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16. Abstract

This report evaluates the operation of freeway high-occupancy vehicle (HOV) lanes in Texas through calendar year 1996. As of the end of 1996, 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.

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AN EVALUATION OF HIGH-OCCUPANCY VEHICLE LANES IN TEXAS, 1996

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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, 1996."* 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.

This report presents data relating to the six operating HOV lanes in Texas and focuses on data collected during calendar year 1996. 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 Wm. R. Stockton (Texas certification number 41188) and Ginger Daniels (Texas certification number 64560).

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

FIGURE **PAGE**

LIST OF FIGURES (CONTINUED)

LIST OF FIGURES (CONTINUED)

FIGURE **PAGE**

LIST OF FIGURES (CONTINUED)

FIGURE **PAGE**

LIST OF FIGURES (CONTINUED)

FIGURE **PAGE**

LIST OF FIGURES (CONTINUED)

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FIGURE **PAGE**

LIST OF FIGURES (CONTINUED)

FIGURE PAGE

LIST OF FIGURES (CONTINUED)

FIGURE **PAGE**

LIST OF FIGURES (CONTINUED)

FIGURE **PAGE**

LIST OF FIGURES (CONTINUED)

FIGURE **PAGE**

LIST OF TABLES

TABLE **PAGE**

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

TABLE **PAGE**

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 (METRO) 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 1996, as well as 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 171 km (106 mi) 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 $800 million. 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 1996 dollars. As of the end of 1996, 103 km (64 mi) of barrier-separated HOV lanes were in place and operational in five corridors, implemented at a cost of approximately $630 million. 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 m (20 ft) 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.

As of December 1996, the Houston HOV lane system served 76,300 daily person trips, a level comparable to December 1995, although park and ride usage was up 6 percent to 9,980 cars

daily. Surveys conducted in Houston 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. As of December 1996, an 8.4 km (5.2 mi) barrier-separated contraflow lane on the East R.L. Thornton (East RLT) Freeway and interim concurrent flow lanes along a 12 km (7mi) stretch of North Stemmons Freeway, completed in late 1996, were the only components of this HOV system in operation. The cost to construct the contraflow lane (in 1996 dollars) was $16.1 million, and the cost to construct the concurrent flow lanes was $7 million. An 86 km (53 mi) network of HOV lanes is currently under consideration. The cost of that system has not been estimated.

In December 1996, the East RLT HOV lane served 13,400 daily person trips. By the end of 1996, 820 cars parked in East RLT corridor park-and-ride lots on a typical day, a slight decrease from 1995.

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 in Texas 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 have public support and should not adversely impact the operation of the freeway general-purpose lanes.

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. A summary table (Table S-1) presents each Texas HOV lane analyzed and indicates how well each performed related to the stated objectives.

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 carry a greater percentage of person movement compared to the percentage of lane capacity it provides. The data show that the HOV lanes in Texas are helping to bring about an increase in person movement per lane.

For the priority HOV lanes to generate increases in person movement, it is necessary to increase the average vehicle occupancy; this has happened in most cases. On the two freeways with the more mature HOV lanes, peak-hour average vehicle occupancies are approximately 1.4 persons per vehicle. Compared to pre-HOV lane conditions, average vehicle occupancy on the North, Katy, Southwest and Northwest Freeways has increased by at least 10 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 new carpools and new transit riders, and in most cases, an increase in average occupancy. These increases in ridesharing have not been experienced on freeways not having HOV lanes.

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 and an increase in schedule reliability, thus adding to the attractiveness of transit.

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.

IMPROVEMENT IN TOTAL ROADWAY EFFICIENCY

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.

HOV PROJECT COST EFFECTIVENESS

The cost effectiveness analysis conducted in this study examines quantifiable benefits derived primarily from savings in delay and vehicle operating costs. Other benefits of HOV facilities that cannot be readily quantified, such as impacts on air quality, bus schedule reliability, regional economic development, etc., have not been part of the evaluation. Notwithstanding these benefits, an analysis of the actual operation of HOV lanes in Texas has shown that HOV lanes are cost-effective improvements based solely on overall savings in user costs and vehicle operating costs. And in examining these savings over the long term, construction of an HOV lane is shown to be a more cost-effective alternative than the construction of two general purpose lanes.

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.

AIR QUALITY AND ENERGY CONSIDERATIONS

Researchers undertook a simulation analysis of the Katy Freeway to compare three different alternatives and their potential air quality and emission benefits. The "add an HOV lane" alternative was compared to both the "do nothing" alternative and the "add a general-purpose lane" alternative. The average vehicle occupancy levels were adjusted between alternatives to reflect the observed impacts of the HOV facility on vehicle occupancy. The demand, as expressed as passenger kilometers using the HOV facility and the general purpose lanes in 1996, was held constant in comparing alternatives.

Based on this analysis, the HOV lane is favorable in terms of reducing both vehicle emissions and energy consumed. The HOV alternative, compared to the add a general purpose lane alternative, had fewer emissions of hydrocarbons and carbon monoxide. The HOV alternative results in a reduction of 59 percent fewer carbon monoxide emissions when directly compared to the "add a lane" alternative. Similar results occur when comparing the two alternatives and the amount of energy consumed. The HOV alternative consumes 12 percent less fuel than the add a general purpose lane alternative. It is noted that the evaluation is a rudimentary analysis of the many systems that interact with each other to obtain emission rates and energy consumption figures.

Additional analysis addressing the impacts of HOV lanes on air quality (e.g., vehicle emissions) are summarized in a companion report entitled, "Mobile Source Emission Impacts of High Occupancy Vehicle Facilities", Texas Transportation Institute Research Report 1353-02, William Knowles, November 1994.

Factors Influencing High-Occupancy Vehicle Lane Utilization

Previous research (1) has identified three factors that 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. That research suggested that, unless the HOV lane offers (on a recurring basis) a peak-hour travel time savings of at least five minutes, relative to the general-purpose lanes, utilization of the priority facility will be marginal.

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 Houston system offers a combined 41 minutes of time savings, or an average of about 0.4 minutes per kilometer (0.6 minutes per mile). The 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 that previous research has shown that the time savings perceived by the users (as determined in surveys of HOV lane users) are much greater than the actual time savings.

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 1996 to assess the performance of the priority lanes in meeting their objectives.

Table S-1 summarizes the success of the various Texas HOV lanes in meeting the objectives of such projects. It shows that while the performance of the HOV lane varies from corridor to corridor, all Texas HOV lanes are effective at their intended purpose.

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

Table S-1. Comparison of HOV Lane Objectives and HOV Lane Performance, 1996

Objective, Measure of Effectiveness	HOV Facility					
	Katy	North	Gulf	Northwest	Southwest	East RLT
HOV lanes should increase person movement.						
· Is daily HOV lane ridership between 10,000 and 15,000?	Yes	Yes	No	Yes	Yes	Yes
· Does the HOV lane move a greater percentage of persons in the peak hour than the percentage of total lane capacity it represents?	Yes	Yes	Yes	Yes	Yes	Yes
· Has peak-hour vehicle occupancy increased by 10% to 15%?	Yes	Yes	No	Yes	NA	No
· Have new carpools increased by at least 25% due to the HOV lane?	Yes	NA	NA	Yes	NA	No
· Has bus ridership increased at least 25% as a result of the HOV lane?	Yes	NA	NA	Yes	NA	No
HOV lanes should enhance bus operations.						
· Have peak-hour bus speeds increased by 50%?	Yes	Yes	Yes	Yes	Yes	Yes
HOV lanes should not result in an adverse impact on freeway general-purpose lane operations.						
· Have general purpose lane speeds been impacted by the HOV lane?	No	No	No	No	No	No
· Has the general purpose lane accident rate increased significantly due to the HOV lane?	No	No	No	No	No	No
Implementation of an HOV lane should increase the overall efficiency of the roadway.						
· Has the roadway per-lane efficiency increased by a value of at least 30 due to the HOV lane?	Yes	Yes	No	Yes	Yes	Yes
HOV lanes should be cost effective.						
· Does the value of the benefits outweigh the costs?	Yes	Yes	Yes	Yes	Yes	Yes
· Does the HOV lane have an equal or greater benefit-to-cost ratio than a general-purpose lane alternative?	Yes	Yes	Yes	Yes	Yes	Yes
HOV lanes should have public support.						
· Do more than 50% of the persons responding to the surveys indicate support for HOV lane development?	Yes	NA	NA	Yes	NA	Yes
HOV lanes should have favorable air quality & energy impacts.						
· Has adding an HOV lane been more effective than a general-purpose freeway lane would have been in terms of air quality and energy impacts?	Yes	NA	NA	NA	NA	NA
Overall Assessment: Is the HOV facility effective?	Effective	Effective	Marginally Effective	Effective	Effective	Effective

NA = Not available.

CHAPTER 1. INTRODUCTION

High-occupancy vehicle lanes (HOV lanes) have been in place for almost two decades in Texas. Beginning with a contraflow lane on I-45 in Houston, the system has expanded to 103.7 km (64.3 mi) of HOV lanes in Houston and 29.9 km(18.5 mi) in Dallas. Much experience has been gained in the planning, design and operation of HOV lanes. The Texas Department of Transportation (TxDOT) has funded a long-term project to document the evolution of the HOV lane system, and to provide an assessment of its effectiveness.

This report is the fifth annual in a series under the auspices of the TxDOT research project. The purpose of this report is to provide up-to-date documentation of the evolution of the HOV lane networks, and through analysis of key data, to provide insight for future development and operation.

HOV lanes frequently spark debate among the public and transportation professionals. Because they portend behavior changes, they are often unfairly denigrated by the ignorant and equally often unjustifiably revered by the supposedly informed. Objective, informed understanding of HOV lanes can only be achieved through the examination of the arguments and the study of the facts. This report is structured to address both the arguments and the facts. Following the initial chapters summarizing policy issues and an historical overview, Chapters 4 and 5 address arguments for and against HOV lanes. Chapters 6 through 12 address, individually, each of the seven primary objectives of HOV lanes introduced in Chapter 4. As with its predecessors, this report also provides in-depth analysis of a few key areas. The reader should note that Chapter 10 expands on previous work related to the cost-effectiveness of HOV lanes, providing the most in-depth analysis to date.

CHAPTER 2. HOV LANES FROM A POLICY PERSPECTIVE

The implementation of HOV lanes is a very important decision. Done right they offer a great opportunity for improving person-movement in a corridor. Done the wrong way or in the wrong place, they can be a significant public relations disaster. This chapter attempts to identify some of the key policy level questions that do (or should) arise from the consideration of HOV lanes, and attempts to shed light on the some of the answers to these questions.

What do HOV lanes do?

In general, the Texas experience is that HOV lanes are most effective when the primary motive is to move people. Average vehicle occupancy on freeways continues to decline nationally. Under highly congested conditions the number of vehicles remains about the same, but the number of total people actually drops. The HOV operations practiced in Texas maintain a high level of service on the HOV lane, thereby assuring HOV lane travelers of a reliable, shorter trip through the congested corridor. Thus HOV lanes attract travelers that are seeking short, reliable travel time, and account for a very significant proportion of the people moved. As will be shown in a later chapter, HOV lanes can carry nearly 40% of the total people in the corridor during the peak hour.

Who benefits from HOV lanes?

In general, the carpoolers, vanpoolers and bus patrons that use the HOV lane are the primary beneficiaries. However, to the degree that the HOV lane removes traffic from the general purpose lanes, the non-users also benefit.

Isn't money better spent on new freeway lanes?

Sometimes. HOV lanes are a valuable tool to be used where appropriate. Each freeway corridor requires a separate, unique analysis to determine whether an HOV lane is appropriate. Tools to aid that decision-making process are identified in a later chapter.

How do we avoid the "empty lane" syndrome?

Motorists in highly congested corridors have expressed frustration with seeing HOV lanes that "...have nobody in them." This frustration can result in strong negative public sentiment, and even in pressure to convert the HOV lane to a general purpose lane. The keys to avoiding the "empty lane syndrome" are effective planning and operation. Effective planning should result in HOV lane construction only in those corridors for which HOV lanes are suitable improvements. It will also provide for those connections to park-and-ride and other facilities that can play a significant role in HOV lane effectiveness.

CHAPTER 3. 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 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 km (9 mi) 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.

The Planned System

A commitment is in place in the Houston area to develop approximately 171 km (106 mi) of high-occupancy vehicle lanes (Figure 1). As of December 1996, five separate HOV facilities were in operation (Table 1). A total of 103.7 km (64.3 mi) of barrier-separated, high-occupancy vehicle lanes were operating.

Table 1. Status of the Houston High-Occupancy Vehicle Lane System, December 1996

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 11 a.m. inbound 2 p.m. to 8 p.m. outbound
North (I-45N)	November 1984[2]	21.8 (13.5)	32.0 (19.9)	2+ vehicles	5 a.m. to 11 a.m .inbound 2 p.m. to 8 p.m. outbound
Gulf (I-45S)	May 1988	19.5 (12.1)	28.5 (17.7)	2+ vehicles	5 a.m. to 11 a.m. inbound 2 p.m. to 8 p.m. outbound
Northwest (U.S. 290)	August 1988	21.8 (13.5)	21.8 (13.5)	2+ vehicles	5 a.m. to 11 a.m. inbound 2 p.m. to 8 p.m. outbound
Southwest (U.S. 59S)	January 1993	19.7 (12.2)	24.2 (15.0)	2+ vehicles	5 a.m. to 11 a.m. inbound 2 p.m. to 8 p.m. outbound
Eastex (U.S. 59N)	Not open in 1996	---	32.5 (20.2)	---	---
Westpark Corridor	Not open in 1996	---	7.2 (4.5)	---	---
Total		103.7 (64.3)	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.

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 km, 5.1 mi).

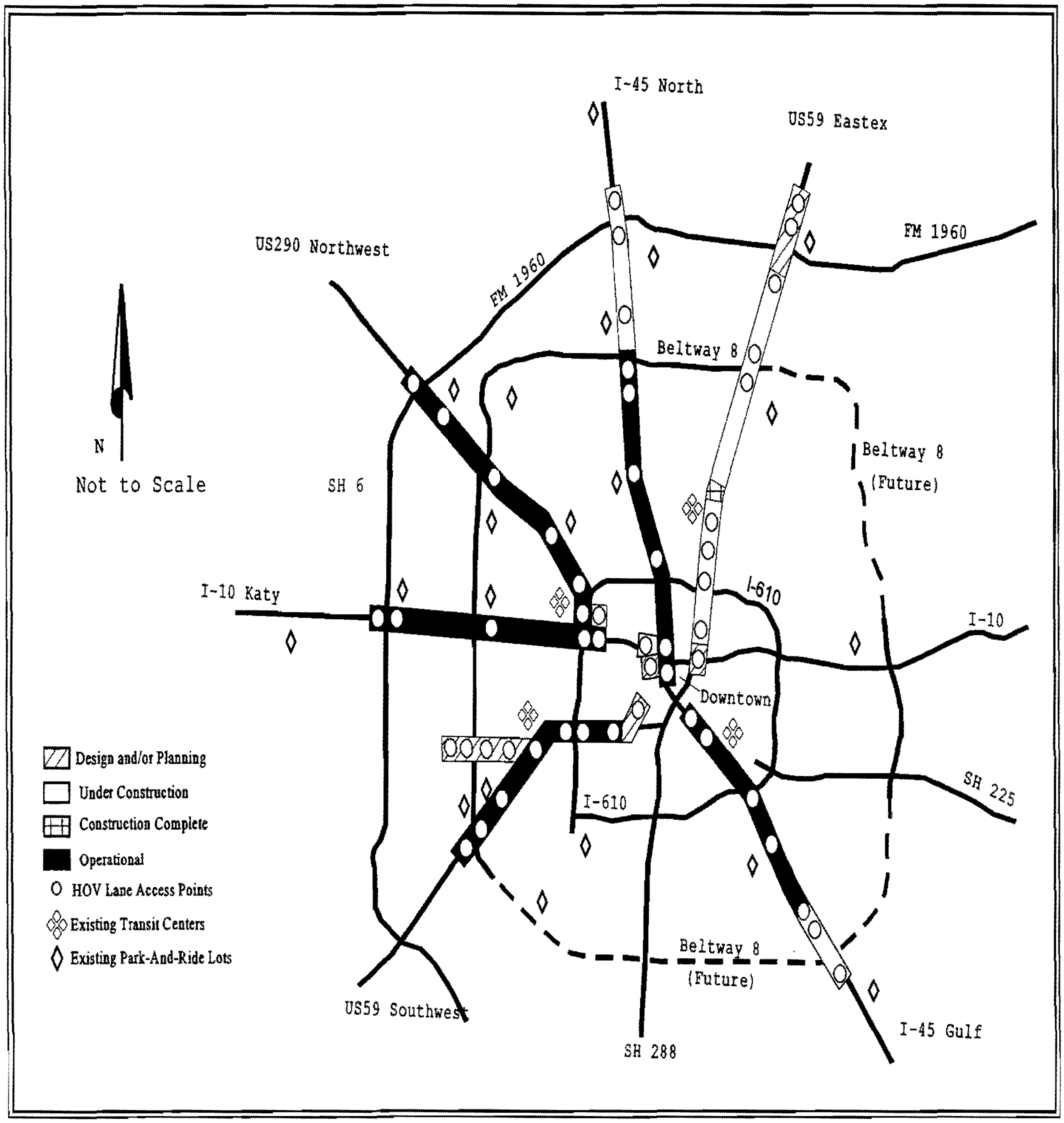


Figure 1. Status of Houston HOV Lane System, December 1996

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 km (5.2 mi) 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 second HOV lane in Dallas began operation in September 1996. The Stemmons Freeway (I-35E) interim concurrent flow lanes were constructed on the existing inside shoulders of the general purpose lanes between I-635 and FM 3040. The facility provides 24-hour operation. Representative HOV lane ridership data were not available prior to December 1996, the end of the study period for this report, but will be included in the 1997 summary report.

The Planned System

A 86.1 km (53.4 mi) network of permanent HOV lanes is being considered for the Dallas area. The Dallas District of TxDOT and DART, however, have been implementing low cost, short-term (interim) transit projects, such as concurrent flow HOV lanes, that will enhance public transportation and overall mobility until permanent treatments can be implemented. The interim HOV lanes, which are detailed in Table 2, are retrofitted into the existing cross section of freeways and typically require design exceptions such as elimination of the inside shoulder and/or narrowing of the freeway general purpose lanes to accommodate the HOV facility. The interim HOV lanes will likely operate until permanent treatments can be implemented. The current plan for the Dallas HOV system is illustrated in Figure 2.

Table 2. Status of the Dallas High-Occupancy Vehicle Lane System, December 1996

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) Interim Contraflow Lane	September 1991[1]	8.4 (5.2)	8.4 (5.2)	2+ vehicles	6 a.m. to 9 a.m. IB 4 p.m. to 7 p.m. OB
North Stemmons (I-35E) Interim Concurrent Flow Lanes	September 1996	11.8 (7.3) IB 9.7 (6.0) OB	11.8 (7.3) IB 9.7 (6.0) OB	2+ vehicles	24 hours, including weekends
LBJ (I-635) Interim Concurrent Flow Lanes	Not open in 1996	---	11.0(6.8) EB 9.8(6.1)WB	---	--- ---
South R.L. Thornton (I-35E) Interim Contraflow Lane	Not open in 1996	---	8.8 (5.5)IB 8.8 (5.5)OB[2]	--- ---	--- ---
Marvin D. Love (U.S. 67) Interim Concurrent Flow Lanes	Not open in 1996	---	3.2 (2.0)IB 6.4 (4.0)OB5[3]	---	---
North Central Expwy. (U.S. 75) Barrier-Separated Reversible Lane	Not open in 1996	---	14 (9)		
Total		29.9 (18.5)	86.1 (53.4)		

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 scheduled for completion in 1999.

[3]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.

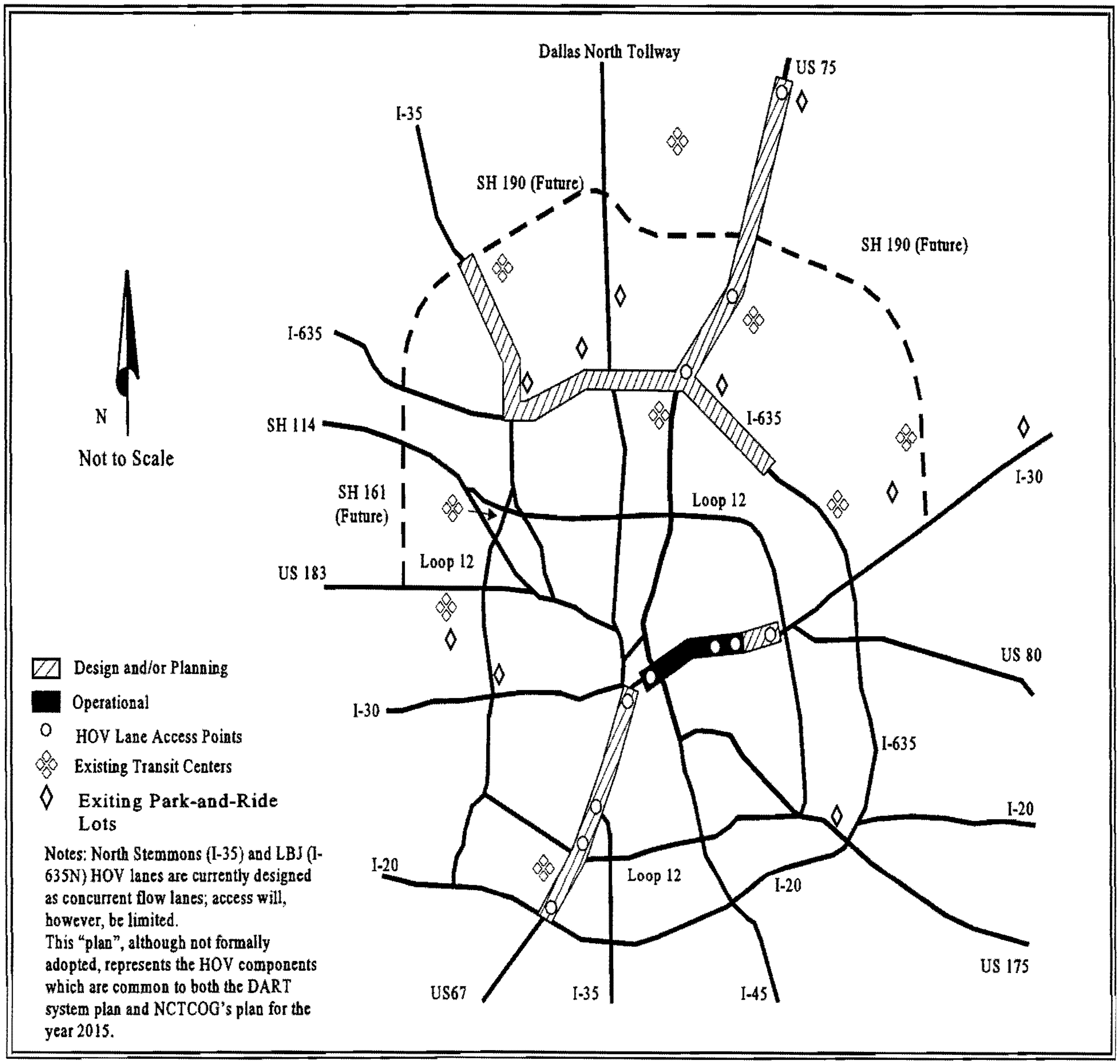


Figure 2. Status of the Dallas HOV Lane System, December 1996

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.

Fort Worth

A feasibility study for HOV facility implementation on Fort Worth's freeways has recently been completed. As a result of this study, plans for a reversible, barrier-separated HOV facility on I.H. 820 (Northeast Loop) and S.H. 183/S.H. 121 (Airport Freeway) have reached the engineering design stage. This proposed facility will stretch from I-35W to the Dallas County Line (a distance of approximately 27 km or 17 mi). Right-of-way or envelopes of space are also being purchased and/or preserved for future HOV lanes on the East Freeway (I-30E), West Freeway (I-30W), South Freeway (I-35W) and possibly the proposed Southwest Freeway/Tollway (S.H. 121 South).

San Antonio

A long-range plan assessing HOV lane feasibility was completed in December 1994 for San Antonio. This analysis addressed both freeways and major arterials. The results of the study provide a guide for identifying corridors in which HOV alternatives need further study through a Major Investment Study (MIS). A MIS has been developed on IH 410 from Culebra Road to IH 35 North and IH 35 (north from Loop 1604 to IH 37/US 281. The MIS on IH 410 concluded HOV lanes were not the preferred alternative. The MIS on IH 35 concluded the addition of two barrier separated express lanes in each direction with one lane being general purpose and the second lane being a HOV lane was the preferred alternative. The MPO is currently updating the Metropolitan Transportation Plan and is doing a city-wide transportation study of all modes of transportation for the year 2025.

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 m (20 ft) wide, is reversible and is separated from the general-purpose freeway mainlanes by concrete median barriers (Figure 3).

Figure 3. HOV Lane in Median of Katy Freeway

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 4). While these are

Figure 4. Slip Ramp for HOV Lane Access/Egress on Katy Freeway

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 5). 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 km (3 to 5 mi) intervals. In some locations, implementation of the Houston HOV lanes was accomplished by narrowing freeway lanes to 3.4 m (11 ft) and reducing inside shoulder widths. A typical section is shown in Figure 6.

Figure 5. Example of Grade Separated HOV Lane Interchange

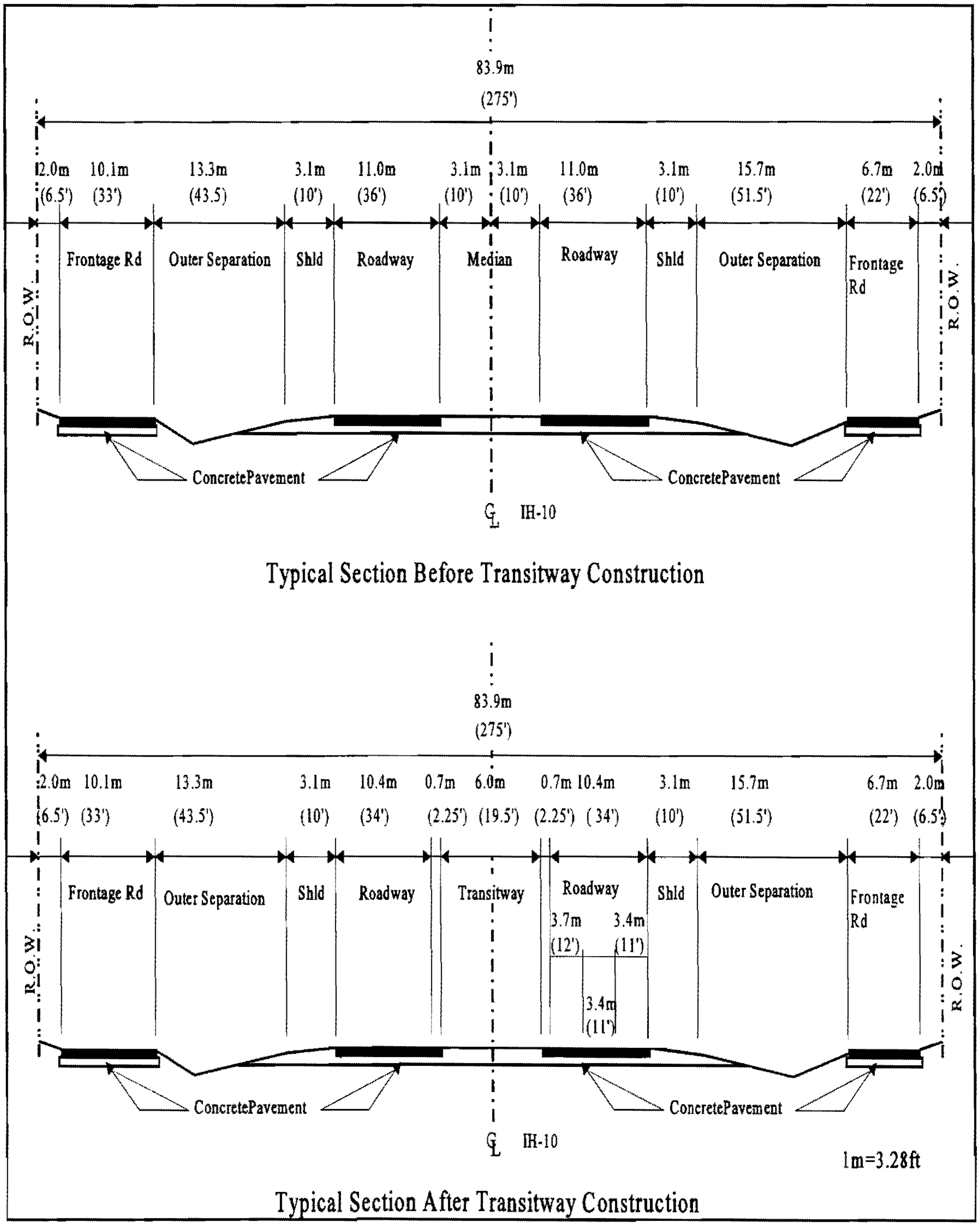


Figure 6. Typical Sections, Before and After Katy HOV Lane Construction

Dallas

The East RLT HOV lane in Dallas is a movable barrier contraflow lane (Figure 7). The movable barrier, which is used to create the 6 m (20 ft) 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 7) to shift the barrier approximately 7 m (22 ft) 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 m (11 ft) and reducing the inside shoulder of the freeway in some locations (Figure 8). Slip ramps such as the one shown in Figure 9 provide access to, and egress from, the East RLT HOV lane.

Figure 7. Machine Used to Shift the Moveable Concrete Barrier on East R.L. Thornton

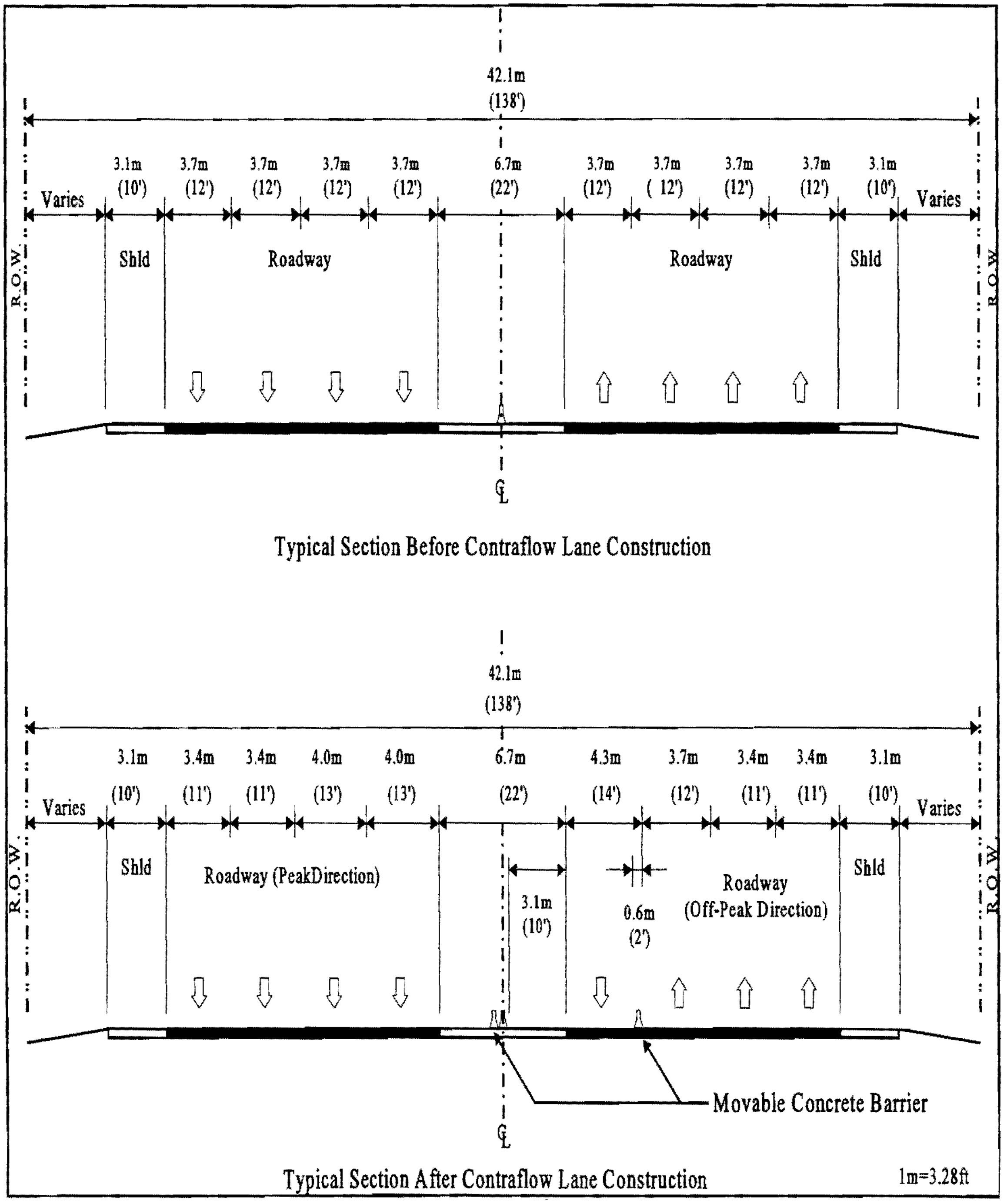


Figure 8. Typical Sections, Before and After East RLT Contraflow Lane Construction

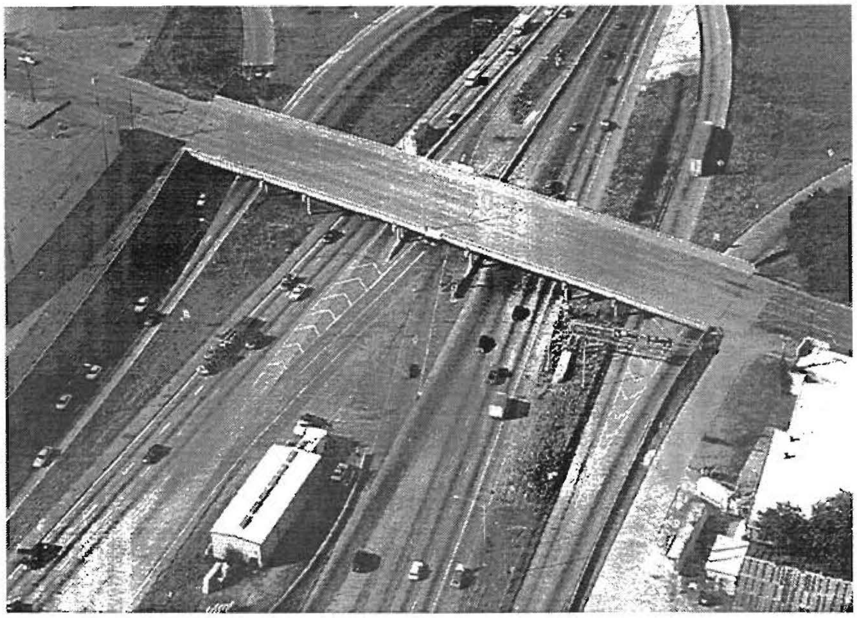


Figure 9. Example of Access Point of East R.L. Thornton HOV Lane

The Stemmons Interim HOV lanes in Dallas consist of a concurrent flow lane in each direction. The implementation of these HOV lanes was accomplished by narrowing freeway lane widths to 3.4 m (11 ft) and reducing the inside shoulder of the freeway (Figure 10). The HOV lanes are 3.6 m (11½ ft) wide and are separated from the general purpose lanes by a 0.8 m (2½ ft) striped buffer. Access and egress points are limited to two locations each direction.

Summary of HOV Usage Data

Table 3 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 10 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.

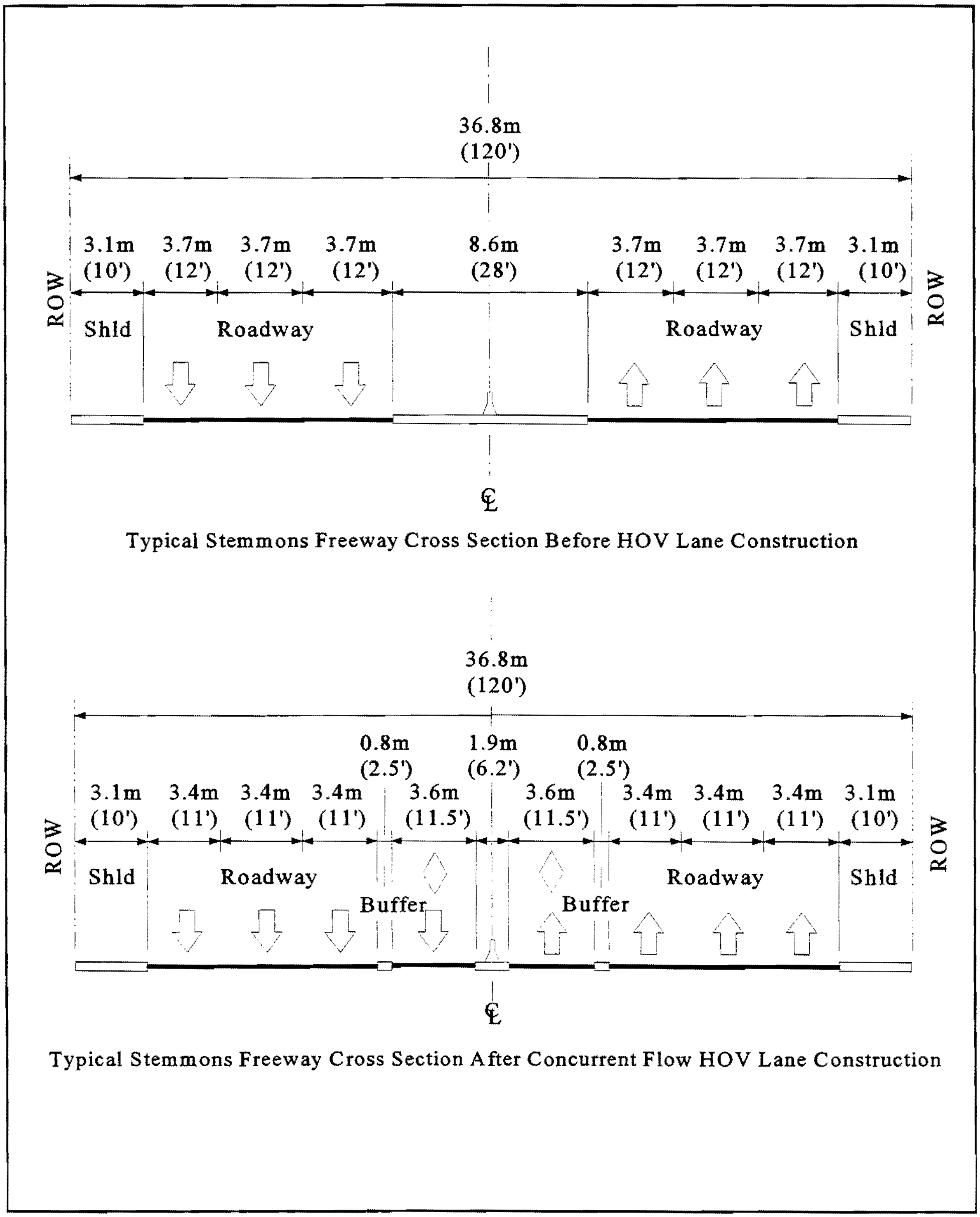


Figure 10. Stemmons Freeway HOV Implementation Cross Section

Table 3. Selected HOV Lane Operating Statistics, December 1996

Time Period and Operating Data	HOV Lane					
	Katy	North	Gulf	Northwest	Southwest	E. RLT
Weekday Operations						
HOV Lane Person Volume						
A.M. Peak Hour	3,340	4,947	2,155	3,715	3,598	3,535
Daily	19,111	20,382	7,922	13,644	15,274	13,423
HOV Lane Vehicle Volume						
A.M. Peak Hour	916[1]	1,338	799	1,429	1,315	1,261
Daily	6,134	5,649	3,000	5,151	5,542	5,101
Percent of Total Person Movement that occurs in the HOV Lane, A.M. Peak-Hour[2]	40%	40%	24%	41%	26%	31%
Vehicles Parked in Corridor Park-and-Ride Lots	1,993	3,310	1,227	1,542	1,904	819
Violation Rate, A.M. Peak Period	17%	6%	3%	5%	2%	<1%

[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.

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, are highlighted herein (*1*). The most recent surveys were completed in 1994 and include the Dallas East R.L. Thornton HOV facility.

Transit Surveys

Table 4 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 five years.

Carpool and Vanpool Surveys

Carpoolers also tend to be young, educated, white-collar professionals (Table 5). 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 6, 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 4. 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 5. 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 6. 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.

CHAPTER 4. REASONS TO CONSIDER HOV LANES

The role of HOV lanes in the transportation network is important, but often misconstrued. More than anything else, HOV lanes are effective in moving people. While other objectives, such as reducing congestion or improving air quality, may be achieved through the application of an HOV lane, the evidence so far does not support those objectives as much as it does people movement. As will be seen in the next chapter, many of the arguments against HOV lanes stem from unsupported expectations, rather than the failure of HOV lanes to perform.

Over the last few years, TTI has developed a set of working objectives for HOV lanes. Those objectives are directed at the following:

- moving people,
- benefitting transit,
- not adversely impacting mixed flow,
- improving overall roadway efficiency,
- financial viability,
- public acceptability, and
- environmentally beneficial or neutral.

Most of these objectives would or should apply to any HOV lane. The degree to which each HOV lane in Texas individually and collectively meets these objectives is documented in this report. The following sections of this chapter introduce the objectives and the measures applied.

Is the HOV Lane Working?

The expectation of the public and the goal of the professionals that design and operate the transportation system is that the elements of the system work as intended. For each identified objective of HOV lanes, there are several measures that can be applied to evaluate the success in meeting that objective.

Objective 1. Increase Roadway Person-Movement (Does the corridor move more people with the HOV lane than without it?)

Of all the objectives, this one should get a resounding "yes"; if not, an HOV lane is not the right improvement. Because it is so critical in determining the success of an HOV lane, several measures have been developed to address this objective. Among the measures analyzed in Chapter 6:

- person-movement characteristics of HOV lane and general purpose lanes,
- comparison of the percentage of persons moved versus the percentage of vehicles and the percentage of pavement used,
- increases in use of HOV lanes compared to overall increases in travel, and
- impact of HOV lanes on overall occupancy in the corridor.

Objective 2. Improve Bus Transit Operating Efficiency (Does it help transit?)

Although attracting carpools is crucial for public perception of HOV lane utilization, in most corridors the "bang for the buck" in person-movement comes from buses. Two measures of the benefit to transit are impact of HOV lanes on bus operating speeds that results from the free flow, and the impact on schedule adherence stemming from increased travel time reliability (Chapter 7).

Objective 3. No Impact on General Purpose Lanes (Can HOV lanes be installed and operated without causing problems for other traffic?)

In the early years of HOV lane development in Texas, HOV lanes were "shoe-horned" into existing freeway medians. This practice usually led to the narrowing of existing general purpose lanes and the elimination of shoulders. There was much concern that the safety and operational impacts of these changes would offset the benefits derived from the HOV lanes, so the general purpose lanes were closely monitored.

More recently HOV lanes have been designed into the reconstruction of congested corridors, alleviating many of the original problems. However, there are still some locations where the merging of HOV lane and general purpose lane traffic occurs. To assure that such interactions do not become a bottleneck, congestion levels, operating speeds and accident rates on the general purpose lanes adjacent to HOV lanes are still monitored (Chapter 8).

Objective 4. Improve Total Roadway Efficiency (Are HOV lanes an effective use of the available pavement/right-of-way?)

Another objective of the HOV lane is to improve the efficiency of the entire roadway (freeway + HOV lane). Such a measure should consider not only the volumes of people moved, but also the speed at which they move. Chapter 9 includes an analysis of efficiency as a function of both person-movement and speed.

Objective 5. HOV Lanes Should be Cost-Effective (Are HOV lanes financially prudent? How do they compare with adding freeway lanes?)

Because resources will always be limited, all transportation improvements should be able to meet the test of financial prudence. Thus, HOV lanes should produce a favorable benefit/cost relationship. Further, they should compare favorably to other improvement alternatives, specifically additional general purpose lanes. Chapter 10 analyzes these relationships for the HOV lanes in Texas. Some general conclusions about the factors that drive the B/C ratios are presented.

Objective 6. Maintain Public Acceptance (Are HOV lanes understood and accepted by the public?)

The significance of public support is best reflected in the short life of the Santa Monica Diamond Lane in Los Angeles in the mid-1970s. Although this carpool lane was actually performing reasonably well for its newness, the public outcry that stemmed from gross misunderstanding resulted in the cancellation of that project and a decade-long hiatus from carpool lane experiments in California. HOV lanes in Texas have been carefully and slowly introduced, with little or no public backlash. In Chapter 11 specific public opinion surveys from users and non-users will reinforce the claim of public support in Houston.

Objective 7. HOV Lanes Should Have a Favorable Impact on Air Quality and Fuel Consumption
(Are HOV lanes good for the environment?)

HOV lanes should have a beneficial impact on the environment. Intuitively, increasing vehicle occupancy should be a good thing, resulting in fewer emissions and less fuel consumption. Both of those desirable outcomes probably do occur, but HOV lanes and associated traffic represent such a small portion of the overall travel demand, even during the peaks, that any savings are hard to isolate using currently available tools and computer models. Chapter 12 provides some additional insight into the possibilities.

CHAPTER 5. ARGUMENTS AGAINST THE USE OF HOV LANES

One of the most important aspects of evaluation is an objective review of the arguments against a project or program. Several advocacy groups and research institutions have raised conscientious arguments against HOV lanes. By addressing those arguments, the true applicability of HOV lanes can be clarified, and where appropriate, myths dispelled. This chapter attempts to broaden the reader's perspective by addressing the counter arguments of HOV lanes.

High Initial Delay Is Essential to Success of HOV Lanes

Some theoretical research into the prudence of HOV lanes has suggested that at initial main lane delays of less than 20 minutes per vehicle, HOV lanes may not be as effective as adding a general purpose lane (*2*). In Texas, HOV lanes have been implemented only where there is a high delay, so there is little experience with low levels of delay. As will be shown in Chapter 13, there is a positive relationship between ridership and travel time savings, suggesting that as congestion grows, the traveler's willingness to carpool or ride the bus on the HOV lane, and thus save time, also grows.

High Initial Proportion of HOVs Required for Success

The research previously cited (*3*), also suggests that unless there are already many carpools on a congested freeway, adding general purpose lanes would be more effective than adding HOV lanes. That research concluded that 20% or more of the pre-HOV lane traffic stream must be HOVs to support the construction of an HOV lane, unless the initial delay is very high (45 minutes per vehicle). This theoretical research assumes that the construction of HOV lanes or general purpose lanes will alleviate congestion, and therefore there will be no growth in demand for HOV lane use. The Texas experience (see Chapter 6) is that there has been growth in HOV demand in all corridors, so much so in some that cases the minimum eligible carpool size has been increased to keep the number of users manageable. Also surveys have shown that willingness to form new carpools and ride the bus increases over the life of the HOV lane (see Chapter 6).

Formation of Carpools Adversely Impacts Emissions

Carpools that meet at a designated point result in more than one engine start, warm up and cool down, thus producing much of the same emissions as if all had traveled as SOVs. At this point there is very little documentation of the emissions implications of HOV lanes. There are numerous competing arguments, all with at least surface validity. The models run for individual freeway/HOV corridors in Texas have indicated that the HOV lanes have had a positive effect (see Chapter 12). In the grand scheme of air quality, HOV lanes may play a very limited role, but their fundamental contribution, increasing vehicular occupancy, should be a counterbalance to limited or even slightly negative air quality impacts.

Absence of the Ability to Document Source of HOVs Can Lead to Erroneous Conclusions

Increased use of HOV lanes has often been attributed to SOVs combining into HOVs. Without documentation of the source of HOVs, it is not possible to assume that emissions and delay have been positively affected. In Texas, surveys of HOV lane users have shown that 35% to 66% of carpoolers and 33% of HOV lane bus riders were previously SOV drivers (*4*).

HOV Lanes May Not Reduce Person Delay or Emissions

Part of the disparity in conclusions drawn from different reports is attributable to the objective measures used to determine "success" or "effectiveness." Dahlgren (*5*) uses person-delay and emissions as the primary measures of effectiveness. For her analysis, total demand was fixed, meaning that adding either HOV lanes or general purpose lanes benefitted all travelers, and in some cases, reduced delay to zero. The principal objective in all of the Texas applications has been increased person-movement, so most of the analyses have examined how well the HOV lanes have supported that objective. Demand for general purpose lane use has remained high even with significant shifts to the HOV lane. Delay reductions have generally accrued only to HOV lane users, with very little direct benefit accruing to general purpose lane users. Over the long-term, land use planning can help address the delay and emissions resulting from congestion; in the short-term, HOV lanes can contribute to the ability of the existing corridor to accommodate existing travel demand.

Eligibility Should Be Limited to Buses and Emergency Vehicles

This statement represents a philosophy rather than a documented experiment. The presumption made by the authors (*6*) is that by providing bus service only, there will be a significant shift to buses. The practical aspect of that philosophy has not been as fruitful. The early years of operation on the Katy HOV lane were limited to buses and official vanpools. Yet significant use of the HOV lane began only when carpools were allowed. Figure 11 illustrates the impact that adding carpools has had on Texas HOV lanes.

HOV Lanes Increase "Fill-in" Solo Driving, Adversely Impacting Air Quality

Intuitively, if the space vacated by solo drivers resulted in more solo drivers choosing to drive during the peak, then the air quality impacts could be neutral or negative. The work done thus far in Texas has not established that air quality is significantly impacted in either direction. There is not any evidence that the number of solo drivers increases; the time they use the freeways during the peak period has changed as a result of conversion by others to HOVs.

Conversion of GP Lanes to HOV Should Be First Choice over New HOV or GP Lanes

There is no relevant experience in Texas to compare, except that some freeway corridors have been "squeezed" to make room for an HOV lane in the middle. Theoretically, if the person-movement objective could be met, this approach would have a much lower cost (assuming the conversion is to concurrent flow design). However, as a disincentive to solo driving, there is a strong history of mostly failure at disincentives and the enforcement thereof.

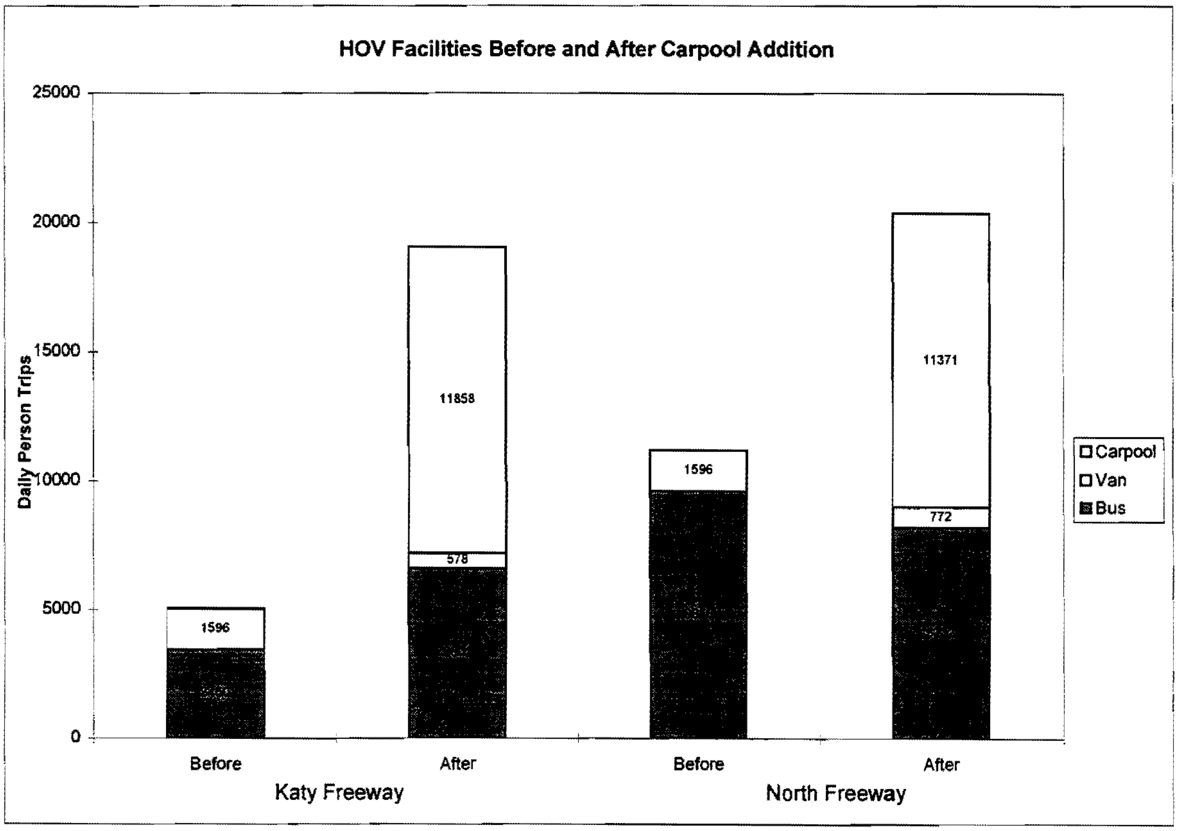


Figure 11. Impacts of Carpool Usage on Daily HOV Lane Person Trips

CHAPTER 6. PERSON MOVEMENT

The primary reason for implementing HOV lanes is to improve the capability of a congested freeway corridor to move more people by increasing the number of persons per vehicle. There is growing recognition of the importance of transportation improvements that are focused on moving people rather than vehicles, and HOV lanes can be a means of achieving this goal. This section of the report presents data that address the impact of HOV facilities on person movement.

Mature HOV lanes in Houston have experienced tremendous growth in peak-period person-movement since their inception, from 150 percent to 400 percent increases in ridership. The newer HOV lanes have experienced growth in ridership as well, ranging from 20 percent to 70 percent. The growth in person-movement on each HOV lane is depicted graphically in the appendices.

To evaluate the effectiveness of HOV lanes in terms of person movement, three specific measures can be examined (*7*):

- the impact of the HOV lane on person-movement efficiency
- the impact of the HOV lane on average vehicle occupancy and
- the impact of the HOV lane on carpooling and bus ridership.

IMPACT ON PERSON-MOVEMENT EFFICIENCY

Evaluation of an HOV lane in terms of person-movement efficiency can be based on how well an HOV lane moves people in comparison with a general purpose lane. Figure 12 illustrates peak-hour characteristics of Texas HOV lanes in persons moved per lane. The HOV lanes in both Houston and Dallas move a greater volume of persons per lane than the freeway lanes, carrying from 30 percent to 150 percent more persons per lane than the freeway lanes.

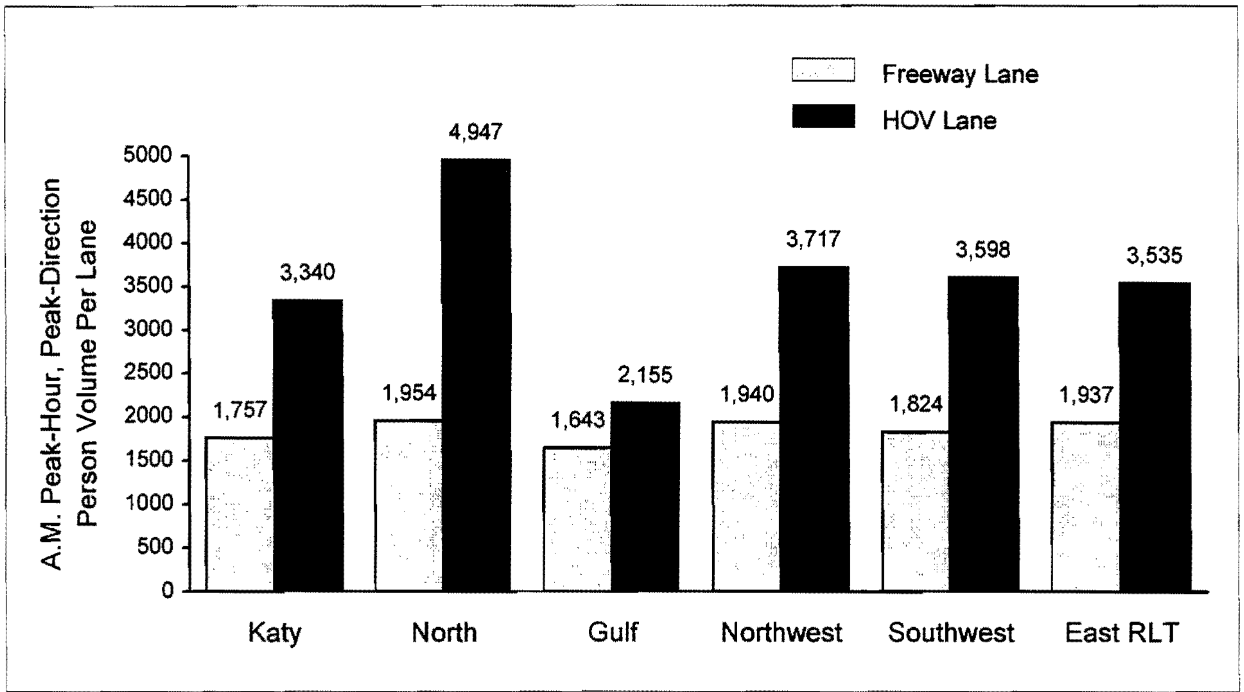


Figure 12. Person Movement, per Lane, on Freeways and HOV Lanes

Within freeway corridors in Texas that include HOV lanes, the HOV lane represents only one of several total directional lanes. Texas HOV lanes operate in conjunction with three to five general purpose lanes each direction. Yet the HOV lanes carry a higher proportion of peak-hour person-movement per lane, as illustrated in Figure 13. Furthermore, the vehicular volume in the HOV lane is relatively low. Comparing the two together demonstrates that for HOV lanes in Texas, a relatively high amount of person movement is achieved at a relatively low vehicle volume.

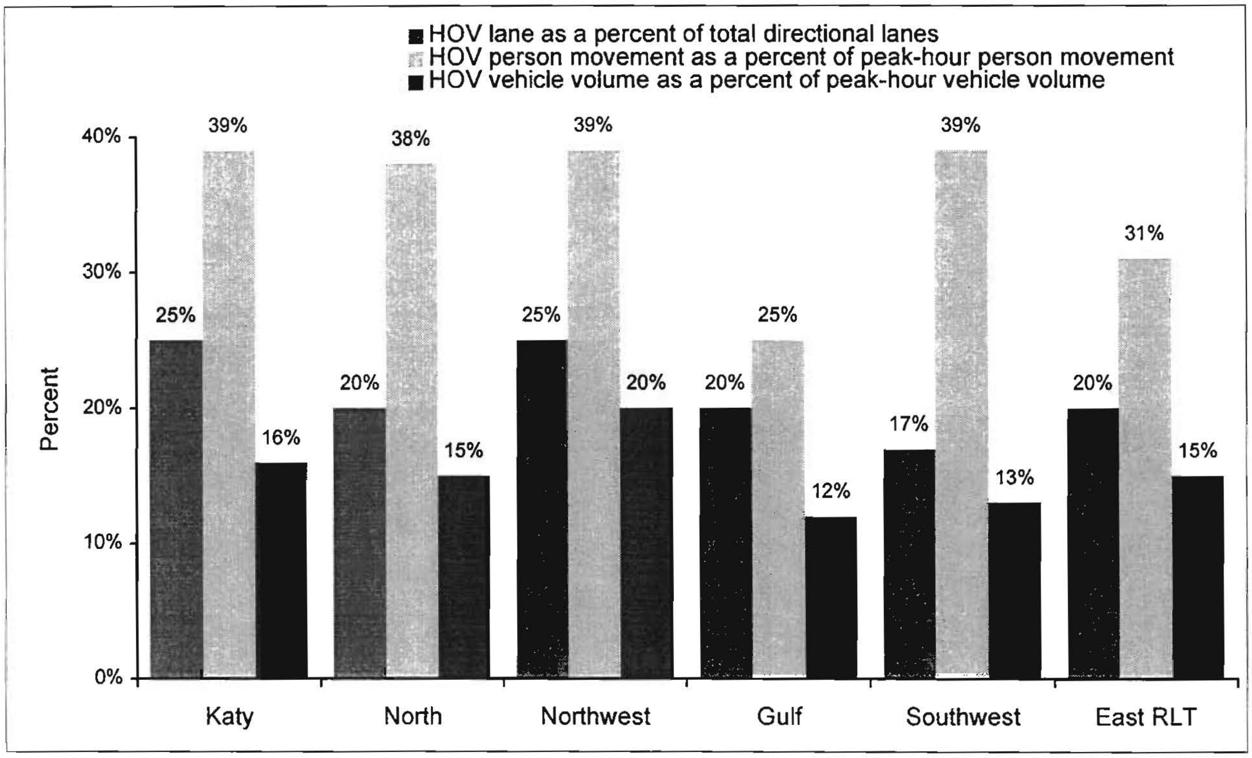


Figure 13. Percent of Peak-Hour Vehicles and Persons Moved on the HOV Lane

IMPACT ON OVERALL VEHICLE OCCUPANCY

For the HOV lanes to generate the disproportionate increases in person movement, it is necessary to increase the average vehicle occupancy (persons per vehicle) characteristic of the roadway. The HOV 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 freeways with the two more mature Houston HOV lanes (Katy and North), peak-hour average vehicle occupancies are unusually high, at approximately 1.4 persons per vehicle (Figure 14). All of the Texas freeway facilities with HOV lanes that are included in this study are experiencing average occupancies higher than the national average of 1.12 for commuting trips (*8*). These occupancies are the combined average of all freeway lanes plus all HOV facility traffic.

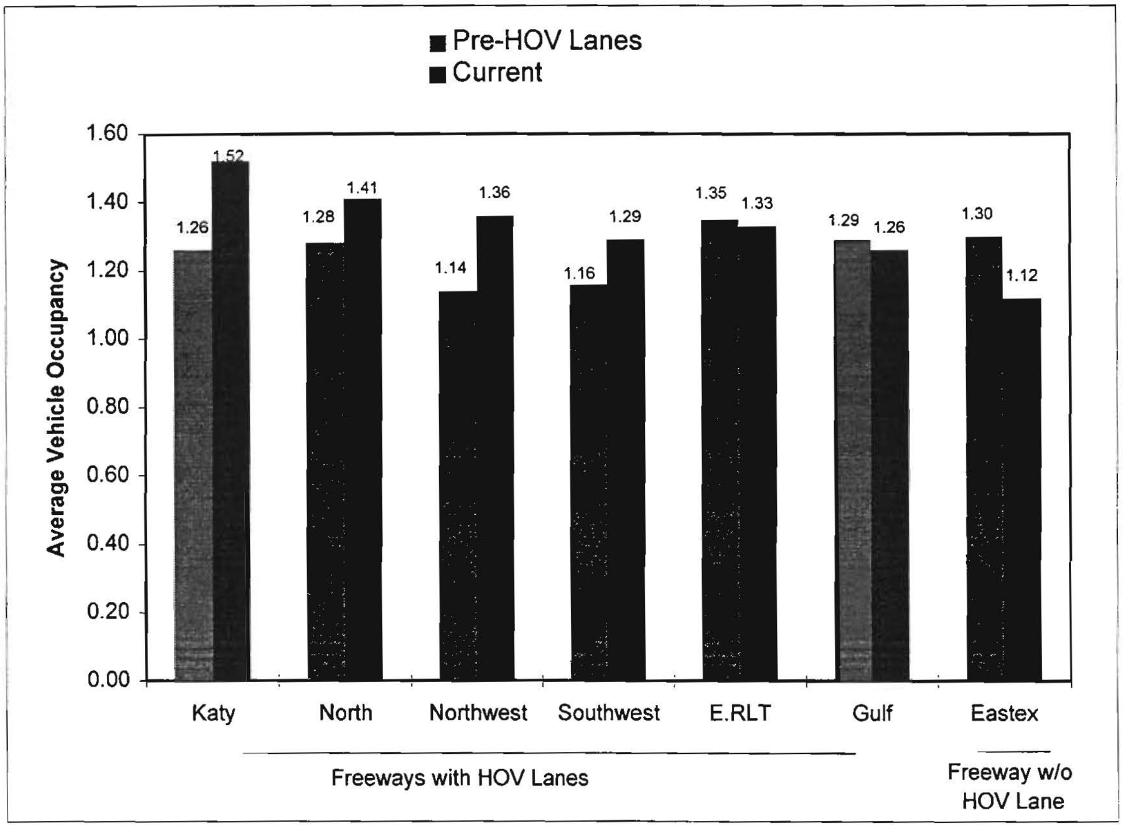


Figure 14. Change in Average Vehicle Occupancy

While four HOV facilities have resulted in increased average vehicle occupancy (Figure 15), two, the Gulf HOV lane in Houston and the East RLT in Dallas, have not. This can be attributed to characteristics or conditions unique to these two facilities, particularly with respect to ongoing freeway and HOV lane construction work. The Gulf freeway has experienced continuous construction activity that has repeatedly modified the HOV lane terminus, preventing stable operating conditions. Similarly, the E. RLT HOV lane was operationally impacted by a three-year, 1.2 km (3/4 mi) project that involved replacement of a bridge structure; the HOV lane itself has only been operational for a total of five years. In addition, the E. RLT previously experienced relatively high levels of bus ridership and carpooling, and thus higher vehicle occupancy, prior to the implementation of the HOV lane. It is not surprising that occupancy has remained essentially unchanged on this facility. Both HOV lanes, therefore, possess unique characteristics, including the lack of stable operating conditions, which affect the ability of the facilities to meet the increased vehicle occupancy measure.

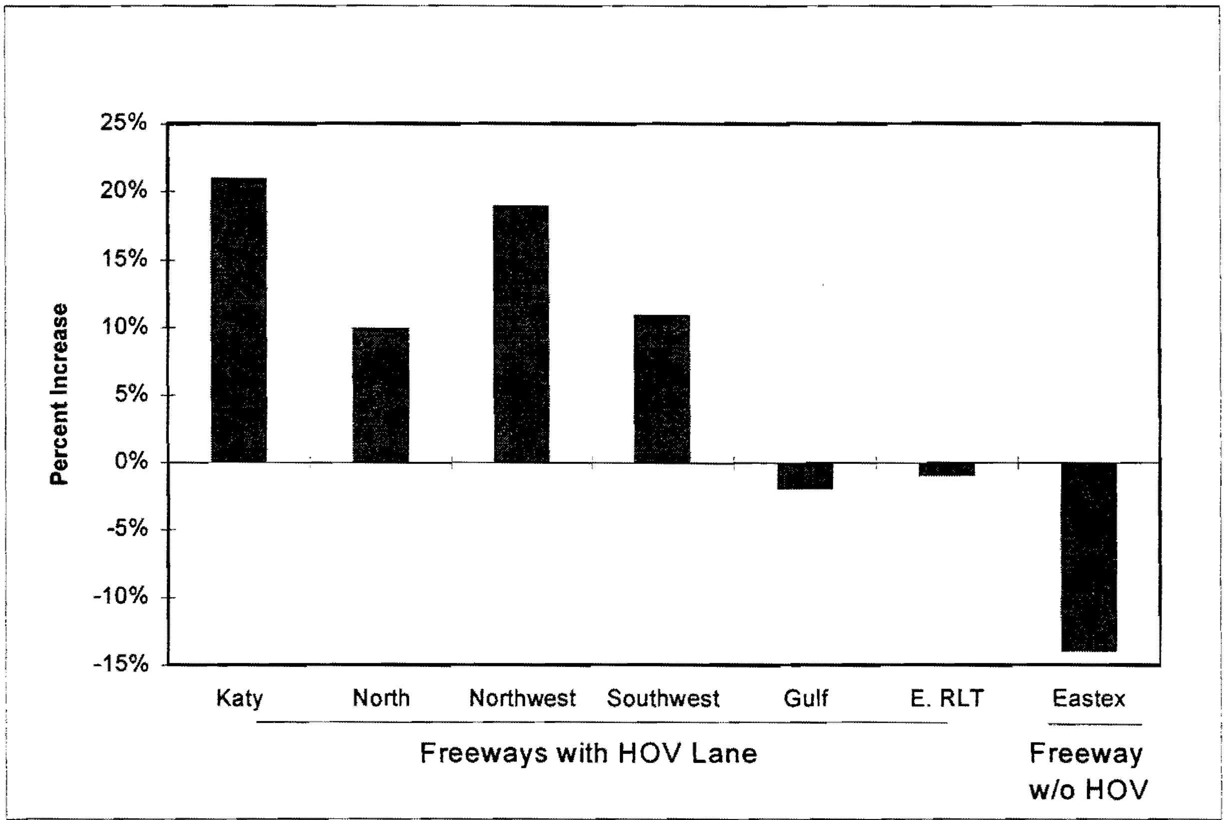


Figure 15. Increase in Peak-Hour Average Vehicle Occupancy

The data clearly show that the presence of the HOV lane has resulted in a meaningful increase in average vehicle occupancy over time, under stable operating conditions. 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 10 percent in most cases. Over the same time period, occupancy on a freeway without an HOV lane has experienced a 14 percent decrease in average vehicle occupancy.

The data 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 chapter review the data relative to changes in carpooling and bus ridership resulting from the HOV implementation.

IMPACT ON HIGH-OCCUPANCY VEHICLE USAGE

Changes in Carpooling

There have been significant increases in carpool volumes since carpools were allowed to use the HOV facilities (Figure 16). Increases of more than 100 percent are typical. To evaluate the person-movement effectiveness of the HOV 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.

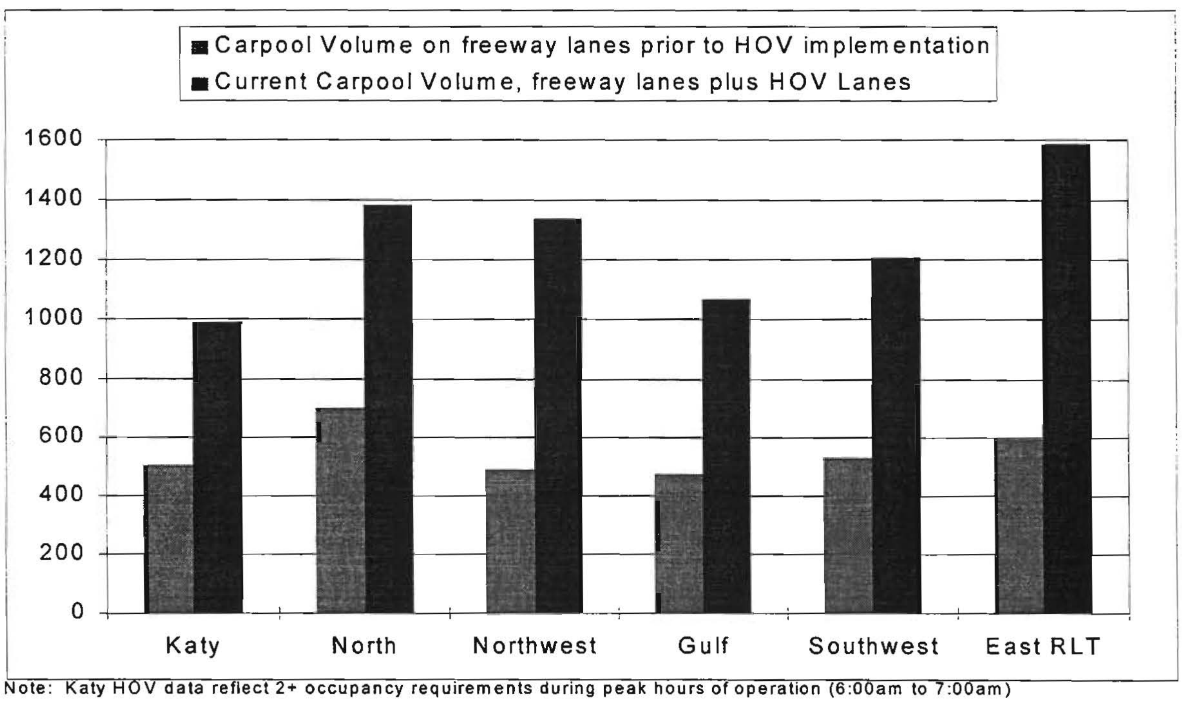


Figure 16. Change in 2+ Carpool Volumes, Absolute Data

There are several possible approaches for defining this impact:

- *If an HOV lane is presumed to have an effect on creating carpools, then the new carpools cannot simply be established carpools diverted from parallel routes.*

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 7)(*9*). This indicates that the increases that occurred in average vehicle occupancy were primarily from factors other than this diversion.

Table 7. Carpools that Diverted to the HOV Facility from Parallel Routes

HOV Facility, including Years of Operation with Carpools Allowed	Percent of HOV Carpoolers Whose Previous Mode Was Carpooling[1]		Percent of Those Carpoolers Who Previously Used a Parallel Route[2]		Percent of Total Carpools Using HOV Lane that Diverted from Parallel Routes	
	1990	1994	1990	1994	1990	1994
Katy - 11 years	29%	19%	13%	11%	4%	2%
North - 6 years	40%	---	19%	---	8%	--
Northwest - 8 years	33%	22%	15%	9%	5%	2%
East RLT - 5 years	---	51%	---	19%	--	9%
Unweighted Average	34%	31%	16%	13%	6%	4%

[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.

- *If HOV lanes create more carpools, it is 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.*

The estimate of new carpools is 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. Available data suggest that carpools in corridors with HOV lanes do remain in existence substantially longer than carpools in corridors without HOV lanes (Figure 17). 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.

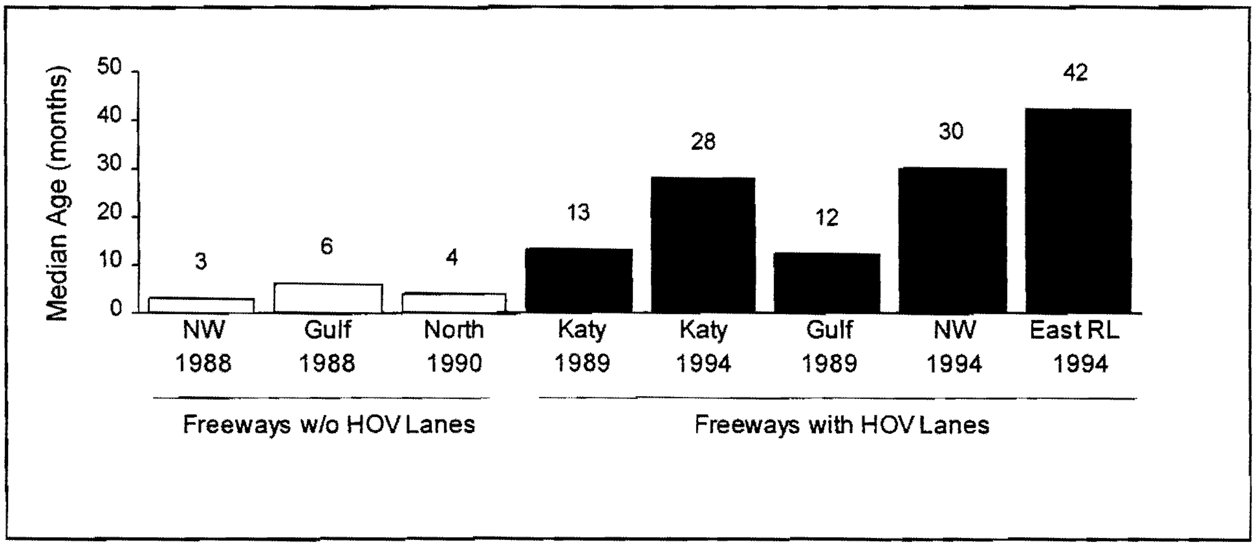


Figure 17. Age of Carpools

- *The impacts of HOV facilities on creating carpools can be isolated by comparing the change in carpool volumes over time between corridors with and without HOV lanes.*

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 18). 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. 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.

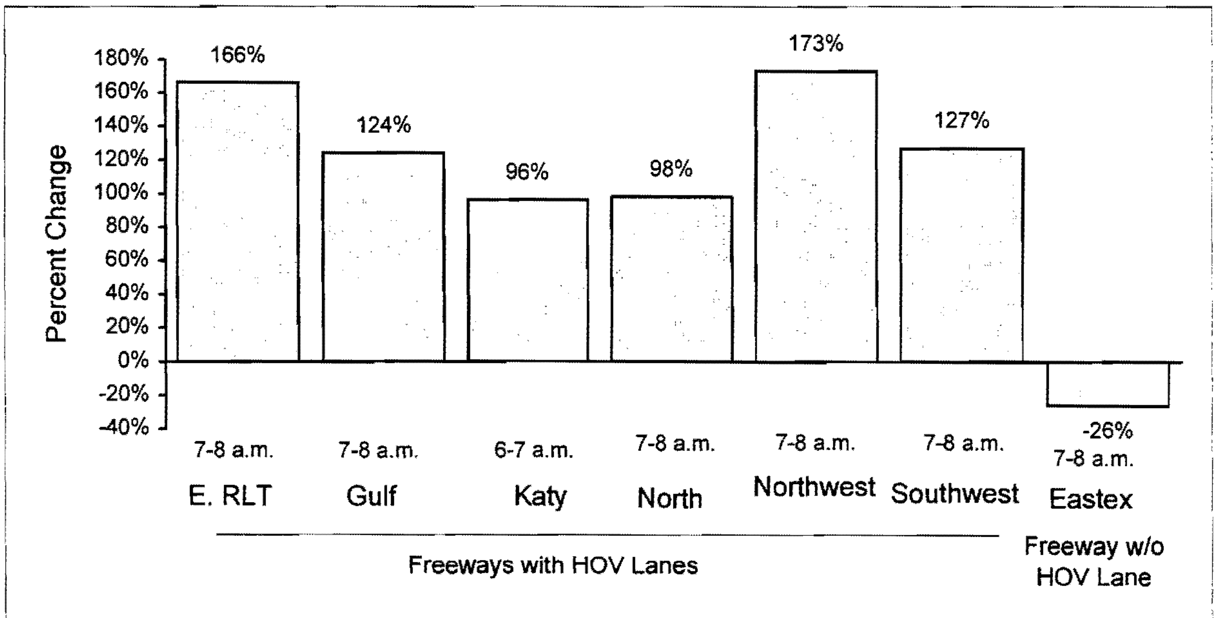


Figure 18. Percent Change (pre-HOV) Lane to Present in 2+ Carpool Volumes, A.M. Peak-Hour, Peak-Direction, Freeway Volumes Plus HOV Lane Volume

- *The previous mode of carpoolers is an indication of the impact of the HOV lane on creating carpools.*

One indicator of HOV lane impact on carpooling is the "previous mode" of travel for carpoolers; that is, how a trip was made prior to carpooling on the HOV lane (Figure 19). Those data indicate that somewhere between 35 percent and 66 percent of carpoolers on HOV lanes were previously in "drive alone" vehicles. It is interesting to note that over half of the carpoolers on East RLT were carpoolers before the HOV lane operation began.

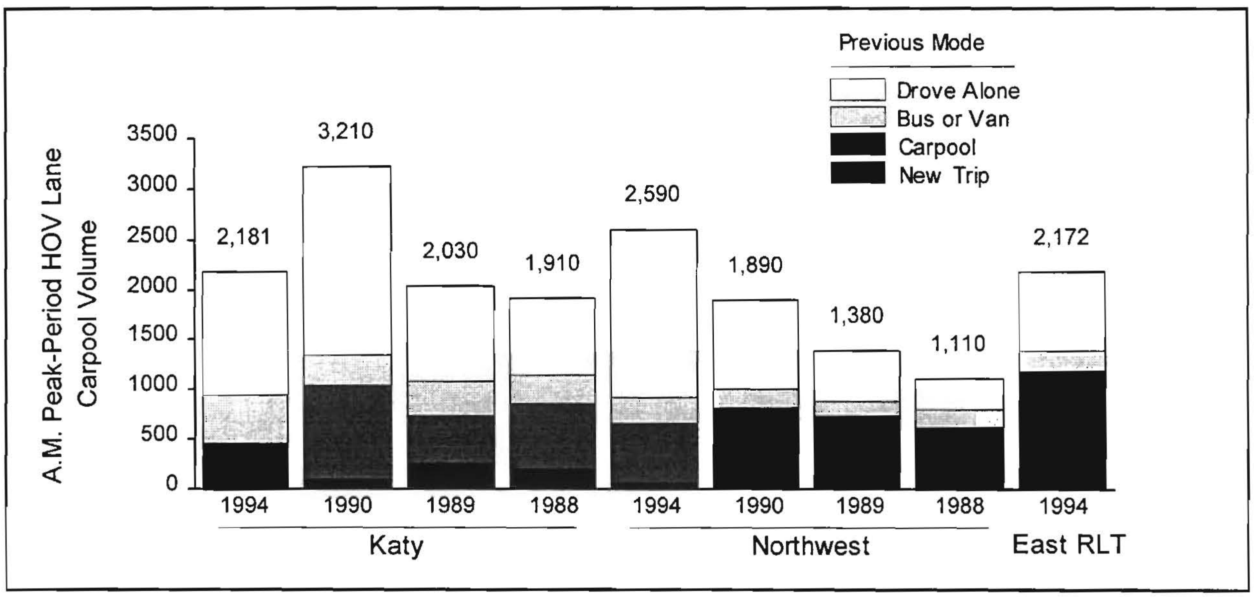
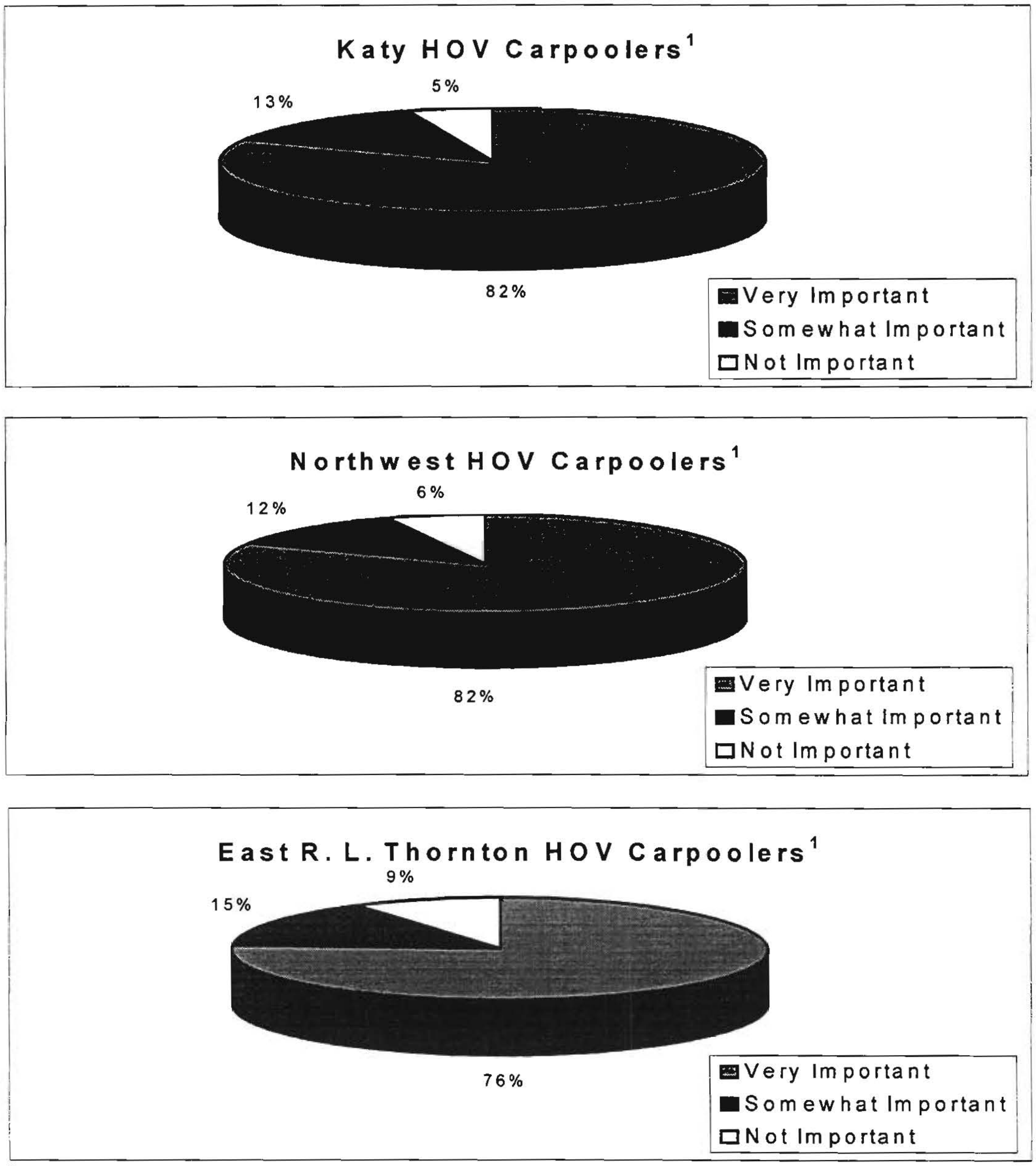


Figure 19. Previous Mode of Travel for HOV Lane Carpoolers

The sum of "drive alone" plus "new trips," can be considered an initial indication of the volume of new carpools created as a result of the HOV lane. However, 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 was present. To try to identify this portion of carpool demand, researchers surveyed carpoolers using the HOV lanes to assess the importance of the HOV lane in their decision to carpool.

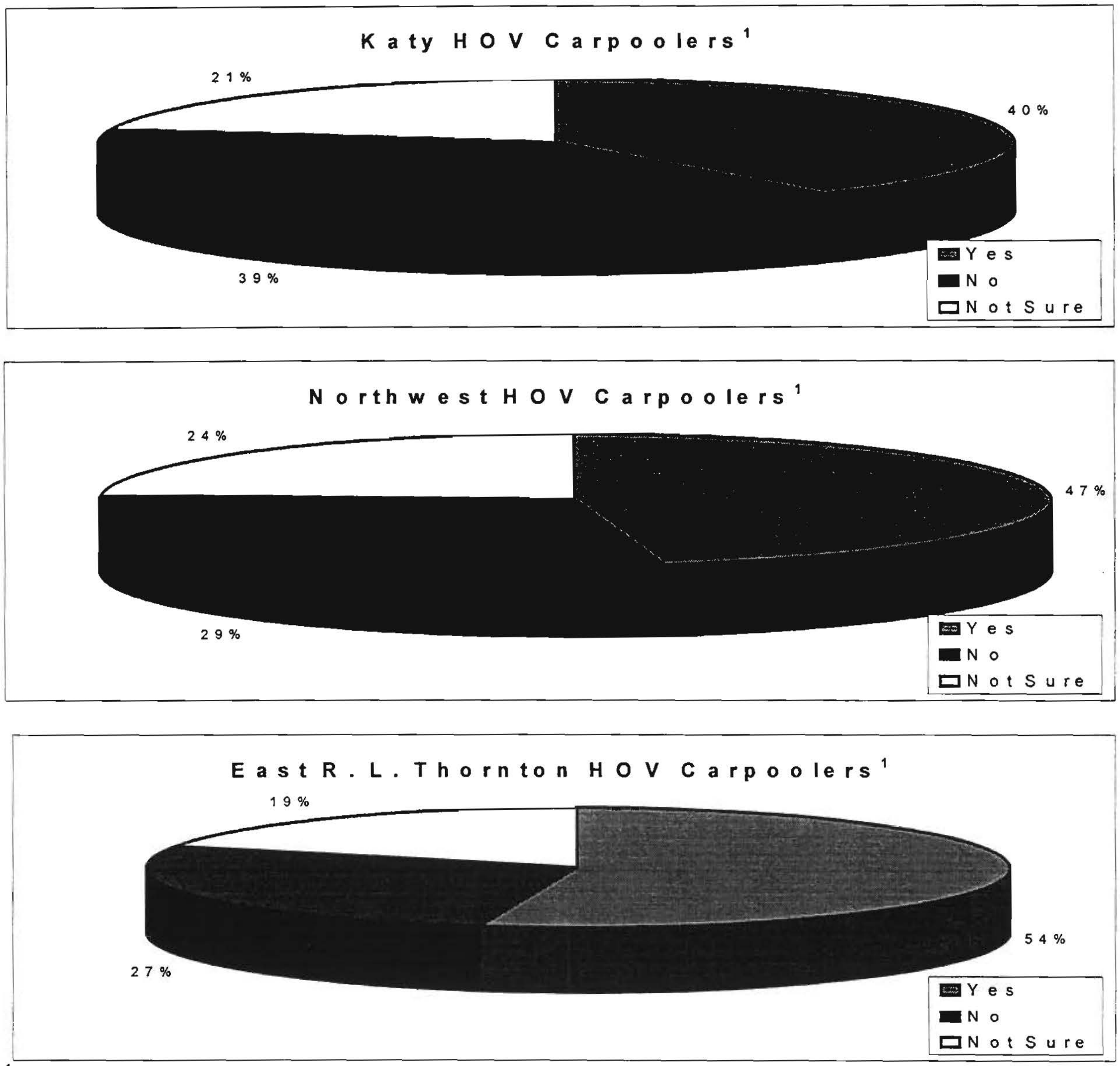
The question asked was, "How important was the HOV lane in your decision to carpool?" The responses (Figure 20) suggest that the HOV lane was "somewhat important" or "very important" in the decision to carpool to approximately 80 percent of the HOV carpoolers surveyed in 1994.

A second question asked carpoolers if they would be carpooling in the absence of the HOV lane (Figure 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.



[1] 1994 Summer Survey Data

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



[1] 1994 Summer Survey Data

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

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 that did not previously experience a significant carpool volume, 40 percent to 50 percent of the current HOV carpoolers formed a carpool as a result of the HOV facility (Table 8).

Table 8. Estimated Impact of HOV Lanes in Forming New Carpools

HOV Facility	Apparent Percent of New Carpools Based on Previous Mode[1]	Would You Carpool If There Were No HOV Lane			Estimated Percent of 1994 HOV Lane Carpools Formed Due to HOV Lane[2]
		Yes	No	Not Sure	
	1994	1994	1994	1994	
Katy	61%	40%	39%	21%	50%
Northwest	67%	47%	29%	23%	42%
E. RLT	35%	73%	14%	13%	21%
Unweighted Average	54%	53%	--	--	38%

[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 lane carpools that were formed due to implementing the HOV lane.

Source: Texas Transportation Institute surveys.

Changes in Bus Ridership

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, another component that contributes to the increase in vehicle occupancy and total person movement. In the previous section, it was 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 22). In the North Freeway corridor, there was essentially no bus service prior to the opening of the contraflow lane in 1979. With the exception of the Gulf and E. RLT, which have experienced some limiting factors described in the previous section of this chapter, it appears that the HOV lanes have had an impact on generating transit ridership increases. It should be noted that the E. RLT already had a relatively high transit ridership prior to the HOV lane, particularly in comparison with total ridership now occurring on a number of the other HOV lanes.

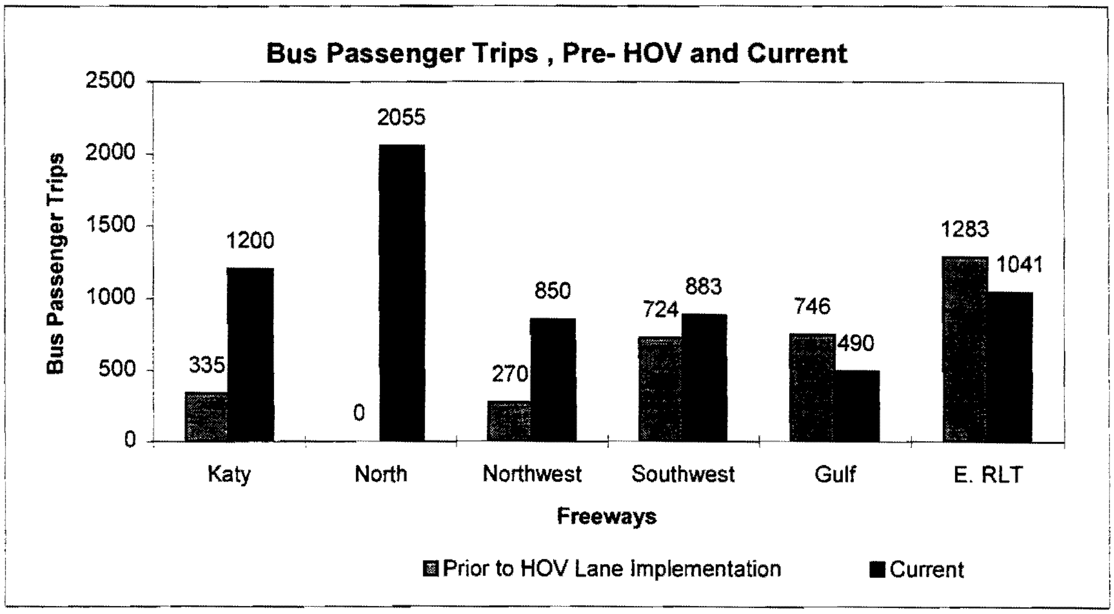


Figure 22. Number of Bus Rides, A.M. Peak-Hour, Peak-Direction, Pre-HOV and Current

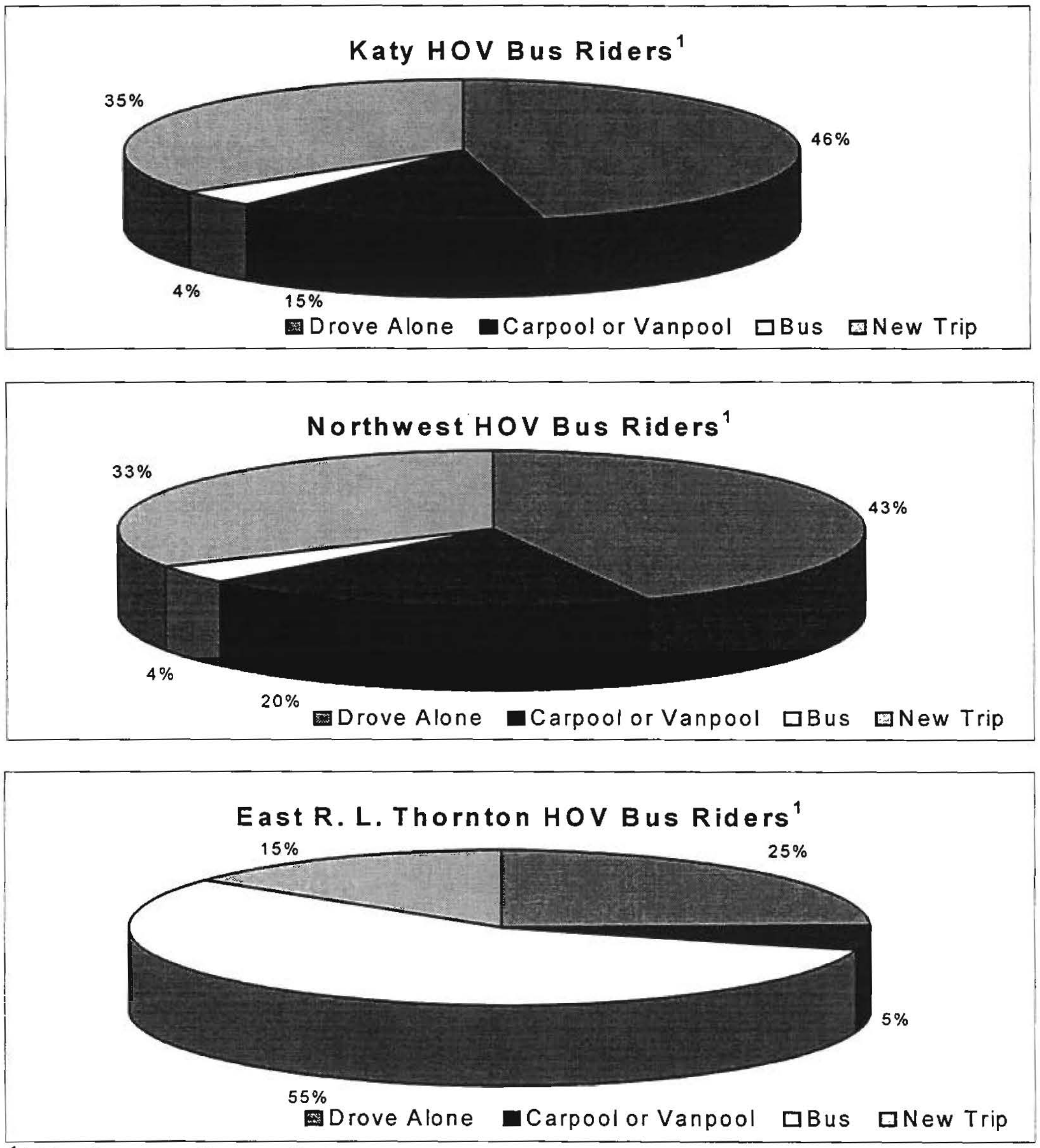
- *The impacts of HOV facilities on increasing bus ridership can be isolated by comparing the change in ridership between corridors with and without HOV lanes.*

Bus ridership has increased more rapidly in corridors having HOV lanes than it has in corridors without HOV lanes, as noted in Figure 22. Again, these data seem to confirm that the HOV lane has been a factor in increasing bus ridership.

- *The previous mode of bus riders is an indication of the impact of the HOV lane on increasing bus ridership.*

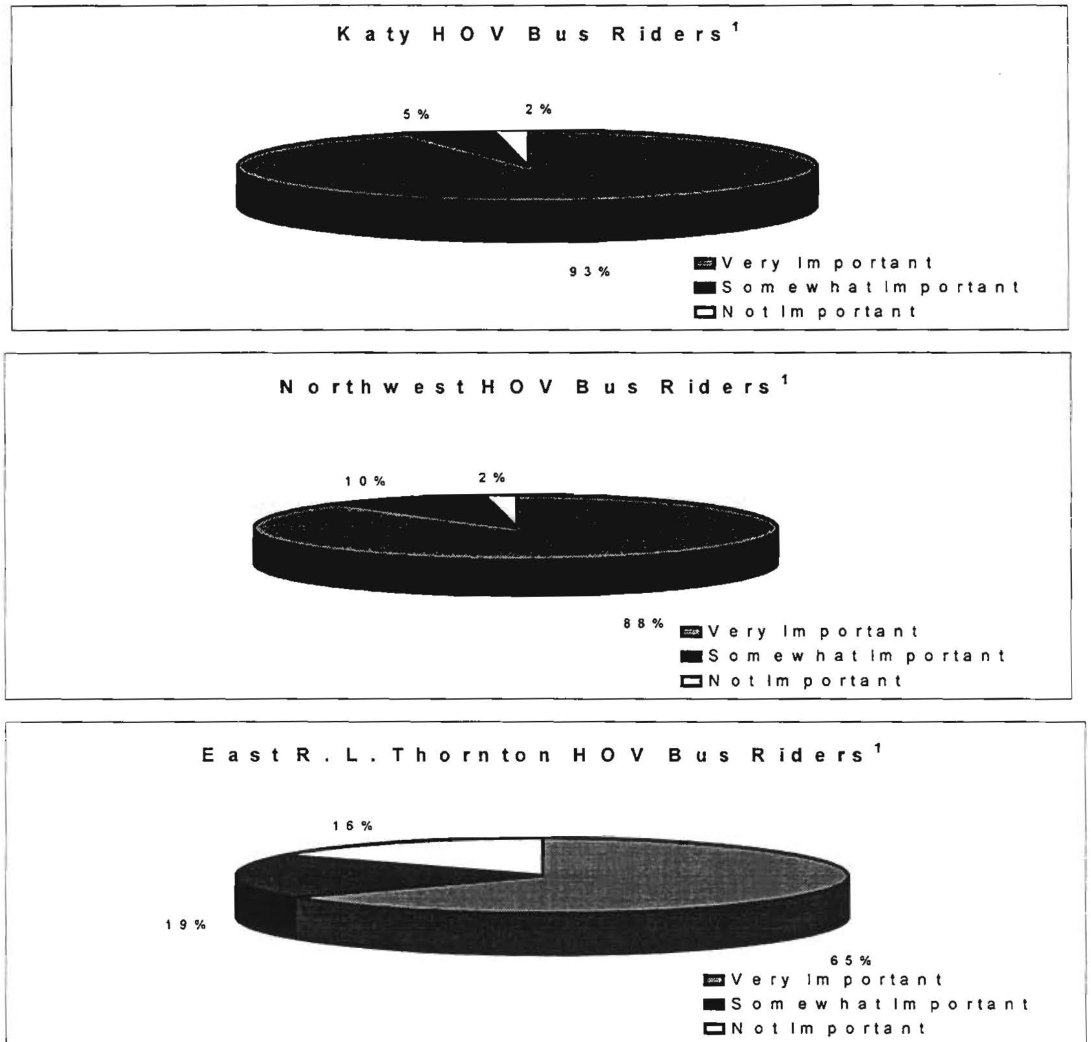
An examination of the previous mode of travel for HOV bus riders provides an indication that the HOV lanes have created new bus riders (Figure 23). These data suggest that fewer than 5 percent of existing HOV lane bus riders on the Katy and Northwest rode a bus prior to using the HOV lane, with over one-third of the bus riders previously driving alone. In Dallas, over one-half of the current bus riders rode the bus prior to the HOV lane, with 25% previously driving alone.

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 (Figure 24).



[1]1994 Summer Survey Data

Figure 23. Response to the Question, "Prior to Riding the Bus, How Did You Normally Make This Trip?"



[1] 1994 Summer Survey Data

Figure 24. Responses to the Question, "How Important was the HOV Lane in Your Decision to Ride the Bus?"

A second question asked of bus riders was whether they would be riding a bus in the absence of the HOV lane. The data for the Houston facilities suggest that 35 percent to 50 percent of total bus ridership would not be riding the bus if there were no HOV facility. Interestingly, 65% of the E. RLT bus riders claim the HOV lane is a very important consideration in their decision to ride the bus, yet 74 percent say they would ride the bus even if the HOV lane was not available.

Implementation of the HOV lanes appears to have increased bus transit ridership. The type of increase in ridership 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 ride the bus. It appears that on the HOV lanes surveyed that did not already experience high transit ridership, approximately 60 percent of the current riders are on buses as a result of the HOV facility (Table 9).

Table 9. Estimated Impact of HOV Lanes on Bus Ridership

HOV Facility	Apparent Percent of New Bus Passenger Trips Based on Previous Mode[1]	If the HOV lane had not opened, would you be riding the bus now?			Estimated Percent of Bus Ridership Due to HOV Lane[2]
		Yes	No	Not Sure	
	1994	1994	1994	1994	
Katy	81%	18%	50%	32%	66%
Northwest	76%	26%	35%	39%	55%
E. RLT	39%	74%	9%	17%	17%
Unweighted Average	65%	39%	31%	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 lane carpools that were formed due to implementing the HOV lane.

Source: Texas Transportation Institute surveys.

CONCLUSIONS

Based on the data presented, HOV lanes can be considered effective in meeting the objective of increasing person movement in a corridor. The following observations can also be made:

- HOV lanes have a greater positive impact than a general-purpose lane on person-movement efficiency in a corridor by carrying more persons per directional lane with fewer vehicles.

- All freeways with HOV lanes that were reviewed in this study have higher average vehicle occupancies than the national average, and those HOV lanes that have operated in a stable environment over time have experienced increases in average vehicle occupancy of 10 percent or more.

- Based on survey results, an HOV lane has the potential to increase carpooling by up to 50 percent in corridors where carpools are not a predominant mode prior to HOV lane implementation.

- The presence of an HOV lane has the potential to increase bus ridership by as much as 60 percent in corridors where transit is not a predominant mode before HOV lane implementation.

CHAPTER 7. IMPROVE BUS TRANSIT OPERATING EFFICIENCY

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. As shown in the previous chapter, substantial increases in bus ridership have resulted from the implementation of HOV lanes. This chapter describes the impacts that HOV lanes have had on bus operations.

Enhancement of Bus Service

Compared to conditions that existed prior to HOV lane implementation, average bus operating speeds have increased dramatically (Table 10). On average, peak-hour bus operating speeds have more than doubled, increasing from 41 kph to 84 kph (26 mph to 52 mph). Also, as shown previously in this report and also documented elsewhere, research 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 (*10*). Figure 25 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. This improvement in bus operations makes bus travel substantially more attractive. That attraction is reflected in the increased ridership compared to pre-HOV conditions, illustrated in Figure 26.

Table 10. 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	36 (23)	84 (52)	133%
North	32 (20)	84 (52)	163%
Gulf	50 (31)	85 (53)	70%
Northwest	47 (29)	79 (49)	68%
Southwest	47 (29)	80 (50)	70%
East RLT	34 (21)	90 (56)	165%
Unweighted Average	41 (26)	84 (52)	105%

Source: See data in appendices.

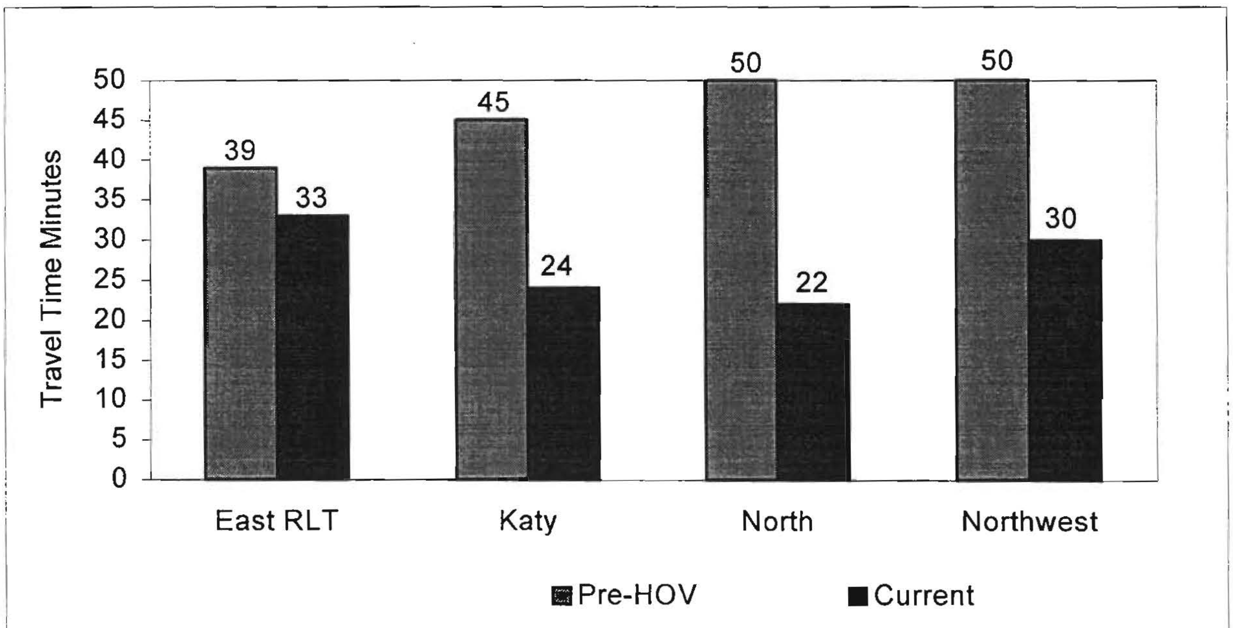


Figure 25. Bus Schedule Time, A.M. Peak

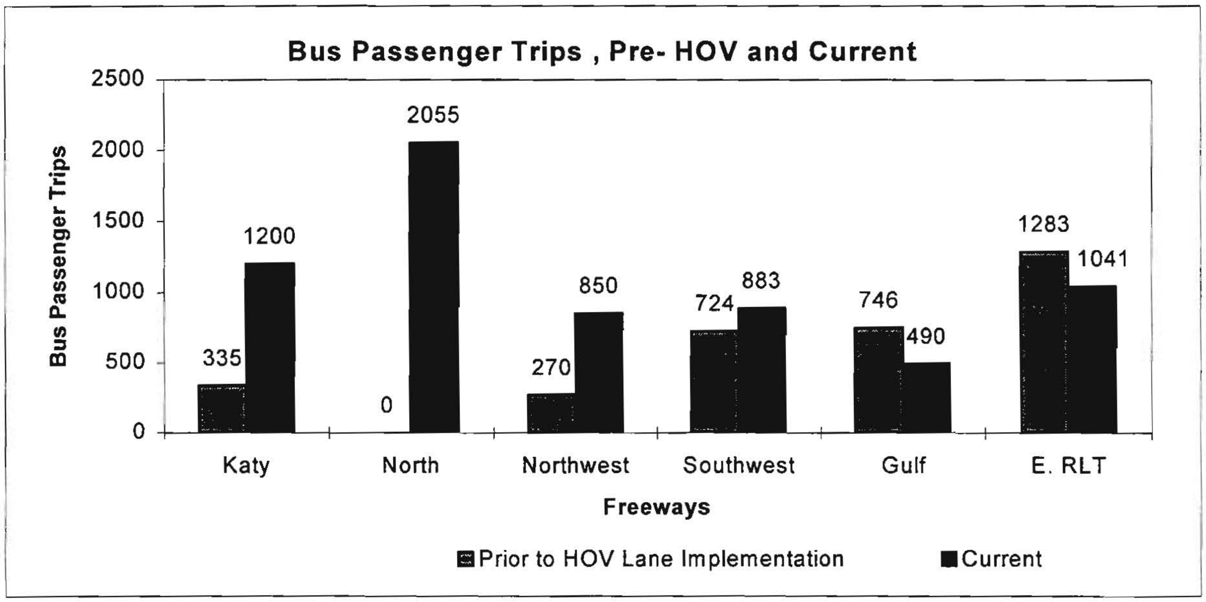


Figure 26. Number of Bus Riders, A.M. Peak-Hour, Peak-Direction, Pre-HOV and Current

Impact on Costs to Transit

Previous research has shown that even minor improvements related to bus use of HOV lanes can have significant impact on operating expenses (*11*). Analysis of 1990 bus operating costs for Houston METRO showed that the extension of one HOV lane, the re-opening of a section of another and the improvement of a connector ramp saved the transit authority more than $300,000 annually. That analysis also showed that 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.

CHAPTER 8. IMPACT ON FREEWAY GENERAL PURPOSE LANES

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.

As proposed 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 of designs similar to those in operation in Houston and Dallas does not greatly affect the operation of the freeway general-purpose lanes. Table 11 shows selected operational characteristics of the six freeways with operating HOV lanes. Freeway volumes have, on average, increased by more than 10 percent in HOV lane corridors. While speeds on some freeways have actually increased since HOV lane implementation, this is largely attributable to factors other than the HOV lane, such as bottleneck removal. Figure 27 shows plots of freeway travel speeds prior to and after HOV lane implementation.

Table 11. 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	1,577	1,650	1,922	1,650	1,530	1,790	1,853	1,640	1,710	1,420	1,813
A.M. Peak Period	1,220	1,408	—	1,528	1,400	1,310	1,460	1,526	1,430	1,507	1,500	1,640
Freeway Peak-Hour Speed[2], kph (mph)	37 (23)	31 (19)	32 (20)	36 (23)	50 (31)	62 (39)	45 (28)	42 (26)	47 (29)	69 (43)	34 (21)	43 (26)
Injury Accidents per 100 MVK[3] (per 100 MVM)	12.4 (20.0)	12.9 (20.9)	18.8 (30.3)	15.6 (25.1)	18.5 (29.8)	12.3 (19.9)	7.3 (11.7)	6.7 (10.9)	16.3 (26.2)	10.2 (16.4)	14.0 (22.6)	17.4 (28.0)

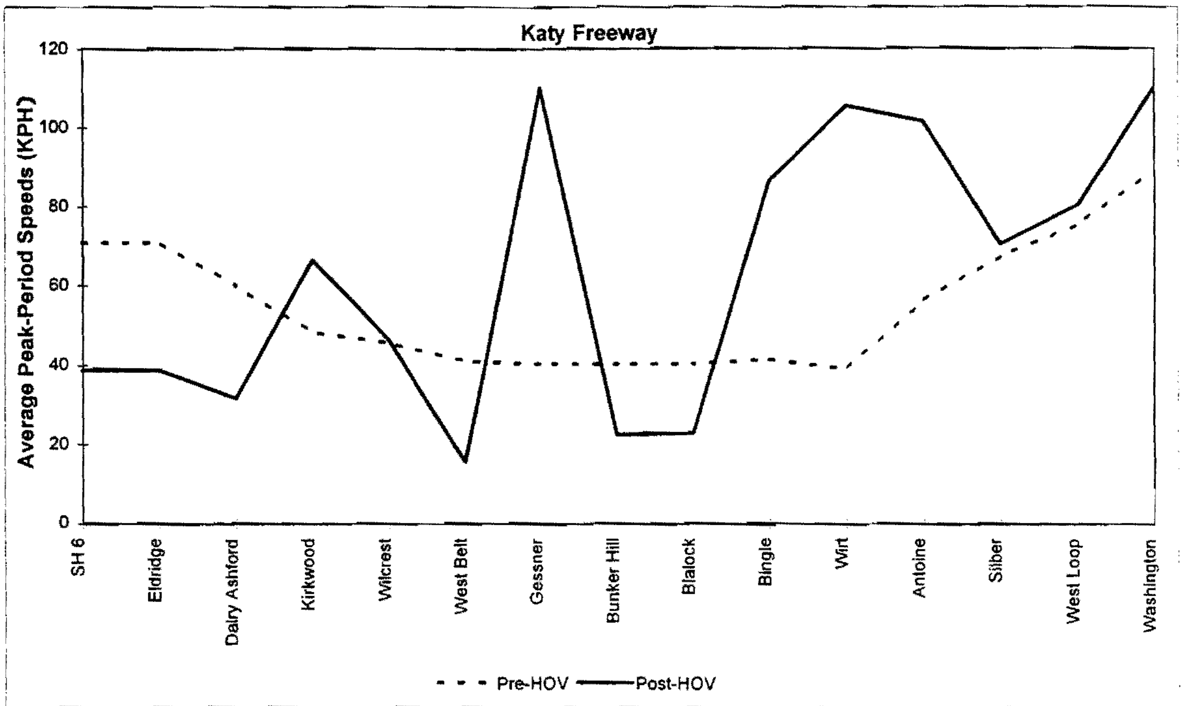
[1]Peak-period volumes are for a 3.5-hour period in Houston and a 3.0-hour period in Dallas (East RLT HOV lane).

[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 Dowling (10.5 km [6.5 mi]); Southwest, Bellfort to South Shepard (18.7 km [11.6 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 11 presents the relevant data. Post-implementation accident rates are slightly higher on the East RLT general-purpose lanes, but consistently lower on Houston freeways. The unweighted average accident rate for the five barrier-separated HOV lanes has declined from 15 to 12 injury accidents per 100 million vehicle-kilometers (MVK) (from 22 to 19 per 100 million vehicle-miles [MVM]). It appears that HOV lane implementation has not significantly impacted freeway accident rates. The increase on the East R.L. Thornton adjacent to the contraflow lane does not appear to be related to the presence of the HOV lane.



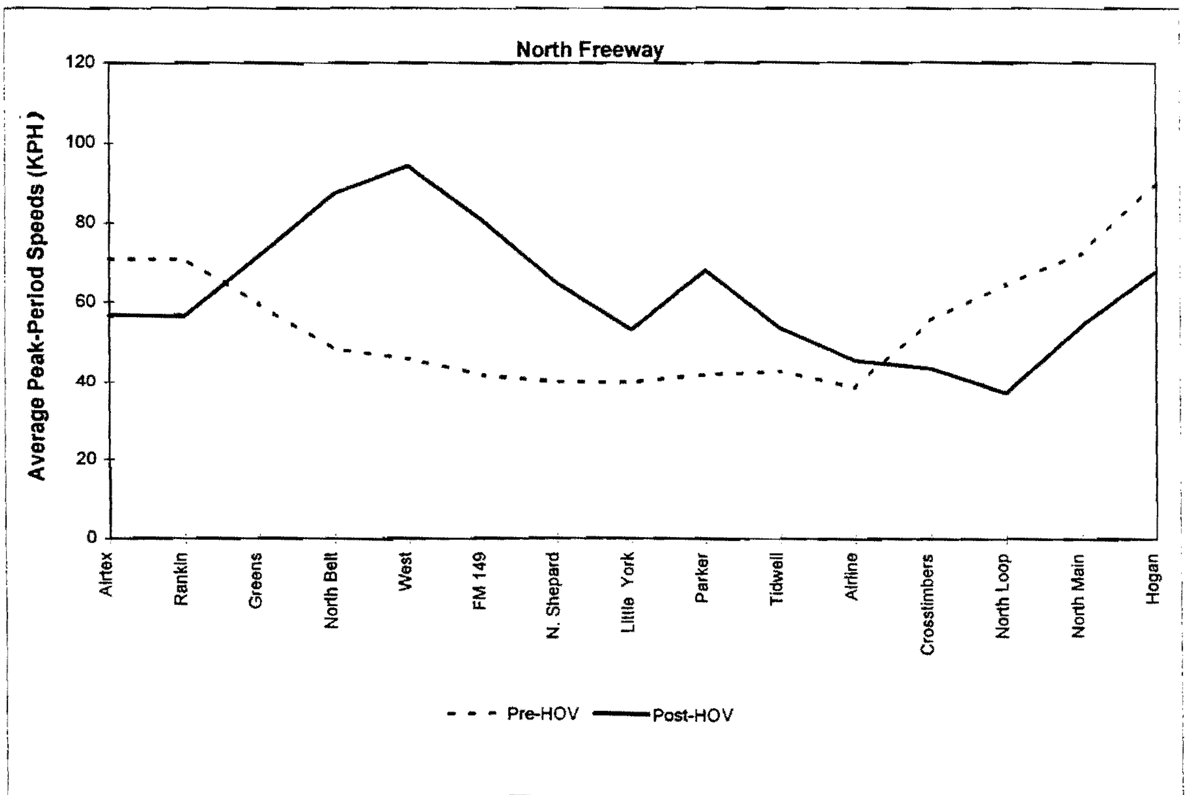
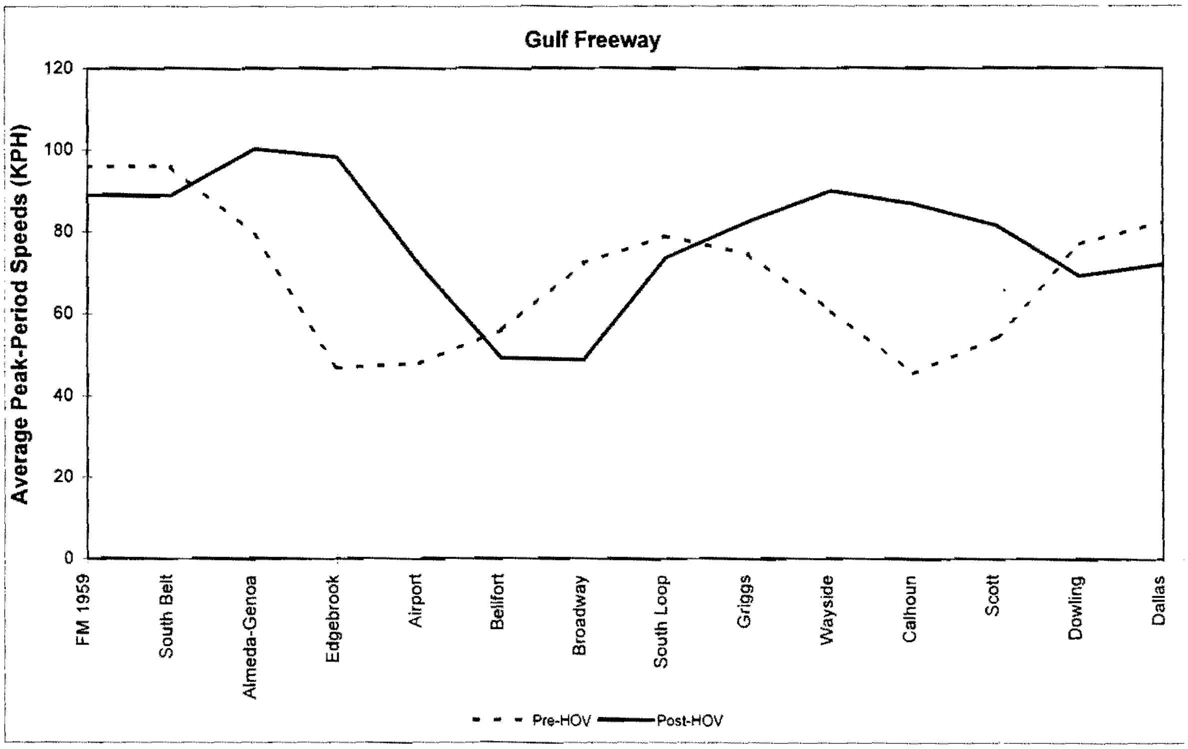
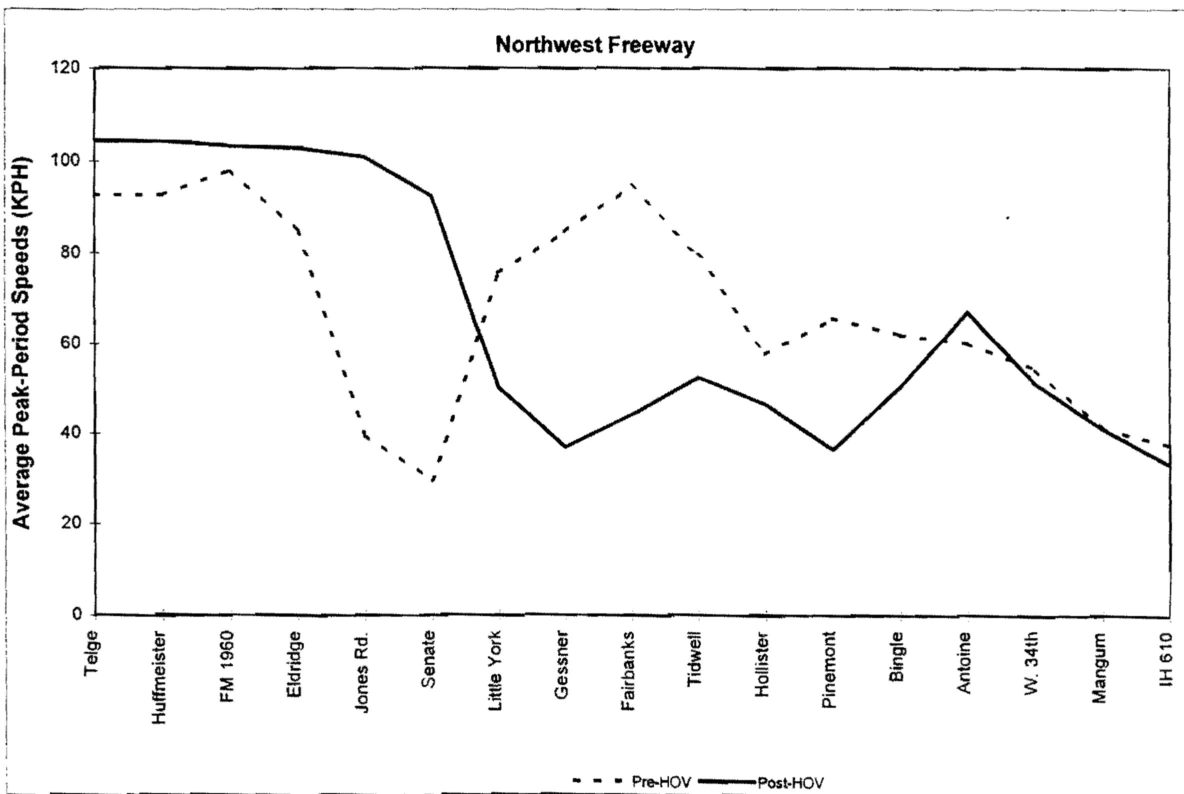
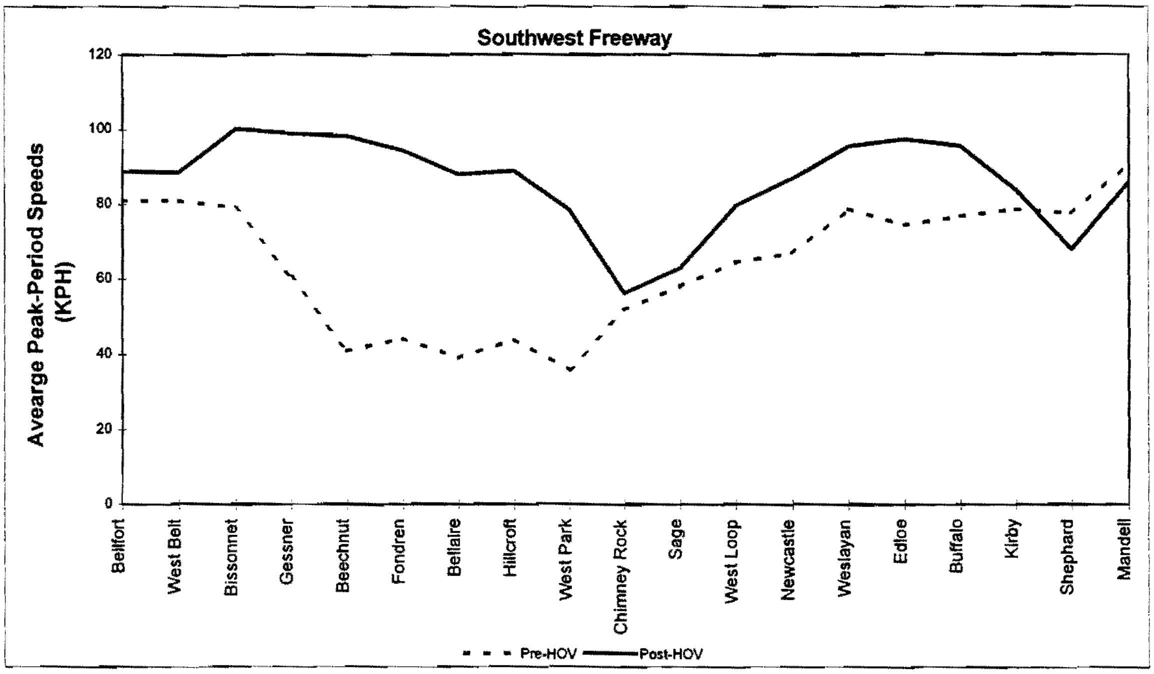
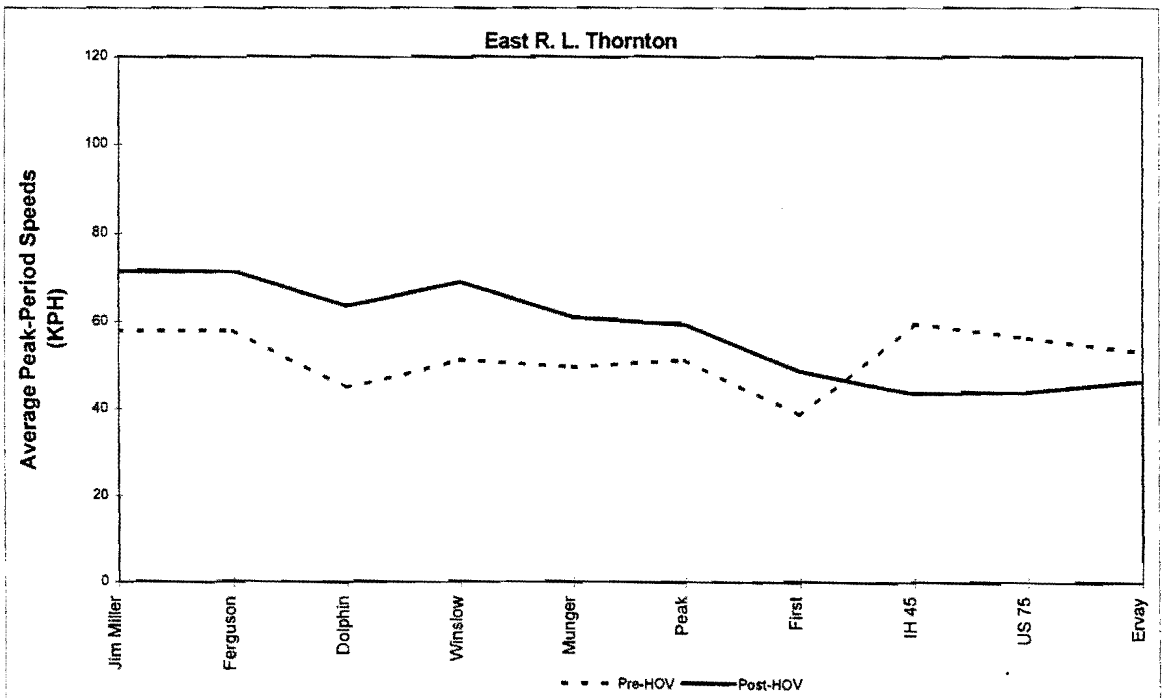


Figure 27. Freeway Peak-Period Speed on Freeway General Purpose Lanes


Gulf Freeway
Average Peak-Period Speeds (KPH)
120
100
80
60
40
20
0
FM 1959
South Belt
Almeda-Genoa
Edgebrook
Airport
Bellfort
Broadway
South Loop
Griggs
Wayside
Calhoun
Scott
Dowling
Dallas
Pre-HOV
Post-HOV


Northwest Freeway
Average Peak-Period Speeds (KPH)
120
100
80
60
40
20
0
Telge
Huffmeister
FM 1960
Eldridge
Jones Rd.
Senate
Little York
Gessner
Fairbanks
Tidwell
Hollister
Pinemont
Bingle
Antoine
W. 34th
Mangum
IH 610
Pre-HOV
Post-HOV


Southwest Freeway
Avearge Peak-Period Speeds (KPH)
0
20
40
60
80
100
120
Bellfort
West Belt
Bissonnet
Gessner
Beechnut
Fondren
Bellaire
Hillcroft
West Park
Chimney Rock
Sage
West Loop
Newcastle
Weslayan
Edloe
Buffalo
Kirby
Shephard
Mandell
Pre-HOV
Post-HOV


East R. L. Thornton
Average Peak-Period Speeds (KPH)
0
20
40
60
80
100
120
Jim Miller
Ferguson
Dolphin
Winslow
Munger
Peak
First
IH 45
US 75
Ervay
Pre-HOV
Post-HOV

CHAPTER 9. IMPROVE TOTAL 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 lane efficiency of the freeway is expressed according to a formula developed by Courage et al. (*12*):

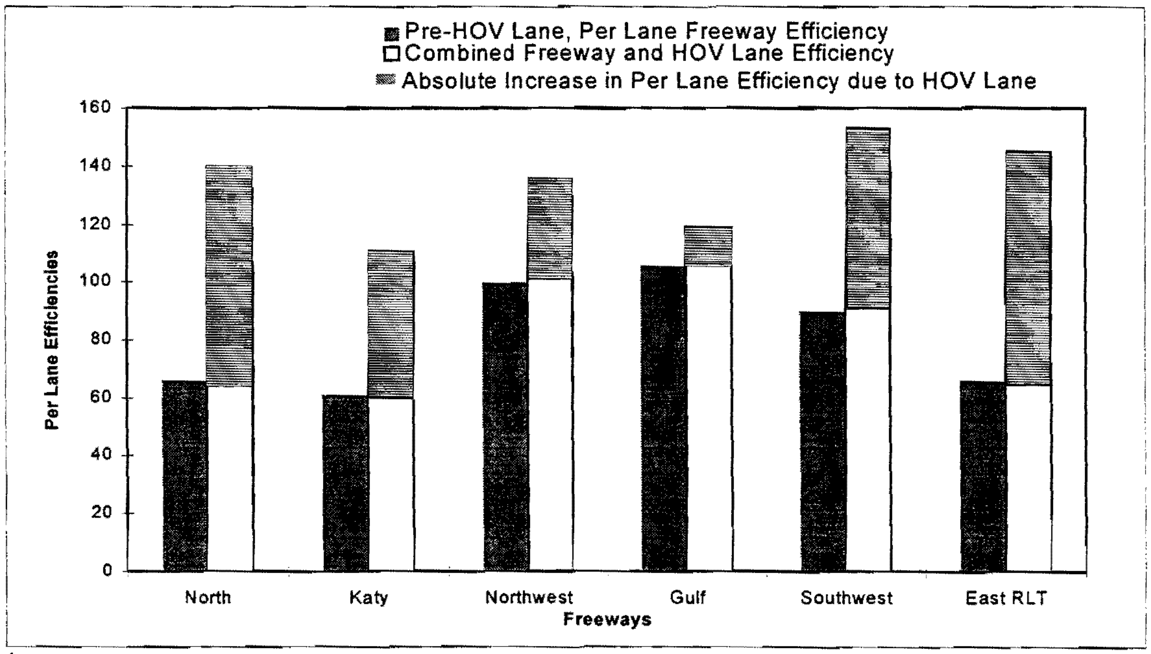
per lane efficiency = (person volume per lane "X" speed) / 1000.

In all cases for which data are available, the implementation of the HOV lane has increased the number of persons moved on the roadway, and thus increased the overall efficiency of the facility (Table 12). It appears that, on a facility with a mature HOV lane, the priority lane should increase the per lane efficiency by an absolute value of at least 30; an increase of 30 represents 1000 people going 30 kph faster (1000 "X" 30 / 1000), or 2000 people going 15 kph faster (2000 "X" 15 / 1000). This level of increase has been observed on the North, Katy, Northwest, Southwest, and East RLT HOV lanes. By comparison, the control freeways that do not have an HOV lane have varied over the years from no change in efficiency to declines (current values in Figures 28).

Table 12. 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	70	415	139	73
Katy	61	54	281	111	50
Northwest	100	81	293	134	34
Gulf	106	102	183	118	12
Southwest	90	126	288	153	63
East RLT	66	81	318	145	79
Eastex[3] (w/o HOV, Houston)	135	104	NA	104	-31
South RLT[4] (w/o HOV, Dallas)	108	104	NA	104	-4

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.



[1]Chart represents peak-hour data.

Figure 28. Changes in per Lane Efficiencies

CHAPTER 10. HIGH-OCCUPANCY VEHICLE LANE COST EFFECTIVENESS

CAPITAL AND OPERATING COSTS OF TEXAS HOV LANES

Houston

The Houston HOV lanes have typically been built as part of freeway construction projects, which makes it difficult to determine the precise capital costs. Information provided by METRO and TxDOT was used in developing the costs. Detailed cost breakdowns for each facility are found in the appendices.

The HOV facilities have been funded by a combination of federal and state highway funds and federal and local transit monies. Approximately 80 percent of the total capital cost is from transit funds. Table 13 summarizes the average capital and operating costs for the HOV lanes currently operating in Houston. Detailed cost figures for each facility are provided in the appendices.

Table 13. Capital and Operating Costs for Reversible HOV Lanes in Houston, 1996

Average total cost of HOV lane construction, per km (per mi)	$5.7 million ($9.2 million)
Average construction cost, including access ramps, per km (per mile)	$3.8 million ($6.2 million)
Average construction cost of support facilities (park-and-ride lots, park-and-pool lots, bus transfer centers), per km (per mile)	$1.7 million ($2.7 million)
Average capital cost of surveillance, communication and control systems for HOV lanes, per km (per mile)	$0.2 million ($0.4 million)
Average annual cost for daily operation and enforcement, per facility	$315,400

Note: Costs are shown in 1996 dollars.

Capital costs do not include the value of the existing freeway rights-of-way in which the HOV lanes were built; state-owned right-of-way has been provided for all facilities with the exception of some ramps and support facilities. The costs also do not include the expense of additional buses required to provide HOV service and the bus maintenance facilities to support them.

Dallas

The Dallas HOV lanes have been constructed jointly by TxDOT and DART. Sixty-six percent of the funds have come from federal sources (primarily Congestion Mitigation Air Quality (CMAQ funds), and the remaining 33 percent have been provided equally by TxDOT and DART.

Tables 14 and 15 summarize the average capital and operating costs for the HOV lanes currently operating in Dallas. Detailed cost figures for E. RLT are provided in the appendix.

Table 14. Capital and Operating Costs of East R.L. Thornton Contraflow HOV Lane in Dallas

Average total cost of HOV lane construction, per km (per mi)	$2.2 million ($3.6 million)
Average annual cost for daily operation and enforcement	$600,000

Note: Costs are shown in 1996 dollars.

Table 15. Capital and Operating Costs of Concurrent Flow HOV Lanes in Dallas

Average total cost of HOV lane construction, per lane-km (per lane-mile)	$0.6 million ($0.9 million)
Average annual cost for daily operation and enforcement, per facility	$200,000

Note: Costs are shown in 1996 dollars.

For the East R.L. Thornton contraflow lane, the capital costs include the inbound direction auxiliary lane constructed in 1994, and the outbound extension built in 1996. Also included are the costs associated with structural upgrades of the pavement for the HOV lane and the access/egress ramps serving the lane. For both contraflow and concurrent flow facilities, the value of the existing freeway right-of-way in which the HOV lanes were constructed is not included. No new support facilities (e.g., park-and-ride lots and bus transfer centers) have been constructed in conjunction with the HOV lanes in Dallas.

Figures 29 and 30 represent costs by facility for construction and for annual operation and enforcement.

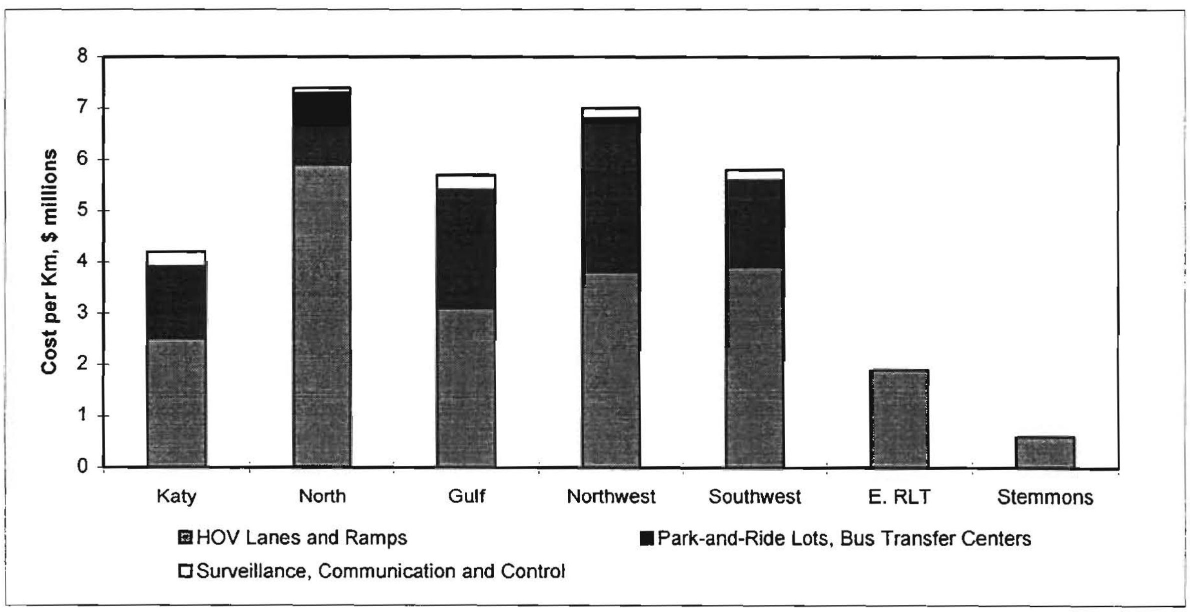


Figure 29. Costs per Kilometer by Facility

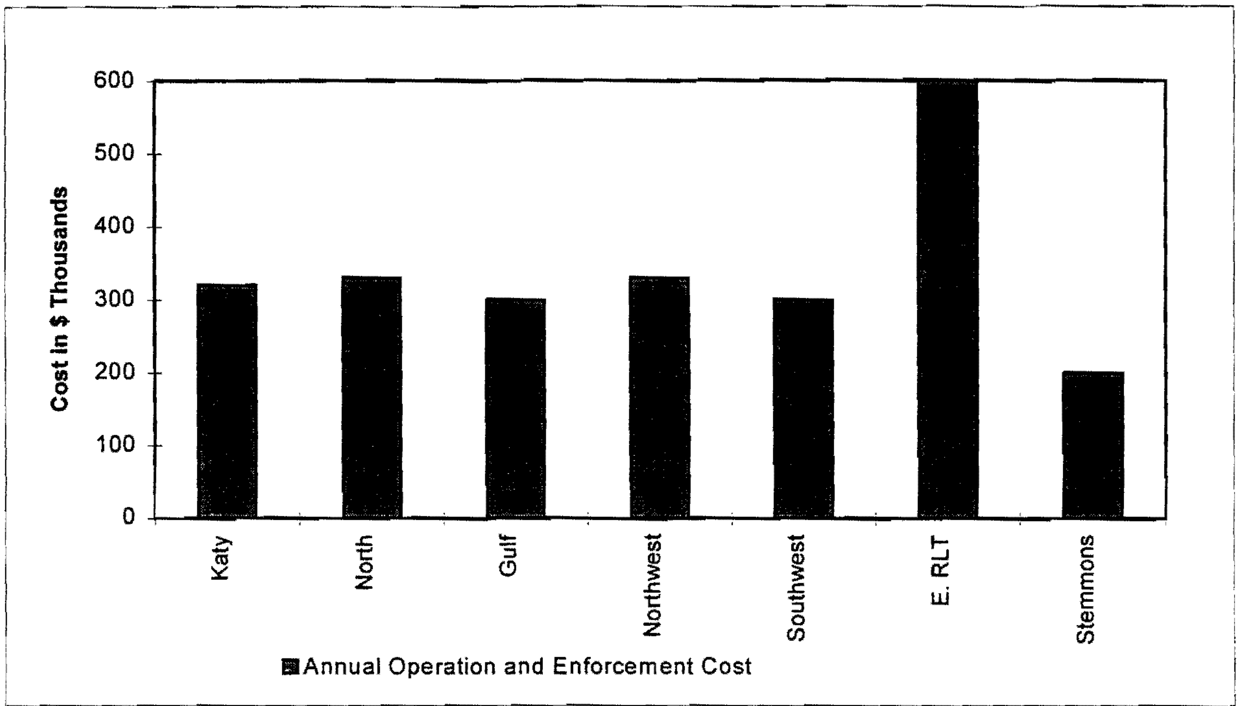


Figure 30. Annual Operation and Enforcement Costs on HOV Facilities

Analysis of HOV Lane Cost Effectiveness

The determination of cost effectiveness in this report focuses on the HOV facilities that have been operational for at least a full year so that sufficient available data could be used in the analysis. Many of the potential benefits associated with HOV lanes, are difficult to quantify. Included in this potential benefit list are factors such as air quality, 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.

In an effort to assess the cost effectiveness based on benefits that can be readily quantified, the HOV facilities were analyzed using MicroBENCOST, a planning-level economic analysis tool developed by TTI under NCHRP Project 7-12 (*13*). The MicroBENCOST program uses standard methodologies for traffic allocation and speed and delay calculations. National averages are provided for user costs and vehicle operation costs. The total costs used to compute the gross benefit-to-cost ratio (B/C) include construction costs of improvements, routine facility maintenance and operation costs, vehicle operating costs and accident costs. Benefits that result from the improvements include savings in delay, reduction in vehicle operating costs including fuel consumption and reduction in accidents. The program calculates costs and benefits for a 24-hour period, 365 days per year over a multi-year time frame by comparing unimproved and improved conditions. Cost effectiveness for this analysis is measured in terms of the benefit-to-cost ratio generated by MicroBENCOST.

MicroBENCOST is capable of analyzing a wide range of highway improvements, including HOV lanes as an "added capacity" measure. The program has the ability to determine the benefits and costs associated with implementation of reversible, concurrent and contraflow HOV lanes. For the purposes of this study, a comparison was made of the existing freeway lane configuration with and without the HOV lane in order to compute the benefit-to-cost ratio. Although some default data are supplied by the program, the majority of data used were actual traffic data and construction costs from HOV lane implementation and operation in Texas in order to obtain the most reliable results for the analysis. Provided below is a summary of actual freeway and HOV lane data used:

- Aggregated construction costs
  - initial construction
  - HOV lane extensions and access ramps
  - improvements such as barrier modifications
  - support facilities, such as park-and-ride lots and bus transfer centers
- Traffic data
  - initial ADT for a base year of 1995
  - average annual traffic growth rate over a 20-year analysis period
  - composition of automobile fleet on the mainlanes, including occupancies

    - composition of truck fleet on the mainlanes
    - distribution of ADT by hour for a 24-hour period
- Geometric data for mainlanes and HOV lane
- Pavement condition data
- Routine maintenance, operation and enforcement costs
- Accident rate data
- HOV lane operational data
    - type of HOV lane
    - vehicle classifications and occupancies
    - hours of operation
    - percent of persons using HOV lane, inbound and outbound

Although the implementation of HOV lanes in Texas has resulted in an increase in bus ridership, incremental costs associated with an increase in commuter bus service directly attributable to HOV lane implementation were not included in the analysis.

The cost-effectiveness analysis was not conducted for the concurrent flow facilities in Dallas. These facilities opened either during or after the study year; therefore, a full year of operational data was not available.

Results of Cost-Effectiveness Analysis

In all cases, the HOV lanes currently operating in Texas produce benefits far outweighing the costs over a 20-year life. Table 16 below provides the results of the economic analysis.

Table 16. Benefit-to-Cost Ratios for Texas HOV Lanes

HOV Facility	Benefit-to-Cost Ratio
Katy	78
East R.L. Thornton	29
Northwest	15
North	11
Gulf	10
Southwest	8

The Katy HOV lane achieves a high benefit-to-cost ratio because it exhibits a combination of a high volume of total daily traffic, high person movement in the HOV lane and a relatively low construction cost (in comparison with other Houston facilities). It outperforms the other facilities with a B/C at least five times greater than other HOV lanes in Houston.

The East R.L. Thornton contraflow lane also achieves a relatively high benefit-to-cost ratio. Although East R.L. Thornton HOV person-movement and freeway congestion levels are comparable to the others, the low total discounted costs appear to contribute most to the higher rate of cost-effectiveness. The total discounted costs for East R.L. Thornton include annual operating costs of $600,000 per year, which is twice the operation and enforcement cost per facility for the other HOV lanes. Yet over a 20-year period, the benefits outweigh the costs by a rate of 29:1.

A limitation of the analysis is the ability to adjust the HOV demand over time as mainlane congestion increases. It has been documented earlier in this report that as travel time savings increases, use of the HOV lane increases. This particular economic analysis accommodates only one initial input for the percentage of person movement during the peak periods that takes place in the HOV lane. For this reason, the analysis assumes a constant proportion of HOV person movement to total person movement, and thus underestimates HOV ridership that may increase over time as the HOV lane becomes a more attractive alternative to congested freeway lanes.

Factors Affecting the Analysis Results

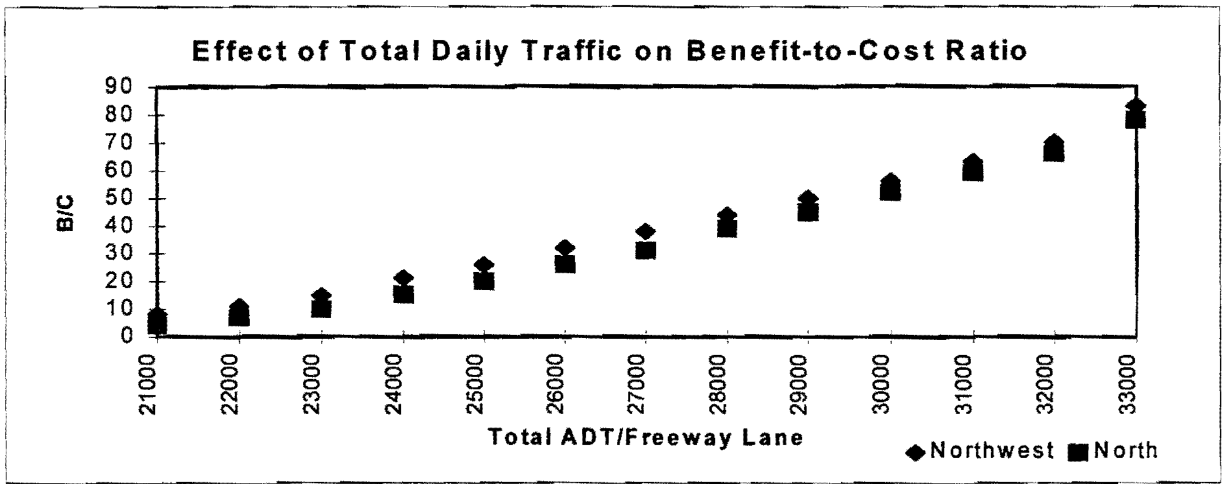
A sensitivity analysis was conducted to determine which factors had the greatest impact on the B/C results. Three specific independent variables were examined using a regression analysis to assess the strength of the relationship between each independent variable and the dependent variable, B/C. Results are provided below in Table 17.

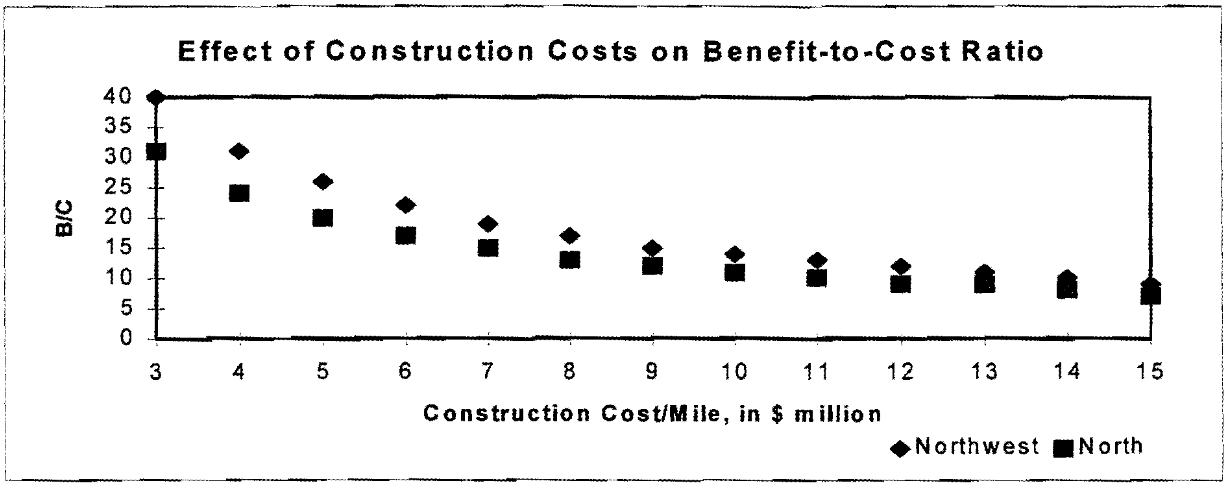
Table 17. Correlation of Input Parameters to B/C Results

Independent Variable	Correlation Coefficient "r"	r^2
Construction costs	-0.43986	0.19435
Average daily traffic, mainlanes and HOV lane	0.97126	0.94336
Person movement in HOV lane	0.63535	0.40367

The resulting values of the correlation coefficient "r" indicate that the variable ADT (average daily traffic) more closely represents a linear relationship with B/C as compared with the other two variables. Furthermore, the r^2 value indicates that a higher proportion of the total variability of B/C is accounted for by its association with the independent variable ADT. Therefore, the final results of the economic analysis appear to be most sensitive to the total volume of traffic carried by the facility. This is a logical conclusion given that the benefits calculated by MicroBENCOST are based on savings derived predominately from reduction in vehicular delay, operating costs and fuel consumption. Other variables besides ADT do, however, play a role in the final outcome.

To further demonstrate this conclusion, additional analyses of the Northwest and North HOV lanes were conducted to gain an understanding of how the model reacts when one independent variable is changed while all others remain constant. For example, the benefit-to-cost ratio was calculated for differing levels of ADT while all other parameters remained constant. A range of values for the independent variable was chosen that represents the lowest value to the highest value across all Texas facilities. The results are illustrated in Figure 31.





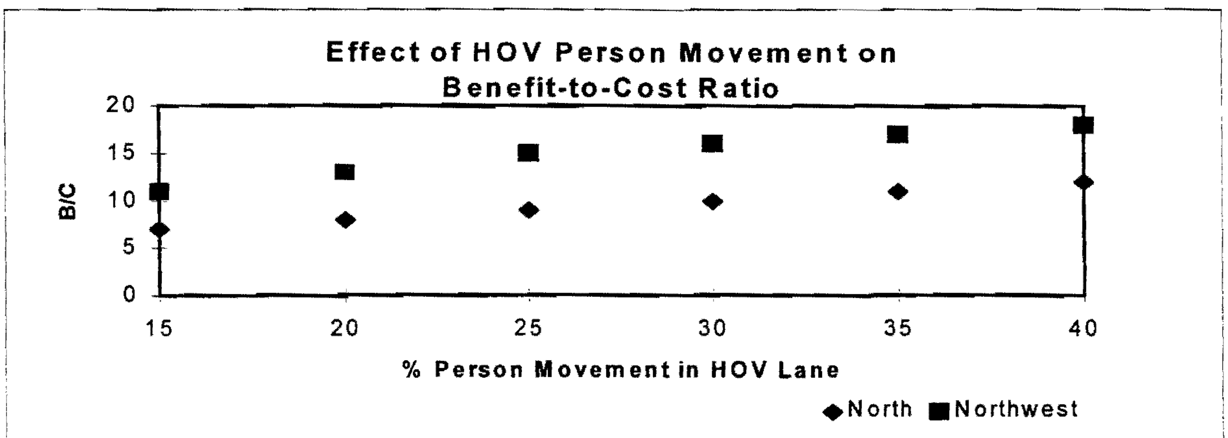


Figure 31. Effects on Benefit-to-Cost-Ratios

The Northwest and North HOV lanes were selected for this particular review because they fall in the middle of the range of B/C results for all facilities (see Table 16). In examining the effects on B/C of the three parameters - ADT, construction cost and HOV lane person movement - it is noted that average daily traffic provides the greatest range of outcomes, from a B/C of 4 to a B/C of 80. The maximum B/C possible under the scenario of varying construction costs, with all other variables remaining constant, is 40. When the percentage of person movement in the HOV lane is varied, a maximum B/C of 18 is achieved, all else remaining constant.

HOV Lanes Versus General Purpose Lanes - Which Alternative is Most Cost Effective?

HOV lanes are considered a capacity-enhancing measure designed to increase person movement through a corridor. A comparable alternative for increasing freeway capacity is the addition of general purpose lanes. It has been argued that in many cases the addition of freeway lanes is a more effective alternative than construction of an HOV lane. To assess the validity of this argument from a cost-effectiveness standpoint, the B/C for the addition of two general purpose lanes to each freeway facility was determined using actual traffic data and general per-lane mile construction costs. The comparative results of the HOV lane and general purpose lane alternatives for each freeway are shown in Table 18.

Table 18. Comparison of B/C Ratios for HOV Lanes Versus a General Purpose Lane Alternative

Freeway	B/C for HOV Lane Alternative	B/C for General Purpose Lane Alternative[1]	Absolute Difference [HOV B/C - GP Lane B/C]
Katy	78	53	25
E.R.L.Thornton	29	11	21
Northwest	15	15	0
North	11	9	2
Gulf	10	7	6
Southwest	8	4	4

[1]General purpose lane construction estimated at a cost of $6,500,000/lane km ($4,000,000/lane mi).

In all but one case, the HOV lane produces greater benefits for the dollars invested in the improvements. The Northwest Freeway is the only case in which the HOV lane and general purpose lane alternatives provide similar benefits relative to costs. As mentioned earlier in this chapter, this economic analysis tool does not allow for any adjustment in the magnitude of HOV lane person movement as mainlane congestion increases. As part of the sensitivity analysis of the model, the Northwest HOV lane was run through an interactive process whereby HOV person movement was adjusted as all other variables remained constant (see Figure 31). In this particular analysis, the B/C for the Northwest HOV lane exceeded a value of 15 when the percentage of person movement was increased above the current value of 25 percent. Therefore, it can be concluded that as mainlane congestion increases over time, the relative benefits of the HOV alternative on the Northwest Freeway will exceed those of the general purpose lane alternative as the attractiveness of the HOV increases.

As noted earlier, the MicroBENCOST analysis is an examination of the quantifiable benefits derived primarily from savings in delay and vehicle operating costs. The benefits of HOV facilities that cannot be readily quantified, such as air quality, bus schedule reliability, etc., have not been factored into the evaluation. Notwithstanding these benefits, an analysis of the actual operational experience of HOV lanes in Texas has demonstrated that HOV lanes are cost-effective improvements based solely on overall savings in user costs and vehicle operating costs. And in examining these savings over the long term, HOV lanes are shown to be a more cost-effective alternative than the construction of two general-purpose lanes.

CHAPTER 11. DEVELOPMENT OF HOV FACILITY SYSTEM SHOULD HAVE PUBLIC SUPPORT

INTRODUCTION

Public attitudes toward continued investment in HOV facility development is a major area of interest among public officials in Houston and Dallas. The lanes are seen as a method of serving future growth in travel and have been built using public monies. Approximately $900 million in tax monies have been utilized in Houston alone to plan, design and construct HOV lanes. Consequently, public perceptions and attitudes pertaining to the HOV lanes is of major consequence regarding the success or failure of this strategy.

TTI researchers have surveyed HOV users (carpoolers and transit riders) as well as general purpose or mainlane users since 1985. However, only the Katy and Northwest HOV lanes have been surveyed with regularity since the surveys were first implemented. The most recent survey was conducted in 1994 and included the East R.L. Thornton facility for the first time. The 1994 surveys were conducted for the Katy, Northwest and East R.L. Thornton corridors only (*14*). For the purposes of this report, only the 1994 data will be highlighted. Historical information regarding previous surveys can be found in earlier HOV analysis reports (*15*).

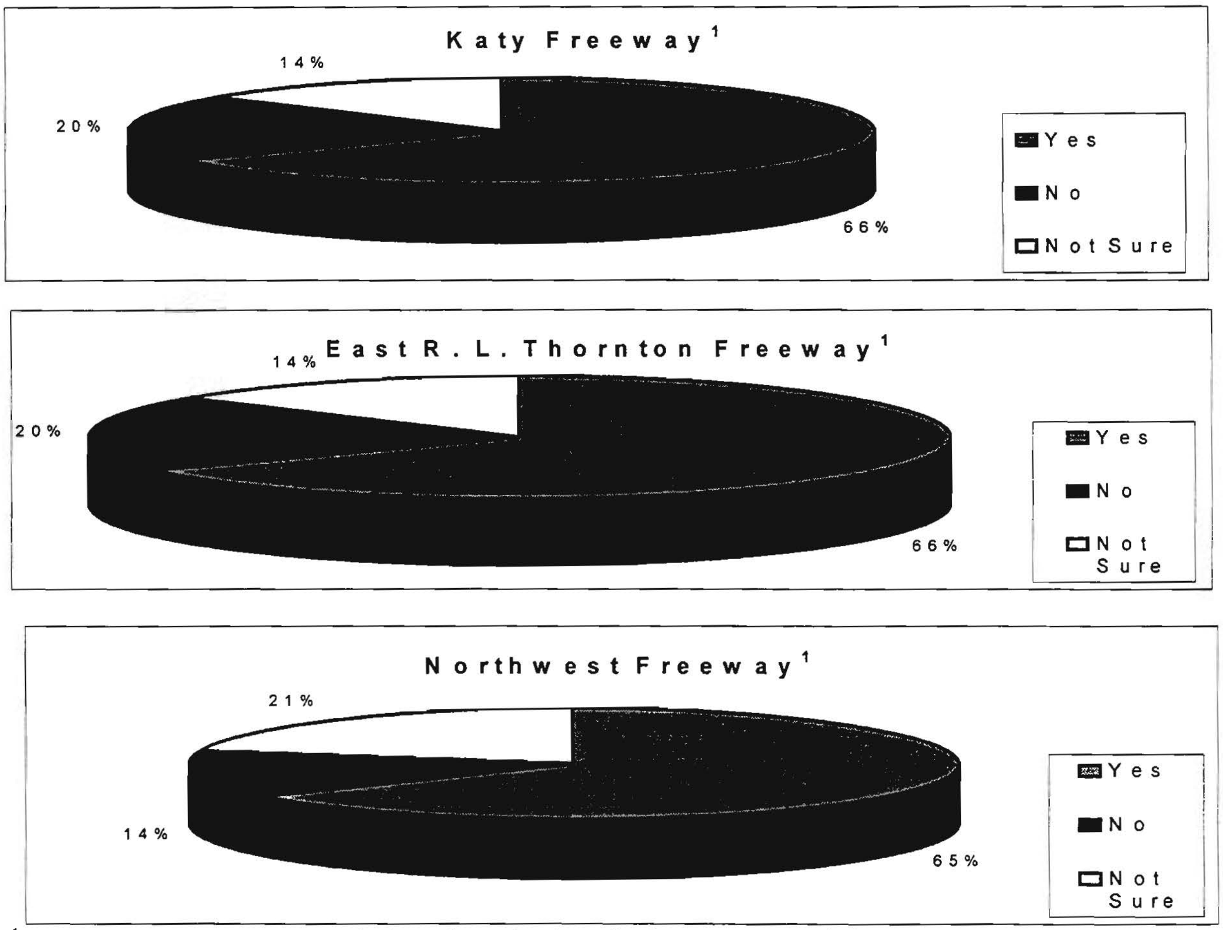
The surveys were developed to identify attitudes and perceptions regarding priority lane utilization. Two primary questions were asked to gauge public acceptance of the HOV lanes in Dallas and Houston: 1) Are the HOV facilities good transportation improvements? and 2) Are the HOV lanes sufficiently utilized? A secondary measure of public acceptance is the impact that the HOV lanes have had on mode choice among carpoolers and transit riders using the HOV lanes. The survey findings regarding public acceptance are discussed next.

ARE THE HOV LANES GOOD TRANSPORTATION IMPROVEMENTS?

In an effort to determine public acceptance of HOV facilities in Houston and Dallas, general purpose lane motorists or non-HOV lane users were surveyed regarding their attitudes towards the priority lanes and their perceptions of HOV lane utilization. The general purpose lane motorists were surveyed because they may receive relatively few direct benefits from the presence of HOV lanes in their respective corridors. Hence, opinions from non-HOV users in each of the corridors may reveal whether the general public views HOV lanes as good transportation improvements. General purpose lane motorists were asked specifically if they felt that the HOV lanes being developed in Houston or Dallas are good transportation improvements.

Based on the survey findings from the Katy, Northwest and East R.L. Thornton corridors, the priority lanes are viewed favorably among non-HOV users in those corridors. Approximately 65 percent of the general purpose lane motorists in each of the three corridors viewed the priority lane projects positively. Acceptance levels in the Katy corridor have remained above 60 percent since 1987. Prior to 1994, positive acceptance of the priority lanes in the Northwest corridor exceeded 70 percent and remained near that figure in 1994 — at 65 percent (*16*). Relatively few motorists surveyed, approximately 20 percent in each corridor, indicated that the priority lanes were not a good transportation improvement in the corridor. Another 14 percent in each of the corridors were unsure of their opinion regarding the HOV lane projects. Figure 32 summarizes the 1994 survey findings from the Katy, Northwest and East R.L. Thornton mainlane motorist surveys.

In each case, the general motoring public favorably responded to the question, "are the HOV lanes a good transportation improvement?" Hence, relatively strong public support exists for the HOV lane program from non-HOV users in corridors with HOV lane improvements. Furthermore, historical trend data available in previous reports also indicates that this support has held true over time (*17*).



[1] 1994 summer survey data of motorists in freeway mainlanes.

Figure 32. Responses to the Question, "Are HOV Lanes Good Transportation Improvements?"

ARE THE HOV LANES SUFFICIENTLY UTILIZED?

In contrast to the positive acceptance of HOV lanes from general purpose lane motorists as good transportation improvements, HOV lanes are generally considered underutilized among non-HOV motorists in the three corridors surveyed. General purpose lane users were asked two distinct questions regarding their perceptions of HOV lane utilization: 1) "Based on your observation of the number of *vehicles* currently using the HOV lanes, do you feel that they are being sufficiently utilized?," and 2) "Based on your perception of the number of *persons* currently being moved on the

HOV lanes, do you feel that they are being sufficiently utilized?" The 1994 surveys were modified to gauge the perception of utilization (by freeway motorists) relative to both vehicles and persons being moved on the HOV lane. Prior to 1994, the freeway motorists on the general purpose lanes were asked to simply indicate whether they felt that the priority lane was sufficiently utilized without regard to persons and vehicles.

Responses from Freeway Motorists

The motivation for asking general purpose lane motorists two separate questions concerning vehicle and person utilization is simple. The perception that the HOV lanes do not carry enough traffic when compared to the mainlanes, and are therefore underutilized, is a concern that has existed since the initiation of the HOV programs in Texas. Although general purpose lane users may feel that vehicle utilization is low (commonly referred to as the "empty lane syndrome"), TTI researchers were also interested in documenting their perceptions concerning the amount of people being moved in the HOV lanes, which is a primary objective of HOV lanes — to move more people than vehicles.

Similar to the survey findings prior to 1994, freeway motorists feel that the HOV lanes are not moving enough traffic or people. Table 19 lists the 1994 survey findings from the Katy, Northwest and East R.L. Thornton general purpose lane surveys. Prior to the 1994 survey, generally less than 40 percent of non-HOV users felt that the lanes were utilized sufficiently (*18*). However, these figures declined to 21 percent and 31 percent, respectively, for the Katy and Northwest Freeway motorists in 1994. The East R.L. Thornton general purpose lane users proved to be the one exception. Non-HOV users on the East R.L. Thornton mainlanes felt that the amount of traffic being moved on the priority lane was sufficient. Approximately 48 percent of the respondents indicated that vehicle utilization was positive.

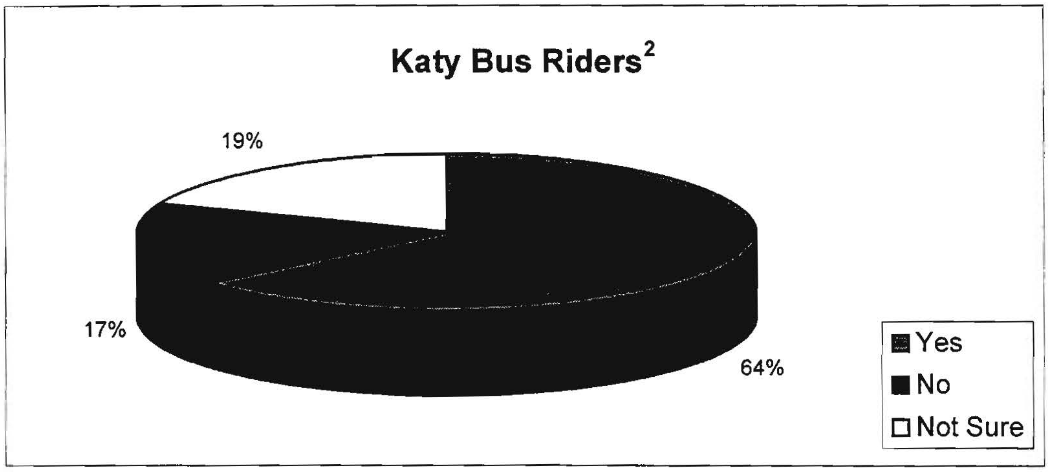
Table 19. Responses from Freeway Mainlane Motorists to the Question, "Is the HOV Lane Sufficiently Utilized?"

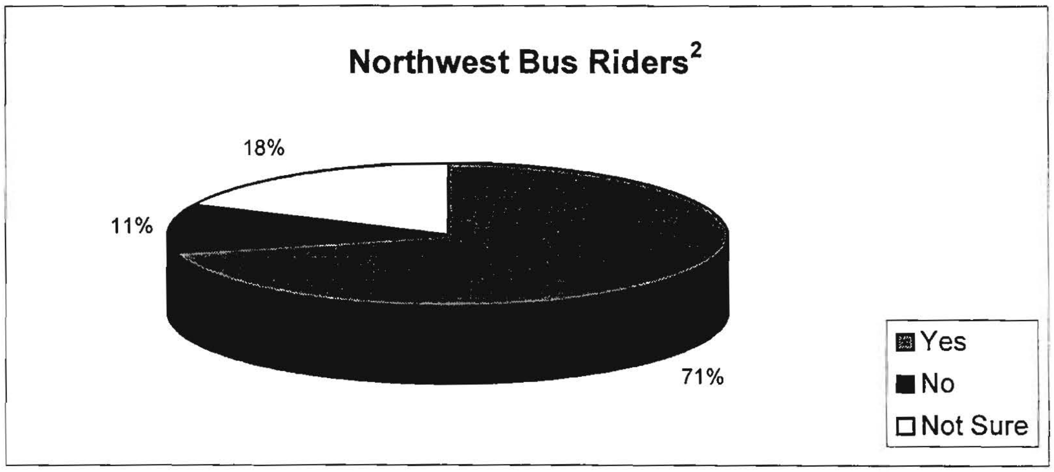
Survey Location and Group Responses to Questions	1994 Survey	
	Is Vehicle Utilization Sufficient?	Is Person Utilization Sufficient?
Katy Freeway Mainlane Motorists		
Yes	21%	19%
No	62%	59%
Not Sure	17%	22%
Northwest Freeway Mainlane Motorists		
Yes	31%	25%
No	41%	43%
Not Sure	28%	32%
East R.L. Thornton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

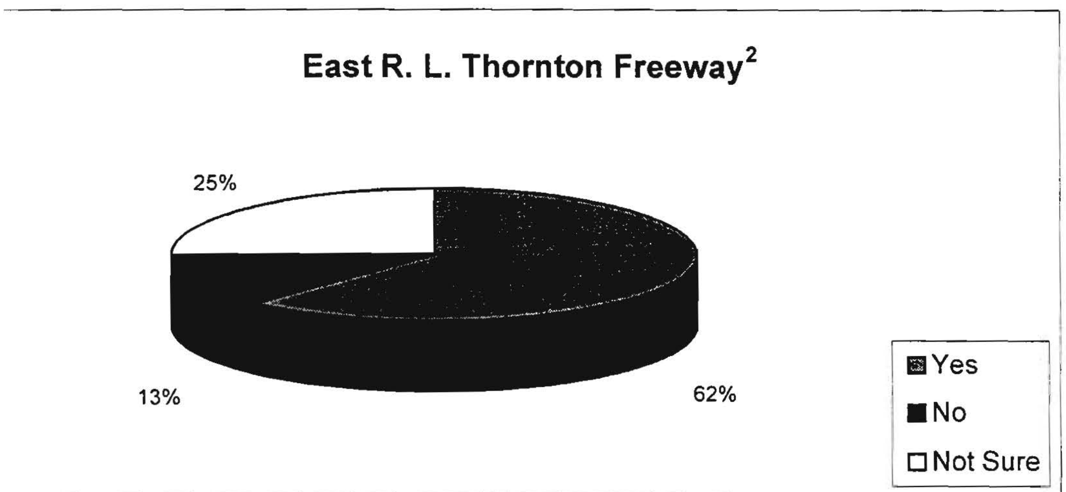
Perceptions about person movement on the priority lanes were generally negative, with the East R.L. Thornton being the one exception where it was viewed equally negative and positive among general purpose lane motorists. Within the Katy corridor, nearly 60 percent of non-HOV users felt that the person-moving characteristics of the priority lane were not sufficient. The Northwest corridor, although lower at 43 percent, also had more people feel that the priority lane was not being utilized by enough people. Since this is the first time that vehicle and person utilization questions were posed, there is no historical data from which to draw extensive conclusions concerning the perceptions of non-HOV users relative to both vehicles and persons being moved in the HOV lanes. The general perception, though, is that the HOV lane is underutilized and has remained that way historically (*19*). Based on these findings, the issue of perceived lane utilization, both vehicle and person, among non-HOV users will continue to be an issue associated with the implementation of a priority lane program.

Responses from HOV Lane Users

People that use the HOV lanes (carpoolers, vanpoolers and bus riders) were also asked to indicate whether they felt that the HOV lane was being sufficiently utilized. This group of people, unlike the general purpose lane motorists, were not specifically asked questions about person or vehicle utilization. This same general question has been asked on surveys in the Katy corridor since 1985 and in the Northwest corridor since 1989 (*20*). Figures 33 and 34 summarize the 1994 survey results. The results indicate that there is a significant difference between HOV users and non-HOV users. In all three corridors, carpoolers, vanpoolers and bus riders resoundingly responded with positive impressions about lane utilization. A minor observation within the data also shows that carpoolers and vanpoolers tend to have a more favorable opinion about how well the lanes are being used when compared to the responses from bus riders. Although general purpose lane drivers question the efficiency of the priority lanes, utilizers of the lanes (carpoolers and bus riders) strongly indicate a favorable opinion of the priority lanes.

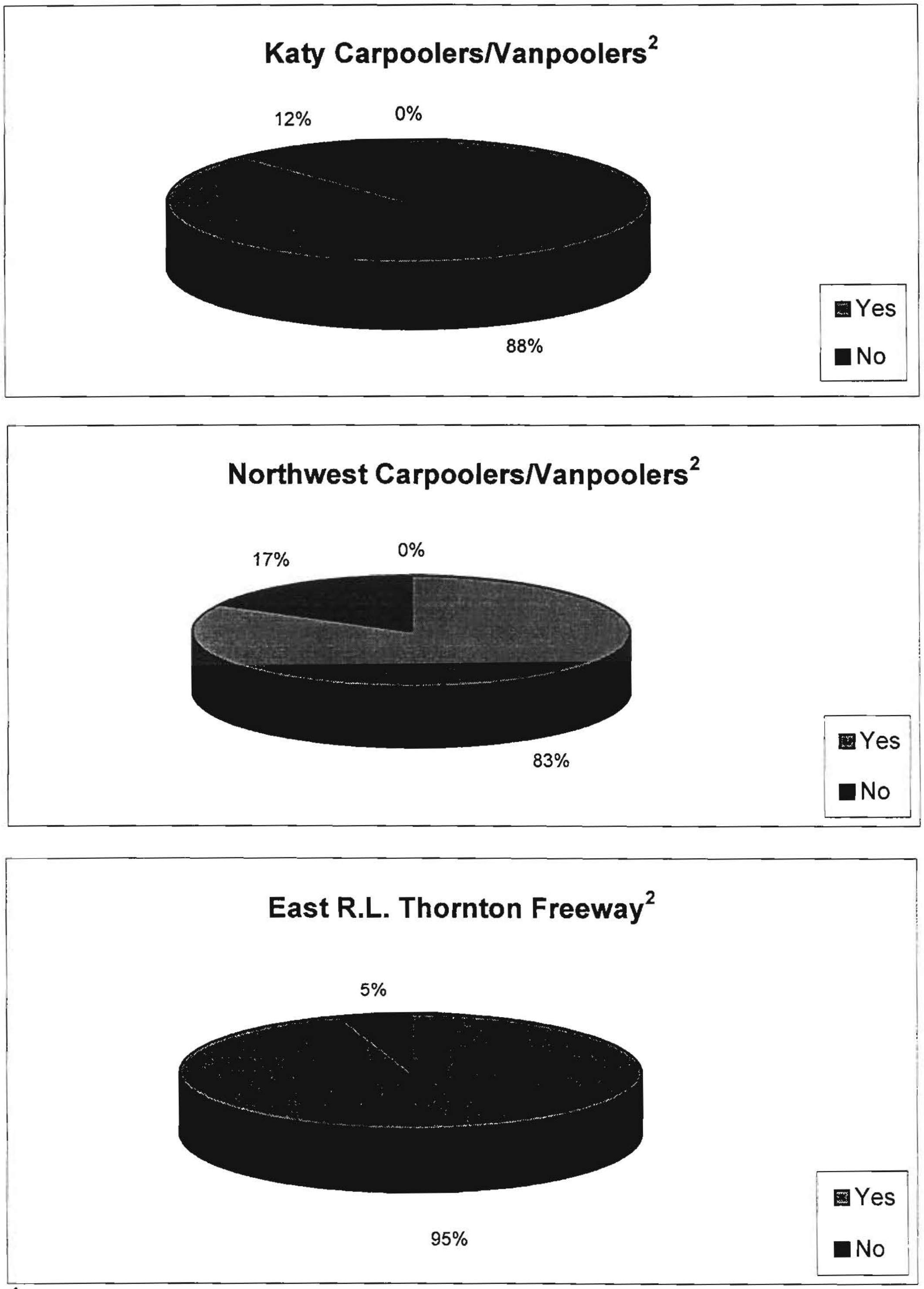






[1]Respondants were asked, "Is the HOV Lane Sufficiently Utilized?"
[2]1994 Summer Survey Data

Figure 33. Perceived HOV Lane Utilization: Bus Riders[1]



[1]Respondants were asked, "Is the HOV Lane Sufficiently Utilized?"

[2]1994 Summery Survey Data

Figure 34. Perceived HOV Lane Utilization: Carpoolers/Vanpoolers[1]

CHAPTER 12. AIR QUALITY AND ENERGY CONSIDERATIONS

INTRODUCTION

Air quality improvements and energy consumption savings have been at the heart of arguments for and against the implementation of priority lanes. Increased emphasis has been given to the air quality and energy conservation impacts of alternative transportation improvements since the enactment of the 1990 Clean Air Act Amendment (CAAA) and the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA). As a result of these two pieces of legislation, public officials have developed programs and strategies that primarily focus on reducing vehicle miles of travel (VMT) and increasing vehicle occupancy levels. HOV lanes attempt to accomplish both of these goals by providing a priority lane that encourages SOVs to take advantage of the travel time differences afforded to higher occupancy vehicles. The 1990 CAAA lists 16 transportation control measures (TCMs) that encourage modal shifts to higher occupancy modes and eliminate or reduce the amount of travel. HOV lanes are listed among the 16 TCMs.

The 1990 CAAA also established criteria for attaining and maintaining the National Ambient Air Quality Standards (NAAQs) and established specific requirements for the different categories of air quality non-attainment status for six pollutants. The six types of pollutants are small particulate matter (PM_{10}), carbon monoxide (CO), sulfur dioxide (SOx), ozone (O_3), nitrogen dioxide (NOx), and lead. Metropolitan areas not meeting the standards are classified as extreme, severe, serious, moderate, and marginal depending on the severity of the air quality problem. Currently, there are a total of 16 counties in Texas that are classified as ozone non-attainment areas. The eight county region surrounding Houston is considered to be a severe ozone air quality non-attainment area, and the four county region making up the Dallas/Fort-Worth metropolitan area is classified as a moderate ozone non-attainment area. Beaumont and El Paso are classified as serious ozone non-attainment areas. El Paso is the only carbon monoxide region in Texas and is in the moderate category. Houston and Dallas have implemented HOV lanes, as well as other TCM strategies, to reduce overall VMT and therefore improve air quality in these metropolitan areas.

The State Implementation Plan (SIP) defines how emissions will be reduced and the standard will be attained. Each non-attainment area must submit a report that inventories the structure or projects for meeting the SIP standards and must provide proof of conformity of reducing volatile organic compounds. These will be put into the 15 percent Rate of Progress Report. Therefore, it is important that HOV lanes demonstrate a reduction in fuel consumed and improved air quality.

The EPA recently released new emission standards that would provide tighter standards for attaining ozone and small particulate matter. These standards are currently being reviewed and have not been finalized. However, should these standards be adopted, several cities in Texas, including San Antonio and Austin, would be reclassified as non-attainment regions and existing non-attainment regions would have to re-evaluate their current transportation plans in order to meet conformity with the new standards.

As mentioned previously, the cost of implementing priority lanes has also added to the importance of demonstrating air quality conformity to overcome critics of priority lanes. Some critics of the priority lanes point to other TCM strategies, such as improving existing transit services or implementing trip reduction ordinances, as more cost-effective strategies. Furthermore, the actual air quality and energy benefits of HOV lanes have been a focus of arguments against implementing a priority lane program. The generation of some of the air quality criticisms are a result of a lack of accepted methods for quantifying energy and emission benefits. Some of the common criticisms associated with air quality benefits and HOV lane programs include:

- With more people removed from the general purpose lanes, the speeds on the lanes will increase on these lanes, which increases the amount of nitrous oxide emissions.

- Emission benefits are often derived using peak-period information and are not calculated on a 24-hour basis. Questions have arisen as to the benefits of an HOV lane that is only used during defined times (typically during severe congestion) to extra mixed flow lanes that would be available to all vehicles during a 24-hour period. What are the actual impacts of limited peak-period benefits compared to 24-hour benefits?

- Emission calculations often use an aggregation of vehicles and VMT rather than recognizing that different vehicle types have different emission rates.

- Currently, the technology and/or the amount of data collected does not account for such information as emission rates created when a car is started after it has been sitting for long periods (cold start), after a car has been re-started after only a short period of inactivity (hot start), or emissions created by evaporation while the car is not driving (e.g., a parked vehicle overnight and a parked vehicle in the sun).

- The latent demand for additional capacity on the general purpose lanes will be accommodated by the shift of people from the general purpose lanes onto the HOV lane. As shown in previous sections, implementing the high-occupancy vehicle lane does not necessarily reduce the vehicular volumes on the freeway general purpose lanes. The HOV lane, though, is in effect, allowing more person movement to be served without increasing congestion on the general purpose lanes. As a result, the travel that takes place in the corridor that serves the HOV facility can be an increase in the total 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, HOV lanes are developed in already congested corridors where demand is projected to continue to increase over time. Hence, the HOV lane can be a strategy for effectively serving the travel demand that is expected to occur over time. A true analysis of this situation would involve a review of several alternatives: "do nothing", "add an HOV lane" and "add another mixed-flow traffic lane."

Unfortunately, evaluating the effectiveness of HOV projects is difficult. There are two approaches being used in Texas to calculate emission and energy benefits of implementing HOV lanes: the use of emission factors and simulation. The North Central Texas Council of Governments (NCTCOG) uses emission factors (grams per mile) based on changes in speed in its study on the effectiveness of various TCMs (*21*). The NCTCOG methodology includes quantifying the benefits of stimulating the formation of new carpools from previously single occupant motorists, the benefits to drivers that previously used parallel facilities but changed routes onto the general purpose lanes because of the higher speeds on the general purpose freeway lanes and the benefits to carpoolers now using the HOV lanes that were using the general purpose lanes.

Simulation packages use models or sketch planning tools to analyze air quality and energy benefits of implementing priority lanes. However, the emission models, to date, have yet to produce endorsed or scientifically approved numbers.

The common assumption in these models and tools has been that the speed differential is smaller on HOV lanes because of the reduced vehicle interaction created by the priority lane. This produces emission benefits over general purpose lanes because speed differentials and vehicle interaction are greater on these lanes. Any analysis that primarily uses speeds, VMT and the number of vehicle trips is simply preliminary and does not take into account a number of other factors that effect mobile emission rates. Factors such as vehicle mix, detailed speed profiles, driving cycles, duration of trip and the inclusion of "hot" and "cold" emission data are needed to accurately predict potential benefits of HOV lanes (*22*). Currently, this type of data is not collected as part of this project and would need to be in order to develop an accurate measure for emission and energy rates.

Another "criticism" of the analysis is emission and energy benefits are associated with vehicles rather than persons, which is contrary to the basic premise of HOV lanes - moving more people than vehicles. The timeline for the development of more accurate tools to analyze TCMs is considered to be near. Until then, accurate conclusions based on current techniques are questionable at best.

ANALYSIS

The air quality and energy consumption analysis presented in this section of the report utilizes a freeway simulation model (FREQ) and applies that model to the Katy Freeway and HOV lane. No other corridor was studied as part of this effort. Differences in volumes to capacity (V/C) ratios between the alternatives is the primary attribute studied to measure emission rates and fuel consumption.

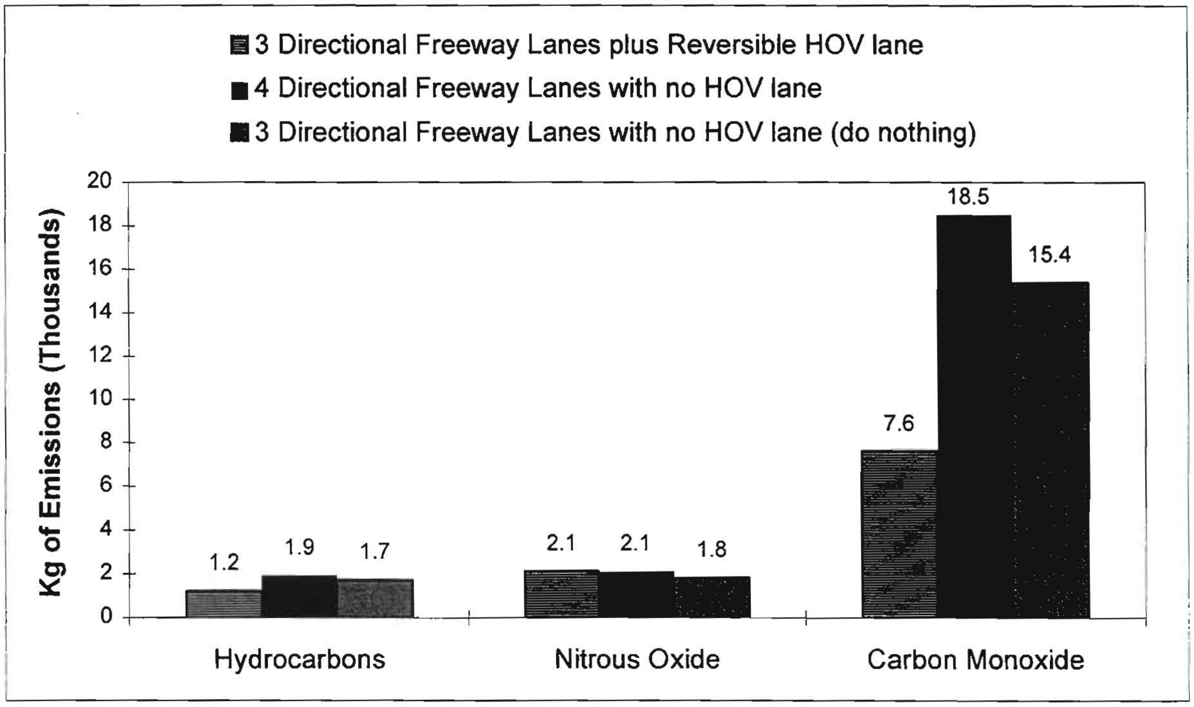
Using the 1996 travel volumes, researchers simulated operation on both the freeway general purpose lanes and the HOV lane. The demand, expressed as passenger-kilometers, that existed in 1996 was held constant in comparing alternatives. The average vehicle occupancy levels, though, were adjusted between 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. This helps provide data to help answer the question, 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 lane? The reversible HOV lane requires approximately the same pavement width as would be required to provide one additional general purpose lane.

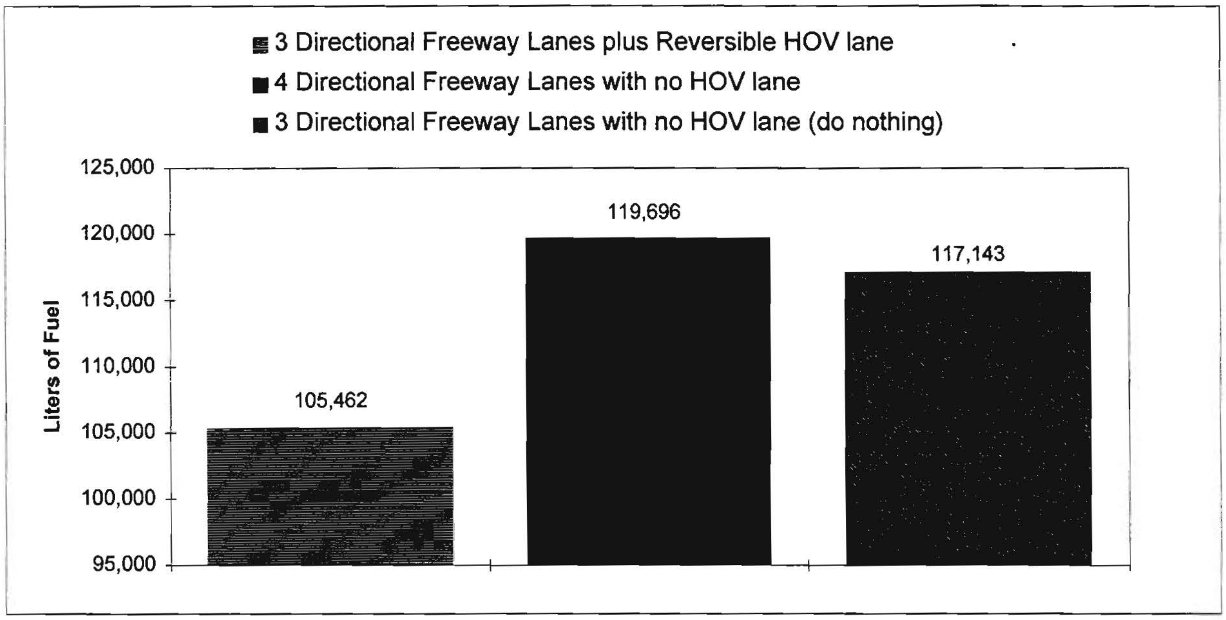
3. **Add an HOV Lane**. This is the improvement that was implemented. A reversible HOV lane was added to the freeway. Three direction general purpose freeway lanes remain.

Figures 35 and 36 show the results of this analysis. The analysis was from 6:00 am - noon, peak direction for 1996 demand levels. Based on the basic analysis of the Katy corridor, the HOV lane alternative has better results for hydrocarbon and carbon monoxide emissions. The HOV alternative is clearly more favorable than the other two strategies when reviewing the data for carbon monoxide emissions. Because of the improved speeds on the general purpose lanes, the nitrous oxide emissions are similar between "add an HOV lane" and "add an extra freeway lane with no HOV lane."



Source: Texas Transportation Institute Simulation Analysis, 6 a.m. - noon, peak direction, 1996 demand levels

Figure 35. Estimated Impacts of HOV Improvements on Air Quality, Katy Freeway and HOV Lane



Source: Texas Transportation Institute Simulation Analysis, 6 a.m. - noon, peak direction, 1996 demand levels

Figure 36. Impacts of HOV Improvements on Energy Consumption, Katy Freeway and HOV Lane

When comparing the three alternatives on the Katy corridor, the HOV lane alternative results in a reduced average of more than 10,000 liters of fuel. This is attributable to the increased vehicle occupancy levels created by the HOV lane versus the other scenarios. The "add an additional freeway lane with no HOV lane" alternative clearly stimulates more consumption of fuel, which may be created by encouraging additional single occupant driving on this facility. The scenario is slightly higher than the "do nothing" alternative.

Since the demand is projected 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 1996 and are unable to serve additional higher volumes. The analysis is limited, as noted earlier, however, it is clear that to serve the passenger-kilometer demand in the peak direction that is occurring today on the Katy freeway, the HOV lane alternative is more favorable in terms of air quality and energy conservation benefits.

Air quality and energy savings analysis of priority lanes clearly needs to be improved in order to strengthen policy arguments based on these two criteria. Analysis of the other corridors with more reliable techniques would improve the overall air quality and energy understanding of these types of facilities being implemented in Houston and Dallas. There is an increased sensitivity towards transportation alternatives and air quality improvements created by the enactment of the 1990 Clean Air Act Amendments, the 1991 Intermodal Surface Transportation Efficiency Act, and the pending attainment measures recently proposed by the EPA. The preliminary analysis of the Katy freeway corridor, though, shows that the HOV lane alternative offers the most favorable impacts on pollutants emitted and energy consumed.

CHAPTER 13. FACTORS AFFECTING HOV LANE OPERATION

RELATIONSHIP BETWEEN TRAVEL TIME SAVINGS AND HOV LANE USAGE

One of the central arguments for HOV lanes is that as the travel time savings increase, the amount of HOV lane usage also increases. This relationship is described by Henk et al. (*23*) using a limited supply of data. The conclusion is intuitively obvious: the more time a traveler can save, the more likely they are to sacrifice some flexibility and give up their single-occupant vehicle.

Unfortunately, as more data has become available, the relationship has become less obvious. A regression analysis of the data confirms that a positive relationship exists. When the data isviewed on a scatter diagram (Figure 37), it becomes apparent that the data points are clustered by facility, causing some skepticism about the ability to draw conclusions from the aggregate data.

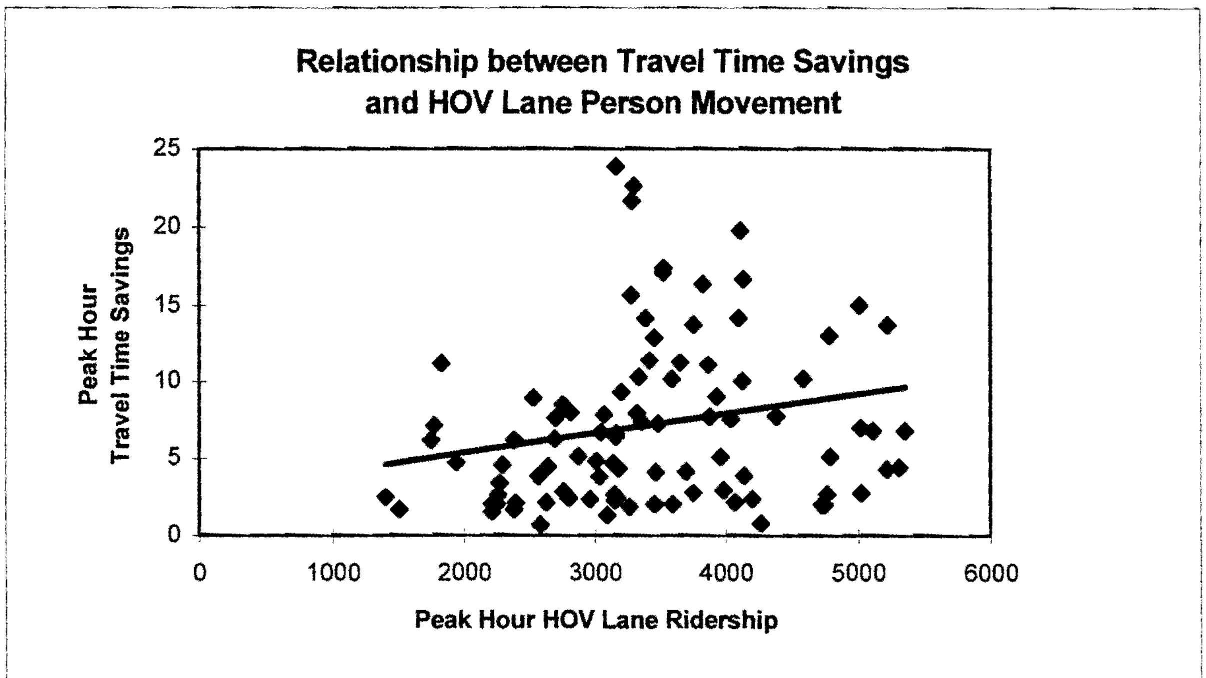


Figure 37. Relationship Between Travel Time Savings and HOV Lane Person Movement

Although the incentive of travel time savings is strong, the traveler would need to anticipate the need to save time prior to making the trip, thus carpooling in the HOV lane to avoid an incident is unlikely. Most HOV lane users will have made their decision prior to departure from home or work. To decide to use the HOV lane means that they have experienced enough consistent delay on the general purpose lanes (or conversely savings on the HOV lane), to justify the additional effort associated with carpooling.

In reflecting on the more than a decade of HOV lane experience in Houston, it may be that the characteristics of each freeway/HOV lane corridor vary so widely that it is difficult to ascertain what it common to all HOV lanes and what is not. Future research in this project will examine each freeway HOV lane corridor as a case study with a goal of establishing more clearly the cause and effect relationships associated with HOV lane use.

TRENDS IN DAILY PERSON-TRIPS

Travel on Houston's network of HOV lanes continues to increase, though the data represented in Figure 38 suggests that growth may be leveling off. Of the five HOV lanes, only the one on the Gulf Freeway shows any sign of decline, and the Gulf HOV lane has been significantly affected by adjacent construction, relocation of entry points and occasional closure over the last three years. The daily volumes on the Katy and North HOV lanes appear to be fairly consistent at around 20,000 person-trips per day, while the Northwest and Southwest HOV lanes appear to continuing to grow. As ADT per lane on those two freeways continues to increase, they could experience HOV lane usage similar to the Katy and North freeways.

Another important trend is the role that the HOV lanes play in absorbing new demand in a freeway corridor. Figure 39 compares the growth rate in HOV lane trips and travel on the general purpose lanes. Though general purpose lane travel has grown steadily over the last 15 years, the growth rate on HOV lanes has been substantially higher, meaning that HOV lanes are absorbing a significant amount of travel demand in their respective corridors.

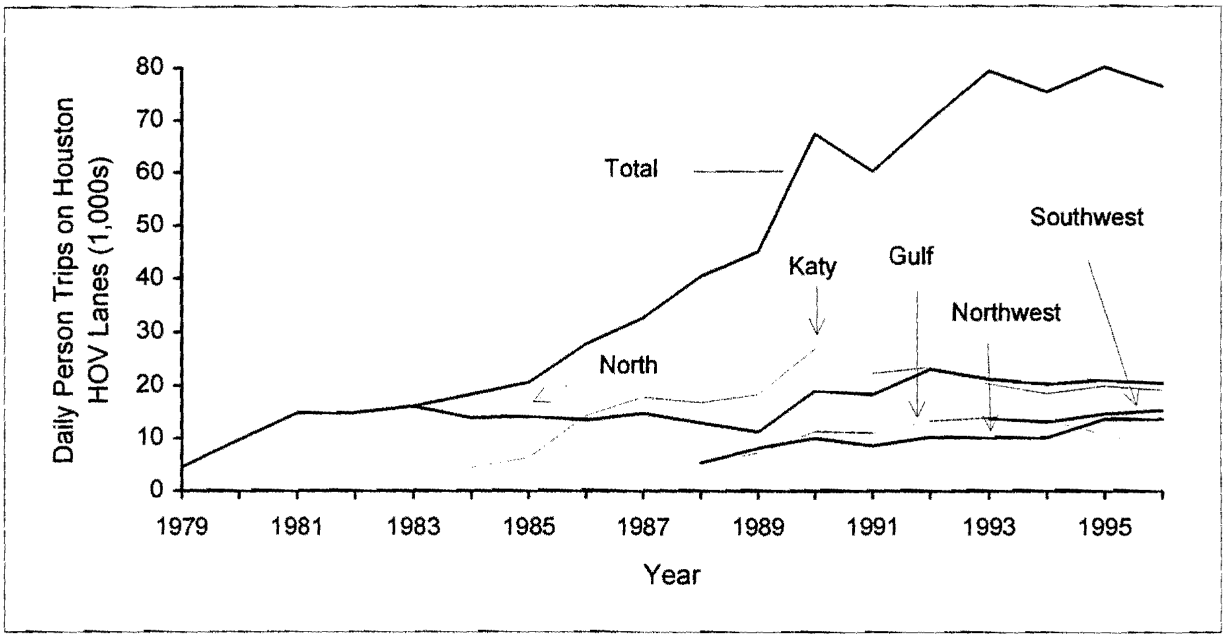


Figure 38. Trends in Daily Person Trips on Houston HOV Lanes

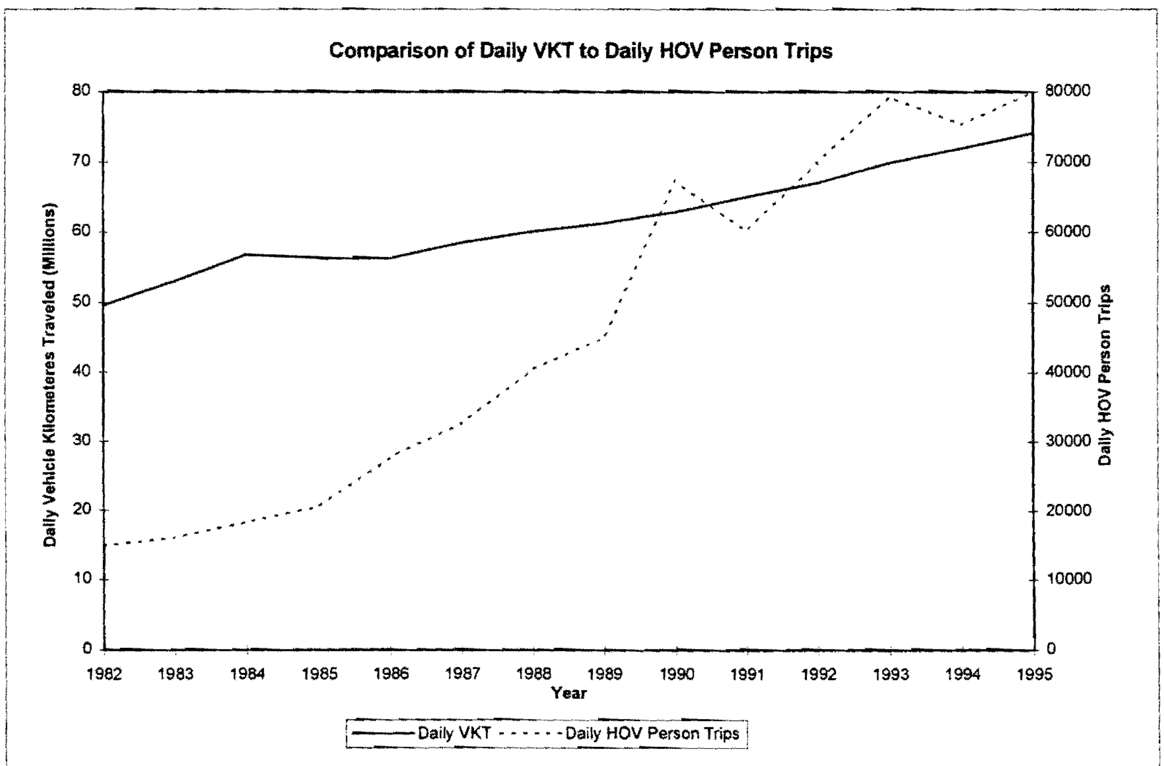


Figure 39. Comparison of Daily VKT to Daily HOV Person Trips

IMPACT OF LONGEVITY ON HOV LANE USAGE

Intuitively, HOV lane use should increase as travelers become more familiar with its use and advantages. One pertinent question that arises is: "How long does it take for an HOV lane to reach a 'mature' state?" Figure 40 shows plots of HOV lane usage versus months of operation. Although each plot depicts the individual character development on each HOV lane, the trend on most is high growth for the first 35-40 months, followed by slower growth and leveling off.

The exceptions to that trend are the East R.L. Thornton HOV lane in Dallas and the Gulf HOV lane in Houston. The East R.L. Thornton facility started at a fairly high usage, and has remained relatively constant. This could be partially explained by the fact that no substantial improvements to access or service has occurred during the life of the HOV lane. On the Gulf facility, there has been significant construction-related impacts that have recently been completed. That change could allow the Gulf to assume a more typical pattern. Future research will document the history of each facility as a case study, and should clarify some of the difference observed in characteristics.

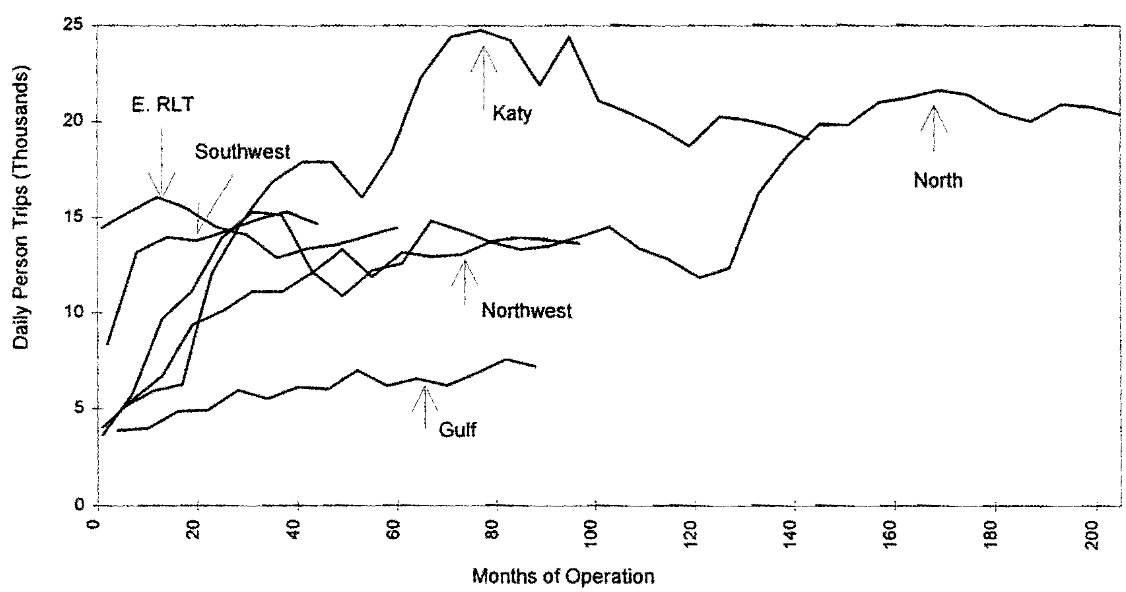


Figure 40. HOV Lane Usage Versus Months of Operation

CHAPTER 14. CONCLUSIONS

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 1996 to assess the extent to which these objectives are being attained (Table 20). 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 move a greater percentage of persons during the peak hour in the peak direction than the percentage of total directional lane capacity the HOV lane represents. For example, if the HOV lane represents 25 percent of the lane capacity (one of four directional lanes), it should carry more than 25 percent of the person movement.

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: Enhance Bus Transit Operations

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

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

1. Implementing the HOV lane should not significantly impact freeway general purpose lane speeds.

2. Implementing the HOV lane should not result in a significant increase in the general purpose lane accident rate.

Objective: Increase the Overall Efficiency of the Roadway

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: HOV Projects Should be Cost Effective

1. The value of the benefits of the HOV lane, such as savings in time, vehicle operating costs, and accidents, should exceed the implementation costs.

2. The HOV lane should have an equal or greater benefit-to-cost ratio than a comparable general purpose lane construction alternative.

Objective: Public Support Should Exist for HOV Development

1. Surveys should show that more than 50 percent of people using the transportation facility, both HOV lane and general purpose lanes, feel the HOV lane is a good transportation project.

Objective: Create Favorable Energy and Air Quality Impacts

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.

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

Continued monitoring of all the committed HOV lane projects in Texas will take place as part of this research project.

Table 20. Comparison of HOV Lane Objectives and HOV Lane Performance, 1996

Objective, Measure of Effectiveness	HOV Facility					
	Katy	North	Gulf	Northwest	Southwest	East RLT
HOV lanes should increase person movement.						
· Is daily HOV lane ridership between 10,000 and 15,000?	Yes	Yes	No	Yes	Yes	Yes
· Does the HOV lane move a greater percentage of persons in the peak hour than the percentage of total lane capacity it represents?	Yes	Yes	Yes	Yes	Yes	Yes
· Has peak-hour vehicle occupancy increased by 10% to 15%?	Yes	Yes	No	Yes	NA	No
· Have new carpools increased by at least 25% due to the HOV lane?	Yes	NA	NA	Yes	NA	No
· Has bus ridership increased at least 25% as a result of the HOV lane?	Yes	NA	NA	Yes	NA	No
HOV lanes should enhance bus operations.						
· Have peak-hour bus speeds increased by 50%?	Yes	Yes	Yes	Yes	Yes	Yes
HOV lanes should not result in an adverse impact on freeway general-purpose lane operations.						
· Have general purpose lane speeds been impacted by the HOV lane?	No	No	No	No	No	No
· Has the general purpose lane accident rate increased significantly due to the HOV lane?	No	No	No	No	No	No
Implementation of an HOV lane should increase the overall efficiency of the roadway.						
· Has the roadway per-lane efficiency increased by a value of at least 30 due to the HOV lane?	Yes	Yes	No	Yes	Yes	Yes
HOV lanes should be cost effective.						
· Does the value of the benefits outweigh the costs?	Yes	Yes	Yes	Yes	Yes	Yes
· Does the HOV lane have an equal or greater benefit-to-cost ratio than a general-purpose lane alternative?	Yes	Yes	Yes	Yes	Yes	Yes
HOV lanes should have public support.						
· Do more than 50% of the persons responding to the surveys indicate support for HOV lane development?	Yes	NA	NA	Yes	NA	Yes
HOV lanes should have favorable air quality & energy impacts.						
· Has adding an HOV lane been more effective than a general-purpose freeway lane would have been in terms of air quality and energy impacts?	Yes	NA	NA	NA	NA	NA
Overall Assessment: Is the HOV facility effective?	Effective	Effective	Marginally Effective	Effective	Effective	Effective

NA = Not available.

ENDNOTES

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2. "In What Situations Do High Occupancy Vehicle Lanes Perform Better Than General Purpose Lanes?" J. Dahlgren; paper submitted for publication at the Transportation Research Board 1996 Annual Meeting, Preprint No. 960293.

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16. "An Evaluation of High Occupancy Vehicle Lanes in Texas, 1995." R.H. Henk, D.E. Morris, D.L. Christiansen; TTI Research Report 1353-4, Texas Department of Transportation, November 1996.

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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, 1996

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)		$88.5	
Person-Movement			
Peak Hour (7-8 a.m.)	---	3,340	---
Peak Period (6-9:30 a.m.)	---	8,496	---
Total Daily	---	19,111	---
Vehicle Volume			
Peak Hour (7-8 a.m.)	---	916	---
Peak Period	---	2,553	---
Vehicle Occupancy, Peak Hour (persons/veh)	---	3.65	---
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM])[1]	---	13.5 (21.8)	---
Vehicle Breakdowns (VKT/Breakdown [VMT/Breakdown])	---	99,473 (61,674)	---
Violation Rate (6-9:30 a.m.)	---	17%	---
Peak Hour Lane Efficiency (1000's)[2]	---	281 (175)	---
Annual Discounted Benefits (millions)[3]	---	$195	---
Annual Delay Savings (millions)[4]	---	$158	---
Freeway Mainlane Data			
Person Movement	5,100	5,246	+3%
Peak Hour	15,655	16,386	+5%
Peak Period (6-9:30 a.m.)			
Vehicle Volume	4,045	4,731	+17%
Peak Hour	12,750	14,788	+16%
Peak Period	1.26	1.12	-11%
Vehicle Occupancy, Peak Hour (persons/veh)	12.4 (20.0)	12.9 (20.9)	-4%
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM])[1]			
Avg. Operating Speed[5] (kph [mph])	37 (23)	31 (19)	-16%
Peak Hour	53 (33)	43 (27)	-19%
Peak Period	61 (38)	54 (33)	-11%
Peak Hour Lane Efficiency (1000's)[2]			

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 km (4.7 mi). 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 12/96. Only officer-reported accidents are included in current files. TTI estimated 1996 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 average annual delay savings, reduced vehicle operating costs and reduced accident costs generated by MicroBENCOST, over a 20-year life.

[4]per MicroBENCOST, over a 20-year life.

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

Table A-1. Summary of A.M. Peak-Direction Katy Freeway and HOV Lane Data, 1996 (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	8,586	+68
Peak Period	15,655	24,882	+59
Vehicle Volume			
Peak Hour	4,045	5,647	+40
Peak Period	12,750	17,341	+36
Vehicle Occupancy			
Peak Hour	1.26	1.46	+21
Peak Period	1.23	1.43	+16
Carpool Volume[1]			
2+, 6 a.m. to 7 a.m.	505	990	+96
3+, 7 a.m. to 8 a.m.	76	419	+451
3+, 5 p.m. to 6 p.m.	104	303	+191
Travel Time (minutes)			
Peak Hour	33.9[2]	14.0[3]	-59
Peak Period	23.1[2]	13.7[3]	-41
Peak Hour Lane Efficiency (1000's)[4]	61 (38)	111 (68)	+82
Transit Data			
Bus Vehicle Trips			
Peak Hour	11	33	+200
Peak Period	32	80	+150
Bus Passenger Trips			
Peak Hour	335	1,200	+258
Peak Period	900	2,728	+203
Bus Occupancy (persons/bus)			
Peak Hour	30.5	36.4	+19
Peak Period	28.1	34.1	+21
Vehicles Parked in Corridor Park-and-Ride Lots	575	1,993	+247
Bus Operating Speed (kph [mph])[5]			
Peak Hour	36 (23)[2]	84 (52)[3]	+133
Peak Period	53 (33)[2]	86 (54)[3]	+62

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 km/hour [passengers x mi/hour]). It is used as a measure of per lane efficiency.
[5]The distance from SH 6 to Washington is 19.6 km (12.2 mi). 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	1.46	+16%
Freeway w/o HOV lane	1.23	1.12	-9%
Peak-Hour 3+ Carpool Volume			
Freeway w/HOV lane	76	419	+451%
Freeway w/o HOV lane	123	55	-55%
Bus Passengers, Peak Period			
Freeway w/HOV lane	900	2,728	+203%
Freeway w/o HOV lane	1,188	941	-21%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	575	1,993	+247%
Freeway w/o HOV lane[1]	1,236	965	-22%
Facility Per Lane Efficiency[2]			
Freeway w/HOV lane	61 (38)	111 (62)	+82%
Freeway w/o HOV lane	138 (86)	104 (64)	-25%

[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 km [4.7 mi]) of the HOV lane opened October 29, 1984.
- The HOV lane is now complete with 20.9 km (13.0 mi) in operation.
- The capital cost (including all support facilities) for the completed facility in 1996 dollars was $88.5 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 km [4.7 mi]) 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 km [6.4 mi]).
- 11/4/85 3+ authorized carpools allowed onto HOV.
- 8/11/86 2+ carpools, no authorization, hours extended.
- 8/25/86 HOV extended to SH 6 (18.5 km [11.5 mi]).
- 6/29/87 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 km [13.0 mi]).
- 4/1/90 Northwest Transit Center opens.
- 5/23/90 3+ carpool hours changed to 6:45 a.m. to 8:00 a.m.
- 9/16/91 3+ carpool restriction, 5:00 p.m. to 6:00 p.m.
- 9/8/92 Motorcycles allowed on HOV facility (no occupancy restrictions).
- 3/7/94 Weekend operation ends.
- 4/4/94 Weekend operation resumes.
- 9/30/96 Hours of operation modified (5:00 a.m. - 11:00 a.m.; 2:00 p.m. - 8:00 p.m.).

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

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1996 dollars
HOV Lane and Ramps			
Eastern Extension (1990)	$7.1	1.27	$ 9.0
Phase 1, Silber to West Belt (1984) Design and	10.5	1.60	16.8
Construction	11.7	1.42	16.6
Phase 2, West Belt to SH 6 (1987) Design and Construction	2.8	1.42	4.0
Addicks North Ramp (1987)	0.3	1.27	0.3
Addicks South Ramp	4.3	1.27	5.5
Misc.			
	$36.7		$51.9
SUB-TOTAL			
	$1.8 ($2.8)		$2.5
Per Kilometer (Mile)			($4.0)
	$4.6	1.42	
Surveillance, Communication & Control (1987)			$6.5
	$4.6		$6.5
SUB-TOTAL			
	$0.2 ($0.4)		
Per Kilometer (Mile)			$0.3
			($0.5)
Support Facilities			
	$4.8	1.60	
West Belt P/R (1984)	3.9	1.80	
Addicks P/R (1981)	6.3	1.37	$7.7
Addicks P/R Expansion (1988)	3.8	1.54	7.0
Kingsland P/R (1985)	0.2	1.42	8.6
Fry Road Park-and-Pool (1987)	0.2	1.48	5.9
Mason Road Park-and-Pool (1986)	0.2	1.48	0.3
Barker-Cypress Park-and-Pool (1986)			0.3
	$19.4		$30.1 0.3
SUB-TOTAL			
	$0.9 ($1.5)		
Per Kilometer (Mile)			
	$60.7		$88.5 $1.4
TOTAL COST			($2.3)
	$2.9 ($4.7)		$4.2 ($6.8)
COST PER KILOMETER (20.9 kilometers [13.0 miles])			

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 km (2.3 Miles)	2000	40.4
Northwest Transit Center/Inner Katy Connection	1998	9.9
Katy-Addicks Park-and-Ride 2nd Expansion	1998	6.6
Temporary Eastern Extension Slip Ramps	1997	0.1
		57.0

PERSON MOVEMENT

- In 1996, the HOV lane served approximately 19,000 person trips per day.
- A.M. Peak Hour, 3,340 persons/hour.
  - 1200 (36%) by bus, 137 (4%) by vanpool, 1,997 (60%) by carpool, and 7 by motorcycle (Figure A-1).
  - Average HOV lane vehicle occupancy = 3.65 persons/vehicle.
- A.M. Peak Period, 8,496 persons.
  - 2728 (32%) by bus, 391 (5%) by vanpool, by carpool 5,357 (63%), and 21 by motorcycle (Figure A-2).

VEHICLE MOVEMENT

- A.M. Peak Hour, 916 vph.
  - 33 (4%) buses, 19 (2%) vans, 858 (94%) carpools, and 7 by motorcycle (Figure A-3).

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

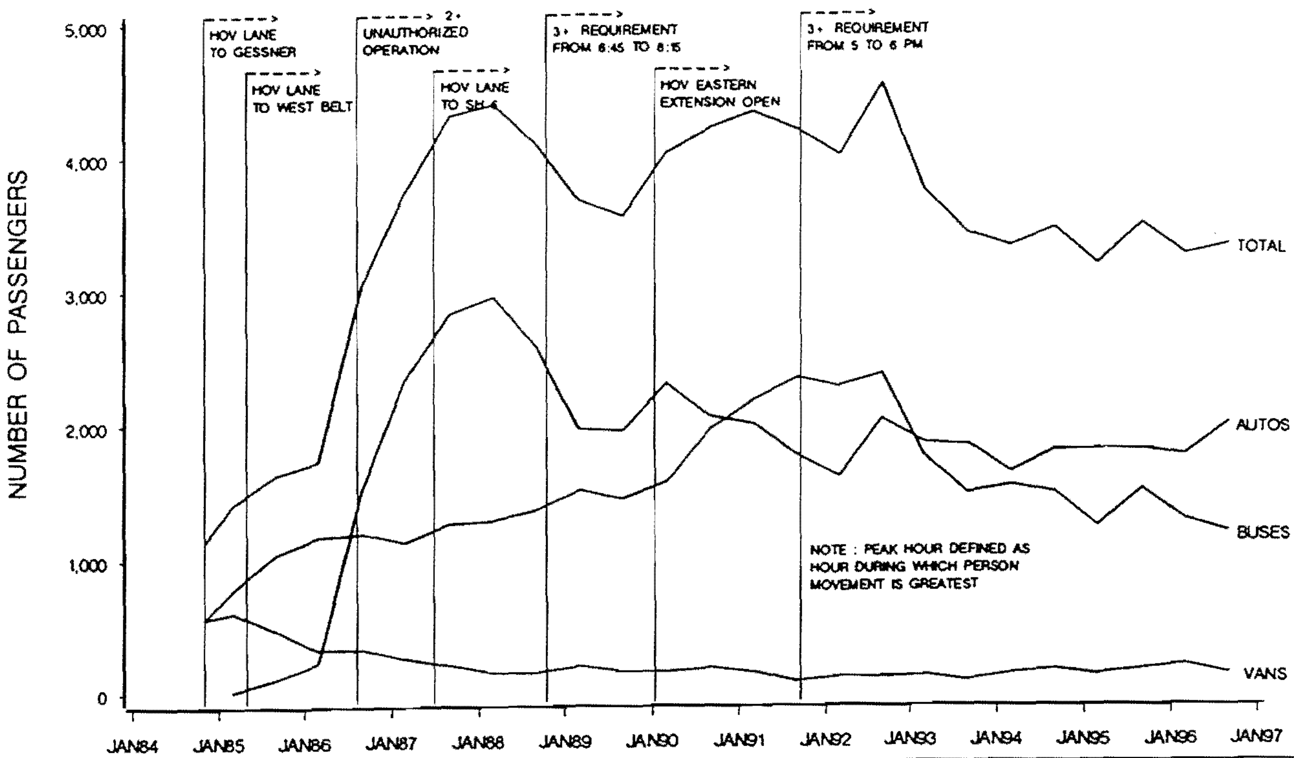


FIGURE A-2. KATY FREEWAY (IH 10W) HOV LANE A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT

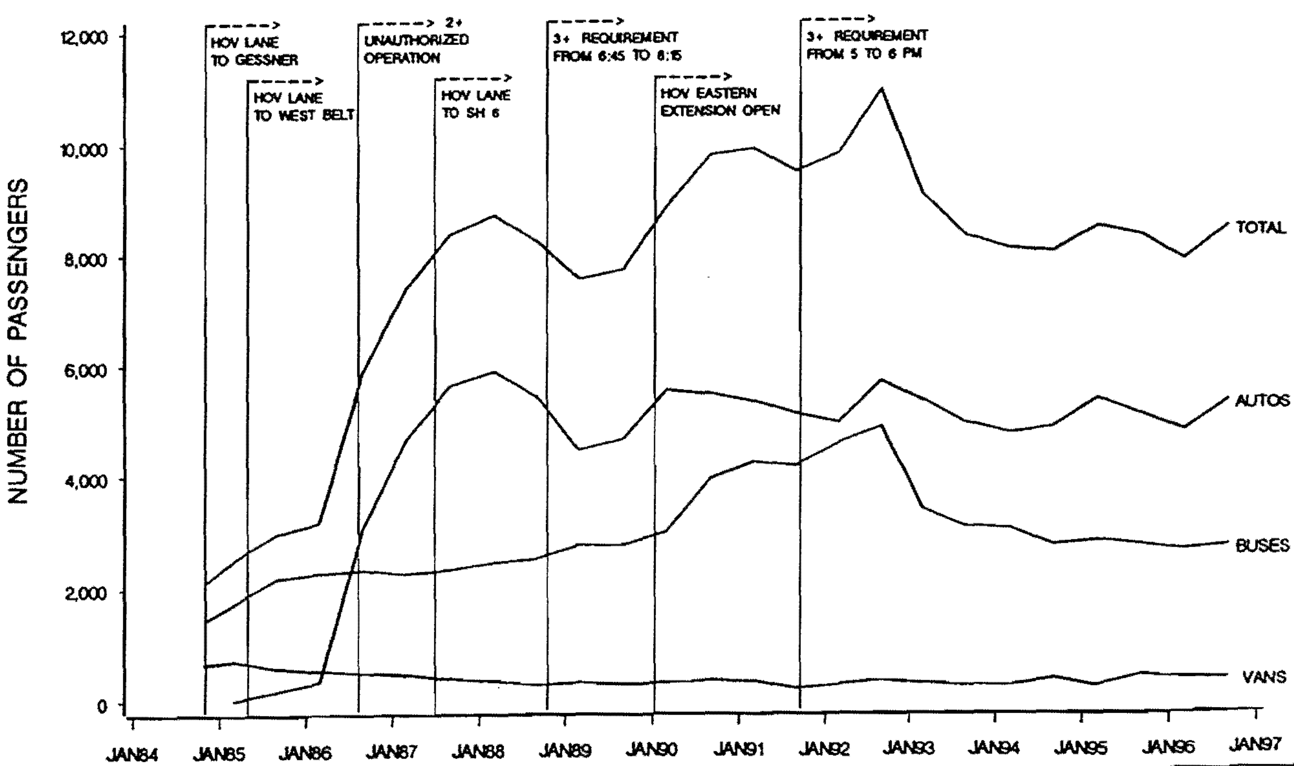


FIGURE A–3. KATY FREEWAY (IH 10W) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION

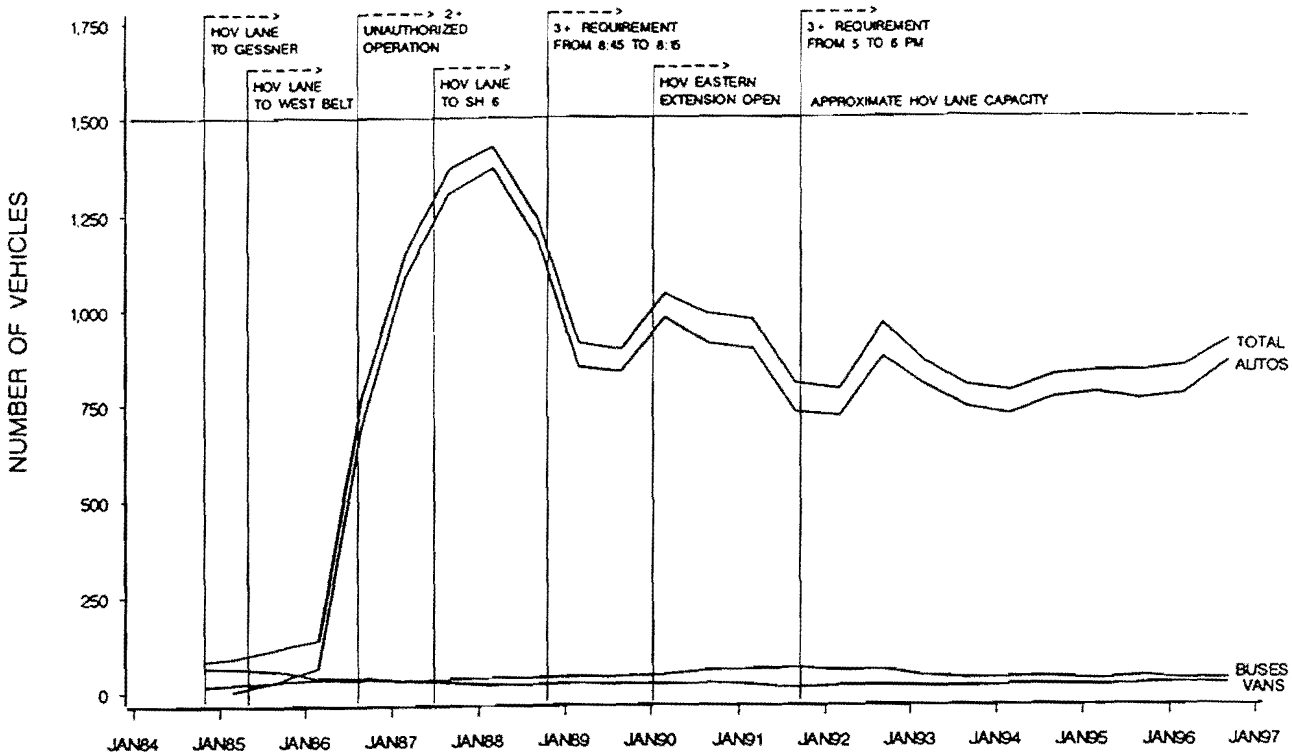
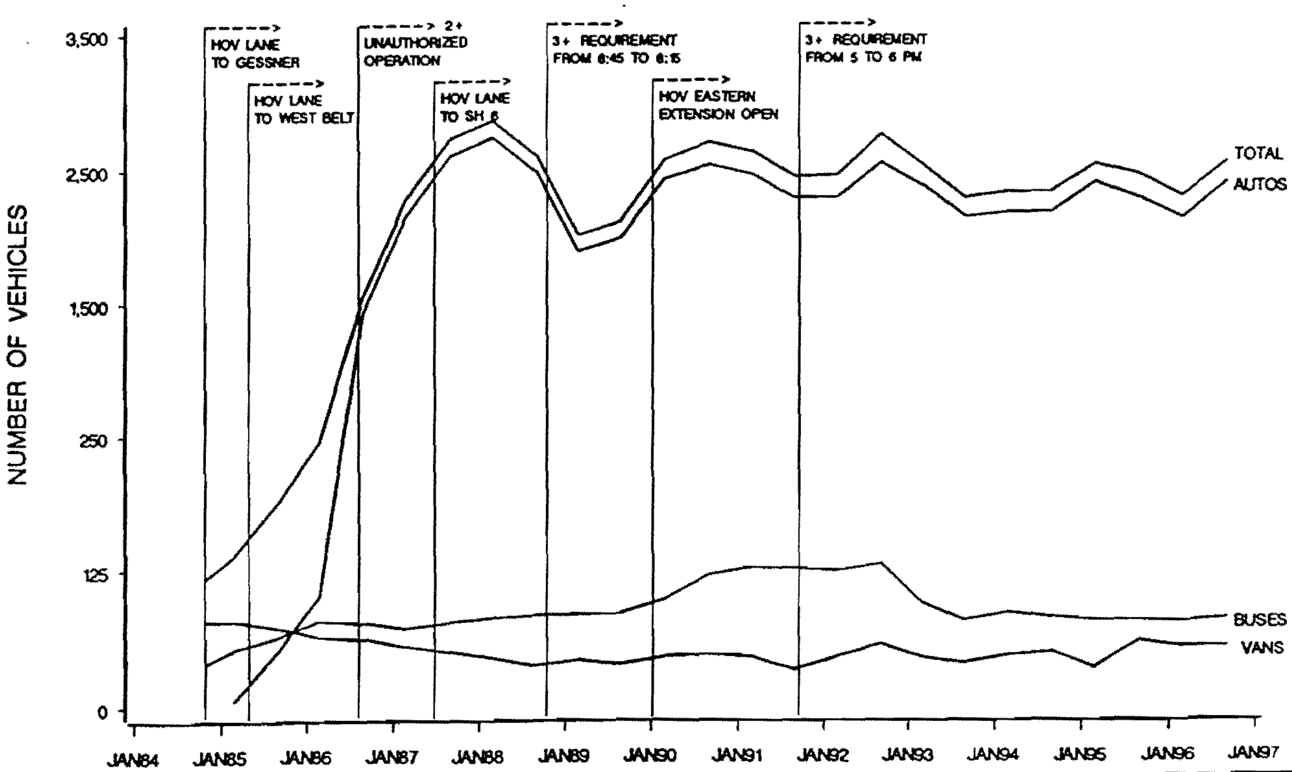


FIGURE A–4. KATY FREEWAY (IH 10W) HOV LANE
A.M. PEAK PERIOD HOV LANE VEHICLE UTILIZATION



- A.M. Peak Period, 2,553 vehicles.
  - 80 (3%) buses, 54 (2%) vans, 2399 (94%) carpools, and 21 by motorcycle (Figure A-4).

ACCIDENT RATE

- For the period from November 1984 through December 1996, the HOV lane accident rate was 13.5 injury accidents per 100 million vehicle kilometers (21.8 injury accidents per 100 million vehicle miles).

VEHICLE BREAKDOWN RATES

- As measured for 11/84 to 12/96, the following rate has been observed.
  - The weighted average for all vehicle types is one breakdown per 99,473 VKT (61,674 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 17 percent.
  - For the period from 7:00 a.m. to 8:15 a.m. (the 3+ operating time), it averaged 42 percent for 1996 and was 35 percent in September.
  - For the p.m. peak hour (the 3+ operating time), the violation rate was 51 percent in 1996.

PEAK-HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is used as a measure of the efficiency of a lane. For the HOV lane, this value (expressed in 1000's) is approximately 281 (3,340 passengers at 84 kph), or 175 (3,340 passengers at 52 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane experienced an average travel time savings of 17 minutes during the morning peak hour in 1996 (Table A-5, Figure A-5).

Table A-5. Travel Time Savings for Katy HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1996)

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	6.35	6.48	-0.13	278	29	60	367	-48.92
6:30	14.11	6.28	7.83	785	32	370	1,187	9,298.13
7:00	23.90	6.16	17.74	380	15	475	870	15,435.24
7:30	18.29	6.28	12.02	443	40	401	884	10,622.72
8:00	16.73	6.23	10.51	853	36	190	1,079	11,338.51
8:30	17.87	6.17	11.70	555	36	100	691	8,084.70
9:00	9.93	6.16	3.77	342	19	57	418	1,574.45
Peak Period Total				3,636	207	1,653	5,496	56,304.83
Section From Gessner Interchange to Washington								
6:00	7.27	7.87	-0.60	377	55	134	566	-339.30
6:30	10.94	7.42	3.52	1,081	79	393	1,553	5,472.56
7:00	17.02	7.40	9.62	750	97	662	1,509	14,514.00
7:30	16.15	7.80	8.35	855	72	726	1,653	13,802.55
8:00	12.32	7.23	5.09	938	40	399	1,377	7,012.47
8:30	11.51	7.35	4.16	692	34	252	978	4,065.83
9:00	9.62	7.18	2.44	394	16	134	544	132.04
Peak Period Total				5,086	393	2,700	8,179	45,855.16
Westbound P.M. Travel Time Savings for Katy HOV Lane								
Section from Washington to Gessner Interchange								
3:30	7.38	7.19	0.19	477	11	121	609	116.63
4:00	8.82	7.31	1.51	710	33	324	1,067	1,608.98
4:30	17.78	7.45	10.33	1,150	76	650	1,875	19,374.94
5:00	19.32	8.97	10.35	687	63	650	1,400	14,487.41
5:30	15.94	7.54	8.40	600	54	672	1,326	11,140.50
6:00	9.10	7.51	1.59	1,023	22	409	1,454	2,313.46
6:30	9.79	7.33	2.47	665	18	206	888	2,191.41
Peak Period Total				5,311	277	3,031	8,618	51,233.34

Table A-5. Travel Time Savings for Katy HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1996) (Continued)

Westbound P.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	6.53	6.18	0.36	295	2	85	382	136.87
4:00	6.37	5.93	0.44	386	11	325	722	318.87
4:30	6.02	6.33	-0.32	668	71	225	964	-305.25
5:00	11.88	6.20	5.68	548	8	414	970	5,504.75
5:30	13.00	6.12	6.88	404	64	476	944	6,552.96
6:00	5.81	6.28	-0.47	619	13	265	897	-418.63
6:30	9.42	6.13	3.28	376	13	80	469	1,539.91
Peak Period Total				3,296	182	1,870	5,348	13,274.41

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 not changed significantly relative to pre-HOV conditions (Figure A-6).

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

VEHICLE VOLUME

- In the a.m. peak hour, vehicle volume has increased by 17 percent, relative to pre-HOV conditions (Figure A-8).

- In the a.m. peak-period, vehicle volume has increased by 16 percent, relative to pre-HOV conditions (Figure A-9).

VEHICLE OCCUPANCY

- In the a.m. peak-hour, mainlane occupancy has decreased by 11 percent, relative to pre-HOV conditions (Figure A-10).

- In the a.m. peak-period, mainlane occupancy has decreased by 12 percent, 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 12.9 accidents/100 MVK (20.9 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 decreased by 16 percent in the peak-hour and 19 percent in the peak-period (Figure A-12).

PEAK HOUR LANE EFFICIENCY

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

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

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

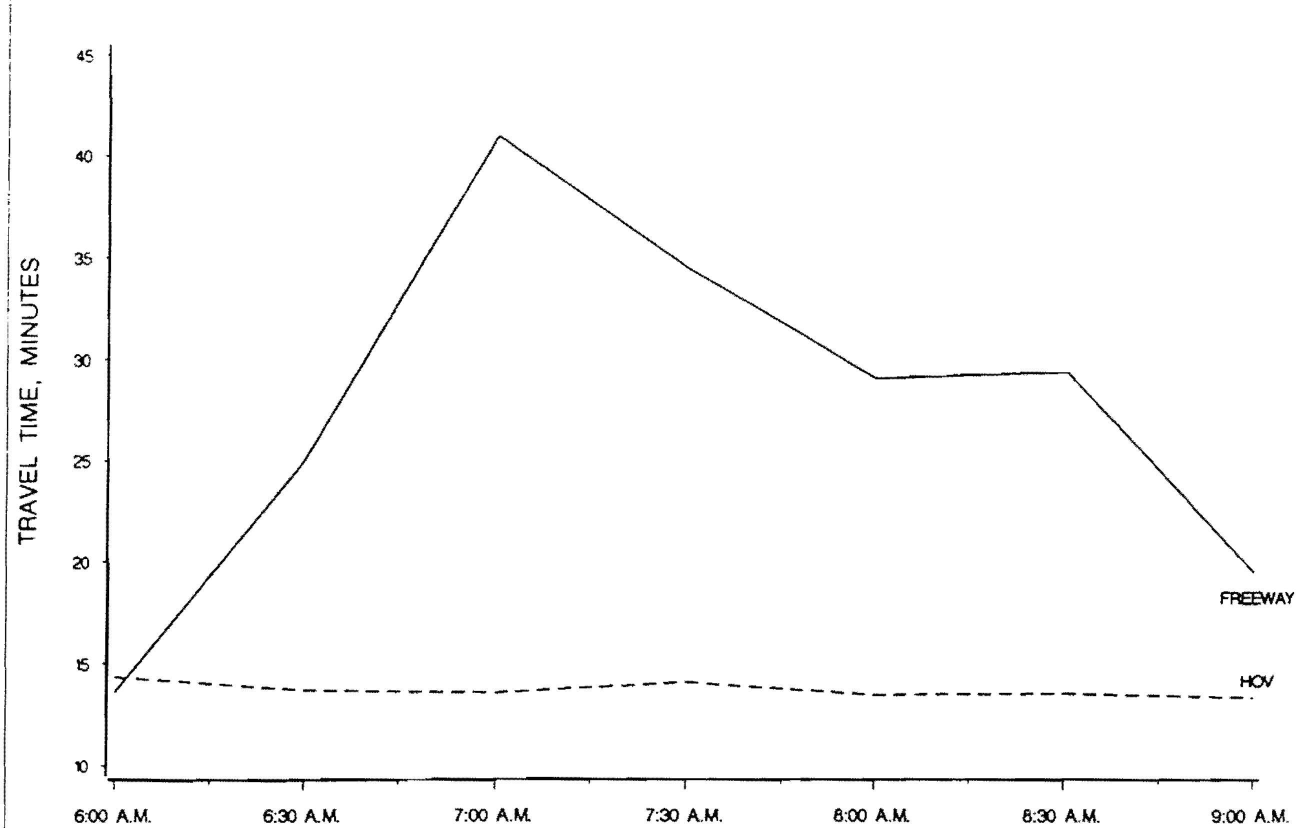


FIGURE A-6. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK HOUR PERSON TRIPS

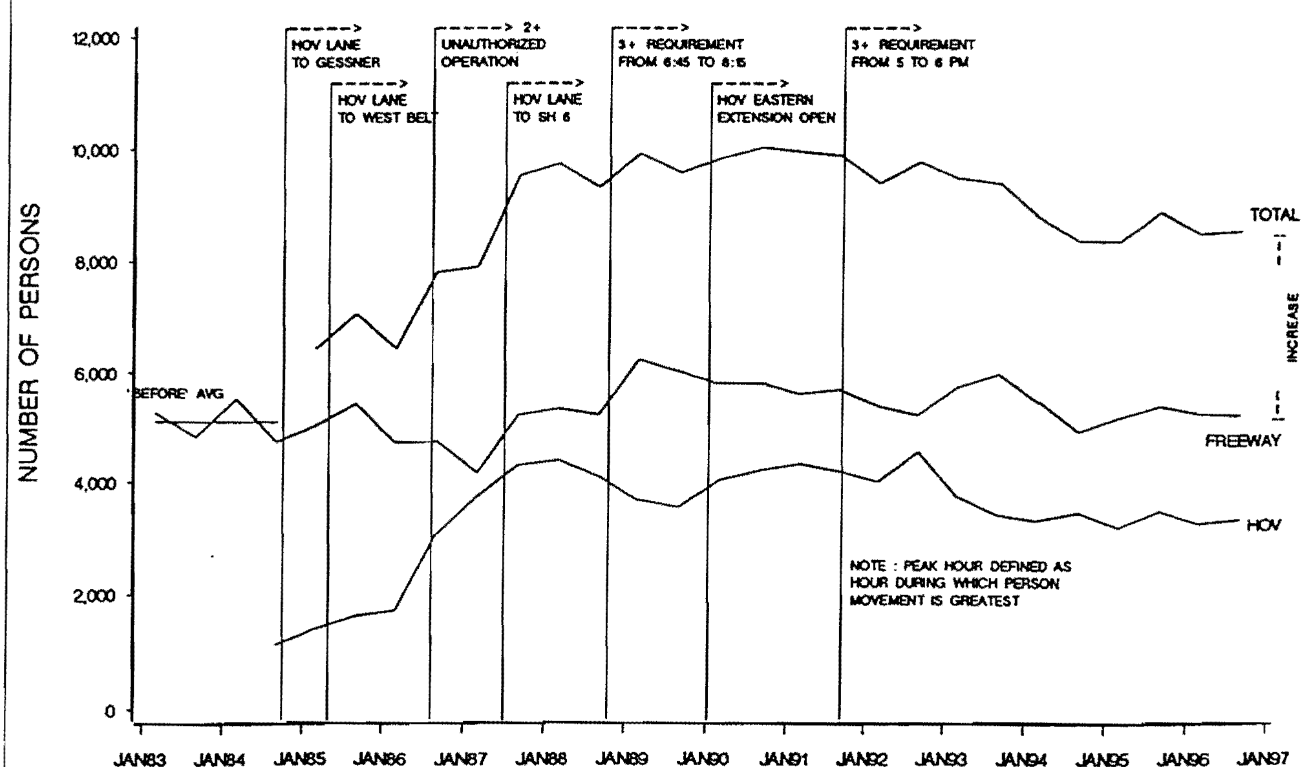


FIGURE A-7. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK PERIOD PERSON TRIPS

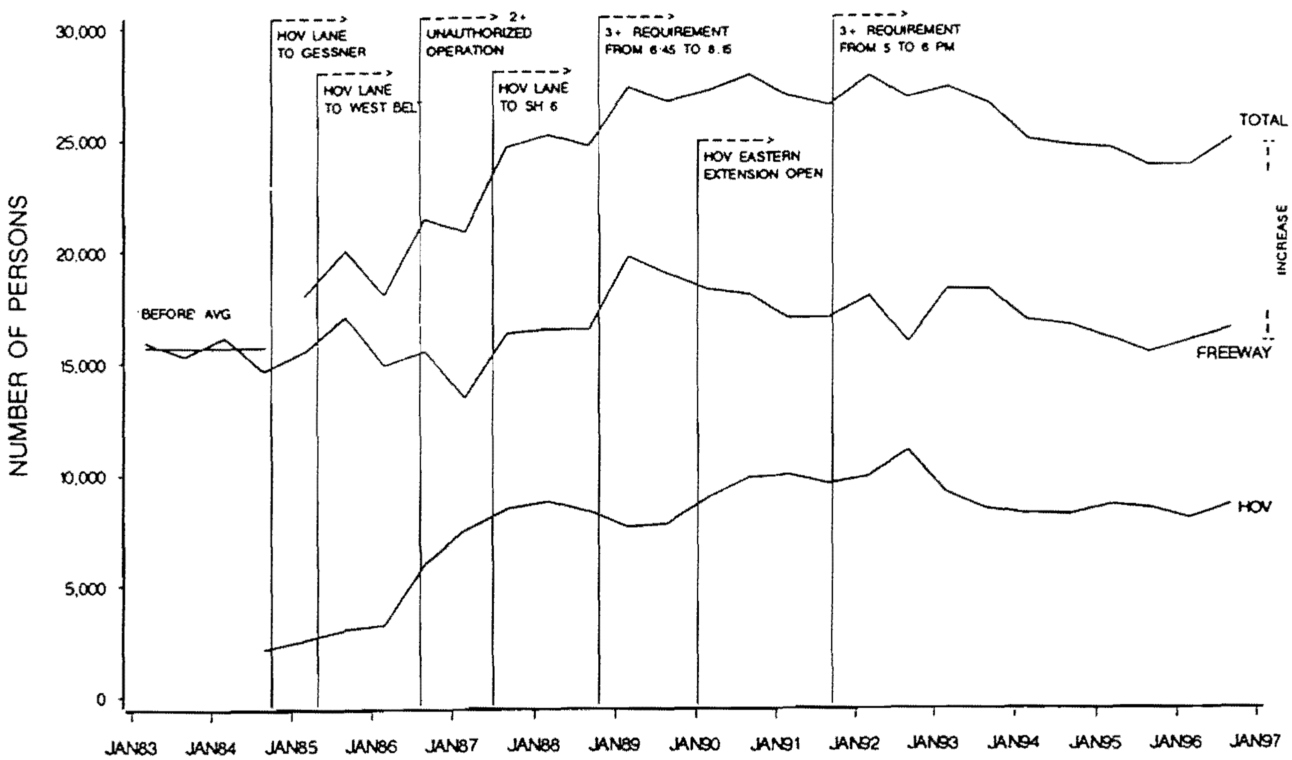


FIGURE A-8. KATY FREEWAY (IH 10W)
A.M. PEAK HOUR MAINLANE TRIPS

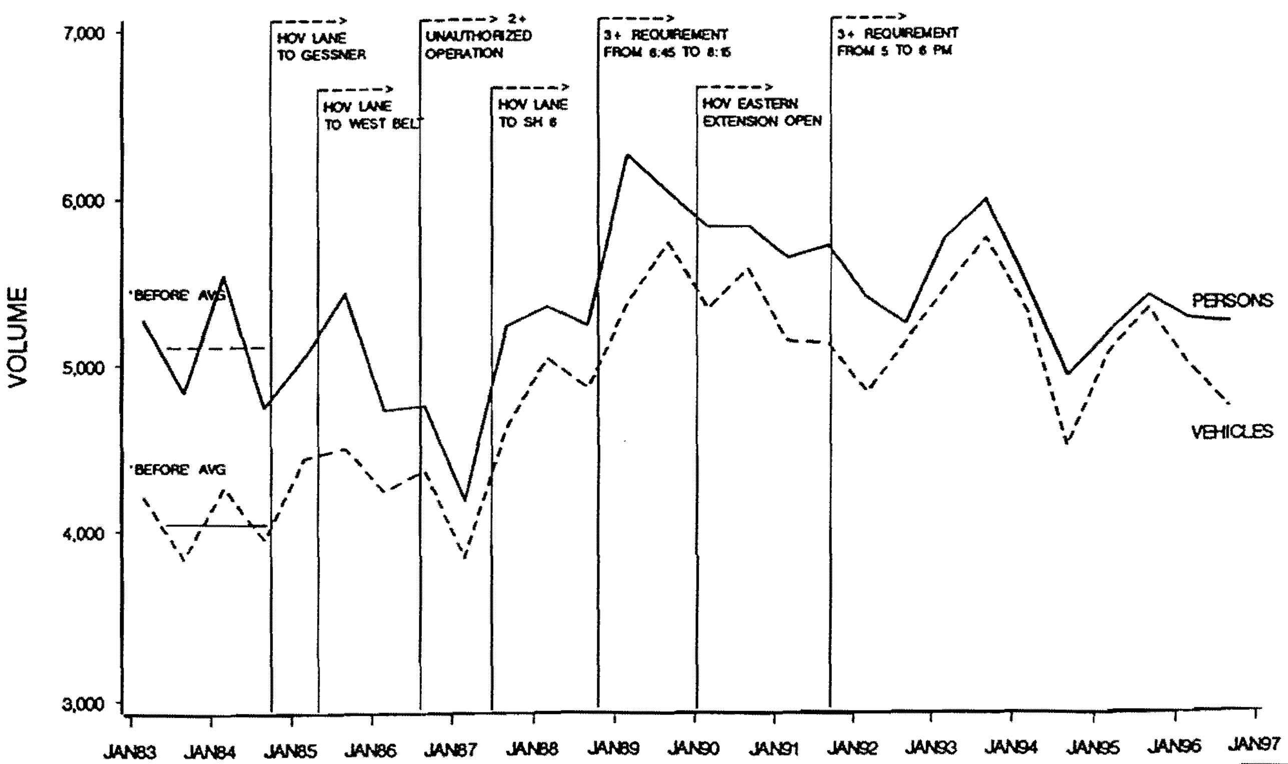


FIGURE A-9. KATY FREEWAY (IH 10W)
A.M. PEAK PERIOD MAINLANE TRIPS

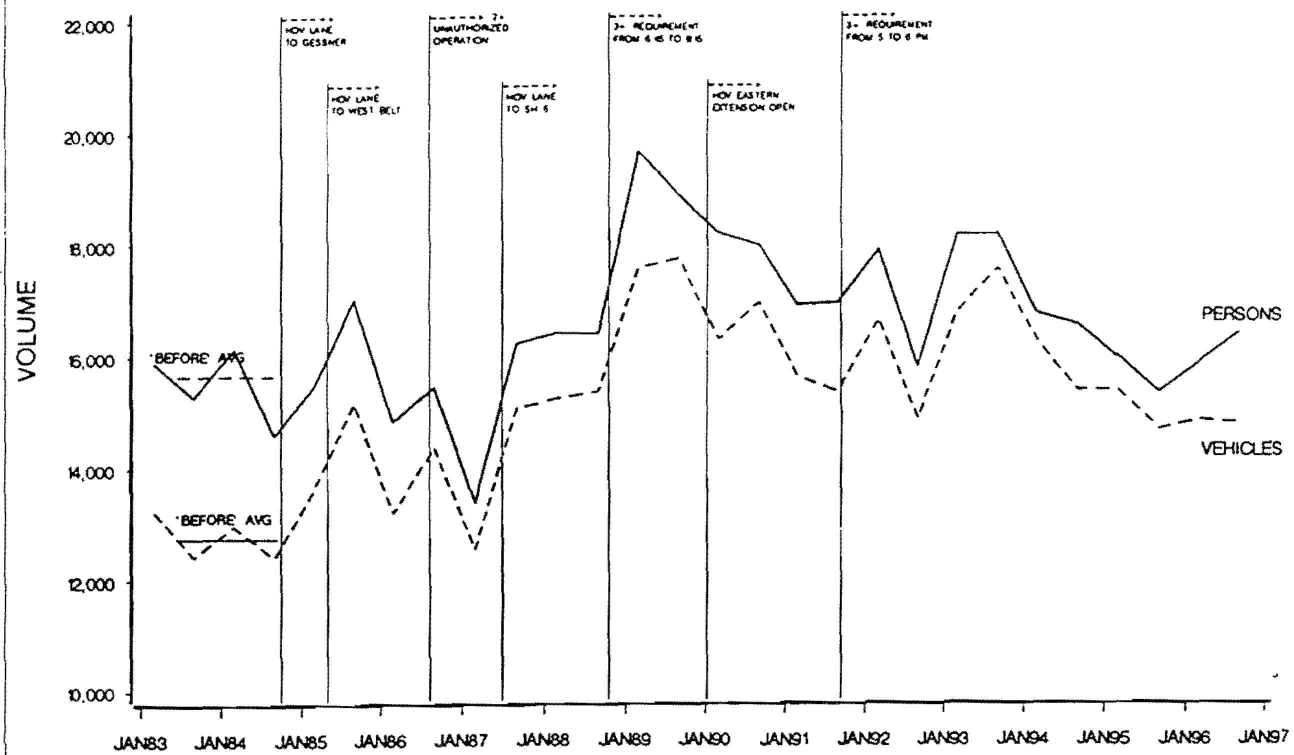


FIGURE A-10. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK HOUR AVERAGE OCCUPANCY

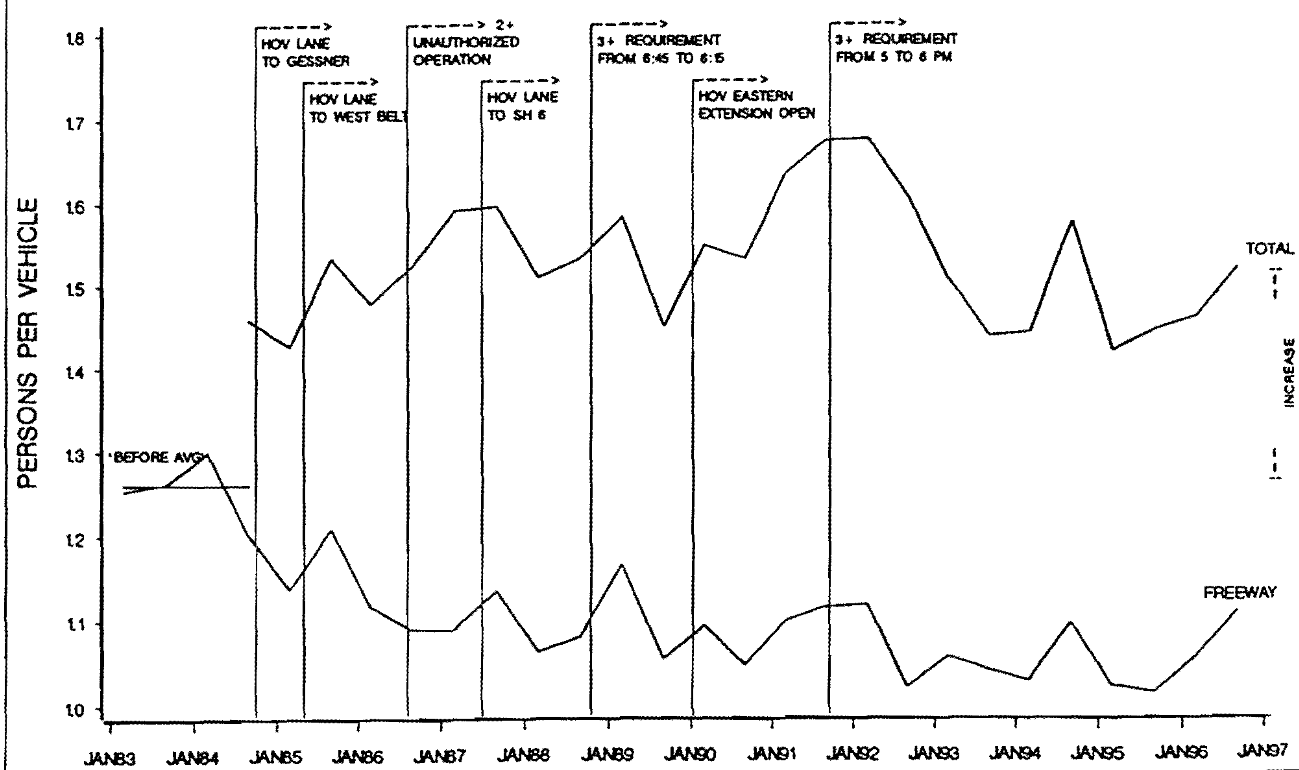


FIGURE A-11. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK PERIOD AVERAGE OCCUPANCY

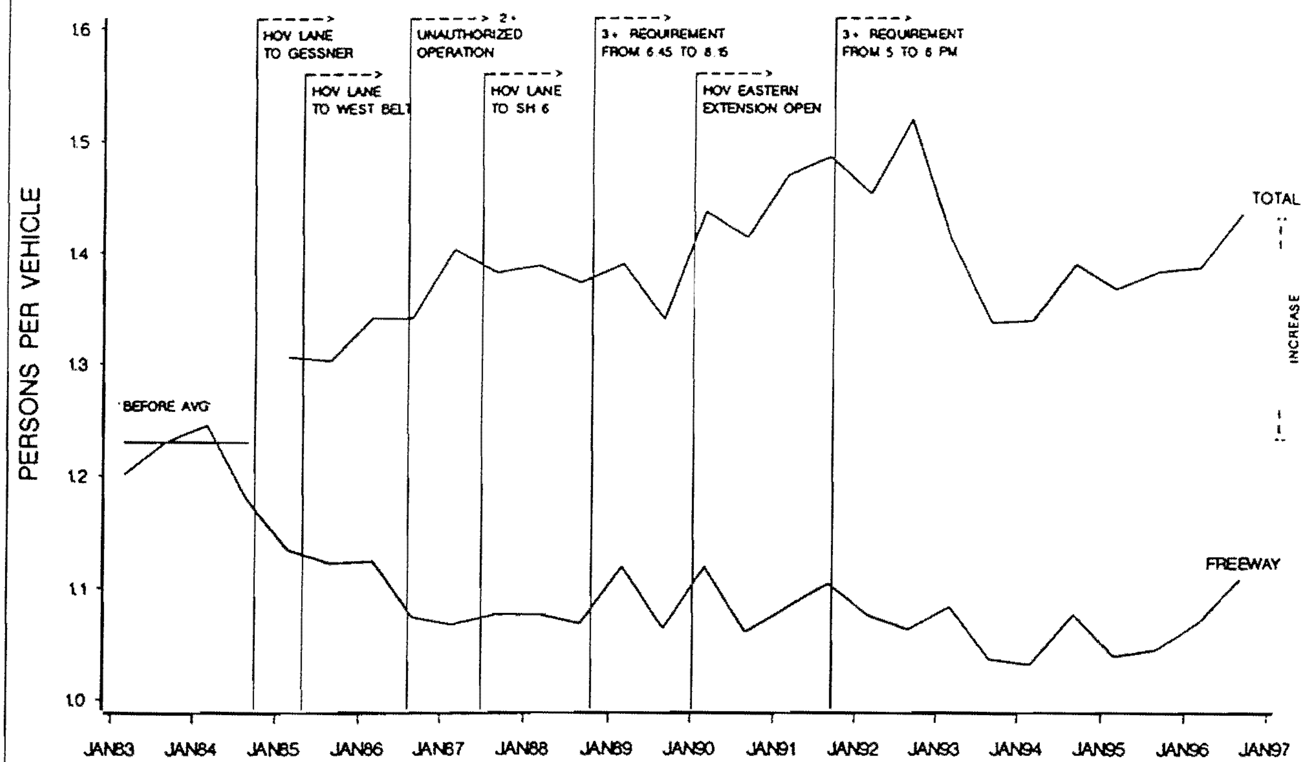
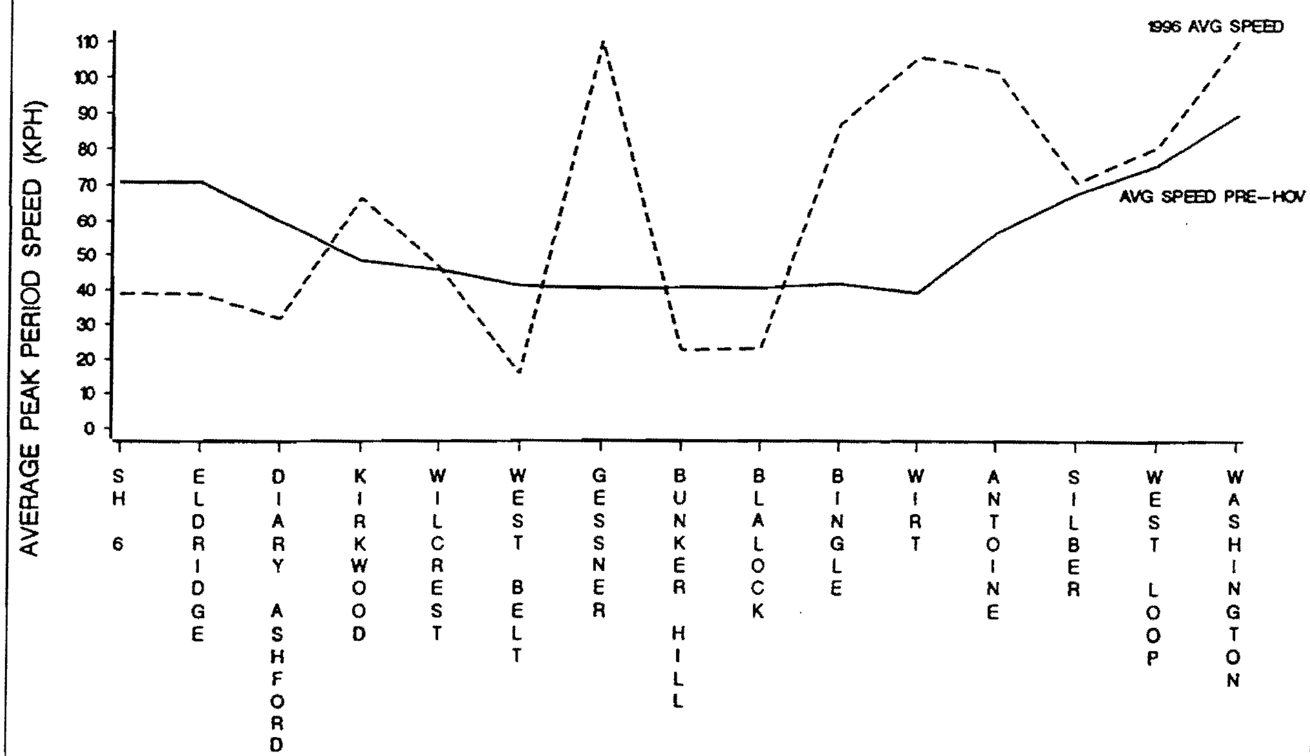


FIGURE A-12. KATY FREEWAY (IH 10W) MAINLANE TRAVEL TIME AND SPEED SURVEY
EASTBOUND, SH 6 TO WASHINGTON
A.M. PEAK PERIOD



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 39 percent of peak-hour person movement (HOV lane = 3,340; freeway = 5,246) and 35 percent of peak-period (HOV lane = 8,496; freeway = 16,386) 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 percent.
  - Total peak-hour person movement has increased by 68 percent from 5,100 to 8,586 (Figure A-6). Peak-period person movement has increased by 59 percent from 15,655 to 24,882 (Figure A-7).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.52, a 21 percent 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 1.43 (16 percent).
- 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 a.m. to 7 a.m. was 505 vehicles - now it is 990 vehicles (Figure A-14).
- In the a.m. peak hour, the total number of 3+ carpools (freeway plus HOV lane) has increased by 451 percent compared to pre-HOV lane levels (Figure A-15).

PEAK HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is used as a measure of the efficiency of a lane. The average efficiency of a lane on the freeway (three freeway lanes plus 1 HOV lane) has increased by 82 percent 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 200 percent since the HOV lane opened, and a 258 percent increase in bus ridership has also resulted (Figure A-17). In the peak period, a 150 percent increase has occurred in bus trips and a 203 percent 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 247 percent to a current level of 1,993 (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—13. A.M. PEAK HOUR AVERAGE OCCUPANCY
KATY FREEWAY AND FREEWAY WITHOUT HOV LANE

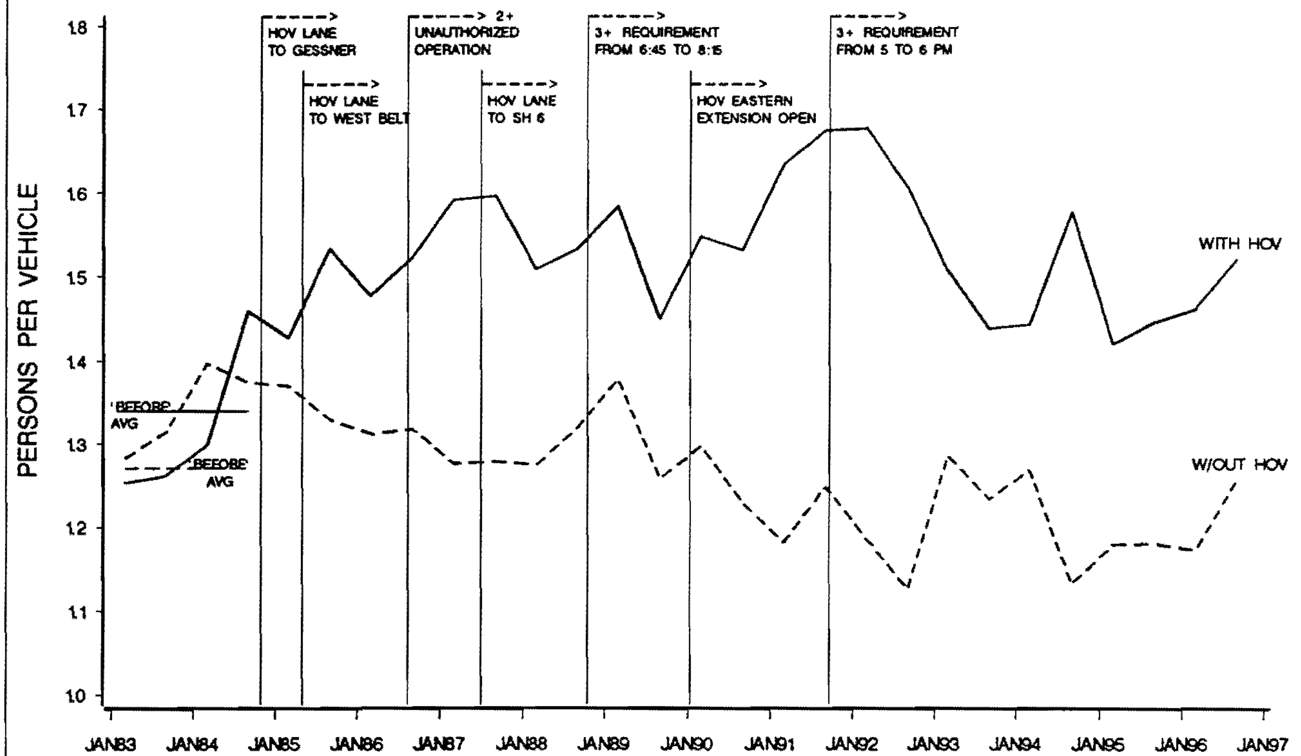


FIGURE A—14. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK HOUR 2+ CARPOOL UTILIZATION

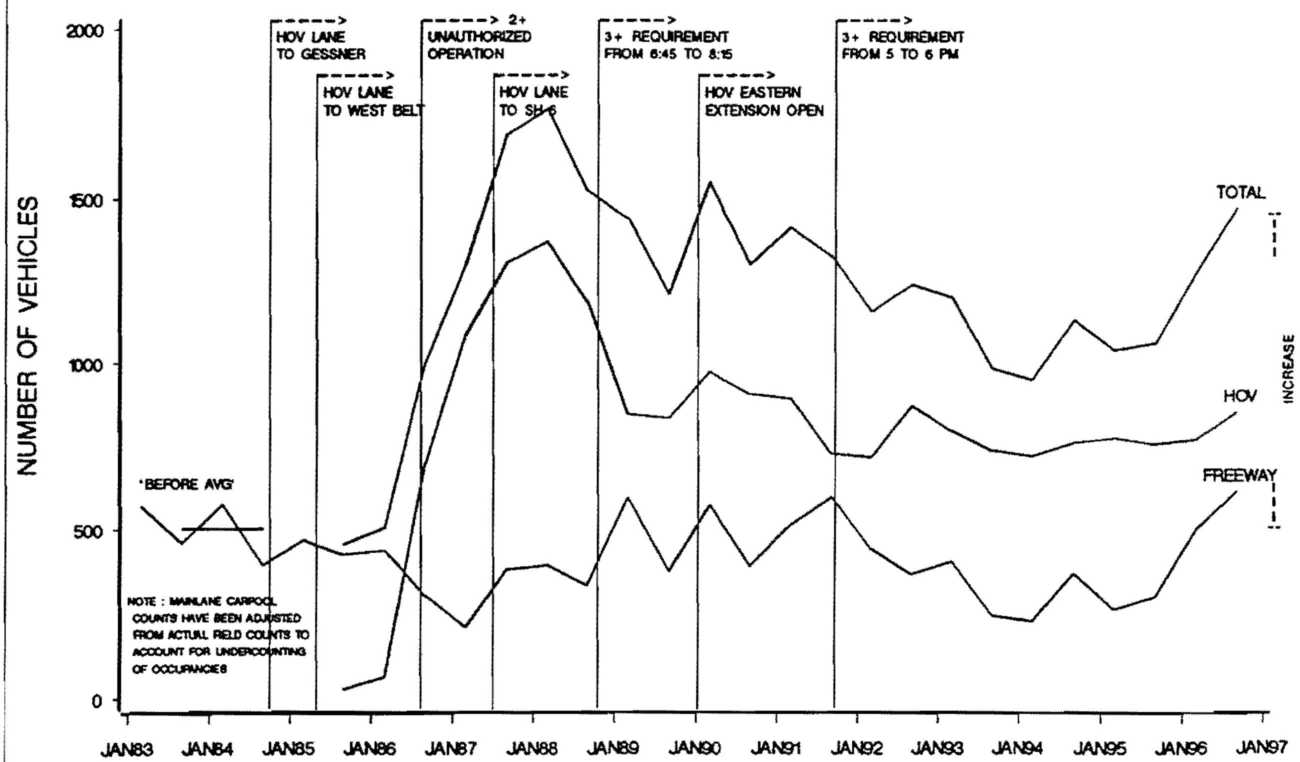


FIGURE A–15. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
7:00 A.M. TO 8:00 A.M. 3+ CARPOOL UTILIZATION

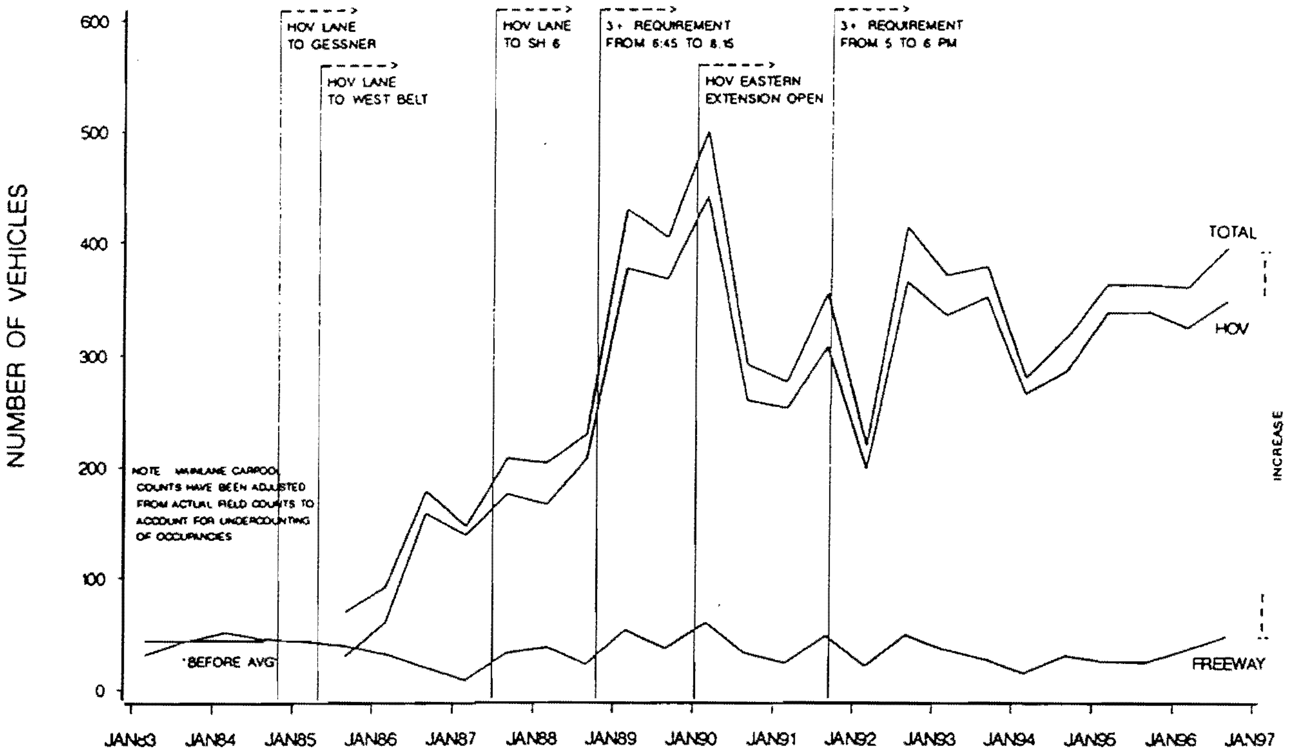


FIGURE A–16. A.M. PEAK HOUR FREEWAY PER LANE EFFICIENCY
KATY FREEWAY AND FREEWAY WITHOUT HOV LANE

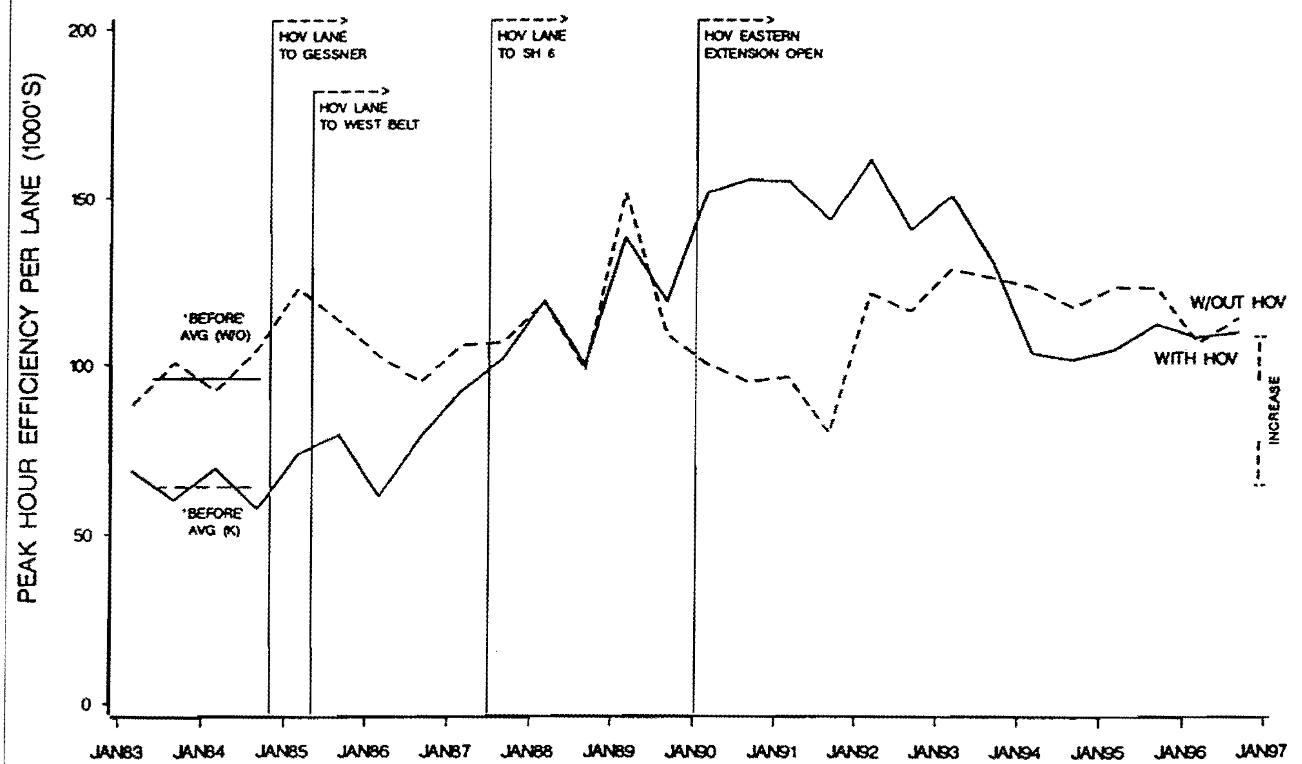


FIGURE A–17. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS

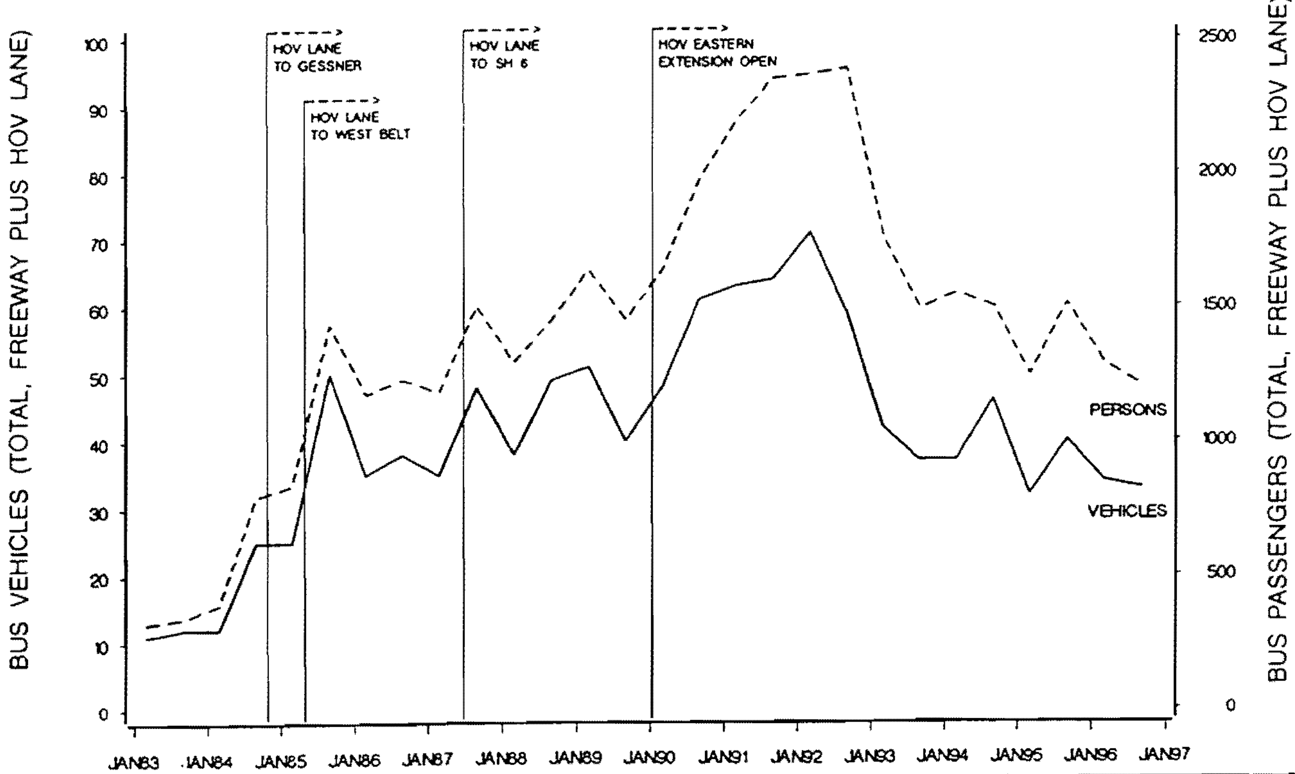


FIGURE A–18. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS

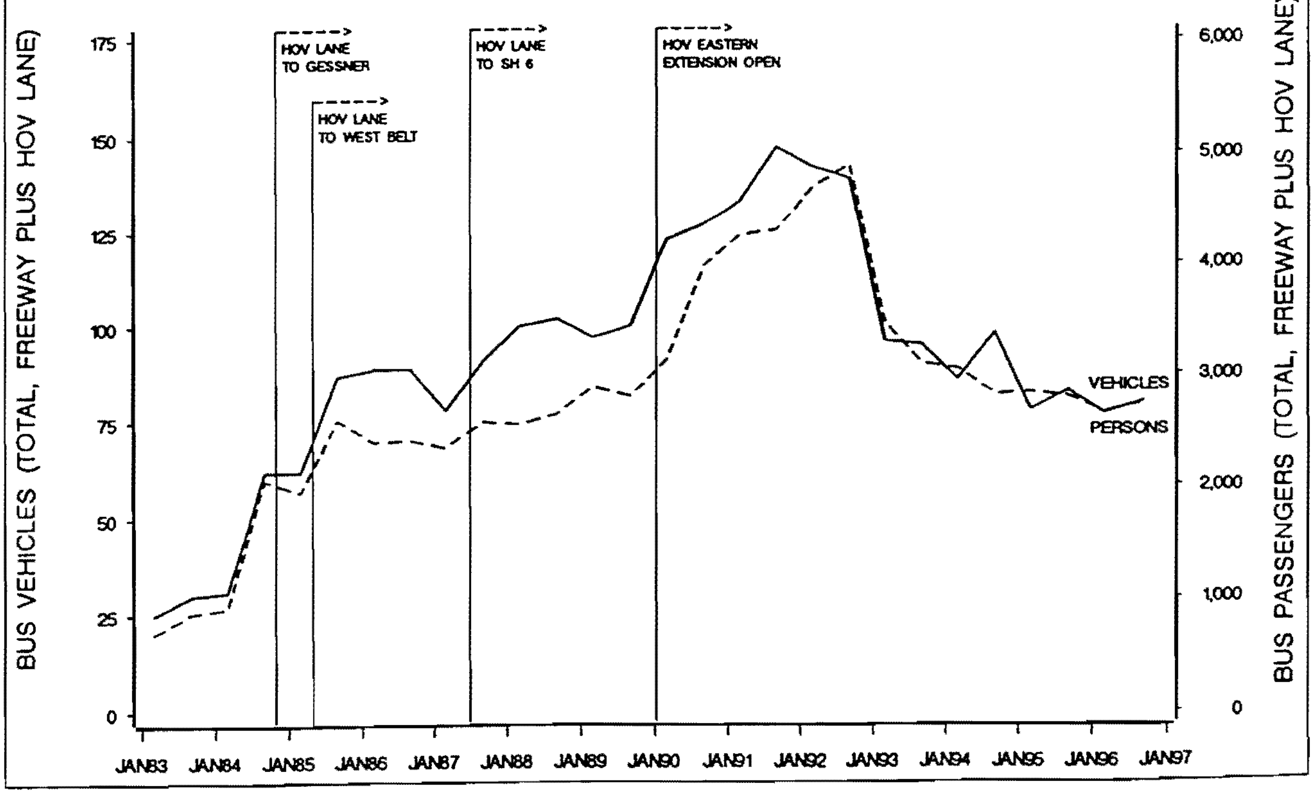


FIGURE A-19. A.M. PEAK PERIOD BUS PASSENGER TRIPS
TOTAL, FREEWAY PLUS HOV LANE VOLUMES
KATY FREEWAY AND FREEWAY WITHOUT HOV LANE

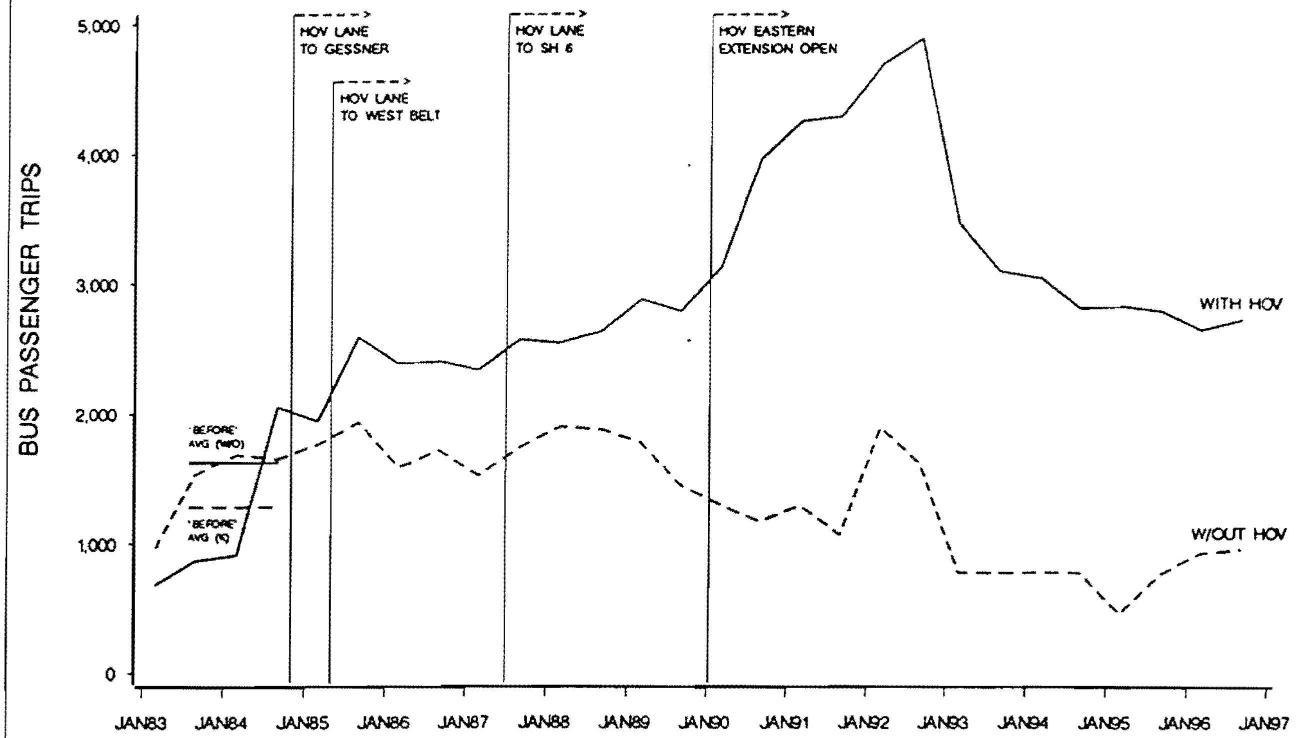


FIGURE A-20. KATY FREEWAY (IH 10W) CORRIDOR PARK-AND-RIDE DEMAND

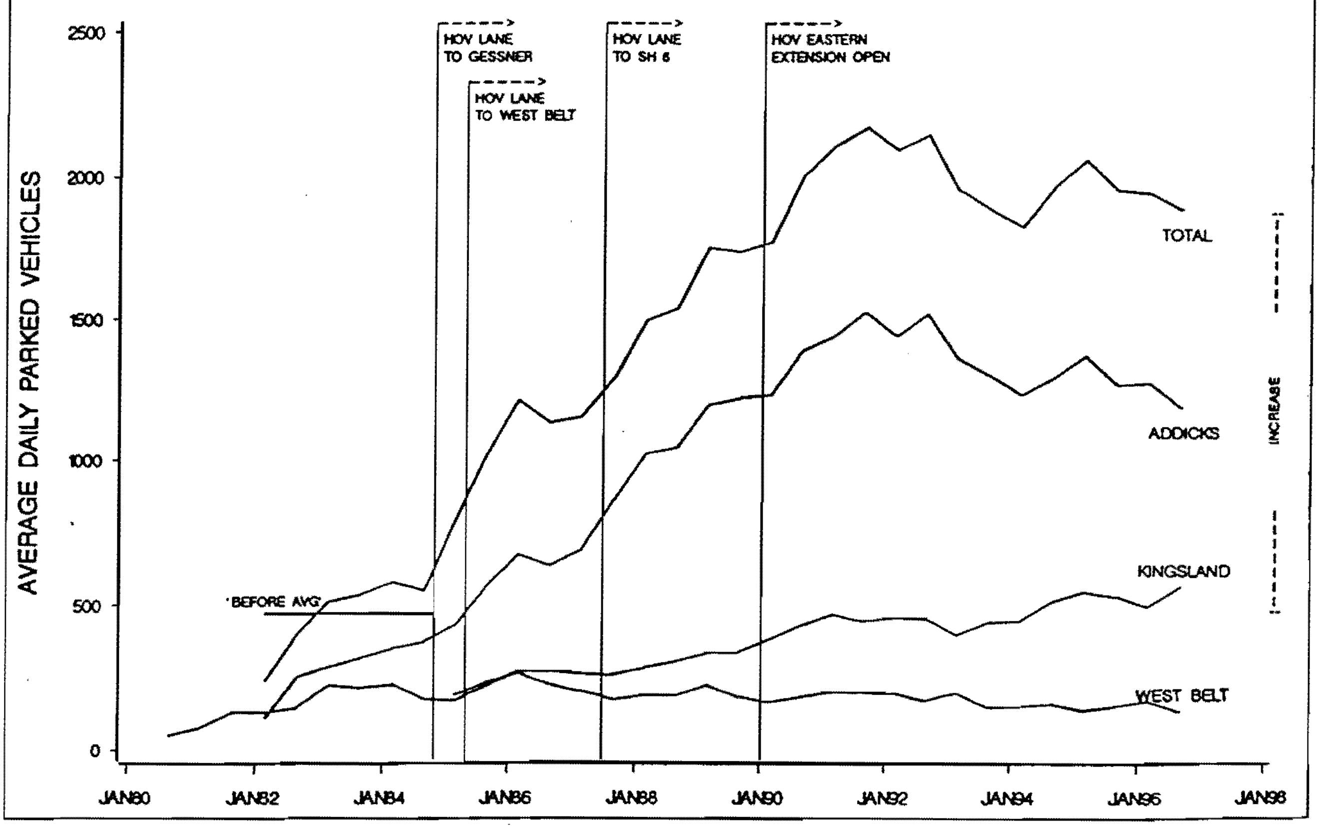
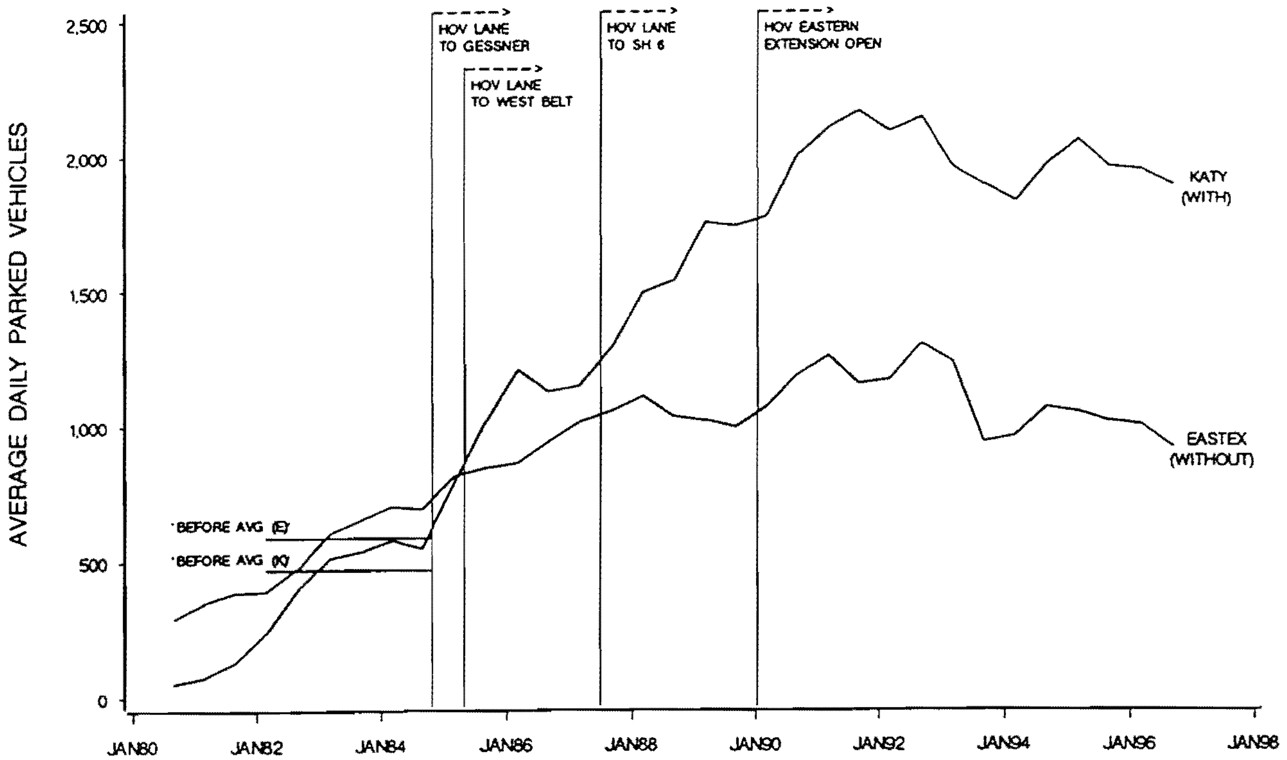


FIGURE A-21. AVERAGE DAILY VEHICLES PARKED AT PARK-AND-RIDE LOTS
KATY FREEWAY AND FREEWAY WITHOUT HOV LANE



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, 1996

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])		21.8 (13.5)	
HOV Lane Cost (millions)		$161.2	
Person-Movement			
Peak Hour (7-8 a.m.)	---	4,947	---
Peak Period (6-9:30 a.m.)	---	9,645	---
Total Daily	---	20,382	---
Vehicle Volumes			
Peak Hour	---	1,338	---
Peak Period	---	2,743	---
Vehicle Occupancy, Peak Hour (persons/veh)	---	3.7	---
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM])[2]	---	25.5 (41.2)	---
Vehicle Breakdowns (VKT/Breakdown [VMT/Breakdown])	---	99,473 (61,674)	---
Violation Rate (6-9:30 a.m.)		6%	
Peak-Hour Lane Efficiency (1000's)[3]	---	415 (262)	---
Annual Discounted Benefits (millions)[4]	---	$48	---
Annual Delay Savings (millions)[5]		$28	
Travel Time (minutes)[2]		13.59	
Peak-Hour		13.05	
Peak-Period			
Freeway Mainlane Data (see note)			
Person Movement	6,335	7,817	+23%
Peak-Hour	---	22,382	---
Peak-Period (6-9:30 a.m.)			
Vehicle Volume	4,950	7,689	+55%
Peak-Hour	---	21,394	---
Peak-Period	1.28	1.02	-20%
Vehicle Occupancy, Peak-Hour (persons/veh)	18.8 (30.3)	15.6 (25.1)	-17%
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM])[2]			
Avg. Operating Speed[6] (kph [mph])	32 (20)	36 (23)	+12%
Peak-Hour	48 (30)	52 (33)	+8%
Peak-Period	66 (41)	70 (44)	+6%
Peak-Hour Lane Efficiency (1000's)[3]			

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 km (7.8 mi). 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 12/96. Only office- reported accidents are included in files. 1996 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 average annual delay savings, reduced vehicle operating costs and reduced accident costs generated by MicroBENCOST over a 20-year life.

[5]Per MicroBENCOST, over a 20-year life.

[6]The distance from North Shepherd to Hogan is 12.6 km (7.8 mi).

Table B-1. Summary of A.M. Peak-Direction North Freeway and HOV Lane Data, 1996 (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	12,764	+101%
Peak-Period	---	32,027	---
Vehicle Volume			
Peak-Hour	4,950	9,027	+82%
Peak-Period	---	24,137	---
Vehicle Occupancy			
Peak-Hour	1.28	1.41	+10%
Peak-Period	1.28	1.32	+3%
2+ Carpool Volumes			
Peak-Hour	700	1,383	+98%
Peak-Hour Lane Efficiency (1000's)[5]	66 (41)	139 (88)	+111%
Transit Data[6]			
Bus Vehicle Trips			
Peak-Hour	---	83	---
Peak-Period	---	111	---
Bus Passenger Trips			
Peak-Hour	---	2,055	---
Peak-Period	---	3,775	---
Bus Occupancy (persons/bus)			
Peak-Hour	---	24.8	---
Peak-Period	---	34.0	---
Vehicles Parked in Corridor Park-and-Ride Lots	---	3,310	---
Bus Operating Speed[2] (kph [mph])			
Peak-Hour	---	84 (52)	---
Peak-Period	---	90 (56)	---

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 km (7.8 mi).

[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	1.41[1]	1.12
Bus Passengers, Peak Period	3,775	941
Cars Parked at Park-and-Ride Lots	3,310	965
Facility Per Lane Efficiency[2]	139 (88)	104 (64)

[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 km [9.1 mi]).
  - 3/31/81 A.M. concurrent flow lane to West Road opens (20.8 km [12.9 mi]).
  - 11/23/84 HOV Lane replaces contraflow.
  - 4/2/90 HOV Lane extended to Beltway 8 (21.8 km [13.5 mi]).
  - 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).
  - 3/14/94 Hours of operation revised.
  - 4/4/94 Hours of operation revised.
  - 9/30/96 Hours of operation revised (5:00 a.m. - 11:00 a.m.; 2:00 p.m. - 8:00 p.m.).

PERSON MOVEMENT

- In 1996, 20,382 person trips per day were served on the HOV lane.
- A.M. Peak Hour, 4,947 persons/hour.
  - 2,055 (42 percent) by bus, 262 (5 percent) by vanpool, 2,594 (52 percent) by carpool, and 10 by motorcycle (Figure B-1).

- Average HOV lane vehicle occupancy = 3.70 persons/vehicle.

- A.M. Peak Period, 9,645 persons.
  - 3,775 (50 percent) by bus, 504 (5 percent) by vanpool, 5,360 (56 percent) by carpool, and nine by motorcycle (Figure B-2).

VEHICLE MOVEMENT

- A.M. Peak Hour, 1,338 vph
  - 57 (4 percent) buses, 27 (2 percent) vans, 1,251 (93 percent) carpools, and four by motorcycle (Figure B-3).

- A.M. Peak Period, 2,743 vehicles.
  - 111 (4 percent) buses, 62 (2 percent) vans, 2,564 (93 percent) carpools, and seven by motorcycle (Figure B-4).

ACCIDENT RATE

- For the period from November 1984 through December 1996, the HOV lane accident rate was 25.5 injury accidents per 100 million vehicle kilometers (41.2 injury accidents per 100 million vehicle miles).

VEHICLE BREAKDOWN RATES

- The following vehicle breakdown rates were observed between December 1984 and December 1996.
  - Overall weighted average: one breakdown per 99,473 VKT (61,674 VMT).

VIOLATION RATE

- The observed violation rate (vehicles on the HOV lane not eligible to use the HOV lane) for 1996 was approximately 6 percent.

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 415 (4,947 passengers at 84 kph), or 262 (4,947 passengers at 52 mph).

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

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1996 Dollars
HOV Lane and Ramps			
Phase 1 Construction (1984)	$17.3	1.60	$27.7
Phase 2 Construction (1987)	50.6	1.42	71.9
Phase 3 Construction (1990) Incl. Aldine-Bender Interchange	5.4	1.27	6.9
Phase 4 Construction (1990)	7.6	1.27	9.7
Connection L	1.9	1.37	2.6
Miscellaneous (all phases), (1988)	6.2	1.19	8.5
HOV Lane Barrier Mod (1996)	0.3	1.0	0.3
SUB-TOTAL	$89.3		$127.6
Per Kilometer (Mile)	$4.1 ($6.6)		$5.9 ($9.5)
Surveillance, Communication and Control (1990)	$2.4	1.27	$3.1
SUB-TOTAL	$2.4		$3.1
Per Kilometer (Mile)	$0.1 ($0.2)		$0.1 ($0.2)
Support Facilities			
North Shepherd P/R (1980)	$2.2	1.87	$4.1
North Shepherd P/R Expansion (1982)	2.1	1.73	3.6
Kuykendahl P/R (1980)	1.7	1.87	3.2
Kuykendahl P/R Expansion (1983)	1.8	1.67	3.0
Spring P/R (1982)	3.7	1.73	6.4
Seton Lake P/R (1983)	3.3	1.67	5.5
Woodlands P/R (1985)	2.6	1.54	4.0
Woodlands P/R Expansion (1991)	0.8	1.22	1.0
SUB-TOTAL	$18.2		$30.8
Per Kilometer (Mile)	$0.8 ($1.3)		$1.4 ($2.3)
TOTAL COST	$109.9		$161.5
COST PER KILOMETER (21.8 kilometers [13.5 miles])	$5.1 ($8.1)		$7.4 ($12.0)

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	1997	$5.9
Airtex to FM 1960	1999	3.8
Kuykendahl Interchange	1997	7.6
FM 1960 Interchange	1999	4.7
Crosstimbers Access Ramp	1998	13.6
SUB-TOTAL		$35.6
Per Kilometer (Mile)		$3.5 ($5.6)
Surveillance, Communication and Control		$2.4
Support Facilities		
Kuykendahl Park-and-Ride Expansion (1996)	1996	11.9
TOTAL COST		$49.9
COST PER KILOMETER (10.3 kilometers [6.4 miles])		$4.8 ($7.8)

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

TRAVEL TIME SAVINGS

- The users of the HOV lane experienced an average travel time savings of 14 minutes during the morning peak hour in 1996 (Table B-5, Figure B-5).

Table B-5. Travel Time Savings for North HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1996)

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	
Southbound A.M. Travel Time Savings for North HOV Lane								
Section from Sam Houston Parkway to N. Shepherd								
6:00	4.76	4.57	0.19	239	146	540	925	177.32
6:30	6.23	4.80	1.42	594	59	470	1,123	1,600.27
7:00	7.71	4.63	3.08	1,038	74	562	1,674	5,161.53
7:30	6.90	4.85	2.05	879	29	250	1,158	2,373.90
8:00	4.92	4.67	0.25	376	38	476	890	222.54
8:30	4.19	4.78	-0.58	241	24	80	345	-201.24
9:00	4.32	4.38	-0.07	139	53	0	192	-12.79
Peak Period Total				3,506	423	2,378	6,307	9,321.54
Section From N. Shepherd to the Hogan Overpass								
6:00	8.13	8.03	0.19	305	70	241	616	56.41
6:30	11.03	8.68	2.36	776	153	818	1,747	4,119.36
7:00	21.58	9.11	12.47	1,244	146	1,065	2,455	30,605.75
7:30	21.00	8.59	12.41	1,399	91	1,064	2,553	31,681.62
8:00	18.26	8.35	9.91	897	40	527	1,464	14,500.87
8:30	10.89	8.27	2.62	541	31	246	818	2,146.55
9:00	8.61	7.72	0.89	280	37	84	401	357.13
Peak Period Total				5,440	567	4,045	10,052	83,467.69
Northbound P.M. Travel Time Savings for North HOV Lane								
Section from Sam Houston Parkway to N. Shepherd								
3:30	4.63	4.43	0.20	106	18	86	210	42.00
4:00	4.70	4.43	0.27	288	59	215	562	149.86
4:30	5.03	4.45	0.58	472	69	193	734	428.14
5:00	5.03	5.31	-0.27	654	79	295	1,028	-282.70
5:30	7.03	4.58	2.44	774	115	481	1,370	3,345.06
6:00	6.23	5.02	1.21	442	45	165	652	787.84
6:30	4.62	4.25	0.37	200	29	65	294	107.80
Peak Period Total				2,936	414	1,500	4,850	4,578.00

Table B-5. Travel Time Savings for North HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1996)

Northbound P.M. Travel Time Savings for North HOV Lane								
Section from N. Shepard to Hogan Overpass								
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	
3:30	8.55	7.75	0.80	252	9	198	459	367.07
4:00	7.67	7.94	-0.27	523	28	403	953	-262.01
4:30	8.26	7.99	0.27	861	138	604	1,602	427.17
5:00	9.48	8.36	1.12	1,142	140	813	2,095	2,339.38
5:30	10.57	9.03	1.54	1,161	70	871	2,101	3,239.01
6:00	7.87	8.26	-0.39	708	24	534	1,265	-495.47
6:30	7.28	7.84	-0.57	371	21	302	693	-392.78
Peak Period Total				5,017	429	3,723	9,168	5,222.37

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 three to four 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 7,817 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 7,689 vehicles used the mainlanes during 1996 (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 21,394 vehicles used the mainlanes (Figure B-7).

- In the a.m. peak-hour, mainlane occupancy is approximately 1.02 (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 12/96, (since the barrier-separated HOV lane opened) the accident rate has been 15.6 injury accidents/100 MVK (25.1 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 70 (1,954) passengers per lane at 36 kph) or 45 (1,954 passengers per lane at 23 mph).

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

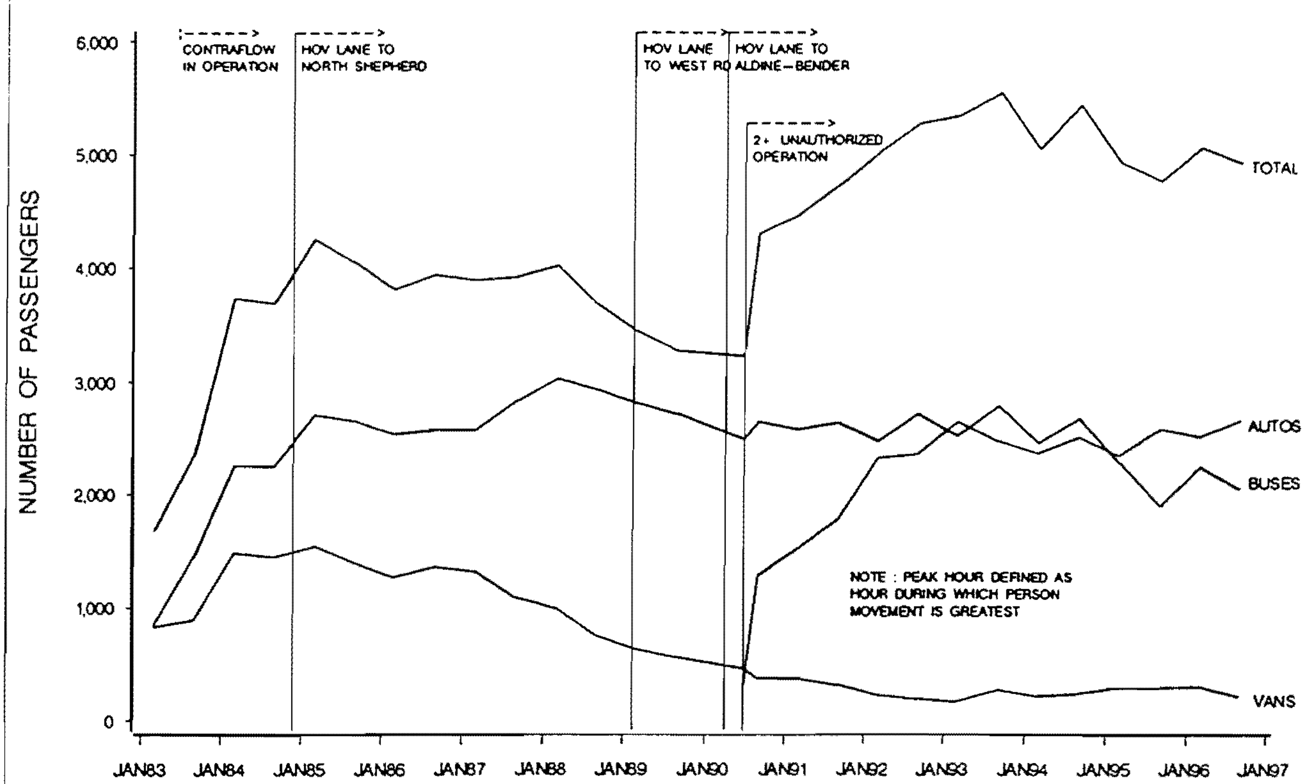


FIGURE B–2. NORTH FREEWAY (IH 45N) HOV LANE
A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT

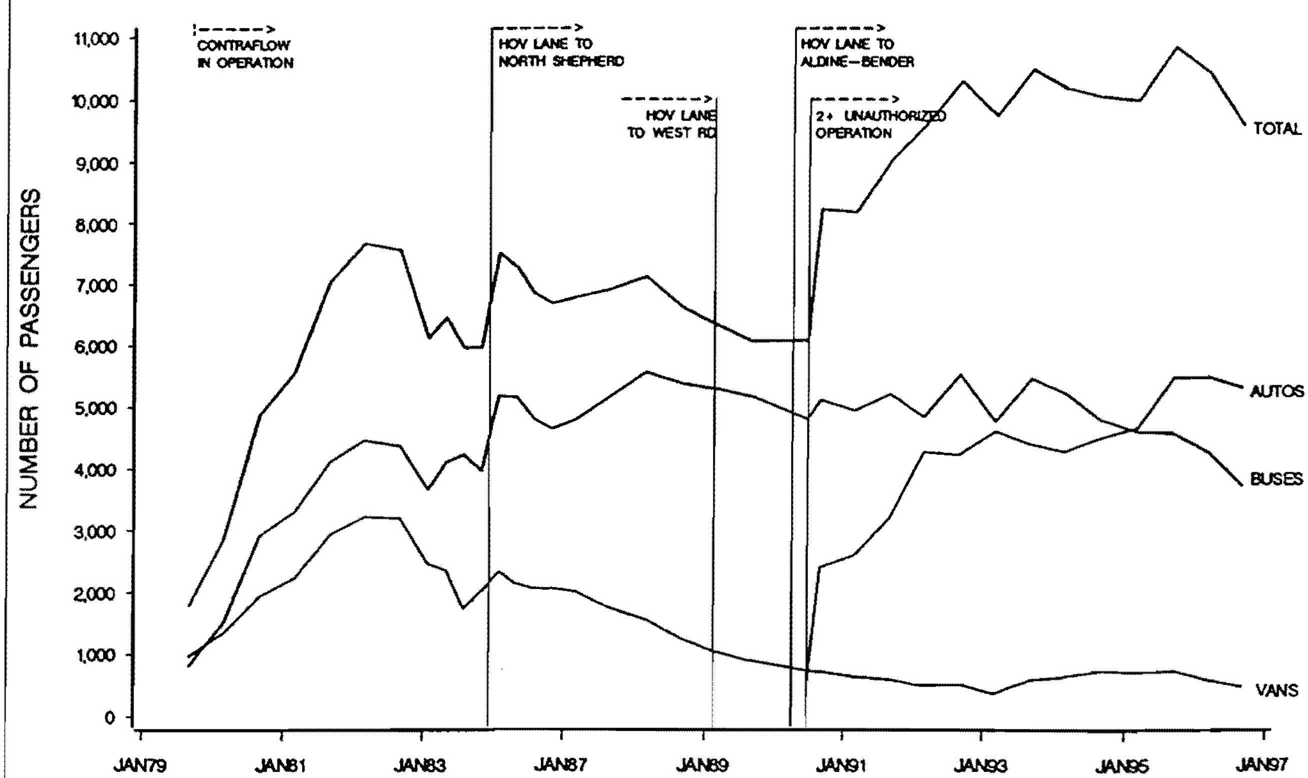


FIGURE B-3. NORTH FREEWAY (IH 45N) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION

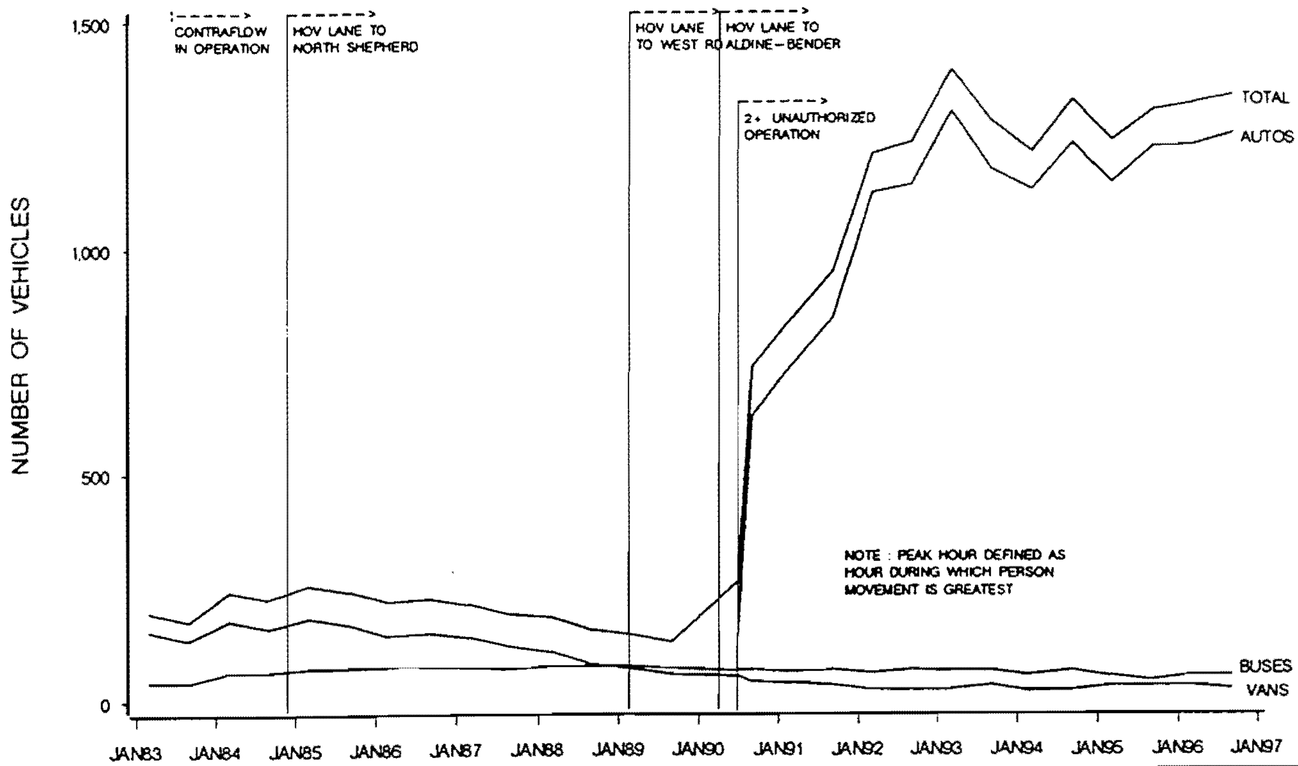


FIGURE B-4. NORTH FREEWAY (IH 45N) HOV LANE
A.M. PEAK PERIOD HOV LANE VEHICLE UTILIZATION

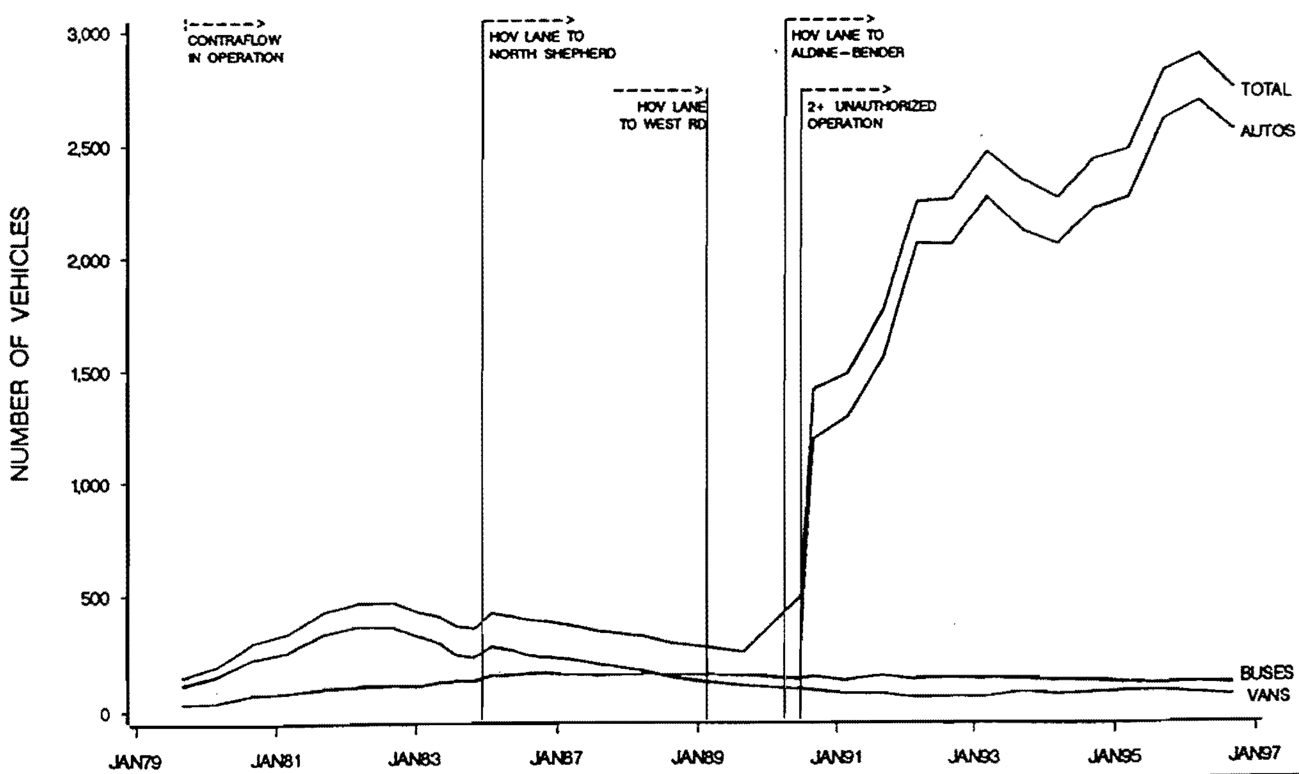


FIGURE B-5. NORTH FREEWAY (IH 45N) MAINLANES AND HOV LANE A.M. TRAVEL TIME

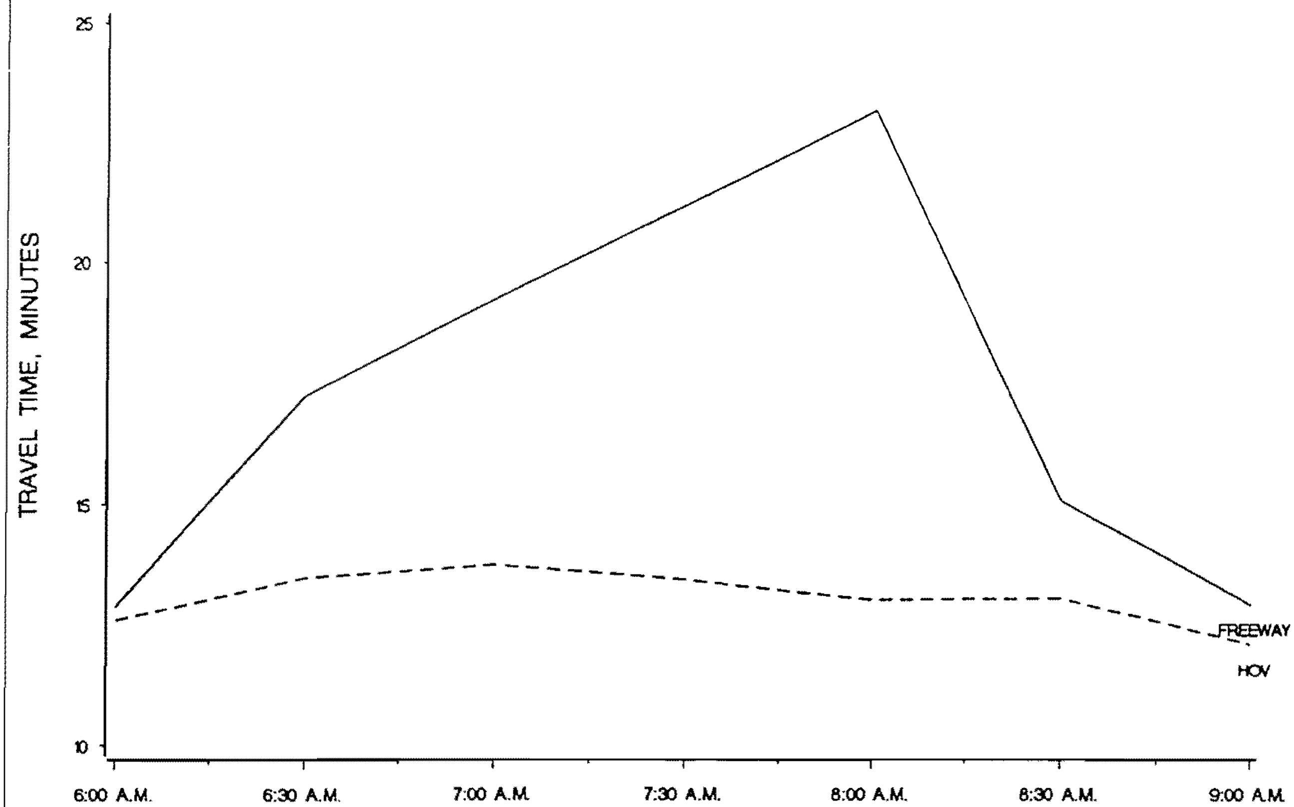


FIGURE B-6. NORTH FREEWAY (IH 45N)
A.M. PEAK HOUR MAINLANE TRIPS

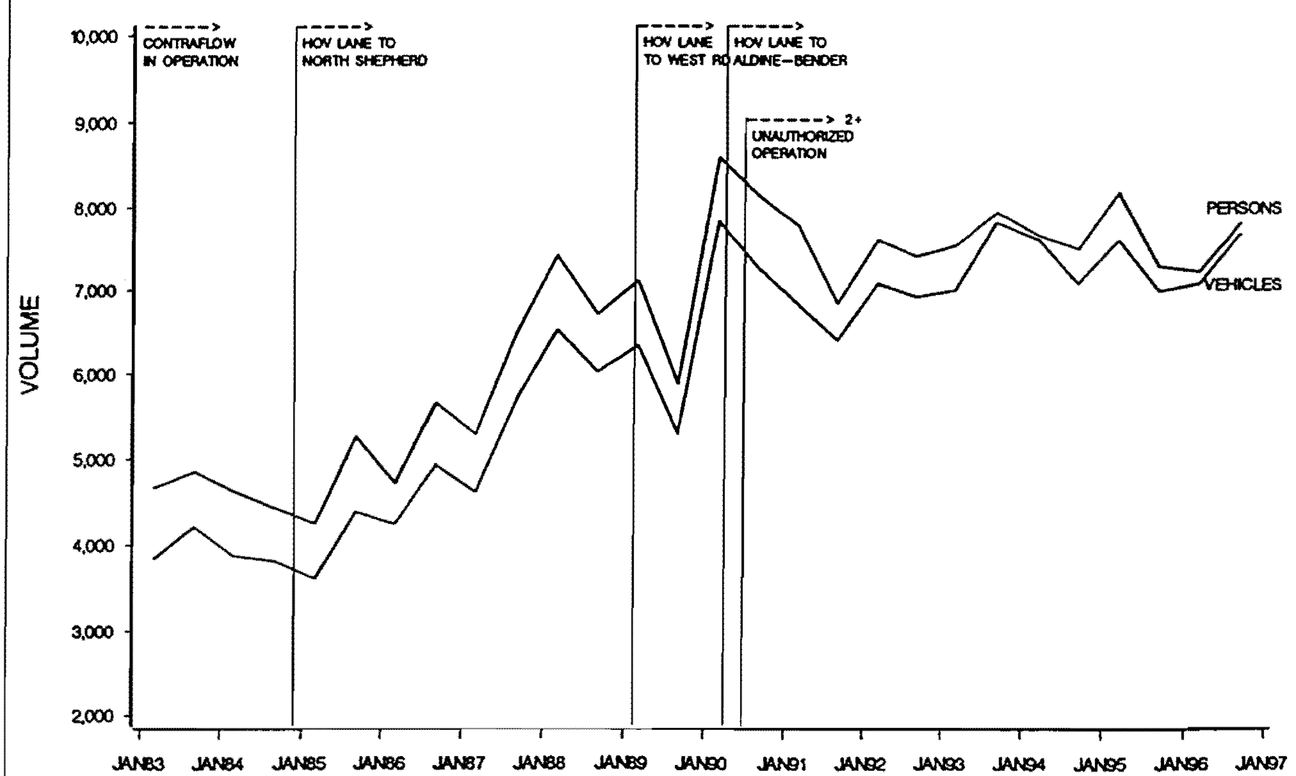


FIGURE B-7. NORTH FREEWAY (IH 45N)
A.M. PEAK PERIOD MAINLANE TRIPS

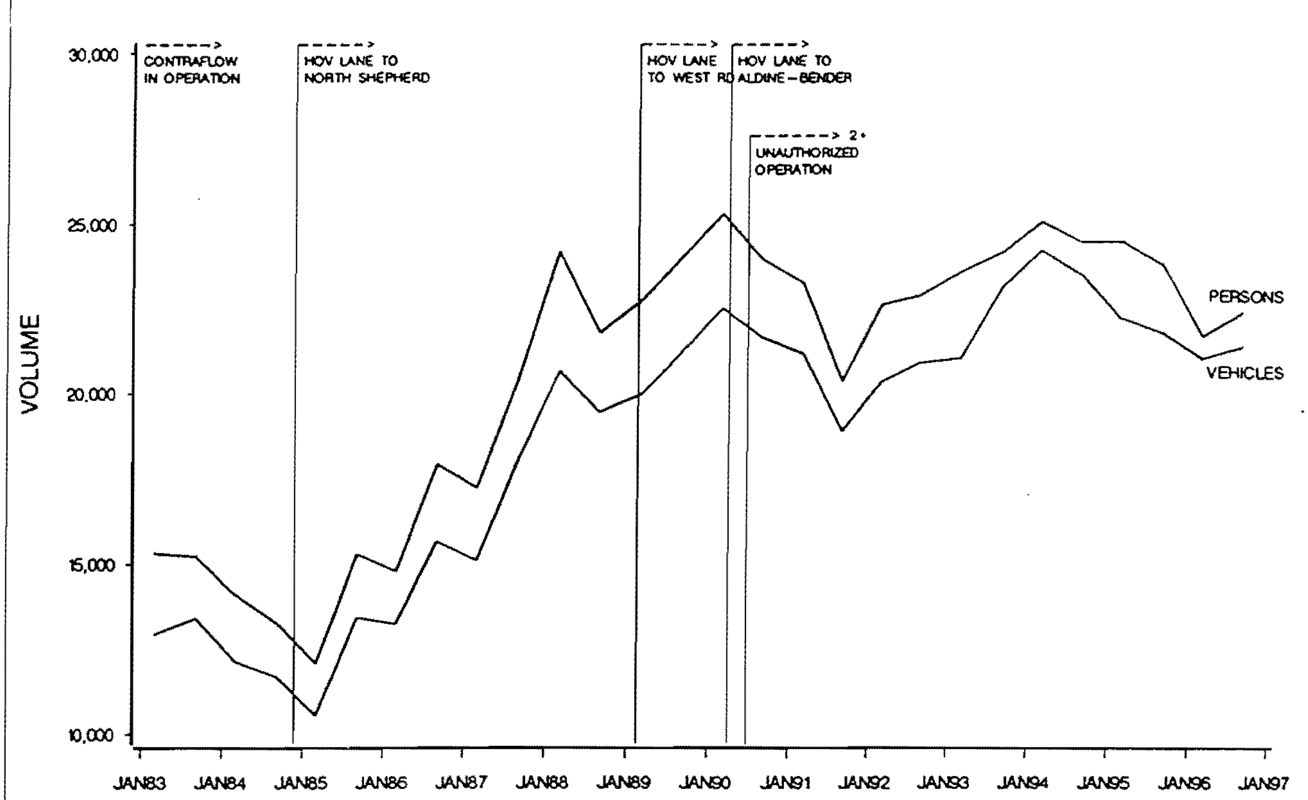


FIGURE B-8. NORTH FREEWAY (IH 45N) MAINLANE AND HOV LANE
A.M. PEAK HOUR AVERAGE OCCUPANCY

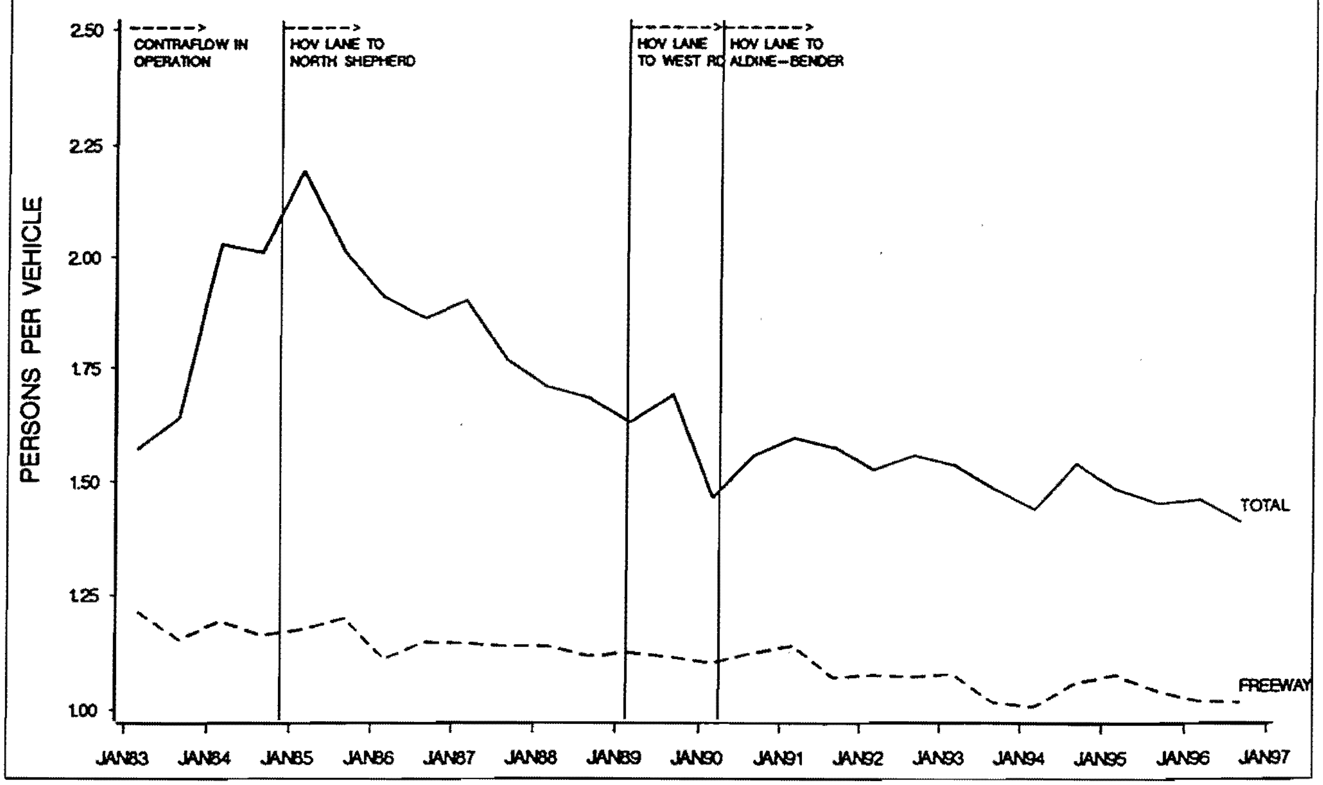


FIGURE B-9. NORTH FREEWAY (IH 45N) MAINLANE AND HOV LANE A.M. PEAK PERIOD AVERAGE OCCUPANCY

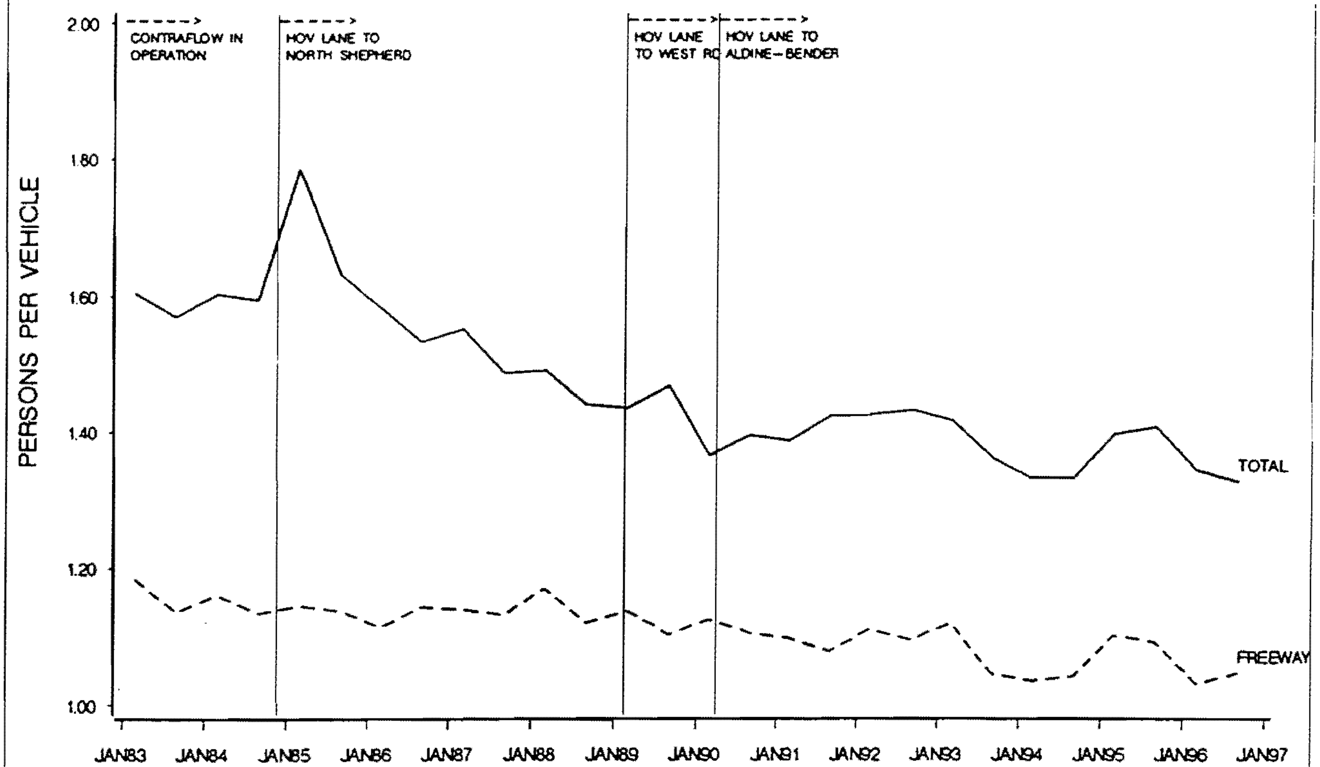
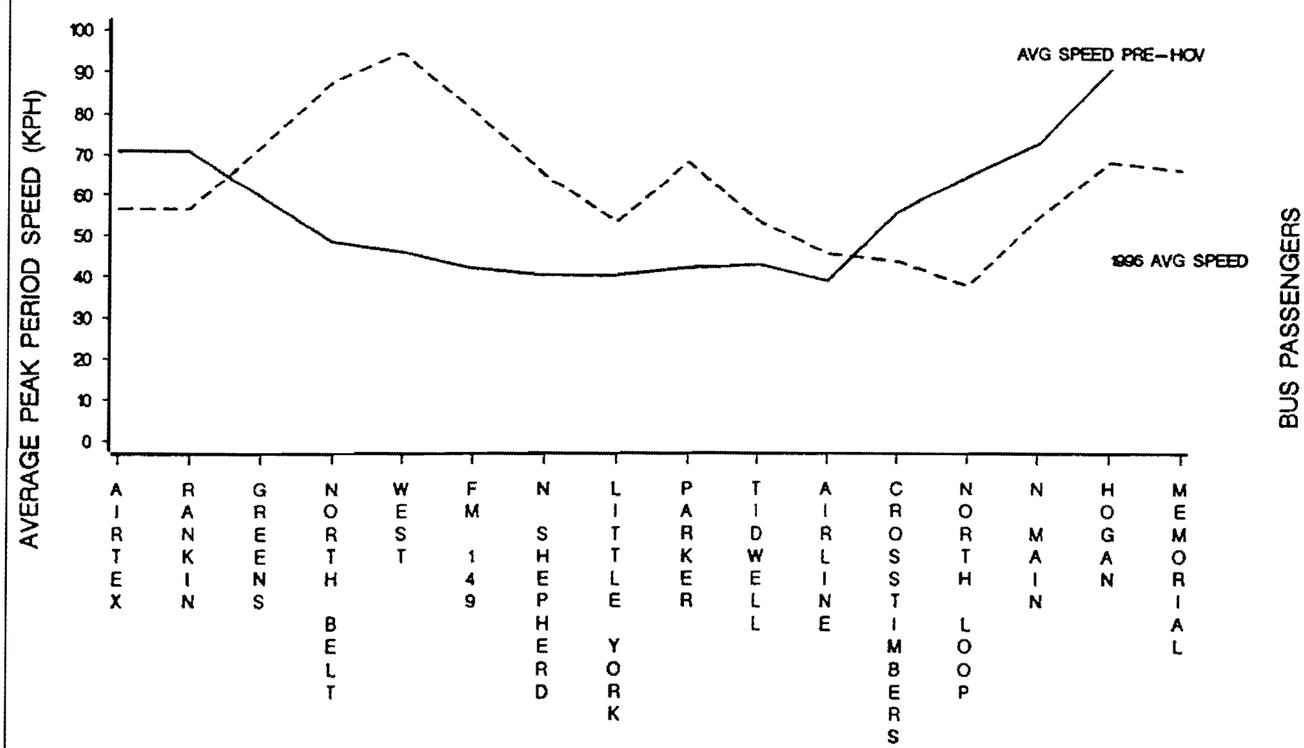


FIGURE B-10. NORTH FREEWAY (IH 45N) MAINLANE TRAVEL TIME AND SPEED SURVEY SOUTHBOUND, AIRTEX TO MEMORIAL A.M. PEAK PERIOD



COMBINED FREEWAY AND HOV LANE DATA

TOTAL PERSON MOVEMENT

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

  - At Little York, the HOV lane is carrying 38 percent of the total peak-hour person movement (Figure B-11). In the peak-period, the HOV lane carries 30 percent of the a.m. peak-period person trips (Figure B-12). Compared to pre-contraflow conditions, peak-hour person movement has increased by 101 percent.

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak-hour is 1.41 versus 1.02 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 139 (persons x kph) or 88 (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 2,055 passengers per peak-hour (Figure B-16) and 3,775 passengers per peak-period (Figure B-17). Likewise, the bus vehicle trips for the peak-period have decreased slightly to 111 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, 3,310 vehicles are parked in the corridor park-and-ride lots. Approximately 45 percent of the 7,386 parking spaces are utilized (Figure B-19).

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

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

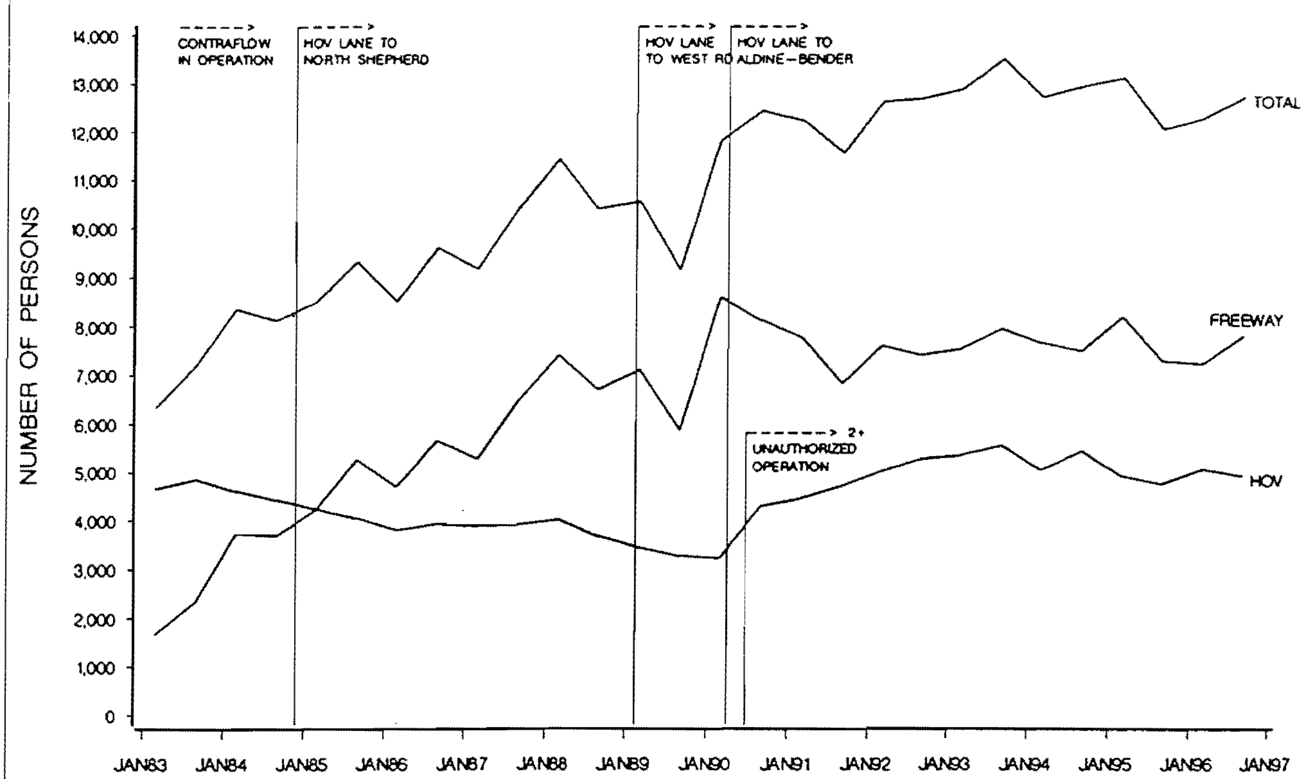


FIGURE B-12. NORTH FREEWAY (IH 45N) MAINLANE AND HOV LANE
A.M. PEAK PERIOD PERSON TRIPS

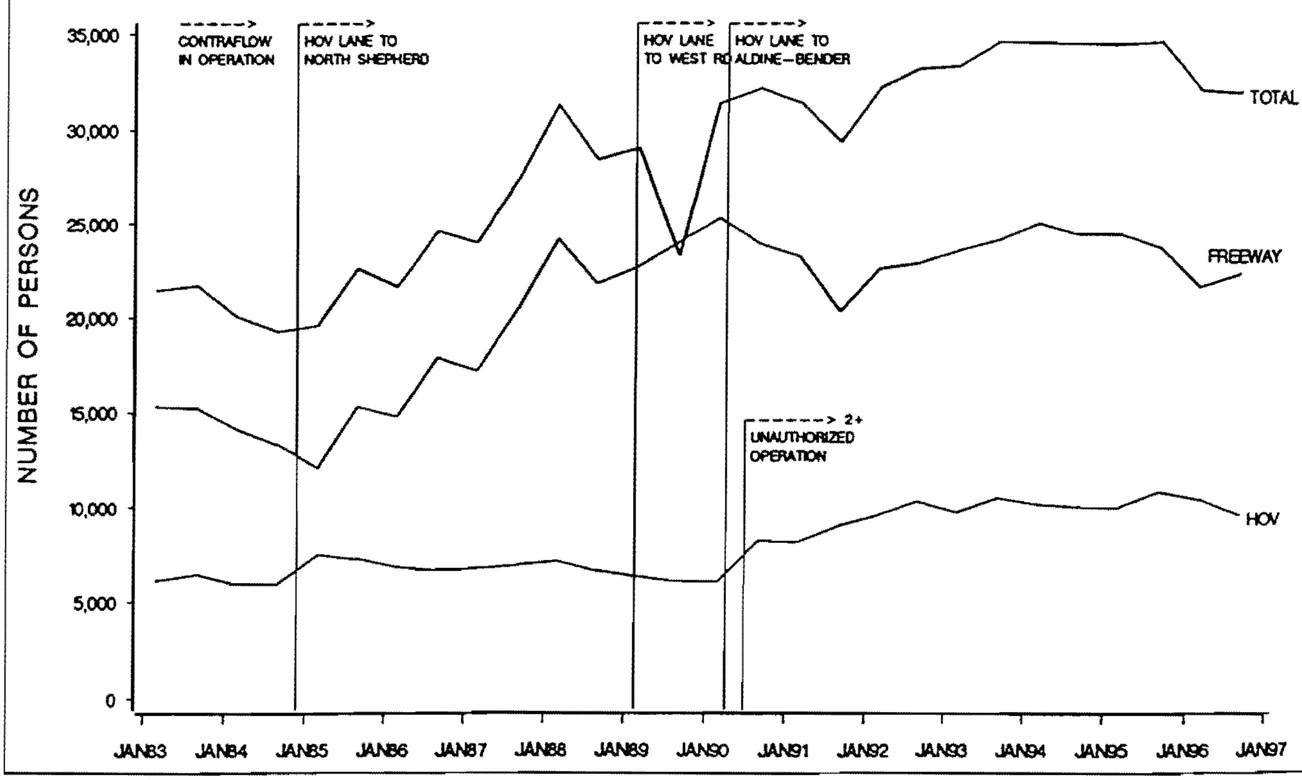


FIGURE B-13. A.M. PEAK HOUR AVERAGE OCCUPANCY
NORTH FREEWAY AND FREEWAY WITHOUT HOV LANE

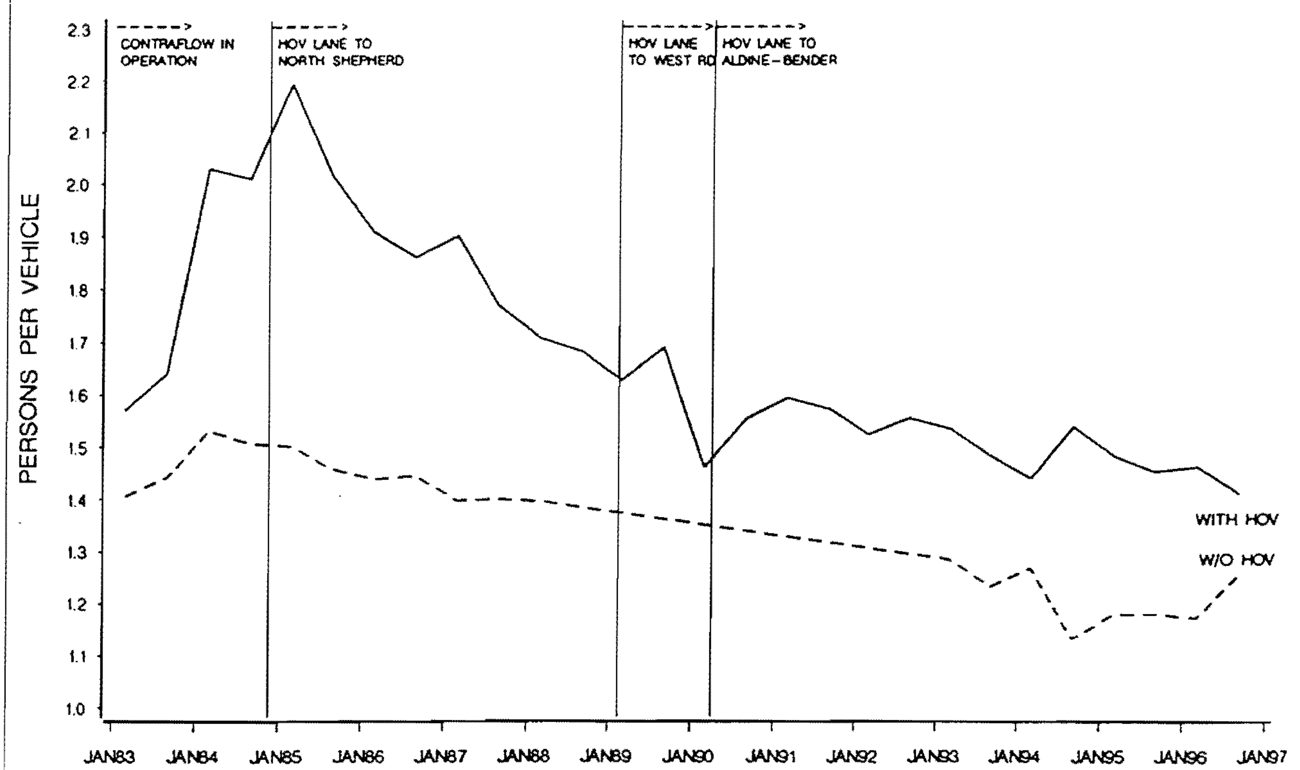


FIGURE B-14. NORTH FREEWAY (IH 45N) MAINLANE AND HOV LANE
A.M. PEAK HOUR 2+ CARPOOL UTILIZATION

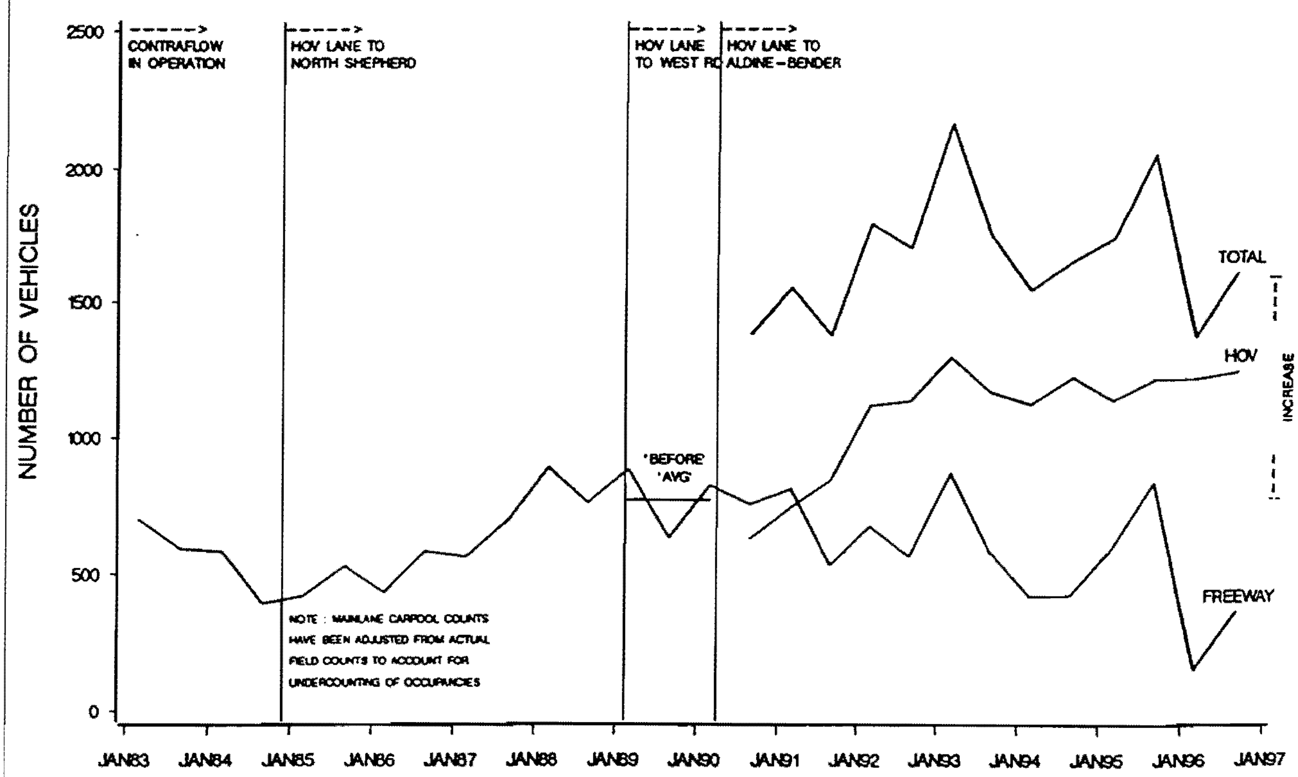


FIGURE B-15. A.M. PEAK HOUR FREEWAY PER LANE EFFICIENCY
NORTH FREEWAY AND FREEWAY WITHOUT HOV LANE

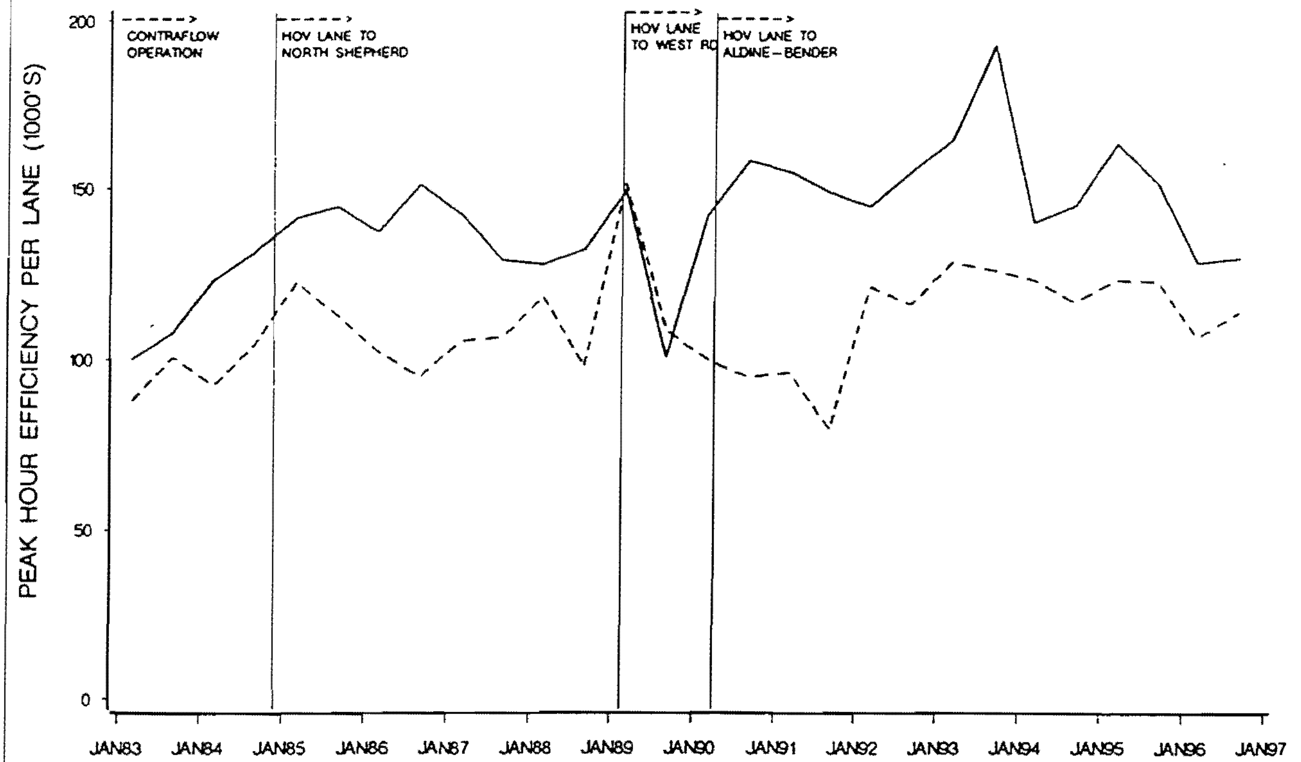


FIGURE B-16. NORTH FREEWAY (IH 45N) HOV LANE
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS

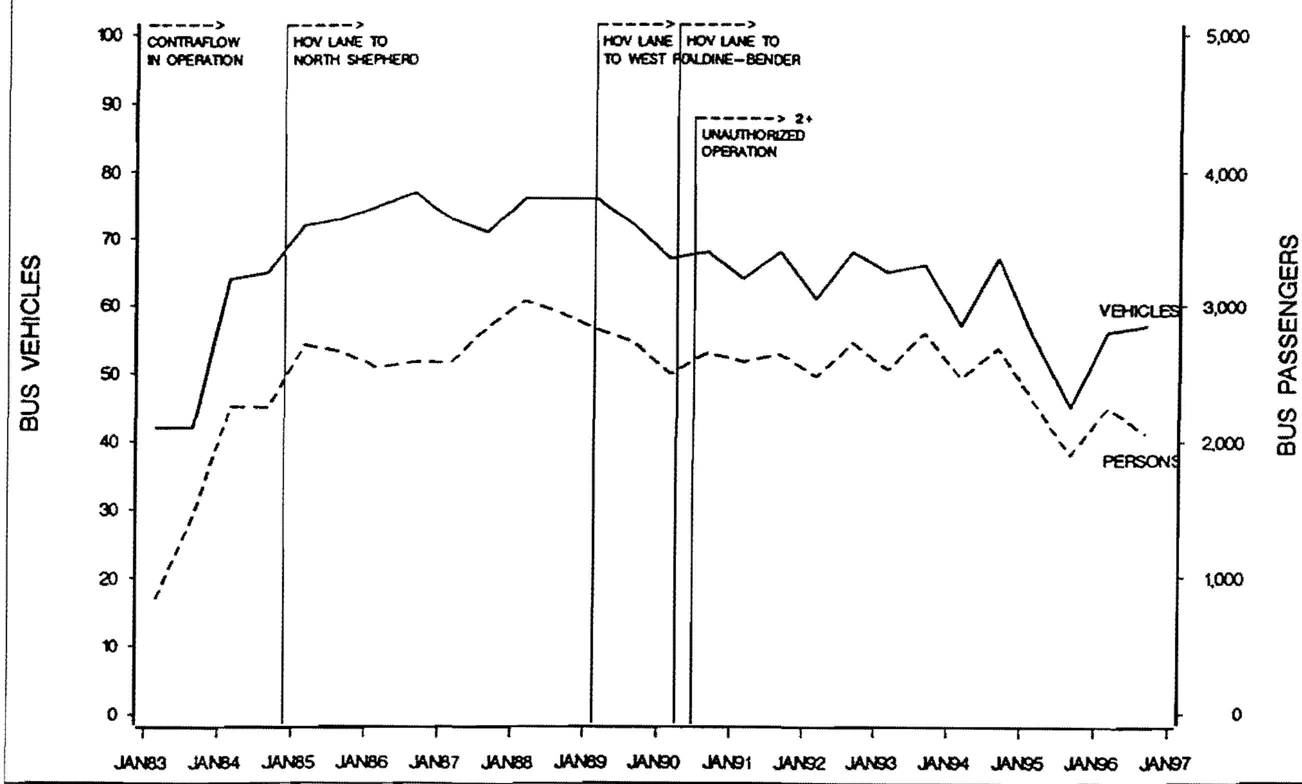


FIGURE B-17. NORTH FREEWAY (IH 45N) HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS

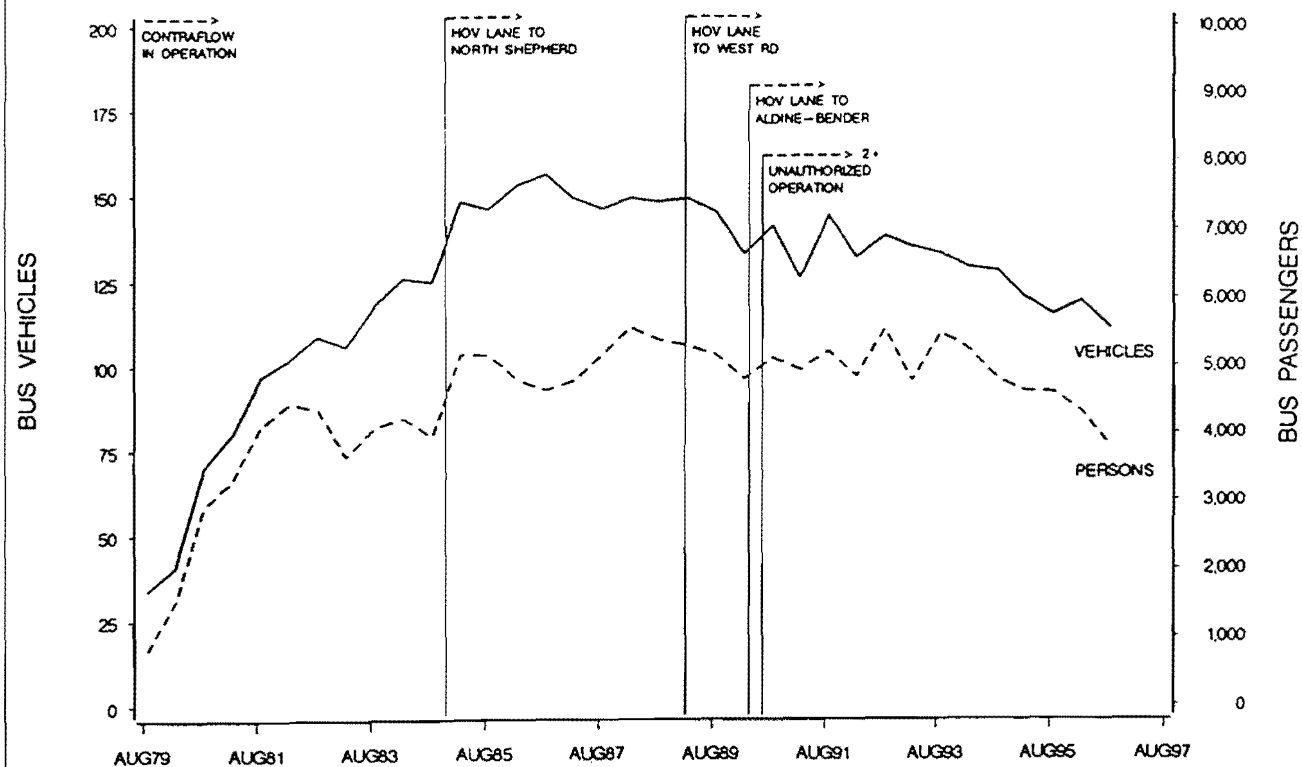


FIGURE B-18. A.M. PEAK PERIOD BUS PASSENGER TRIPS
TOTAL, FREEWAY PLUS HOV LANE VOLUMES
NORTH FREEWAY AND FREEWAY WITHOUT HOV LANE

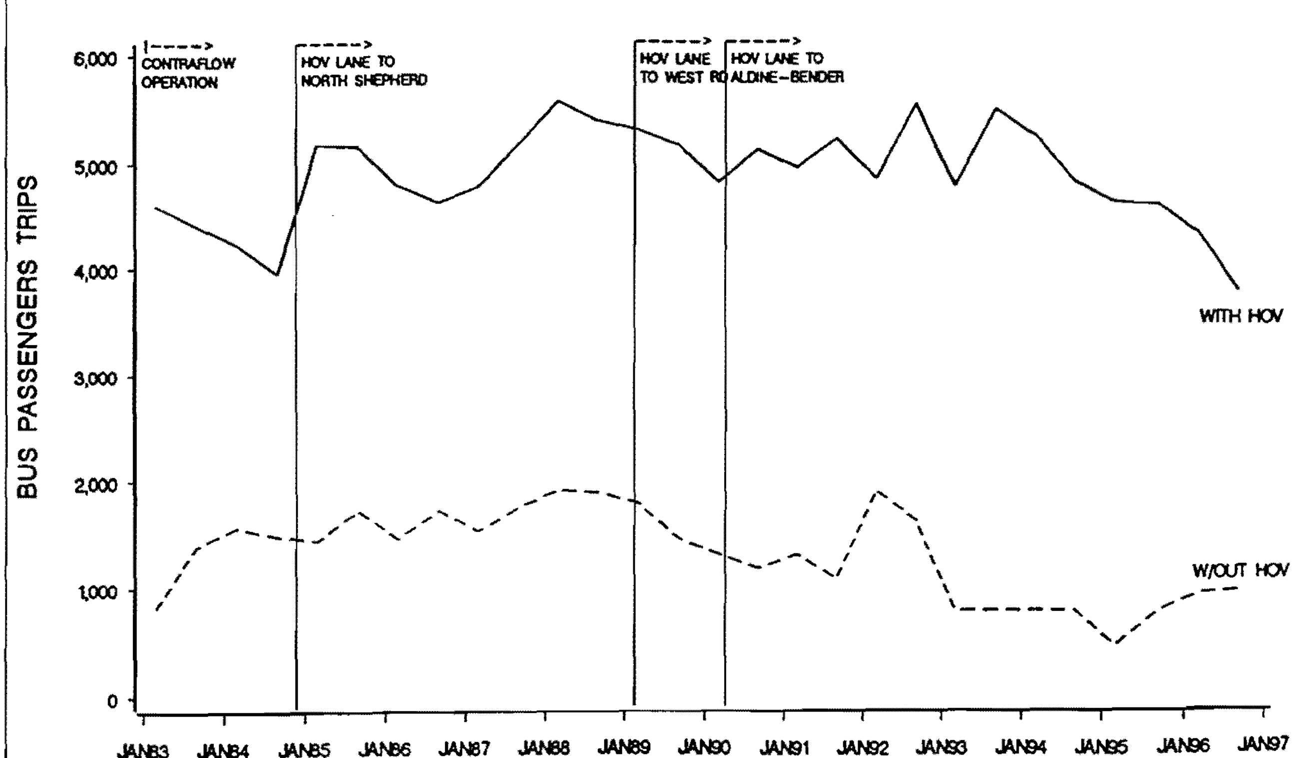


FIGURE B-19. NORTH FREEWAY (IH 45N) CORRIDOR PARK-AND-RIDE DEMAND

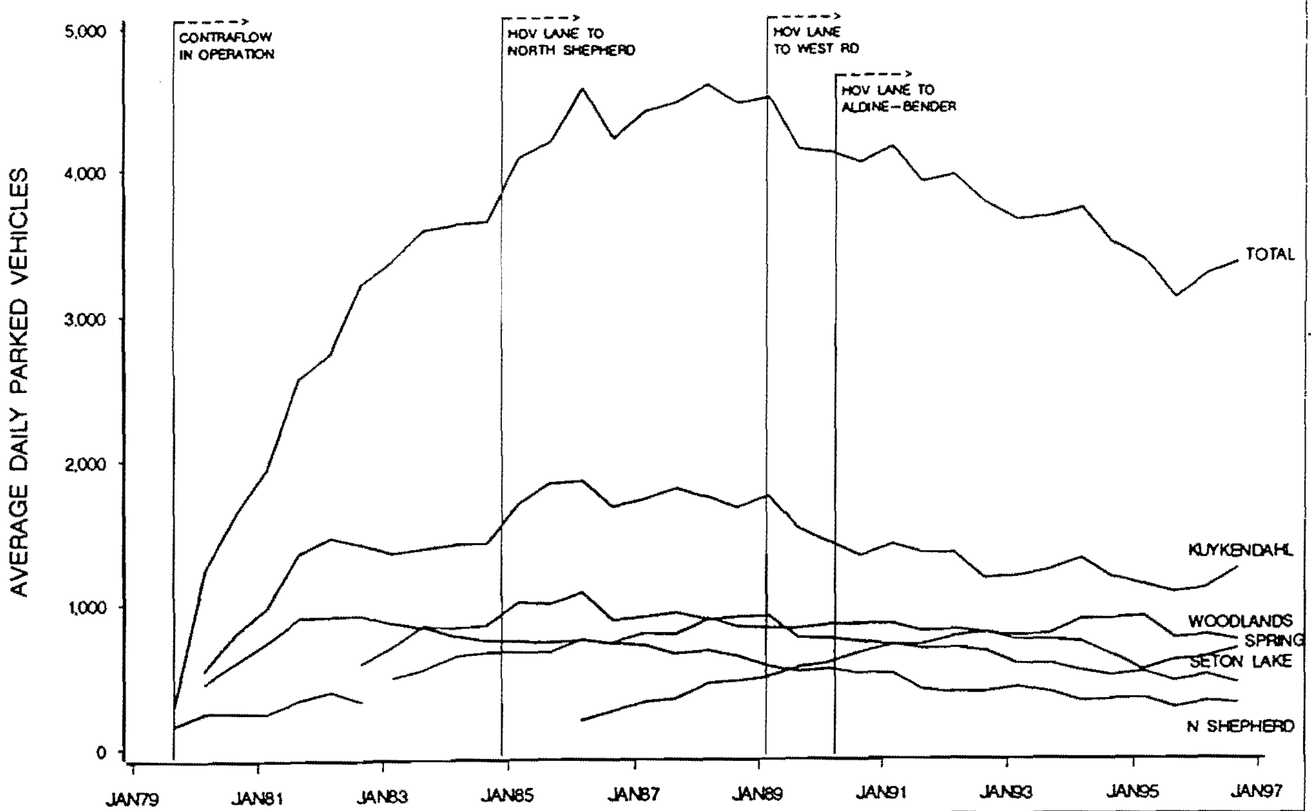
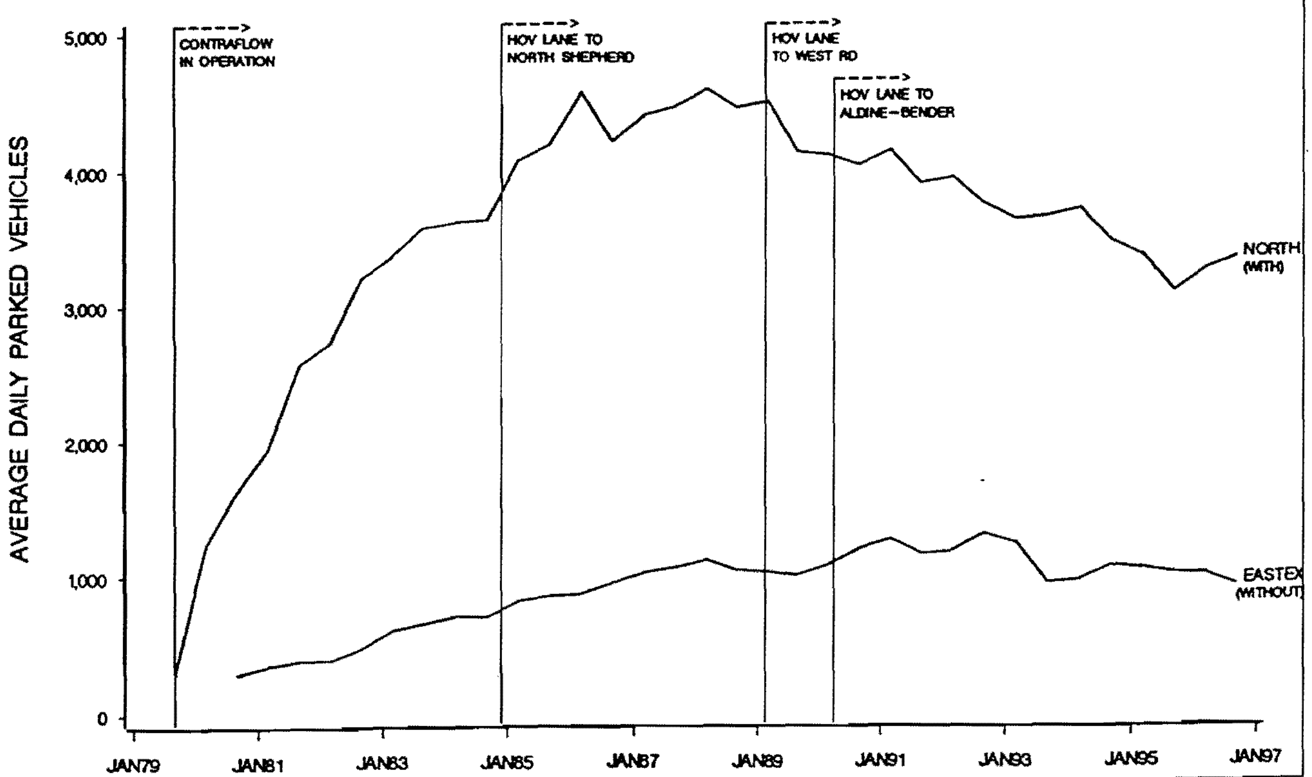


FIGURE B-20. AVERAGE DAILY VEHICLES PARKED AT PARK-AND-RIDE LOTS
NORTH FREEWAY AND FREEWAY WITHOUT HOV LANE



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, 1996

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 (12.1)	
HOV Lane Cost (millions)		110.7	
Person-Movement			
Peak-Hour (7-8 a.m.)	---	2,155	---
Peak-Period (6-9:30 a.m.)	---	4,033	---
Total Daily	---	7,922	---
Vehicle Volumes			
Peak-Hour	---	799	---
Peak-Period	---	1,530	---
Vehicle Occupancy, Peak Hour (persons/veh)	---	2.7	---
Accident Rate (Injury accidents/100 MVK [/100 MVM])[2]	---	5.5 (8.9)	---
Vehicle Breakdowns (VKT/Breakdown [VMT/Breakdown])	---	134,225 (73,130)	---
Violation Rate (6-9:30 a.m.)	---	3%	---
Travel Time (minutes)[1]			---
Peak-Hour	9.7[3]	5.5[4]	---
Peak-Period	8.1[3]	5.3[4]	
Peak-Hour Lane Efficiency (1000's)[5]	---	183 (114)	
Annual Discounted Benefits (millions)[6]	---	$ 30	
Annual Delay Savings (millions)[7]		$ 23	
Freeway Mainlane Data (see note)			
Person Movement	6,415	6,573	+2 %
Peak-Hour	17,845	19,594	+10%
Peak-Period (6-9:30 a.m.)			
Vehicle Volume	4,962	6,123	+23%
Peak-Hour	14,740	18,327	+24%
Peak-Period	1.29	1.07	-17%
Vehicle Occupancy, Peak-Hour (persons/veh)	18.5 (29.8)	12.3 (19.9)	-34%
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM])[2]			
Avg. Operating Speed[8] (kph [mph])	50 (31)	62 (39)	+24%
Peak-Hour	58 (36)	75 (46)	+29%
Peak-Period	106 (66)	102 (76)	-4%
Peak-Hour Lane Efficiency (1000's)[5]			

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 km (6.5 mi), 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 12/96.

[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]Based on average annual delay savings, reduced vehicle operating costs and reduced accident costs generated by MicroBENCOST over a 20-year life.

[7]Per MicroBENCOST, over a 20-year life.

[8]From Broadway to Almeda-Genoa a distance of 18.7 km (11.6 mi).

Table C-1. Summary of A.M. Peak-Direction Gulf Freeway and HOV Lane Data, 1996 (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	8,728	+36%
Peak-Period	17,845	23,627	+32%
Vehicle Volume			
Peak-Hour	4,962	6,922	+40%
Peak-Period	14,740	19,857	+35%
Vehicle Occupancy			
Peak-Hour	1.29	1.26	-2%
Peak-Period	1.21	1.19	-1%
2+ Carpool Volumes			
Peak-Hour	475	1,067	+124%
Peak-Period	1,304	2,571	+97%
Peak-Hour Lane Efficiency (1000's)[1]	106 (66)	118 (84)	+11%
Transit Data			
Bus Vehicle Trips			
Peak-Hour	23[2]	11	-52%
Peak-Period	40[2]	25	-38%
Bus Passenger Trips			
Peak-Hour	746[2]	490	-34%
Peak-Period	1,230[2]	860	-30%
Bus Occupancy (persons/bus)			
Peak-Hour	32.6[2]	44.6	+37%
Peak-Period	30.8[2]	34.4	+11%
Vehicles Parked in Corridor Park-and-Ride Lots	1,115	1,227	+10%
Bus Operating Speed (kph [mph])[3]			
Peak-Hour	50 (31)[4]	85 (53)[5]	+70%
Peak-Period	58 (36)[4]	89 (56)[5]	+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]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.
[2]Data collected at Monroe.
[3]From Broadway to Almeda-Genoa, a distance of 18.7 km (11.6 mi).
[4]Data pertain to operation in the freeway mainlanes.
[5]Data pertain to operation in the HOV lane.

Table C-2. Comparison of Measures of Effectiveness, Freeway with (Gulf I-45S) 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	1.26	-2%
Freeway w/o HOV lane	1.23	1.12	-9%
A.M. Peak Hour, 2+ Carpool Volume			
Freeway w/HOV lane	475	1,067	+125%
Freeway w/o HOV lane	600	573	-5%
Bus Passengers, Peak Period			
Freeway w/HOV lane	1,230	490	-60%
Freeway w/o HOV lane	1,188	941	-21%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	1,115	1,227	+10%
Freeway w/o HOV lane	1,236	965	-22%
Facility Per Lane Efficiency[3]			
Freeway w/HOV lane	106 (66)	118 (84)	+11%
Freeway w/o HOV lane	138 (86)	104 (64)	-25%

[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 km [6.5 mi]) 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 (1996 dollars) will be $136.2 million. Table C-3 provides a more detailed cost breakdown (including dates).

- Selected milestone dates are listed below. The capital cost table (Table C-4) shows other dates.

  - 5/16/88 CBD to Broadway opens (10.5 km [6.5 mi]).
  - 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 km (5.1 mi)--bringing the total operational HOV length to 18.7 km (11.6 mi).

- 4/4/94 Hours of operation revised.
- 1/17/95 Monroe Park-and-Ride opened.
- 6/14/96 Edgebrook Park-and-Ride closed.
- 6/17/96 Fuqua Park-and-Ride opened.
- 9/30/96 Hours of operation revised (5:00 a.m. - 11:00 a.m.; 2:00 p.m. - 8:00 p.m.).

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

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1996 Dollars
HOV Lane and Ramps			
Phase 1 Metro (1988)	$1.6	1.37	$2.2
Phase 2 Metro (1988)	0.4	1.37	0.6
Phase 1 SDHPT (1988)	14.0	1.37	19.2
Phase 2 SDHPT (1988)	6.4	1.37	8.8
Phase 3 (1995)	24.4	1.04	25.4
Miscellaneous (1995)	3.6	1.04	3.7
SUB-TOTAL	$50.4		$59.9
Per Kilometer (Mile)	$2.5 ($4.0)		$3.1 ($5.0)
Surveillance, Communication and Control (1988)	$3.8	1.37	$5.2
SUB-TOTAL	$3.8		$5.2
Per Kilometer (Mile)	$0.2 ($0.3)		$0.3 ($0.3)
Support Facilities			
Bay Area P/R (1984)	$3.7	1.67	$6.2
Edgebrook P/R (1981)	3.3	1.80	5.9
Eastwood Transit Center (1988)	5.0	1.37	6.9
Monroe P/R (1994)	9.1	1.08	9.8
Fuqua P/R (1995)	10.4	1.04	10.8
Fuqua Park/Pool (1995)	5.9	1.04	6.1
SUB-TOTAL	$37.4		$45.7
Per Kilometer (Mile)	$1.9 ($2.9)		$2.3 ($3.8)
TOTAL COST	$91.6		$110.8
COST PER KILOMETER (19.5 kilometers [12.1 miles])	$4.6 ($7.3)		$5.7 ($9.2)

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

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

Cost Component	Estimated Year of Completion	Estimated Cost ($Millions)
HOV Lane and Ramps		
Phase 3 Broadway to Almeda-Genoa	1996	$19.1
Almeda-Genoa Slip Ramp	1996	0.4
Hobby West Access Ramp	1996	0.5
Miscellaneous		3.6
SUB-TOTAL		$23.6
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		$25.5
COST PER KILOMETER (9.0 kilometers [5.6 miles])		$2.8 ($7.4)

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

PERSON MOVEMENT

- In 1996, the HOV lane served 7,922 person trips per day.
- A.M. peak hour, 2,155 persons/hour.
  - 490 (23 percent) by bus, 34 (2 percent) by vanpool, 1,629 (76 percent) by carpool, and two by motorcycle (Figure C-1).
  - Average HOV lane vehicle occupancy = 2.70 persons/vehicle.
- A.M. peak period, 4,033 persons.
  - 860 (21 percent) by bus, 101 (3 percent) by vanpool, 3,069 (76 percent) by carpool, and three by motorcycle (Figure C-2).

VEHICLE MOVEMENT

- A.M. Peak Hour, 799 vph
  - 11 (1 percent) buses, 5 (1 percent) vans, 781 (98 percent) carpools, and two by motorcycle (Figure C-3).

- A.M. Peak Period, 1,530 vehicles.
  - 25 (2 percent) buses, 19 (1 percent) vans, 1,483 (97 percent) carpools, and three by motorcycle (Figure C-4).

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 km (100 MVK) (29.8 accidents per 100 million vehicle mi [100 MVM]). The "after HOV lane" accident rate for the mainlanes is 5.5 accidents per 100 MVK (8.9 accidents per 100 MVM) and includes the period 5/88 to 12/96. Current accident files include only officer-reported accidents.

VEHICLE BREAKDOWN RATES

- As measured from September 1, 1988 through December, 1996, the following rate has been observed.

  - Weighted average: one breakdown per 134,225 VKT (83,130 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 183 (2,155 passengers x 85 kph) or 114 (2,155 passengers x 53 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane are experiencing a travel time savings of approximately four minutes during the peak hour (Table C-5, Figure C-5).

Table C-5. Travel Time Savings for Gulf Freeway HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1996)

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	
Northbound AM Travel Time Savings for Gulf HOV Lane								
Section from Almeda-Genoa to Broadway								
6:00	4.95	5.21	-0.26	170	2	30	202	-52.19
6:30	5.70	5.00.14	0.56	519	57	190	766	427.70
7:00	9.32	5.38	3.93	805	32	240	1,077	4,236.16
7:30	11.61	5.60	6.01	824	2	250	1,076	6,464.98
8:00	13.29	5.33	7.97	464	0	110	574	4,572.86
8:30	5.25	5.06	0.19	207	0	40	247	47.34
9:00	4.77	5.39	-0.63	80	8	0	88	-55.00
Peak Period Total				3,069	101	860	4,030	15,641.85
Northbound AM Travel Time Savings for Gulf HOV Lane								
Section from Broadway to Dowling								
6:00	6.42	7.19	-0.77	87	12	145	244	-188.89
6:30	6.68	6.90	-0.22	447	30	278	754	-169.71
7:00	6.87	7.70	-0.83	848	61	383	1,292	-1,076.48
7:30	9.13	7.81	1.33	1,072	2	400	1,500	1,987.83
8:00	9.73	7.11	2.62	697	12	230	938	2,455.12
8:30	6.56	6.98	-0.42	379	8	181	567	-240.97
9:00	6.52	7.02	-0.50	123	8	53	184	-92.13
Peak Period Total				3,652	158	1,669	5,480	2,674.77
Southbound PM Travel Time Savings for Gulf HOV Lane								
Section From Broadway to Dowling								
3:30	6.35	7.61	-1.26	186	9	76	271	-340.37
4:0	6.71	7.10	-0.39	444	21	118	583	-228.36
4:30	8.19	8.13	0.07	645	43	264	951	63.43
5:00	8.88	7.38	1.49	1,059	75	411	1,544	2,303.48
5:30	7.88	7.41	0.47	837	31	386	1,254	595.41
6:00	7.66	7.08	0.58	431	6	220	657	382.94
6:30	6.39	7.37	-0.97	218	8	65	291	-283.95
Peak Period Total				3,819	193	1,539	5,550	2,492.58

Table C-5. Travel Time Savings for Gulf HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1996)

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	
Southbound PM Travel Time Savings for Gulf HOV Lane								
Section from Almeda-Genoa to Broadway								
3:30	5.38	5.58	-0.19	131	0	40	171	-32.78
4:00	5.26	5.31	-0.05	183	5	40	228	-11.40
4:30	5.63	6.52	-0.89	351	24	100	475	-423.53
5:00	7.00	5.65	1.44	592	50	200	842	1,213.87
5:30	7.92	6.56	1.36	715	38	320	1,073	1,457.51
6:00	7.83	5.33	2.49	430	0	121	551	1,372.93
6:30	5.95	5.55	0.40	181	0	20	201	80.40
Peak Period Total				2,583	117	841	3,541	3,656.99

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 6,573.

- The a.m. peak-period, person volume was approximately 17,845 (Figure C-7). This volume has risen to 19,594.

VEHICLE VOLUME

- In the a.m. peak-hour, the vehicle volume was 4,962 vph prior to HOV lane implementation and is now 6,123 (Figure C-6).

- In the a.m. peak-period, the vehicle volume was 14,740 and is now 18,327 (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.

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 102 (1,643 passengers at 62) or 76 (1,643 at 39 mph).

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

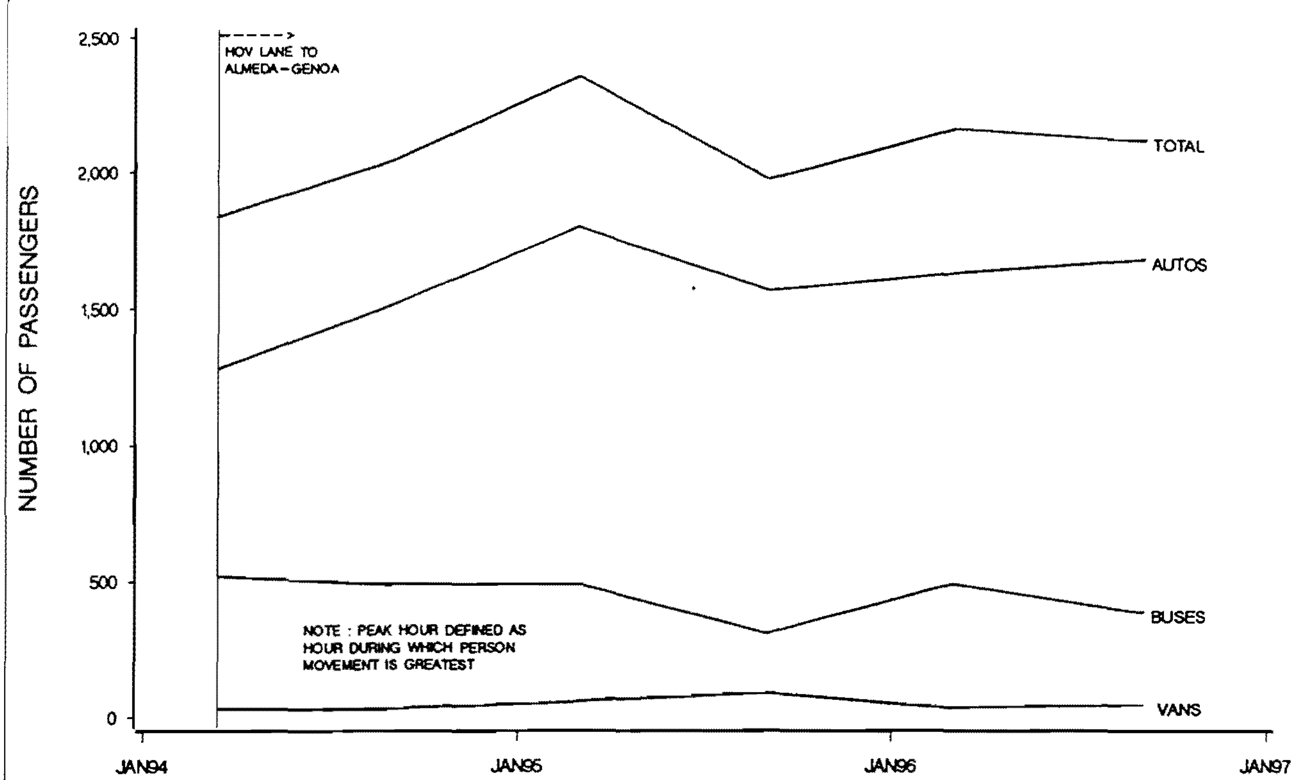
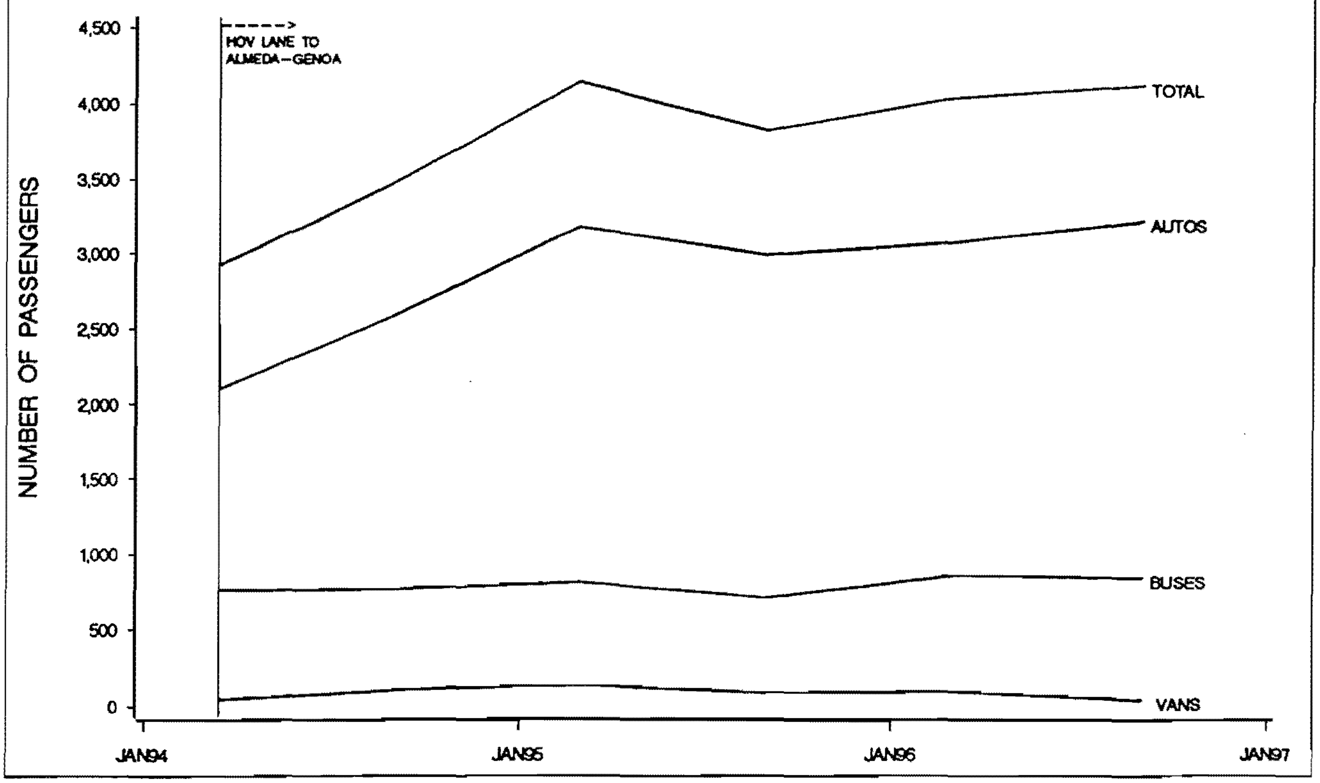


FIGURE C-2. GULF FREEWAY (IH 45S) HOV LANE
A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT



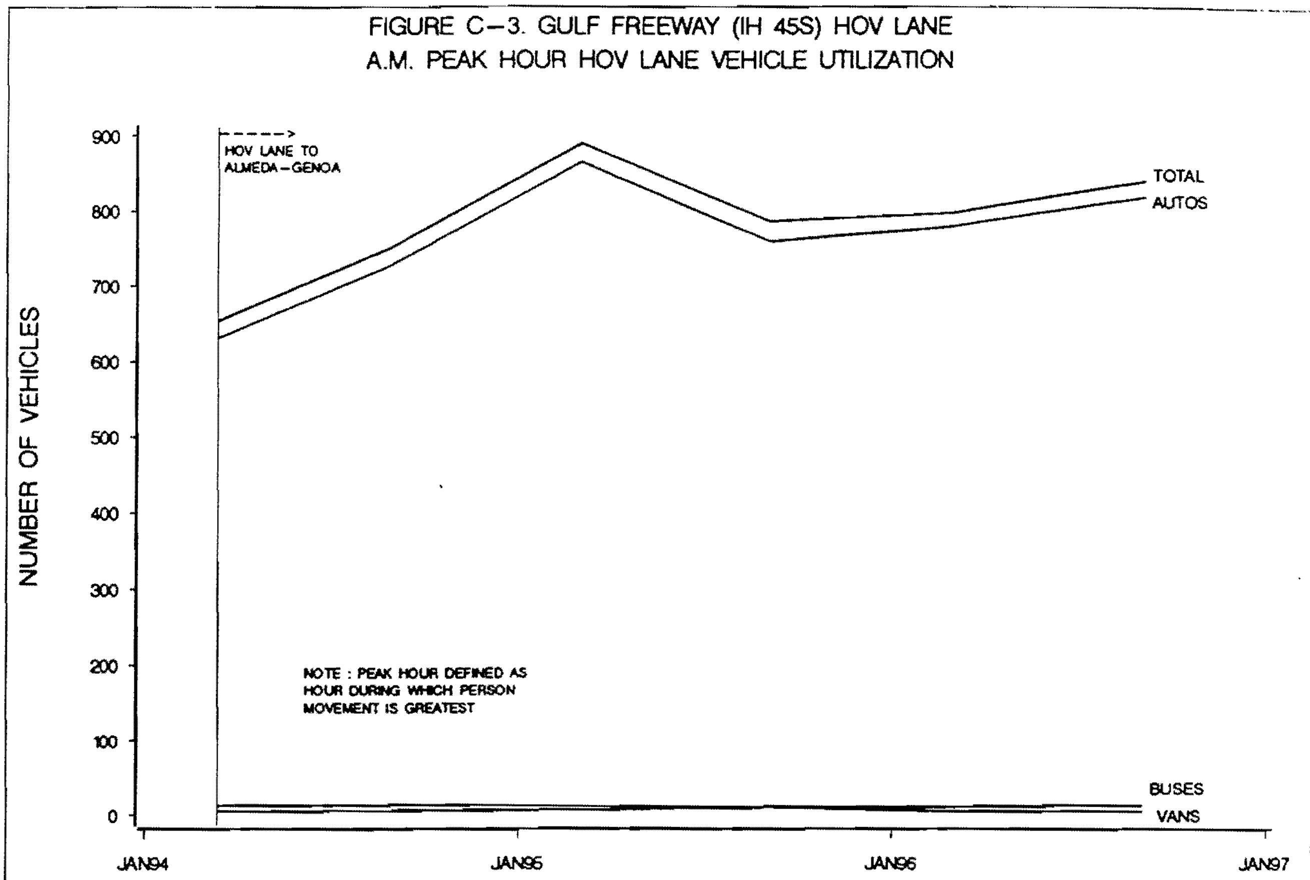


FIGURE C-3. GULF FREEWAY (IH 45S) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION
NUMBER OF VEHICLES
900
800
700
600
500
400
300
200
100
0
HOV LANE TO
ALMEDA-GENOA
TOTAL
AUTOS
NOTE : PEAK HOUR DEFINED AS
HOUR DURING WHICH PERSON
MOVEMENT IS GREATEST
BUSES
VANS
JAN94
JAN95
JAN96
JAN97

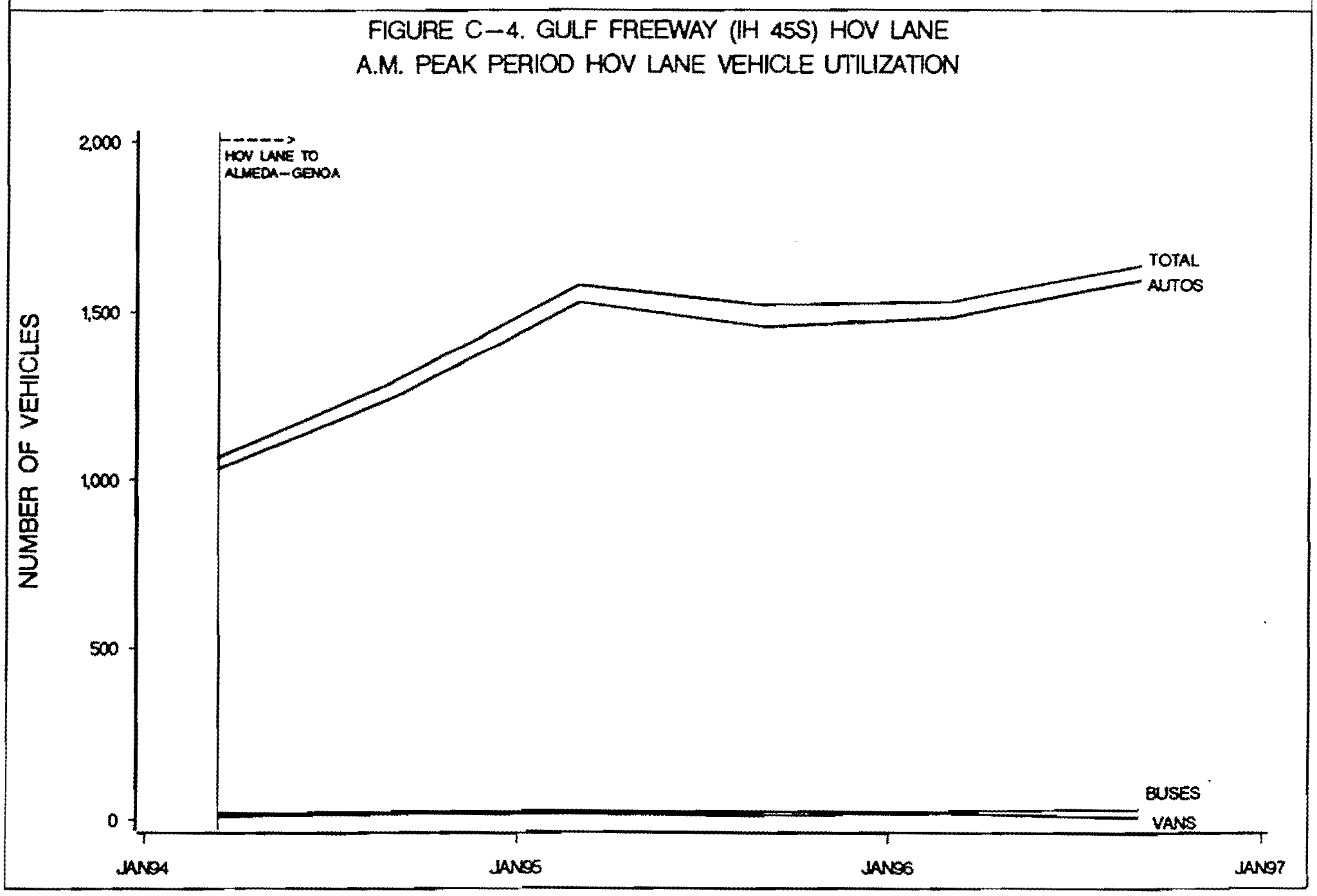


FIGURE C-4. GULF FREEWAY (IH 45S) HOV LANE
A.M. PEAK PERIOD HOV LANE VEHICLE UTILIZATION
NUMBER OF VEHICLES
2,000
1,500
1,000
500
0
HOV LANE TO
ALMEDA-GENOA
TOTAL
AUTOS
BUSES
VANS
JAN94
JAN95
JAN96
JAN97

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

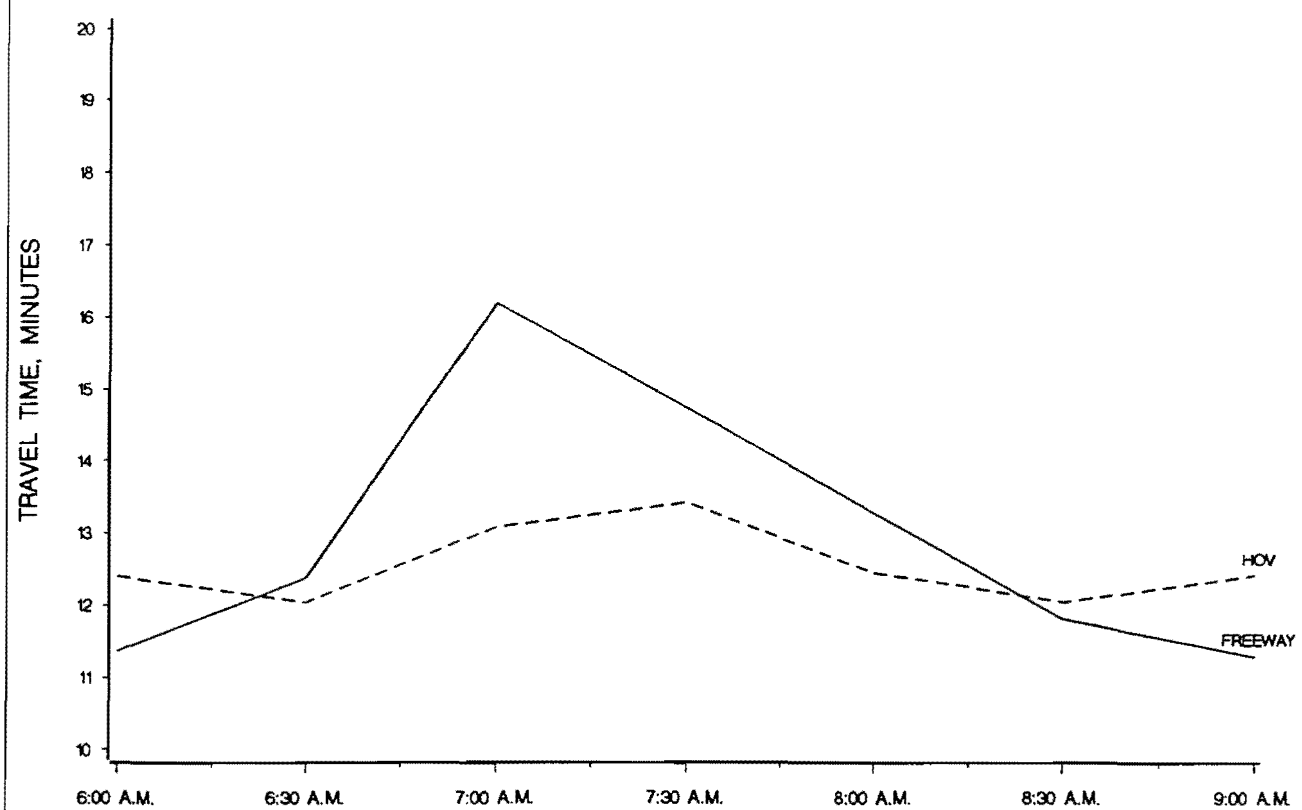


FIGURE C-6. GULF FREEWAY (IH 45S)
A.M. PEAK HOUR MAINLANE TRIPS

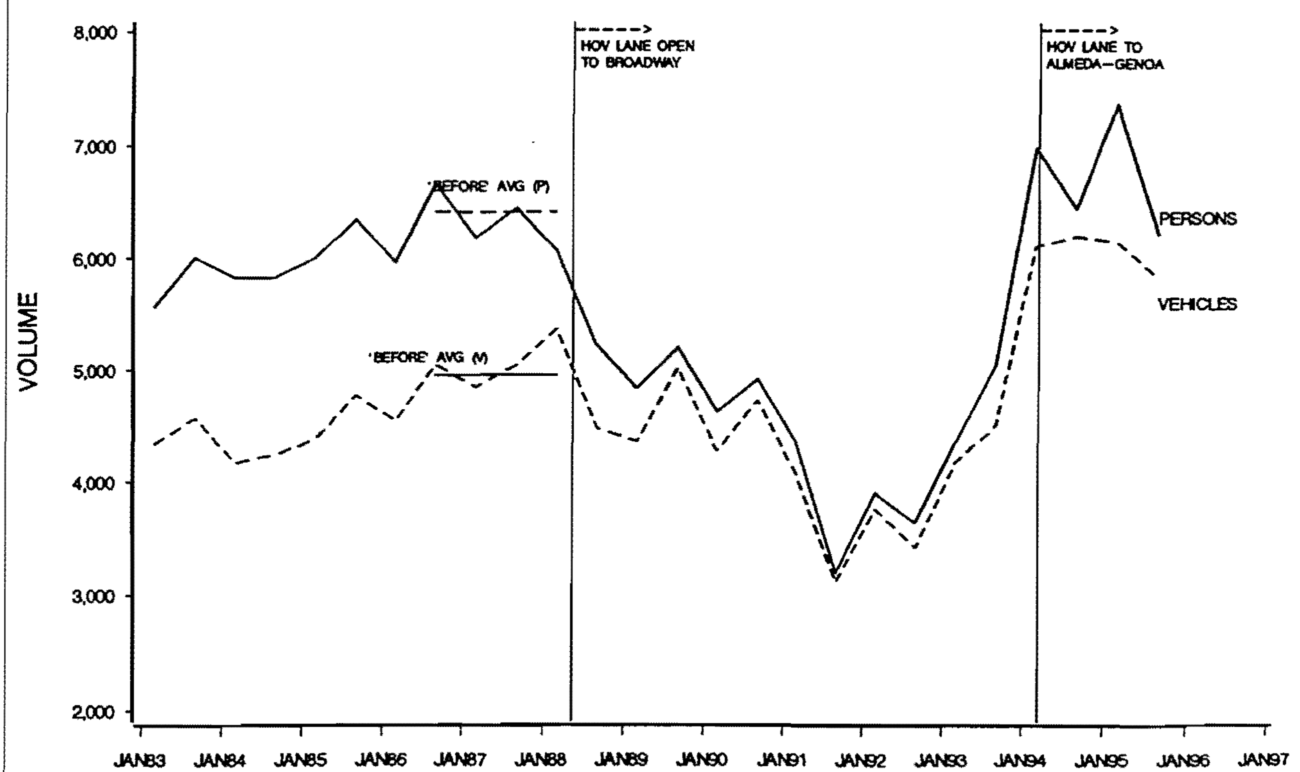


FIGURE C-7. GULF FREEWAY (IH 45S)
A.M. PEAK PERIOD MAINLANE TRIPS

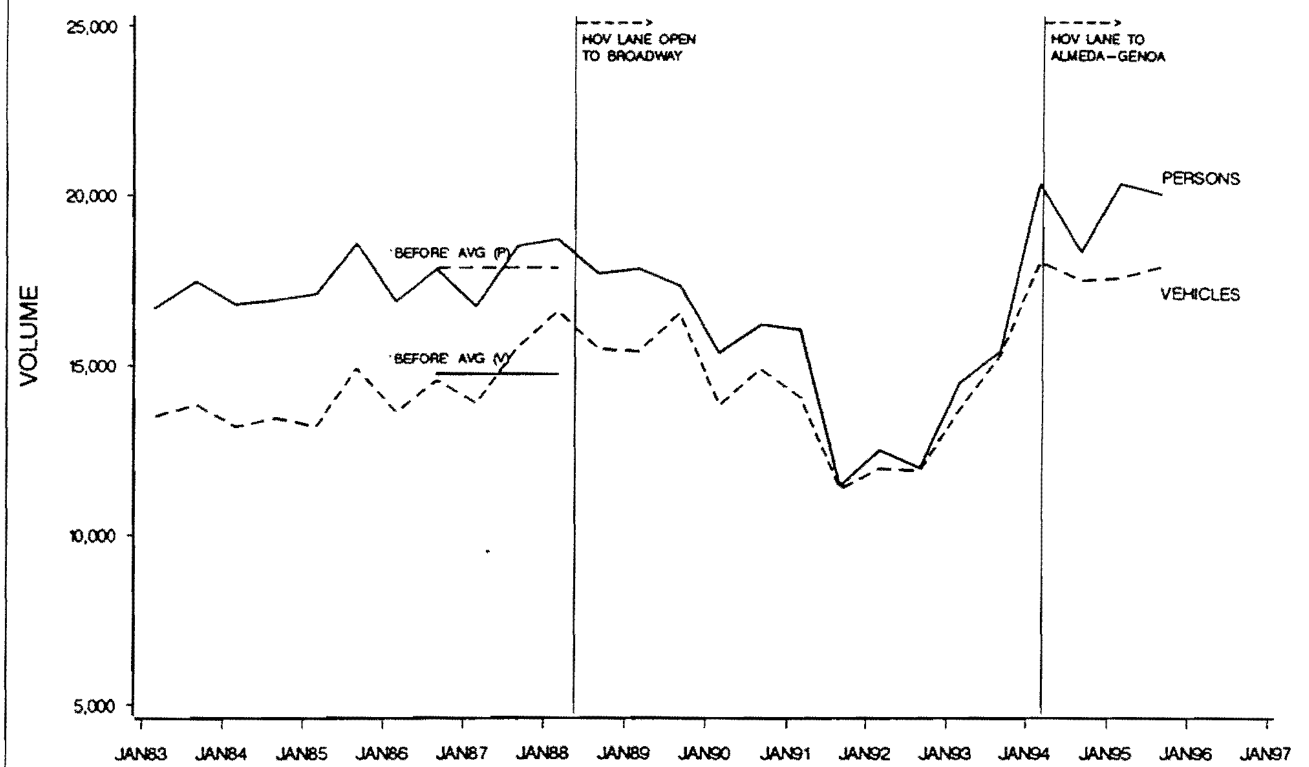
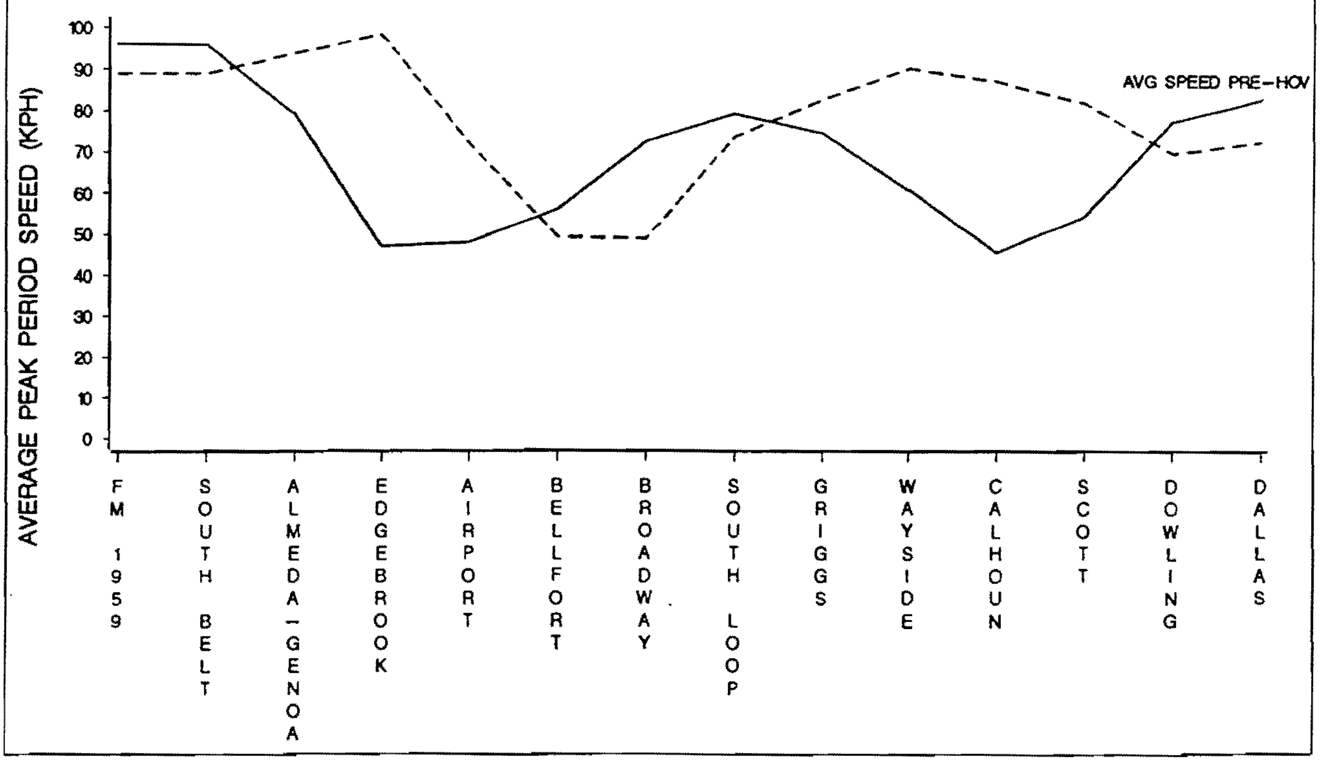


FIGURE C-8. GULF FREEWAY (IH 45S) MAINLANE TRAVEL TIME AND SPEED SURVEY
NORTHBOUND, FM 1959 TO DALLAS
A.M. PEAK PERIOD



COMBINED FREEWAY AND HOV LANE DATA

TOTAL PERSON MOVEMENT

- Percent by HOV lane, a.m. peak.
  - At Monroe, the HOV lane is carrying 25% of the total peak-hour person movement (Figure C-9). In the peak period, the HOV lane carries 17% 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 1.26 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 124 percent 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 1,067 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 11% 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 percent to a current level of 1,227 (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-9. GULF FREEWAY (IH 45S) MAINLANE AND HOV LANE
A.M. PEAK HOUR PERSON TRIPS

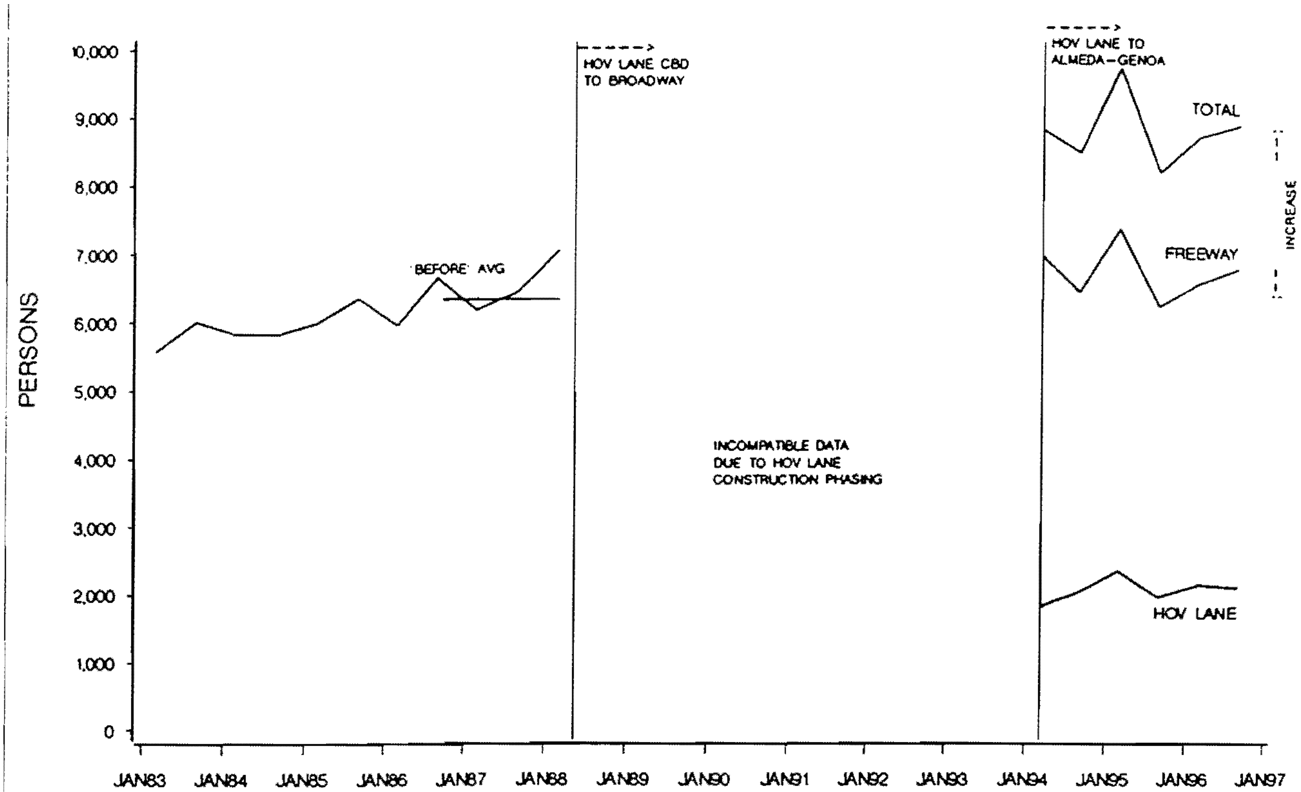


FIGURE C-10. GULF FREEWAY (IH 45S) MAINLANE AND HOV LANE
A.M. PEAK PERIOD PERSON TRIPS

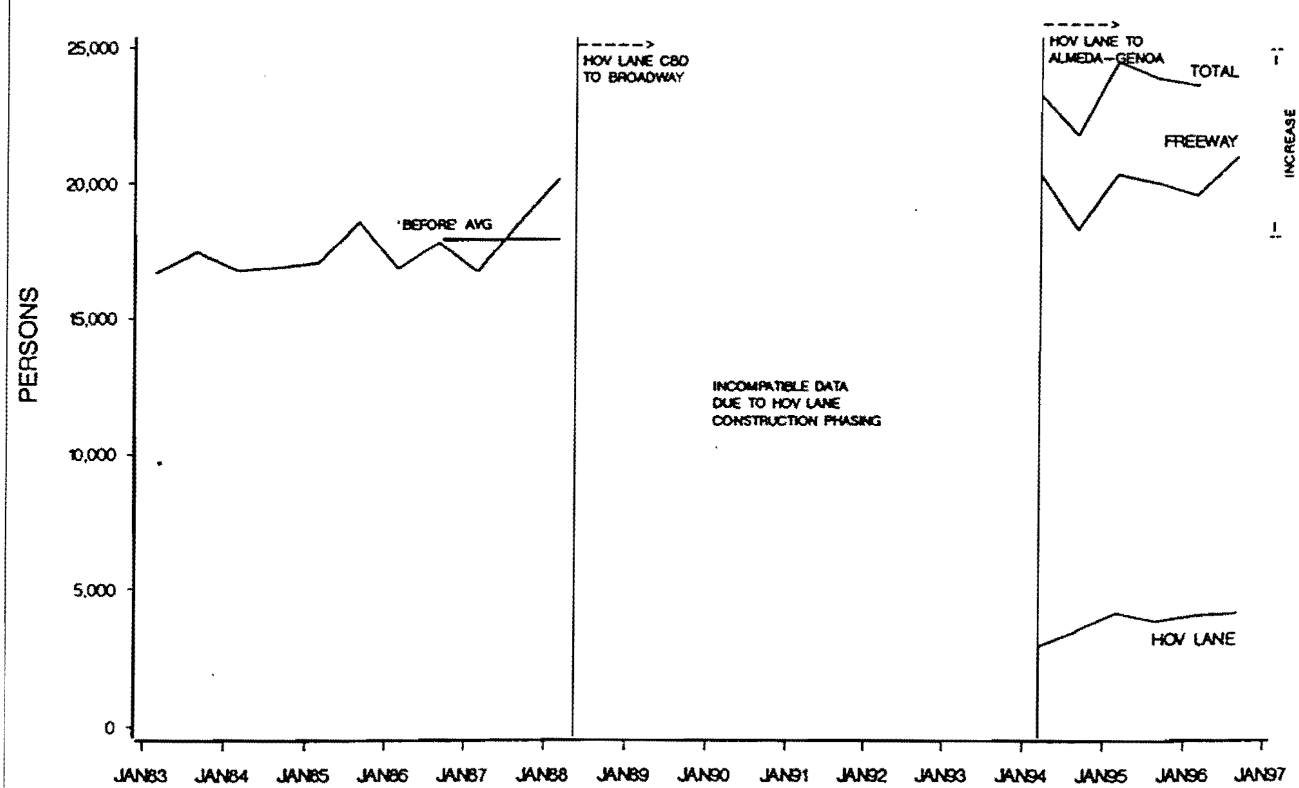


FIGURE C-11. GULF FREEWAY (IH 45S) MAINLANE AND HOV LANE
A.M. PEAK HOUR AVERAGE OCCUPANCY

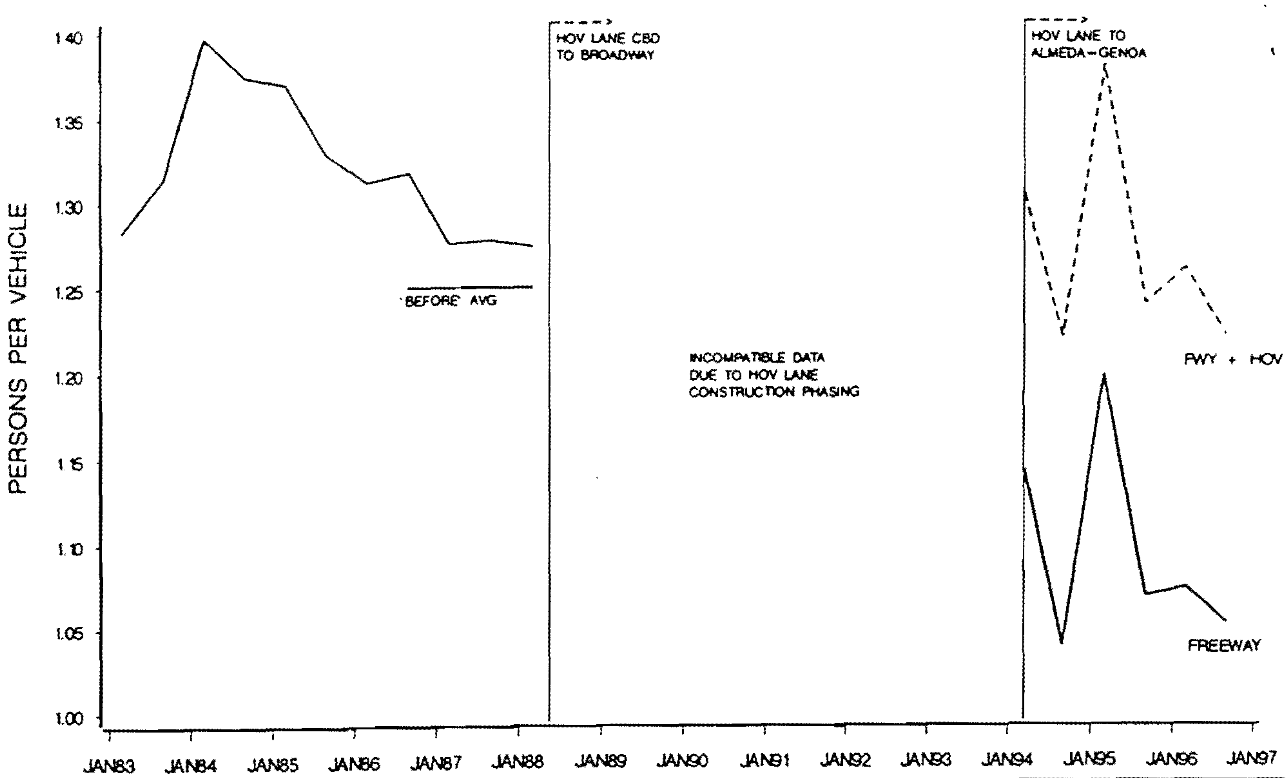


FIGURE C-12. GULF FREEWAY (IH 45S) MAINLANE AND HOV LANE
A.M. PEAK PERIOD AVERAGE OCCUPANCY

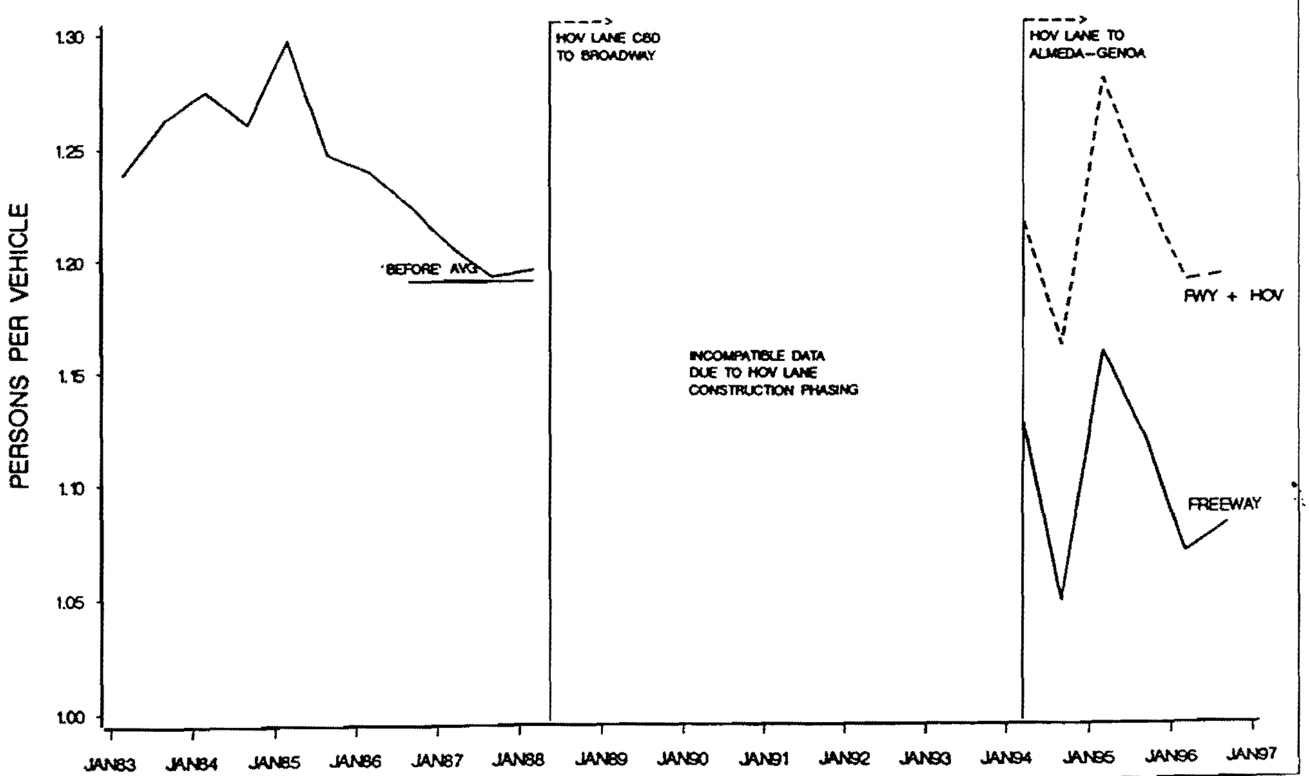


FIGURE C-13. A.M. PEAK HOUR AVERAGE OCCUPANCY
GULF FREEWAY AND FREEWAY WITHOUT HOV LANE

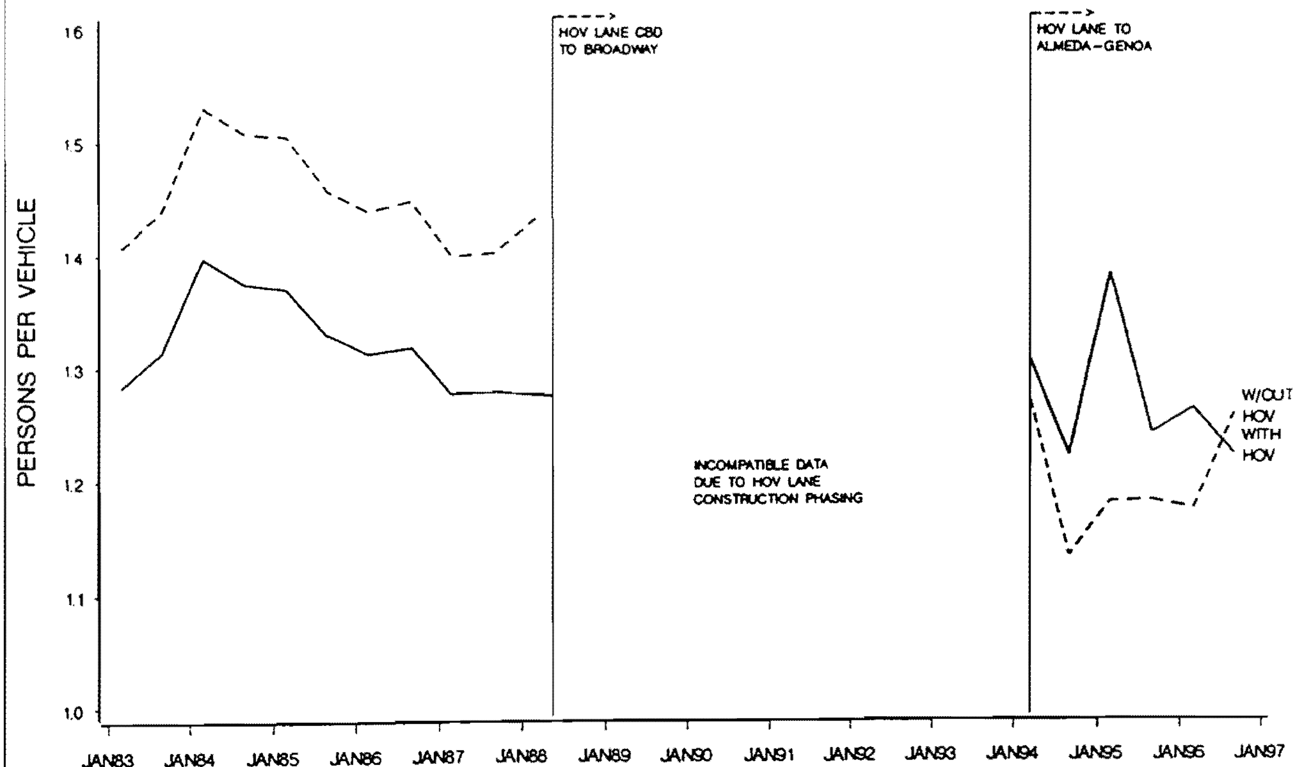


FIGURE C-14. GULF FREEWAY (IH 45S) MAINLANE AND HOV LANE
A.M. PEAK HOUR 2+ CARPOOL UTILIZATION

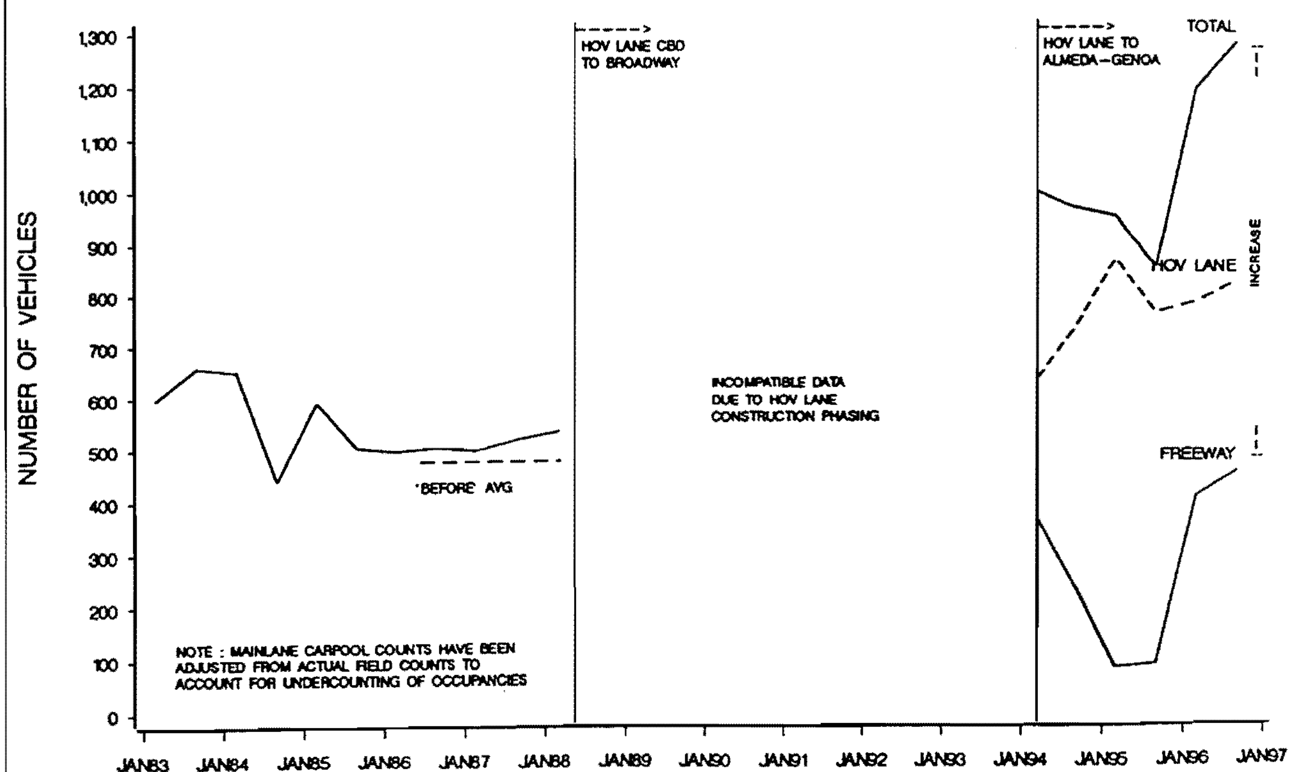


FIGURE C-15. A.M. PEAK HOUR FREEWAY PER LANE EFFICIENCY
GULF FREEWAY AND FREEWAY WITHOUT HOV LANE

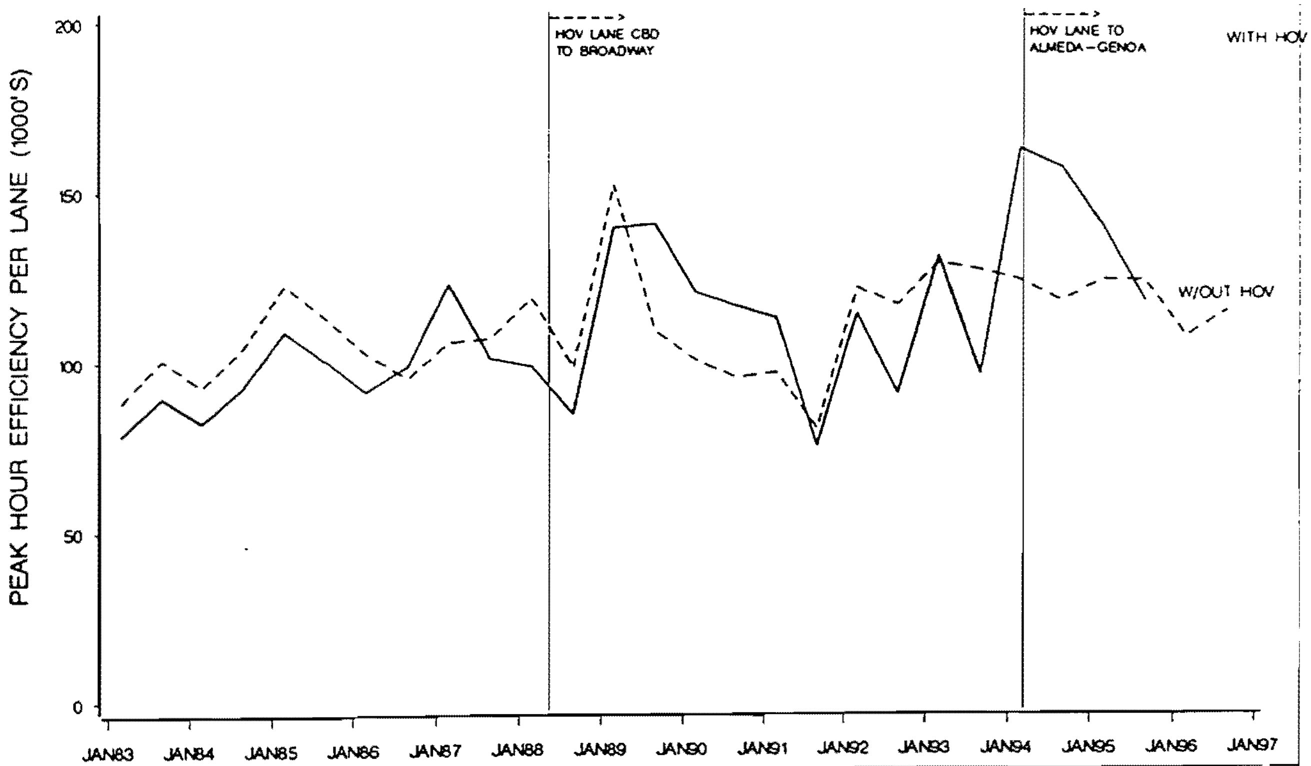


FIGURE C-16. GULF FREEWAY (IH 45S) MAINLANE AND HOV LANE
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS

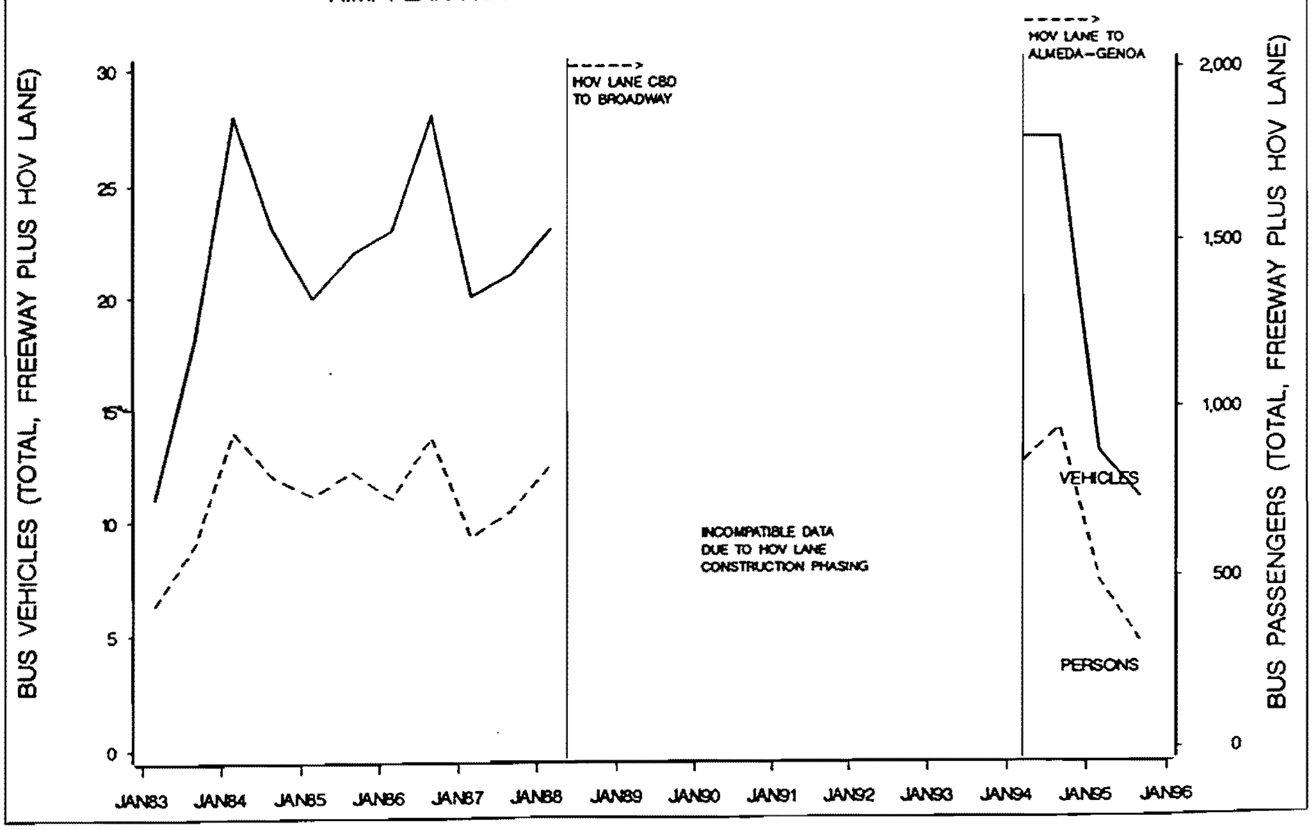


FIGURE C-17. GULF FREEWAY (IH 45S) MAINLANE AND HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS

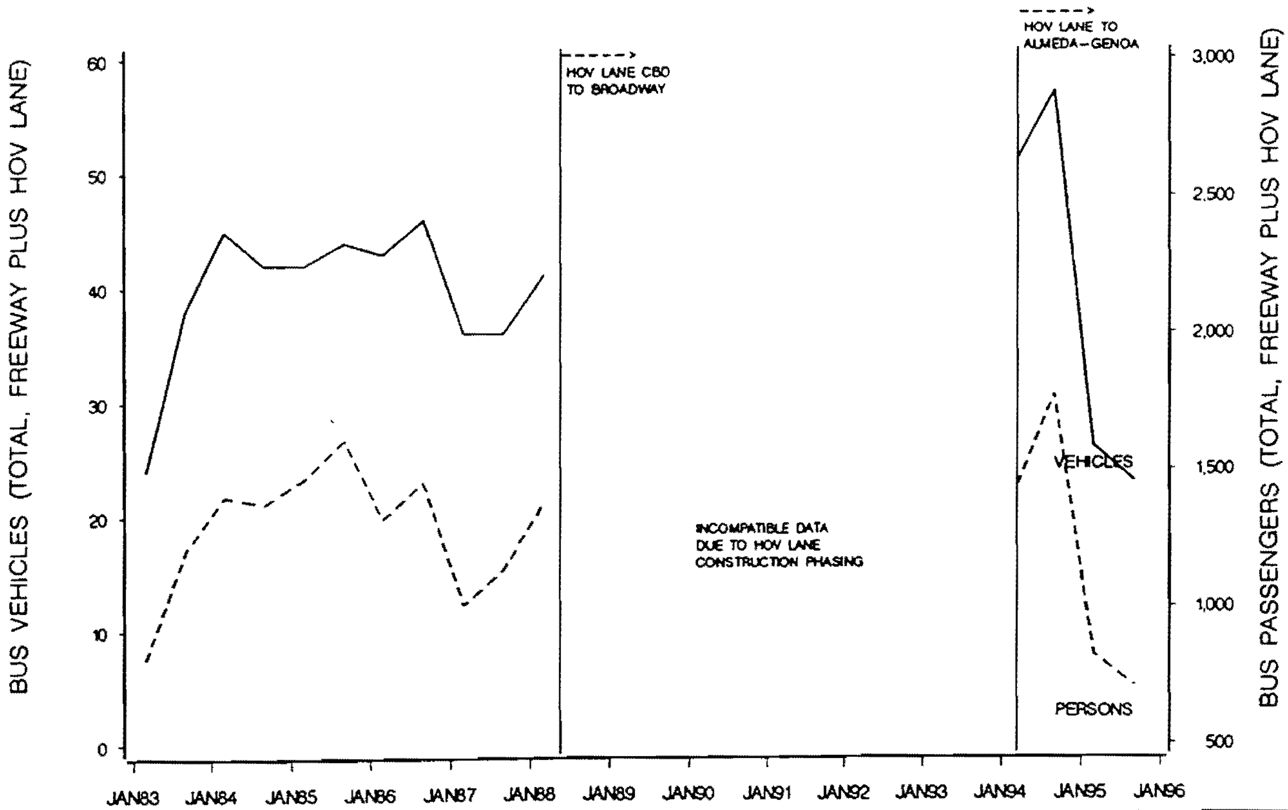


FIGURE C-18. A.M. PEAK PERIOD BUS PASSENGER TRIPS
TOTAL, FREEWAY PLUS HOV LANE VOLUMES
GULF FREEWAY AND FREEWAY WITHOUT HOV LANE

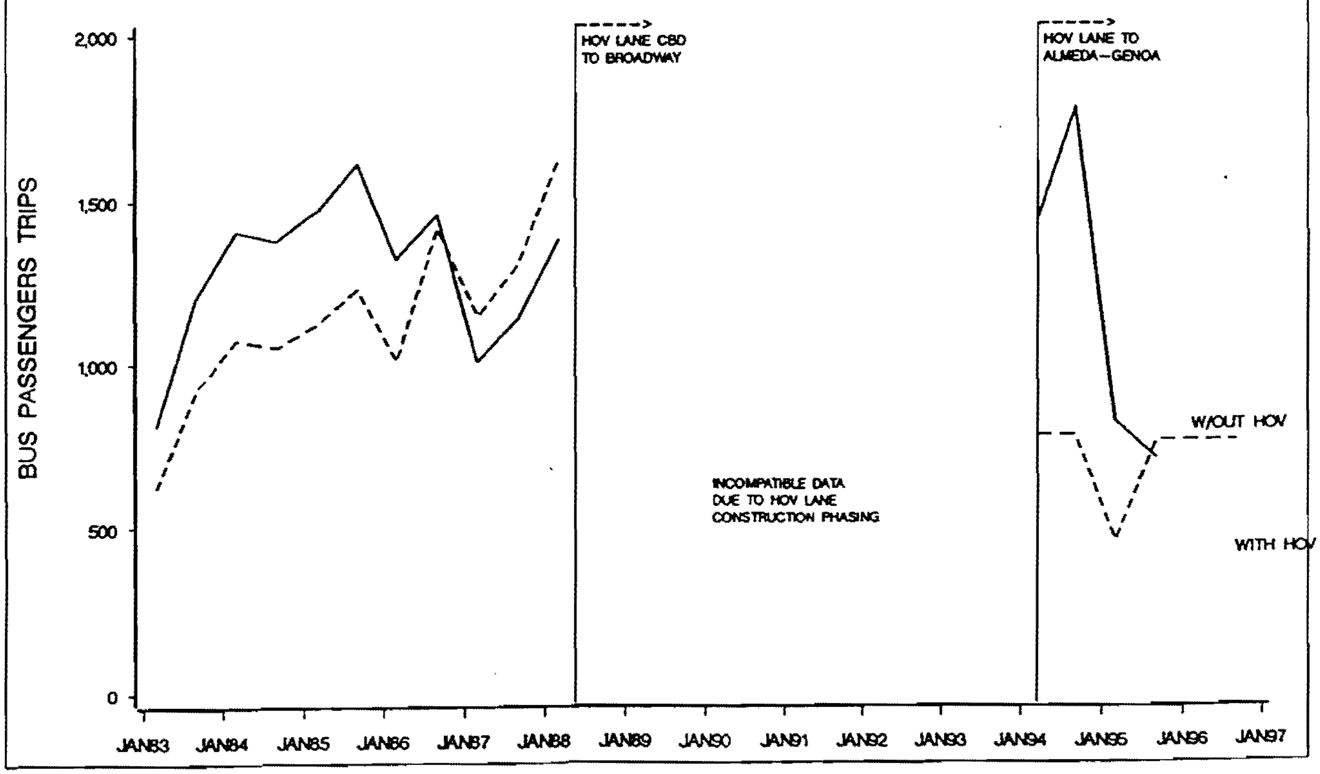


FIGURE C-19. GULF FREEWAY (IH 45S) CORRIDOR PARK-AND-RIDE DEMAND

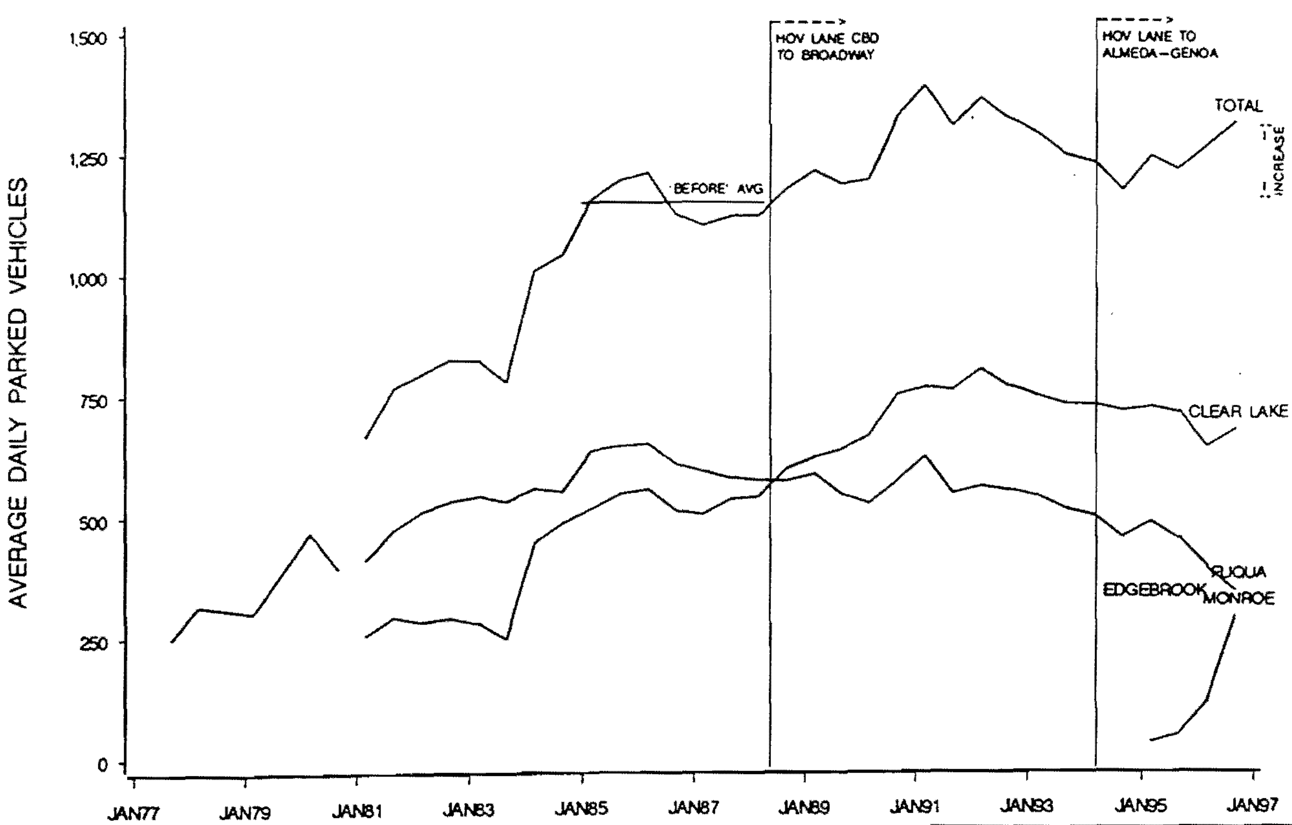
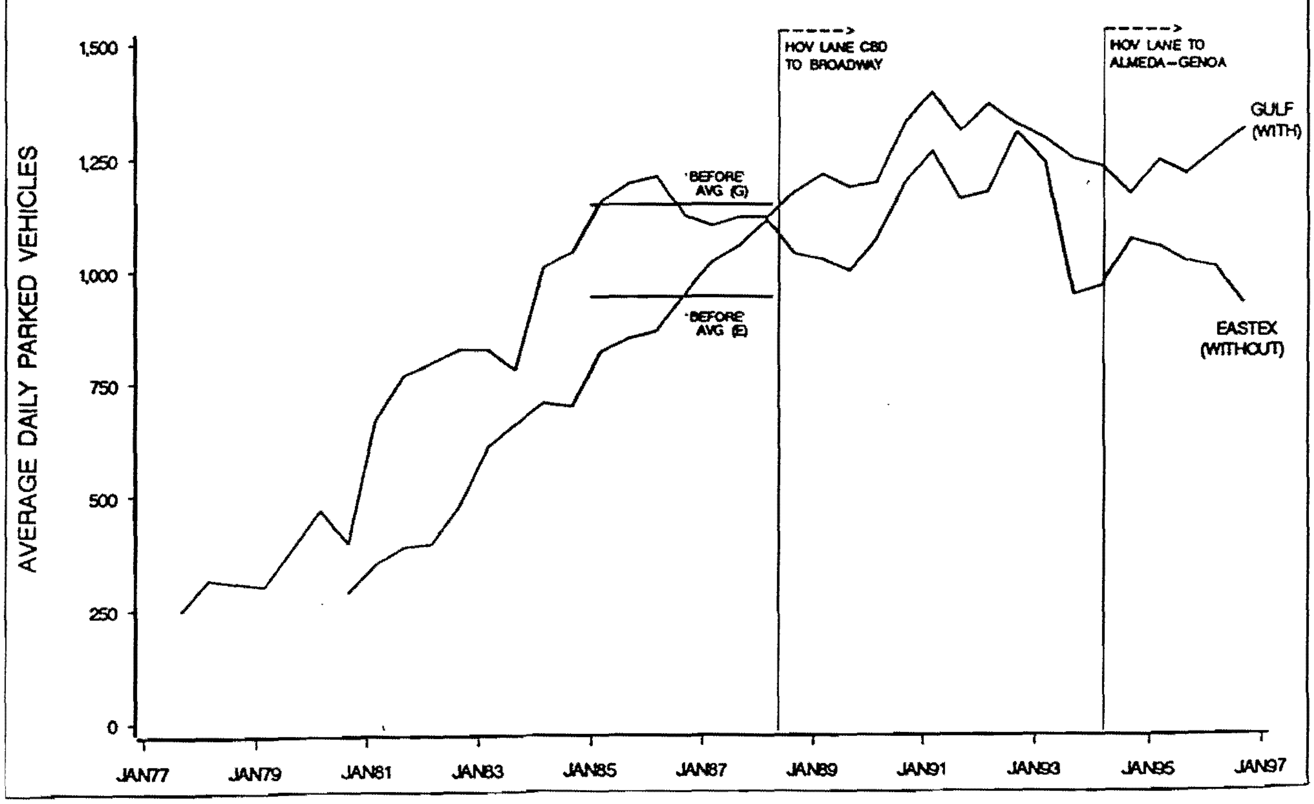


FIGURE C-20. AVERAGE DAILY VEHICLES PARKED AT PARK-AND-RIDE LOTS GULF FREEWAY AND FREEWAY WITHOUT HOV LANE



APPENDIX D

NORTHWEST FREEWAY AND HOV LANE DATA

NORTHWEST FREEWAY (U.S. 290) AND HOV LANE, HOUSTON

Table D-1. Summary of A.M. Peak-Direction Northwest Freeway and HOV Lane Data, 1996

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)		$151.4	
Person-Movement			
Peak-Hour (7-8 a.m.)	---	3,717	---
Peak-Period (6-9:30 a.m.)	---	6,852	---
Total Daily	---	13,644	---
Vehicle Volumes			
Peak-Hour	---	1,429	---
Peak-Period	---	2,703	---
Travel Time (minutes)	---	9.4	---
Peak-Hour	---	7.8	---
Peak-Period	---	2.6	---
Vehicle Occupancy, Peak Hour (persons/veh)	---	7.8 (12.6)	---
Accident Rate (i.e., Injury accidents/100 MVK [/MVM])[1]	---	138,919 (86,130)	---
Vehicle Breakdowns (VKT/Breakdown [VMT/Breakdown])	---		---
Violation Rate (6-9:30 a.m.)		5%	
Peak Hour Lane Efficiency (1000's)[2]		293 (182)	
Annual Discounted Benefits (millions)[3]		$62	
Annual Dealy Savings (millions)[4]		$46	
Freeway Mainlane Data (see note)			
Person Movement	6,140	5,821	-5%
Peak-Hour	17,450	17,110	-2%
Peak-Period (6-9:30 a.m.)			
Vehicle Volume	5,370	5,560	+4%
Peak-Hour	15,295	16,026	+5%
Peak-Period	1.14	1.05	-8%
Vehicle Occupancy, Peak Hour (persons/veh)	7.3 (11.7)	6.7 (10.9)	-8%
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM])[1]			
Avg. Operating Speed[5] (kph [mph])	45 (28)	42 (26)	-7%
Peak-Hour	64 (40)	64 (40)	+2%
Peak-Period	100 (62)	81 (50)	-19%
Peak-Hour Lane Efficiency (1000's)[2]			

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 km (7.7 mi). 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 12/96. 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 average annual delay savings, reduced vehicle operating costs and reduced accident costs generated by MicroBENCOST over a 20-year life.

[4]Per MicroBENCOST over a 20-year life.

[5]The distance from Little York to IH 610 is 12.4 km (7.7 mi). The remaining 2.9 km (1.8 mi) of HOV lane is inside IH 610.

Table D-1. Summary of A.M. Peak-Direction Northwest Freeway and HOV Lane Data, December 1996 (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	9,538	+55%
Peak-Period	17,450	23,962	+37%
Vehicle Volume			
Peak-Hour	5,370	6,989	+30%
Peak-Period	15,295	18,729	@23%
Vehicle Occupancy			
Peak-Hour	1.14	1.36	+19%
Peak-Period	1.14	1.28	+12%
2+ Carpool Volumes			
Peak-Hour	490	1,337	+173%
Peak-Period	1,365	2,961	+117%
Peak-Hour Lane Efficiency (1000's)[4]	100 (62)	134 (83)	+34%
Transit Data			
Bus Vehicle Trips			
Peak-Hour	7	19	+171%
Peak-Period	17	37	+118%
Bus Passenger Trips			
Peak-Hour	270	850	+251%
Peak-Period	605	1,545	+155%
Bus Occupancy (persons/bus)			
Peak-Hour	39	44.7	+15%
Peak-Period	36	41.8	+16%
Vehicles Parked in Corridor Park-and-Ride Lots	430	1,542	+259%
Bus Operating Speed (kph [mph])			
Peak-Hour	47 (29)[2]	79(49)[1]	+68%
Peak-Period	79 (49)[2]	95(59)[1]	+20%

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 km (7.7 mi). The remaining 2.9 km (1.8 mi) 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	1.36	+19%
Freeway w/o HOV lane	1.23	1.12	-9%
A.M. Peak Hour, 2+ Carpool Volume Change			
Freeway w/HOV lane	490	1,337	+173%
Freeway w/o HOV lane	600	573	-5%
Bus Passengers, Peak Period			
Freeway w/HOV lane	605	1,545	+155%
Freeway w/o HOV lane	1,188	941	-21%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	430	1,542	+257%
Freeway w/o HOV lane	1,236	965	-22%
Facility Per Lane Efficiency[2]			
Freeway w/HOV lane	100 (62)	134 (83)	+34%
Freeway w/o HOV lane	138 (86)	104 (64)	-25%

[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 to 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 km [9.5 mi]) of the HOV lane opened August 29, 1988.
- The HOV lane is now complete with 21.7 km (13.5 mi) in operation.
- The capital cost (including all support facilities) for the completed facility in 1996 dollars was $151.4 million.
- Selected milestone dates are listed below. The capital cost table (Table D-3) shows other dates.
  - 8/29/88 Northwest Transit Center to Little York opens (15.3 km [9.5 mi]).
  - 2/6/90 HOV extended to FM 1960 (21.7 km [13.5 mi]).
  - 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).

- 3/14/94 Hours of operation revised.
- 4/4/94 Hours of operation revised.
- 9/30/96 Hours of operation revised (5:00 a.m. - 11:00 a.m.; 2:00 p.m. - 8:00 p.m.).

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

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1996 Dollars
HOV Lane and Ramps			
Phase I	$54.7	1.27	$69.5
FM 1960 to FM 529 (1990)	3.2	1.27	4.1
FM 529 to Little York (1990)	2.4	1.27	3.1
Phase 2A, N.W. Station Ramp (1990)	3.4	1.27	4.3
Phase 2B, W. Little York Ramp (1988)	1.2	1.37	1.6
Miscellaneous	0.4	1.27	0.5
SUB-TOTAL	$65.3		$83.1
Per Kilometer (Mile)	$3.0 ($4.8)		$3.8 ($6.2)
Surveillance, Communication & Control (1990)	$2.9	1.27	$3.7
SUB-TOTAL	$2.9		$3.7
Per Kilometer (Mile)	$0.1 ($0.2)		$0.2 ($0.3)
Support Facilities			
W. Little York P/R (1988)	$6.9	1.37	$9.5
Pinemont P/R (1989)	9.4	1.37	12.9
Northwest Transit Center (1990)	21.3	1.27	27.1
N.W. Station P/R (1984)	4.0	1.60	7.2
N.W. Station P/R Modification (1990)	1.5	1.27	1.9
N.W. Station P/R 2nd Expansion (1993)	5.9	1.12	6.6
SUB-TOTAL	$49.0		$64.6
Per Kilometer (Mile)	$2.3 ($3.6)		$3.0 ($4.8)
TOTAL COST	$117.2		$151.4
COST PER KILOMETER (21.7 kilometers [13.5 miles])	$5.4 ($8.7)		$7.0 ($11.2)

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

PERSON MOVEMENT

- In 1996, 13,644 person trips per day were served on the HOV lane.

- A.M. peak hour, 3,717 persons/hour.
  - 850 (23 percent) by bus, 52 (1 percent) by vanpool, 2,809 (76 percent) by carpool, and seven by motorcycle (Figure D-1).
  - Average HOV lane vehicle occupancy = 2.6 persons/vehicle.

- A.M. peak period, 6,852 persons.

  - 1,545 (23 percent) by bus, 84 (1 percent) by vanpool, 5,204 (76 percent) by carpool, and 20 by motorcycle (Figure D-2).

VEHICLE MOVEMENT

- A.M. peak hour, 1,429 vph
  - 19 (1 percent) buses, 11 (1 percent) vans, 1,393 (98 percent) carpools, and six by motorcycle (Figure D-3).

- A.M. peak period, 2,703 vehicles.
  - 37 (1 percent) buses, 16 (1 percent) vans, 2,625 (97 percent) carpools, and 22 by motorcycle (Figure D-4).

ACCIDENT RATE

- For the period 8/88 through 12/96, the HOV lane accident rate was 7.8 accidents per 100 million vehicle kilometers (12.6 accidents per 100 million vehicle miles).

VEHICLE BREAKDOWN RATES

- As measured from September 1, 1988 through December 1996, the following rate has been observed:

  - The weighted average for all vehicle types is one breakdown per 138,919 VKT (86,130 VMT).

VIOLATION RATE

- The observed violation rate (vehicles on the HOV lane not eligible to use the HOV lane) is approximately 5.4 percent.

PEAK-HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is used as a measure of the efficiency of a lane. For the HOV lane, this value (expressed in 1000's) is approximately 293 (3,717 passengers x 79 kph) or 182 (3,717 passengers x 49 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane experience an average travel time savings of 22 minutes in the a.m. peak hour (Table D-5, Figure D-5).

Table D-4. Travel Time Savings for Northwest HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1996)

Time of Day	Measured Travel Time: Freeway (min)	HOV (min)	Savings (min)	HOV Lane Person Trips: Carpool	Vanpool	Bus	Total	Travel Time Saved (Person-Minutes)
Southbound A.M. Travel Time Savings for Northwest HOV Lane								
Section from Eldridge to Senate								
6:00	2.76	2.86	-0.10	251	5	70	326	-32.58
6:30	3.56	3.20	0.36	789	36	370	1,195	428.17
7:00	3.36	3.00	0.36	986	8	105	1,099	393.83
7:30	2.93	3.00	-0.07	1,094	0	195	1,289	-85.91
8:00	2.77	2.78	-0.02	705	0	305	1,010	-16.87
8:30	2.68	3.28	-0.61	157	0	185	342	-208.06
9:00	2.75	3.14	-0.39	54	0	45	99	-38.77
Peak Period Total				4,036	49	1,275	5,360	439.80
Section From Senate to S.P. Railroad								
6:00	11.70	14.02	-2.32	149	8	119	276	-639.59
6:30	24.04	15.44	8.60	713	45	188	1,045	8,987.00
7:00	30.58	15.86	14.73	1,317	46	460	1,824	26,851.13
7:30	29.83	17.26	12.58	1,483	10	432	1,925	24,201.64
8:00	27.99	14.35	13.64	833	3	221	1,057	14,422.63
8:30	23.88	14.31	9.58	452	0	113	564	5,402.69
9:00	18.86	14.33	4.53	247	0	95	342	1,548.68
Peak Period Total				5,193	113	1,727	7,033	80,774.19
Northbound P.M. Travel Time Savings for Northwest HOV Lane								
Section from Senate to Eldridge								
3:30	2.88	2.81	0.07	104	0	15	119	8.92
4:00	2.90	2.77	0.13	281	2	46	329	43.86
4:30	2.87	2.68	0.10	576	27	250	853	163.52
5:00	3.15	2.91	0.24	786	74	61	921	222.61
5:30	2.87	2.70	0.17	893	10	416	1,319	219.88
6:00	2.82	2.68	0.13	481	8	200	689	91.88
6:30	2.90	2.71	0.19	255	0	135	390	74.74
Peak Period Total				3,376	121	1,123	4,620	825.40

Table D-4. Travel Time Savings for Northwest HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1996)

Northbound P.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	12.55	15.03	-2.47	147	11	78	236	-582.86
4:00	13.56	13.30	0.26	346	11	178	535	138.21
4:30	19.40	14.83	4.58	623	51	295	970	4,435.46
5:00	22.53	15.62	6.92	1,136	53	341	1,530	10,579.09
5:30	22.05	15.90	6.15	1,092	20	404	1,516	9,320.33
6:00	18.43	15.92	2.51	694	10	374	1,078	2,702.69
6:30	16.28	14.43	1.85	330	3	153	487	902.04
Peak Period Total				4,367	159	1,823	6,349	27,494.97

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 three lanes in each direction.

PERSON MOVEMENT

- In the a.m. peak-hour, compared to pre-HOV conditions, person movement has decreased by 5 percent (Figure D-6).

- In the a.m. peak-period, compared to pre-HOV conditions, person movement has decreased by 2 percent (Figure D-7).

VEHICLE VOLUME

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

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

VEHICLE OCCUPANCY

- In the a.m. peak-hour, compared to pre-HOV conditions, mainlane occupancy has declined by 8 percent (Figure D-11).

- In the a.m. peak-period, compared to pre-HOV conditions, mainlane occupancy has declined by 6 percent (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 (9/88-12/96) after the HOV lane opened indicate an accident rate of 6.7 accidents/100 MVK (10.9 accidents/100 MVM).

AVERAGE OPERATING SPEED

- In comparison to pre-HOV lane conditions, mainlane operating speeds have decreased in the peak hour and increased 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 used as a measure of per lane efficiency.

- For the freeway mainlanes, decreased travel speeds have resulted in a increase in per lane efficiency of 19 percent.

COMBINED FREEWAY AND HOV LANE DATA

TOTAL PERSON MOVEMENT

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

  - At Pinemont, the HOV lane is responsible for 39 percent of peak-hour person movement (HOV lane = 3,717; freeway = 5,821) and 29 percent of peak-period (HOV lane = 6,852; freeway = 17,110) person movement (Figure D-10).

- Increase in a.m. person movement at Pinemont

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

  - Total peak-hour person movement has increased by 55 percent, from 6,140 to 9,538 (Figure D-9). Peak-period person movement has increased by 37 percent, from 17,450 to 23,962 (Figure D-10).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.36, a 19 percent increase over the pre-HOV lane occupancy (Figure D-11). Occupancy in the peak period is 12 percent 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 173 percent compared to pre-HOV lane levels (Figure D-14). In the a.m. peak-period, the increase has been 117 percent. 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 34 percent since the implementation of the HOV lane (Figure D-15). Per-lane efficiency has at the same time, decreased by 25 percent 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 percent since the HOV lane opened, and a 215 percent increase in bus ridership has resulted (Figure D-16). In the peak-period, a 118 percent increase has occurred in bus vehicle trips, and a 155 percent 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 259 percent to a current level of 1,542 (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

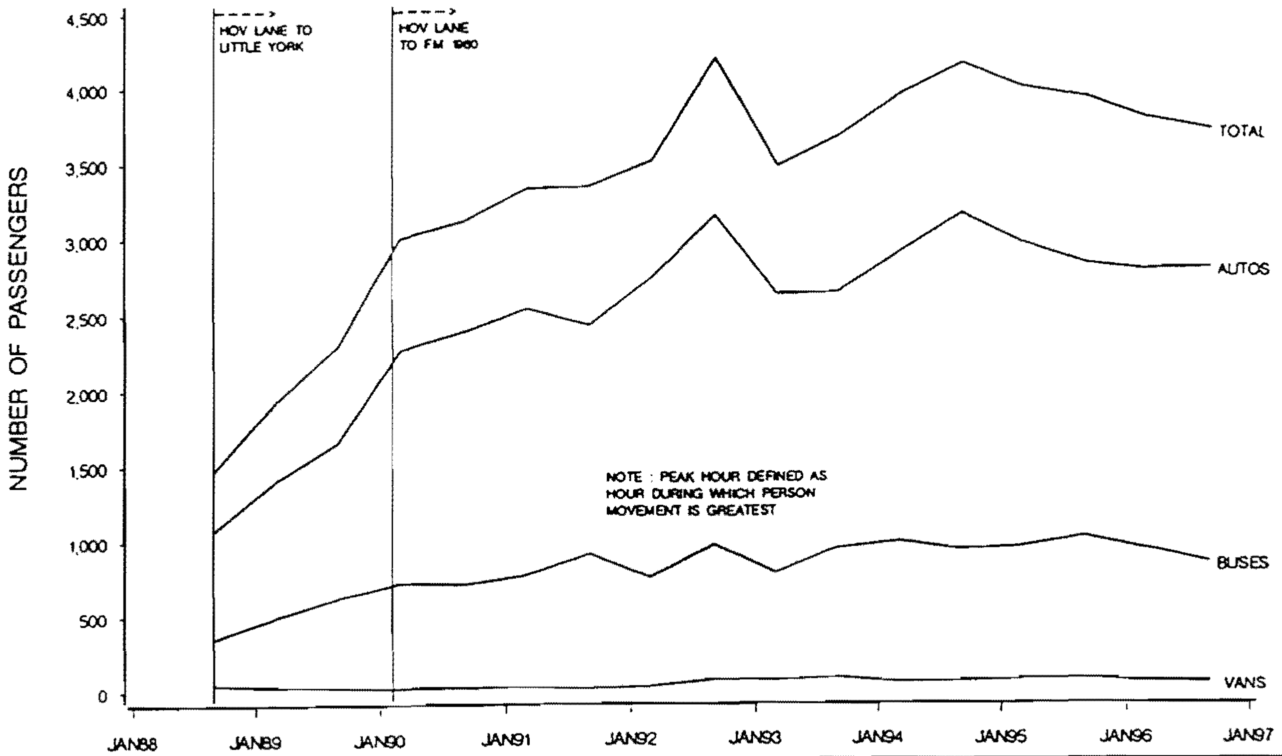


FIGURE D-2. NORTHWEST FREEWAY (US 290) HOV LANE
A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT

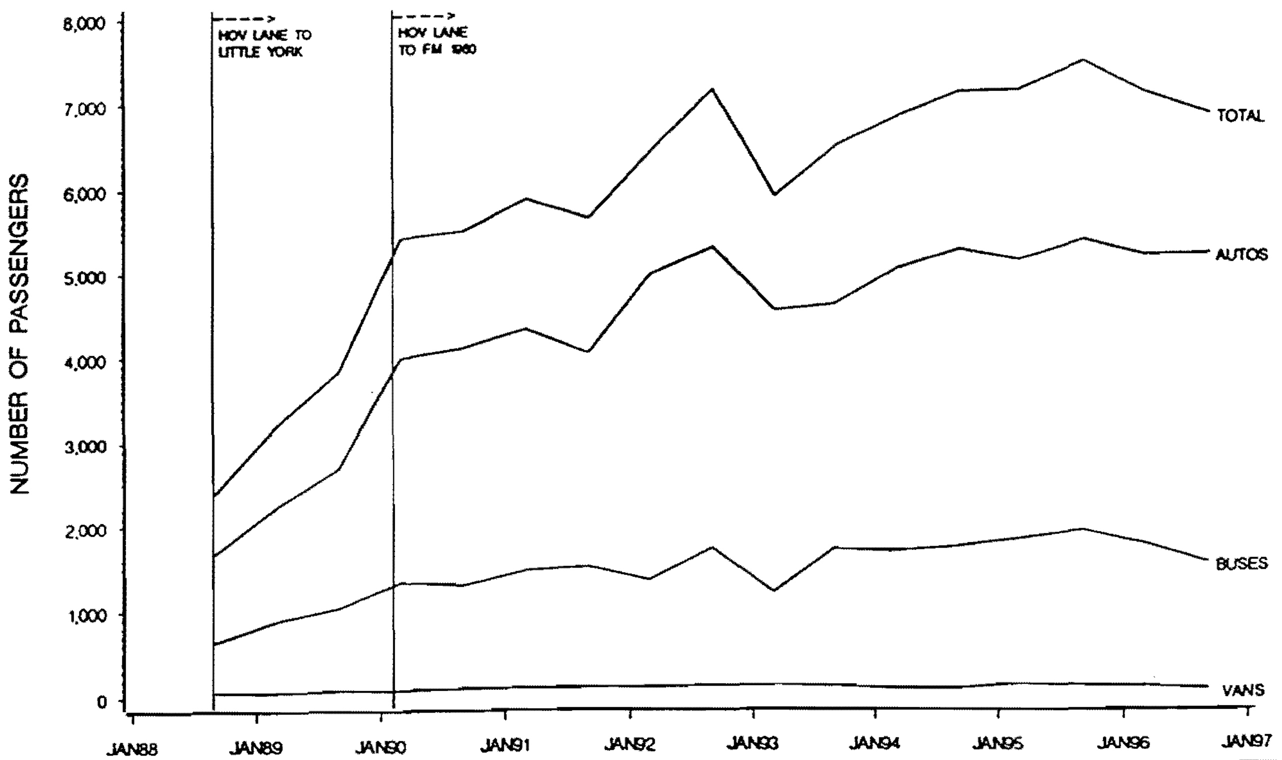


FIGURE D-3. NORTHWEST FREEWAY (US 290) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION

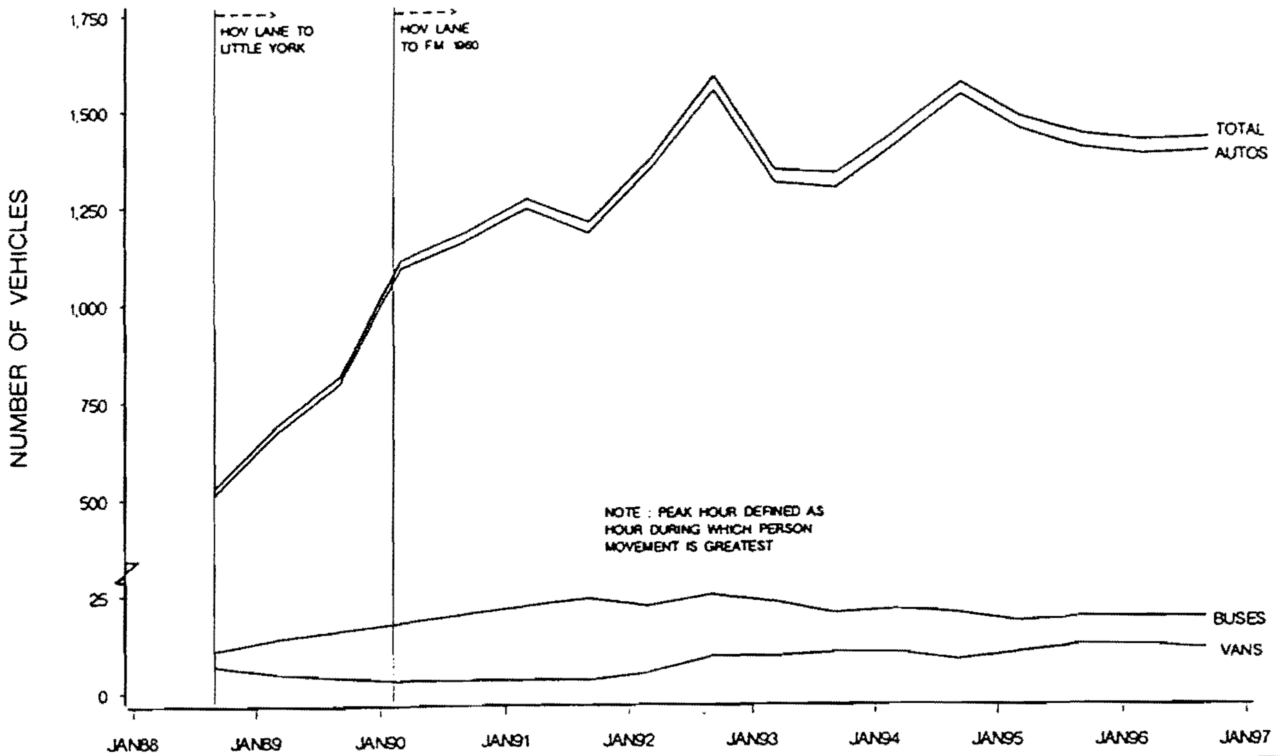


FIGURE D-4. NORTHWEST FREEWAY (US 290) HOV LANE
A.M. PEAK PERIOD HOV LANE VEHICLE UTILIZATION

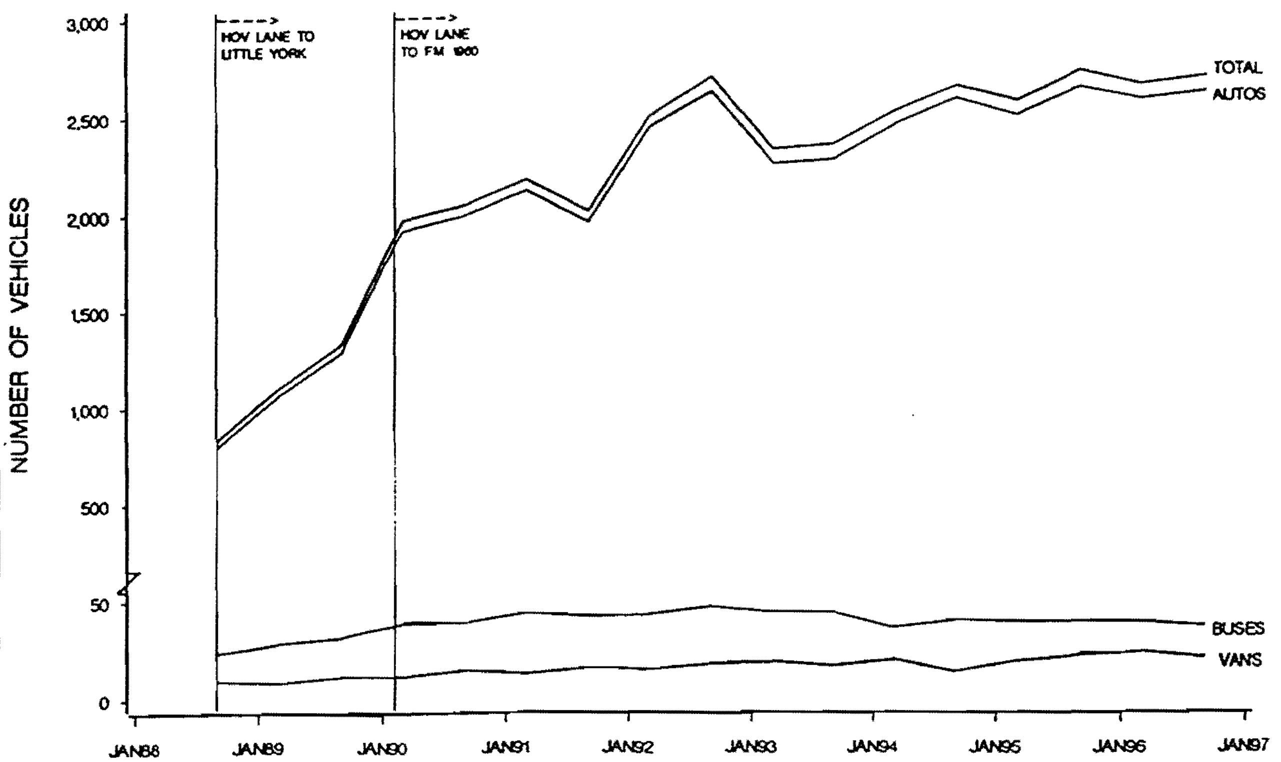


FIGURE D-5. NORTHWEST FREEWAY (US 290) MAINLANES AND HOV LANE A.M. TRAVEL TIME

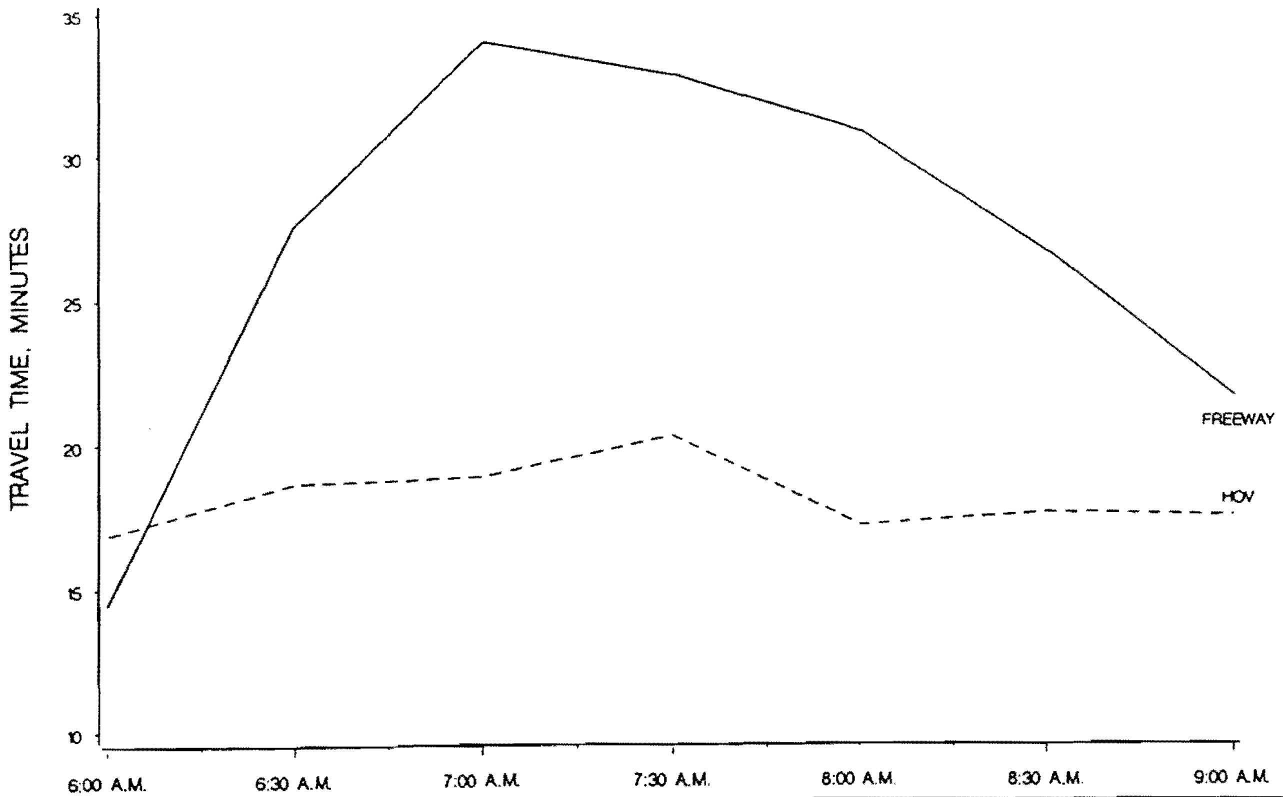


FIGURE D-6. NORTHWEST FREEWAY (U.S. 290)
A.M. PEAK HOUR MAINLANE TRIPS

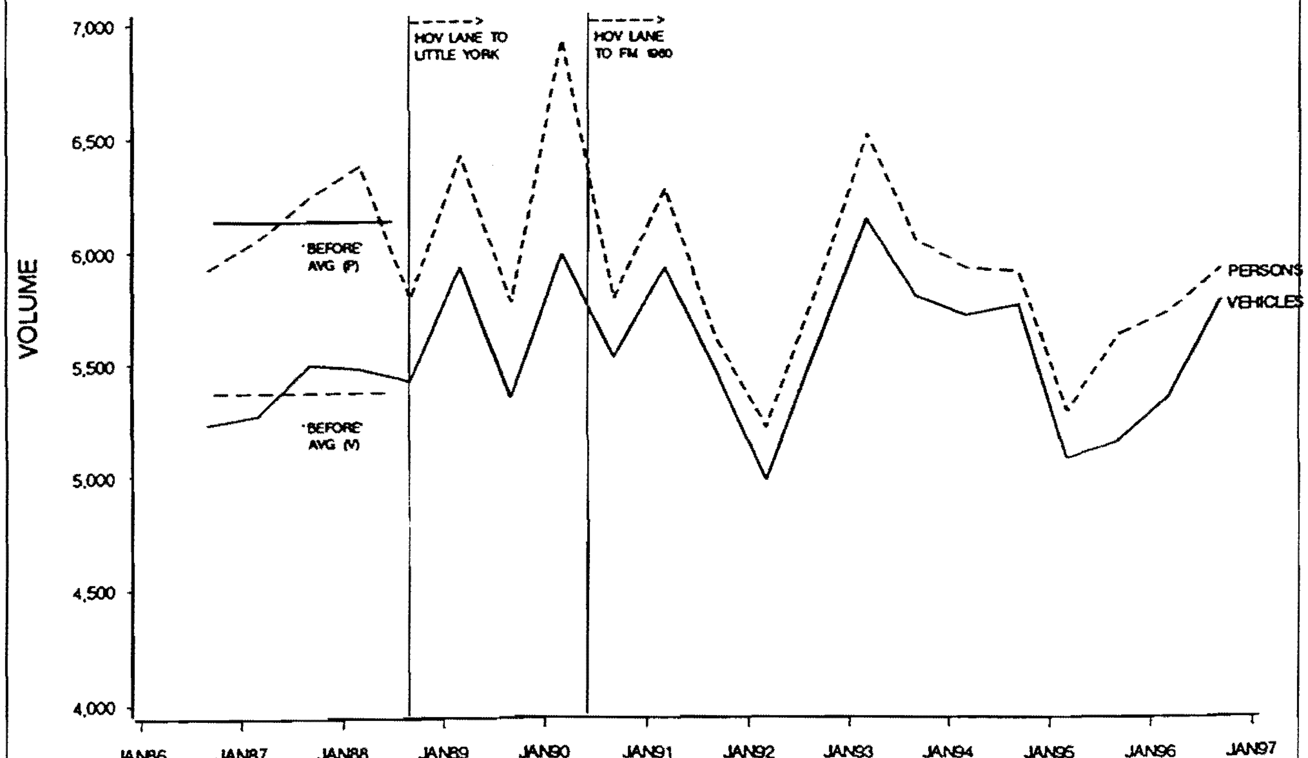


FIGURE D-7. NORTHWEST FREEWAY (U.S. 290)
A.M. PEAK PERIOD MAINLANE TRIPS

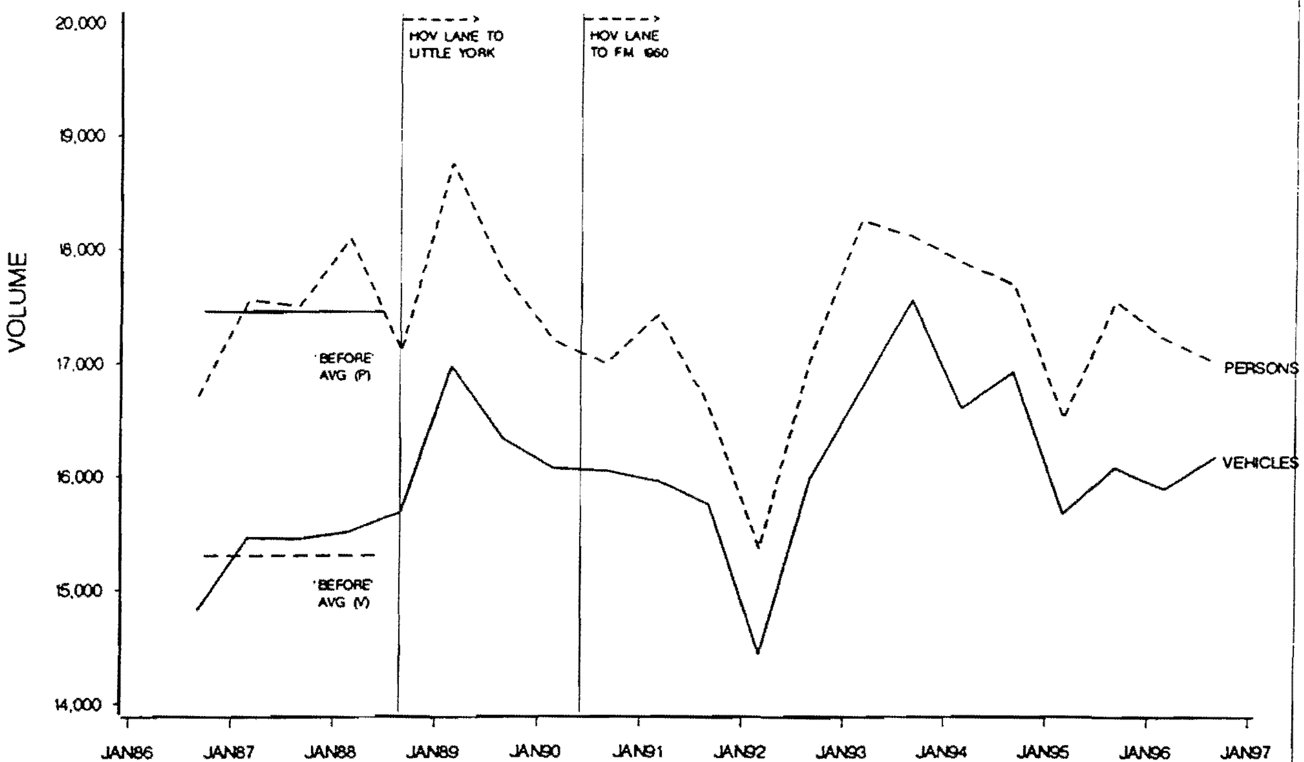


FIGURE D-8. NORTHWEST FREEWAY (U.S. 290) MAINLANE TRAVEL TIME AND SPEED SURVEY
SOUTHBOUND, TELGE TO IH 610
A.M. PEAK PERIOD

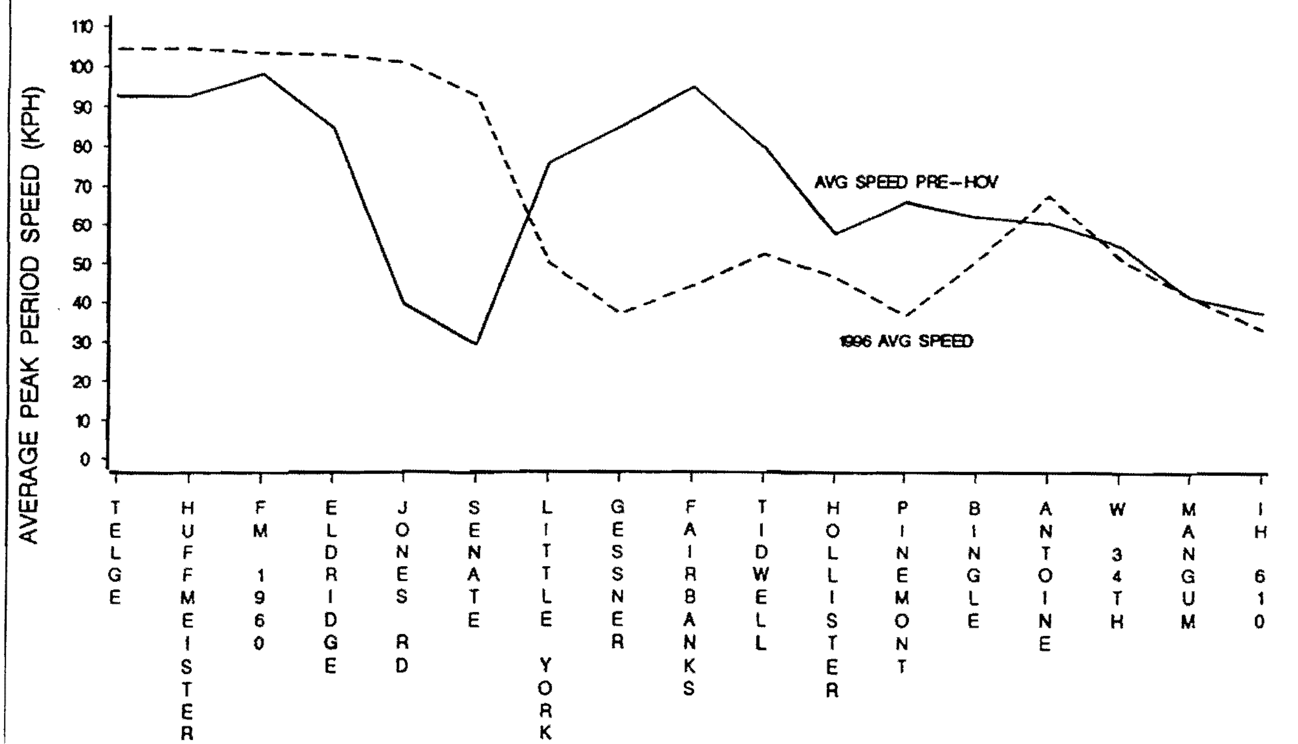


FIGURE D-9. NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE
A.M. PEAK HOUR PERSON TRIPS

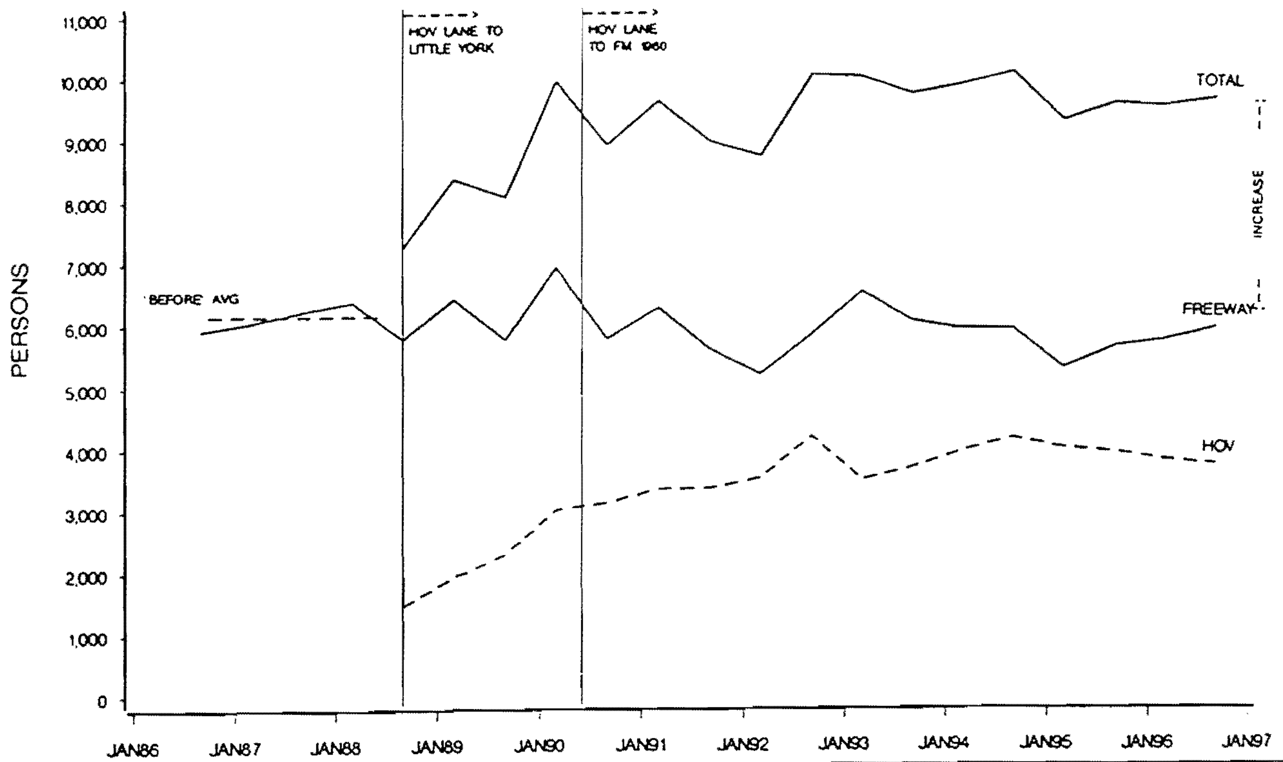


FIGURE D-10. NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE
A.M. PEAK PERIOD PERSON TRIPS

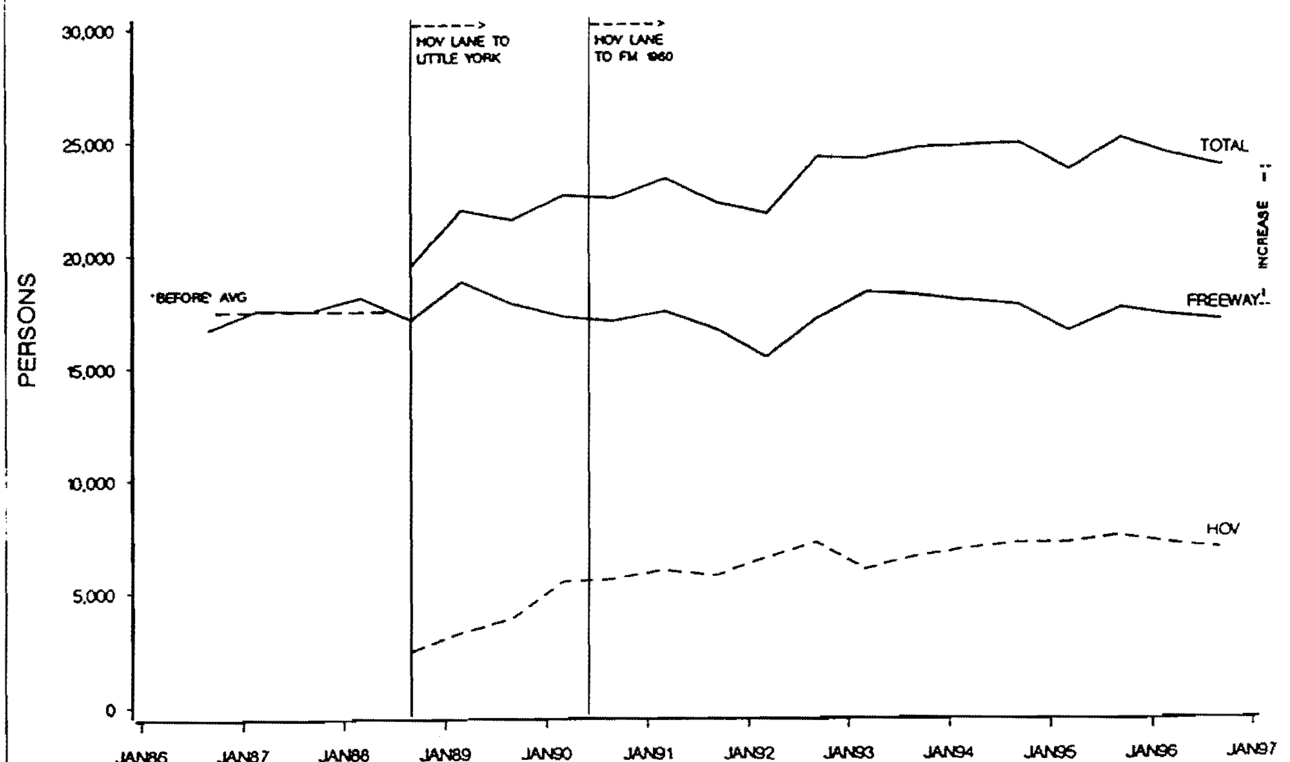


FIGURE D-11. NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE
A.M. PEAK HOUR AVERAGE OCCUPANCY

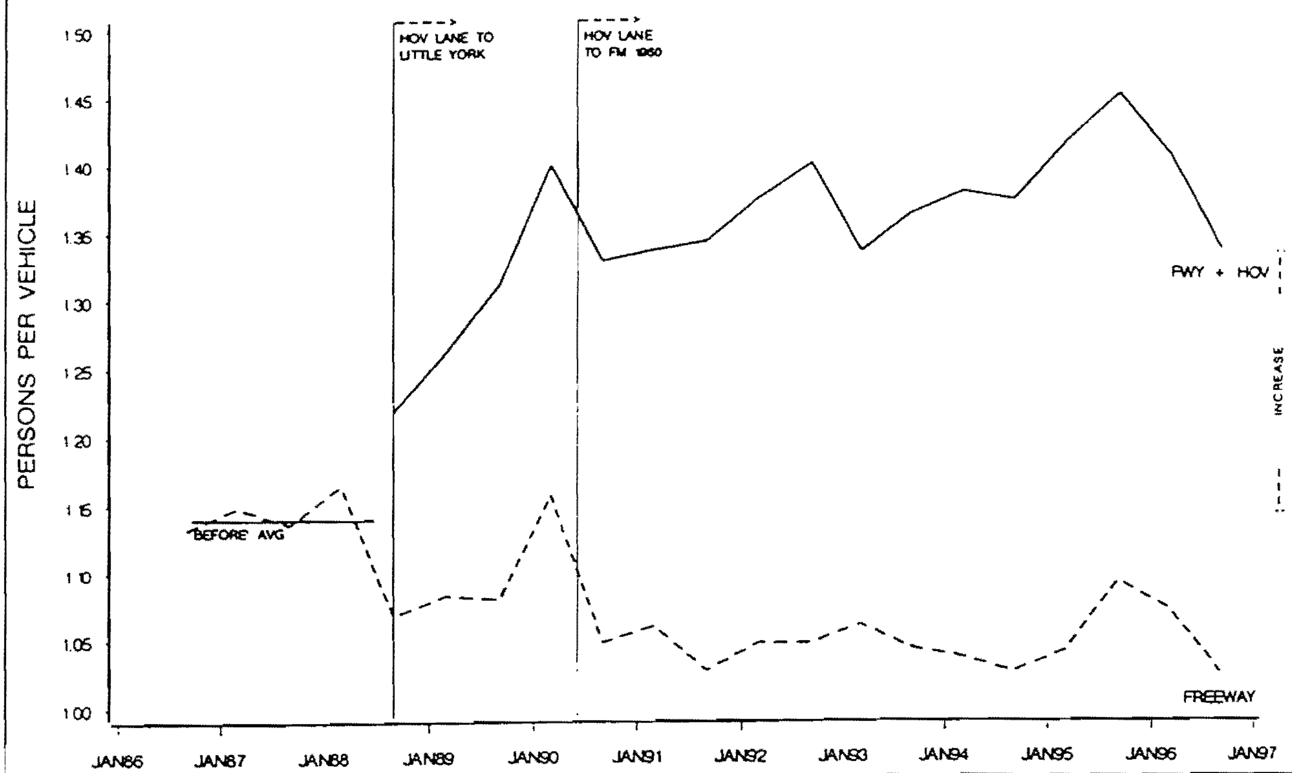


FIGURE D-12. NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE
A.M. PEAK PERIOD AVERAGE OCCUPANCY

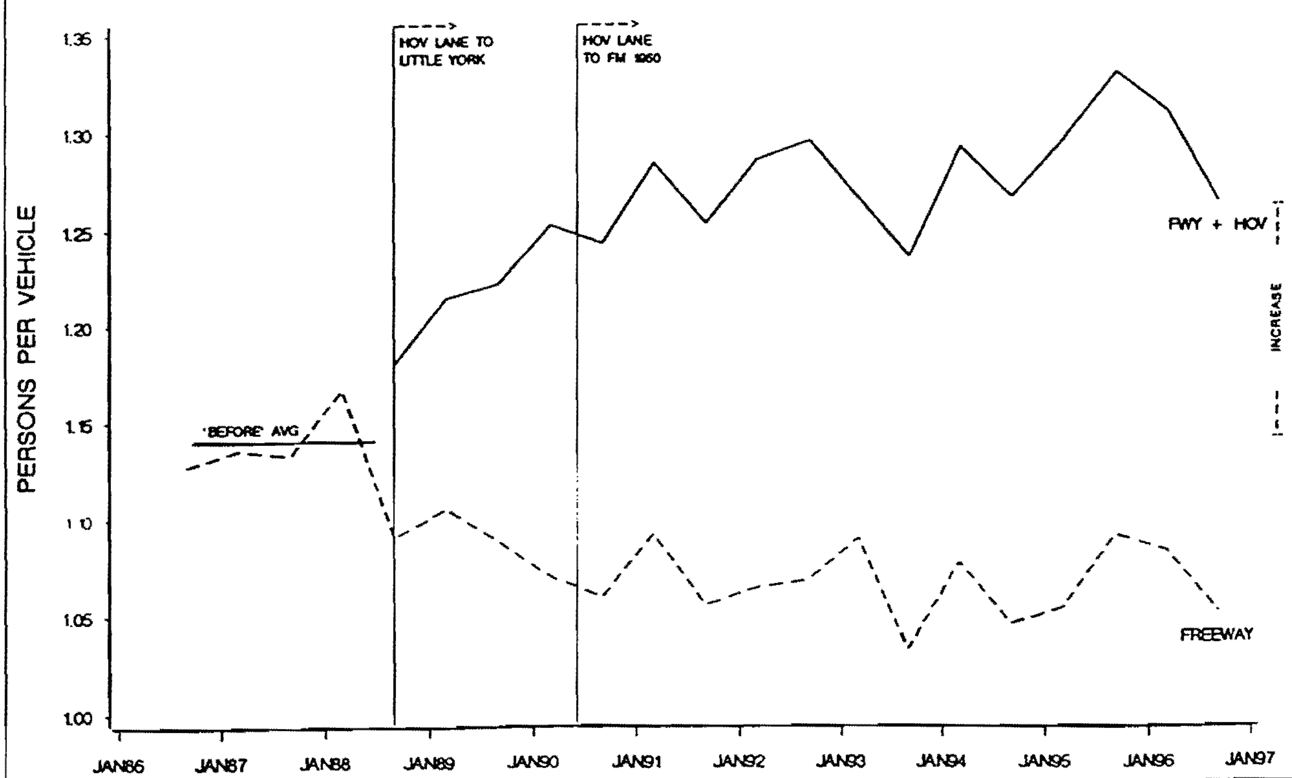


FIGURE D-13. A.M. PEAK HOUR AVERAGE OCCUPANCY NORTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

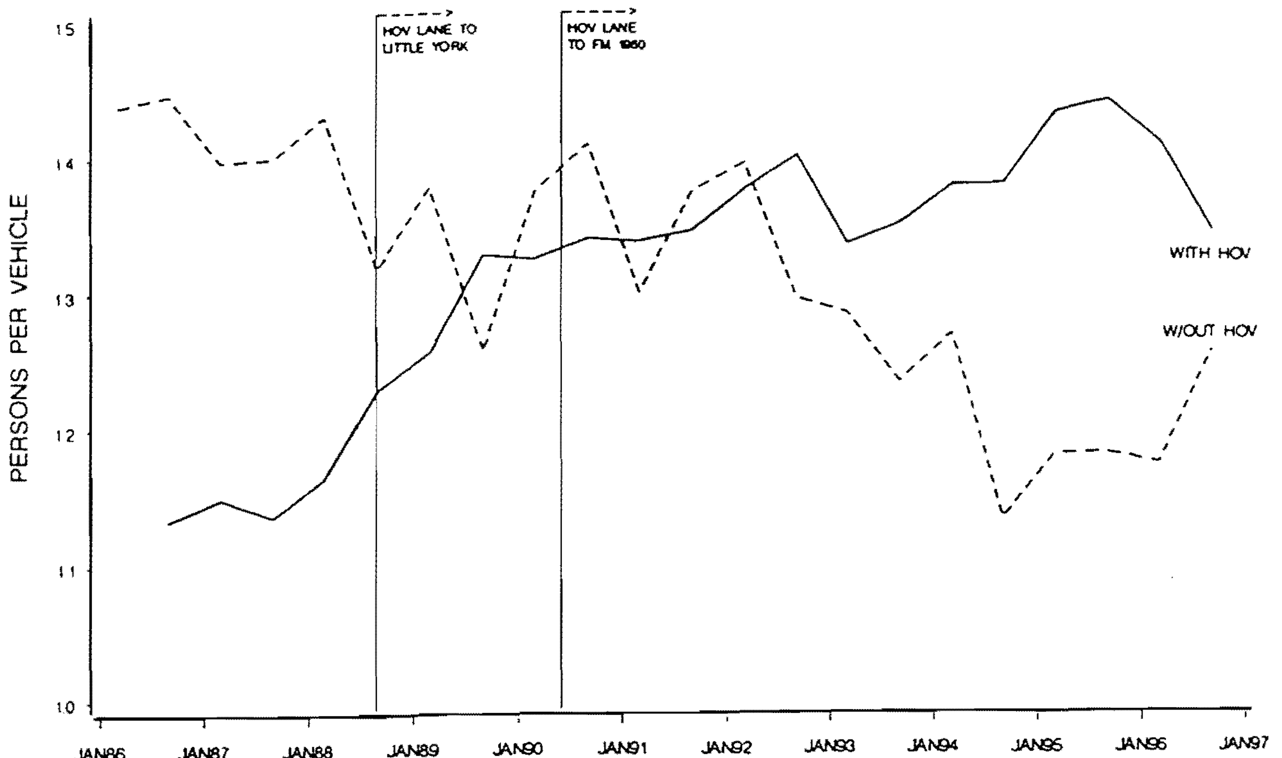


FIGURE D-14. NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE A.M. PEAK HOUR 2+ CARPOOL UTILIZATION

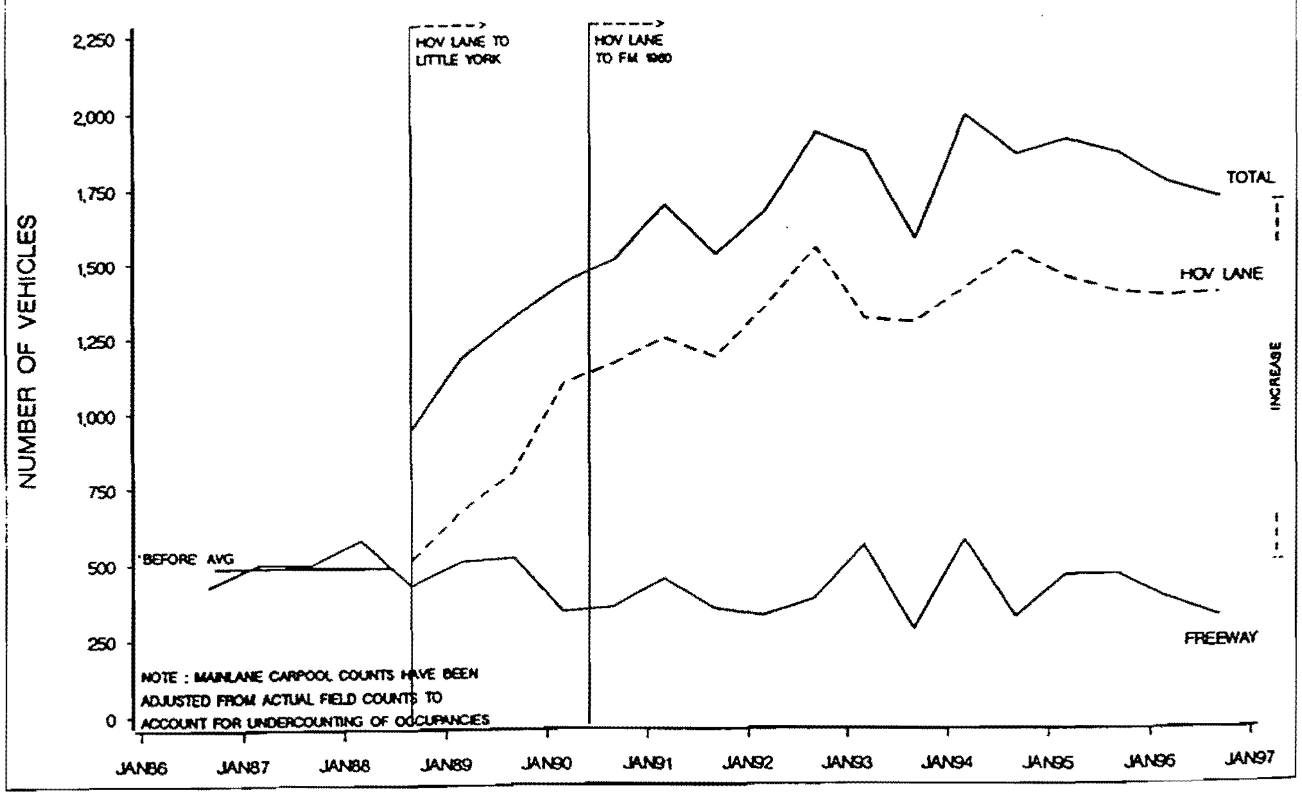


FIGURE D-15. A.M. PEAK HOUR FREEWAY PER LANE EFFICIENCY
NORTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

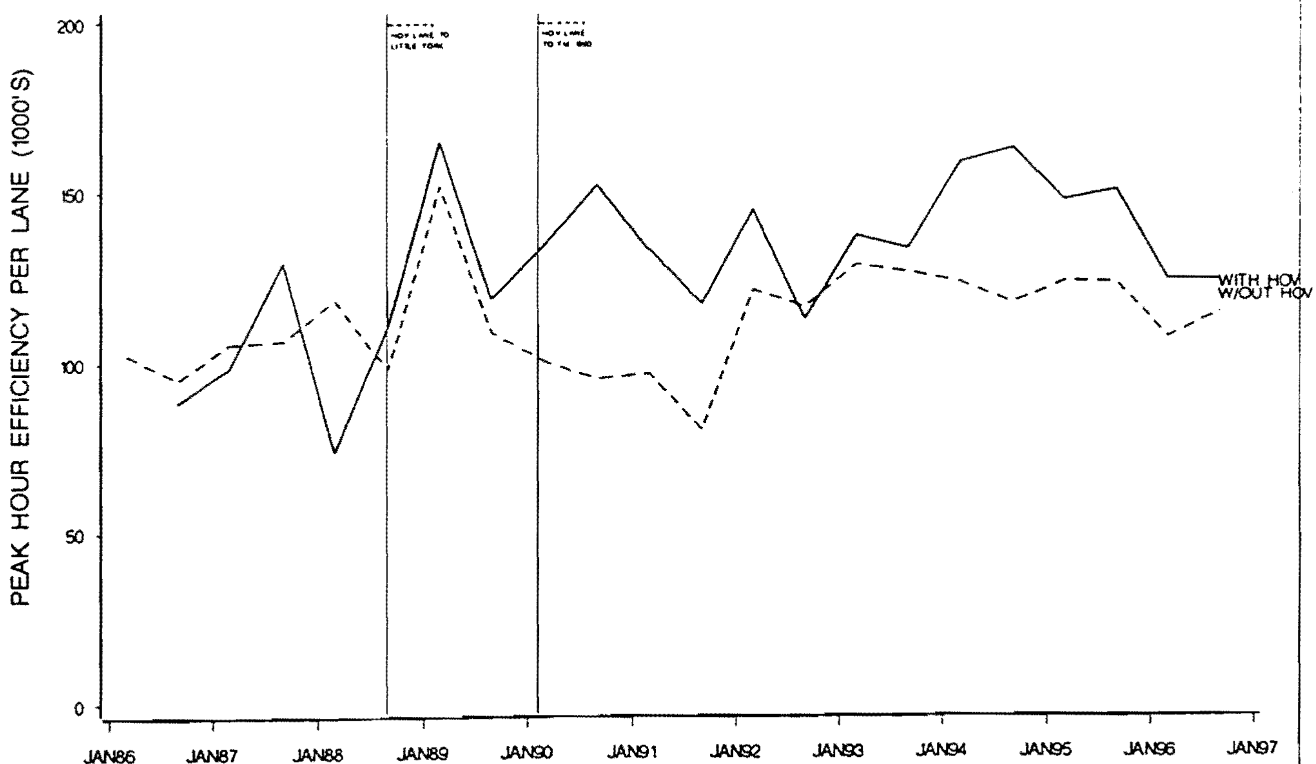


FIGURE D-16. NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS

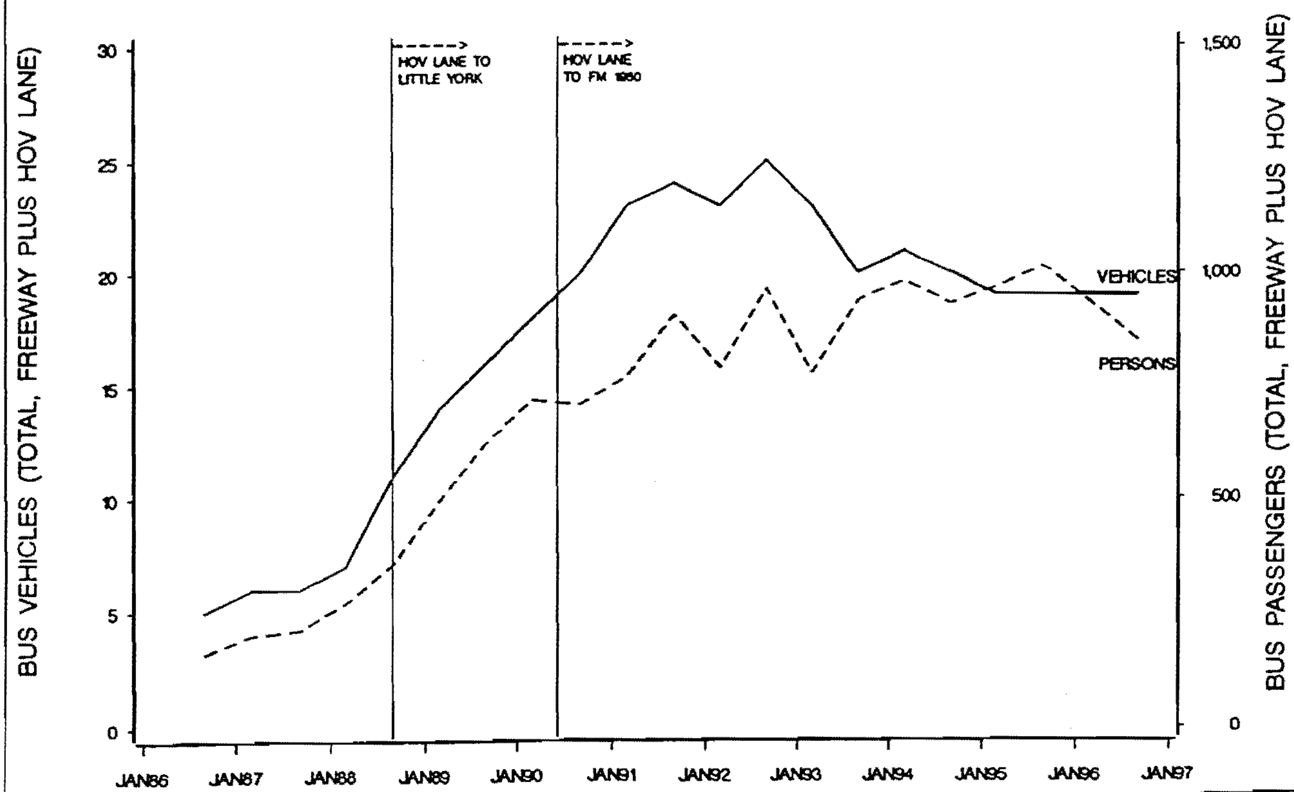


FIGURE D-17. NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS

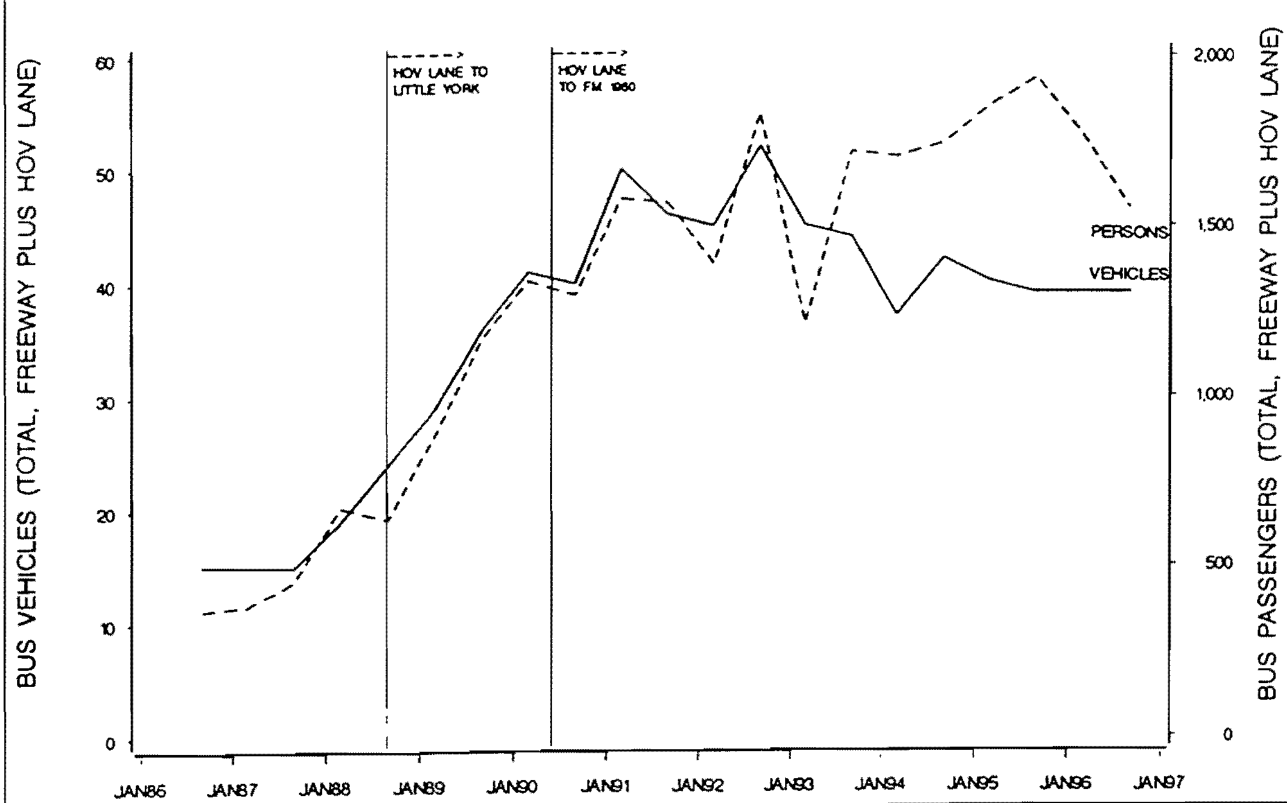


FIGURE D-18. A.M. PEAK PERIOD BUS PASSENGER TRIPS
TOTAL, FREEWAY PLUS HOV LANE VOLUMES
NORTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

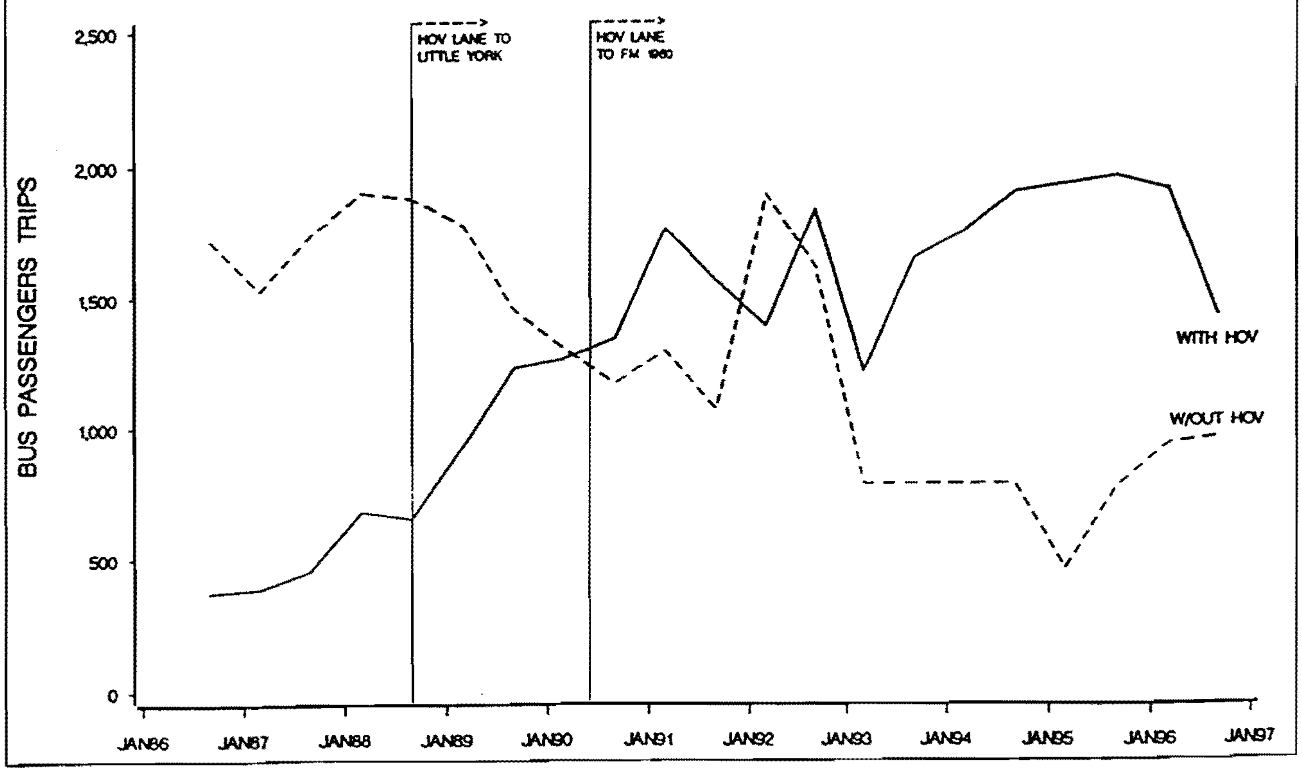


FIGURE D-19. NORTHWEST FREEWAY (U.S. 290) CORRIDOR PARK-AND-RIDE DEMAND

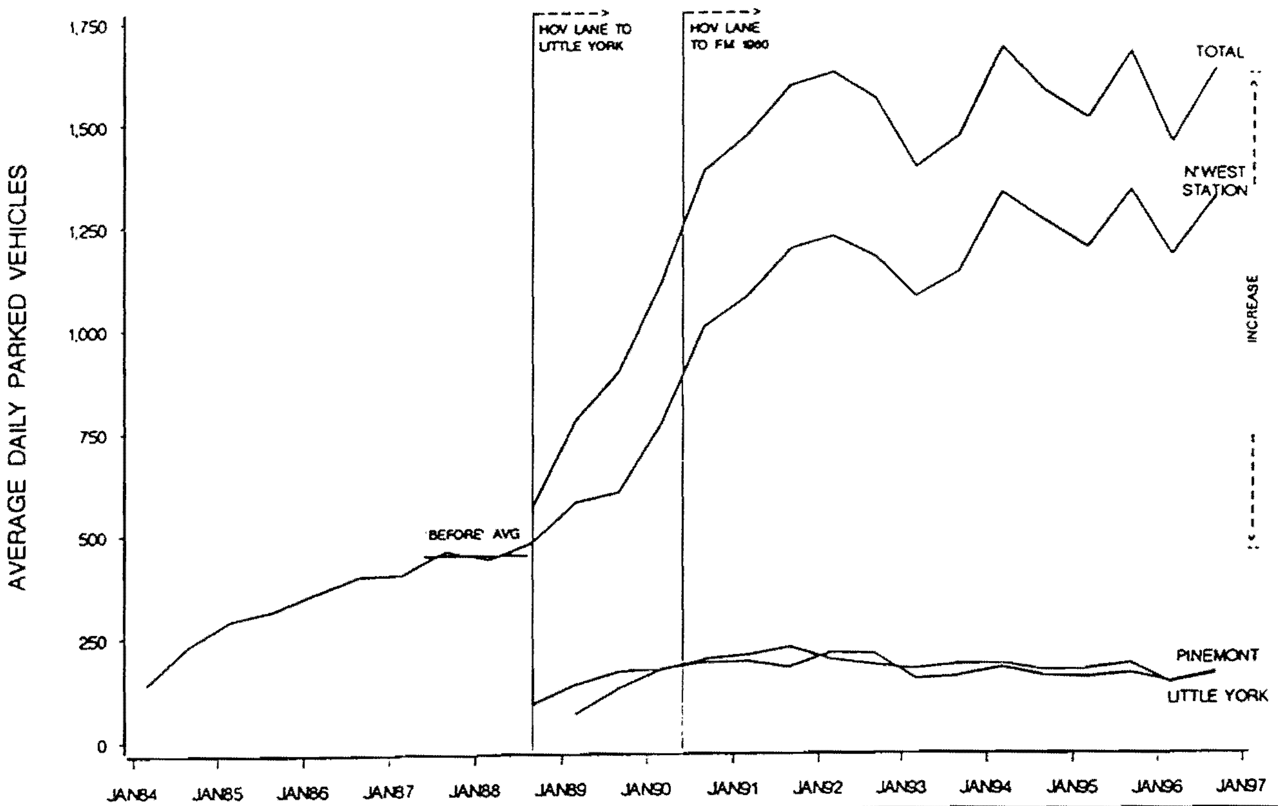
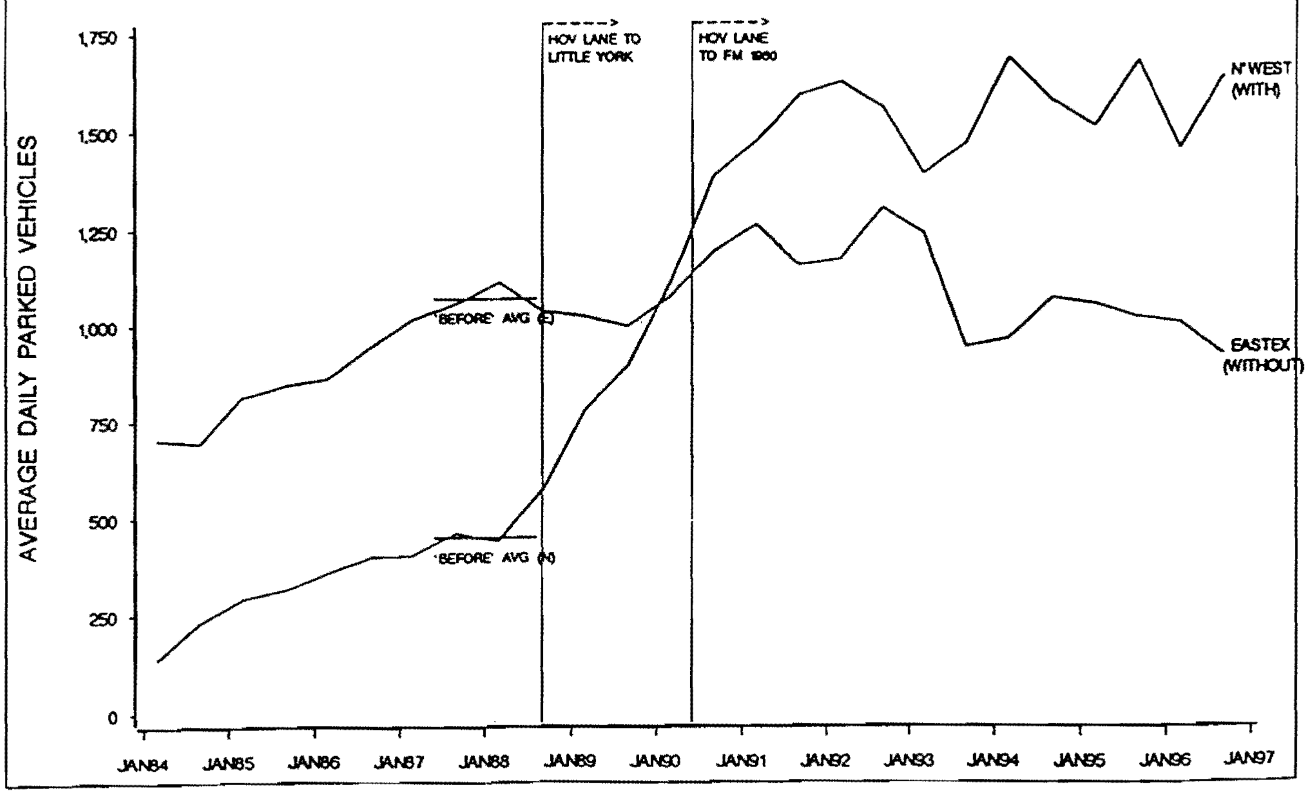


FIGURE D-20. AVERAGE DAILY VEHICLES PARKED AT PARK-AND-RIDE LOTS
NORTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE



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, 1996

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])		19.7 (12.2)	
HOV Lane Cost (millions)		$114.5	
Person-Movement			
Peak-Hour (7-8 a.m.)	---	3,598	---
Peak-Period (6-9:30 a.m.)	---	7,112	---
Total Daily	---	15,274	---
Vehicle Volumes			
Peak-Hour	---	1,315	---
Peak-Period	---	2,582	---
Vehicle Occupancy, Peak Hour (persons/veh)	---	2.74	---
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM])[1]	---	8.8 (14.2)	---
Vehicle Breakdown Rate (VKT/Breakdown [VMT/Breakdown])		118,137 (73,245)	---
Violation Rate (6-9:30 a.m.)	---	2%	---
Peak-Hour Lane Efficiency (1000's)[2]	---	288 (180)	---
Annual Discounted Benefits (millions)[3]	---	$25	---
Annual Delay Savings (millions)[4]		$13	
Freeway Mainlane Data (see note)			
Person Movement			
Peak-Hour	5,685	9,121	+60%
Peak-Period (6-9:30 a.m.)	17,357	27,206	+57%
Vehicle Volume			
Peak-Hour	4,922	8,548	+74%
Peak-Period	15,032	26,365	+75%
Vehicle Occupancy, Peak Hour (persons/veh)	1.16	1.07	-8%
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM])[1]	16.3 (26.2)	10.2 (16.4)	-37%
Avg. Operating Speed[5] (kph [mph])			
Peak-Hour	47 (29)	69(43)	+46%
Peak-Period	66 (41)	86(53)	+30%
Peak-Hour Lane Efficiency (1000's)[2]	90 (56)	126(78)	+40%

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 18.5 km (12.3 mi). 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 12/96. TTI estimated 1996 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 average annual delay savings, reduced vehicle operating costs and reduced accident costs generated by MicroBENCOST over a 20-year life.

[4]Per MicroBENCOST over a 20-year life.

[5]From Bellfort to S. Shepherd, the distance is 18.7 km (11.6 mi).

Table E-1. Summary of A.M. Peak-Direction Southwest Freeway and HOV Lane Data, December 1996 (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	12,719	+124%
Peak-Period	17,357	34,318	+98%
Vehicle Volume			
Peak-Hour	4,922	9,863	+100%
Peak-Period	15,032	28,492	+90%
Vehicle Occupancy			
Peak-Hour	1.16	1.29	+11%
Peak-Period	1.16	1.20	+3%
2+ Carpool Volumes			
Peak-Hour	531	1,206	+127%
Peak-Period	1,235	2,386	+93%
Travel Time (minutes)[1]			
Peak-Hour	16.2[2]	14.0[3]	-14%
Peak-Period	11.4[2]	12.8[3]	+12%
Peak-Hour Lane Efficiency (1000's)[4]	90 (56)	153 (113)	+70%
Transit Data			
Bus Vehicle Trips			
Peak-Hour	25	27	+8%
Peak-Period	75	57	-24%
Bus Passenger Trips			
Peak-Hour	724	883	+22%
Peak-Period	1,670	1,763	+8%
Bus Occupancy (persons/bus)			
Peak-Hour	20	32.7	+64%
Peak-Period	18	30.9	+72%
Vehicles Parked in Corridor Park-and-Ride Lots	1,441	1,904	+32%
Bus Operating Speed[1] (kph [mph])			
Peak Hour	47 (29)[2]	80 (50)	+70%
Peak Period	79 (49)[2]	88 (55)	+11%

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 km (11.6 mi).
[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 U.S. 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	1.29	+11%
Freeway w/o HOV lane	1.30	1.12	-14%
A.M. Peak Hour, 2+ Carpool Volume Change			
Freeway w/HOV lane	531	1,206	+127%
Freeway w/o HOV lane	779	573	-26%
Bus Passengers, Peak Period			
Freeway w/HOV lane	1,670	883	-47%
Freeway w/o HOV lane	1,067	941	-12%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	1,441	1,904	32%
Freeway w/o HOV lane	1,222	965	-21%
Facility Per Lane Efficiency[2]			
Freeway w/HOV lane	90 (56)	153 (113)	+70%
Freeway w/o HOV lane	120 (74)	104 (64)	-13%

[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 to 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 (19.7 km [12.2 mi]) of the HOV lane opened January 11, 1993.
- The capital cost (including all support facilities) for the completed facility in 1996 dollars was $114.5 million. The following pages (Table E-3, Table E-4) provide a more detailed cost breakdown including dates.
- Selected milestone dates are listed below.
  - 1/11/93 Shepherd to Bellfort opens (19.7 km [12.2 mi]).
  - 3/14/94 Hours of operation revised.
  - 4/4/94 Hours of operation revised.
  - 9/30/96 Hours of operation revised (5:00 a.m. - 11:00 a.m.; 2:00 p.m. - 8:00 p.m.).
  - 11/4/96 HOV lane extended to county line.

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

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1996 Dollars
<u>HOV Lane and Ramps</u>			
Segment I (1991)	$25.1	1.22	$30.6
Segment II (1992)	9.9	1.17	11.6
Segment III (1992)	13.0	1.17	15.2
Segment IV (1992)	6.3	1.17	7.4
W. Belfort T-Ramp (1992)	3.6	1.17	4.2
Segment IA (1996)	6.4	1.17	7.5
Miscellaneous	4.2	1.0	4.2
SUB-TOTAL	$64.3		$76.5
Per Kilometer (Mile)	$3.4 ($5.5)		$3.9 ($6.3)
<u>Surveillance, Communication and Control (1990)</u>	$3.5	1.27	$4.5
SUB-TOTAL	$3.5		
Per Kilometer (Mile)	$0.2 ($0.3)		$0.2 ($0.4)
<u>Support Facilities</u>			
W. Bellfort P/R (1991)	$8.6	1.22	$10.5
Westwood P/R (1991)	3.3	1.22	4.0
Hillcroft Transit Center (1992)	16.2	1.17	19.0
SUB-TOTAL	$28.1		$33.5
Per Kilometer (Mile)	$1.5 ($2.4)		$1.7 ($2.7)
TOTAL COST	$95.9		$114.5
COST PER KILOMETER (19.7 kilometers [12.2 miles])	$5.2 ($8.3)		$5.8 ($9.4)

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 Completion	Year of Construction Cost	
HOV Lane and Ramps			
Segment V	2002		$21.9
Greenway Plaza Ramp	1999		8.0
SUB-TOTAL		$29.9	
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		$30.6	
COST PER KILOMETER (4.5 kilometers [2.8 miles])			$6.8 ($10.9)

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

PERSON MOVEMENT

- In 1996, 15,274 person trips per day were served on the HOV lane.
- A.M. peak-hour, 3,598 persons/hour.
  - 883 (25 percent) by bus, 52 (1 percent) by vanpool, 2,659 (73 percent) by carpool, and four by motorcycle (Figure E-1).
  - Average HOV lane vehicle occupancy = 2.74 persons/vehicle.
- A.M. peak-period, 7,112 persons.
  - 1,763 (25 percent) by bus, 167 (2 percent) by vanpool, 5,171 (73 percent) by carpool, and 11 by motorcycle (Figure E-2).

VEHICLE MOVEMENT

- A.M. peak-hour, 1,315 vehicles.
  - 26 (2 percent) buses, 7 (1 percent) vans, 1,278 (97 percent) carpools, and four by motorcycle (Figure E-3).

- A.M. peak-period, 2,582 vph
  - 57 (2 percent) buses, 22 (1 percent) vans, 2,492 (97 percent) carpools, 11 by motorcycle (Figure E-4).

ACCIDENT RATE

- For the period 1/93 through12/96, the HOV lane accident rate was 8.8 accidents per 100 million vehicle kilometers (14.2 per 100 million vehicle miles).

VEHICLE BREAKDOWN RATES

- As measured from January 11, 1993 through December 1996, the following rate has been observed.

  - The weighted average for all vehicle types is one breakdown per 118,137 VKT (73,245 VMT).

VIOLATION RATE

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

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 288 (3,598 passengers x 80 kph) or 180 (3,598 passengers x 50 mph).

TRAVEL TIME SAVINGS

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

Table E-5. Travel Time Savings for Southwest HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1996)

Northbound 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	5.00	5.47	-0.47	180	11	40	231	-107.80
6:30	5.76	6.02	-0.26	587	37	110	734	-189.59
7:00	8.60	6.38	2.22	1,073	18	320	1,411	3,127.69
7:30	8.65	7.28	1.37	1,476	8	110	1,594	2,178.44
8:00	6.94	6.80	0.14	663	2	180	845	119.74
8:30	6.30	5.75	0.55	391	0	51	442	243.10
9:00	5.25	5.43	-0.18	193	0	0	193	-35.39
Peak Period Total				4,563	76	811	5,450	5,336.19
Section From Hillcroft Flyover to S Shepherd								
6:00	5.70	6.23	-0.53	169	35	148	352	-187.72
6:30	6.45	6.48	-0.03	719	46	288	1,054	-26.34
7:00	7.52	7.17	0.35	1,211	46	437	1,694	592.90
7:30	7.30	7.14	0.16	1,477	13	407	1,897	300.35
8:00	6.00	6.36	-0.36	929	13	274	1,215	-435.40
8:30	5.95	6.67	-0.72	538	14	144	695	-498.05
9:00	5.87	6.19	-0.31	195	9	37	241	-74.24
Peak Period Total				5,237	175	1,734	7,147	-328.49
Southbound P.M. Travel Time Savings for Southwest HOV Lane								
Section from S Shepherd to Hillcroft Flyover								
3:30	6.66	6.51	0.15	231	2	103	336	50.42
4:00	6.29	6.18	0.12	467	20	202	689	80.31
4:30	6.93	7.58	-0.66	744	40	289	1,074	-706.90
5:00	9.48	8.68	0.80	1,092	40	465	1,597	1,277.20
5:30	12.00	8.08	3.93	1,059	17	483	1,559	6,117.11
6:00	10.84	7.53	3.32	691	25	212	928	3,077.62
6:30	8.28	7.43	0.86	444	60	127	631	541.10
Peak Period Total				4,727	204	1,881	6,812	10,436.95

Table E-5. Travel Time Savings for Southwest HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1996) (Continued)

Southbound P.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	5.48	5.68	-0.19	70	7	11	88	-16.87
4:00	5.57	5.22	0.35	474	23	120	617	215.92
4:30	6.72	6.34	0.38	554	42	53	649	243.38
5:00	7.22	6.18	1.03	637	13	200	850	878.31
5:30	9.28	6.05	3.23	632	35	101	768	2,483.17
6:00	8.10	5.68	2.42	567	31	141	739	1,785.94
6:30	6.22	5.63	0.58	349	55	41	445	259.57
Peak Period Total				3,283	206	667	4,156	5,849.41

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 5 lanes in each direction.

PERSON MOVEMENT

- In the a.m. peak-hour, compared to pre-HOV conditions, person movement has increased by 60 percent (Figure E-6).

- In the a.m. peak-period, compared to pre-HOV conditions, person movement has increased by 57 percent (Figure E-7).

VEHICLE VOLUME

- In the a.m. peak-hour, vehicle volume has increased by 74 percent (Figure E-6).

- In the a.m. peak-period, vehicle volume has increased by 75 percent (Figure E-7).

VEHICLE OCCUPANCY

- In the a.m. peak-hour, compared to pre-HOV conditions, mainlane occupancy has declined by 8 percent (Figure E-11).

- In the a.m. peak-period, compared to pre-HOV conditions, mainlane occupancy has declined by 11 percent (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 (1/93-12/95) after the HOV lane opened indicate an accident rate of 10.2 accidents/100 MVK (16.4 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, increased travel speeds have resulted in an increase in per lane efficiency of 40 percent.

FIGURE E-1. SOUTHWEST FREEWAY (US 59S) HOV LANE
A.M. PEAK HOUR HOV LANE PERSON MOVEMENT

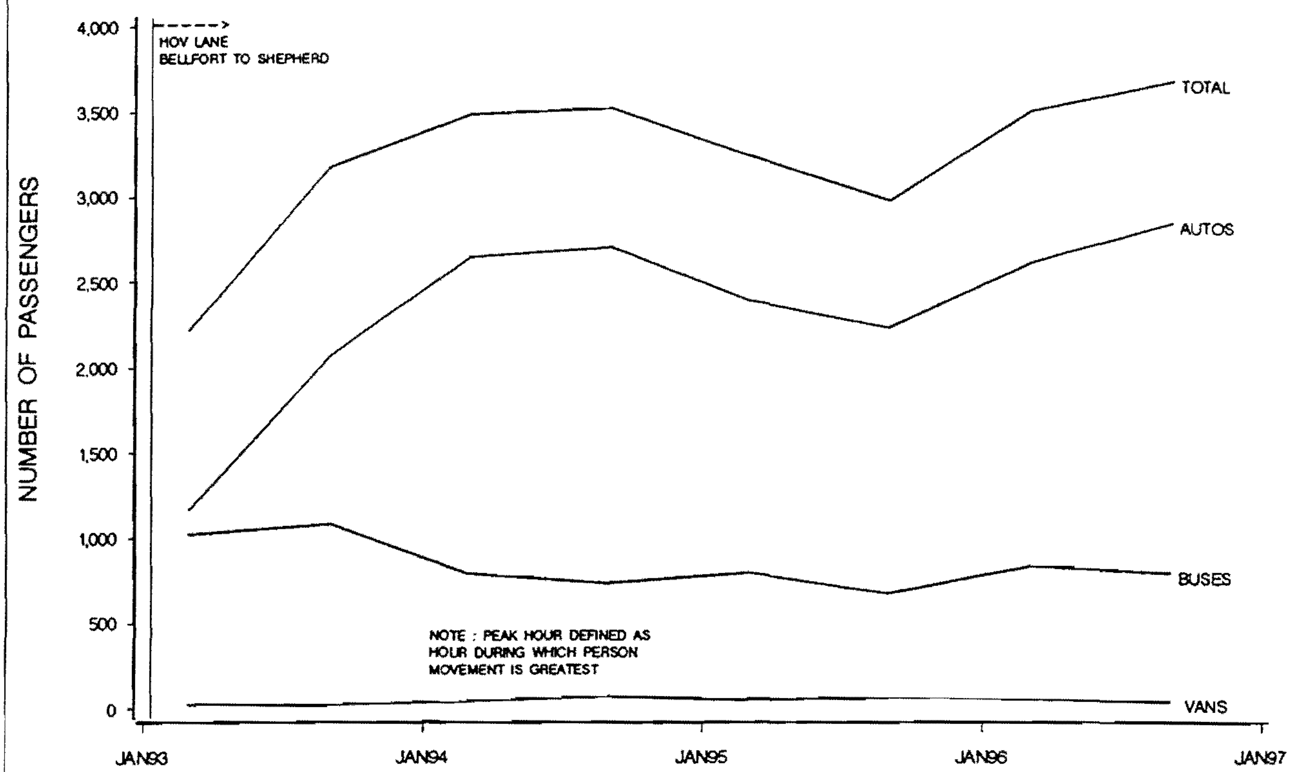


FIGURE E-2. SOUTHWEST FREEWAY (US 59S) HOV LANE
A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT

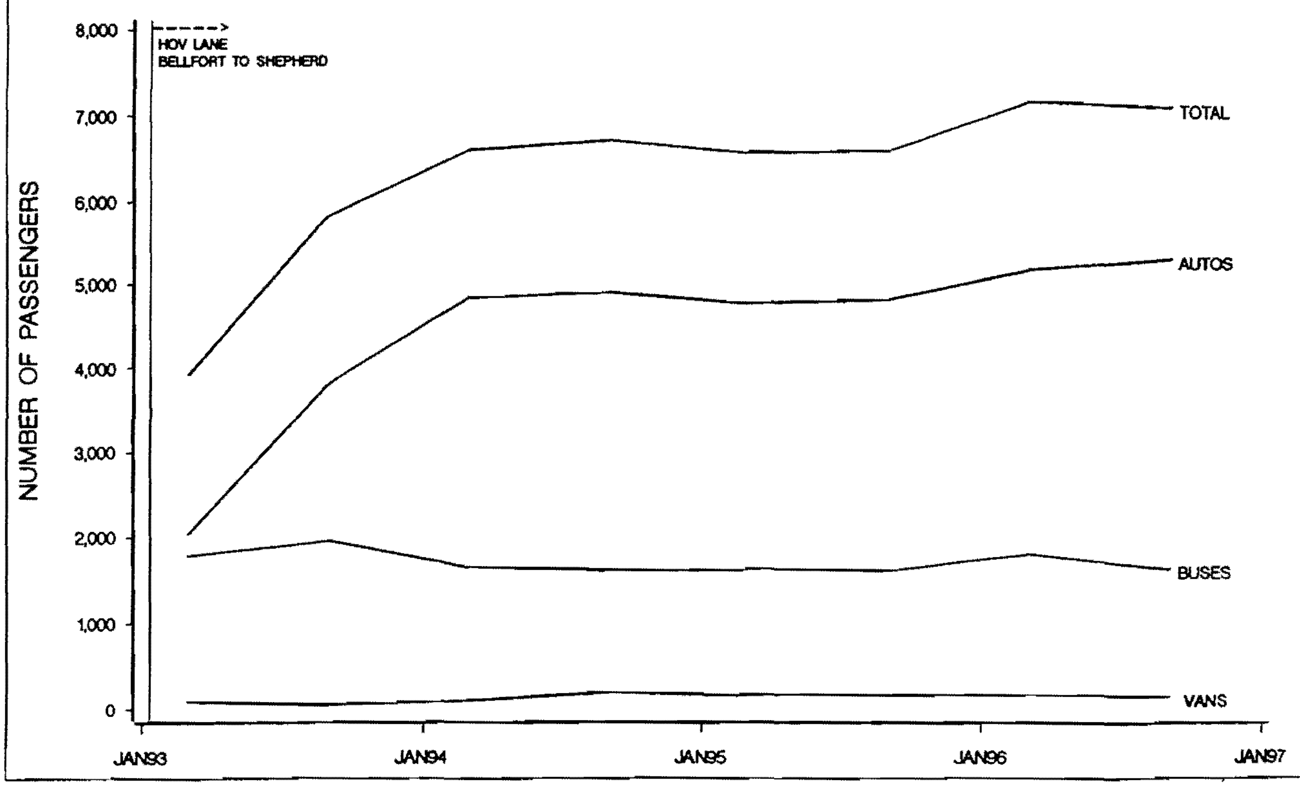


FIGURE E-3. SOUTHWEST FREEWAY (US 59S) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION

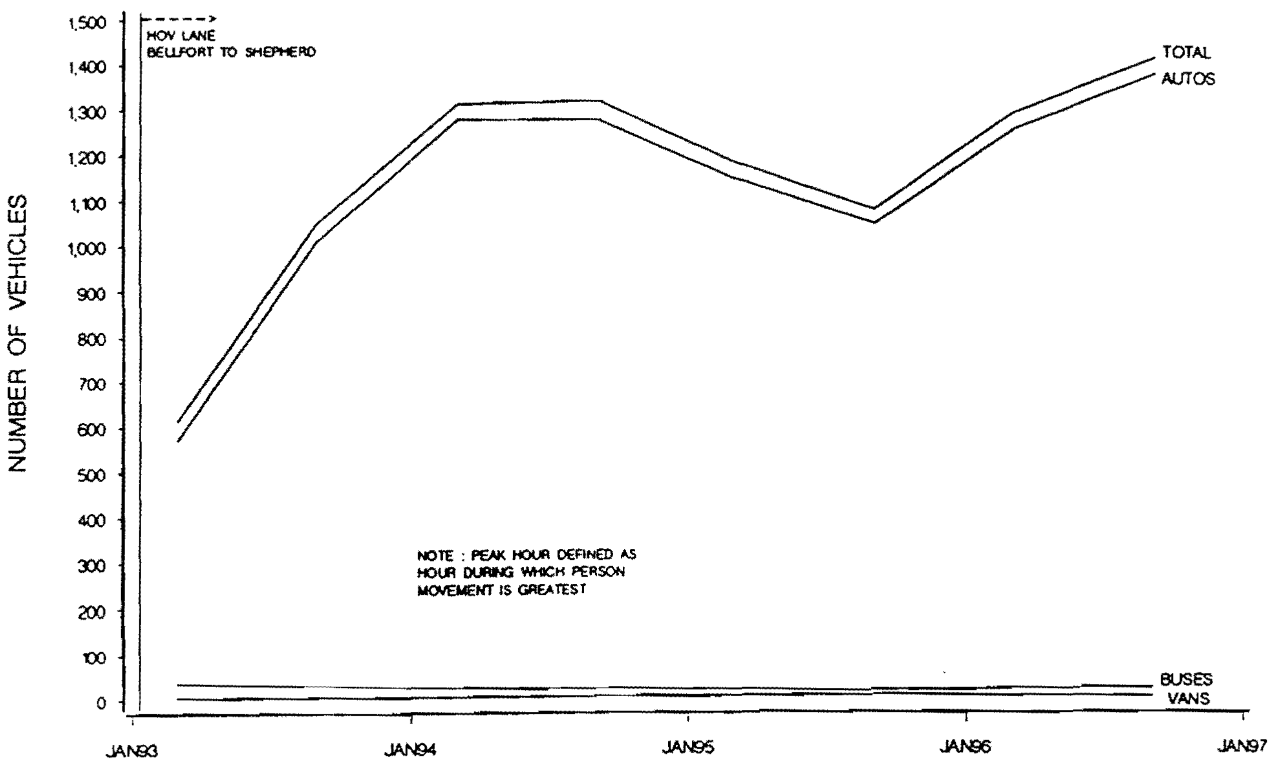


FIGURE E-4. SOUTHWEST FREEWAY (US 59S) HOV LANE
A.M. PEAK PERIOD HOV LANE VEHICLE UTILIZATION

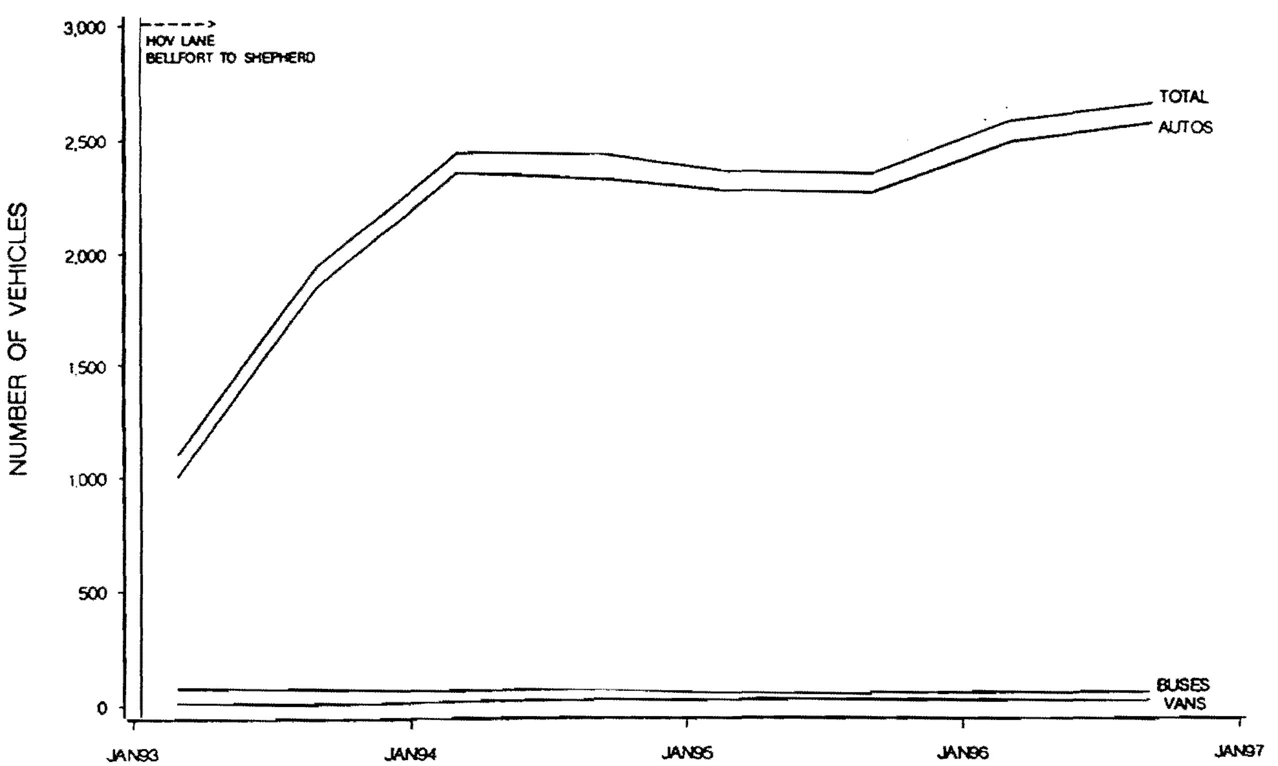


FIGURE E-5. SOUTHWEST FREEWAY (US 59S) MAINLANES AND HOV LANE A.M. TRAVEL TIME

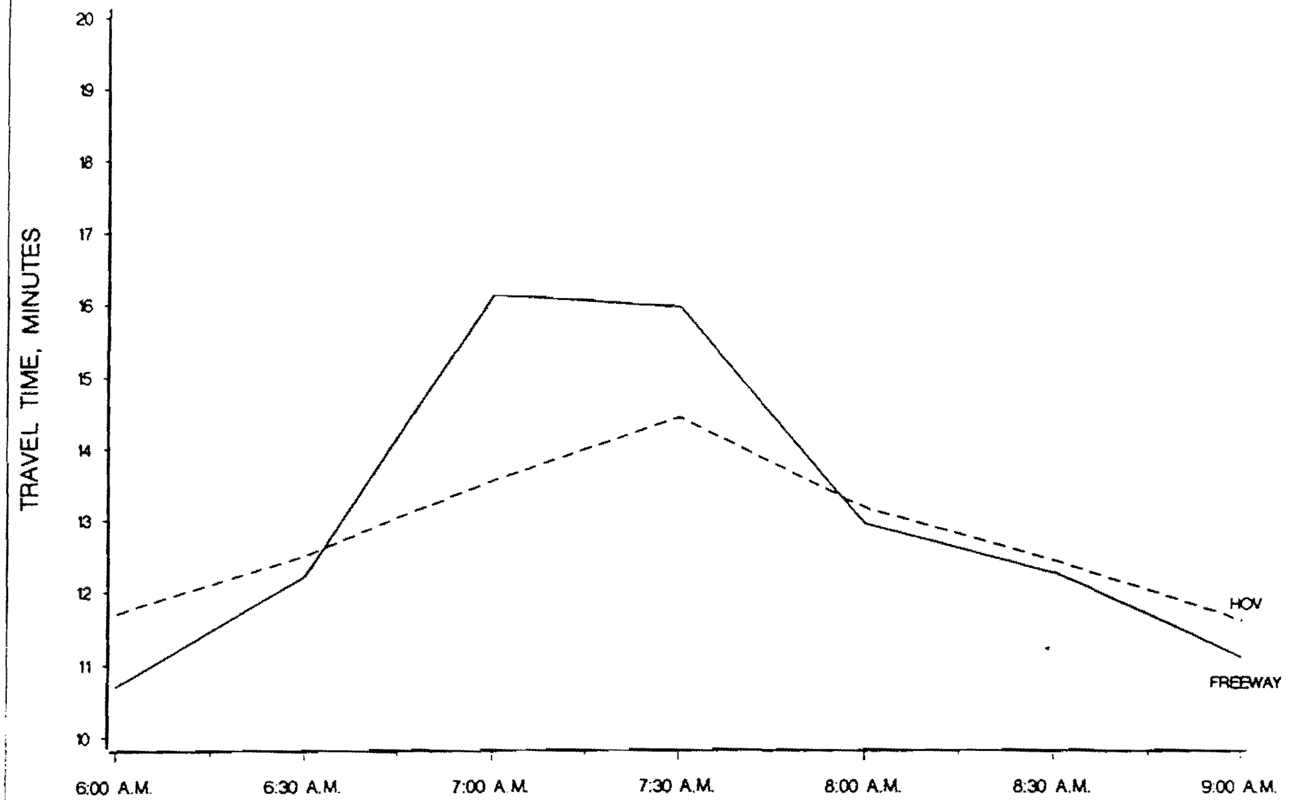


FIGURE E-6. SOUTHWEST FREEWAY (U.S. 59S)
A.M. PEAK HOUR MAINLANE TRIPS

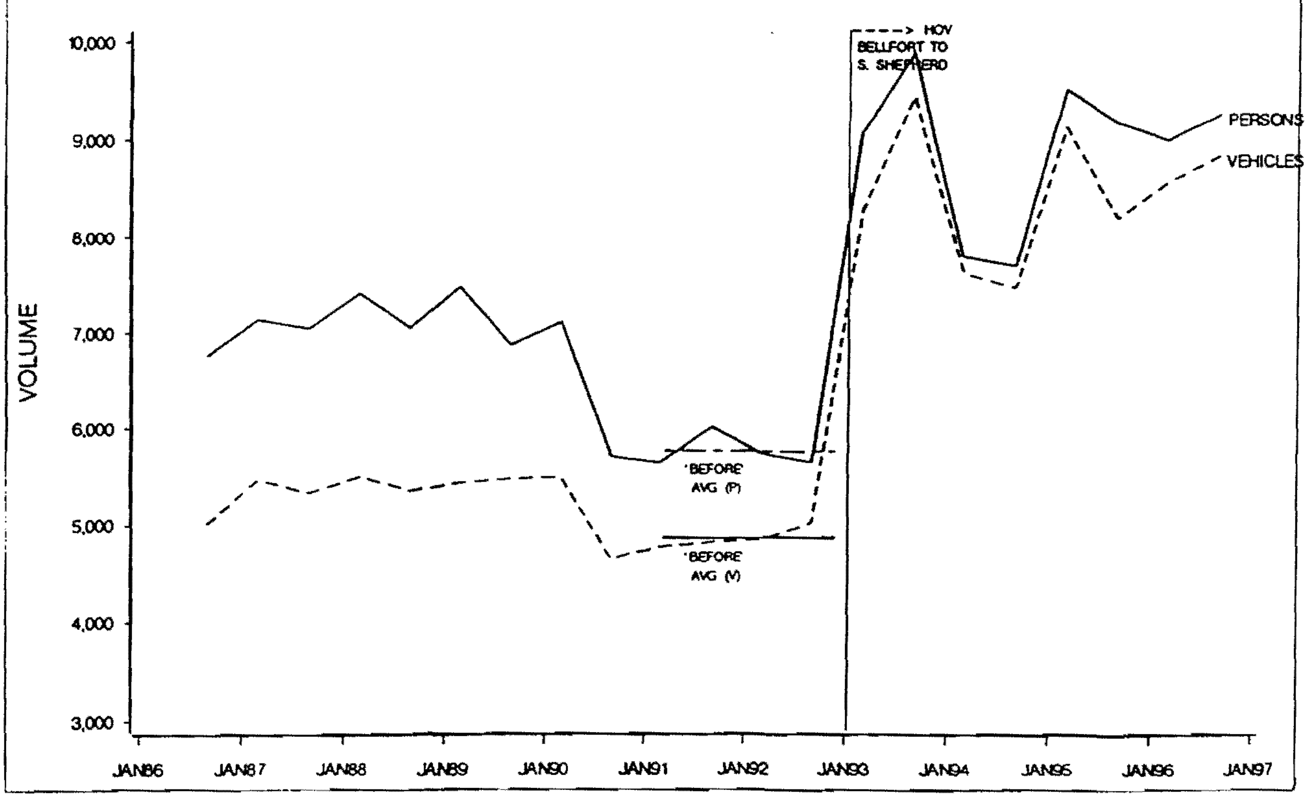


FIGURE E-7. SOUTHWEST FREEWAY (U.S. 59S)
A.M. PEAK PERIOD MAINLANE TRIPS

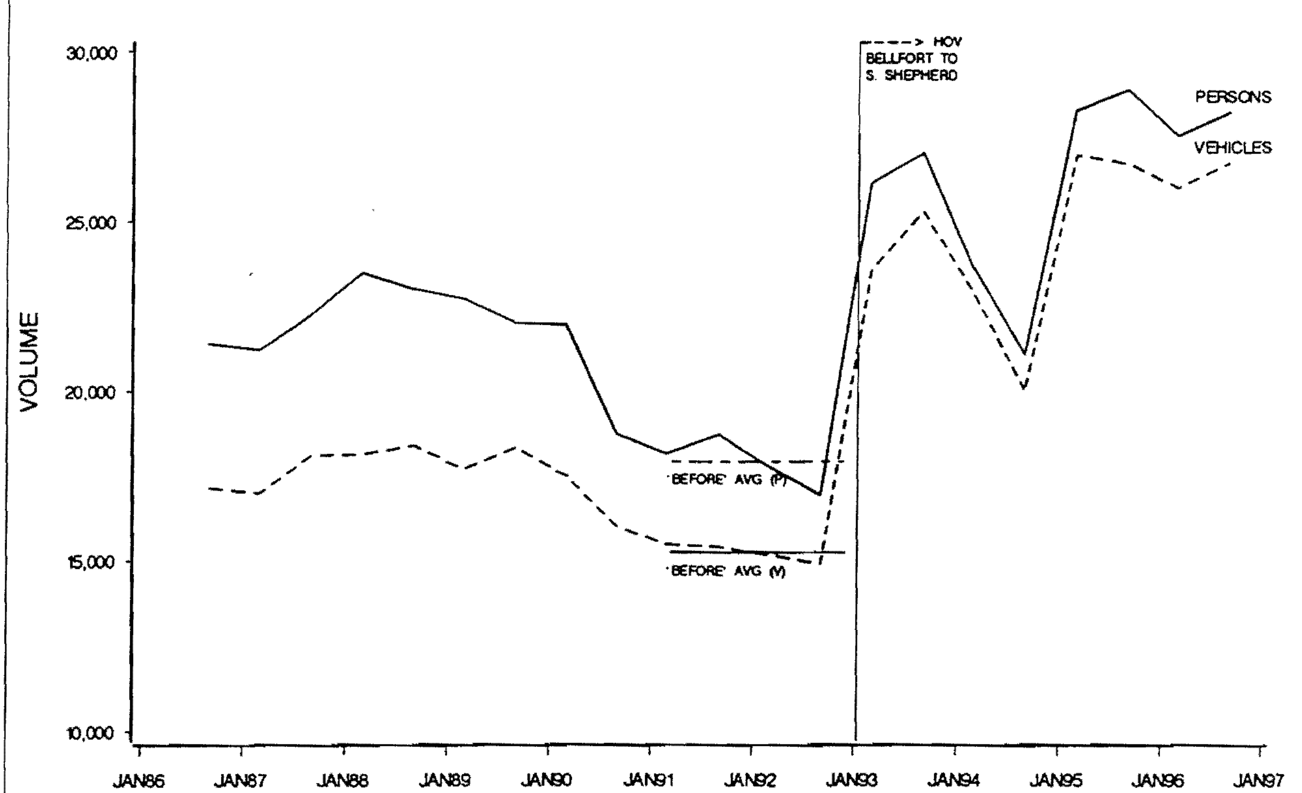


FIGURE E-8. SOUTHWEST FREEWAY (U.S. 59S) MAINLANE TRAVEL TIME AND SPEED SURVEY
NORTHBOUND, BELLFORT TO MANDELL
A.M. PEAK PERIOD

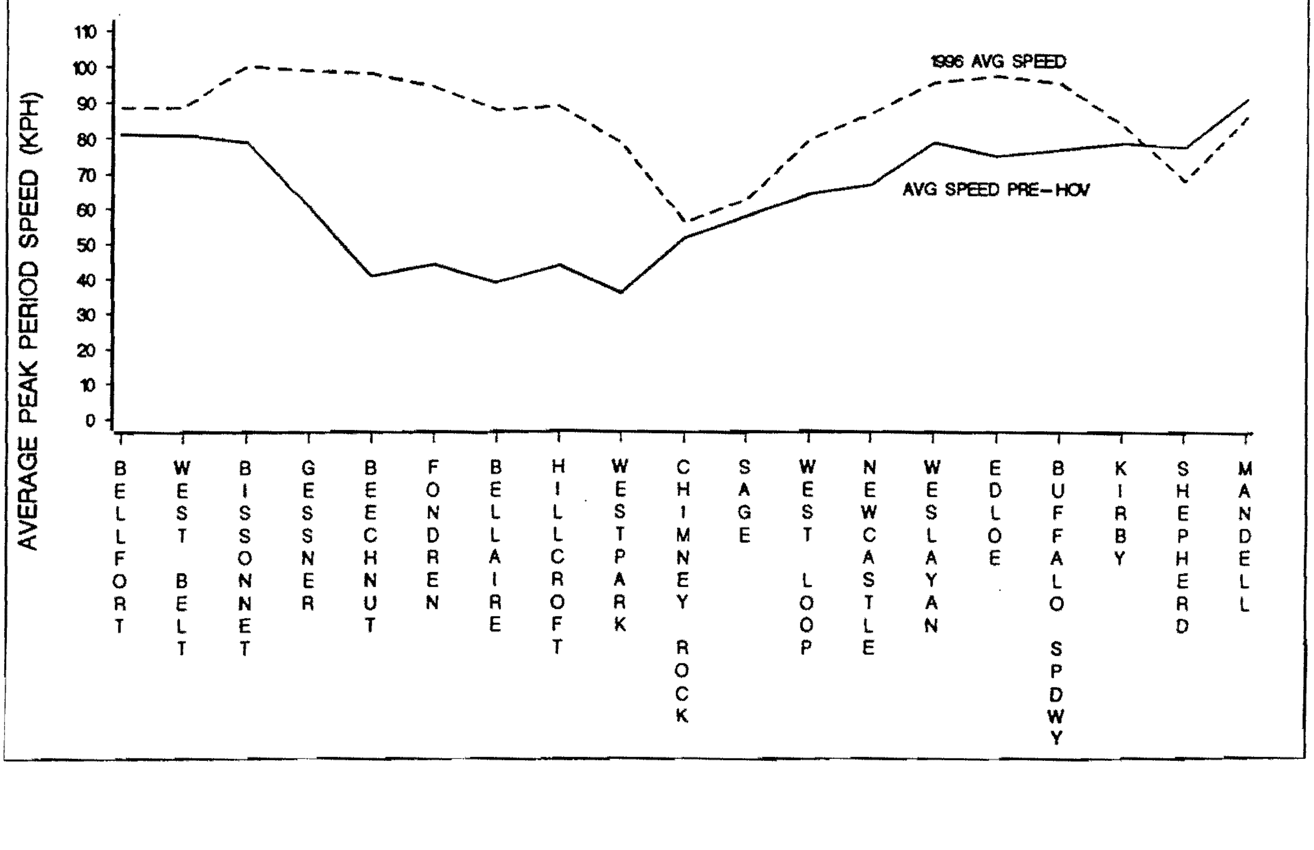


FIGURE E-9. SOUTHWEST FREEWAY (U.S. 59S) MAINLANE AND HOV LANE
A.M. PEAK HOUR PERSON TRIPS

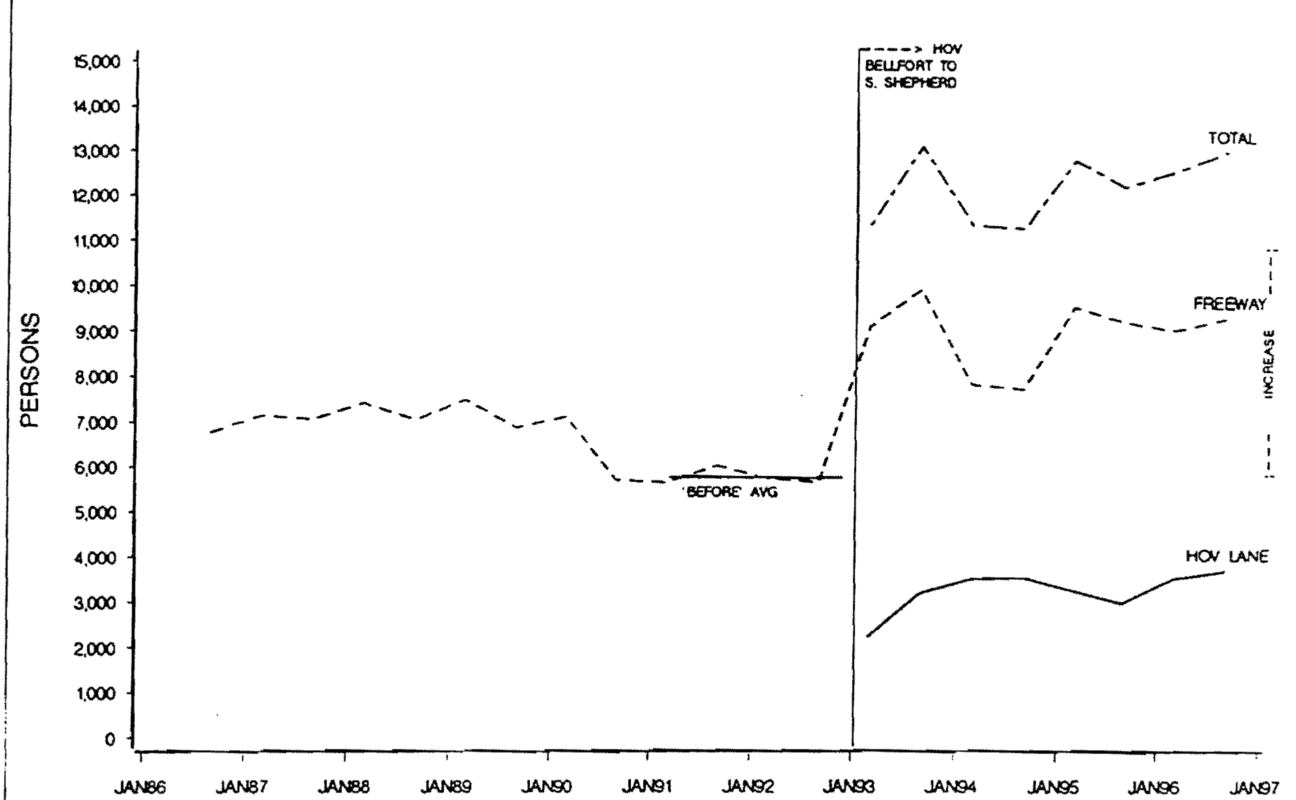


FIGURE E-10. SOUTHWEST FREEWAY (U.S. 59S) MAINLANE AND HOV LANE
A.M. PEAK PERIOD PERSON TRIPS

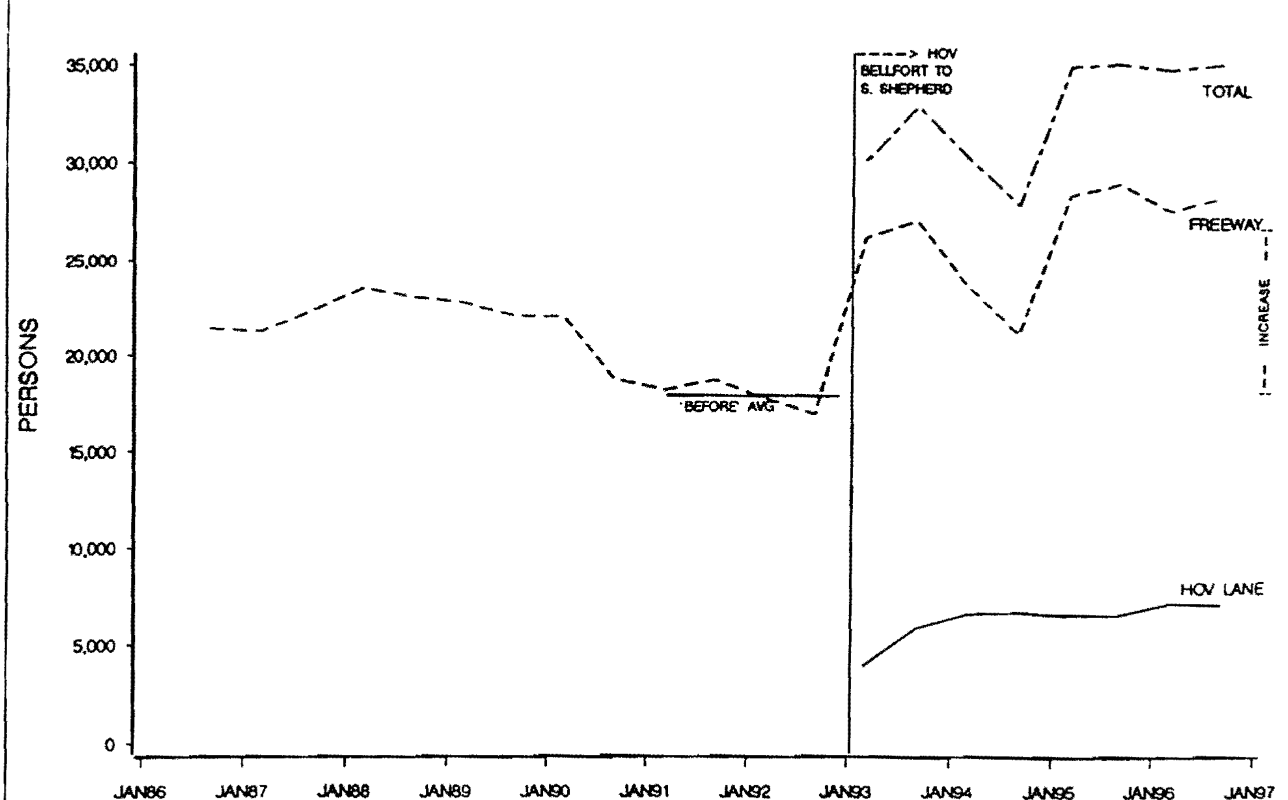


FIGURE E-11. SOUTHWEST FREEWAY (U.S. 59S) MAINLANE AND HOV LANE
A.M. PEAK HOUR AVERAGE OCCUPANCY

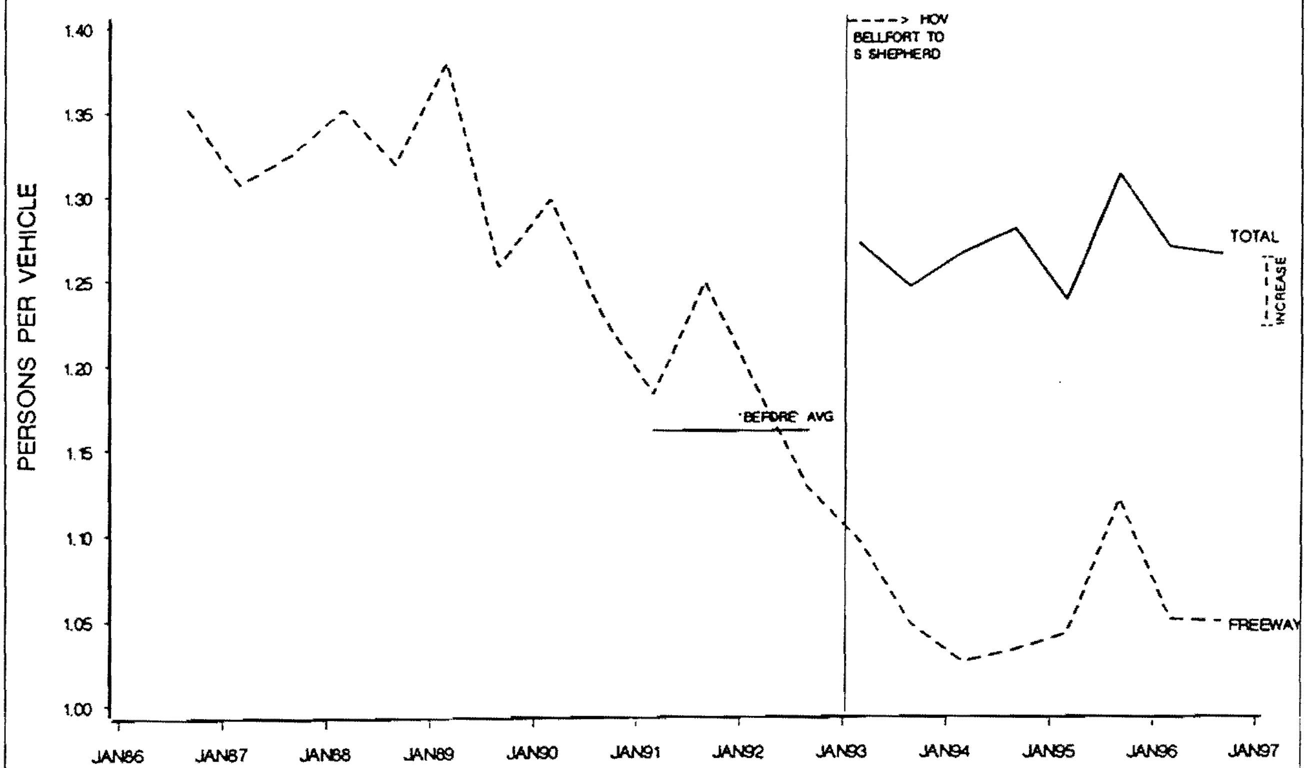
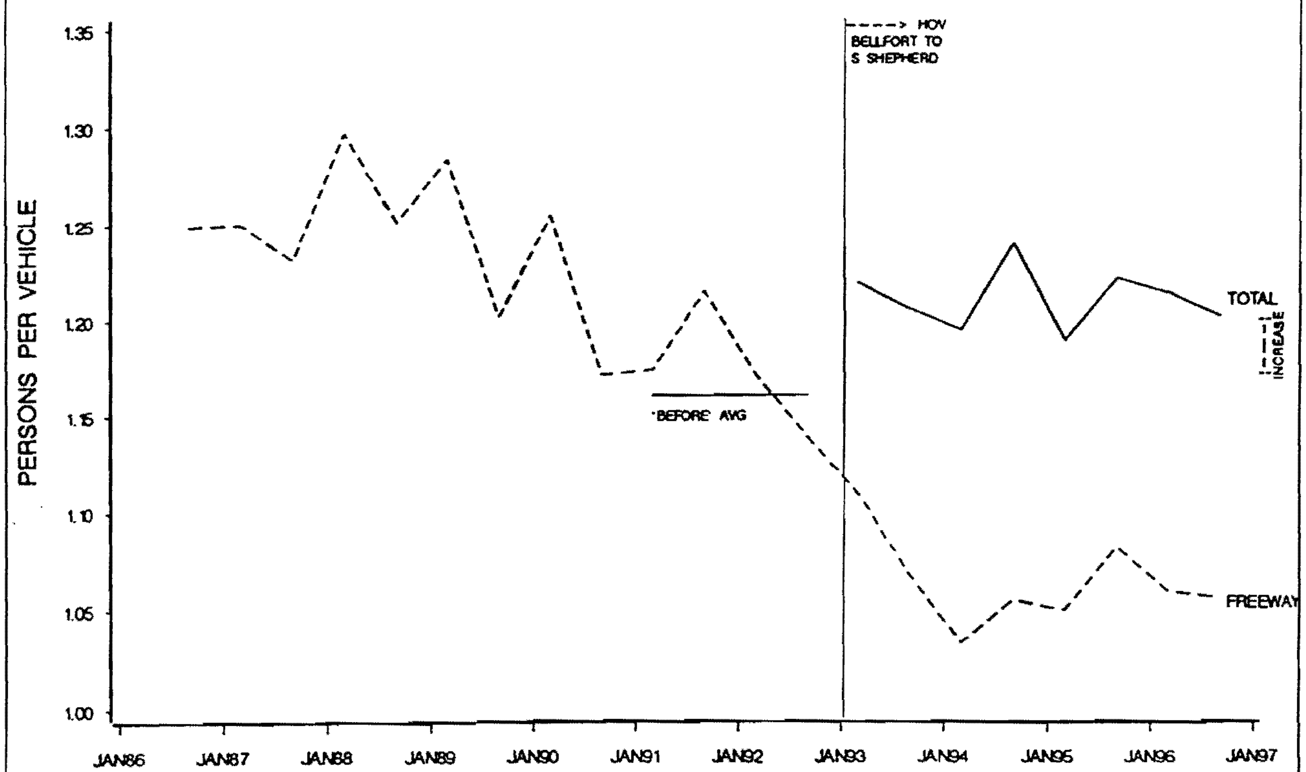


FIGURE E-12. SOUTHWEST FREEWAY (U.S. 59S) MAINLANE AND HOV LANE
A.M. PEAK PERIOD AVERAGE OCCUPANCY



COMBINED FREEWAY AND HOV LANE DATA

TOTAL PERSON MOVEMENT

- Percent by HOV lane, a.m. peak.
  - At Pinemont, the HOV lane is responsible for 39 percent of peak-hour person movement (HOV lane = 3,598; freeway = 9,121) and 26 percent of peak-period (HOV lane = 7,112; freeway = 27,206) person movement (Figure E-10).
- Increase in a.m. person movement at Pinemont
  - Provision of the HOV lane increased total directional lanes by 33 percent.
  - Total peak-hour person movement has increased by 123 percent, from 5,685 to 12,719 (Figure E-9). Peak-period person movement has increased by 97 percent, from 17,357 to 34,318 Figure E-10).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak-hour is 1.29, an 11 percent increase over the pre-HOV lane occupancy (Figure E-11). Occupancy in the peak-period is 3 percent 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 127 percent compared to pre-HOV lane levels (Figure E-14). In the a.m. peak-period, the increase has been 93 percent. 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 (five freeway lanes plus one HOV lane) has increased by 70 percent 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 increase of 22 percent in bus ridership has resulted (Figure E-16). In the peak-period, a 24 percent decrease has occurred in bus vehicle trips, and a 8 percent increase 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 32 percent to a current level of 1,904 (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-13. A.M. PEAK HOUR AVERAGE OCCUPANCY
SOUTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

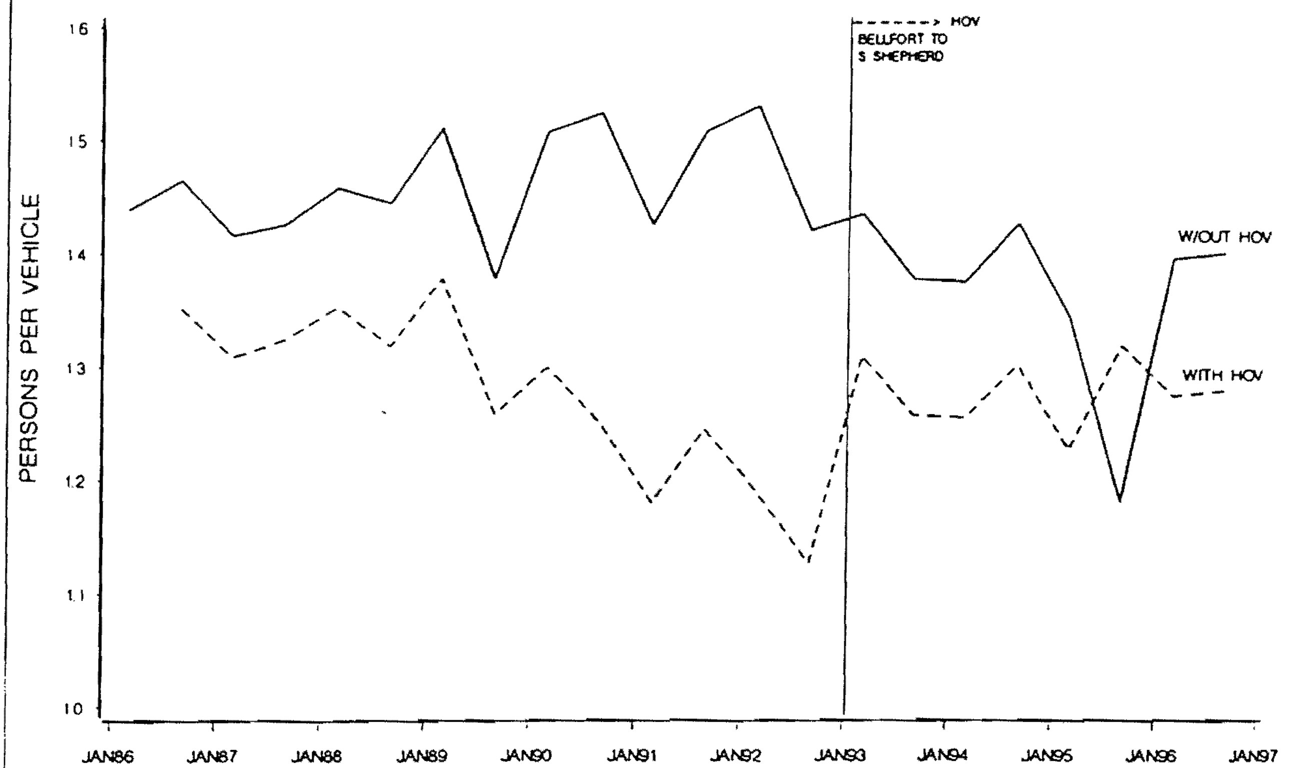


FIGURE E-14. SOUTHWEST FREEWAY (U.S. 59) MAINLANE AND HOV LANE
A.M. PEAK HOUR 2+ CARPOOL UTILIZATION

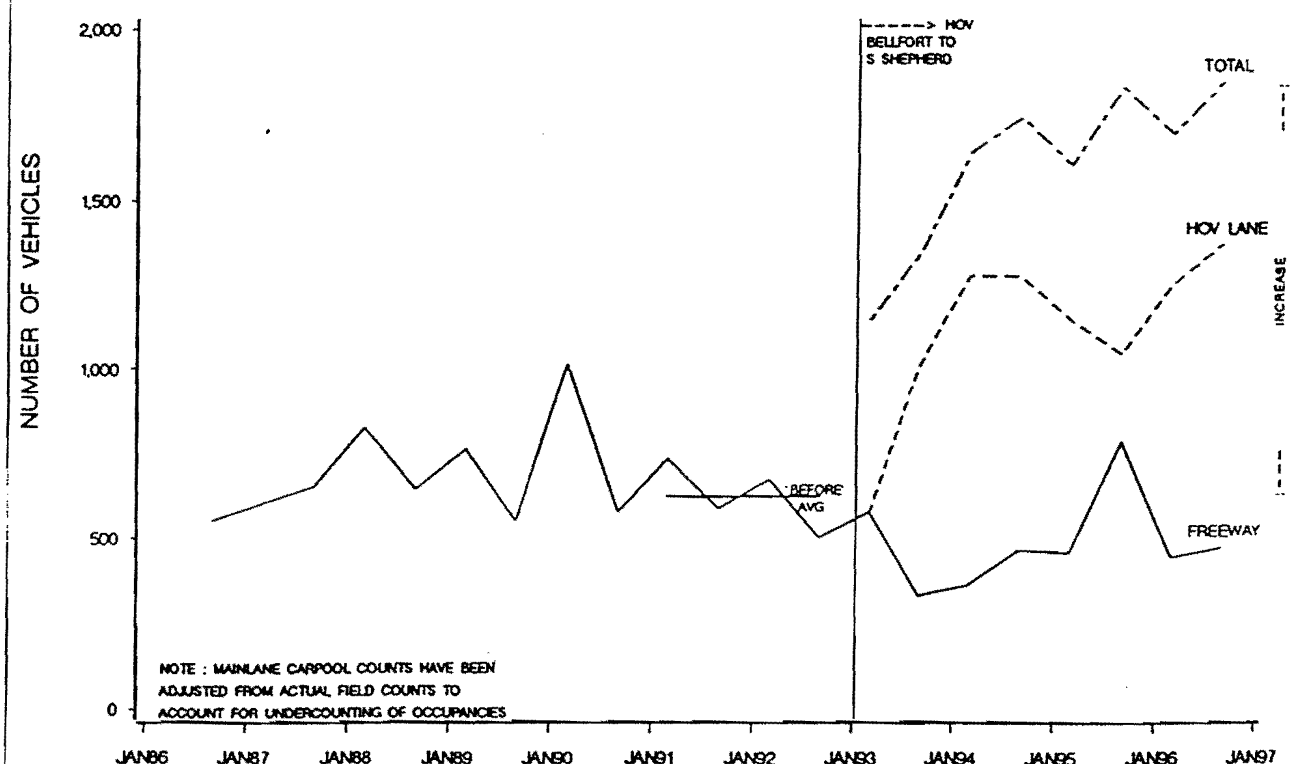


FIGURE E-15. A.M. PEAK HOUR FREEWAY PER LANE EFFICIENCY
SOUTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

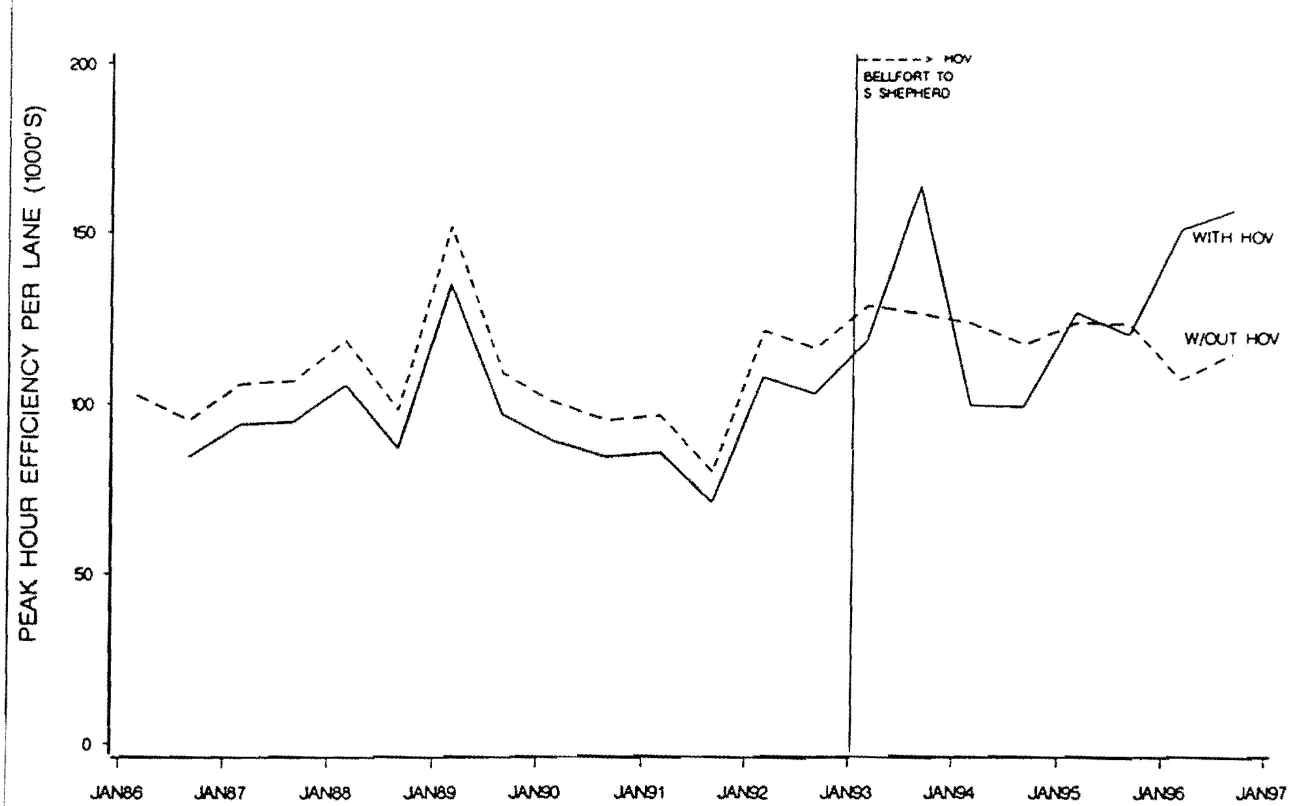


FIGURE E-16. SOUTHWEST FREEWAY (U.S. 59S) MAINLANE AND HOV LANE
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS

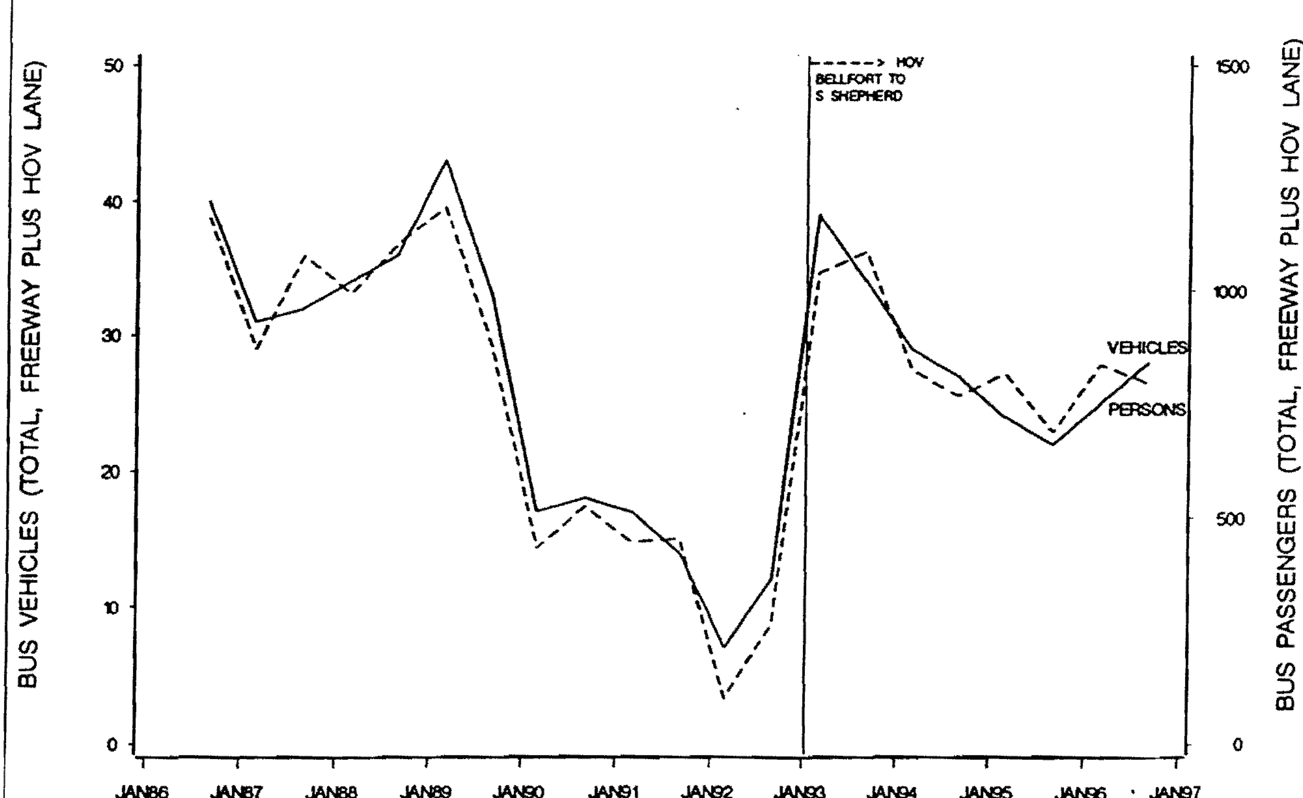


FIGURE E-17. SOUTHWEST FREEWAY (U.S. 59S) MAINLANE AND HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS

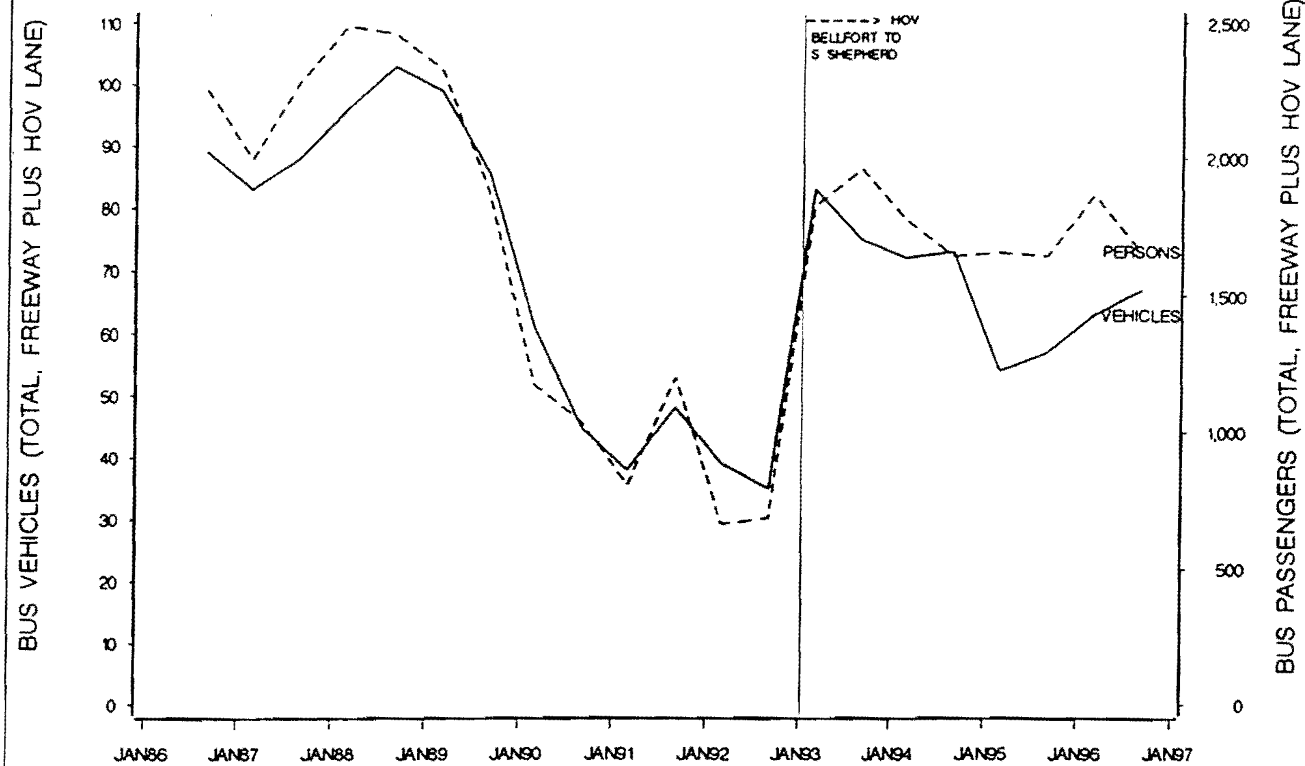


FIGURE E-18. A.M. PEAK PERIOD BUS PASSENGER TRIPS
TOTAL, FREEWAY PLUS HOV LANE VOLUMES
SOUTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

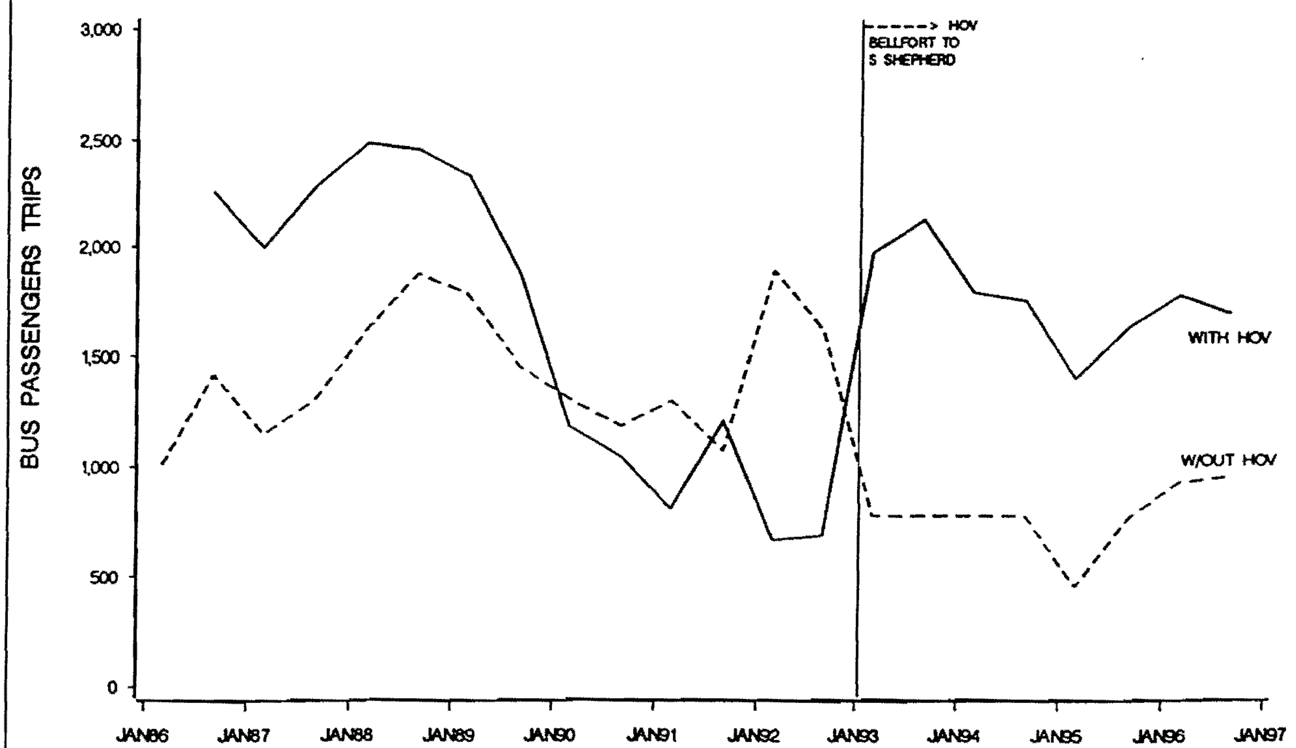


FIGURE E-19. SOUTHWEST FREEWAY (U.S. 59S) CORRIDOR PARK-AND-RIDE DEMAND

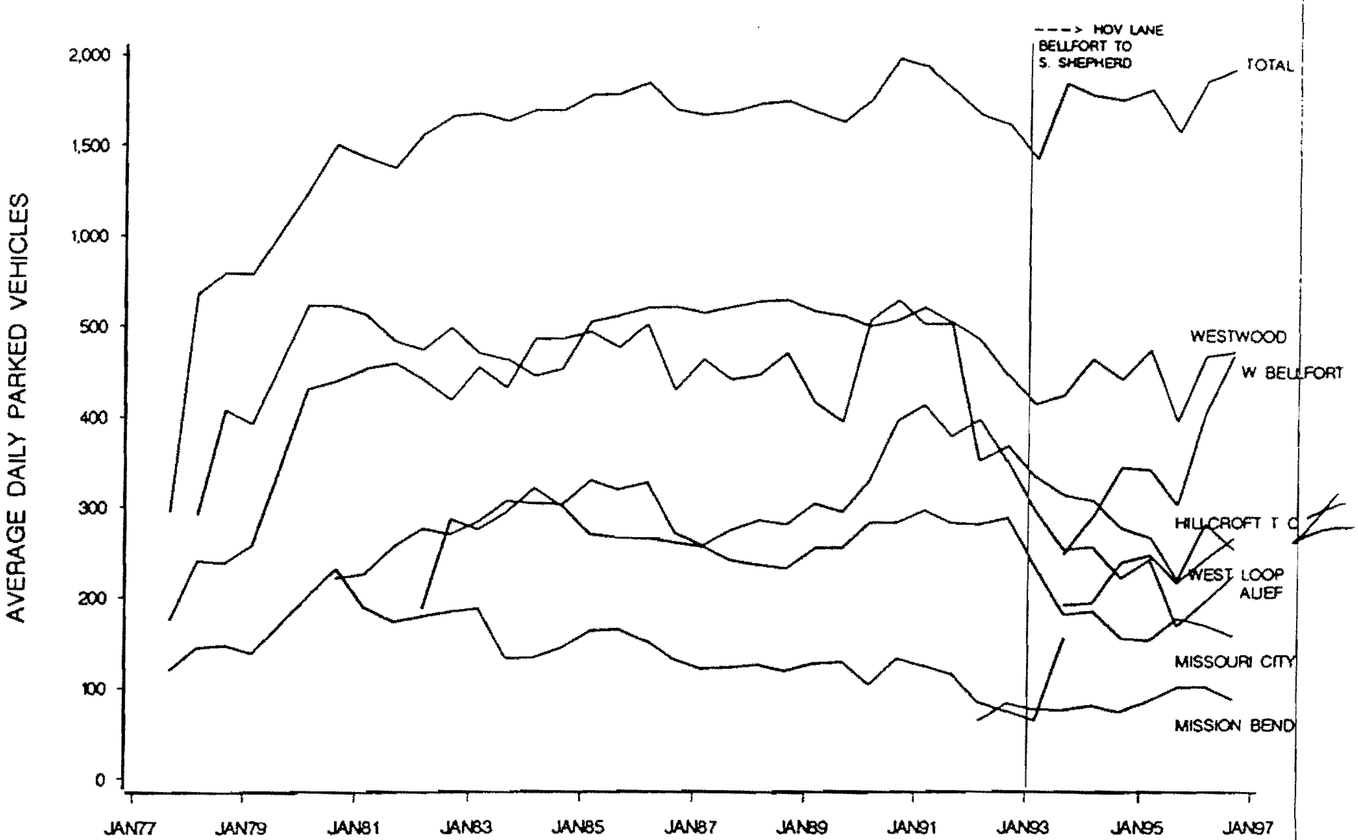
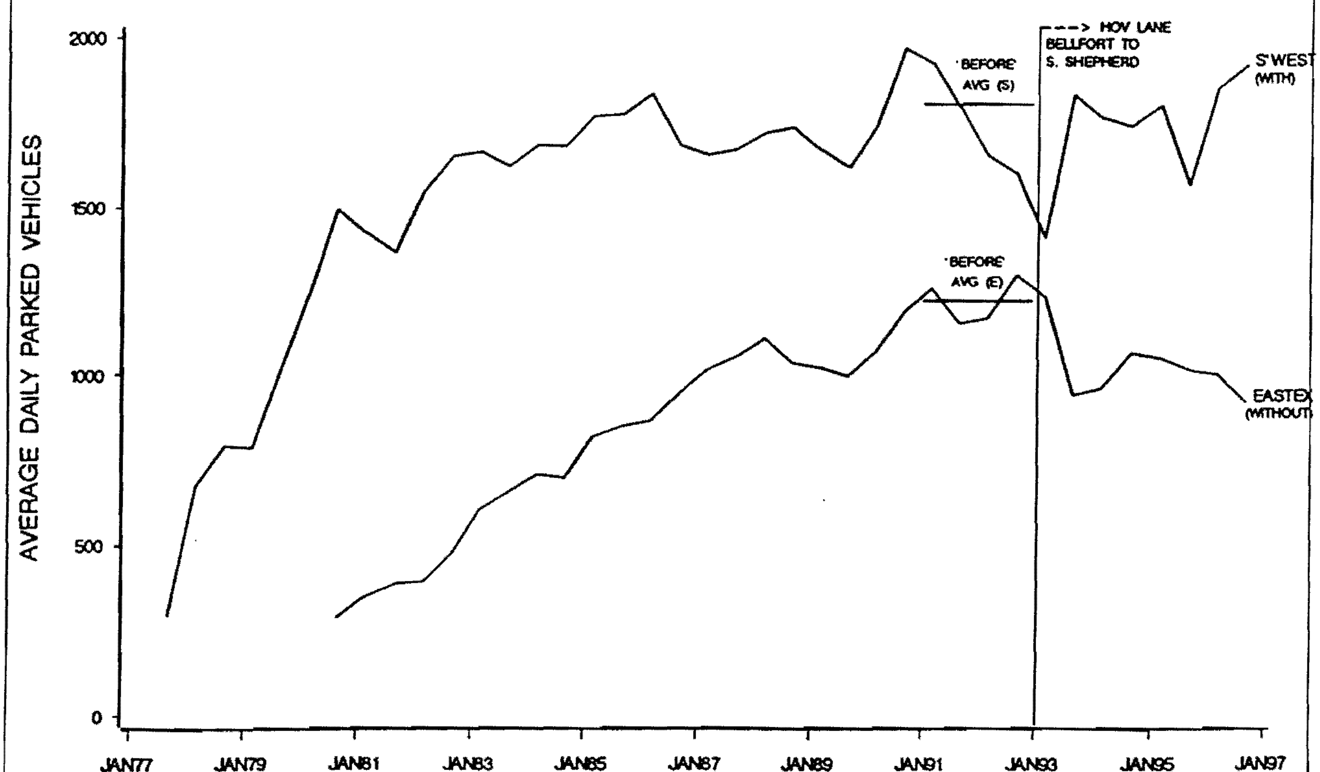


FIGURE E-20. AVERAGE DAILY VEHICLES PARKED AT PARK-AND-RIDE LOTS
SOUTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE



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, 1996

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)		8.4 (5.2)	
HOV Lane Cost (millions of 1990 dollars)		16.1	
Person-Movement			
Peak-Hour (7:00-8:00 a.m.)		3,535	---
Peak-Period (6:00-9:00 a.m.)		6,975	---
Total Daily		13,423	---
Vehicle Volumes			
Peak-Hour		1,261	---
Peak-Period		2,521	---
Vehicle Occupancy, Peak Hour (persons/veh)		2.8	---
Accident Rate (i.e. Injury accidents/100 MVK [/100 MVM])[1]		11.5 (18.5)	---
Vehicle Breakdowns (VMK/Breakdown [VMT/Breakdown])		53,425 (33,123)	---
Violation Rate (6:00-9:00 a.m.)		0.9%	---
Peak-Hour Lane Efficiency (1000's)[2]		318 (198)	---
Annual Discounted Benefits (millions)[3]		30.0	---
Annual Delay Savings (millions)[4]		2.3	
Freeway Mainlane Data (see note)			
Person Movement	7,689	7,749	0%
Peak-Hour	23,030	21,143	-8%
Peak-Period (6:00-9:00 a.m.)			
Vehicle Volume	5,692	7,253	+27%
Peak-Hour	17,946	19,675	+10%
Peak-Period	1.35	1.07	-21%
Vehicle Occupancy, Peak Hour (persons/veh)	14.0 (22.6)	17.4 (28.0)	+24%
Accident Rate (i.e. Injury accidents/100 MVK [/100 MVM])[1]			
Avg. Operating Speed[5] (kph [mph])	34 (21)	43 (26)	+24%
Peak-Hour	48 (30)	60 (37)	+25%
Peak-Period	66 (41)	81 (50)	+23%
Peak-Hour Lane Efficiency (1000's)[2]			

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 km (5.2 mi). "Before" data are for the period 9/90 through 9/91. "After" data are for the period from 10/91 to 12/96. Current files include only officer-reported accidents. 1996 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 average annual delay, reduced vehicle operating costs and reduced accident costs generated by MicroBENCOST over a 20-year life.

[4]per MicroBENCOST, over 20-year life.

[5]From Jim Miller to Central Expressway, the distance is 8.4 km (5.2 mi).

Table F-1. Summary of A.M. Peak-Direction East R. L. Thornton Freeway and HOV Lane Data, December 1996 (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	11,284	+47%
Peak-Period	23,030	28,118	+22%
Vehicle Volume			
Peak-Hour	5,692	8,514	+50%
Peak-Period	17,946	22,196	+24%
Vehicle Occupancy			
Peak-Hour	1.35	1.33	-1%
Peak-Period	1.26	1.27	+1%
2+ Carpool Volumes			
Peak-Hour	596	1,587	+166%
Peak-Period	1,903	3,499	+84%
Travel Time (minutes)			
Peak-Hour	14.7[1]	5.9[2]	-60%
Peak-Period	10.6[1]	5.7[2]	-46%
Peak-Hour Lane Efficiency (1000's)[3]	66 (41)	145 (80)	+120%
Transit Data			
Bus Vehicle Trips			
Peak-Hour	41	64	+56%
Peak-Period	103	139	+35%
Bus Passenger Trips			
Peak-Hour	1,283	1,041	-19%
Peak-Period	2,819	2,089	-26%
Bus Occupancy (persons/bus)			
Peak-Hour	31.3	16.3	-48%
Peak-Period	27.4	15.0	-45%
Vehicles Parked in Corridor Park-and-Ride Lots	847	819	-3%
Bus Operating Speed[4] (kph [mph])			
Peak-Hour	34 (21)[1]	90 (56)[2]	+165%
Peak-Period	48 (30)[1]	94 (58)[2]	+96%

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

[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 km (5.2 mi). The HOV lane is in place over this section.

Table F-2. Comparison of Measures of Effectiveness, Freeway with (East R.L.Thornton, I-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	1.33	-1%
Freeway w/o HOV lane	1.25	1.21	-3%
Peak-Hour 2+ Carpool Volume			
Freeway w/HOV lane	596	1,587	+166%
Freeway w/o HOV lane	802	679	-15%
Bus Passengers, Peak-Period			
Freeway w/HOV lane	2,819	2,089	-26%
Freeway w/o HOV lane	2,540	1,453	-54%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	847	819	-3%
Freeway w/o HOV lane	425	480	+13%
Facility Per Lane Efficiency[1]			
Freeway w/HOV lane	66 (41)	145 (80)	+120%
Freeway w/o HOV lane	108 (67)	104 (64)	-4%

[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 km [3.3 mi]) opened September 23, 1991.
- The morning operation (5.3 km [3.3 mi]) opened September 30, 1991.
- The morning operation (8.4 km [5.2 mi]) extended November 4, 1991.
- The evening operation (8.4 km [5.2 mi]) extended February, 1996.
- 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 (Table F-3) shows other dates.

- 9/23/91 Evening lane opens Central Expressway to Dolphin Road (5.3 km [3.3 mi]), used by buses and vans.
- 9/30/91 Morning lane opens Dolphin Road to Central Expressway (5.3 km [3.3 mi]), 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 km [5.2 mi, total]).
- 11/25/91 DART adds bus service to existing routes.
- 5/93 Reconstruction of Fair Park Bridge begins, AM operating hours shortened.
- 7/93 AM operating hours extended.
- 12/93 E. Garland Park-and-Ride closes.
- 3/94 Audoban Park-and-Ride closes. Lake Ray Hubbard Park-and-Ride opens.
- 7/94 Westbound Auxillary Lane added at contraflow lane egress.
- 4/95 Construction of PM extension begins.
- 10/95 AM operating limits shortened due to construction of PM extension.
- 2/96 Construction of PM extension ends. Reconstruction of Fair Park Bridge ends.

Table F-3. Estimated Capital Cost (millions), East R. L. Thornton HOV Lane

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1996 dollars
HOV Lane and Ramps (1990)			
Barrier	$6.0	1.27	$7.6
Barrier Machine(s)	0.9	1.27	1.1
Contraflow Lane	5.6	1.27	7.1
Support Vehicles	0.2	1.27	0.3
TOTAL COST	$12.7		$16.1
COST PER KILOMETER (8.4 km [5.2 mi])	$1.5 ($2.4)		$1.9 ($3.1)

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

PERSON MOVEMENT

- In September 1996, the HOV lane served an average of 13,423 person trips per day.
- A.M. Peak-Hour, 3,535 persons/hour.
  - 1,170 (32 percent) by bus, 23 (1 percent) by vanpool, 2,514 (67 percent) by carpool, and three by motorcycle (Figure F-1).
  - Average HOV lane vehicle occupancy = 2.86 persons/vehicle.

- A.M. Peak-Period, 6,975 persons.
  - 2,270 (32 percent) by bus, 41 (1 percent) by vanpool, by carpool 4,839 (67 percent), and seven by motorcycle (Figure F-2).

VEHICLE MOVEMENT

- A.M. Peak-Hour, 1,261 vph
  - 54 (4 percent) buses, 4 (1 percent) vans, 1,224 (95 percent) carpools, and three (1 percent) by motorcycle (Figure F-3).
- A.M. Peak-Period, 2,521 vehicles
  - 125 (5 percent) buses, 10 (1 percent) vans, 2,355 (93 percent) carpools, and seven (1 percent) by motorcycle (Figure F-4).

ACCIDENT RATE

- For the period from October 1991 through December 1996, the HOV lane accident rate was 11.5 injury accidents per 100 million vehicle kilometers of travel (18.5 injury accidents per 100 million vehicle miles).

VEHICLE BREAKDOWN RATES

- As measured for 1/93 to 12/96, the following rate has been observed.
  - The weighted average for all vehicle types is one breakdown per 53,425 VKT (33,123 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 0.87 percent.

PEAK-HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is used as a measure of the efficiency of a lane. For the HOV lane, this value (expressed in 1000's) is approximately 318 (3,535 passengers at 90 kph) or 198 (3,535 passengers at 56 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane experienced an average travel time savings of six minutes during the morning peak hour in 1996 (Table F-4, Figure F-5).

Table F-4. Travel Time Savings for R. L. Thornton HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1996)

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	
Westbound A.M. Travel Time Savings for Thornton HOV Lane								
Section from Jim Miller to Central Expressway								
6:00	5.56	5.56	0.10	77	0	65	142	14
6:15	6.79	5.82	0.97	239	4	135	378	366
6:30	7.85	5.65	2.20	349	0	145	494	1,087
6:45	7.98	5.66	2.32	458	5	153	615	1,425
7:00	8.51	5.77	2.74	527	8	273	808	2,209
7:15	12.32	5.98	6.35	654	8	284	946	6,002
7:30	13.88	5.60	8.29	672	13	278	963	7,974
7:45	14.24	5.75	8.49	611	3	185	799	6,783
8:00	10.82	5.53	5.29	480	3	168	651	3,441
8:15	8.23	5.46	2.78	388	5	130	523	1,451
8:30	6.67	5.54	1.13	284	4	88	375	425
8:45	5.84	5.47	0.38	187	5	53	245	92
Peak Period Total				4,926	58	1,957	6,939	31,269
Eastbound P.M. Travel Time Savings for Thornton HOV Lane								
Section from Central Expressway to Dolphin								
4:00	5.61	5.92	-0.30	227	4	145	376	-114
4:15	6.02	5.76	0.26	293	1	150	444	116
4:30	6.13	6.21	-0.08	464	2	106	572	-47
4:45	7.74	6.61	1.13	511	4	275	790	890
5:00	7.56	6.29	1.28	542	17	219	777	991
5:15	9.09	6.16	2.93	649	1	345	995	2,912
5:30	9.13	6.58	2.55	467	3	225	694	1,770
5:45	7.04	5.96	1.08	392	6	145	543	588
6:00	7.94	5.74	2.20	343	5	120	468	1,030
6:15	8.01	5.87	2.14	239	1	83	322	690
6:30	7.97	5.36	2.61	198	1	68	267	695
6:45	8.63	5.76	2.87	132	1	48	181	520
Peak Period Total				4,457	46	1,929	6,429	10,041

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 remained the same relative to pre-HOV conditions (Figure F-6).

- In the a.m. peak-period, person movement has decreased by 8 percent relative to pre-HOV conditions (Figure F-7).

VEHICLE VOLUME

- In the a.m. peak-hour, vehicle volume has increased by 27 percent relative to pre-HOV conditions (Figure F-6).

- In the a.m. peak-period, vehicle volume has increased by 10 percent relative to pre-HOV conditions (Figure F-7).

VEHICLE OCCUPANCY

- In the a.m. peak-hour, mainlane occupancy has decreased by 21 percent relative to pre-HOV conditions (from 1.35 to 1.07).

- In the a.m. peak-period, mainlane occupancy has decreased by 17 percent, 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 12/96, the freeway accident rate was 17.4 accidents/100 MVK (28.0 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 24 percent in the peak-hour and 25 percent in the peak-period (Figure F-8).

PEAK-HOUR LANE EFFICIENCY

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

- For the freeway mainlanes, an increase in per lane efficiency of 23 percent has occurred.

FIGURE F-1. EAST R.L. THORNTON FREEWAY (IH 30E) HOV LANE
A.M. PEAK HOUR HOV LANE PERSON MOVEMENT

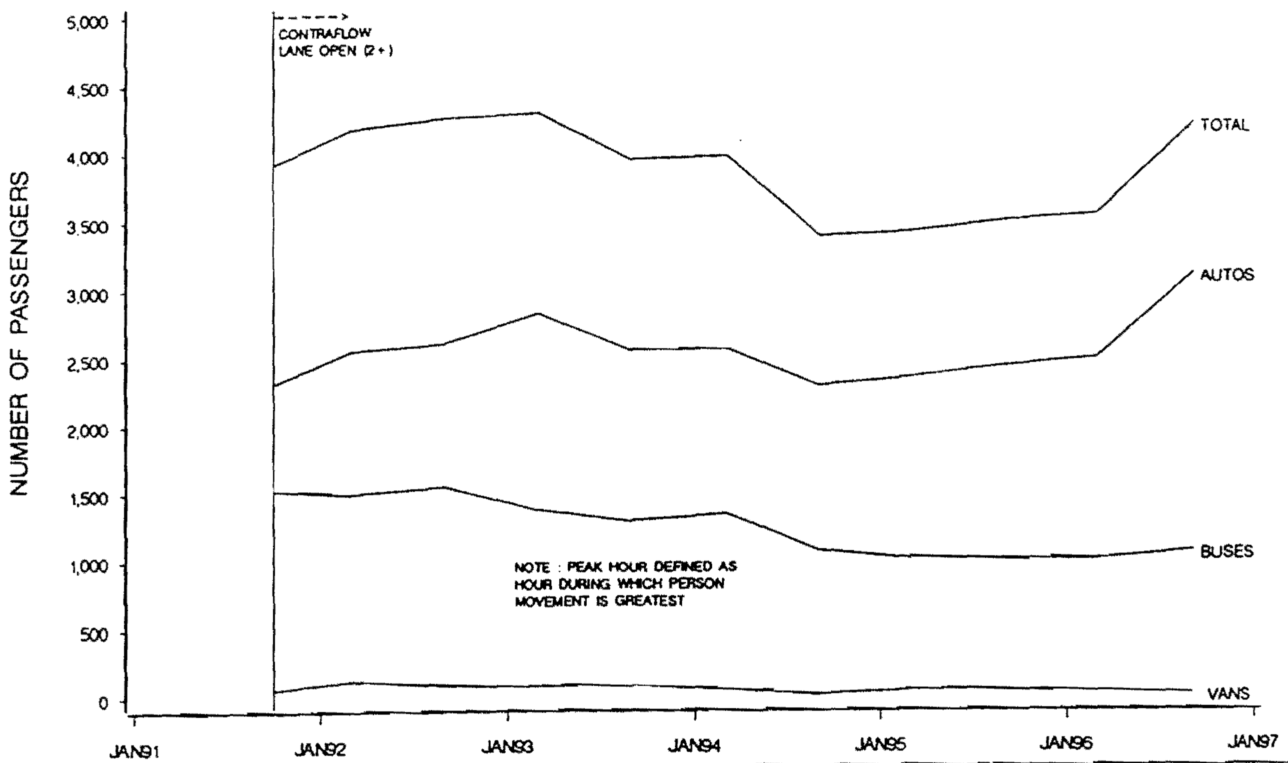


FIGURE F-2. EAST R.L. THORNTON FREEWAY (IH 30E) HOV LANE
A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT

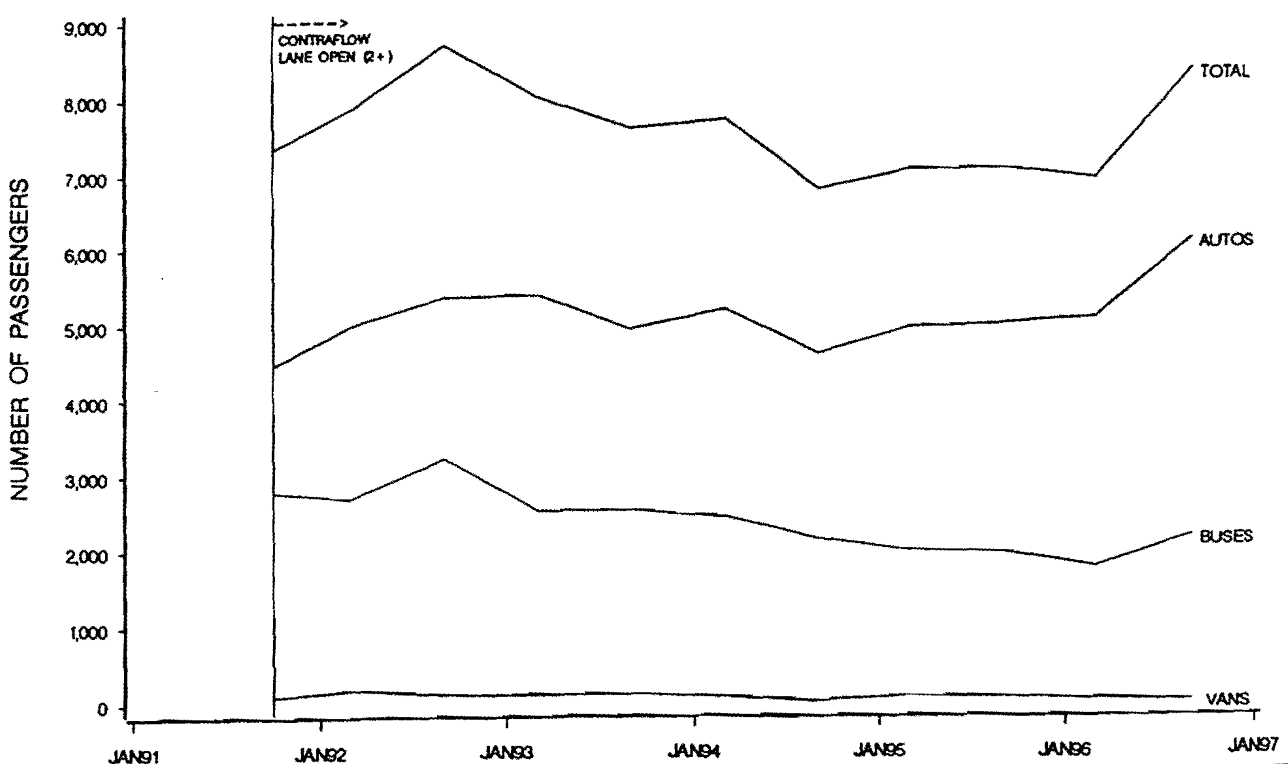


FIGURE F-3. EAST R.L. THORNTON FREEWAY (IH 30E) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION

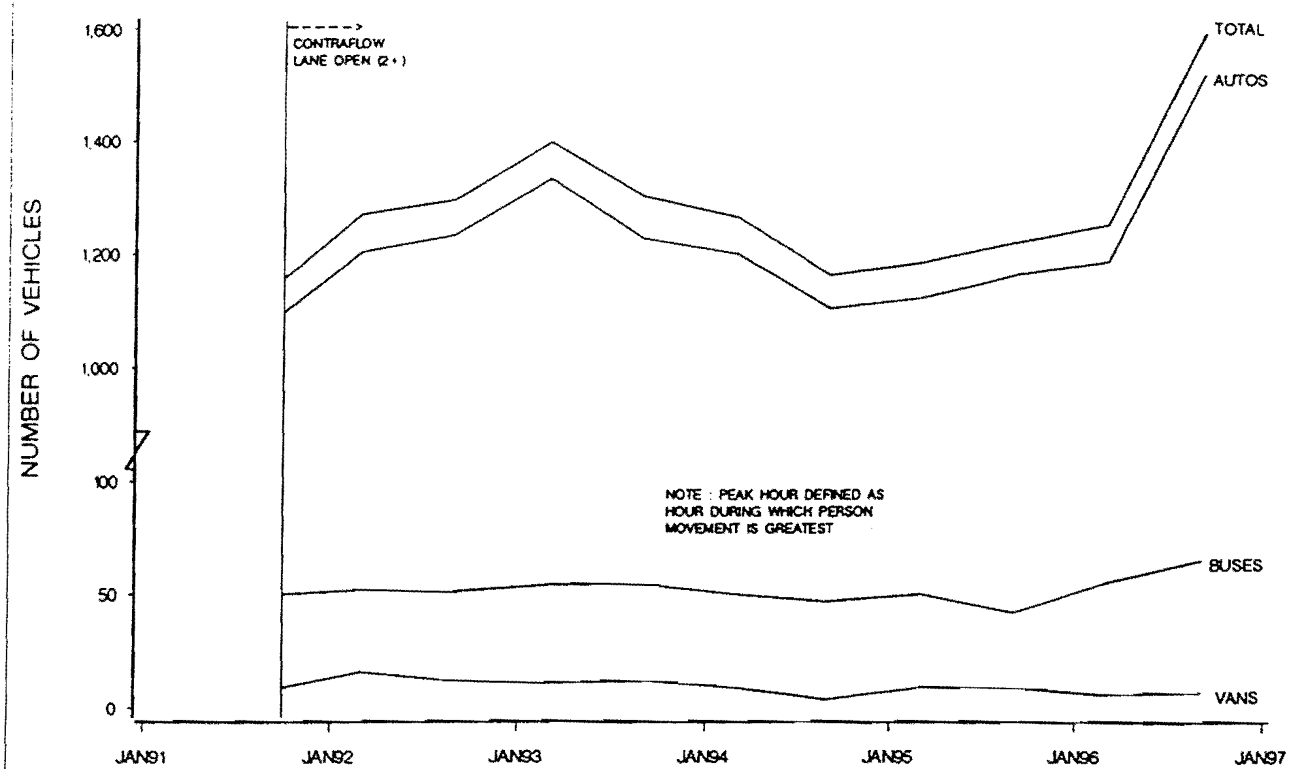


FIGURE F-4. EAST R.L. THORNTON FREEWAY (IH 30E) HOV LANE
A.M. PEAK PERIOD HOV LANE VEHICLE UTILIZATION

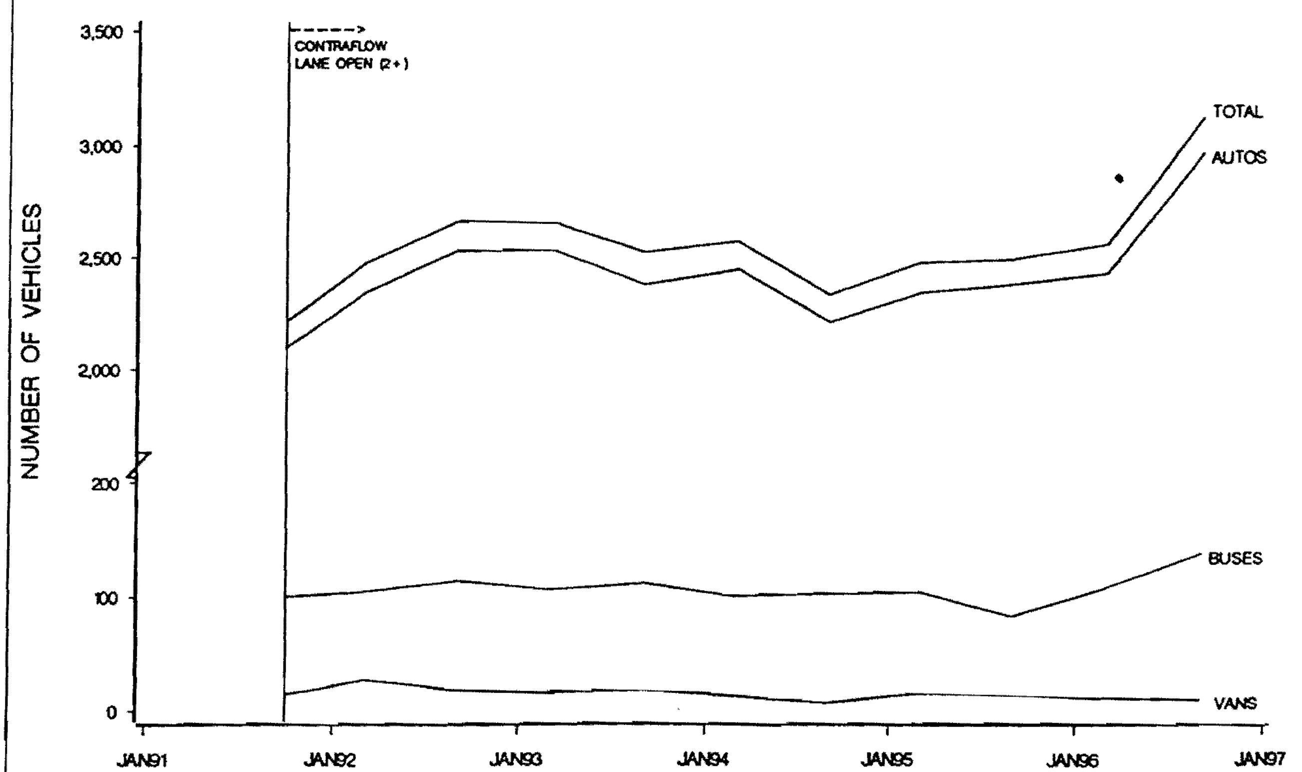


FIGURE F-5. EAST R.L. THORNTON (IH 30E) MAINLANES AND HOV LANE A.M. TRAVEL TIME

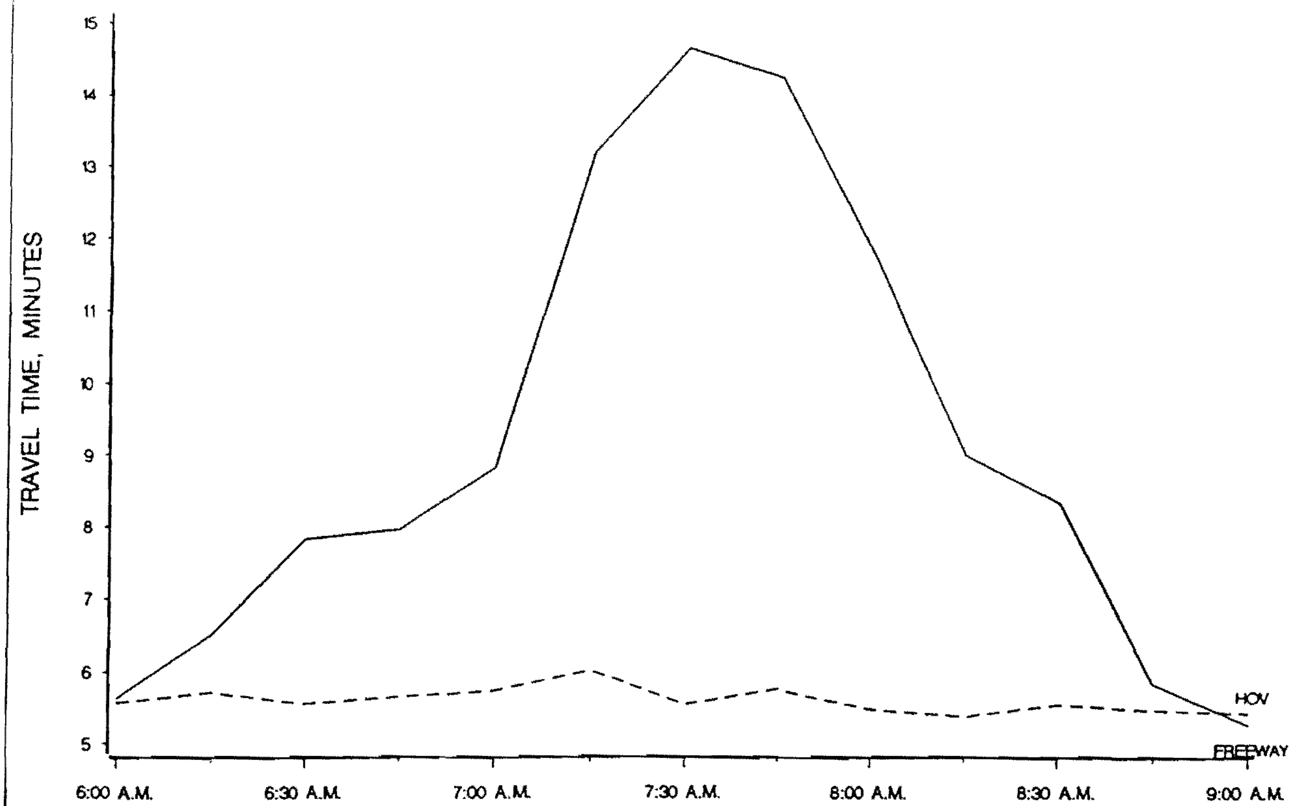


FIGURE F-6. EAST R.L. THORNTON FREEWAY (IH 30E)
A.M. PEAK HOUR MAINLANE TRIPS

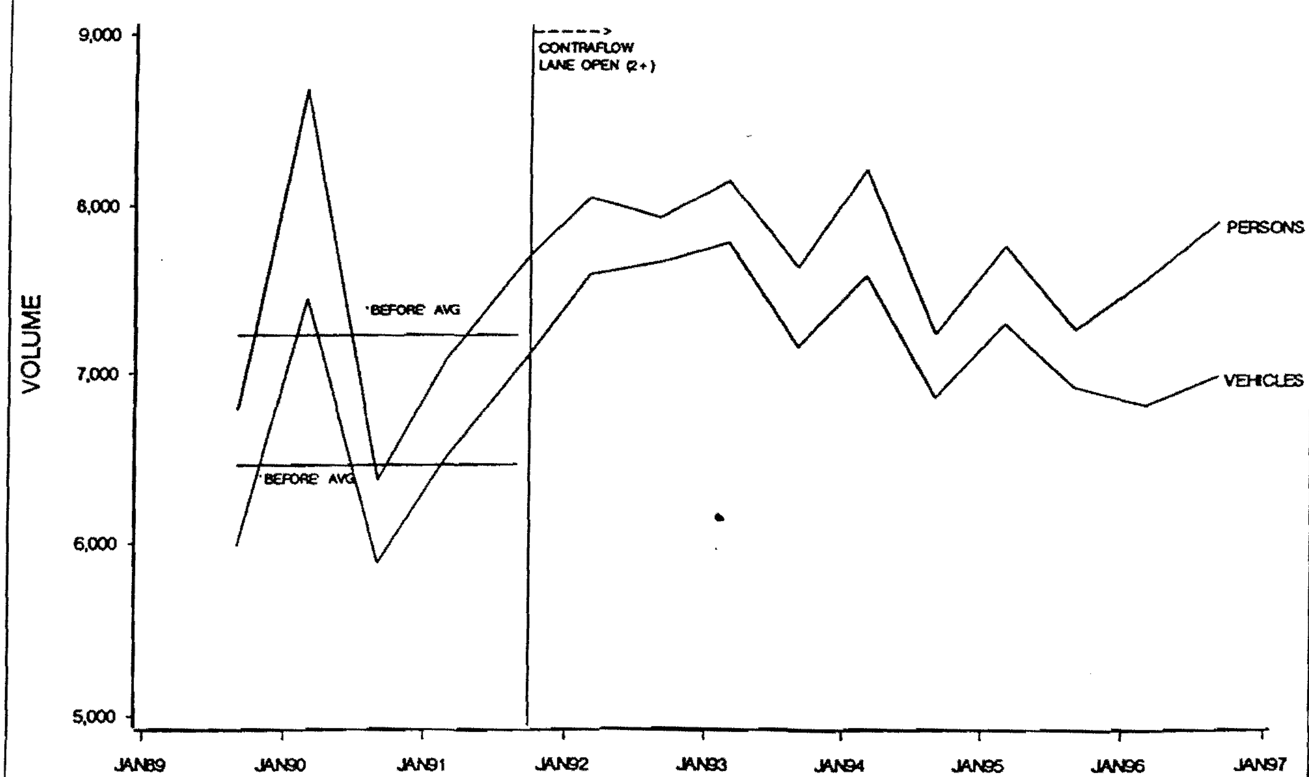


FIGURE F-7. EAST R.L. THORNTON FREEWAY (IH 30E)
A.M. PEAK PERIOD MAINLANE TRIPS

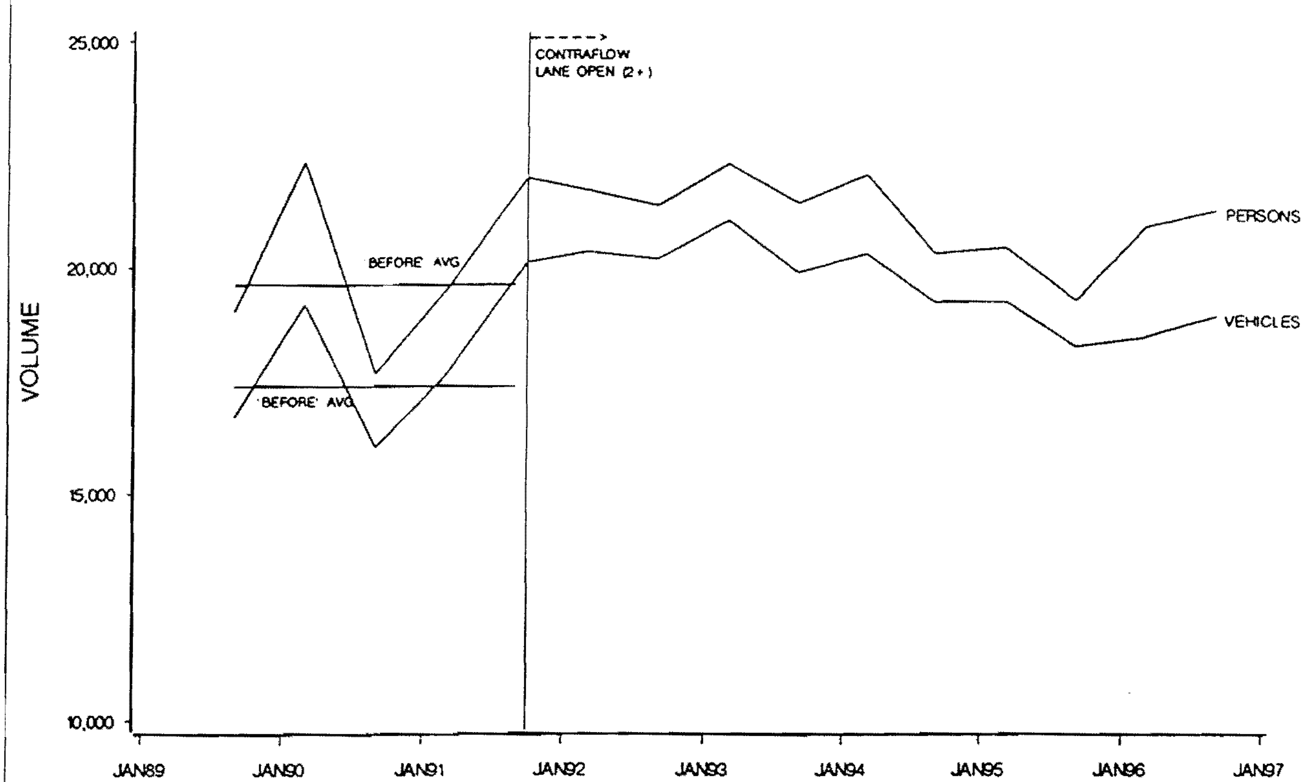
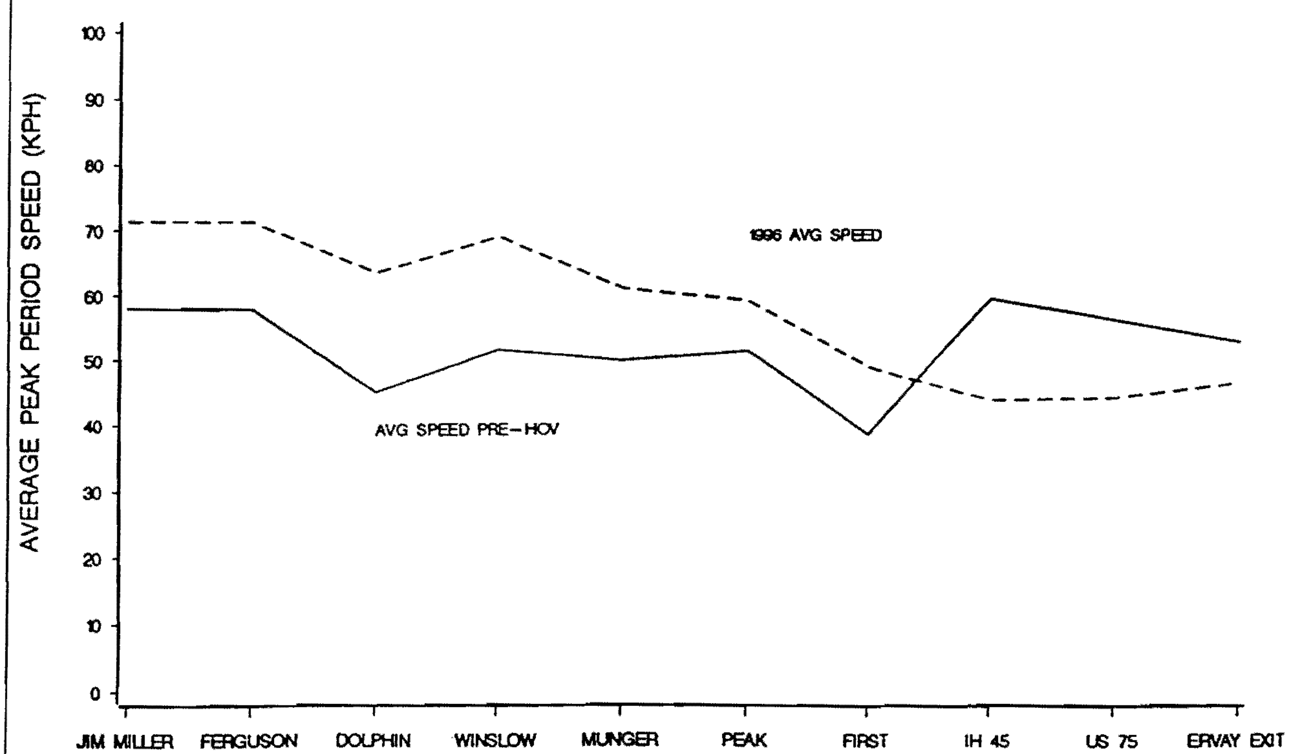


FIGURE F-8. EAST R.L. THORNTON (IH 30E) MAINLANE TRAVEL TIME AND SPEED SURVEY
WESTBOUND, JIM MILLER TO ERVAY EXIT
A.M. PEAK PERIOD



COMBINED FREEWAY MAINLANE AND HOV LANE DATA

TOTAL PERSON MOVEMENT

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

    - The HOV lane is responsible for 31 percent of peak-hour person movement (HOV lane = 3,535; freeway = 7,749) and 25 percent of peak-period (HOV lane = 6,975; freeway = 21,143) 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 percent in the peak-period.

    - Total peak-hour person movement has increased by 47 percent from 7,689 to 11,284 (Figure F-9). Peak-period person movement has increased by 22 percent from 23,030 to 28,118 (Figure F-10).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak-hour is 1.33 -- a 1 percent 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 166 percent compared to pre-HOV lane levels (Figure F-14).

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 (four freeway lanes plus one HOV lane) has increased by 120 percent 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 56 percent since the HOV lane opened, and a 19 percent decrease in bus ridership has also resulted (Figure F-16). In the peak-period, a 35 percent increase has occurred in bus trips and a 26 percent 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 decreased three percent to a current level of 819 (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 percent). (Figure F-20).

FIGURE F-9. EAST R.L. THORNTON FREEWAY (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK HOUR PERSON TRIPS

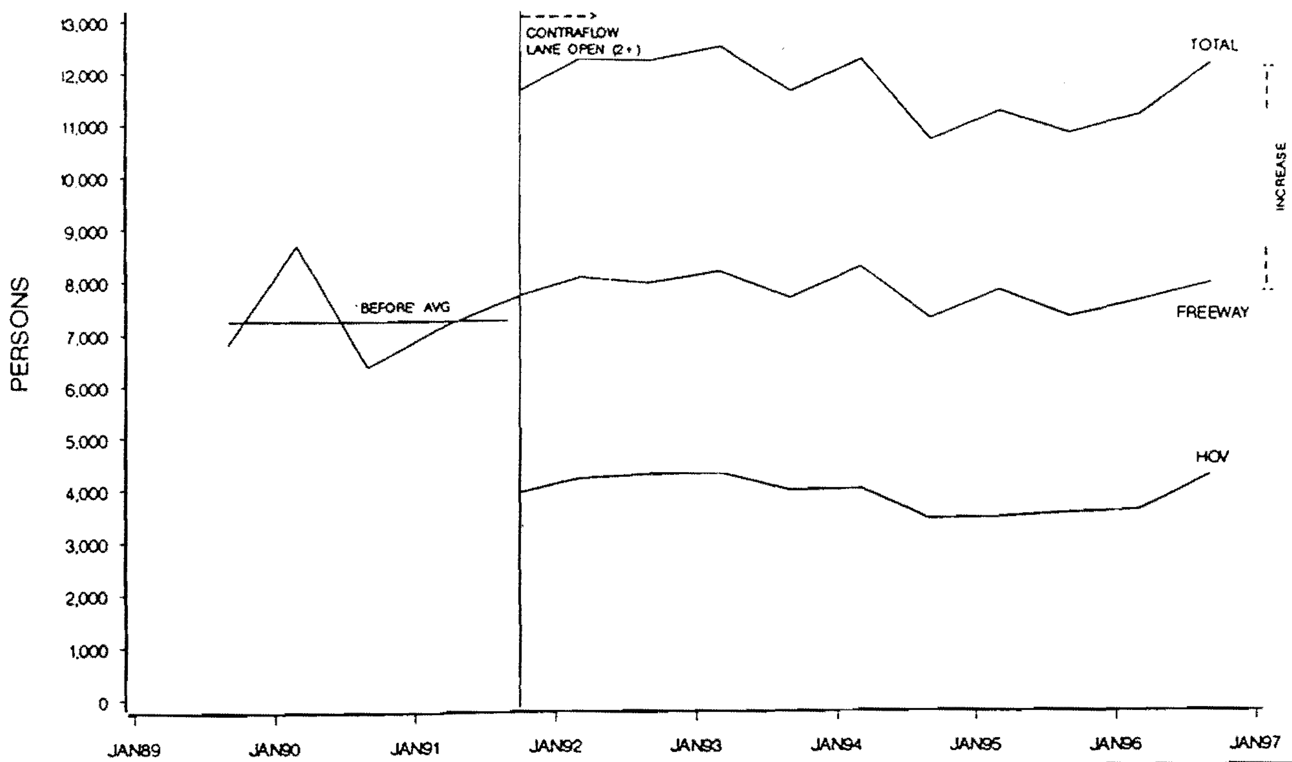


FIGURE F-10. EAST R.L. THORNTON FREEWAY (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK PERIOD PERSON TRIPS

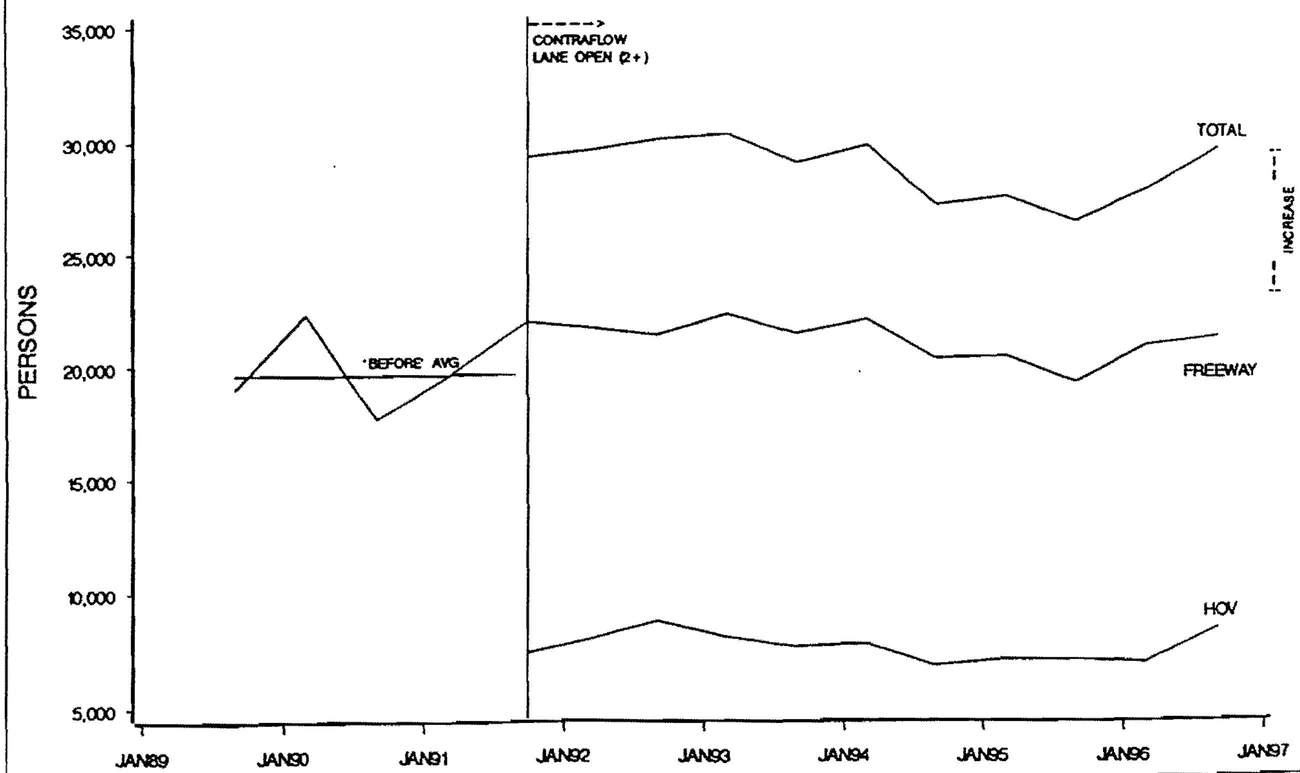


FIGURE F-11. EAST R.L. THORNTON FREEWAY (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK HOUR AVERAGE OCCUPANCY

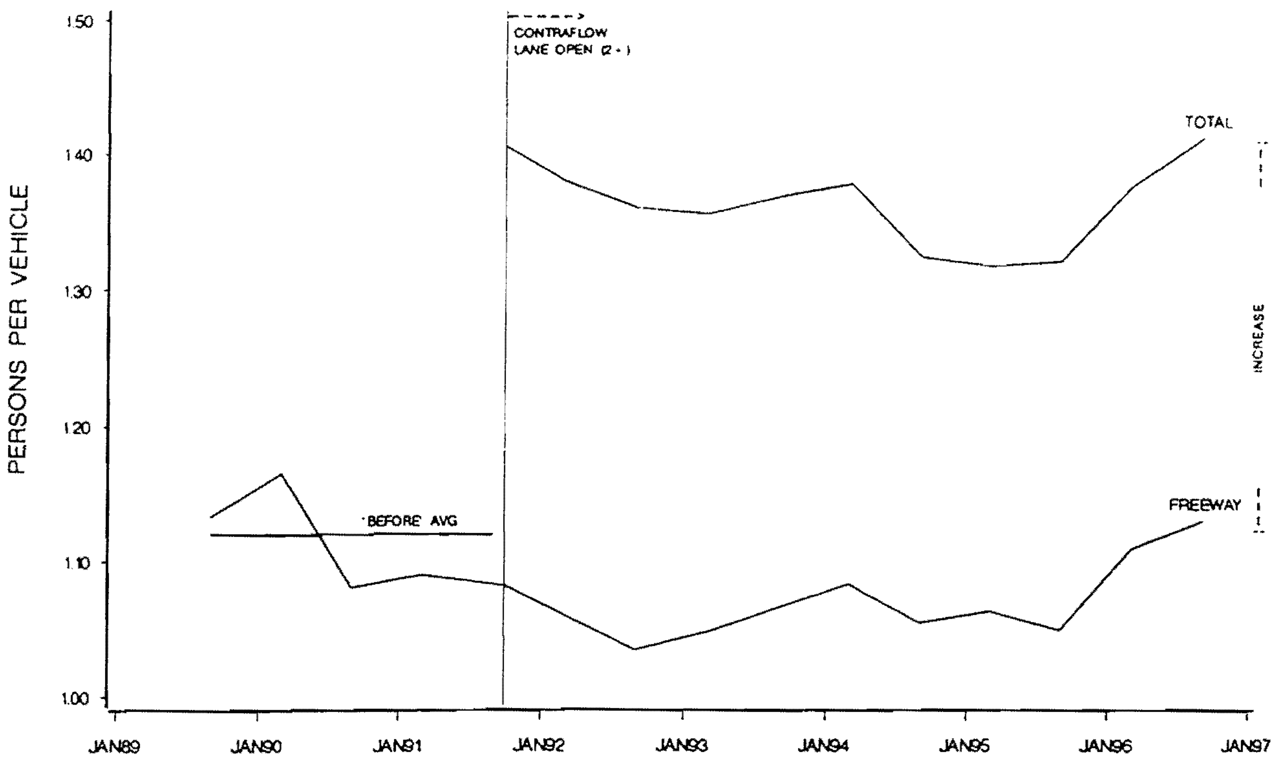


FIGURE F-12. EAST R.L. THORNTON FREEWAY (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK PERIOD AVERAGE OCCUPANCY

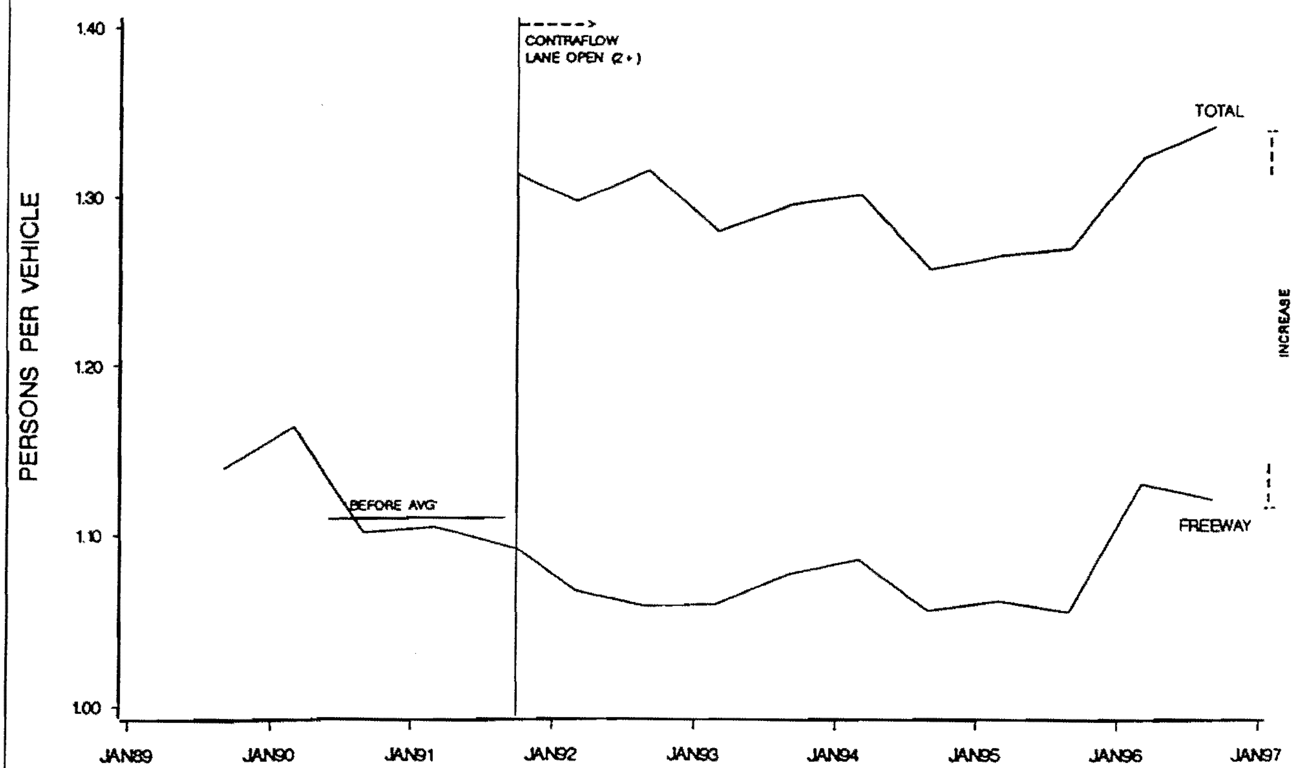


FIGURE F-13. A.M. PEAK HOUR AVERAGE OCCUPANCY
EAST R.L. THORNTON (IH 30E) AND FREEWAY WITHOUT HOV LANE

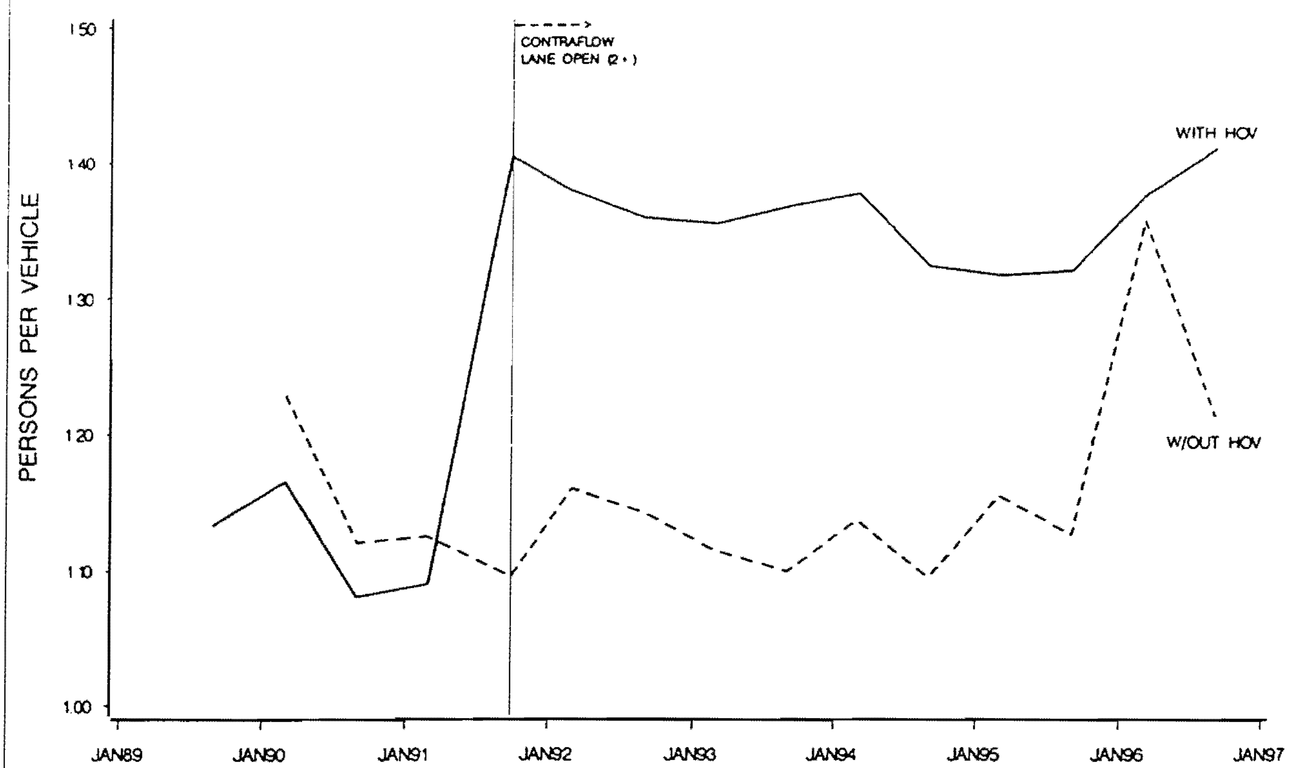


FIGURE F-14. EAST R.L. THORNTON (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK HOUR 2+ CARPOOL UTILIZATION

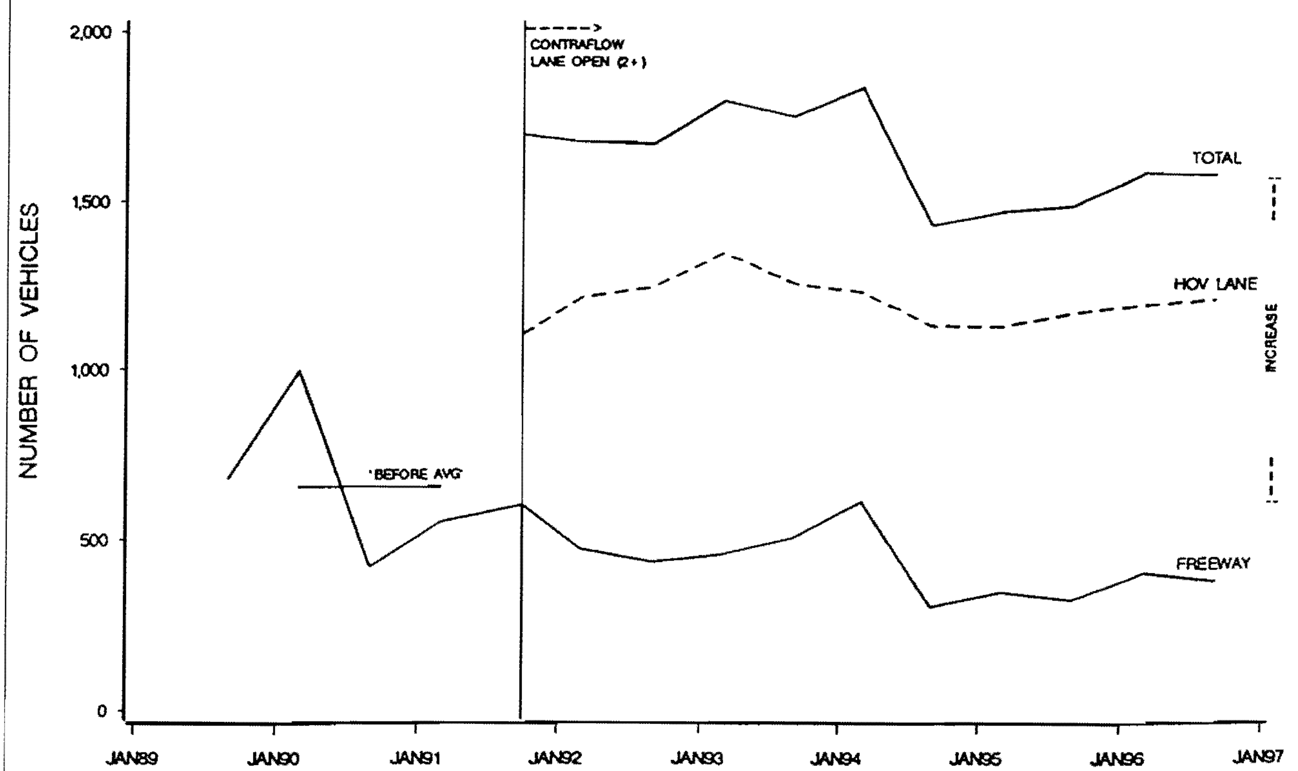


FIGURE F-15. A.M. PEAK HOUR FREEWAY PER LANE EFFICIENCY
EAST R.L. THORNTON FREEWAY AND FREEWAY WITHOUT HOV LANE

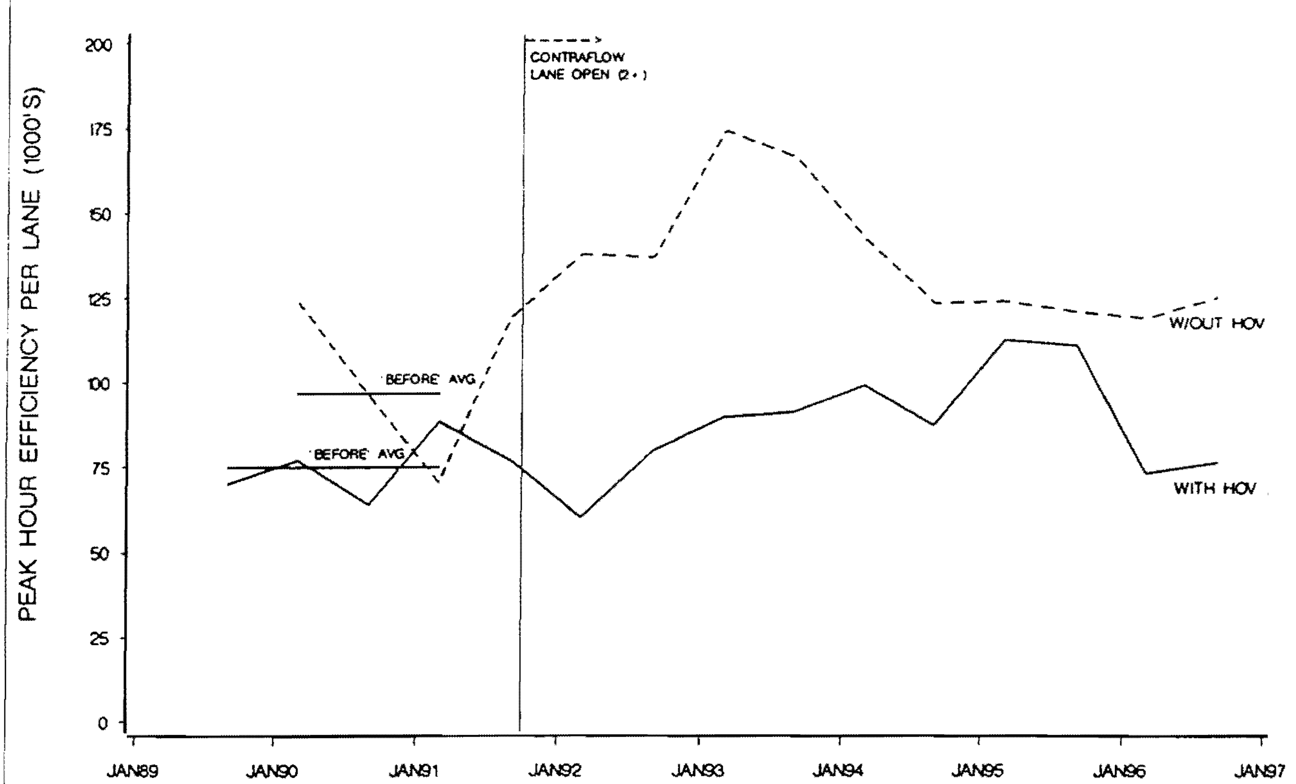


FIGURE F-16. EAST R.L. THORNTON (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS

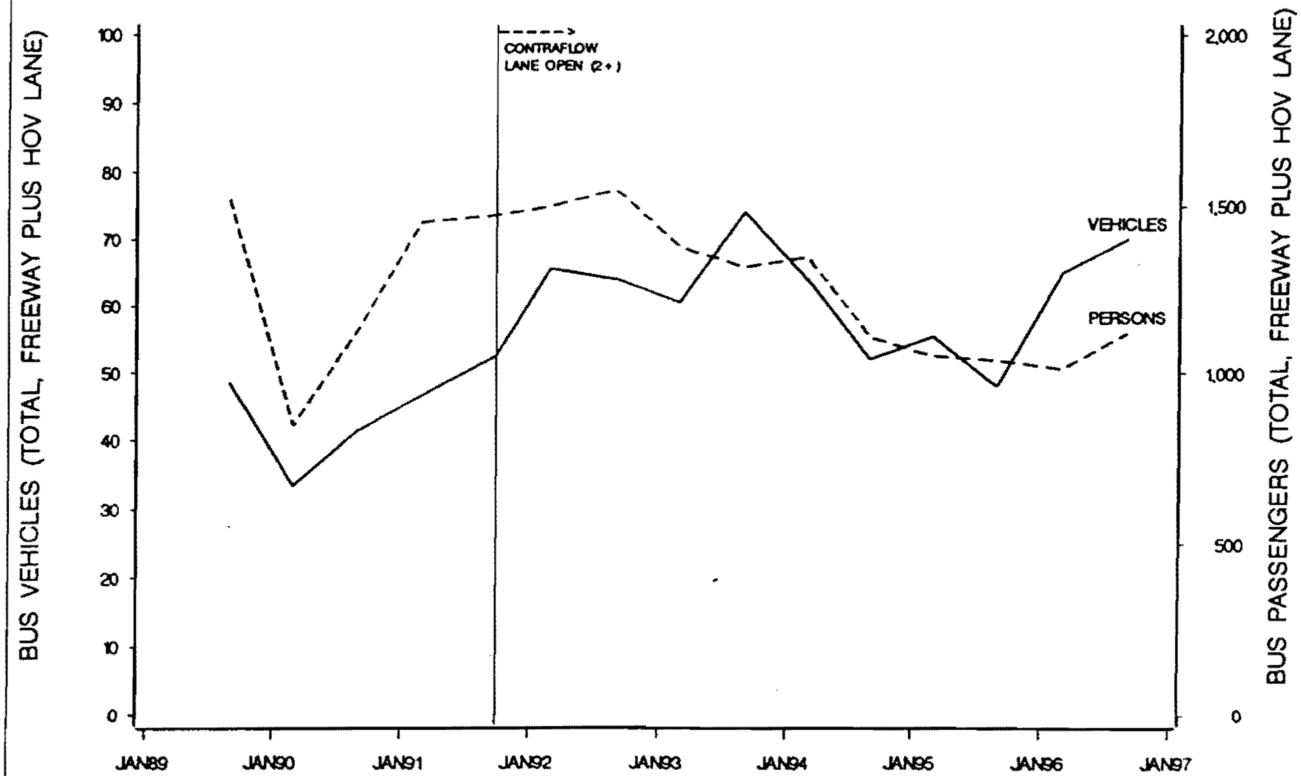


FIGURE F-17. EAST R.L. THORNTON (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS

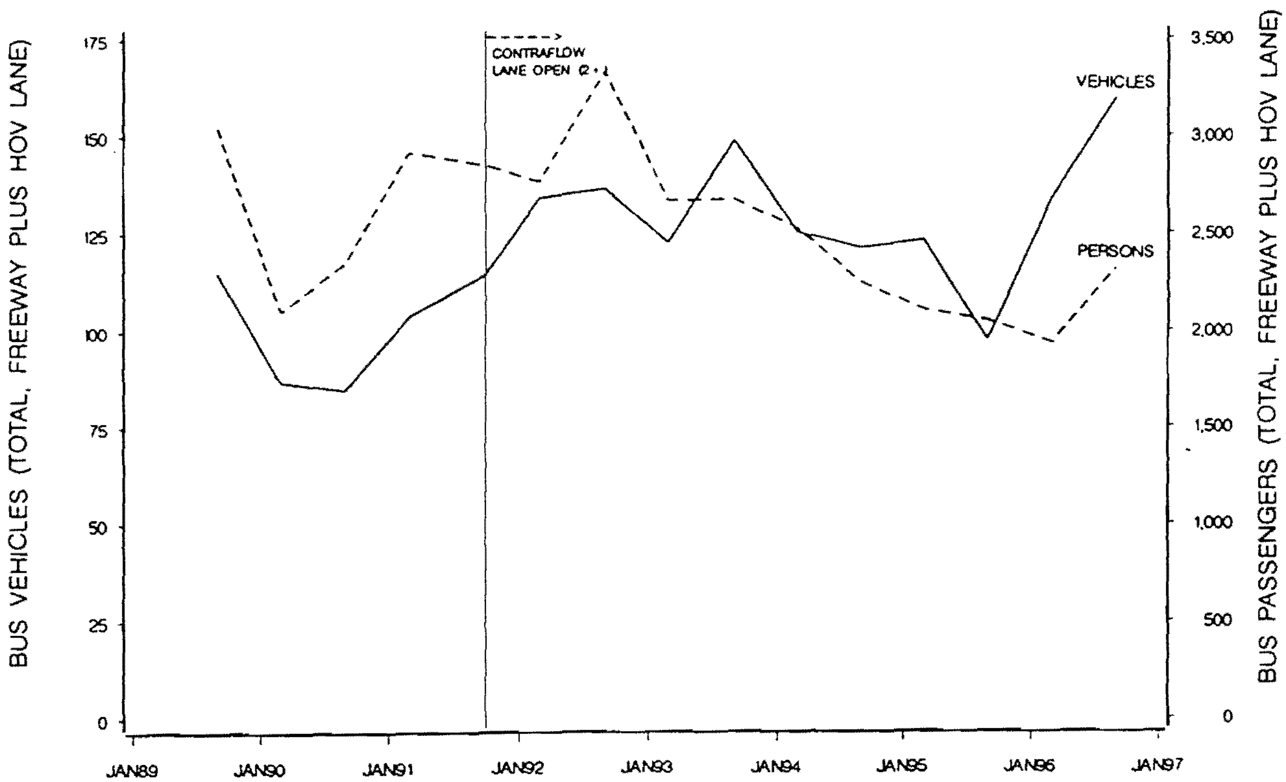


FIGURE F-18. A.M. PEAK PERIOD BUS PASSENGER TRIPS
TOTAL, FREEWAY PLUS HOV LANE
EAST R.L. THORNTON FREEWAY AND FREEWAY WITHOUT HOV LANE

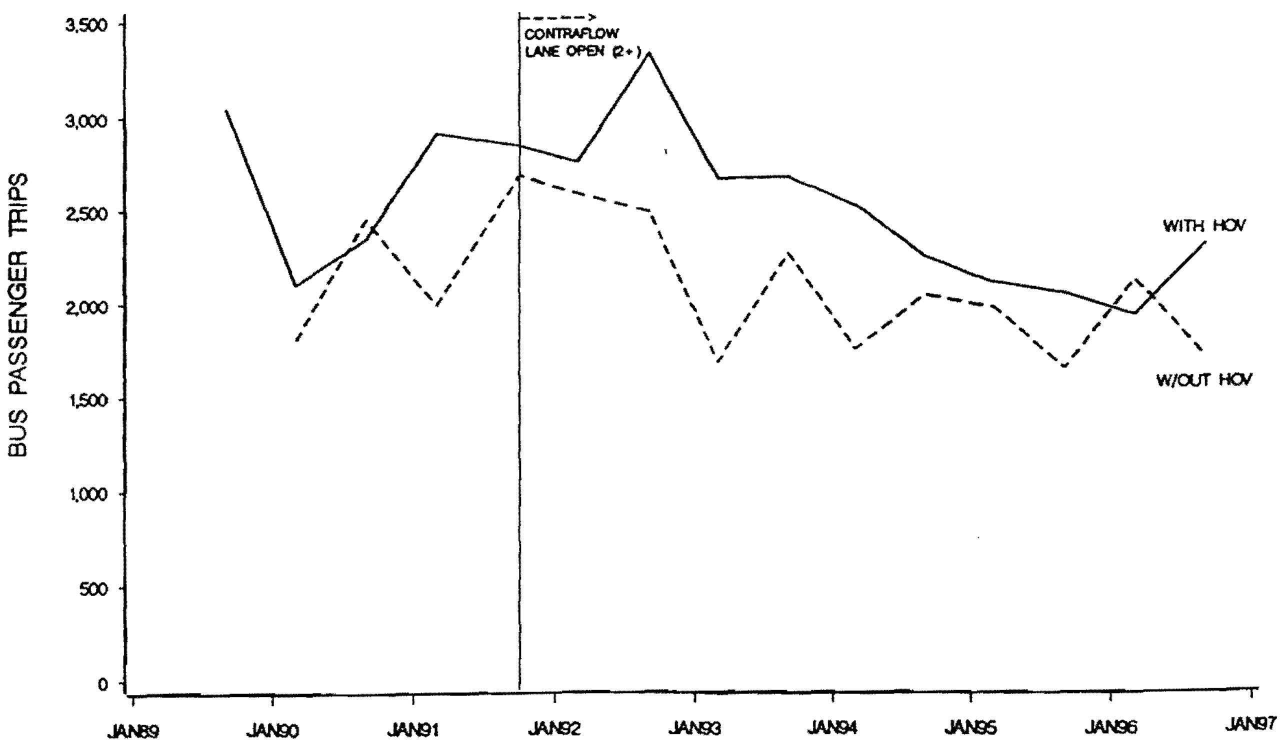


FIGURE F-19. EAST R.L. THORNTON FREEWAY (IH 30E) CORRIDOR PARK-AND-RIDE DEMAND

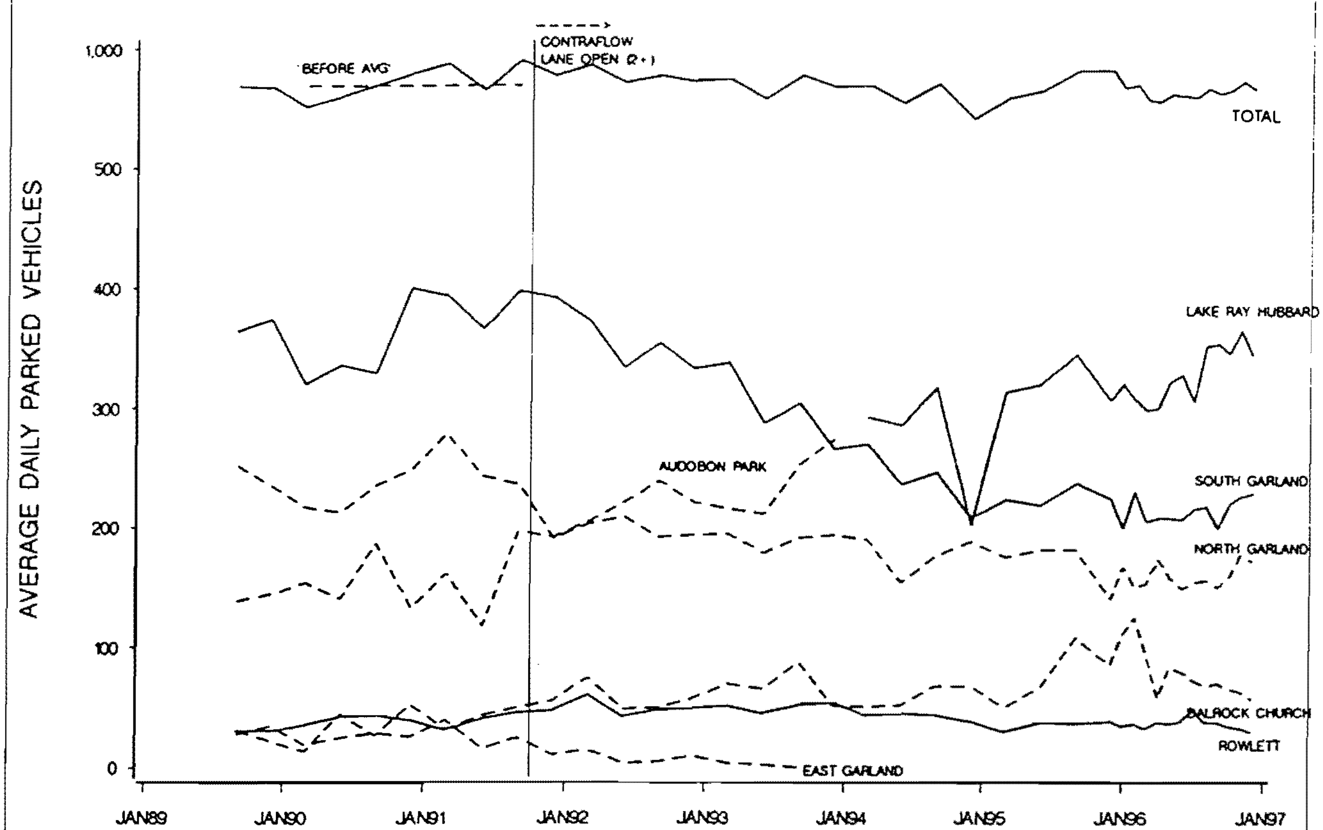


FIGURE F-20. AVERAGE DAILY VEHICLES AT PARK-AND-RIDE LOTS
EAST R.L. THORNTON FREEWAY AND FREEWAY WITHOUT HOV LANE