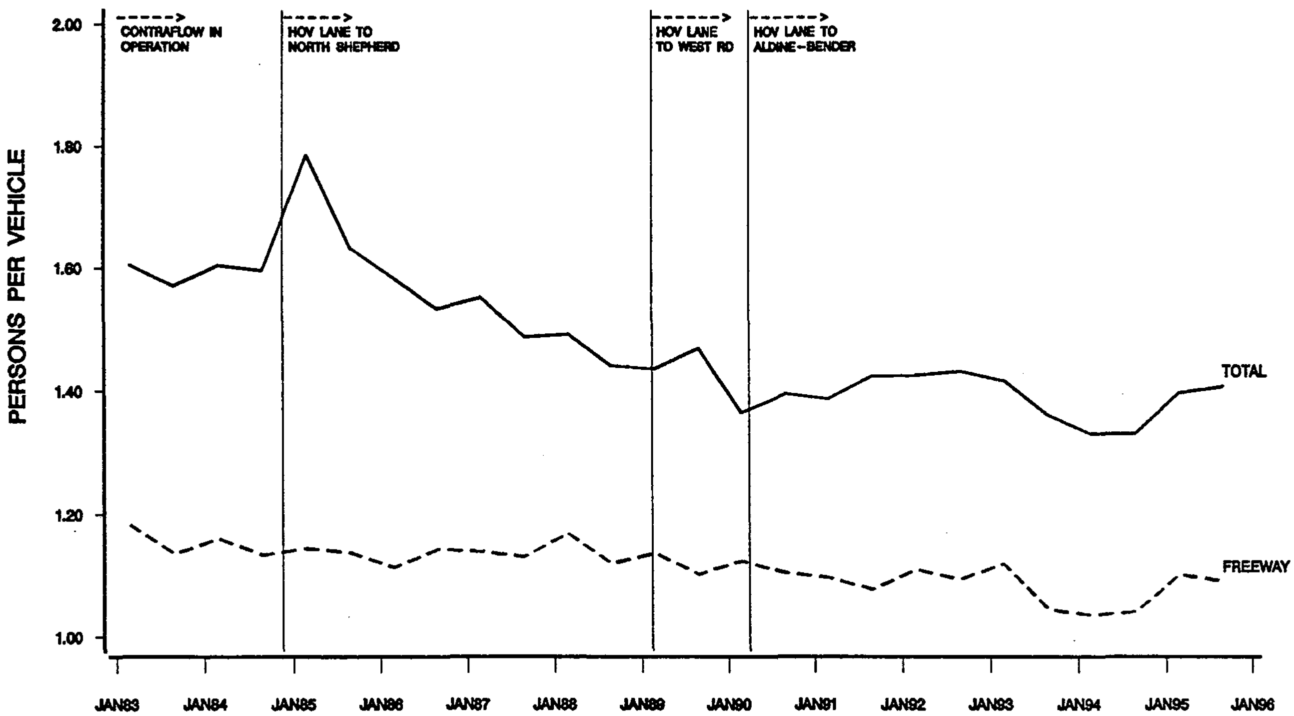


FIGURE B-10. NORTH FREEWAY (IH 45N) MAINLANE TRAVEL TIME AND SPEED SURVEY
SOUTHBOUND, AIRTEX TO MEMORIAL
A.M. PEAK PERIOD

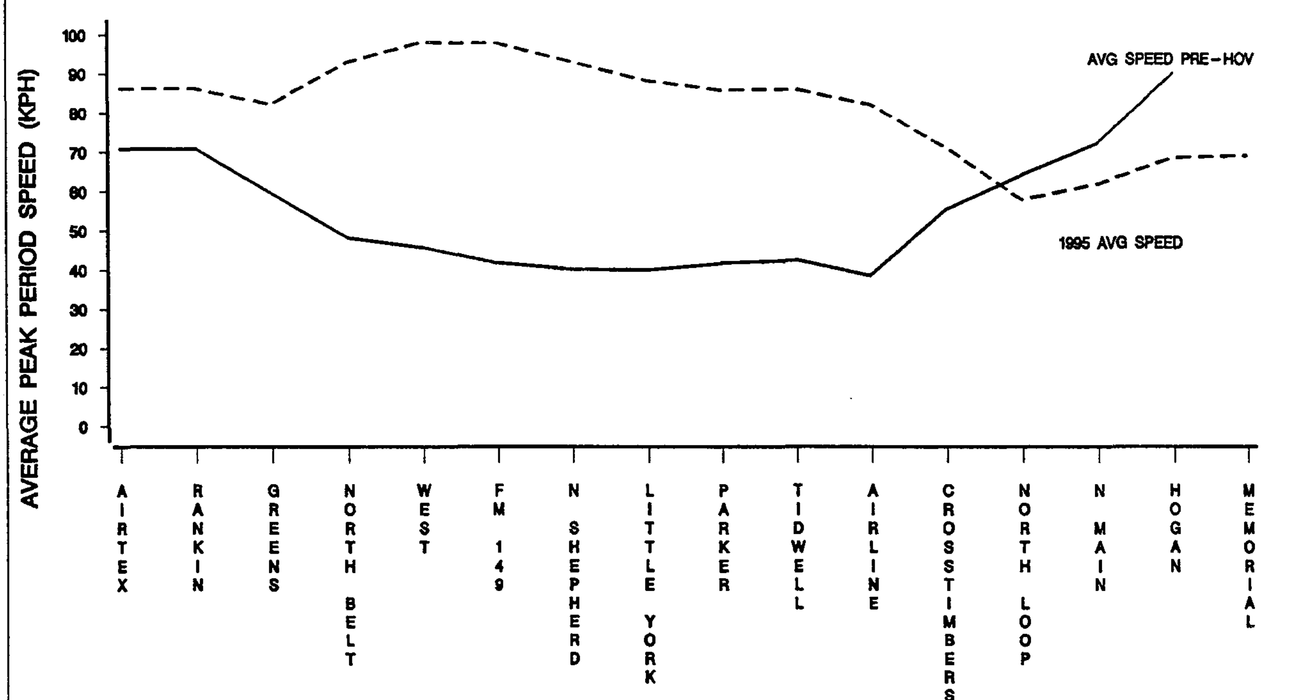


FIGURE B-11. NORTH FREEWAY (IH 45N) MAINLANE AND HOV LANE
A.M. PEAK HOUR PERSON TRIPS

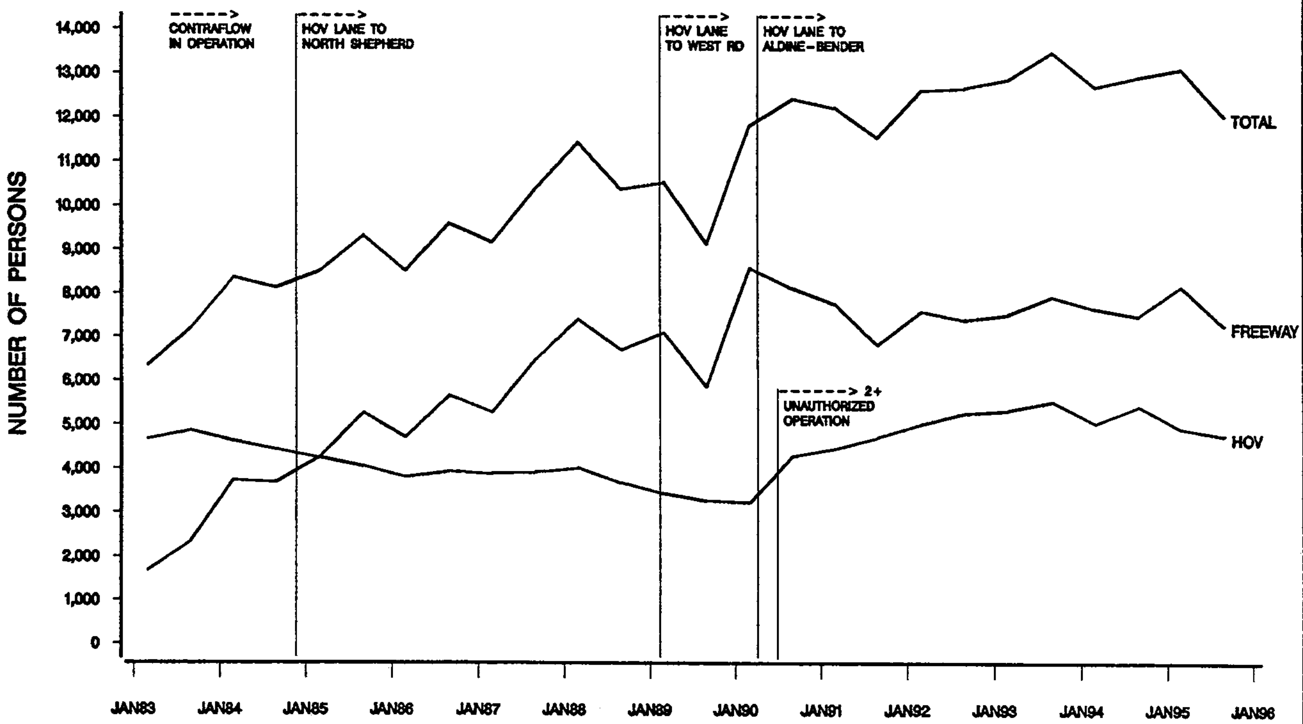


FIGURE B-12. NORTH FREEWAY (IH 45N) MAINLANE AND HOV LANE
A.M. PEAK PERIOD PERSON TRIPS

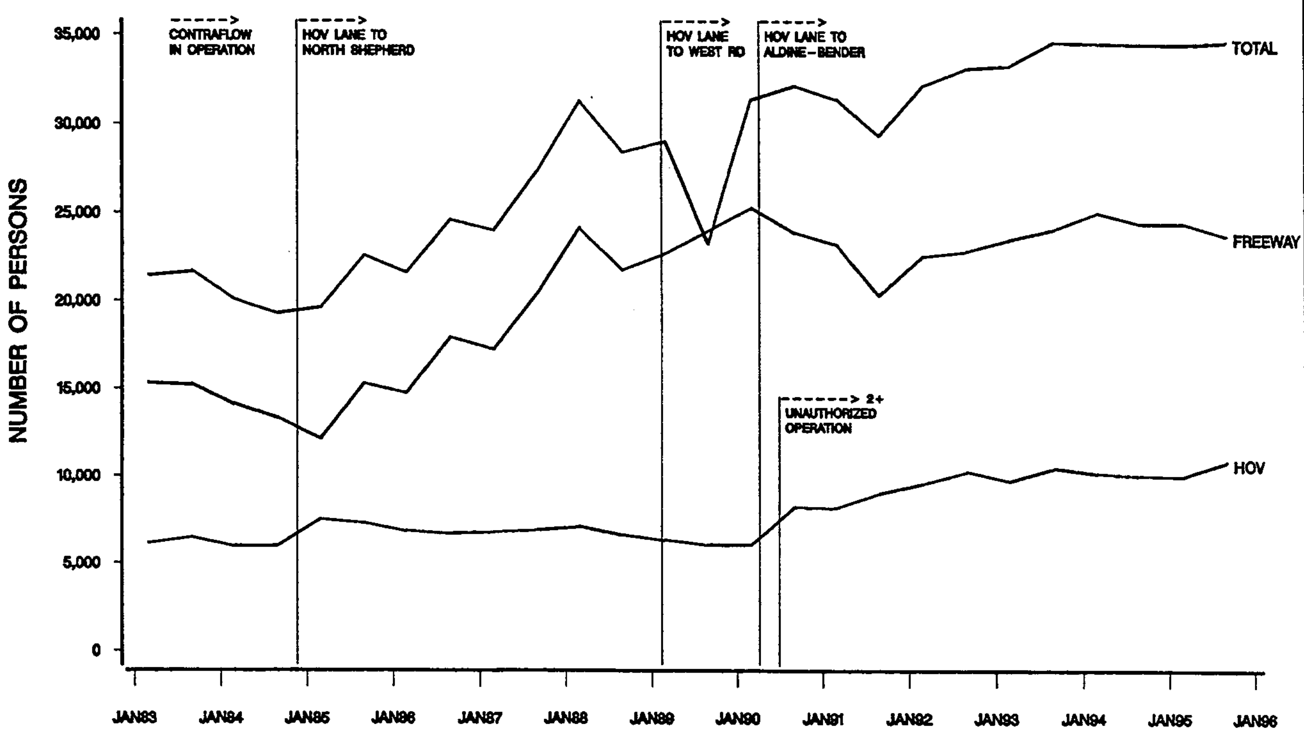


FIGURE B-13. A.M. PEAK HOUR AVERAGE OCCUPANCY
NORTH FREEWAY AND FREEWAY WITHOUT HOV LANE

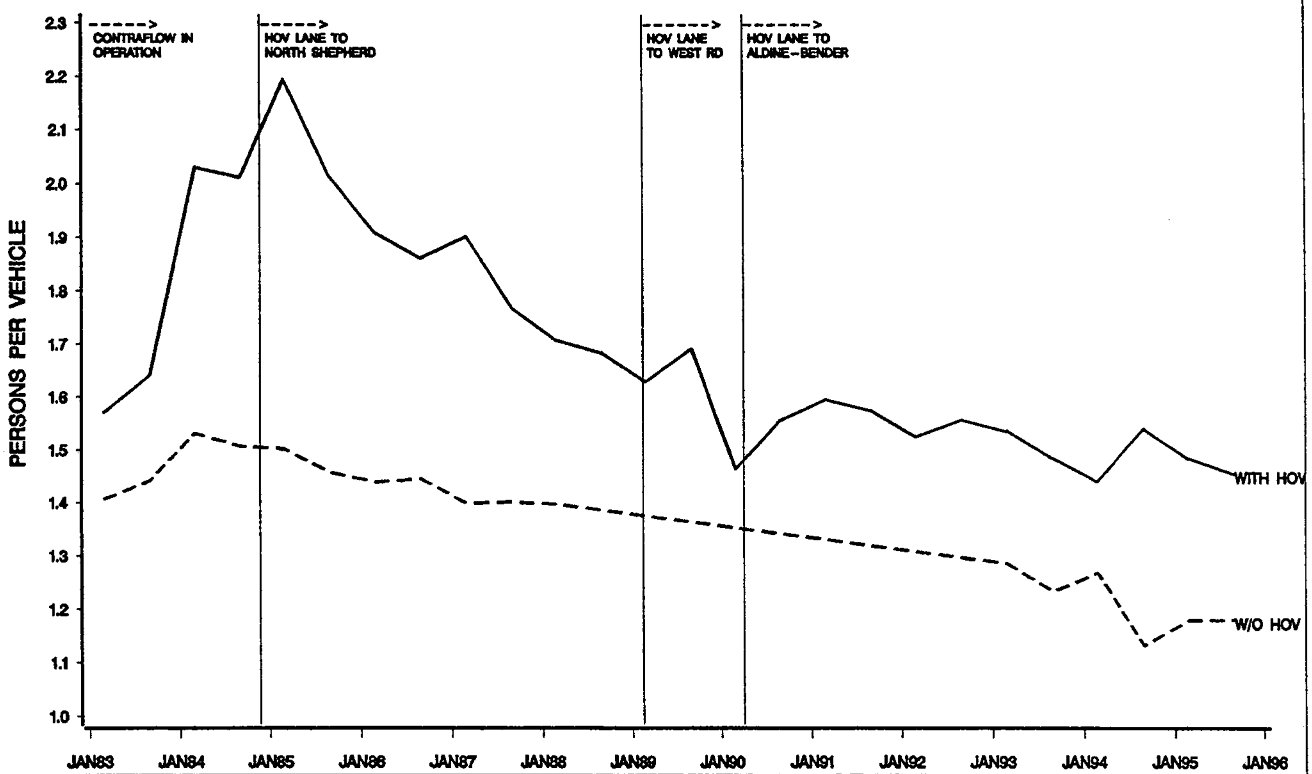
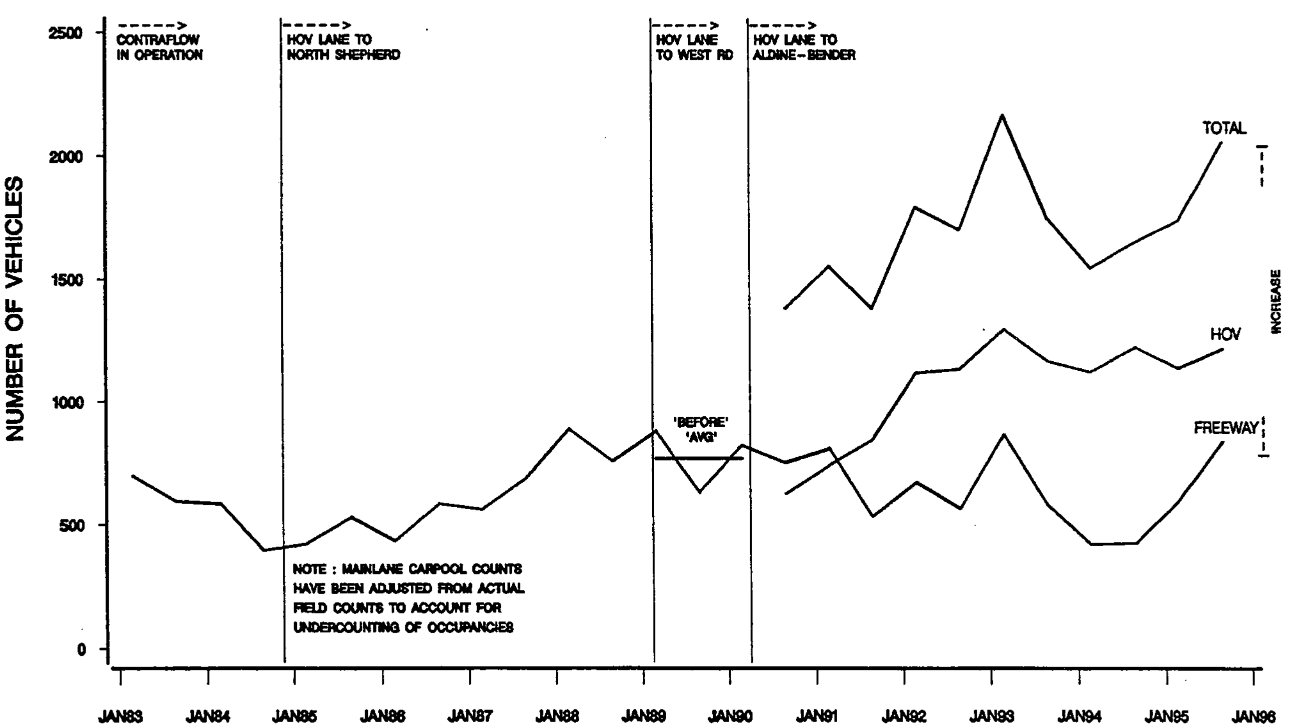


FIGURE B-14. NORTH FREEWAY (IH 45N) MAINLANE AND HOV LANE
A.M. PEAK HOUR 2+ CARPOOL UTILIZATION



B-15. A.M. PEAK HOUR FREEWAY PER LANE EFFICIENCY
NORTH FREEWAY AND FREEWAY WITHOUT HOV LANE

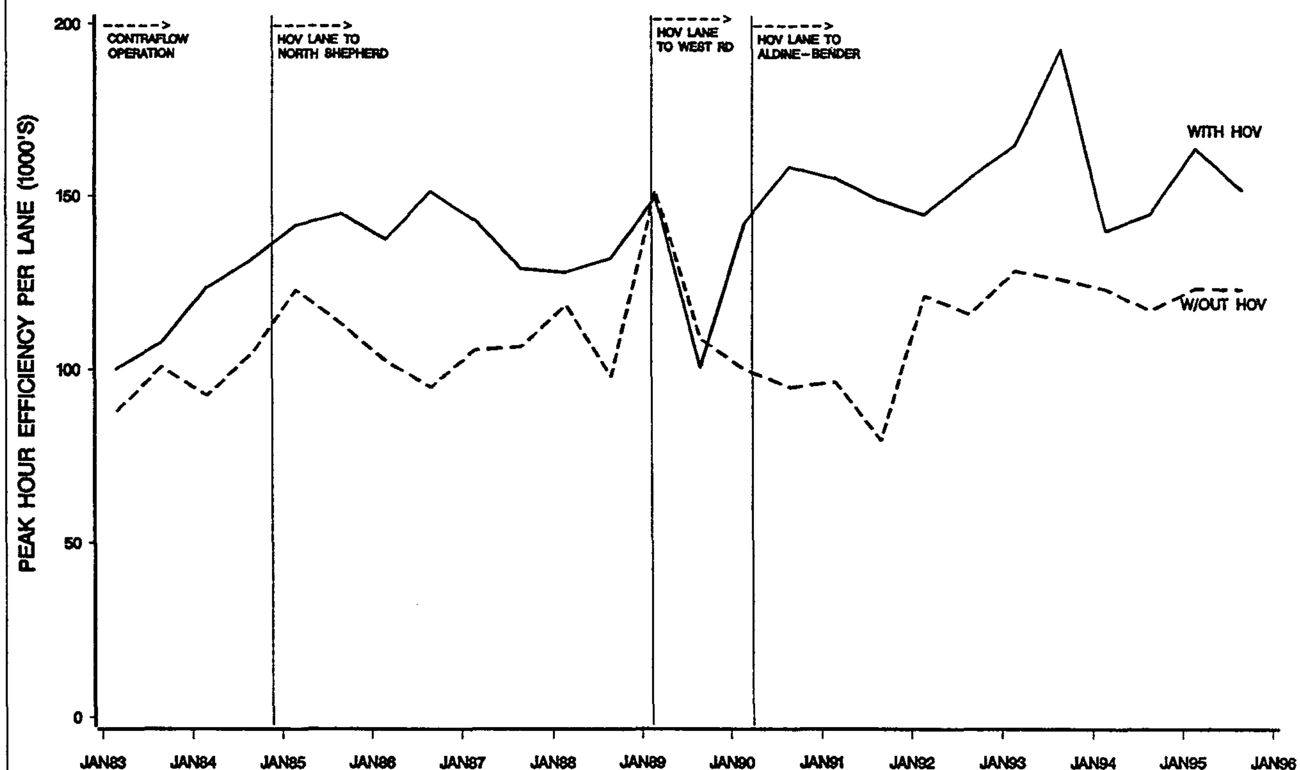


FIGURE B-16. NORTH FREEWAY (IH 45N) HOV LANE
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS

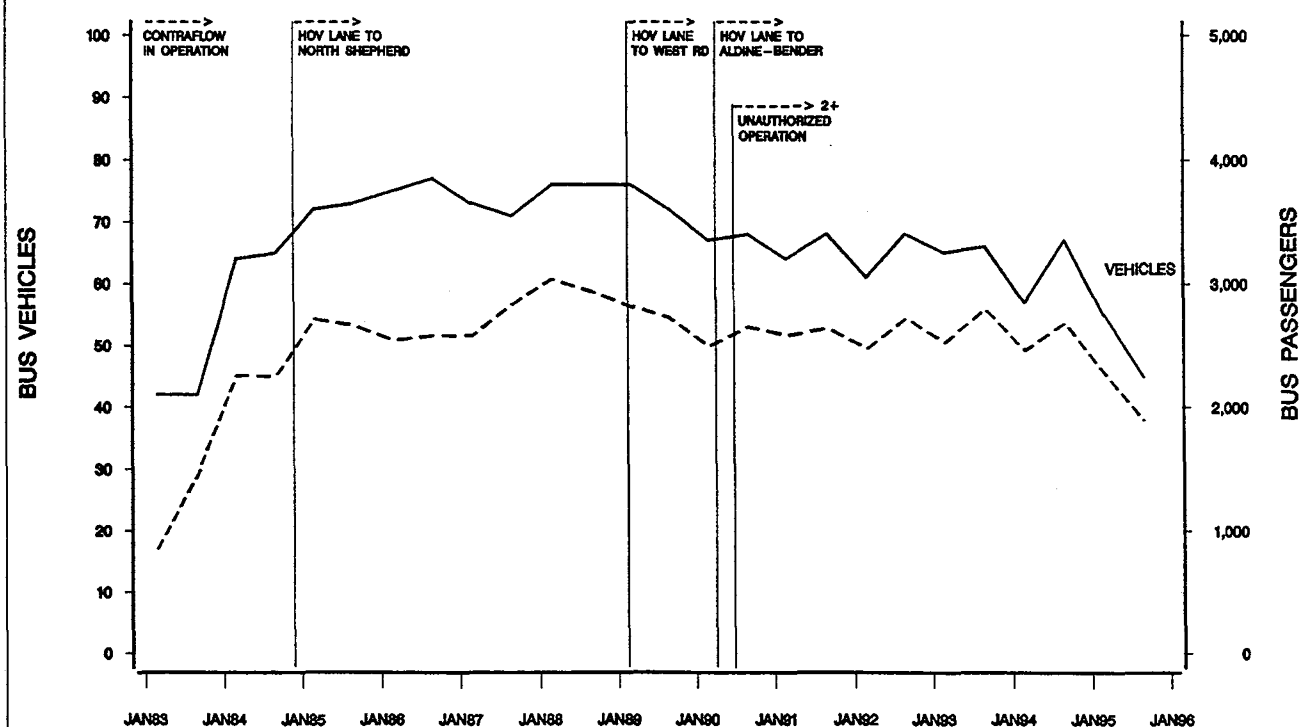


FIGURE B-17. NORTH FREEWAY (IH 45N) HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS

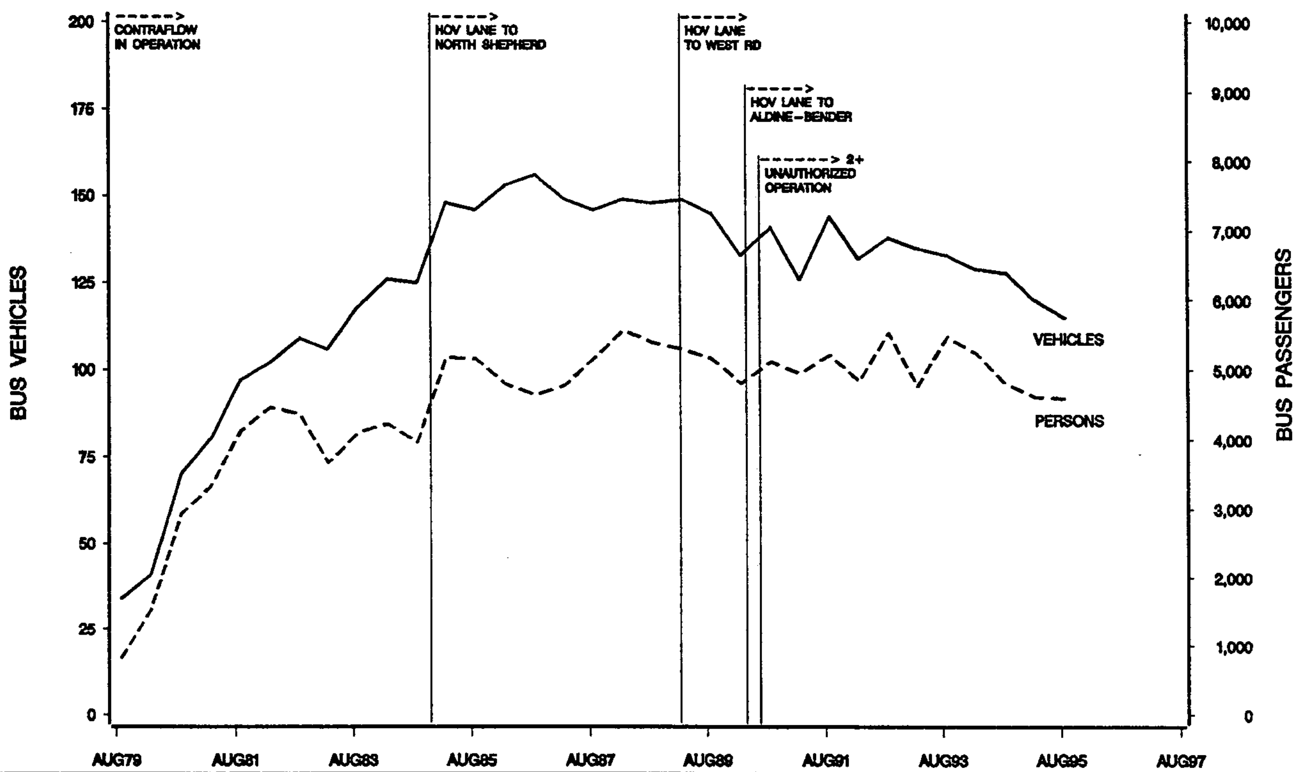


FIGURE B-18. A.M. PEAK PERIOD BUS PASSENGER TRIPS
TOTAL, FREEWAY PLUS HOV LANE VOLUMES
NORTH FREEWAY AND FREEWAY WITHOUT HOV LANE

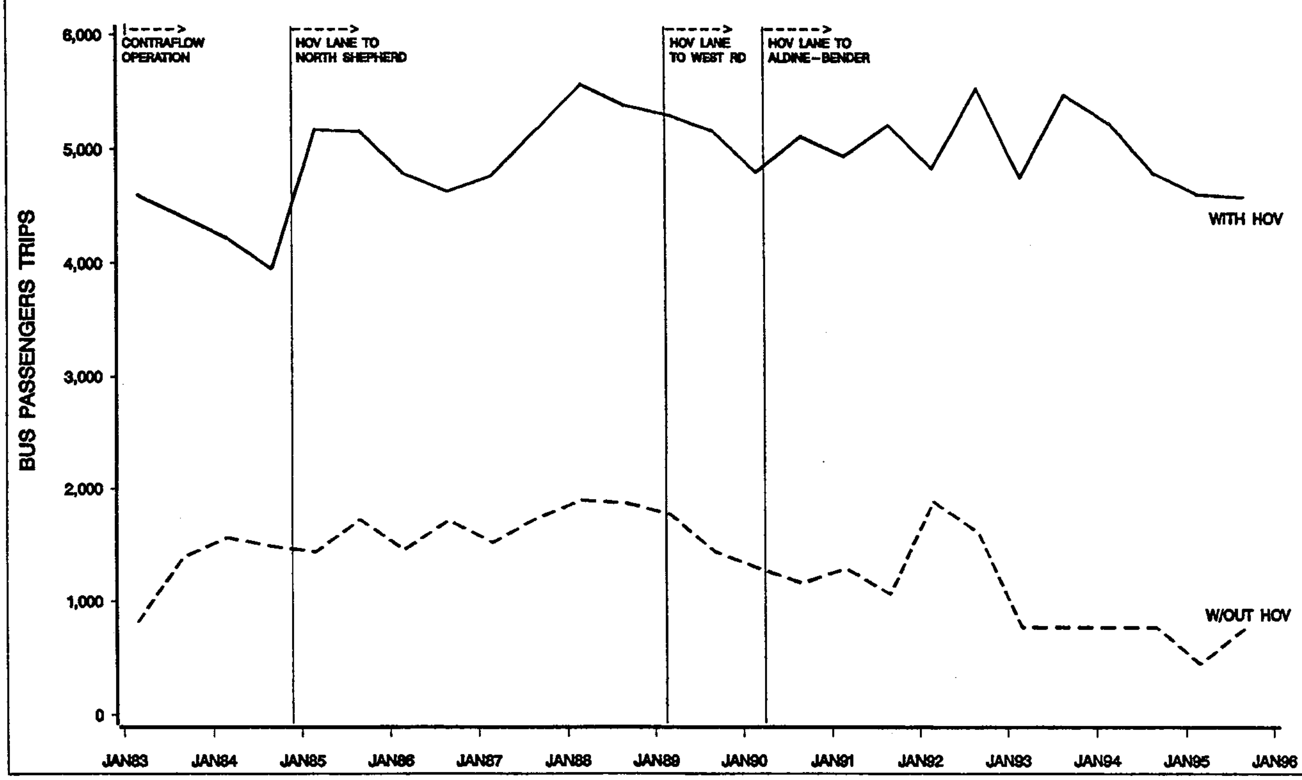


FIGURE B-19. NORTH FREEWAY (IH 45N) CORRIDOR PARK-AND-RIDE DEMAND

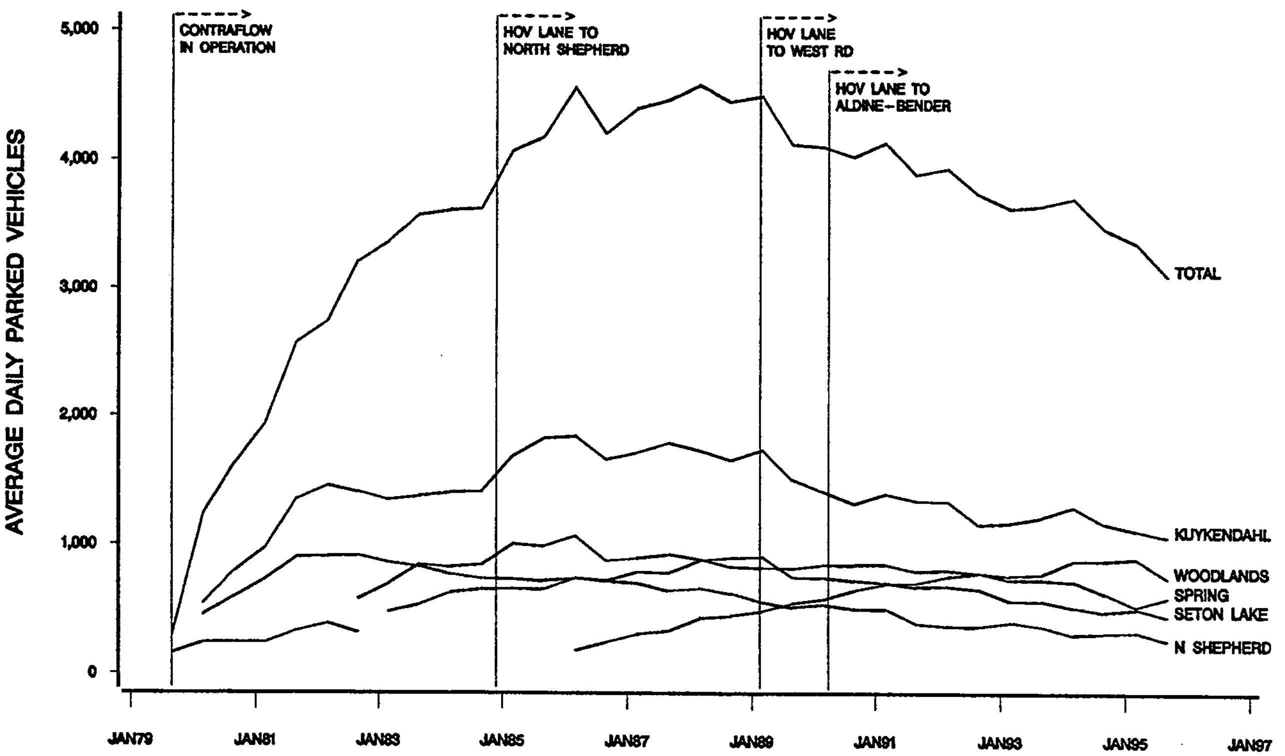
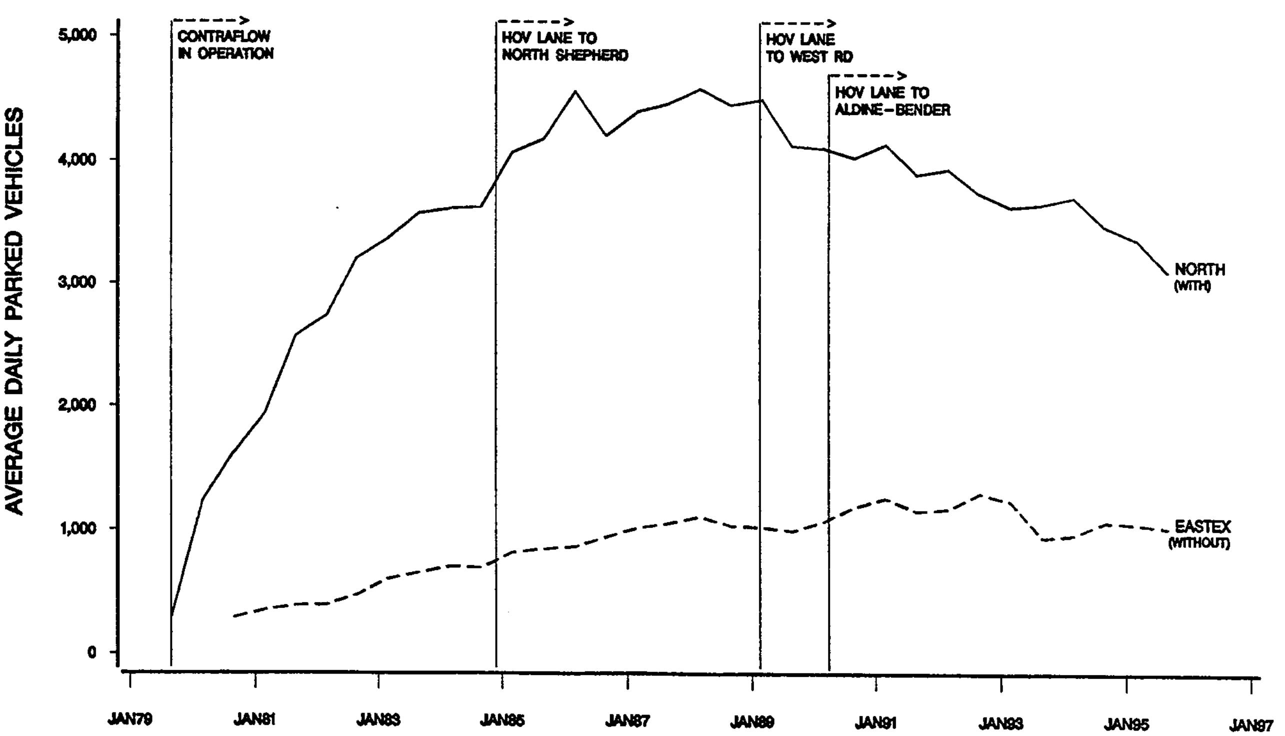


FIGURE B-20. AVERAGE DAILY VEHICLES PARKED AT PARK-AND-RIDE LOTS NORTH FREEWAY AND FREEWAY WITHOUT HOV LANE



APPENDIX C

GULF FREEWAY AND HOV LANE DATA

GULF FREEWAY (I-45S) AND HOV LANE, HOUSTON

Table C-1. Summary of A.M. Peak-Direction Gulf Freeway and HOV Lane Data, December 1995

Type of Data[1] Phase 1 of HOV Lane Became Operational 5/16/88	"Representative" Pre-HOV Lane Value	"Representative" Current Value	Percent Change
HOV Lane Data			
HOV Lane Length kilometers (miles)		19.5 (12.5)	
HOV Lane Cost (millions)		98.3	
Person-Movement			
Peak Hour (7-8 a.m.)	---	1,974	---
Peak Period (6-9:30 a.m.)	---	3,817	---
Total Daily	---	7,233	---
Vehicle Volumes			
Peak Hour	---	787	---
Peak Period	---	1,520	---
Vehicle Occupancy, Peak Hour (persons/veh)	---	2.51	---
Accident Rate (Injury accidents/100 MVK [/100 MVM]) 11/84-12/94[2]	---	7.1 (11.4)	---
Vehicle Breakdowns (VKT/Breakdown [VMT/Breakdown]), 11/84-12/94	---	127,601 (79,255)	---
Violation Rate (6-9:30 a.m.)	---	2.9%	---
Peak Hour Lane Efficiency (1000's)[3]	---	166 (103)	---
Annual Value of User Time Saved (millions)[4]	---	1.2 - 2.5	---
Freeway Mainlane Data (see note)			
Person Movement			
Peak Hour	6,415	6,234	-3 %
Peak Period (6-9:30 a.m.)	17,845	20,032	+12%
Vehicle Volume			
Peak Hour	4,962	5,836	+18%
Peak Period	14,740	17,880	+21%
Vehicle Occupancy, Peak Hour (persons/veh)	1.29	1.07	-17%
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM])[2]	18.5 (29.8)	12.5 (20.1)	-32%
Avg. Operating Speed[5] (kph [mph])			
Peak Hour	50 (31)	48 (30)	+4%
Peak Period	58 (36)	64 (40)	+10%
Peak Hour Lane Efficiency (1000's)[3]	106 (66)	100 (62)	-6%

Source: Texas Transportation Institute. The Texas A&M University System.

[1]HOV lane and freeway data are collected at Monroe.

[2]Due to inconsistencies in reporting accidents in Harris County, this analysis includes only injury accidents. Accidents were analyzed between Broadway and Dowling, a distance of approximately 10.5 kilometers (6.5 miles), which corresponds to Phase 1 of the HOV lane. The pre-HOV lane includes four years of mainlane accident data from 5/16/84 to 5/15/88. The current value is from 5/16/88 to 8/95.

[3]This represents the multiple of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.

[4]Based on time savings for HOV lane users in 1995, an annual estimate of travel time savings to HOV lane users is developed. A value of time of $11.37/hour is used based on the value applied in the Highway Economic Evaluation Model.

[5]From Broadway to Almeda-Genoa a distance of 18.7 kilometers (11.6 miles).

Table C-1. Summary of A.M. Peak-Direction Gulf Freeway and HOV Lane Data, December 1995 (Continued)

Type of Data	"Representative" Pre-HOV Lane Value	"Representative" Current Value	Percent Change
Combined Freeway Mainlane and HOV Lane Data			
Total Person Movement			
Peak Hour	6,415	8,208	+28%
Peak Period	17,845	23,489	+34%
Vehicle Volume			
Peak Hour	4,962	6,623	+33%
Peak Period	14,740	19,400	+32%
Vehicle Occupancy			
Peak Hour	1.29	1.24	-4%
Peak Period	1.21	1.23	+2%
2+ Carpool Volumes			
Peak Hour	475	808	+70%
Peak Period	1,304	2,298	+76%
Travel Time (minutes)[1]			
Peak Hour	9.7[2]	7.5[3]	-23%
Peak Period	8.1[2]	7.0[3]	-14%
Peak Hour Lane Efficiency (1000's)[4]	106 (66)	116 (72)	+9%
Transit Data			
Bus Vehicle Trips			
Peak Hour	23[5]	11	-52%
Peak-Period	40[5]	23	-43%
Bus Passenger Trips			
Peak Hour	746[5]	310	-58%
Peak Period	1,230[5]	710	-42%
Bus Occupancy (persons/bus)			
Peak Hour	32.6[5]	28.2	+13%
Peak Period	30.8[5]	30.9	0%
Vehicles Parked in Corridor Park & Ride Lots	1,115	1,226	+10%
Bus Operating Speed (kph [mph])[1]			
Peak Hour	50 (31)[2]	84 (52)[3]	+68%
Peak Period	58 (36)[2]	89 (55)[3]	+53%

Note: Site-specific data collected at Monroe. For purposes of visibility and safety, the freeway volumes are counted between an exit and an entrance ramp. Thus, the mainlane volumes may be low.

[1]From Broadway to Almeda-Genoa, a distance of 18.7 kilometers (11.6 miles).
[2]Data pertain to operation in the freeway mainlanes.
[3]Data pertain to operation in the HOV lane.
[4]This represents the product of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.
[5]Data collected at Monroe.

Table C-2. Comparison of Measures of Effectiveness, Freeway With (Gulf I-45) and Freeway Without (Eastex U.S. 59) HOV Lane, Houston[1,2]

Measure of Effectiveness	"Representative" Pre-HOV Lane Value	"Representative" Current Value	Percent Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/HOV lane	1.29	1.24	-4%
Freeway w/o HOV lane	1.23	1.18	-4%
A.M. Peak Hour, 2+ Carpool Volume			
Freeway w/HOV lane	475	808	+70%
Freeway w/o HOV lane	600	571	-5%
Bus Passengers, Peak Period			
Freeway w/HOV lane	1,230	710	-42%
Freeway w/o HOV lane	1,188	762	-36%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	1,115	1,226	+10%
Freeway w/o HOV lane	1,236	1,035	-16%
Facility Per Lane Efficiency[3]			
Freeway w/HOV lane	106 (66)	116 (72)	+9%
Freeway w/o HOV lane	138 (86)	123 (77)	-11%

[1]HOV lane data are collected at Telephone Road, and freeway data are collected at Monroe. Since the HOV lane does not yet extend to Monroe, it is not possible at this time to combine freeway and HOV lane data.
[2]Data for freeways without HOV lanes are a composite of data collected on the Gulf Freeway during the time in which no HOV lane existed on that facility (6/83-4/88), the Southwest Freeway (9/86 to present) and the Eastex Freeway (1/93 to present).
[3]This represents the product of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.

HOV LANE DATA

DESCRIPTION

- Phase 1 (10.5 kilometers [6.5 miles]) of the HOV lane opened 5/16/88. Weekend operation began 10/1/89. The capital cost for the operating segment (including all support facilities) in 1990 dollars was $44.2 million. The cost to complete the entire facility (1990 dollars) will be $121.1 million. The following pages provide a more detailed cost breakdown (including dates).

- Selected milestone dates are listed below. The capital cost table shows other dates.

  - 5/16/88 CBD to Broadway opens (10.5 kilometers [6.5 miles]).
  - 10/1/89 Weekend HOV operation begins.
  - 10/5/91 Weekend HOV operation ends.
  - 9/8/92 Motorcycles allowed on HOV facility (no occupancy restrictions).
  - 3/14/94 HOV lane extended to Almeda-Genoa; an additional distance of 8.2 kilometers (5.1 miles)--bringing the total operational HOV length to 18.7 kilometers (11.6 miles).

PERSON MOVEMENT

- In December 1995, the HOV lane served 7,233 person trips per day.
- A.M. peak hour, 1,974 persons/hour.
  - 310 (16%) by bus, 91 (5%) by vanpool, 1,568 (79%) by carpool, and 5 by motorcycle (Figure C-1).
  - Average HOV lane vehicle occupancy = 2.51 persons/vehicle.
- A.M. peak period, 3,817 persons.
  - 710 (19%) by bus, 91 (2%) by vanpool, 2,986 (78%) by carpool, and 30 (1%) by motorcycle (Figure C-2).

Table C-3. Estimated Capital Cost (millions), Gulf HOV Lane Operating Segment

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1995 Dollars
HOV Lane and Ramps			
Phase 1 Metro (1988)	$1.6	1.18	$1.9
Phase 2 Metro (1988)	0.4	1.18	0.5
Phase 1 SDHPT (1988)	14.0	1.18	16.2
Phase 2 SDHPT (1988)	6.4	1.18	7.5
Phase 3 (1995)	24.4	1.00	24.4
Miscellaneous (1995)	3.6	1.00	3.6
SUB-TOTAL	$50.4		$54.1
Per Kilometer (Mile)	$2.5 ($4.0)	1.10	$2.7 ($4.3)
Surveillance, Communication and Control	$3.8		$4.2
SUB-TOTAL	$3.8		$4.2
Per Kilometer (Mile)	$0.2 ($0.3)		$0.2 ($0.3)
Support Facilities			
Bay Area P/R (1984)	$3.7	1.13	$4.2
Edgebrook P/R (1981)	3.3	1.27	4.2
Eastwood Transit Center (1988)	5.0	1.18	5.9
Monroe P/R (1994)	9.1	1.03	9.4
Fuqua P/R (1995)	10.4	1.00	10.4
Fuqua Park/Pool (1995)	5.9	1.00	5.9
SUB-TOTAL	$37.4		$40.0
Per Kilometer (Mile)	$1.9 ($2.9)		$2.0 ($3.2)
TOTAL COST	$91.6		$98.3
COST PER KILOMETER (19.5 kilometers [12.1 miles])	$4.6 ($7.3)		$4.9 ($7.9)

Source: Compiled by TTI from data provided by Metro and TxDOT.

Table C-4. Estimated Capital Cost (millions), Gulf HOV Lane, Future Segments

Cost Component	Estimated Year of Completion	Estimated Cost ($Millions)	
HOV Lane and Ramps			
Phase 3 Broadway to Choate	1996		$13.3
Almeda-Genoa Slip Ramp	1996		0.4
Hobby West Access Ramp	1996		0.5
Miscellaneous			3.6
SUB-TOTAL		$17.8	
Per Kilometer (Mile)			$8.4 ($5.2)
Surveillance, Communication and Control			$1.9
SUB-TOTAL		$1.9	
Per Kilometer (Mile)			$0.1 ($0.2)
TOTAL COST		$19.7	
COST PER KILOMETER (5.5 kilometers [3.4 miles])		$3.6 ($5.8)	

Source: Compiled by TTI from data provided by Metro and TxDOT.

VEHICLE MOVEMENT

- A.M. Peak Hour, 787 vph
  - 11 (1%) buses, 11 (1%) vans, 760 (97%) carpools, and 5 by motorcycle (Figure C-3).
- A.M. Peak Period, 1,520 vehicles.
  - 23 (2%) buses, 11 (1%) vans, 1,456 (96%) carpools, and 30 (2%) by motorcycle (Figure C-4).

VEHICLE BREAKDOWN RATES

- As measured from September 1, 1988 through September 1995, the following rate has been observed.
  - Weighted average: 1 breakdown per 127,601 VKT (79,255 VMT).

PEAK HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. For the HOV lane, this value (expressed in 1000's) is approximately 166 (1,974 passengers x 84 kph) or 103 (1,974 passengers x 52 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane are experiencing a travel time savings of approximately 5 minutes during the peak hour (Figure C-5).
- The table on the following page indicates that on a typical non-incident day, travel time savings of approximately 433 hours (25,967 min.) are realized. Assuming 250 days of operation, annual savings would be 108,250 hours. At $11.37/hour, this equates to $1.23 million per year. This estimate is extremely conservative since it does not consider travel time savings due to incidents on the freeway. Data from Houston suggest that increasing this value by 100% to account for incidents would be reasonable. Thus, estimated travel time savings to HOV lane users are in the range of $1.23 to $2.46 million per year.

Table C-5. Travel Time Savings for Gulf HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1995)

Northbound A.M. Travel Time Savings for Gulf HOV Lane								
Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section from Broadway to Dowling								
6:00	6.73	7.33	-0.59	102	28	145	274	-162
6:30	6.93	6.43	0.49	395	34	235	664	326
7:00	12.03	7.53	4.51	837	70	385	1,292	5,823
7:30	13.48	7.52	5.97	915	47	325	1,287	7,676
8:00	12.24	7.01	5.23	580	20	146	745	3,899
8:30	8.23	6.78	1.45	273	9	96	378	547
9:00	7.72	6.73	0.99	123	4	15	142	140
Peak Period Total				3,224	210	1,347	4,780	18,249
Section From Broadway to Dowling								
3:30	8.07	7.46	0.61	167	9	148	324	197
4:0	9.33	7.22	2.11	360	30	200	590	1,244
4:30	8.40	7.21	1.19	528	38	256	822	979
5:00	9.17	7.67	1.50	898	102	486	1,485	2,228
5:300	9.48	7.62	1.86	820	83	262	1,165	2,164
6:00	7.97	7.30	0.67	465	23	250	738	498
6:30	6.48	7.68	-1.20	225	16	40	281	-337
Peak Period Total				3,463	301	1,640	5,403	6,973
Southbound PM Travel Time Savings for Gulf HOV Lane								
Section from Almeda-Genoa to Broadway								
6:00	3.40	6.17	-2.77	177	8	35	220	-609
6:30	3.27	4.18	-0.92	524	66	145	735	-674
7:00	4.30	5.45	-1.15	854	39	185	1,078	-1,240
7:30	4.92	5.77	-0.85	862	3	215	1,079	-917
8:00	4.34	5.48	-1.14	416	0	101	516	-589
8:30	4.37	4.22	0.15	182	0	82	263	39
9:00	4.03	4.38	-0.35	69	0	1	69	-24
Peak Period Total				3,082	116	763	3,960	-4,014

Table C-5. Travel Time Savings for Gulf HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1995) (Continued)

Northbound A.M. Travel Time Savings for Gulf HOV Lane								
Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section Almeda-Genoa to Broadway								
3:30	5.62	5.49	0.13	75	6	25	106	13
4:00	5.48	5.32	0.17	133	11	20	164	27
4:30	6.33	5.29	1.04	285	4	110	399	416
5:00	7.46	5.75	1.71	543	71	180	794	1,356
5:30	8.53	5.91	2.62	630	42	225	897	2,355
6:00	6.68	5.91	0.77	401	0	76	477	369
6:30	6.08	5.20	0.88	240	3	10	253	223
Peak Period Total				2,307	136	646	3,088	4,759

FREEWAY DATA

NOTE

- Freeway data collected in the Gulf corridor since 1983 have been, for a variety of reasons (primarily safety), collected at Monroe.

PERSON MOVEMENT

- Prior to HOV lane implementation, the average a.m. peak hour person volume was 6,415 (Figure C-6). This volume is now 6,234.

- The a.m. peak period, person volume was approximately 17,845 (Figure C-7). This volume has risen to 20,032.

VEHICLE VOLUME

- In the a.m. peak hour, the vehicle volume was 4,962 vph prior to HOV lane implementation and is now 5,836 (Figure C-6).

- In the a.m. peak period, the vehicle volume was 14,740 and is now 17,880 (Figure C-7).

VEHICLE OCCUPANCY

- In the a.m. peak hour, mainlane occupancy was 1.29 persons per vehicle prior to HOV lane implementation and has decreased to 1.07 persons per vehicle.

ACCIDENT RATE

- Implementation of the HOV lane resulted in narrower freeway lanes and no inside emergency shoulder.

- For the section of Gulf Freeway between Broadway and downtown, the accident rate for the mainlanes for four years of operation (5/16/84 to 5/15/88) was 18.5 accidents per 100 million vehicle kilometers (100 MVK) (29.8 accidents per 100 million vehicle miles [100 MVM]). The "after HOV lane" accident rate for the mainlanes is 12.5 accidents per 100 MVK (20.1 accidents per 100 MVM) and includes the period 5/88 to 12/94. Current accident files include only officer-reported accidents.

AVERAGE OPERATING SPEED

- In comparison to pre-HOV lane conditions, mainlane operating speeds in the peak period increased between South Loop 610 and Dowling—the portion of the Gulf corridor which corresponds to Phase I of the HOV lane. Speeds have also increased outside South Loop 610, where Phase II of the HOV lane has now been implemented (Figure C-8).

PEAK HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of per lane efficiency.

- The pre-HOV freeway efficiency, as measured at Monroe, was 106 (2,138 passengers per lane at 50 kph) or 66 (2,138 passengers per lane at 31 mph). It is now 100 (2,078 passengers at 71) or 62 (2,078 at 44 mph).

COMBINED FREEWAY AND HOV LANE DATA

TOTAL PERSON MOVEMENT

- Percent by HOV lane, a.m. peak.
  - At Monroe, the HOV lane is carrying 24% of the total peak-hour person movement (Figure C-9). In the peak period, the HOV lane carries 16% of the a.m. peak period person trips (Figure C-10).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.24 compared to 1.07 for the mainlanes (Figure C-11). Occupancy in the peak period has increased with the opening of the HOV lane (Figure C-12).

CARPOOL VOLUMES

- In the a.m. peak hour, the total number of 2+ carpools (freeway plus HOV lane) has increased by 70% compared to pre-HOV lane levels (Figure C-14).

- Prior to the HOV lane, the peak hour 2+ carpool volume was 475. Now it is 808 vehicles (Figure C-14).

PEAK HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by an average speed is sometimes used as a measure of the efficiency of the lane. The average efficiency of a lane on the freeway (4 freeway lanes plus 1 HOV lane) has increased by 9% since the implementation of the HOV lane (Figure C-15).

BUS TRANSIT DATA

NOTE

- HOV lane data are routinely collected at Telephone Road and freeway data at Monroe. Data from these two locations are not directly comparable. Therefore, the summary table reports only pre-HOV data.

BUS VEHICLE AND PASSENGER TRIPS

- Pre-HOV bus vehicle and passenger trips, as counted at Monroe, show 23 peak-hour bus vehicle trips and 746 bus passenger trips (Figure C-16); and 40 peak-period bus vehicle trips and 1,230 bus passenger trips (Figure C-17).

PARK-AND-RIDE

- Prior to opening the HOV lane, approximately 1,115 vehicles were parked in corridor park-and-ride lots. This has increased 10% to a current level of 1,226 (Figure C-19).

- Figure C-20 shows a comparison of Eastex Freeway (freeway without an HOV lane) and Gulf Freeway park-and-ride utilization.

FIGURE C-1. GULF FREEWAY (IH 45S) HOV LANE
A.M. PEAK HOUR HOV LANE PERSON MOVEMENT

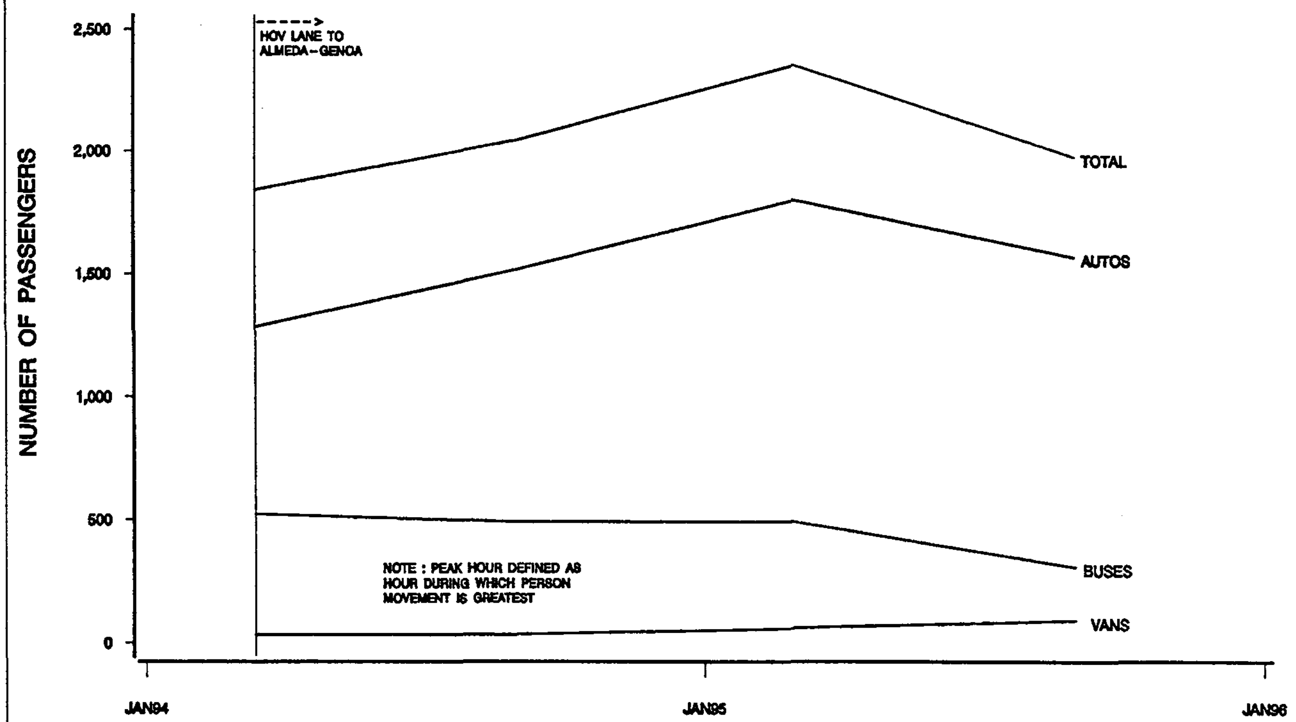


FIGURE C-2. GULF FREEWAY (IH 45S) HOV LANE
A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT

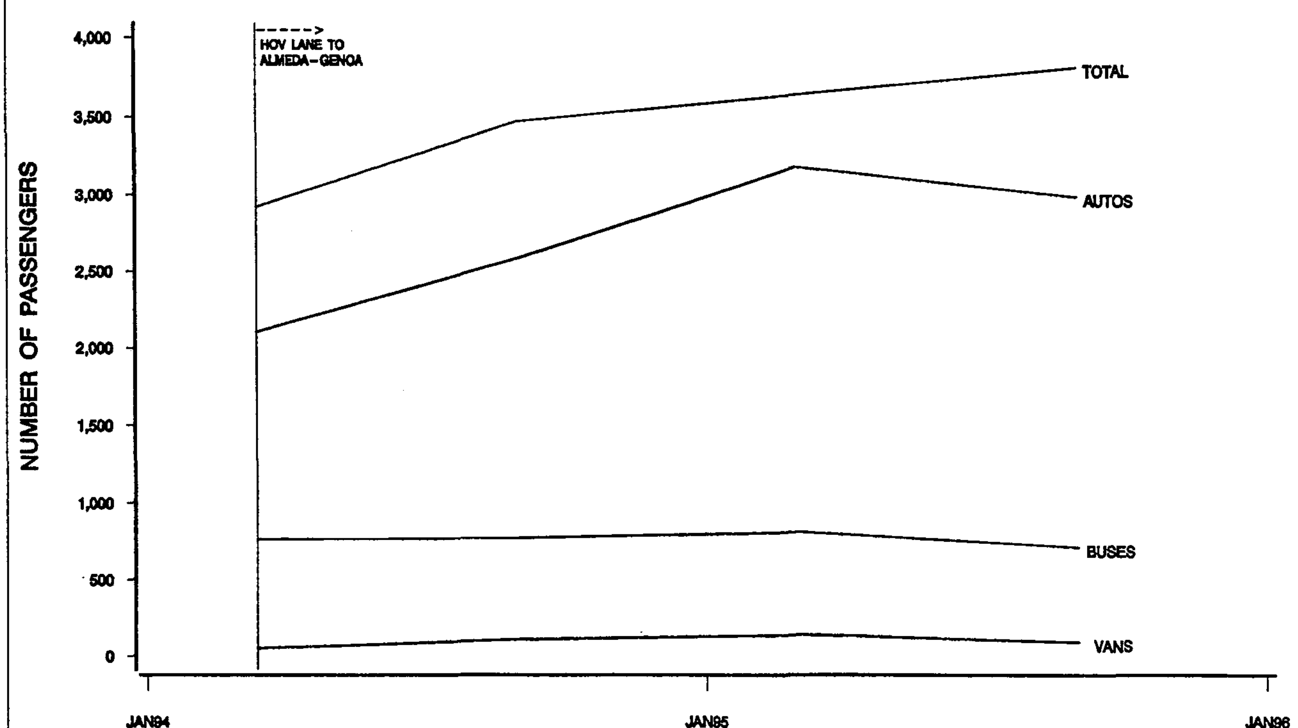


FIGURE C-3. GULF FREEWAY (IH 45S) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION

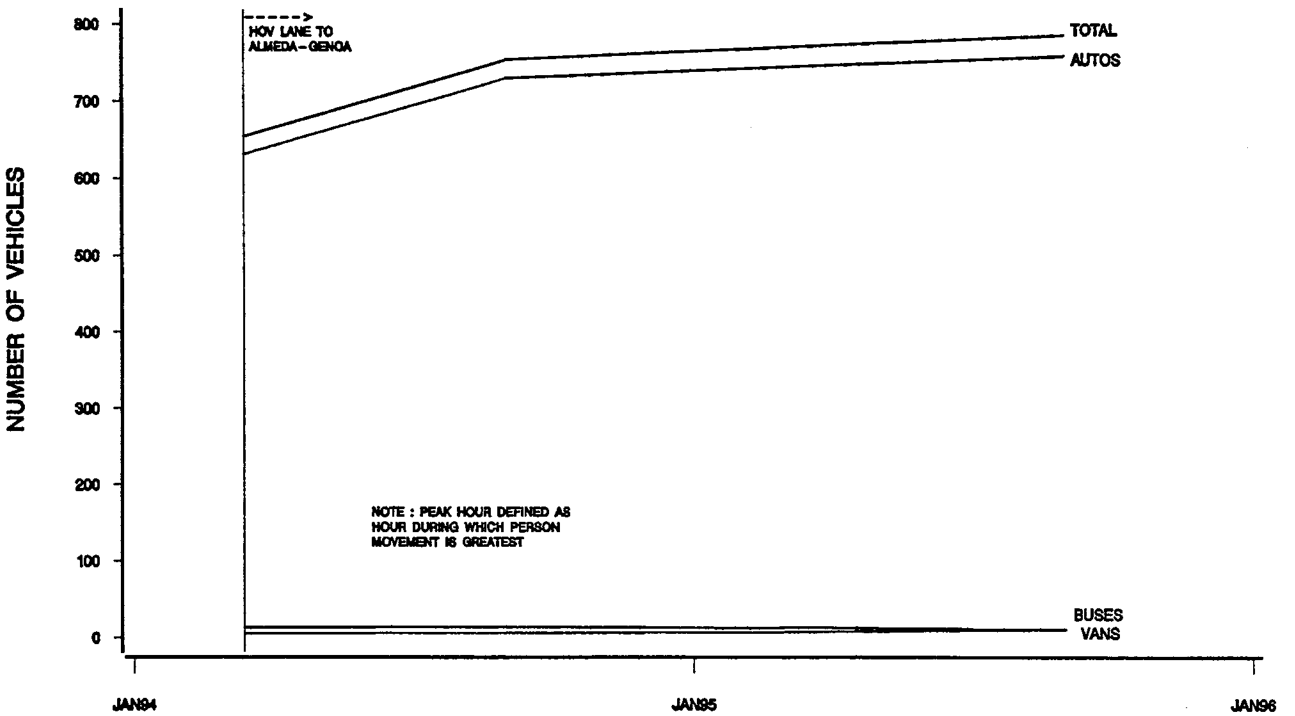


FIGURE C-4. GULF FREEWAY (IH 45S) HOV LANE
A.M. PEAK PERIOD HOV LANE VEHICLE UTILIZATION

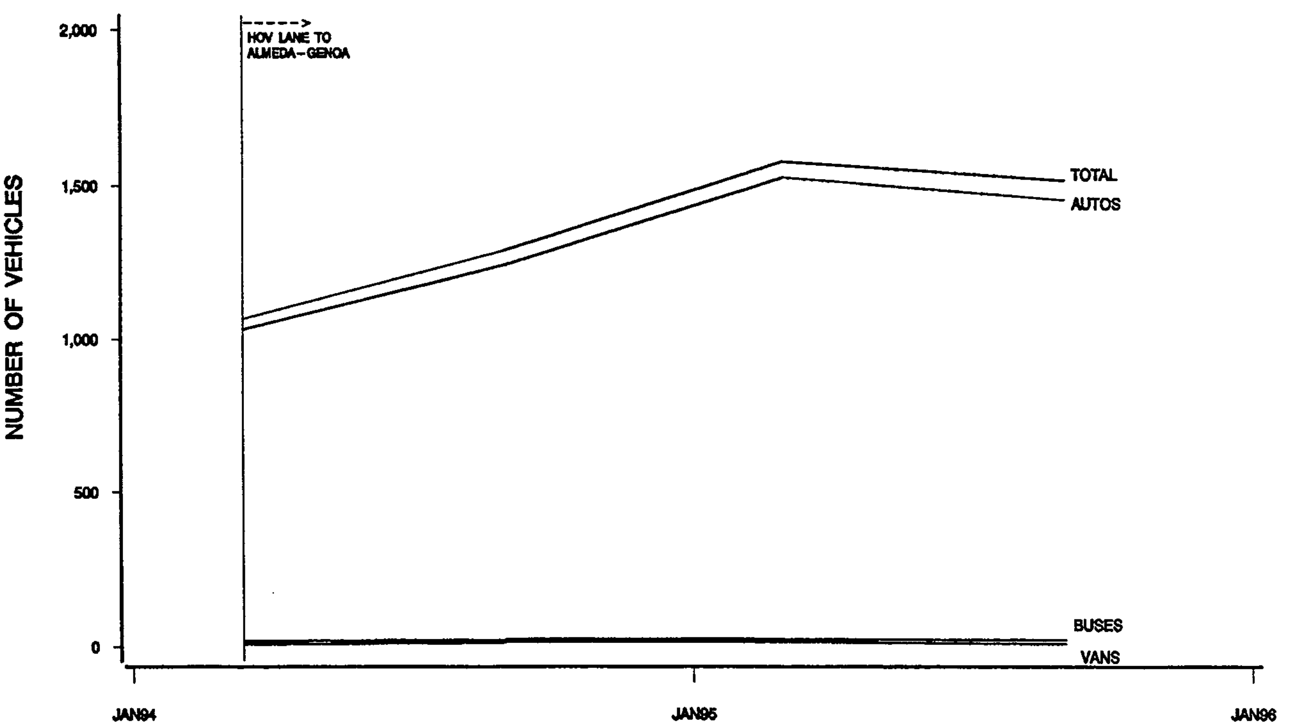


FIGURE C-5. GULF FREEWAY (IH 45S) MAINLANES AND HOV LANE A.M. TRAVEL TIME

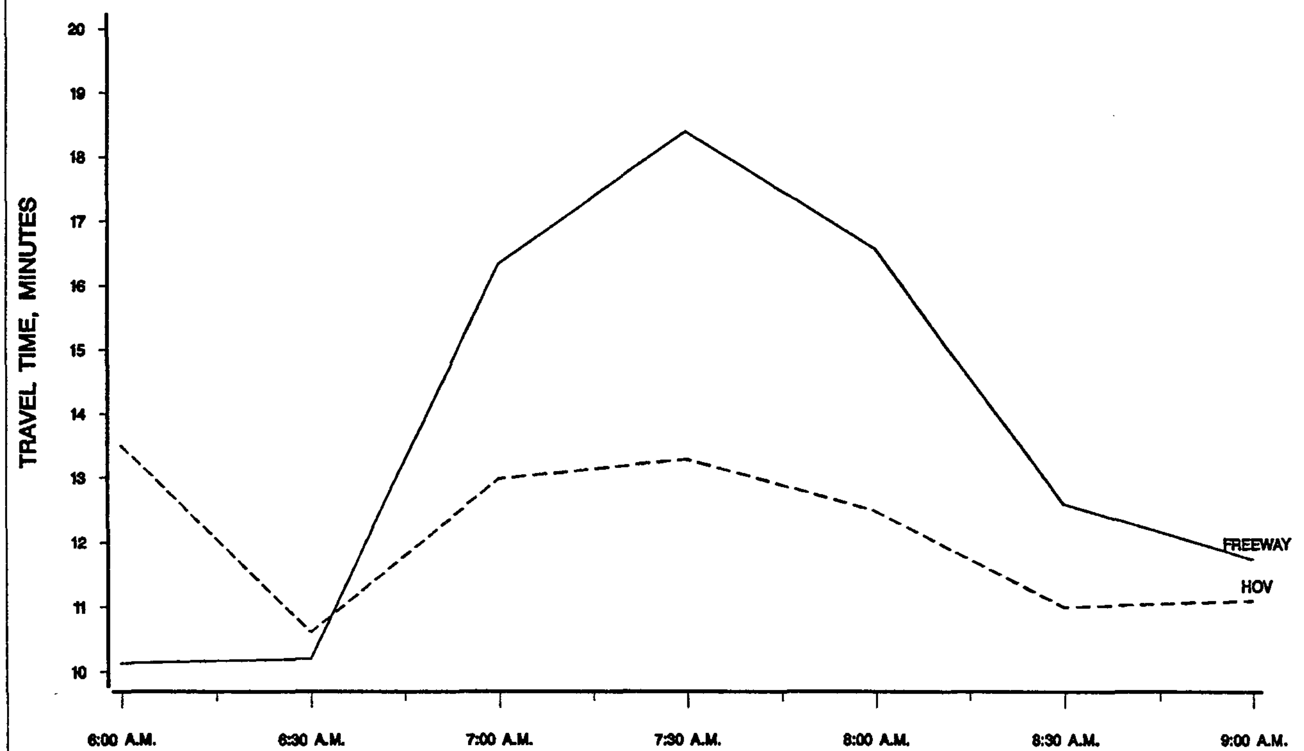


FIGURE C-6. GULF FREEWAY (IH 45S)
A.M. PEAK HOUR MAINLANE TRIPS

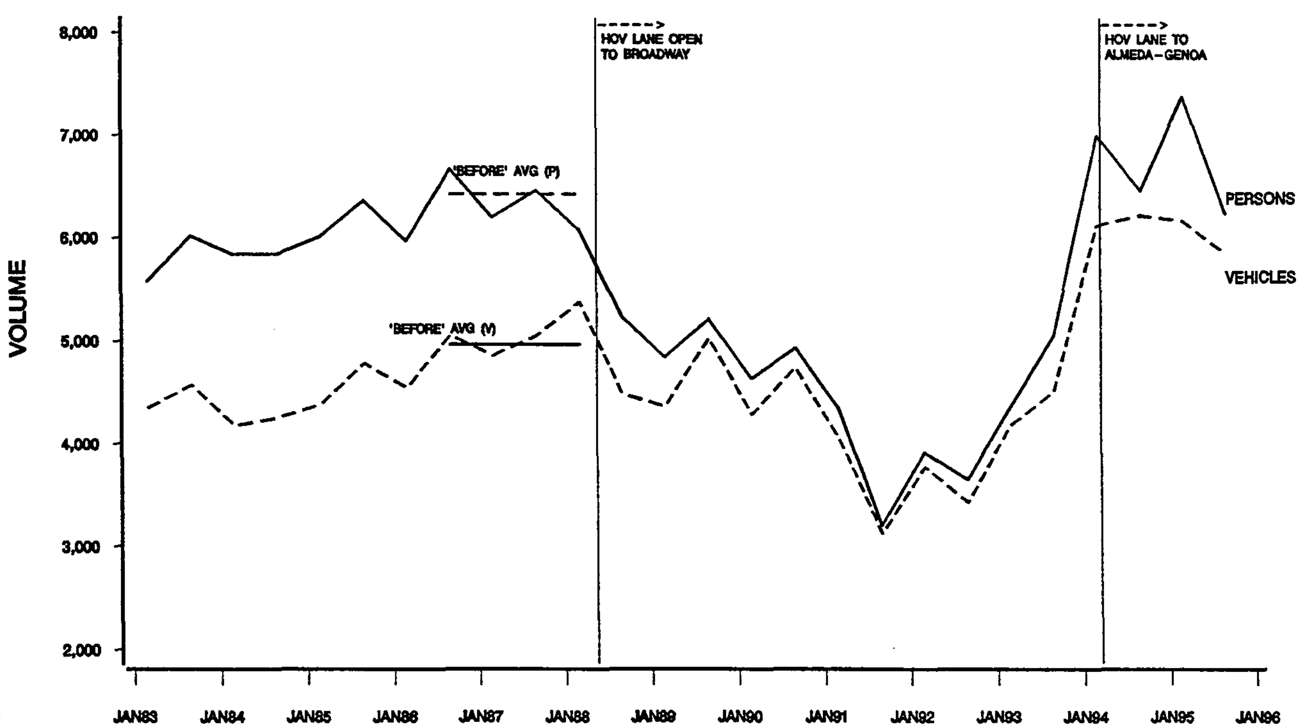


FIGURE C-7. GULF FREEWAY (IH 45S)
A.M. PEAK PERIOD MAINLANE TRIPS

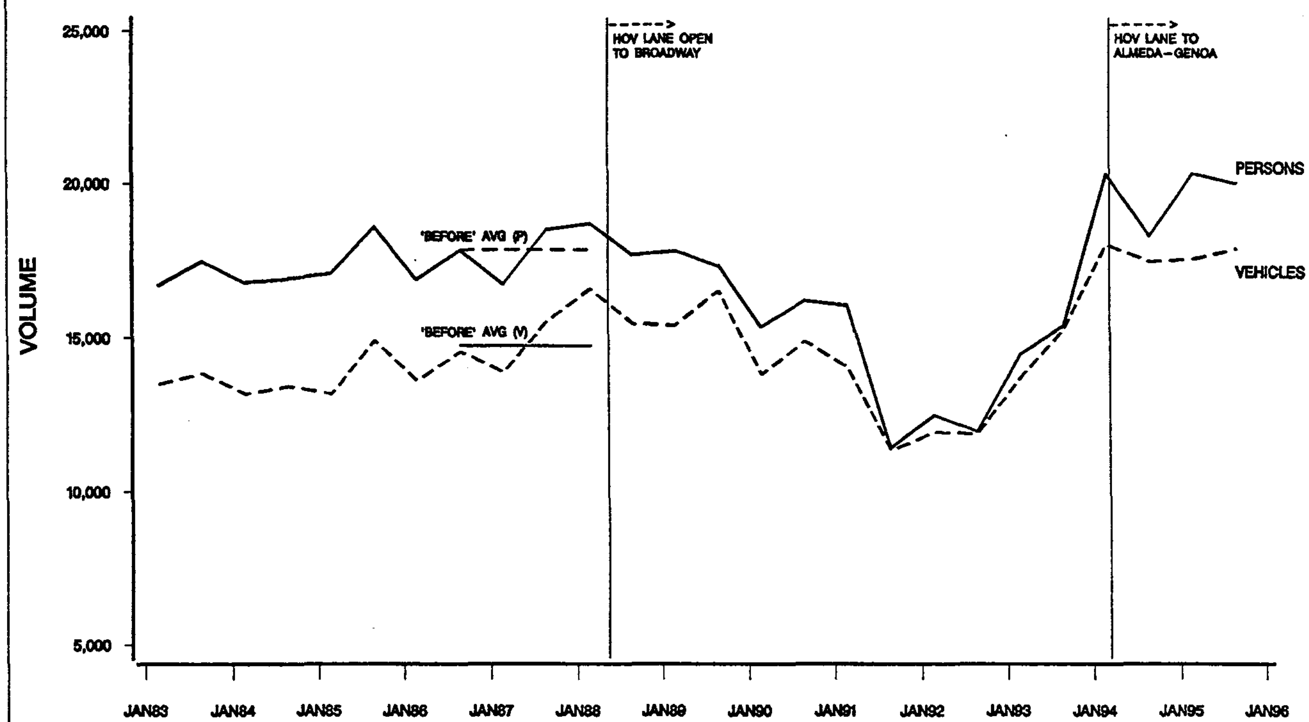


FIGURE C-8. GULF FREEWAY (IH 45S) MAINLANE TRAVEL TIME AND SPEED SURVEY
NORTHBOUND, FM 1959 TO DALLAS
A.M. PEAK PERIOD

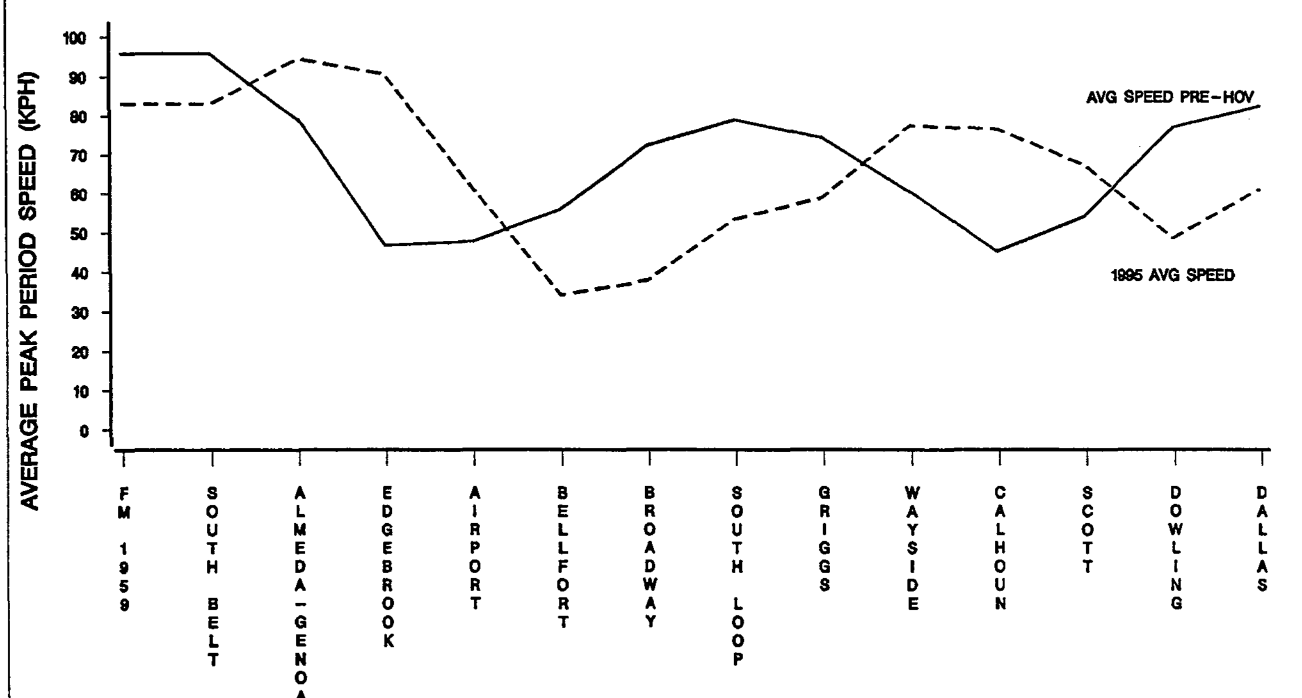


FIGURE C-9. GULF FREEWAY (IH 45S) MAINLANE AND HOV LANE
A.M. PEAK HOUR PERSON TRIPS

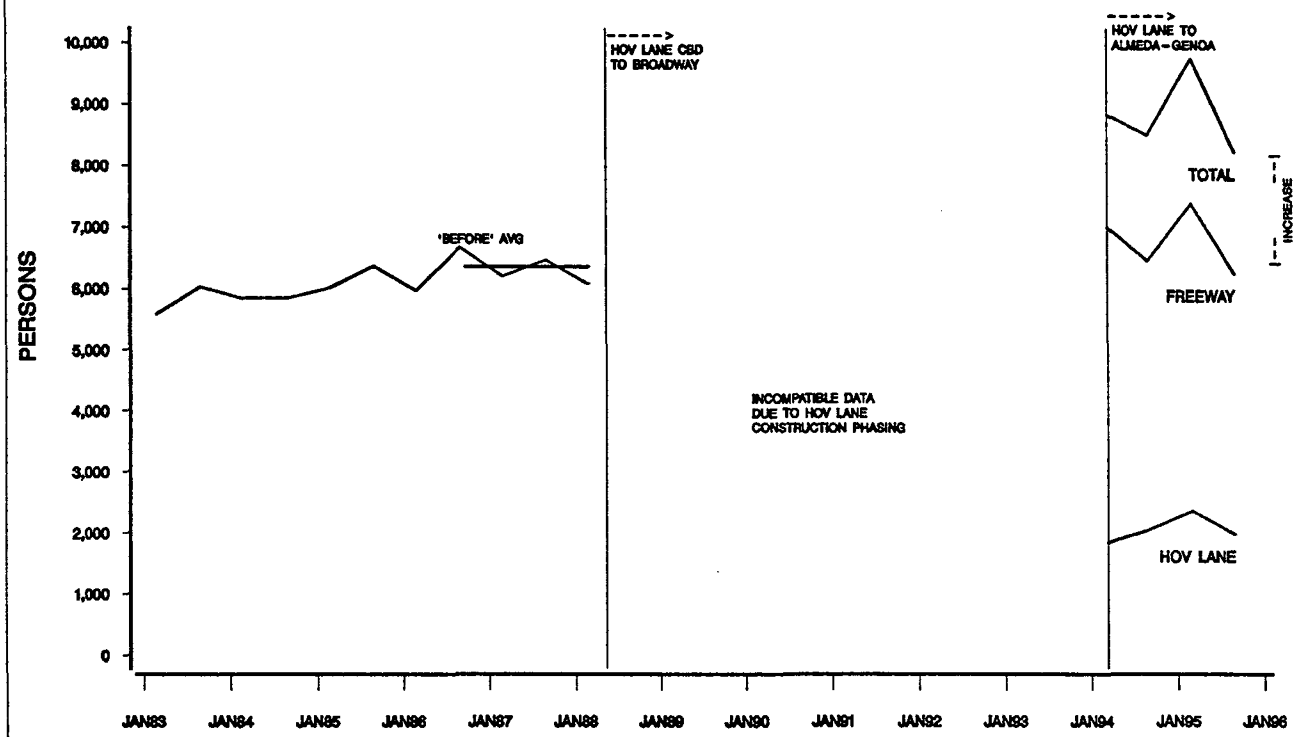


FIGURE C-10. GULF FREEWAY (IH 45S) MAINLANE AND HOV LANE
A.M. PEAK PERIOD PERSON TRIPS

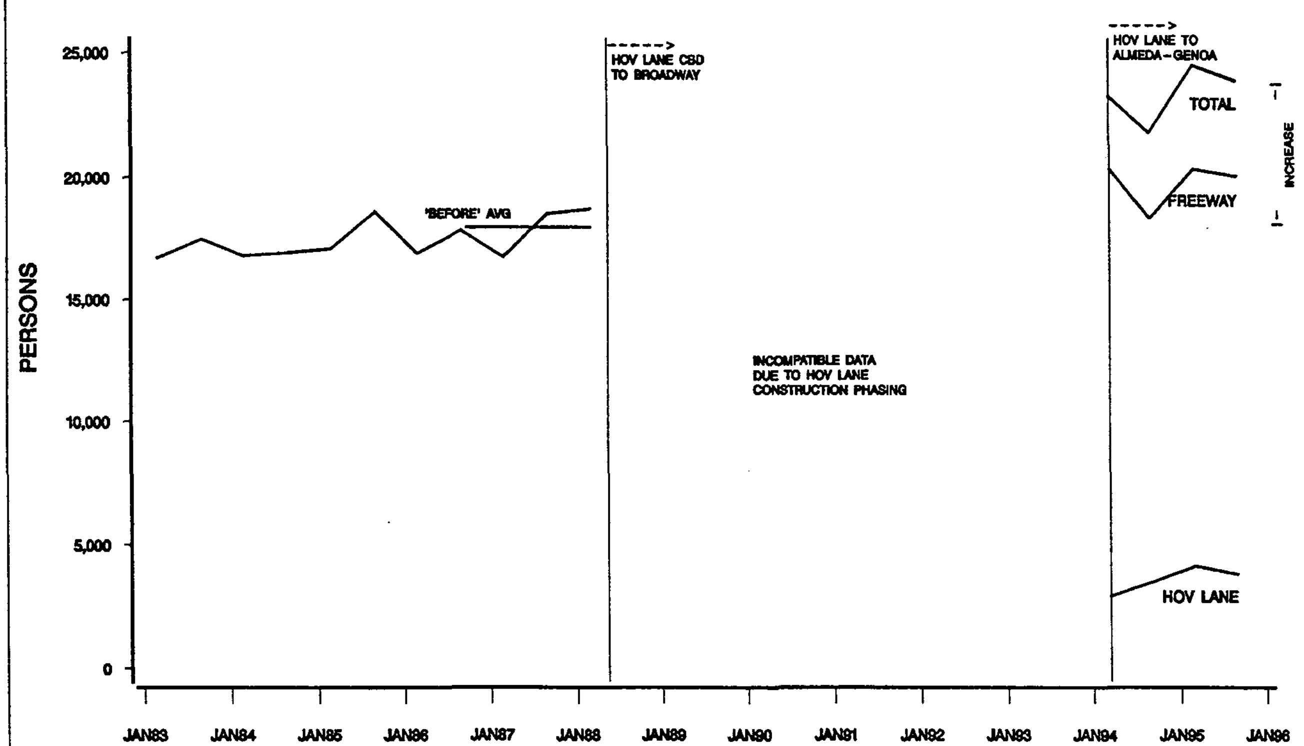


FIGURE C-11. GULF FREEWAY (IH 45S) MAINLANE AND HOV LANE
A.M. PEAK HOUR AVERAGE OCCUPANCY

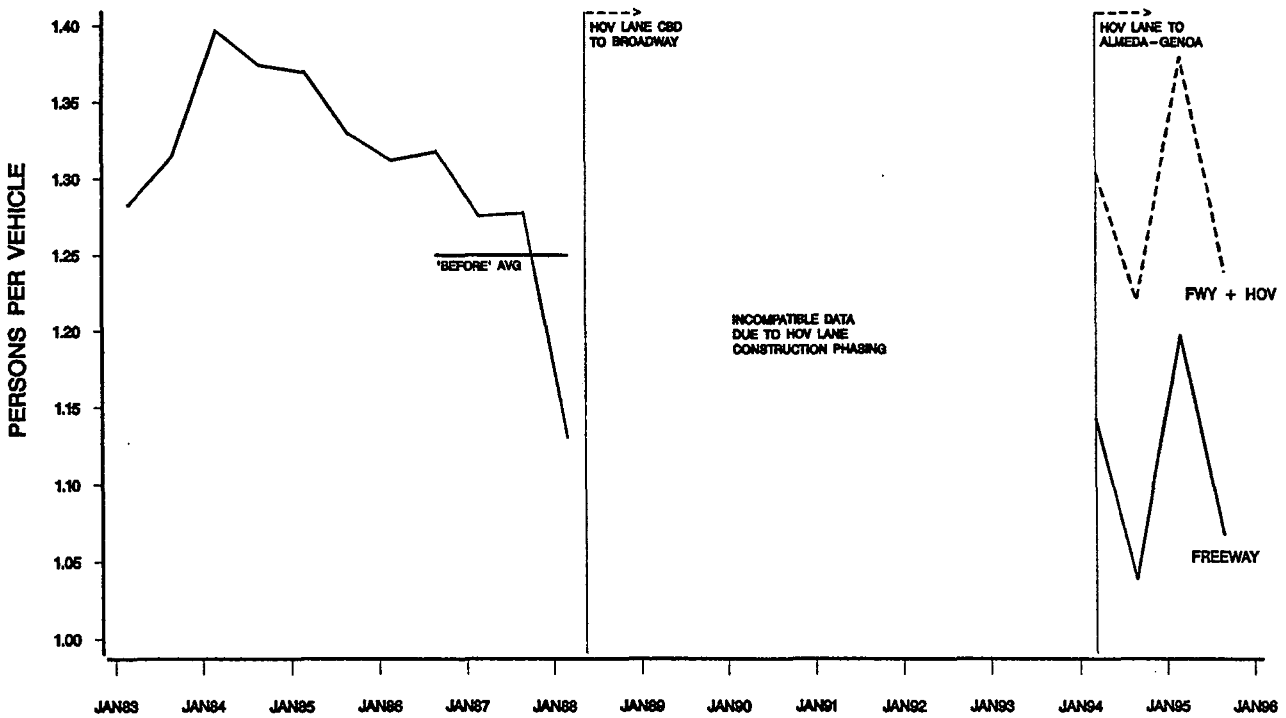


FIGURE C-12. GULF FREEWAY (IH 45S) MAINLANE AND HOV LANE
A.M. PEAK PERIOD AVERAGE OCCUPANCY

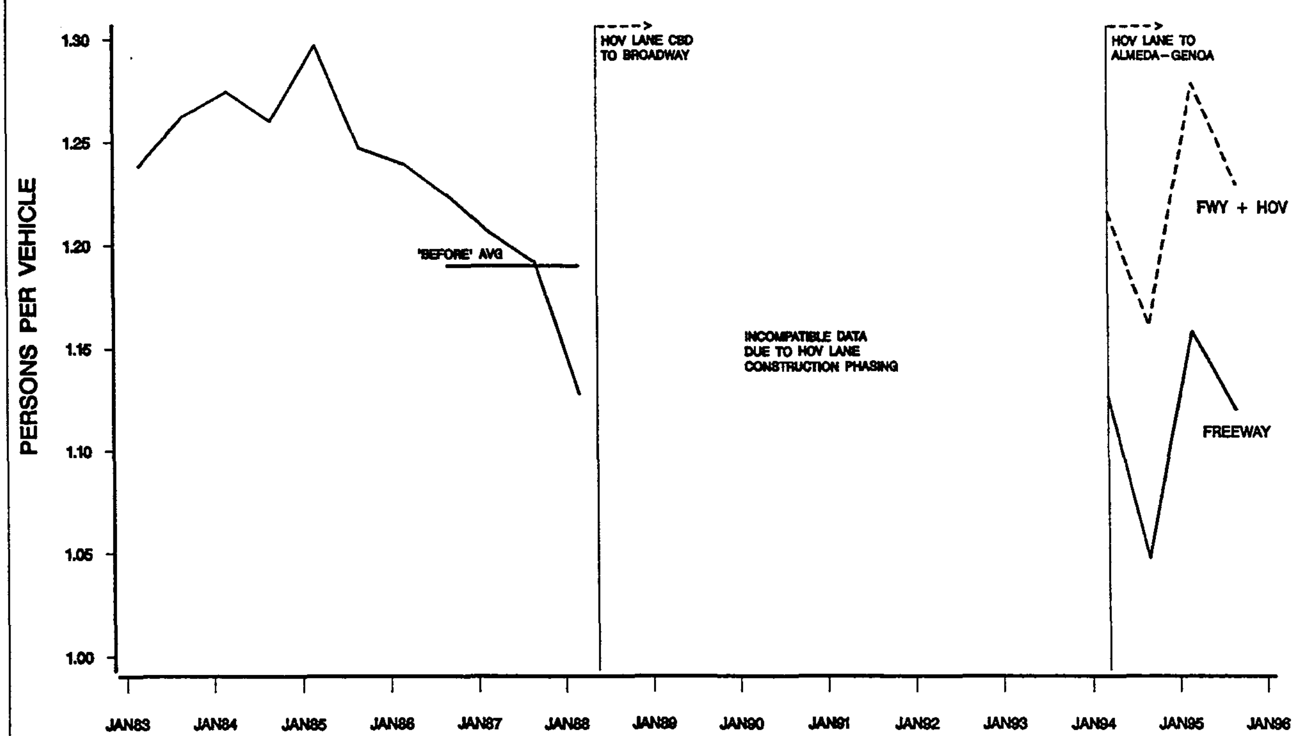


FIGURE C-13. A.M. PEAK HOUR AVERAGE OCCUPANCY
GULF FREEWAY AND FREEWAY WITHOUT HOV LANE

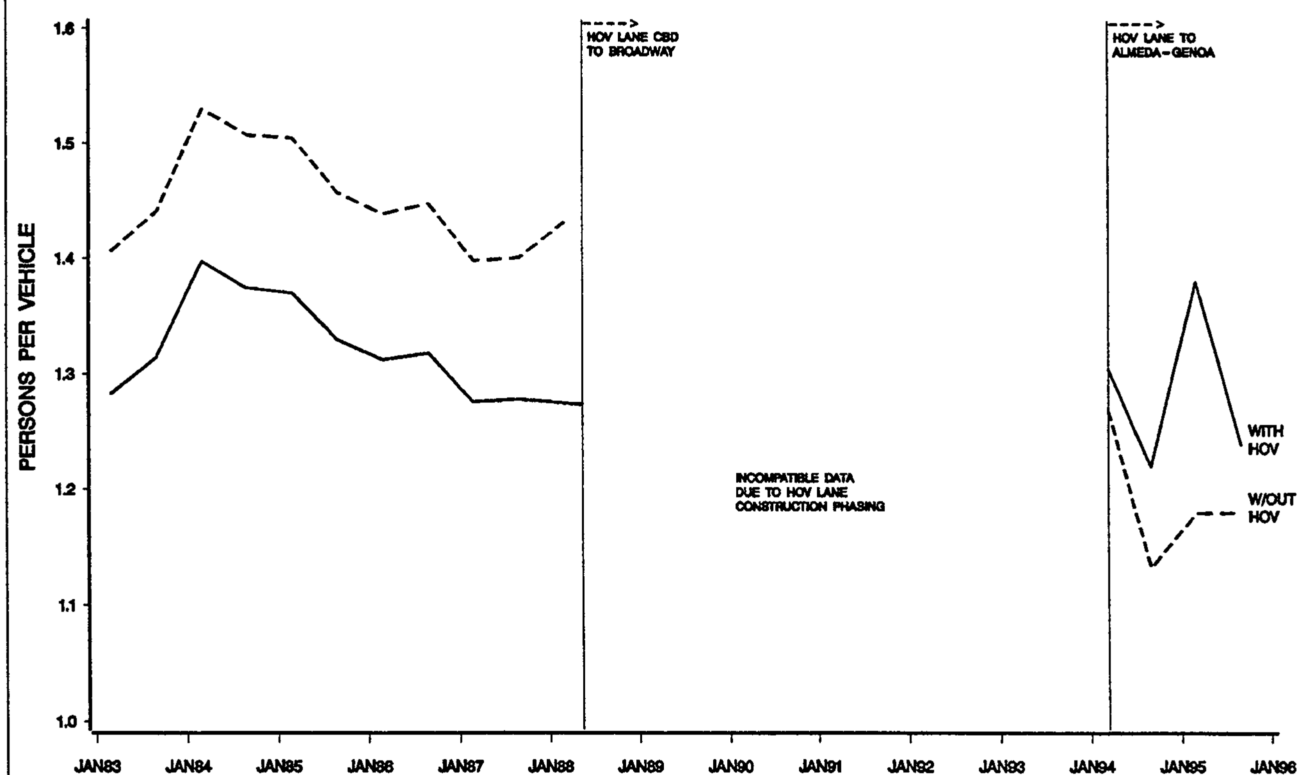


FIGURE C-14. GULF FREEWAY (IH 45S) MAINLANE AND HOV LANE
A.M. PEAK HOUR 2+ CARPOOL UTILIZATION

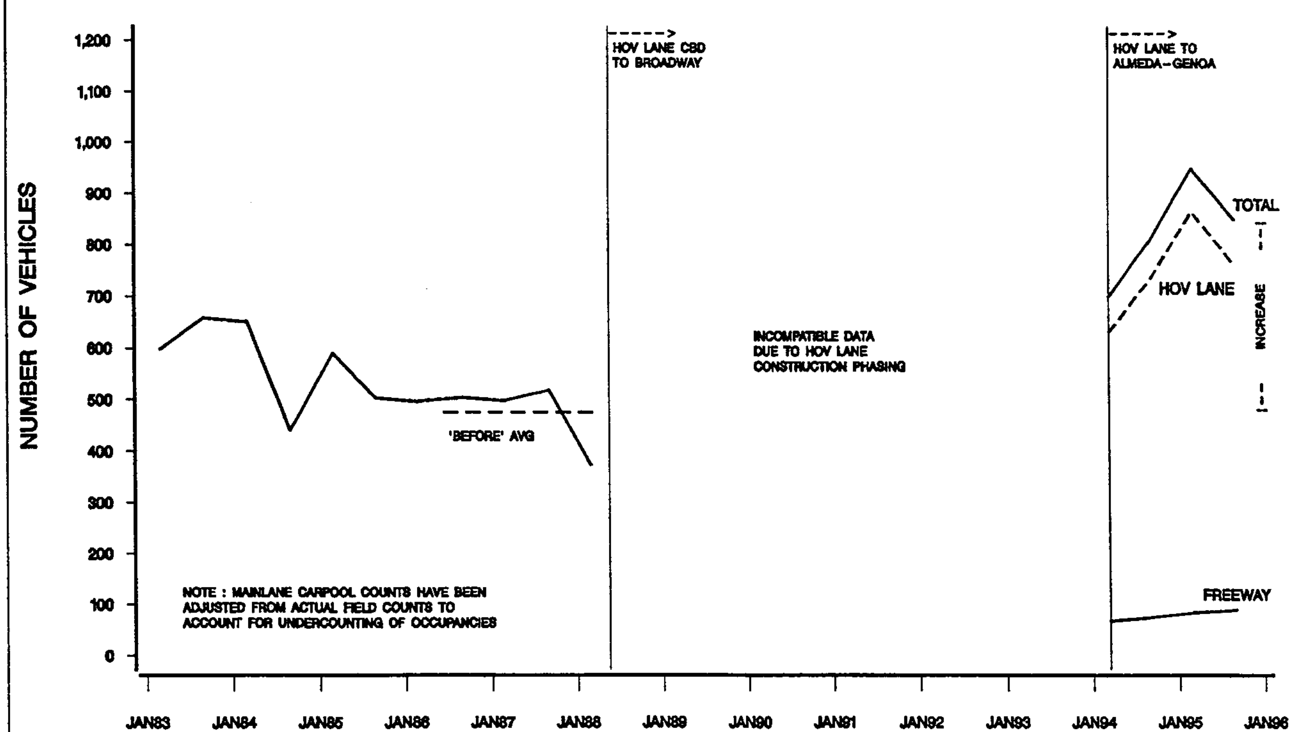


FIGURE C-15. A.M. PEAK HOUR FREEWAY PER LANE EFFICIENCY
GULF FREEWAY AND FREEWAY WITHOUT HOV LANE

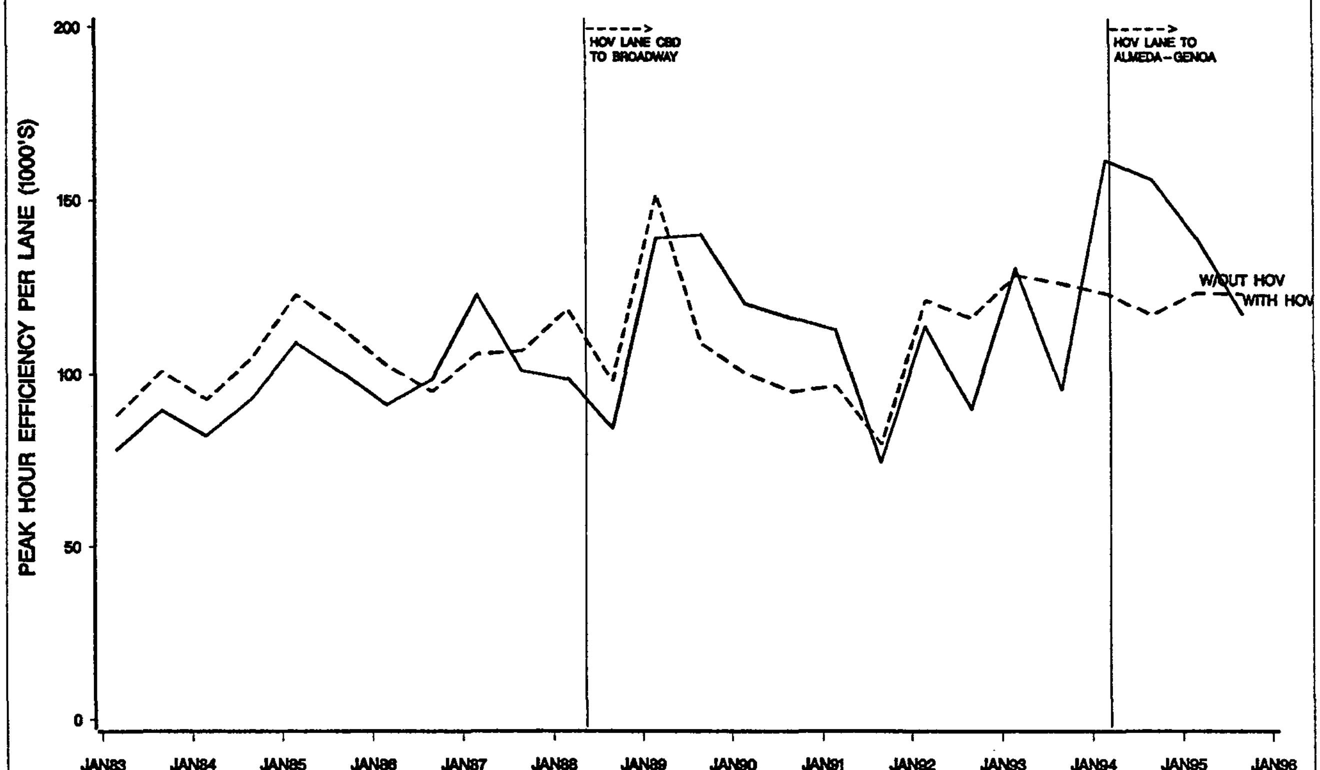


FIGURE C-16. GULF FREEWAY (IH 45S) MAINLANE AND HOV LANE
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS

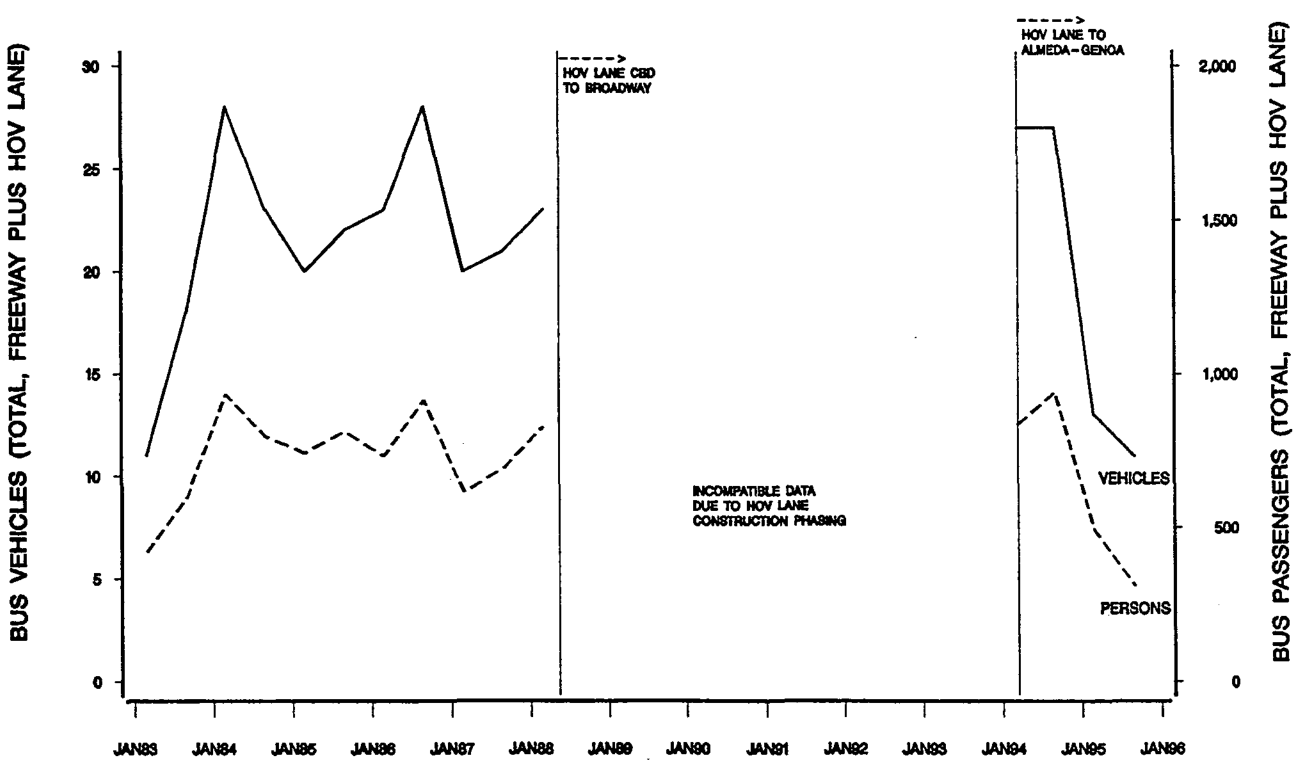


FIGURE C-17. GULF FREEWAY (IH 45S) MAINLANE AND HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS

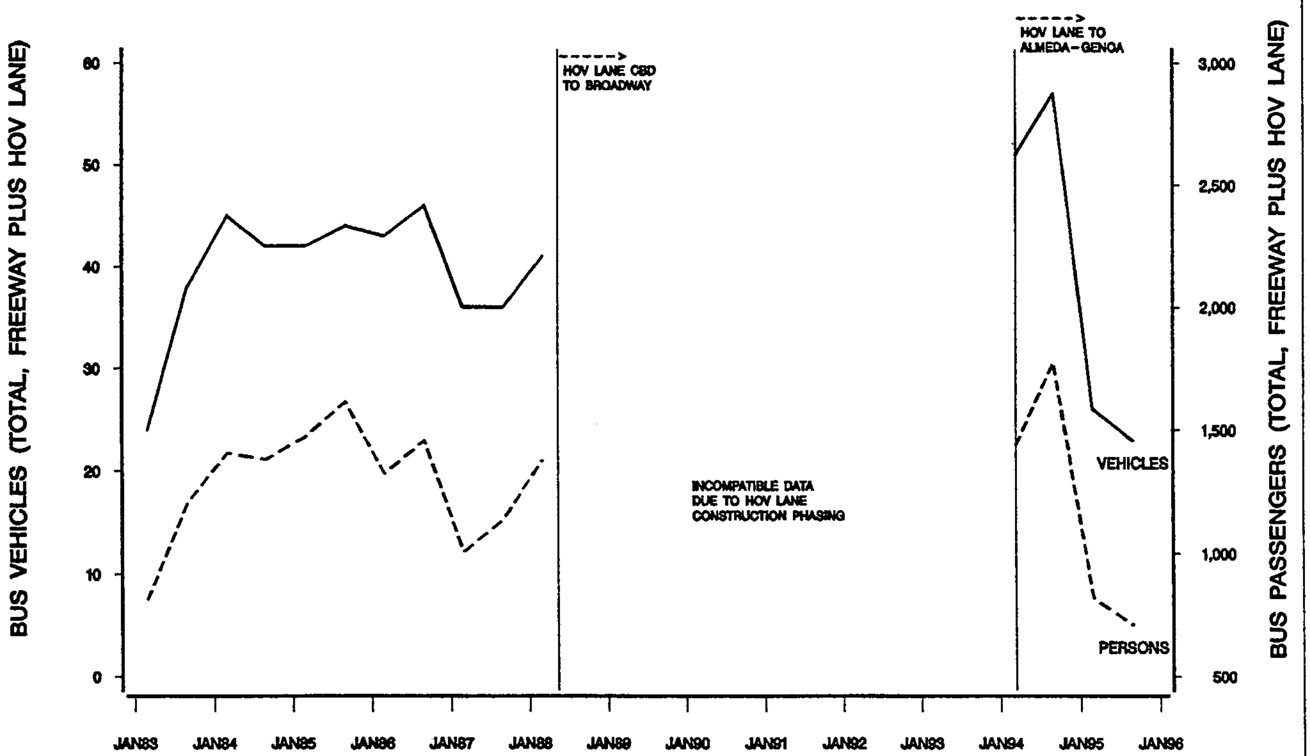


FIGURE C-18. A.M. PEAK PERIOD BUS PASSENGER TRIPS
TOTAL, FREEWAY PLUS HOV LANE VOLUMES
GULF FREEWAY AND FREEWAY WITHOUT HOV LANE

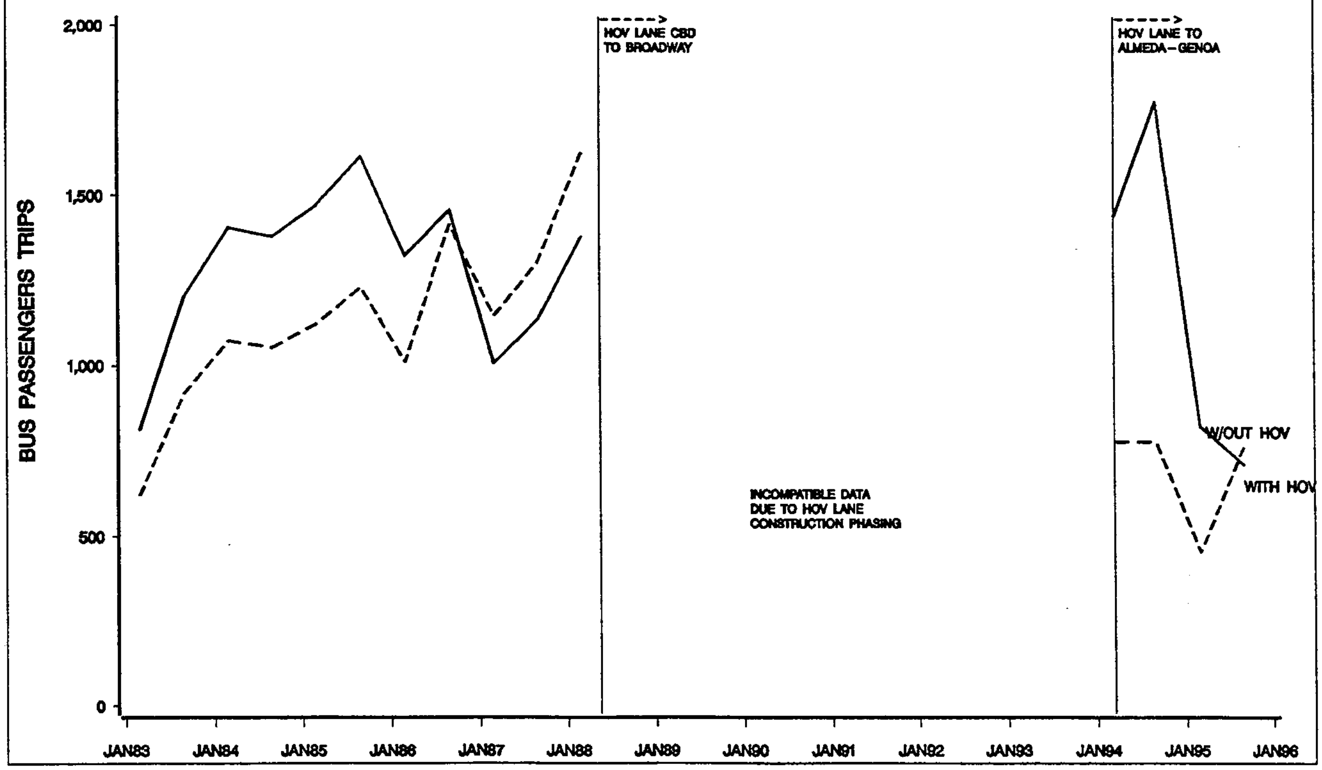


FIGURE C-19. GULF FREEWAY (IH 45S) CORRIDOR PARK-AND-RIDE DEMAND

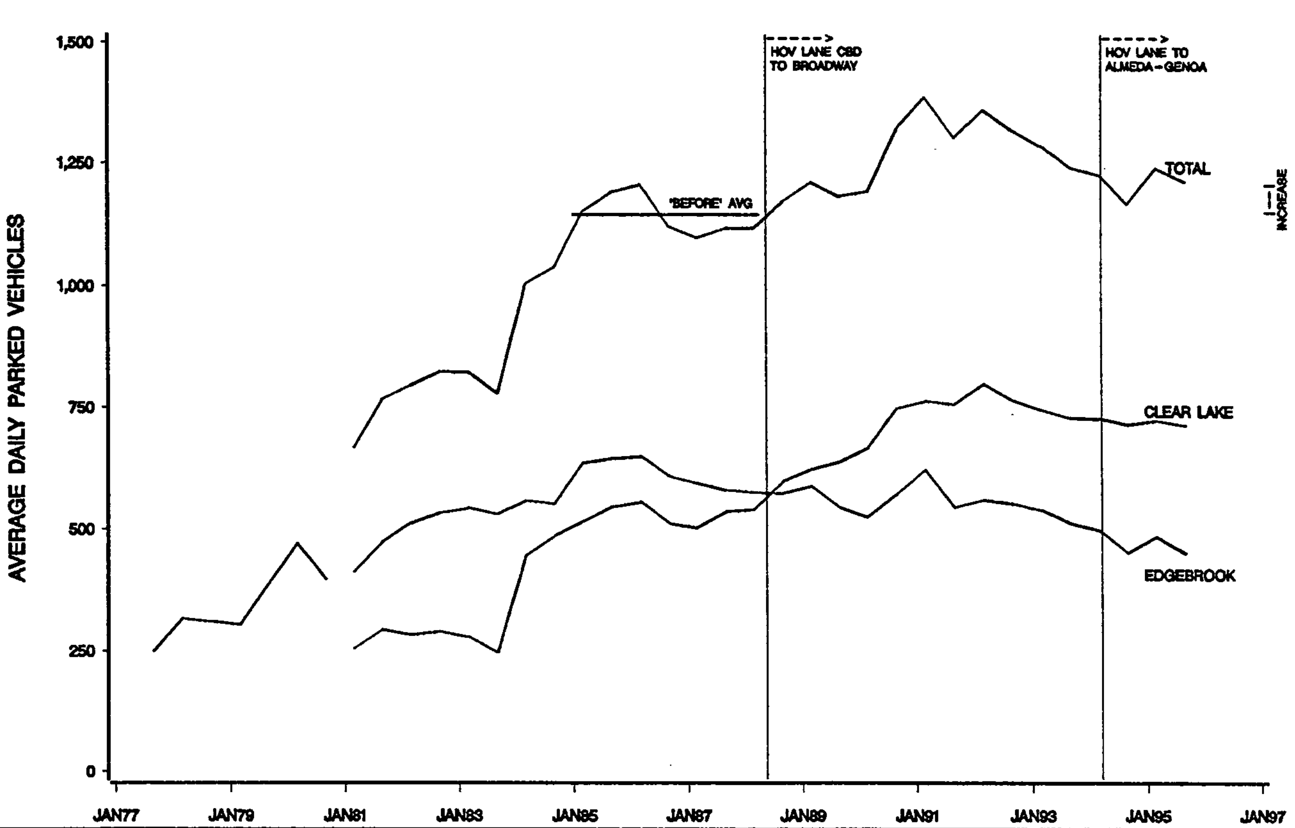
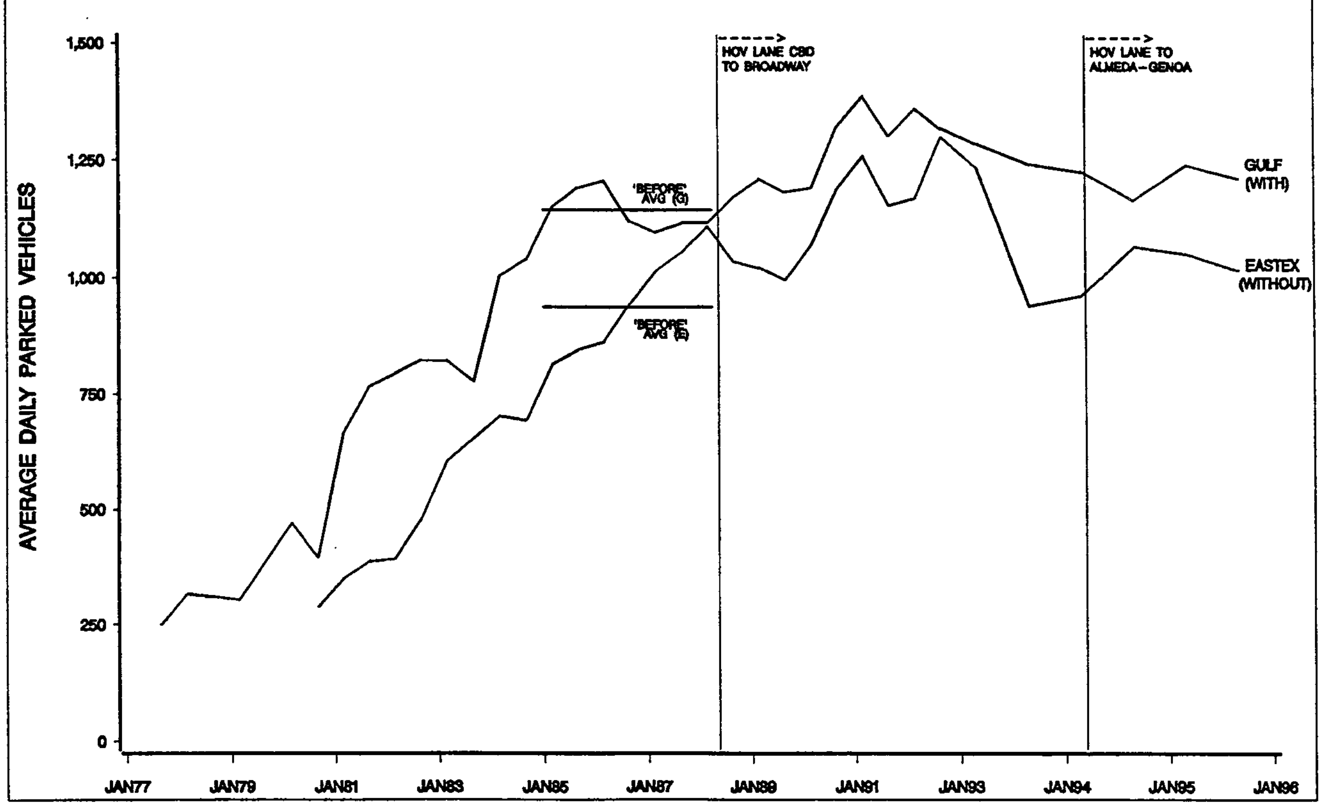


FIGURE C-20. AVERAGE DAILY VEHICLES PARKED AT PARK-AND-RIDE LOTS GULF FREEWAY AND FREEWAY WITHOUT HOV LANE



APPENDIX D

NORTHWEST FREEWAY AND HOV LANE DATA

NORTHWEST FREEWAY (US 290) AND HOV LANE, HOUSTON

Table D-1. Summary of A.M. Peak-Direction Northwest Freeway and HOV Lane Data, December 1995

Type of Data Phase 1 of HOV Lane Became Operational 8/29/88	"Representative" Pre-HOV Lane Value	"Representative" Current Value	Percent Change
HOV Lane Data			
HOV Lane Length (kilometers [miles])		21.7 (13.5)	
HOV Lane Cost (millions)		$99.4	
Person-Movement			
Peak Hour (7-8 a.m.)	---	3,920	---
Peak Period (6-9:30 a.m.)	---	7,446	---
Total Daily	---	13,946	---
Vehicle Volumes			
Peak Hour	---	1,434	---
Peak Period	---	2,729	---
Vehicle Occupancy, Peak Hour (persons/veh)	---	2.74	---
Accident Rate (i.e., Injury accidents/100 MVK [/MVM]), 11/84-12/93[1]	---	7.2 (11.3)	---
Vehicle Breakdowns (VKT/Breakdown [VMT/Breakdown]), 11/84-12/93	---	135,156 (83,948)	---
Violation Rate (6-9:30 a.m.)	---	7.4%	---
Peak Hour Lane Efficiency (1000's)[2]	---	322 (200)	---
Annual Value of User Time Saved (millions)[3]	---	$1.9 to $3.8	---
Freeway Mainlane Data (see note)			
Person Movement			
Peak Hour	6,140	5,622	-8%
Peak Period (6-9:30 a.m.)	17,450	17,536	0%
Vehicle Volume			
Peak Hour	5,370	5,147	-4%
Peak Period	15,295	16,068	+5%
Vehicle Occupancy, Peak Hour (persons/veh)	1.14	1.10	-4%
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM])[1]	7.3 (11.7)	6.8 (10.9)	-7%
Avg. Operating Speed[4] (kph [mph])			
Peak Hour	45 (28)	50 (31)	+11%
Peak Period	64 (40)	66 (41)	+3%
Peak Hour Lane Efficiency (1000's)[2]	100 (62)	93 (58)	-7%

Source: Texas Transportation Institute. The Texas A&M University System.

[1]Due to inconsistencies in reporting accidents in Harris County, this analysis includes only injury accidents. Accidents were analyzed between Little York and IH 610, a distance of approximately 12.4 kilometers (7.7 miles). This corresponds to Phase 1 of the HOV lane. "Before" data are for the period from 1/82 to 8/88. "Current" accident data are for the period 9/88 to 8/95. TTI estimated 1995 freeway volumes to compute rates.

[2]This represents the multiple of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.

[3]Based on time savings from HOV lane users in 1995, an annual estimate of travel time savings to HOV lane users is developed. A value of time of $11.37/hour is used based on the value applied in the Highway Economic Evaluation Model.

[4]The distance from Little York to IH 610 is 12.4 kilometers (7.7 miles). The remaining 2.9 kilometers (1.8 miles) of HOV lane is inside IH 610.

Table D-1. Summary of A.M. Peak-Direction Northwest Freeway and HOV Lane Data, December 1995 (Continued)

Type of Data	"Representative" Pre-HOV Lane Value	"Representative" Current Value	Percent Change
Combined Freeway Mainlane and HOV Lane Data			
Total Person Movement			
Peak Hour	6,140	9,542	+55%
Peak Period	17,450	24,982	+43%
Vehicle Volume			
Peak Hour	5,370	6,578	+22%
Peak Period	15,295	18,797	+23%
Vehicle Occupancy			
Peak Hour	1.14	1.45	+27%
Peak Period	1.14	1.33	+17%
2+ Carpool Volumes			
Peak Hour	490	1,800	+267%
Peak Period	1,365	3,456	+153%
Travel Time (minutes)[1]			
Peak Hour	16.2[2]	16.0[3]	-1%
Peak Period	11.4[2]	8.6[3]	-25%
Peak Hour Lane Efficiency (1000's)[4]	100 (62)	151 (94)	+51%
Transit Data			
Bus Vehicle Trips			
Peak Hour	7	19	+171%
Peak-Period	17	39	+129%
Bus Passenger Trips			
Peak Hour	270	1,013	+275%
Peak Period	605	1,930	+219%
Bus Occupancy (persons/bus)			
Peak Hour	39	53.3	+37%
Peak Period	36	49.5	+38%
Vehicles Parked in Corridor Park & Ride Lots	430	1,591	+270%
Bus Operating Speed (kph [mph])			
Peak Hour	47 (29)[2]	82 (51)	+74%
Peak Period	79 (49)[2]	87 (54)[1]	+10%

Note: Site-specific data collected at Pinemont. For purposes of visibility and safety, the freeway volumes are counted between an exit and an entrance ramp. Thus, the mainlane volumes may be low.

[1]From Little York to IH 610, the distance is 12.4 kilometers (7.7 miles). The remaining 2.9 kilometers (1.8 miles) of HOV lane is inside IH 610.
[2]Data pertain to operation in the freeway mainlanes.
[3]Data pertain to operation in the HOV lane.
[4]This represents the multiple of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.

Table D-2. Comparison of Measures of Effectiveness, Freeway With (Northwest U.S. 290) and Freeway Without (Eastex U.S. 59) HOV Lane, Houston[1]

Measure of Effectiveness	"Representative" Pre-HOV Lane Value	"Representative" Current Value	Percent Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/HOV lane	1.14	1.45	+27%
Freeway w/o HOV lane	1.23	1.18	-4%
A.M. Peak Hour, 2+ Carpool Volume Change			
Freeway w/HOV lane	490	1,800	+267%
Freeway w/o HOV lane	600	571	-5%
Bus Passengers, Peak Period			
Freeway w/HOV lane	605	1,930	+219%
Freeway w/o HOV lane	1,188	762	-36%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	430	1,591	+270%
Freeway w/o HOV lane	1,236	1,035	-16%
Facility Per Lane Efficiency[2]			
Freeway w/HOV lane	100 (62)	151 (94)	+51%
Freeway w/o HOV lane	138 (86)	123 (77)	-11%

[1]Data for freeways without HOV lanes are a composite of data collected on the Gulf Freeway during the time in which no HOV lane existed on that facility (6/83 - 4/88), the Southwest Freeway (9/86 to 12/92) and the Eastex Freeway (1/93 to present).

[2]This represents the product of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.

HOV LANE DATA

DESCRIPTION

- Phase 1 (15.3 kilometers [9.5 miles]) of the HOV lane opened August 29, 1988.

- The HOV lane is now complete with 21.7 kilometers (13.5 miles) in operation.

- The capital cost (including all support facilities) for the completed facility in 1990 dollars was $98.1 million. The following page provides a more detailed cost breakdown including dates.

- Selected milestone dates are listed below. The capital cost table shows other dates.

  - 8/29/88 Northwest Transit Center to Little York opens (15.3 kilometers [9.5 miles]).
  - 2/6/90 HOV extended to FM 1960 (21.7 kilometers [13.5 miles]).
  - 4/1/90 Northwest Transit Center opens.
  - 10/6/90 Weekend HOV operation begins.
  - 10/5/91 Weekend HOV operation ends.
  - 9/8/92 Motorcycles allowed on HOV facility (no occupancy restrictions).

PERSON MOVEMENT

- In September 1995, 13,946 person trips per day were served on the HOV lane.

- A.M. peak hour, 3,920 persons/hour.
  - 1,013 (26%) by bus, 76 (2%) by vanpool, 2,826 (72%) by carpool, and 6 by motorcycle (Figure D-1).
  - Average HOV lane vehicle occupancy = 2.74 persons/vehicle.

- A.M. peak period, 7,446 persons.

  - 1,930 (26%) by bus, 137 (2%) by vanpool, 5,327 (72%) by carpool, and 22 by motorcycle (Figure D-2).

Table D-3. Estimated Capital Cost (millions), Northwest HOV Lane

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1995 Dollars
HOV Lane and Ramps			
Phase I	$54.7	1.21	$66.2
FM 1960 to FM 529 (1990)	3.2	1.21	3.9
FM 529 to Little York (1990)	2.4	1.21	2.9
Phase 2A, N.W. Station Ramp (1990)	3.4	1.21	4.1
Phase 2B, W. Little York Ramp (1988)	1.2	1.18	1.4
Miscellaneous	0.4	1.21	0.5
SUB-TOTAL	$65.3		$79.0
Per Kilometer (Mile)	$3.0 ($4.8)	1.21	$3.6 ($5.8)
Surveillance, Communication & Control (1990)	$2.9		$3.5
SUB-TOTAL	$2.9	1.21	$3.5
Per Kilometer (Mile)	$0.1 ($0.2)		$0.2 ($0.3)
Support Facilities			
W. Little York P/R (1988)	$6.9	1.18	$8.1
Pinemont P/R (1989)	9.4	1.18	11.1
Northwest Transit Center (1990)	21.3	1.21	25.8
N.W. Station P/R (1984)	4.0	1.13	4.5
N.W. Station P/R Modification (1990)	1.5	1.21	1.8
N.W. Station P/R 2nd Expansion (1993)	5.9	1.12	6.6
SUB-TOTAL	$49.0		$57.9
Per Kilometer (Mile)	$2.3 ($3.6)		$2.7 ($4.3)
TOTAL COST	$117.2		$140.4
COST PER KILOMETER (21.7 kilometers [13.5 miles])	$5.4 ($8.7)		$6.5 ($10.4)

Source: Compiled by TTI from data provided by Metro and TxDOT.

VEHICLE MOVEMENT

- A.M. peak hour, 1,434 vph
  - 19 (1%) buses, 12 (1%) vans, 1,395 (97%) carpools, and 6 by motorcycle (Figure D-3).

- A.M. peak period, 2,729 vehicles.
  - 39 (1%) buses, 22 (1%) vans, 2,647 (97%) carpools, and 22 (1%) by motorcycle (Figure D-4).

ACCIDENT RATE

- For the period 8/88 through 8/95, the HOV lane accident rate was 7.2 accidents per 100 million vehicle kilometers (11.3 accidents per 100 million vehicle miles).

VEHICLE BREAKDOWN RATES

- As measured from September 1, 1988 through December 1995, the following rate has been observed:
  - The weighted average for all vehicle types is 1 breakdown per 135,156 VKT (83,948 VMT).

VIOLATION RATE

- The observed violation rate (vehicles on the HOV lane not eligible to use the HOV lane) is approximately 7.4%.

PEAK HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. For the HOV lane, this value (expressed in 1000's) is approximately 322 (3,920 passengers x 82 kph) or 200 (3,920 passengers x 51 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane experience an average travel time savings of 7 minutes in the a.m. peak hour (Figure D-5).
- The table on the following page indicates that, on a typical non-incident day, travel time savings of approximately 40,370 minutes, or 673 hours, are realized. Assuming 250 days of operation and a value of time of $11.37/hour, this equates to $1.91 million per year. This is extremely conservative since it does not consider travel time savings due to incidents on the freeway. Data from Houston suggest that increasing this value by 100% to account for incidents would be reasonable. Thus, estimates of travel time savings to HOV lane users are in the range of $1.9 million to $3.8 million per year.

Table D-4. Travel Time Savings for Northwest HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1995)

Southbound A.M. Travel Time Savings for Northwest HOV Lane								
Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section from Eldridge to Senate								
6:00	2.95	3.02	-0.07	329	10	120	459	-31
6:30	2.97	3.03	-0.06	967	45	270	1,282	-75
7:00	2.94	3.22	-0.27	1,371	9	413	1,793	-493
7:30	2.86	3.11	-0.24	1,227	0	285	1,512	-368
8:00	2.86	3.01	-0.15	547	0	155	702	-105
8:30	3.03	2.97	-0.07	318	0	30	348	23
9:00	2.85	2.95	-0.10	53	0	0	53	-5
Peak Period Total				4.812	64	1,273	6,148	-1,054
Section From Senate to S.P. Railroad								
6:00	12.49	14.58	-2.08	175	12	165	352	-732
6:30	18.35	14.28	4.07	771	80	360	1,211	4,925
7:00	20.88	15.15	5.73	1,539	56	523	2,118	12,140
7:30	23.53	17.12	6.42	1,562	13	460	2,035	13,053
8:00	16.05	14.48	1.57	859	0	361	1,219	1,910
8:30	12.67	13.94	-1.28	370	0	100	470	-599
9:00	12.72	14.90	-2.18	76	0	10	86	-188
Peak Period Total				5,351	161	1,978	7,490	30,508
Northbound P.M. Travel Time Savings for Northwest HOV Lane								
Section from Senate to Eldridge								
3:30	2.98	3.25	-0.27	63	5	53	121	-32
4:00	2.97	3.22	-0.24	177	12	83	272	-66
4:30	3.06	3.02	0.04	475	8	185	668	28
5:00	3.03	3.20	-0.17	753	36	340	1,129	-198
5:30	2.95	3.01	-0.06	940	11	443	1,393	-81
6:00	3.12	3.13	-0.02	569	4	240	813	-14
6:30	2.89	3.02	-0.13	266	3	98	366	-46
Peak Period Total				3,243	78	1,440	4,761	-408

Table D-4. Travel Time Savings for Northwest HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1995) (Continued)

Southbound A.M. Travel Time Savings for Northwest HOV Lane								
Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section from the S.P. Railroad to Senate								
3:30	12.15	14.48	-2.33	88	0	95	183	-427
4:00	13.06	14.71	-1.65	169	6	75	250	-413
4:30	14.19	15.23	-1.03	309	23	93	424	-438
5:00	20.59	14.87	5.72	468	36	303	807	4,617
5:30	23.13	15.18	7.95	597	9	208	814	6,467
6:00	17.01	13.93	3.08	426	4	98	528	1,622
6:30	13.38	13.88	-0.50	144	0	65	209	-104
Peak Period Total				2,200	78	936	3,213	11,324

FREEWAY DATA

NOTE

- For purposes of safety and visibility, freeway volumes are counted at the Pinemont overpass between an exit ramp and an entrance ramp. Thus, freeway volumes may be low in comparison to actual freeway operations. Data are collected in a section with 3 lanes in each direction.

PERSON MOVEMENT

- In the a.m. peak hour, compared to pre-HOV conditions, person movement has decreased by 8% (Figure D-6).

- In the a.m. peak period, compared to pre-HOV conditions, person movement has not changed (Figure D-7).

VEHICLE VOLUME

- In the a.m. peak hour, vehicle volume has decreased by 4% (Figure D-6).

- In the a.m. peak period, vehicle volume has increased by 5% (Figure D-7).

VEHICLE OCCUPANCY

- In the a.m. peak hour, compared to pre-HOV conditions, mainlane occupancy has declined by 4% (Figure D-11).

- In the a.m. peak period, compared to pre-HOV conditions, mainlane occupancy has declined by 4% (Figure D-12).

ACCIDENT RATE

- Implementation of the HOV lane resulted in narrower freeway lanes and inside emergency shoulder.

- For the section between Little York and I-610, the accident rate for the period (1/82- 8/88) preceding the opening of the HOV lane was 7.3 accidents per 100 million vehicle kilometers (100 MVK) (11.7 accidents per 100 million vehicle miles [100 MVM]). The accident data available for the period (9/88-8/95) after the HOV lane opened indicate an accident rate of 6.8 accidents/100 MVK (10.9 accidents/100 MVM).

AVERAGE OPERATING SPEED

- In comparison to pre-HOV lane conditions, mainlane operating speeds have increased in the peak hour and the peak period. The data in Figure D-8 show the average of all travel time runs made both before and after the HOV lane opened for the a.m. peak period.

PEAK HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of per lane efficiency.

- For the freeway mainlanes, decreased travel speeds have resulted in a decrease in per lane efficiency of 7%.

COMBINED FREEWAY AND HOV LANE DATA

TOTAL PERSON MOVEMENT

- Percent by HOV lane, a.m. peak.

  - At Pinemont, the HOV lane is responsible for 41% of peak-hour person movement (HOV lane = 3,920; freeway = 5,622) and 30% of peak-period (HOV lane = 7,446; freeway = 17,536) person movement (Figure D-10).

- Increase in a.m. person movement at Pinemont

  - Provision of the HOV lane increased total directional lanes by 33%.

  - Total peak-hour person movement has increased by 55%, from 6,140 to 9,542 (Figure D-9). Peak-period person movement has increased by 43%, from 17,450 to 24,982 (Figure D-10).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.45, a 27% increase over the pre-HOV lane occupancy (Figure D-11). Occupancy in the peak period is 17% greater than pre-HOV lane levels (Figure D-12).

- While the occupancy on the Northwest Freeway has increased, on freeways which do not have HOV lanes, occupancy has decreased (Figure D-13).

CARPOOL VOLUMES

- In the a.m. peak hour, the total number of 2+ carpools (freeway plus HOV lane) has increased by 267% compared to pre-HOV lane levels (Figure D-14). In the a.m. peak period, the increase has been 153%. These increases have not been experienced on freeways not having HOV lanes.

PEAK HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. The average efficiency of a lane on the freeway (3 freeway lanes plus 1 HOV lane) has increased by 51% since the implementation of the HOV lane (Figure D-15). Per-lane efficiency has at the same time, decreased by 11% on freeways without HOV lanes.

BUS TRANSIT DATA

BUS VEHICLE AND PASSENGERS TRIPS

- In the a.m. peak hour, bus vehicle trips have been increased by 171% since the HOV lane opened, and a 275% increase in bus ridership has resulted (Figure D-16). In the peak period, a 129% increase has occurred in bus vehicle trips, and a 219% increase in bus ridership has resulted (Figure D-17).

- While bus passenger trips have increased in the Northwest Freeway corridor, in the corridors which do not have HOV lanes, bus passenger trips have decreased significantly (Figure D-18).

PARK-AND-RIDE

- Prior to opening the HOV lane, approximately 430 vehicles were parked in corridor park-and-ride lots. This has increased 270% to a current level of 1,591 (Figure D-19).
- The increase in cars parked in the Northwest corridor has not occurred in the freeway corridor that does not have an HOV lane (Figure D-20).

FIGURE D-1. NORTHWEST FREEWAY (US 290) HOV LANE
A.M. PEAK HOUR HOV LANE PERSON MOVEMENT

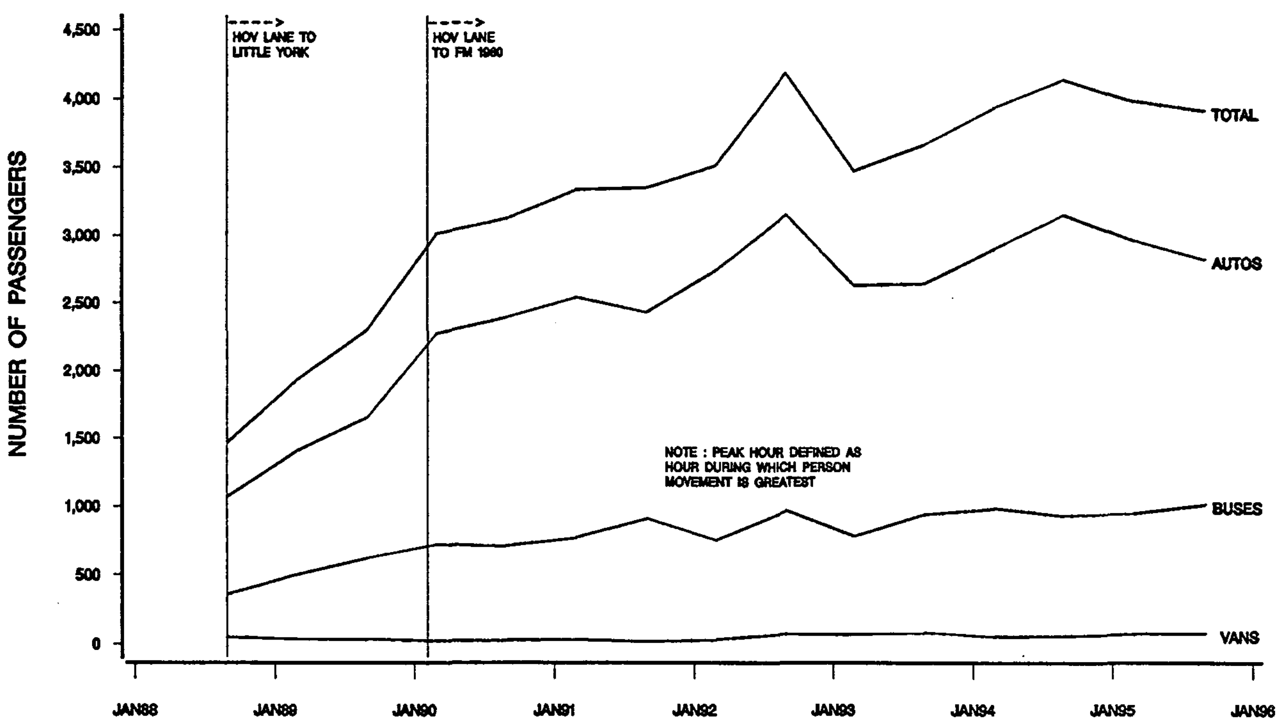


FIGURE D-2. NORTHWEST FREEWAY (US 290) HOV LANE
A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT

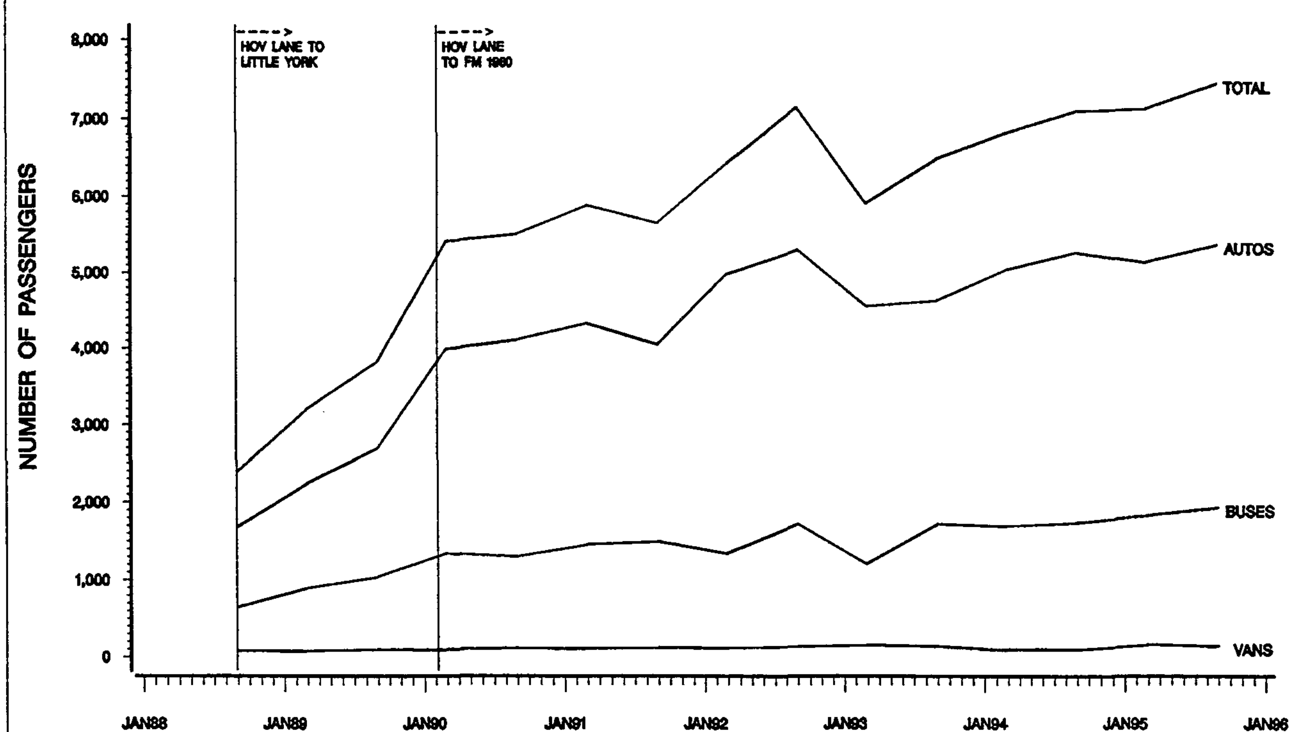


FIGURE D-3. NORTHWEST FREEWAY (US 290) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION

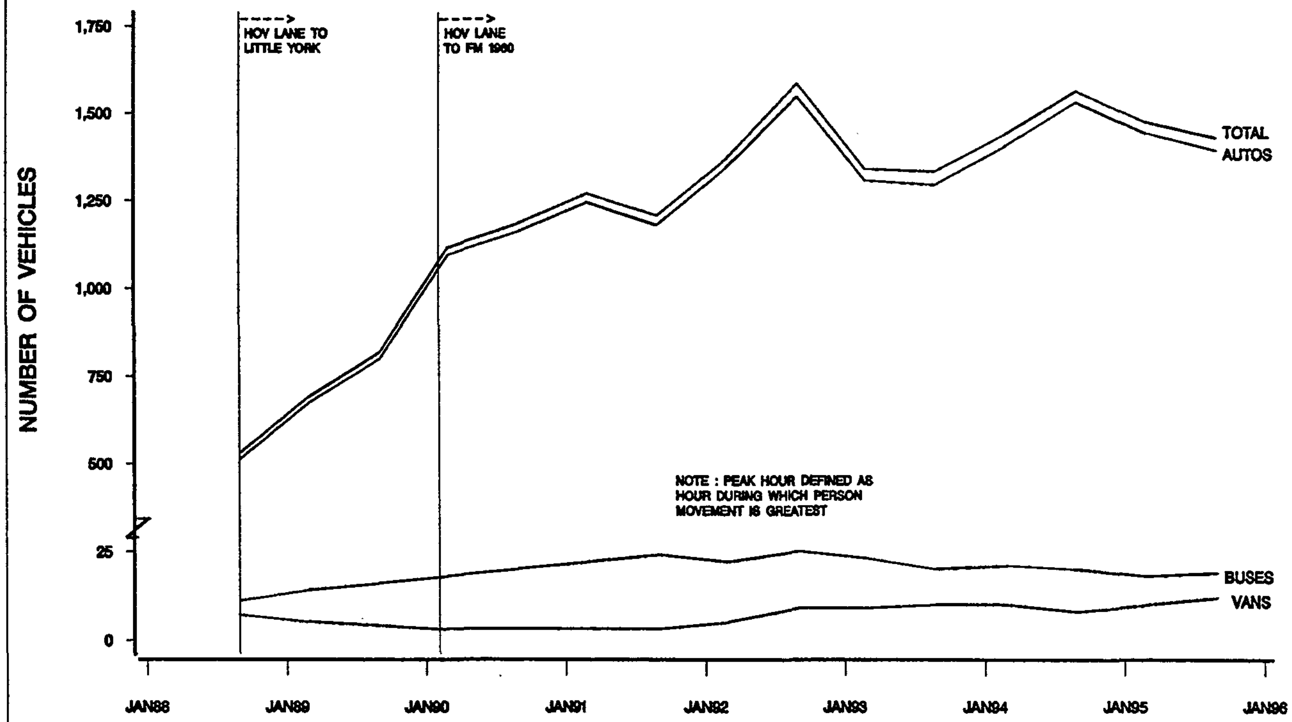


FIGURE D-4. NORTHWEST FREEWAY (US 290) HOV LANE
A.M. PEAK PERIOD HOV LANE VEHICLE UTILIZATION

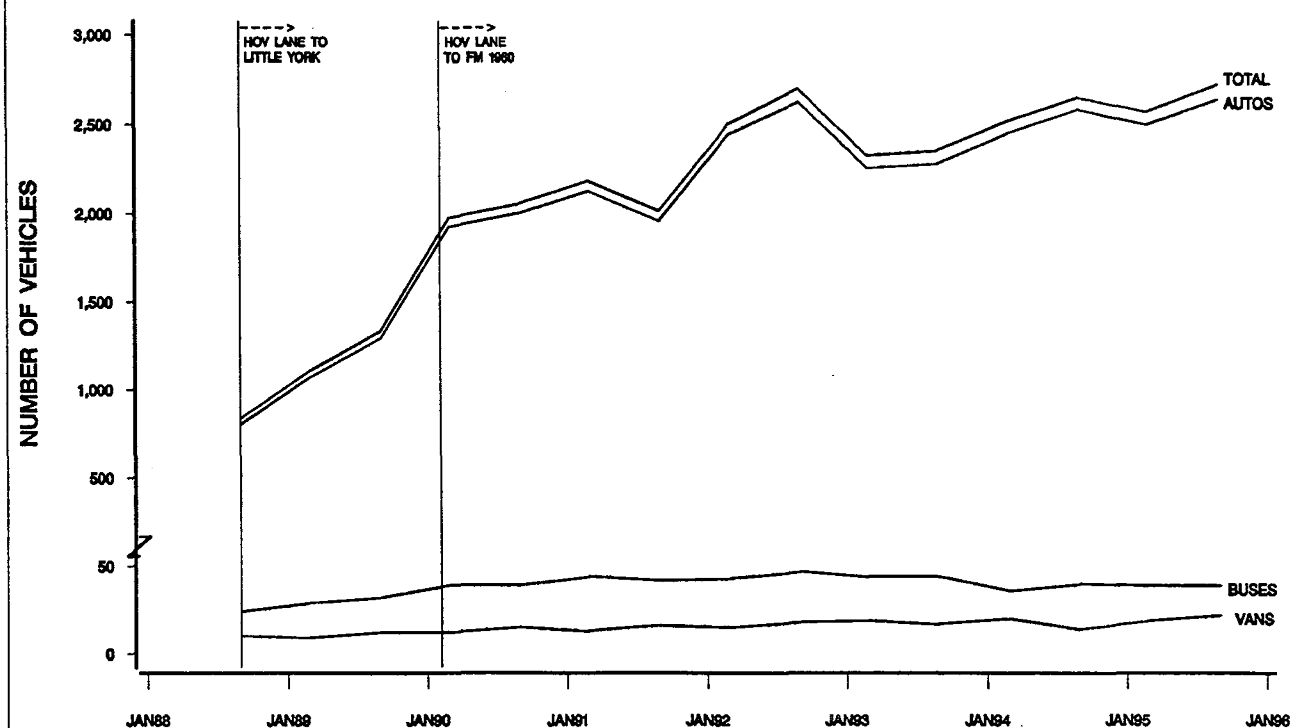


FIGURE D-5. NORTHWEST FREEWAY (US 290) MAINLANES AND HOV LANE A.M. TRAVEL TIME

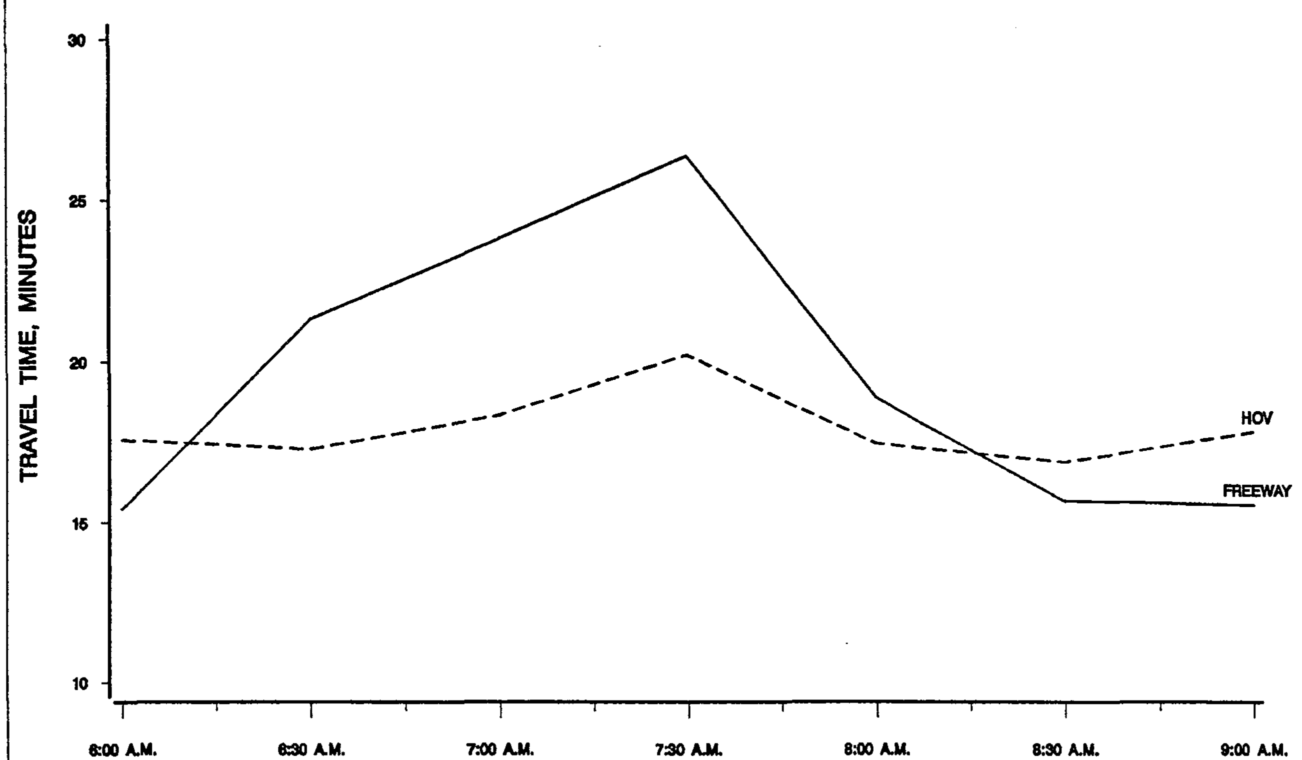


FIGURE D-6. NORTHWEST FREEWAY (U.S. 290)
A.M. PEAK HOUR MAINLANE TRIPS

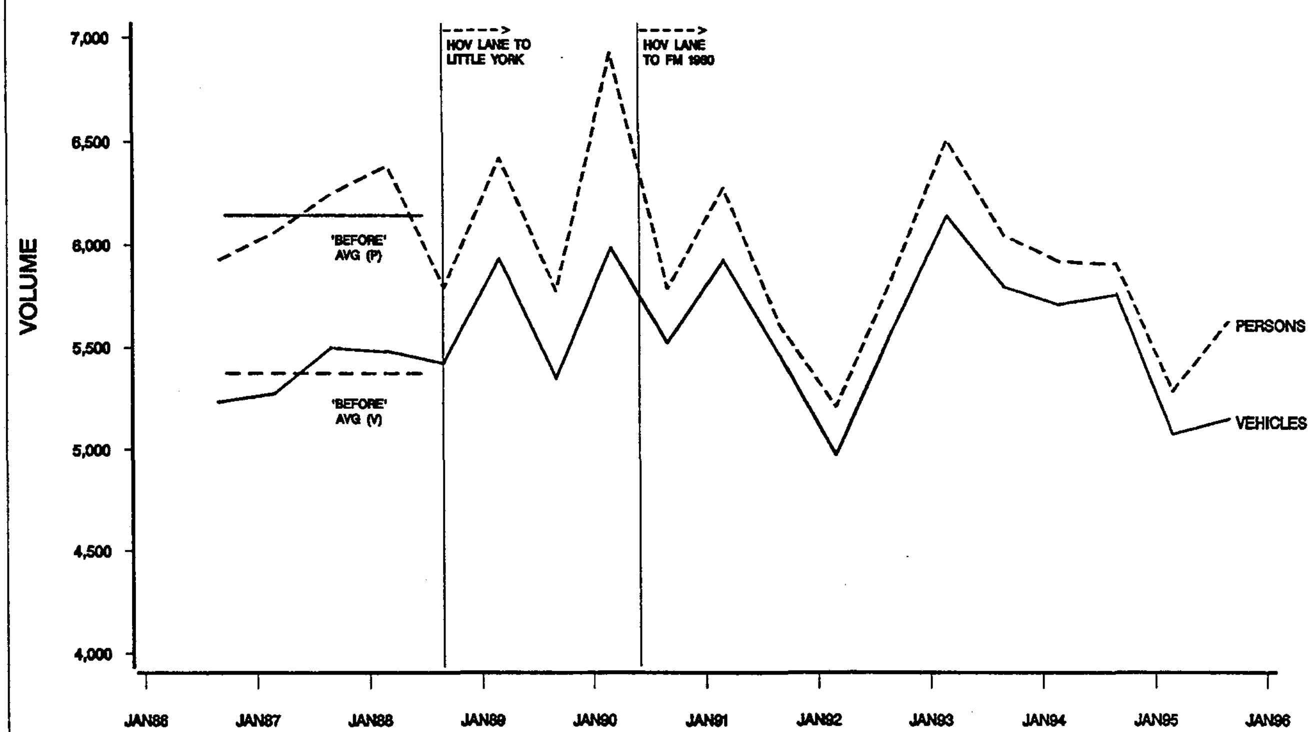


FIGURE D-7. NORTHWEST FREEWAY (U.S. 290)
A.M. PEAK PERIOD MAINLANE TRIPS

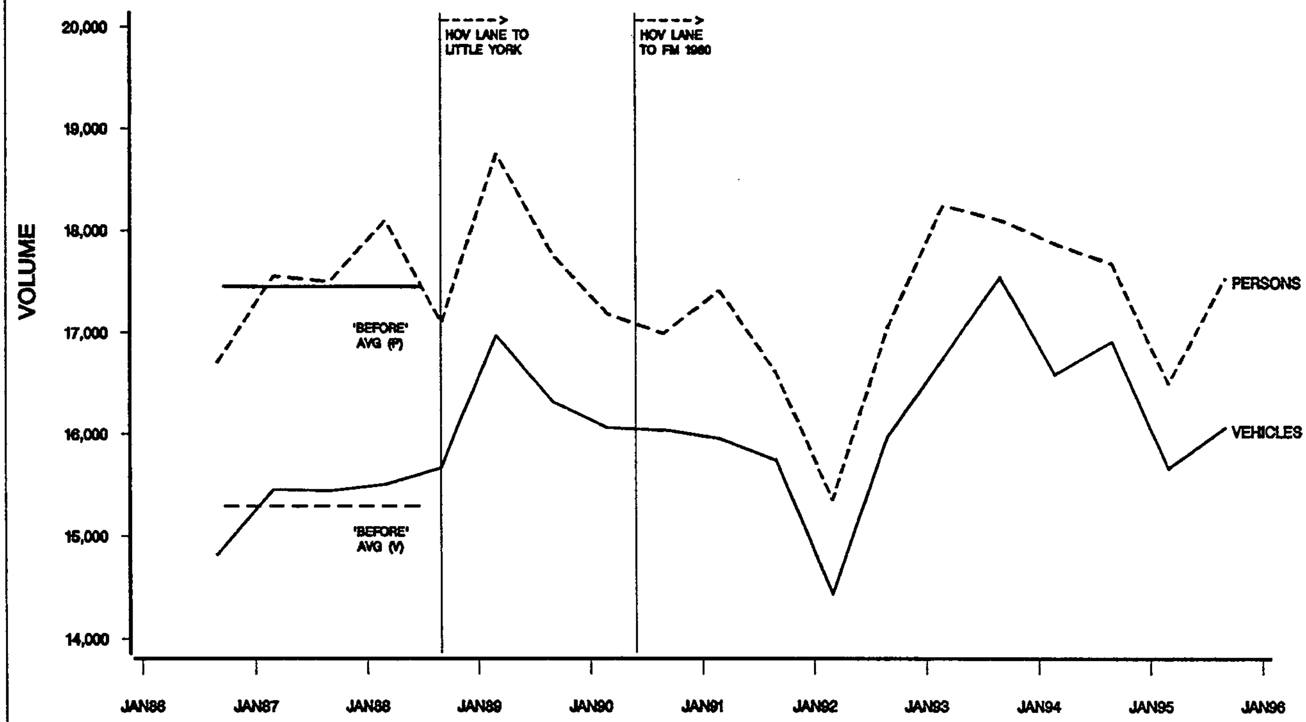


FIGURE D-8. NORTHWEST FREEWAY (U.S. 290) MAINLANE TRAVEL TIME AND SPEED SURVEY
SOUTHBOUND, TELGE TO IH 610
A.M. PEAK PERIOD

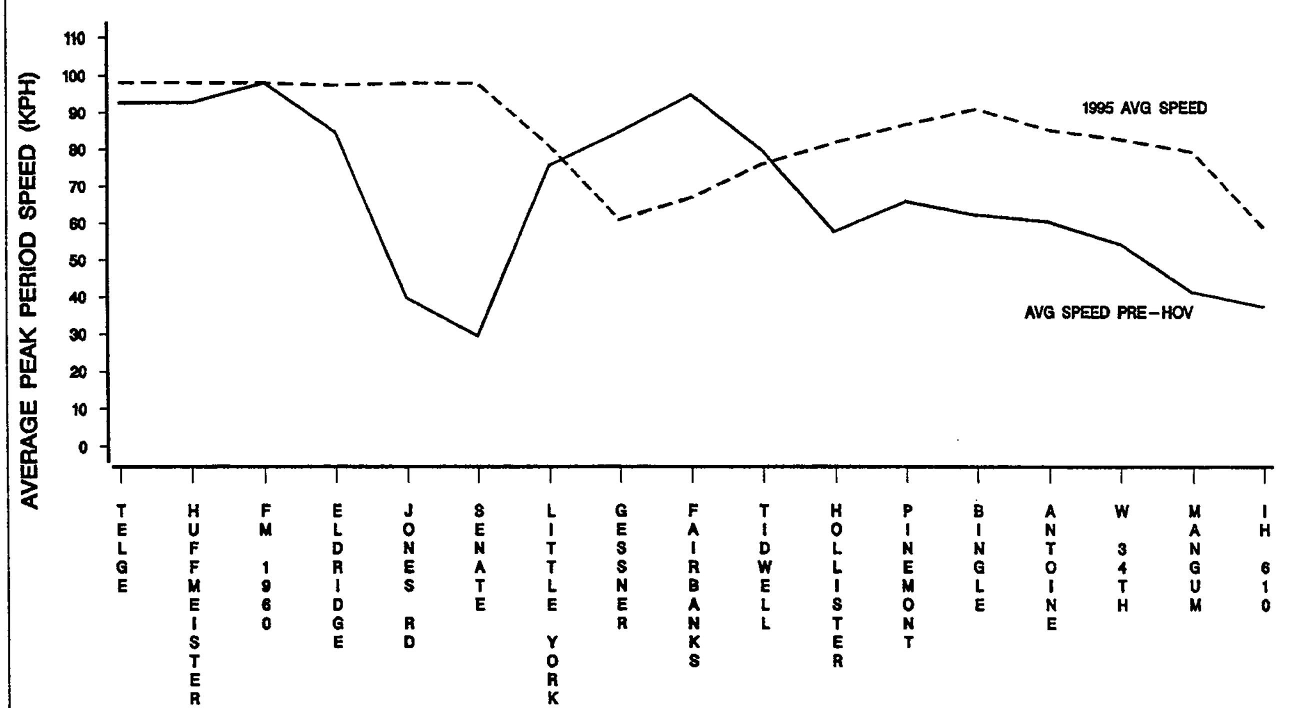


FIGURE D-9. NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE
A.M. PEAK HOUR PERSON TRIPS

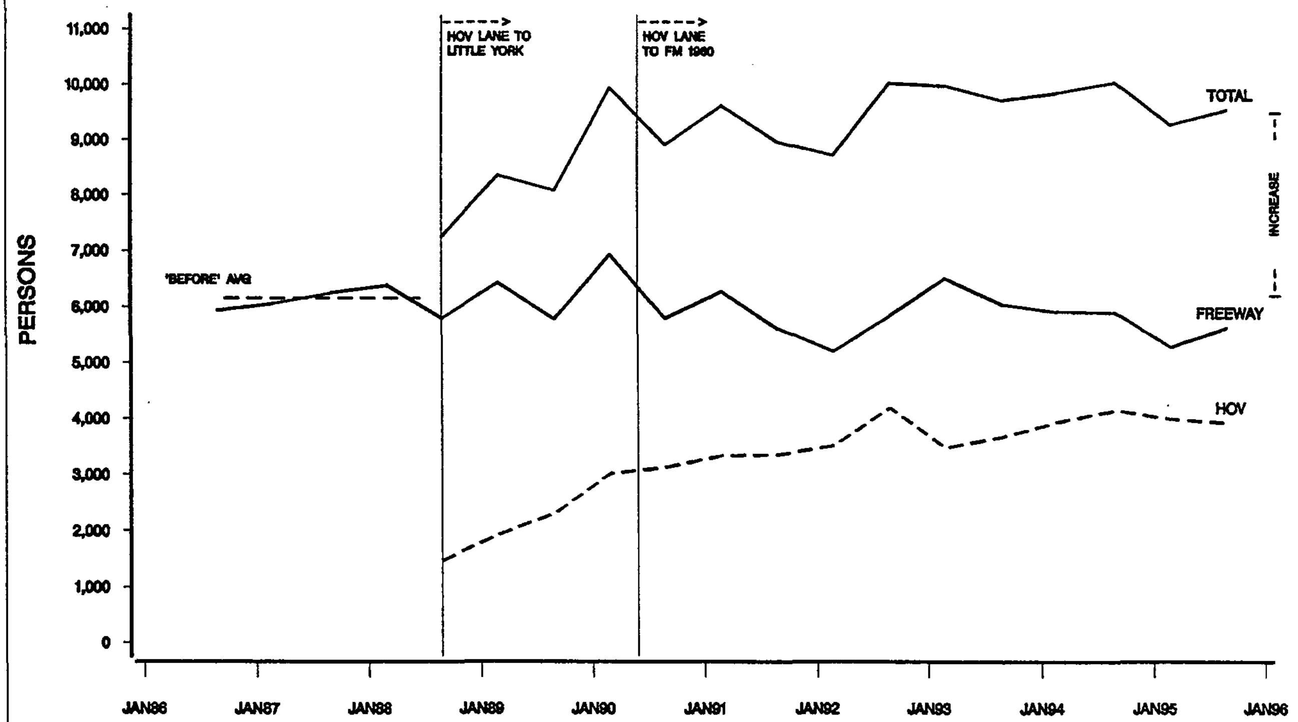


FIGURE D-10. NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE
A.M. PEAK PERIOD PERSON TRIPS

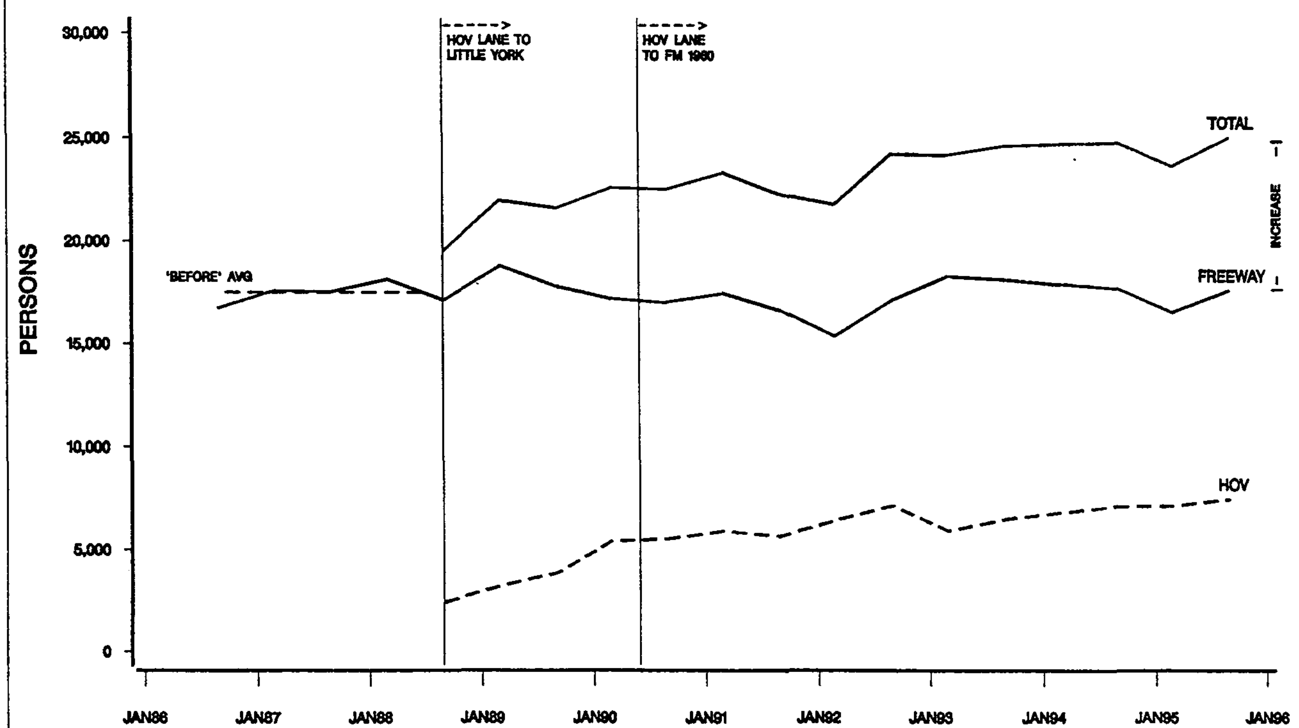


FIGURE D-11. NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE
A.M. PEAK HOUR AVERAGE OCCUPANCY

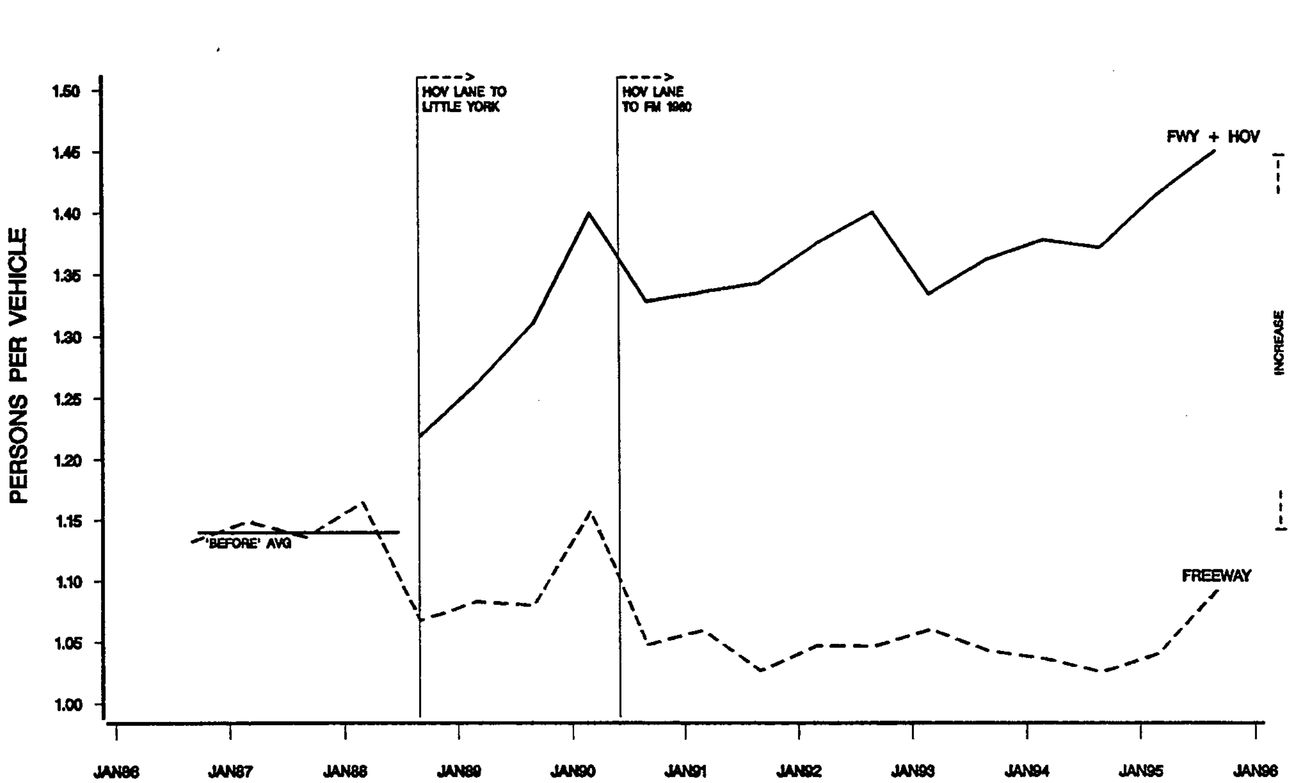


FIGURE D-12. NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE
A.M. PEAK PERIOD AVERAGE OCCUPANCY

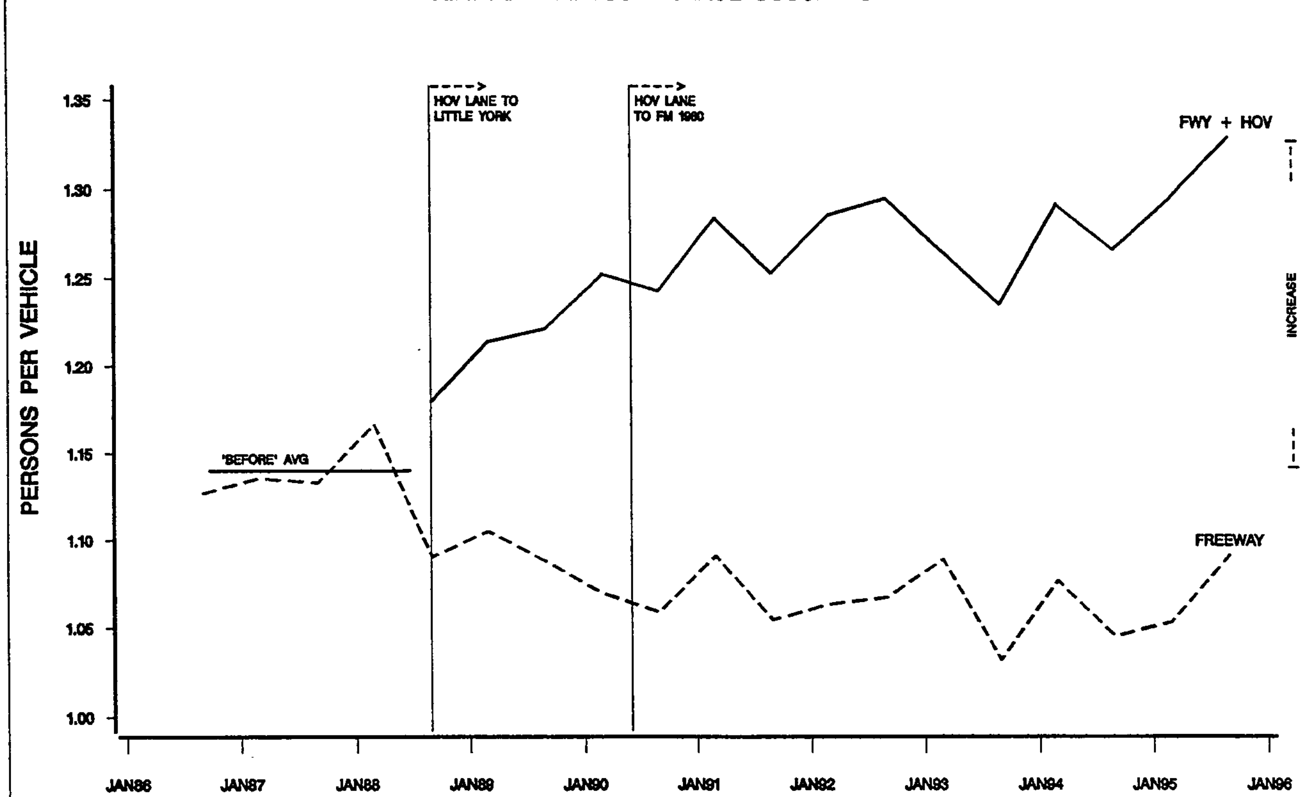


FIGURE D-13. A.M. PEAK HOUR AVERAGE OCCUPANCY
NORTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

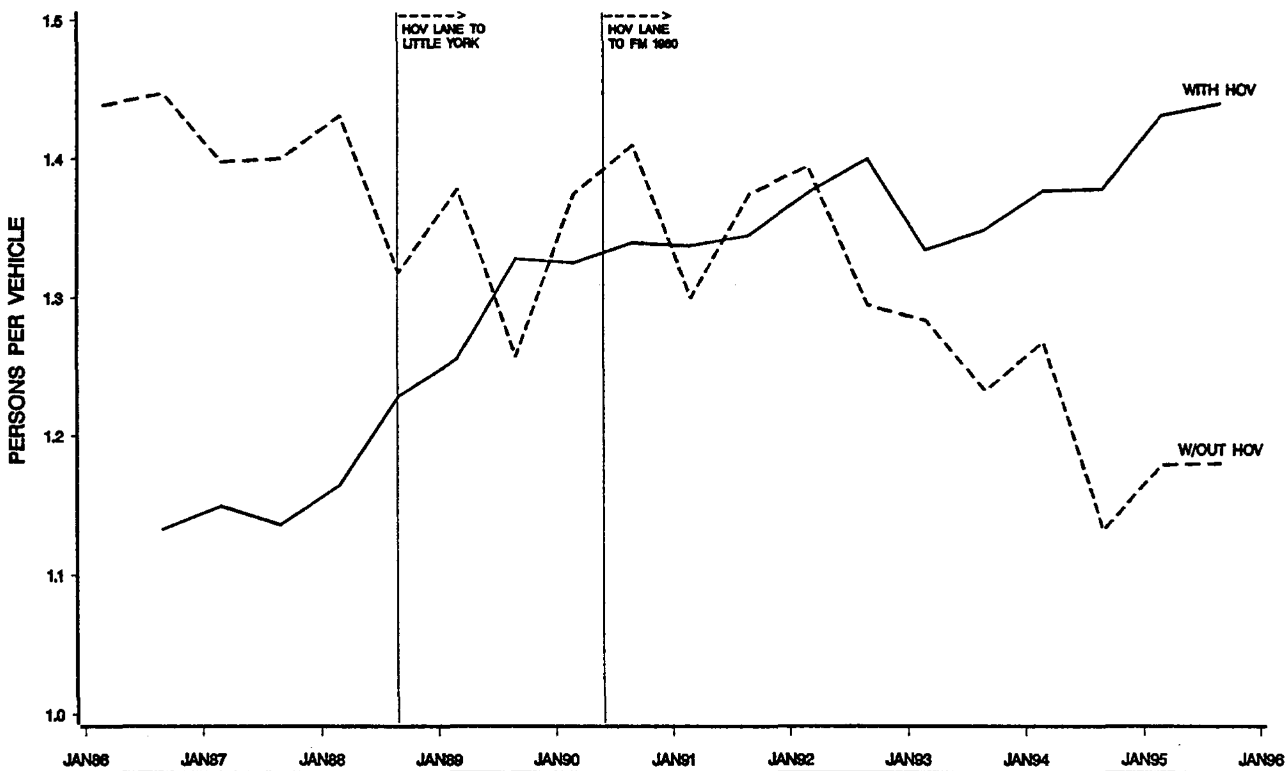


FIGURE D-14. NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE
A.M. PEAK HOUR 2+ CARPOOL UTILIZATION

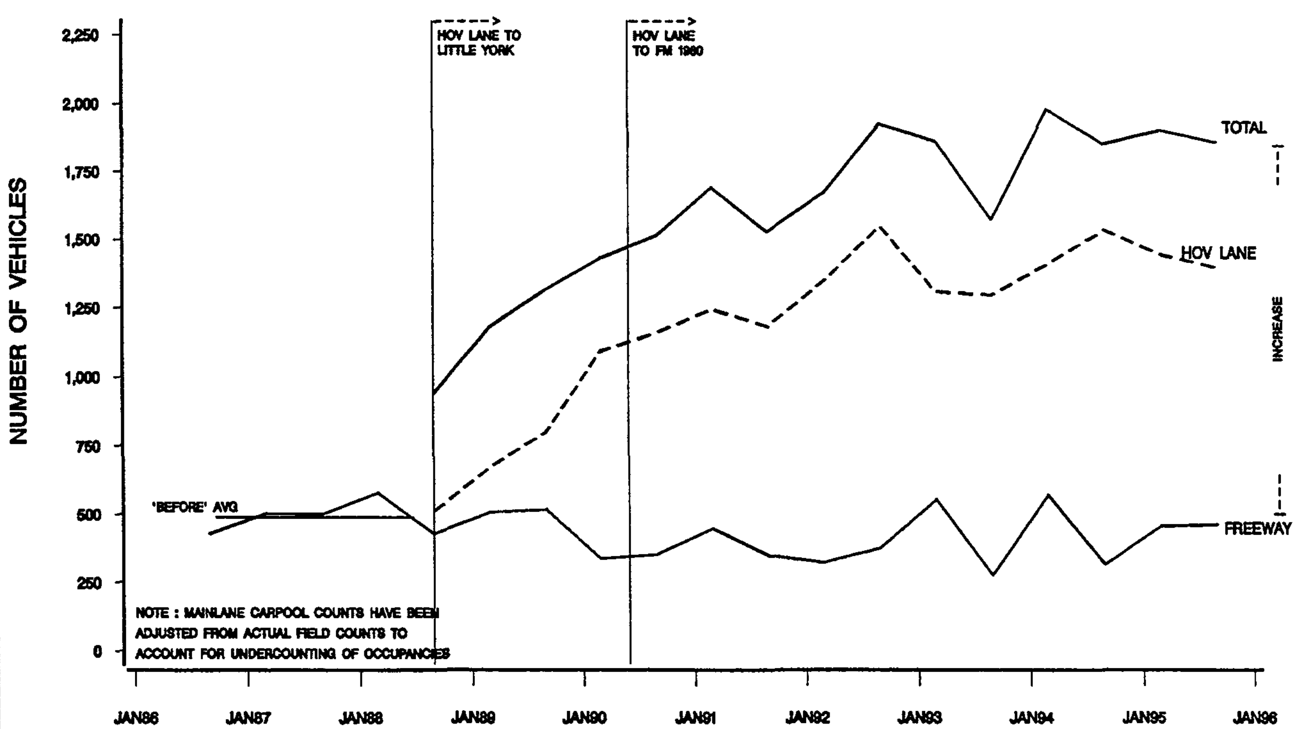


FIGURE D-15. A.M. PEAK HOUR FREEWAY PER LANE EFFICIENCY
NORTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

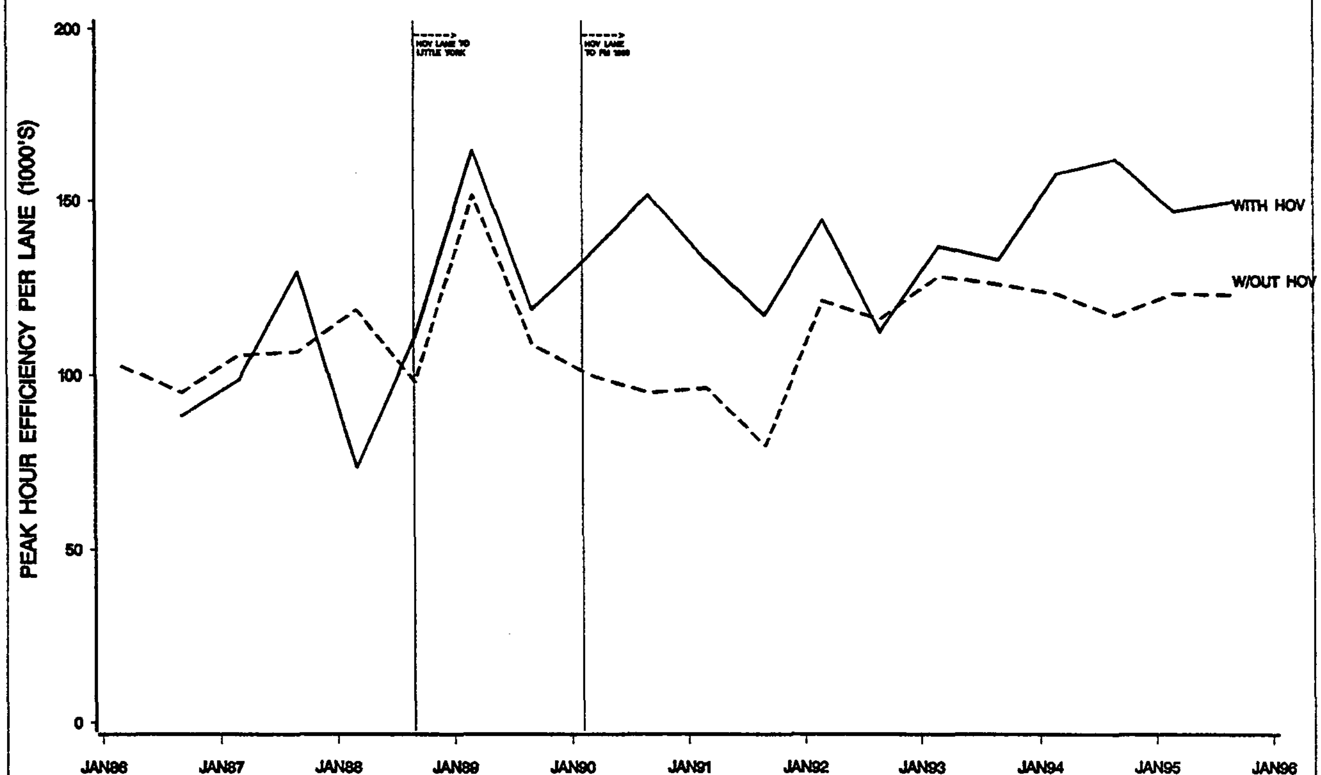


FIGURE D-16. NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS

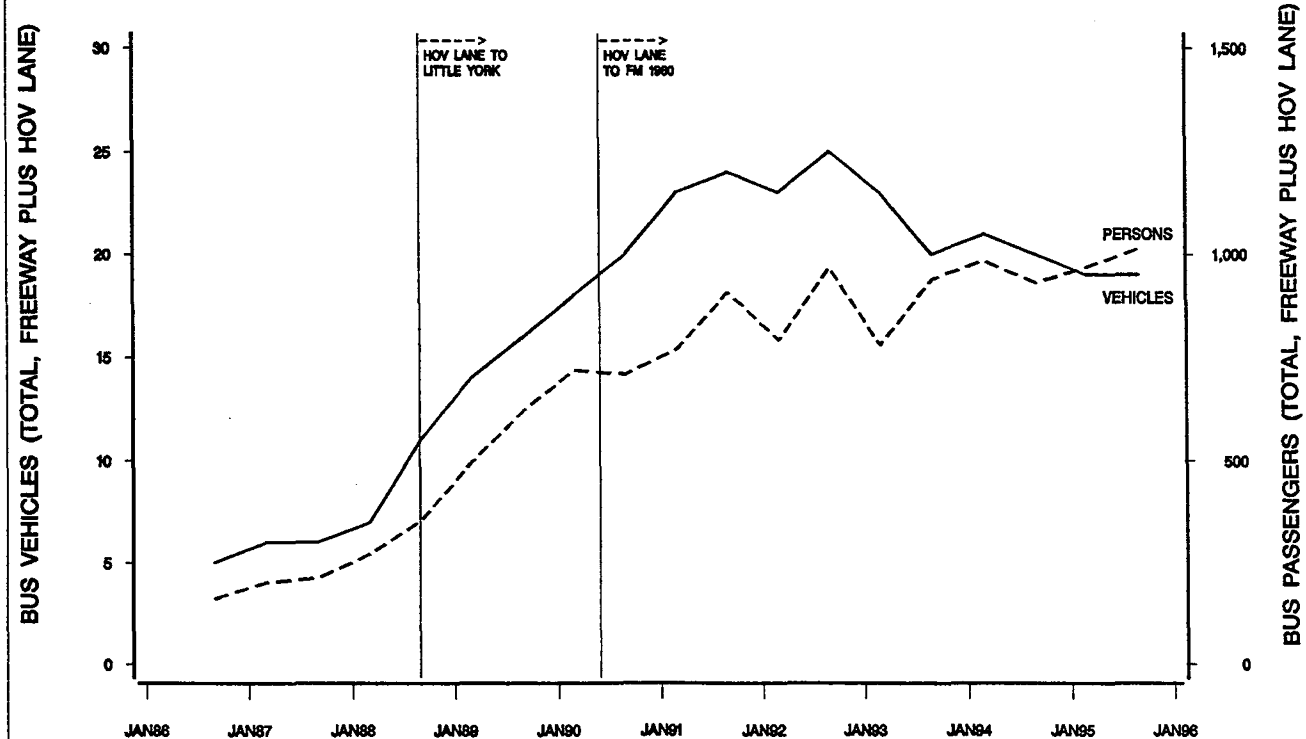


FIGURE D-17. NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS

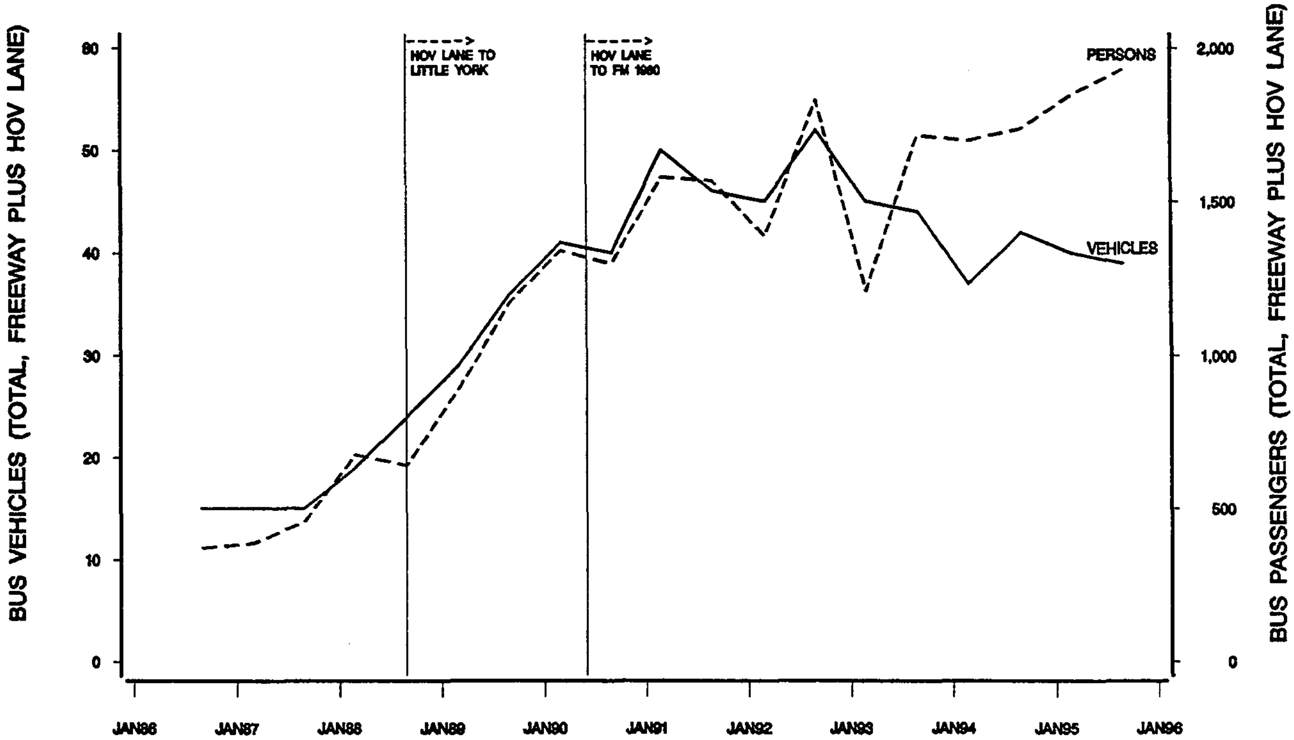


FIGURE D-18. A.M. PEAK PERIOD BUS PASSENGER TRIPS
TOTAL, FREEWAY PLUS HOV LANE VOLUMES
NORTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

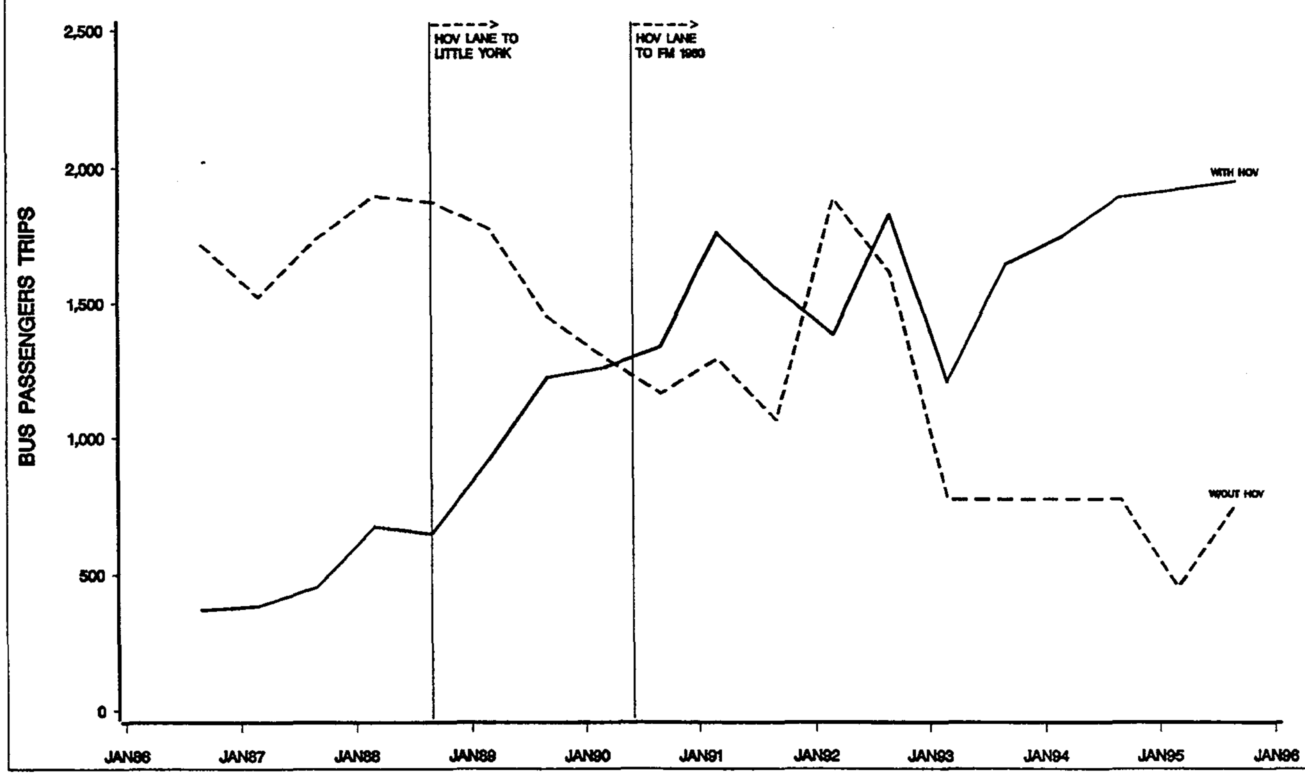


FIGURE D-19. NORTHWEST FREEWAY (U.S. 290) CORRIDOR PARK-AND-RIDE DEMAND

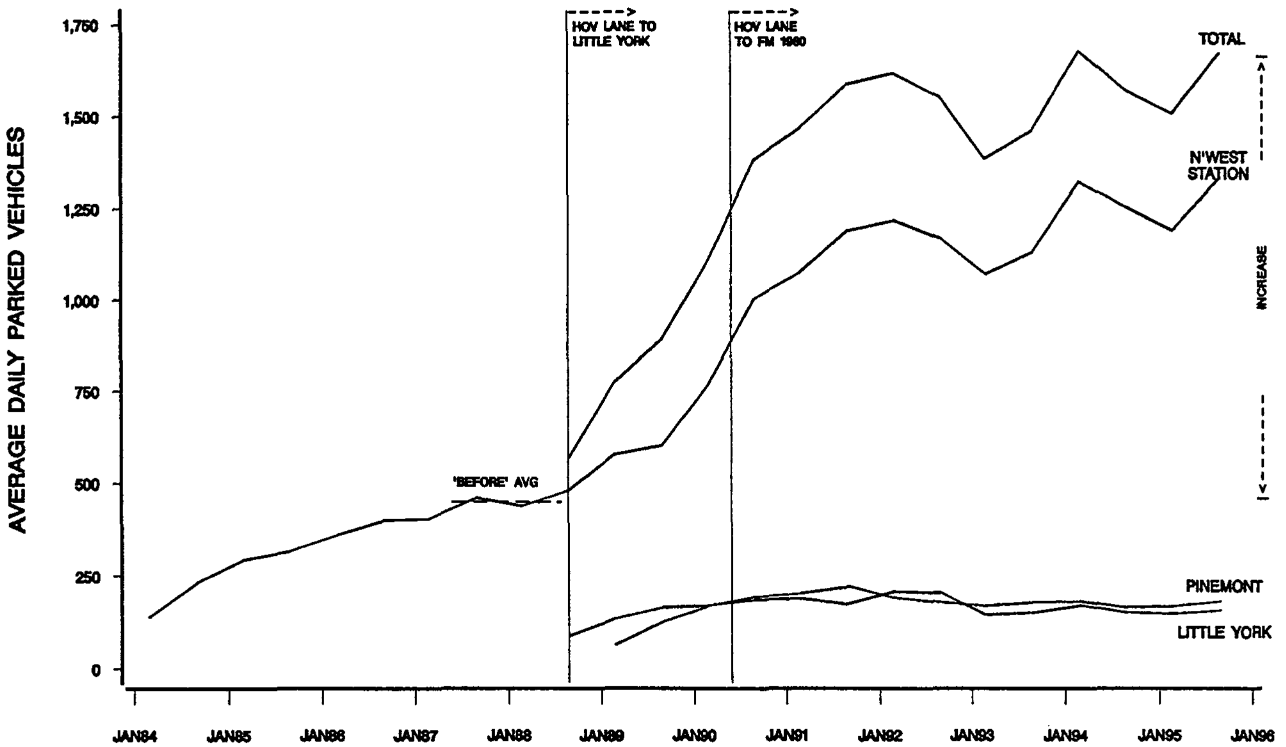
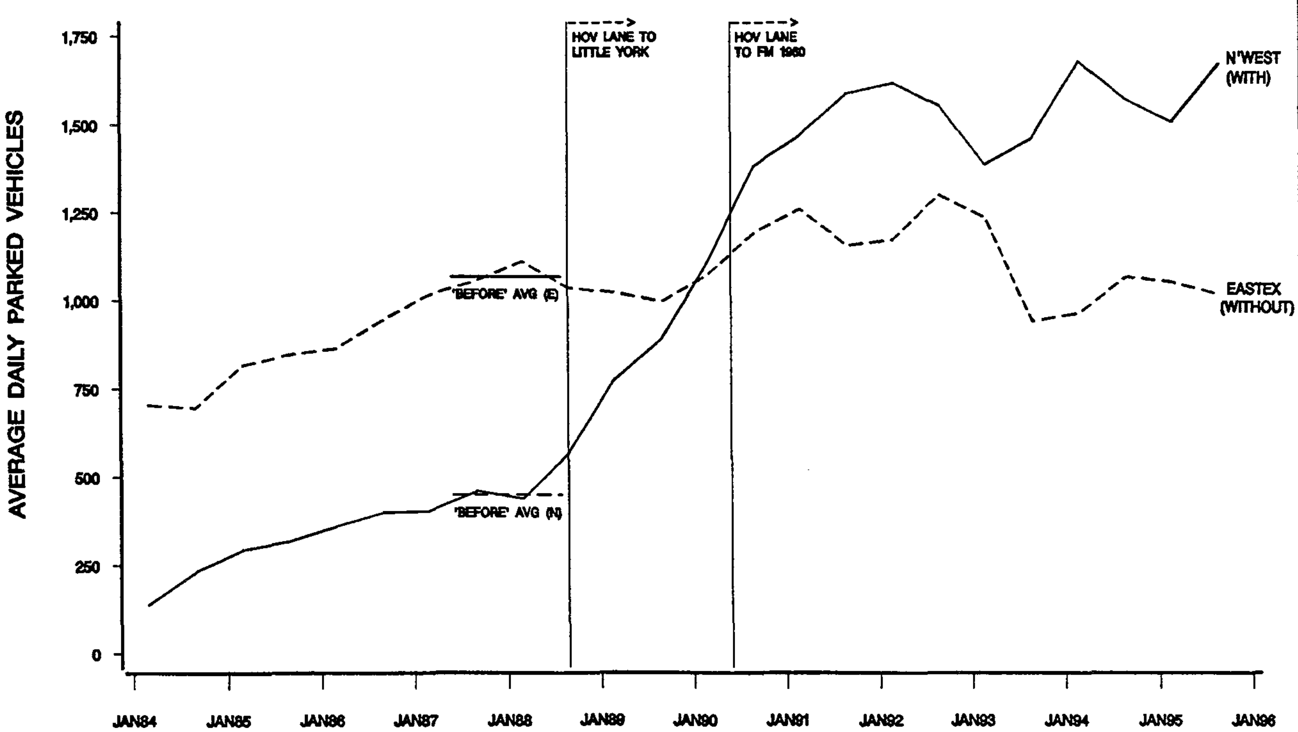


FIGURE D-20. AVERAGE DAILY VEHICLES PARKED AT PARK-AND-RIDE LOTS
NORTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE



APPENDIX E

SOUTHWEST FREEWAY AND HOV LANE DATA

SOUTHWEST FREEWAY (U.S. 59S) AND HOV LANE, HOUSTON

Table E-1. Summary of A.M. Peak-Direction Southwest Freeway and HOV Lane Data, December 1995

Type of Data Phase 1 of HOV Lane Became Operational 1/11/93	"Representative" Pre-HOV Lane Value	"Representative" Current Value	Percent Change
HOV Lane Data			
HOV Lane Length (kilometers [miles])		18.7 (11.6)	
HOV Lane Cost (millions)		$62.2	
Person-Movement			
Peak Hour (7-8 a.m.)	---	3,222	---
Peak Period (6-9:30 a.m.)	---	6,638	---
Total Daily	---	14,873	---
Vehicle Volumes			
Peak Hour	---	1,181	---
Peak Period	---	2,384	---
Vehicle Occupancy, Peak Hour (persons/veh)	---	2.73	---
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM]), 1/93-12/94[1]	---	10.5 (17.0)	---
Vehicle Breakdown Rate (VKT/Breakdown [VMT/Breakdown]), 1/93-12/94		117,696 (73,103)	---
Violation Rate (6-9:30 a.m.)	---	2.1%	---
Peak Hour Lane Efficiency (1000's)[2]	---	265 (164)	---
Annual Value of User Time Saved (millions)[3]	---	$2.0 to 4.0	---
Freeway Mainlane Data (see note)			
Person Movement			
Peak Hour	5,685	9,166	+61%
Peak Period (6-9:30 a.m.)	17,357	28,886	+66%
Vehicle Volume			
Peak Hour	4,922	8,186	+66%
Peak Period	15,032	26,696	+78%
Vehicle Occupancy, Peak Hour (persons/veh)	1.16	1.12	-3%
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM])[1]	16.3 (26.2)	10.6 (17.0)	-35%
Avg. Operating Speed[4] (kph [mph])			
Peak Hour	47 (29)	52 (32)	+11%
Peak Period	66 (41)	74 (46)	+12%
Peak Hour Lane Efficiency (1000's)[2]	90 (56)	95 (59)	+6%

Source: Texas Transportation Institute. The Texas A&M University System.

[1]Due to inconsistencies in reporting accidents in Harris County, this analysis includes only injury accidents. Accidents analyzed between Bellfort and S. Shepherd, a distance of approximately 18.7 kilometers (11.6 miles). This corresponds to Phase 1 of the HOV lane. "Before" data are for the period from 1/91 to 12/92. "Current" accident data are for the period from 1/93 to 12/95. TTI estimated 1995 freeway volumes to compute rates.

[2]This represents the multiple of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.

[3]Based on time savings from HOV lane users in 1995, an annual estimate of travel time savings to HOV lane users is developed. A value of time of $11.37/hour is used based on the value applied in the Highway Economic Evaluation Model.

[4]From Bellfort to S. Shepherd, the distance is 18.7 kilometers (11.6 miles).

Table E-1. Summary of A.M. Peak-Direction Southwest Freeway and HOV Lane Data, December 1995 (Continued)

Type of Data	"Representative" Pre-HOV Lane Value	"Representative" Current Value	Percent Change
Combined Freeway Mainlane and HOV Lane Data			
Total Person Movement			
Peak Hour	5,685	12,388	+118%
Peak Period	17,357	35,524	+105%
Vehicle Volume			
Peak Hour	4,922	9,367	+90%
Peak Period	15,032	29,080	+93%
Vehicle Occupancy			
Peak Hour	1.16	1.32	+14%
Peak Period	1.16	1.22	+5%
2+ Carpool Volumes			
Peak Hour	531	1,656	+212%
Peak Period	1,235	3,534	+186%
Travel Time (minutes)[1]			
Peak Hour	16.2[2]	13.7[3]	-15%
Peak Period	11.4[2]	12.9[3]	+13%
Peak Hour Lane Efficiency (1000's)[4]	90 (56)	123 (76)	+37%
Transit Data			
Bus Vehicle Trips			
Peak Hour	25	22	-12%
Peak-Period	75	57	-24%
Bus Passenger Trips			
Peak Hour	724	686	-5%
Peak Period	1,670	1,643	-2%
Bus Occupancy (persons/bus)			
Peak Hour	20	31.2	+56%
Peak Period	18	28.8	+60%
Vehicles Parked in Corridor Park & Ride Lots	1,441	1,456	+1%
Bus Operating Speed[1] (kph [mph])			
Peak Hour	47 (29)[2]	82 (51)	+74%
Peak Period	79 (49)[2]	87 (54)	+10%

Note: Site-specific data collected at Pinemont. For purposes of visibility and safety, the freeway volumes are counted between an exit and an entrance ramp. Thus, the mainlane volumes may be low.

[1]From Bellfort to S. Shepherd, the distance is 18.7 kilometers (11.6 miles).
[2]Data pertain to operation in the freeway mainlanes.
[3]Data pertain to operation in the HOV lane.
[4]This represents the multiple of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.

Table E-2. Comparison of Measures of Effectiveness, Freeway With (Southwest US 59S) and Freeway Without (Eastex U.S. 59) HOV Lane, Houston[1]

Measure of Effectiveness	"Representative" Pre-HOV Lane Value	"Representative" Current Value	Percent Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/HOV lane	1.16	1.31	+13%
Freeway w/o HOV lane	1.30	1.18	-9%
A.M. Peak Hour, 2+ Carpool Volume Change			
Freeway w/HOV lane	531	1,656	+212%
Freeway w/o HOV lane	779	571	-27%
Bus Passengers, Peak Period			
Freeway w/HOV lane	1,670	1,643	-2%
Freeway w/o HOV lane	1,067	762	-29%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	1,441	1,456	+1%
Freeway w/o HOV lane	1,222	1,035	-15%
Facility Per Lane Efficiency[2]			
Freeway w/HOV lane	90 (56)	123 (77)	+37%
Freeway w/o HOV lane	120 (74)	123 (77)	+3%

[1]Data for freeways without HOV lanes are a composite of data collected on the Gulf Freeway during the time in which no HOV lane existed on that facility (6/83 - 4/88), the Southwest Freeway (9/86 to 12/92), and on the Eastex Freeway (1/93 to present).
[2]This represents the product of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.

HOV LANE DATA

DESCRIPTION

- Phase 1 (18.7 kilometers [11.6 miles]) of the HOV lane opened January 11, 1993.

- The capital cost (including all support facilities) for the completed facility in 1995 dollars was $62.2 million. The following page provides a more detailed cost breakdown including dates.

- Selected milestone dates are listed below. The capital cost table shows other dates.

  - 1/11/93 Shepherd to Bellfort opens (18.7 kilometers [11.6 miles]).

PERSON MOVEMENT

- In September 1995, 14,873 person trips per day were served on the HOV lane.

- A.M. peak hour, 3,222 persons/hour.
  - 730 (23%) by bus, 73 (2%) by vanpool, 2,416 (75%) by carpool, and 3 by motorcycle (Figure E-1).
  - Average HOV lane vehicle occupancy = 2.77 persons/vehicle.

- A.M. peak period, 6,638 persons.
  - 1,620 (24%) by bus, 165 (2%) by vanpool, 4,844 (73%) by carpool, and 9 by motorcycle (Figure E-2).

Table E-3. Estimated Capital Cost (millions), Southwest HOV Lane, Operating Segments

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1995 Dollars
HOV Lane and Ramps			
Segment I (1991)	$25.1	1.18	$29.6
Segment II (1992)	9.9	1.14	11.3
Segment III (1992)	13.0	1.14	14.8
Segment IV (1992)	6.3	1.14	7.2
W. Belfort T-Ramp (1992)	3.6	1.14	4.1
Miscellaneous	6.4	1.14	7.3
SUB-TOTAL	$64.3		$74.3
Per Kilometer (Mile)	$3.4 ($5.5)		$4.0 ($6.4)
Surveillance, Communication and Control (1990)	$3.5		
SUB-TOTAL	$3.5	1.21	$4.2
Per Kilometer (Mile)	$0.2 ($0.3)		$0.2 ($0.4)
Support Facilities			
W. Bellfort P/R (1991)	$8.6	1.18	$10.1
Westwood P/R (1991)	3.3	1.18	3.9
Hillcroft Transit Center (1992)	16.2	1.14	18.5
SUB-TOTAL	$28.1		$32.5
Per Kilometer (Mile)	$1.5 ($2.4)		$1.7 ($2.8)
TOTAL COST	$95.9		$111.0
COST PER KILOMETER (18.5 kilometers [11.5 miles])	$5.2 ($8.3)		$5.9 ($9.6)

Source: Compiled by TTI from data provided by Metro and TxDOT.

Table E-4. Estimated Capital Cost (millions), Southwest HOV Lane, Future Segments

Cost Component	Year of Construction Cost
HOV Lane and Ramps	
Segment V	$21.9
Greenway Plaza Ramp	7.6
SUB-TOTAL	$29.5
Per Kilometer (Mile)	$6.5 ($10.5)
Surveillance, Communication and Control	$0.7
SUB-TOTAL	$0.7
Per Kilometer (Mile)	$0.2 ($0.3)
TOTAL COST	$30.2
COST PER KILOMETER (3.5 kilometers [2.8 miles])	$6.7 ($10.8)

Source: Compiled by TTI from data provided by Metro and TxDOT.

VEHICLE MOVEMENT

- A.M. peak hour, 1,181 vehicles.
  - 22 (2%) buses, 10 (1%) vans, 1,145 (97%) carpools, and 4 by motorcycle (Figure E-3).
- A.M. peak period, 2,384 vph
  - 52 (2%) buses, 22 (1%) vans, 2,302 (97%) carpools, 8 by motorcycle (Figure E-4).

ACCIDENT RATE

- For the period 1/93 through 8/95, the HOV lane accident rate was 10.5 accidents per 100 million vehicle kilometers (17.0 per 100 million vehicle miles).

VEHICLE BREAKDOWN RATES

- As measured from January 11, 1993 through December 1994, the following rate has been observed.
  - The weighted average for all vehicle types is 1 breakdown per 117,696 VKT (73,103 VMT).

VIOLATION RATE

- The observed violation rate (vehicles on the HOV lane not eligible to use the HOV lane) is approximately 2%.

PEAK HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. For the HOV lane, this value (expressed in 1000's) is approximately 265 (3,222 passengers x 82 kph) or 164 (3,222 passengers x 51 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane experience an average travel time savings of 10 minutes in the a.m. peak hour (Figure E-5).

- The table on the following page indicates that, on a typical non-incident day, travel time savings of approximately 42,387 minutes, or 706 hours, are realized. Assuming 250 days of operation and a value of time of $11.37/hour, this equates to $2.01 million per year. This is extremely conservative since it does not consider travel time savings due to incidents on the freeway. Data from Houston suggest that increasing this value by 100% to account for incidents would be reasonable. Thus, estimates of travel time savings to HOV lane users are in the range of $2.01 to $4.02 million per year.

Table E-5. Travel Time Savings for Southwest HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1995)

Southbound A.M. Travel Time Savings for Southwest HOV Lane								
Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section from Bellfort to Hillcroft Flyover								
6:00	5.47	6.48	-1.02	224	51	60	335	-341
6:30	6.08	5.75	0.33	557	0	50	607	202
7:00	15.22	6.15	9.07	985	23	150	1,158	10,499
7:30	10.48	7.45	3.03	1,097	0	60	1,157	3,510
8:00	12.40	5.90	6.50	814	0	100	914	5,941
8:30	5.27	5.98	-0.72	490	0	60	550	-394
9:00	5.07	5.68	-0.62	96	0	220	316	-195
Peak Period Total				4,263	74	700	5,037	19,223
Section From Hillcroft Flyover to S Shepherd								
6:00	6.30	7.00	-0.70	195	51	222	468	-328
6:30	6.60	6.68	-0.08	865	11	320	1,196	-100
7:00	11.40	7.42	3.98	1,183	33	313	1,529	6,090
7:30	17.17	7.08	10.08	1,230	22	310	1,562	15,750
8:00	6.53	7.20	-0.68	882	5	222	1,109	-758
8:30	5.97	7.03	-1.07	401	0	63	464	-495
9:00	5.98	6.37	-0.38	275	10	161	446	-171
Peak Period Total				5,031	132	1,611	6,774	19,990
Northbound P.M. Travel Time Savings for Southwest HOV Lane								
Section from S Shepherd to Hillcroft Flyover								
3:30	6.47	6.71	-0.24	131	0	53	183	-44
4:00	6.45	6.50	-0.05	267	12	196	474	-23
4:30	6.43	7.22	-0.79	496	42	112	650	-515
5:00	10.73	7.43	3.29	1,284	69	491	1,844	6,076
5:30	7.33	8.70	-1.37	515	25	108	647	-884
6:00	6.50	7.18	-0.68	752	48	222	1,022	-698
6:30	6.18	6.54	-0.37	179	8	114	300	-110
Peak Period Total				3,622	204	1,294	5,120	3,801

Table E-5. Travel Time Savings for Southwest HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1995) (Continued)

Southbound A.M. Travel Time Savings for Southwest HOV Lane								
Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section from the Hillcroft Flyover to Bellfort								
3:30	5.53	5.76	-0.23	75	1	1	77	-18
4:00	5.50	5.63	-0.13	0	0	0	0	0
4:30	5.53	5.82	-0.29	253	8	61	321	-94
5:00	5.62	5.58	0.03	743	27	111	881	30
5:30	6.78	6.03	0.74	447	24	61	532	395
6:00	6.12	7.35	-1.23	679	26	31	736	-908
6:30	5.62	5.79	-0.17	168	4	20	192	-32
Peak Period Total				2,364	90	285	2,738	-627

FREEWAY DATA

NOTE

- For purposes of safety and visibility, freeway volumes are counted at Westpark overpass between an exit ramp and an entrance ramp. Thus, freeway volumes may be low in comparison to actual freeway operations. Data are collected in a section with 3 lanes in each direction.

PERSON MOVEMENT

- In the a.m. peak hour, compared to pre-HOV conditions, person movement has increased by 61% (Figure E-6).

- In the a.m. peak period, compared to pre-HOV conditions, person movement has increased by 66% (Figure E-7).

VEHICLE VOLUME

- In the a.m. peak hour, vehicle volume has increased by 66% (Figure E-6).

- In the a.m. peak period, vehicle volume has increased by 78% (Figure E-7).

VEHICLE OCCUPANCY

- In the a.m. peak hour, compared to pre-HOV conditions, mainlane occupancy has declined by 3% (Figure E-11).

- In the a.m. peak period, compared to pre-HOV conditions, mainlane occupancy has declined by 6% (Figure E-12).

ACCIDENT RATE

- Implementation of the HOV lane resulted in narrower freeway lanes and inside emergency shoulder.

- For the section between Shepherd and Bellfort, the accident rate for the period preceding the opening of the HOV lane was 16.3 accidents per 100 million vehicle kilometers (100 MVK) (26.2 accidents per 100 million vehicle miles [100 MVM]). The accident data available for the period (1/93-8/95) after the HOV lane opened indicate an accident rate of 10.6 accidents/100 MVK (17.0 accidents/100 MVM).

AVERAGE OPERATING SPEED

- In comparison to pre-HOV lane conditions, mainlane operating speeds have decreased in the peak hour, but show improvement in the peak period. The data in Figure E-8 show the average of all travel time runs made both before and after the HOV lane opened for the a.m. peak period.

PEAK HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of per lane efficiency.

- For the freeway mainlanes, decreased travel speeds have resulted in an increase in per lane efficiency of 6%.

COMBINED FREEWAY AND HOV LANE DATA

TOTAL PERSON MOVEMENT

- Percent by HOV lane, a.m. peak.

  - At Pinemont, the HOV lane is responsible for 25% of peak-hour person movement (HOV lane = 3,222; freeway = 9,166) and 19% of peak-period (HOV lane = 6,638; freeway = 28,886) person movement (Figure E-10).

- Increase in a.m. person movement at Pinemont

  - Provision of the HOV lane increased total directional lanes by 33%.

  - Total peak-hour person movement has increased by 118%, from 5,685 to 12,388 (Figure E-9). Peak-period person movement has increased by 105%, from 17,357 to 35,524 Figure E-10).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.32, a 14% increase over the pre-HOV lane occupancy (Figure E-11). Occupancy in the peak period is 5% greater than pre-HOV lane levels (Figure E-12).

- While the occupancy on the Southwest Freeway has increased, on freeways which do not have HOV lanes, occupancy has decreased (Figure E-13).

CARPOOL

- In the a.m. peak hour, the total number of 2+ carpools (freeway plus HOV lane) has increased by 212% compared to pre-HOV lane levels (Figure E-14). In the a.m. peak period, the increase has been 186%. Freeways without HOV lanes have not experienced these increases.

PEAK HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. The average efficiency of a lane on the freeway (3 freeway lanes plus 1 HOV lane) has increased by 37% since the implementation of the HOV lane (Figure E-15). Currently, no discernable trend in efficiency is evident when the Southwest Freeway is compared with freeways that have no HOV lane (Figure E-15).

BUS TRANSIT DATA

BUS VEHICLE AND PASSENGER TRIPS

- In the a.m. peak hour, bus vehicle trips have not changed since the HOV lane opened, and a decrease of 5% in bus ridership has resulted (Figure E-16). In the peak period, a 24% decrease has occurred in bus vehicle trips, and a 2% decrease in bus ridership has resulted (Figure E-17).

- While bus passenger trips have remained relatively constant in the Southwest Freeway corridor, in the corridors which do not have HOV lanes, bus passenger trips have remained fairly constant as well (Figure E-18).

PARK-AND-RIDE

- Prior to opening the HOV lane, approximately 1,441 vehicles were parked in corridor park-and-ride lots. This has increased 1% to a current level of 1,456 (Figure E-19).

- The increase in cars parked in the Southwest corridor has not occurred in the freeway corridor that does not have an HOV lane (Figure E-20).

FIGURE E-1. SOUTHWEST FREEWAY (US 59S) HOV LANE
A.M. PEAK HOUR HOV LANE PERSON MOVEMENT

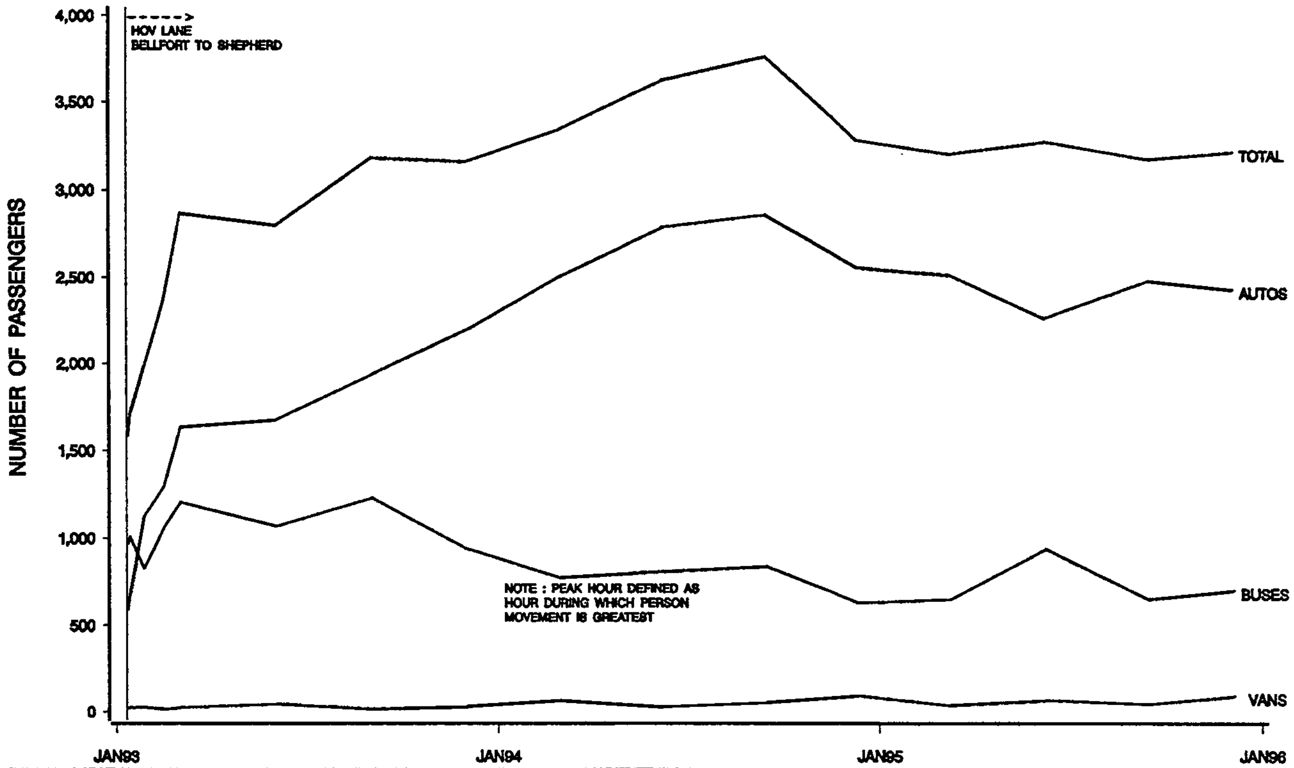


FIGURE E-2. SOUTHWEST FREEWAY (US 59S) HOV LANE
A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT

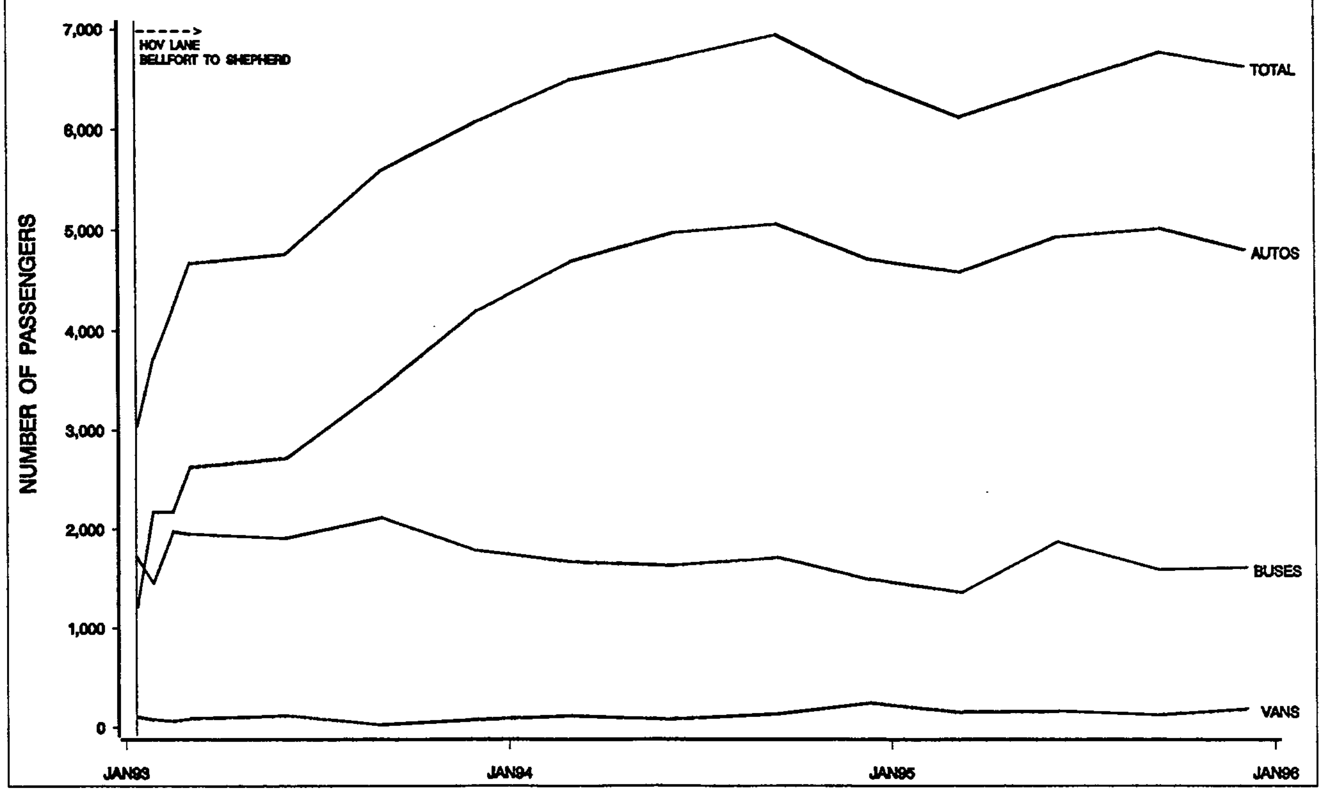


FIGURE E-3. SOUTHWEST FREEWAY (US 59S) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION

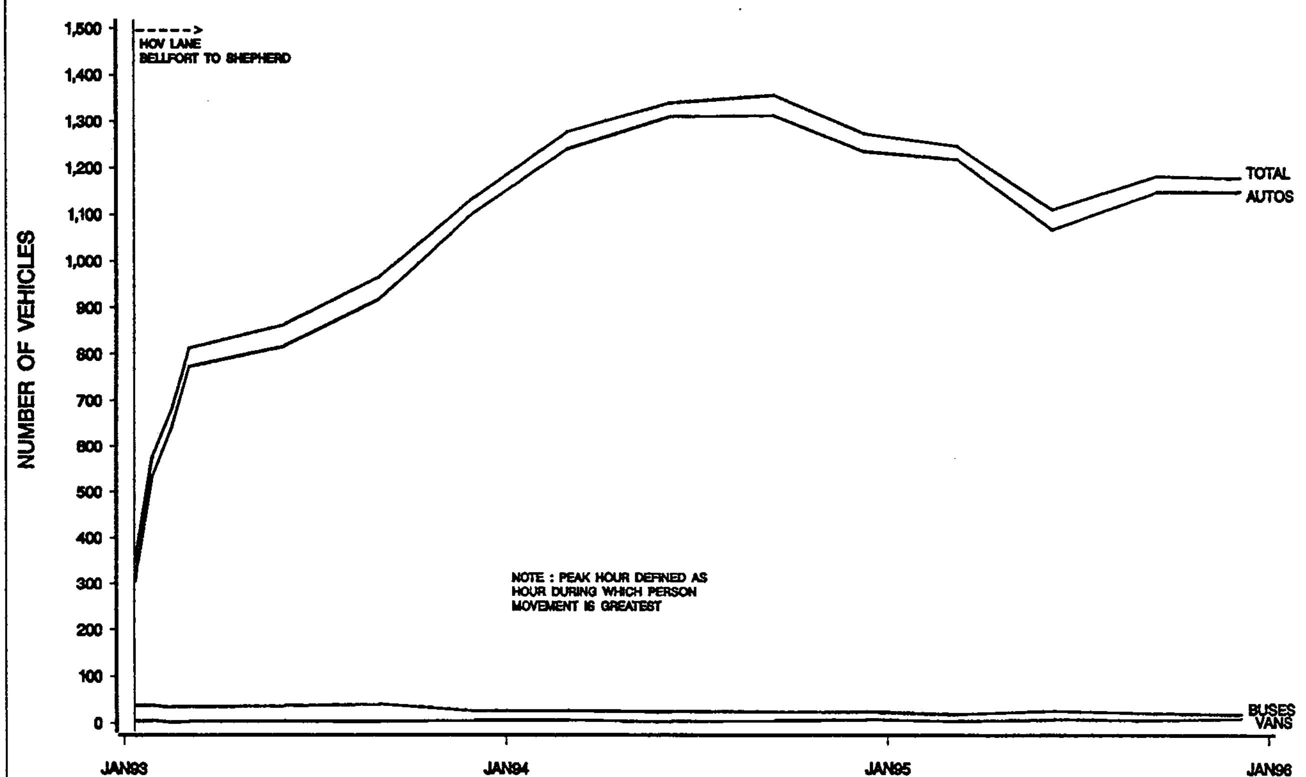


FIGURE E-4. SOUTHWEST FREEWAY (US 59S) HOV LANE
A.M. PEAK PERIOD HOV LANE VEHICLE UTILIZATION

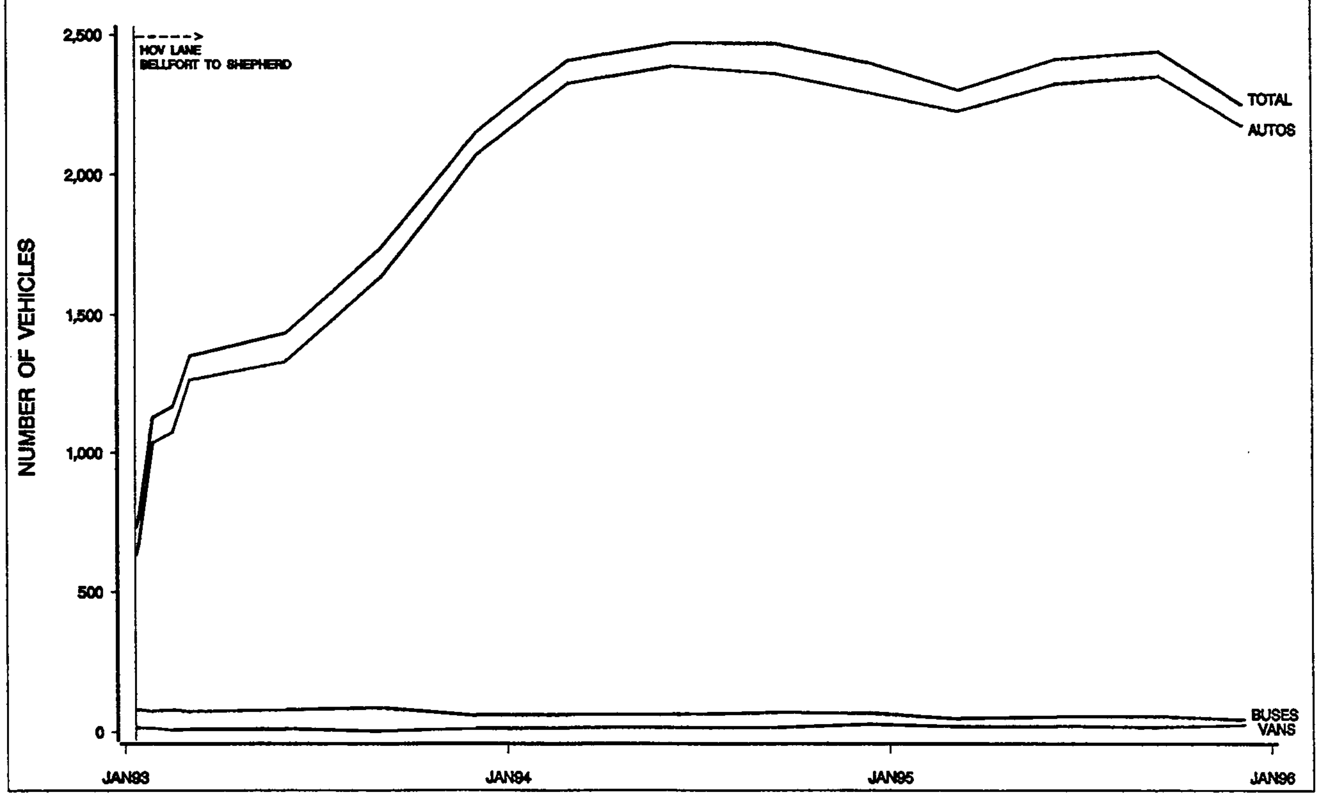


FIGURE E-5. SOUTHWEST FREEWAY (US 59S) MAINLANES AND HOV LANE A.M. TRAVEL TIME

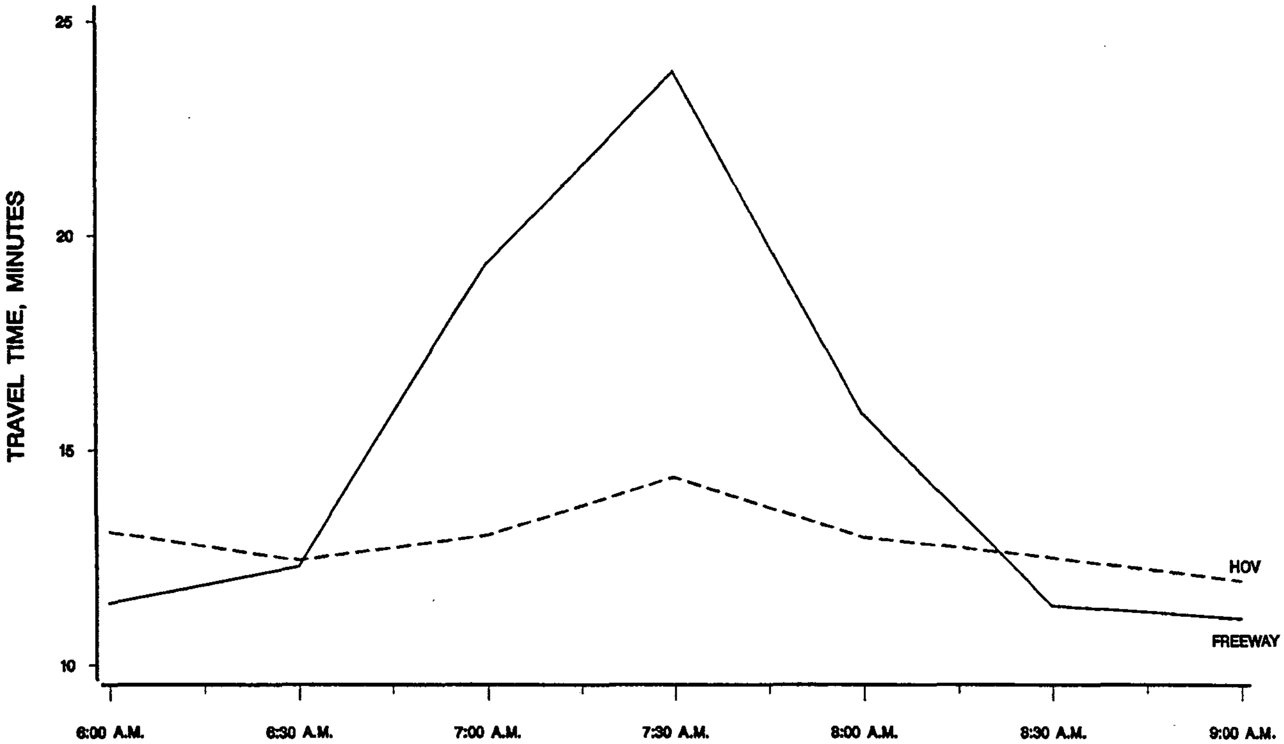


FIGURE E-6. SOUTHWEST FREEWAY (U.S. 59S)
A.M. PEAK HOUR MAINLANE TRIPS

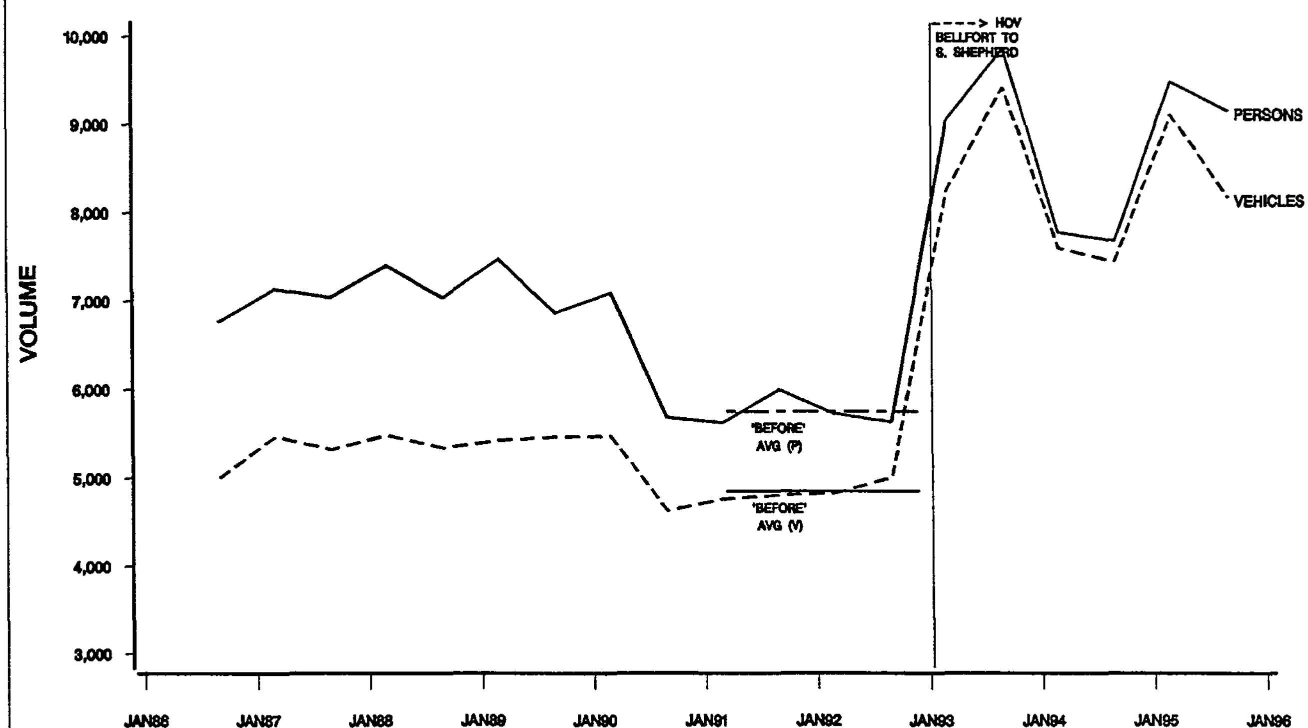


FIGURE E-7. SOUTHWEST FREEWAY (U.S. 59S)
A.M. PEAK PERIOD MAINLANE TRIPS

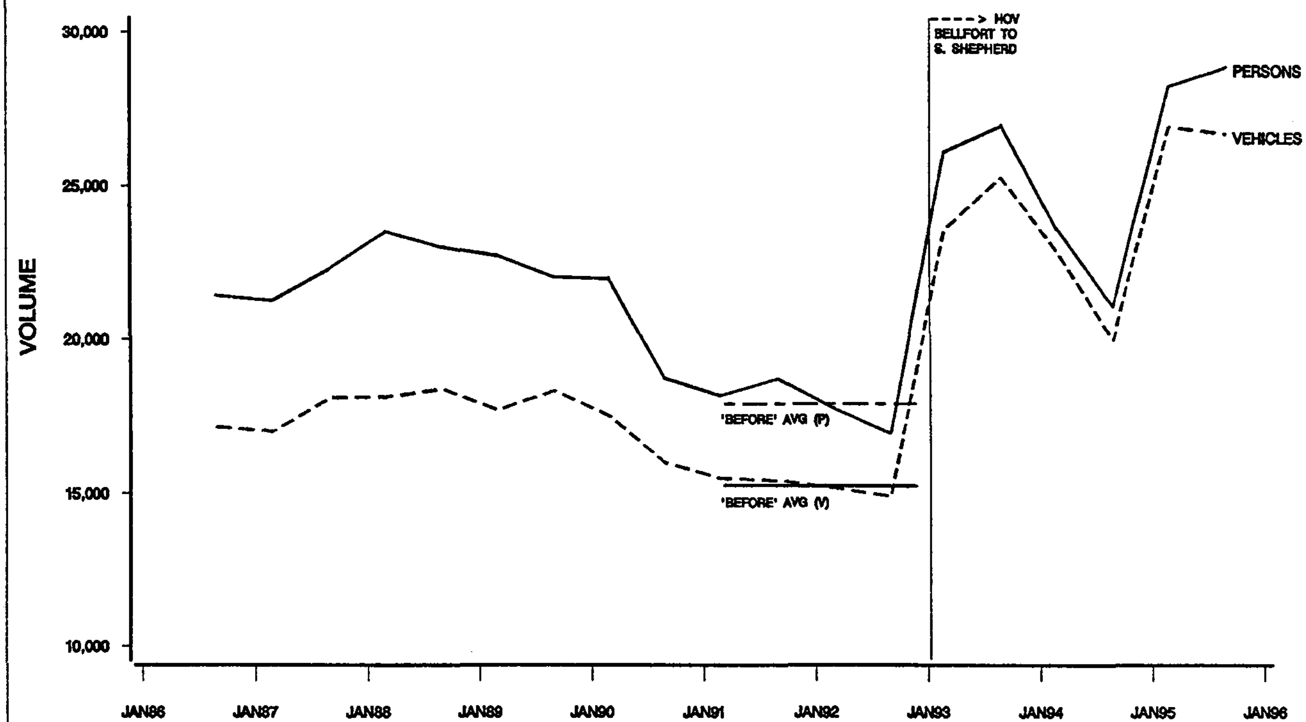


FIGURE E-8. SOUTHWEST FREEWAY (U.S. 59S) MAINLANE TRAVEL TIME AND SPEED SURVEY
NORTHBOUND, BELLFORT TO MANDELL
A.M. PEAK PERIOD

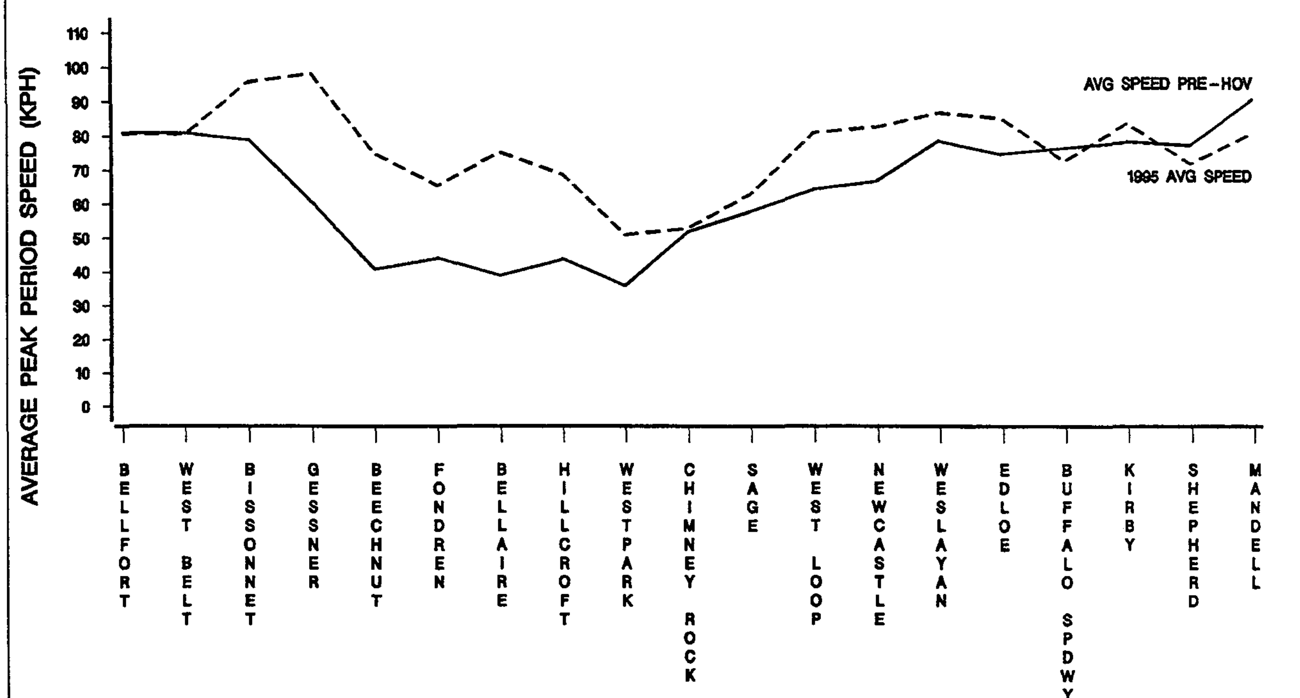


FIGURE E-9. SOUTHWEST FREEWAY (U.S. 59S) MAINLANE AND HOV LANE
A.M. PEAK HOUR PERSON TRIPS

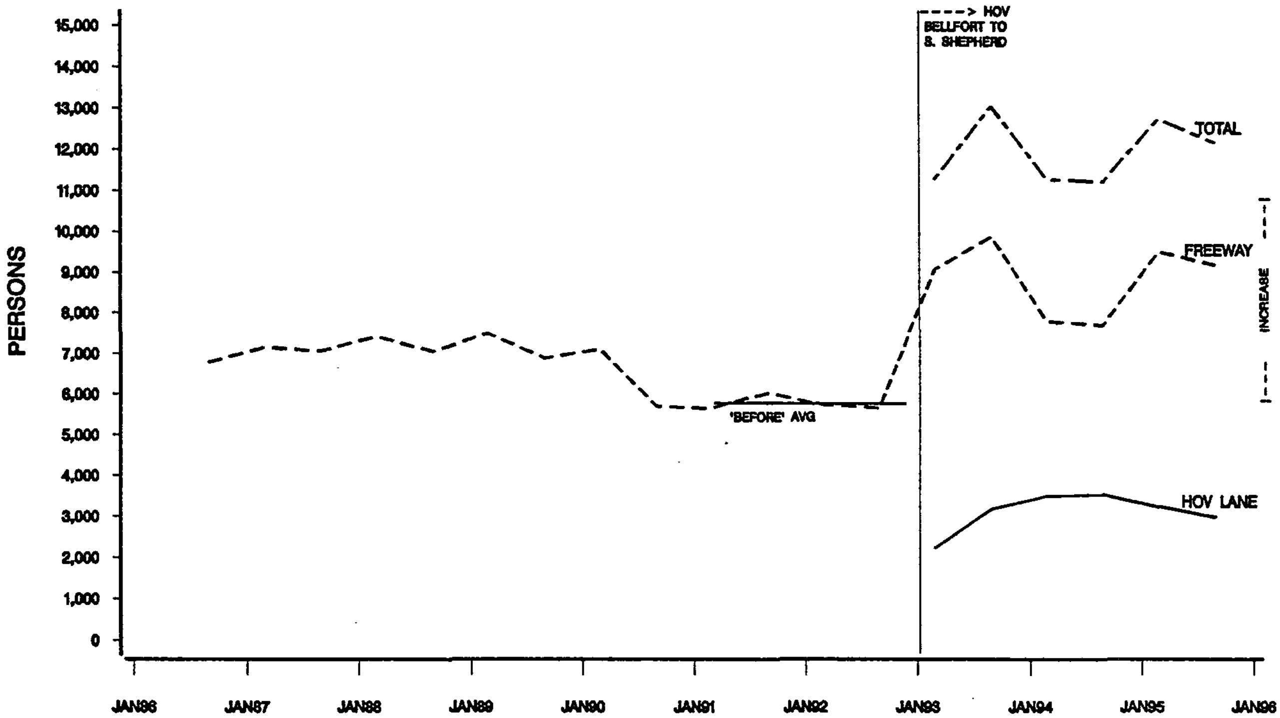


FIGURE E-10. SOUTHWEST FREEWAY (U.S. 59S) MAINLANE AND HOV LANE
A.M. PEAK PERIOD PERSON TRIPS

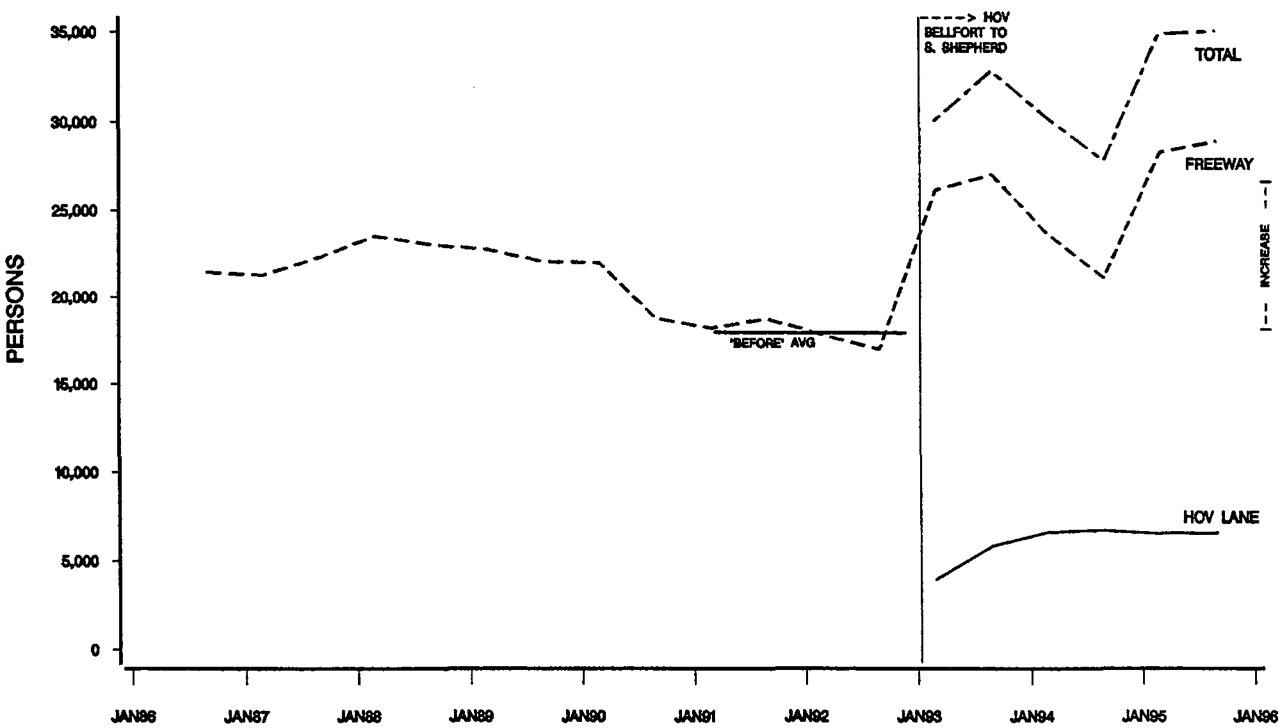


FIGURE E-11. SOUTHWEST FREEWAY (U.S. 59S) MAINLANE AND HOV LANE
A.M. PEAK HOUR AVERAGE OCCUPANCY

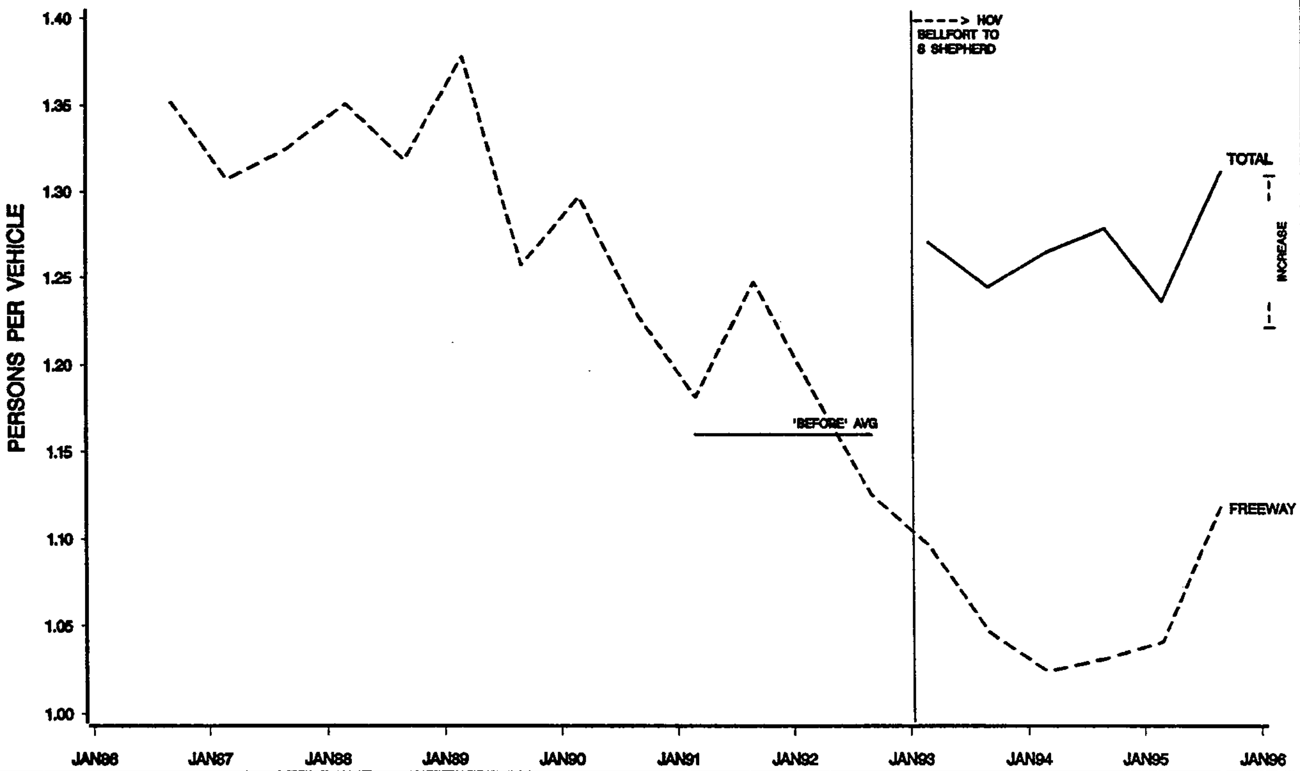


FIGURE E-12. SOUTHWEST FREEWAY (U.S. 59S) MAINLANE AND HOV LANE
A.M. PEAK PERIOD AVERAGE OCCUPANCY

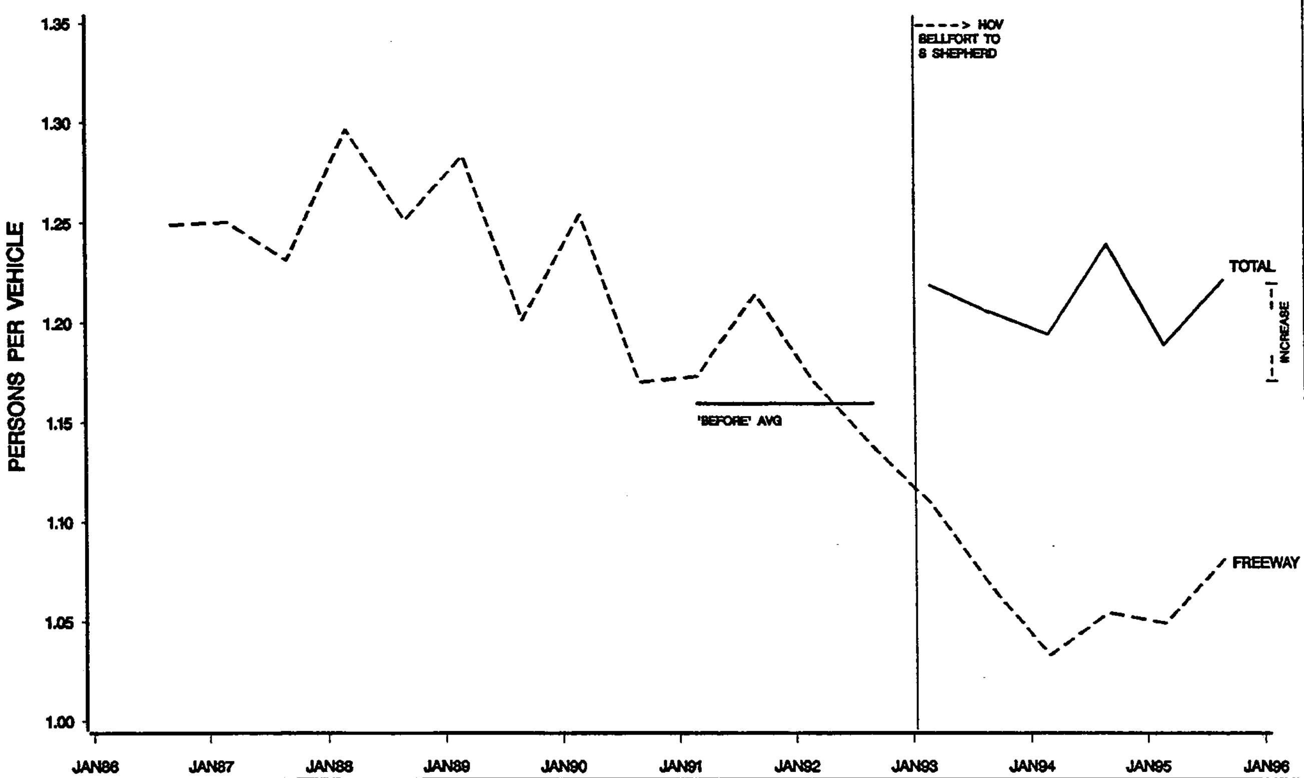


FIGURE E-13. A.M. PEAK HOUR AVERAGE OCCUPANCY SOUTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

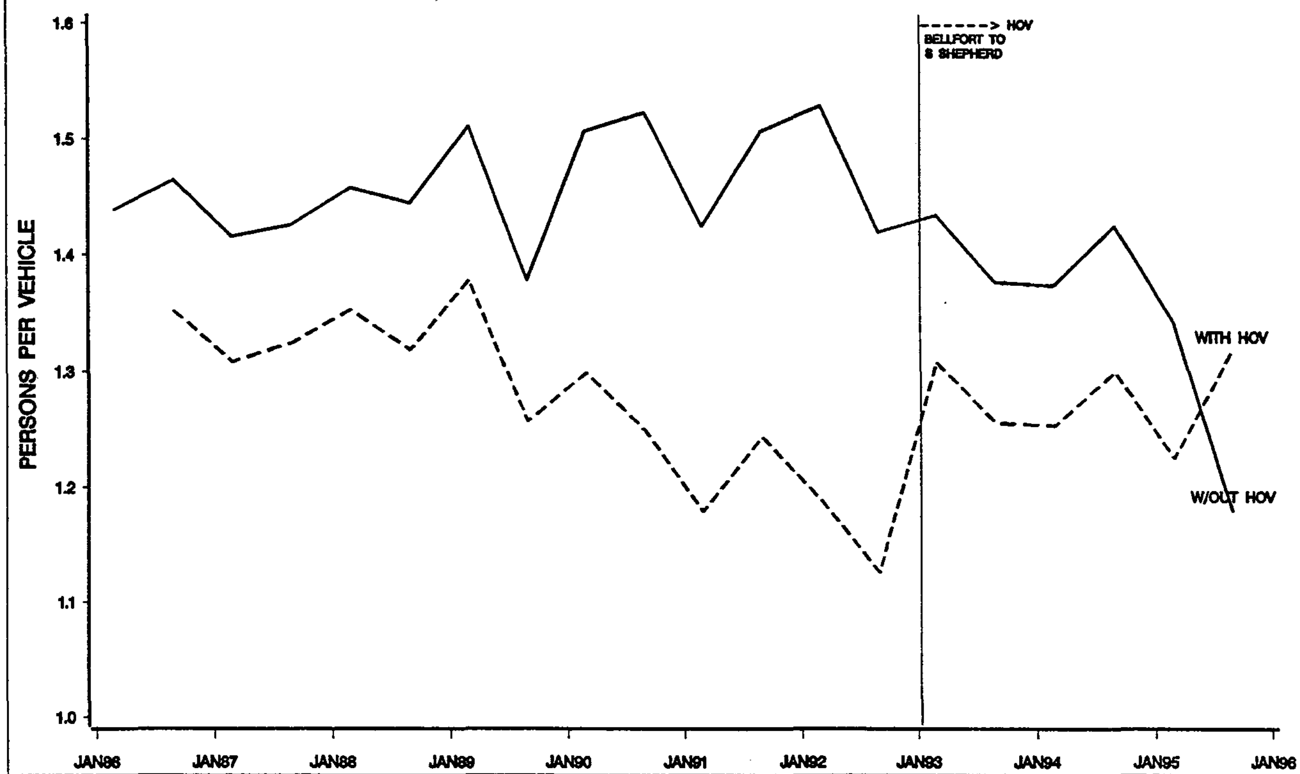


FIGURE E-14. SOUTHWEST FREEWAY (U.S. 59) MAINLANE AND HOV LANE A.M. PEAK HOUR 2+ CARPOOL UTILIZATION

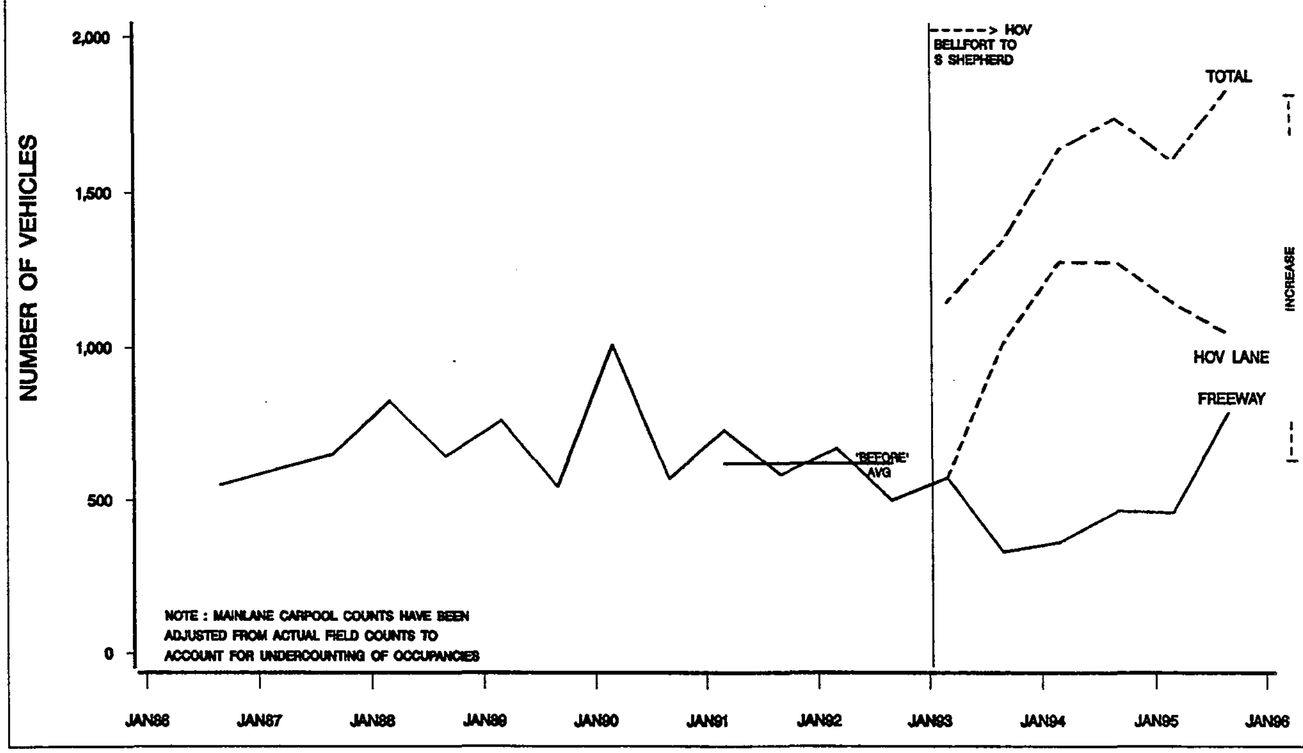


FIGURE E-15. A.M. PEAK HOUR FREEWAY PER LANE EFFICIENCY SOUTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

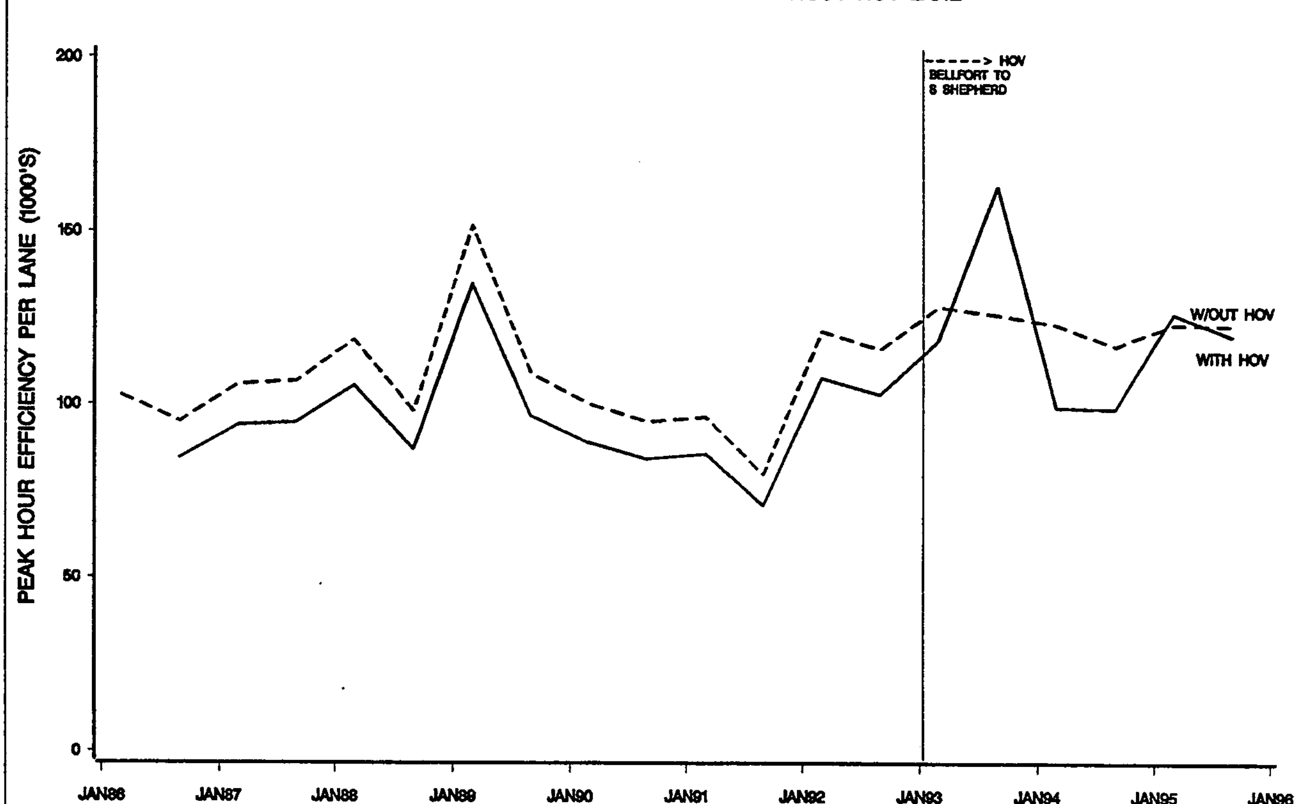


FIGURE E-16. SOUTHWEST FREEWAY (U.S. 59S) MAINLANE AND HOV LANE A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS

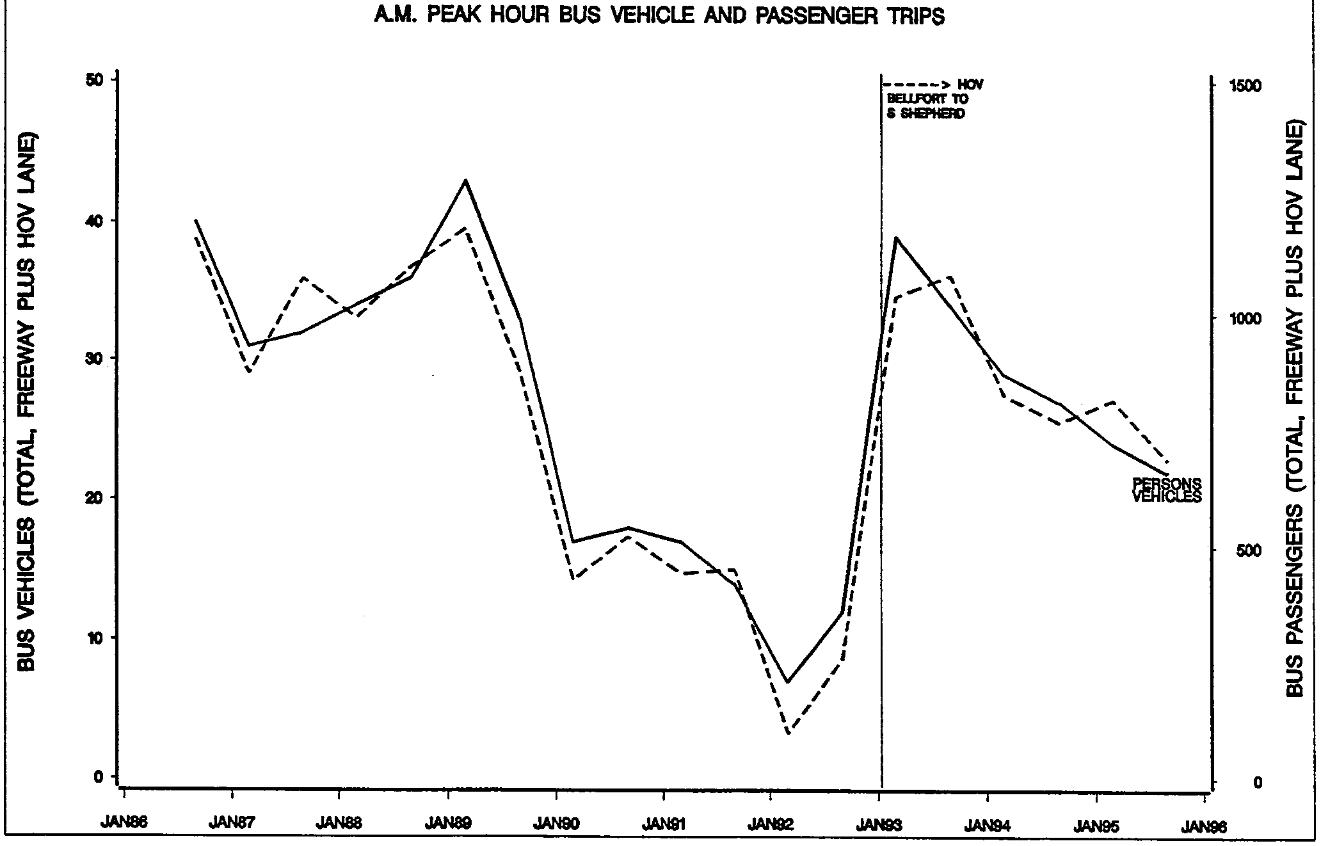


FIGURE E-17. SOUTHWEST FREEWAY (U.S. 59S) MAINLANE AND HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS

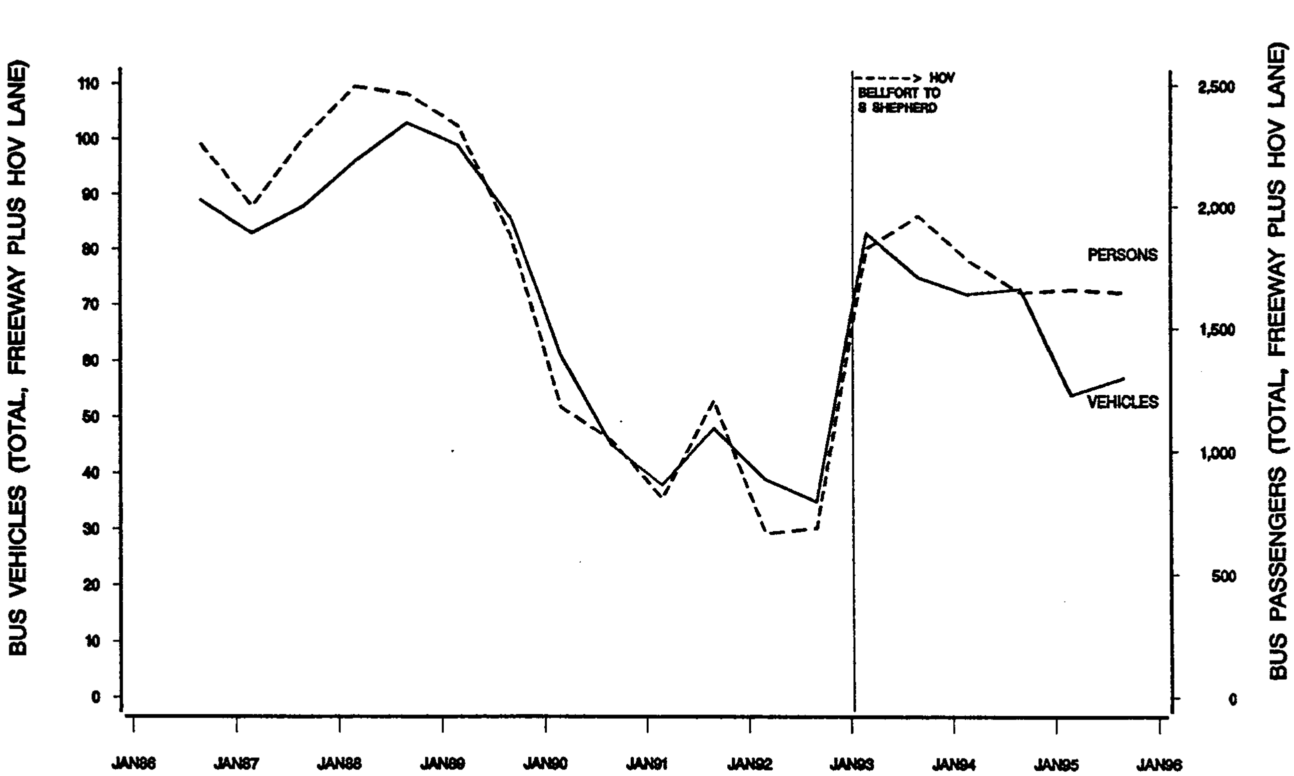


FIGURE E-18. A.M. PEAK PERIOD BUS PASSENGER TRIPS
TOTAL, FREEWAY PLUS HOV LANE VOLUMES
SOUTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

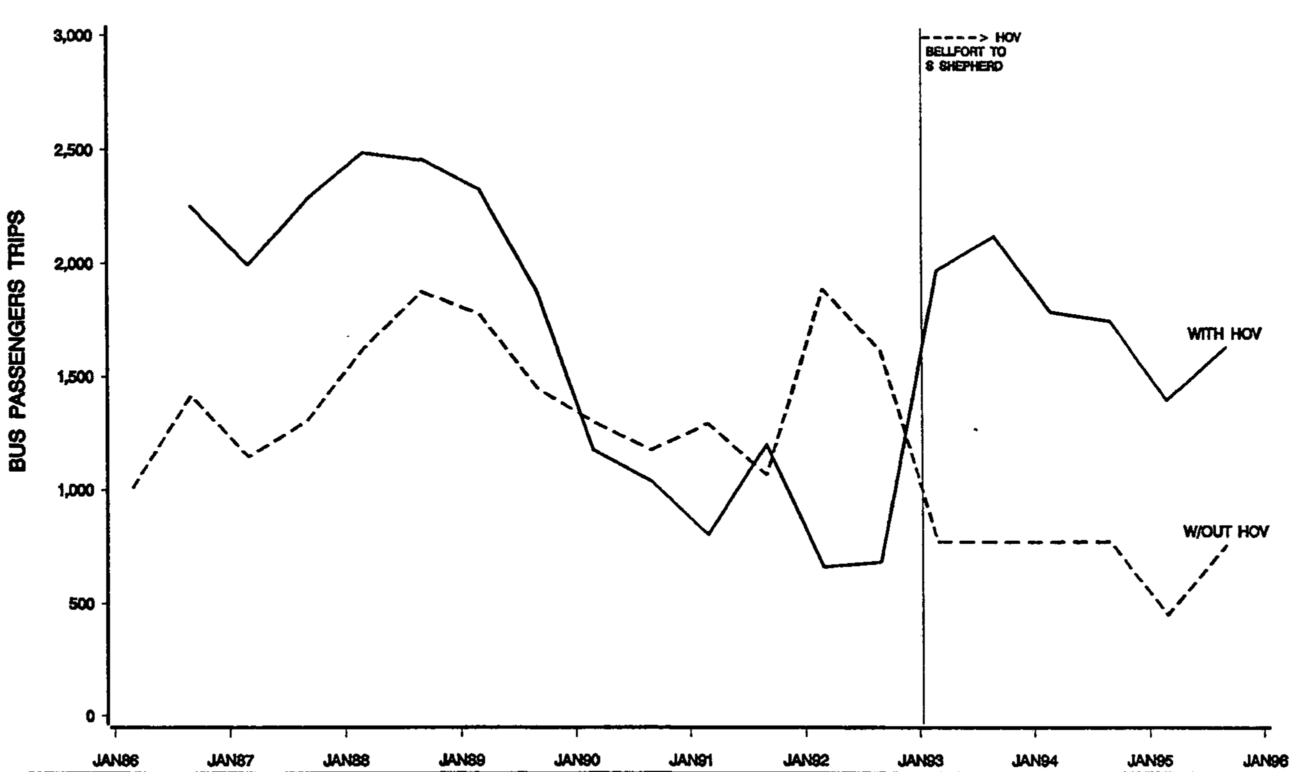


FIGURE E-19. SOUTHWEST FREEWAY (U.S. 59S) CORRIDOR PARK-AND-RIDE DEMAND

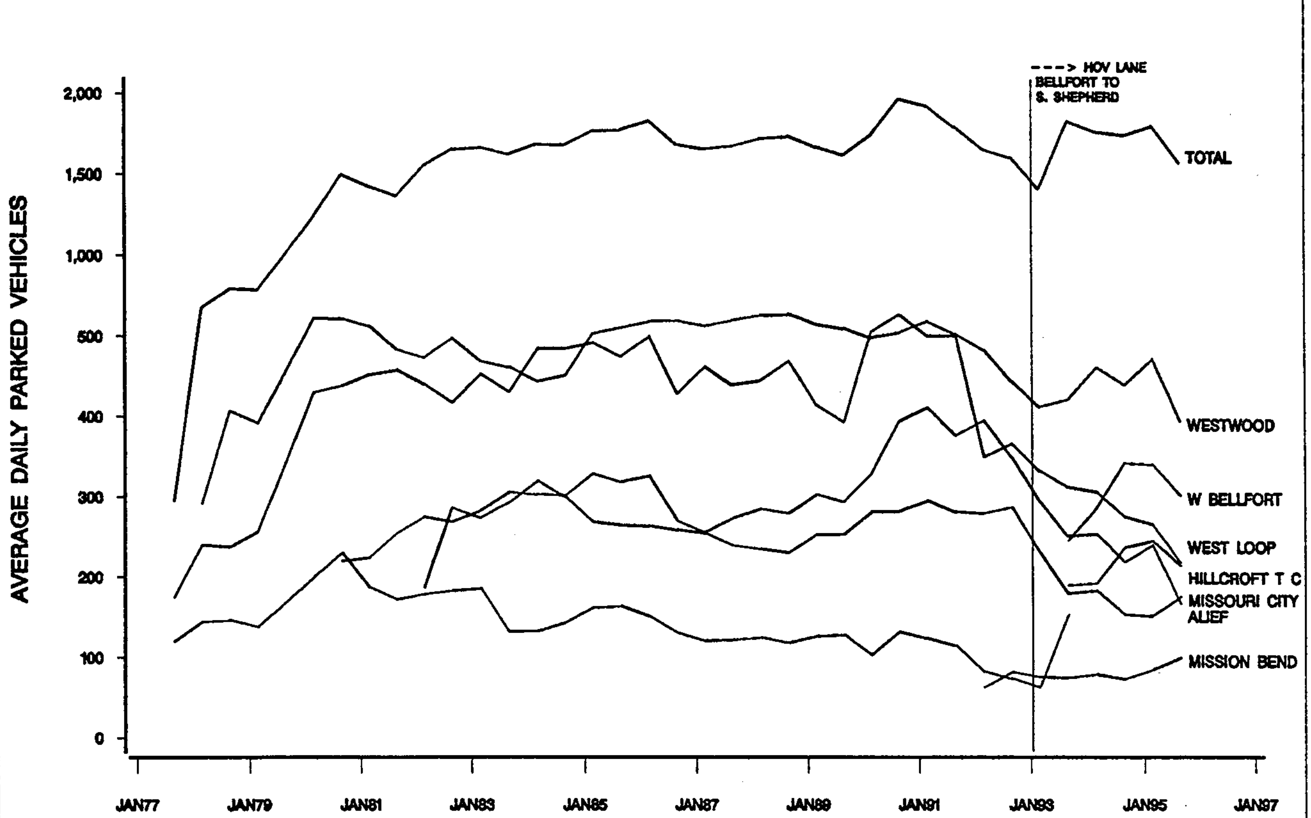
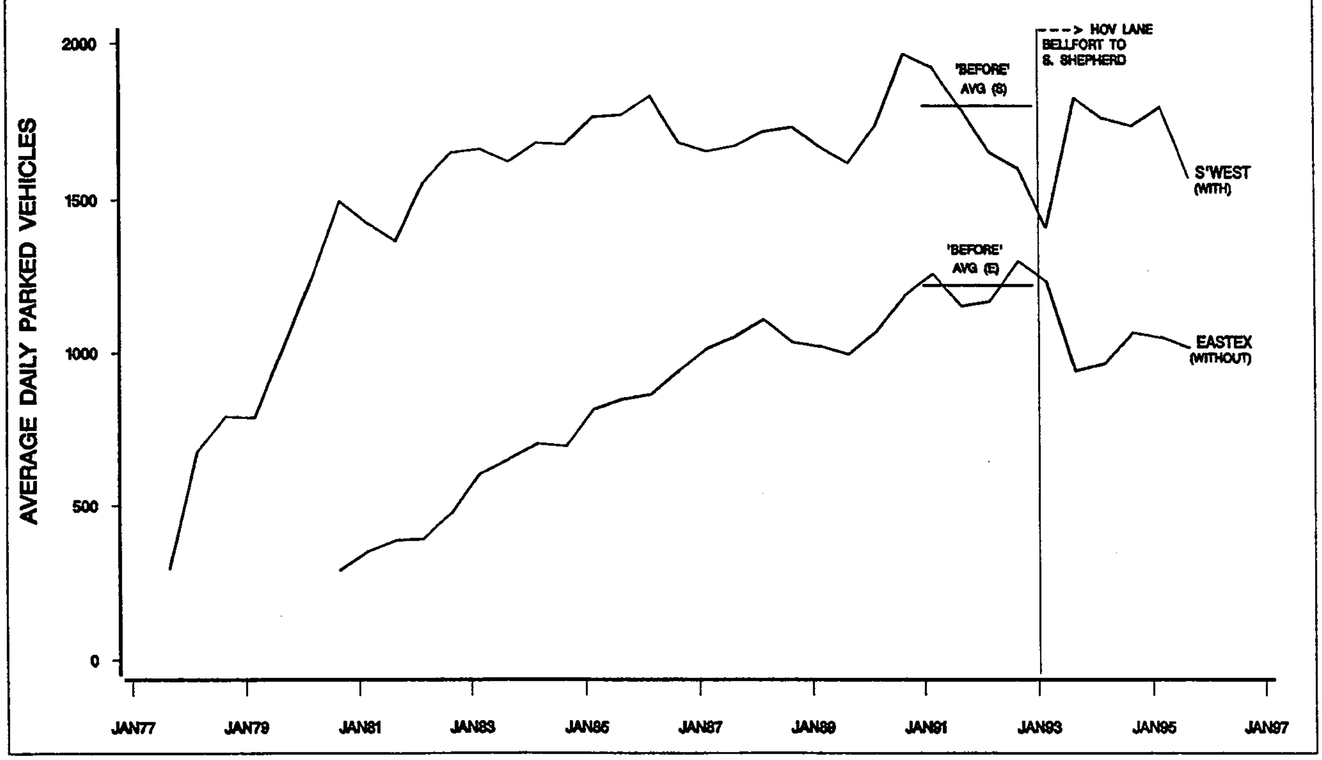


FIGURE E-20. AVERAGE DAILY VEHICLES PARKED AT PARK-AND-RIDE LOTS SOUTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE



APPENDIX F

EAST R. L. THORNTON FREEWAY AND HOV LANE DATA

EAST R. L. THORNTON FREEWAY (IH 30E) & HOV LANE, DALLAS

Table F-1. Summary of A.M. Peak-Direction East R. L. Thornton Freeway and HOV Lane Data, December 1995

Type of Data HOV Lane Became Operational 9/23/91	"Representative" Pre-HOV Lane	"Representative" Current Value	Percent Change
HOV Lane Data			
HOV Lane Length kilometers (miles)			
Morning		8.4 (5.2)	---
Evening		5.3 (3.3)	---
HOV Lane Cost (millions of 1990 dollars)		$12.7	---
Person-Movement			
Peak Hour (7:00-8:00 a.m.)	—	3,494	---
Peak Period (6:00-9:00 a.m.)	—	7,088	---
Total Daily	—	13,572	---
Vehicle Volumes			
Peak Hour	—	1,221	---
Peak Period	—	2,500	---
Vehicle Occupancy, Peak Hour (persons/veh)	—	2.86	---
Accident Rate (i.e. Injury accidents/100 MVK [/100 MVM]), 10/91-12/93[1]	—	5.6 (9.0)	---
Vehicle Breakdowns (VMK/Breakdown [VMT/Breakdown]), 10/91-12/93	—	52,750 (32,764)	---
Violation Rate (6:00-9:00 a.m.)	—	0.7%	---
Peak Hour Lane Efficiency (1000's)[2]	—	270 (168)	---
Annual Value of User Time Saved (millions)[3]	—	$1.6 - $3.2	---
Freeway Mainlane Data (see note)			
Person Movement			
Peak Hour	7,689	7,270	-5%
Peak Period (6:00-9:00 a.m.)	23,030	19,271	-16%
Vehicle Volume			
Peak Hour	5,692	6,927	+22%
Peak Period	17,946	18,260	+2%
Vehicle Occupancy, Peak Hour (persons/veh)	1.35	1.05	-22%
Accident Rate (i.e. Injury accidents/100 MVK [/100 MVM])[1]	14.0 (22.6)	17.3 (27.9)	+24%
Avg. Operating Speed[4] (kph [mph])			
Peak Hour	34 (21)	43 (27)	+26%
Peak Period	48 (30)	61 (38)	+27%
Peak Hour Lane Efficiency (1000's)[2]	66 (41)	79 (49)	+20%

Source: Texas Transportation Institute. The Texas A&M University System.

[1]In order to directly compare accidents to Houston, this analysis includes only injury accidents. Accidents were analyzed between Pearl/Central Expressway and Jim Miller Road, a distance of approximately 8.4 kilometers (5.2 miles). "Before" data are for the period 9/90 through 9/91. "After" data are for the period from 10/91 to 12/95. Current files include only officer-reported accidents. 1995 freeway volumes estimated by TTI.

[2]This represents the multiple of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.

[3]Based on time savings for HOV lane users in 1995 and HOV lane volumes in 1995, an annual estimate of travel time savings to HOV lane users is developed. A value of time of $11.37/hour is used based on the value applied in the Highway Economic Evaluation Model.

[4]From Jim Miller to Central Expressway, the distance is 8.4 kilometers (5.2 miles). The morning HOV lane is in place over this section.

Table F-1. Summary of A.M. Peak-Direction East R. L. Thornton Freeway and HOV Lane Data, December 1995 (Continued)

Type of Data HOV Lane Became Operational 9/23/91	"Representative" Pre-HOV Lane	"Representative" Current Value	Percent Change
Combined Freeway Mainlane and HOV Lane Data			
Total Person Movement			
Peak Hour	7,689	10,764	+40%
Peak Period	23,030	24,869	+8%
Vehicle Volume			
Peak Hour	5,692	8,148	+43%
Peak Period	17,946	20,760	+16%
Vehicle Occupancy			
Peak Hour	1.35	1.32	-2%
Peak Period	1.26	1.26	0%
2+ Carpool Volumes[1]			
Peak Hour	596	1,619	+172%
Peak Period	1,903	3,411	+79%
Travel Time (minutes)			
Peak Hour	14.7[2]	6.9[3]	-53%
Peak Period	10.6[2]	6.3	-41%
Peak Hour Lane Efficiency (1000's)[4]	66 (41)	118 (73)	+78%
Transit Data			
Bus Vehicle Trips			
Peak Hour	41	48	+17%
Peak Period	103	105	+2%
Bus Passenger Trips			
Peak Hour	1,283	1,038	-19%
Peak Period	2,819	2,149	-24%
Bus Occupancy (persons/bus)			
Peak Hour	31.3	21.6	-31%
Peak Period	27.4	20.5	-25%
Vehicles Parked in Corridor Park & Ride Lots	847	908	+7%
Bus Operating Speed[5] (kph [mph])			
Peak Hour	34 (21)[2]	77 (48)[3]	+126%
Peak Period	48 (30)[2]	84 (52)	+75%

Source: Texas Transportation Institute. The Texas A&M University System.

[1]Carpool counts are adjusted in an effort to compensate for under counting of occupancies in the field.

[2]Data pertain to operation in the freeway mainlanes.

[3]Data pertain to operation in the HOV lane.

[4]This represents the multiple of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.

[5]From Jim Miller to Central Expressway, the distance is 8.4 kilometers (5.2 miles). The HOV lane is in place over this section.

Table F-2. Comparison of Measures of Effectiveness, Freeway with (East Thornton, IH 30E) and Freeway Without (South Thornton IH 35E) HOV Lane, Dallas

Measure of Effectiveness	"Representative" Pre-HOV Lane Value	"Representative" Current Value	Percent Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/HOV lane	1.35	1.32	-2%
Freeway w/o HOV lane	1.25	1.13	-10%
Peak-Hour 2+ Carpool Volume			
Freeway w/HOV lane	596	1,619	+172%
Freeway w/o HOV lane	802	846	+5%
Bus Passengers, Peak Period			
Freeway w/HOV lane	2,819	2,149	-24%
Freeway w/o HOV lane	2,540	1,642	-35%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	847	908	+7%
Freeway w/o HOV lane	425	487	+15%
Facility Per Lane Efficiency[1]			
Freeway w/HOV lane	66 (41)	118 (73)	+79%
Freeway w/o HOV lane	108 (67)	111 (69)	+3%

[1]This represents the multiple of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.

HOV LANE DATA

DESCRIPTION

- The evening operation (5.3 kilometers [3.3 miles]) opened September 23, 1991.
- The morning operation (5.3 kilometers [3.3 miles]) opened September 30, 1991.
- The morning operation (8.4 kilometers [5.2 miles]) extended November 4, 1991.
- The capital cost for the completed facility in 1990 dollars was $12.7 million. The following page provides a more detailed cost breakdown (including dates).
- Selected milestone dates are listed below. The capital cost table shows other dates.
- 9/23/91 Evening lane opens Central Expressway to Dolphin Road (5.3 kilometers [3.3 miles]), used by buses and vans.
- 9/30/91 Morning lane opens Dolphin Road to Central Expressway (5.3 kilometers [3.3 miles]), used by buses and vans.
- 10/7/91 3+ carpools allowed onto HOV lane.
- 10/21/91 2+ carpools allowed onto HOV lane.

- 11/04/91 Morning operation extended to begin at Jim Miller (8.4 kilometers [5.2 miles, total]).
- 11/25/91 DART adds bus service to existing routes.

Table F-3. Estimated Capital Costs (millions), East R.L. Thornton HOV Lane

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1995 dollars
HOV Lane and Ramps (1990)			
Barrier	$6.0	1.21	$7.3
Barrier Machine(s)	0.9	1.21	1.1
Contraflow Lane	5.6	1.21	6.8
Support Vehicles	0.2	1.21	0.2
TOTAL COST	$12.7		$15.4
COST PER KILOMETER (8.4 kilometers [5.2 miles])	$1.5 ($2.4)		$1.8 ($3.0)

Source: Compiled by TTI from data provided by DART and TxDOT.

PERSON MOVEMENT

- In September 1995, HOV lane served 13,572 person trips per day.
- A.M. Peak Hour, 3,494 persons/hour.
  - 1,003 (29%) by bus, 49 (1%) by vanpool, 2,435 (70%) by carpool, and 7 by motorcycle (Figure F-1).
  - Average HOV lane vehicle occupancy = 2.86 persons/vehicle.
- A.M. Peak Period, 7,088 persons.
  - 1,977 (28%) by bus, 89 (1%) by vanpool, by carpool 5,009 (71%), and 13 by motorcycle (Figure F-2).

VEHICLE MOVEMENT

- A.M. Peak Hour, 1,221 vph
  - 42 (3%) buses, 9 (1%) vans, 1,164 (95%) carpools, and 6 (1%) by motorcycle (Figure F-3).
- A.M. Peak Period, 2,500 vehicles
  - 84 (3%) buses, 16 (1%) vans, 2,386 (95%) carpools, and 14 (1%) by motorcycle (Figure F-4).

ACCIDENT RATE

- For the period from October 1991 through September 1995, the HOV lane accident rate was 5.6 injury accidents per 100 million vehicle kilometers of travel (9.0 injury accidents per 100 million vehicle miles).

VEHICLE BREAKDOWN RATES

- As measured for 1/93 to 9/95, the following rate has been observed.
  - The weighted average for all vehicle types is one breakdown per 52,750 VKT (32,764 VMT).

VIOLATION RATE

- The observed violation rate (vehicles on the HOV lane not eligible to use the HOV lane), varies by time period.
  - For the overall a.m. peak period, it is 0.7%.

PEAK HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. For the HOV lane, this value (expressed in 1000's) is approximately 270 (3,494 passengers at 77 kph) or 168 (3,494 passengers at 48 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane experienced an average travel time savings of 6 minutes during the morning peak hour in 1994 (Figure F-5).

- Table F-4 indicates that, on a typical non-incident day, travel time savings of approximately 549 hours (32,951 min.) are realized. Assuming 250 days of operation, annual savings would be 137,432 hours. At $11.37/hour, this equates to $1.56 million per year. This is extremely conservative since it does not consider travel time savings due to incidents on the freeway. Data from Houston suggest that increasing this value by 100% to account for incidents would be reasonable. Thus, conservative estimates of travel time savings to HOV lane users in the range of $1.56 to $3.12 million per year.

FREEWAY DATA

NOTES

- For purposes of safety and visibility, freeway volumes are counted near Dolphin Road between an entrance ramp and an exit ramp. This location is not necessarily the highest traffic volume section; however, the location gives reasonable estimates of traffic volumes which can be used for monitoring trends.

PERSON MOVEMENT

- In the a.m. peak hour, person movement has decreased by 5% relative to pre-HOV conditions (Figure F-6).

- In the a.m. peak period, person movement has decreased by 16% relative to pre-HOV conditions (Figure F-7).

VEHICLE VOLUME

- In the a.m. peak hour, vehicle volume has increased by 22% relative to pre-HOV conditions (Figure F-6).

- In the a.m. peak period, vehicle volume has increased by 2% relative to pre-HOV conditions (Figure F-7).

VEHICLE OCCUPANCY

- In the a.m. peak hour, mainlane occupancy has decreased by 22% relative to pre-HOV conditions (from 1.35 to 1.05).

- In the a.m. peak period, mainlane occupancy has decreased by 17%, relative to pre-HOV conditions (from 1.28 to 1.06).

ACCIDENT RATE

- Implementation of the HOV lane resulted in narrower freeway lanes and no inside emergency shoulder in the off-peak direction during HOV lane operation.

- The accident data shown are for the section between Pearl/Central Expressway and Jim Miller Road. The accident rate for the period (10/90-9/91) preceding Phase 1 of the HOV lane was 14.0 accidents per 100 million vehicle kilometers (100 MVK) (22.6 accidents per 100 million vehicle miles [100 MVM]). For the period from 10/91 to 9/95, the freeway accident rate was 17.3 accidents/100 MVK (27.9 accidents/100 MVM). These statistics do not include driver reported accidents; current accident files include only officer reported accidents.

AVERAGE OPERATING SPEED

- In comparison to pre-HOV lane conditions, mainlane operating speeds have increased by 26% in the peak hour and 27% in the peak period (Figure F-8).

PEAK HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of per lane efficiency.

- For the freeway mainlanes, an increase in per lane efficiency of 20% has occurred.

COMBINED FREEWAY MAINLANE AND HOV LANE DATA

TOTAL PERSON MOVEMENT

- Percent by HOV lane, a.m. peak hour.
    - The HOV lane is responsible for 32% of peak-hour person movement (HOV lane = 3,494; freeway = 7,270) and 27% of peak-period (HOV lane = 7,088; freeway = 19,271) person movement.

- Increase in a.m. person movement at Dolphin Road relative to pre-HOV lane operations.
    - Provision of the HOV lane increased total directional lanes by 25% in the peak period.
    - Total peak-hour person movement has increased by 40% from 7,689 to 10,764 (Figure F-9). Peak-period person movement has increased by 8% from 23,030 to 24,869 (Figure F-10).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.32 -- a 2% decrease over the pre-HOV lane occupancy (Figure F-11). Occupancy in the peak period has remained relatively constant (Figure F-12).

- While the occupancy on the East Thornton Freeway has increased, freeways which do not have HOV lanes have experienced a decrease in occupancy (Figure F-13).

CARPOOL VOLUMES

- In the a.m. peak hour, the total number of 2+ carpools (freeway plus HOV lane) has increased by 172% compared to pre-HOV lane levels (Figure F-14).

Table F-4. Travel Time Savings for R. L. Thornton HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1995)

Time of Day	Measured Travel Time: Freeway (min)	Measured Travel Time: HOV (min)	Measured Travel Time: Savings (min)	HOV Lane Person Trips: Carpool	HOV Lane Person Trips: Vanpool	HOV Lane Person Trips: Bus	HOV Lane Person Trips: Total	Travel Time Saved (Person-Minutes)
Westbound A.M. Travel Time Savings for Thornton HOV Lane								
Section from Jim Miller to Central Expressway								
6:00	5.50	5.75	-0.25	94	1	85	181	-46
6:15	7.33	5.91	1.42	244	6	185	435	617
6:30	8.38	6.26	2.11	330	5	163	498	1,052
6:45	8.25	6.59	1.66	416	5	178	601	997
7:00	8.28	6.70	1.58	529	10	225	764	1,210
7:15	10.30	7.16	3.14	612	12	231	857	2,687
7:30	14.67	6.83	7.83	636	21	325	984	7,704
7:45	14.05	7.10	6.95	617	7	223	848	5,890
8:00	10.53	6.40	4.13	454	4	141	601	2,480
8:15	9.22	6.26	2.95	463	4	73	540	1,595
8:30	6.28	5.70	0.58	325	11	90	426	245
8:45	5.52	5.52	0.00	266	7	60	334	0.00
9:00	5.40	5.52	-0.12	---	---	---	---	---
Peak Period Total				4,984	91	1,978	7,067	24,430
Eastbound P.M. Travel Time Savings for Thornton HOV Lane								
Section from Central Expressway to Dolphin								
4:00	3.77	3.54	0.23	311	2	153	466	107
4:15	3.95	3.87	0.09	318	3	163	484	42
4:30	3.87	3.77	0.09	467	4	173	644	59
4:45	5.19	4.46	0.73	490	3	243	737	537
5:00	6.07	4.46	1.61	547	28	230	806	1,297
5:15	7.49	5.14	2.35	578	5	398	982	2,311
5:30	8.22	5.64	2.58	451	4	185	641	1,654
5:45	7.57	4.24	3.32	429	6	131	566	1,883
6:00	5.70	4.15	1.55	292	1	90	383	594
6:15	4.02	3.94	0.08	220	1	65	287	22
6:30	3.44	3.42	0.02	191	0	55	246	5
6:45	3.51	3.43	0.09	108	0	15	123	11
Peak Period Total				4,401	57	1,899	6,365	8,521

PEAK HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. The average efficiency of a lane on the freeway (4 freeway lanes plus 1 HOV lane) has increased by 79% since the implementation of the HOV lane (Figure F-15). The per-lane efficiency has increased slightly during this same time period on freeways not having HOV lanes.

BUS TRANSIT DATA

BUS VEHICLE AND PASSENGER TRIPS

- In the a.m. peak hour, bus vehicle trips have been increased by 17% since the HOV lane opened, and a 19% decrease in bus ridership has also resulted (Figure F-16). In the peak period, a 2% increase has occurred in bus trips and a 24% decrease in bus ridership has resulted (Figure F-17).

PARK-AND-RIDE

- Prior to opening the HOV lane, approximately 847 vehicles were parked in corridor park-and-ride lots; this has increased 7% to a current level of 908 (Figure F-19).

- The number of parked vehicles in the representative freeway corridor without an HOV lane (South R.L. Thornton Freeway) has increased (15%). (Figure F-20).

FIGURE F-1. EAST R.L. THORNTON FREEWAY (IH 30E) HOV LANE
A.M. PEAK HOUR HOV LANE PERSON MOVEMENT

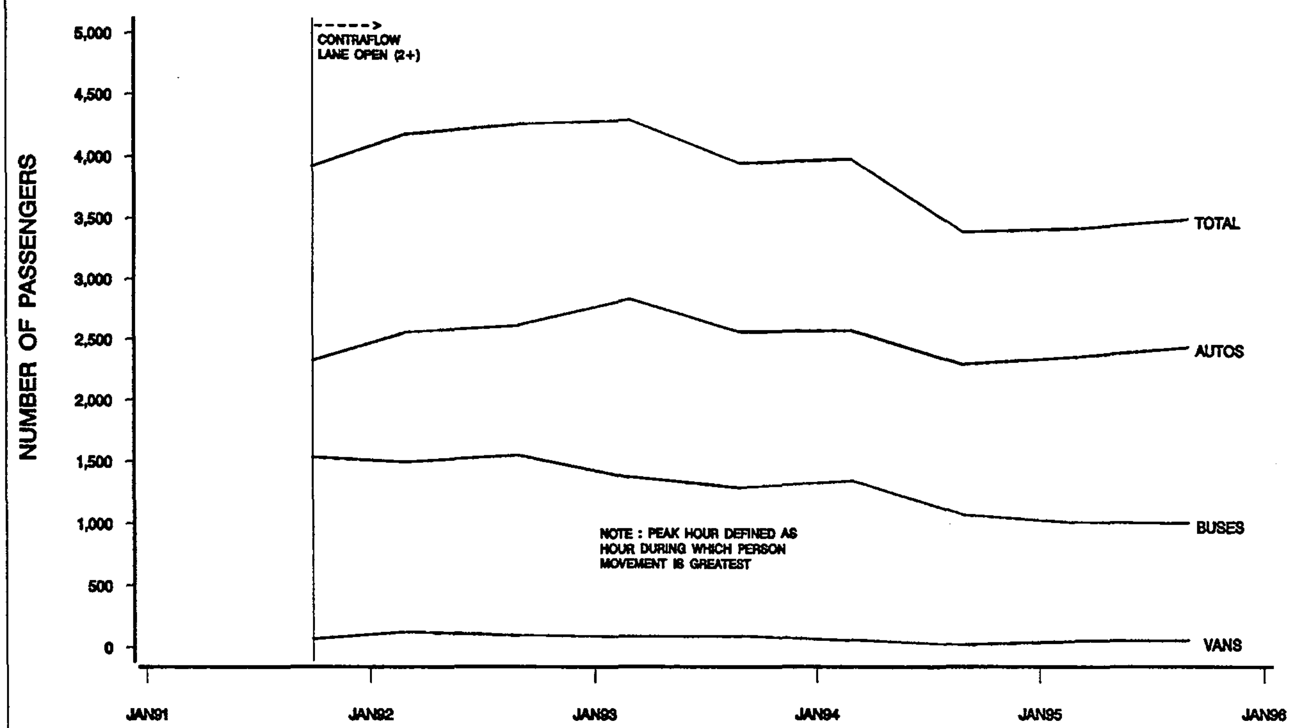


FIGURE F-2. EAST R.L. THORNTON FREEWAY (IH 30E) HOV LANE
A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT

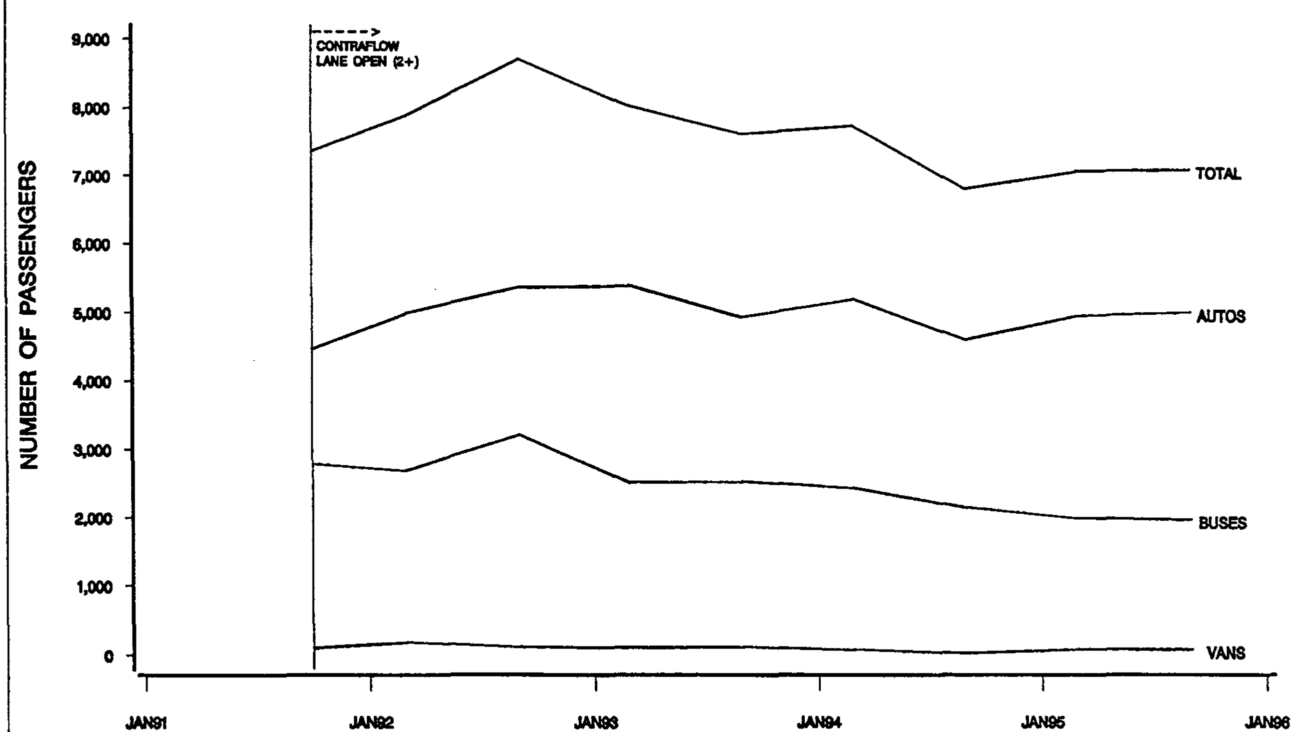


FIGURE F-3. EAST R.L. THORNTON FREEWAY (IH 30E) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION

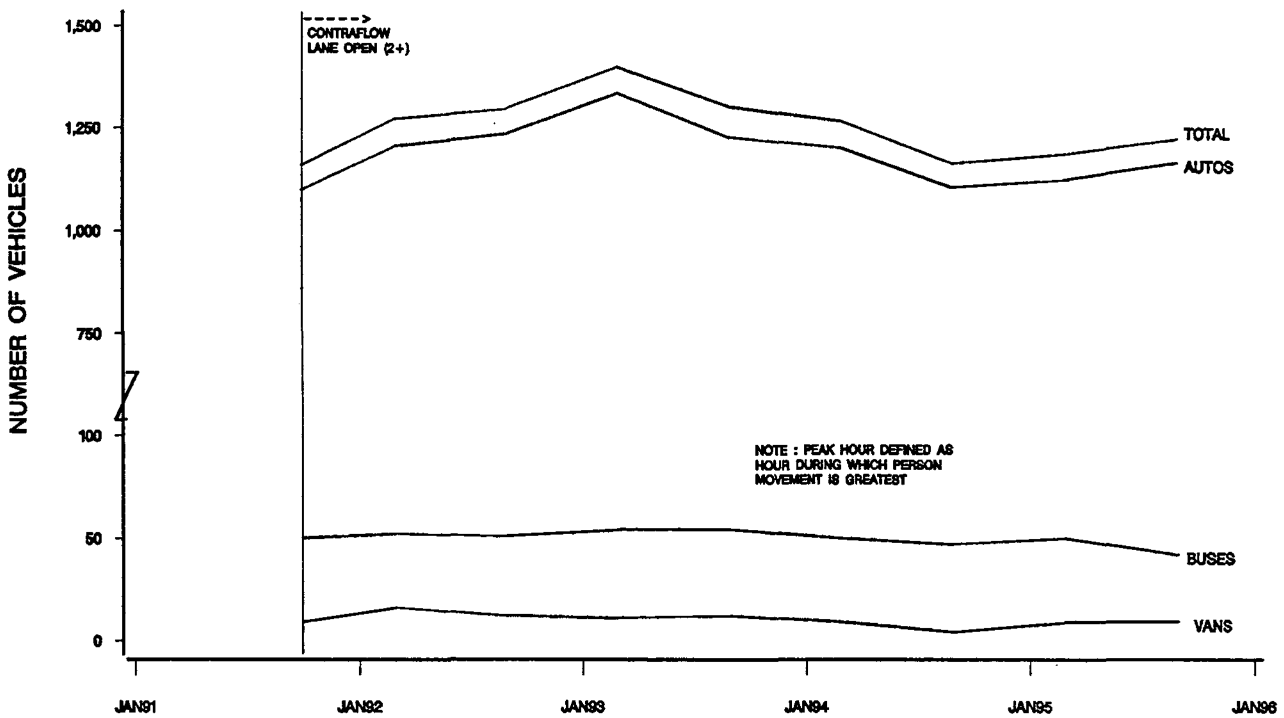


FIGURE F-4. EAST R.L. THORNTON FREEWAY (IH 30E) HOV LANE
A.M. PEAK PERIOD HOV LANE VEHICLE UTILIZATION

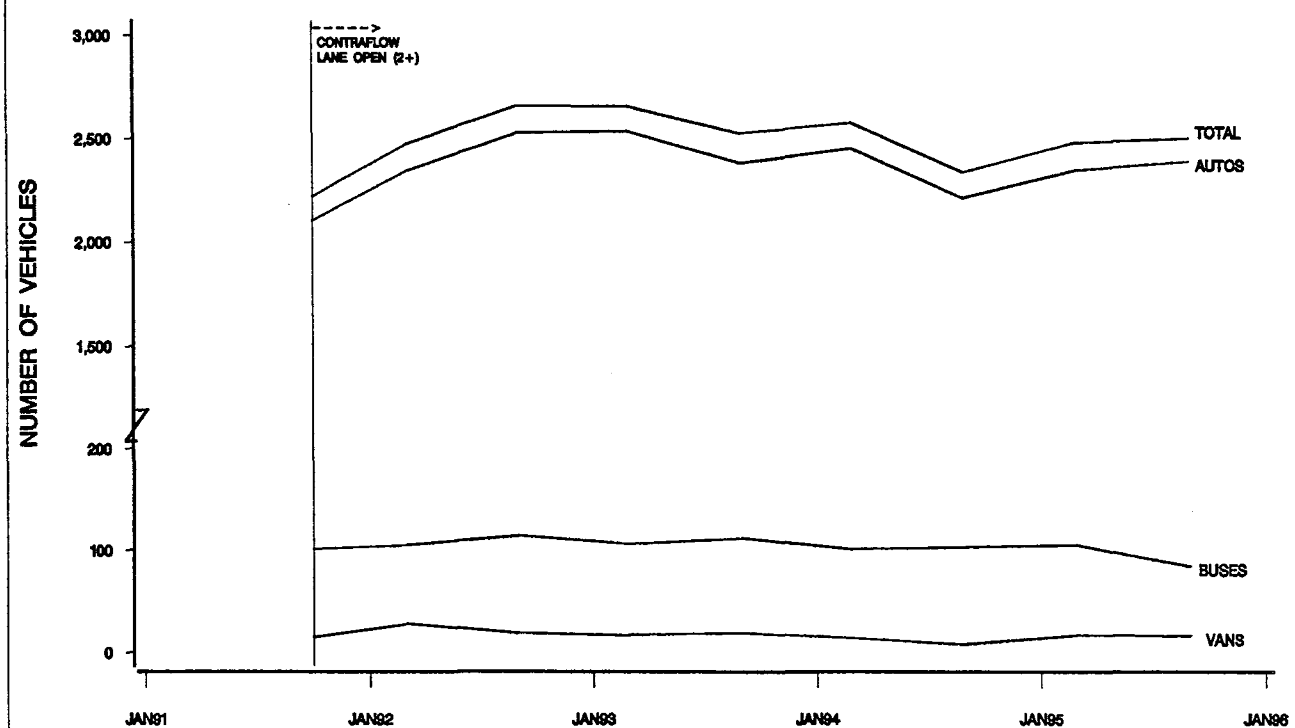


FIGURE F-5. EAST R.L. THORNTON (IH 30E) MAINLANES AND HOV LANE A.M. TRAVEL TIME

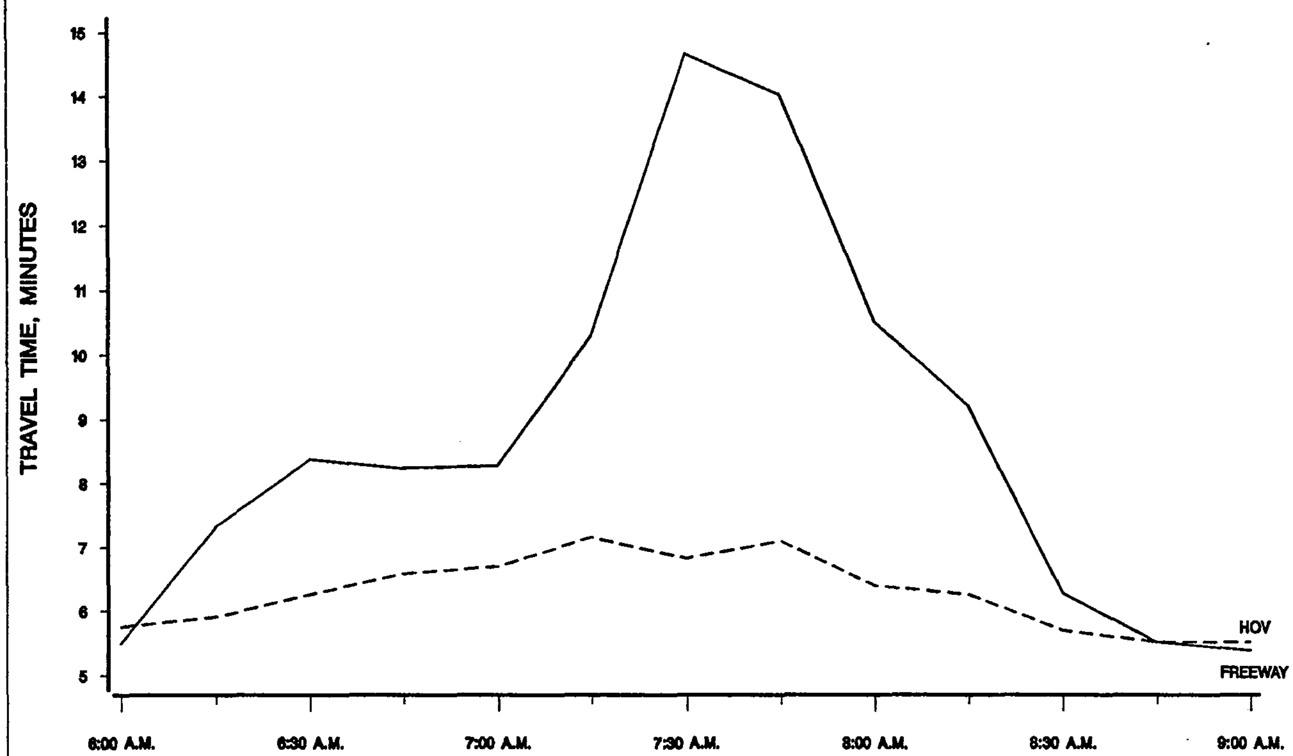


FIGURE F-6. EAST R.L. THORNTON FREEWAY (IH 30E)
A.M. PEAK HOUR MAINLANE TRIPS

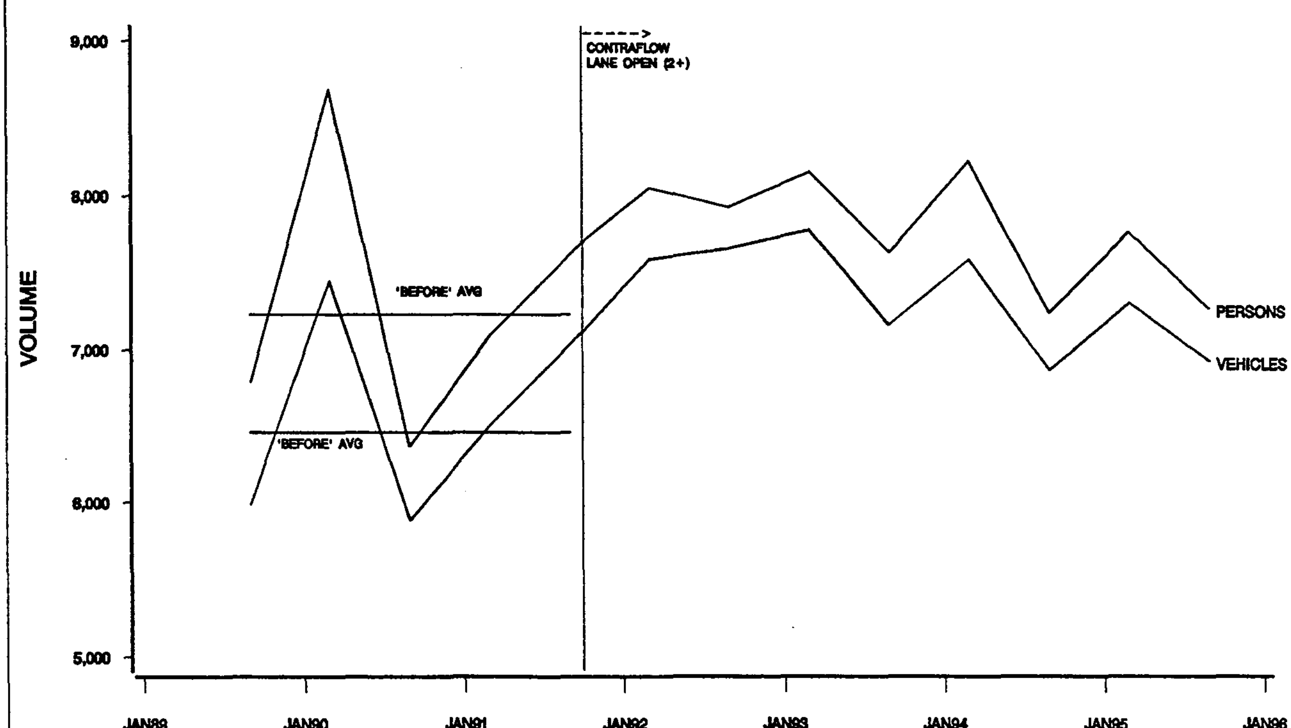


FIGURE F-7. EAST R.L. THORNTON FREEWAY (IH 30E)
A.M. PEAK PERIOD MAINLANE TRIPS

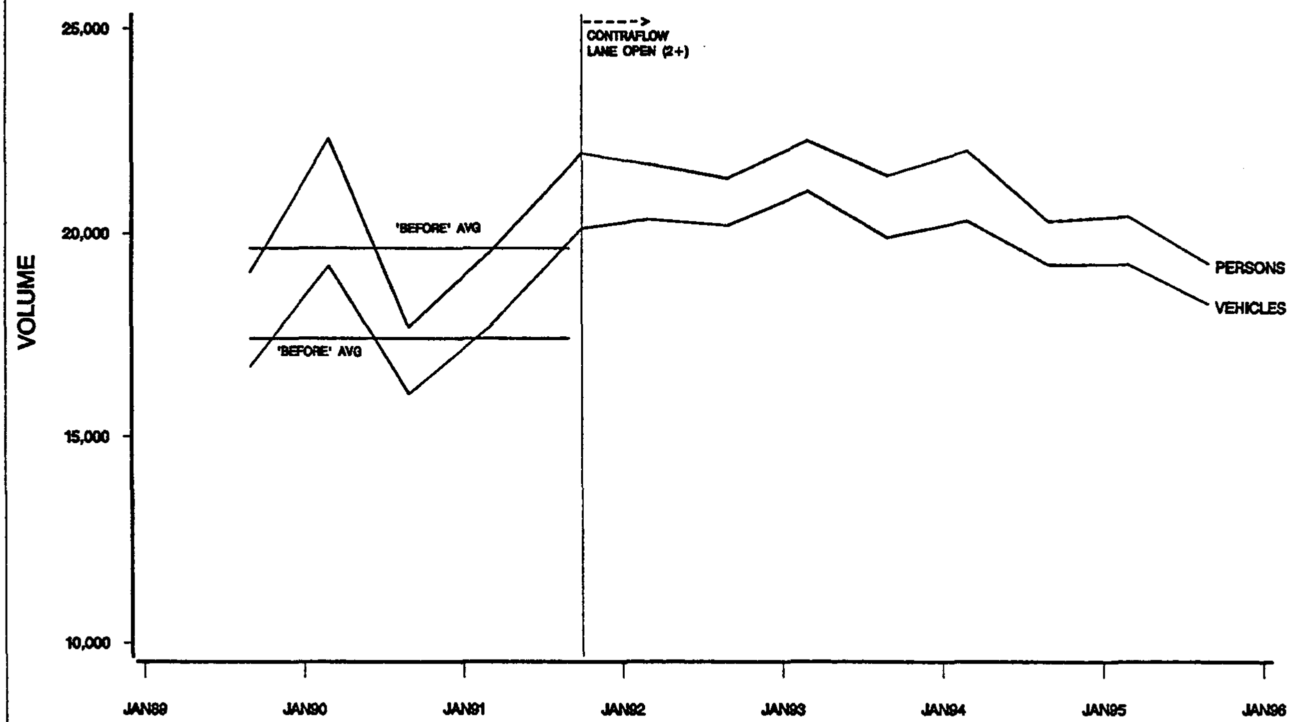


FIGURE F-8. EAST R.L. THORNTON (IH 30E) MAINLANE TRAVEL TIME AND SPEED SURVEY
WESTBOUND, JIM MILLER TO ERVAY EXIT
A.M. PEAK PERIOD

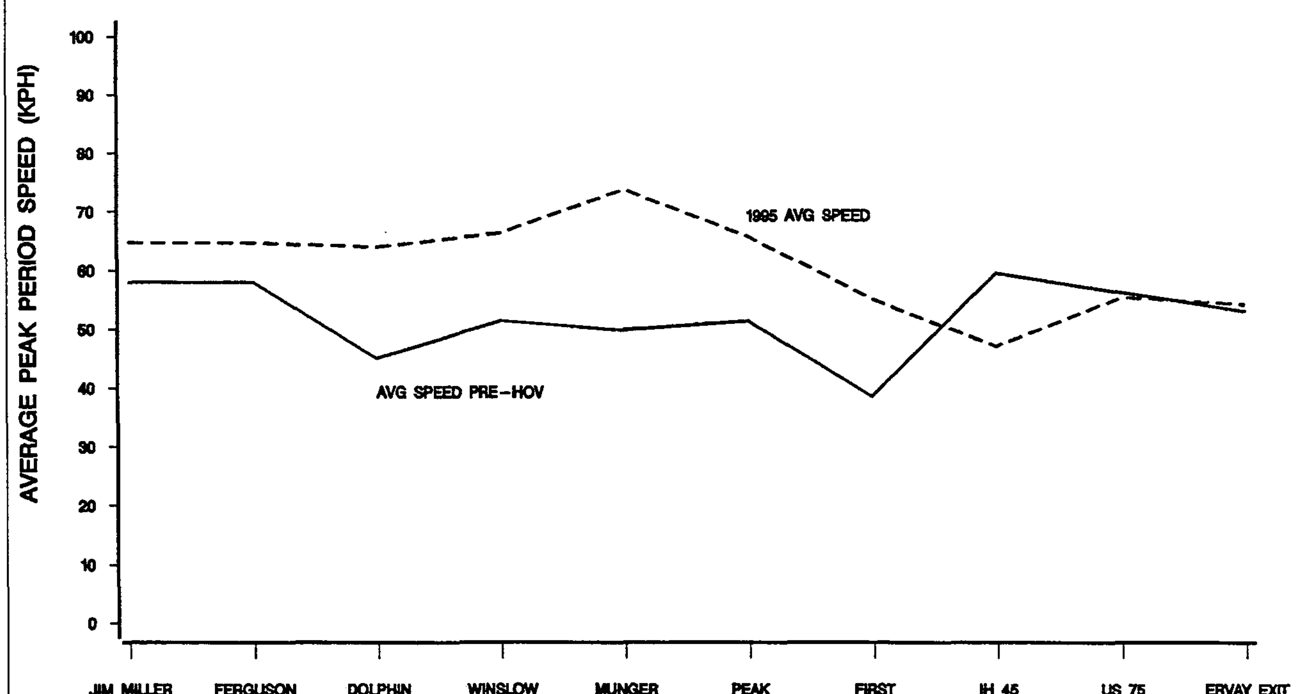


FIGURE F-9. EAST R.L. THORNTON FREEWAY (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK HOUR PERSON TRIPS

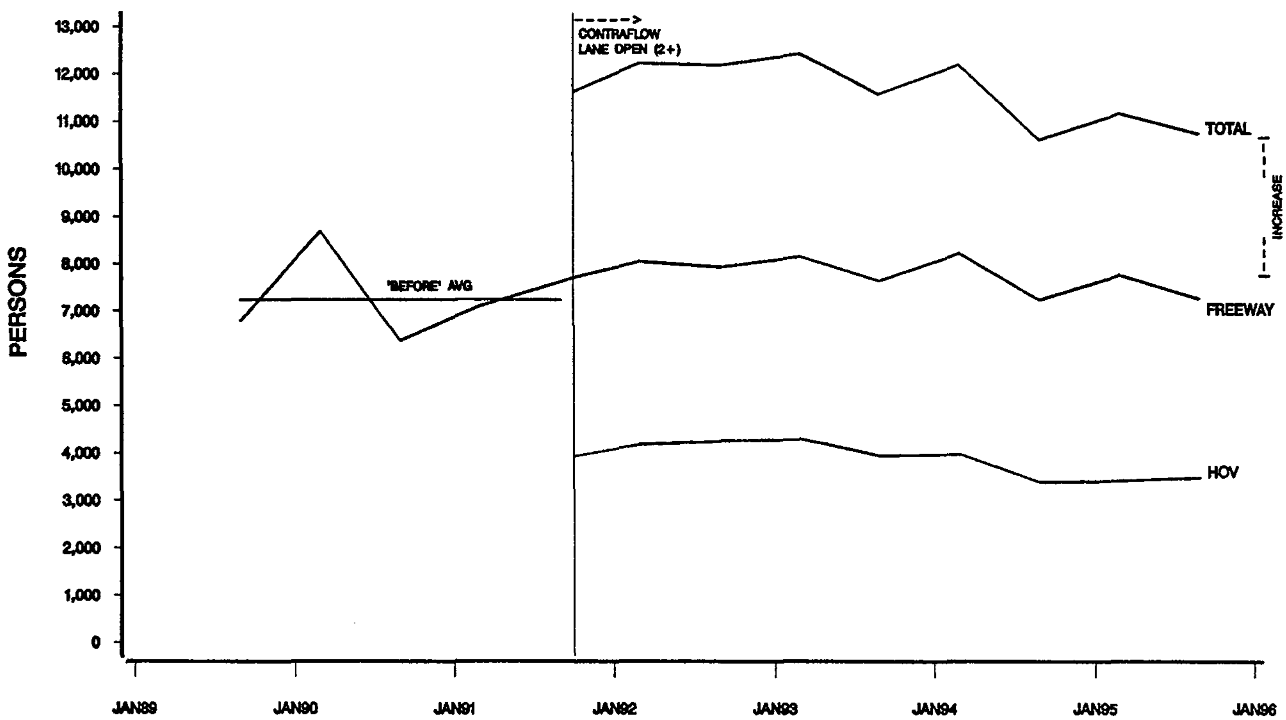


FIGURE F-10. EAST R.L. THORNTON FREEWAY (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK PERIOD PERSON TRIPS

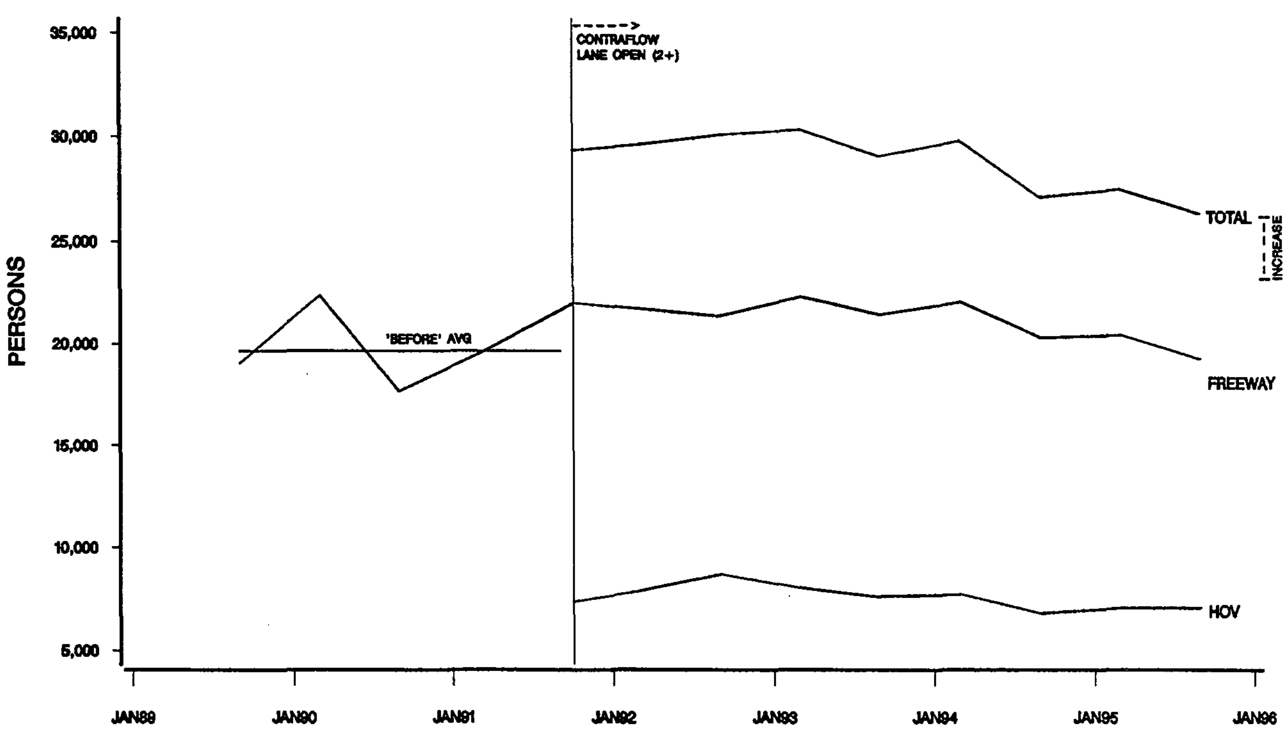


FIGURE F-11. EAST R.L. THORNTON FREEWAY (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK HOUR AVERAGE OCCUPANCY

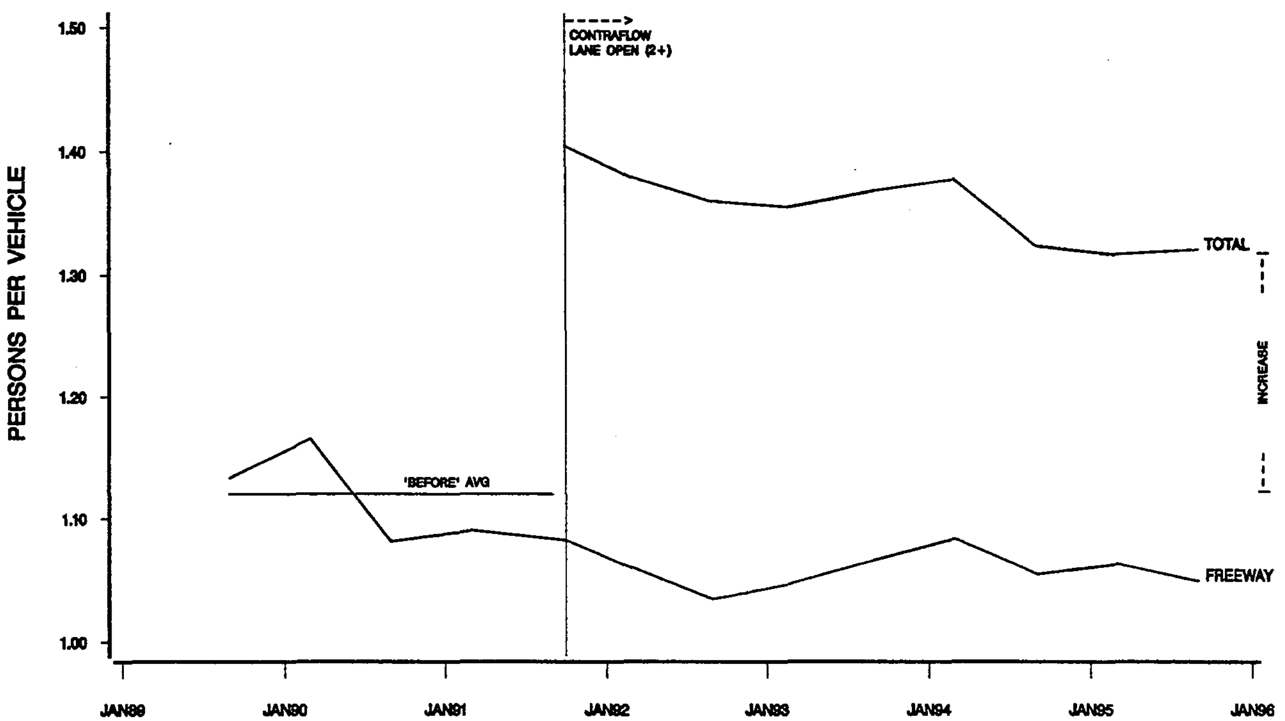


FIGURE F-12. EAST R.L. THORNTON FREEWAY (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK PERIOD AVERAGE OCCUPANCY

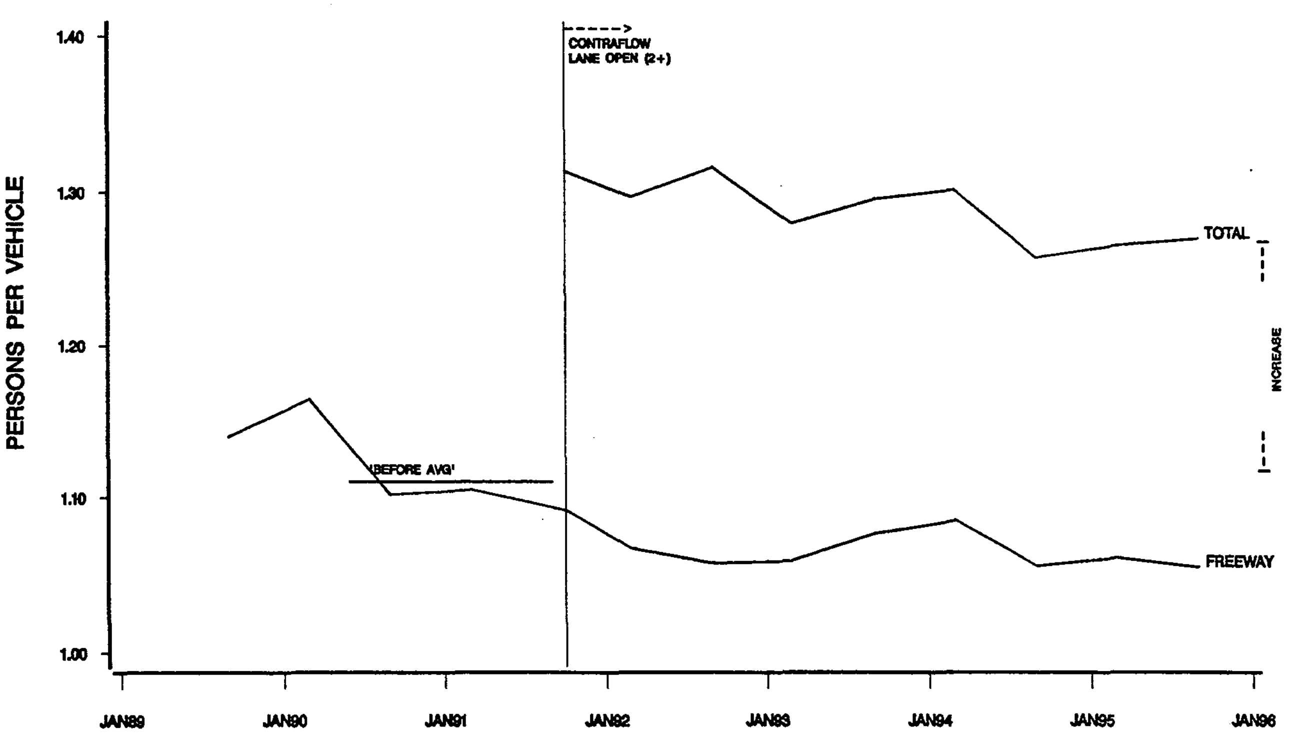


FIGURE F-13. A.M. PEAK HOUR AVERAGE OCCUPANCY
EAST R.L. THORNTON (IH 30E) AND FREEWAY WITHOUT HOV LANE

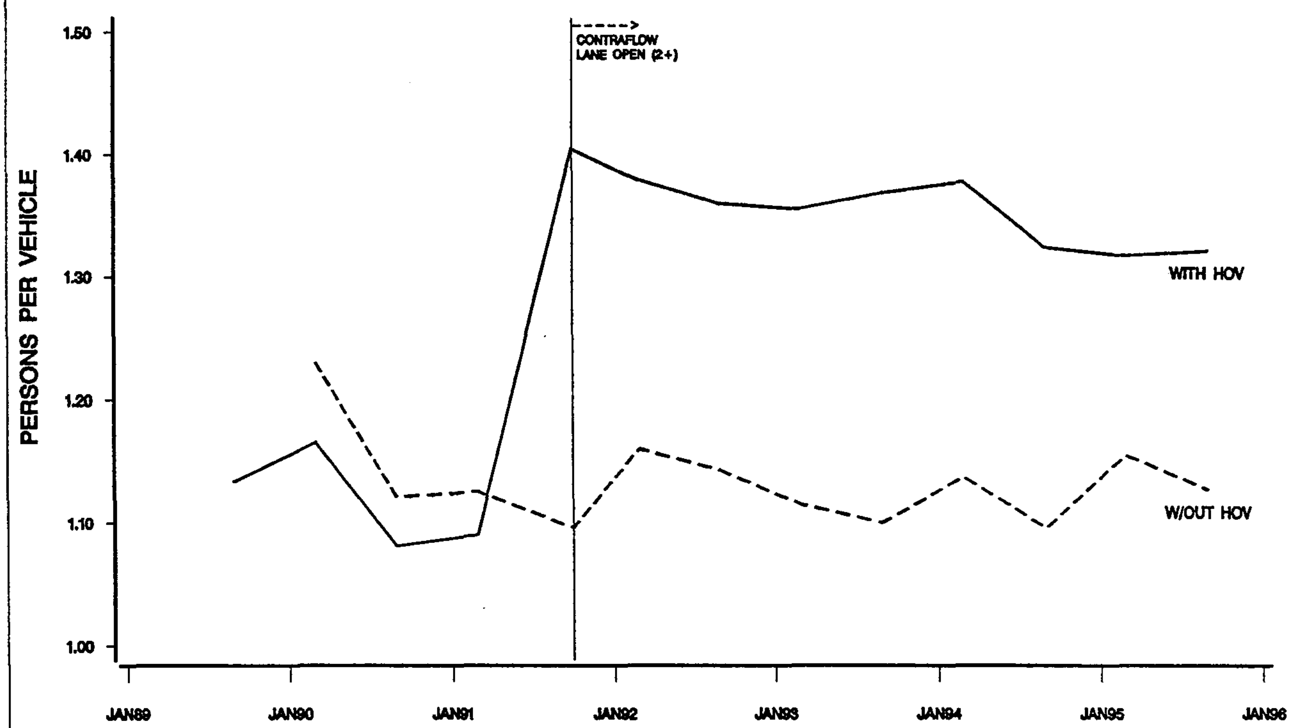


FIGURE F-14. EAST R.L. THORNTON (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK HOUR 2+ CARPOOL UTILIZATION

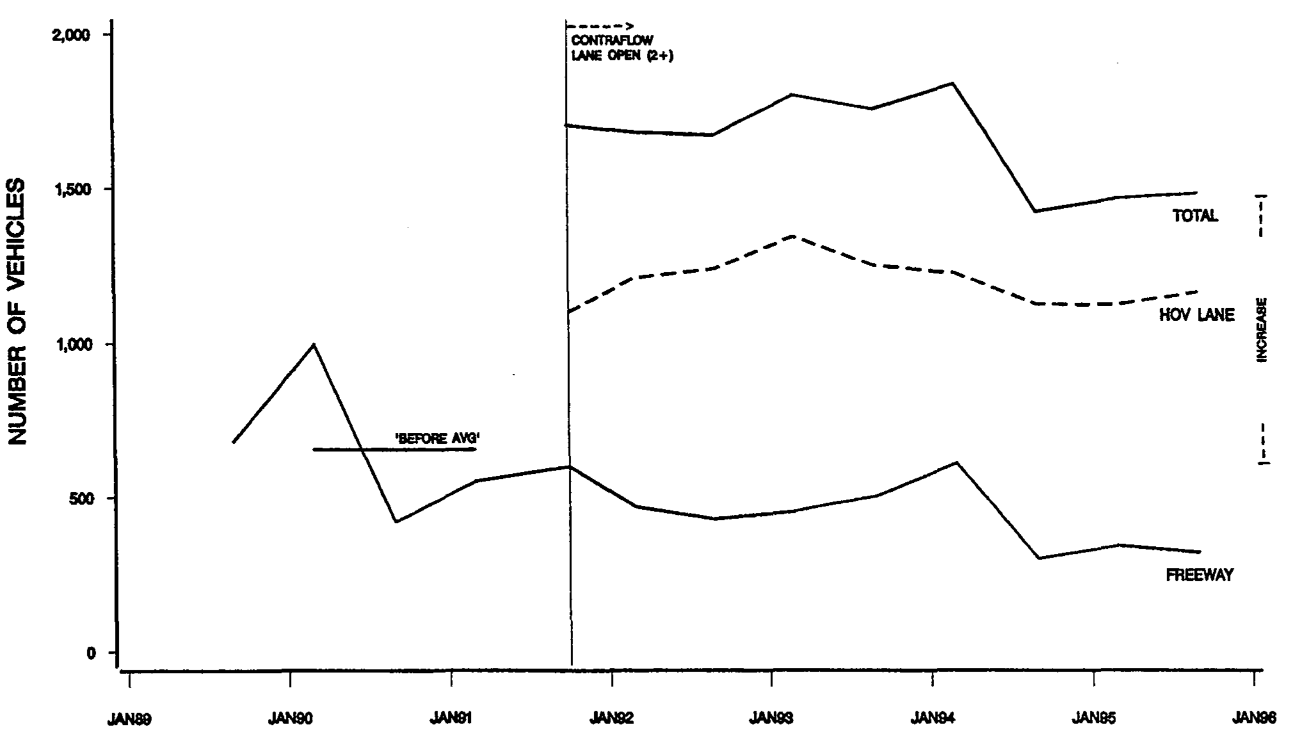


FIGURE F-15. A.M. PEAK HOUR FREEWAY PER LANE EFFICIENCY
EAST R.L. THORNTON FREEWAY AND FREEWAY WITHOUT HOV LANE

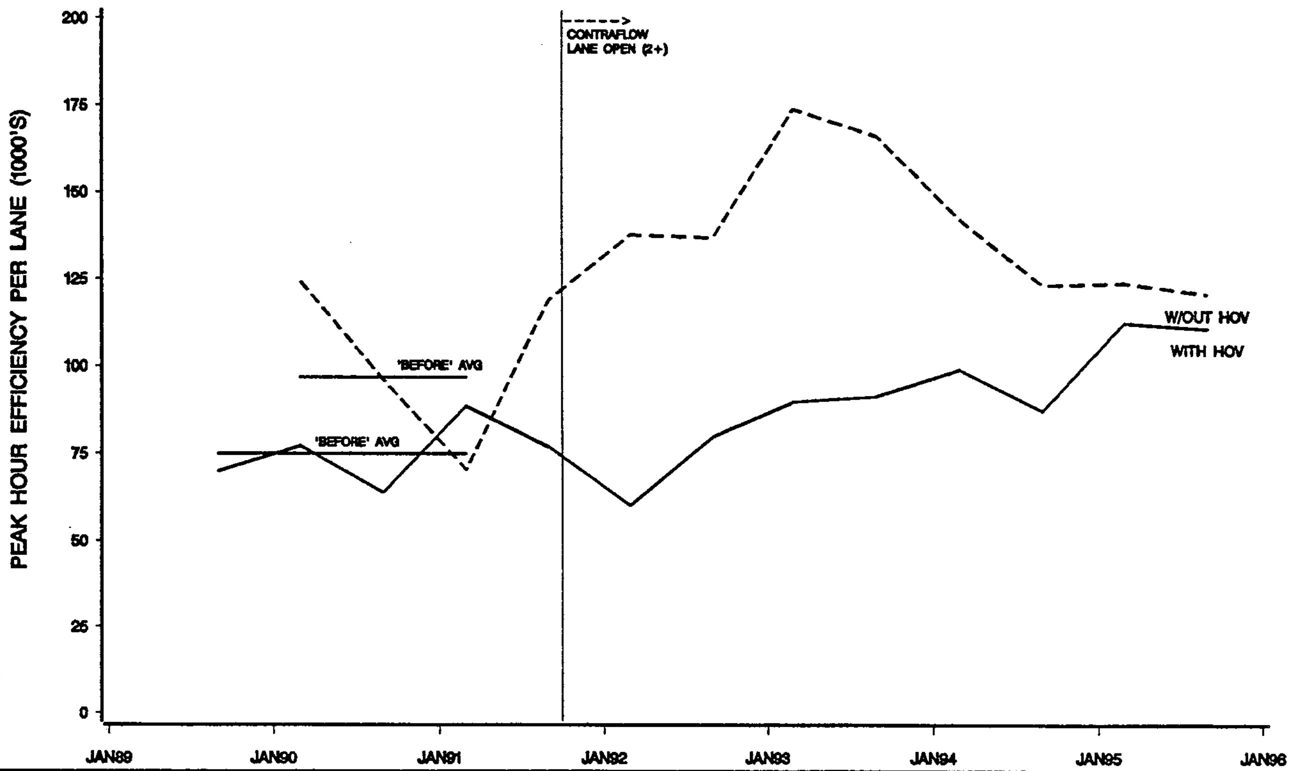


FIGURE F-16. EAST R.L. THORNTON (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS

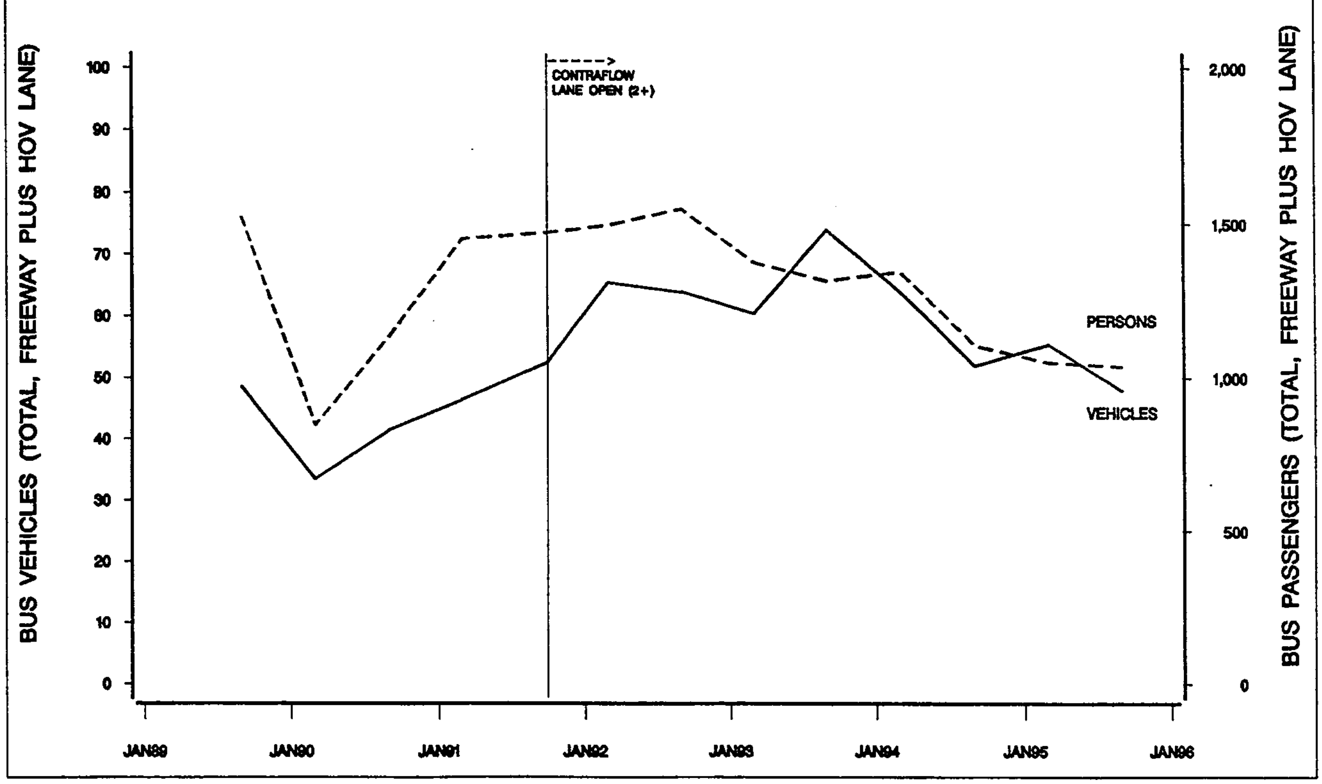


FIGURE F-17. EAST R.L. THORNTON (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS

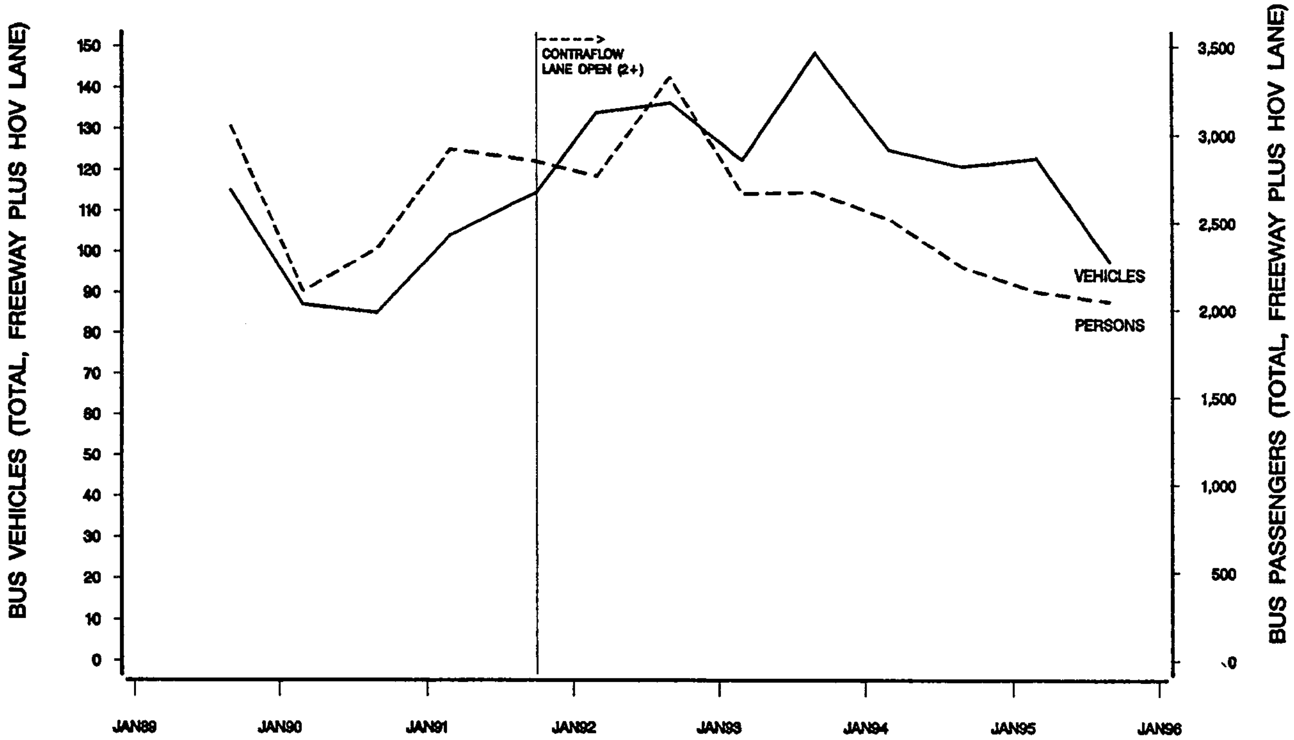


FIGURE F-18. A.M. PEAK PERIOD BUS PASSENGER TRIPS
TOTAL, FREEWAY PLUS HOV LANE
EAST R.L. THORNTON FREEWAY AND FREEWAY WITHOUT HOV LANE

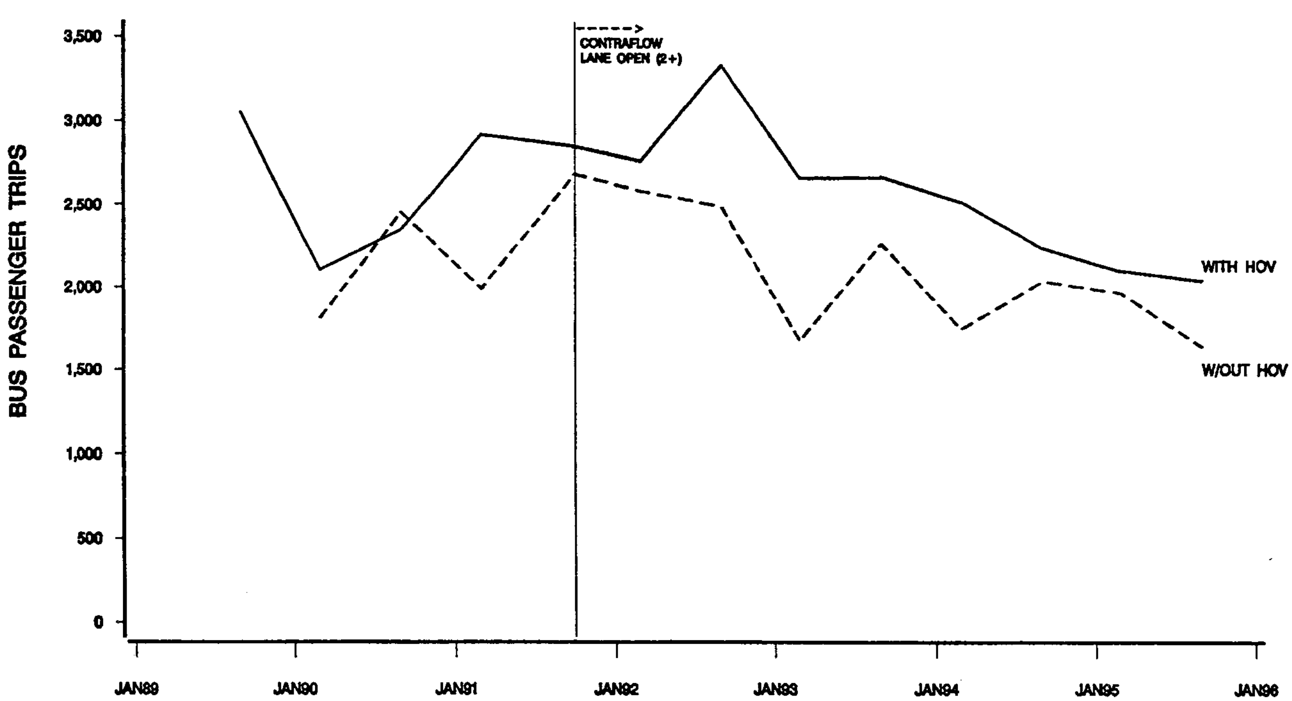


FIGURE F-19. EAST R.L. THORNTON FREEWAY (IH 30E) CORRIDOR PARK-AND-RIDE DEMAND

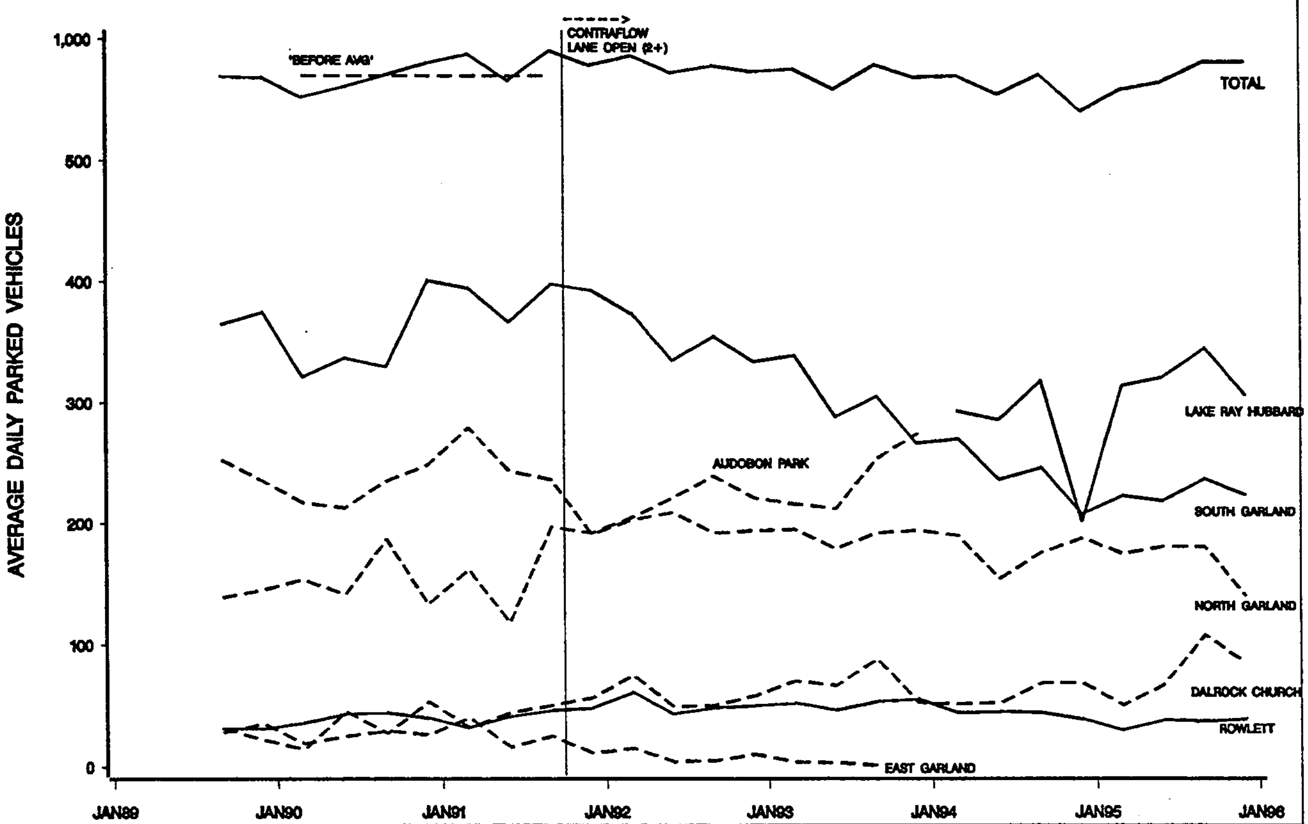


FIGURE F-20. AVERAGE DAILY VEHICLES AT PARK-AND-RIDE LOTS
EAST R.L. THORNTON FREEWAY AND FREEWAY WITHOUT HOV LANE