Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-94/1353-1		

4. Title and Subtitle AN EVALUATION OF HIGH-OCCUPANCY VEHICLE LANES IN TEXAS, 1993	5. Report Date October 1994 6. Performing Organization Code
7. Author(s) Russell H. Henk, Daniel E. Morris, and Dennis L. Christiansen	8. Performing Organization Report No. Research Report 1353-1
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135	10. Work Unit No. (TRAIS) 11. Contract or Grant No. Study No. 0-1353
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Transfer Office P. O. Box 5080 Austin, Texas 78763-5080	13. Type of Report and Period Covered Interim: September 1993 - August 1994 14. Sponsoring Agency Code

15. Supplementary Notes

Research performed in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.
Research Study Title: An Evaluation of High-Occupancy Vehicle Projects in Texas

16. Abstract

This report evaluates the operation of freeway high-occupancy vehicle (HOV) lanes in Texas through calendar year 1993. As of the end of 1993, 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 1993 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" trend line analysis (where applicable) and a comparison to control freeways are used as a means of assessing the impacts of the HOV facilities.

As of December 1993, 93.5 kilometers (58.1 miles) of barrier-separated HOV facilities were in operation in Houston, while 8.4 kilometers (5.2 miles) were in operation in Dallas. Approximately 78,000 daily person trips are served on the Houston HOV lane system. Sixty-four percent of total person trips on the Houston HOV lanes are being served by carpools and vanpools, with the remaining 36 percent being served by buses. The East R. L. Thornton HOV lane in Dallas serves approximately 14,000 daily person trips. Sixty-five percent of these trips are being served by carpools and vanpools, with the remaining 35 percent being served by buses.

17. Key Words	18. Distribution Statement
High-Occupancy Vehicle Lanes, Carpools, HOV Facilities, Authorized Vehicle Lanes, Priority Treatment for High-Occupancy Vehicles	No restrictions. This document is available to the public through NTIS: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	338	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

AN EVALUATION OF

HIGH-OCCUPANCY VEHICLE LANES IN TEXAS, 1993

by

Russell H. Henk
Assistant Research Engineer
Texas Transportation Institute

Daniel E. Morris
Research Associate
Texas Transportation Institute

and

Dennis L. Christiansen
Research Engineer
Texas Transportation Institute

Research Report 1353-1

Research Study Number 0-1353

Research Study Title: An Evaluation of High-Occupancy Vehicle Projects in Texas

Sponsored by the
Texas Department of Transportation
in Cooperation with the
U.S. Department of Transportation
Federal Highway Administration

October 1994

TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

IMPLEMENTATION STATEMENT

This report was sponsored by the Texas Department of Transportation as part of an overall effort entitled "An Evaluation of High-Occupancy Vehicle Lanes in Texas." The principal objective of this effort is to collect, analyze, and interpret data that can be used to assess the performance and effectiveness of the committed freeway HOV lanes now being implemented in Texas.

The first permanent HOV facility in Texas was opened in Houston on the Katy Freeway (I-10W) in October 1984. In November 1984, the contraflow lane (which was implemented in 1979) on the North Freeway (I-45N) was converted to a barrier-separated HOV lane, and, in 1988, priority facilities were opened on both the Northwest Freeway (U.S. 290) and the Gulf Freeway (I-45S). In 1990, extensions of the Katy, North, and Northwest HOV lanes were completed, carpool use of the North HOV lane began, and construction of the Eastex (U.S. 59N) facility was initiated. The Southwest Freeway (U.S. 59S) HOV lane opened for use to vehicles with two or more occupants (2+) in January 1993. High-occupancy vehicle lane construction continues in the Gulf Freeway (I-45S) and Eastex Freeway (U.S. 59N) corridors—with the completion of the Gulf Freeway HOV lane scheduled for March 1994.

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

This report presents data relating to the six operating HOV lanes in Texas and focuses on data collected during calendar year 1993. The results of this research have helped the implementing agencies learn from the early experience with HOV lanes in order to allow future projects to be developed more effectively.

DISCLAIMER

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

ACKNOWLEDGMENT

The authors would like to gratefully acknowledge the assistance of the following individuals in preparing this report: Kandis Salazar (clerical support/editing); Ivan Lorenz (graphics); Patrick Beck (graphics); Michael Ogden (data collection); Kelley Klaver (data collection); Renee Cook (data collection); and Pam Rowe (clerical support). Without the hard work and dedication of these individuals, the successful publication of this document would not have been possible. In addition, the authors would like to recognize the support of the Texas Department of Transportation and Federal Highway Administration officials who sponsored this research.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

Page

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF TABLES (continued)

SUMMARY

In response to congestion and related concerns, a variety of transportation actions are being taken in Texas urban areas. One of these actions involves the implementation of priority lanes for high-occupancy vehicles (HOV) on freeways in Houston and Dallas. In Houston, these facilities are being jointly developed by the Texas Department of Transportation (TxDOT) and the Metropolitan Transit Authority of Harris County; 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 1993.

A commitment is in place to develop 154 kilometers (95.5 miles) of barrier-separated high-occupancy vehicle (HOV) lanes in Houston. The cost of the entire HOV lane system, including all support facilities, will be approximately \$640 million.[1] As of the end of 1993, 93.5 kilometers (58.1 miles) of barrier-separated HOV lanes were in place and operational in five corridors, implemented at a cost of approximately \$348 million.[1] While some sections of two-direction HOV lanes have been developed, the typical Houston HOV lane is located in the freeway median, is approximately 6 meters (20 feet) wide, is reversible, and is separated from the freeway general-purpose mainlanes by concrete median barriers. Grade-separated ramps provide access/egress to most HOV lanes.

In December 1993, the Houston HOV lane system served 78,096 daily person trips—a 12 percent increase compared to December 1992. At the end of 1993, 10,030 cars were parked in Houston HOV lane corridor park-and-ride lots on a typical day. 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.

---

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

The Dallas HOV system is in its relative infancy. A plan is, however, currently in place in Dallas to construct approximately 60 kilometers (37 miles) of HOV lanes. This "plan" consists of the components which are common to both the DART system plan and the North Central Texas Council of Government's (NCTCOG) current plan for the year 2010. The cost of this system is yet to be determined. As of December 1993, an 8.4-kilometer (5.2-mile) barrier-separated contraflow lane on the East R.L. Thornton (East RLT) Freeway was the only component of this HOV system in operation. The cost to construct this contraflow lane was $12.7 million.

In December of 1993, the East RLT HOV lane served 14,017 daily person trips. By the end of 1993, 841 cars were parked in East RLT corridor park-and-ride lots on a typical day.

MEASURES OF HIGH-OCCUPANCY VEHICLE LANE EFFECTIVENESS

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

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

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

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

On a typical non-incident day, the HOV lanes in Houston and Dallas offer a travel time savings to users during the peak hour. In Houston, these savings range from five minutes on the Northwest HOV lane to 14 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 93.5-kilometer (58.1-mile) system in Houston offers 38 minutes of time savings, or about 0.4 minutes per kilometer (0.7 minutes per mile). The 8.4-kilometer (5.2-mile) East RLT HOV lane in Dallas offers a time savings of approximately 0.6 minutes per kilometer (1.0 minute per mile). It is of interest to note, however, that the time savings perceived by the users (as determined in surveys of HOV lane users) are much greater than the actual time savings.

Factors Influencing High-Occupancy Vehicle Lane Utilization

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

Changes in Roadway Person Movement

A major reason for implementing HOV lane improvements is to increase the effective person-movement capacity of a roadway. Since implementation of the HOV lane increases the number of directional roadway lanes, the high-occupancy vehicle lane should *at least* increase person movement by an amount greater than the increase in lanes added to the roadway. The data show that the HOV lanes in Texas are helping to bring about an increase in person movement (Table S-1). During the peak hour, the HOV lanes are moving 72 percent (Gulf) to 180 percent (North) more persons per lane than are the freeway general-purpose lanes.

Changes in Average Vehicle Occupancy

For the priority HOV lanes to generate increases in person movement, it is necessary to increase the average vehicle occupancy; this has happened. On the two freeways with the more mature HOV lanes, peak-hour average vehicle occupancies are in excess of 1.4 persons per vehicle (Tables S-1 and S-2). Compared to pre-HOV lane conditions, average vehicle occupancy on the North, Katy, and Northwest Freeways has increased by over 15 percent. This type of increase has not been experienced on freeways without HOV lanes.

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

HOV LANE IMPACTS ON BUS OPERATIONS

The HOV lanes have generated a large increase in transit use and have attracted a new type of transit rider. Young, educated, white-collar Texans are making extensive use of transit. Also, in comparing pre-HOV conditions to the present, average bus operating speeds during the peak hour have nearly doubled, increasing from 42 kph (26 mph) to 79 kph (49 mph). The result has been a reduction in schedule times.

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

Measure of Effectiveness	HOV Facility					
	Katy	North	Gulf	Northwest	Southwest	East RLT
Change in Roadway Person Movement						
% Increase in directional lanes due to HOV lane	33%	25%	—	33%	20%	25%
% Increase in a.m. person volume[1]	84%	113%	—	58%	91%	41%
Change in Average Vehicle Occupancy (persons/vehicle)[1]						
Occupancy before HOV lane	1.26	1.28	—	1.14	1.16	1.35
Occupancy in December 1993	1.44	1.48	—	1.36	1.29	1.34
% Change, Pre-HOV lane to current	+14%	+16%	—	+19%	+11%	-1%
% Change in 2+ Carpool Volume[1]	+56%	+140%	—	+207%	142%	+145%
% of carpools formed due to HOV lane[2] (1990)	53%[3]	46%	26%	47%	—	—
% Change in Bus Passengers (peak hour)[1]	+344%	—	—	+247%	+50%	+15%
% New bus riders due to HOV lane[2] (1990)	47%	52%	33%	47%	—	—
% Change, Freeway Mainlane Vehicle Volume per Lane[1,4]	+42%	+18%	—	+8%	-10%	+21%
% Change, Freeway Mainlane Speed (Peak Hour)[1,4]	+20%	+102%	—	+11%	+31%	+34%
% Change, Freeway Mainlane Accident Rate[5]	+2%	-13%	-30%	-7%	-26%	-4%
% Change, Freeway Per Lane Efficiency[1,6]	+130%	+185%	—	+55%	+38%	+80%
Comparison, HOV Lane vs. Freeway Lane[7] (HOV lane improvement as a % of freeway improvement)						
Fuel consumption (liters)	84%	—	—	—	—	—
Air quality (kg of CO)	69%	—	—	—	—	—
Annual Value of Travel Time Saved on HOV Lane[8] ($ millions)	$7.7	$5.4	$2.8	$1.8	$2.9	$2.8
Travel time saved as a % of construction cost[9]	28%	9%	9%	3%	6%	13%
Are HOV Lanes Good Improvements[10]						
Yes	71%	81%	63%	75%	—	—
No	16%	9%	21%	11%	—	—
Not Sure	13%	10%	16%	14%	—	—

[1]A.M. peak-hour, peak-direction. Percentage change from pre-HOV lane conditions to current conditions (mixed lanes).
[2]Estimated percent of total carpools or bus passengers using the HOV lane that have been created because of the HOV lane.
[3]The percentage change in 3+ carpool volume during the peak hour has been +374%.
[4]Data for the freeway general-purpose mainlanes.
[5]Percentage change in accident rate (injury accidents per 100 million vehicle-kilometers) from pre-HOV to current.
[6]Freeway per lane efficiency is expressed as the multiple of persons moved and average speed. Analysis combines freeway general-purpose lane performance with HOV lane performance.
[7]Simulation was used on the Katy Freeway to estimate what conditions would have been had an extra general-purpose lane been provided instead of the HOV lane. The values of fuel consumption and air quality (CO emissions) are those characteristic of the HOV alternative as a % of those estimated to be characteristic of the all-mainlane alternative. Both alternatives serve essentially the same demand, expressed in passenger-miles.
[8]This is an estimate of the annual value of time saved by users of the HOV lane.
[9]This is the estimated annual value of travel time savings for HOV lane users expressed as a percent of the cost of constructing the operating segment of the HOV lane (not including support facilities). A simplistic analysis suggests that, if this value exceeds 10%, the project is cost effective.
[10]Responses from motorists in the general-purpose freeway lanes to the question "Do you feel the HOV lanes being developed in Houston are good transportation improvements?"

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

Measure of Effectiveness	Representative Pre-HOV Lane Value	Representative Current Value	% Change
A.M. Peak-Hour, Peak-Direction Avg. Vehicle Occupancy			
Freeways With HOV Lanes			
Katy	1.26	1.44	+14%
North	1.28	1.48	+16%
Northwest	1.14	1.36	+19%
Southwest	1.16	1.29	+11%
Freeway Without HOV Lane	1.23	1.21	-2%
Peak-Hour Peak-Direction 2+ Carpool Volume			
Freeways With HOV Lanes			
North	700	1,683	+140%
Northwest	490	1,502	+207%
Southwest	531	1,285	+142%
Freeway Without HOV Lane	600	531	-12%
Peak-Hour Peak-Direction 3+ Carpool Volume			
Freeway With HOV Lane			
Katy	76	360	+374%
Freeway Without HOV Lane	123	92	-25%
A.M. Peak-Period Bus Ridership (3.5 hours)			
Freeways With HOV Lanes			
Katy	900	3,090	+243%
North	0	5,473	—
Northwest	605	1,715	+183%
Southwest	676	1,958	+190%
Freeways Without HOV Lane	1,188	775	-35%
Cars Parked at Park-and-Ride Lots			
Freeways With HOV Lanes			
Katy	575	2,088	+249%
North	—	3,730	—
Gulf	1,115	1,227	+ 10%
Northwest	430	1,583	+250%
East RLT	847	841	-1%
Freeway Without HOV Lane	1,236	942	-24%

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

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 increased significantly after HOV lane implementation. In reviewing accident data for the six freeways with HOV lanes, accident rates have typically declined (in some cases substantially) on the mainlanes.

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

AIR QUALITY AND ENERGY CONSIDERATIONS

A simulation analysis (a.m. inbound, 6 a.m. to noon) was undertaken to compare the "add an HOV lane" alternative to both the "do nothing" alternative and the "add a general-purpose freeway lane" alternative. If all alternatives serve the same demand (expressed as the combined passenger-miles using the HOV lane and the freeway in 1993), the HOV lane is considerably more favorable in terms of both a reduction in energy consumption and pollution emissions (Table S-1). The HOV alternative, compared to the add a general-purpose lane alternative, resulted in a 16 percent reduction in fuel consumed and a 31 percent reduction in carbon monoxide emissions. Additional analyses addressing the impacts of HOV lanes on air quality (i.e., vehicle emissions) have been summarized in a companion report entitled "Mobile Source Emission Impacts of High Occupancy Vehicle Facilities (Research Report 1353-02)."

HOV PROJECT COST EFFECTIVENESS

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

However, if an HOV project is even marginally cost effective based on the travel time savings experienced by HOV lane users, that project would simply be even more cost effective if all benefits were quantified. Based on this analysis (using 1993 data), the Katy, North, and East RLT HOV lanes are cost effective, while the Gulf, Northwest, and Southwest facilities are less than cost effective.

If some of the additional benefits referred to previously are considered, the benefit-cost ratio can increase markedly. For example, with this type of analysis, in 1993 the benefit-cost ratio for the Katy HOV project was in excess of 3.7 (see Table 33, p. 90). For that facility, the value of all quantified benefits was six times greater than the value of user time saved. For the entire Houston area, estimates are that HOV lanes presently reduce areawide congestion levels by about four percent. This equates to a reduction in the areawide annual cost of congestion of approximately $130 million.

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 1990 surveys in Houston, over 70 percent of the motorists in the freeway general-purpose lanes (not HOV lane users) viewed these project as being good transportation improvements. On average, fewer than 15 percent stated the projects were not good improvements.

CONCLUSIONS

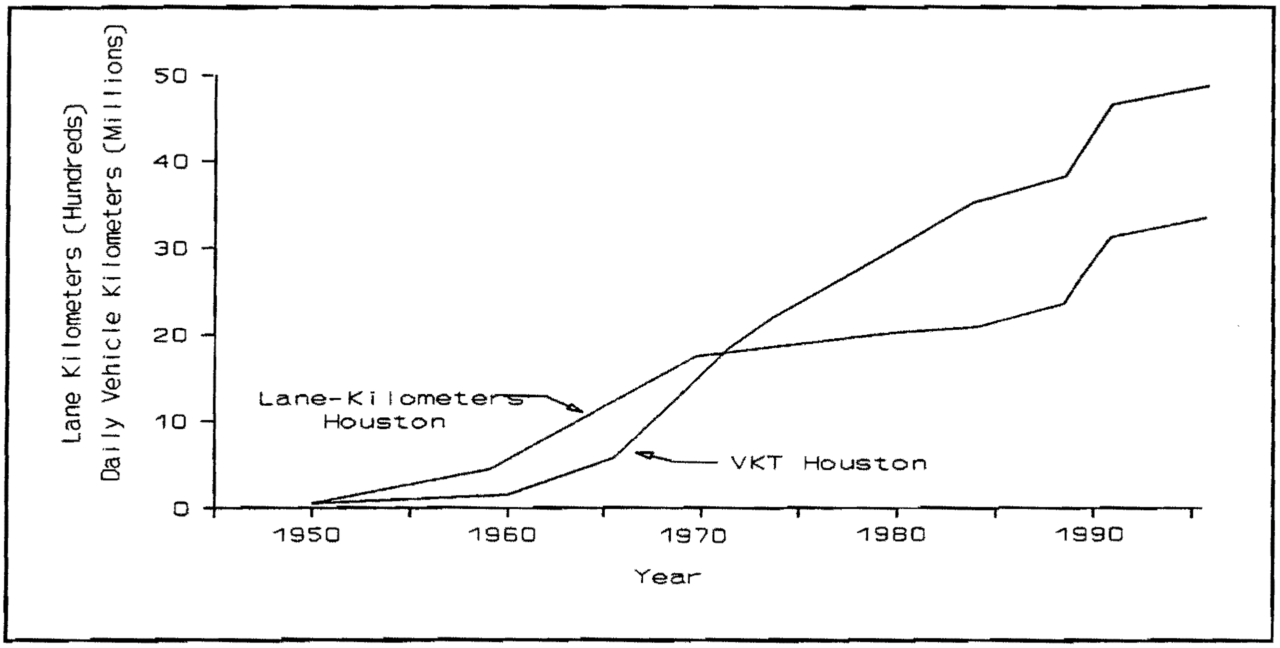
This report identified the objectives associated with developing high-occupancy vehicle lanes in Texas. The report reviews and analyzes data collected through calendar year 1993 to assess the performance of the priority lanes in meeting their objectives.

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

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

I. INTRODUCTION

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



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

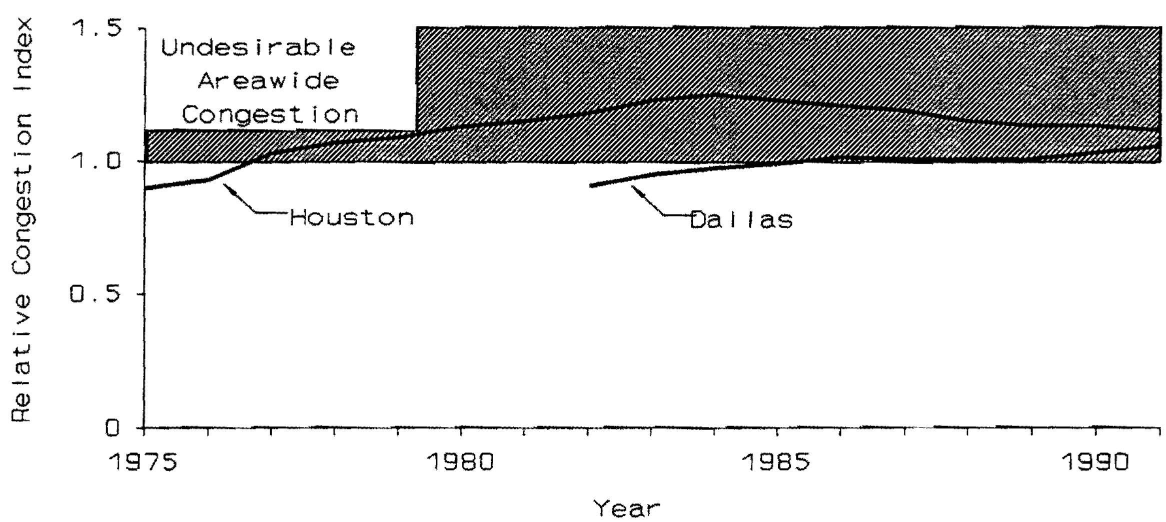
Figure 1. Relationship Between Freeway Vehicle-Kilometers of Travel and Lane-Kilometers of Freeway, Houston

Monitoring of overall urban congestion in major cities clearly indicated that mobility in both Houston and Dallas deteriorated significantly during the late 1970s and early 1980s.

[2]Texas Transportation Institute Research Report 431-1F.

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

Areawide congestion levels increased by 39 percent between 1975 and 1984 in Houston and by 24 percent between 1982 and 1986 in Dallas.[4] However, as the result of an aggressive multimodal effort to restore mobility in these urban areas, congestion has been moderating in recent years (Figure 2). Between 1984 and 1991, the congestion index in Houston actually declined by ten percent, even though vehicle-miles of travel increased by almost eleven percent during that time period. The congestion index for Dallas increased slightly between 1986 and 1991. Nevertheless, Houston and Dallas remain relatively congested cities (Table 1).



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

Figure 2. Relative Mobility Levels for Houston and Dallas, 1975-1991

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

---

[4]Texas Transportation Institute Research Report 339-8.

Table 1. Relative Mobility Levels in Major United States Cities, 1991

Urban Area	Relative Mobility Index[1]	Urban Area	Relative Mobility Index[1]
1. Los Angeles	1.56	8. San Bernardino	1.20
2. Washington, D.C.	1.39	9. New York	1.14
3. San Francisco-Oakland	1.34	10. Atlanta	1.14
4. Miami	1.28	11. Honolulu	1.13
5. Chicago	1.28	12. New Orleans	1.12
6. San Diego	1.22	13. HOUSTON	1.11
7. Seattle	1.20	17. DALLAS	1.06

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

Source: Texas Transportation Institute Research Report No. 1131-5.

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

This report presents and evaluates data relative to high-occupancy vehicle facility and freeway operations in Houston and Dallas through December 1993. Data are presented for all six of the operational HOV lanes in these urban areas.

ORGANIZATION OF THE REPORT

The following section of this report provides an overview description of the entire high-occupancy vehicle facility systems in Houston and Dallas. The six sections after that review the available data to help determine the current effectiveness of the HOV lanes. The last section of the report presents the conclusions. A series of appendices provide a listing of milestone dates in the development of these HOV lanes, and more detailed data on each of the HOV lane projects are also included.

II. OVERVIEW OF HIGH-OCCUPANCY VEHICLE FACILITIES IN TEXAS

HISTORICAL BACKGROUND

Houston

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

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

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

Dallas

Dallas began experiencing significant traffic congestion in the late 1980s. Influenced by the success of HOV lanes in Houston (as well as other areas of the nation), TxDOT and Dallas Area Rapid Transit (DART) made a decision to test the high-occupancy vehicle lane concept in Dallas. An 8.4-kilometer (5.2-mile) barrier-separated contraflow lane was consequently developed and opened for operation on East R.L Thornton 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. After having been opened for less than one year, the contraflow lane was serving 16,000 daily person trips and saving its users approximately 0.6 minutes per kilometer (one minute per mile) in travel time during the morning peak hour. The early success of the East RLT contraflow lane has helped give rise to a plan for constructing additional HOV lanes in the Dallas urban area.

THE PLANNED SYSTEMS

Houston

A commitment is in place in the Houston area to develop approximately 154 kilometers (96 miles) of high-occupancy vehicle lanes (Figure 3). As of December 1993, five separate HOV facilities were in operation (Table 2). A total of 93.5 kilometers (58.1 miles) of barrier-separated, high-occupancy vehicle lanes were operating. The first phase of the Southwest HOV lane opened in January 1993. Construction is continuing in the Southwest, Gulf, and Eastex corridors. The final segments of the Gulf and Southwest HOV lanes should be completed in March 1994 and 1996, respectively.

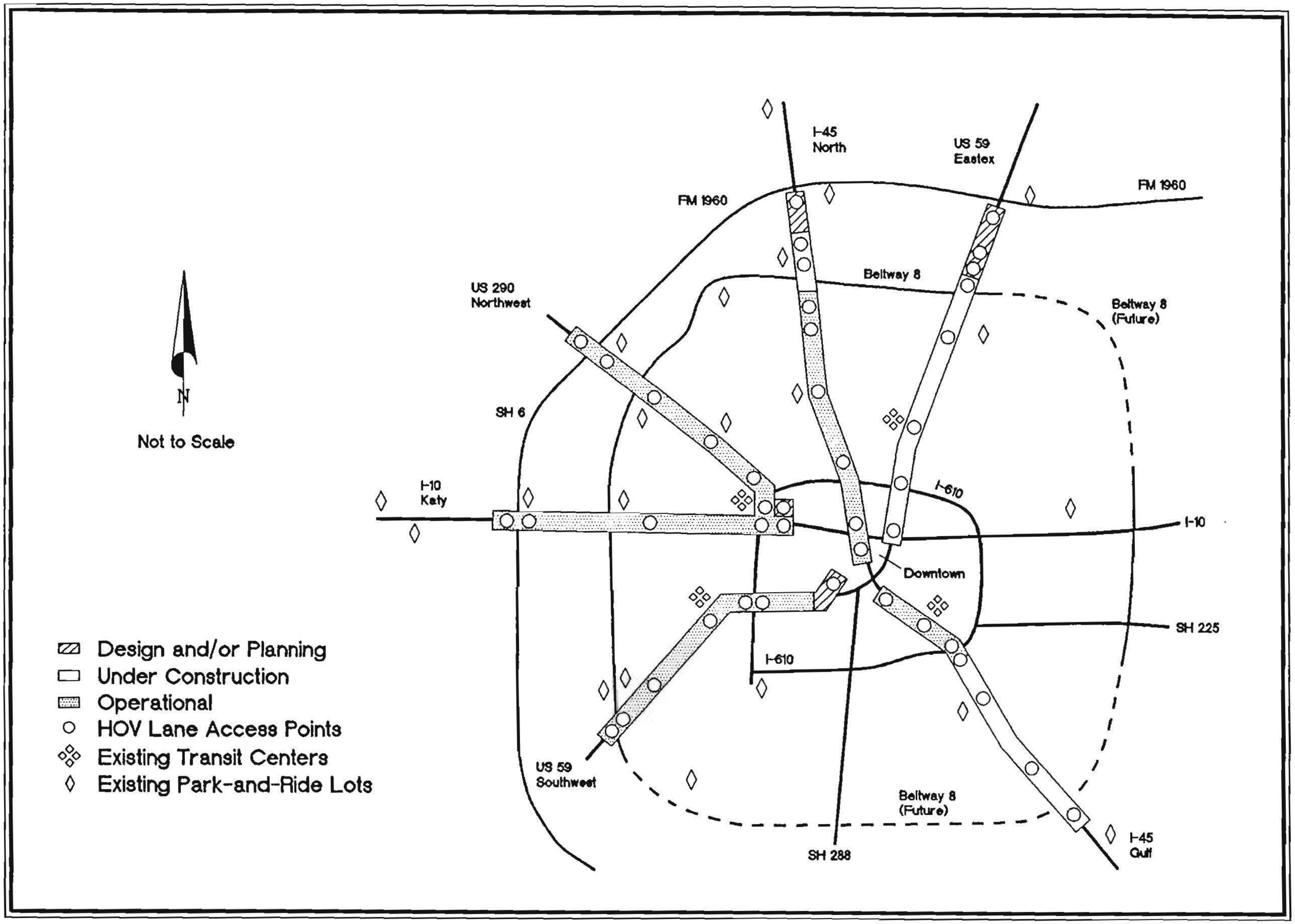


Figure 3. Status of Houston HOV Lane System, December 1993

Table 2. Status of the Houston High-Occupancy Vehicle Lane System, December 1993

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)	20.9 (13.0)	3+ vehicles from 6:45 to 8:00 a.m. 5:00 to 6:00 p.m. 2+ during other operating hours	4 a.m. to 1 p.m. inbound 2 p.m. to 10 p.m. outbound
North (I-45N)	November 1984[2]	21.7 (13.5)	31.7 (19.7)[3]	2+ vehicles	4 a.m. to 1 p.m. inbound 2 p.m. to 10 p.m. outbound
Gulf (I-45S)	May 1988	10.5 (6.5)	25.0 (15.5)[4]	2+ vehicles	4 a.m. to 1 p.m. inbound 2 p.m. to 10 p.m. outbound
Northwest (U.S. 290)	August 1988	21.7 (13.5)	21.7 (13.5)	2+ vehicles	4 a.m. to 1 p.m. inbound 2 p.m. to 10 p.m. outbound
Southwest (U.S. 59S)	January 1993	18.7 (11.6)	22.2 (13.3)[3]	2+ vehicles	4 a.m. to 1 p.m. inbound 2 p.m. to 10 p.m. outbound
Eastex (U.S. 59N)	Not open in 1992	—	32.2 (20.0)	—	—
Total		93.5 (58.1)	153.8 (95.5)		

[1]Beginning in October 1989, the Katy and Gulf HOV lanes were opened to 2+ carpools on weekends; those facilities operate outbound on Saturday (4 a.m. to 10 p.m.) and inbound on Sundays (4 a.m. to 10 p.m.). In June 1990, the North HOV lane opened on weekends, and in October 1990 the Northwest HOV lane opened on weekends. Weekend use of all HOV lanes except the Katy was discontinued in October 1991 due to low usage.

[2]A contraflow lane was implemented on the North Freeway in August 1979. It was replaced with a barrier-separated, reversible lane in November 1984.

[3]Scheduled for completion in 1996.

[4]Scheduled for completion in 1994.

Dallas

Compared to Houston, the Dallas HOV lane system is in its infancy. A plan is, however, currently in place to construct approximately 60 kilometers (37 miles) of HOV lanes (Figure 4). This "plan," although not formally adopted, consists of the HOV components which are common to both the DART system plan and the North Central Texas Council of Government's (NCTCOG) current plan for the year 2010. As of December 1993, the East RLT HOV lane was the only operational component of this system (Table 3). An extension of the East RLT HOV lane is scheduled for completion in 1995, while additional HOV facilities are in the planning and design stage for five other Dallas freeways.

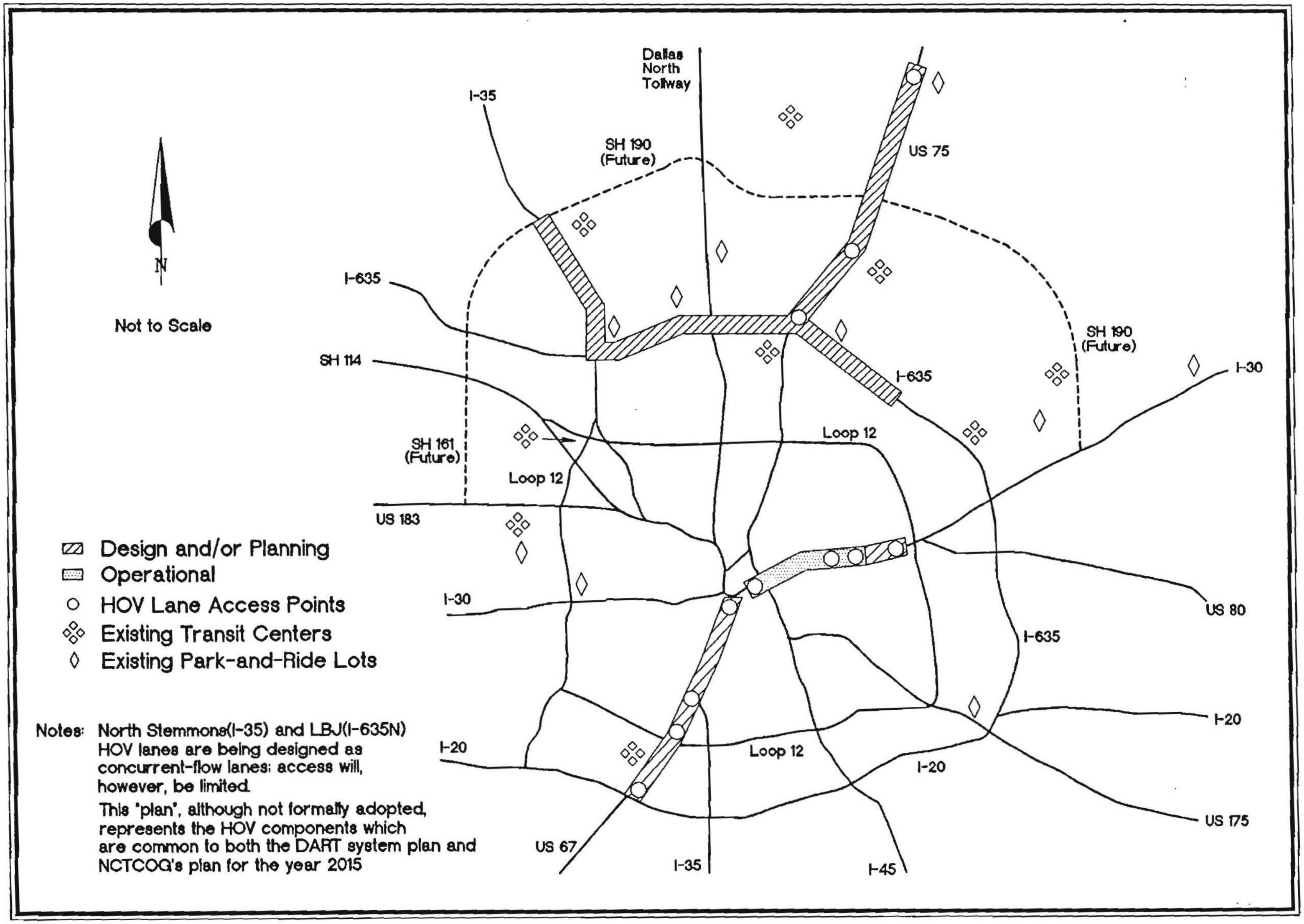


Figure 4. Status of Dallas HOV Lane System, December 1993

Table 3. Status of the Dallas High-Occupancy Vehicle Lane System, December 1993

HOV Facility	Date First Phase Opened	Kilometers (Miles) in Operation	Ultimate Kilometers (Miles)	Vehicles Allowed to Use HOV Lane	Hours of Weekday Operation
East R.L. Thornton (I-30)	September 1991[1]	8.4 (5.2) IB 5.3 (3.3) OB	8.4 (5.2) IB 8.4 (5.2) OB[2]	2+ vehicles	6 a.m. to 9 a.m. IB 4 p.m. to 7 p.m. OB
North Stemmons (I-35E)	Not open in 1993	—	15.6 (9.7)[3]	—	—
South R.L. Thornton (I-35E)	Not open in 1993	—	14.5 (9.0)[4]	—	—
Marvin D. Love (U.S. 67)	Not open in 1993	—	10.0 (6.2)[4]	—	—
LBJ (I-635)	Not open in 1993	—	10.5 (6.5)[5]	—	—
North Central Expwy. (U.S. 75)	Not open in 1993	—	—[6]	—	—

NOTE: IB = inbound, OB = outbound

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

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

[3]Concurrent flow lane scheduled for completion in 1995.

[4]Movable barrier contraflow lane scheduled for completion in 1995.

[5]Concurrent flow lane feasibility study currently under evaluation.

[6]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.

PHYSICAL DESCRIPTION OF THE HIGH-OCCUPANCY VEHICLE LANES

Houston

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

Access to the median HOV facilities is provided in a variety of manners. At some locations, "slip ramps" are used to provide access and egress to/from the inside freeway lane (Figure 6). While these are relatively inexpensive, depending on their location, they may create a variety of operational problems. As a consequence, grade-separated interchanges of various designs provide most access to the median HOV lanes (Figure 7). The HOV lanes become elevated in the median, and ramps go over the freeway lanes to connect with streets, park-and-ride lots, or bus transfer centers. These grade-separated interchanges are typically constructed at a cost in the range of $2 to $7 million each; access to the HOV lanes is typically provided at 5- to 8-kilometer (3- to 5-mile) intervals. In some locations, implementation of the Houston HOV lanes was accomplished by narrowing freeway lanes to 3.4 meters (11 feet) and reducing inside shoulder widths. A typical section is shown in Figure 8.

Figure 5. HOV Lane in Median of Katy Freeway

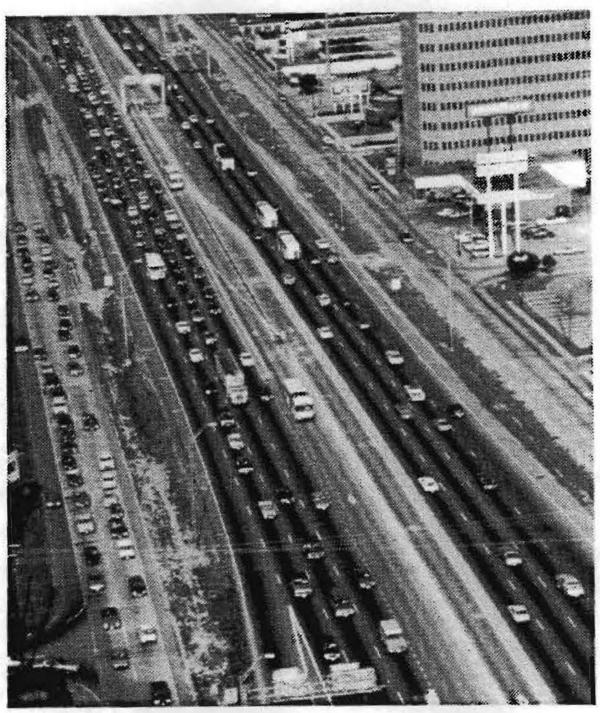
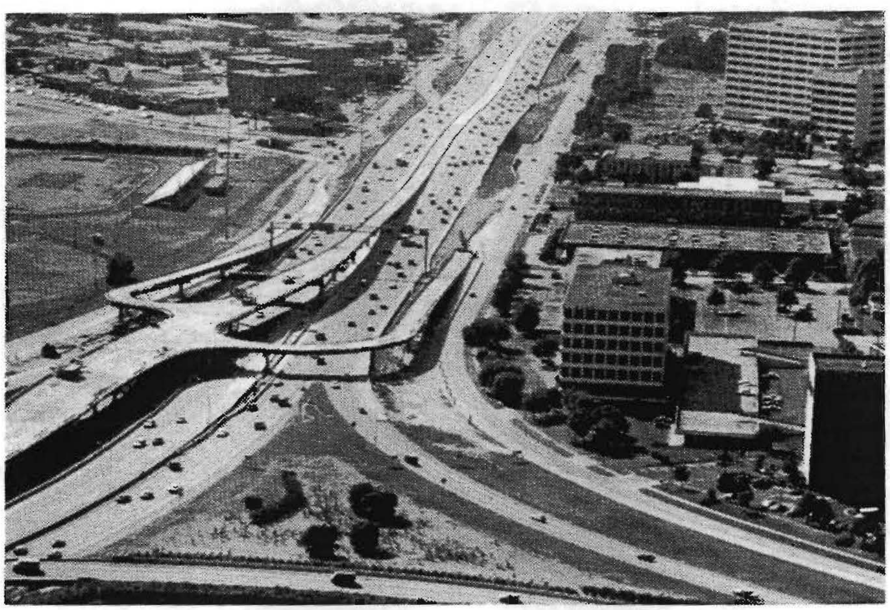


Figure 6. Slip Ramp for HOV Lane Access/Egress on Katy Freeway

Direct Ramp to Eastwood Bus Transit Center, Gulf HOV Lane



Ramps to Frontage Roads, Northwest HOV Lane

Figure 7. Examples of Grade-Separated HOV Lane Interchanges

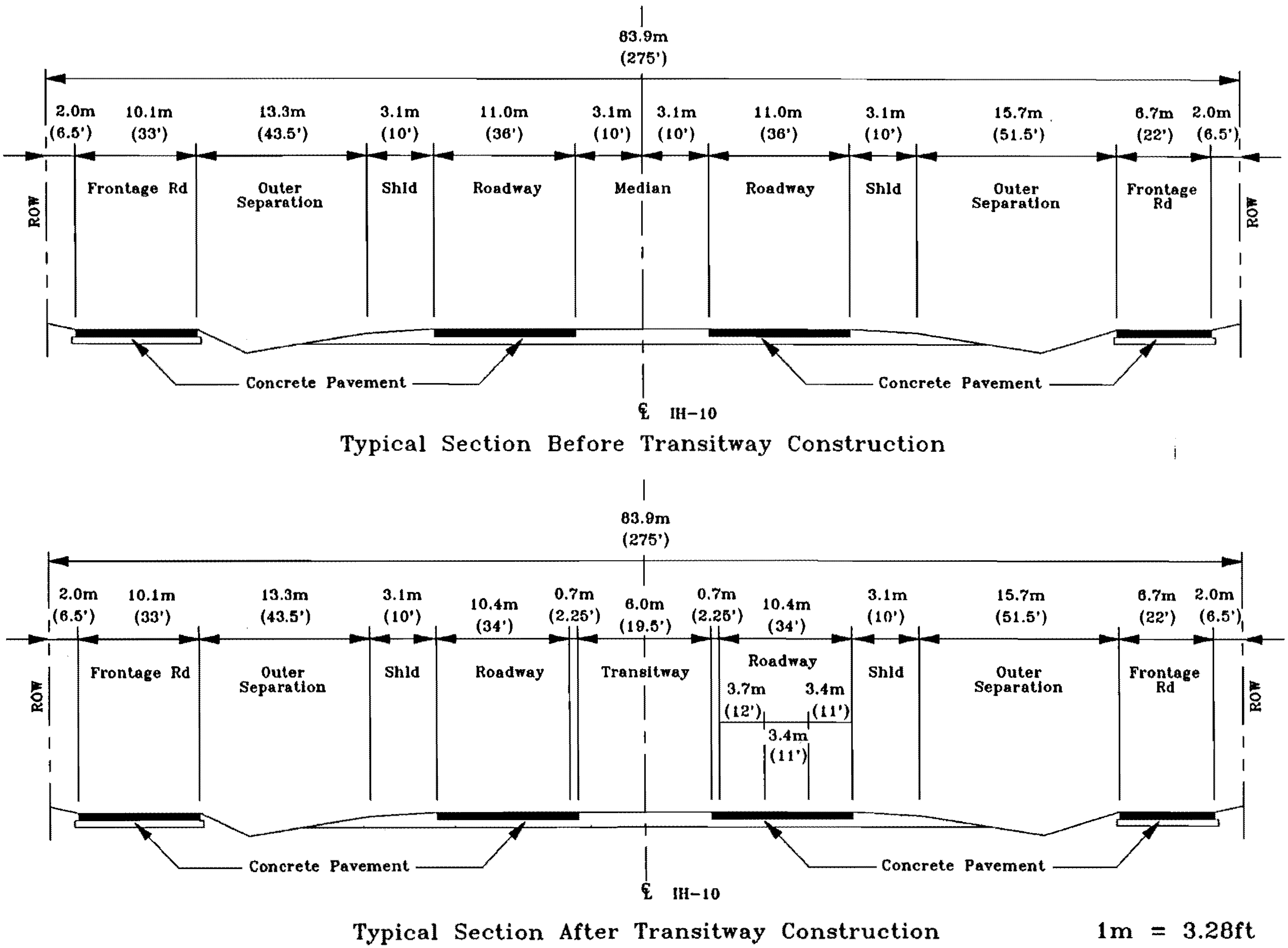


Figure 8. Typical Sections, Before and After Katy HOV Lane Construction

Dallas

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

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

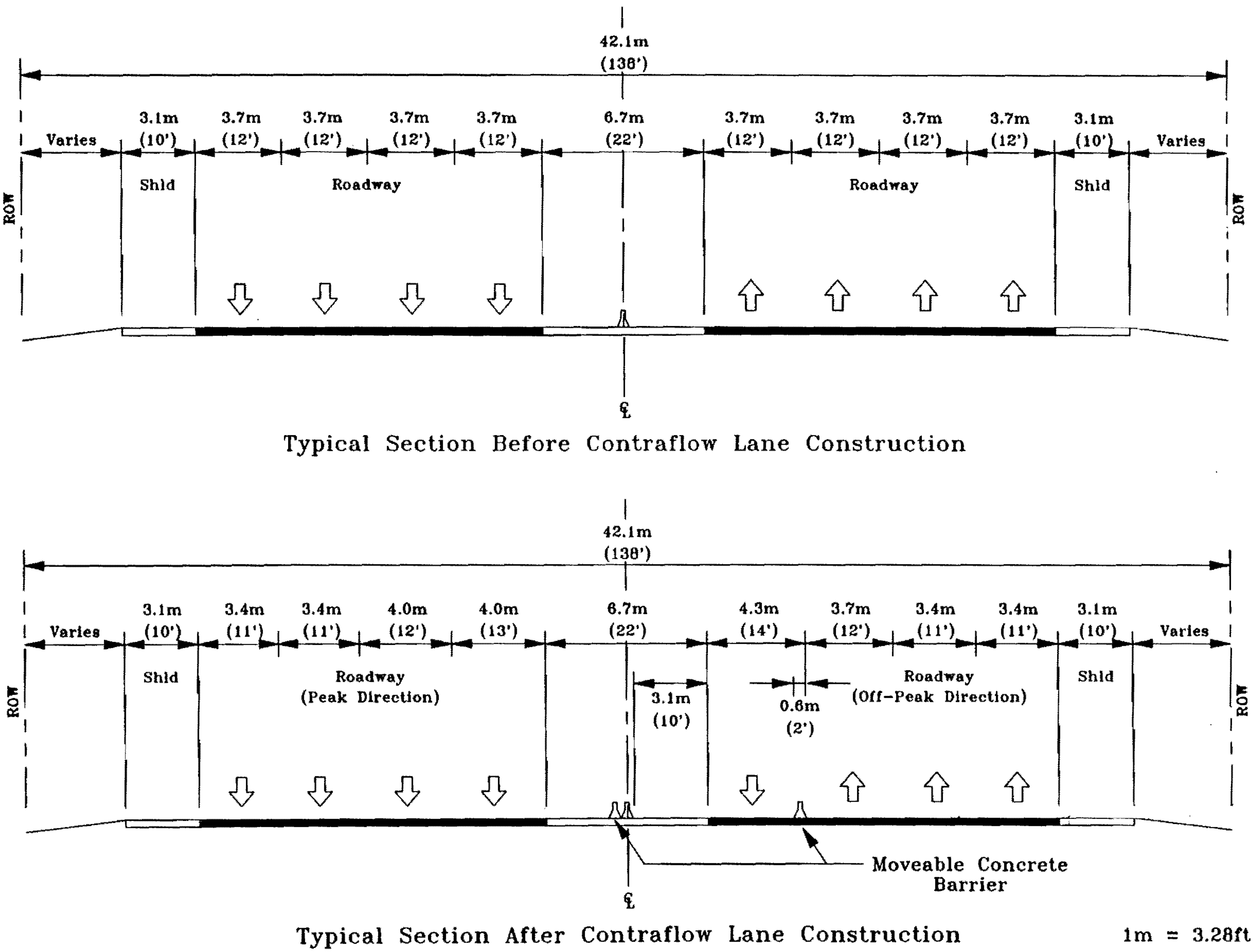


Figure 10. Typical Sections, Before and After East RLT Contraflow Lane Construction

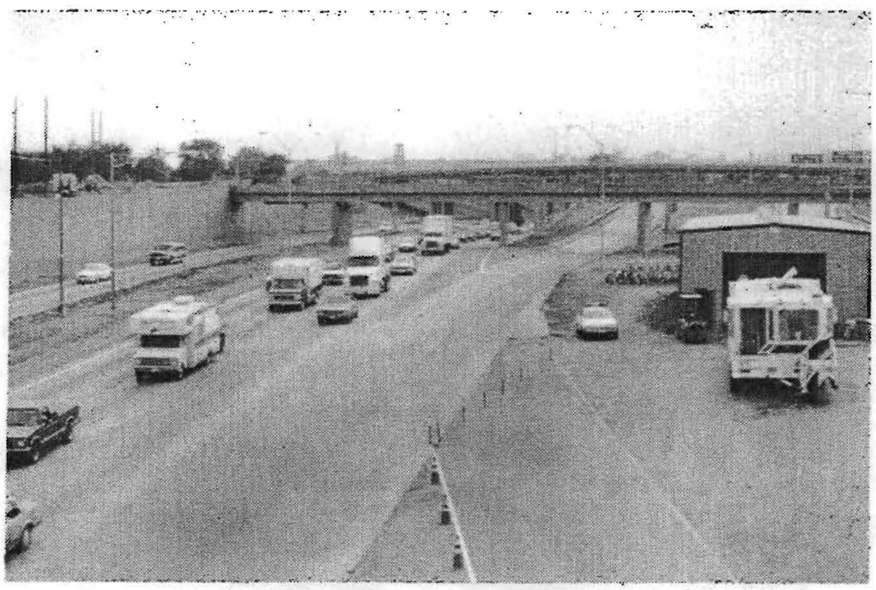


Figure 11. Example of Access Point on East R.L. Thornton HOV Lane

ESTIMATED CAPITAL COST

Houston

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

The HOV lanes in operation today, including all access ramps, have typically been built at an average cost of $2.4 million per kilometer ($4 million per mile) (Table 4). An extensive system of support facilities (i.e., park-and-ride lots, park-and-pool lots, and bus transfer facilities) also has been provided in each corridor. Some of these facilities would have been provided even if there were no HOV lanes. In total, a substantial investment (typically about $1.2 million per kilometer [$2 million per mile]) exists in these support facilities. A surveillance, communication, and control system is being installed on the Houston HOV lanes at an average cost of approximately $200,000 per kilometer ($300,000 per mile). The total cost for all project elements is in the range of $4 million per kilometer ($6 million per mile). Total capital expenditures (year-of-construction dollars) for the operating segments have been approximately $348 million. Figure 12 summarizes current capital expenditures in the Houston HOV system.

Table 4. Estimated Capital Cost[1] of the Operational Houston HOV Lane System, 1993

HOV Lane	Kilometers (Miles) in Operation	Estimated Capital Cost, Millions[1,2]							
		HOV Lane Plus Ramps[3]		Support Facilities[4]		Surveillance, Communication and Control[5]		Total	
		Total	Per Kilometer (Mile)	Total	Per Kilometer (Mile)	Total	Per Kilometer (Mile)	Total	Per Kilometer (Mile)
Katy (I-10W)	20.9 (13.0)	$27.5	$1.3 ($2.1)	$30.0	$1.4 ($2.3)	$5.5	$0.3 ($0.4)	$63.0	$3.0 ($4.8)
North (I-45N)	21.7 (13.5)	$57.8	$2.7 ($4.3)	$18.2	$0.8 ($1.3)	$2.6	$0.1 ($0.2)	$78.6	$3.6 ($5.8)
Gulf (I-45S)	10.5 (6.5)	$30.5	$2.9 ($4.7)	$12.6	$1.2 ($1.9)	$1.9	$0.2 ($0.3)	$45.0	$4.3 ($6.9)
Northwest (U.S. 290)	21.7 (13.5)	$62.7	$2.9 ($4.6)	$33.8	$1.6 ($2.5)	$2.9	$0.1 ($0.2)	$99.4	$4.6 ($7.4)
Southwest (U.S. 59S)	18.7 (11.6)	$45.1	$2.4 ($3.9)	$13.6	$0.7 ($1.2)	$3.5	$0.2 ($0.3)	$62.2	$3.3 ($5.4)
	—	—	—	—	—	—	—	—	—
Total	93.5 (58.1)	$223.6	$2.4 ($3.9)	$108.2	$1.2 ($1.9)	$16.4	$0.2 ($0.3)	$348.2	$3.7 ($6.0)

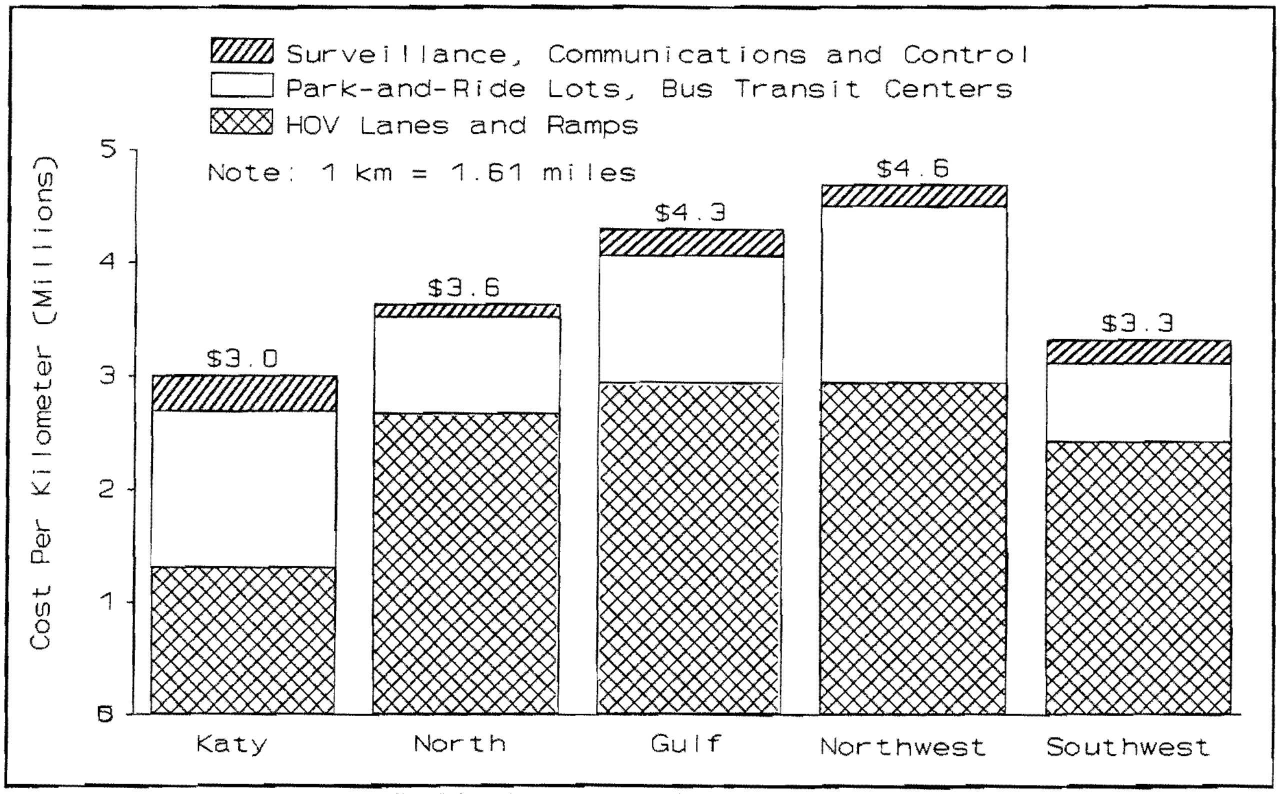
[1]Estimated capital costs are shown in year-of-construction dollars.
[2]Costs do not include the value of the existing freeway rights-of-way in which HOV lanes have been located. The costs of additional buses required to provide the HOV service and the bus maintenance facilities needed to serve those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

Source: Developed from information provided to TTI by Metro and TxDOT. An additional cost breakdown is included in the appendices.

Approximately 60 percent of the ultimate HOV lane system in Houston was operating in 1993. Table 5 provides an estimate of the cost of the completed system. The ultimate capital cost for the HOV lanes and ramps will be approximately $3.0 million per kilometer ($5.0 million per mile). The HOV support facilities will cost an additional $1.0 million per kilometer

($1.5 million per mile). The entire completed system will cost approximately $640 million, or about $4.2 million per kilometer ($6.7 million per mile).

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



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

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

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

HOV Lane	Ultimate System Kilometers (Miles)	Estimated Capital Cost, Millions[1,2]							
		HOV Lane Plus Ramps[3]		Support Facilities[4]		Surveillance, Communication and Control[5]		Total	
		Total	Per Kilometer (Mile)	Total	Per Kilometer (Mile)	Total	Per Kilometer (Mile)	Total	Per Kilometer (Mile)
Katy (I-10W)	20.9 (13.0)	$ 27.5	$1.3 ($2.1)	$29.3	$1.4 ($2.3)	$ 4.7	$0.3 ($0.4)	$59.1	$3.0 ($4.8)
North (I-45N)	31.7 (19.7)	$104.8	$3.3 ($5.3)	$26.6	$0.8 ($1.4)	$ 4.1	$0.1 ($0.2)	$135.5	$4.3 ($6.9)
Gulf (I-45S)	25.0 (15.5)	$ 89.4	$3.6 ($5.8)	$28.4	$1.1 ($1.8)	$ 3.3	$0.1 ($0.2)	$121.1	$4.8 ($7.8)
Northwest (U.S. 290)	21.7 (13.5)	$ 62.7	$2.9 ($4.6)	$33.2	$1.5 ($2.5)	$ 2.9	$0.1 ($0.2)	$ 98.1	$4.5 ($7.3)
Southwest (U.S. 59S)	22.2 (13.8)	$ 66.8	$3.0 ($4.8)	$13.6	$0.6 ($1.0)	$ 4.1	$0.2 ($0.3)	$84.5	$3.8 ($6.1)
Eastex (U.S. 59N)	32.2 (20.0)	$119.3	$3.7 ($6.0)	$15.0	$0.5 ($0.8)	$ 7.3	$0.3 ($0.4)	$141.6	$4.4($7.1)
Total	153.8 (95.5)	$470.5	$3.1 ($4.9)	$146.1	$1.0 ($1.5)	$26.8	$0.2 ($0.3)	$639.9	$4.2 ($6.7)

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

Source: Developed from information provided to TTI by Metro and TxDOT. An additional cost breakdown is included in the appendices.

Dallas

Total capital costs for the operating portion of the East RLT HOV lane have amounted to approximately $12.7 million (Table 6). The movable concrete barriers and barrier machines account for $6.9 million of this cost. The majority of the remaining cost has been associated with upgrading the structural integrity of the shoulders next to the freeway median.

Table 6. Estimated Cost of the East RLT HOV Lane

Kilometers (Miles) in Operation	Estimated Capital Cost, Millions[1,2]					
	HOV Lane Plus Ramps[3]		Barrier Machines and Barrier[4]		Total[5]	
	Total	Per Kilometer (Mile)	Total	Per Kilometer (Mile)	Total	Per Kilometer (Mile)
8.4 (5.2)[6]	$5.8	$0.7 ($1.1)	$6.9	$0.8 ($1.3)	$12.7	$1.5 ($2.4)

[1]Estimated costs are in year-of-construction dollars (1991).
[2]Costs do not include the value of the existing freeway rights-of-way in which the HOV lane is located. The costs of any additional buses required to provide HOV service and any associated increases in bus maintenance costs are not included.
[3]Includes the cost of any structural upgrades of pavement for the HOV lane and the access/egress ramps serving the lane.
[4]Includes the cost of the movable concrete barriers and the machines required to move those barriers.
[5]No new support facilities (e.g., park-and-ride lots and bus transfer centers) have been provided as part of this project.
[6]The East RLT HOV lane operates 8.4 kilometers (5.2 miles) inbound and 5.3 kilometers (3.3 miles) outbound. The HOV lane will eventually operate 8.4 kilometers (5.2 miles) in each direction.

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

FACILITY OPERATING AND ENFORCEMENT COST

Houston

The daily operation and enforcement of the Houston HOV lanes is the responsibility of the Metropolitan Transit Authority. On average, this is costing approximately $200,000 per HOV lane per year (Table 7). This is equivalent to 0.4 cents per passenger-kilometer (0.8 cents per passenger-mile).[5]

Table 7. Estimated Annual Cost of Operating and Enforcing the Operating Houston HOV Lanes, 1993

Type of Cost	Annual Budget
Daily Operations	$ 600,000
Enforcement[1]	$ 530,000
Total	$1,130,000
Average Per HOV Lane (unweighted)	$ 226,000

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

Source: Metropolitan Transit Authority

Additional discussion of the operating costs associated with providing bus transit service on the HOV lanes is presented subsequently in this report. Those analyses indicate that an operating subsidy of approximately $3.27 is required for each bus passenger using the HOV facilities. This equates to an annual subsidy of approximately $23 million to provide the bus service on the HOV facilities.

[5]In 1993, approximately 320 million passenger-kilometers (200 million passenger-miles) were served on the Houston HOV facilities. At $1,130,000 per year for operations and enforcement, this equates to 0.3 cents per passenger-kilometer (0.3 cents per passenger-mile).

Thus, the total annual public operating costs for the HOV lanes is approximately $24 million; $1.13 million is for operations and enforcement, and $23 million is for bus operating subsidies. Figure 13 provides a summary of operating cost data. More detail on those costs is provided subsequently in this report.

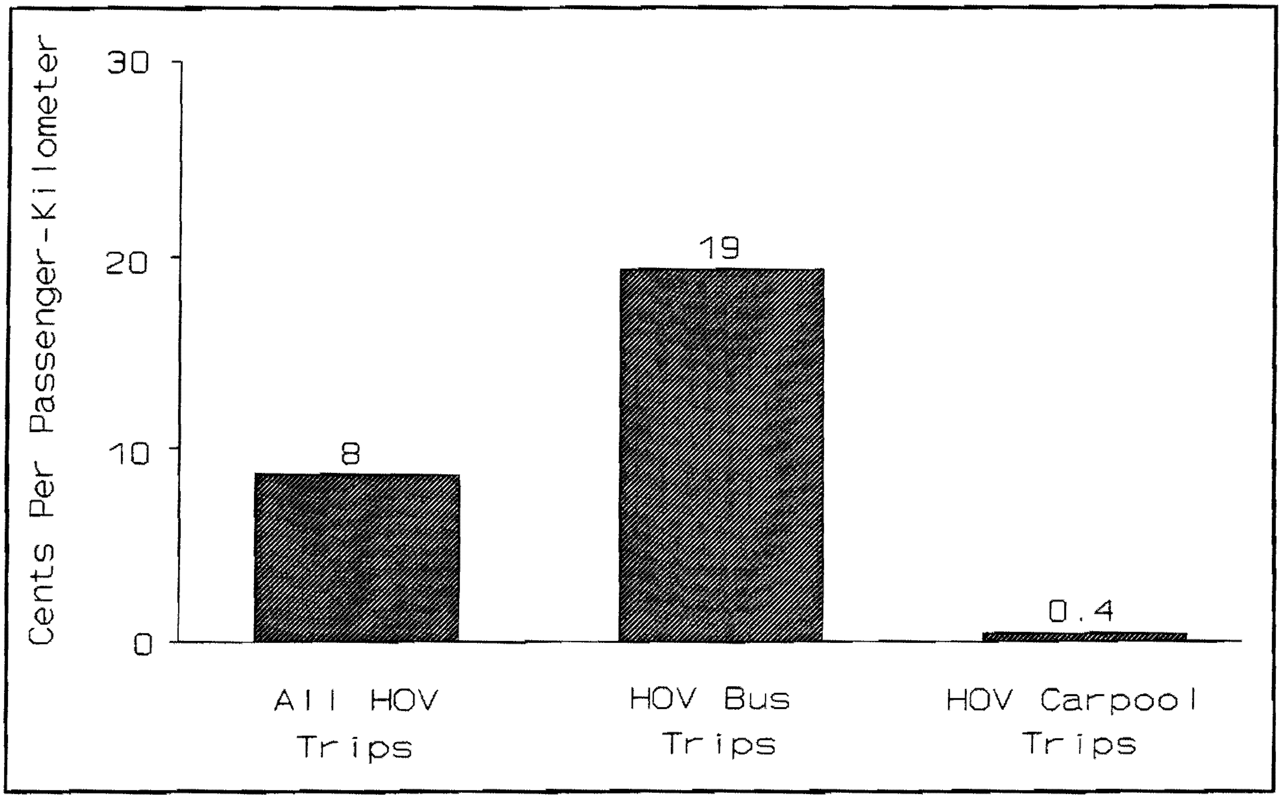


Figure 13. Operating Cost Per Passenger-Kilometer for the Operating Houston HOV Facilities, 1993

Dallas

Operation and enforcement of the East RLT HOV lane is the responsibility of DART. The cost of operating and enforcing this HOV lane amounts to approximately $645,000 per year in 1993 (Table 8). The majority of this cost is associated with the daily transfer of the movable concrete barriers used in conjunction with the contraflow lane. The data required to calculate the operating cost per passenger-kilometer are unavailable at this time.

Table 8. Estimated Annual Cost of Operating and Enforcing the East RLT HOV Lane, 1993

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

Source: Dallas Area Rapid Transit

GENERAL TRENDS IN HOUSTON HOV SYSTEM UTILIZATION

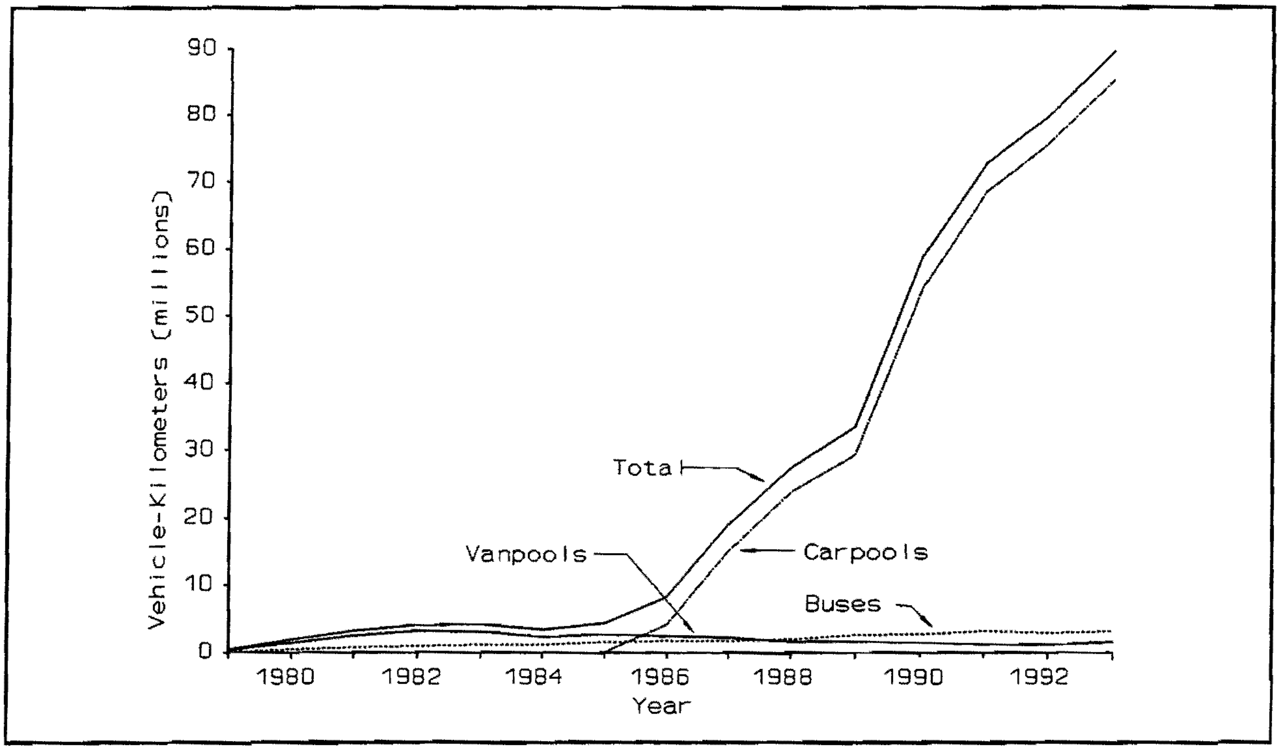
This section briefly overviews system-wide data that help describe the usage of the Houston HOV lanes over time. A more detailed evaluation of these data is included in a subsequent section of this report. The appendices include additional data for both the Houston and Dallas HOV lanes.

Trends in System-wide HOV Usage

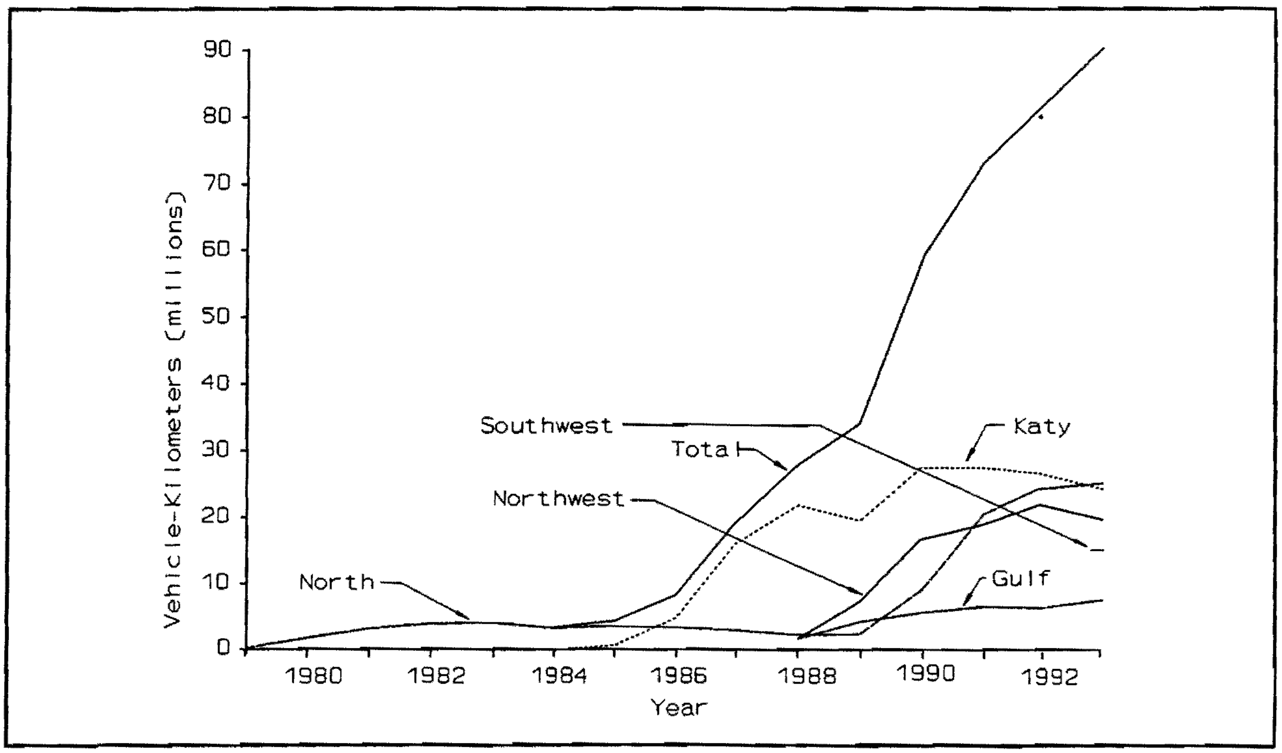
Annual vehicle-kilometers of travel on the HOV lanes and annual passenger-kilometers traveled are depicted in Figures 14 and 15. Since carpools were first allowed to use the HOV lanes in 1985, vehicle-kilometers of HOV lane usage have increased rapidly. With this carpool use and the continued opening of HOV lanes and HOV lane extensions, annual passenger-kilometers on the HOV system have also been increasing.

Figure 16 depicts total daily system-wide HOV usage in Houston. Daily person trips in December 1993 totaled 78,096—a 12 percent increase over the ridership level in December 1992.

Historically, the annual increase in HOV lane usage has been much greater than the increase in overall travel on the freeways and principal arterials in the Houston area (Figure 17). Between 1985 and 1993, the kilometers of operating HOV facility have increased by 260 percent. During that same time period, daily person trips on the HOV lanes have increased by 270 percent. Person trips have, thus, been increasing at a rate slightly greater than that of the expansion of the HOV lane system.

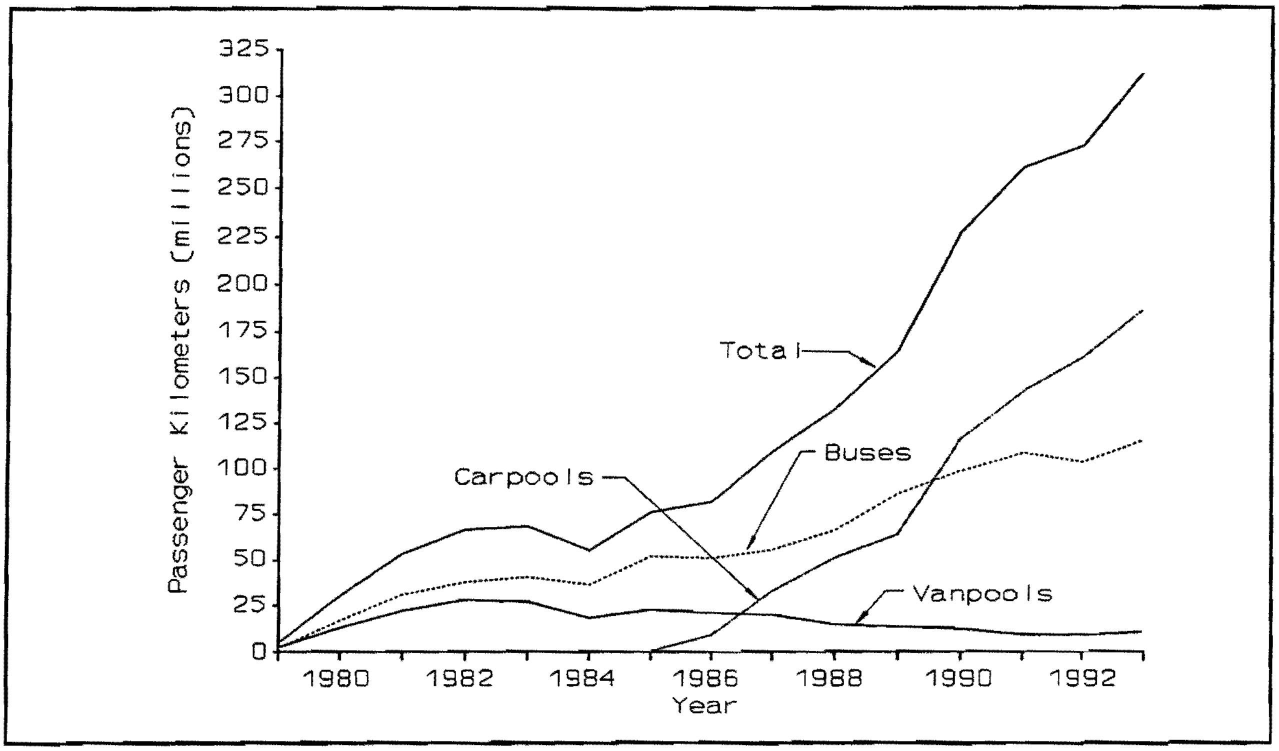


Source: See data in appendices.

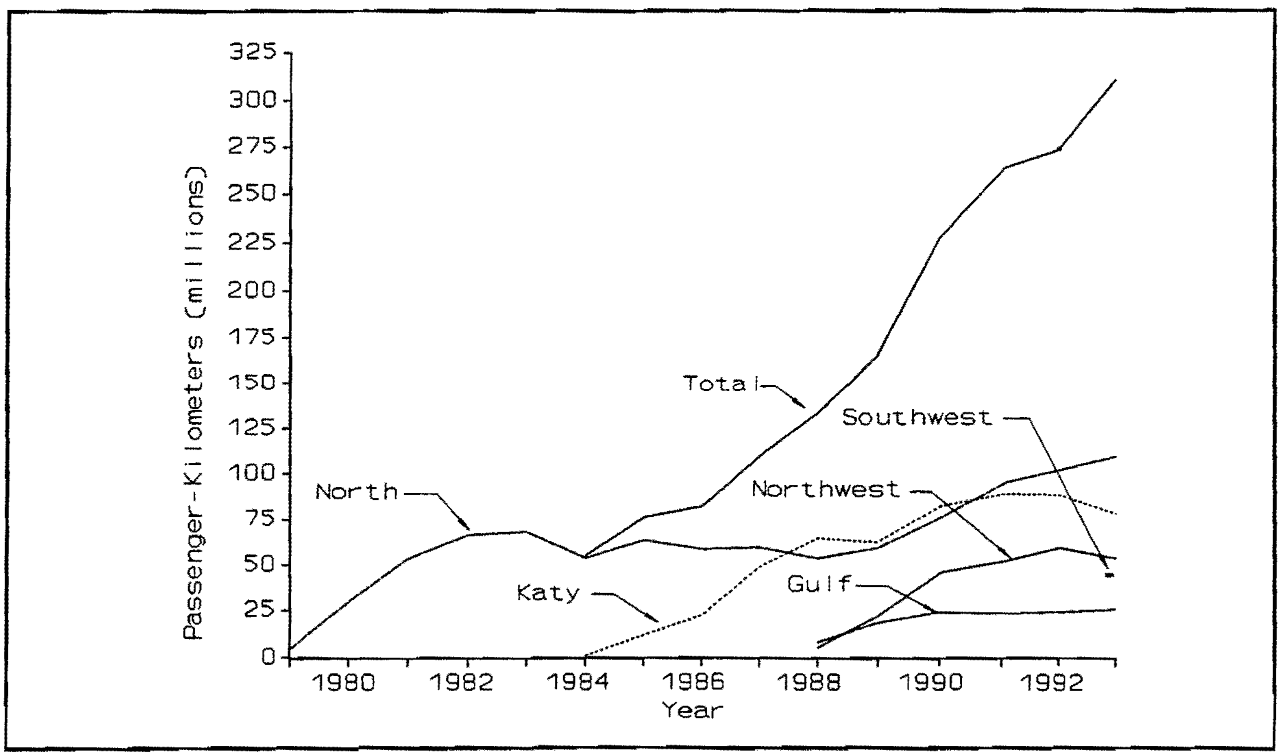


Source: See data in appendices.

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

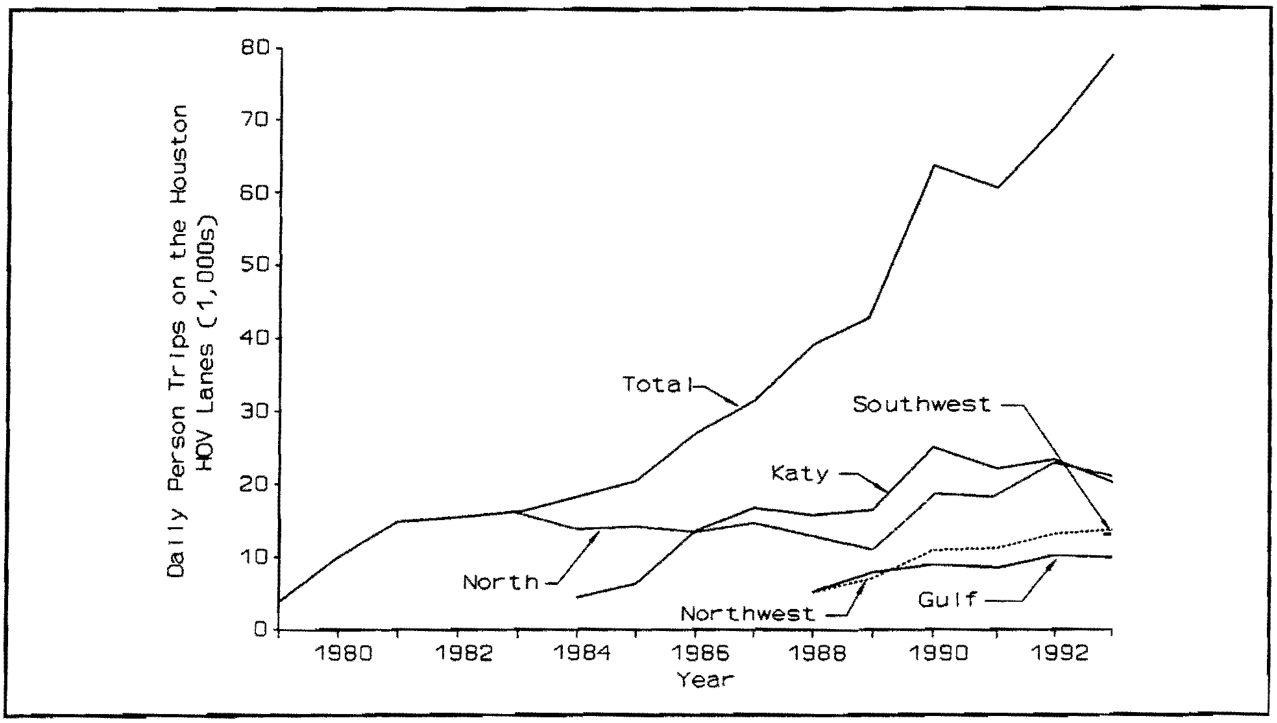


Source: See data in appendices.



Source: See data in appendices.

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



Source: See data in appendices.

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

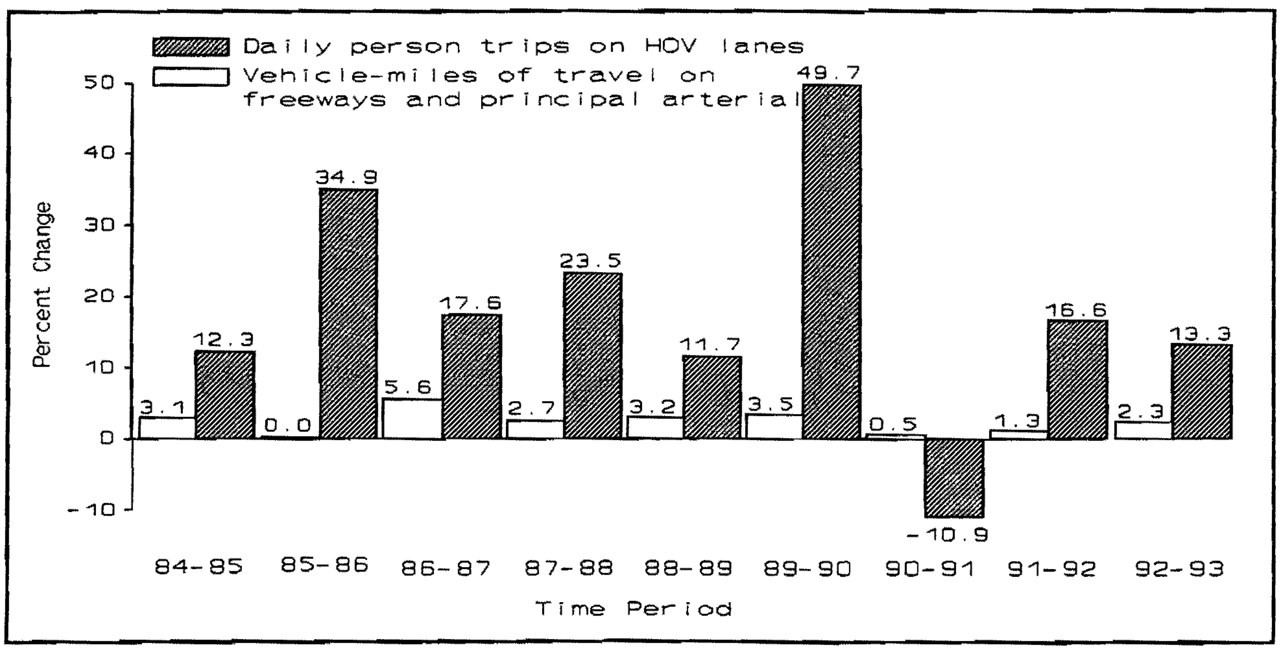


Figure 17. Annual Percentage Increase in HOV Person Trips and in Vehicle-Kilometers of Travel on Freeways and Principal Arterials

Comparison to Other Fixed-Guideway Projects

Simply as a basis of comparison, the operating Houston HOV lane system (93.5 kilometers [58.1 miles]) has been constructed for a capital cost of approximately $348 million, and this system serves approximately 78,000 person trips per day. The public operating cost per passenger-kilometer is roughly 8 cents (13 cents per passenger-mile). The Miami heavy rail system (34 kilometers [21 miles]) was constructed at a cost of approximately $1.2 billion and is serving about 55,000 daily person trips. The public operating cost per passenger-kilometer on that system is 22 cents (36 cents per passenger-mile). This simplistic comparison (Figure 18) is not intended to lead to a conclusion that either of the projects is necessarily good or bad, but it helps to demonstrate the relative significance of the HOV investment in Houston.

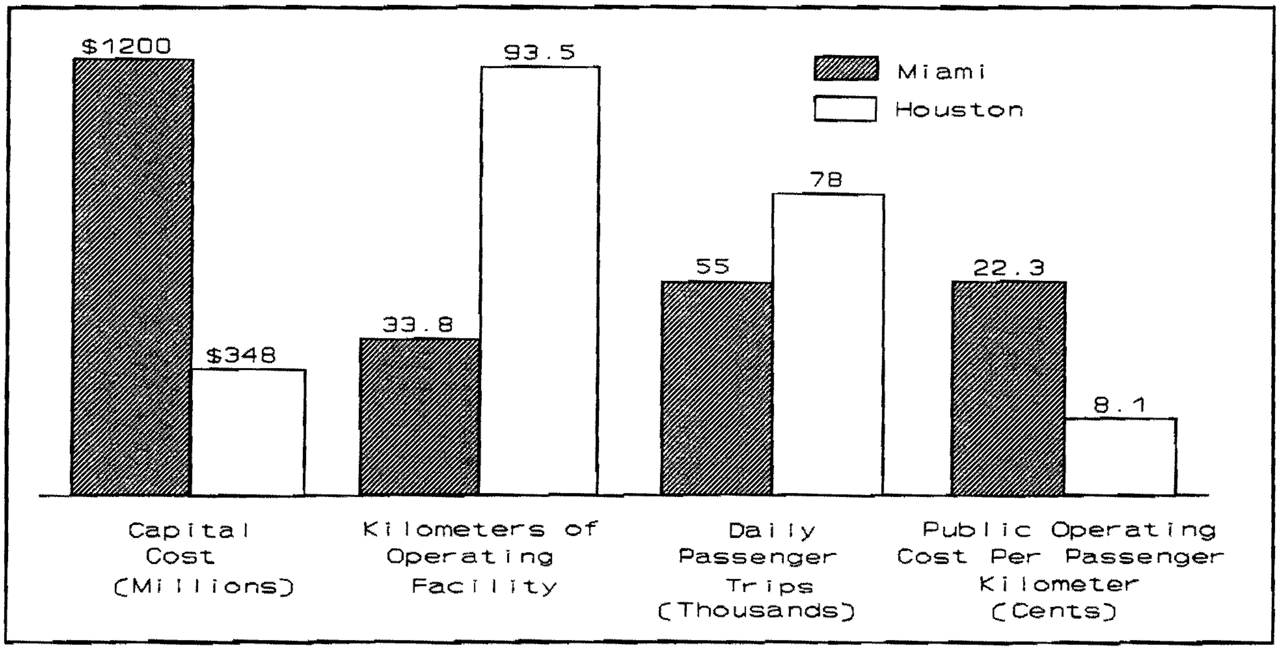


Figure 18. Comparative Data for the Operating Houston HOV Lanes and the Miami Rail Transit System

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

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

City and Transit Improvement	Length in Kilometers (Miles)	Capital Cost Per Kilometer (Mile)[1] (millions)	Average Weekday Person Trips[2]	Maximum Ridership, Peak-Hour, Peak-Direction
Houston HOV Lanes				
Katy (I-10W)	20.9 (13.0)	$3.0 ($4.8)	20,460	3,420
North (I-45N)	21.7 (13.5)	$3.6 ($5.8)	21,650	5,550
Gulf (I-45S)	10.5 (6.5)	$4.3 ($6.9)	9,630	2,760
Northwest (U.S. 290)	21.7 (13.5)	$4.6 ($7.4)	13,161	3,670
Southwest (U.S. 59S)	18.7 (11.6)	$3.4 ($5.4)	13,200	3,180
Average	18.7 (11.6)	$3.7 ($6.0)	15,620	3,710
U.S. Light Rail Lines				
Los Angeles	35.4 (22.0)	$24.8 ($39.9)	40,250	N/A
Portland	24.3 (15.1)	$ 8.8 ($14.1)	24,400	2,100
Sacramento	29.5 (18.3)	$ 7.3 ($11.8)	22,400	2,800
San Diego (San Ysidro)				
Route 510	26.2 (16.3)	$ 5.7 ($ 9.2)	40,500	2,500
Route 520	30.6 (19.0)	$ 5.6 ($9.0)	22,200	2,100
San Jose	32.0 (19.9)	$12.9 ($20.8)	20,100	1,500
Average	29.7 (18.4)	$11.7 ($18.8)	28,300	2,200

N/A - Not available
[1]HOV capital costs from Table 4. All costs are in year-of-construction dollars.
[2]Houston HOV data for December 1993. LRT ridership data represent average annual operations during 1993.

Source: Texas Transportation Institute and respective transit agencies.

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

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

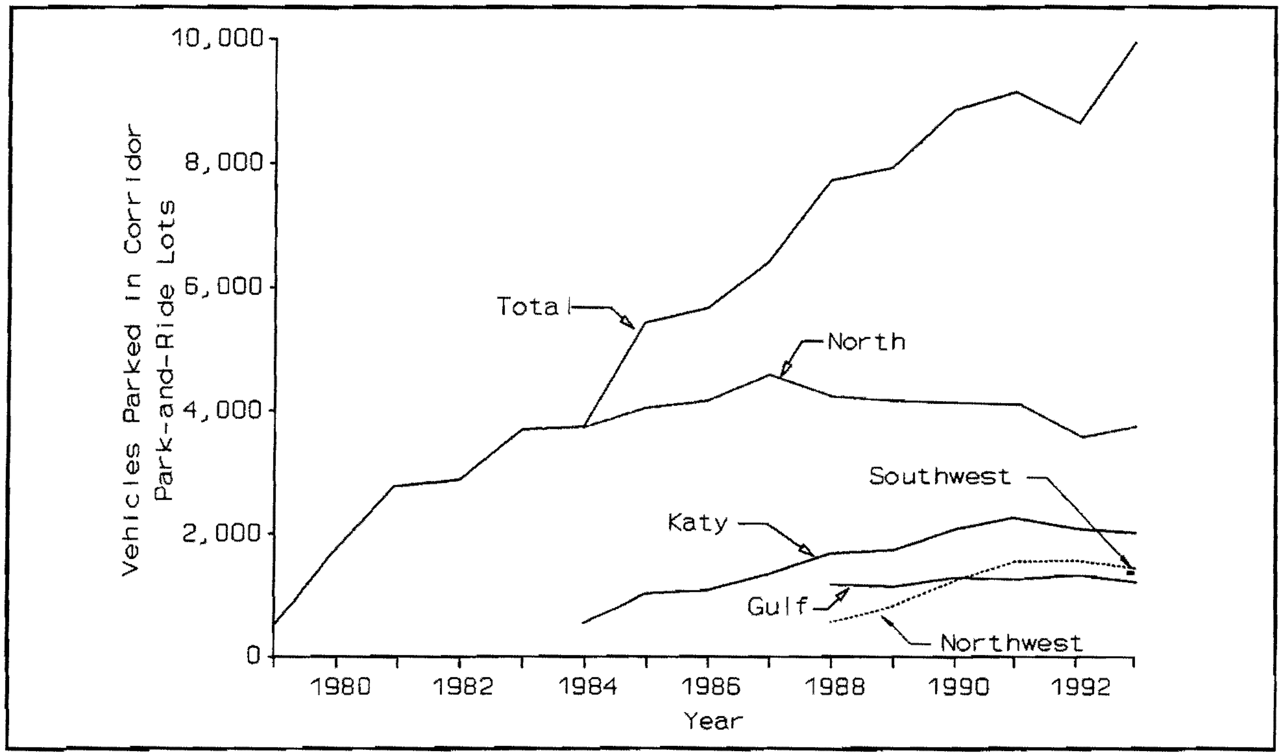
Fixed Guideway	Operating Cost Per Passenger-Kilometer (Passenger-Mile), cents	
Houston HOV System[1], 1993	8 (13)	
Rail Transit Systems, 1993		
Unweighted Average	20 (32)	
Atlanta		11 (17)
Miami		22 (36)
Portland		17 (28)
Sacramento		30 (49)
San Diego		12 (19)
San Jose		29 (46)
Washington, D.C.		18 (29)

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

Source: Respective transit agencies

Park-and-Ride Usage

Between December 1992 and December 1993, there has been an increase of 16 percent in the use of park-and-ride lots in the corridors served by HOV lanes (Figure 19). This increase has primarily been due to the addition of the park-and-ride lots in the Southwest HOV lane corridor. In December 1993, approximately 10,030 cars were parked at park-and-ride lots; in December 1992 that number was 8,625. On an areawide basis, park-and-ride patronage in Houston has been declining over this same time period. Reductions over the past year have been significant in corridors without HOV lanes. For instance, the park-and-ride patronage in the Eastex Freeway corridor decreased 23 percent between December 1992 and December 1993.



Source: See data in appendices.

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

Summary of HOV Usage Data

Table 11 presents selected HOV operating data. Except for the Katy HOV lane during the period when carpool usage is restricted to 3+, violations have not been a problem and have been less than five percent. The accident rates on the HOV lanes have generally been equal to, or less than, the rates on the freeway general-purpose lanes. Weekend operation for North, Gulf, and Northwest HOV lanes ended in October of 1991.

Table 11. Selected HOV Lane Operating Statistics, December 1993

Time Period and Operating Data	HOV Lane				
	Katy	North	Gulf	Northwest	Southwest
Weekday Operations					
HOV Lane Person Volume					
A.M. Peak Hour	3,424	5,546	2,755	3,667	3,175
Daily	20,462	21,645	9,628	13,161	13,200
HOV Lane Vehicle Volume					
A.M. Peak Hour	796	1,275	872	1,333	1,052
Daily	6,348	4,832	2,933	4,625	4,431
Percent of Total A.M. Peak-Hour, Peak-Direction Person Volume on HOV Lane[1]	36%	41%	—[3]	38%	29%
Vehicles Parked in Corridor Park-and-Ride Lots	2,008	3,730	1,227	1,503	1,454
Weekend Operations[2]					
Daily Saturday Vehicles	2,610	—	—	—	—
Daily Sunday Vehicles	2,863	—	—	—	—

[1]Data collected at HOV lane maximum load point. The remaining percentage is in the freeway general-purpose lanes.
[2]Scheduled bus service does not use the HOV lanes on weekends. Weekend operations for North, Gulf, and Northwest HOV lanes ended October 1991.
[3]Mainlane data not collected.

Source: Texas Transportation Institute data collection, see appendices.

CHARACTERISTICS OF HIGH-OCCUPANCY VEHICLE LANE USERS

On several occasions, TTI has surveyed both bus patrons and carpoolers using the HOV facilities. Those surveys, which are thoroughly documented elsewhere,[6] are highlighted herein. The most recent surveys were completed in 1990.

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

Transit Surveys

Table 12 summarizes selected data. The HOV facilities have attracted young, educated, white-collar professionals to ride transit. The bus is being used to serve long-distance commute trips, primarily to downtown. These individuals are using the HOV lanes primarily to save time, avoid having to drive 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. Over 60 percent of the bus passengers have all or part of their bus fare paid by their employer. Interestingly, on the two HOV facilities surveyed in 1990 that have been open to carpool use for at least two years (Katy and Northwest), about half of the bus riders have at some time carpooled or vanpooled on the HOV lane.

Carpool and Vanpool Surveys

Carpoolers also tend to be young, educated, white-collar professionals (Table 13). They are using the HOV lane for a long-distance commute trip. The carpools are more effective at serving dispersed trip patterns; compared to bus patrons, fewer destinations are in the downtown. Over 60 percent of the carpools are made up of family members. Fewer than 20 percent of the carpools are formed at either a park-and-ride or a park-and-pool lot.

Table 12. Selected Characteristics of HOV Lane Bus Patrons, 1990

Characteristic	HOV Lane			
	Katy	North	Northwest	Gulf[2]
A.M. Trip Destination				
Downtown	93%	91%	95%	86%
City Post Oak	2%	0%	2%	1%
Greenway Plaza	1%	1%	0%	0%
Texas Medical Center	1%	6%	1%	5%
Trip Purpose (% Work)	97%	98%	99%	96%
Age, Years (50th Percentile)	36	38	35	34
Sex (% Male)	48%	40%	43%	30%
Education, Years (50th Percentile)	16	15	16	14
Occupation				
Professional	50%	43%	45%	41%
Managerial	19%	17%	17%	16%
Clerical	20%	30%	25%	32%
Sales	5%	3%	8%	2%
Auto Available for Trip (% Yes)	91%	95%	92%	87%
Does Employer Pay for Transit				
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)	46%	32%	50%	—

[1]Data from 1986 transit user survey
[2]Data from 1989 transit user survey

Source: Texas Transportation Institute surveys.

Table 13. Selected Characteristics of Carpoolers Using the HOV Facilities, 1990

Characteristic	HOV Lane			
	Katy	North	Northwest	Gulf[2]
A.M. Trip Destination				
Downtown	55%	76%	40%	78%
City Post Oak	13%	3%	28%	6%
Greenway Plaza	5%	2%	5%	2%
Texas Medical Center	6%	7%	6%	4%
Other	21%	12%	21%	10%
Trip Purpose				
% Work	88%	95%	90%	98%
% School	2%	5%	10%	2%
Age, Years (50th Percentile)	38[1]	37	36	38
Sex (% Male)	55%[1]	53%	38%	41%
Education, Years (50th Percentile)	15[1]	15	15	14
Occupation				
Professional	45%[1]	38%	49%	46%
Managerial	18%[1]	21%	19%	15%
Clerical	14%[1]	21%	15%	26%
Sales	6%[1]	11%	7%	4%
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	—	61%	62%	—
Neighbors	—	13%	13%	—
Co-workers	—	25%	25%	—
Does Carpool Stage at Park/Pool Lot (% Yes)	—	11%	17%	—

[1]Data from 1989 survey
[2]Data from 1986 survey

Source: Texas Transportation Institute surveys.

III. MEASURES OF HIGH-OCCUPANCY VEHICLE LANE EFFECTIVENESS

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

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

In concept, if the HOV lanes perform as intended, provision of the priority lanes offers a means to help accommodate some of this future growth. If design year volumes of 7,000 to 10,000 persons per hour per lane are achieved on these lanes, the person-movement capacity of the freeway will effectively have been doubled at a cost of $3 to $5 million per kilometer ($5 to $8 million per mile), and future volumes can be served acceptably. However, this will be the case only if the HOV lanes perform as expected. As a result, their performance is being closely monitored to assess the effectiveness of the improvements.

POTENTIAL MEASURES OF EFFECTIVENESS

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

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

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

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

---

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

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

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

Objective. Improve the efficiency of bus transit operations.

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

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

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

Objective. The HOV lane project should be cost effective.

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

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

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

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

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

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

THE TIME FACTOR

As of the end of 1993, the oldest HOV lanes in Texas (the Katy and North HOV lanes in Houston) have been in operation for just over eight years. Until 1990, none of the high-occupancy vehicle facilities had been completed in its final form. In assessing the worth of these improvements, it should be recognized that these facilities are being looked to as a means of helping to serve the growth in travel that will be occurring over the next 10 to 20 years. Design year demand estimates are two to three times greater than the current demand on some of the HOV lanes.

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

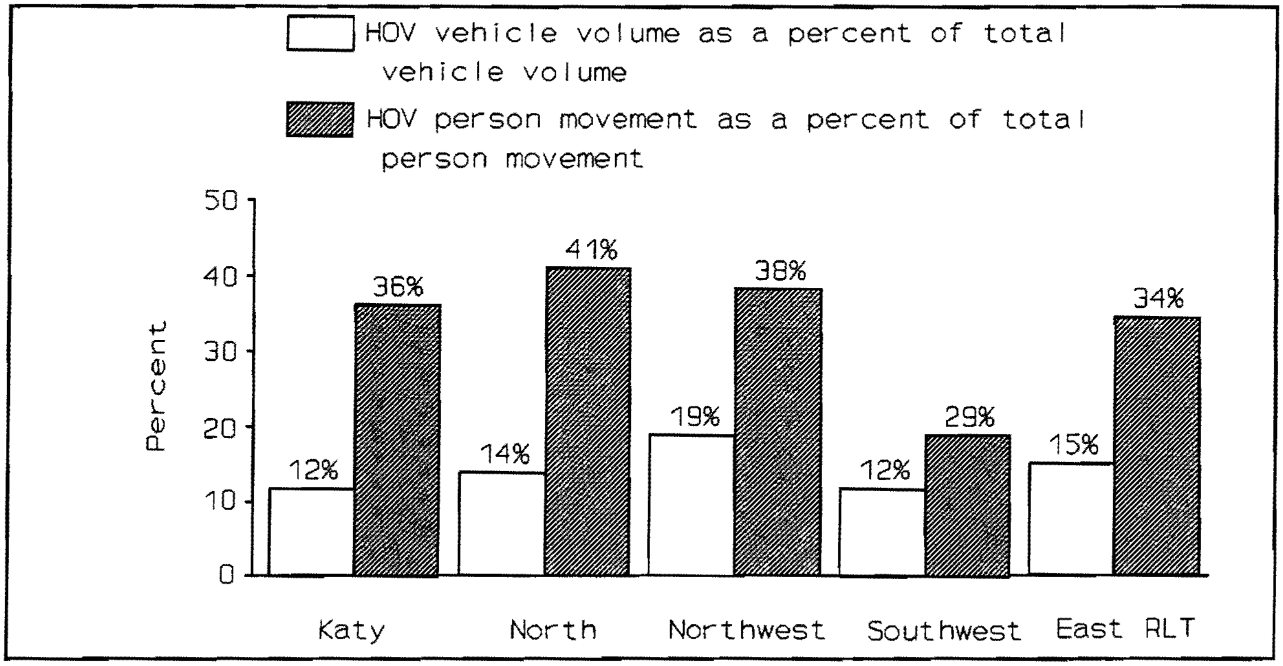
IV. PERSON MOVEMENT, OCCUPANCY, AND TRANSIT EFFICIENCY

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

HIGH-OCCUPANCY VEHICLE LANE UTILIZATION

In December 1993, 78,096 daily person trips were counted on the Houston HOV lane system. This level of ridership represents a 12 percent increase in comparison to 1992. The East RLT HOV lane in Dallas served 14,017 daily person trips in December 1993. By comparison, this facility served 16,472 daily person trips in December 1992.

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



Source: See data in appendices.

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

FACTORS INFLUENCING HIGH-OCCUPANCY VEHICLE LANE UTILIZATION

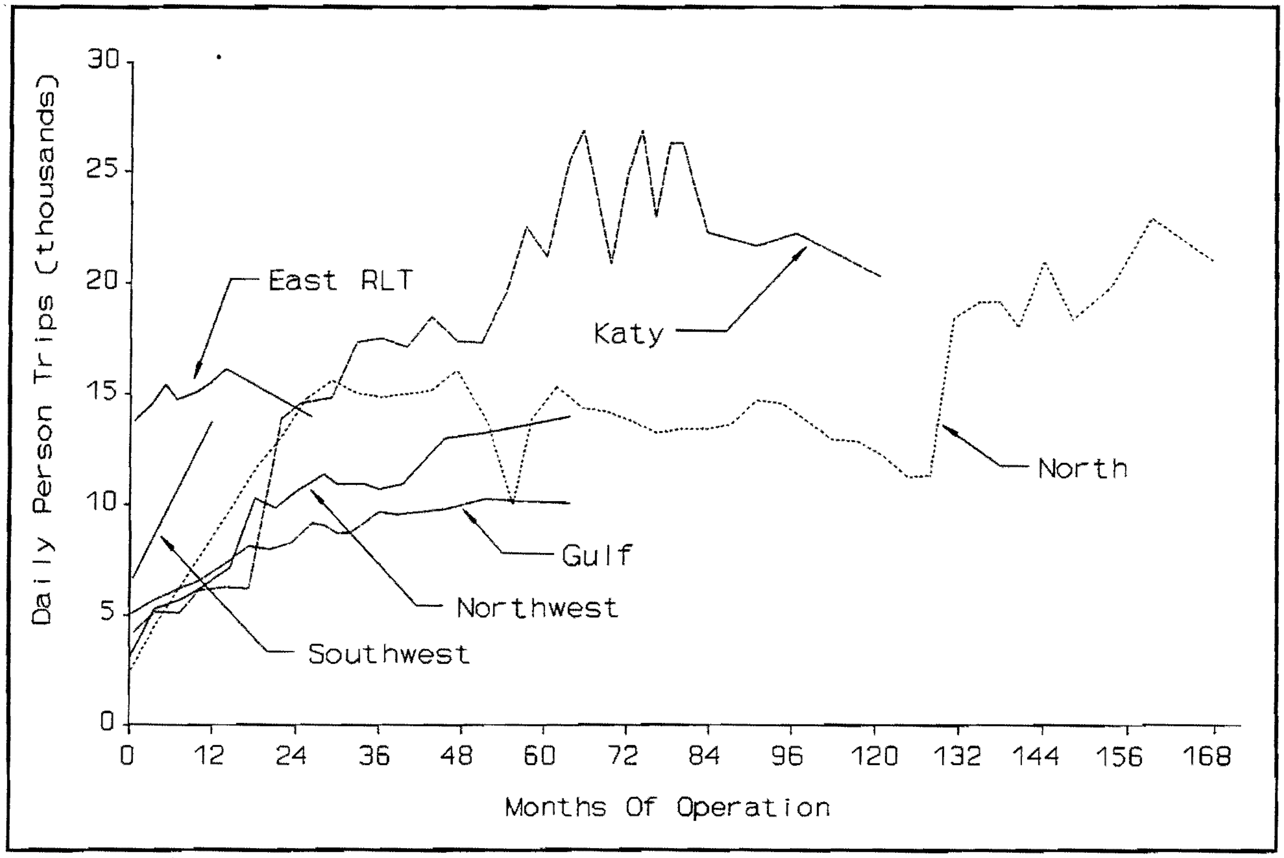
It is evident that a number of factors influence both bus ridership and carpooling on an HOV lane. Some of those factors, such as parking cost, are the ones used in traditional mode split models. A review of the Houston data suggests that at least three factors appear to be significant in helping to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

Length of Time HOV Lane Has Operated

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

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

This occurrence of rapid growth in usage during the early years of operation has been observed on the Houston HOV facilities (Figure 21). Both the North and Katy HOV lanes have been in operation long enough to have experienced this early-year growth surge. The same is now beginning to be true for the Gulf and Northwest HOV lanes, which opened in 1988. The Southwest HOV lane has experienced significant growth since opening in January 1993, but has been open a very short period of time. The East RLT HOV lane has not followed this general trend; ridership declined during 1993 due partly to operational problems associated with the evening merge point between the HOV lane and freeway general-purpose lanes. This problem will soon be removed with the extension of the evening operations to Jim Miller Road.



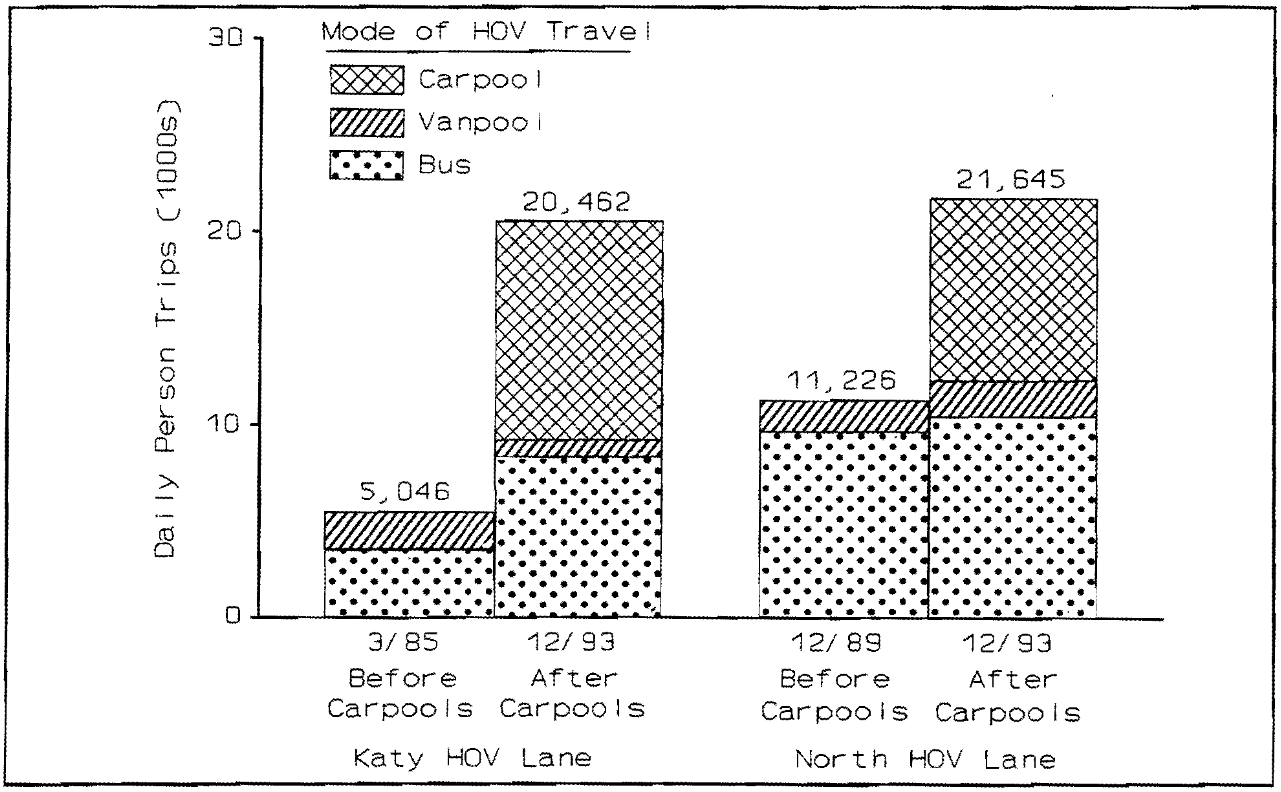
Source: See data in appendices.

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

Vehicle Groups Allowed to Use the HOV Lane

As would be expected, either allowing carpools to use an HOV lane or reducing carpool occupancy requirements will result in an increase in HOV lane usage (as long as the vehicular capacity of the priority lane is not exceeded). This is reflected in the fact that 61 percent of total HOV person trips on the Houston HOV lanes and 62 percent of HOV person trips on the East RLT HOV lane are in carpools or vanpools.

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



Source: Texas Transportation Institute data collection.

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

Travel Time Savings and Reliability Offered by the HOV Lane

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

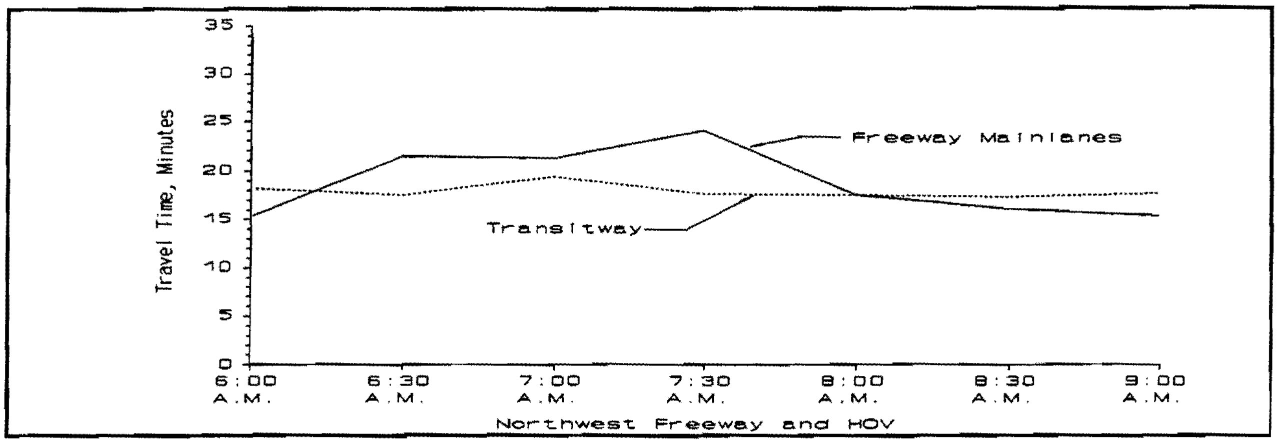
As part of this research project, travel time data are collected on a quarterly basis for each freeway and HOV lane. These data are averaged to estimate the representative travel time savings offered by the HOV lanes. A plot of the a.m. travel times is shown in Figure 23.

Table 14 presents selected usage and time savings data related to the Houston HOV facilities for 1992 and 1993. Statistics indicate a slight decrease in the average usage of the HOV facilities during 1993. The decrease in travel time savings relative to 1992 may at least partly explain this decrease in usage of the HOV lanes.

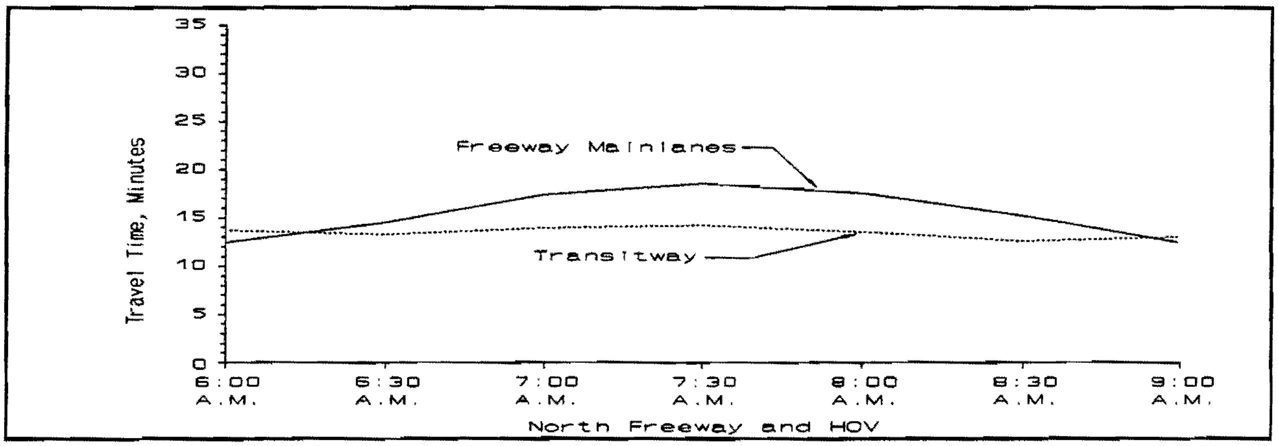
In the case of the Katy HOV lane, a significant amount of bus service (approximately 30 buses during the peak hour) was diverted to the Southwest HOV lane in January 1993. Data collected during 1993 indicate that this change in bus operations, as well as a diversion of carpools from Katy to the Southwest HOV lane, has accounted for the significant decrease in vehicle and person volumes on the Katy HOV lane. Having been (to this point) one of the most highly-utilized HOV facilities in Houston, the significant decrease in usage has, in turn, had a notable impact on 1993 HOV system usage relative to 1992 operations.

---

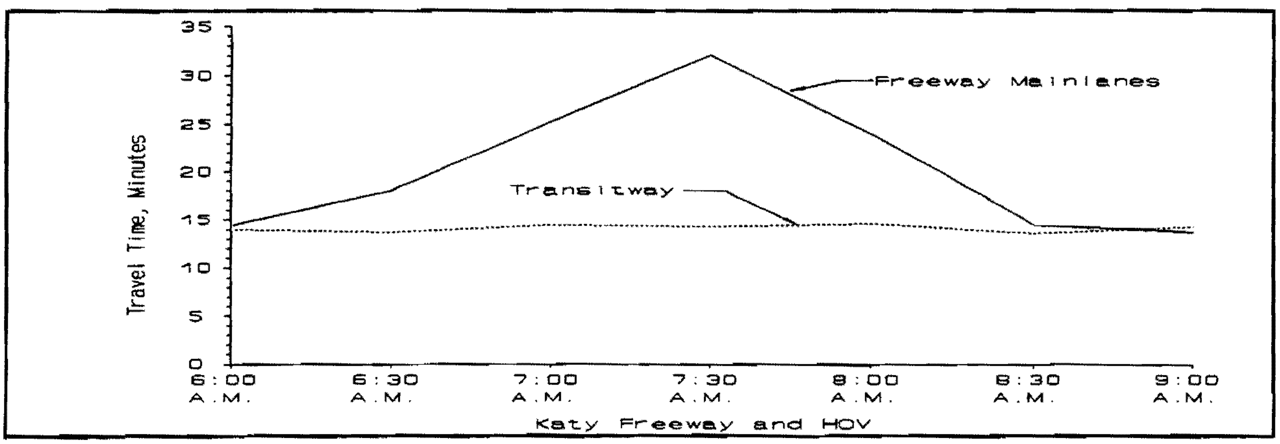
[9]D. Baugh and Associates. "Freeway High-Occupancy Vehicle Lanes and Ramp Metering Evaluation Study." Prepared for U.S. Department of Transportation, 1979.



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

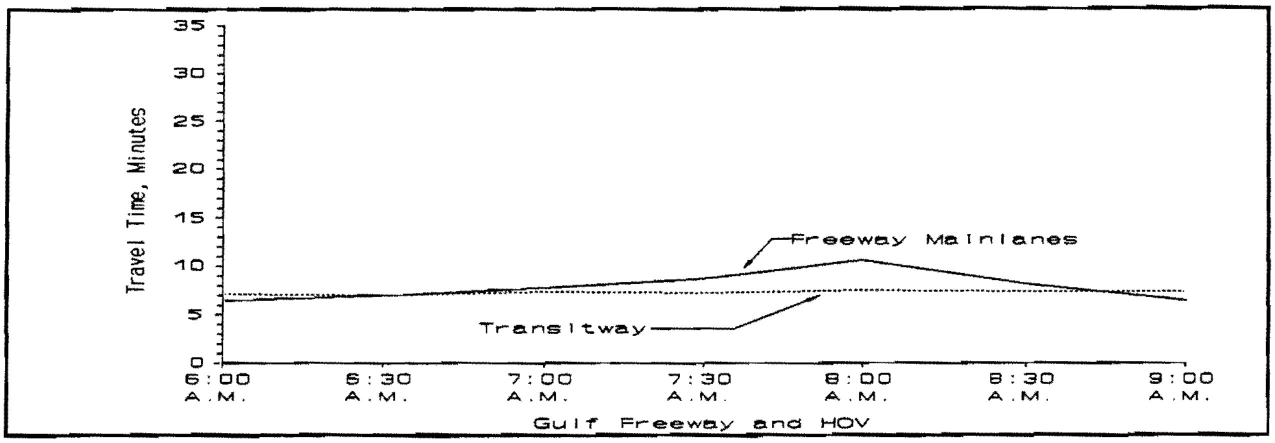


Note: Travel times are from Beltway 8 to Hogan.

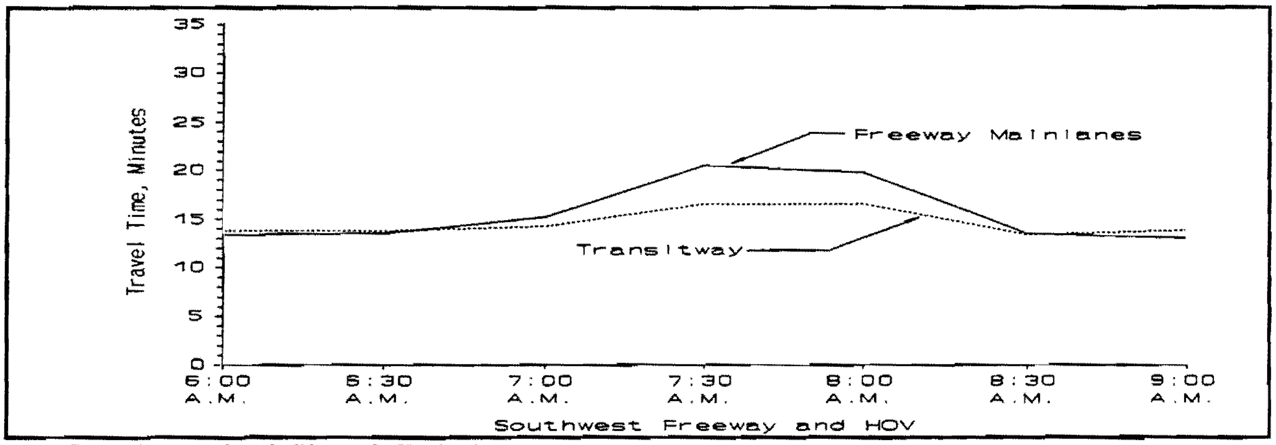


Note: Travel times are from SH 6 to the S.P. Railroad.

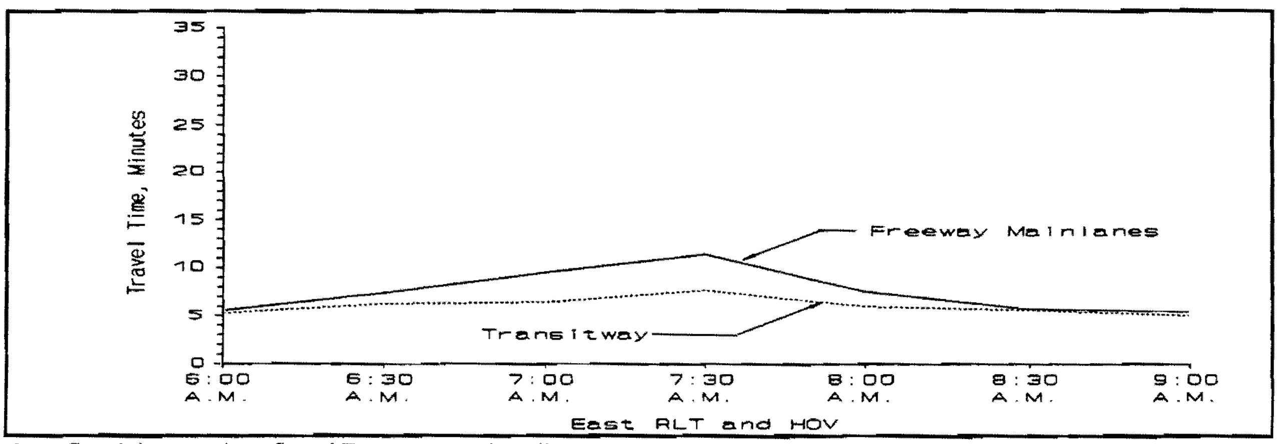
Figure 23. A.M. Peak Period Travel Time, Houston and Dallas Freeway HOV Lanes



Note: Travel times are from Park Place to Dowling.



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



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

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

Table 14. Summary of Selected Data Relating to Usage and Travel Time Savings on the Houston HOV Lanes

Data	Katy			North			Northwest			Gulf			Total, 4 HOV Lanes[1]		
	12/92	12/93	% Change	12/92	12/93	% Change	12/92	12/93	% Change	12/92	12/93	% Change	12/92	12/93	% Change
Miles of HOV Lane	13.0	13.0	0	13.5	13.5	0	13.5	13.5	0	6.5	6.5	0	46.5	46.5	0
HOV Lane Person Volume															
Daily	23,434	20,462	-12.7	23,030	21,645	-6.0	13,296	13,161	-1.0	10,196	9,268	-5.6	69,956	64,896	-7.2
A.M. Peak Hour	4,524	3,424	-24.3	5,560	5,546	0	3,969	3,667	-7.6	3,218	2,775	-13.8	17,271	15,412	-10.8
A.M. Peak Period	10,702	8,308	-22.4	10,994	10,485	-4.7	7,049	6,482	-8.0	5,165	4,613	-10.7	33,910	29,888	-11.9
P.M. Peak Hour	4,535	3,140	-30.8	5,403	4,757	-12.0	2,979	3,572	+19.9	2,627	2,392	-8.9	15,544	13,861	-10.8
P.M. Peak Period	9,950	8,828	-11.3	11,278	10,196	-9.6	5,785	6,594	+14.0	4,529	4,767	+5.3	31,542	30,385	-3.7
HOV Lane Vehicle Volume															
Daily	6,829	6,348	-7.0	4,892	4,832	-1.2	4,928	4,625	-6.1	3,018	2,933	-2.8	19,667	18,738	-4.7
A.M. Peak Hour	977	796	-18.5	1,256	1,275	+1.5	1,504	1,333	-11.4	1,013	872	-13.9	4,750	4,276	-10.0
A.M. Peak Period	2,755	2,283	-17.1	2,345	2,338	0	2,685	2,358	-12.2	1,544	1,429	-7.4	9,329	8,408	-9.9
P.M. Peak Hour	1,072	835	-22.1	1,049	1,068	+1.8	1,058	1,161	+9.7	653	600	-8.1	3,832	3,664	-4.4
P.M. Peak Period	2,683	2,561	-4.5	2,168	2,111	-2.6	2,012	2,183	+8.5	1,223	1,228	0	8,086	8,083	0
Avg. HOV Lane Vehicle Occupancy, A.M. Peak Hour	4.63	4.30	-7.1	4.4	4.35	-1.1	2.64	2.75	+4.2	3.2	3.16	-1.3	3.56	3.46	-2.8
HOV Lane Travel Time Savings, Avg. Peak Hour (min)[2]	14.5	13.2	-9.0	5.9	5.4	-8.5	7.8	5.6	-28.2	5.4	5.4	0	33.6	29.6	-11.9

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

[1]Only the Katy, North, Gulf, and Northwest facilities are used due to the presence of only one year worth of data for the Southwest HOV lane.

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

Source: Texas Transportation Institute.

Table 15 includes selected usage and time savings data for the East RLT HOV facility. These statistics indicate a moderate decrease in usage of the facility and a slight increase in average peak hour time savings. As is the case on the North and Northwest HOV lanes in Houston (Table 14), vehicle volumes on the East RLT HOV have reached the point that free-flow conditions are not always maintained during the peak hour.

Table 15. Summary of Selected Data Relating to Usage and Travel Time Savings on the East RLT HOV Lane

Data	12/92	12/93	% Change
Miles of HOV Lane			
Morning	5.2	5.2	0
Evening	3.3	3.3	0
HOV Lane Person Volume			
Daily	16,472	14,017	-14.9
A.M. Peak Hour	4,043	3,640	-10.0
A.M. Peak Period	8,932	7,276	-18.5
P.M. Peak Hour	4,140	3,596	-13.1
P.M. Peak Period	7,540	6,741	-10.6
HOV Lane Vehicle Volume			
Daily	5,043	4,714	-6.5
A.M. Peak Hour	1,222	1,243	+1.7
A.M. Peak Period	2,717	2,507	-7.7
P.M. Peak Hour	1,171	1,144	-2.3
P.M. Peak Period	2,326	2,207	-5.1
Avg. HOV Lane Vehicle Occupancy, A.M. Peak Hour	3.31	2.93	-11.5
HOV Lane Travel Time Savings, Avg. Peak Hour (min)[1]	2.5	3.2	+28.0

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

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

The data in Tables 14 and 15 show the average peak-hour travel time savings measured on the Houston and Dallas HOV lanes. It should be noted that variability exists in travel times on a daily basis; plus, there is some error in the measurement of travel times. As a result, differences or changes of only two to three minutes have little significance. It is interesting to note that the surveys show that the users of the HOV lanes typically perceive a much greater time savings than is actually realized (Table 16).

Table 16. Comparison of Actual and Perceived Travel Time Savings[1] on the HOV Lanes, 1990

HOV Facility	Measured Peak-Hour Travel Time Savings (min)		Perceived HOV Travel Time Savings (min.)			
			Transit Riders		Carpoolers	
	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.
Katy	14.2	13.8	17	19	19	19
North	6.9	4.5	15	19	15	19
Gulf[1]	2.1	1.5	10	15	12	15
Northwest	7.3	2.1	18	18	19	19

[1]Perceived travel time savings are 1989 data.

Source: Texas Transportation Institute surveys and data collection.

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

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

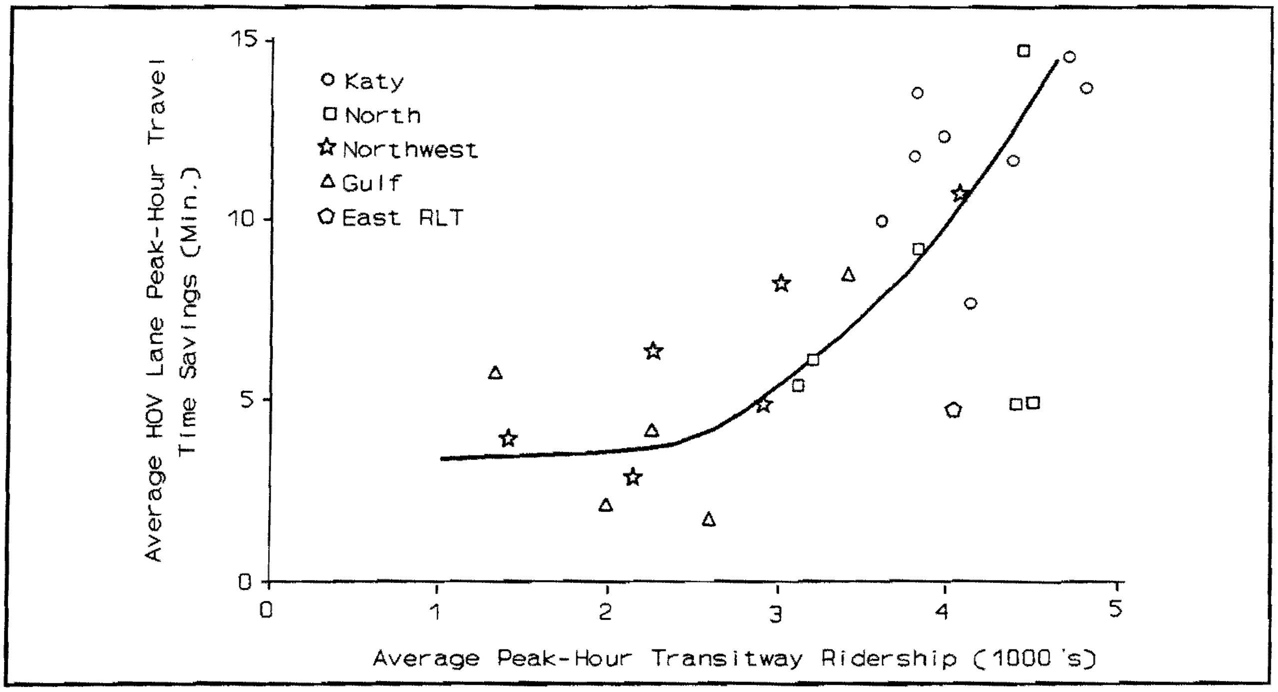


Figure 24. Relationship Between Peak-Hour HOV Lane Ridership and Peak-Hour HOV Lane Travel Time Savings

Travel time reliability is an additional characteristic of HOV lanes which appears to have a positive influence on the utilization of these priority facilities. Table 17 includes average speed and speed variability data for the Katy and East RLT Freeways. Examination of Table 17 shows that the speed variability (as illustrated by the standard deviation) for each of the HOV lanes is considerably less than that of the adjacent general-purpose lanes. The standard deviations in speed range from 4.8 kph (3.0 mph) to 9.8 kph (6.1 mph) for the HOV lanes, while the general-purpose lane standard deviations range from 12.8 kph (8.0 mph) to 26.9 kph (16.7 mph).

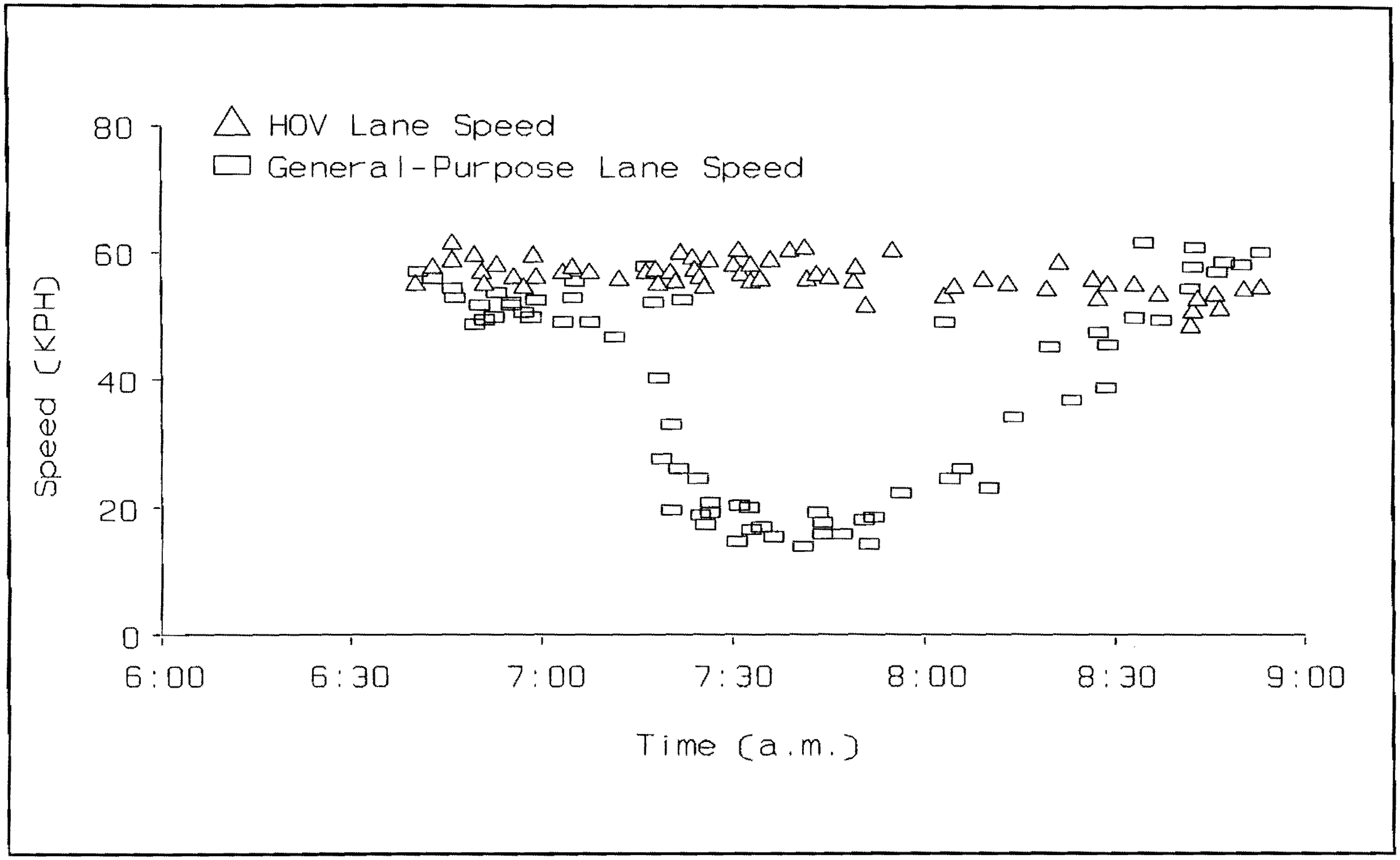
Table 17. Summary of Travel Time Reliability Data for Selected HOV Facilities, 1993

Facility	Peak Period[1,2]	Segment	General-Purpose Lanes		HOV Lane	
			Average Speed, kph (mph)	Standard Deviation, kph (mph)	Average Speed, kph (mph)	Standard Deviation, kph (mph)
Katy	Morning	SH6 to Gessner	45 (28)	12.8 (8.0)	100 (62)	5.5 (3.4)
	Morning	Gessner to Washington	74 (46)	13.6 (8.4)	88 (55)	5.4 (3.4)
	Evening	Washington to Gessner	54 (34)	16.1 (10.0)	93 (58)	5.1 (3.2)
	Evening	Gessner to SH6	76 (47)	16.0 (9.9)	92 (57)	4.8 (3.0)
East RLT	Morning	Jim Miller to Central	61 (38)	26.3 (16.3)	83 (52)	9.0 (5.6)
	Evening	Central to Dolphin	74 (46)	26.9 (16.7)	96 (60)	9.8 (6.1)

[1]Morning peak period for Katy and East RLT Freeways are 6:00 to 9:00 a.m.
[2]Evening peak period for Katy Freeway is 3:30 to 6:30 p.m., while East RLT Freeway is 4:00 to 7:00 p.m.

Source: Texas Transportation Institute data collection.

Statistical analyses of the data included in Table 17 indicate a significant difference (at a 95% confidence level, $\alpha = 0.05$) between the travel time reliability offered by the HOV lanes versus general-purpose freeway lanes. A typical peak period speed profile illustrating this significant difference is included in Figure 25.



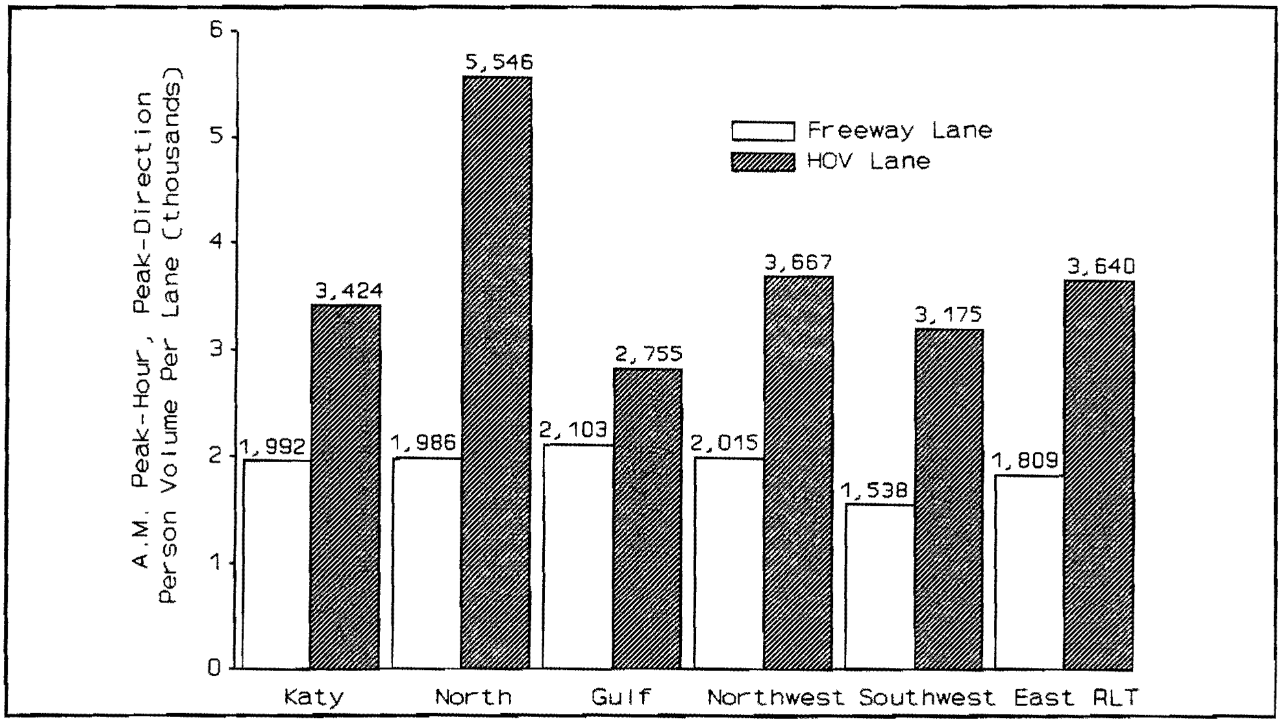
Note: Average speeds from Jim Miller Road to Central Expressway.

Source: Texas Transportation Institute data collection.

Figure 25. Morning Peak Period Speed Profile, East RLT Freeway and HOV Lane (1993).

CHANGES IN ROADWAY PERSON MOVEMENT

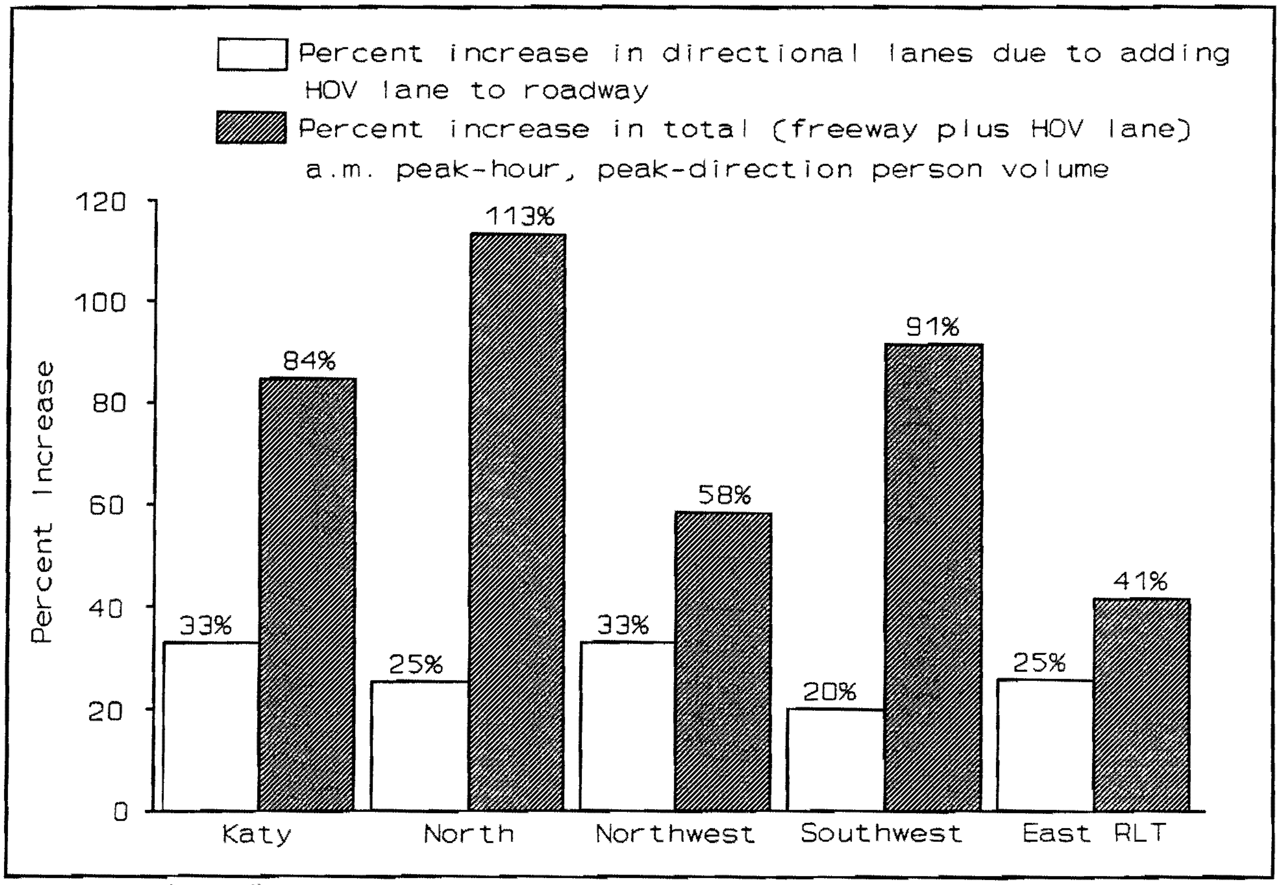
A major reason for implementing high-occupancy vehicle lanes is to increase the effective person-movement capacity of a roadway. There is increasing recognition that emphasis needs to begin to be focused on moving people rather than vehicles. The HOV facilities are intended to be an incentive to help bring about this increase in person movement. The HOV lanes do move a greater volume of persons than do the freeway lanes (Figure 26). During the peak hour, the HOV lanes are moving 31 percent to 179 percent more persons per lane than are the freeway mainlanes. To an extent, however, this would be expected since nearly all of the higher-occupancy vehicles have been put into one lane.



Source: See data in appendices.

Figure 26. Peak-Hour, Peak-Direction Person Volumes Per Lane on Houston Freeways and HOV Lanes

Since implementation of the HOV lane does increase the number of directional lanes, for the priority lane to be effective it should at least increase person movement by an amount greater than the increase in lanes added to the roadway due to implementing an HOV lane. If this is not the case, the effectiveness of the HOV lane is questionable. The data show that the HOV lanes in Texas are helping to result an increase in person movement (Figure 27). In all instances where data are available, the increase in person movement exceeds the increase in lanes provided.



Source: See data in appendices.

Figure 27. Increase in Total (Freeway plus HOV Lane) A.M. Peak-Hour, Peak-Direction Person Movement, Comparison of Pre-HOV Lane Conditions to Present

CHANGES IN AVERAGE VEHICLE OCCUPANCY

For the HOV lanes to generate the disproportionate increases in person movement reflected in Figure 27, it is necessary to increase the average vehicle occupancy (persons per vehicle) characteristic of the roadway. The high-occupancy vehicle lane is intended to offer a travel alternative that a significant percentage of commuters will find attractive and will, as a result, choose to either carpool or ride a bus. If this occurs, it should be reflected by an increase in average vehicle occupancy.

On the two more mature Houston HOV lanes (Katy and North), peak-hour average vehicle occupancies are unusually high for Texas (or other southwestern states) freeways, being well over 1.4 persons per vehicle (Figure 28). These occupancies are the combined average of all freeway mainlane plus all HOV facility traffic.

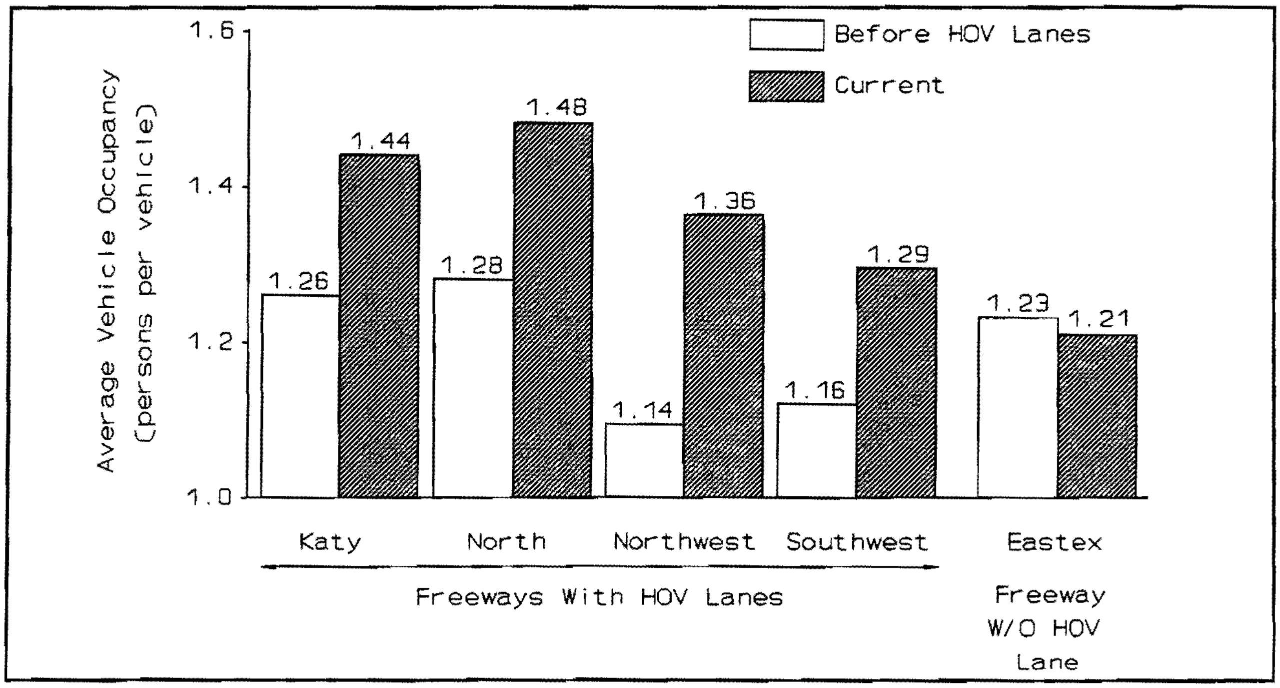


Figure 28. Change in A.M. Peak-Hour, Peak-Direction Average Vehicle Occupancy, Freeways With and Without HOV Lanes

During the time period being studied, the percentage increase in average vehicle occupancy on the freeways with HOV lanes has been significant. This has not been the case on a freeway not having an HOV facility (Figure 29).

The data clearly show that the presence of the HOV lane has resulted in a meaningful increase in average vehicle occupancy. On the freeways with HOV lanes, in comparison to pre-HOV lane conditions, the average peak-hour, peak-direction vehicle occupancy has generally increased by over 15 percent. Over the same time period, occupancy on a freeway without an HOV lane has experienced a two percent decrease in average vehicle occupancy.

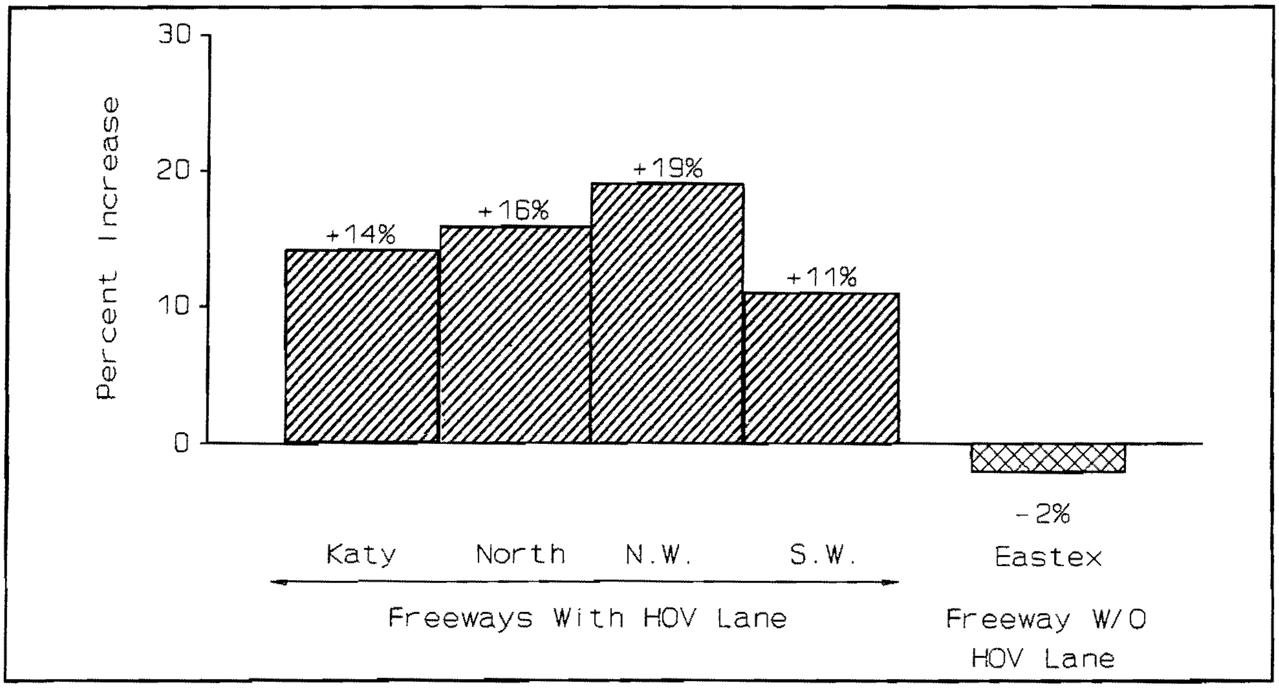


Figure 29. Percentage Change (Pre-HOV Lane to Present) in Average Vehicle Occupancy, A.M. Peak-Hour, Peak-Direction, Freeways With and Without HOV Lanes

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

CHANGES IN CARPOOLING

Survey data suggest that relatively few carpools now using the HOV lanes were existing carpools that diverted to the HOV lane from parallel routes (Table 18). This indicates that the increases that occurred in average vehicle occupancy were primarily from factors other than this diversion.

Table 18. Carpools That Diverted to the HOV Facility From Parallel Routes

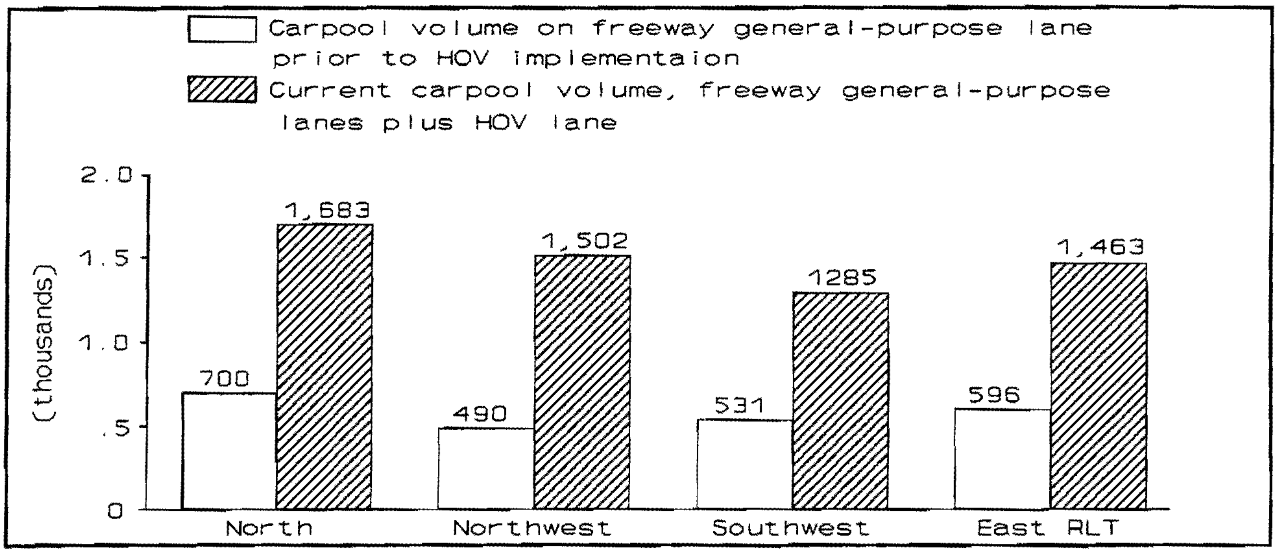
HOV Facility	Percent of HOV Carpoolers Whose Previous Mode Was Carpooling[1]		Percent of Those Carpoolers Who Previously Used a Parallel Route[2]	
	1989	1990	1989	1990
Katy	26%	29%	15%	13%
North	—	40%	—	19%
Gulf	44%	—	14%	—
Northwest	46%	33%	11%	15%
Unweighted Average	39%	34%	13%	16%

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

Source: Texas Transportation Institute surveys.

There have been significant increases in carpool volumes since carpools were allowed to use the HOV facilities (Figure 30). Increases approaching 100 percent are typical. To assess the effectiveness of the high-occupancy vehicle lanes, it is necessary to develop estimates of how many of the carpools using the HOV lanes are new carpools formed largely due to the implementation of these priority lanes.

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

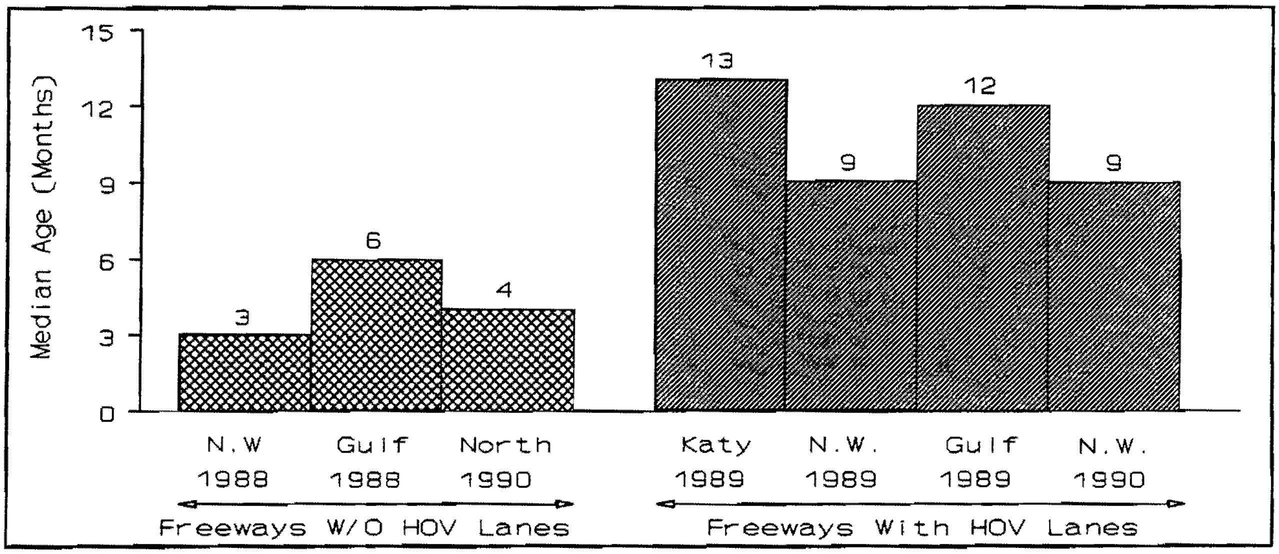


Note: Katy HOV data reflect 3+ occupancy requirements during peak hours of operation (6:45 to 8:00 a.m. and 5:00 to 6:00 p.m.).
Source: See data in appendices.

Figure 30. Volume of 2+ Carpools (Freeway Plus HOV Lane), A.M. Peak-Hour, Peak-Direction, Pre-HOV Lane and Current

Available data suggest that carpools in corridors with HOV lanes do remain in existence longer than carpools in corridors without HOV lanes (Figure 31). The median age of a carpool on an HOV facility is over two times greater than the median carpool age on a non-HOV facility. It appears that the presence of an HOV lane is causing carpools to remain in existence longer.

Comparing what has occurred on freeways with HOV lanes to what has taken place over the same time period on freeways without HOV lanes helps to isolate the impacts of the HOV facilities (Figure 32). The magnitude of increase that has occurred on the freeways with priority lanes simply has not taken place in the corridor without a HOV lane. The increase in carpools on the freeways with HOV lanes has been several times greater than what has been experienced on a freeway without an HOV lane. Since the major difference in the corridors being compared is the availability of an HOV lane, a conclusion is that the priority lane is a significant factor in creating new carpools.



Source: Texas Transportation Institute surveys.

Figure 31. Median Age of a Carpool in Corridors With and Without High-Occupancy Vehicle Lanes

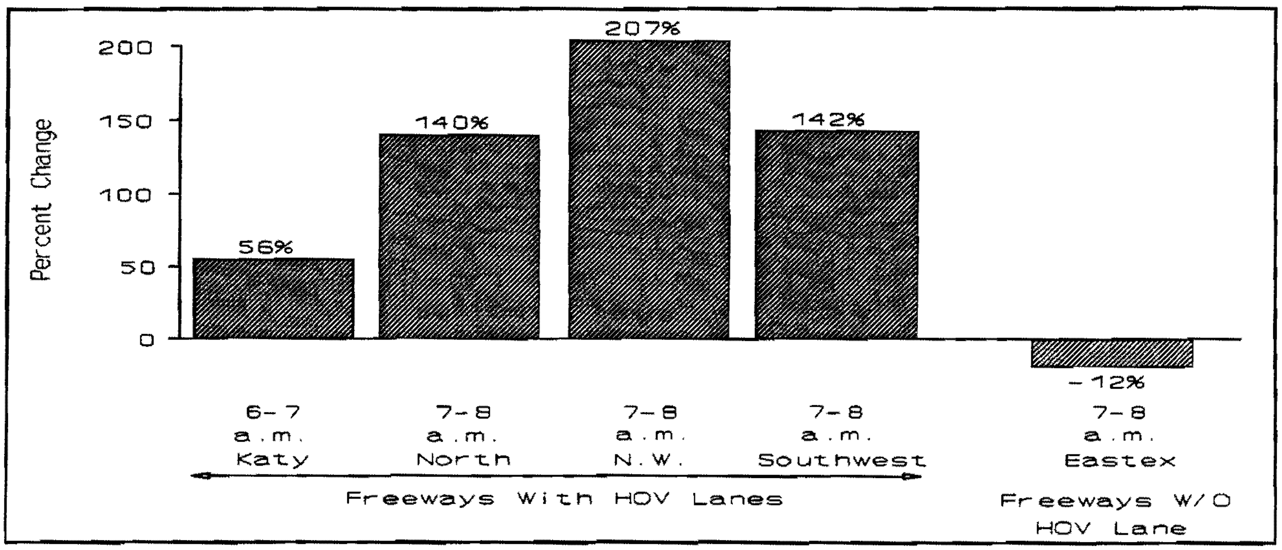
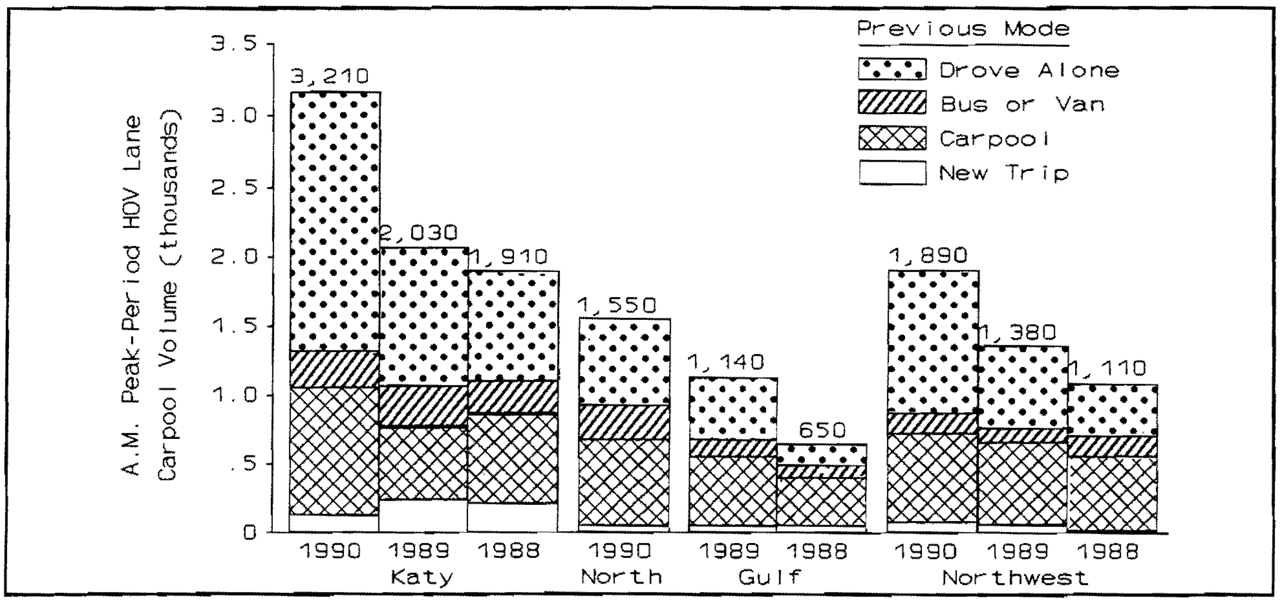


Figure 32. Percent Change (Pre-HOV Lane to Present) in 2+ Carpool Volumes, A.M. Peak-Hour, Peak-Direction, Freeway Volume Plus HOV Lane Volume

Other approaches exist for identifying that component of carpooling that has been created as a result of the HOV lane. One indicator is the "previous mode" of travel for carpoolers; that is, prior to carpooling on the HOV lane, how was the trip made (Figure 33). Those data indicate that somewhere between 40 percent and 60 percent of carpoolers on the HOV lanes in 1990 were previously in "drive alone" vehicles; as the HOV lanes become more mature and carpool volumes increase, this percentage has also been increasing. The sum of "drive alone" plus "new trips," which in 1990 was in the range of 43 percent to 63 percent of total carpools on the HOV lanes, can be considered as an initial indication of the volume of new carpools created as a result of the HOV lane.



Source: See data in appendices.

Figure 33. Previous Mode of Travel for HOV Lane Carpoolers, 1990

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

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

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

One question asked was "how important was the HOV lane in your decision to carpool?" The responses (Table 19) suggest that the HOV lane was "somewhat important" or "very important" in the decision to carpool to over 80 percent of the HOV carpoolers surveyed in 1990; that percentage has generally been increasing over time as more carpools form.

Table 19. Responses to Question "How Important Was the HOV Lane in Your Decision to Carpool?"

HOV Facility	Response (percent)					
	Very Important		Somewhat Important		Not Important	
	1989	1990	1989	1990	1989	1990
Katy	73	64	14	20	13	17
North	—	60	—	21	—	19
Gulf	48	—	19	—	33	—
Northwest	56	74	20	9	24	17
Unweighted Average	59	66	18	17	23	17

Source: Texas Transportation Institute surveys.

A second question asked carpoolers if they would be carpooling if there were no HOV lane (Table 20). In the 1990 surveys, over half the respondents said "no" or "not sure."

Table 20. Responses to Question "If the HOV Lane Had Not Opened to Carpools, Would You Be Carpooling Now?"

HOV Facility	Response (percent)					
	Yes		No		Not Sure	
	1989	1990	1989	1990	1989	1990
Katy	42	37	42	43	16	20
North	—	48	—	40	—	12
Gulf	68	—	20	—	12	—
Northwest	52	45	30	39	18	16
Unweighted Average	54	43	31	41	15	16

Source: Texas Transportation Institute surveys.

Implementation of the HOV lanes appears to have lengthened the median life of a carpool and increased the volume of carpools. The type of increase in carpooling experienced on freeways with HOV facilities simply has not taken place on a freeway that does not have an HOV facility. The surveys indicate that the HOV lane is an important factor in the decision to carpool. It appears that, on the HOV lanes surveyed in 1990, approximately half of the current HOV carpoolers previously drove alone and formed a carpool as a result of the HOV facility (Table 21).

Table 21. Estimated Impact of HOV Lanes in Forming New Carpools

HOV Facility	Apparent % New Carpools Based on Previous Mode[1]		Would You Carpool if No HOV Lane[2]						Est. % of 1990 HOV Lane Carpools Formed Due to HOV Lane
			Yes		No		Not Sure		
	1989	1990	1989	1990	1989	1990	1989	1990	
Katy	61%	62%	42%	37%	42%	43%	16%	20%	53%
North	—	43%	—	48%	—	40%	—	12%	46%
Gulf	45%	—	68%	—	20%	—	12%	—	26%[4]
Northwest	48%	57%	52%	45%	30%	39%	18%	16%	47%
Unweighted Average	51%	54%	54%	43%	31%	41%	15%	16%	43%

[1]The sum of "drove alone" and "new trips."
[2]See Table 20.
[3]It is assumed that the sum of "no" responses plus one-half of the "not sure" responses equals the percentage of total HOV lane carpools that were formed due to implementing the HOV lane. The previous mode response provides a logic check for this conclusion.
[4]1989 data.
Source: Texas Transportation Institute surveys.

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

HOV Carpool Benefits

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

Perception of Underutilization

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

---

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

[12]Additional discussion of this perception issue is included in Section VIII of this report.

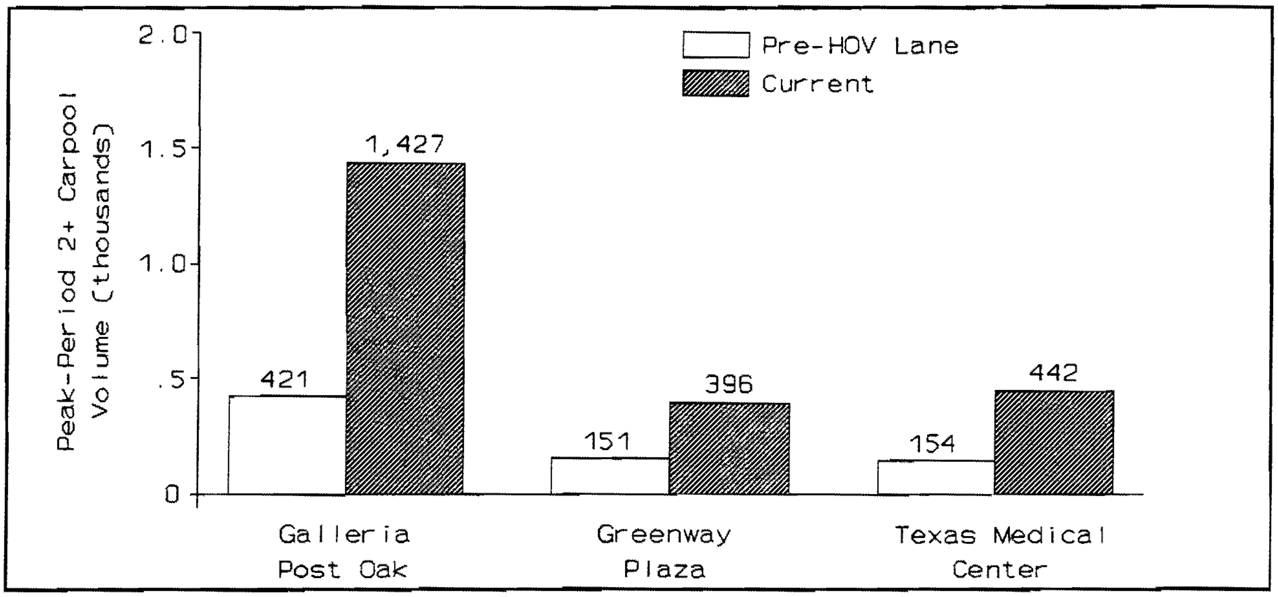
Travel to Locations Other Than Downtown

As was shown previously in this report (see Table 12), the overwhelming majority of HOV bus service is oriented to downtown. While that serves a useful purpose, it does not necessarily help in serving the growing travel to other major employment centers. A significant percentage of HOV carpool trips are not to downtown (see Table 13), and implementing the HOV lanes has greatly increased the volume of carpools traveling to the other three major activity centers (Table 22). That volume has almost tripled (Figure 34). Being able to help serve these dispersed trips contributes to the effectiveness of the HOV lanes.

Table 22. Increases in A.M. Peak-Period Carpooling to the Major Suburban Activity Centers, Pre-HOV Lane to Present

HOV Facility	Activity Center and 2+ Carpool Vehicle Volumes					
	Galleria/Post Oak		Greenway Plaza		Texas Medical Center	
	Pre-HOV Volume	1991 Volume	Pre-HOV Volume	1991 Volume	Pre-HOV Volume	1991 Volume
Katy	170	354	49	135	43	150
% increase	—	+108%	—	+176%	—	+249%
North	169	315	75	112	56	125
% increase	—	+ 86%	—	+ 49%	—	+123%
Northwest	82	638	27	125	55	125
% increase	—	+678%	—	+363%	—	+127%
TOTAL	421	1,308	151	373	154	400
% increase	—	+211%	—	+147%	—	+160%

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



Source: Texas Transportation Institute data collection.

Figure 34. Increase (Pre-HOV to Present) in Peak-Period 2+ Carpool Volumes Destined to Major Non CBD Activity Centers, All Houston HOV Lanes

Marginal Public Operating Cost

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

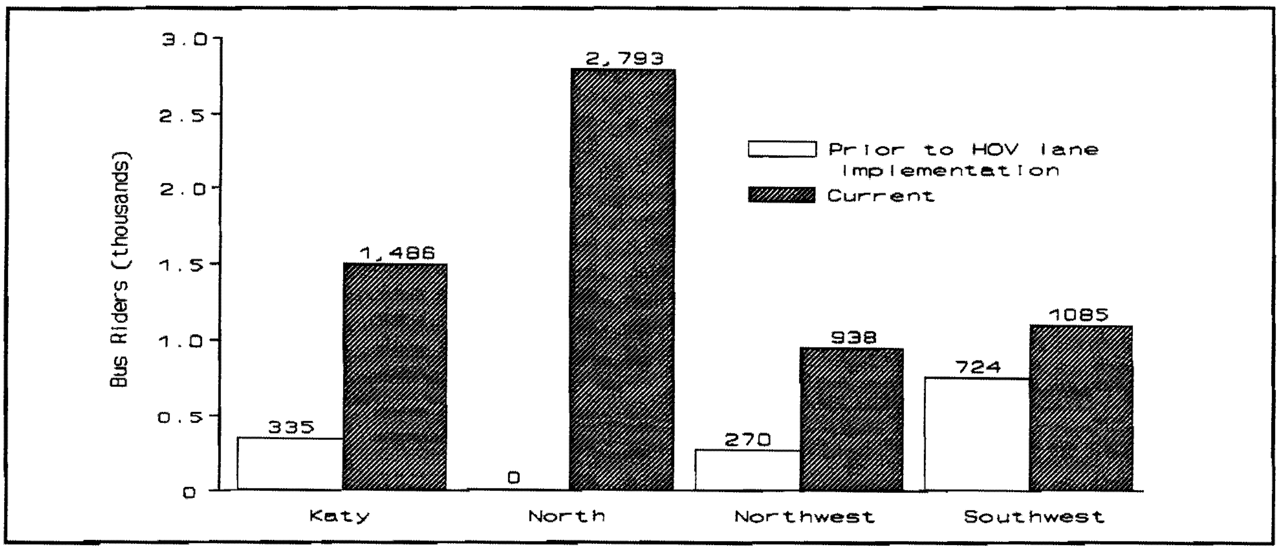
BUS TRANSIT OPERATIONS

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

Changes in Bus Ridership

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

With the opening of the HOV lanes, increases in bus ridership have been realized (Figure 35). In the North Freeway corridor, there was essentially no bus service prior to the opening of the contraflow lane in 1979. It appears that the HOV lanes have been a meaningful factor in generating the ridership increases that have been observed.



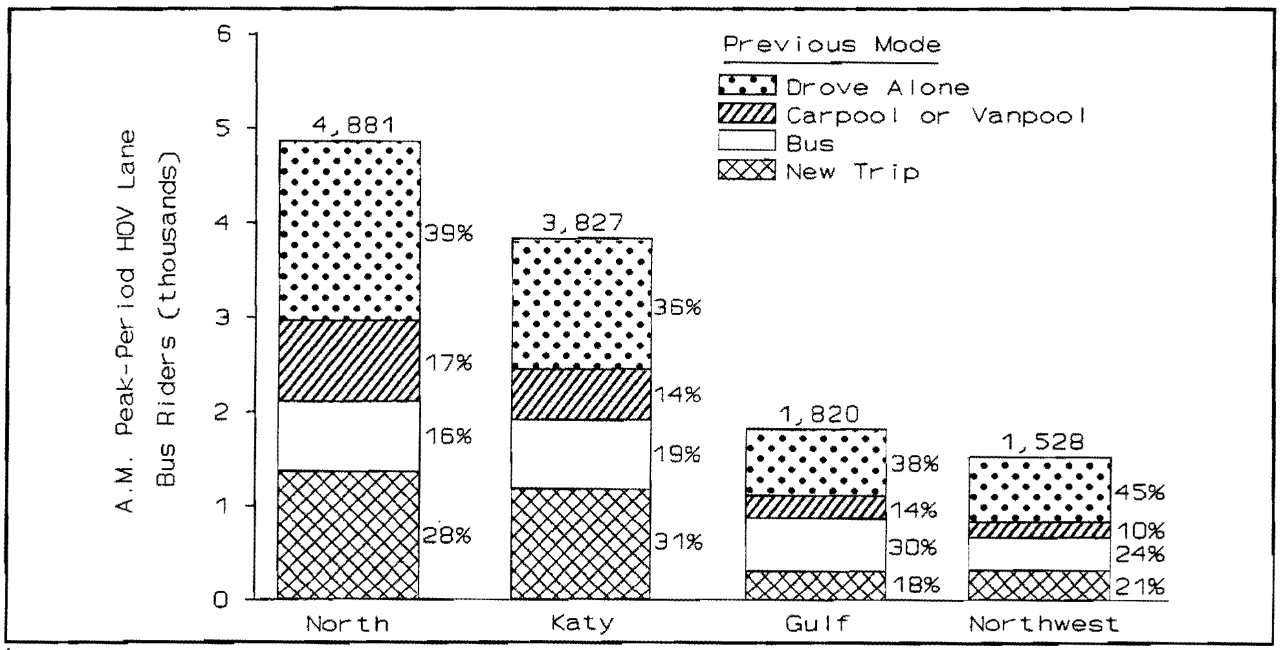
Source: See data in appendices.

Figure 35. Number of Bus Riders, A.M. Peak-Hour, Peak-Direction, Pre-HOV Lane and Current

An examination of the previous mode of travel for HOV bus riders provides an indication that the HOV lanes have created new bus riders (Figure 36). These data suggest that fewer than

30 percent of existing HOV lane bus riders rode a bus prior to using the HOV lane. Over a third previously drove alone. The unweighted average of the survey data regarding previous mode of travel indicates that: 39 percent drove alone; 14 percent carpooled or vanpooled; 22 percent rode a bus; and 25 percent did not make the trip.

The HOV lane bus riders have been surveyed 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 an important consideration in deciding to ride a bus (Table 23). Over time, the importance of the HOV lane in attracting riders appears to be increasing.



[1]Volume data for 1990, previous mode percentages from 1989 survey.
Source: See data in appendices.

Figure 36. Previous Mode of Travel for HOV Lane Bus Riders, 1990

Table 23. Responses to Question "How Important Was the Opening of the HOV Lane in Your Decision to Ride a Bus?"

HOV Facility	Response to Question (percent)								
	Very Important			Somewhat Important			Not Important		
	1988	1989	1990	1988	1989	1990	1988	1989	1990
Katy	68	72	72	18	17	19	14	11	9
North	—	—	73	—	—	17	—	—	10
Gulf	—	54	—	—	22	—	—	24	—
Northwest	—	71	76	—	21	15	—	8	9
Unweighted Average	68	66	74	18	20	17	14	14	9

Source: Texas Transportation Institute surveys.

A second question asked bus riders if they would be riding a bus if there were no HOV lane (Table 24). For the more mature facilities (North and Katy), approximately 33 percent of the bus riders said "yes." The data for the facilities surveyed in 1990 suggest that about half of total bus ridership would not be riding the bus if there were no HOV facility.

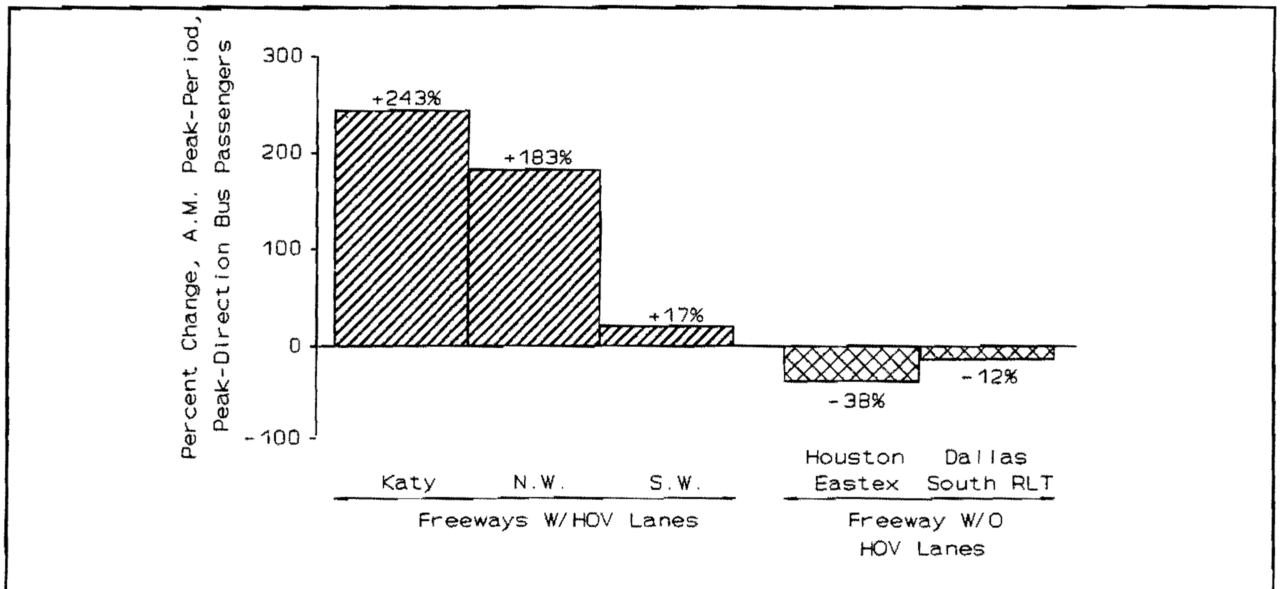
Table 24. Responses to Question "If the HOV Lane Had Not Opened, Would You be Riding a Bus Now?"

HOV Facility	Apparent % New 1990 Bus Riders Based on Previous Mode[1]	Response to Question (percent)						Est. % of 1990 Bus Ridership Formed Due to HOV Lane[2]
		Yes		No		Not Sure		
		1989	1990	1989	1990	1989	1990	
Katy	52	32	35	36	31	32	33	47%
North	52	—	33	—	37	—	30	52%
Gulf	47	56	—	22	—	22	—	33%[3]
Northwest	55	41	41	39	35	20	24	47%
Unweighted Average	52	43	36	32	34	25	29	45%

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

Bus ridership has increased more rapidly in corridors having HOV lanes than it has in a corridor without an HOV lane (Figure 37). Again, these data seem to confirm that the HOV lane has been a primary force in increasing bus ridership. Peak-period, peak-direction ridership has increased by 180 to 240 percent in the corridors with HOV lanes in Houston; the increases in peak-hour ridership have been even greater than the peak-period increases.

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



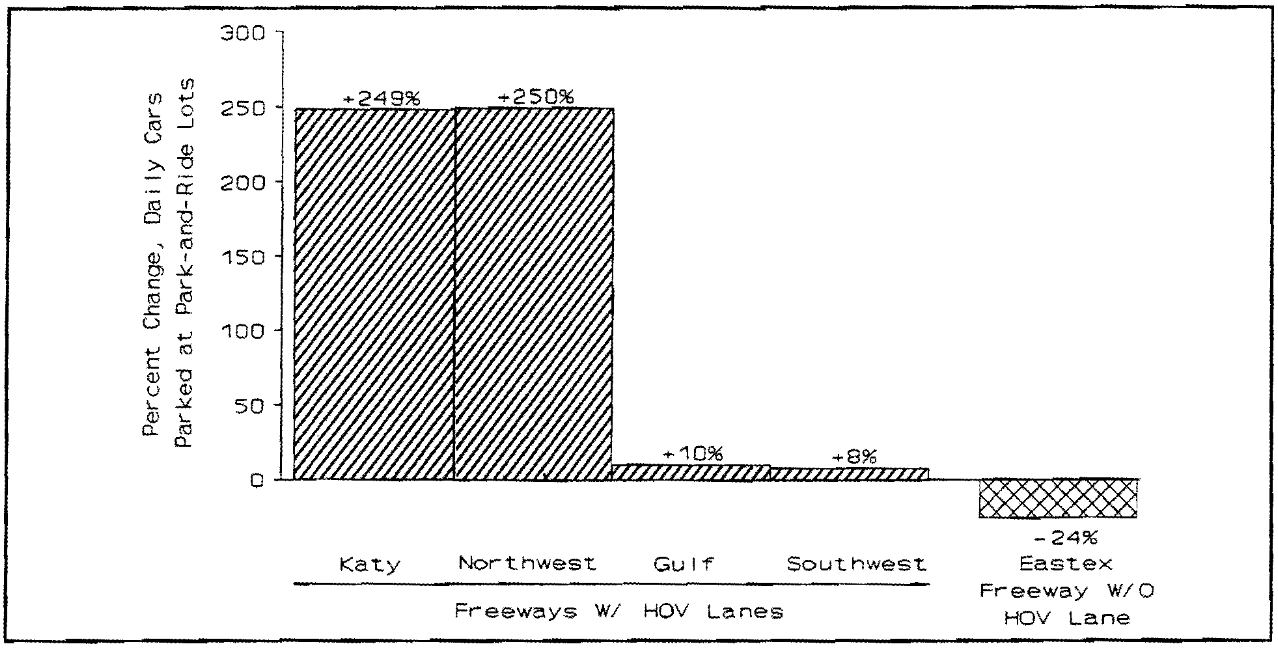
Note: North Freeway data are not shown since no bus service existed prior to implementation of the HOV contraflow lane.

Source: See data in appendices.

Figure 37. Change (Pre-HOV Lane to Present) in A.M. Peak-Period, Peak-Direction Bus Ridership, Freeways With and Without HOV Lanes

Change in Park-and-Ride Lot Utilization

As would be expected, significant increases in the use of park-and-ride lots has also occurred in the corridors with high-occupancy vehicle lanes (Figure 38). In both the Northwest and the Katy corridors, an increase of approximately 250 percent in the use of the park-and-ride lots has been experienced. In a corridor not having a high-occupancy vehicle lane, there has been a slight decrease in park-and-ride usage during the same period of time.



Source: See data in appendices.

Figure 38. Percent Change (Pre-HOV Lane to Present) in Daily Vehicles Parked in Corridor Park-and-Ride Lots

Enhancement of Bus Service

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

Compared to conditions that existed prior to HOV lane implementation, average bus operating speeds have increased dramatically (Table 25). On average, peak-hour bus operating speeds have doubled, increasing from 41 kph to 82 kph (26 mph to 51 mph). Also, as shown previously in this report and also documented elsewhere, research[13] has illustrated that, based

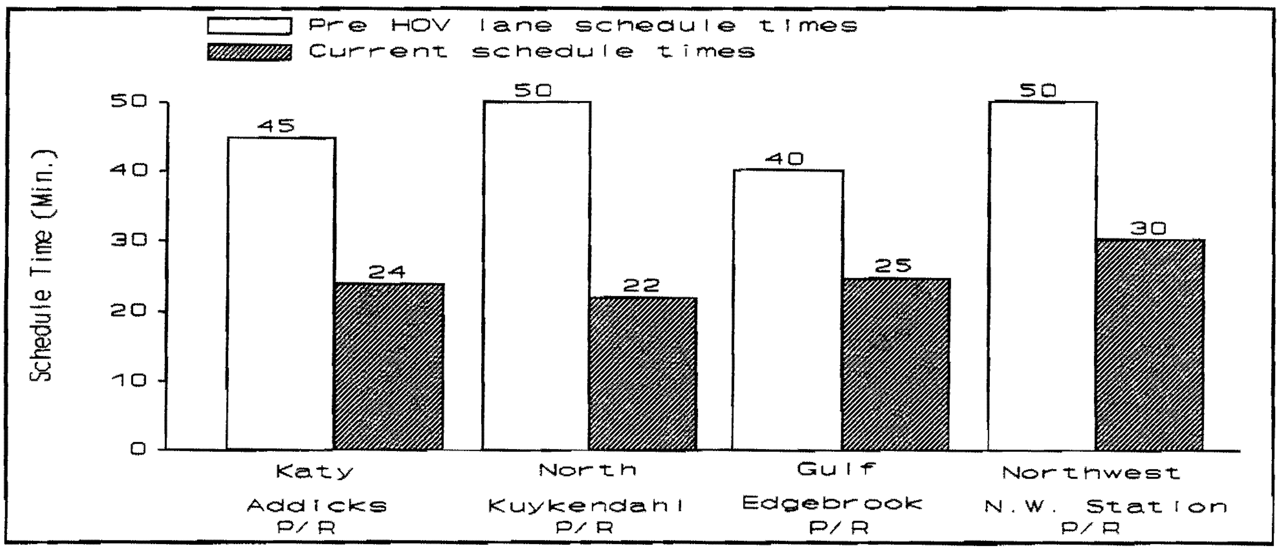
[13]Texas Transportation Institute Research Report 339-12.

on a comparison of standard deviations, travel times in the HOV lanes are much more reliable and consistent than are travel times on the freeway mainlanes. Figure 39 provides an indication of the impacts that the HOV lanes can have on bus schedules during the peak hour. Due to the increase in bus operating speeds, schedule times have been cut significantly.

Table 25. Average A.M. Peak-Hour Bus Operating Speeds, Before HOV Implementation and Current

Freeway	Bus Operating Speed kph (mph)		
	Before HOV	Current	Percent Increase
Katy	37 (23)	87 (54)	135%
North	32 (20)	84 (51)	162%
Gulf	50 (31)	81 (50)	62%
Northwest	47 (29)	86 (54)	83%
Southwest	47 (29)	85 (53)	81%
East RLT	34 (21)	71 (44)	110%
Unweighted Average	41 (26)	82 (51)	100%

Source: See data in appendices.



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

Source: Metropolitan Transit Authority bus schedules.

Figure 39. Bus Schedule Time, A.M. Peak-Hour Service to Downtown, "Before" and "After" HOV Lane Development

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

- Northwest HOV Lane. In April 1990, the direct ramp from the Northwest Station park-and-ride lot to the HOV lane was opened.

- North Freeway. For construction purposes, the 6.1-kilometer (3.8-mile) section of HOV lane from North Shepherd to West Road was closed during 1988; it reopened in January 1989.

- Katy Freeway. A 2.4-kilometer (1.5-mile) eastern extension of the 18.5-kilometer (11.5-mile) Katy HOV lane opened in January 1990.

A summary of the impacts of these improvements is presented in Table 26.

Table 26. Bus Operational Impacts of Enhancements to the HOV Facilities

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

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

Source: Metropolitan Transit Authority of Harris County.

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

While the changes in Metro service are noticeable, in comparison to the opening of the major sections of HOV lane, the impacts of these modest HOV lane enhancements are small. During 1990, the presence of the HOV lanes reduced the revenue bus-hours required to provide the service by over 31,000. For commuter bus service in 1990, the average Metro cost was $152 per revenue hour. Thus, the HOV time savings effectively reduced Metro's 1990 bus operating costs by approximately $4.8 million.

Bus Operating Costs[15]

On a system-wide basis, Metro recovers about 22 percent of operating costs from the fare box (Table 27). The commuter routes, which have a higher fare structure, perform somewhat better than the local routes in this regard. However, the operating subsidy per passenger is greater for the commuter system.

Table 27. Revenue-Cost Ratios and Subsidy Per Passenger, Metro Bus Service, Average Weekday, 1993

Type of Service	Passenger Boardings	Revenue/Cost[2]	Subsidy Per Passenger
Local	257,595	19%	$1.70
Commuter[1]	22,407	37%	$3.37
System-wide	280,002	22%	$1.98

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

Source: Metropolitan Transit Authority of Harris County.

Thus, providing the commuter bus service on the HOV lanes requires an operating subsidy. Table 28 provides an estimate of the annual subsidy per passenger required to operate the bus service on the high-occupancy vehicle lanes. The HOV bus service operated from the park-and-ride lots shown in that table recovers approximately 38 percent of operating costs from fare box revenue.

---

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

Table 28. Selected Characteristics of Bus Service on the High-Occupancy Vehicle Lanes, 1993

HOV Lane and Bus Route[1]	Avg. Weekday Passenger-Trips	Subsidy Per Passenger Trip[2]	Revenue/Cost[2]	Estimated Annual Subsidy[3] (1000s)
Katy				
West Belt (210)	375	$5.22	25%	$ 497
Addicks (228)	2,617	$2.37	46%	$ 419
Kingsland (221)	938	$4.22	39%	$ 1,110
Sub-Total	3,930	$3.10	41%	$ 2,026
North[4]				
N. Shepherd (201)	703	$5.06	24%	$ 887
Kuykendahl (202)	2,660	$3.00	41%	$ 616
Seton Lake (212)	1,431	$3.16	38%	$ 465
Spring (204)	1,492	$1.22	65%	$ 145
FM 1960 (207)	220	$8.90	25%	$ 478
Sub-Total	6,606	$3.05	40%	$ 2,591
Gulf				
Edgebrook (245)	1,214	$4.21	31%	$ 461
Bay Area (246)	1,615	$2.09	53%	$ 1,002
Sub-Total	2,829	$3.00	41%	$ 1,464
Northwest				
W. Little York (216)	258	$5.16	28%	$ 189
Pinemont (218)	345	$3.50	33%	$ 102
N.W. Station (214)	2,322	$2.48	45%	$ 481
Sub-Total	2,925	$2.84	41%	$ 771
Southwest[5]				
Westwood (262)	1,046	$4.54	28%	$ 620
Alief (263)	676	$6.28	22%	$ 1,130
Bellfort (265)[6]	NA	NA	NA	$ NA
Missouri City (270)	563	$4.67	27%	$ 828
Sub-Total	2,285	$5.09	25	$ 2,578
Total HOV System	18,375	$3.27	38%	$ 9,430

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

Source: Metropolitan Transit Authority.

In general, an operating subsidy of $3.27 is required for each passenger trip using the HOV lanes on a bus. Data suggest that, in 1993, approximately 7.02 million passenger trips were made by bus on the HOV lanes; thus, the total bus operating subsidy for HOV lane service was in the range of $23 million in 1993.

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

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

IMPACTS ON FREEWAY GENERAL-PURPOSE LANE OPERATIONS

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

Available data suggest that the implementation of high-occupancy vehicle lanes, with a design similar to those being used in Houston and Dallas, does not greatly affect the operation of the freeway general-purpose lanes, in spite of the fact that these priority facilities are moving several thousand persons in the peak hour (Table 29). Current per lane volumes on the Southwest Freeway are ten percent less than they were prior to HOV lane implementation, while volumes have increased significantly (18 to 42 percent) on the Katy, North, and East RLT Freeways. The Northwest Freeway has experienced a moderate increase of eight percent. The increased volume on the Katy Freeway appears to be attributable to eliminating a downstream bottleneck. While speeds on some freeways have actually increased since HOV lane implementation, this is largely attributable to factors other than the priority facility implementation. Plots of freeway travel speeds, prior to HOV lane implementation and current, are shown in Figure 40.

Table 29. Freeway General-Purpose Lane Operation, Prior to HOV and Current

Freeway General-Purpose Lane Data	HOV Facility or Freeway									
	Katy		North		Northwest		Southwest		East RLT	
	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	1,320	1,910	1,650	1,950	1,790	1,930	1,640	1,470	1,420	1,720
A.M. Peak Period	1,250	1,670	—	1,650	1,460	1,670	1,430	1,140	1,500	1,590
Freeway Peak-Hour Speed[2], kph (mph)	37 (23)	45 (28)	32 (20)	65 (40)	45 (28)	50 (31)	47 (29)	61 (38)	34 (21)	47 (29)
Injury Accidents per 100 MVK[3] (per 100 MVM)	12.4 (20.0)	12.7 (20.4)	18.8 (30.3)	16.4 (26.4)	7.3 (11.7)	6.8 (10.9)	16.3 (26.2)	12.1 (19.5)	14.0 (22.6)	13.5 (21.8)

[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 (10.1 km [6.3 mi.]); and East RLT, Central Expressway to Jim Miller (8.4 km [5.2 mi.]).

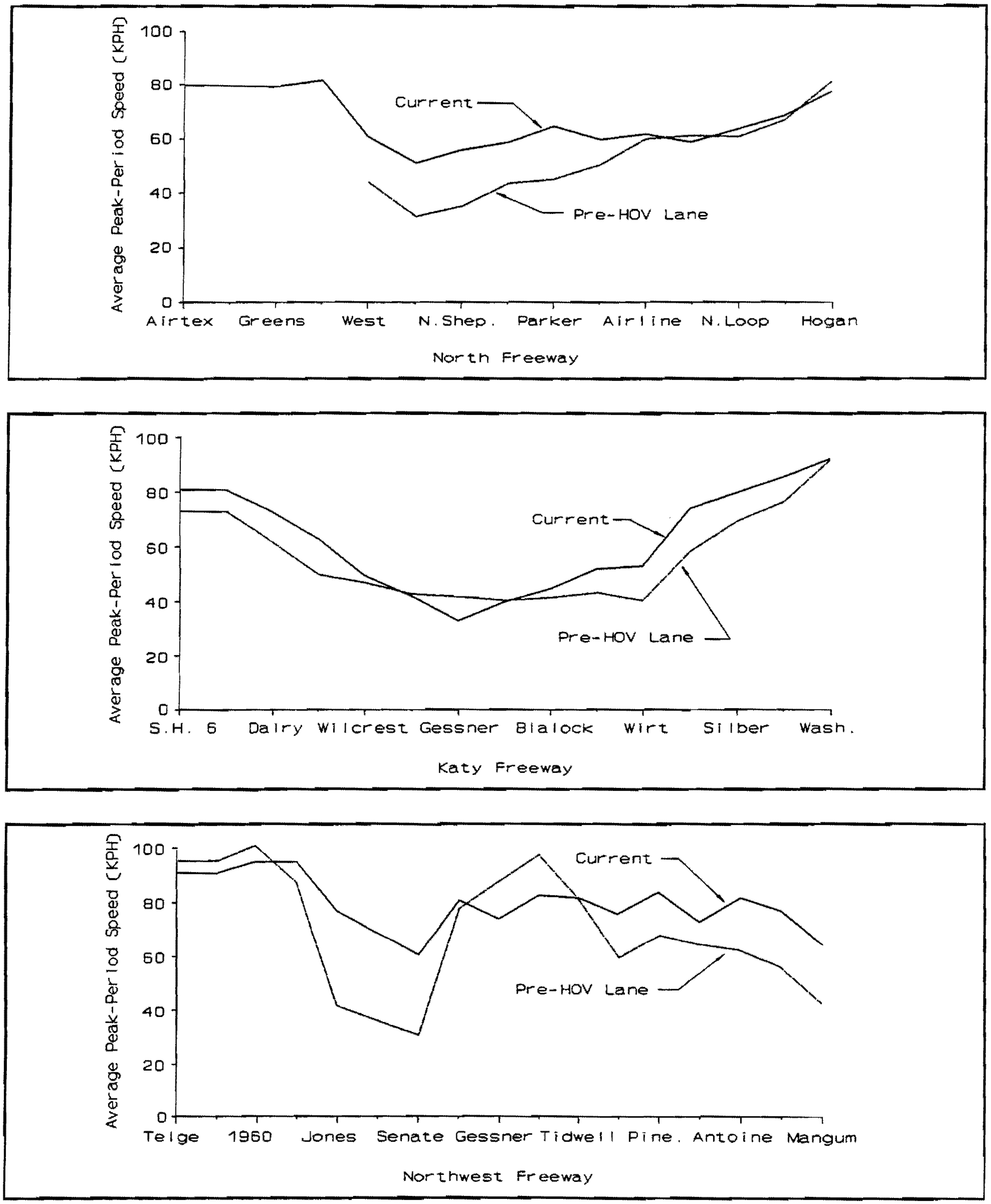
Source: See data in appendices.

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 29 presents the relevant data. Accident rates are slightly higher on some roadways and slightly lower on others; the unweighted average accident rate has declined from 14 injury accidents per 100 million vehicle-kilometers (MVK) (22 injury accidents per 100 million vehicle-miles [MVM]) prior to the HOV lanes to 12 injury accidents per 100 MVK (20 accidents per 100 MVM) currently. It appears that HOV lane implementation has not significantly impacted freeway accident rates.

Parallel Route Volumes

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

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



Source: See data in appendices.

Figure 40. Freeway Peak-Period Speeds on Mainlanes, Pre-HOV and Current

A summary of the survey data from the HOV carpool surveys is in Table 30. It appears that between 10 percent and 20 percent of HOV lane carpoolers previously traveled on a parallel roadway. Given typical carpool volumes on the HOV lanes, this would equate to roughly 75 to 150 vehicles in the peak hour.

Table 30. HOV Lane Carpooler Responses to the Question "Prior to Carpooling on the HOV Lane, How Did you Normally Make the Trip?"

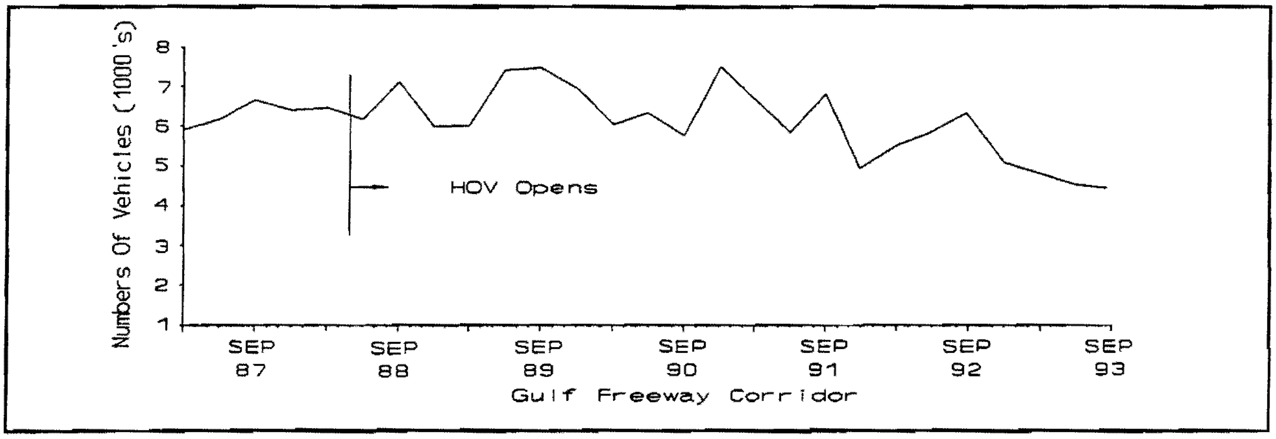
Response	HOV Lane							
	Katy		North		Gulf		Northwest	
	1989	1990	1989	1990	1989	1990	1989	1990
On the HOV lane (bus or van)	16%	15%	—	22%	17%	—	17%	14%
On the freeway general-purpose lanes	64%	68%	—	58%	68%	—	68%	67%
On a parallel street or highway	9%	13%	—	19%	10%	—	10%	15%
Did not make this trip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

Source: Texas Transportation Institute surveys.

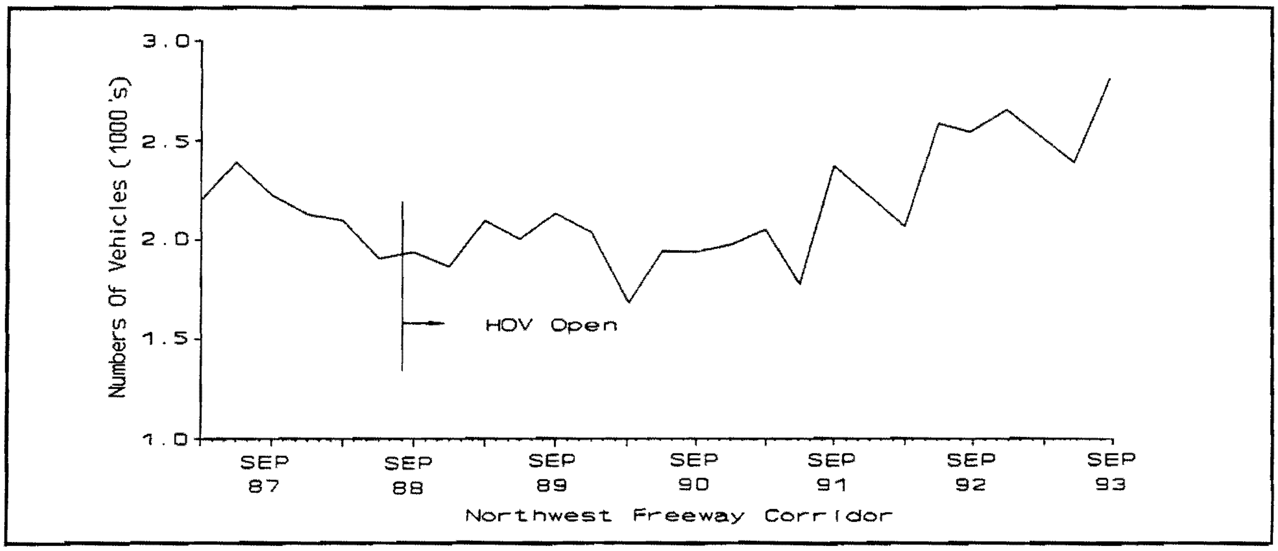
In two of the corridors, volume counts have been conducted on parallel routes. These data are depicted in Figure 41. There is no reason to conclude from these data that the opening of the HOV lanes brought about a significant decrease in parallel route volumes, although a small decline may have occurred. Rather than reducing peak vehicle volumes, the HOV lanes appear to be a means of increasing person volume without a corresponding increase in vehicle volume.

IMPACTS ON OVERALL ROADWAY EFFICIENCY

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



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



Note: Parallel route is Hempstead Highway.

Figure 41. A.M. Peak-Period (6-9:30), Peak-Direction Vehicle Volumes on Parallel Routes in the Gulf and Northwest Freeway Corridors

In all cases for which data are available, the implementation of the HOV lane has increased the overall efficiency of the facility (Table 31). It appears that, on a facility with a mature HOV lane, the priority lane should increase the per lane efficiency, compared to pre-HOV conditions, by an absolute value of at least 30; this level of increase has been attained on the North, Katy, Northwest, Southwest, and East RLT HOV lanes. These increases in efficiency have been larger than those experienced on freeways that do not have an HOV lane (Figures 42 and 43).

Table 31. 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	129	466	197	131
Katy	61	88	300	141	80
Northwest	100	101	316	155	55
Southwest	90	95	269	124	34
East RLT	66	83	261	119	53
Eastex[3] (w/o HOV, Houston)	135	126	NA	126	-9
South RLT[4] (w/o HOV, Dallas)	108	100	NA	100	-8

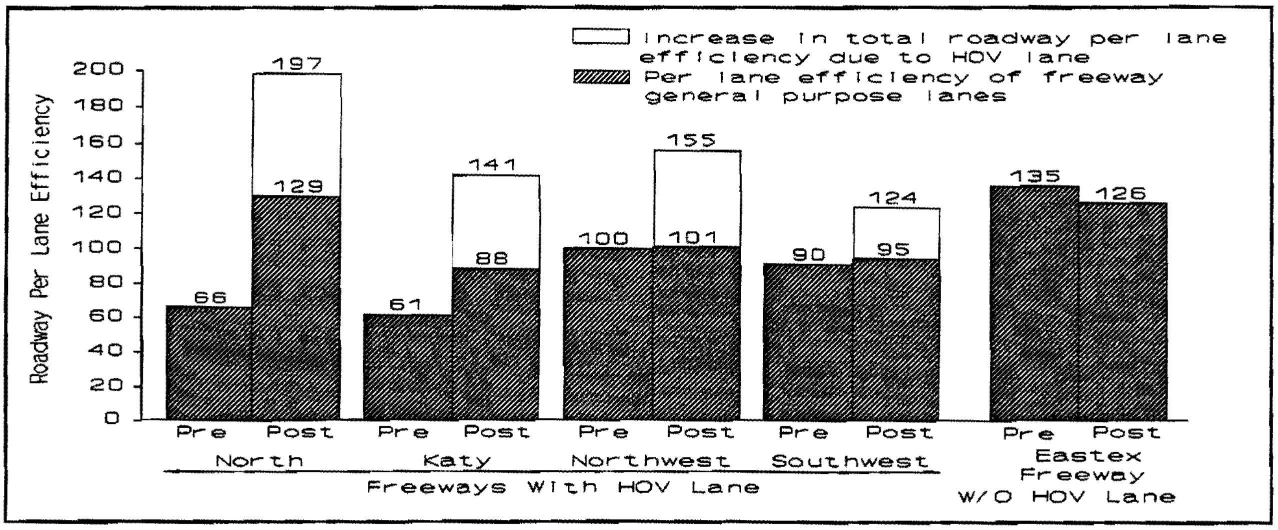
NA - Not applicable.

[1]Peak-hour per lane efficiency is defined as the person volume per lane times the average speed divided by 1000. Thus, it is a measure both of the person volume moved and the speed at which that volume is moved.

[2]Calculated as follows. Column (4) minus Column (1).

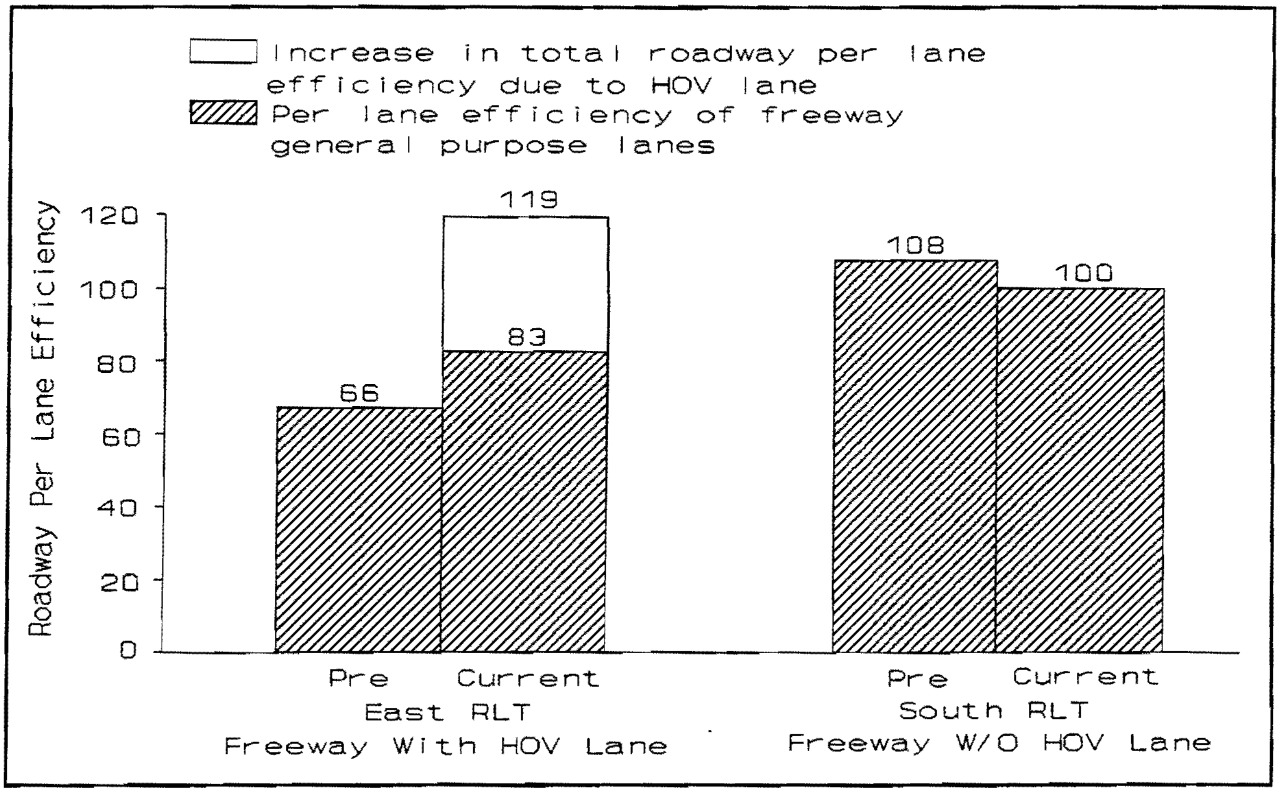
[3]For comparison, this is a freeway without an HOV lane. The pre-HOV value is the average of conditions on the Eastex Freeway prior to implementation of the Katy, the Northwest, and the Gulf HOV lanes.

[4]For comparison to East RLT, this is a freeway without an HOV lane in Dallas.



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

Figure 42. Change (Pre-HOV Lane to Current) in A.M. Peak-Hour, Peak-Direction Roadway Efficiency, Freeways With and Without HOV Lanes in Houston



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

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

This criterion has weaknesses. While it can be used to show what the HOV lane has done to change per lane efficiency, it does not address what would have happened to overall roadway efficiency had the new lane been used as another mixed-flow lane rather than as an HOV lane. This issue merits more attention.

VI. AIR QUALITY AND ENERGY CONSIDERATIONS

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

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

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

---

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

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

The analysis presented in this section of the report utilized a freeway simulation model (FREQ) and applied that model to the Katy Freeway and HOV lane. Operation on both the freeway mainlanes and the HOV lane, based on 1993 travel volumes, were simulated. The demand, expressed as passenger-kilometers, that existed in 1993 was held constant in comparing alternatives. Average vehicle occupancy was adjusted between alternatives as necessary to reflect the observed impacts of the HOV facility on vehicle occupancy.

The following three alternatives were evaluated:

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

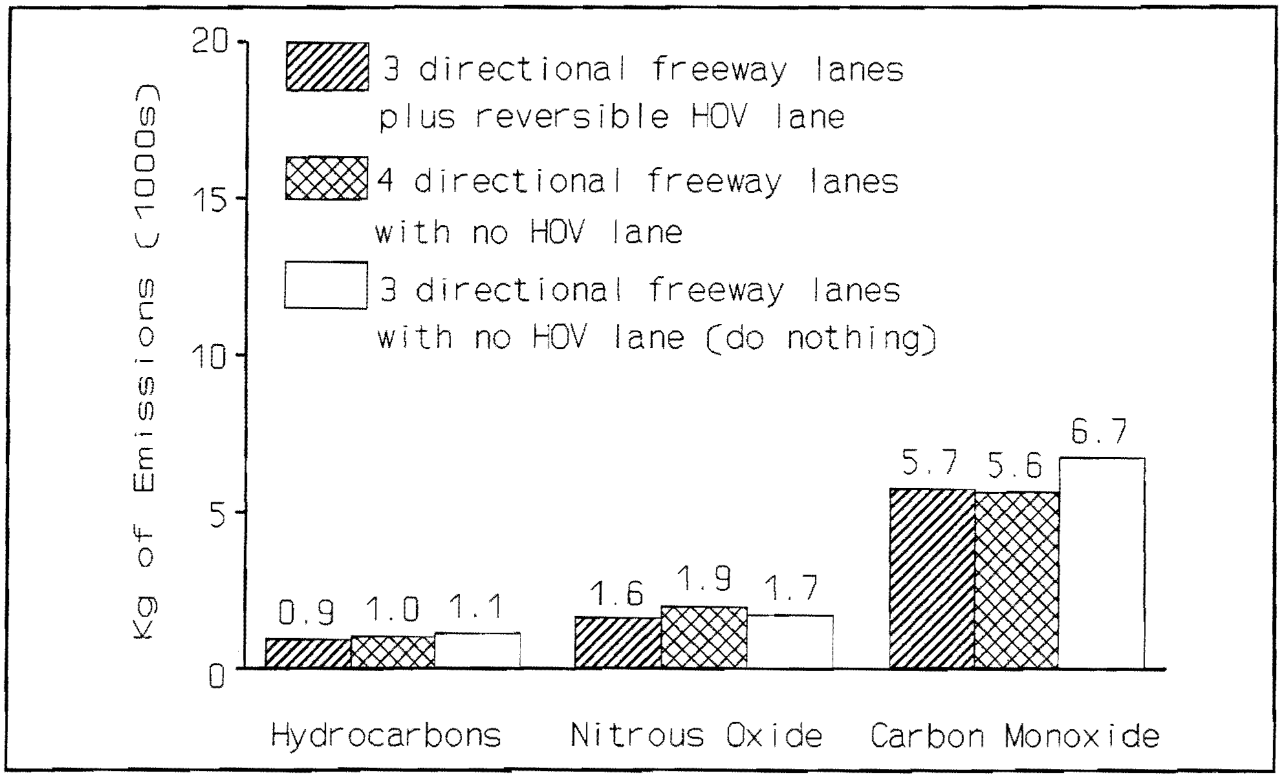
2. **Add a general-purpose freeway lane.** This would result in four general-purpose freeway lanes in each direction with no HOV facility. It is the condition that would have resulted had an additional freeway general-purpose lane been added to the freeway instead of an HOV lane.

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

Figures 44 and 45 show the results of this analysis. Since demand is projected to continue to increase in the future, the HOV lane should (over time) continue to look even more favorable; the HOV alternative provides capacity to serve additional growth, while the alternatives that provide only freeway mainlanes operate at capacity in 1993 and are unable to

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

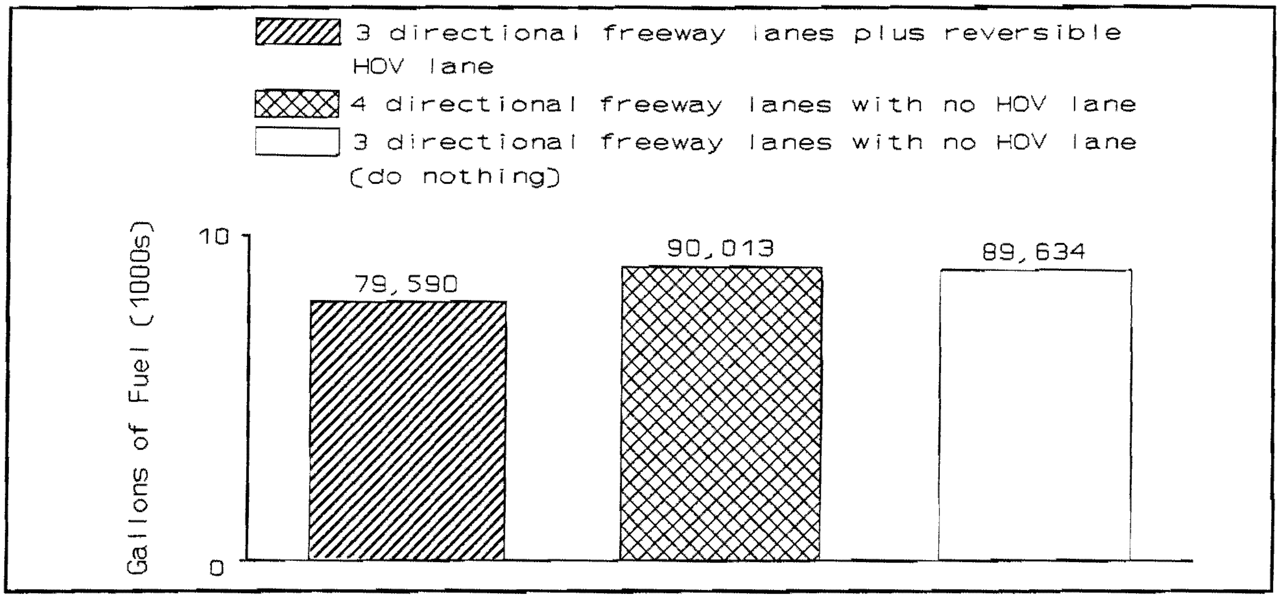
serve higher volumes. It is recognized that this analysis has limitations (e.g., it does not consider the benefits that would accrue from having an additional mixed-flow lane available to serve off-peak and off-peak direction travel, and it does not address cold start and hot soak issues). However, it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



Source: Texas Transportation Institute simulation analyses, 6 a.m. to noon, peak direction, 1993 demand levels.

Figure 44. Estimated Impacts of HOV Improvements on Air Quality, Katy Freeway and HOV Lane

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



Source: Texas Transportation Institute simulation analyses, 6 a.m. to noon, peak direction, 1993 demand levels.

Figure 45. Estimated Impacts of HOV Improvements on Energy Consumption, Katy Freeway and HOV Lane

VII. HIGH-OCCUPANCY VEHICLE LANE COST EFFECTIVENESS

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

Data presented previously in this report (Figures 44 and 45) provided an indication of how an HOV lane project compares to a general-purpose lane project in one corridor. In that corridor, the HOV alternative results in a reduction in total travel time and energy consumption relative to the alternative of adding a general-purpose highway lane. Since those are principal variables in determining cost effectiveness, it can be argued that, in at least the Katy Freeway corridor, the HOV lane was a more effective improvement than would have been the addition of another general-purpose mainlane. This conclusion should be viewed with caution and not generalized. The implication is that, in some highly congested corridors with appropriate travel patterns, the HOV alternative will rate highly in a benefit-cost analysis. This certainly will not be the conclusion for all (or probably even most) highway corridors. A rather specific set of conditions need to be present in a corridor to enhance the relative attractiveness of the HOV alternative. In many instances, if an either/or decision needs to be made, general-purpose freeway improvements may be preferable to HOV lane implementation.

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

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

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

---

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

[19]Assuming a constant stream of benefits over the life of the project (which is conservative since benefits should increase over time as HOV utilization and freeway congestion both increase), a 20-year project life (again, conservative since no salvage value is included), a 4% discount rate, and a $10.78/hour value of time, the present worth factor would be 13.6. Thus, if operating and maintenance costs are not included (they are relatively small), a benefit/cost ratio of approximately 1.4 would result if the annual benefit stream equalled 10% of the initial construction cost.

For reasons cited in the footnote, the average annual value of time saved over the life of the project should be greater than the amount saved in the early years of the project.[19] Previous discussions in this report have identified specific reasons why time savings should be expected to increase on all of the Texas HOV lanes. However, if the project appears cost effective based on today's level of use, it should prove to be even more cost effective as HOV lane use increases. Table 31 summarizes this analysis.

Table 32. Annual Value of Time Saved by HOV Lane Users as a Percent of HOV Lane Construction Cost

HOV Facility	Annual Value of Time Saved[1] ($ millions)	Estimated Construction Cost For Operating Segment[2] ($ millions)		Annual Value of Time Saved as a % of Construction Costs	
		HOV Lane and Ramps	HOV Lane, Ramps and Support Facilities	HOV Lane and Ramps	HOV Lane, Ramps and Support Facilities
Katy	$ 7.7	$27.5	$57.5	28.0%	13.4%
North	$ 5.4	$57.8	$76.0	9.3%	7.1%
Gulf	$ 2.8	$30.5	$43.1	9.1%	6.5%
Northwest	$ 1.8	$62.7	$96.5	2.9%	1.9%
Southwest	$ 2.9	$45.1	$58.7	6.4%	4.9%
East RLT	$ 2.8	$12.7	$12.7	13.1%[3]	13.1%[3]
Total	$23.4	$236.3	$344.5	9.9%[3]	6.8%[3]

[1]Based on 1993 time savings for HOV lane users. Does not include any time savings by motorists in the freeway mainlanes.
[2]See Tables 4 and 6 and appendices.
[3]The 10-year life of the contraflow lane on East RLT Freeway (as opposed to the 20-year assumed life of the Houston HOV lanes) has been taken into account. This adjustment results in a present worth factor of 8.1 rather than 13.6 and is reflected in the values shown.

Based on this simplistic analysis, under 1993 operating conditions, the Katy and East RLT HOV facilities are clearly effective, and the other HOV lanes are less effective.

However, the analysis shown in Table 32 does not include many potential benefits. In an effort to compile a more complete listing of costs and benefits associated with one of the HOV facilities, Table 33 was prepared.

Table 33. Estimated Costs and Benefits of the Katy HOV Lane, 1993

Cost or Benefit Category	Dollars (millions)	
Cost		
Capital Cost[1]	$5.8	
Operating Cost		
Enforcement and Operations[2]	0.2	
Bus Subsidy[3]	7.2	
TOTAL COST		$13.2
Benefits		
HOV User Travel Time Savings[4]	$7.7	
Bus Operating Cost Savings[5]	1.5	
Freeway Construction Foregone[6]	17.6	
Freeway General-Purpose Travel Time Savings[7]	18.5	
Reduced Fuel Consumption[8]	3.9	
TOTAL Benefits		$49.2
Benefit/Cost Ratio		3.7

[1]10 percent of HOV capital cost, assumed to be the annualized cost.
[2]Based on $230,000 per year for operating and enforcement support.
[3]Based on a subsidy of $4.03 per bus passenger on the Katy HOV lane (see Table 28).
[4]The value of the time saved by users of the HOV facility (see Table 32).
[5]The reduction in bus operating costs due to the reduction of revenue hours of bus service due to the higher bus operating speeds on the HOV lane. Cost per revenue hour for Metro commuter bus service is $152.
[6]Assumes that, if the HOV lanes were not provided, at least four additional general-purpose lanes would be needed to provide the equivalent peak-hour capacity. Cost per lane-kilometer assumed to be $2.5 million. Ten percent of total cost is assumed to be the annual cost. Counting both freeway construction foregone and freeway general-purpose travel time savings could be considered as double counting benefits.
[7]Simulation analyses suggest that person-hours of travel time in the freeway mainlanes would increase significantly if the HOV lane did not exist and all person movement was handled in the general-purpose lanes. This is an estimate of the value of the increase that would result in travel time on the general-purpose lanes if there were no HOV lane.
[8]The HOV alternative, compared with an all general-purpose lane alternative, reduces fuel consumption.

Based on the costs and benefits listed in that table, and based on usage levels in 1993, the Katy HOV facility had a benefit-cost ratio of 3.7. The actual benefits quantified in that table are six times greater than the value of the time saved by HOV lane users (that value of time is the only benefit considered in Table 32).

On a regular basis, the Texas Transportation Institute has quantified the annual congestion cost in Houston. Analyses suggest that the HOV lanes presently in place are reducing the congestion index in the Houston area by approximately five percent. This translates to an annual reduction in the cost of congestion of approximately $130 million in Houston.[20]

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

VIII. DOES THE HOV LANE PROGRAM HAVE PUBLIC SUPPORT?

Since the HOV lane system being developed in Houston is unique, is viewed as a major means of serving future growth in travel, and involves the expenditure of approximately $650 million in tax monies, public attitudes pertaining to HOV facility development have been an area of continued interest. Desirably, for this program to continue to move forward, it should have public support.

Since 1985, both individuals that use the HOV facilities as well as individuals not using the high-occupancy vehicle lanes have been surveyed to identify their attitudes concerning these priority lane projects. Surveys have been performed both on freeways that have HOV lanes (Katy, North, Northwest, and Gulf) and on a freeway (Eastex) that does not presently have an HOV lane. Two primary issues have been addressed: 1) are the HOV facilities good transportation improvements; and 2) are the HOV lanes sufficiently utilized.

The most recent of these surveys was conducted in 1990. Additional surveys will be conducted in both Houston and Dallas during 1994 and 1995.

ARE THE HOV LANES GOOD TRANSPORTATION IMPROVEMENTS?

Acceptance of the high-occupancy vehicle facilities as effective improvements is extremely high and has been increasing over time. In all three of the corridors surveyed in 1990 (Table 34), over 70 percent of the motorists in the freeway mainlanes (not HOV lane users) viewed these projects favorably. Of those motorists surveyed, fewer than 15 percent felt the HOV lanes were not good transportation improvements; this is similar to what was found in a 1988 survey on a freeway (Eastex) that does not have an HOV lane. Figure 46 reflects the trend of increasing acceptance of the HOV lanes over time.

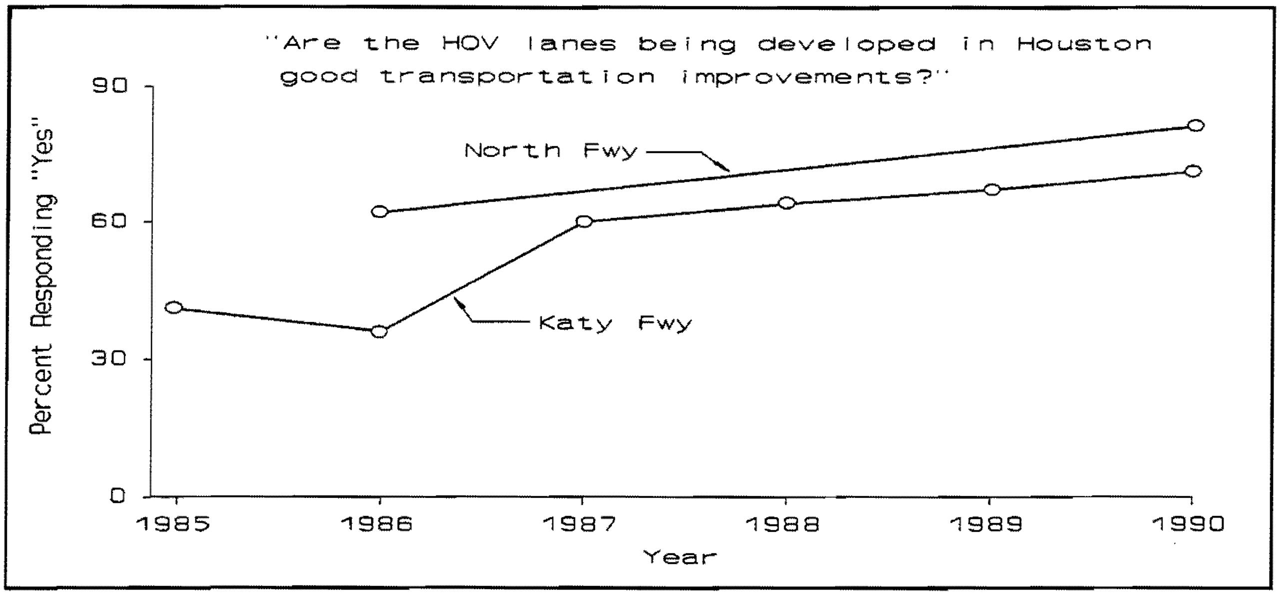


Figure 46. Trends in Public Attitudes Concerning HOV Lane Development

The responses shown in Table 34 and Figure 46 are those of the motorists using the congested freeway mainlanes during peak periods. While these individuals may perceive that they are receiving relatively few direct benefits (e.g., freeway congestion has not, in general, been noticeably reduced) from the HOV lane development, they nevertheless strongly indicate that, in their opinion, the high-occupancy vehicle lanes represent good transportation improvements.

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

ARE THE HOV LANES SUFFICIENTLY UTILIZED?

While the responses in Table 34 indicate that HOV lanes are being overwhelmingly accepted as worthwhile transportation improvements, there is less agreement as to whether these priority lanes are sufficiently utilized (Tables 35 and 36). The perception that the HOV lanes do not carry enough traffic and are, therefore, underutilized is a concern that has existed since the initiation of the HOV programs in Texas.

Table 34. Responses to the Question "Do You Feel the HOV Lanes Being Developed in Houston are Good Transportation Improvements?"

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

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

Over 75 percent of those who use the HOV lanes feel that those facilities are sufficiently utilized (Table 35). This percentage has generally been increasing over time.

Table 35. Responses from Users of the HOV Lane to the Question "Is the HOV Lane Sufficiently Utilized?"[1]

Survey Location and Group Responses to Question	Year of Survey					
	1985	1986	1987	1988	1989	1990
Katy HOV Lane Users						
Bus Riders						
Yes	49%	66%	77%	72%	85%	81%
No	33%	14%	7%	8%	5%	4%
Not Sure	18%	20%	16%	20%	10%	9%
Carpoolers & Vanpoolers[2]						
Yes	33%	43%	82%	45%	77%	75%
No	46%	35%	9%	35%	14%	15%
Not Sure	21%	22%	9%	20%	9%	10%
North HOV Lane Users						
Bus Riders						
Yes	—	81%	—	—	—	88%
No	—	6%	—	—	—	4%
Not Sure	—	13%	—	—	—	8%
Vanpoolers and Carpoolers[3]						
Yes	—	84%	—	—	—	88%
No	—	7%	—	—	—	5%
Not Sure	—	9%	—	—	—	7%
Northwest HOV Lane Users						
Bus Riders						
Yes	—	—	—	—	72%	88%
No	—	—	—	—	6%	6%
Not Sure	—	—	—	—	22%	6%
Carpoolers & Vanpoolers						
Yes	—	—	—	—	75%	87%
No	—	—	—	—	12%	6%
Not Sure	—	—	—	—	13%	7%
Gulf HOV Lane Users						
Bus Riders						
Yes	—	—	—	—	75%	—
No	—	—	—	—	9%	—
Not Sure	—	—	—	—	16%	—
Carpoolers & Vanpoolers						
Yes	—	—	—	—	72%	—
No	—	—	—	—	14%	—
Not Sure	—	—	—	—	14%	—

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

However, the motorists using the general-purpose mainlanes do not feel that the HOV lanes are sufficiently utilized (Table 36). The plurality of responses in the three corridors in which surveys were conducted in 1990 was that the HOV lanes were not sufficiently utilized. This has been a consistent finding over the years. While the percentage of responses indicating that the HOV lanes are sufficiently utilized has been increasing noticeably over time, this is an issue that will, nevertheless, need to continue to be addressed in the formulation of strategies for operating the HOV facilities.

Table 36. Responses from Non-Users of the HOV Lane to the Question "Is the HOV Lane Sufficiently Utilized?"

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

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

Source: Texas Transportation Institute surveys.

IX. CONCLUSIONS

A 153.8-kilometer (95.5-mile) system of freeway HOV lanes is being developed in Houston. As of the end of 1993, 93.5 kilometers (58.1 miles) of that barrier-separated system were operational, with priority facilities operating in five different freeway corridors. The Dallas HOV lane system is currently planned to consist of approximately 60 kilometers (37 miles) of HOV facilities. As of December 1993, an 8.4-kilometer (5.2-mile) barrier-separated contraflow lane was the only operational component of this system.

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

This report reviews and analyzes data collected through calendar year 1993 to assess the extent to which these objectives are being attained (Tables 37 and 38). In assessing the performance of the HOV lanes, the following quantitative values can be used as guides.

Objective: Increase Roadway Person Movement

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

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

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

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

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

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

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

Objective: Increase the Overall Efficiency of the Roadway

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

Objective: Create Favorable Energy and Air Quality Impacts

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

Objective: Enhance Bus Transit Operations

1. Peak-hour bus operating speeds should be increased by at least 50 percent on the HOV lanes.
2. A safer bus operating environment should result. HOV accident rates should be equal to, or less than, freeway general-purpose lane rates.
3. Significant savings in bus operating costs should result.

Objective: HOV Projects Should be Cost Effective

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

Objective: Public Support Should Exist for HOV Development

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

A review of these performance measures based on the HOV evaluations performed in Houston and Dallas leads to several general observations (Table 39). The performance measures suggest that, at today's level of usage, the Katy and East RLT HOV lanes are fulfilling their intended purpose. The North, Northwest, Southwest, and Gulf HOV lanes are considered to be marginally effective at this time. Less than half the length of the ultimate Gulf HOV lane is now operating, and the section that is operating offers only marginal benefits; the Gulf facility will be extended in March 1994.

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

Table 37. Potential Performance Measures for the Houston HOV Lanes, A.M. Peak-Hour, Peak-Direction

Performance Measure[1]	Freeway					
	Katy[2] w/ HOV Lane	North[2] w/HOV Lane	Gulf[2] w/HOV Lane	Northwest[2] w/HOV Lane	Southwest[2] w/HOV Lane	Eastex[3] w/o HOV Lane
Daily HOV Lane Person Trips (12/93)	20,462	21,645	9,628	13,161	13,200	NA
Percent Change over 12/92	-13%	-6%	-6%	-1%	NA	NA
% Change in Number of Lanes[4]	+33%	+25%	NA	33%	20%	NA
% Change in Person Volume[5]	+84%	+113%	NA	+58%	+91%	-2%
% Change in Average Vehicle Occupancy[5] (persons/vehicle)	+14%	+16%	NA	+19%	+11%	-2%
% Change in 2+ Carpool Volumes[5]	+56%[11]	+140%	NA	+207%	+142%	-12%
% New Carpools Due to HOV Lane[6] (1990)	53%	46%	26%	47%	NA	NA
% Change in Peak-Period Bus Riders	+243%	NA	NA	+183%	+17%	-35%
% New Bus Riders Due to HOV Lane[7]	47%	52%	33%	47%	NA	NA
% Change in Peak-Hour Bus Speeds	+140%	NA	+63%	+83%	+80%	+12%
Annual Savings in Bus Operating Costs Due to HOV Lane (millions) (1990)	$4.8	—	—	—	—	—
% Change in Vehicles at Park-and-Ride Lots	+249%	NA	+12%	+250%	+8%	-24%
% Change, Freeway Vehicle Volumes Per Lane[8]	+42%	+18%	NA	+8%	-10%	+7%
% Change, Roadway Efficiency[9]	+130%	+198%	NA	+55%	+38%	-8%
HOV Travel Time Savings as a % of Construction Cost[10]	28%	9%	9%	3%	6%	NA

NA = Either not available or not applicable.
[1]The percent change is a comparison of current values with representative pre-HOV lane values.
[2]These freeways have operating HOV lanes as of 12/93.
[3]This freeway does not have an HOV lane and represents a basis of comparison to the freeways with HOV lanes.
[4]The HOV added one lane; this is the percent increase in the number of total lanes (freeway plus HOV) resulting from implementing the HOV lane.
[5]A.M. peak-hour, peak-direction, combined mainlane and HOV data.
[6]This is an estimate of the percent of total carpools using the HOV lane that are new carpools created as a result of the HOV lane.
[7]This is an estimate of the percent of total bus riders using the HOV lane that are new bus riders created as a result of the HOV lane.
[8]Data for freeway mainlanes. A.M. peak-hour, peak-direction.
[9]Freeway per lane efficiency is expressed as the multiple of persons moved times average speed, a.m. peak-hour, peak-direction.
[10]This is the estimated annual value of 1993 travel time savings for HOV lane users expressed as a percent of the cost of constructing the segment of the HOV lane in operation in 1993.
[11]6 a.m. to 7 a.m. volume is used for this calculation due to the 3+ requirement during both the a.m. and p.m. peak hours as of 9/16/91.

Table 38. Potential Performance Measures for the Dallas HOV Lane, A.M. Peak-Hour, Peak-Direction

Performance Measure[1]	Freeway	
	East RLT[2] w/ HOV Lane	South RLT[3] w/o HOV Lane
Daily HOV Lane Person Trips (12/93)	14,017	NA
Percent Change over 12/92	-15%	NA
% Change in Number of Lanes[4]	+25%	NA
% Change in Person Volume[5]	+41%	+3%
% Change in Average Vehicle Occupancy[5] (persons/vehicle)	-1%	-3%
% Change in 2+ Carpool Volumes	+145%	-4%
% Change in Peak-Period Bus Riders	-1%	-12%
% Change in Peak-Hour Bus Speeds	+109%	+21%
% Change in Vehicles at Park-and-Ride Lots	-1%	-8%
% Change, Freeway Vehicle Volumes Per Lane[6]	+21%	+2%
% Change, Roadway Efficiency[7]	+80%	-8%
HOV Travel Time Savings as a % of Construction Cost[8]	+13%	NA

NA = Either not available or not applicable.
[1]The percent change is a comparison of current values with representative pre-HOV lane values.
[2]Freeway with an operating HOV lane as of 12/93.
[3]This freeway does not have an HOV lane and represents a basis of comparison to the freeways with HOV lanes.
[4]The HOV added one lane; this is the percent increase in the number of total lanes (freeway plus HOV) resulting from implementing the HOV lane.
[5]A.M. peak-hour, peak-direction, combined mainlane and HOV data.
[6]Data for freeway mainlanes. A.M. peak-hour, peak-direction.
[7]Freeway per lane efficiency is expressed as the multiple of persons moved times average speed, a.m. peak-hour, peak-direction.
[8]This is the estimated annual value of 1993 travel time savings for HOV lane users expressed as a percent of the cost of constructing the segment of the HOV lane in operation in 1993.

Table 39. Comparison of HOV Lane Objectives and HOV Lane Performance, 1993

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

NA = Either not available or not applicable.

APPENDIX A

KATY FREEWAY AND HOV LANE DATA

KATY FREEWAY (IH 10) AND HOV LANE, HOUSTON

Table A-1. Summary of A.M. Peak-Direction Katy Freeway and HOV Lane Data, December 1993

Type of Data Phase 1 of HOV Lane Became Operational 10/29/84	"Representative" Pre-HOV Lane	"Representative" Current Value	Percent Change
HOV Lane Data			
HOV Lane Length (kilometers [miles])		20.9 (13.0)	
HOV Lane Cost (millions)		$63.0	
Person-Movement			
Peak Hour (7-8 a.m.)	—	3,424	—
Peak Period (6-9:30 a.m.)	—	8,308	—
Total Daily	—	20,462	—
Vehicle Volumes			
Peak Hour	—	796	—
Peak Period	—	2,283	—
Vehicle Occupancy, Peak Hour (persons/veh)	—	4.30	—
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM]), 11/84-12/93[1]	—	12.0 (19.3)	—
Vehicle Breakdowns (VKT/Breakdown [VMT/Breakdown]), 11/84-12/93	—	68,103 (42,300)	—
Violation Rate (6-9:30 a.m.)	—	13%	—
Peak Hour Lane Efficiency (1000's)[2]	—	300 (186)	—
Annual Value of User Time Saved (millions)[3]	—	$3.85 to $7.7	—
Freeway Mainlane Data (see note)			
Person Movement			
Peak Hour	5,100	5,976	+17%
Peak Period (6-9:30 a.m.)	15,655	18,175	+16%
Vehicle Volume			
Peak Hour	4,045	5,742	+42%
Peak Period	12,750	17,547	+38%
Vehicle Occupancy, Peak Hour (persons/veh)	1.26	1.04	-17%
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM])[1]	12.4 (20.0)	12.7 (20.4)	+2%
Avg. Operating Speed[4] (kph [mph])			
Peak Hour	37 (23)	44 (28)	+20%
Peak Period	53 (33)	62 (39)	+17%
Peak Hour lane Efficiency (1000's)[2]	61 (38)	88 (55)	+44%

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

[1]Due to inconsistencies in reporting accidents in Harris County, only injury accidents are included in this analysis. Accidents were analyzed between Gessner and Post Oak, a distance of approximately 7.6 kilometers (4.7 miles). This corresponds to Phase 1 of the HOV lane. "Before" data are for the period 1/82 through 10/84. "After" data are for the period from 11/84 to 8/93. Only officer-reported accidents are included in current files. 1993 freeway volumes were estimated by TTI.

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

[3]Based on time savings for HOV lane users in 1993 and HOV lane volumes in 1993, an annual estimate of travel time savings to HOV lane users is developed. A value of time of $10.78/hour is used based on the value applied in the Highway Economic Evaluation Model.

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

Table A-1. Summary of A.M. Peak-Direction Katy Freeway and HOV Lane Data, December 1993 (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	9,400	+84%
Peak Period	15,655	26,483	+69%
Vehicle Volume			
Peak Hour	4,045	6,538	+62%
Peak Period	12,750	19,830	+56%
Vehicle Occupancy			
Peak Hour	1.26	1.44	+14%
Peak Period	1.23	1.34	+9%
Carpool Volumes[1]			
2+, 6 a.m. to 7 a.m.	505	791	+56%
3+, 7 a.m. to 8 a.m.	76	360	+374%
3+, 5 p.m. to 6 p.m.	104	269	+159%
Travel Time (minutes)			
Peak Hour	33.9[2]	14.5[3]	-57%
Peak Period	23.1[2]	14.2[3]	-39%
Peak Hour Lane Efficiency (1000's)[4]	61 (38)	141 (88)	+130%
Transit Data			
Bus Vehicle Trips			
Peak Hour	11	37	+236%
Peak Period	32	95	+197%
Bus Passenger Trips			
Peak Hour	335	1,486	+344%
Peak Period	900	3,090	+243%
Bus Occupancy (persons/bus)			
Peak Hour	30.5	40.2	+31%
Peak Period	28.1	32.5	+16%
Vehicles Parked in Corridor Park & Ride Lots	575	2,008	+249%
Bus Operating Speed (kph [mph])[5]			
Peak Hour	36 (23)[2]	87 (54)[3]	+140%
Peak Period	53 (33)[2]	89 (56)[3]	+67%

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

[1]Carpool counts are adjusted in an effort to compensate for undercounting of occupancies in the field.
[2]Data pertain to operation in the freeway mainlanes.
[3]Data pertain to operation in the HOV lane.
[4]This represents the multiple of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.
[5]The distance from SH 6 to Washington is 19.6 kilometers (12.2 miles). The HOV lane is in place over this section.

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

Measure of Effectiveness	"Representative" Pre-HOV Lane Value	"Representative" 12/93 Value	Percent Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/HOV lane	1.26	1.44	+14%
Freeway w/o HOV lane	1.23	1.21	-2%
Peak-Hour 3+ Carpool Volume			
Freeway w/HOV lane	76	360	+374%
Freeway w/o HOV lane	123	92	-25%
Bus Passengers, Peak Period			
Freeway w/HOV lane	900	3,090	+243%
Freeway w/o HOV lane	1,188	775	-35%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	575	2,008	+249%
Freeway w/o HOV lane[1]	1,236	942	-24%
Facility Per Lane Efficiency[2]			
Freeway w/HOV lane	61 (38)	141 (88)	+130%
Freeway w/o HOV lane	138 (86)	126 (78)	-8%

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

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

HOV LANE DATA

DESCRIPTION

- Phase 1 (7.6 kilometers [4.7 miles]) of the HOV lane opened October 29, 1984.
- The HOV lane is now complete with 20.9 kilometers (13.0 miles) in operation.
- The capital cost (including all support facilities) for the completed facility in 1990 dollars was $59.1 million. A more detailed cost breakdown (including dates) is provided on the following page.
- Selected milestone dates are listed below. Other dates are shown in the capital cost table.

- 10/29/84 Post Oak to Gessner (7.6 kilometers [4.7 miles]) opens, used by buses and vans
- 4/1/85 4+ authorized carpools allowed onto HOV
- 5/2/85 HOV extended to West Belt (10.3 kilometers [6.4 miles])

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

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

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1990 dollars
HOV Lane and Ramps			
Eastern Extension (1990)	$5.5	1.00	$5.5
Phase 1, Silber to West Belt (1984) Design and Construction	10.5	0.93	9.8
Phase 2, West Belt to SH 6 (1987) Design and Construction	8.7	0.85	7.4
Addicks North Ramp (1987)	2.8	0.85	2.4
SUB-TOTAL	$27.5		$25.1
Per Kilometer (Mile)	$1.3 ($2.1)		$1.2 ($1.9)
Surveillance, Communication & Control (1987)	$5.5	0.85	$4.7
SUB-TOTAL	$5.5		$4.7
Per Kilometer (Mile)	$0.3 ($0.4)		$0.2 ($0.4)
Support Facilities			
West Belt P/R (1984)	$4.8	0.93	$4.5
Addicks P/R (1981)	3.9	1.05	4.1
Addicks P/R Expansion (1988)	6.3	0.98	6.2
Kingsland P/R (1985)	3.8	0.92	3.5
1/2 N.W. Transit Center (1988)	10.6	0.98	10.4
Fry Road Park-and-Pool (1987)	0.2	0.85	0.2
Mason Road Park-and-Pool (1986)	0.2	0.79	0.2
Barker-Cypress Park-and-Pool (1986)	0.2	0.79	0.2
SUB-TOTAL	$30.0		$29.3
Per Kilometer (Mile)	$1.4 ($2.3)		$1.4 ($2.2)
TOTAL COST	$63.0		$59.1
COST PER KILOMETER (20.9 kilometers [13.0 miles])	$3.0 ($4.8)		$4.5 ($2.8)

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

PERSON MOVEMENT

- In December 1993, 20,462 person trips per day were served on the HOV lane.

- A.M. Peak Hour, 3,424 persons/hour.

  - 1,483 (43%) by bus, 86 (3%) by vanpool, 1,855 (54%) by carpool (Figure A-1).
  - Average HOV lane vehicle occupancy = 4.30 persons/vehicle.

- A.M. Peak Period, 8,308 persons.

  - 3,073 (37%) by bus, 272 (3%) by vanpool, by carpool 4,963 (60%) (Figure A-2).

VEHICLE MOVEMENT

- A.M. Peak Hour, 796 vph

  - 34 (4%) buses, 12 (2%) vans, 750 (94%) carpools (Figure A-3).

- A.M. Peak Period, 2,283 vehicles

  - 78 (3%) buses, 39 (2%) vans, 2,166 (95%) carpools (Figure A-4).

ACCIDENT RATE

- For the period from November 1984 through December 1993, the HOV lane accident rate was 12.0 injury accidents per 100 million vehicle kilometers (19.3 injury accidents per 100 million vehicle miles).

VEHICLE BREAKDOWN RATES

- As measured for 11/84 to 12/93, the following rate has been observed.
  - The weighted average for all vehicle types is one breakdown per 68,103 VKT (42,300 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 13%.
  - For the period from 7:00 a.m. to 8:15 a.m. (the 3+ operating time), it averaged 35% for 1993 and was 29% in December.
  - For the p.m. peak period, the violation rate is 10%.
  - For the p.m. peak hour (the 3+ operating time), the violation rate is 33%.

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 300 (3,424 passengers at 87 kph), or 186 (3,424 passengers at 54 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane experienced an average travel time savings of 14 minutes during the morning peak hour in 1993 (Figure A-5).

- The tables on the following page indicate that, on a typical non-incident day, travel time savings of approximately 1,428 hours (85,684 min.) are realized. Assuming 250 days of operation, annual savings would be 357,000 hours. At $10.78/hour, this equates to $3.85 million per year. This is extremely conservative since it does not consider travel time savings due to incidents on the freeway. Data from Houston suggest increasing this value by 100% to account for incidents would be reasonable. Thus, travel time savings to HOV lane users are conservatively estimated to be in the range of $3.85 to $7.70 million per year.

FREEWAY DATA

NOTES

- For purposes of safety and visibility, freeway volumes are counted at Bunker Hill between an exit ramp and an entrance ramp. Thus, freeway volumes may be low in comparison to actual freeway operations. Also, a downstream bottleneck was alleviated with the opening of the Chimney Rock extension; as a result, volumes at the count location have increased significantly.

PERSON MOVEMENT

- In the a.m. peak hour, person movement has increased by 17% relative to pre-HOV conditions (Figure A-6).

- In the a.m. peak period, person movement has increased by 16% relative to pre-HOV conditions (Figure A-7).

VEHICLE VOLUME

- In the a.m. peak hour, vehicle volume has increased by 42%, relative to pre-HOV conditions (Figure A-8).

- In the a.m. peak period, vehicle volume has increased by 38%, relative to pre-HOV conditions (Figure A-9).

VEHICLE OCCUPANCY

- In the a.m. peak hour, mainlane occupancy has decreased by 17%, relative to pre-HOV conditions (Figure A-10).

- In the a.m. peak period, mainlane occupancy has decreased by 14%, relative to pre-HOV conditions (from 1.23 to 1.06, 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 (the freeway section west of Gessner was impacted by toll road construction). 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 8/93, the freeway accident rate was 12.7 accidents/100 MVK (20.4 accidents/100 MVM). These statistics do not include driver reported accidents; only officer reported accidents are included in current accident files. TTI estimated 1993 freeway volumes to compute accident rates.

AVERAGE OPERATING SPEED

- In comparison to pre-HOV lane conditions, mainlane operating speeds have increased by 20% in the peak hour and 17% in the peak period (Figure A-12).

PEAK HOUR LANE EFFICIENCY

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

- For the freeway mainlanes, an increase in per lane efficiency of 44% has occurred.

Table A-4. Eastbound A.M. Travel Time Savings for Katy HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1993)

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	6.74	6.40	0.34	448	28	177	652	225
6:30	9.05	6.27	2.78	961	38	377	1,375	3,828
7:00	12.95	6.69	6.26	447	27	564	1,038	6,499
7:30	18.08	6.57	11.51	409	14	427	850	9,784
8:00	12.36	6.61	5.75	596	11	209	816	4,690
8:30	6.57	6.20	0.37	307	4	54	364	133
9:00	6.29	6.43	-0.14	154	4	14	172	-24
Peak Period Total				3,322	126	1,820	5,268	25,135
Section From Gessner Interchange to Washington								
6:00	7.83	7.55	0.28	338	47	353	739	206
6:30	8.91	7.48	1.43	1,100	61	470	1,631	2,332
7:00	12.31	7.79	4.52	768	66	1,041	1,875	8,469
7:30	13.86	7.74	6.12	698	34	833	1,566	9,579
8:00	11.66	8.10	3.56	982	17	447	1,446	5,145
8:30	7.92	7.59	0.33	759	4	182	944	312
9:00	7.58	7.79	-0.21	444	11	24	479	-101
Peak Period Total				5,089	241	3,350	8,680	25,942
Westbound P.M. Travel Time Savings for Katy HOV Lane								
Section from Washington to Gessner Interchange								
3:30	7.81	7.78	0.03	534	53	169	756	23
4:00	8.64	7.82	0.82	811	45	338	1,194	982
4:30	11.34	7.85	3.49	1,158	67	622	1,847	6,446
5:00	10.47	7.62	2.85	626	67	816	1,508	4,298
5:30	12.82	7.85	4.97	603	36	844	1,484	7,375
6:00	12.46	9.76	2.70	843	11	297	1,152	3,108
6:30	9.68	7.68	2.00	416	1	180	597	1,197
Peak Period Total				4,991	281	3,267	8,538	23,429

Table A-4. Eastbound A.M. Travel Time Savings for Katy HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1993) (continued)

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	6.27	6.38	-0.11	206	18	55	279	-31
4:00	6.53	6.16	0.37	348	62	132	541	201
4:30	6.93	6.53	0.40	627	39	229	895	361
5:00	10.35	6.26	4.09	678	56	351	1,085	4,439
5:30	10.39	6.37	4.02	374	34	559	966	3,887
6:00	9.41	6.22	3.19	502	18	196	716	2,284
6:30	6.41	6.33	0.08	358	7	117	482	37
Peak Period Total				3,093	234	1,638	4,965	11,178

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 36% of peak-hour person movement (HOV lane = 3,424; freeway = 5,976) and 31% of peak-period (HOV lane = 8,308; freeway = 18,175) person movement.
- Increase in a.m. person movement at Bunker Hill relative to pre-HOV lane operations.
  - Provision of the HOV lane increased total directional lanes by 33%.
  - Total peak-hour person movement has increased by 84% from 5,100 to 9,400 (Figure A-6). Peak-period person movement has increased by 69% from 15,655 to 26,483 (Figure A-7).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.44, a 14% 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 1.34 (9%).

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

CARPOOL VOLUMES

- In the a.m. peak hour, the total number of 3+ carpools (freeway plus HOV lane) has increased by 700% compared to pre-HOV lane levels (Figure A-14).

- Prior to the HOV lane, 2+ carpool volume from 6 to 7 a.m. was 505 vehicles -- now it is nearly 800 vehicles (Figure A-15).

PEAK HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. The average efficiency of a lane on the freeway (3 freeway lanes plus 1 HOV lane) has increased by 130% since the implementation of the HOV lane (Figure A-16). This large of an increase has not occurred on freeways not having HOV lanes (Figure A-17).

BUS TRANSIT DATA

BUS VEHICLE AND PASSENGER TRIPS

- In the a.m. peak hour, bus vehicle trips have been increased by 236% since the HOV lane opened, and a 344% increase in bus ridership has also resulted (Figure A-18). In the peak period, a 197% increase has occurred in bus trips and a 243% increase in bus ridership has resulted (Figure A-19).

- 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-20).

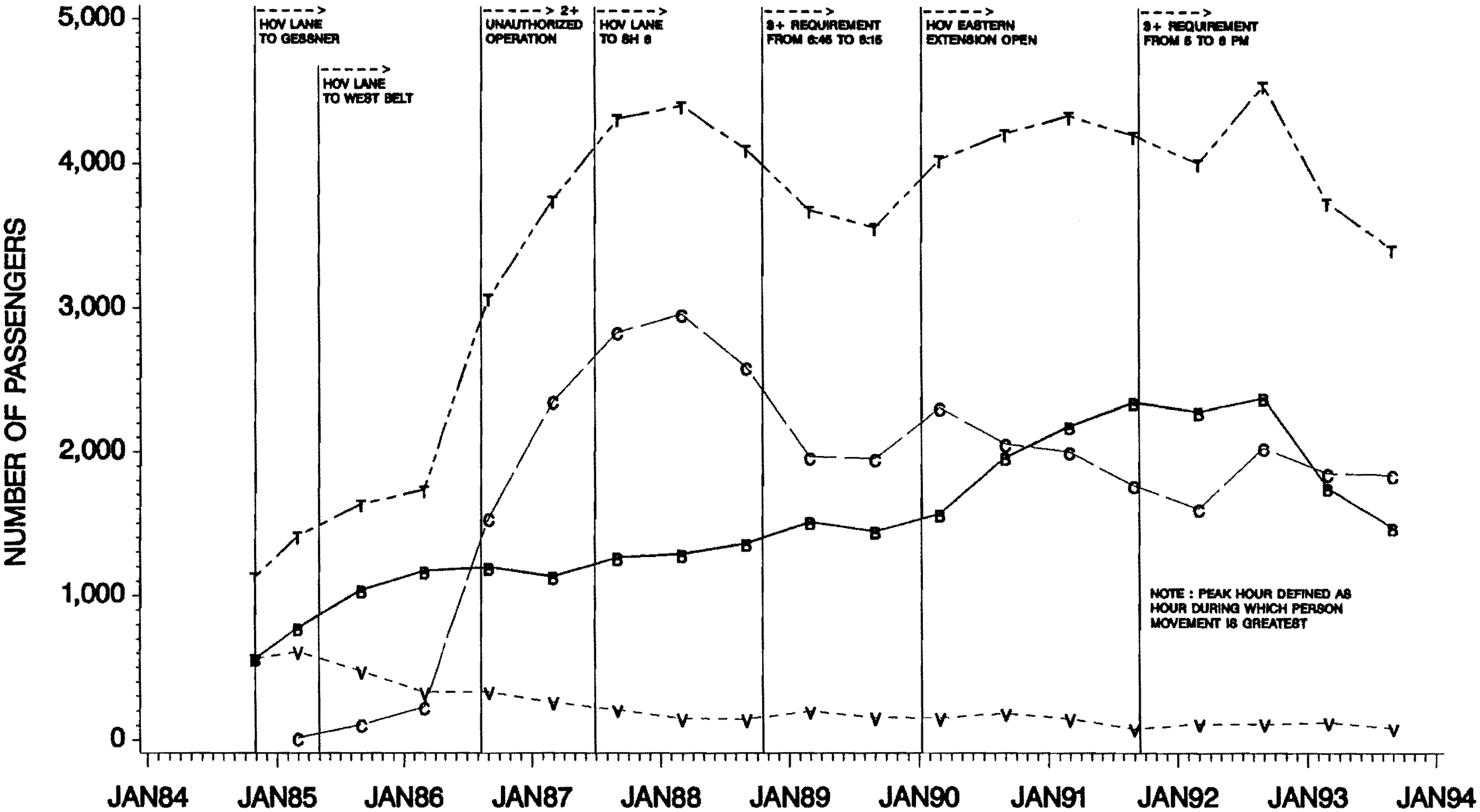
PARK-AND-RIDE

- Prior to opening the HOV lane, approximately 575 vehicles were parked in corridor park-and-ride lots. This has increased 249% to a current level of 2,008 (Figure A-21).

- 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-22).

FIGURE A-1

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

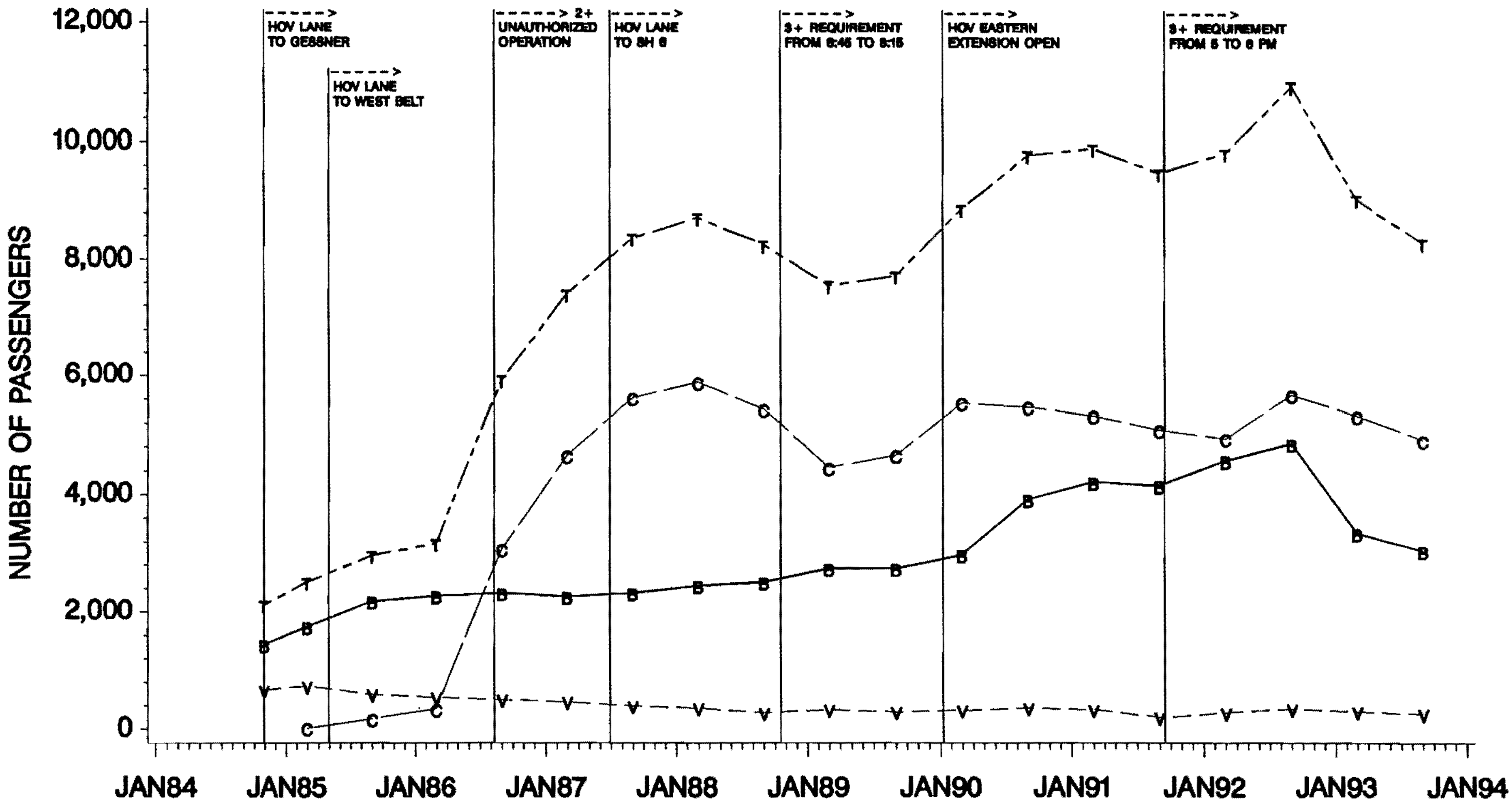


KATY HOV LANE PHASE 1, POST OAK TO GESSNER (7.57 KM [4.7 MI]), OPENED OCTOBER 29, 1984
HOV LANE EXTENSION FROM GESSNER TO WEST BELT (2.74 KM [1.7 MI]) OPENED MAY 2, 1985
OFF–PEAK, UNAUTHORIZED & 2+ CARPOOL OPERATION BEGAN AUGUST 11, 1986
HOV LANE EXTENSION FROM WEST BELT TO SH 6 (8.05 KM [5.0 MI]) OPENED JUNE 29, 1987
3+ CARPOOL REQUIREMENT FROM 6:45 TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
HOV LANE EASTERN EXTENSION (1.88 KM [1.17 MI]) OPENED JANUARY 9, 1990
DATA COLLECTED BETWEEN GESSNER AND POST OAK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL HOV PASSENGERS
B = TOTAL BUS PASSENGERS
V = TOTAL VANPOOLERS
C = TOTAL CARPOOLERS

FIGURE A-2

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

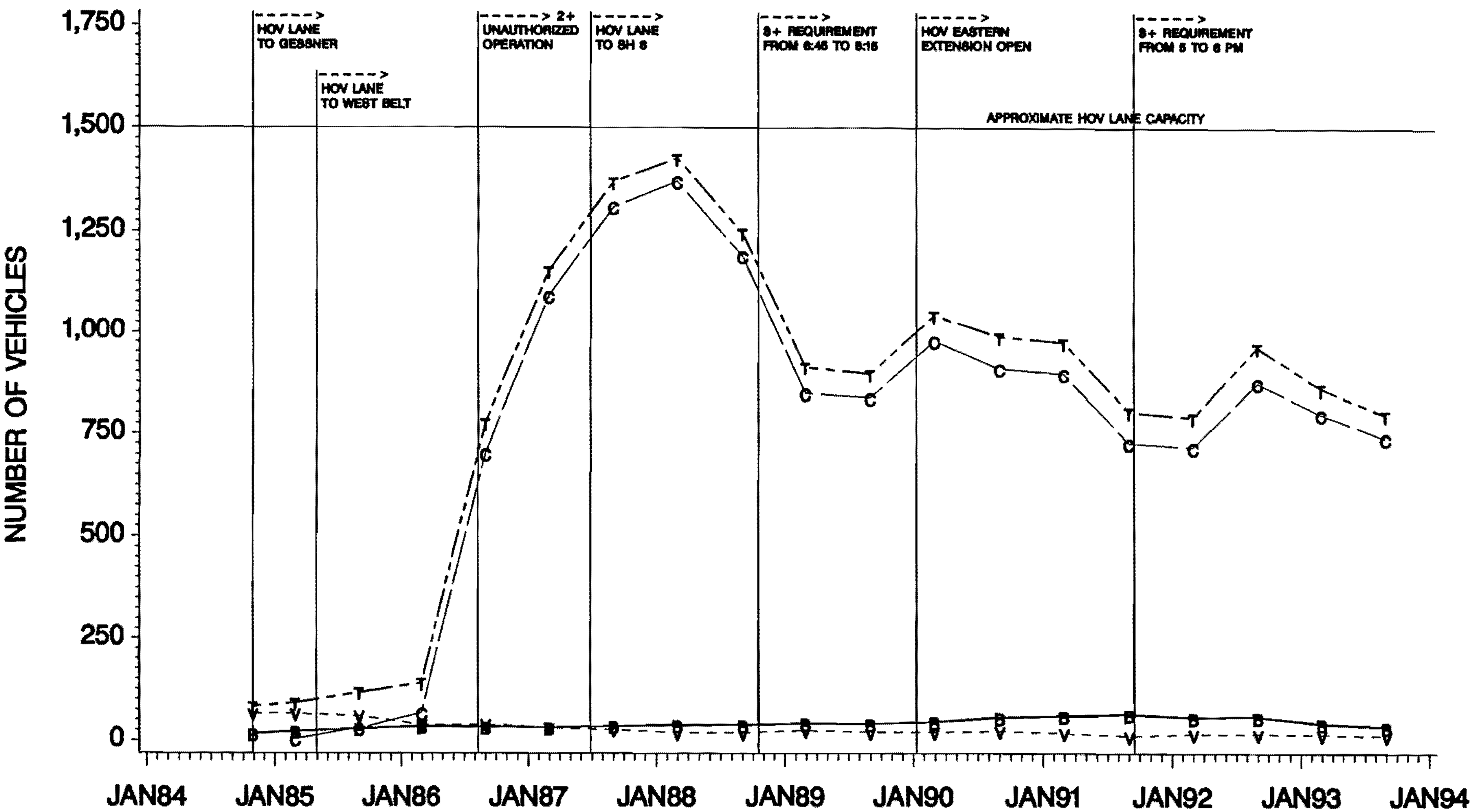


KATY HOV LANE PHASE 1, POST OAK TO GESSNER (7.57 KM [4.7 MI]), OPENED OCTOBER 29, 1984
HOV LANE EXTENSION FROM GESSNER TO WEST BELT (2.74 KM [1.7 MI]) OPENED MAY 2, 1985
OFF-PEAK, UNAUTHORIZED & 2+ CARPOOL OPERATION BEGAN AUGUST 11, 1986
HOV LANE EXTENSION FROM WEST BELT TO SH 6 (8.05 KM [5.0 MI]) OPENED JUNE 29, 1987
3+ CARPOOL REQUIREMENT FROM 6:45 TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
HOV LANE EASTERN EXTENSION (1.88 KM [1.17 MI]) OPENED JANUARY 9, 1990
PEAK PERIOD IS 6:00 – 9:30 A.M.
DATA COLLECTED BETWEEN GESSNER AND POST OAK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL HOV PASSENGERS
B = TOTAL BUS PASSENGERS
V = TOTAL VANPOOLERS
C = TOTAL CARPOOLERS

FIGURE A-3

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

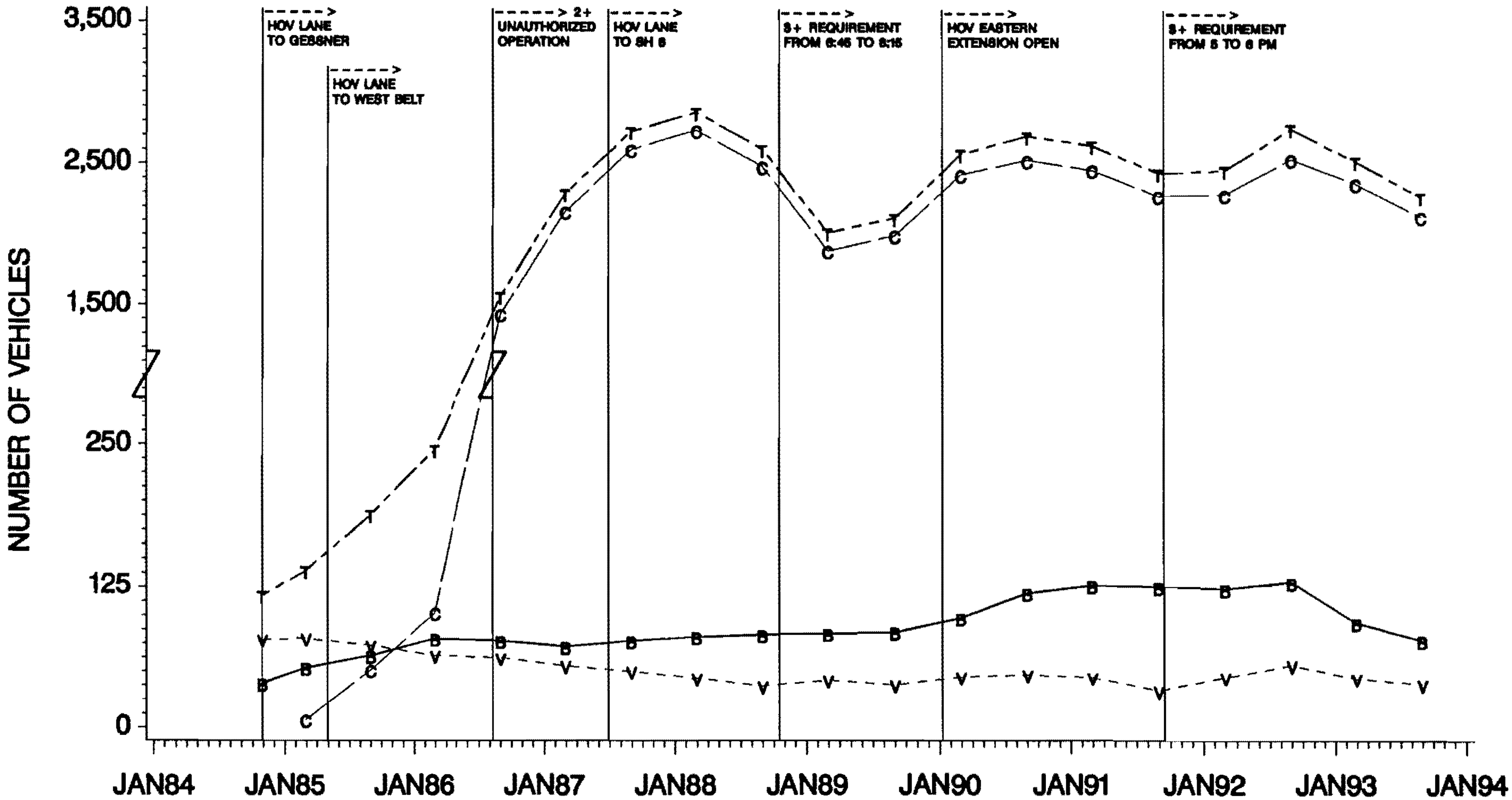


KATY HOV LANE PHASE 1, POST OAK TO GESSNER (7.57 KM [4.7 MI]), OPENED OCTOBER 29, 1984
HOV LANE EXTENSION FROM GESSNER TO WEST BELT (2.74 KM [1.7 MI]) OPENED MAY 2, 1985
OFF-PEAK, UNAUTHORIZED & 2+ CARPOOL OPERATION BEGAN AUGUST 11, 1986
HOV LANE EXTENSION FROM WEST BELT TO SH 6 (8.05 KM [5.0 MI]) OPENED JUNE 29, 1987
3+ CARPOOL REQUIREMENT FROM 6:45 TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
HOV LANE EASTERN EXTENSION (1.88 KM [1.17 MI]) OPENED JANUARY 9, 1990
DATA COLLECTED BETWEEN GESSNER AND POST OAK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL HOV VEHICLES
B = TOTAL BUSES
V = TOTAL VANPOOLS
C = TOTAL CARPOOLS

FIGURE A-4

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

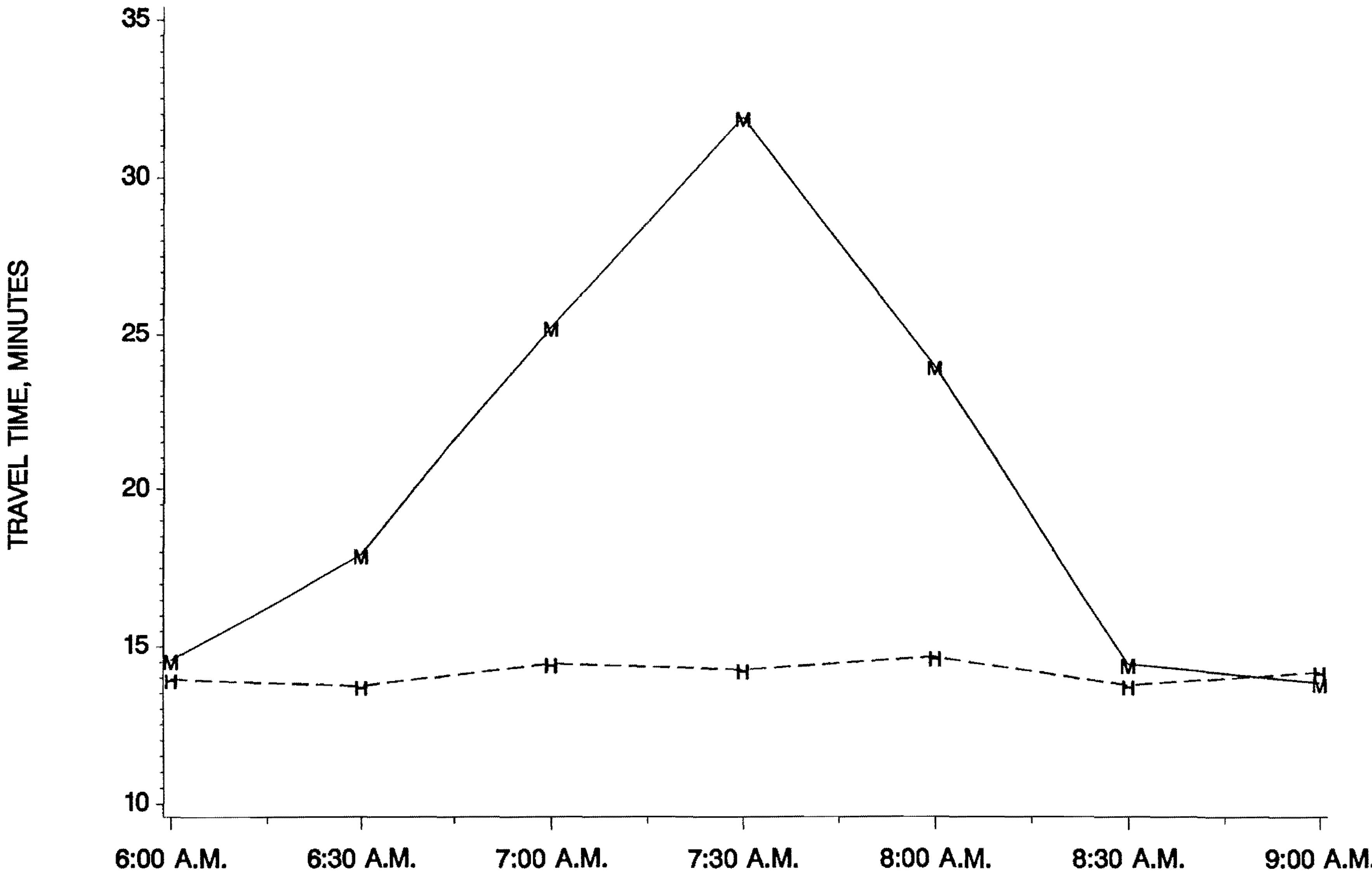


KATY HOV LANE PHASE 1, POST OAK TO GESSNER (7.57 KM [4.7 MI]), OPENED OCTOBER 29, 1984
HOV LANE EXTENSION FROM GESSNER TO WEST BELT (2.74 KM [1.7 MI]) OPENED MAY 2, 1985
OFF-PEAK, UNAUTHORIZED & 2+ CARPOOL OPERATION BEGAN AUGUST 11, 1986
HOV LANE EXTENSION FROM WEST BELT TO SH 6 (8.05 KM [5.0 MI]) OPENED JUNE 29, 1987
3+ CARPOOL REQUIREMENT FROM 6:45 TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
HOV LANE EASTERN EXTENSION (1.88 KM [1.17 MI]) OPENED JANUARY 9, 1990
PEAK PERIOD IS 6:00 – 9:30 A.M.
DATA COLLECTED BETWEEN GESSNER AND POST OAK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL HOV VEHICLES
B = TOTAL BUSES
V = TOTAL VANPOOLS
C = TOTAL CARPOOLS

FIGURE A-5

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



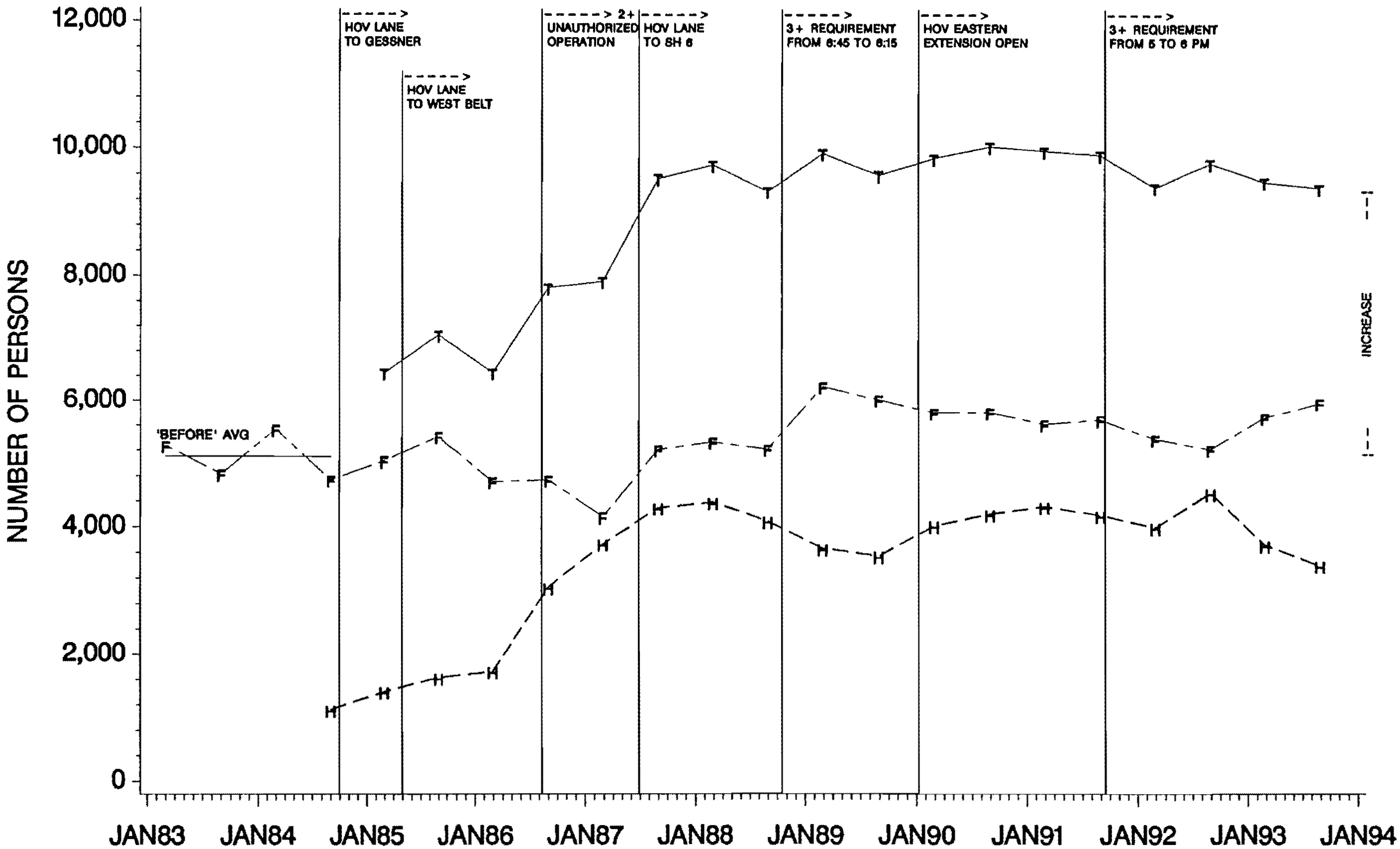
TRAVEL TIMES ARE AN AVERAGE OF 4 QUARTERLY TRAVEL TIME SURVEYS CONDUCTED IN 1993
TRAVEL TIMES ARE FROM THE WESTERN HOV LANE TERMINUS TO WASHINGTON AVE
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : M – MAINLANE TRAVEL TIME
H – HOV LANE TRAVEL TIME

A-16

FIGURE A-6

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

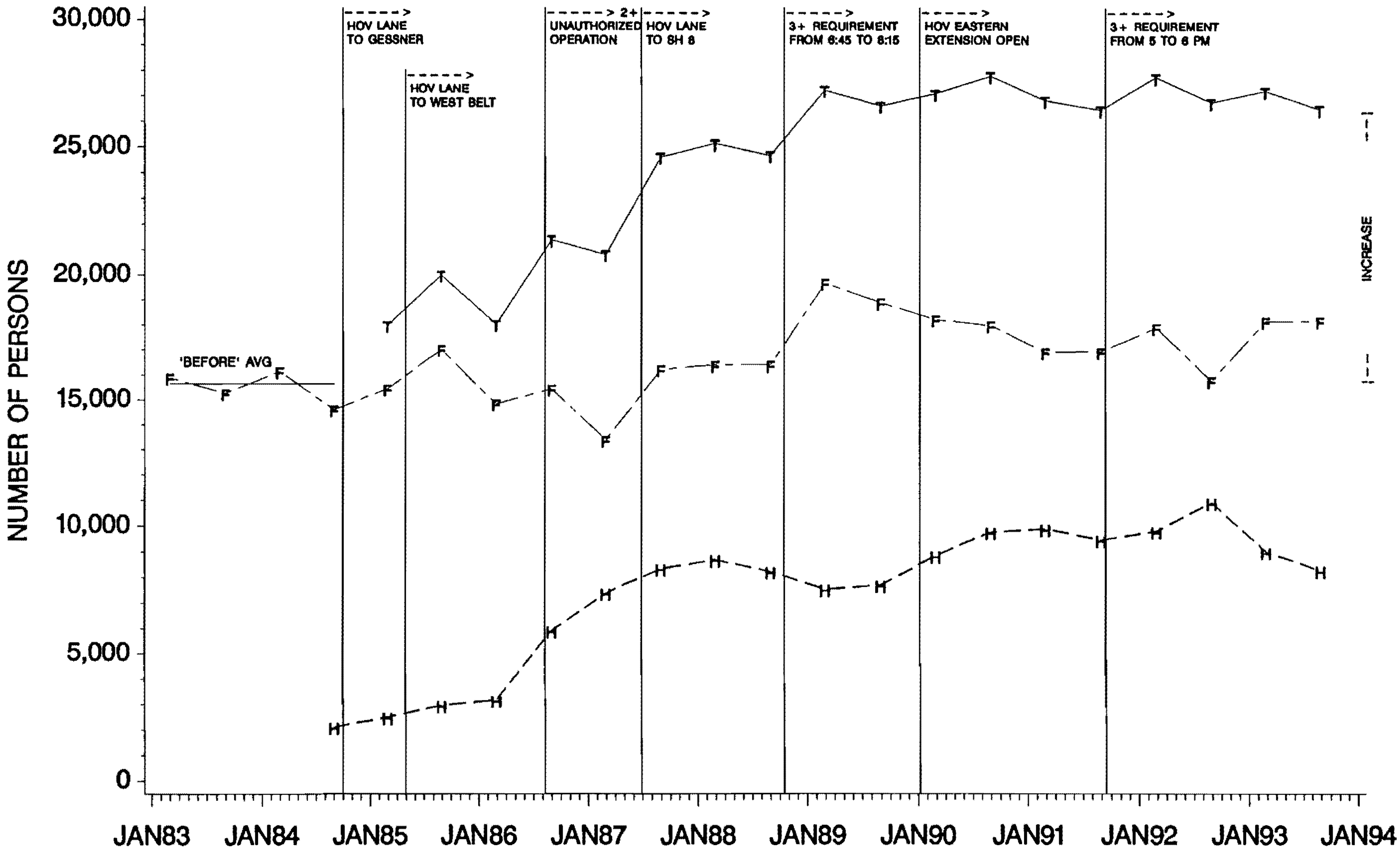


DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
3+ REQUIREMENT FROM 6:45 A.M. TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL PERSONS
F = MAINLANE PERSONS
H = HOV LANE PERSONS

FIGURE A-7

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

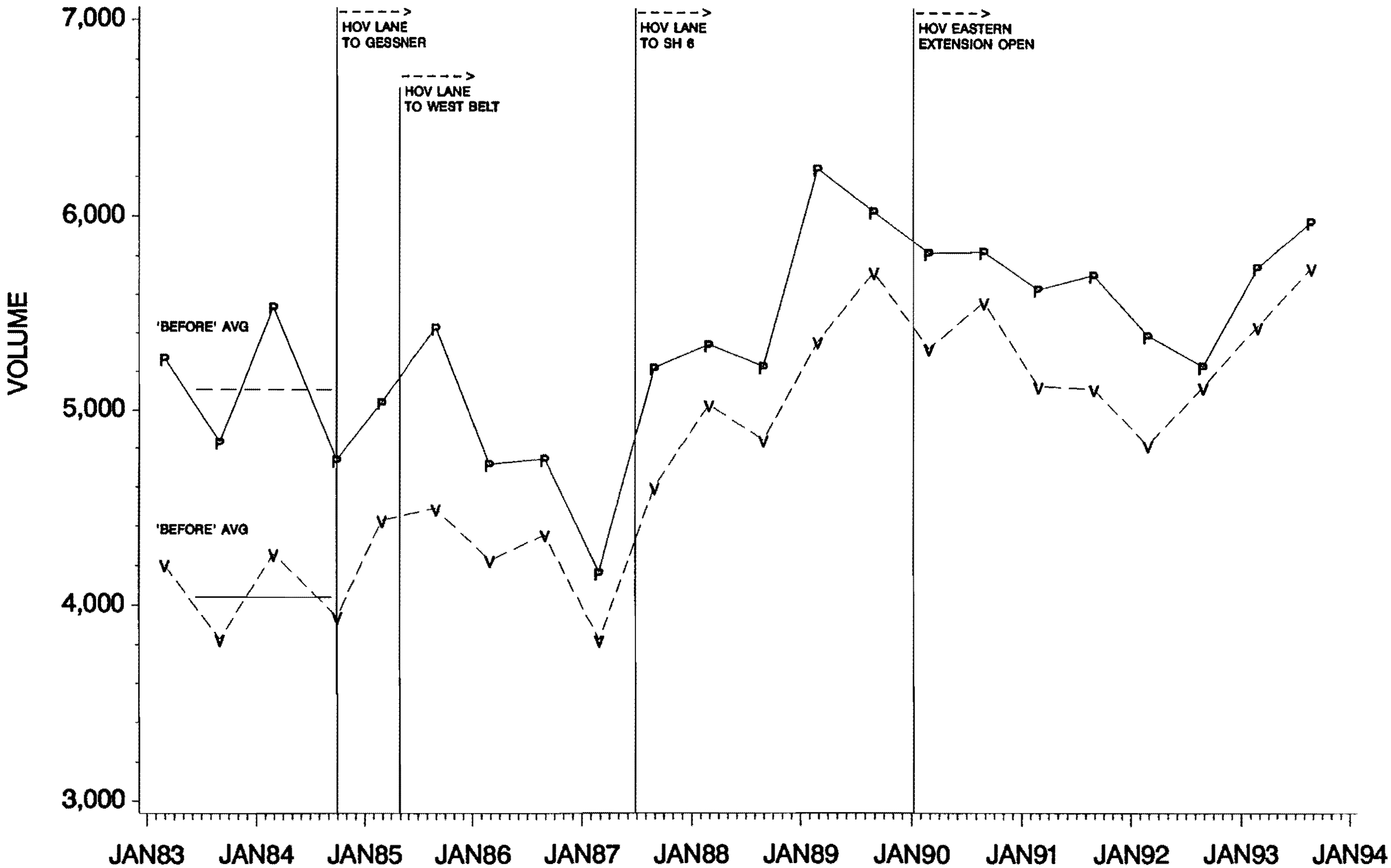


A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M
DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
3+ REQUIREMENT FROM 6:45 A.M. TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL PERSONS
F = MAINLANE PERSONS
H = HOV LANE PERSONS

FIGURE A-8

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



DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = MAINLANE PERSONS
V = MAINLANE VEHICLES

FIGURE A-9

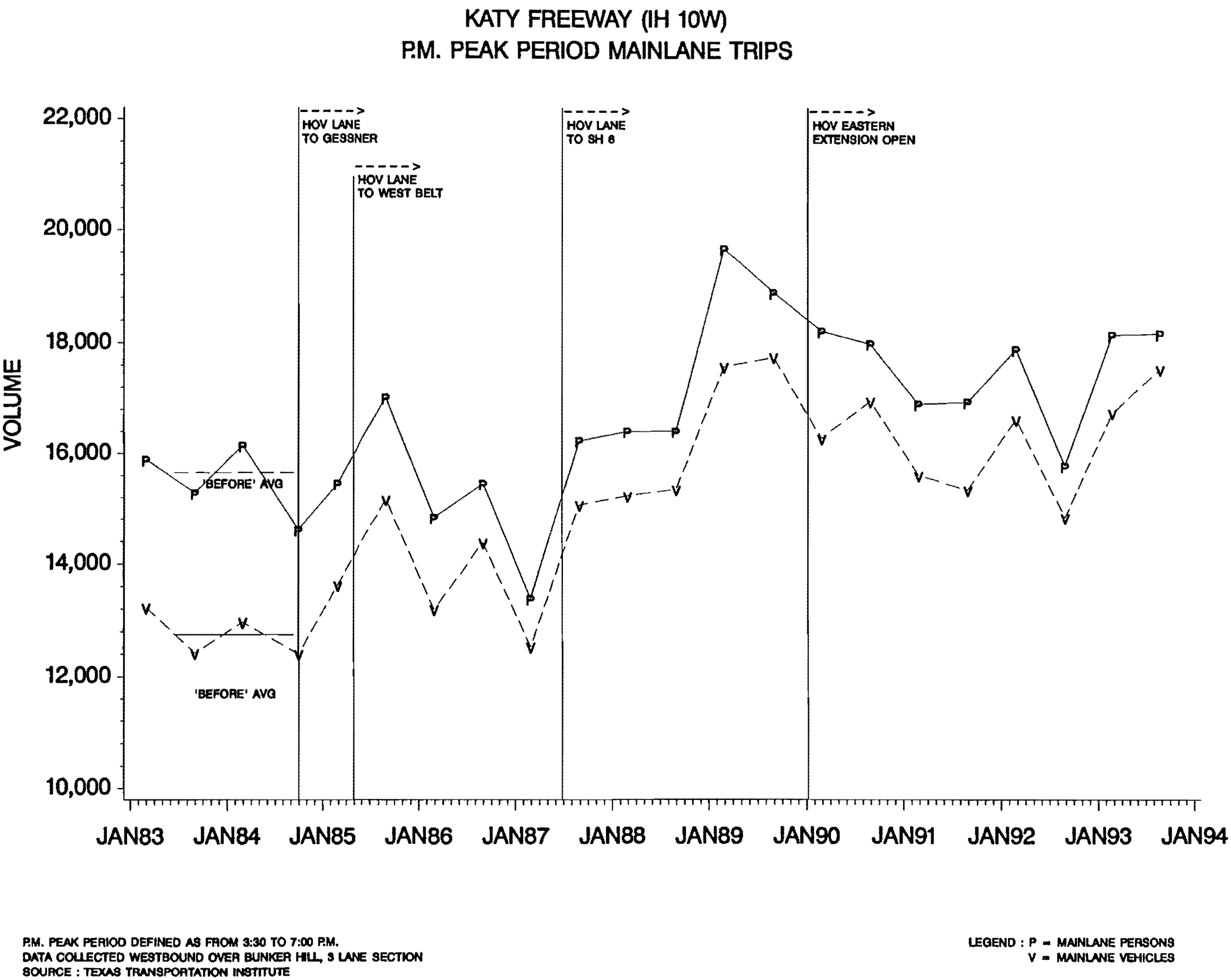
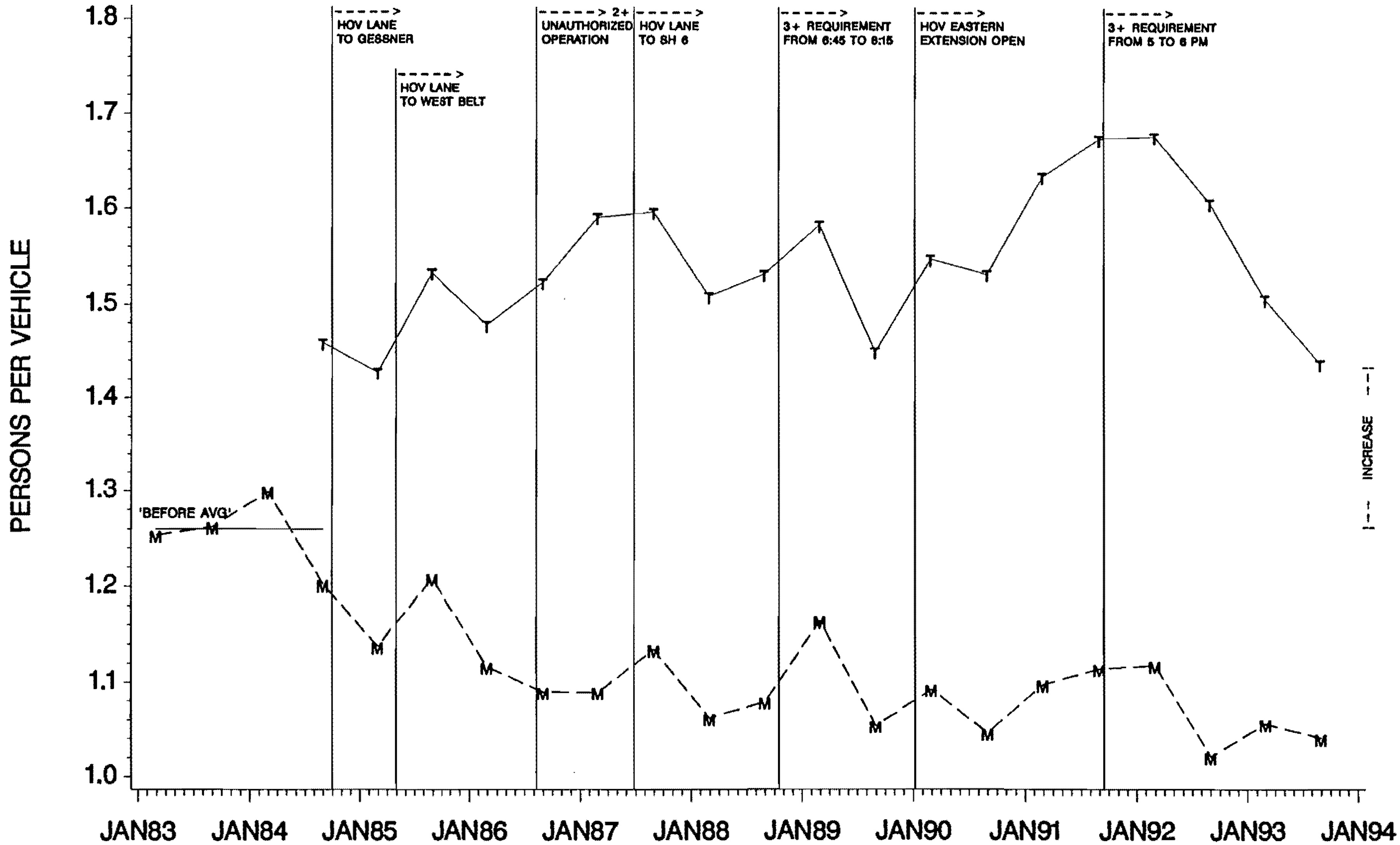

KATY FREEWAY (IH 10W)
P.M. PEAK PERIOD MAINLANE TRIPS
22,000
20,000
18,000
16,000
14,000
12,000
10,000
VOLUME
HOV LANE TO GESSNER
HOV LANE TO WEST BELT
HOV LANE TO SH 6
HOV EASTERN EXTENSION OPEN
'BEFORE' AVG
'BEFORE' AVG
JAN83
JAN84
JAN85
JAN86
JAN87
JAN88
JAN89
JAN90
JAN91
JAN92
JAN93
JAN94
P.M. PEAK PERIOD DEFINED AS FROM 3:30 TO 7:00 P.M.
DATA COLLECTED WESTBOUND OVER BUNKER HILL, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE
LEGEND : P = MAINLANE PERSONS
V = MAINLANE VEHICLES

FIGURE A-10

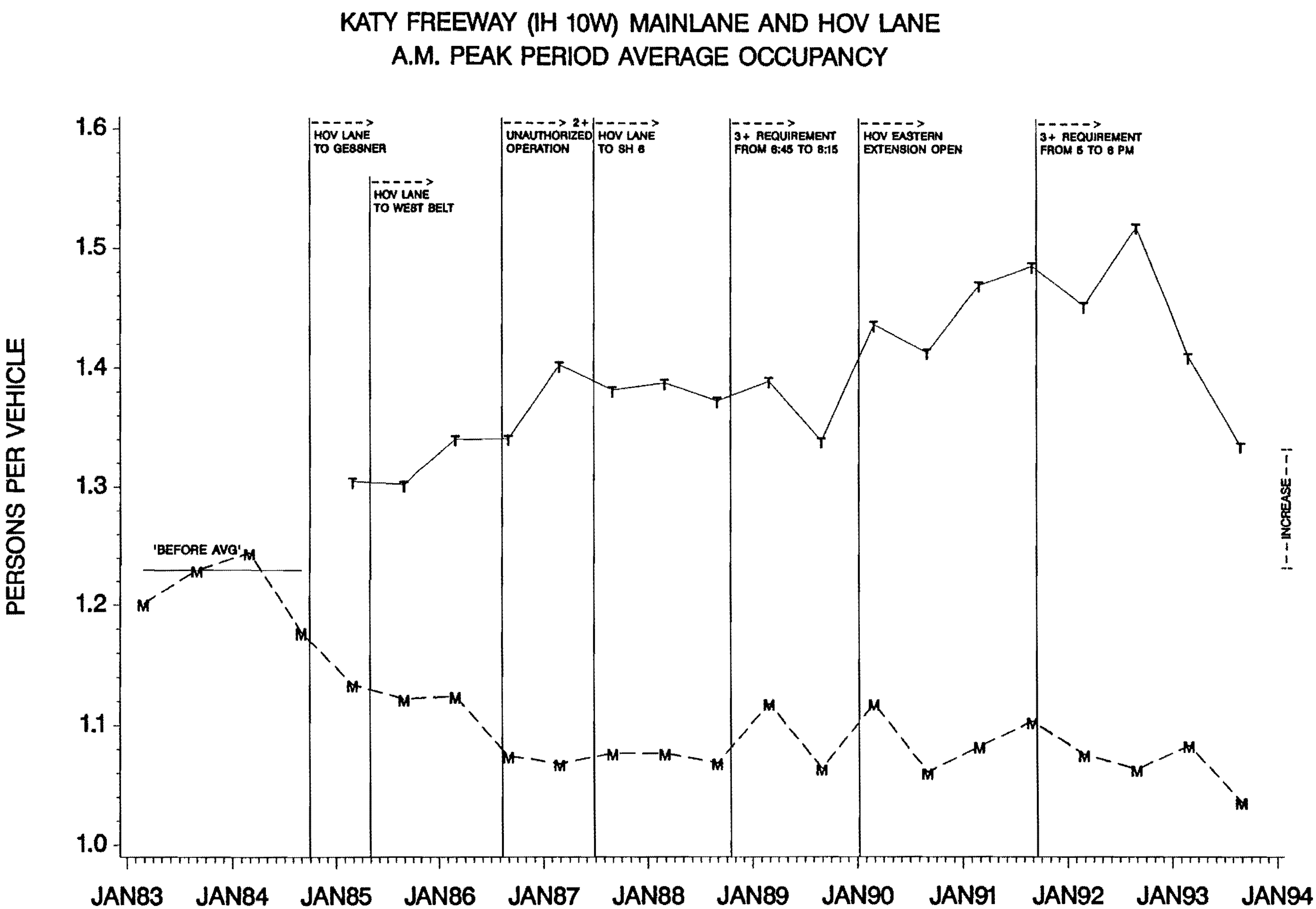
KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK HOUR AVERAGE OCCUPANCY



DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
3+ REQUIREMENT FROM 6:45 A.M. TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : M = MAINLANE OCCUPANCY
T = TOTAL OCCUPANCY (FREEWAY PLUS HOV LANE)

FIGURE A-11

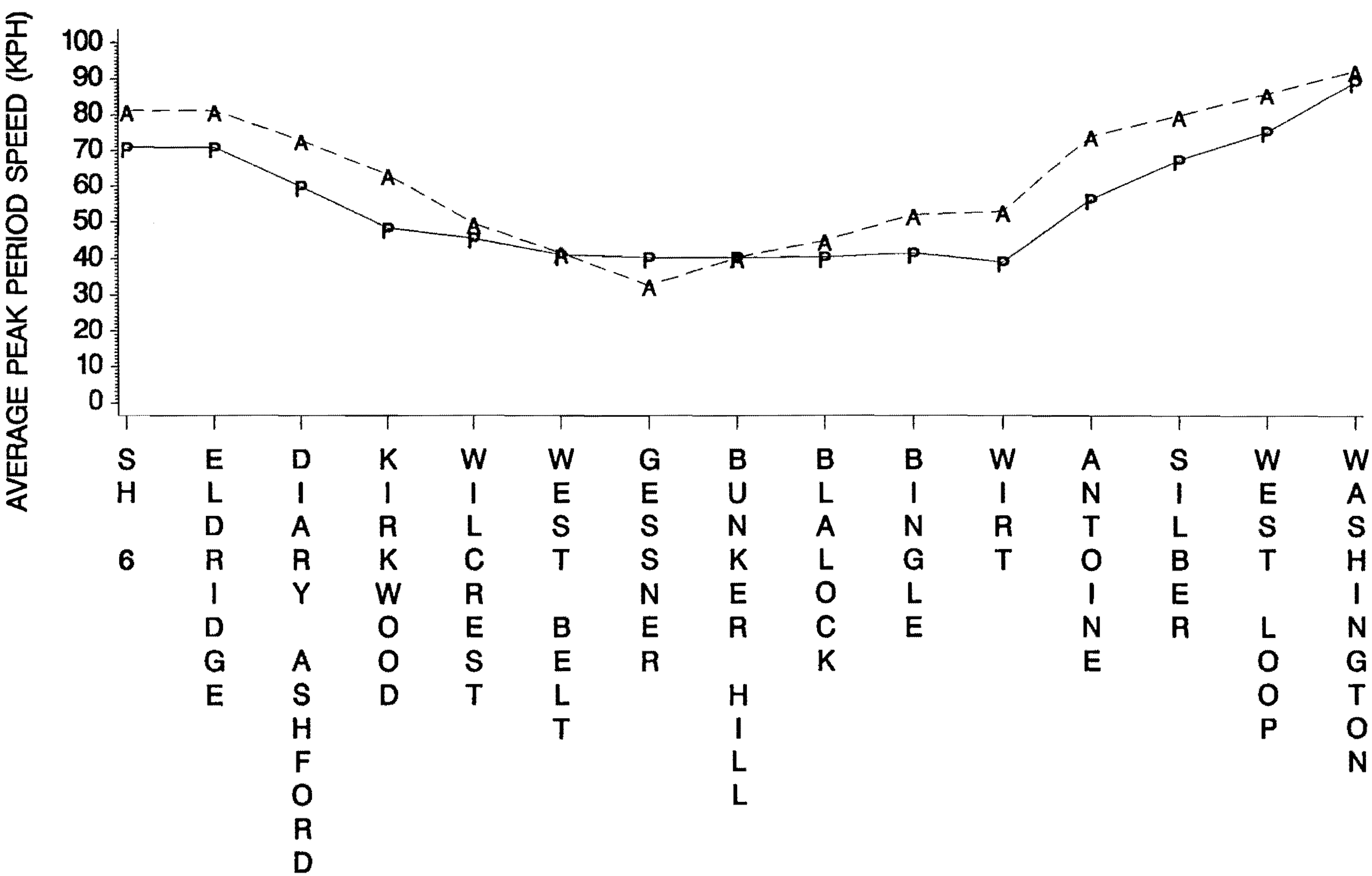


A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M
DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
3+ REQUIREMENT FROM 6:45 A.M. TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : M = MAINLANE OCCUPANCY
T = TOTAL OCCUPANCY
(MAINLANE PLUS HOV LANE)

FIGURE A-12

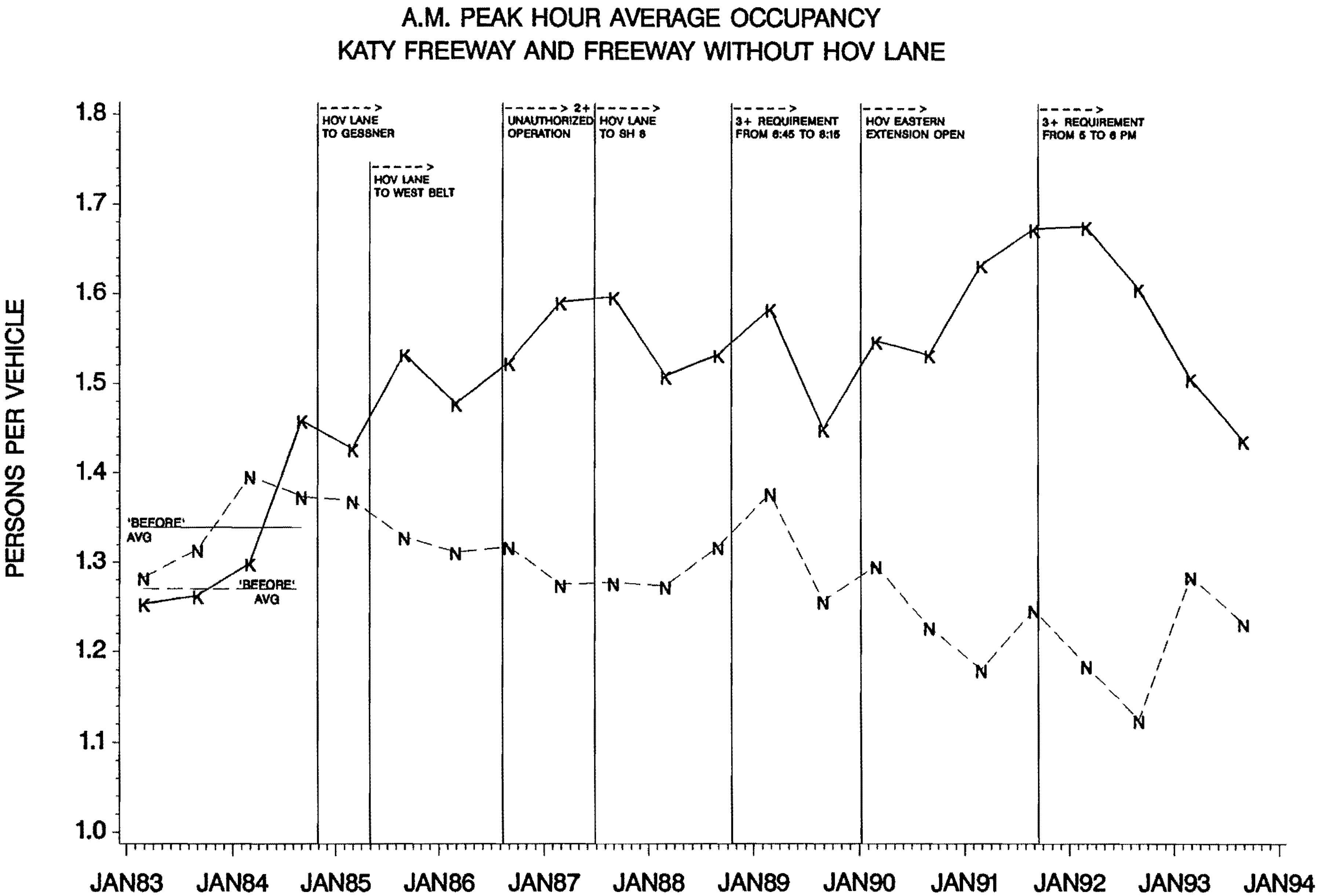
KATY FREEWAY (IH 10W) MAINLANE TRAVEL TIME AND SPEED SURVEY
EASTBOUND, SH 6 TO WASHINGTON
A.M. PEAK PERIOD



NOTE : TO CONVERT SPEEDS FROM METRIC TO ENGLISH UNITS MULTIPLY KPH BY 0.62
DATA COLLECTED 6:00 TO 9:30 A.M.
DATA COLLECTED FROM JUNE, 1983 TO SEPTEMBER, 1993
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = AVERAGE SPEED PRIOR TO OPENING HOV LANE
A = AVERAGE SPEED SINCE HOV LANE OPEN TO SH 6 (6/87)

FIGURE A-13

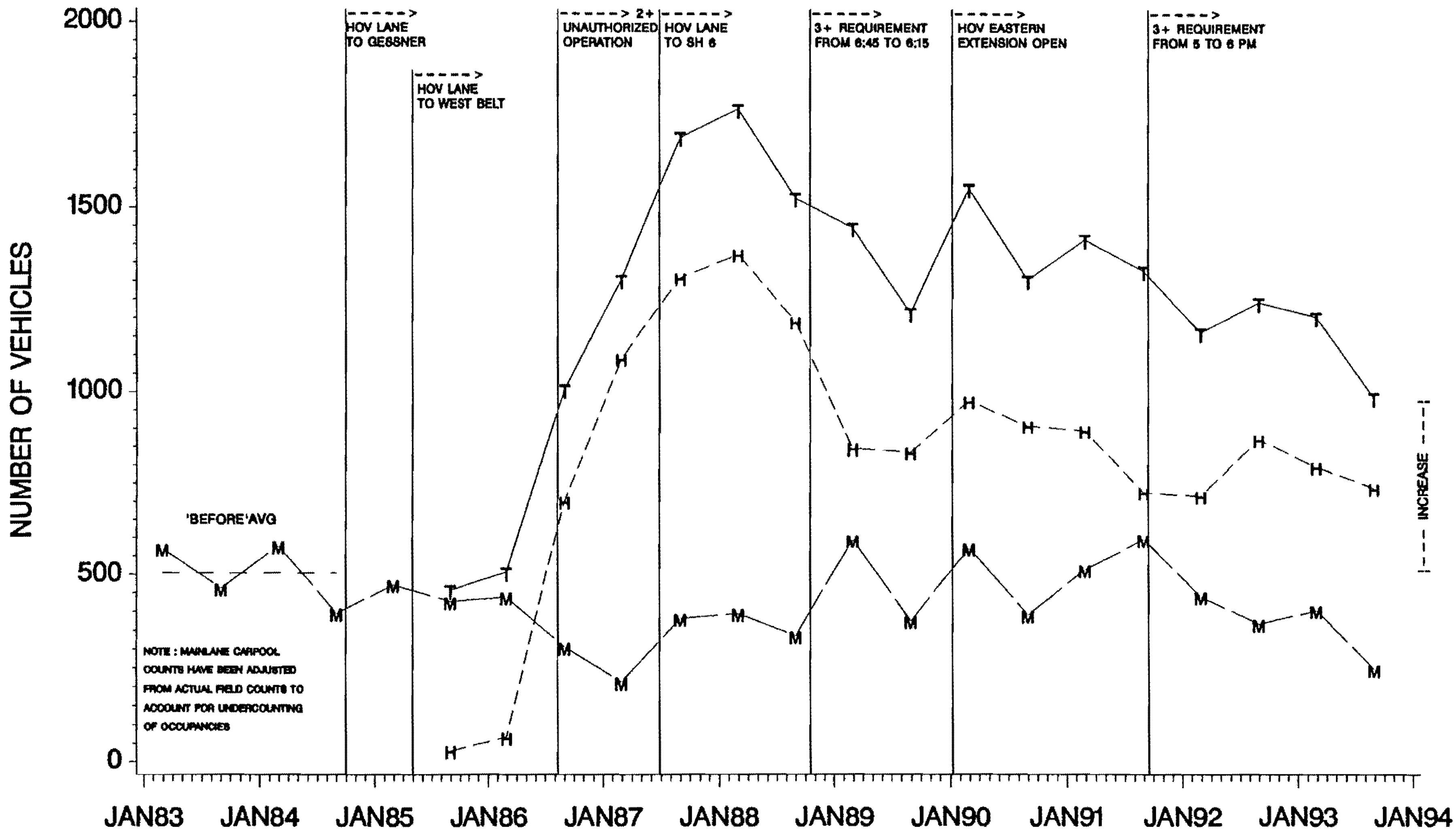


DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF GULF FWY (6/83 – 4/86), SOUTHWEST FWY (9/86 – 12/92) AND EASTEX FWY (1/93 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : K = KATY FREEWAY AT BUNKER HILL (WITH HOV LANE)
N = FREEWAYS WITHOUT HOV LANE

FIGURE A-14

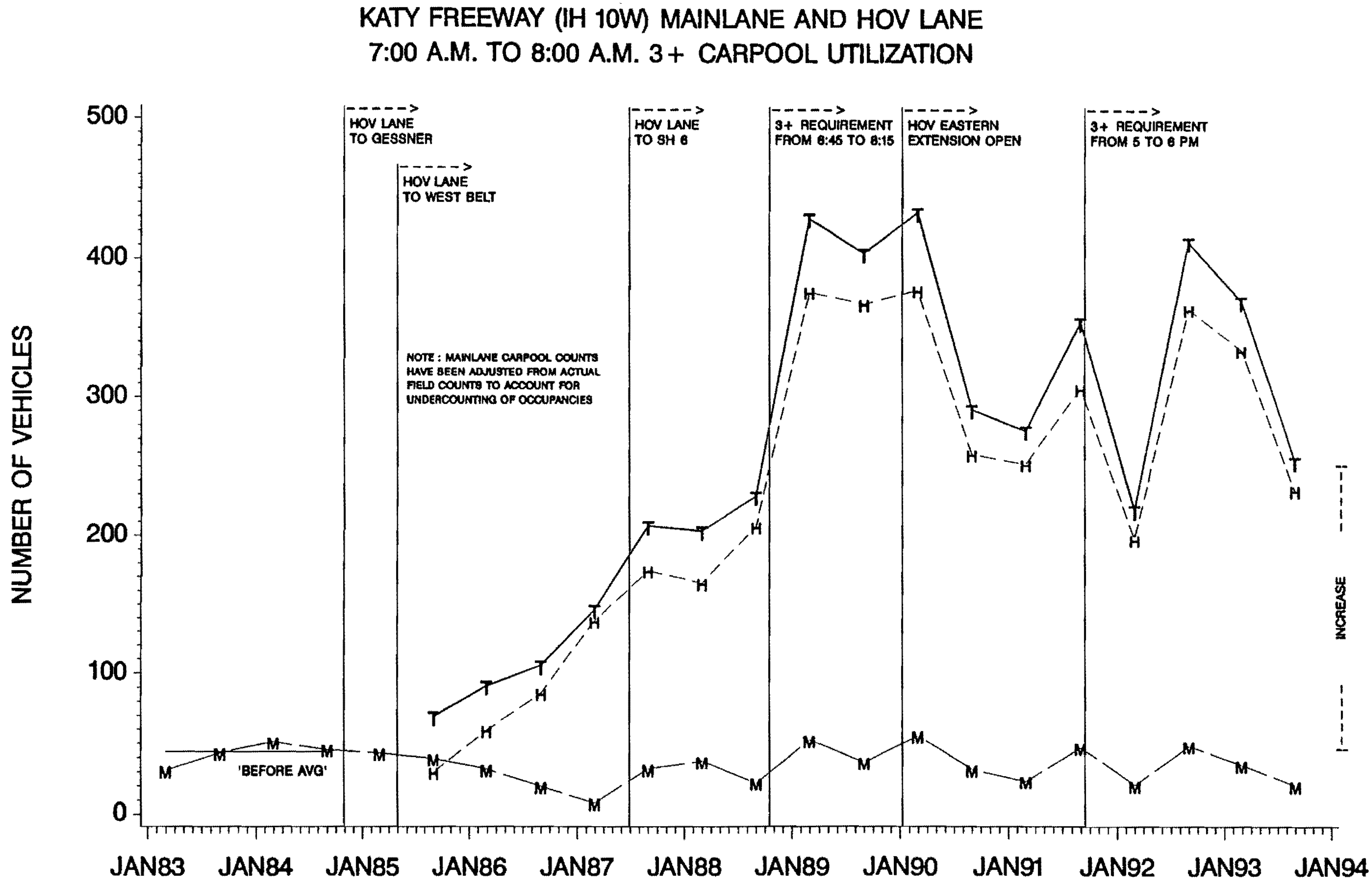
KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK HOUR 2+ CARPOOL UTILIZATION



KATY HOV LANE PHASE 1, POST OAK TO GESSNER (7.57 KM (4.7 MI)) OPENED OCTOBER 29,1984
HOV LANE EXTENSION FROM GESSNER TO WEST BELT (2.74 KM (1.7 MI)) OPENED MAY 2, 1985
OFF-PEAK, UNAUTHORIZED & 2+ CARPOOL OPERATION BEGAN AUGUST 11, 1986
HOV LANE EXTENSION FROM WEST BELT TO SH 6 (8.05 KM (5.0 MI)) OPENED JUNE 29, 1987
3+ CARPOOL REQUIREMENT FROM 6:45 TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
HOV LANE EASTERN EXTENSION (1.88 KM (1.17 MI)) OPENED JANUARY 9, 1990
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL 2+ CARPOOLS
H = TOTAL HOV LANE 2+ CARPOOLS
M = TOTAL MAINLANE 2+ CARPOOLS

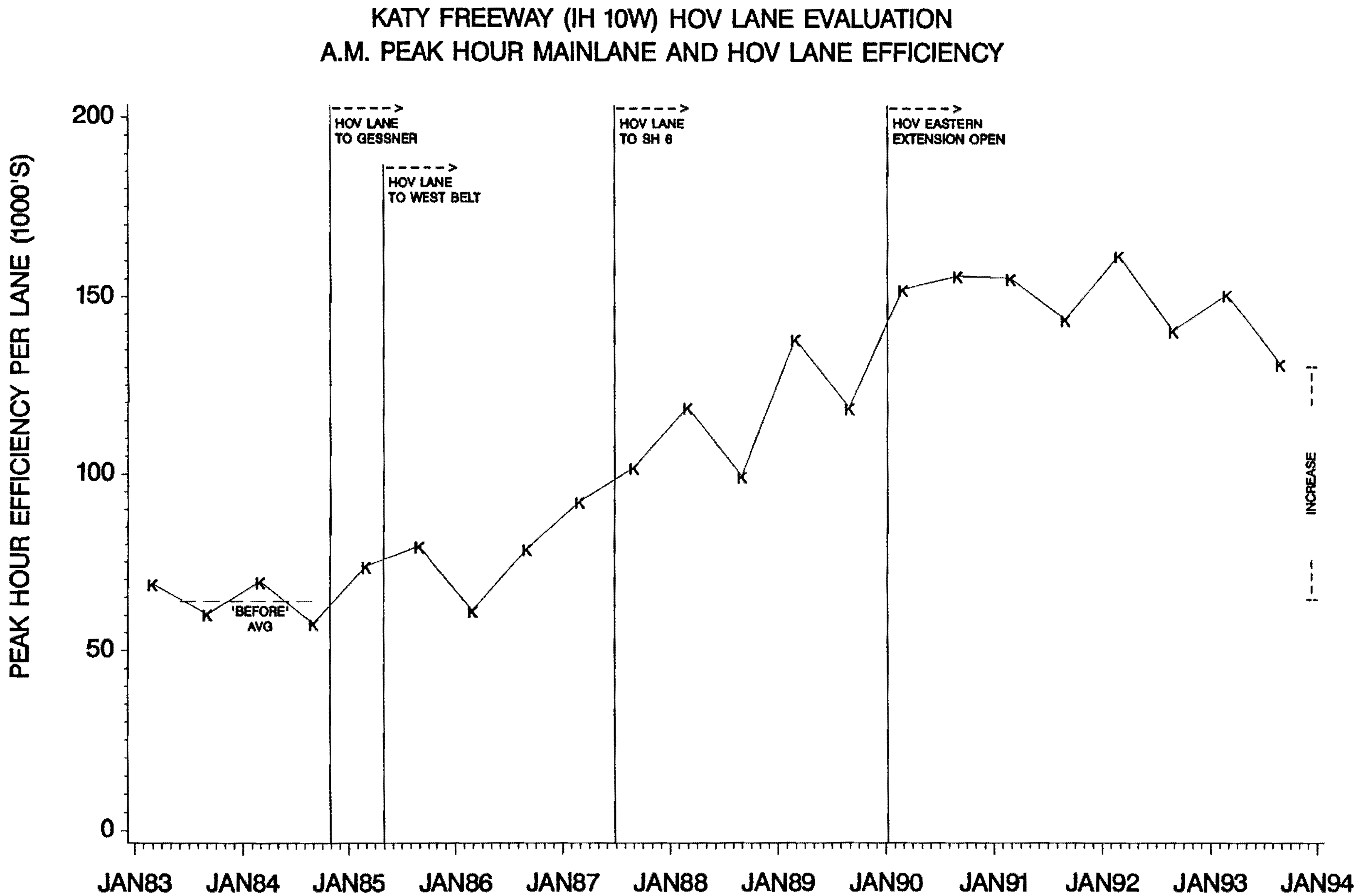
FIGURE A-15



KATY HOV LANE PHASE 1, POST OAK TO GESSNER (7.57 KM (4.7 MI)), OPENED OCTOBER 29, 1984
HOV LANE EXTENSION FROM GESSNER TO WEST BELT (2.74 KM (1.7 MI)) OPENED MAY2, 1985
OFF-PEAK, UNAUTHORIZED & 2+ CARPOOL OPERATION BEGAN AUGUST 11, 1986
HOV LANE EXTENSION FROM WEST BELT TO SH 6 (8.05 KM (5.0 MI)) OPENED JUNE 29, 1987
HOV LANE EASTERN EXTENSION (1.88 KM (1.17 MI)) OPENED JANUARY 9, 1990
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL 3+ CARPOOLS
H = TOTAL HOV LANE 3+ CARPOOLS
M = TOTAL MAINLANE 3+ CARPOOLS

FIGURE A-16

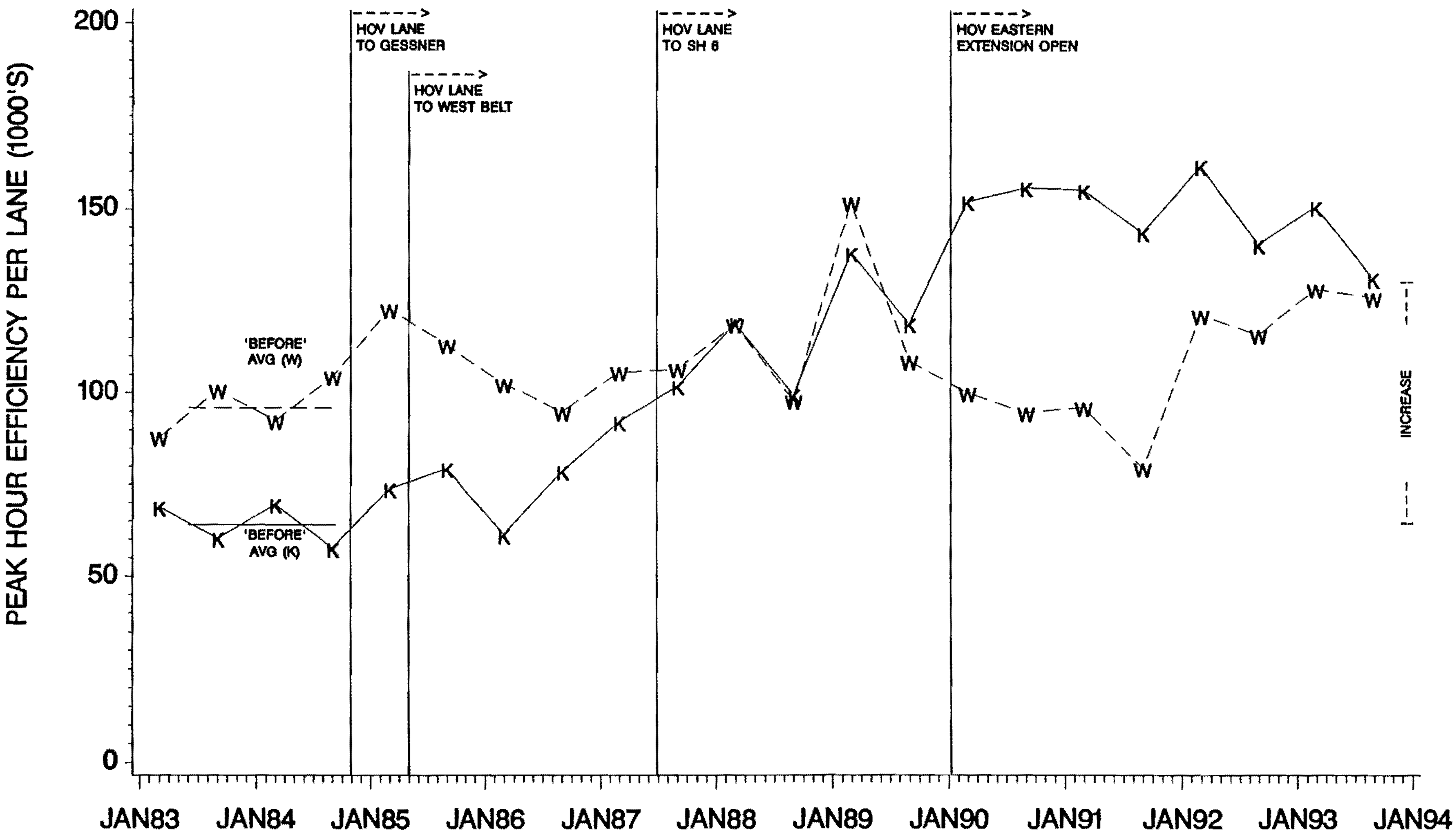


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE HOV LANE, IT REPRESENTS TOTAL PERSONS (FREEWAY + HOV LANE)
TO CONVERT EFFICIENCY FROM METRIC TO ENGLISH UNITS MULTIPLY BY 0.62
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : K = KATY FREEWAY EFFICIENCY

FIGURE A-17

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

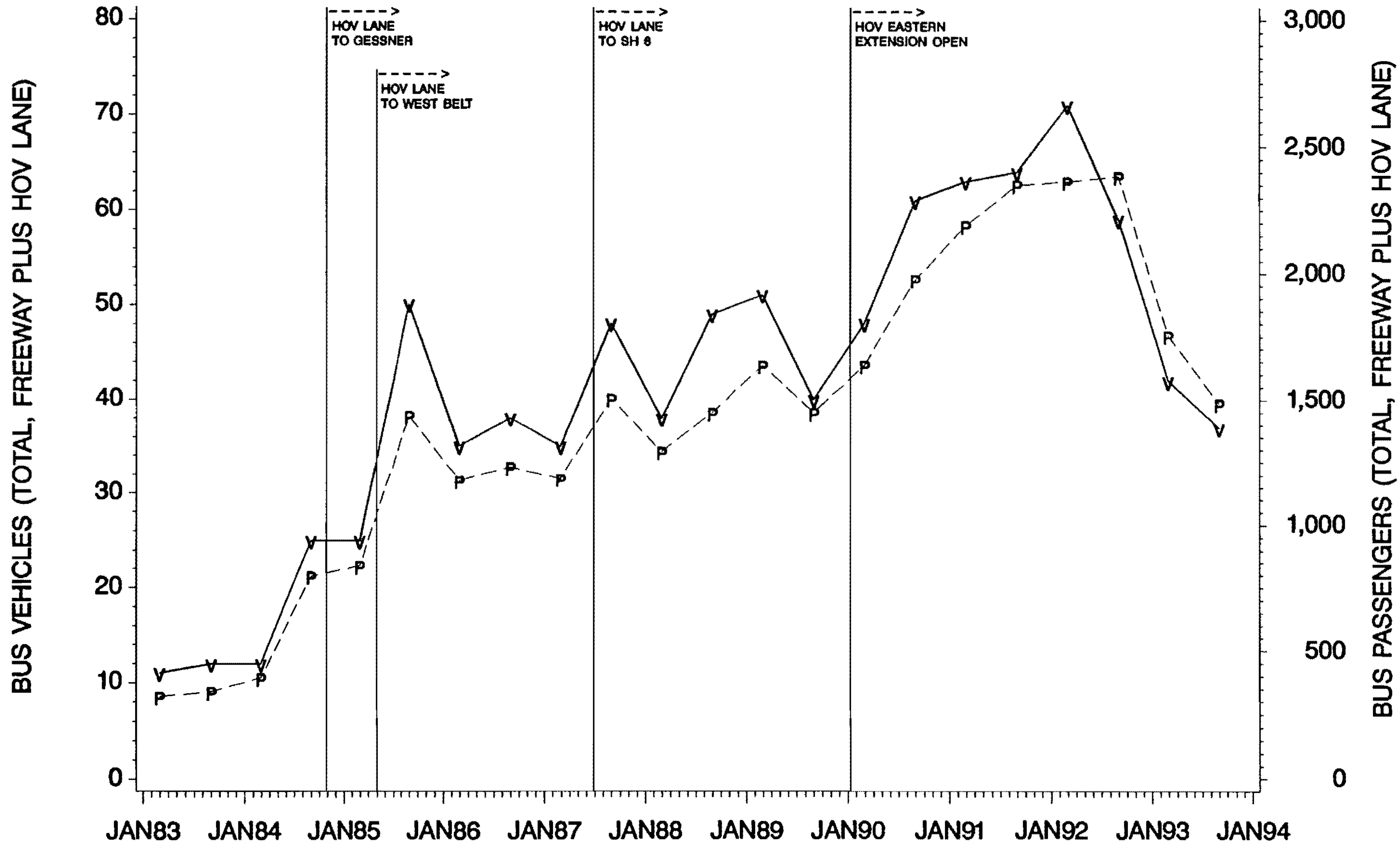


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE HOV LANE, IT REPRESENTS TOTAL PERSONS (FREEWAY + HOV LANE) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 4 LANES
DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF
GULF FWY (6/83 – 4/88), SOUTHWEST FWY (6/86 – 12/92) AND EASTEX FWY (1/93 – PRESENT) DATA
TO CONVERT EFFICIENCIES FROM METRIC TO ENGLISH UNITS MULTIPLY BY 0.62
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : K = KATY FREEWAY EFFICIENCY
W = FREEWAYS WITHOUT HOV LANE

FIGURE A-18

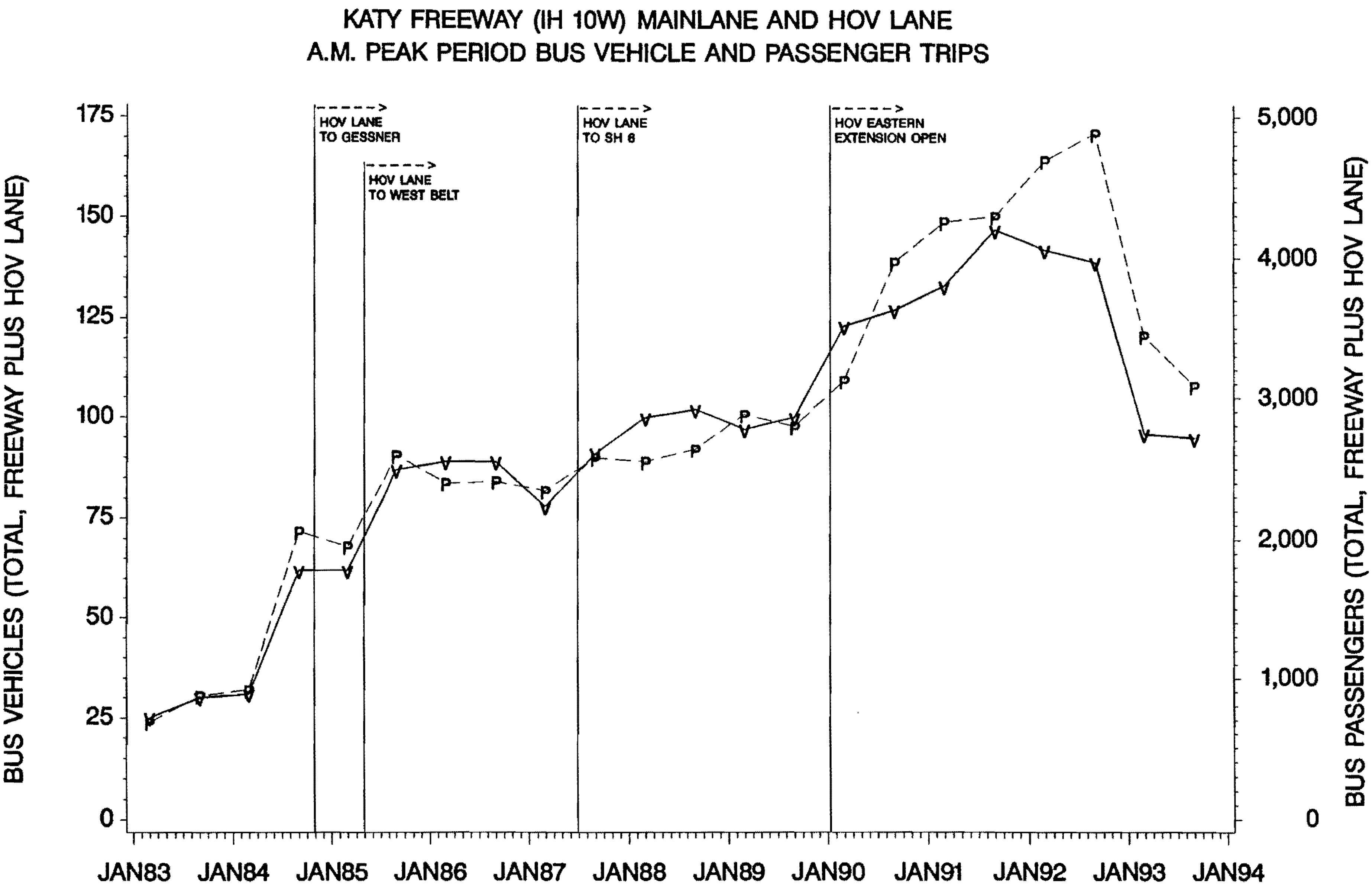
KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS



DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : V – BUS VEHICLE VOLUME
P – BUS PASSENGER VOLUME

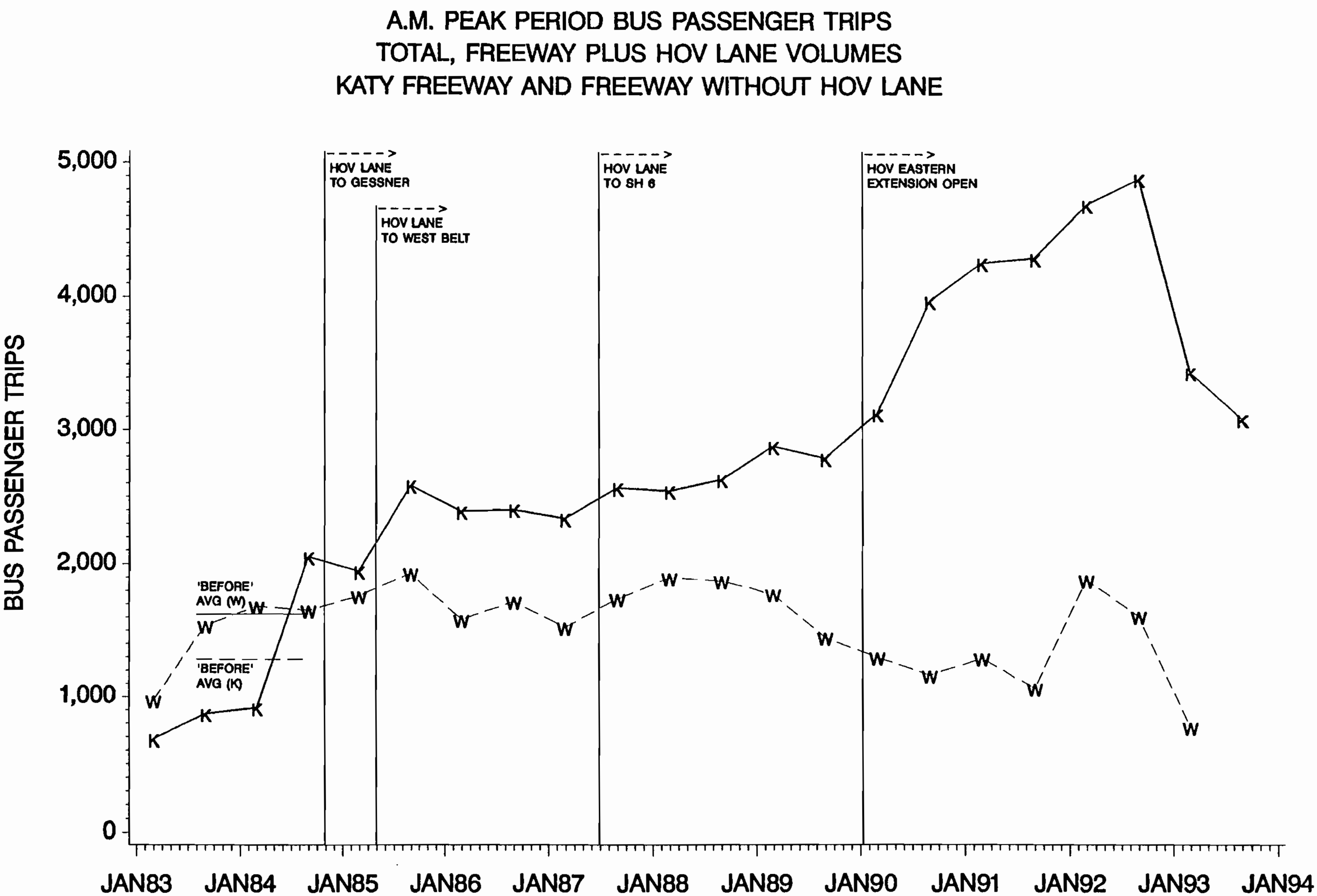
FIGURE A-19



A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : V – BUS VEHICLE VOLUME
P – BUS PASSENGER VOLUME

FIGURE A-20

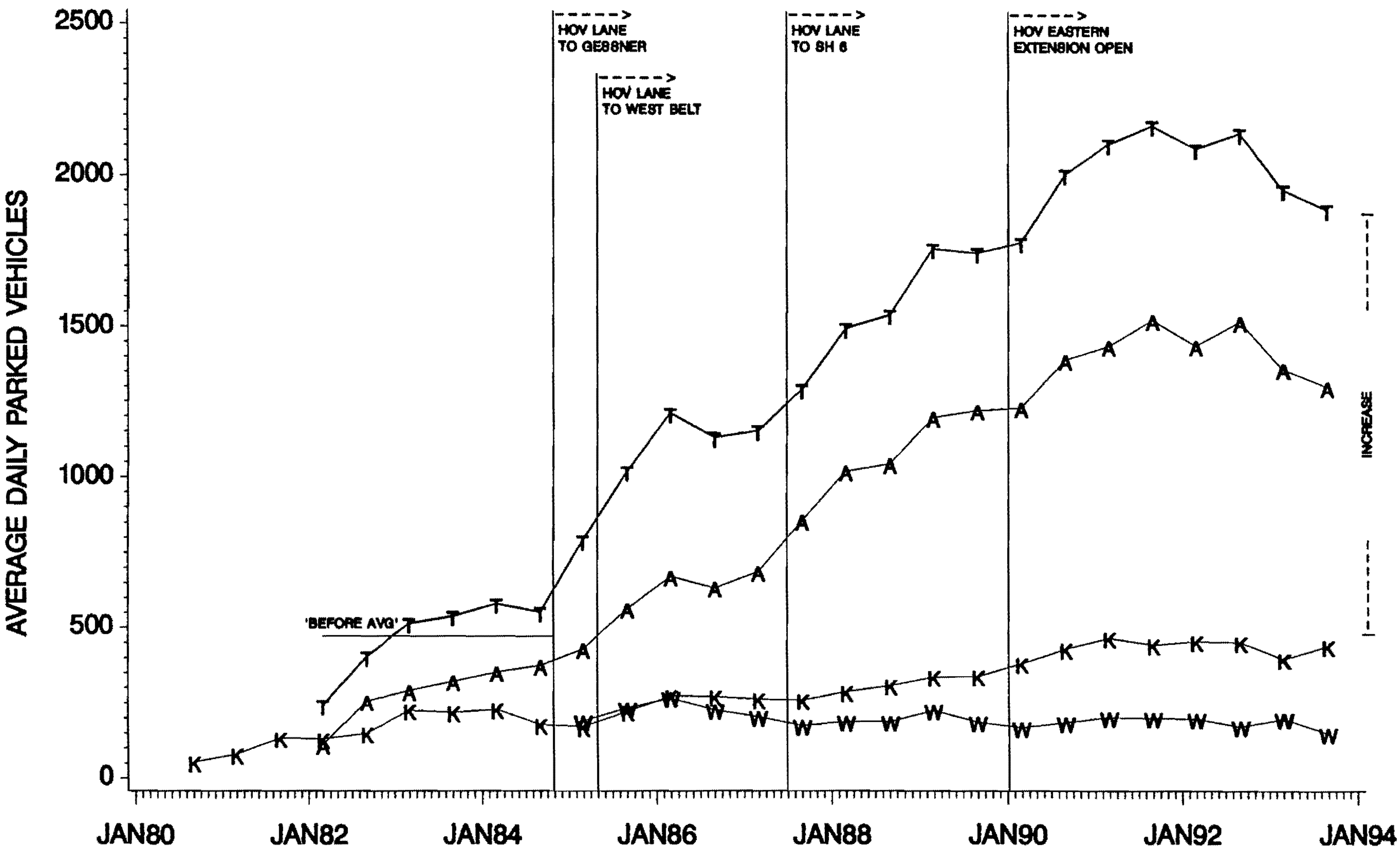


A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF GULF FWY (6/83 – 4/86), SOUTHWEST FWY (9/86 – 6/89) AND EASTEX FWY (9/89 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : K – KATY FREEWAY AT BUNKER HILL (WITH HOV LANE)
W – FREEWAYS WITHOUT HOV LANE

FIGURE A-21

KATY FREEWAY (IH 10W) CORRIDOR PARK-AND-RIDE DEMAND

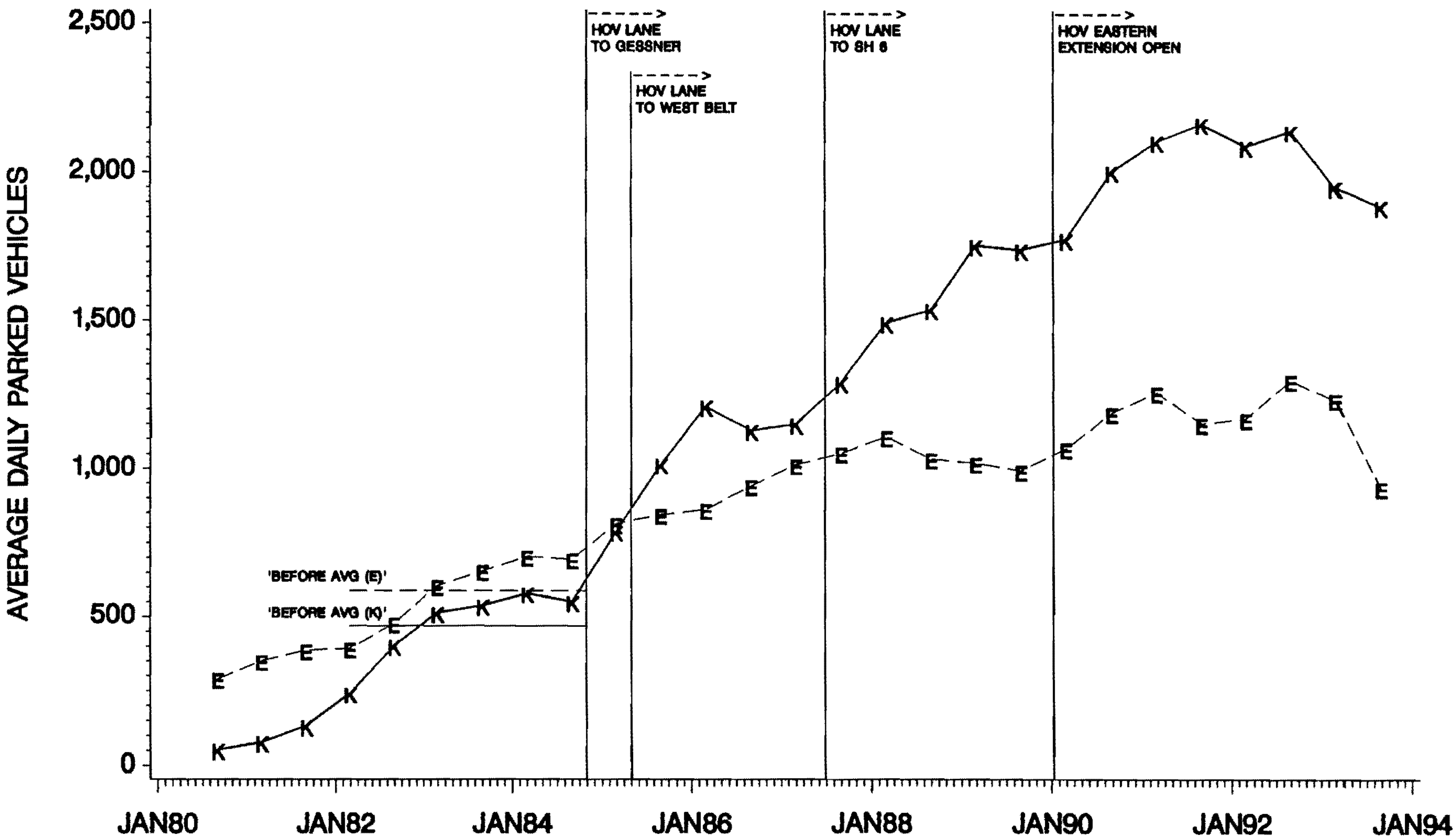


KATY HOV LANE PHASE 1, POST OAK TO GESSNER (7.57 KM [4.7 MI]), OPENED OCTOBER 29, 1984
HOV LANE EXTENSION FROM GESSNER TO WEST BELT (2.74 KM [1.7 MI]) OPENED MAY 2, 1985
HOV LANE EXTENSION FROM WEST BELT TO SH 6 (8.05 KM [5.0 MI]) OPENED JUNE 29, 1987
HOV LANE EASTERN EXTENSION (1.88 KM [1.17 MI]) OPENED JANUARY 9, 1990
CURRENT TOTAL CORRIDOR PARKING CAPACITY = 4,082 SPACES
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL PARKED VEHICLES
K = KINGSLAND LOT (1,306 SPACES)
W = WEST BELT LOT (1,175 SPACES)
A = ADDICKS LOT (1,601 SPACES)

FIGURE A-22

AVERAGE DAILY VEHICLES PARKED AT PARK–AND–RIDE LOTS KATY FREEWAY AND FREEWAY WITHOUT HOV LANE



KATY HOV LANE PHASE 1, POST OAK TO GESSNER (7.57 KM [4.7 MI]), OPENED OCTOBER 29, 1984
HOV LANE EXTENSION FROM GESSNER TO WEST BELT (2.74 KM [1.7 MI]) OPENED MAY 2, 1985
HOV LANE EXTENSION FROM WEST BELT TO SH 6 (8.05 KM [5.0 MI]) OPENED JUNE 29, 1987
HOV LANE EASTERN EXTENSION (1.88 KM [1.17 MI]) OPENED JANUARY 9, 1990
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : K – KATY FREEWAY
E – FREEWAY WITHOUT HOV LANE (EASTEX)

APPENDIX B

NORTH FREEWAY AND HOV LANE DATA

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

Table B-1. Summary of A.M. Peak-Direction North Freeway and HOV Lane Data, December 1993

Type of Data Phase 1 of HOV Lane Became Operational 11/23/84 Contraflow Lane Became Operational 8/79	"Representative" Pre-Contraflow Value[1]	"Representative" Current Value	Percent Change
HOV Lane Data			
HOV Lane Length (kilometers [miles])		21.7 (13.5)	
HOV Lane Cost (millions)		$78.6	
Person-Movement			
Peak Hour (7-8 a.m.)	—	5,546	—
Peak Period (6-9:30 a.m.)	—	10,485	—
Total Daily	—	21,645	—
Vehicle Volumes			
Peak Hour	—	1,275	—
Peak Period	—	2,338	—
Vehicle Occupancy, Peak Hour (persons/veh)	—	4.35	—
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM]),4/84-12/93[2]	—	26.3 (42.3)	—
Vehicle Breakdowns (VKT/Breakdown [VMT/Breakdown]), 4/84-12/93	—	83,559 (51,900)	—
Violation Rate (6-9:30 a.m.)		4.5%	
Peak Hour Lane Efficiency (1000's)[3]	—	466 (290)	—
Annual Value of User Time Saved (millions)[4]	—	$2.7 to $5.4	—
Freeway Mainlane Data (see note)			
Person Movement			
Peak Hour	6,335	7,942	+25%
Peak Period (6-9:30 a.m.)	—	24,125	—
Vehicle Volume			
Peak Hour	4,950	7,813	+58%
Peak Period	—	23,074	—
Vehicle Occupancy, Peak Hour (persons/veh)	1.28	1.02	-20%
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM])[2]	18.8 (30.3)	16.4 (26.4)	-13%
Avg. Operating Speed[5] (kph [mph])			
Peak Hour	32 (20)	65 (40)	+102%
Peak Period	48 (30)	80 (47)	+57%
Peak Hour Lane Efficiency (1000's)[3]	66 (41)	129 (80)	+96%

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. The contraflow lane was replaced by a barrier separated reversible HOV lane in November 1984. Pre-contraflow data are for 1978.

[2]Due to inconsistencies in reporting accidents in Harris County, only injury accidents are included in this analysis. Accidents analyzed are between North Shepherd and Hogan, a distance of approximately 12.6 kilometers (7.8 miles). This corresponds to Phase 1 of the HOV lane. "Before" data are for the period 1/82 through 11/84. "After" accident rate shown is for the time period from 12/84 to 8/93. Only officer reported accidents are included in files. 1993 freeway volumes were estimated by TTI to compute rates.

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

[4]Based on time savings for HOV lane users in 1993, an annual estimate of travel time savings to HOV lane users is developed. A value of time of $10.78/hour is used based on the value applied in the Highway Economic Evaluation Model.

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

Table B-1. Summary of A.M. Peak-Direction North Freeway and HOV Lane Data, December 1993 (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	13,488	+113%
Peak Period	—	34,610	—
Vehicle Volume			
Peak Hour	4,950	9,088	+84%
Peak Period	—	25,412	—
Vehicle Occupancy			
Peak Hour	1.28	1.48	+16%
Peak Period	1.28	1.36	+6%
2+ Carpool Volumes			
Peak Hour	700	1,683	+140%
Travel Time (minutes)[2]			
Peak Hour	23.2[3]	9.2[4]	-60%
Peak Period	15.5[3]	8.8[4]	-43%
Peak Hour Lane Efficiency (1000's)[5]	66 (41)	197 (122)	+198%
Transit Data[6]			
Bus Vehicle Trips			
Peak Hour	—	66	—
Peak-Period	—	133	—
Bus Passenger Trips			
Peak Hour	—	2,793	—
Peak Period	—	5,473	—
Bus Occupancy (persons/bus)			
Peak Hour	—	42.3	—
Peak Period	—	41.2	—
Vehicles Parked in Corridor Park & Ride Lots	—	3,730	—
Bus Operating Speed[2] (kph [mph])			
Peak Hour	—	84 (51)	—
Peak Period	—	87 (54)	—

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. The contraflow lane was replaced by a barrier separated reversible HOV lane in November 1984. Pre-contraflow data are for 1978.
[2]The distance from North Shepherd to Hogan is 12.6 kilometers (7.8 miles).
[3]Data pertain to operation in the freeway mainlanes.
[4]Data pertain to operation in the HOV lane.
[5]This represents the multiple of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.
[6]Prior to opening the contraflow lane in 1979, virtually no transit service was provided in this freeway corridor.

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

Measure of Effectiveness	North Freeway	Eastex Freeway
Average A.M. Peak-Hour Vehicle Occupancy	1.48[1]	1.21
Bus Passengers, Peak Period	5,473	775
Cars Parked at Park-and-Ride Lots	3,730	942
Facility Per Lane Efficiency[2]	197 (122)	126 (78)

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

HOV LANE DATA

DESCRIPTION

- The contraflow lane operation began 8/28/79.
- Phase 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 total cost for the completed HOV lane (1990 dollars) was $142.1 million. A more detailed cost breakdown is provided on the following two pages.
- Selected milestone dates are listed below. Other dates are shown in the capital cost tables.
  - 8/29/79 Contraflow lane operations begin (14.7 kilometers [9.1 miles])
  - 3/31/81 A.M. concurrent flow lane to West Road opens (20.8 kilometers [12.9 miles])
  - 11/23/84 HOV Lane replaces contraflow
  - 4/2/90 HOV Lane extended to Beltway 8 (21.7 kilometers [13.5 miles])
  - 6/26/90 Carpools allowed on HOV
  - 6/30/90 Weekend operations begin
  - 10/5/91 Weekend operations end
  - 9/8/92 Motorcycles allowed on HOV facility (no occupancy restrictions)

PERSON MOVEMENT

- In December 1993, 21,645 person trips per day were served on the HOV lane.
- A.M. Peak Hour, 5,546 persons/hour.
  - 2,793 (50%) by bus, 272 (5%) by vanpool, and 2,481 (45%) by carpool, (Figure B-1).
  - Average HOV lane vehicle occupancy = 4.35 persons/vehicle.
- A.M. Peak Period, 10,485 persons.
  - 5,473 (52%) by bus, 601 (6%) by vanpool, and 4,411 (42%) by carpool (Figure B-2).

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

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1990 Dollars
HOV Lane and Ramps			
Design, Phases 1 and 2 (1984)	$4.1	0.93	$3.8
Phase 1 Construction (1984)	13.1	0.93	12.2
Phase 2 Construction (1987)	11.1	0.85	9.4
Phase 3 Construction (1990) Incl. Aldine-Bender Interchange	14.7	1.00	14.7
North Shepherd Interchange (1990)	2.1	1.00	2.1
Downtown Terminus (1990)	7.2	1.00	7.2
Miscellaneous (all phases), (1988)	5.5	0.98	5.4
SUB-TOTAL	$57.8		$54.8
Per Kilometer (Mile)	$2.6 ($4.3)		$2.5 ($4.1)
Surveillance, Communication and Control (1990)	$2.6	1.00	$2.6
SUB-TOTAL	$2.6		$2.6
Per Kilometer (Mile)	$0.1 ($0.2)		$0.1 ($0.2)
Support Facilities			
North Shepherd P/R (1980)	$2.2	1.07	$2.4
North Shepherd P/R Expansion (1982)	2.1	1.03	$2.2
Kuykendahl P/R (1980)	1.7	1.07	1.8
Kuykendahl P/R Expansion (1983)	1.8	1.01	1.8
Spring P/R (1982)	3.7	1.03	3.8
Seton Lake P/R (1983)	3.3	1.01	3.3
Woodlands P/R (1985)	2.6	0.92	2.4
Woodlands P/R Expansion (1991)	0.8	1.00	0.8
SUB-TOTAL	$18.2		$18.5
Per Kilometer (Mile)	$0.8 ($1.3)		$0.9 ($1.4)
TOTAL COST	$78.6		$75.9
COST PER KILOMETER (21.7 kilometers [13.5 miles])	$3.6 ($5.8)		$3.5 ($5.6)

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	Year of Construction Cost	Factor	Estimated Cost 1990 Dollars
HOV Lane and Ramps			
Beltway 8 to Airtex	$14.2	1.00	$14.2
Airtex to FM 1960	10.5	1.00	10.5
Kuykendahl Interchange	10.7	1.00	10.7
FM 1960 Interchange	13.8	1.00	13.8
SUB-TOTAL	$49.2		$49.2
Per Kilometer (Mile)	$4.9 ($7.9)		$7.9
Surveillance, Communication and Control	$1.5	1.00	$1.5
Support Facilities			
Kuykendahl P/R Expansion	$7.4	1.00	$7.4
SUB-TOTAL	$7.4		$ 7.4
Per Kilometer (Mile)	$0.7 ($1.2)		$0.7 ($1.2)
TOTAL COST	$58.1		$58.1
COST PER KILOMETER (10.0 kilometers [6.2 miles])	$5.8 ($9.4)		$5.8 ($9.4)

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

VEHICLE MOVEMENT

- A.M. Peak Hour, 1,275 vph
  - 66 (5%) buses, 34 (3%) vans, and 1,175 (92%) carpools (Figure B-3).
- A.M. Peak Period, 2,338 vehicles.
  - 133 (6%) buses, 80 (3%) vans, and 2,125 (91%) carpools (Figure B-4).

ACCIDENT RATE

- For the period from November 1984 through December 1993, the HOV lane accident rate was 26.3 injury accidents per 100 million vehicle kilometers (42.3 injury accidents per 100 million vehicle miles).

VEHICLE BREAKDOWN RATES

- The following vehicle breakdown rates were observed between December, 1984 and December 1993.
  - Overall weighted average; 1 breakdown per 83,559 VKT (51,900 VMT).

VIOLATION RATE

- The observed violation rate (vehicles on the HOV lane not eligible to use the HOV lane) for December 1993 was approximately 4.5%.

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 466 (5,546 passengers at 84 kph), or 290 (5,546 passengers at 52 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane experienced a travel time savings of 4 minutes during the morning peak hour in 1993 (Figure B-5).
- The tables on the following page indicate that, on a typical non-incident day, travel time savings of approximately 1,010 hours (60,597 min.) are realized. Assuming 250 days of operation, annual savings would be 252,488 hours. At $10.78/hour, this equates to $2.72 million per year. This is extremely conservative since it does not consider travel time savings due to incidents on the freeway. Data from Houston suggest increasing this value by 100% to account for incidents would be reasonable. Thus, travel time savings to HOV lane users are estimated to be in the range of $2.72 to $5.44 million per year.

Table B-5. Southbound A.M. Travel Time Savings for North HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1993)

Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section from Sam Houston Parkway to N. Shepherd								
6:00	4.59	4.85	-0.26	301	101	419	821	-213
6:30	5.16	4.90	0.26	712	119	717	1,547	404
7:00	5.34	4.91	0.43	1,119	131	831	2,080	896
7:30	5.41	4.77	0.64	868	43	949	1,862	1,184
8:00	4.64	4.72	-0.08	449	8	487	944	-73
8:30	4.65	4.54	0.11	182	9	126	317	34
9:00	4.62	4.64	-0.02	73	1	20	93	-2
Peak Period Total				3,703	413	3,548	7,664	2,230
Section From N. Shepherd to the Hogan Overpass								
6:00	8.04	9.02	-0.98	289	120	481	890	-874
6:30	9.39	8.36	1.03	765	135	927	1,826	1,875
7:00	12.13	9.07	3.06	1,356	110	1,202	2,668	8,157
7:30	13.19	9.33	3.86	1,256	42	1,337	2,635	10,175
8:00	13.06	8.81	4.25	606	21	549	1,176	4,995
8:30	10.61	8.22	2.39	230	7	217	454	1,086
9:00	7.96	8.41	-0.45	81	5	30	116	-52
Peak Period Total				4,583	441	4,743	9,766	25,362
Northbound P.M. Travel Time Savings for North HOV Lane								
Section from Sam Houston Parkway to N. Shepherd								
3:30	4.57	5.00	-0.43	98	37	88	223	-95
4:00	4.99	4.64	0.35	417	119	314	849	298
4:30	4.83	5.72	-0.89	681	79	318	1,077	-960
5:00	5.50	5.54	-0.04	568	142	780	1,490	-62
5:30	9.77	5.73	4.04	703	113	898	1,713	6,927
6:00	8.69	5.42	3.27	431	24	582	1,037	3,391
6:30	5.92	4.98	0.94	198	16	228	442	417
Peak Period Total				3,096	529	3,207	6,831	9,916

Table B-5. Southbound A.M. Travel Time Savings for North HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1993) (continued)

Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section from N. Shepherd to the Hogan Overpass								
3:30	8.92	8.66	0.26	243	51	240	534	139
4:00	8.99	8.25	0.74	367	157	508	1,032	763
4:30	10.64	9.13	1.51	581	102	934	1,616	2,437
5:00	10.93	8.75	2.18	832	156	1,295	2,283	4,977
5:30	12.61	8.99	3.62	1,084	100	1,597	2,780	10,064
6:00	11.34	8.54	2.80	569	29	952	1,550	4,337
6:30	9.41	8.84	0.57	320	6	358	685	390
Peak Period Total				3,995	600	5,884	10,479	23,107

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 actual freeway operations. The cross section at the count location has been expanded from 3 to 4 lanes per direction; the southbound expansion was completed in June 1987 and the northbound expansion in 1988.

PERSON MOVEMENT

- In the a.m. peak hour, person movement has been increasing and is currently at 7,942 persons in the peak hour (Figure B-6). Prior to contraflow implementation, limited data suggest this value was 6,335.
- A.M. peak period mainlane person trips are shown in Figure B-7.

VEHICLE VOLUME

- In the a.m. peak hour, an average of 7,813 vehicles used the mainlanes during 1993 (Figure B-6). Prior to contraflow implementation, limited data suggest this value was 4,950.
- In the a.m. peak period, an average of 23,074 vehicles used the mainlanes (Figure B-7).

VEHICLE OCCUPANCY

- 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 1.08 (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 8/93, (since the barrier-separated HOV lane opened) the accident rate has been 16.4 injury accidents/100 MVK (26.4 injury accidents/100 MVM). Only officer reported accidents are included. 1993 freeway volumes estimated by TTI were used to obtain these rates.

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 129 (1,986 passengers per lane at 65 kph) or 80 (1,986 passengers per lane at 40 mph).

COMBINED FREEWAY AND HOV LANE DATA

TOTAL PERSON MOVEMENT

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

  - At Little York, the HOV lane is carrying 41% of the total peak-hour person movement (Figure B-11). In the peak period, the HOV lane carries 30% of the a.m. peak period person trips (Figure B-12). Compared to pre-contraflow conditions, peak-hour person movement has increased by 113%.

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.48 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 197 (persons x kph) or 122 (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 remained relatively consistent over the past five years -- with about 2,800 passengers per peak hour (Figure B-16) and about 5,500 passengers per peak period (Figure B-17). Likewise, the bus vehicle trips for the peak period have also remained consistent at approximately 150 bus trips per peak period (Figure B-17).

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

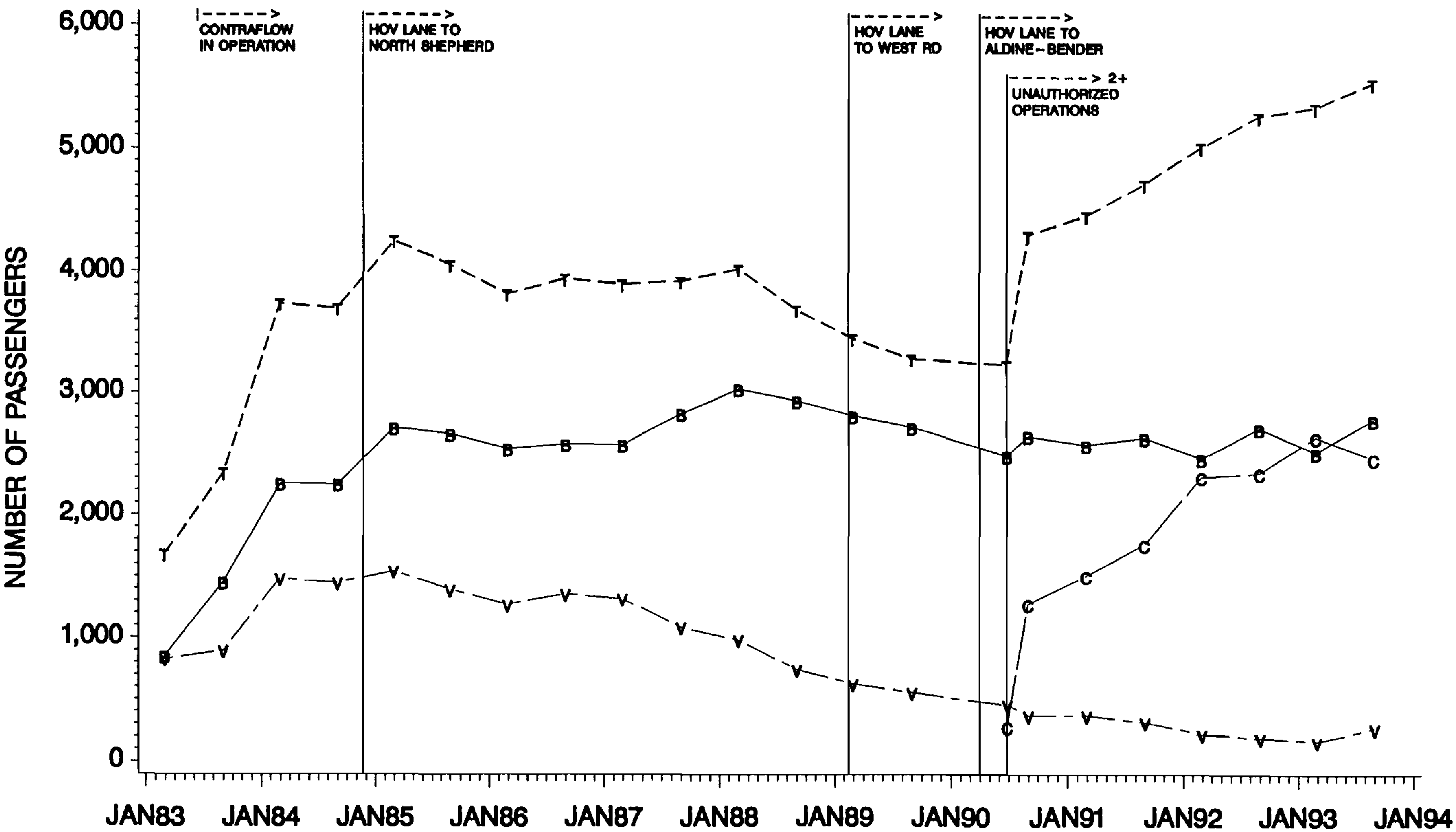
PARK-AND-RIDE

- Currently, 3,730 vehicles are parked in the corridor park-and-ride lots. Approximately 51% of the 7,386 parking spaces are utilized (Figure B-19).

- The Eastex Freeway corridor (which does not have a HOV lane) has 75% less park-and-ride patrons than the North Freeway corridor. Eastex Freeway park-and-ride lots are operating at only 25% capacity as opposed to 51% on North Freeway (Figure B-20).

FIGURE B-1

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

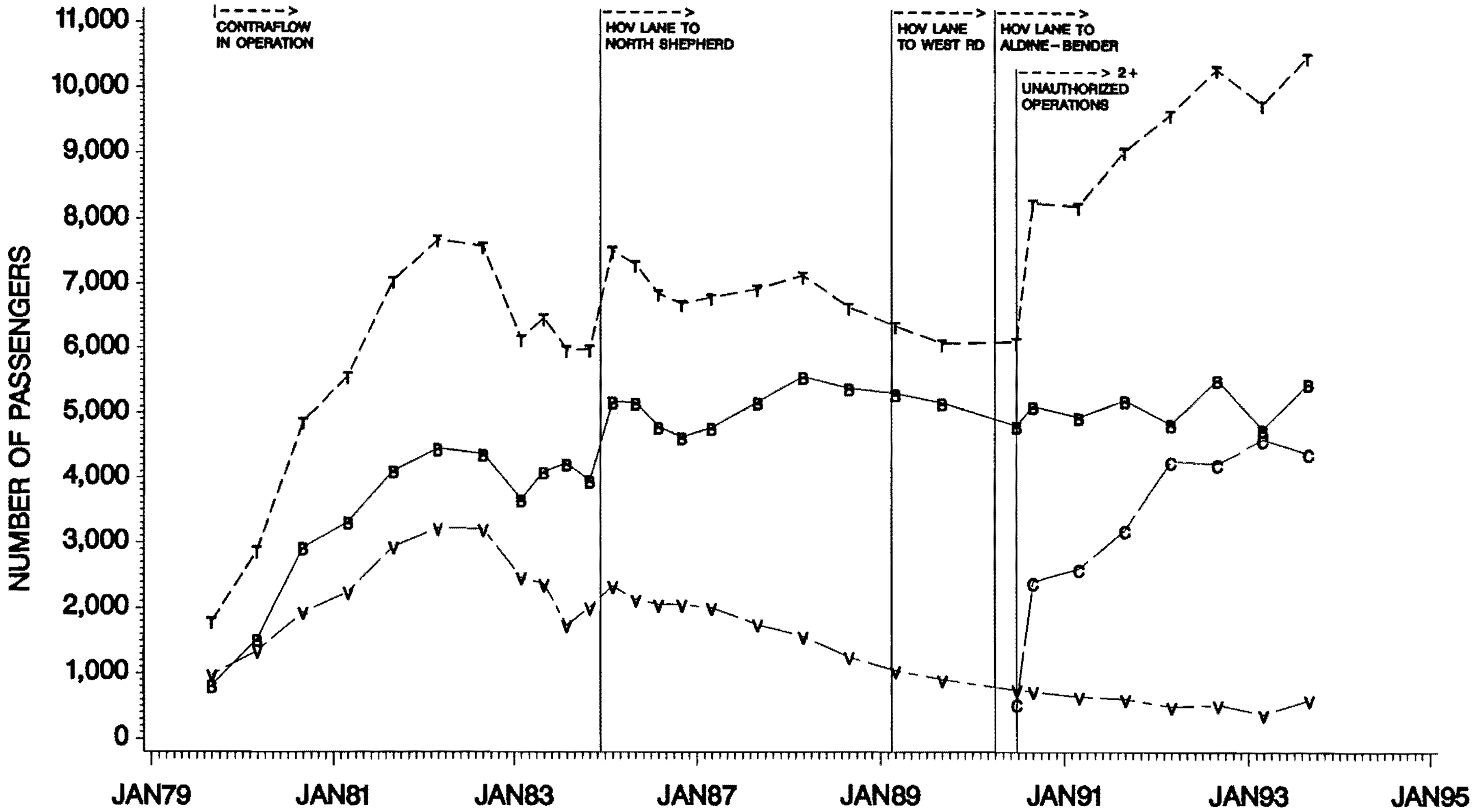


CONTRAFLOW OPERATION, CBD TO N SHEPHERD (14.65 KM [9.1 MI]), BEGAN AUGUST 28, 1979
HOV LANE OPERATION, CBD TO N SHEPHERD (14.65 KM [9.1 MI]), BEGAN NOVEMBER 23, 1984
HOV LANE EXTENSION, N SHEPHERD TO ALDINE-BENDER (6.91 KM [4.29 MI]), OPENED APRIL 2, 1990
2+ CARPOOL AND OFF-PEAK OPERATION BEGAN JUNE 28, 1990
DATA COLLECTED SOUTHBOUND AT LITTLE YORK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL HOV PASSENGERS
B = TOTAL BUS PASSENGERS
V = TOTAL VANPOOLERS
C = TOTAL CARPOOLERS

FIGURE B-2

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

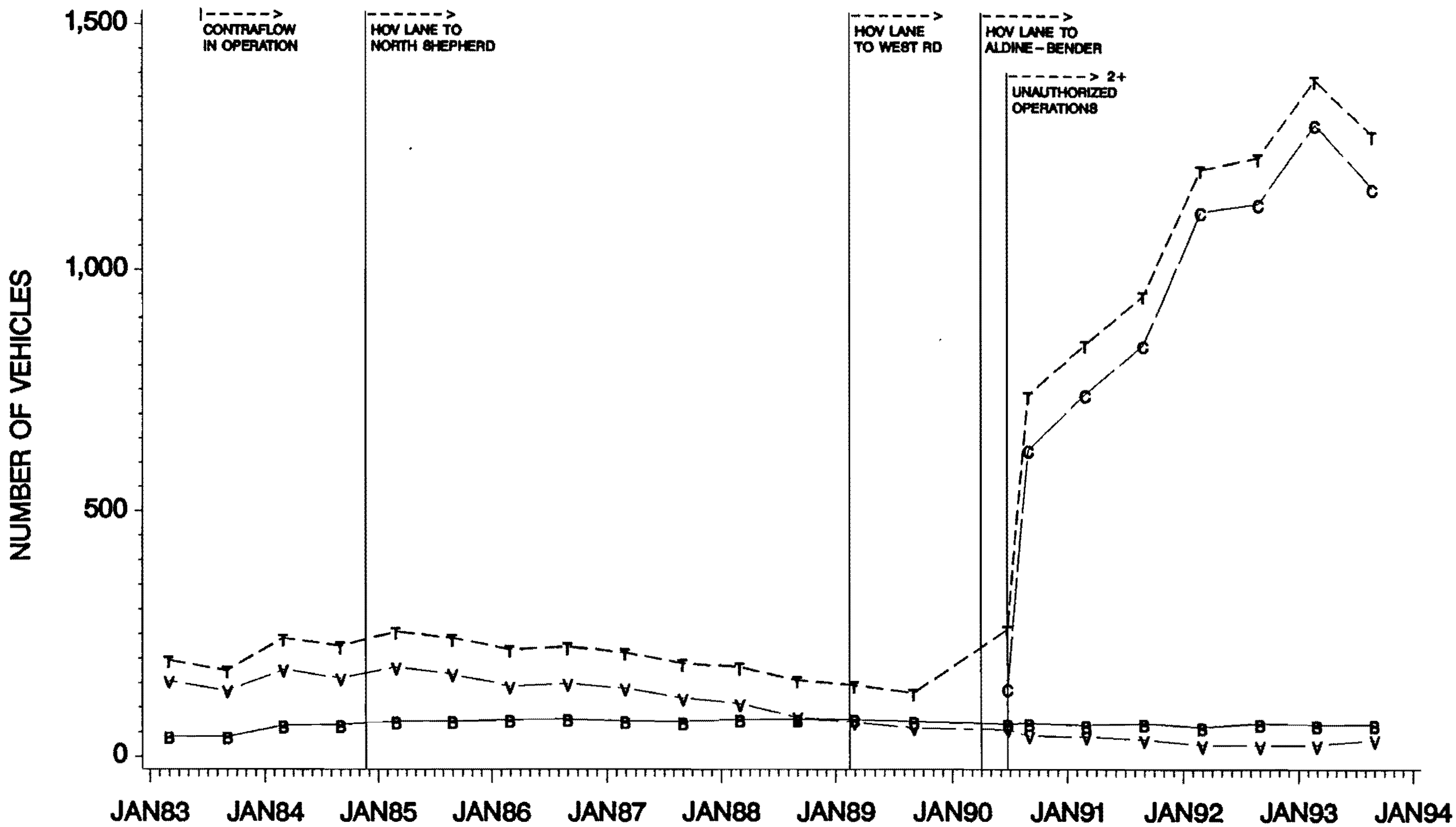


THE A.M. PEAK PERIOD IS 6:00 TO 8:45 A.M. FROM AUGUST 1979 THROUGH JUNE 1990
SINCE JUNE 1990 THE A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M
CONTRAFLOW OPERATION, CBD TO N SHEPHERD (14.65 KM [9.1 MI]), BEGAN AUGUST 28, 1979
HOV LANE OPERATION, CBD TO N SHEPHERD (14.65 KM [9.1 MI]), BEGAN NOVEMBER 23, 1984
HOV LANE EXTENSION, N SHEPHERD TO ALDINE-BENDER (6.91 KM [4.29 MI]), OPENED APRIL 2, 1990
2+ CARPOOL AND OFF-PEAK OPERATION BEGAN JUNE 28, 1990
DATA COLLECTED SOUTHBOUND AT LITTLE YORK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL HOV PASSENGERS
B = TOTAL BUS PASSENGERS
V = TOTAL VANPOOLERS
C = TOTAL CARPOOLERS

FIGURE B-3

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

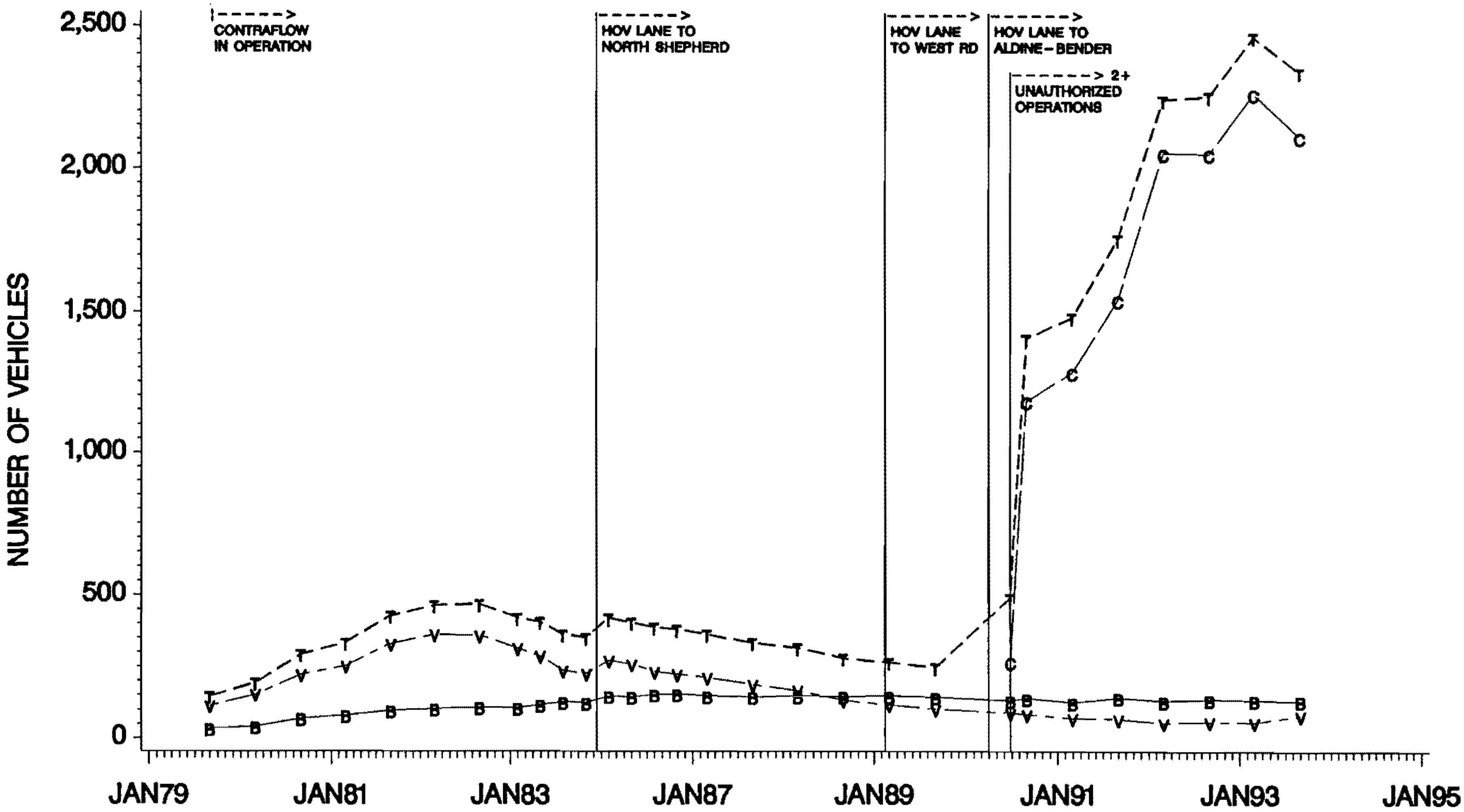


CONTRAFLOW OPERATION, CBD TO N SHEPHERD (14.66 KM [9.1 MI]), BEGAN AUGUST 26, 1979
HOV LANE OPERATION, CBD TO N SHEPHERD (14.65 KM [9.1 MI]), BEGAN NOVEMBER 23, 1984
HOV LANE EXTENSION, N SHEPHERD TO ALDINE-BENDER (6.91 KM [4.29 MI]), OPENED APRIL 2, 1990
2+ CARPOOL AND OFF-PEAK OPERATION BEGAN JUNE 26, 1990
DATA COLLECTED SOUTHBOUND AT LITTLE YORK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL HOV VEHICLES
B = TOTAL BUSES
V = TOTAL VANPOOLS
C = TOTAL CARPOOLS

FIGURE B-4

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

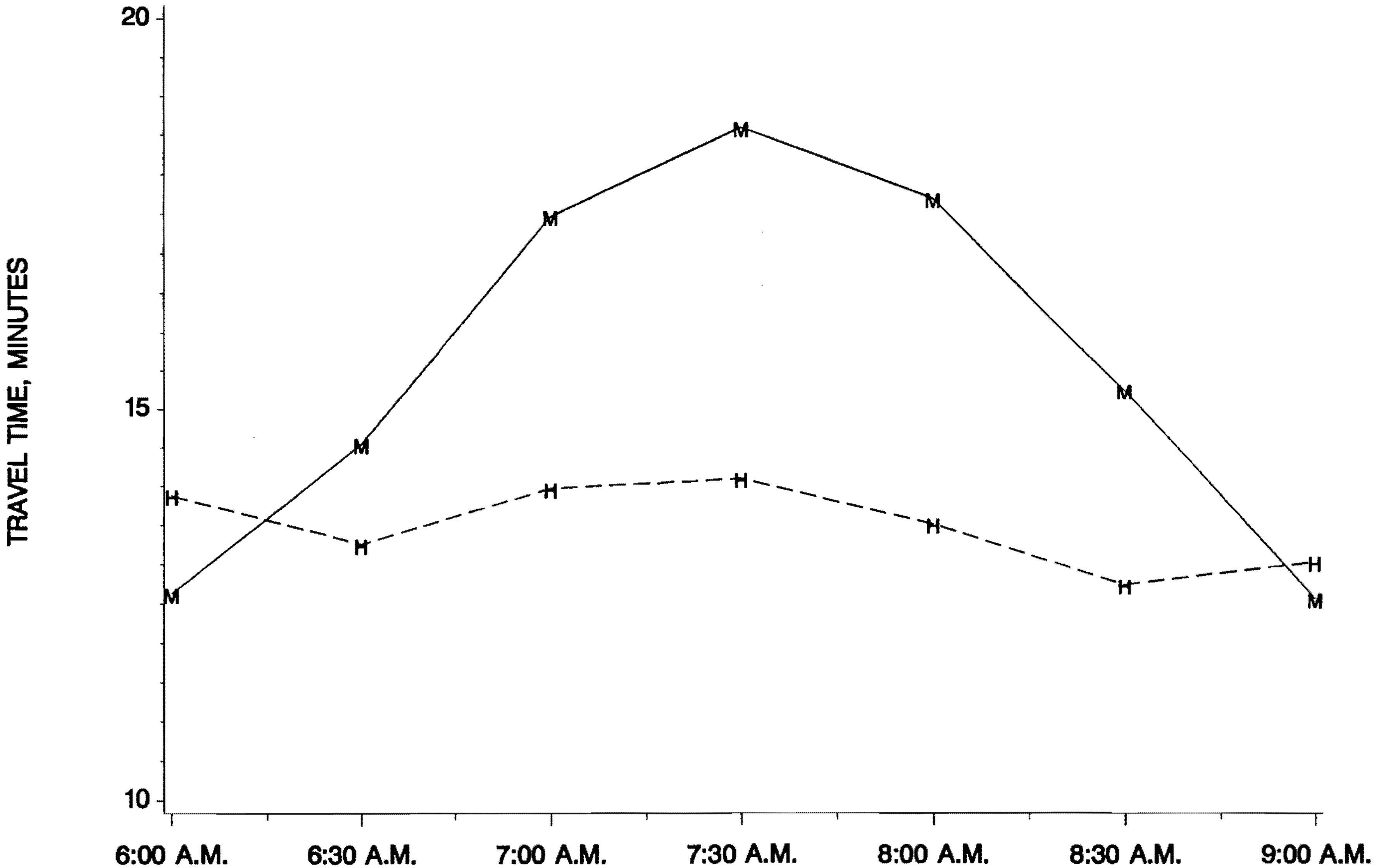


THE A.M. PEAK PERIOD IS 6:00 TO 8:45 A.M. FROM AUGUST 1979 THROUGH JUNE 1990
SINCE JUNE 1990 THE A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M
CONTRAFLOW OPERATION, CBD TO N SHEPHERD (14.65 KM [9.1 MI]), BEGAN AUGUST 28, 1979
HOV LANE OPERATION, CBD TO N SHEPHERD (14.65 KM [9.1 MI]), BEGAN NOVEMBER 23, 1984
HOV LANE EXTENSION, N SHEPHERD TO ALDINE-BENDER (6.91 KM [4.29 MI]), OPENED APRIL 2, 1990
2+ CARPOOL AND OFF-PEAK OPERATION BEGAN JUNE 26, 1990
DATA COLLECTED SOUTHBOUND AT LITTLE YORK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL HOV VEHICLES
B = TOTAL BUSES
V = TOTAL VANPOOLS
C = TOTAL CARPOOLS

FIGURE B-5

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

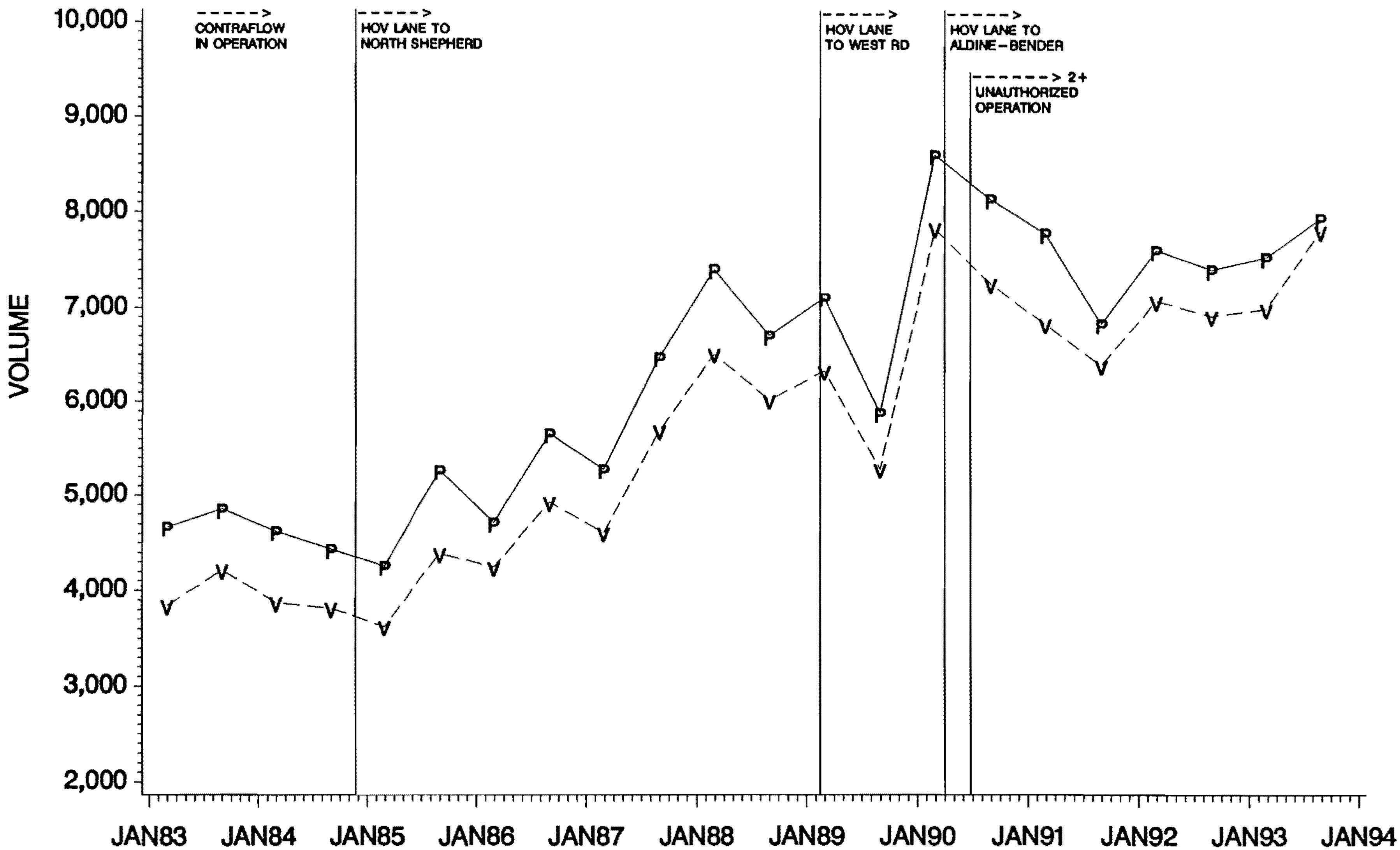


TRAVEL TIMES ARE AN AVERAGE OF 4 QUARTERLY TRAVEL TIME SURVEYS CONDUCTED IN 1993
TRAVEL TIMES ARE FROM NORTH SAM HOUSTON PARKWAY TO HOGAN
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : M – MAINLANE TRAVEL TIME
H – HOV LANE TRAVEL TIME

FIGURE B-6

NORTH FREEWAY (IH 45N)
A.M. PEAK HOUR MAINLANE TRIPS

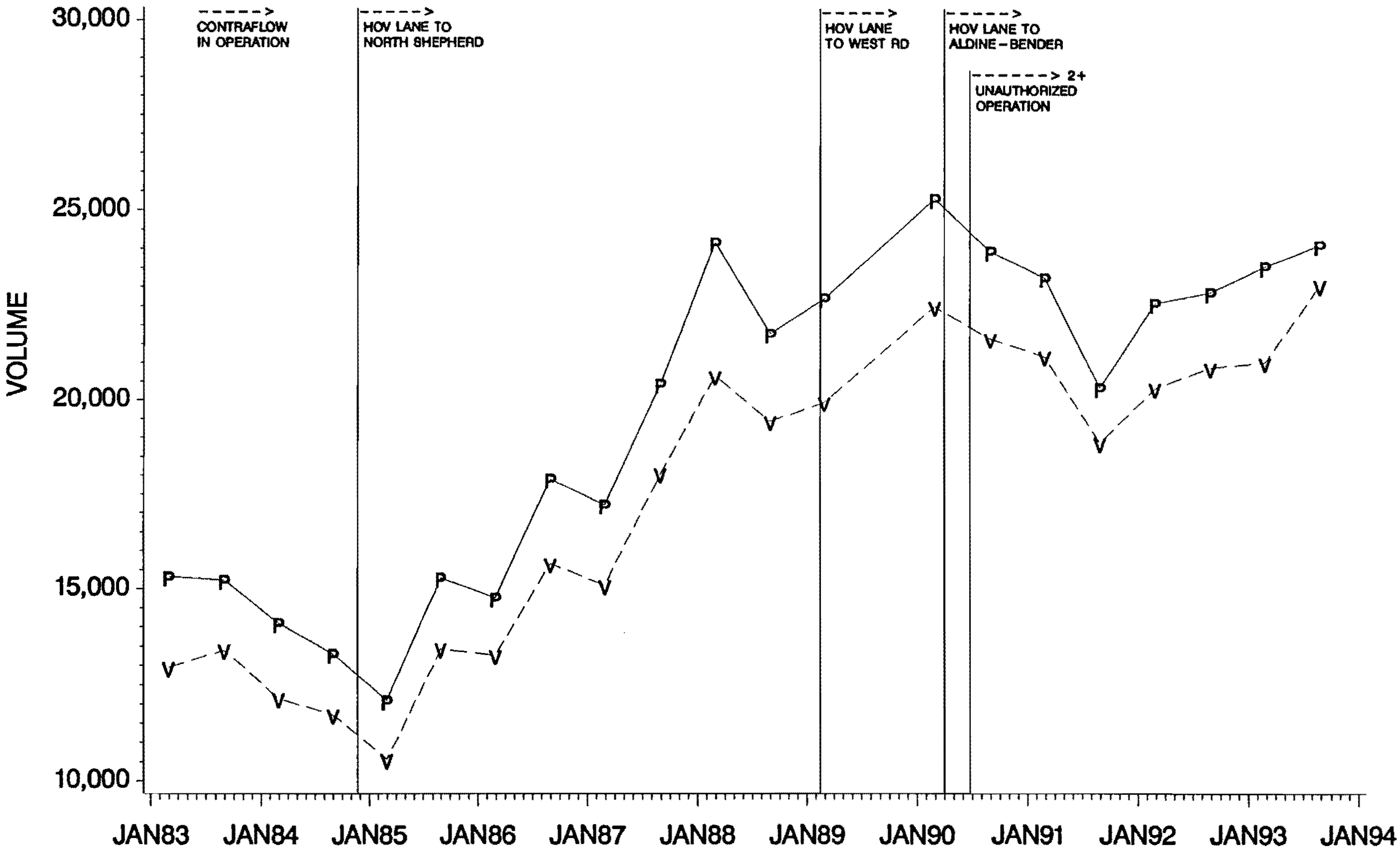


DATA COLLECTED SOUTHBOUND AT LITTLE YORK
SOUTHBOUND CROSS SECTION AT LITTLE YORK EXPANDED FROM 3 TO 4 LANES IN JUNE, 1987
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = MAINLANE PERSONS
V = MAINLANE VEHICLES

FIGURE B-7

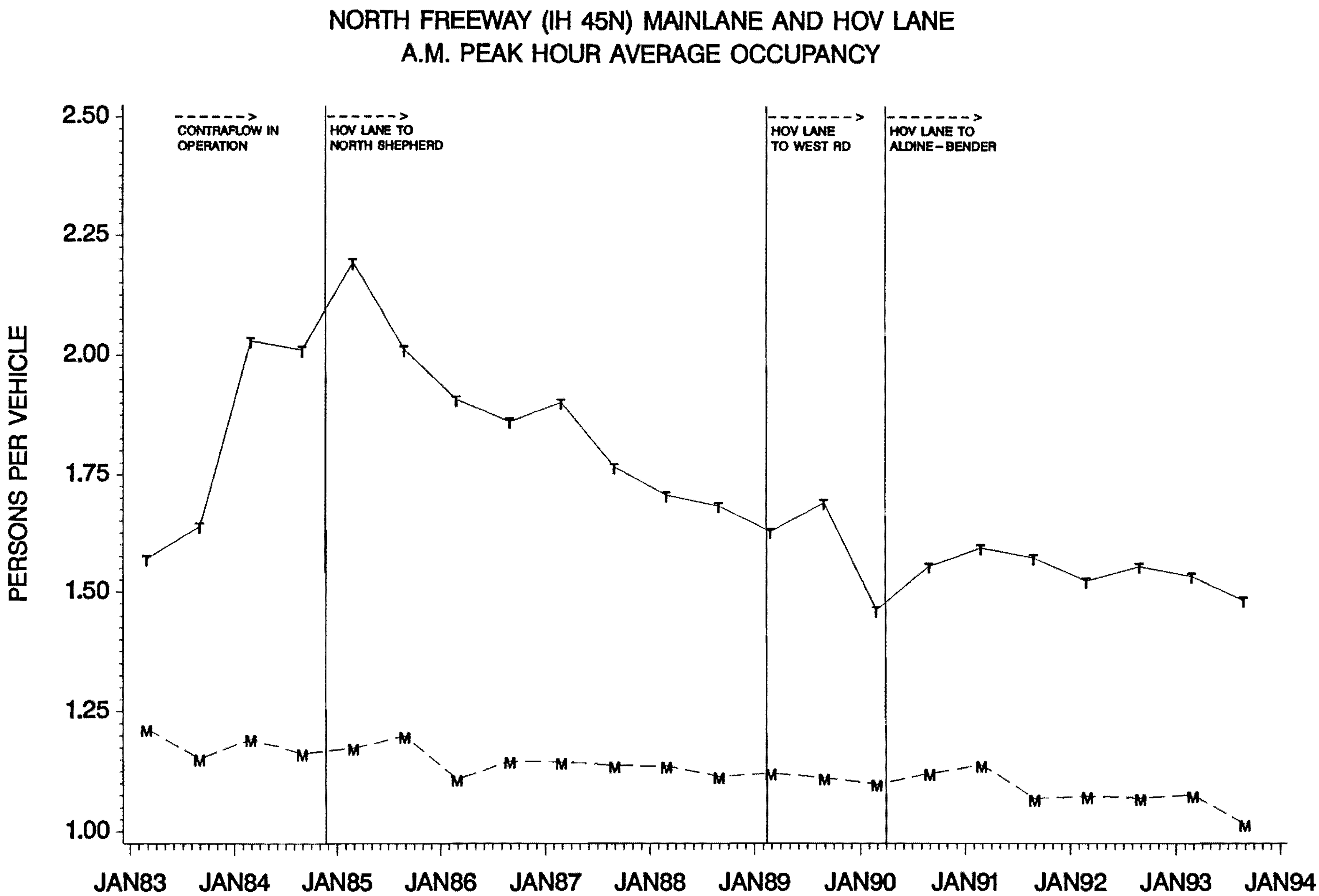
NORTH FREEWAY (IH 45N)
A.M. PEAK PERIOD MAINLANE TRIPS



A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA COLLECTED SOUTHBOUND AT LITTLE YORK
SOUTHBOUND CROSS SECTION AT LITTLE YORK EXPANDED FROM 3 TO 4 LANES IN JUNE, 1987
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = MAINLANE PERSONS
V = MAINLANE VEHICLES

FIGURE B-8

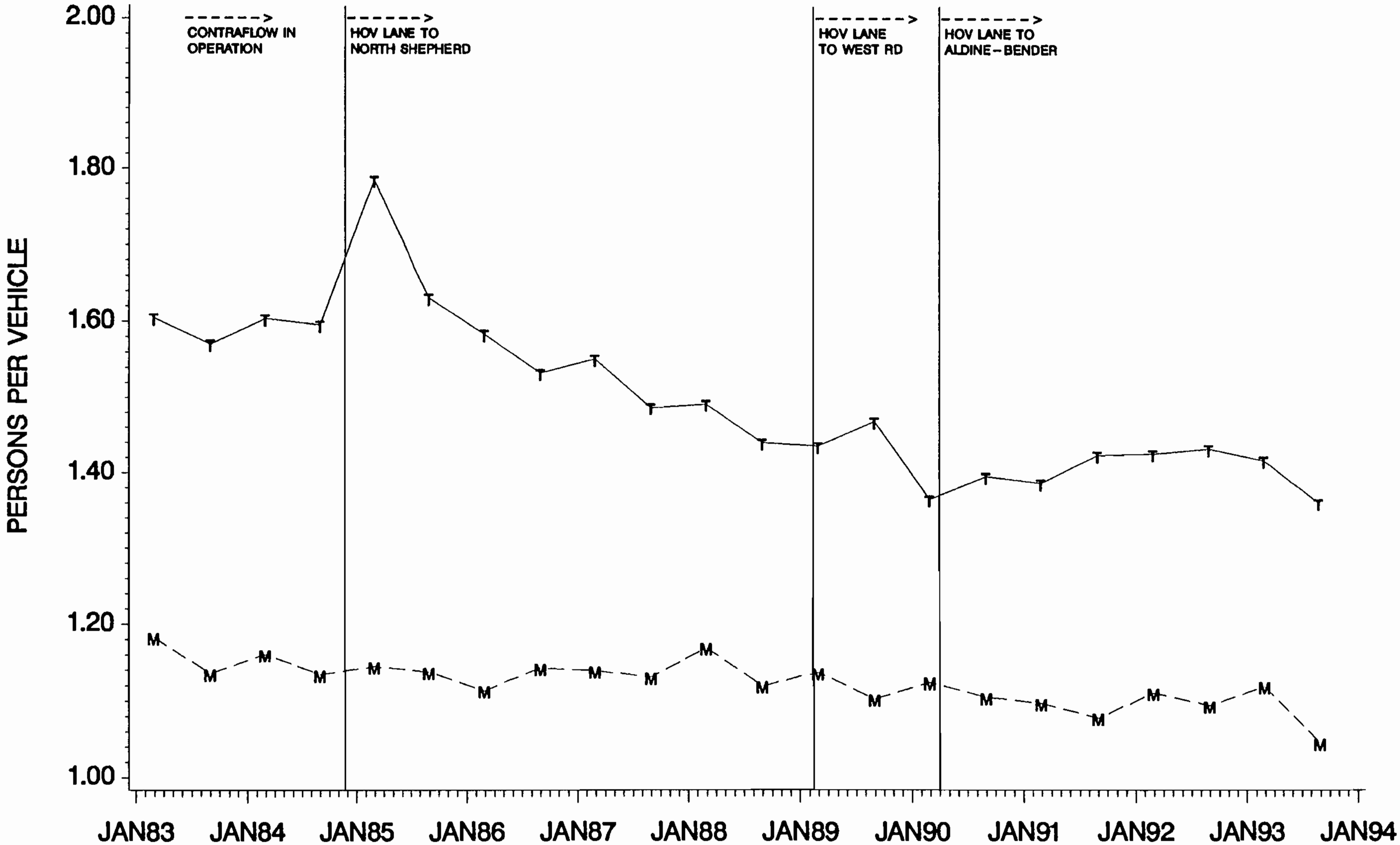


DATA COLLECTED SOUTHBOUND AT LITTLE YORK
SOUTHBOUND FREEWAY CROSS SECTION INCREASED FROM 3 TO 4 LANES IN JUNE 1987
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : M = MAINLANE OCCUPANCY
T = TOTAL OCCUPANCY
(MAINLANES PLUS HOV LANE)

FIGURE B-9

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

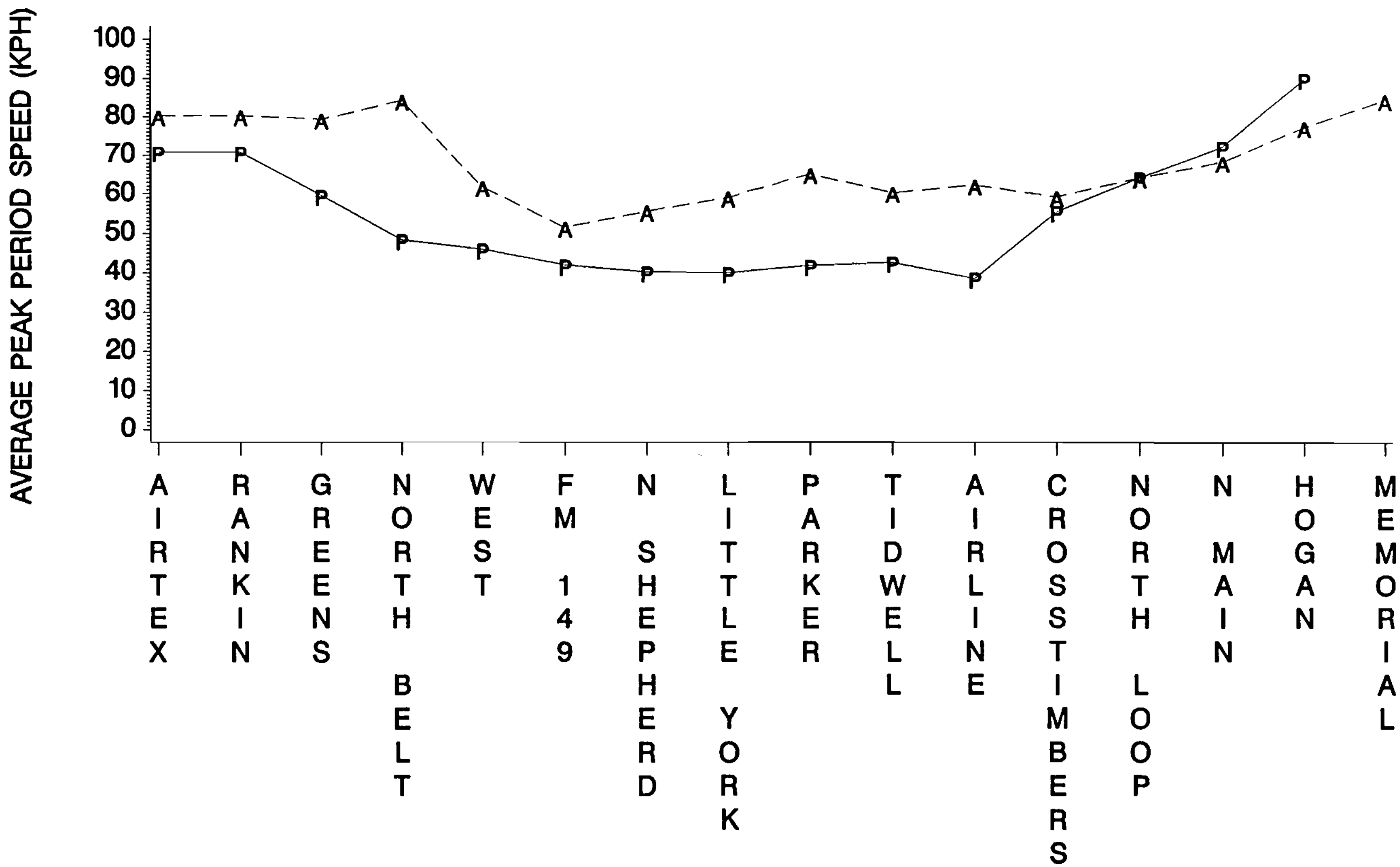


DATA COLLECTED SOUTHBOUND AT LITTLE YORK
PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
SOUTHBOUND FREEWAY CROSS SECTION INCREASED FROM 3 TO 4 LANES IN JUNE 1987
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : M = MAINLANE OCCUPANCY
T = TOTAL OCCUPANCY (MAINLANES PLUS HOV LANE)

FIGURE B-10

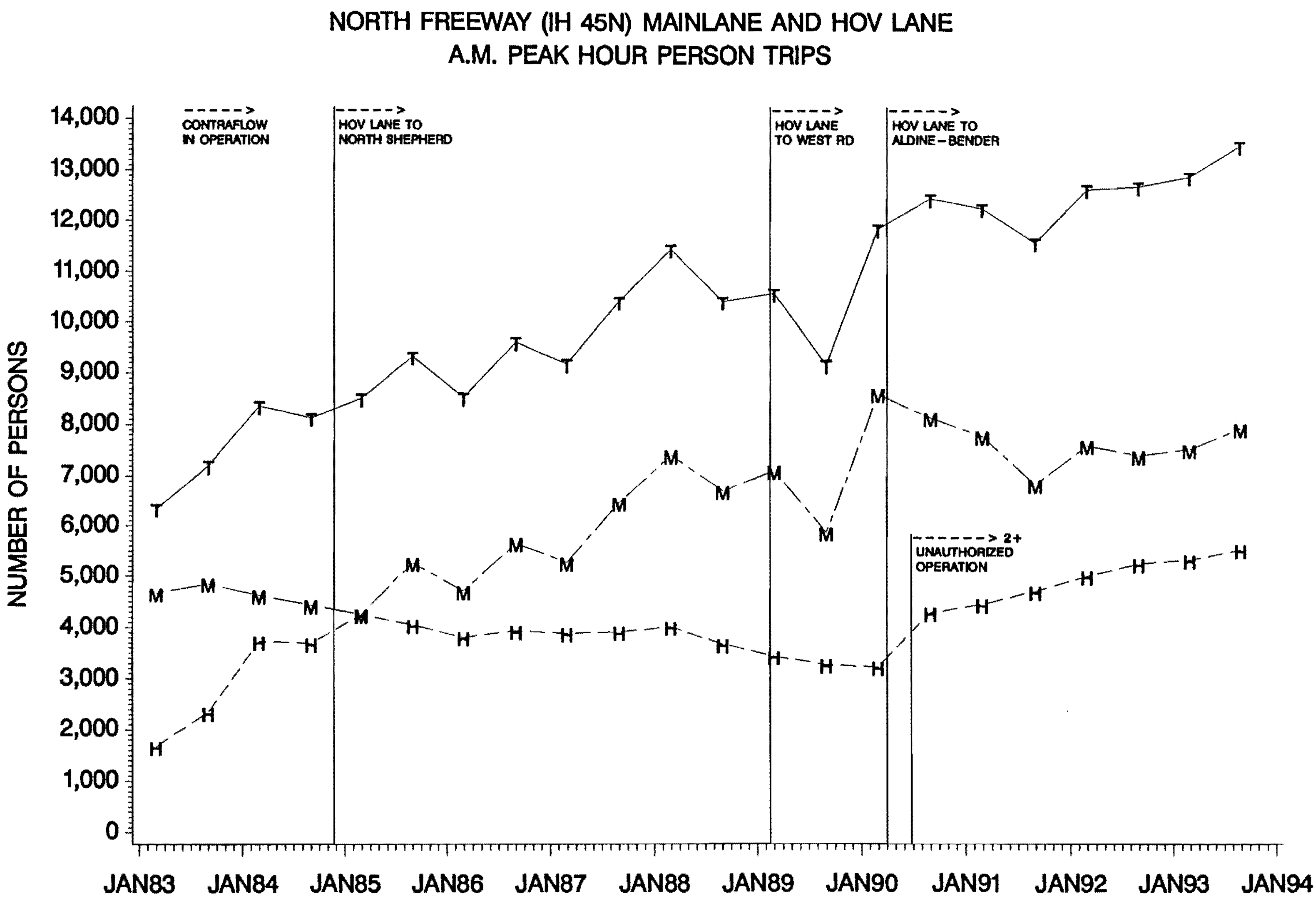
NORTH FREEWAY (IH 45N) MAINLANE TRAVEL TIME AND SPEED SURVEY
SOUTHBOUND, AIRTEX TO MEMORIAL
A.M. PEAK PERIOD



NOTE : TO CONVERT SPEEDS FROM METRIC TO ENGLISH UNITS MULTIPLY KPH BY 0.62
DATA COLLECTED 6:00 TO 9:30 A.M.
DATA COLLECTED FROM JUNE, 1983 TO SEPTEMBER, 1993
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = AVERAGE SPEED PRIOR TO OPENING HOV LANE
A = AVERAGE SPEED SINCE HOV LANE OPENED

FIGURE B-11

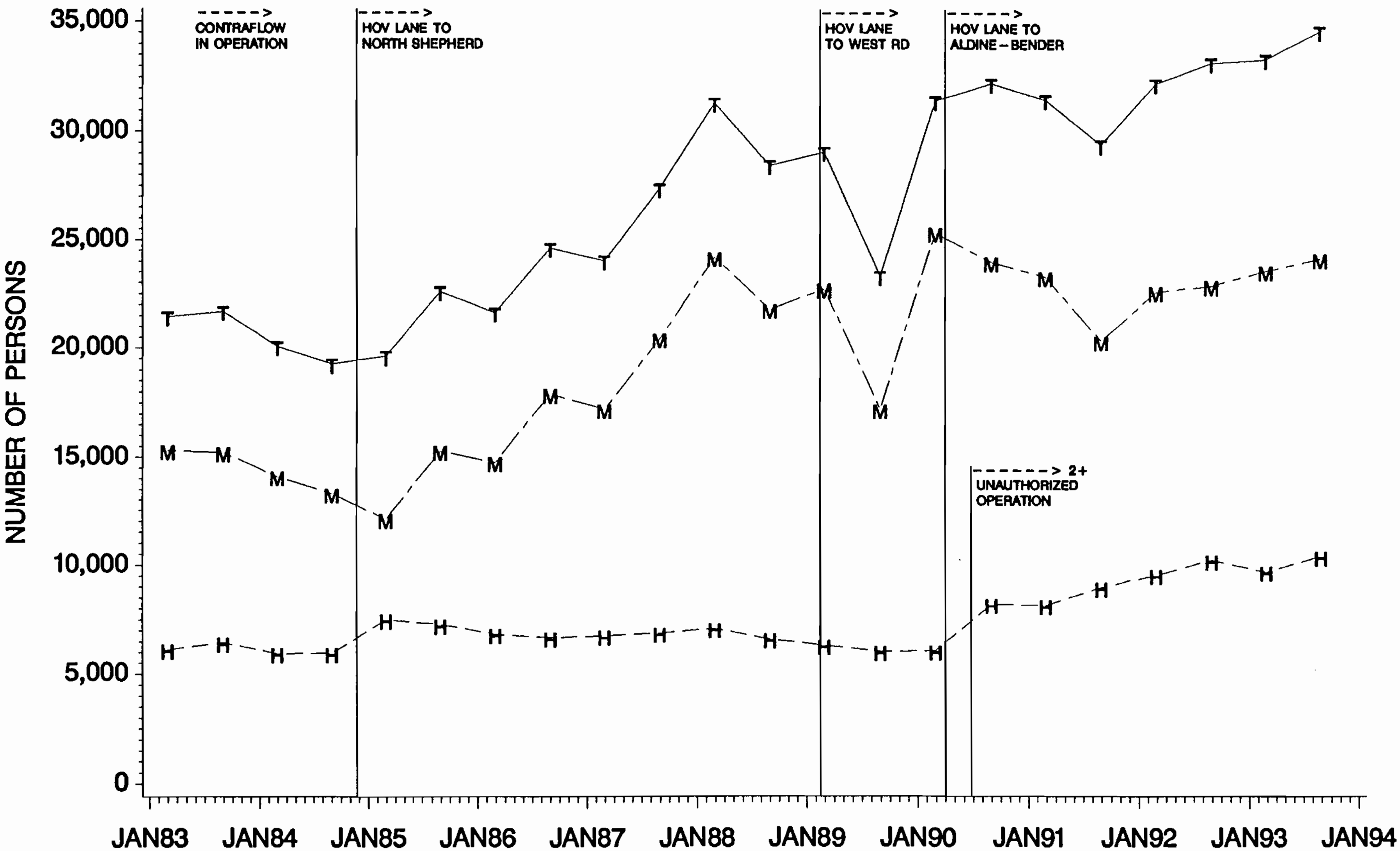


DATA COLLECTED SOUTHBOUND AT LITTLE YORK, 4 LANE SECTION
SOUTHBOUND CROSS SECTION AT LITTLE YORK EXPANDED FROM 3 TO 4 LANES IN JUNE, 1987
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL PERSONS
M = MAINLANE PERSONS
H = HOV LANE PERSONS

FIGURE B-12

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

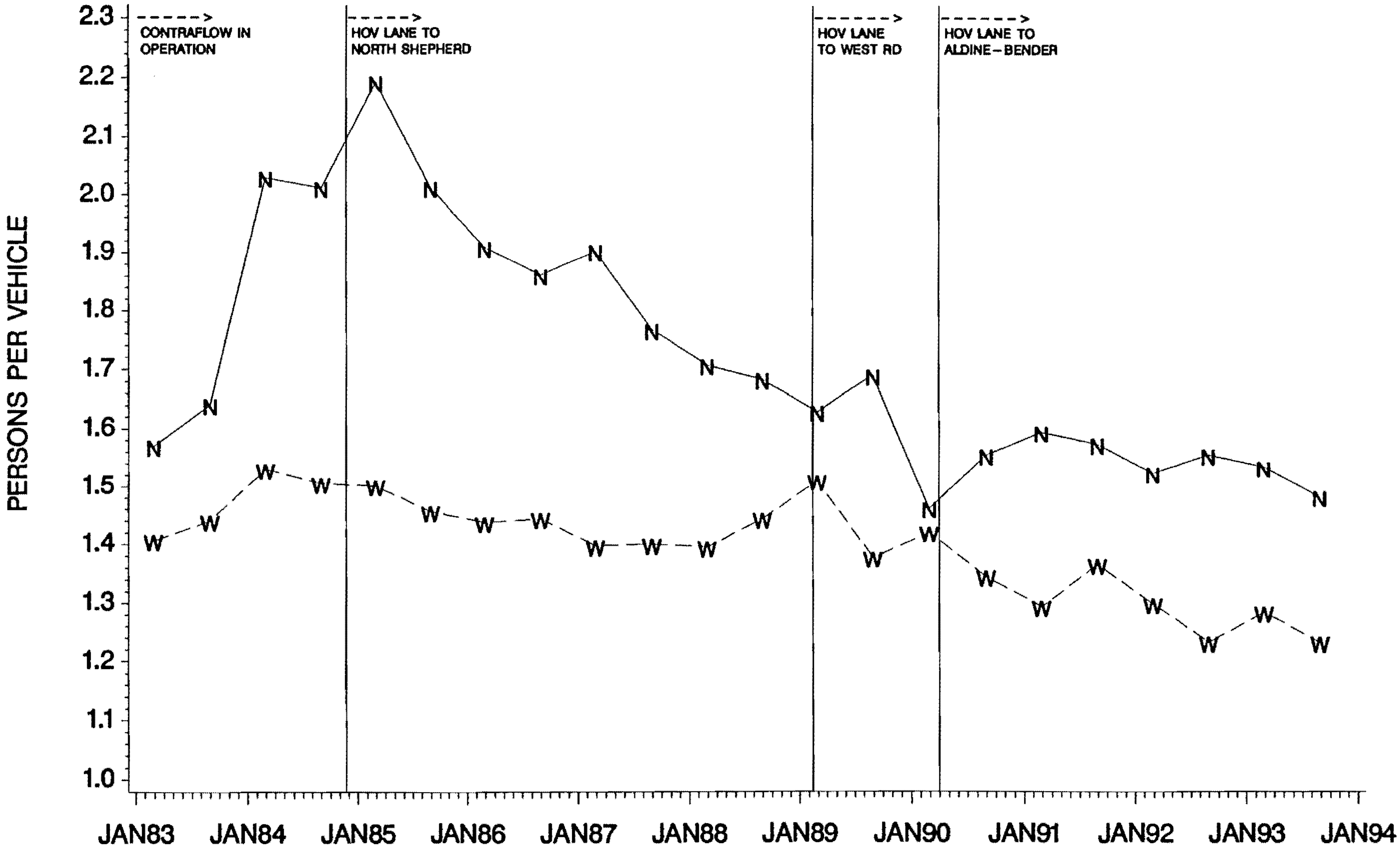


A.M. PEAK PERIOD DEFINED AS FROM 6:00 TO 9:30 A.M.
DATA COLLECTED SOUTHBOUND AT LITTLE YORK, 4 LANE SECTION
SOUTHBOUND CROSS SECTION AT LITTLE YORK EXPANDED FROM 3 TO 4 LANES IN JUNE, 1987
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL PERSONS
M = MAINLANE PERSONS
H = HOV LANE PERSONS

FIGURE B-13

A.M. PEAK HOUR AVERAGE OCCUPANCY
NORTH FREEWAY AND FREEWAY WITHOUT HOV LANE

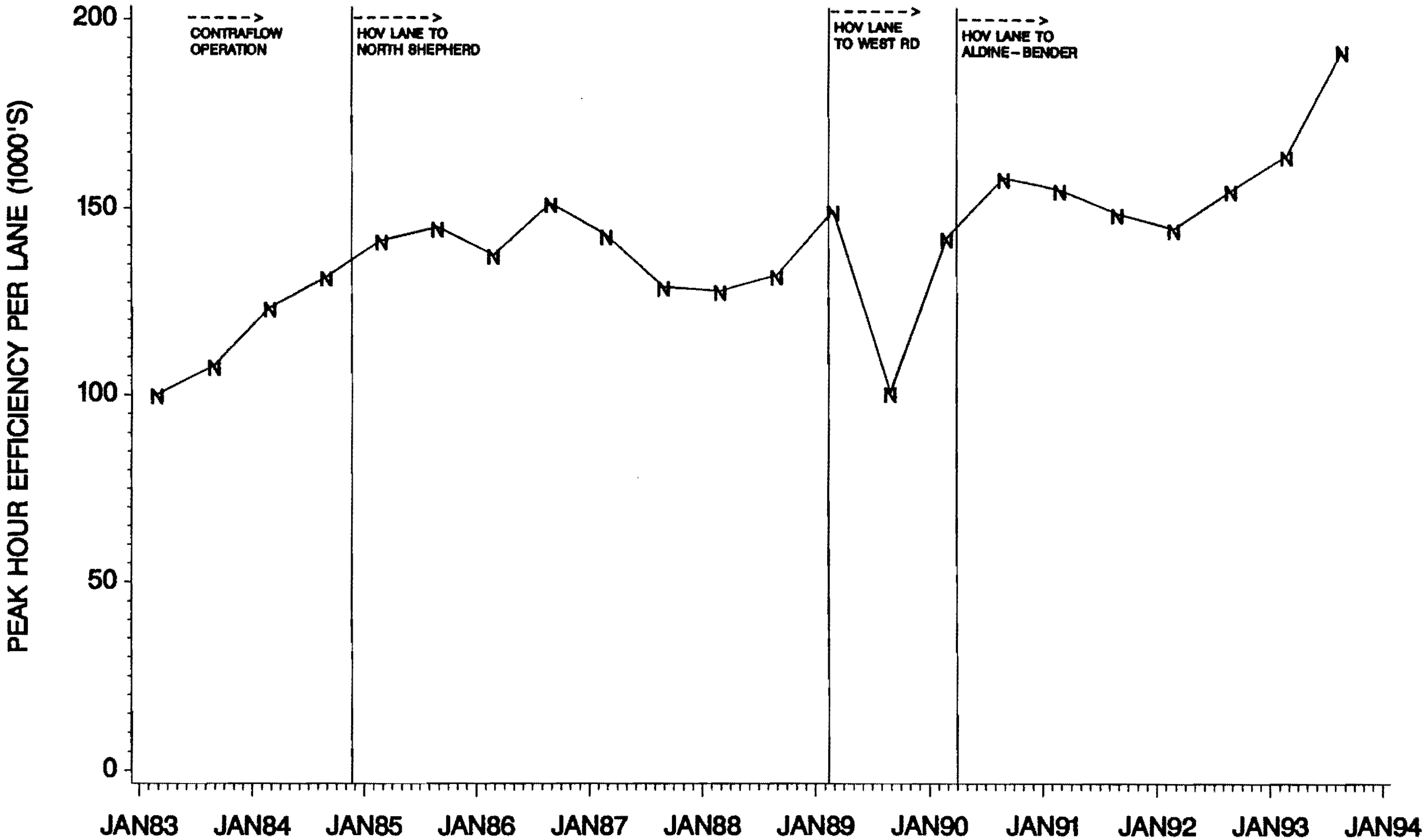


DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF
GULF FWY (6/83 – 4/88), SOUTHWEST FWY (9/88 – 12/92) AND EASTEX FWY (1/93 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : N = NORTH FREEWAY AT LITTLE YORK (WITH HOV LANE)
W = FREEWAYS WITHOUT HOV LANE

FIGURE B-14

NORTH FREEWAY (IH 45N) HOV LANE EVALUATION
A.M. PEAK HOUR MAINLANE AND HOV LANE EFFICIENCY

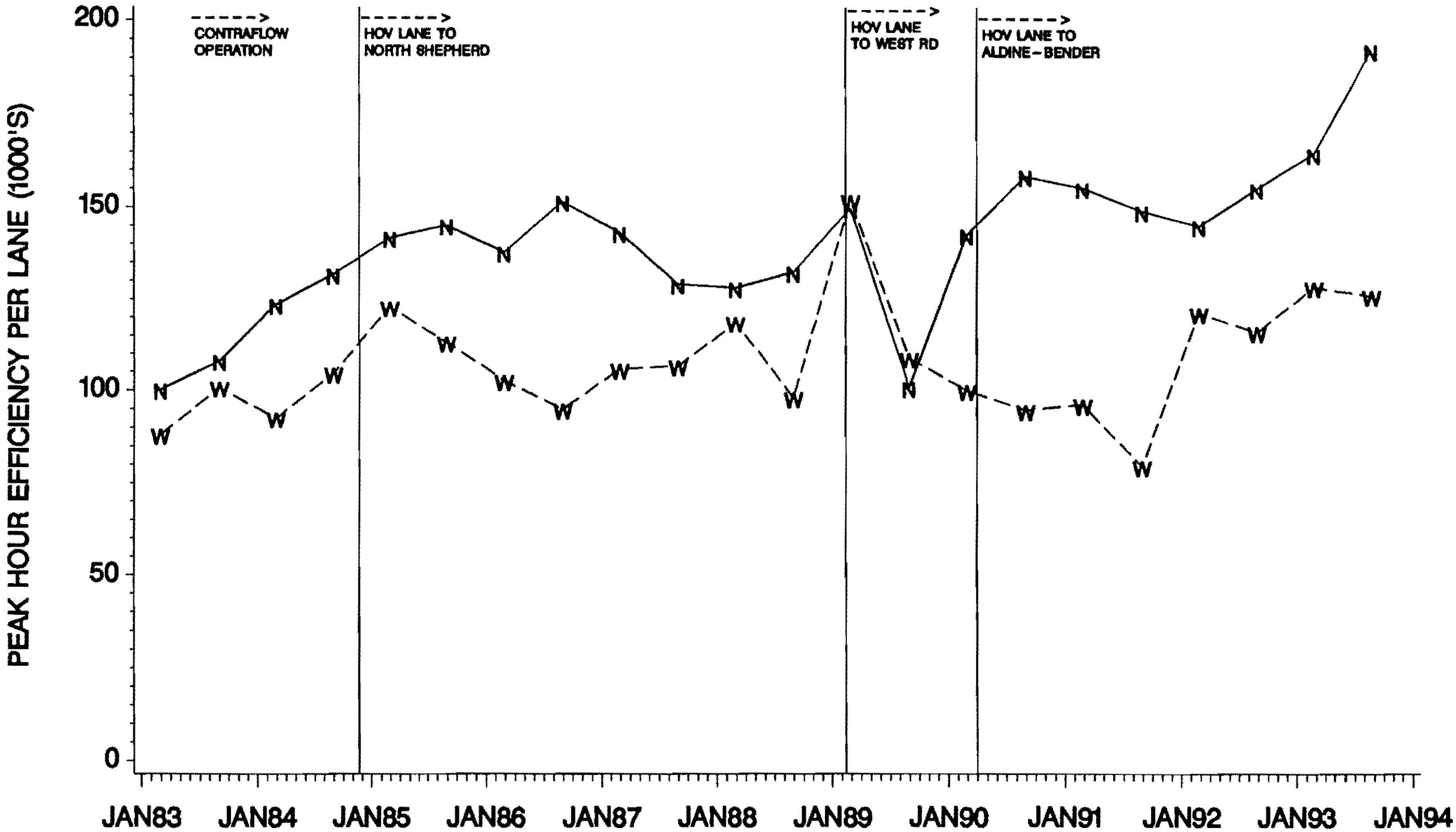


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE HOV LANE, IT REPRESENTS TOTAL PERSONS (FREEWAY + HOV LANE) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 5 LANES
TO CONVERT EFFICIENCY FROM METRIC TO ENGLISH UNITS MULITPLY BY 0.62
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : N = NORTH FREEWAY EFFICIENCY

FIGURE B-15

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

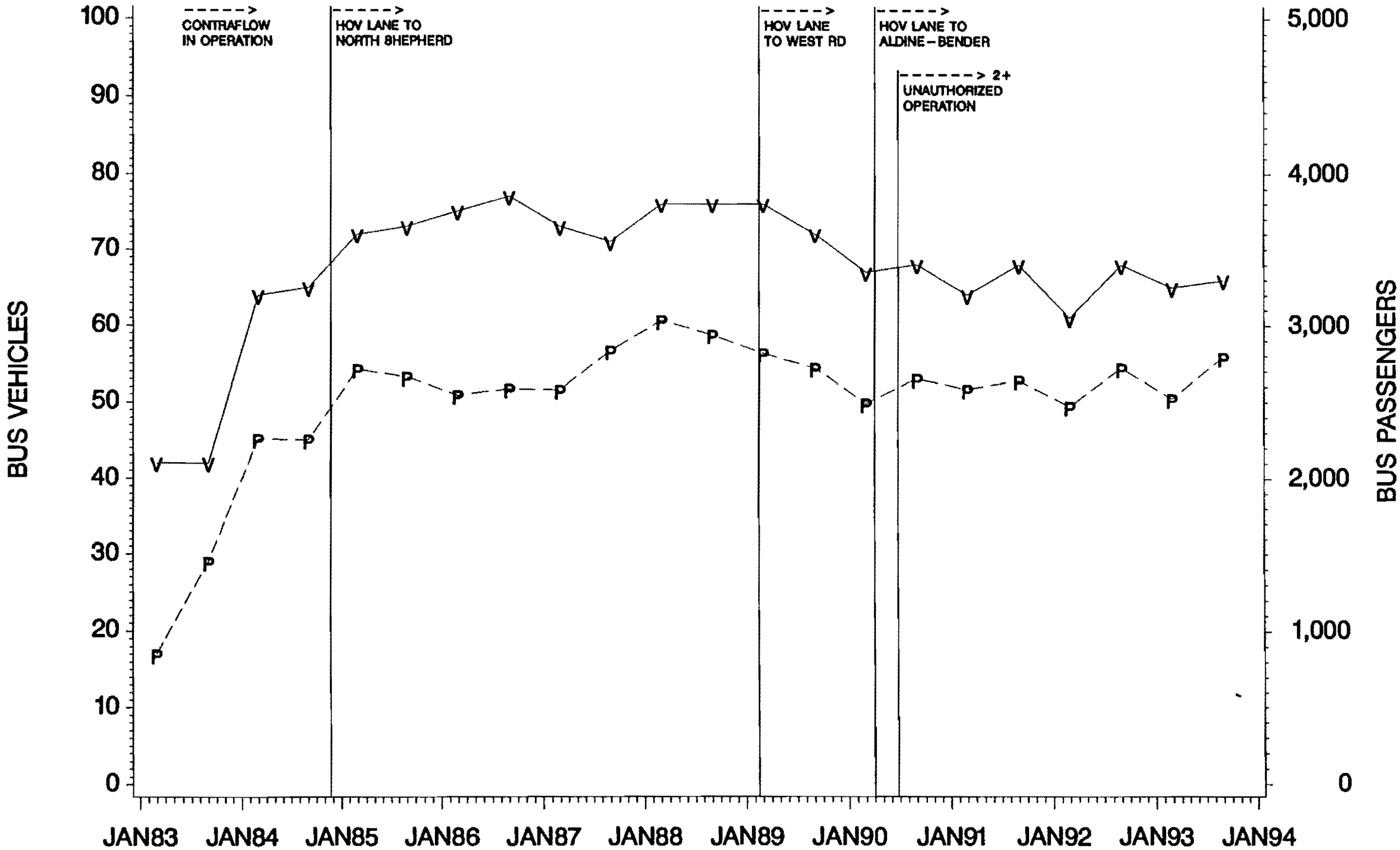


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE HOV LANE, IT REPRESENTS TOTAL PERSONS (FREEWAY + HOV LANE) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 4 LANES
DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF GULF FWY (6/83 – 4/88), SOUTHWEST FWY (5/88 – 12/92) AND EASTEX FWY (1/93 – PRESENT) DATA
TO CONVERT EFFICIENCIES FROM METRIC TO ENGLISH UNITS MULITPLY BY 0.62
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : N = NORTH FREEWAY EFFICIENCY
W = FREEWAYS WITHOUT HOV LANE

FIGURE B-16

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



DATA COLLECTED OVER LITTLE YORK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : V – BUS VEHICLES VOLUME
P – BUS PASSENGER VOLUME

FIGURE B-17

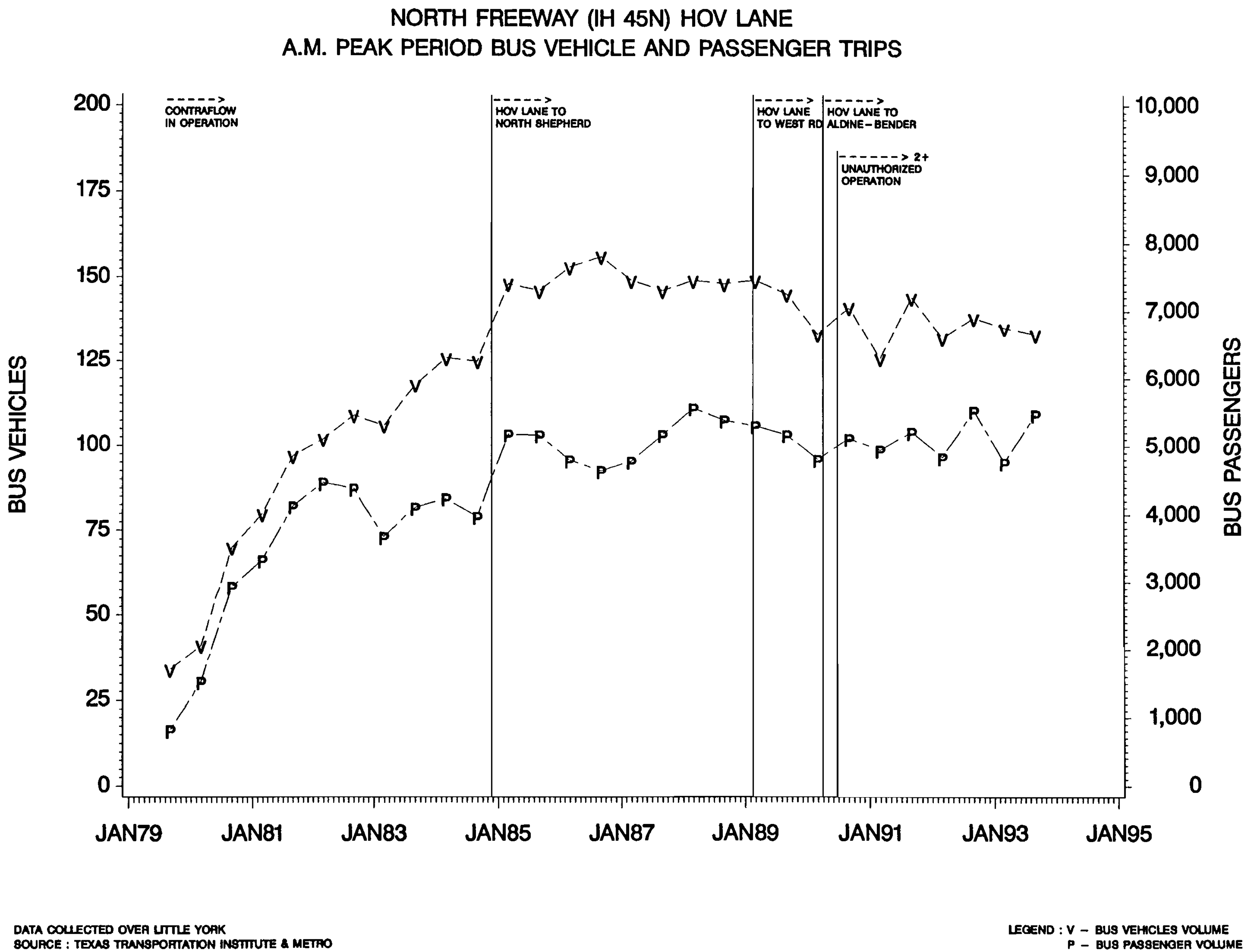
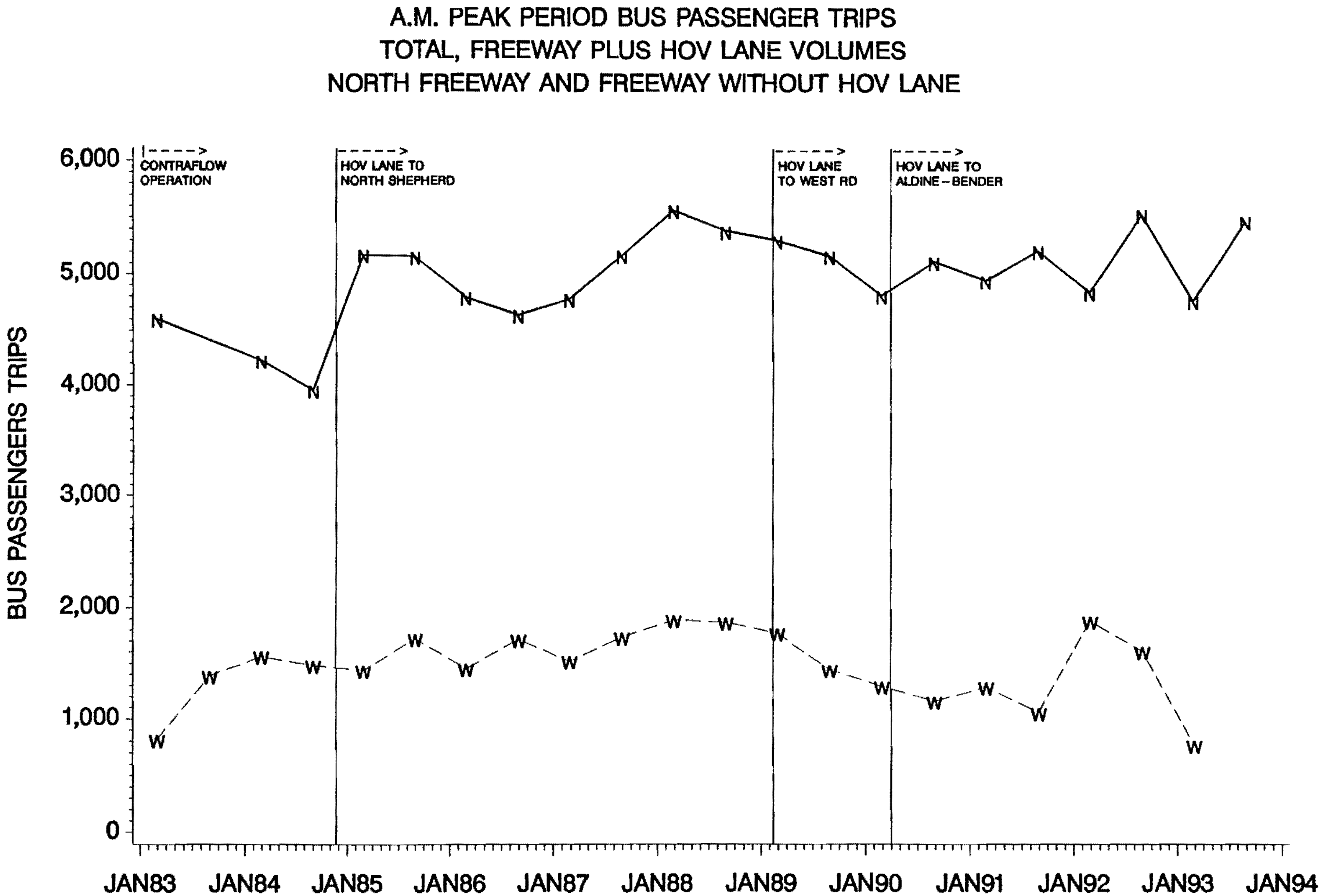

NORTH FREEWAY (IH 45N) HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS
CONTRAFLOW IN OPERATION
HOV LANE TO NORTH SHEPHERD
HOV LANE TO WEST RD
HOV LANE TO ALDINE-BENDER
2+ UNAUTHORIZED OPERATION
BUS VEHICLES
BUS PASSENGERS
200
175
150
125
100
75
50
25
0
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
JAN79
JAN81
JAN83
JAN85
JAN87
JAN89
JAN91
JAN93
JAN95
DATA COLLECTED OVER LITTLE YORK
SOURCE : TEXAS TRANSPORTATION INSTITUTE & METRO
LEGEND : V - BUS VEHICLES VOLUME
P - BUS PASSENGER VOLUME

FIGURE B-18

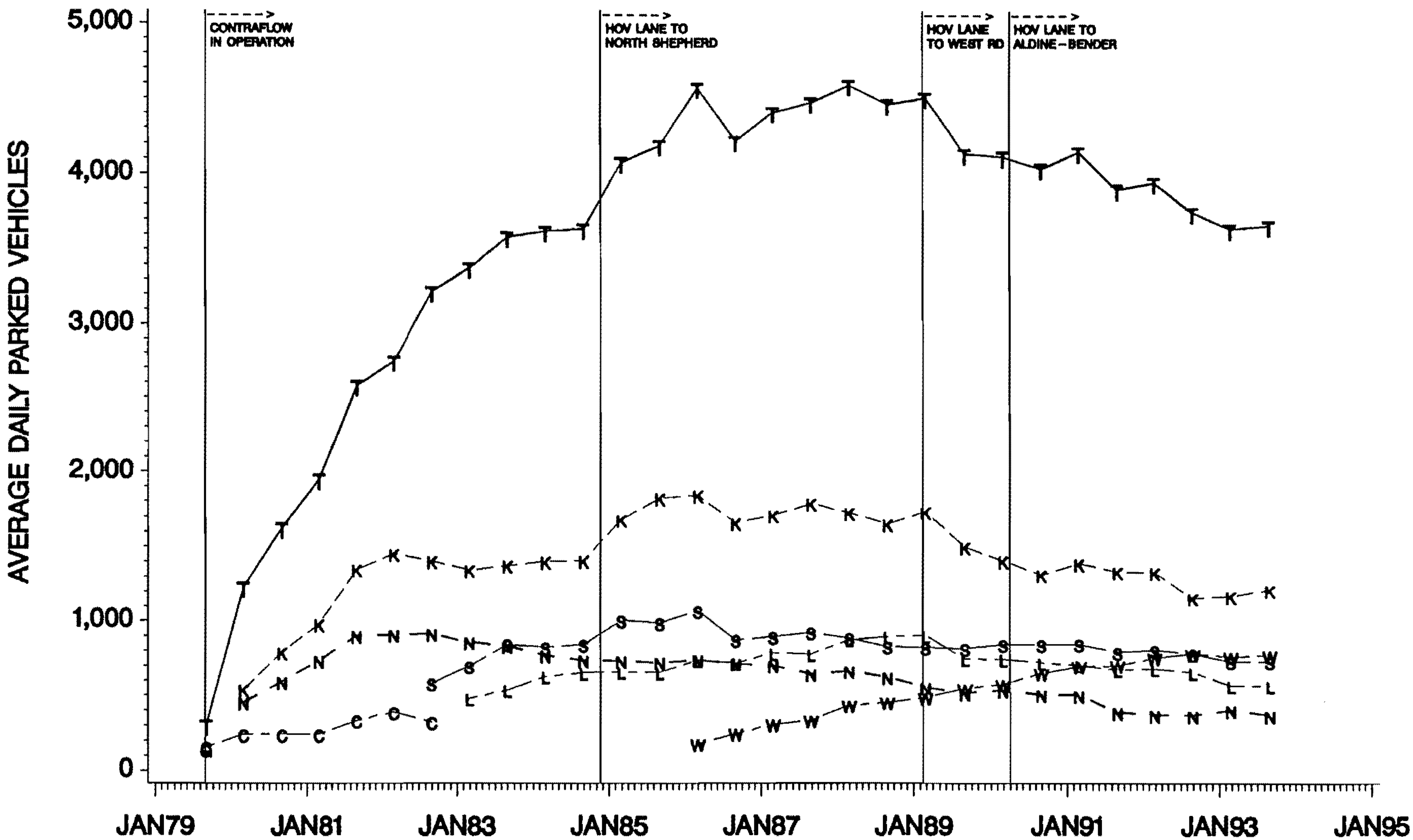


PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF
GULF FWY (8/83 – 4/88), SOUTHWEST FWY (9/86 – 6/89) AND EASTEX FWY (9/89 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : N = NORTH FREEWAY AT LITTLE YORK (WITH HOV LANE)
W = FREEWAYS WITHOUT HOV LANE

FIGURE B-19

NORTH FREEWAY (IH 45N) CORRIDOR PARK-AND-RIDE DEMAND

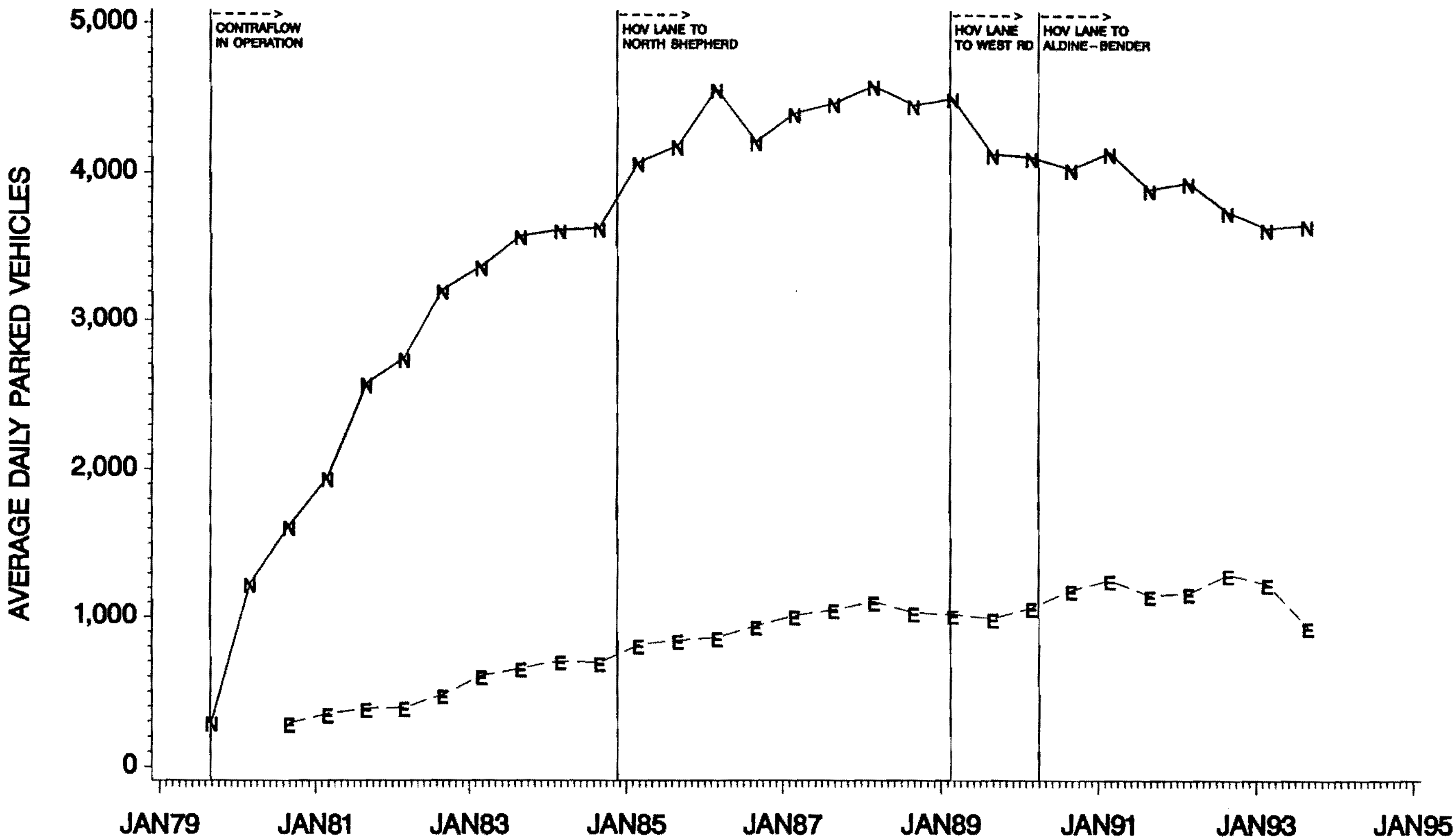


NORTH CFL FROM DOWNTOWN TO NORTH SHEPHERD (15.46 KM [9.6 MI]) OPENED AUGUST, 1979
CONCURRENT FLOW LANE (A.M. ONLY) FROM NORTH SHEPHERD TO WEST RD (5.31 KM [3.3 MI]) OPENED MARCH, 1981
NORTH HOV LANE FROM DOWNTOWN TO NORTH SHEPHERD (15.46 KM [9.6 MI]) OPENED NOVEMBER, 1984
HOV LANE EXTENSION FROM NORTH SHEPHERD TO ALDINE-BENDER (6.92 KM [4.3 MI]) OPENED APRIL, 1990
CURRENT TOTAL CORRIDOR PARKING CAPACITY = 7,386 SPACES
CHAMPIONS (C) AND GREENSPOINT (G) LOTS WERE TEMPORARY LOTS
SOURCE : TEXAS TRANSPORTATION INSTITUTE, METRO & BRAZOS TRANSIT

LEGEND : T = TOTAL PARKED VEHICLES
K = KUYKENDAHL LOT (2,244 SPACES)
L = SETON LAKE LOT (1,286 SPACES)
N = NORTH SHEPHERD LOT (1,603 SPACES)
S = SPRING LOT (1,263 SPACES)
W = THE WOODLANDS LOT (990 SPACES)

FIGURE B-20

AVERAGE DAILY VEHICLES PARKED AT PARK-AND-RIDE LOTS
NORTH FREEWAY AND FREEWAY WITHOUT HOV LANE



NORTH CFL FROM DOWNTOWN TO NORTH SHEPHERD (15.45 KM [9.6 MI]) OPENED AUGUST, 1979
CONCURRENT FLOW LANE (A.M. ONLY) FROM NORTH SHEPHERD TO WEST RD (5.31 KM [3.3 MI]) OPENED MARCH, 1981
NORTH HOV LANE FROM DOWNTOWN TO NORTH SHEPHERD (15.45 KM [9.6 MI]) OPENED NOVEMBER, 1984
HOV LANE EXTENSION FROM NORTH SHEPHERD TO ALDINE-BENDER (6.92 KM [4.3 MI]) OPENED APRIL, 1990
SOURCE : TEXAS TRANSPORTATION INSTITUTE, METRO & BRAZOS TRANSIT

LEGEND : N - NORTH FREEWAY
E - FREEWAY WITHOUT HOV LANE (EASTEX)

APPENDIX C

GULF FREEWAY AND HOV LANE DATA

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

Table C-1. Summary of A.M. Peak-Direction Gulf Freeway and HOV Lane Data, December 1993

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)		10.5 (6.5)	
HOV Lane Cost (millions)		$45.0	
Person-Movement			
Peak Hour (7-8 a.m.)	—	2,755	—
Peak Period (6-9:30 a.m.)	—	4,613	—
Total Daily	—	9,628	—
Vehicle Volumes			
Peak Hour	—	872	—
Peak Period	—	1,429	—
Vehicle Occupancy, Peak Hour (persons/veh)	—	3.16	—
Accident Rate (Injury accidents/100 MVK [/100 MVM]) 11/84-12/93[2]	—	6.1 (9.8)	—
Vehicle Breakdowns (VKT/Breakdown [VMT/Breakdown]), 11/84-12/93	—	117,530 (73,000)	—
Violation Rate (6-9:30 a.m.)	—	3.6%	—
Peak Hour Lane Efficiency (1000's)[3]	—	222 (138)	—
Annual Value of User Time Saved (millions)[4]	—	$1.4 to $2.8	—
Freeway Mainlane Data (see note)			
Person Movement			
Peak Hour	6,415	—	—
Peak Period (6-9:30 a.m.)	17,845	—	—
Vehicle Volume			
Peak Hour	4,962	—	—
Peak Period	14,740	—	—
Vehicle Occupancy, Peak Hour (persons/veh)	1.29	—	—
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM])[2]	18.5 (29.8)	13.0 (20.9)	-30%
Avg. Operating Speed[5] (kph [mph])			
Peak Hour	50 (31)	—	—
Peak Period	58 (36)	—	—
Peak Hour Lane Efficiency (1000's)[3]	106 (66)	—	—

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

[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 and/or compare freeway and HOV lane data.

[2]Due to inconsistencies in reporting accidents in Harris County, only injury accidents are included in this analysis. Accidents were analyzed between Broadway and Dowling, a distance of approximately 10.5 kilometers (6.5 miles), which corresponds to Phase 1 of the HOV lane. The pre-HOV lane includes four years of mainlane accident data from 5/16/84 to 5/15/88. The current value is from 5/16/88 to 8/93.

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

[4]Based on time savings for HOV lane users in 1993, an annual estimate of travel time savings to HOV lane users is developed. A value of time of $10.78/hour is used based on the value applied in the Highway Economic Evaluation Model.

[5]From Broadway to Dowling a distance of 10.5 kilometers (6.5 miles).

Table C-1. Summary of A.M. Peak-Direction Gulf Freeway and HOV Lane Data, December 1993 (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	—	—	—
Peak Period	—	—	—
Vehicle Volume			
Peak Hour	—	—	—
Peak Period	—	—	—
Vehicle Occupancy			
Peak Hour	—	—	—
Peak Period	—	—	—
2+ Carpool Volumes			
Peak Hour	475	—	—
Peak Period	1,304	—	—
Travel Time (minutes)[1]			
Peak Hour	9.7[2]	7.5[3]	-23%
Peak Period	8.1[2]	7.3[3]	-10%
Peak Hour Lane Efficiency (1000's)[4]	—	—	—
Transit Data			
Bus Vehicle Trips			
Peak Hour	23[5]	—	—
Peak-Period	40[5]	—	—
Bus Passenger Trips			
Peak Hour	746[5]	—	—
Peak Period	1,230[5]	—	—
Bus Occupancy (persons/bus)			
Peak Hour	32.6[5]	—	—
Peak Period	30.8[5]	—	—
Vehicles Parked in Corridor Park & Ride Lots	1,115	1,247	+12%
Bus Operating Speed (kph [mph])[1]			
Peak Hour	50 (31)[2]	81 (50)[3]	+63%
Peak Period	58 (36)[2]	83 (52)[3]	+42%

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

[1]From Broadway to Dowling, a distance of 10.5 kilometers (6.5 miles).
[2]Data pertain to operation in the freeway mainlanes.
[3]Data pertain to operation in the HOV lane.
[4]This represents the product of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.
[5]Data collected at Monroe.

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

Measure of Effectiveness	"Representative" Pre-HOV Lane Value	"Representative" 12/93 Value	Percent Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/HOV lane	1.29	—	—
Freeway w/o HOV lane	1.23	1.21	-2%
A.M. Peak Hour, 2+ Carpool Volume			
Freeway w/HOV lane	475	—	—
Freeway w/o HOV lane	600	531	-12%
Bus Passengers, Peak Period			
Freeway w/HOV lane	1,230	—	—
Freeway w/o HOV lane	1,188	775	-35%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	1,115	1,227	+10%
Freeway w/o HOV lane	1,236	942	-24%
Facility Per Lane Efficiency[3]			
Freeway w/HOV lane	106 (66)	—	—
Freeway w/o HOV lane	138 (86)	126 (78)	-8%

[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 on the Eastex Freeway (1/93 to present).
[3]This represents the product of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.

HOV LANE DATA

DESCRIPTION

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

- Selected milestone dates are listed below. Other dates are shown in the capital cost table.

  - 5/16/88 CBD to Broadway opens (10.5 kilometers [6.5 miles])
  - 10/1/89 Weekend HOV operation begins
  - 10/5/91 Weekend HOV operation ends
  - 9/8/92 Motorcycles allowed on HOV facility (no occupancy restrictions)

PERSON MOVEMENT

- In December 1993, 9,628 person trips per day were served on the HOV lane.
- A.M. peak hour, 2,755 persons/hour.
  - 930 (34%) by bus, 78 (3%) by vanpool, and 1,747 (63%) by carpool (Figure C-1).
  - Average HOV lane vehicle occupancy = 3.16 persons/vehicle.
- A.M. peak period, 4,613 persons.
  - 1,655 (36%) by bus, 160 (3%) by vanpool, and 2,798 (61%) by carpool (Figure C-2).

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

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1990 Dollars
HOV Lane and Ramps			
Phase 1 Metro (1988)	$1.6	0.98	$1.6
Phase 2 Metro (1988)	0.4	0.98	0.4
Phase 1 SDHPT (1988)	16.0	0.98	15.7
Phase 2 SDHPT (1988)	12.5	0.98	12.2
SUB-TOTAL	$30.5		$29.9
Per Kilometer (Mile)	$2.9 ($4.7)		$2.8 ($4.6)
Surveillance, Communication and Control	$1.9	1.00	$1.9
SUB-TOTAL	$1.9		$1.9
Per Kilometer (Mile)	$0.2 ($0.3)		$0.2 ($0.3)
Support Facilities			
Bay Area P/R (1984)	$3.7	0.93	$3.4
Edgebrook P/R (1981)	3.3	1.05	3.5
Eastwood Transit Center (1988)	5.6	0.98	5.5
SUB-TOTAL	$12.6		$12.4
Per Kilometer (Mile)	$1.2 ($1.9)		$1.2 ($1.9)
TOTAL COST	$45.0		$44.2
COST PER KILOMETER (10.5 kilometers [6.5 miles])	$4.3 ($6.9)		$4.2 ($6.8)

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

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

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1990 Dollars
HOV Lane and Ramps			
Phase 3 Metro	$4.0	1.00	$4.0
Phase 3 SDHPT	42.7	1.00	42.7
Hobby West Access Ramp	6.8	1.00	6.8
Fuqua Access Ramps	6.0	1.00	6.0
SUB-TOTAL	$59.5		$59.5
Per Kilometer (Mile)	$4.1 ($6.6)		$4.1 ($6.6)
Surveillance, Communication and Control	$1.4	1.00	$1.4
SUB-TOTAL	$1.4		$1.4
Per Kilometer (Mile)	$0.1 ($0.2)		$0.1 ($0.2)
Support Facilities			
Hobby East P/R	$5.0	1.00	$5.0
Fuqua West P/R	$6.0	1.00	6.0
Fuqua East P/R	5.0	1.00	5.0
SUB-TOTAL	$16.0		$16.0
Per Kilometer (Mile)	$1.1 ($1.8)		$1.1 ($1.8)
TOTAL COST	$76.9		$76.9
COST PER KILOMETER (14.5 kilometers [9.0 miles])	$5.3 ($8.5)		$5.3 ($8.5)

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

VEHICLE MOVEMENT

- A.M. Peak Hour, 872 vph
  - 27 (3%) buses, 12 (1%) vans, and 833 (96%) carpools (Figure C-3).

- A.M. Peak Period, 1,429 vehicles.
  - 53 (4%) buses, 24 (2%) vans, and 1,352 (94%) carpools (Figure C-4).

VEHICLE BREAKDOWN RATES

- As measured from September 1, 1988 through December 1993, the following rate has been observed.

  - Weighted average; 1 breakdown per 117,530 VKT (73,000 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 222 (2,755 passengers x 81 kph) or 138 (2,755 passengers x 50 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane experience an average travel time savings of 4 minutes during the peak hour (Figure C-5).

- The tables on the following page indicate that, on a typical non-incident day, travel time savings of approximately 516 hours (30,980 min.) are realized. Assuming 250 days of operation, annual savings would be 129,084 hours. At $10.78/hour, this equates to $1.39 million per year. This is extremely conservative since it does not consider travel time savings due to incidents on the freeway. Data from Houston suggest that increasing this value by 100% to account for incidents would be reasonable. Thus, travel time savings to HOV lane users are estimated to be in the range of $1.39 to $2.78 million per year.

Table C-5. Northbound A.M. Travel Time Savings for Gulf HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1993)

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 Park Place to Dowling								
6:00	6.56	7.15	-0.59	30	3	104	138	-81
6:30	7.02	6.94	0.08	190	18	260	468	-37
7:00	7.99	7.43	0.56	559	60	450	1,069	594
7:30	8.87	7.37	1.50	1,100	43	623	1,766	2,641
8:00	10.46	7.66	2.80	601	19	343	963	2,694
8:30	8.22	7.25	0.97	203	7	114	323	312
9:00	6.47	7.27	-0.80	94	3	27	123	-98
Peak Period Total				2,776	152	1,921	4,849	6,099
Southbound PM Travel Time Savings for Gulf HOV Lane								
Section from Park Place to Dowling								
3:30	6.83	7.12	-0.29	111	18	77	206	-60
4:00	8.82	7.17	1.65	270	25	160	455	749
4:30	7.87	7.10	0.77	427	34	331	792	607
5:00	18.44	7.51	10.93	755	92	600	1,447	15,809
5:30	12.48	7.37	5.11	544	32	388	964	4,921
6:00	12.84	7.52	5.32	282	4	187	473	2,516
6:30	10.18	7.22	2.96	81	1	34	115	341
Peak Period Total				2,468	207	1,776	4,451	24,883

FREEWAY DATA

NOTE

- Freeway data which have been collected in the Gulf corridor since 1983 have been, for a variety of reasons (primarily safety), collected at Monroe. The HOV lane does not yet extend to Monroe. As a result, the freeway data are not at this time comparable to the HOV lane data. As a result, the freeway data are generally shown as being "Pre-HOV Lane" in the summary sheet but are not combined with HOV lane data to illustrate current values or trends.

PERSON MOVEMENT

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

- The a.m. peak period, person volume was approximately 17,845 (Figure C-7).

VEHICLE VOLUME

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

- In the a.m. peak period, the vehicle volume was 14,740 (Figure C-7).

VEHICLE OCCUPANCY

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

ACCIDENT RATE

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

- For the section of Gulf Freeway between Broadway and downtown, the accident rate for the mainlanes for four years of operation (5/16/84 to 5/15/88) was 18.5 accidents per 100 million vehicle kilometers (100 MVK) (29.8 accidents per 100 million vehicle miles [100 MVM]). The "after HOV lane" accident rate for the mainlanes is 13.0 accidents per 100 MVK (20.9 accidents per 100 MVM) and includes the period 5/88 to 12/93. Only officer-reported accidents are included in current accident files. 1993 volumes estimated by TTI were used to compute rates.

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 dropped outside South Loop 610, where the HOV lane has yet to be 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) (Figure C-9).

COMBINED FREEWAY AND HOV LANE DATA

NOTE

- The freeway data collected at Monroe (the HOV lane is not yet completed to Monroe) cannot be combined or compared to the HOV lane data collected at Telephone at this time. As a result, the combined data are not shown for those instances where Monroe and Telephone data would need to be combined.

TOTAL PERSON MOVEMENT (see note)

VEHICLE OCCUPANCY (see note)

CARPOOL VOLUMES (see note)

PEAK HOUR LANE EFFICIENCY (see note)

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. Only pre-HOV data are, therefore, reported in the summary table.

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; and 40 peak-period bus vehicle trips and 1,230 bus passenger trips.

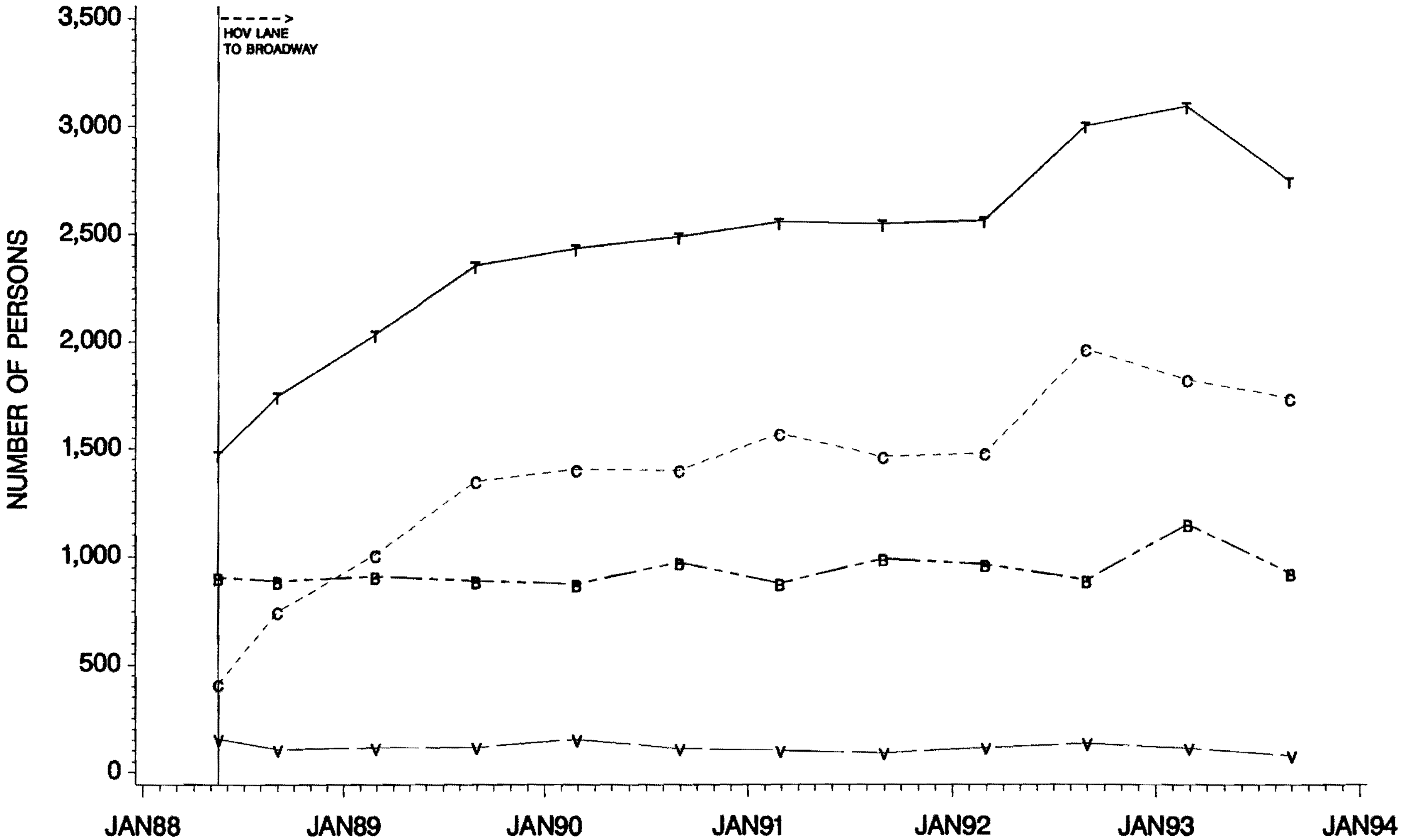
PARK-AND-RIDE

- Prior to opening the HOV lane, approximately 1,115 vehicles were parked in corridor park-and-ride lots. This has increased 12% to a current level of 1,247 (Figure C-12).

- Comparison of Southwest Freeway (freeway without an HOV lane) and Gulf Freeway park-and-ride utilization is shown in Figure C-13.

FIGURE C-1

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



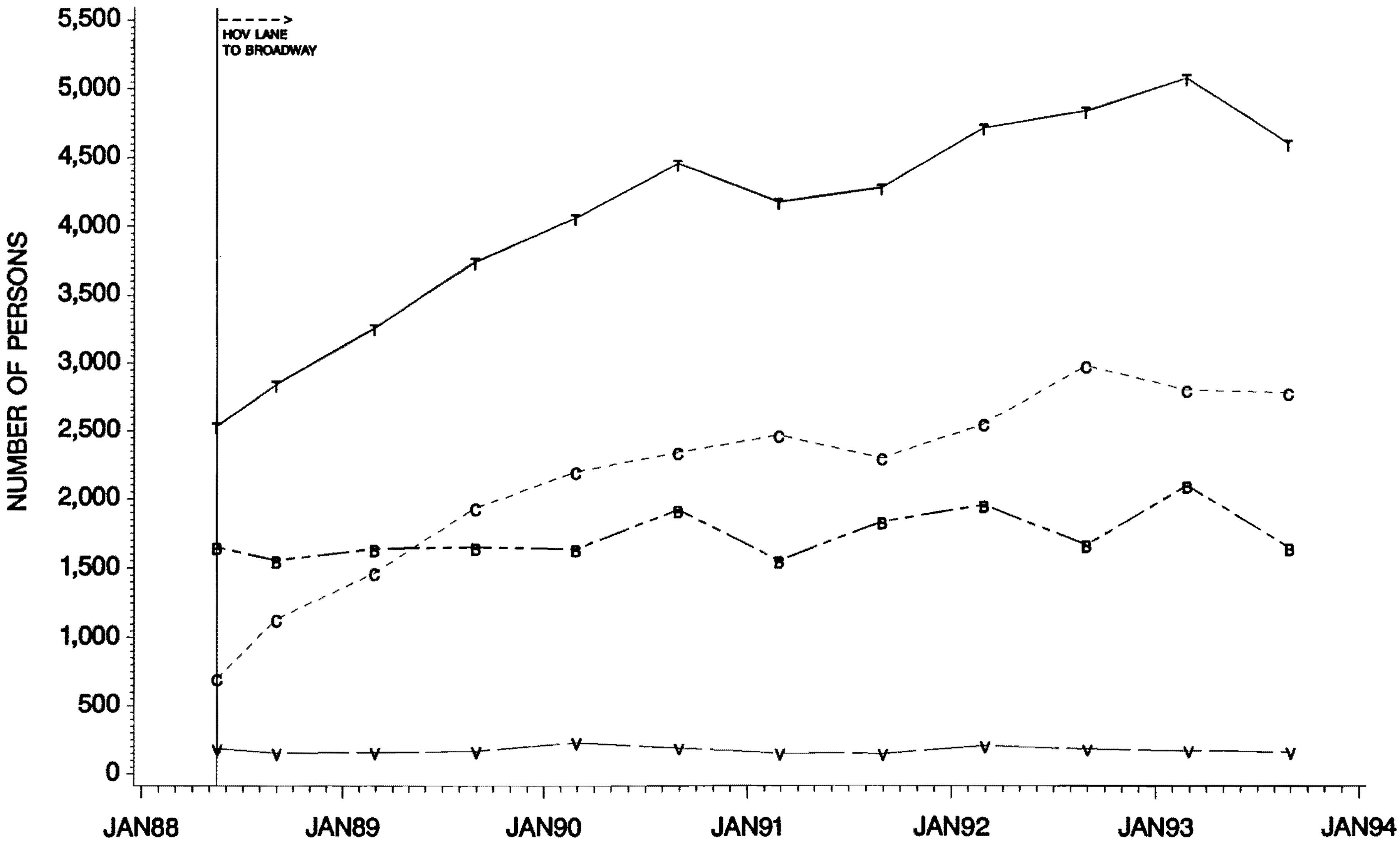
GULF HOV LANE, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988

SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL HOV PASSENGERS
B = TOTAL BUS PASSENGERS
V = TOTAL VANPOOLERS
C = TOTAL CARPOOLERS

FIGURE C-2

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



GULF HOV LANE, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988
PEAK PERIOD IS FROM 6:00 – 9:30 A.M.

SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL HOV PASSENGERS
B = TOTAL BUS PASSENGERS
V = TOTAL VANPOOLERS
C = TOTAL CARPOOLERS

FIGURE C-3

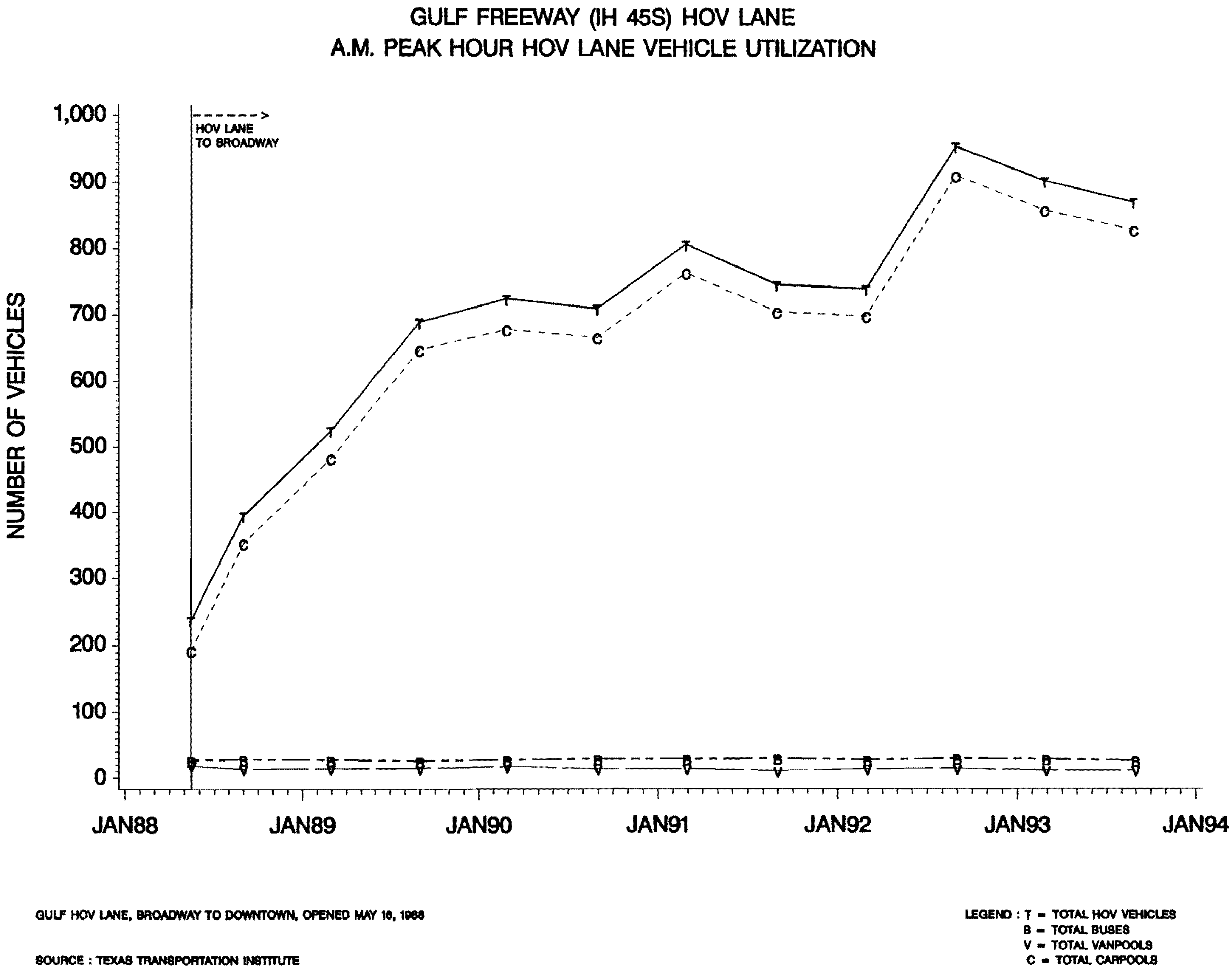
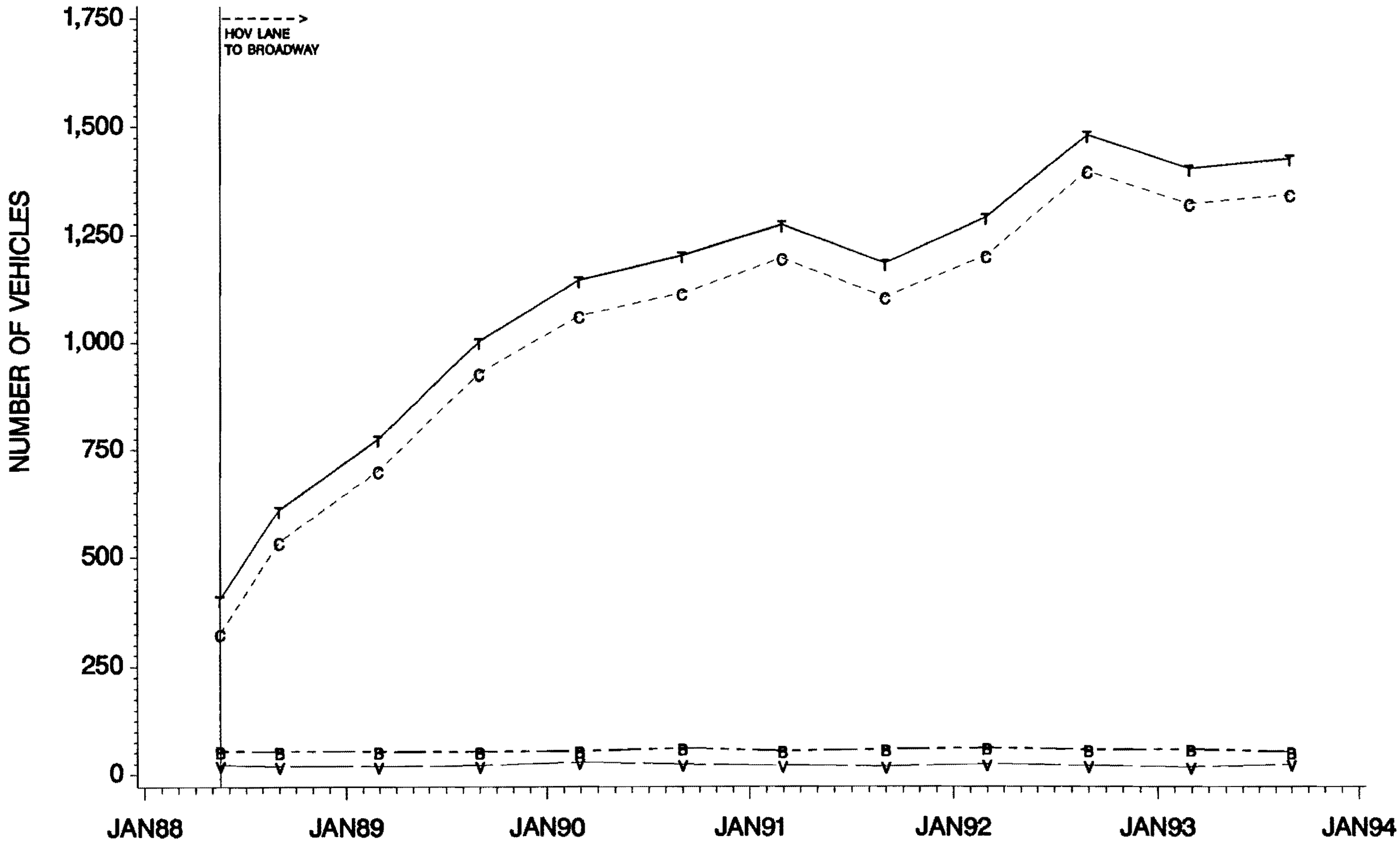

GULF FREEWAY (IH 45S) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION
NUMBER OF VEHICLES
1,000
900
800
700
600
500
400
300
200
100
0
HOV LANE
TO BROADWAY
JAN88
JAN89
JAN90
JAN91
JAN92
JAN93
JAN94
GULF HOV LANE, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988
SOURCE : TEXAS TRANSPORTATION INSTITUTE
LEGEND : T = TOTAL HOV VEHICLES
B = TOTAL BUSES
V = TOTAL VANPOOLS
C = TOTAL CARPOOLS

FIGURE C-4

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



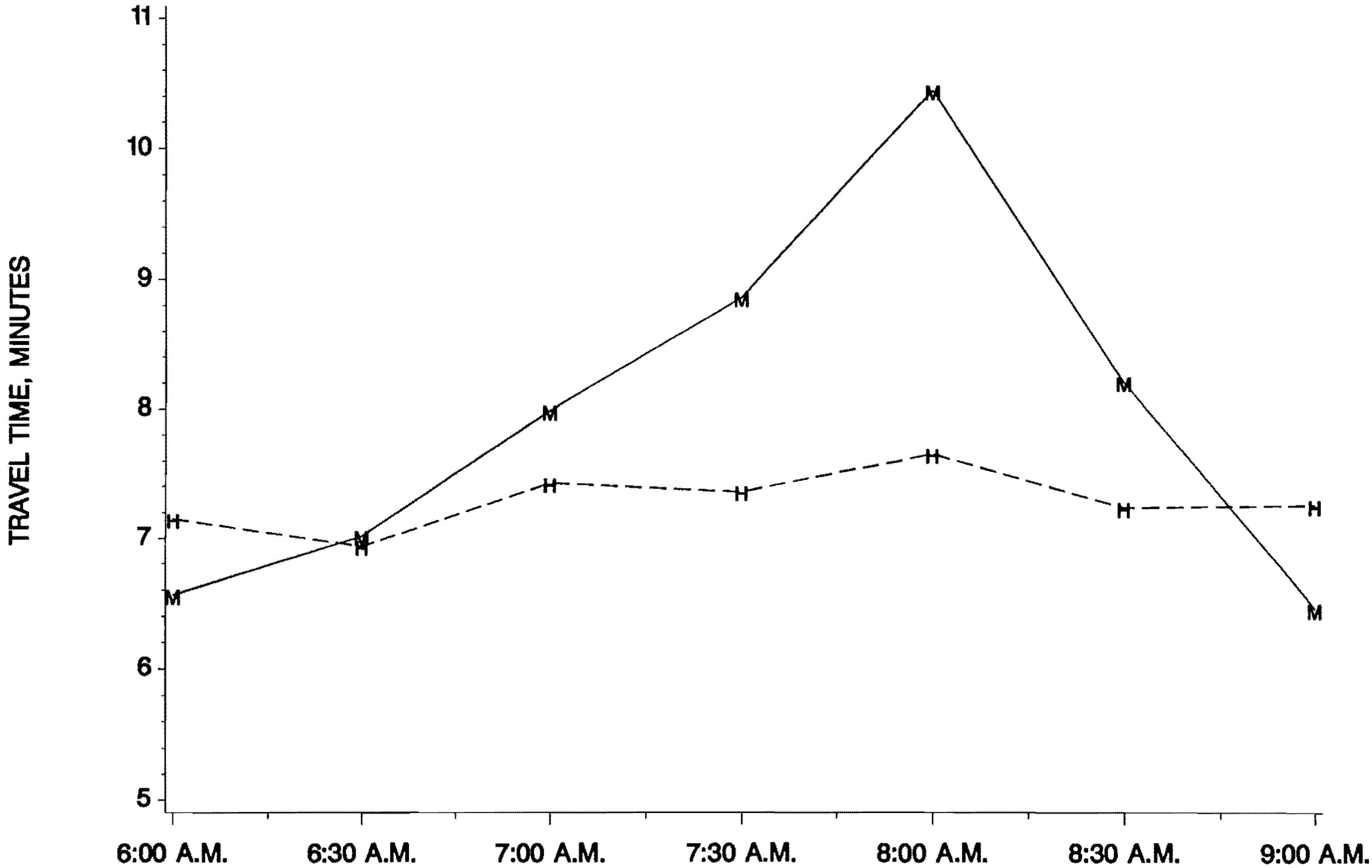
GULF HOV LANE, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988
PEAK PERIOD IS FROM 6:00 – 9:30 A.M.

SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL HOV VEHICLES
B = TOTAL BUSES
V = TOTAL VANPOOLS
C = TOTAL CARPOOLS

FIGURE C-5

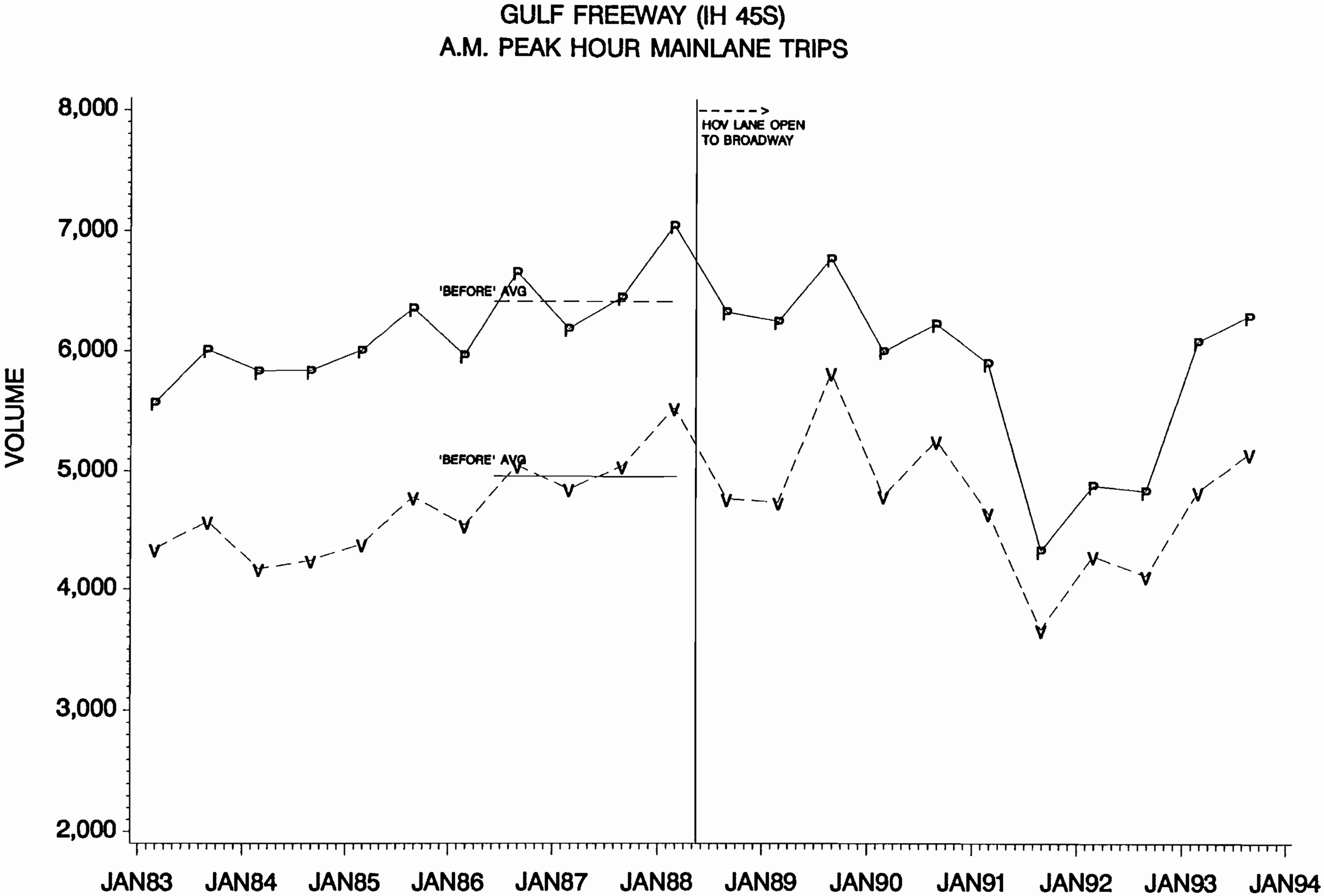
GULF FREEWAY (IH 45S) MAINLANES AND HOV LANE A.M. TRAVEL TIME



TRAVEL TIMES ARE AN AVERAGE OF 4 QUARTERLY TRAVEL TIME SURVEYS CONDUCTED IN 1993
TRAVEL TIMES ARE FROM PARK PLACE TO DOWLING
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : M – MAINLANE TRAVEL TIME
H – HOV LANE TRAVEL TIME

FIGURE C-6



DATA COLLECTED AT MONROE
HOV LANE NOT YET COMPLETED TO MONROE; FREEWAY DATA NOT DIRECTLY COMPARABLE WITH HOV LANE DATA AT THIS TIME
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = MAINLANE PERSONS
V = MAINLANE VEHICLES

FIGURE C-7

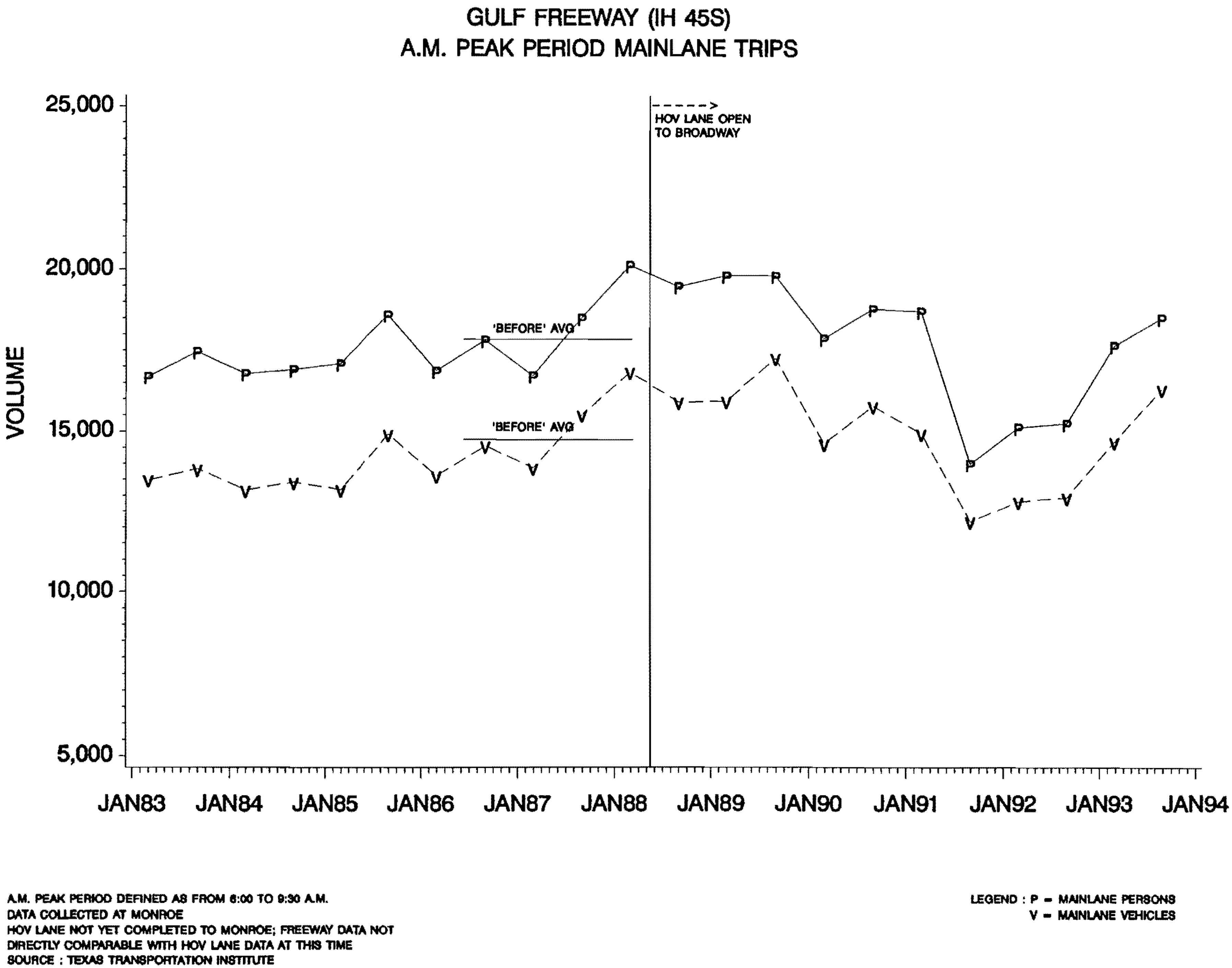
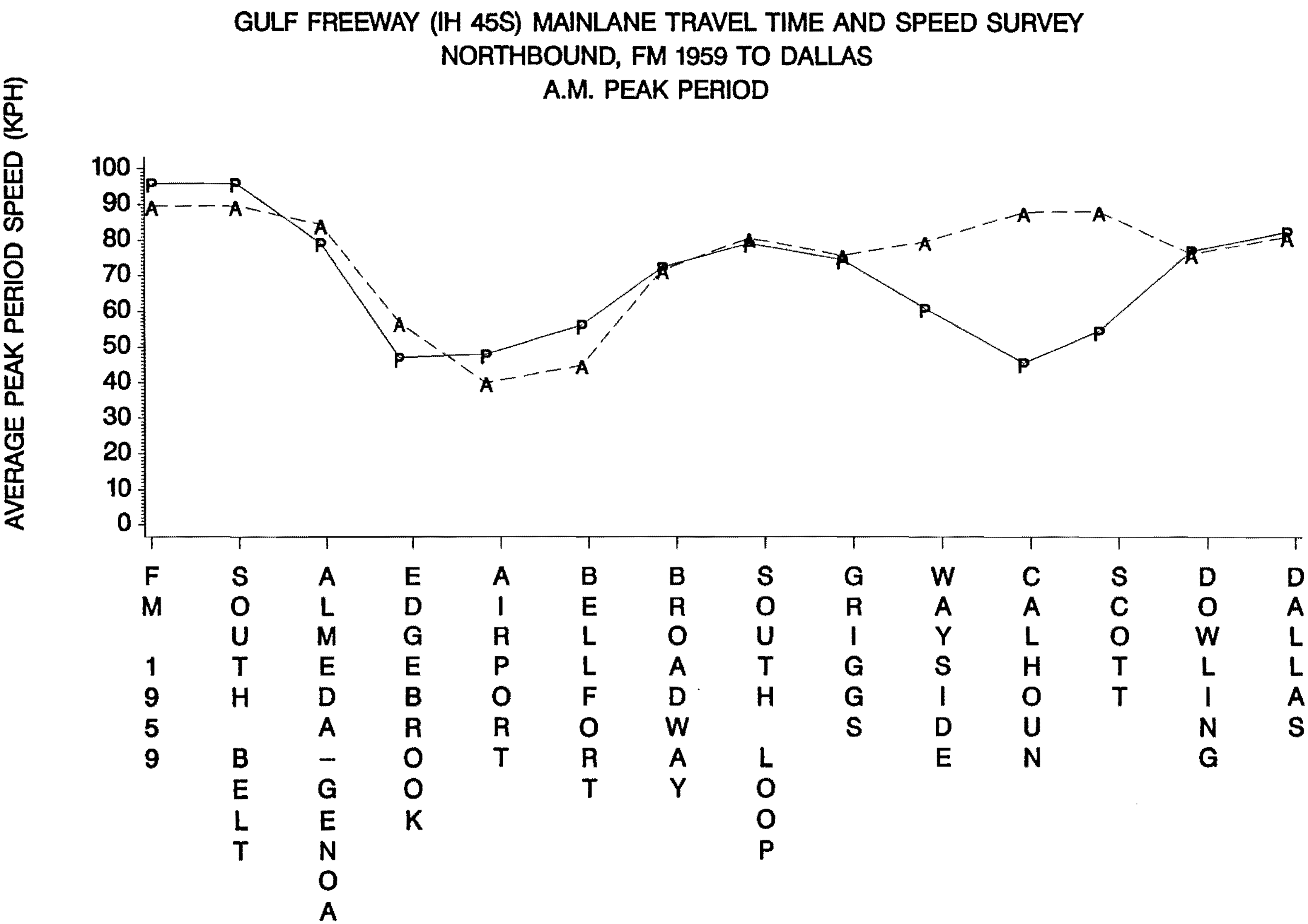

GULF FREEWAY (IH 45S)
A.M. PEAK PERIOD MAINLANE TRIPS
VOLUME
25,000
20,000
15,000
10,000
5,000
HOV LANE OPEN
TO BROADWAY
'BEFORE' AVG
'BEFORE' AVG
JAN83
JAN84
JAN85
JAN86
JAN87
JAN88
JAN89
JAN90
JAN91
JAN92
JAN93
JAN94
A.M. PEAK PERIOD DEFINED AS FROM 6:00 TO 9:30 A.M.
DATA COLLECTED AT MONROE
HOV LANE NOT YET COMPLETED TO MONROE; FREEWAY DATA NOT
DIRECTLY COMPARABLE WITH HOV LANE DATA AT THIS TIME
SOURCE : TEXAS TRANSPORTATION INSTITUTE
LEGEND : P = MAINLANE PERSONS
V = MAINLANE VEHICLES

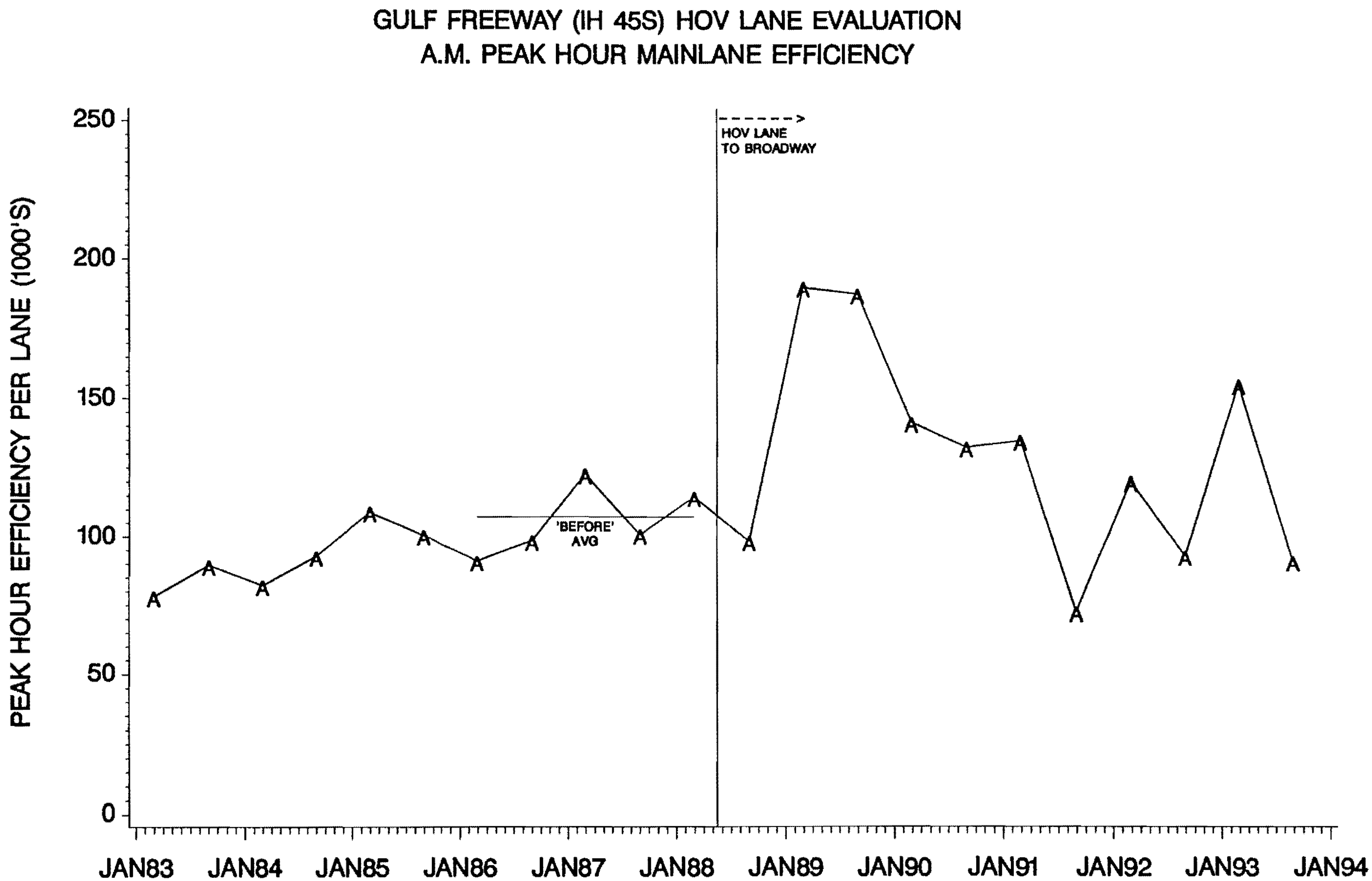
FIGURE C-8



NOTE : TO CONVERT SPEEDS FROM METRIC TO ENGLISH UNITS MULTIPLY KPH BY 0.62
DATA COLLECTED 6:00 TO 9:30 A.M.
DATA COLLECTED FROM JUNE, 1983 TO SEPTEMBER, 1993
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = AVERAGE SPEEDS PRIOR TRANSITWAY OPENED
A = AVERAGE SPEEDS AFTER TRANSITWAY OPENED

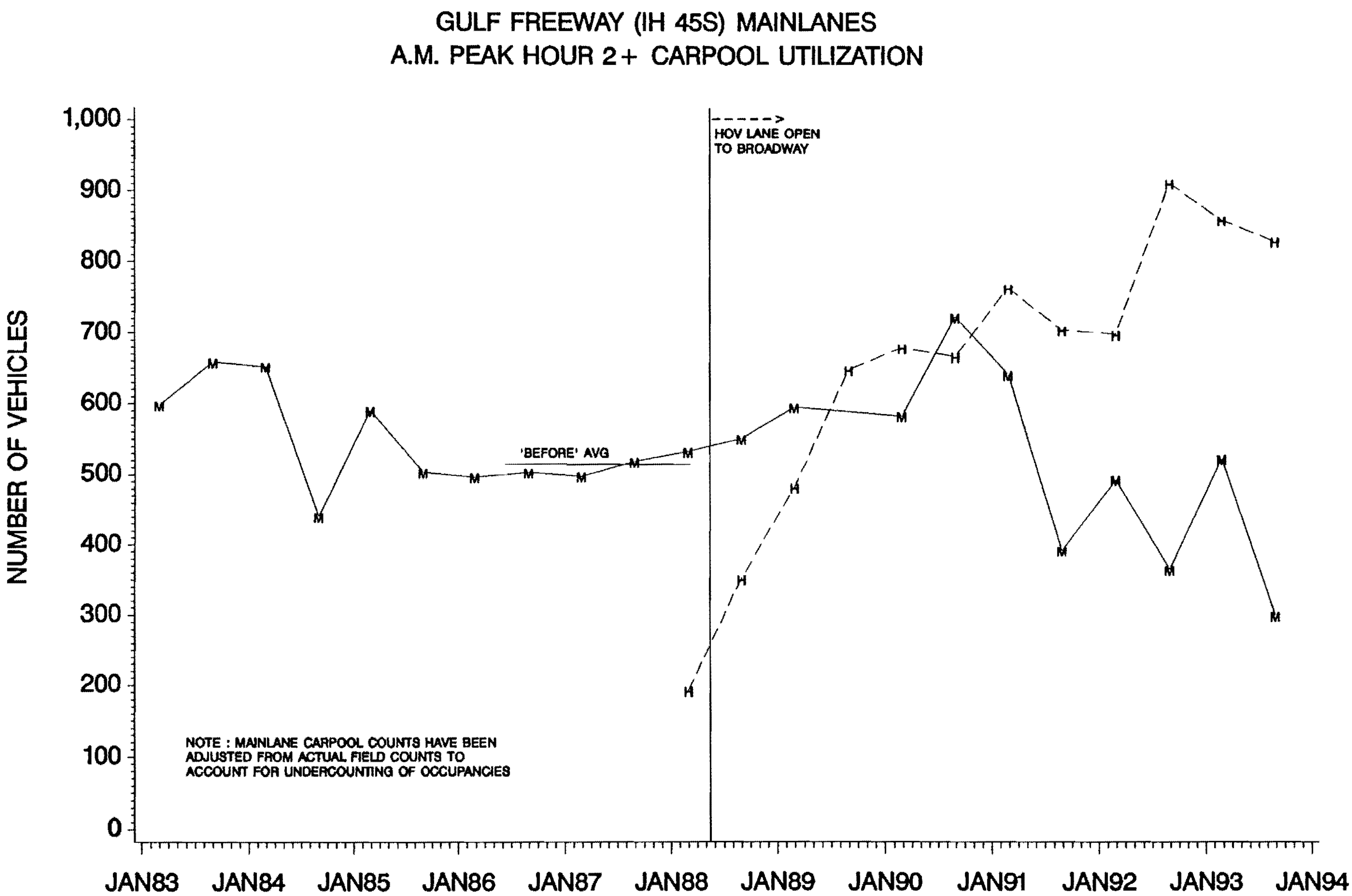
FIGURE C-9



PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE
OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED
DATA COLLECTED AT MONROE
HOV LANE NOT YET COMPLETED TO MONROE; FREEWAY DATA ARE NOT
COMPARABLE WITH HOV LANE DATA AT THIS TIME
TO CONVERT EFFICIENCY FROM METRIC TO ENGLISH UNITS MULTIPLY BY 0.62
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : A = A.M. PEAK HOUR EFFICIENCY

FIGURE C-10

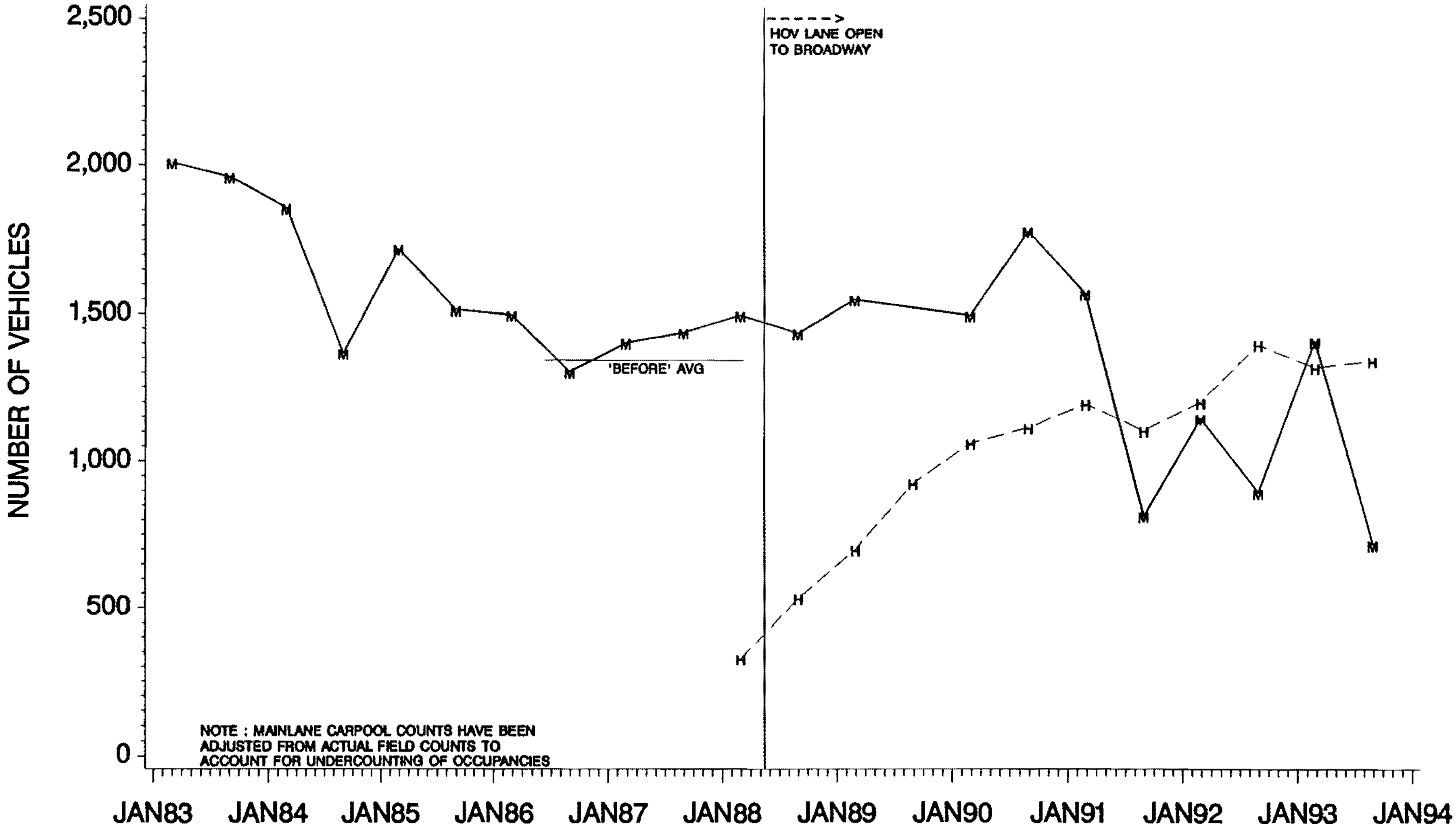


GULF HOV LANE, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988
DATA COLLECTED AT MONROE
HOV LANE NOT YET COMPLETED TO MONROE; FREEWAY DATA ARE NOT DIRECTLY COMPARABLE TO HOV LANE DATA AT THIS TIME
SOURCE : TEXAS TRANSPORTATION INSTITUTE

H = TOTAL HOV LANE 2+ CARPOOLS
M = TOTAL MAINLANE 2+ CARPOOLS

FIGURE C-11

GULF FREEWAY (IH 45S) MAINLANES
A.M. PEAK PERIOD 2+ CARPOOL UTILIZATION

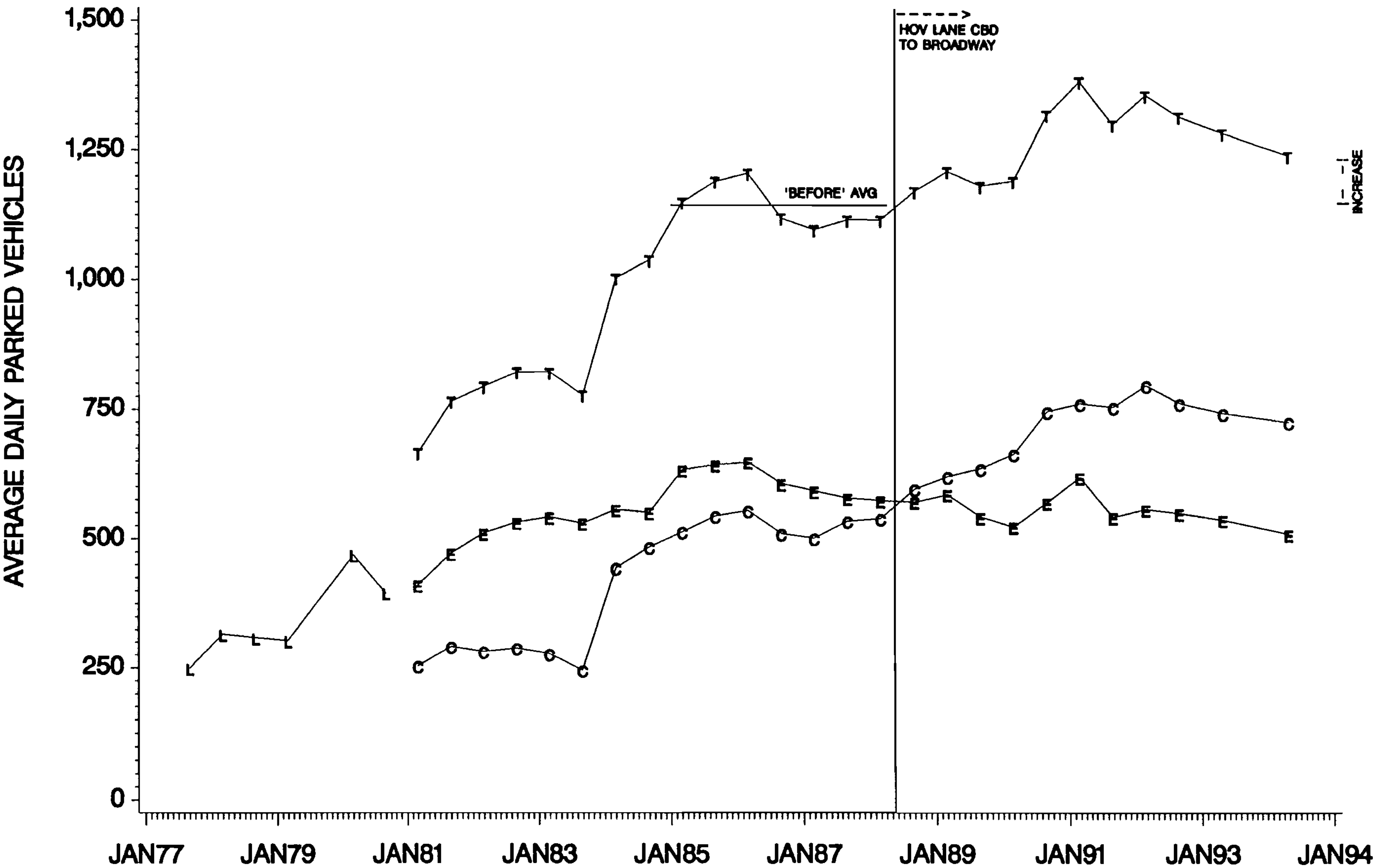


GULF HOV LANE, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988
DATA COLLECTED AT MONROE
HOV LANE NOT YET COMPLETED TO MONROE; FREEWAY DATA ARE NOT
DIRECTLY COMPARABLE TO HOV LANE DATA AT THIS TIME
PEAK PERIOD IS 6:00 – 9:30 A.M.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

H = TOTAL HOV LANE 2+ CARPOOLS
M = TOTAL MAINLANE 2+ CARPOOLS

FIGURE C-12

GULF FREEWAY (IH 45S) CORRIDOR PARK-AND-RIDE DEMAND



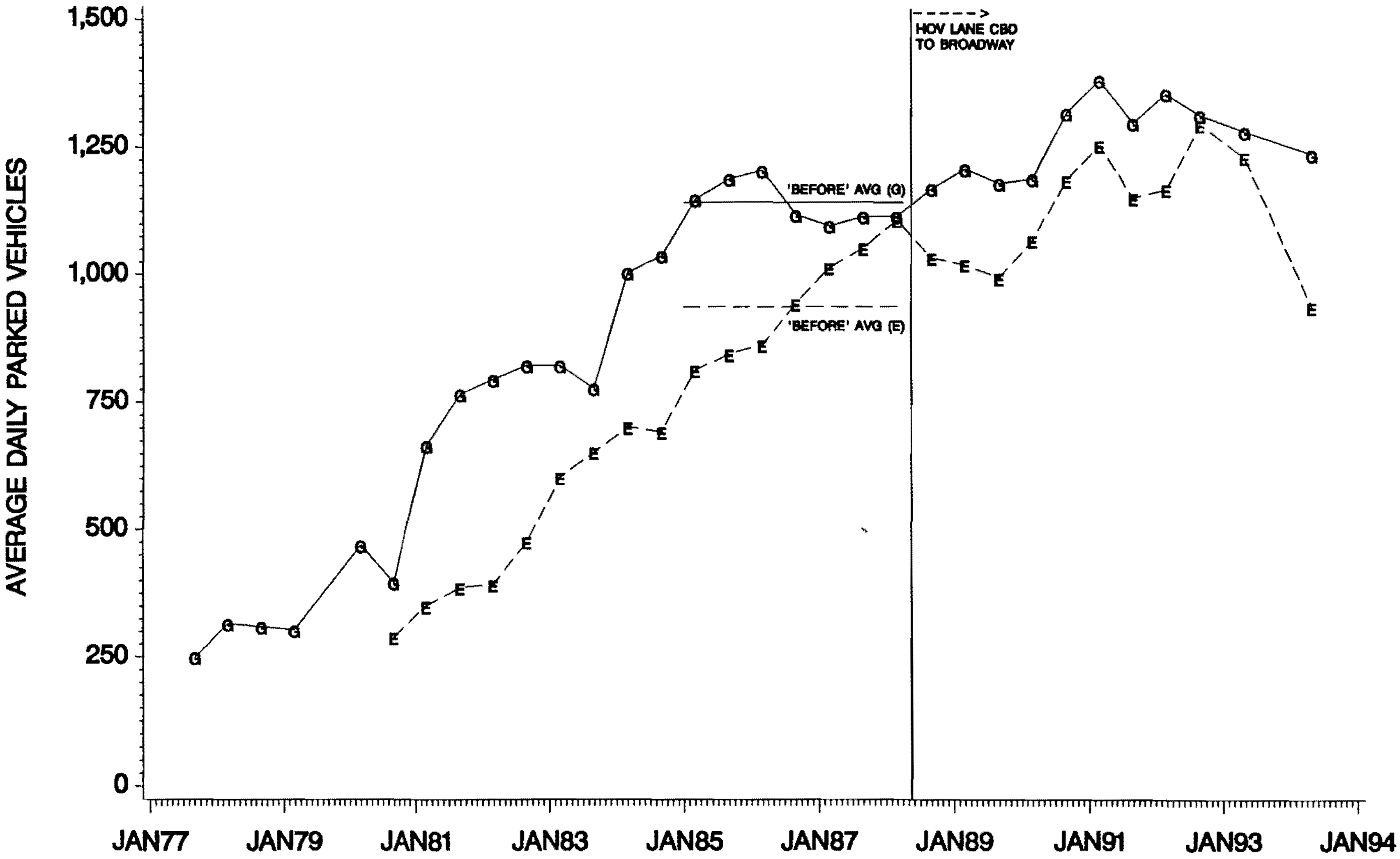
GULF HOV LANE, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988
CURRENT TOTAL CORRIDOR PARKING CAPACITY = 2,164 SPACES

SOURCE : TEXAS TRANSPORTATION INSTITUTE & METRO

LEGEND : T = TOTAL PARKED VEHICLES
E = EDGEBROOK LOT (1,009 SPACES)
C = CLEAR LAKE LOT (1,155 SPACES)
L = LEASED LOTS

FIGURE C-13

AVERAGE DAILY VEHICLES PARKED AT PARK–AND–RIDE LOTS GULF FREEWAY AND FREEWAY WITHOUT HOV LANE



GULF HOV LANE, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988
SOURCE : TEXAS TRANSPORTATION INSTITUTE & METRO

LEGEND : G – GULF FREEWAY
E – FREEWAY WITHOUT HOV LANE (EASTEX)

APPENDIX C

GULF FREEWAY AND HOV LANE DATA

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

Table C-1. Summary of A.M. Peak-Direction Gulf Freeway and HOV Lane Data, December 1993

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)		10.5 (6.5)	
HOV Lane Cost (millions)		$45.0	
Person-Movement			
Peak Hour (7-8 a.m.)	—	2,755	—
Peak Period (6-9:30 a.m.)	—	4,613	—
Total Daily	—	9,628	—
Vehicle Volumes			
Peak Hour	—	872	—
Peak Period	—	1,429	—
Vehicle Occupancy, Peak Hour (persons/veh)	—	3.16	—
Accident Rate (Injury accidents/100 MVK [/100 MVM]) 11/84-12/93[2]	—	6.1 (9.8)	—
Vehicle Breakdowns (VKT/Breakdown [VMT/Breakdown]), 11/84-12/93	—	117,530 (73,000)	—
Violation Rate (6-9:30 a.m.)	—	3.6%	—
Peak Hour Lane Efficiency (1000's)[3]	—	222 (138)	—
Annual Value of User Time Saved (millions)[4]	—	$1.4 to $2.8	—
Freeway Mainlane Data (see note)			
Person Movement			
Peak Hour	6,415	—	—
Peak Period (6-9:30 a.m.)	17,845	—	—
Vehicle Volume			
Peak Hour	4,962	—	—
Peak Period	14,740	—	—
Vehicle Occupancy, Peak Hour (persons/veh)	1.29	—	—
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM])[2]	18.5 (29.8)	13.0 (20.9)	-30%
Avg. Operating Speed[5] (kph [mph])			
Peak Hour	50 (31)	—	—
Peak Period	58 (36)	—	—
Peak Hour Lane Efficiency (1000's)[3]	106 (66)	—	—

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

[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 and/or compare freeway and HOV lane data.

[2]Due to inconsistencies in reporting accidents in Harris County, only injury accidents are included in this analysis. Accidents were analyzed between Broadway and Dowling, a distance of approximately 10.5 kilometers (6.5 miles), which corresponds to Phase 1 of the HOV lane. The pre-HOV lane includes four years of mainlane accident data from 5/16/84 to 5/15/88. The current value is from 5/16/88 to 8/93.

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

[4]Based on time savings for HOV lane users in 1993, an annual estimate of travel time savings to HOV lane users is developed. A value of time of $10.78/hour is used based on the value applied in the Highway Economic Evaluation Model.

[5]From Broadway to Dowling a distance of 10.5 kilometers (6.5 miles).

Table C-1. Summary of A.M. Peak-Direction Gulf Freeway and HOV Lane Data, December 1993 (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	—	—	—
Peak Period	—	—	—
Vehicle Volume			
Peak Hour	—	—	—
Peak Period	—	—	—
Vehicle Occupancy			
Peak Hour	—	—	—
Peak Period	—	—	—
2+ Carpool Volumes			
Peak Hour	475	—	—
Peak Period	1,304	—	—
Travel Time (minutes)[1]			
Peak Hour	9.7[2]	7.5[3]	-23%
Peak Period	8.1[2]	7.3[3]	-10%
Peak Hour Lane Efficiency (1000's)[4]	—	—	—
Transit Data			
Bus Vehicle Trips			
Peak Hour	23[5]	—	—
Peak-Period	40[5]	—	—
Bus Passenger Trips			
Peak Hour	746[5]	—	—
Peak Period	1,230[5]	—	—
Bus Occupancy (persons/bus)			
Peak Hour	32.6[5]	—	—
Peak Period	30.8[5]	—	—
Vehicles Parked in Corridor Park & Ride Lots	1,115	1,247	+12%
Bus Operating Speed (kph [mph])[1]			
Peak Hour	50 (31)[2]	81 (50)[3]	+63%
Peak Period	58 (36)[2]	83 (52)[3]	+42%

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

[1]From Broadway to Dowling, a distance of 10.5 kilometers (6.5 miles).
[2]Data pertain to operation in the freeway mainlanes.
[3]Data pertain to operation in the HOV lane.
[4]This represents the product of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.
[5]Data collected at Monroe.

APPENDIX D

NORTHWEST FREEWAY AND HOV LANE DATA

NORTHWEST FREEWAY (US 290) AND HOV LANE, HOUSTON

Table D-1. Summary of A.M. Peak-Direction Northwest Freeway and HOV Lane Data, December 1993

Type of Data Phase 1 of HOV Lane Became Operational 8/29/88	"Representative" Pre-HOV Lane Value	"Representative" Current Value	Percent Change
HOV Lane Data			
HOV Lane Length (kilometers [miles])		21.7 (13.5)	
HOV Lane Cost (millions)		$99.4	
Person-Movement			
Peak Hour (7-8 a.m.)	—	3,667	—
Peak Period (6-9:30 a.m.)	—	6,482	—
Total Daily	—	13,161	—
Vehicle Volumes			
Peak Hour	—	1,333	—
Peak Period	—	2,358	—
Vehicle Occupancy, Peak Hour (persons/veh)	—	2.75	—
Accident Rate (i.e., Injury accidents/100 MVK [/MVM]), 11/84-12/93[1]	—	8.4 (13.6)	—
Vehicle Breakdowns (VKT/Breakdown [VMT/Breakdown]), 11/84-12/93	—	125,580 (78,000)	—
Violation Rate (6-9:30 a.m.)	—	9.4%	—
Peak Hour Lane Efficiency (1000's)[2]	—	316 (196)	—
Annual Value of User Time Saved (millions)[3]	—	$0.9 to $1.8	—
Freeway Mainlane Data (see note)			
Person Movement			
Peak Hour	6,140	6,043	-2%
Peak Period (6-9:30 a.m.)	17,450	18,106	+4%
Vehicle Volume			
Peak Hour	5,370	5,793	+8%
Peak Period	15,295	17,546	+15%
Vehicle Occupancy, Peak Hour (persons/veh)	1.14	1.04	-9%
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM])[1]	7.3 (11.7)	6.8 (10.9)	-7%
Avg. Operating Speed[4] (kph [mph])			
Peak Hour	45 (28)	50 (31)	+11%
Peak Period	64 (40)	75 (47)	+17%
Peak Hour Lane Efficiency (1000's)[2]	100 (62)	101 (63)	+2%

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

[1]Due to inconsistencies in reporting accidents in Harris County, only injury accidents are included in this analysis. Accidents were analyzed between Little York and IH 610, a distance of approximately 12.4 kilometers (7.7 miles). This corresponds to Phase 1 of the HOV lane. "Before" data are for the period from 1/82 to 8/88. "Current" accident data are for the period 9/88 to 8/93. 1993 freeway volumes were estimated by TTI to compute rates.

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

[3]Based on time savings from HOV lane users in 1993, an annual estimate of travel time savings to HOV lane users is developed. A value of time of $10.78/hour is used based on the value applied in the Highway Economic Evaluation Model.

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

NORTHWEST FREEWAY (US 290) AND HOV LANE, HOUSTON

Table D-1. Summary of A.M. Peak-Direction Northwest Freeway and HOV Lane Data, December 1993 (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	9,710	+58%
Peak Period	17,450	24,588	+41%
Vehicle Volume			
Peak Hour	5,370	7,126	+30%
Peak Period	15,295	19,904	+33%
Vehicle Occupancy			
Peak Hour	1.14	1.36	+19%
Peak Period	1.14	1.24	+9%
2+ Carpool Volumes			
Peak Hour	490	1,502	+207%
Peak Period	1,365	2,684	+97%
Travel Time (minutes)[1]			
Peak Hour	16.2[2]	14.7[3]	-9%
Peak Period	11.4[2]	9.8[3]	-14%
Peak Hour Lane Efficiency (1000's)[4]	100 (62)	155 (96)	+55%
Transit Data			
Bus Vehicle Trips			
Peak Hour	7	20	+186%
Peak-Period	17	44	+159%
Bus Passenger Trips			
Peak Hour	270	938	+247%
Peak Period	605	1,715	+183%
Bus Occupancy (persons/bus)			
Peak Hour	39	47	+21%
Peak Period	36	39	+8%
Vehicles Parked in Corridor Park & Ride Lots	430	1,503	+250%
Bus Operating Speed (kph [mph])[1]			
Peak Hour	47 (29)[2]	86 (54)	+83%
Peak Period	79 (49)[2]	89 (55)	+12%

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

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

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

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

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

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

Measure of Effectiveness	"Representative" Pre-HOV Lane Value	"Representative" 12/93 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	1.21	-2%
A.M. Peak Hour, 2+ Carpool Volume Change			
Freeway w/HOV lane	490	1,502	+207%
Freeway w/o HOV lane	600	531	-12%
Bus Passengers, Peak Period			
Freeway w/HOV lane	605	1,715	+183%
Freeway w/o HOV lane	1,188	775	-35%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	430	1,503	+250%
Freeway w/o HOV lane	1,236	942	-24%
Facility Per Lane Efficiency[2]			
Freeway w/HOV lane	100 (62)	155 (96)	+55%
Freeway w/o HOV lane	138 (86)	126 (78)	-8%

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

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

HOV LANE DATA

DESCRIPTION

- Phase 1 (15.3 kilometers [9.5 miles]) of the HOV lane opened August 29, 1988.
- The HOV lane is now complete with 21.7 kilometers (13.5 miles) in operation.
- The capital cost (including all support facilities) for the completed facility in 1990 dollars was $98.1 million. A more detailed cost breakdown including dates is provided on the following page.
- Selected milestone dates are listed below. Other dates are shown in the capital cost table.
  - 8/29/88 Northwest Transit Center to Little York opens (15.3 kilometers [9.5 miles])
  - 2/6/90 HOV extended to FM 1960 (21.7 kilometers [13.5 miles])
  - 4/1/90 Northwest Transit Center opens
  - 10/6/90 Weekend HOV operation begins
  - 10/5/91 Weekend HOV operation ends
  - 9/8/92 Motorcycles allowed on HOV facility (no occupancy restrictions)

PERSON MOVEMENT

- In December 1993, 13,161 person trips per day were served on the HOV lane.
- A.M. peak hour, 3,667 persons/hour.
  - 938 (26%) by bus, 81 (2%) by vanpool, and 2,948 (72%) by carpool (Figure D-1).
  - Average HOV lane vehicle occupancy = 2.75 persons/vehicle.
- A.M. peak period, 6,482 persons.
  - 1,715 (27%) by bus, 134 (2%) by vanpool, and 4,633 (71%) by carpool (Figure D-2).

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

Cost Component	Year of Construction Cost		Factor	Estimated Cost 1990 Dollars	
HOV Lane and Ramps					
Design (1988)		$4.6	0.98		$4.5
FM 1960 to FM 529 (1990)		2.6	1.00		$2.6
FM 529 to Little York (1990)		2.7	1.00		$2.7
Phase 2A, N.W. Station Ramp (1990)		3.7	1.00		$3.7
Phase 2B, W. Little York Ramp (1988)		2.1	0.98		$2.1
W. Little York to N.W. Transit Center (1988)		46.0	0.98		$45.1
Project Management (1988)		1.0	0.98		1.0
SUB-TOTAL	$62.7			$62.0	
Per Kilometer (Mile)		$2.9 ($4.6)			$2.9 ($4.6)
Surveillance, Communication & Control (1990)		$2.9	1.00		$2.9
SUB-TOTAL	$2.9			$2.9	
Per Kilometer (Mile)		$0.1 ($0.2)			$0.1 ($0.2)
Support Facilities					
W. Little York P/R (1988)		$7.1	0.98		$7.0
Pinemont P/R (1989)		9.5	0.98		9.3
1/2 Northwest Transit Center (1990)		10.6	1.00		10.6
N.W. Station P/R (1984)		4.0	0.93		3.7
N.W. Station P/R Modification (1990)		1.4	1.00		1.4
N.W. Station P/R 2nd Expansion (1993)		1.2	1.00		1.2
SUB-TOTAL	$33.8			$33.2	
Per Kilometer (Mile)		$1.6 ($2.5)			$1.5 ($2.4)
TOTAL COST	$99.4			$98.1	
COST PER KILOMETER (21.7 kilometers [13.5 miles])	$4.6 ($7.4)			$4.5 ($7.3)	

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

VEHICLE MOVEMENT

- A.M. peak hour, 1,333 vph
  - 938 (70%) buses, 81 (6%) vans, and 314 (24%) carpools (Figure D-3).

- A.M. peak period, 2,358 vehicles.
  - 44 (2%) buses, 17 (1%) vans, and 2,297 (97%) carpools (Figure D-4).

ACCIDENT RATE

- For the period 8/88 through 12/93, the HOV lane accident rate was 8.4 accidents per 100 million vehicle kilometers (13.6 accidents per 100 million vehicle miles).

VEHICLE BREAKDOWN RATES

- As measured from September 1, 1988 through December 1993, the following rate has been observed.
  - The weighted average for all vehicle types is 1 breakdown per 125,580 VKT (78,000 VMT). Bus breakdowns occurred once every 41,400 VKT, while cars broke down once every 77,800 VKT.

VIOLATION RATE

- The observed violation rate (vehicles on the HOV lane not eligible to use the HOV lane) is approximately 9.4%.

PEAK HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. For the HOV lane, this value (expressed in 1000's) is approximately 316 (3,667 passengers x 86 kph) or 196 (3,667 passengers x 54 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane experience an average travel time savings of 4 minutes in the a.m. peak hour (Figure D-5).
- The tables on the following page indicate that, on a typical non-incident day, travel time savings of approximately 19,720 minutes, or 329 hours, are realized. Assuming 250 days of operation and a value of time of $10.78/hour, this equates to $885,738 per year. This is extremely conservative since it does not consider travel time savings due to incidents on the freeway. Data from Houston suggest increasing this value by 100% to account for incidents would be reasonable. Thus, travel time savings to HOV lane users are estimated to be in the range of $885,738 to $1.77 million per year.

Table D-4. Southbound A.M. Travel Time Savings for Northwest HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1993)

Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section from Eldridge to Senate								
6:00	2.94	3.12	-0.18	373	22	160	555	-101
6:30	3.11	3.01	0.10	854	45	358	1,256	126
7:00	2.93	3.14	-0.21	1,257	22	360	1,638	-343
7:30	3.08	2.99	0.09	916	0	282	1,197	103
8:00	2.94	3.07	-0.13	409	4	170	583	-75
8:30	3.12	2.97	0.15	146	0	17	162	24
9:00	2.96	3.12	-0.16	69	0	0	69	-11
Peak Period Total				4,023	93	1,346	5,461	-277
Section From Senate to S.P. Railroad								
6:00	12.52	15.08	-2.56	125	7	42	173	-442
6:30	18.27	14.57	3.70	635	46	213	893	3,304
7:00	18.38	16.25	2.13	1,192	59	390	1,641	3,495
7:30	21.03	14.81	6.22	1,311	7	430	1,748	10,872
8:00	14.61	14.51	0.10	637	7	193	837	81
8:30	13.02	14.19	-1.17	261	0	33	295	-343
9:00	12.28	14.61	-2.33	64	0	0	64	-150
Peak Period Total				4,224	125	1,301	5,651	16,817
Northbound P.M. Travel Time Savings for Northwest HOV Lane								
Section from Senate to Eldridge								
3:30	3.01	3.11	-0.10	82	5	20	107	-11
4:00	3.12	3.11	0.01	219	15	82	316	4
4:30	2.91	3.06	-0.15	435	51	182	668	-98
5:00	3.20	3.42	-0.22	753	86	350	1,189	-262
5:30	3.14	3.08	0.06	993	30	248	1,271	76
6:00	3.22	3.05	0.17	661	11	173	845	141
6:30	2.99	3.17	-0.18	334	6	59	399	-71
Peak Period Total				3,477	204	1,114	4,795	-221

Table D-4. Southbound A.M. Travel Time Savings for Northwest HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1993) (continued)

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	12.18	14.04	-1.86	104	2	27	133	-245
4:00	12.65	14.22	-1.57	253	12	100	365	-571
4:30	12.74	14.22	-1.48	649	47	330	1,027	-1,517
5:00	16.19	15.43	0.76	1,065	44	446	1,555	1,179
5:30	20.06	15.29	4.77	1,053	15	284	1,352	6,448
6:00	12.83	14.92	-2.09	600	3	165	768	-1,607
6:30	13.32	14.25	-0.93	219	0	110	329	-305
Peak Period Total				3,942	123	1,462	5,528	3,382

FREEWAY DATA

NOTE

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

PERSON MOVEMENT

- In the a.m. peak hour, compared to pre-HOV conditions, person movement has decreased by 2% (Figure D-6).

- In the a.m. peak period, compared to pre-HOV conditions, person movement has increased by 4% (Figure D-7).

VEHICLE VOLUME

- In the a.m. peak hour, vehicle volume has increased by 8% (Figure D-6).

- In the a.m. peak period, vehicle volume has increased by 15% (Figure D-7).

VEHICLE OCCUPANCY

- In the a.m. peak hour, compared to pre-HOV conditions, mainlane occupancy has declined by 9% (Figure D-11).

- In the a.m. peak period, compared to pre-HOV conditions, mainlane occupancy has declined by 7% (Figure D-12).

ACCIDENT RATE

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

- For the section between Little York and I-610, the accident rate for the period (1/82-8/88) preceding the opening of the HOV lane was 7.3 accidents per 100 million vehicle kilometers (100 MVK) (11.7 accidents per 100 million vehicle miles [100 MVM]). The accident data available for the period (9/88-8/93) after the HOV lane opened indicate an accident rate of 6.8 accidents/100 MVK (10.9 accidents/100 MVM). 1993 freeway volumes estimated by TTI were used to compute rates.

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 D-8 show the average of all travel time runs made both before and after the HOV lane opened for the a.m. peak period.

PEAK HOUR LANE EFFICIENCY

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

- For the freeway mainlanes, increased travel speeds have resulted in an increase in per lane efficiency of 11%.

COMBINED FREEWAY AND HOV LANE DATA

TOTAL PERSON MOVEMENT

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

- At Pinemont, the HOV lane is responsible for 38% of peak-hour person movement (HOV lane = 3,667; freeway = 6,043) and 26% of peak-period (HOV lane = 6,482; freeway = 18,106) person movement (Figure D-10).

- Increase in a.m. person movement at Pinemont

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

  - Total peak-hour person movement has increased by 58%, from 6,140 to 9,710 (Figure D-9). Peak-period person movement has increased by 41%, from 17,450 to 24,588 (Figure D-10).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.36, a 19% increase over the pre-HOV lane occupancy (Figure D-11). Occupancy in the peak period is 9% 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 remained relatively constant (Figure D-13).

CARPOOL VOLUMES

- In the a.m. peak hour, the total number of 2+ carpools (freeway plus HOV lane) has increased by 207% compared to pre-HOV lane levels (Figure D-14). In the a.m. peak period, the increase has been 97% (Figure D-15). These increases have not been experienced on freeways not having HOV lanes (Figure D-16).

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 55% since the implementation of the HOV lane (Figure D-17). Currently, no discernable trend in efficiency is evident when the Northwest Freeway is compared with freeways that have no HOV lane (Figure D-18).

BUS TRANSIT DATA

BUS VEHICLE AND PASSENGERS TRIPS

- In the a.m. peak hour, bus vehicle trips have been increased by 186% since the HOV lane opened, and a 247% increase in bus ridership has resulted (Figure D-19). In the peak period, a 159% increase has occurred in bus vehicle trips, and a 183% increase in bus ridership has resulted (Figure D-20).

- While bus passenger trips have increased in the Northwest Freeway corridor, in the corridors which do not have HOV lanes, bus passenger trips have remained fairly constant (Figure D-21).

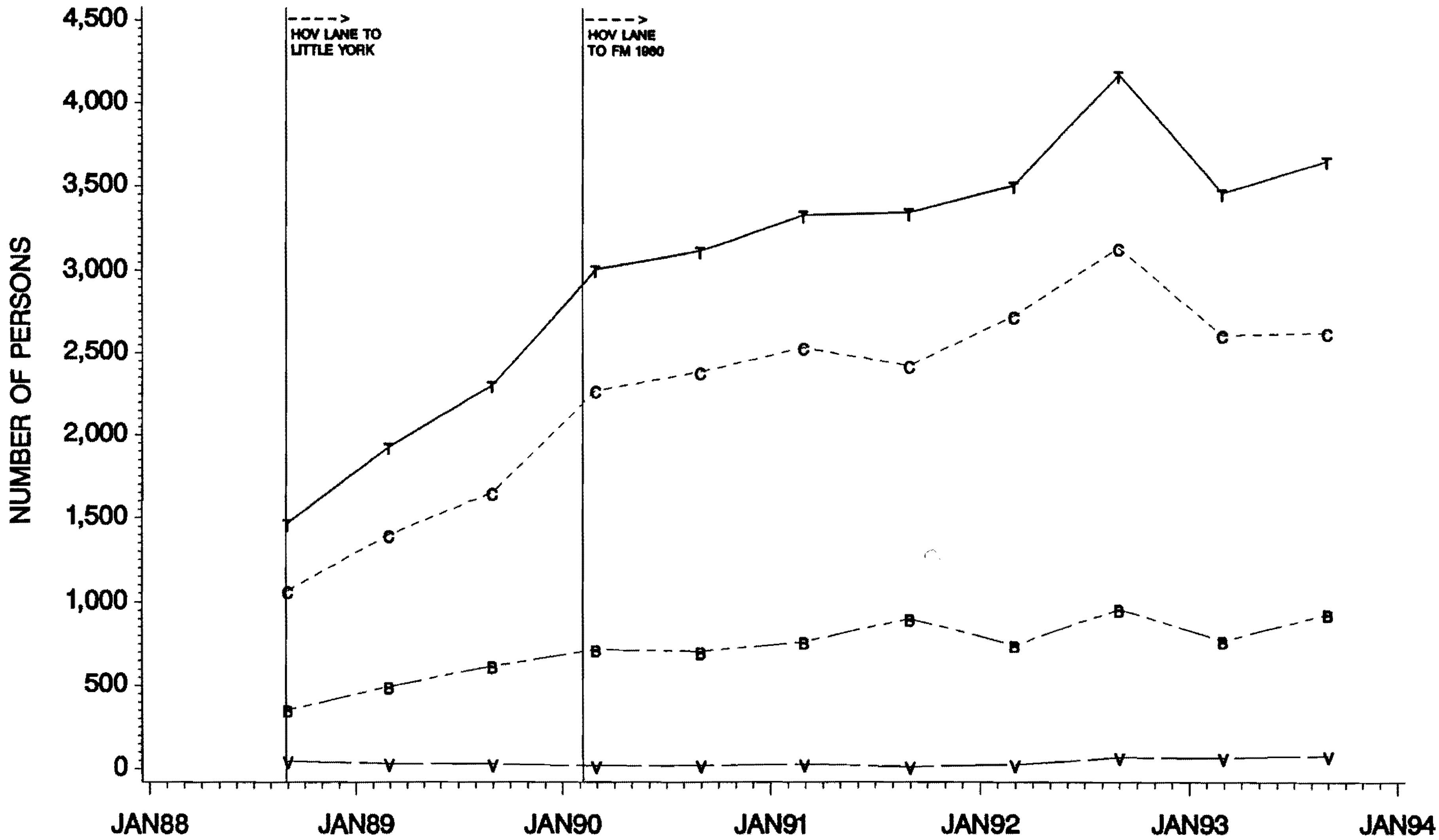
PARK-AND-RIDE

- Prior to opening the HOV lane, approximately 430 vehicles were parked in corridor park-and-ride lots. This has increased 250% to a current level of 1,503 (Figure D-22).

- 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-23).

FIGURE D-1

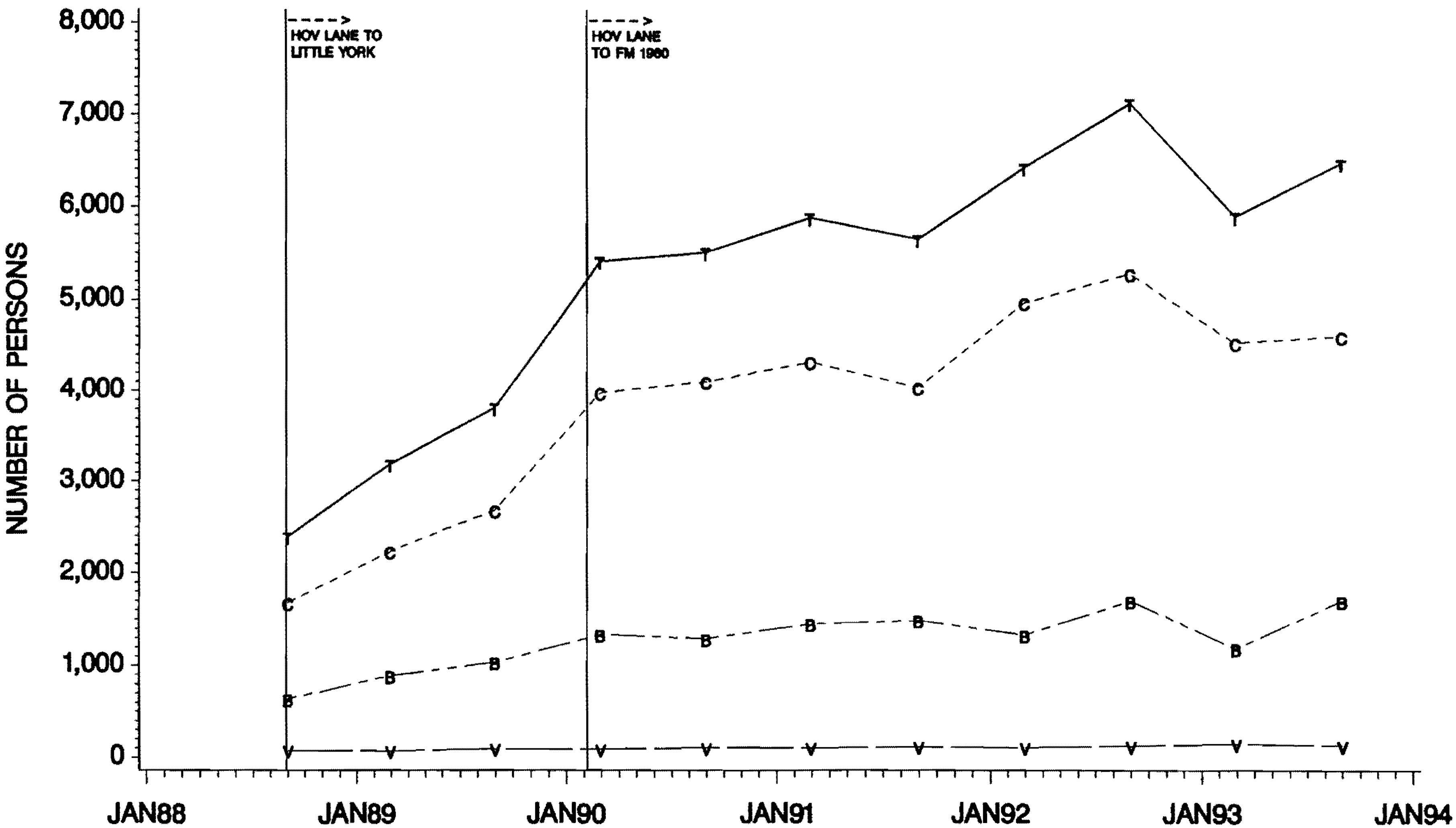
NORTHWEST FREEWAY (U.S. 290) HOV LANE
A.M. PEAK HOUR HOV LANE PERSON MOVEMENT



NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (15.30 KM [9.5 MI]), OPENED AUGUST 29, 1988
NORTHWEST HOV LANE PHASE 2, LITTLE YORK TO FM 1960 (3.9 MI.), OPENED FEBRUARY 6, 1990
DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

FIGURE D-2

NORTHWEST FREEWAY (U.S. 290) HOV LANE
A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT

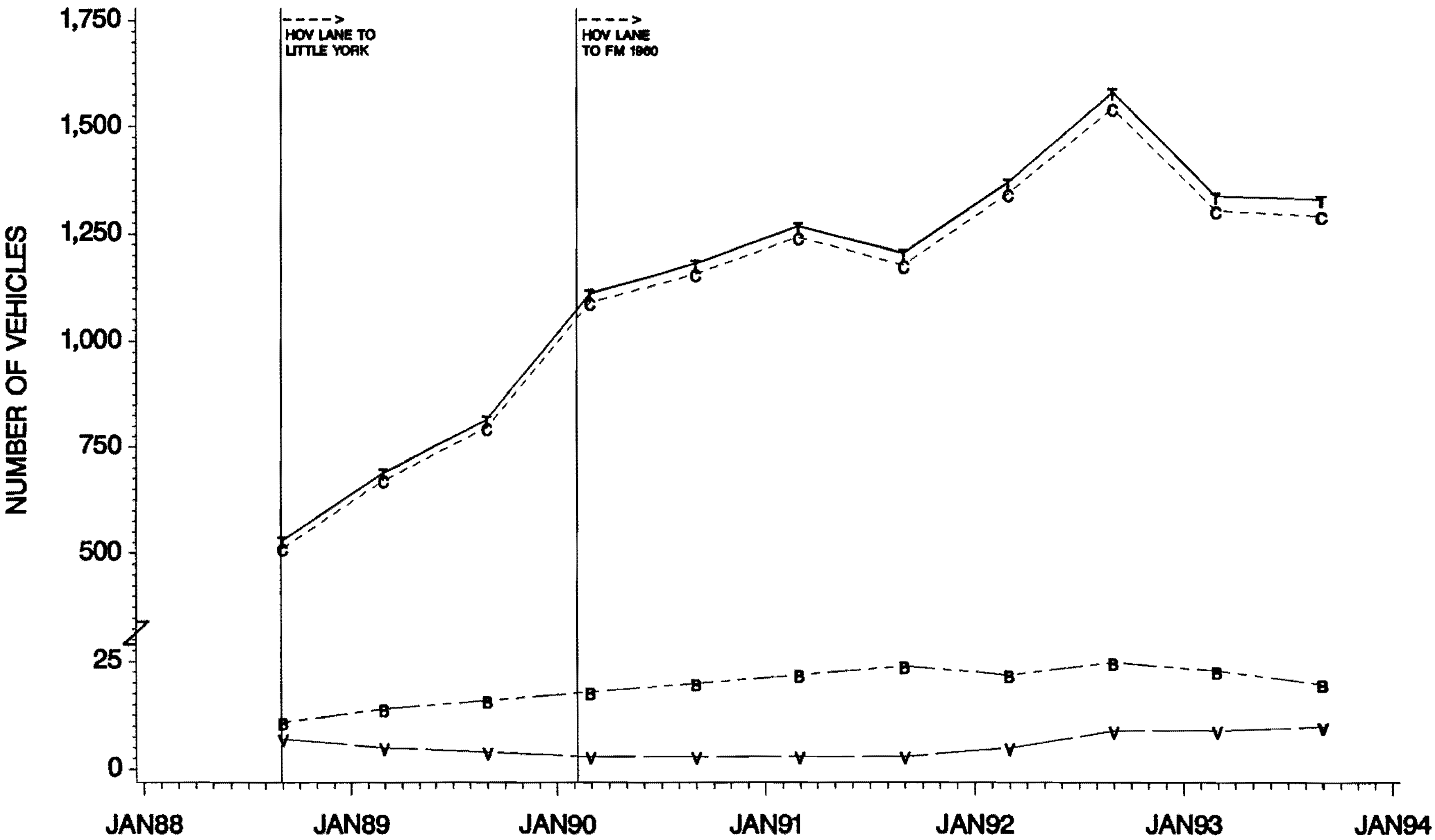


NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER TO
LITTLE YORK (15.30 KM [9.5 MI]), OPENED AUGUST 29, 1988
NORTHWEST HOV LANE PHASE 2, LITTLE YORK TO FM 1960 (8.9 ML), OPENED FEBRUARY 6, 1990
PEAK PERIOD IS 6:00 – 9:30 A.M.
DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL HOV PASSENGERS
B = TOTAL BUS PASSENGERS
V = TOTAL VANPOOLERS
C = TOTAL CARPOOLERS

FIGURE D-3

NORTHWEST FREEWAY (U.S. 290) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION

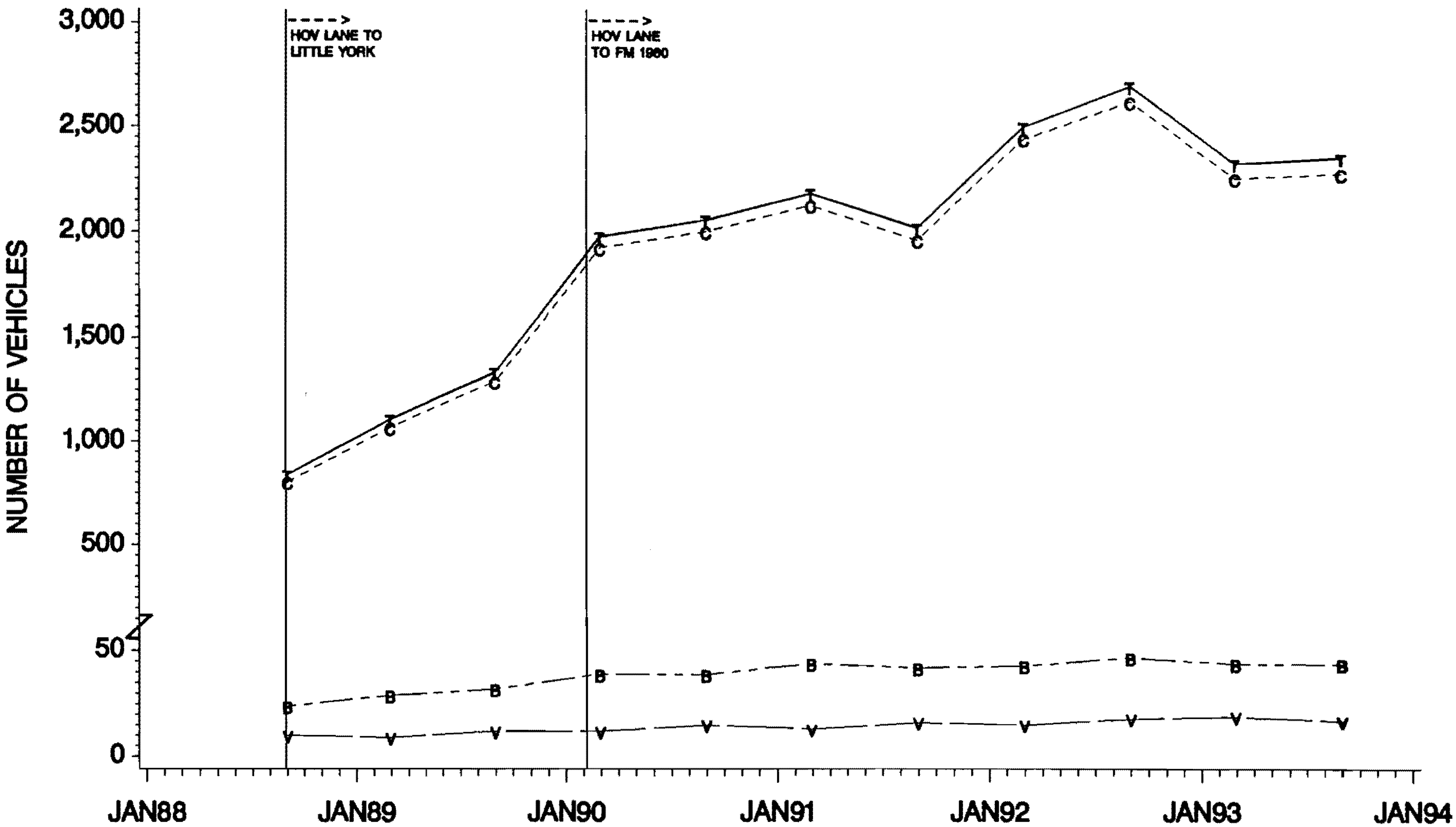


NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER TO
LITTLE YORK (15.30 KM (9.5 MI)), OPENED AUGUST 29,1988
NORTHWEST HOV LANE PHASE 2, LITTLE YORK TO FM 1960 (3.9 ML), OPENED FEBRUARY 6, 1990
DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL HOV VEHICLES
B = TOTAL BUSES
V = TOTAL VANPOOLS
C = TOTAL CARPOOLS

FIGURE D-4

NORTHWEST FREEWAY (U.S. 290) HOV LANE
A.M. PEAK PERIOD HOV LANE VEHICLE UTILIZATION

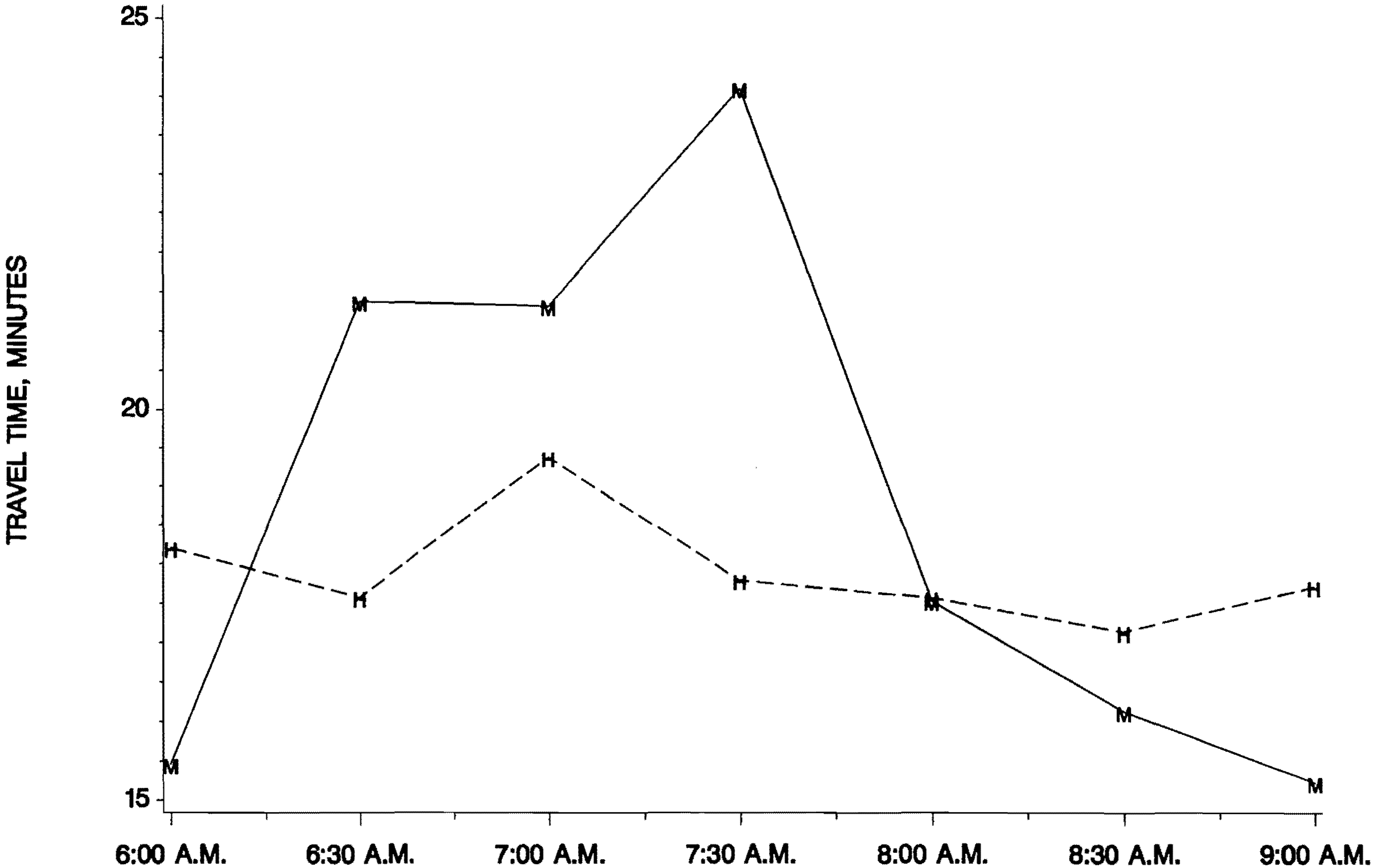


NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER TO
LITTLE YORK (15.30 KM [9.5 MI]), OPENED AUGUST 29, 1988
NORTHWEST HOV LANE PHASE 2, LITTLE YORK TO FM 1960 (8.9 MI.), OPENED FEBRUARY 6, 1990
PEAK PERIOD IS 6:00 – 9:30 A.M.
DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL HOV VEHICLES
B = TOTAL BUSES
V = TOTAL VANPOOLS
C = TOTAL CARPOOLS

FIGURE D-5

NORTHWEST FREEWAY (U.S. 290) MAINLANES AND HOV LANE A.M. TRAVEL TIME

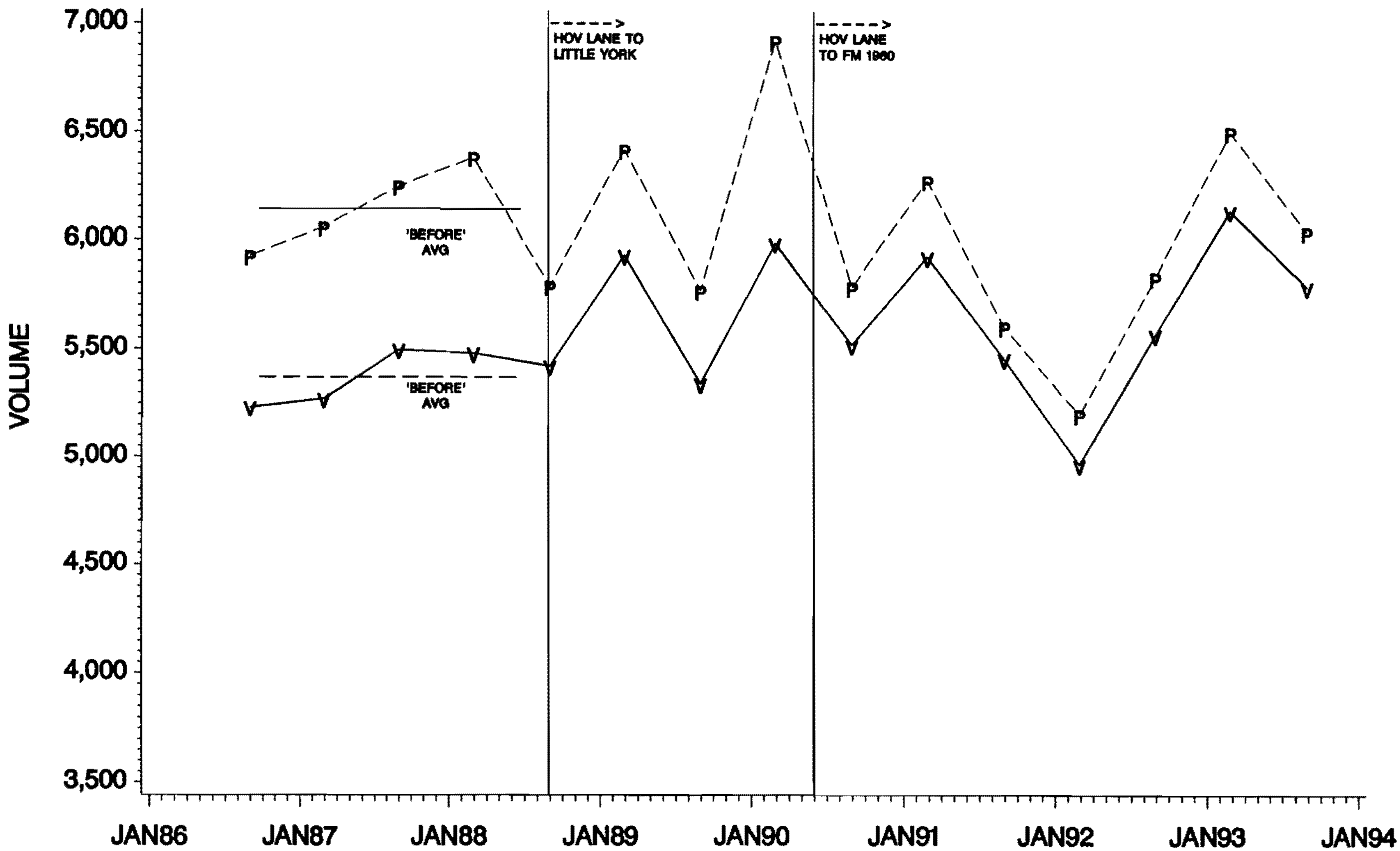


TRAVEL TIMES ARE AN AVERAGE OF 4 QUARTERLY TRAVEL TIME SURVEYS CONDUCTED IN 1993
TRAVEL TIMES ARE FROM ELDRIDGE TO S.P.R.R. @ KATY FREEWAY
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : M – MAINLANE TRAVEL TIME
H – HOV LANE TRAVEL TIME

FIGURE D-6

NORTHWEST FREEWAY (U.S. 290)
A.M. PEAK HOUR MAINLANE TRIPS

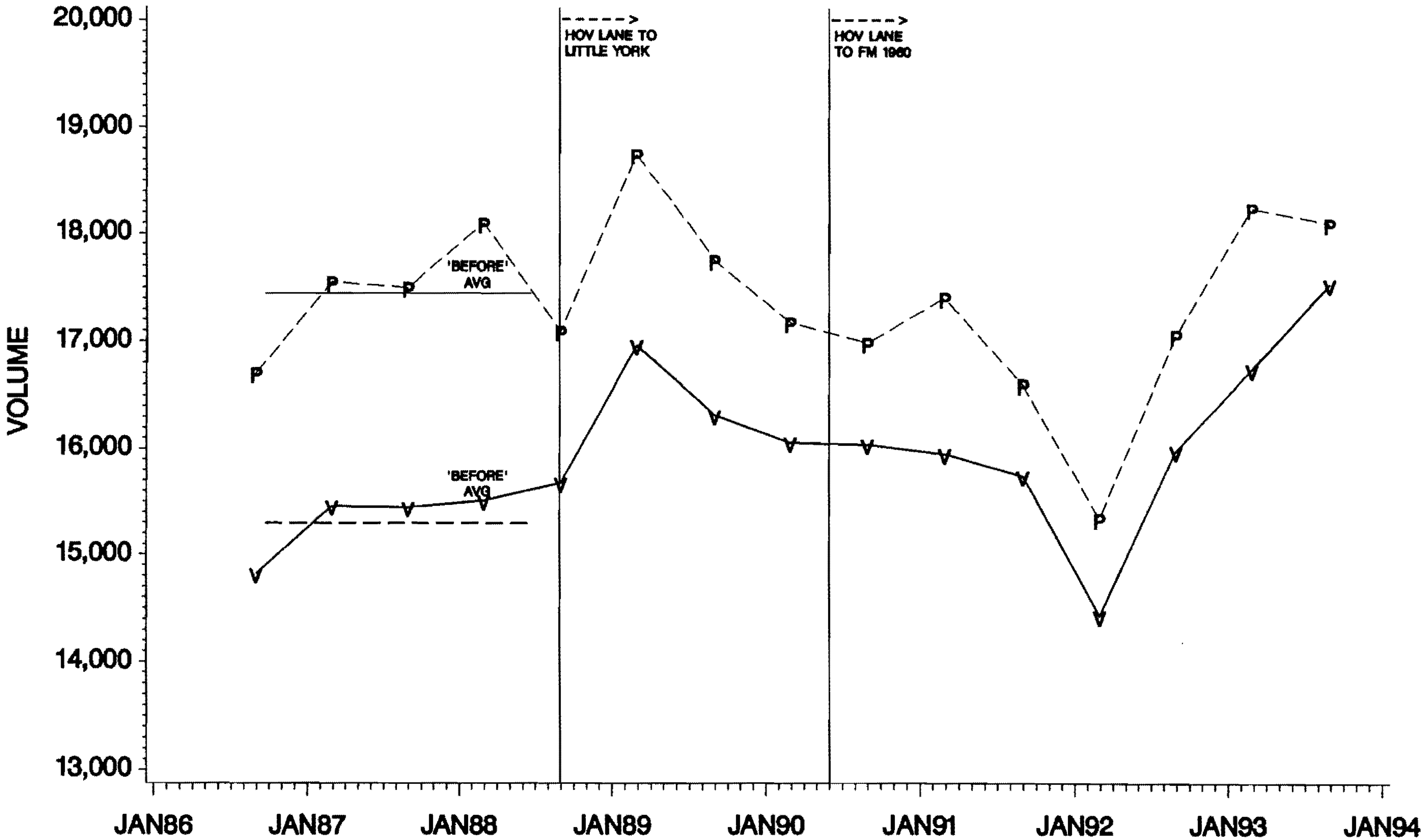


NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (15.30 KM [9.5 MI]), OPENED AUGUST 29, 1988
NORTHWEST HOV LANE PHASE 2, LITTLE YORK TO FM 1960 (6.28 KM [3.9 MI]), OPENED FEBRUARY 6, 1990
DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : V = TOTAL VEHICLE TRIPS
P = TOTAL PERSON TRIPS

FIGURE D-7

NORTHWEST FREEWAY (U.S. 290)
A.M. PEAK PERIOD MAINLANE TRIPS

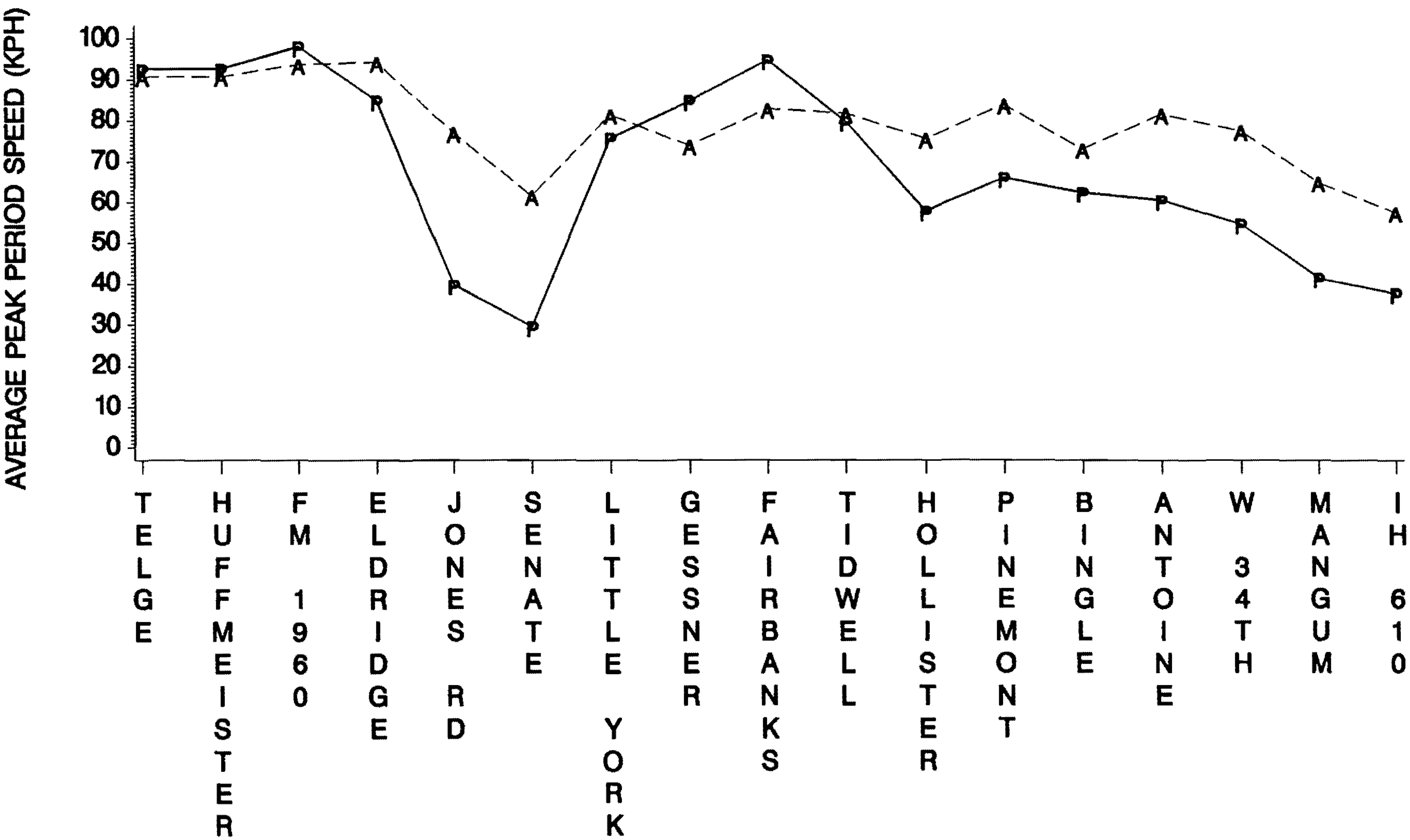


NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (15.30 KM [9.5 MI]), OPENED AUGUST 29, 1988
NORTHWEST HOV LANE PHASE 2, LITTLE YORK TO FM 1960 (6.28 KM [3.9 MI]), OPENED FEBRUARY 6, 1990
PEAK PERIOD IS 6:00 TO 9:30 A.M.
DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : V = TOTAL VEHICLE TRIPS
P = TOTAL PERSON TRIPS

FIGURE D-8

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

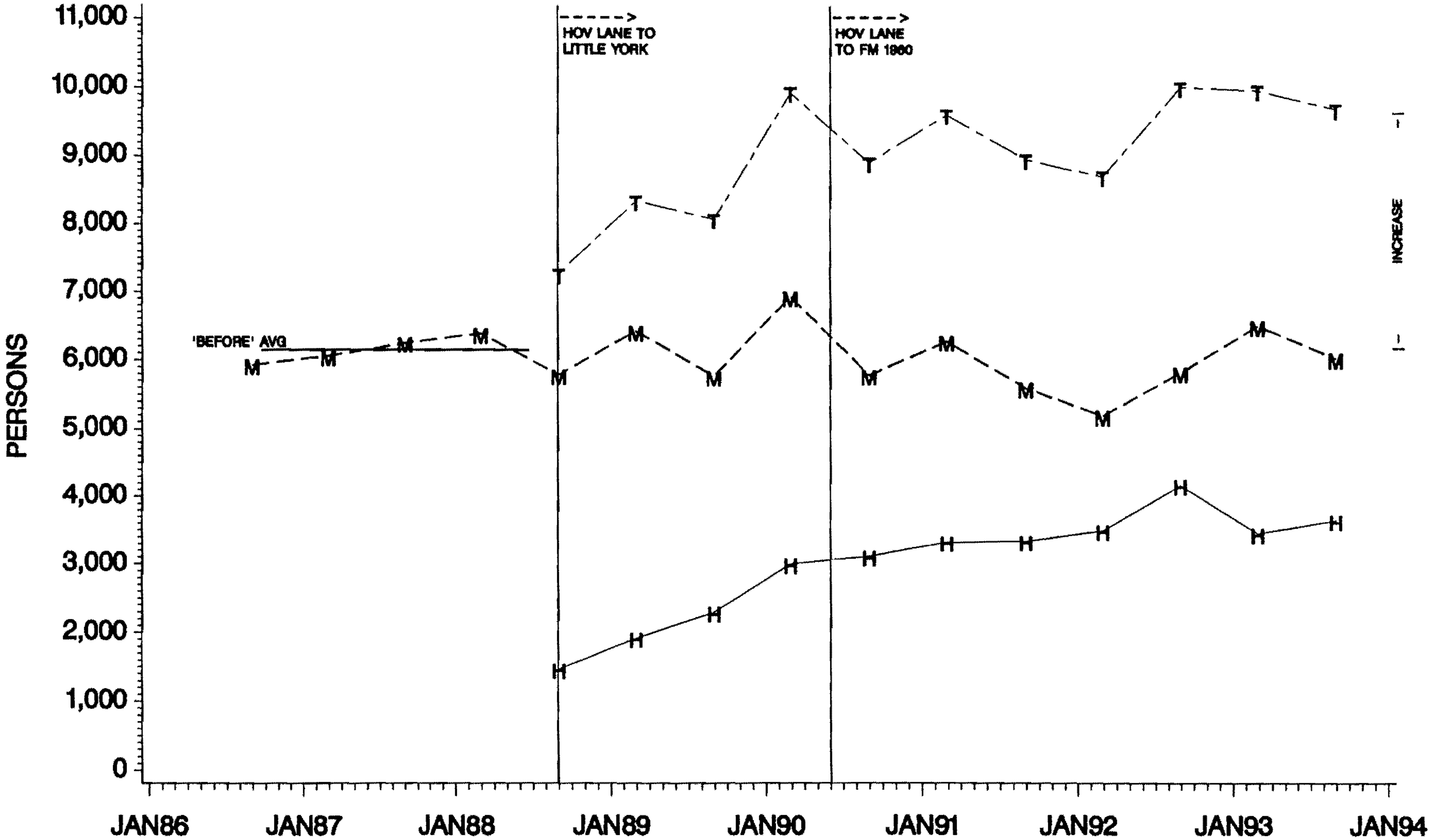


NOTE : TO CONVERT SPEEDS FROM METRIC TO ENGLISH UNITS MULTIPLY KPH BY 0.62
DATA COLLECTED 6:00 TO 9:30 A.M.
DATA COLLECTED FROM SEPTEMBER, 1986 TO SEPTEMBER, 1993
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = AVERAGE SPEED PRIOR TO OPENING HOV LANE
A = AVERAGE SPEED SINCE HOV LANE OPENED

FIGURE D-9

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



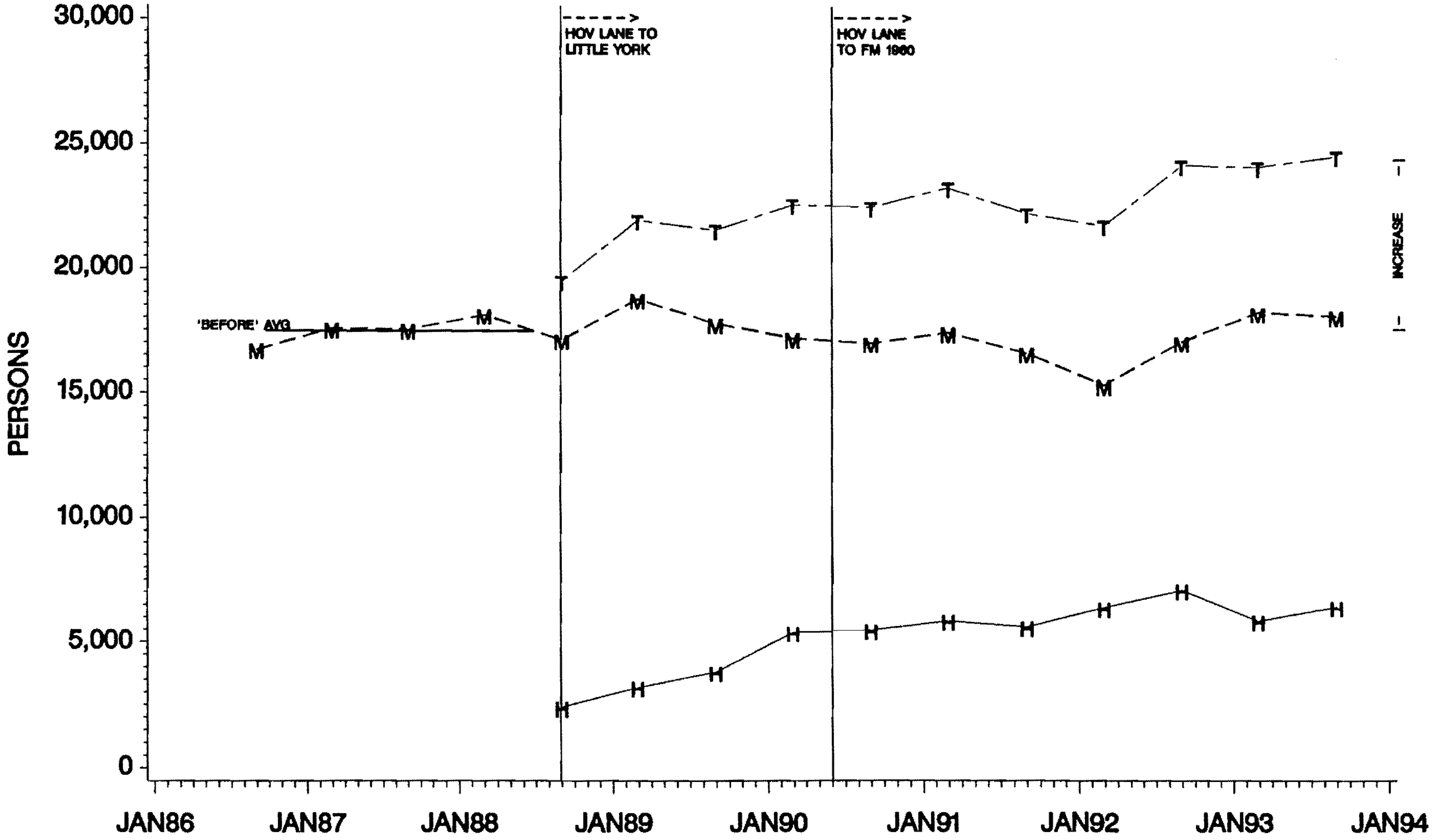
NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (15.30 KM [9.5 MI]), OPENED AUGUST 29, 1988
NORTHWEST HOV LANE PHASE 2, LITTLE YORK TO FM 1960 (6.28 KM [3.9 MI]), OPENED FEBRUARY 6, 1990
DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION

SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = TOTAL PERSONS
M = MAINLANE PERSONS
H = HOV LANE PERSONS

FIGURE D-10

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

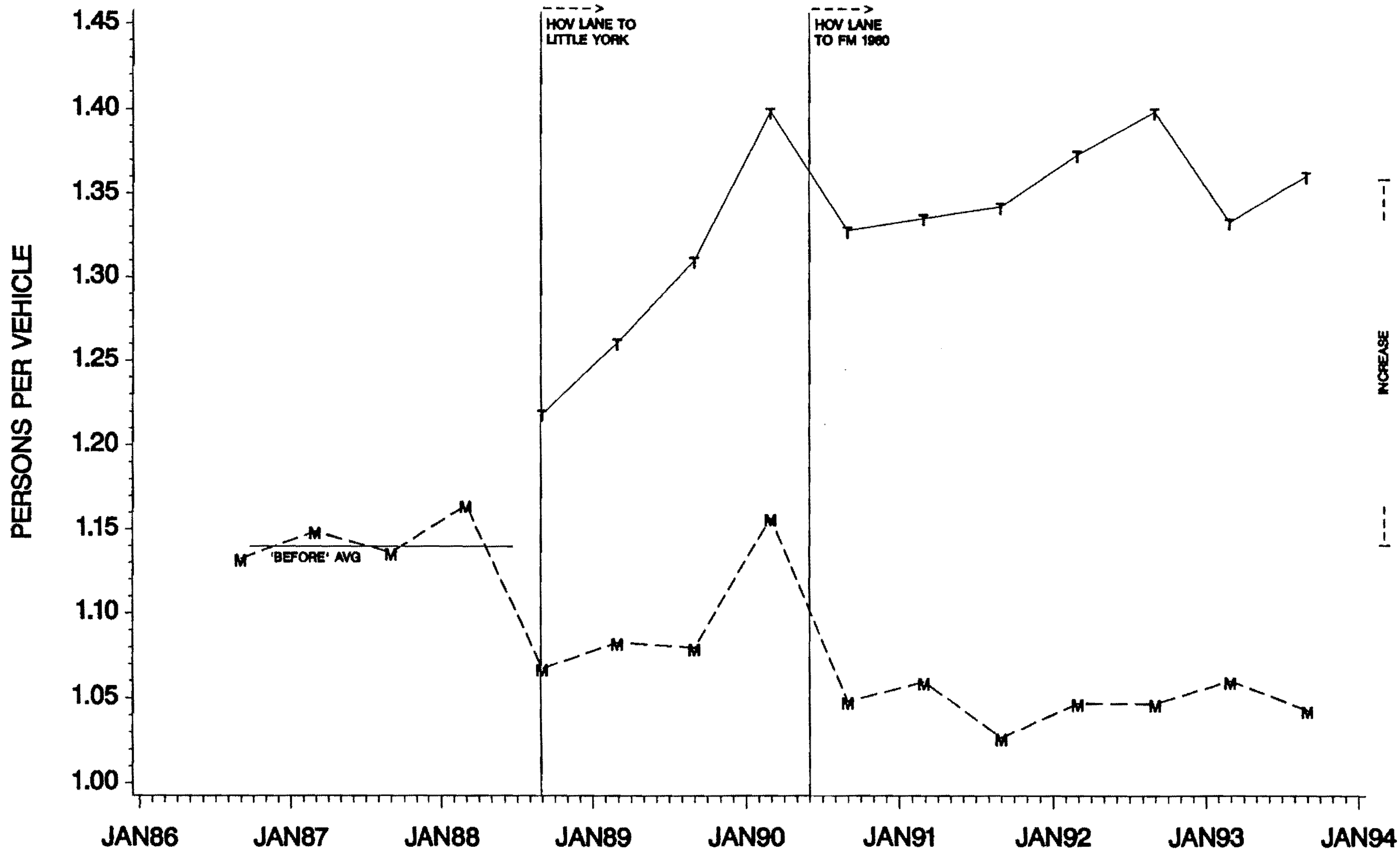


NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (15.30 KM [9.5 MI]), OPENED AUGUST 29, 1988
NORTHWEST HOV LANE PHASE 2, LITTLE YORK TO FM 1960 (6.28 KM [3.9 MI]), OPENED FEBRUARY 6, 1990
DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION
PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = TOTAL PERSONS
M = MAINLANE PERSONS
H = HOV LANE PERSONS

FIGURE D-11

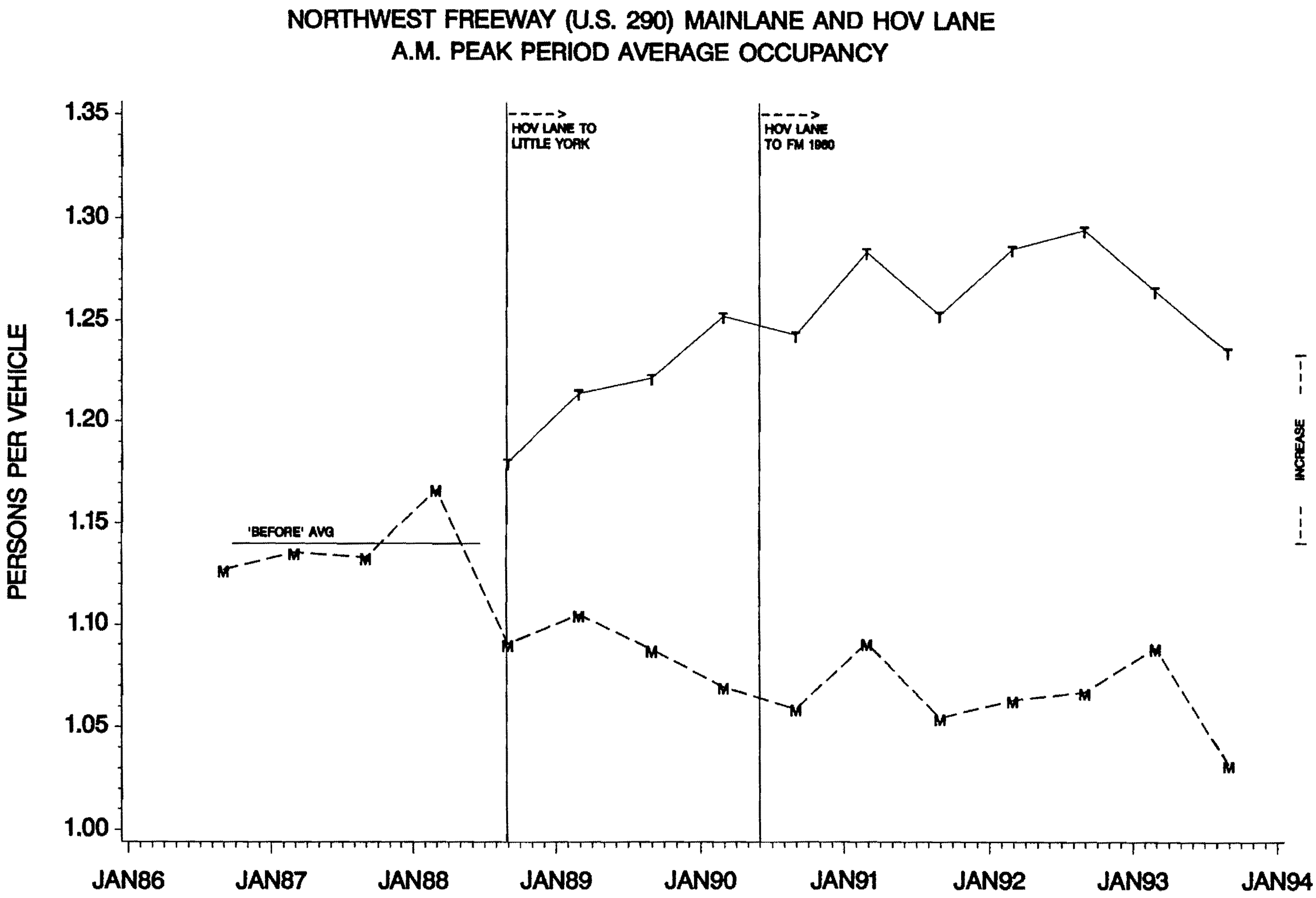
NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE A.M. PEAK HOUR AVERAGE OCCUPANCY



DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : M = MAINLANE OCCUPANCY
T = TOTAL OCCUPANCY (FREEWAY PLUS HOV LANE)

FIGURE D-12

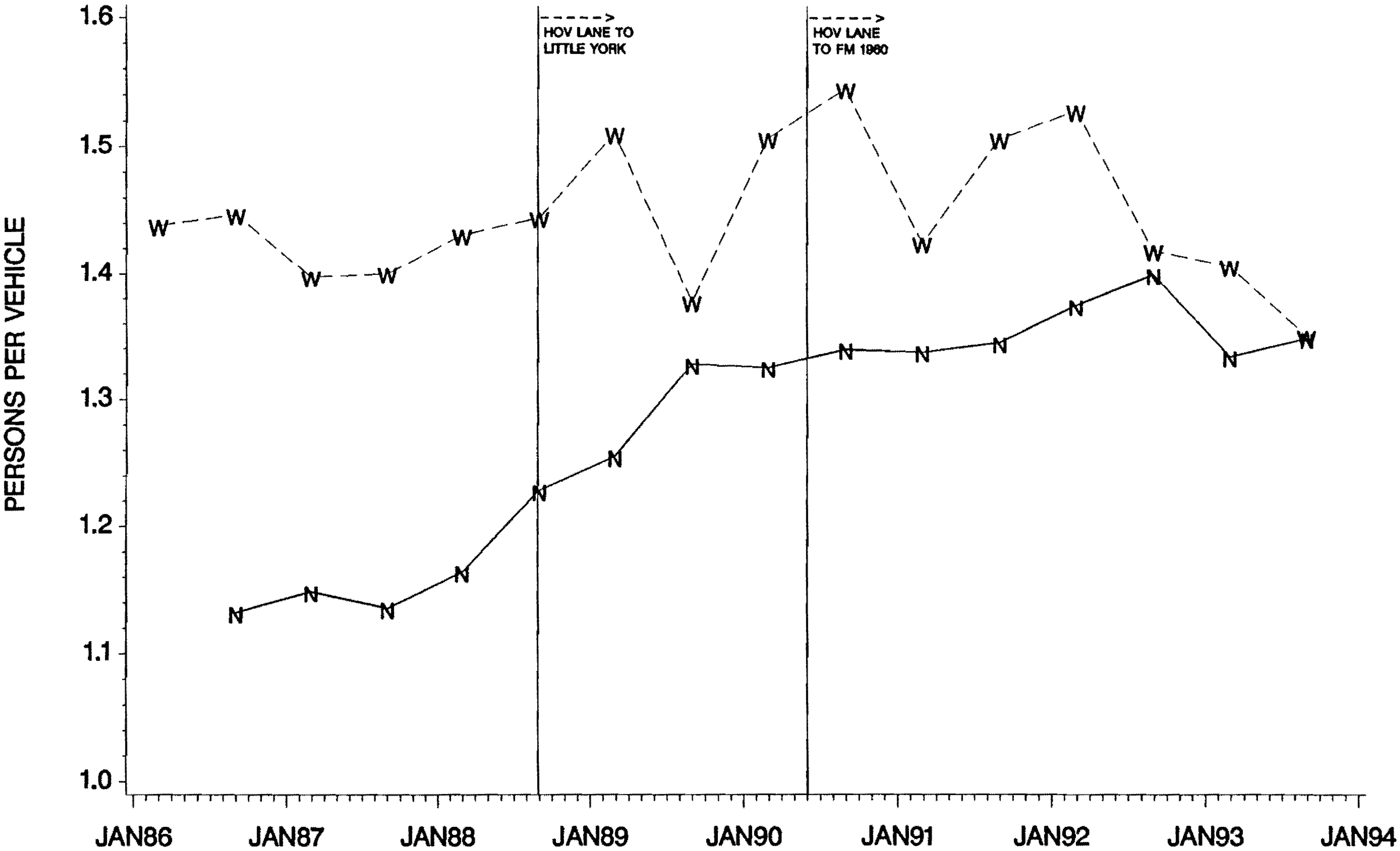


DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION
PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : M = MAINLANE OCCUPANCY
T = TOTAL OCCUPANCY (FREEWAY PLUS HOV LANE)

FIGURE D-13

A.M. PEAK HOUR AVERAGE OCCUPANCY
NORTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

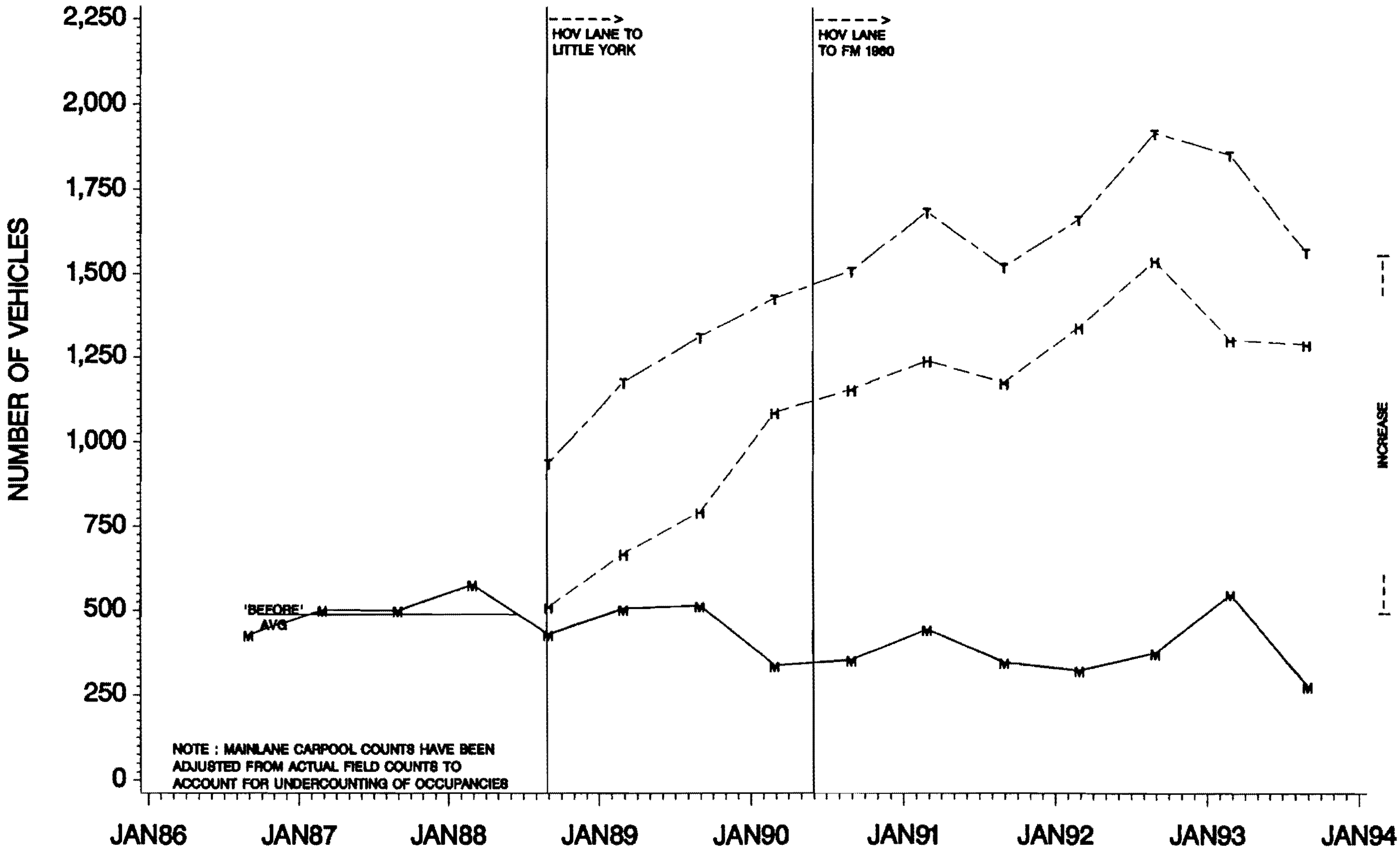


DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF SOUTHWEST FWY (9/86 – 12/92) AND EASTEX FWY (1/93 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : N = NORTHWEST FREEWAY AT PINEMONT (WITH HOV LANE)
W = FREEWAYS WITHOUT HOV LANE

FIGURE D-14

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

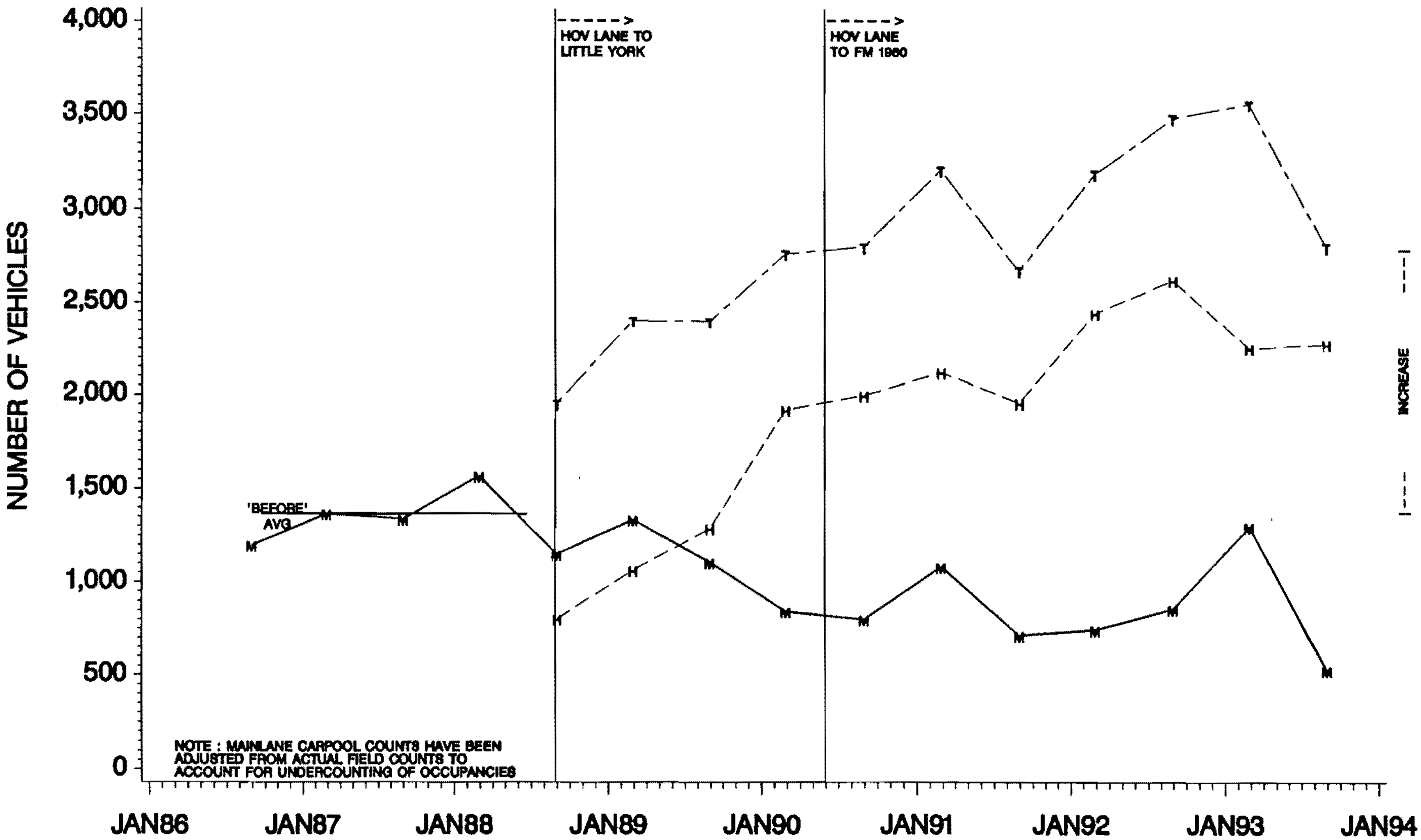


NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (15.30 KM [9.5 MI]), OPENED AUGUST 29, 1988
DATA COLLECTED SOUTHBOUND UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL 2+ CARPOOLS
H = TOTAL HOV LANE 2+ CARPOOLS
M = TOTAL MAINLANE 2+ CARPOOLS

FIGURE D-15

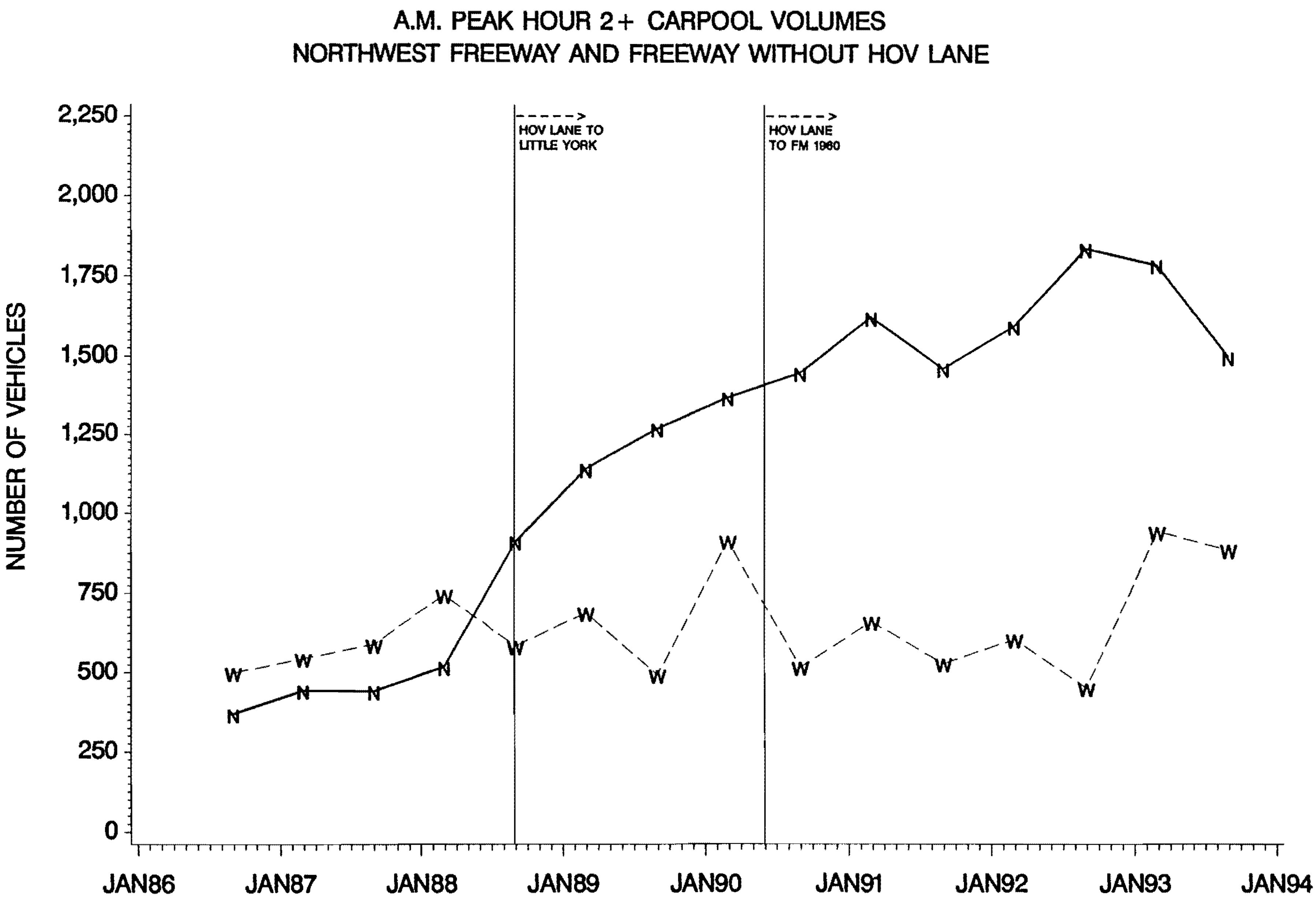
NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE
A.M. PEAK PERIOD 2+ CARPOOL UTILIZATION



NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER TO
LITTLE YORK (15.30 KM [9.5 MI]), OPENED AUGUST 29, 1988
PEAK PERIOD IS 6:00 – 9:30 A.M.
DATA COLLECTED SOUTHBOUND UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL 2+ CARPOOLS
H = TOTAL HOV LANE 2+ CARPOOLS
M = TOTAL MAINLANE 2+ CARPOOLS

FIGURE D-16

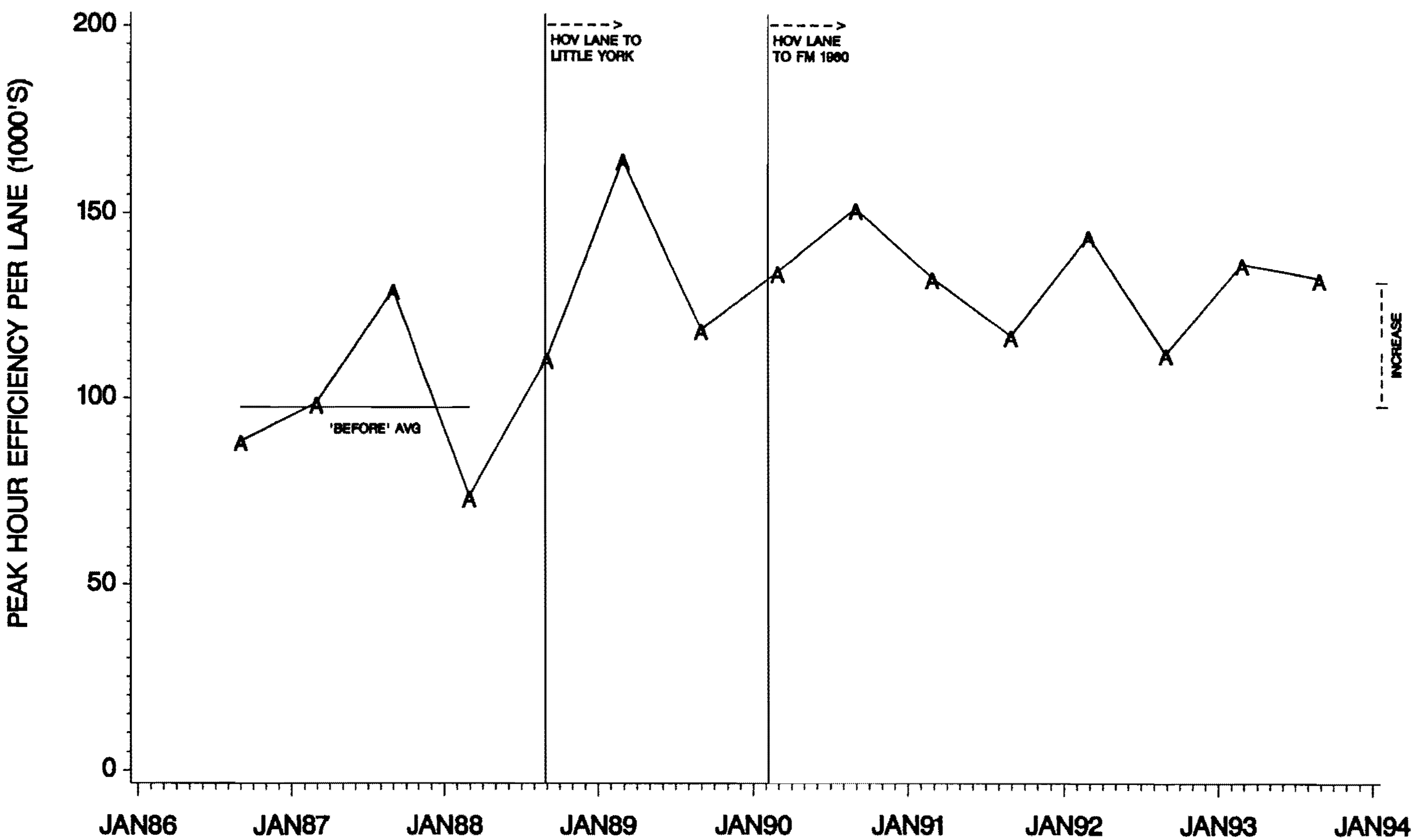


DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF
GULF FWY (6/83 – 4/88), SOUTHWEST FWY (6/88 – 12/92) AND EASTEX FWY (1/93 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : N = NORTHWEST FREEWAY 2+ CARPOOLS
W = FREEWAYS WITHOUT HOV LANE

FIGURE D-17

NORTHWEST FREEWAY (U.S. 290) EVALUATION
A.M. PEAK HOUR MAINLANE AND HOV LANE EFFICIENCY

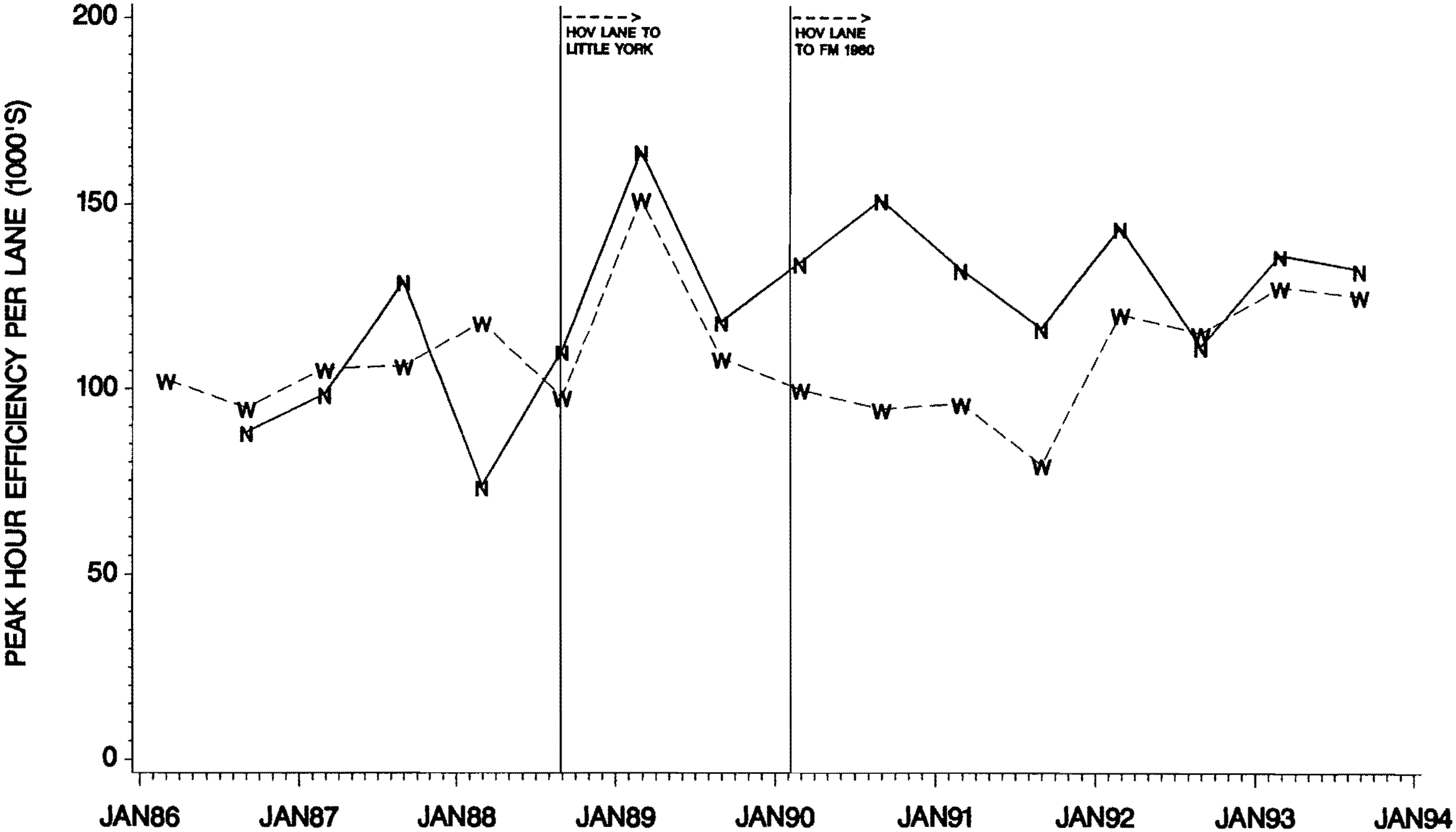


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE HOV LANE, IT REPRESENTS TOTAL PERSONS (FREEWAY + HOV LANE) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 4 LANES
TO CONVERT EFFICIENCY FROM METRIC TO ENGLISH UNITS MULTIPLY BY 0.62
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : A = A.M. PEAK HOUR EFFICIENCY

FIGURE D-18

A.M. PEAK HOUR FREEWAY PER LANE EFFICIENCY
NORTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

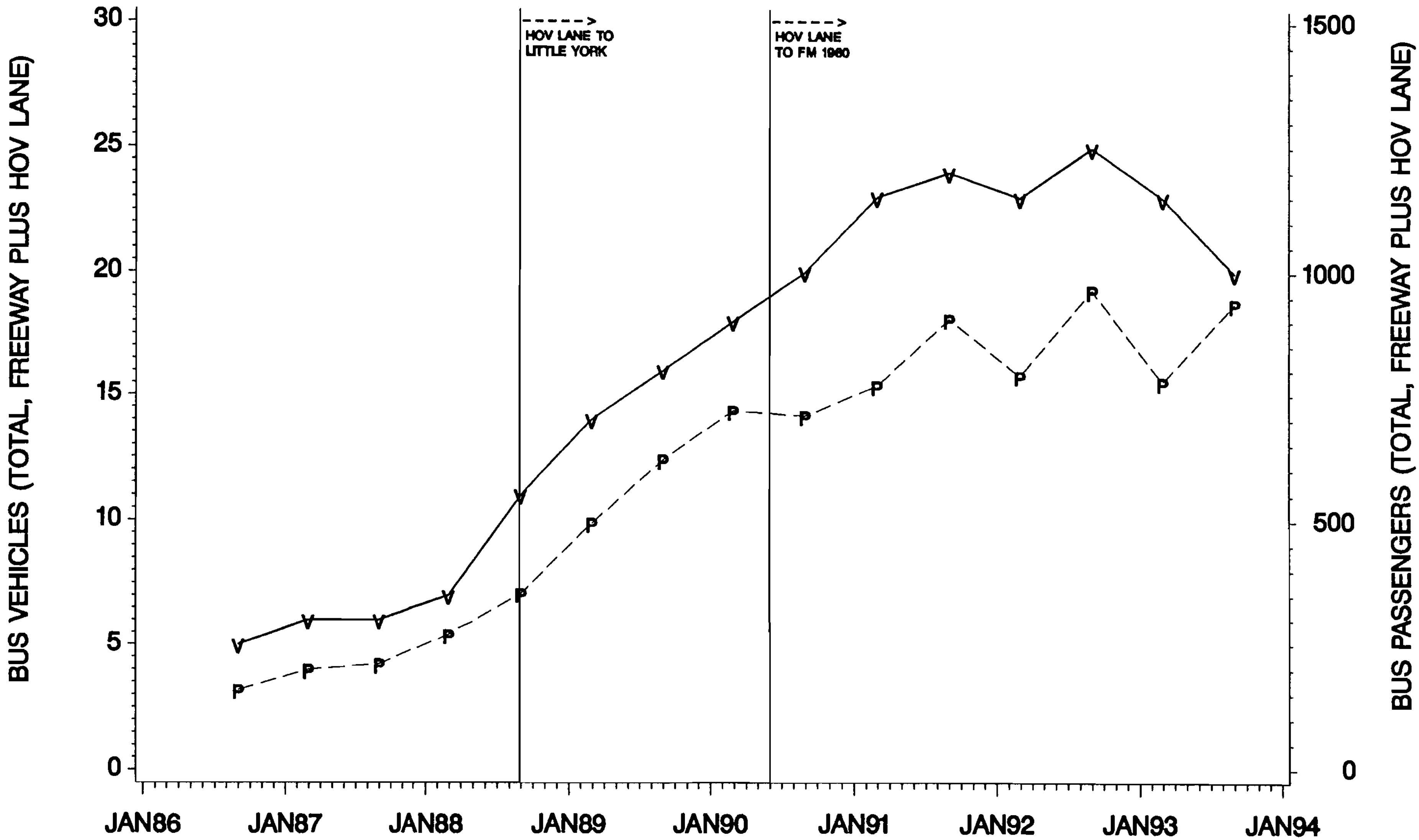


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE HOV LANE, IT REPRESENTS TOTAL PERSONS (FREEWAY + HOV LANE) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 4 LANES
DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF
GULF FWY (6/83 – 4/88), SOUTHWEST FWY (6/88 – 12/92) AND EASTEX FWY (1/93 – PRESENT) DATA
TO CONVERT EFFICIENCIES FROM METRIC TO ENGLISH UNITS MULTIPLY BY 0.62
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : N = NORTHWEST FREEWAY EFFICIENCY
W = FREEWAYS WITHOUT HOV LANE

FIGURE D-19

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

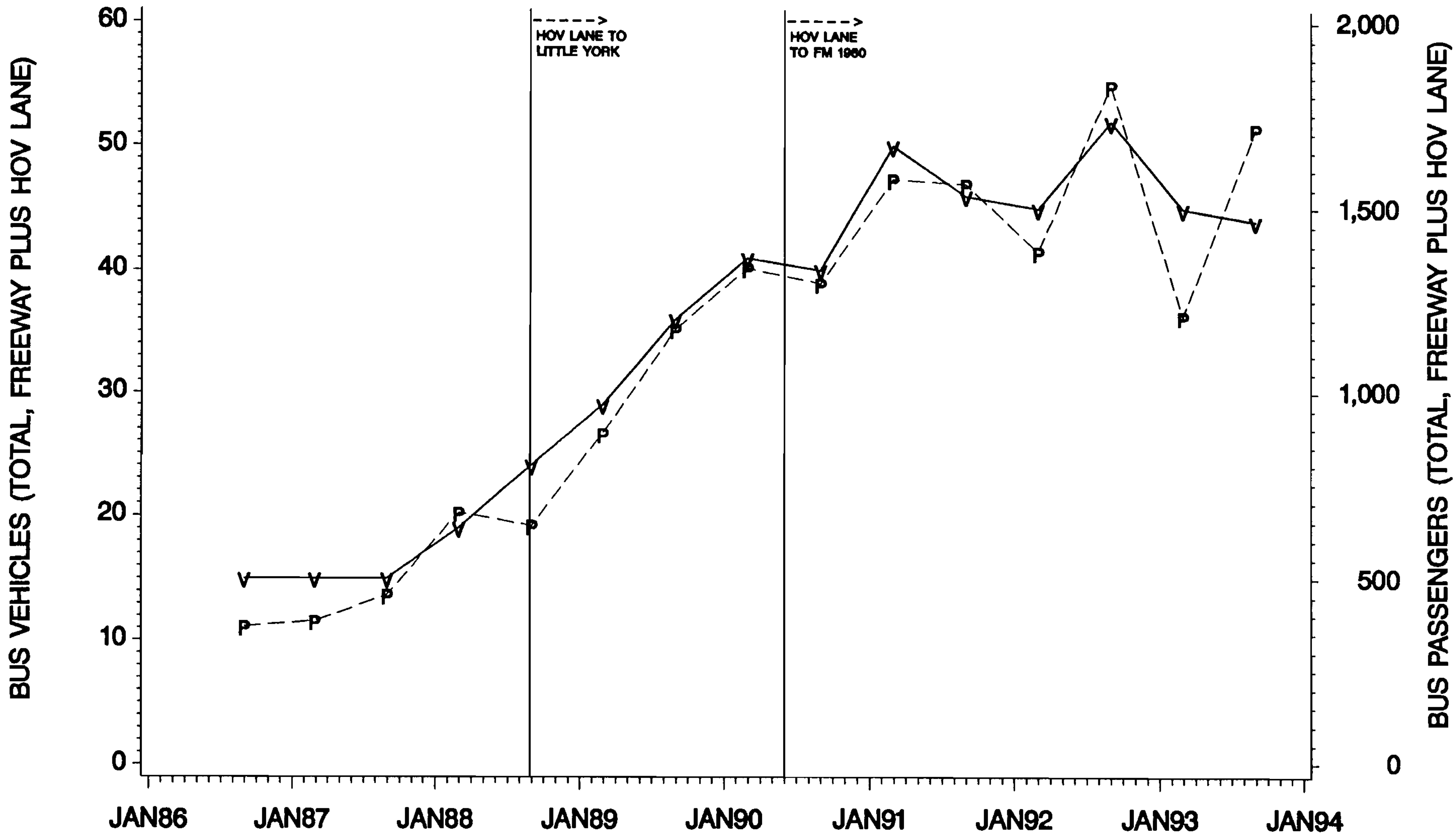


DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = BUS PASSENGER VOLUME
V = BUS VEHICLE VOLUME

FIGURE D-20

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

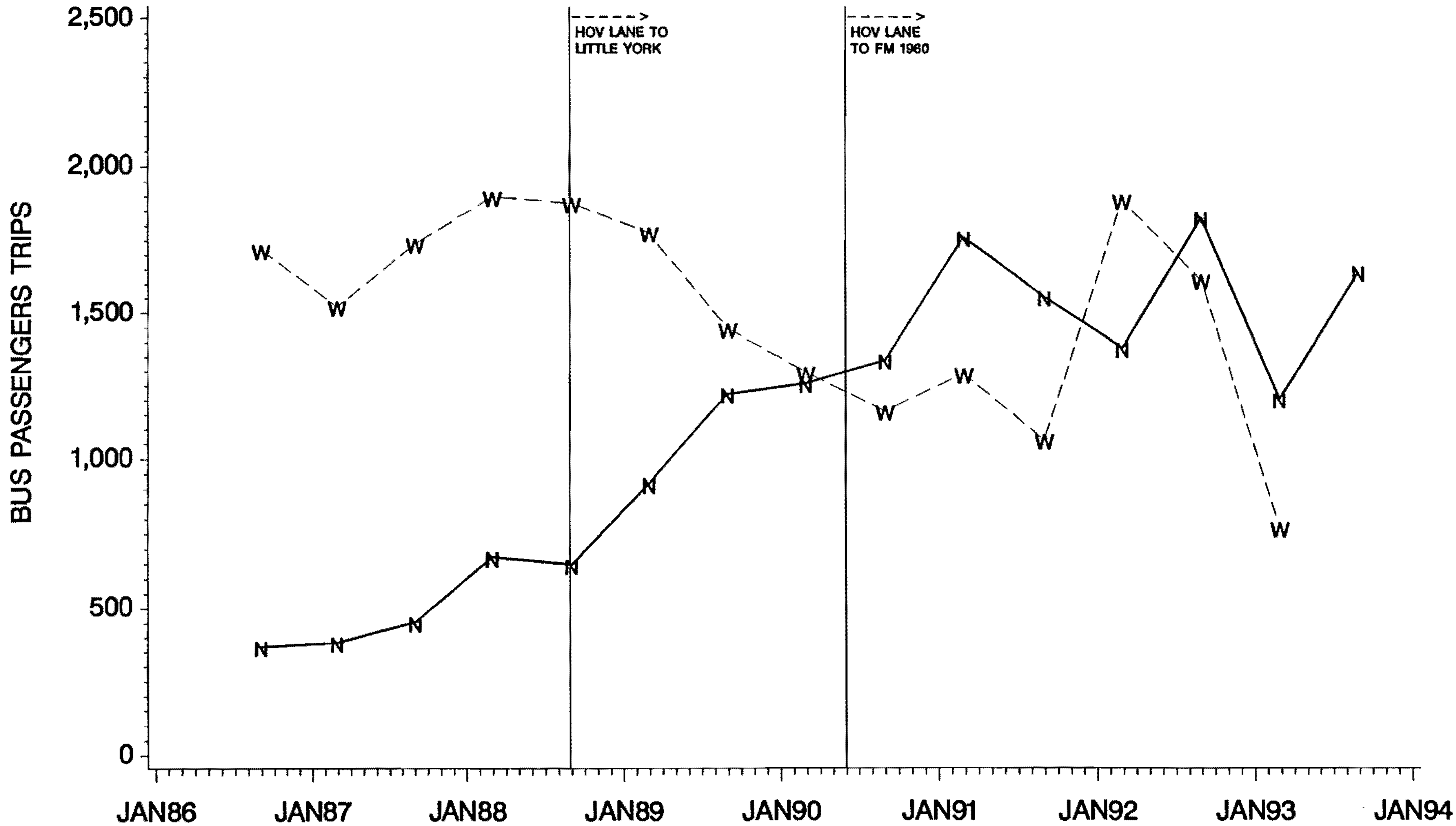


PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = BUS PASSENGER VOLUME
V = BUS VEHICLE VOLUME

FIGURE D-21

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

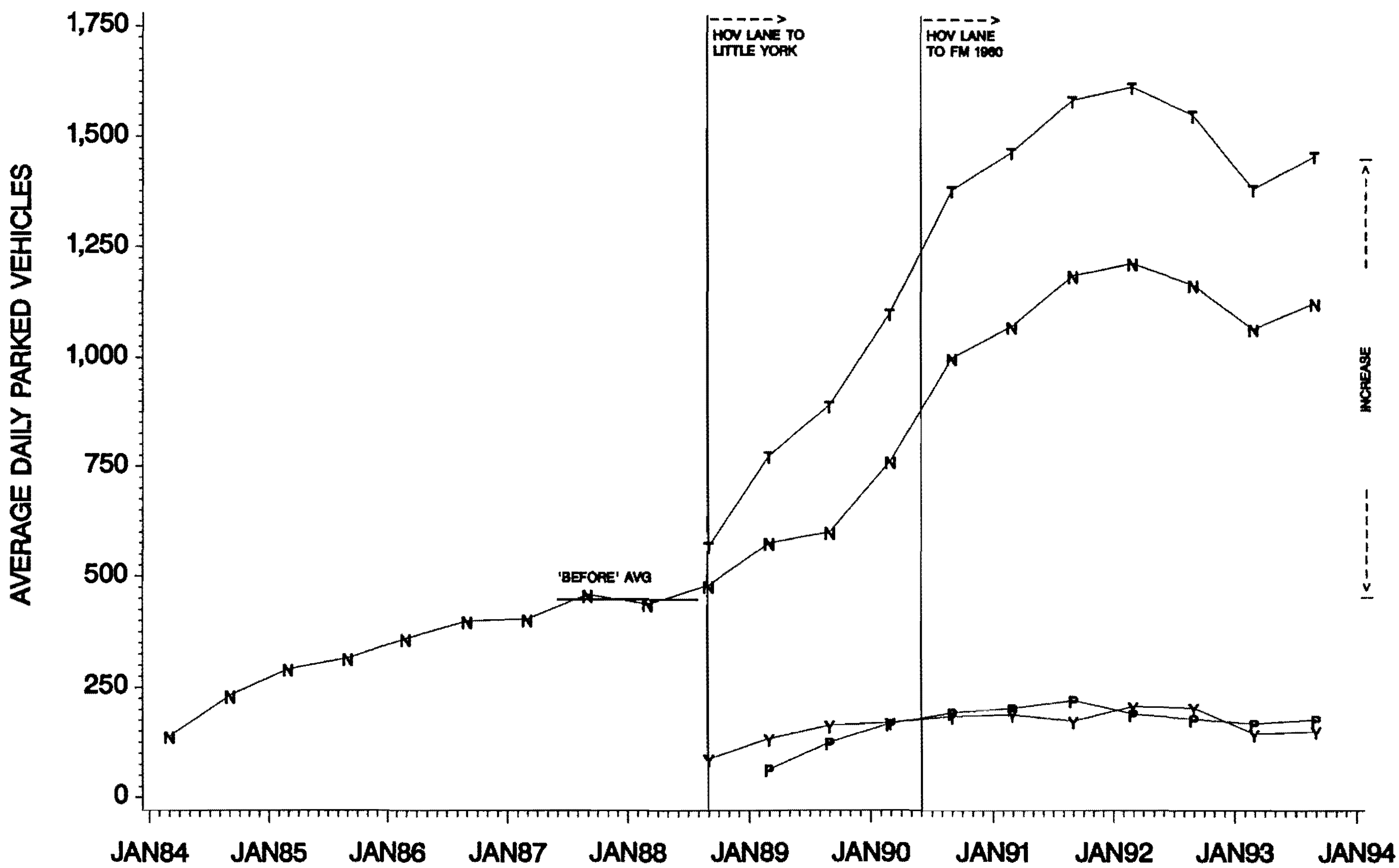


PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF SOUTHWEST FWY (9/86 – 6/89) AND EASTEX FWY (9/89 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : N = NORTHWEST FREEWAY AT PINEMONT (WITH HOV LANE)
W = FREEWAYS WITHOUT HOV LANE

FIGURE D-22

NORTHWEST FREEWAY (U.S. 290) CORRIDOR PARK–AND–RIDE DEMAND

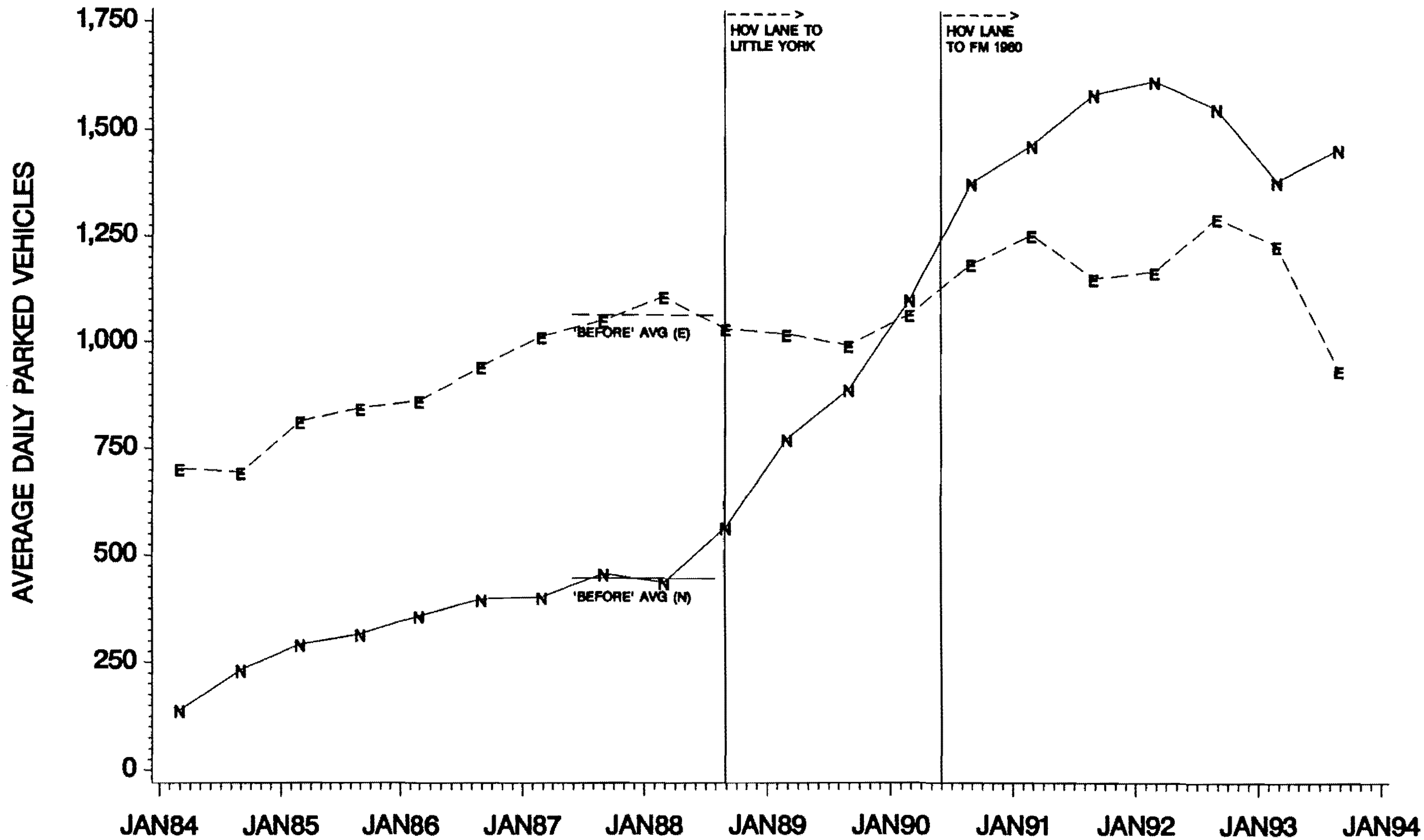


NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER
TO LITTLE YORK (15.30 KM [9.5 MI]), OPENED AUGUST 29, 1988
CURRENT TOTAL CORRIDOR PARKING CAPACITY = 3,242 SPACES
HOV LANE EXTENSION FROM LITTLE YORK TO FM 1960 (6.28 KM [3.9 MI]) OPENED JUNE 2, 1990
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL PARKED VEHICLES
N = NORTHWEST STATION (1,202 SPACES)
Y = LITTLE YORK LOT (1,102 SPACES)
P = PINEMONT LOT (938 SPACES)

FIGURE D-23

AVERAGE DAILY VEHICLES PARKED AT PARK-AND-RIDE LOTS
NORTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE



NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER
TO LITTLE YORK (15.30 KM [9.5 MI]), OPENED AUGUST 29, 1988
HOV LANE EXTENSION FROM LITTLE YORK TO FM 1960 (6.28 KM [3.9 MI]) OPENED JUNE 2, 1990
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : N – NORTHWEST FREEWAY
E – FREEWAY WITHOUT HOV LANE (EASTEX)

APPENDIX E

SOUTHWEST FREEWAY AND HOV LANE DATA

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

Table E-1. Summary of A.M. Peak-Direction Southwest Freeway and HOV Lane Data, December 1993

Type of Data Phase 1 of HOV Lane Became Operational 1/11/93	"Representative" Pre-HOV Lane Value	"Representative" Current Value	Percent Change
HOV Lane Data			
HOV Lane Length (kilometers [miles])		18.7 (11.6)	
HOV Lane Cost (millions)		$62.2	
Person-Movement			
Peak Hour (7-8 a.m.)	—	3,175	—
Peak Period (6-9:30 a.m.)	—	5,837	—
Total Daily	—	13,200	—
Vehicle Volumes			
Peak Hour	—	1,052	—
Peak Period	—	1,944	—
Vehicle Occupancy, Peak Hour (persons/veh)	—	2.98	—
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM]), 1/93-12/93[1]	—	6.8 (11.0)	—
Vehicle Breakdown Rate (VKT/Breakdown [VMT/Breakdown]), 1/93-12/93		95,795 (59,500)	—
Violation Rate (6-9:30 a.m.)	—	5.8%	—
Peak Hour Lane Efficiency (1000's)[2]	—	269 (167)	—
Annual Value of User Time Saved (millions)[3]	—	$1.5 to $2.9	—
Freeway Mainlane Data (see note)			
Person Movement			
Peak Hour	5,685	7,687	+35%
Peak Period (6-9:30 a.m.)	17,357	21,207	+22%
Vehicle Volume			
Peak Hour	4,922	7,343	+49%
Peak Period	15,032	19,868	+32%
Vehicle Occupancy, Peak Hour (persons/veh)	1.16	1.05	-9%
Accident Rate (i.e., Injury accidents/100 MVK [/100 MVM])[1]	16.3 (26.2)	12.1 (19.5)	-26%
Avg. Operating Speed[4] (kph [mph])			
Peak Hour	47 (29)	61 (38)	+31%
Peak Period	66 (41)	79 (49)	+20%
Peak Hour Lane Efficiency (1000's)[2]	90 (56)	95 (59)	+5%

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

[1]Due to inconsistencies in reporting accidents in Harris County, only injury accidents are included in this analysis. Accidents analyzed between Bellfort and S. Shepherd, a distance of approximately 18.7 kilometers (11.6 miles). This corresponds to Phase 1 of the HOV lane. "Before" data are for the period from 1/91 to 12/92. "Current" accident data are for the period from 1/93 to 12/93. 1993 freeway volumes were estimated by TTI to compute rates.

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

[3]Based on time savings from HOV lane users in 1993, an annual estimate of travel time savings to HOV lane users is developed. A value of time of $10.78/hour is used based on the value applied in the Highway Economic Evaluation Model.

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

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

Table E-1. Summary of A.M. Peak-Direction Southwest Freeway and HOV Lane Data, December 1993 (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	10,862	+91%
Peak Period	17,357	27,044	+56%
Vehicle Volume			
Peak Hour	4,922	8,395	+71%
Peak Period	15,032	21,812	+45%
Vehicle Occupancy			
Peak Hour	1.16	1.29	+11%
Peak Period	1.16	1.24	+7%
2+ Carpool Volumes			
Peak Hour	531	1,285	+142%
Peak Period	1,235	2,742	+122%
Travel Time (minutes)[1]			
Peak Hour	16.2[2]	13.2[3]	-19%
Peak Period	11.4[2]	12.9[3]	+13%
Peak Hour Lane Efficiency (1000's)[4]	90 (56)	124 (77)	+38%
Transit Data			
Bus Vehicle Trips			
Peak Hour	25	34	+36%
Peak-Period	75	74	-1%
Bus Passenger Trips			
Peak Hour	724	1,085	+50%
Peak Period	1,670	1,958	+17%
Bus Occupancy (persons/bus)			
Peak Hour	20	32	+60%
Peak Period	18	26	+44%
Vehicles Parked in Corridor Park & Ride Lots	1,441	1,563	+8%
Bus Operating Speed[1] (kph [mph])			
Peak Hour	47 (29)[2]	85 (53)[3]	+80%
Peak Period	79 (49)[2]	87 (54)[3]	+9%

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

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

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

Measure of Effectiveness	"Representative" Pre-HOV Lane Value	"Representative" 12/93 Value	Percent Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/HOV lane	1.16	1.24	+7%
Freeway w/o HOV lane	1.30	1.23	-5%
A.M. Peak Hour, 2+ Carpool Volume Change			
Freeway w/HOV lane	531	1,285	+142%
Freeway w/o HOV lane	779	890	+14%
Bus Passengers, Peak Period			
Freeway w/HOV lane	1,670	1,958	+17%
Freeway w/o HOV lane	1,067	775	-27%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	1,441	1,563	+8%
Freeway w/o HOV lane	1,222	942	-23%
Facility Per Lane Efficiency[2]			
Freeway w/HOV lane	90 (56)	124 (77)	+38%
Freeway w/o HOV lane	120 (74)	126 (78)	+5%

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

HOV LANE DATA

DESCRIPTION

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

- The capital cost (including all support facilities) for the completed facility in 1990 dollars was million. A more detailed cost breakdown including dates is provided on the following page.

- Selected milestone dates are listed below. Other dates are shown in the capital cost table.

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

PERSON MOVEMENT

- In December 1993, 13,200 person trips per day were served on the HOV lane.

- A.M. peak hour, 3,175 persons/hour.
  - 1,085 (34%) by bus, 24 (1%) by vanpool, and 2,066 (65%) by carpool (Figure E-1).
  - Average HOV lane vehicle occupancy = 2.98 persons/vehicle.

- A.M. peak period, 5,837 persons.

  - 1,958 (34%) by bus, 54 (1%) by vanpool, and 3,825 (65%) by carpool (Figure E-2).

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

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1990 Dollars
HOV Lane and Ramps			
Design (1990)	$4.0	1.00	$4.0
Co. Line to Beltway 8 (1990)	3.1	1.00	3.1
Beltway 8 to Beechnut (1990)	8.3	1.00	8.3
Beechnut to Westpark (1991)	8.2	1.00	8.2
Westpark to IH 610 (1991)	10.3	1.00	10.3
IH 610 to Shepherd (1992)	7.0	1.00	7.0
W. Bellfort T-Ramp (1992)	3.1	1.00	3.1
Project Management (1991)	1.1	1.00	1.1
SUB-TOTAL	$45.1		$45.1
Per Kilometer (Mile)	$2.4 ($3.9)		$2.5 ($3.9)
Surveillance, Communication & Control (1990)	$3.5	1.00	$3.5
SUB-TOTAL	$3.5		$3.5
Per Kilometer (Mile)	$0.2 ($0.3)		$0.2 ($0.3)
Support Facilities			
W. Bellfort P/R (1991)	$4.1	1.00	$4.1
Westwood P/R (1991)	2.1	1.00	2.1
Hillcroft Transit Center (1992)	7.6	1.00	7.6
SUB-TOTAL	$13.8		$13.8
Per Kilometer (Mile)	$0.7 ($1.2)		$0.7 ($1.2)
TOTAL COST	$62.4		$62.4
COST PER KILOMETER (18.7 kilometers [11.6 miles])	$3.3 ($5.4)		$3.3 ($5.4)

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 Construction Cost		Factor	Estimated Cost 1990 Dollars	
HOV Lane and Ramps					
Shepherd to Spur 527		$15.6	1.00		$15.6
HOV Connector Ramp @ Edloe		$5.0	1.00		$5.0
Project Management		$0.4	1.00		$0.4
SUB-TOTAL	$21.0			$21.0	
Per Kilometer (Mile)		$6.0 ($9.7)			$6.0 ($9.7)
Surveillance, Communication & Control		$0.7	1.00		$0.7
SUB-TOTAL	$0.7			$0.7	
Per Kilometer (Mile)		$0.2 ($0.3)			$0.2 ($0.3)
TOTAL COST	$21.7			$21.7	
COST PER KILOMETER (3.5 kilometers [2.2 miles])		$6.2 ($9.9)			$6.2 ($9.9)

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

VEHICLE MOVEMENT

- A.M. peak hour, 1,052 vehicles.
  - 34 (3%) buses, 5 (1%) vans, and 1,012 (96%) carpools (Figure E-4).

- A.M. peak period, 1,944 vph
  - 74 (4%) buses, 9 (1%) vans, and 1,861 (95%) carpools (Figure E-3).

ACCIDENT RATE

- For the period 1/93 through 12/93, the HOV lane accident rate was 6.8 accidents per 100 million vehicle kilometers (11.0 per 100 million vehicle miles).

VEHICLE BREAKDOWN RATES

- As measured from January 11, 1993 through December 1993, the following rate has been observed.
  - The weighted average for all vehicle types is 1 breakdown per 95,795 VKT (59,500 VMT). Bus breakdowns occurred once every 41,400 VKT, while cars broke down once every 77,800 VMK.

VIOLATION RATE

- The observed violation rate (vehicles on the HOV lane not eligible to use the HOV lane) is approximately 6%.

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 269 (3,175 passengers x 85 kph) or 167 (3,175 passengers x 53 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane experience an average travel time savings of 5 minutes in the a.m. peak hour (Figure E-5).
- The tables on the following page below indicate that, on a typical non-incident day, travel time savings of approximately 32,667 minutes, or 544 hours, are realized. Assuming 250 days of operation and a value of time of $10.78/hour, this equates to $1.47 million per year. This is extremely conservative since it does not consider travel time savings due to incidents on the freeway. Data from Houston suggest that increasing this value by 100% to account for incidents would be reasonable. Thus, travel time savings to HOV lane users are estimated to be in the range of $1.47 to $2.93 million per year.

Table E-5. Southbound A.M. Travel Time Savings for Southwest HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1993)

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	5.56	6.07	-0.50	82	34	113	230	-115
6:30	5.76	6.11	-0.35	255	27	173	456	-158
7:00	6.28	6.04	0.25	631	17	343	992	245
7:30	8.75	6.33	2.42	753	4	275	1,031	2,497
8:00	9.57	6.03	3.54	364	0	140	504	1,784
8:30	5.99	5.89	0.10	163	4	47	213	21
9:00	5.64	5.82	-0.18	30	0	0	30	-5
Peak Period Total				2,278	86	1,092	3,456	4,269
Section From Hillcroft Flyover to S Shepherd								
6:00	6.51	6.76	-0.25	93	28	131	252	-63
6:30	6.84	6.60	0.24	287	19	310	616	148
7:00	6.97	6.98	-0.01	764	25	641	1,430	-13
7:30	9.98	6.94	3.04	986	4	530	1,520	4,620
8:00	7.72	7.03	0.69	496	4	256	756	521
8:30	6.52	6.61	-0.09	216	0	92	309	-29
9:00	6.42	6.68	-0.44	42	0	16	58	-26
Peak Period Total				2,884	81	1,976	4,941	5,158
Northbound P.M. Travel Time Savings for Southwest HOV Lane								
Section from S Shepherd to Hillcroft Flyover								
3:30	7.11	6.93	0.18	144	7	37	188	34
4:00	6.65	6.83	-0.18	216	39	215	470	-84
4:30	8.11	6.91	1.20	411	37	341	789	948
5:00	9.38	7.46	1.92	602	24	624	1,250	2,401
5:30	12.61	7.89	4.72	814	8	503	1,324	6,246
6:00	11.69	7.80	3.89	508	2	302	812	3,160
6:30	8.64	7.61	1.03	238	0	91	329	339
Peak Period Total				2,933	117	2,113	5,163	13,044

Table E-5. Southbound A.M. Travel Time Savings for Southwest HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1993) (continued)

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	5.47	5.98	-0.51	98	7	0	105	-53
4:00	5.59	5.98	-0.38	184	39	140	363	-140
4:30	5.82	5.86	-0.04	317	33	177	527	-22
5:00	9.88	6.10	3.79	593	35	367	995	3,769
5:30	12.61	6.00	6.60	651	29	343	1,023	6,754
6:00	6.21	6.28	-0.07	393	2	177	571	-41
6:30	5.73	6.09	-0.35	159	0	40	199	-71
Peak Period Total				2,395	145	1,244	3,783	10,196

FREEWAY DATA

NOTE

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

PERSON MOVEMENT

- In the a.m. peak hour, compared to pre-HOV conditions, person movement has increased by 35% (Figure E-6).
- In the a.m. peak period, compared to pre-HOV conditions, person movement has increased by 22% (Figure E-7).

VEHICLE VOLUME

- In the a.m. peak hour, vehicle volume has increased by 49% (Figure E-6).
- In the a.m. peak period, vehicle volume has increased by 32% (Figure E-7).

VEHICLE OCCUPANCY

- In the a.m. peak hour, compared to pre-HOV conditions, mainlane occupancy has declined by 9% (Figure E-11).

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

ACCIDENT RATE

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

- For the section between Shepherd and Bellfort, the accident rate for the period preceding the opening of the HOV lane was 16.3 accidents per 100 million vehicle kilometers (100 MVK) (26.2 accidents per 100 million vehicle miles [100 MVM]). The accident data available for the period (1/93-8/93) after the HOV lane opened indicate an accident rate of 12.1 accidents/100 MVK (19.5 accidents/100 MVM). 1993 freeway volumes estimated by TTI were used to compute rates.

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 5%.

COMBINED FREEWAY AND HOV LANE DATA

TOTAL PERSON MOVEMENT

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

- At Pinemont, the HOV lane is responsible for 29% of peak-hour person movement (HOV lane = 3,175; freeway = 7,687) and 22% of peak-period (HOV lane = 5,837; freeway = 21,207) person movement (Figure E-10).

- Increase in a.m. person movement at Pinemont

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

  - Total peak-hour person movement has increased by 91%, from 5,685 to 10,862 (Figure E-9). Peak-period person movement has increased by 56%, from 17,357 to 27,044 (Figure E-10).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.29, an 11% increase over the pre-HOV lane occupancy (Figure E-11). Occupancy in the peak period is 7% 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 142% compared to pre-HOV lane levels (Figure E-14). In the a.m. peak period, the increase has been 122% (Figure E-15). These increases have not been experienced on freeways not having HOV lanes (Figure E-16).

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 38% since the implementation of the HOV lane (Figure E-17). Currently, no discernable trend in efficiency is evident when the Southwest Freeway is compared with freeways that have no HOV lane (Figure E-18).

BUS TRANSIT DATA

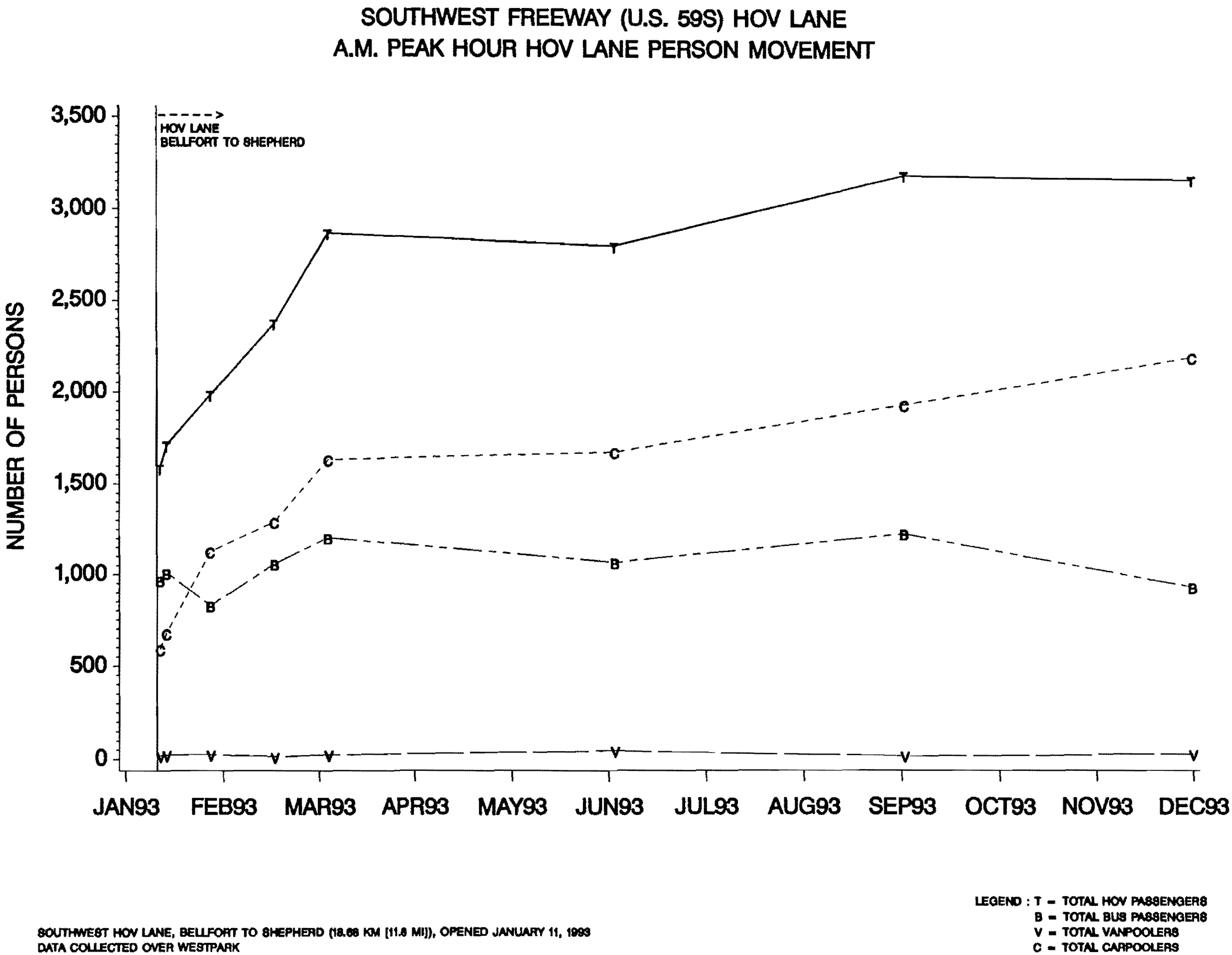
BUS VEHICLE AND PASSENGER TRIPS

- In the a.m. peak hour, bus vehicle trips have been increased by 278% since the HOV lane opened, and a 506% increase in bus ridership has resulted (Figure E-19). In the peak period, a 100% increase has occurred in bus vehicle trips, and a 190% increase in bus ridership has resulted (Figure E-20).
- While bus passenger trips have increased in the Southwest Freeway corridor, in the corridors which do not have HOV lanes, bus passenger trips have remained fairly constant (Figure E-21).

PARK-AND-RIDE

- Prior to opening the HOV lane, approximately 1,803 vehicles were parked in corridor park-and-ride lots. This has decreased 19% to a current level of 1,457 (Figure E-22).
- 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-23).

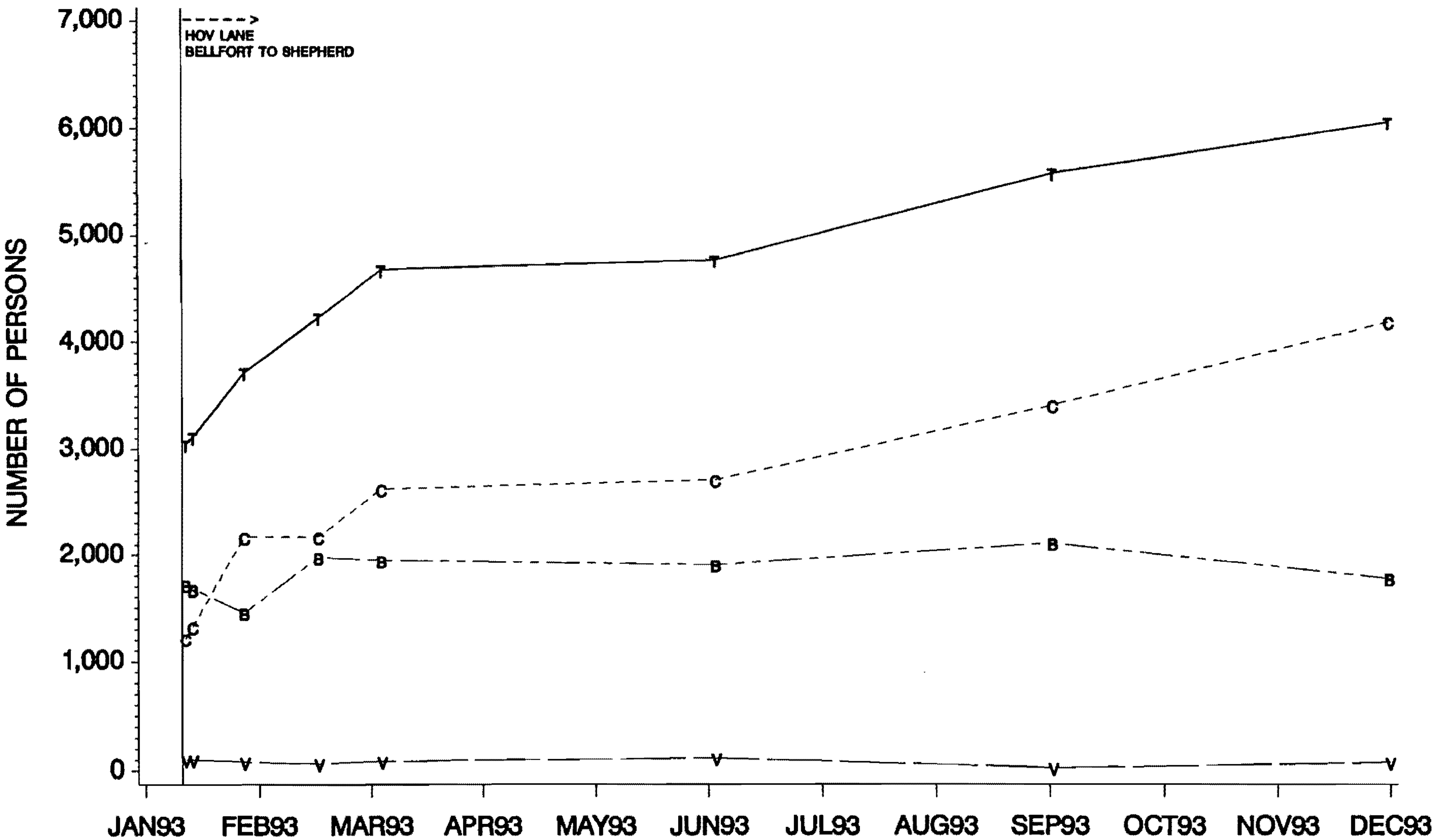
FIGURE E-1



SOUTHWEST HOV LANE, BELLFORT TO SHEPHERD (18.68 KM [11.6 MI]), OPENED JANUARY 11, 1993
DATA COLLECTED OVER WESTPARK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

FIGURE E-2

SOUTHWEST FREEWAY (U.S. 59S) HOV LANE
A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT

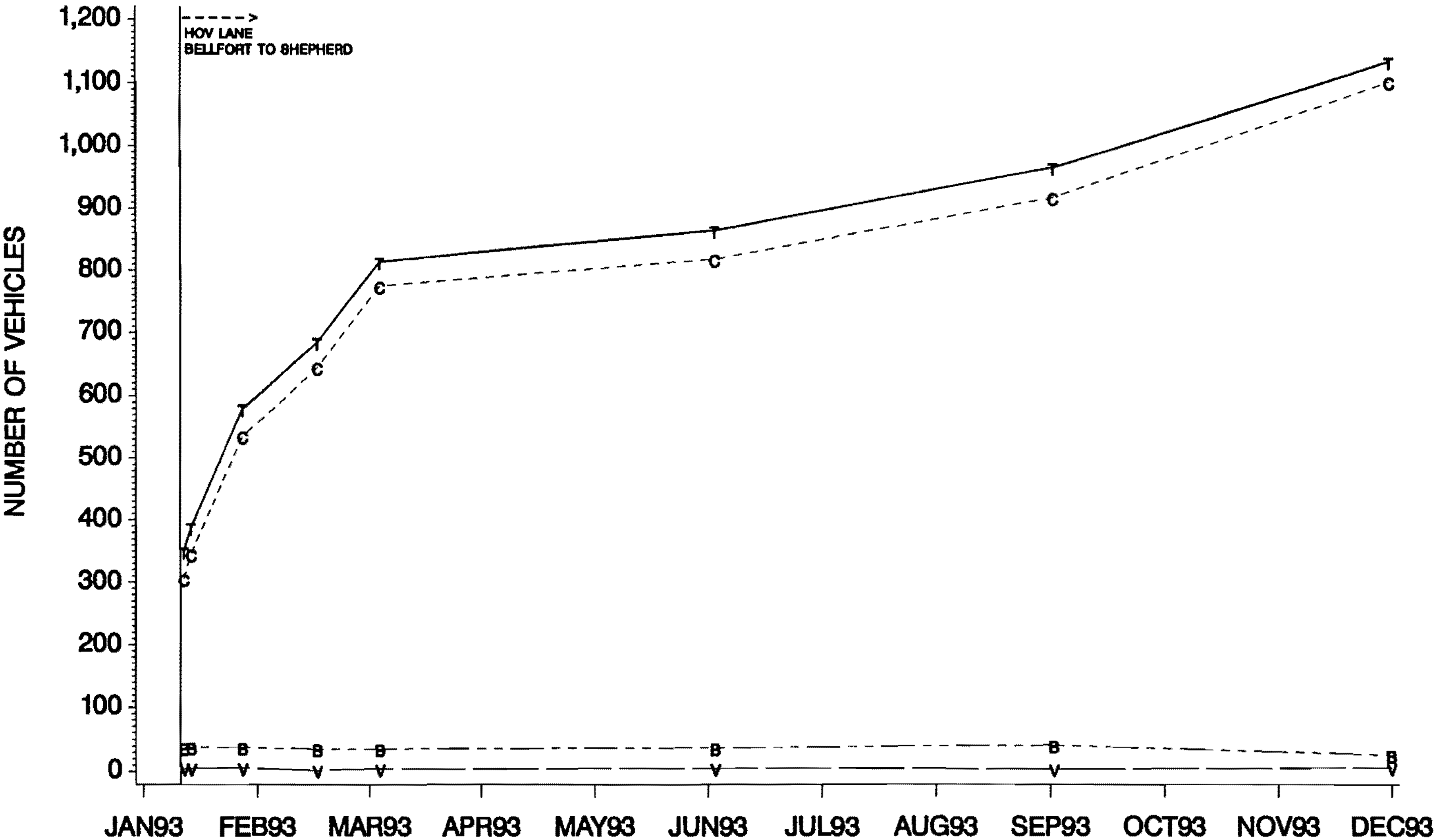


SOUTHWEST HOV LANE, BELLFORT TO SHEPHERD (18.68 KM [11.6 MI]), OPENED JANUARY 11, 1993
DATA COLLECTED OVER WESTPARK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL HOV PASSENGERS
B = TOTAL BUS PASSENGERS
V = TOTAL VANPOOLERS
C = TOTAL CARPOOLERS

FIGURE E-3

SOUTHWEST FREEWAY (U.S. 59S) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION

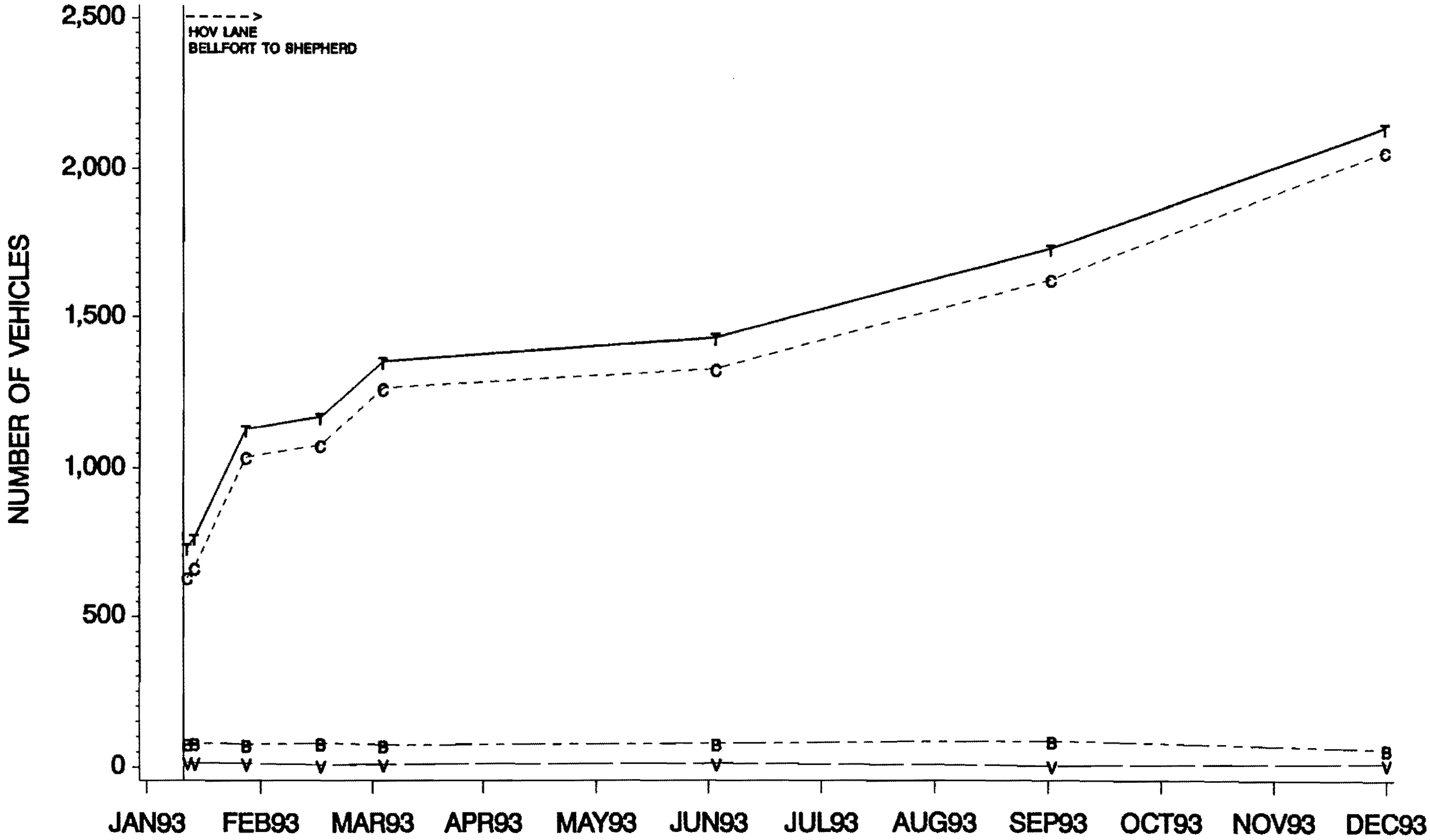


SOUTHWEST HOV LANE, BELLFORT TO SHEPHERD (18.68 KM [11.6 MI]), OPENED JANUARY 11, 1993
DATA COLLECTED OVER WESTPARK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL HOV PASSENGERS
B = TOTAL BUS PASSENGERS
V = TOTAL VANPOOLERS
C = TOTAL CARPOOLERS

FIGURE E-4

SOUTHWEST FREEWAY (U.S. 59S) HOV LANE
A.M. PEAK PERIOD HOV LANE VEHICLE UTILIZATION

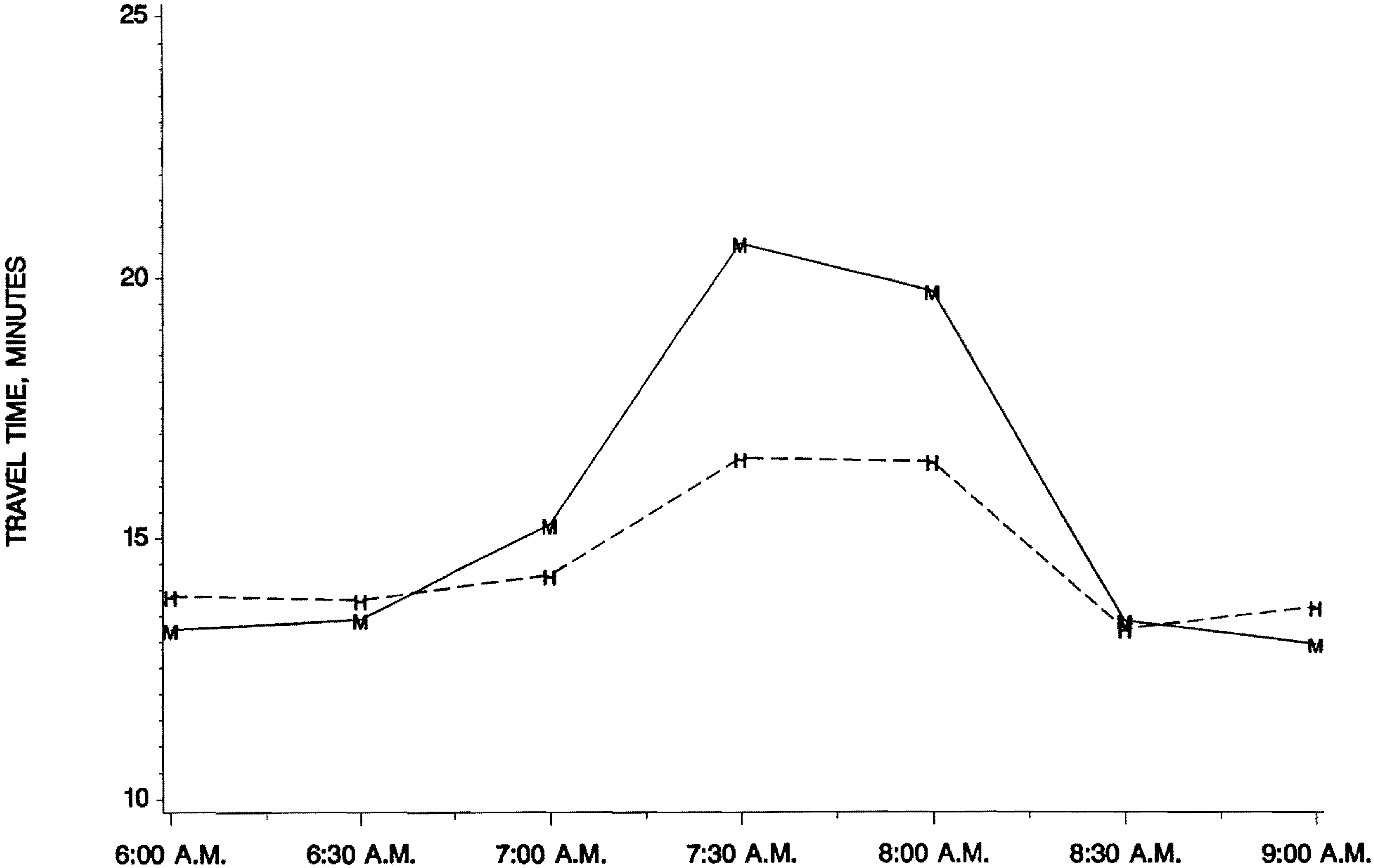


SOUTHWEST HOV LANE, BELLFORT TO SHEPHERD (18.68 KM [11.6 MI]), OPENED JANUARY 11, 1993
DATA COLLECTED OVER WESTPARK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL HOV PASSENGERS
B = TOTAL BUS PASSENGERS
V = TOTAL VANPOOLERS
C = TOTAL CARPOOLERS

FIGURE E-5

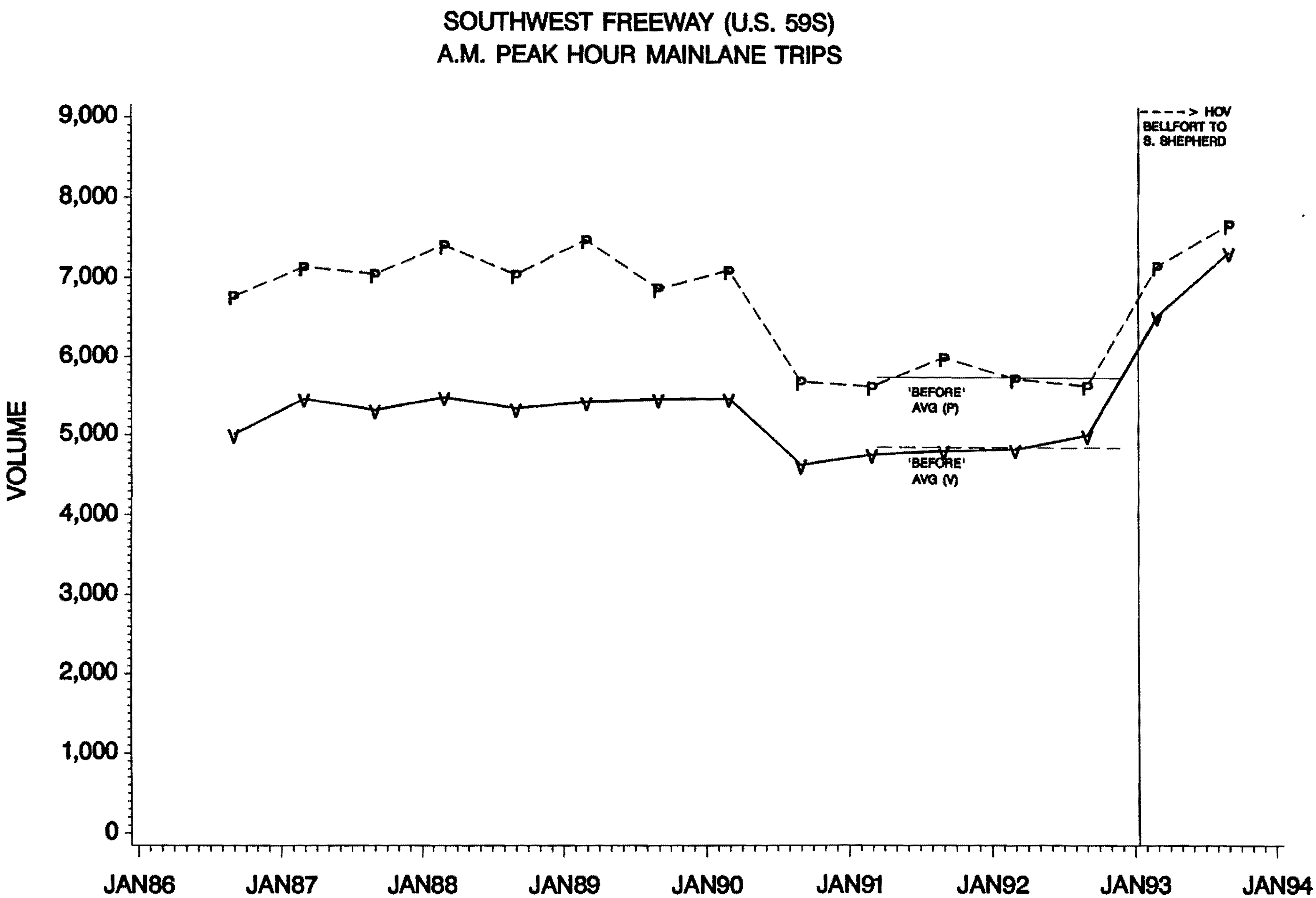
SOUTHWEST FREEWAY (U.S. 59S) MAINLANES AND HOV LANE A.M. TRAVEL TIME



TRAVEL TIMES ARE AN AVERAGE OF 4 QUARTERLY TRAVEL TIME SURVEYS CONDUCTED IN 1993
TRAVEL TIMES ARE FROM BELLFORT TO S. SHEPHERD
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : M – MAINLANE TRAVEL TIME
H – HOV LANE TRAVEL TIME

FIGURE E-6

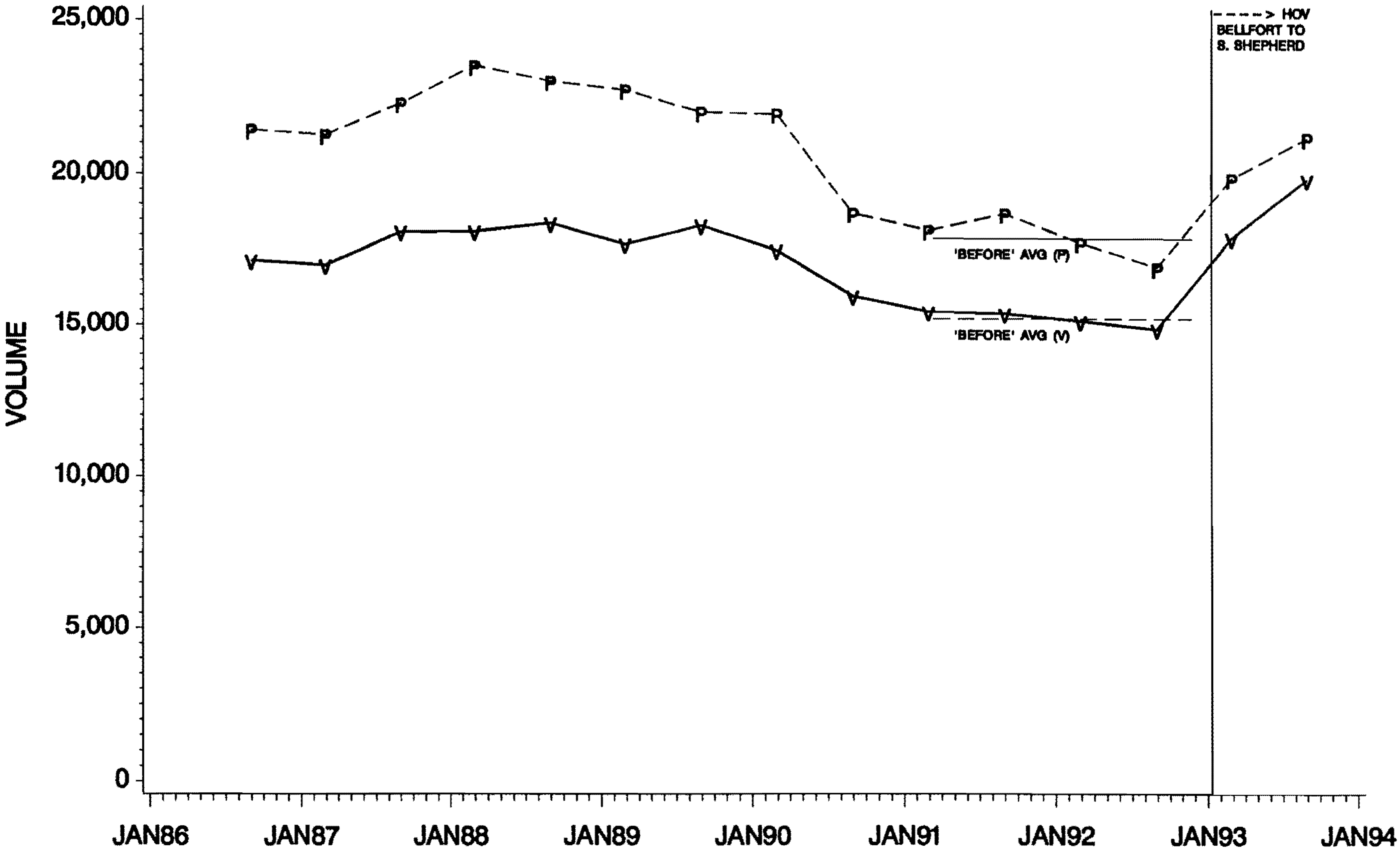


SOUTHWEST HOV LANE, BELLFORT TO SHEPHERD (18.68 KM [11.6 MI]), OPENED JANUARY 11,1993
DATA COLLECTED OVER WESTPARK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : V = TOTAL VEHICLE TRIPS
P = TOTAL PERSON TRIPS

FIGURE E-7

SOUTHWEST FREEWAY (U.S. 59S)
A.M. PEAK PERIOD MAINLANE TRIPS

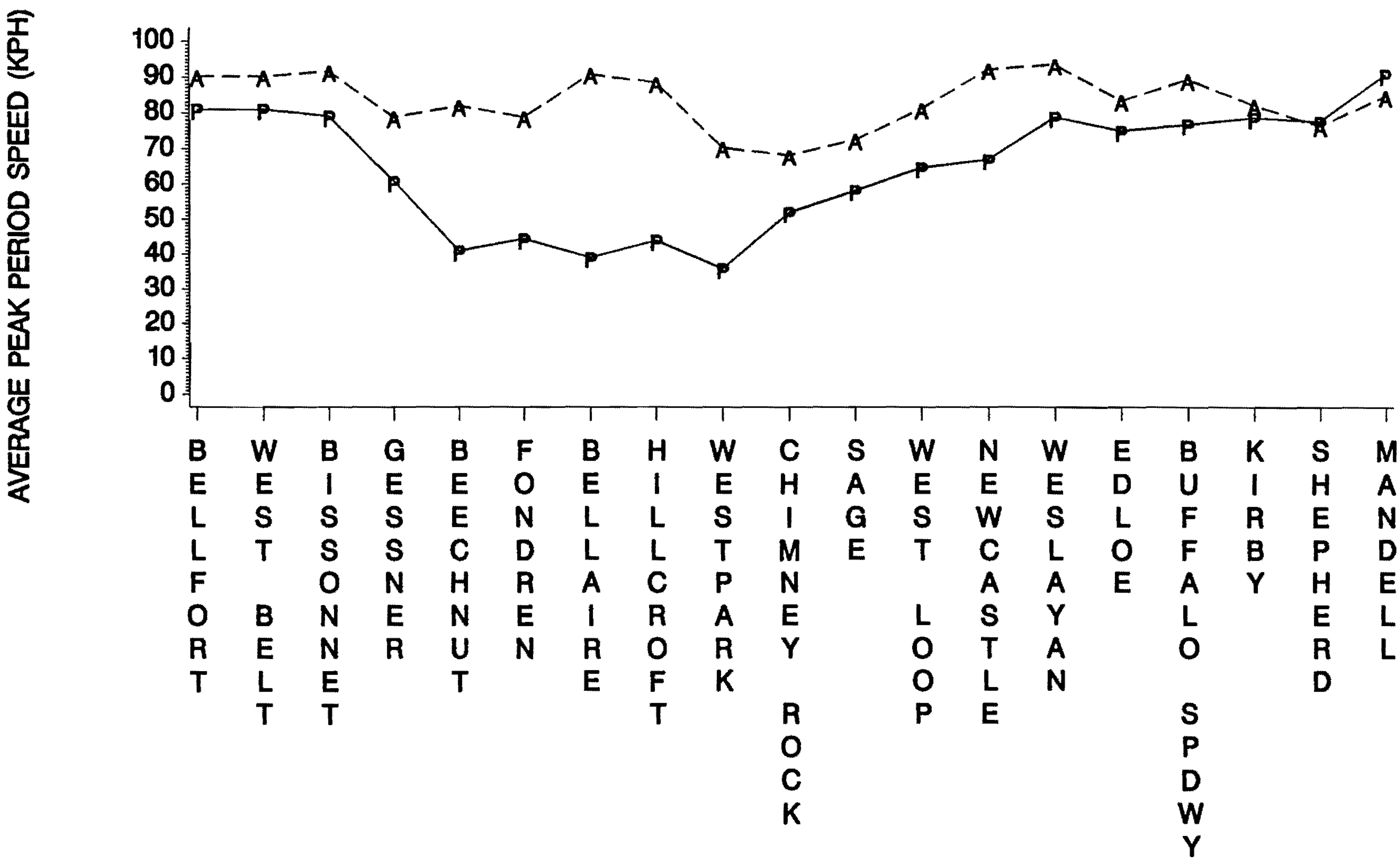


SOUTHWEST HOV LANE, BELLFORT TO SHEPHERD (18.66 KM [11.6 MI]), OPENED JANUARY 11,1993
PEAK PERIOD IS 6:00 TO 9:30 A.M.
DATA COLLECTED OVER WESTPARK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : V = TOTAL VEHICLE TRIPS
P = TOTAL PERSON TRIPS

FIGURE E-8

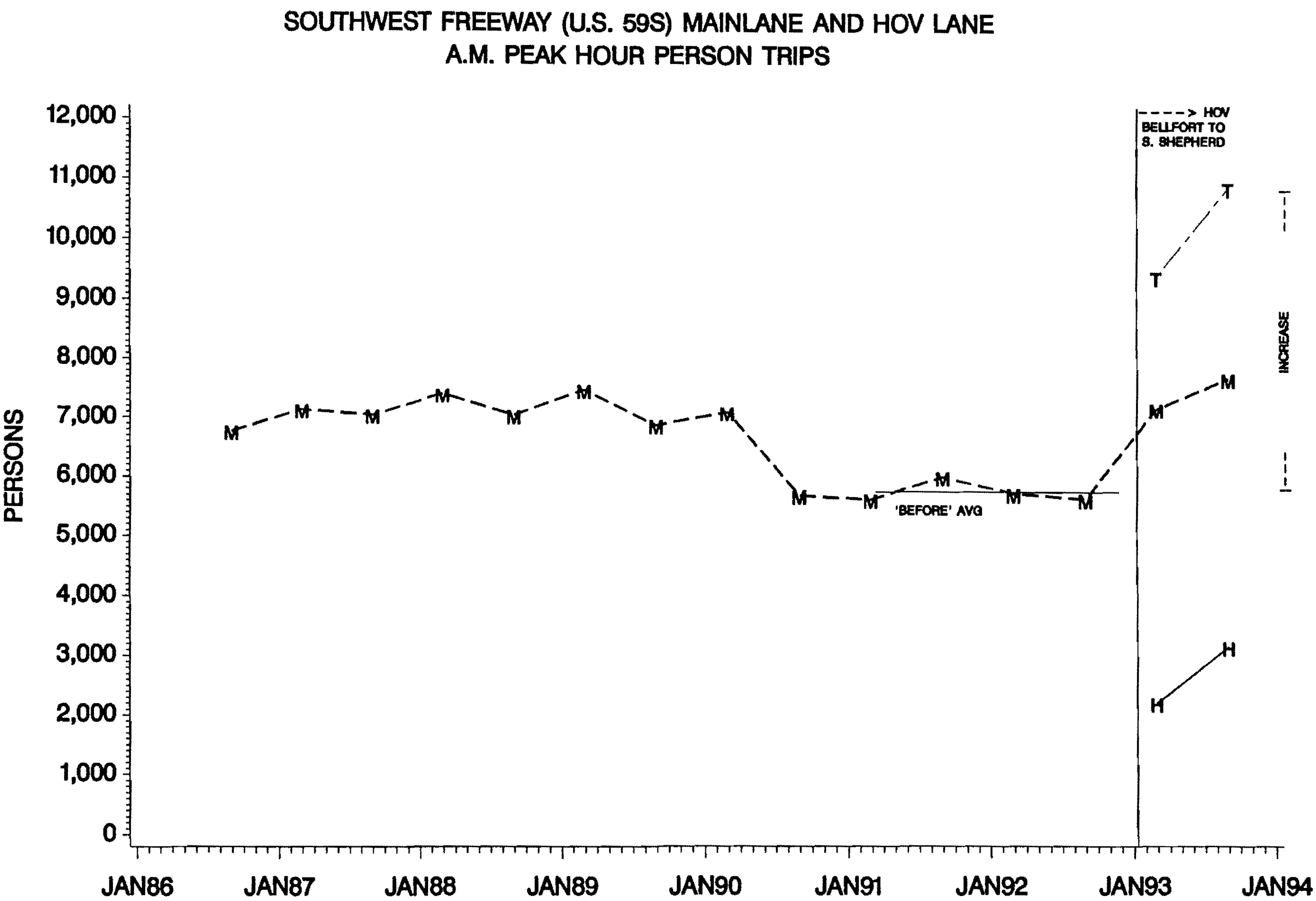
SOUTHWEST FREEWAY (U.S. 59S) MAINLANE TRAVEL TIME AND SPEED SURVEY
NORTHBOUND, BELLFORT TO MANDELL
A.M. PEAK PERIOD



NOTE : TO CONVERT SPEEDS FROM METRIC TO ENGLISH UNITS MULTIPLY KPH BY 0.62
DATA COLLECTED 6:00 TO 9:30 A.M.
DATA COLLECTED FROM SEPTEMBER, 1986 TO SEPTEMBER, 1993
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = AVERAGE SPEED PRIOR TO OPENING HOV LANE
A = AVERAGE SPEED SINCE HOV LANE OPENED

FIGURE E-9

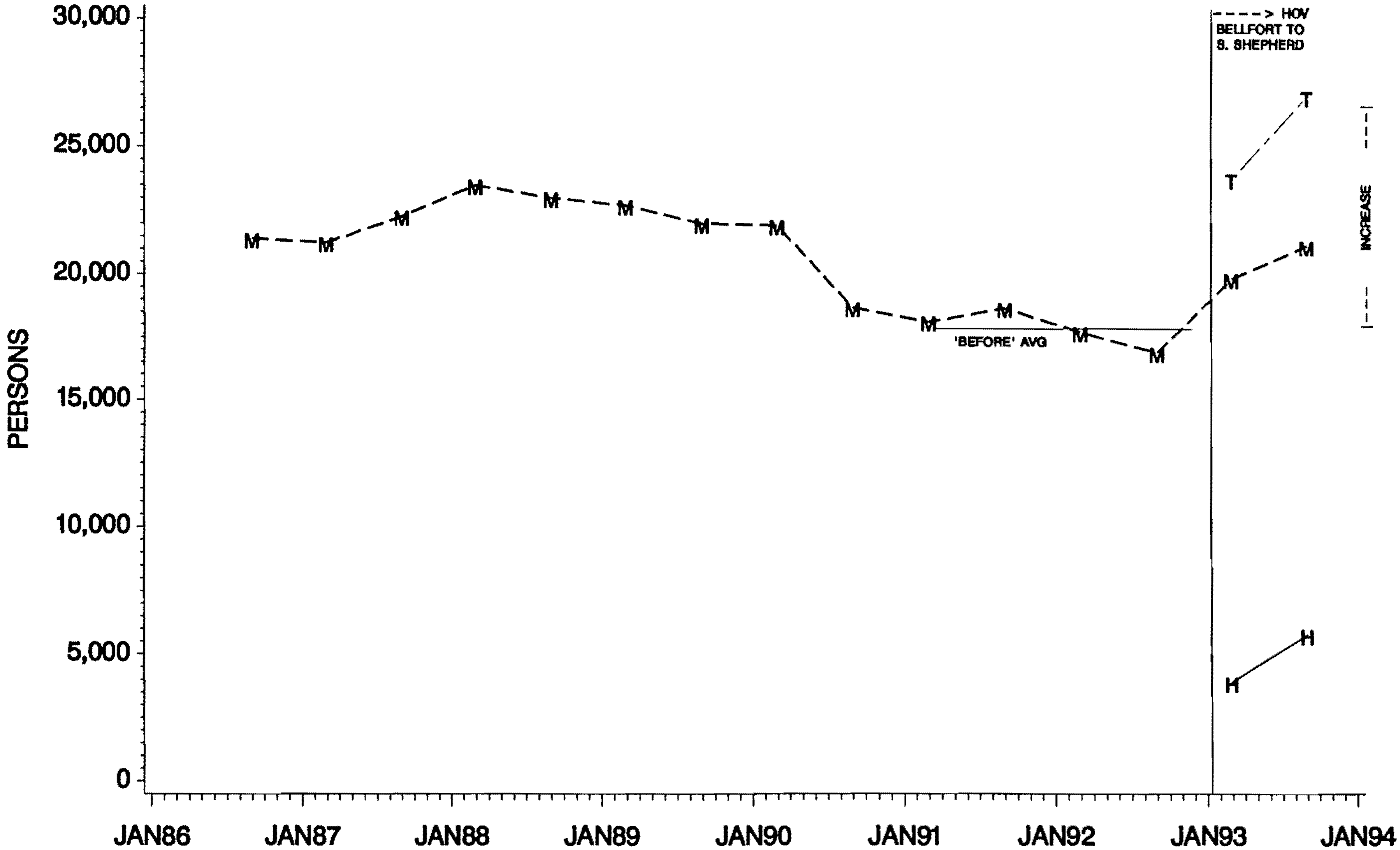


SOUTHWEST HOV LANE, BELLFORT TO SHEPHERD (18.68 KM [11.6 MI]), OPENED JANUARY 11,1993
DATA COLLECTED OVER WESTPARK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL PERSONS
M = MAINLANE PERSONS
H = HOV LANE PERSONS

FIGURE E-10

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

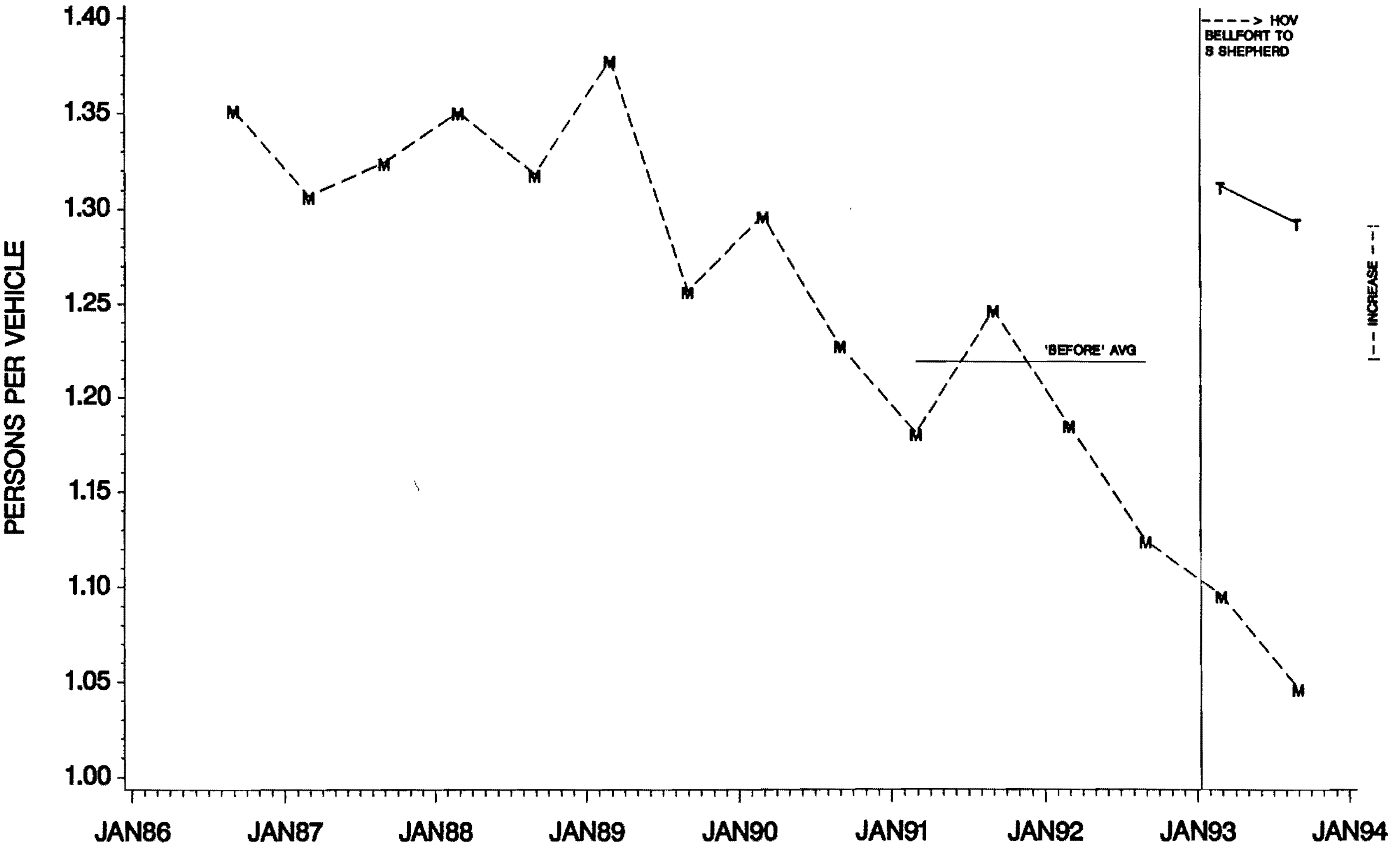


SOUTHWEST HOV LANE, BELLFORT TO SHEPHERD (18.68 KM [11.6 MI]), OPENED JANUARY 11,1993
DATA COLLECTED OVER WESTPARK
PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL PERSONS
M = MAINLANE PERSONS
H = HOV LANE PERSONS

FIGURE E-11

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

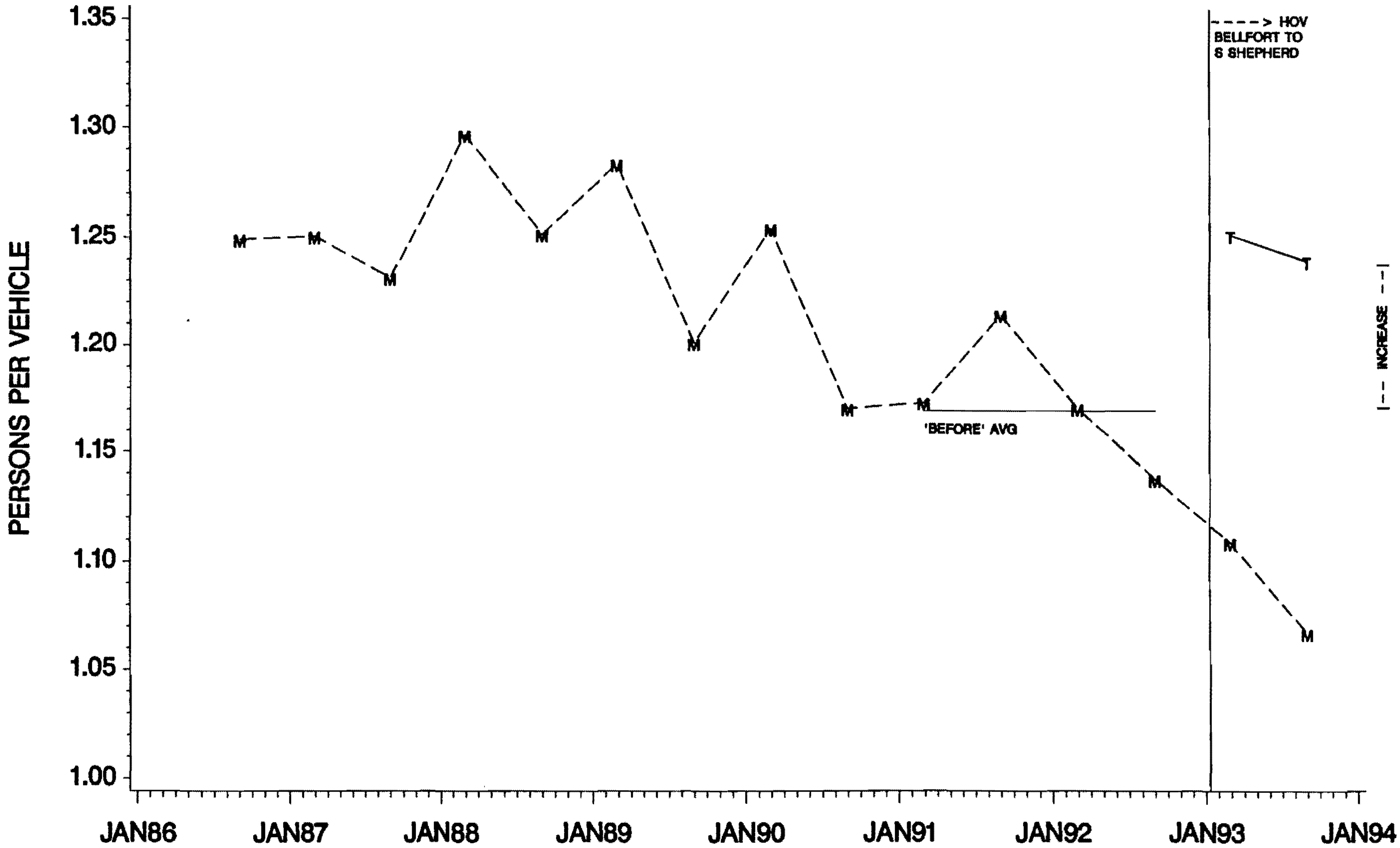


SOUTHWEST HOV LANE, BELLFORT TO SHEPHERD (18.68 KM [11.6 MI]), OPENED JANUARY 11, 1993
DATA COLLECTED OVER WESTPARK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : M = MAINLANE OCCUPANCY
T = TOTAL OCCUPANCY
(FREEWAY PLUS HOV LANE)

FIGURE E-12

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

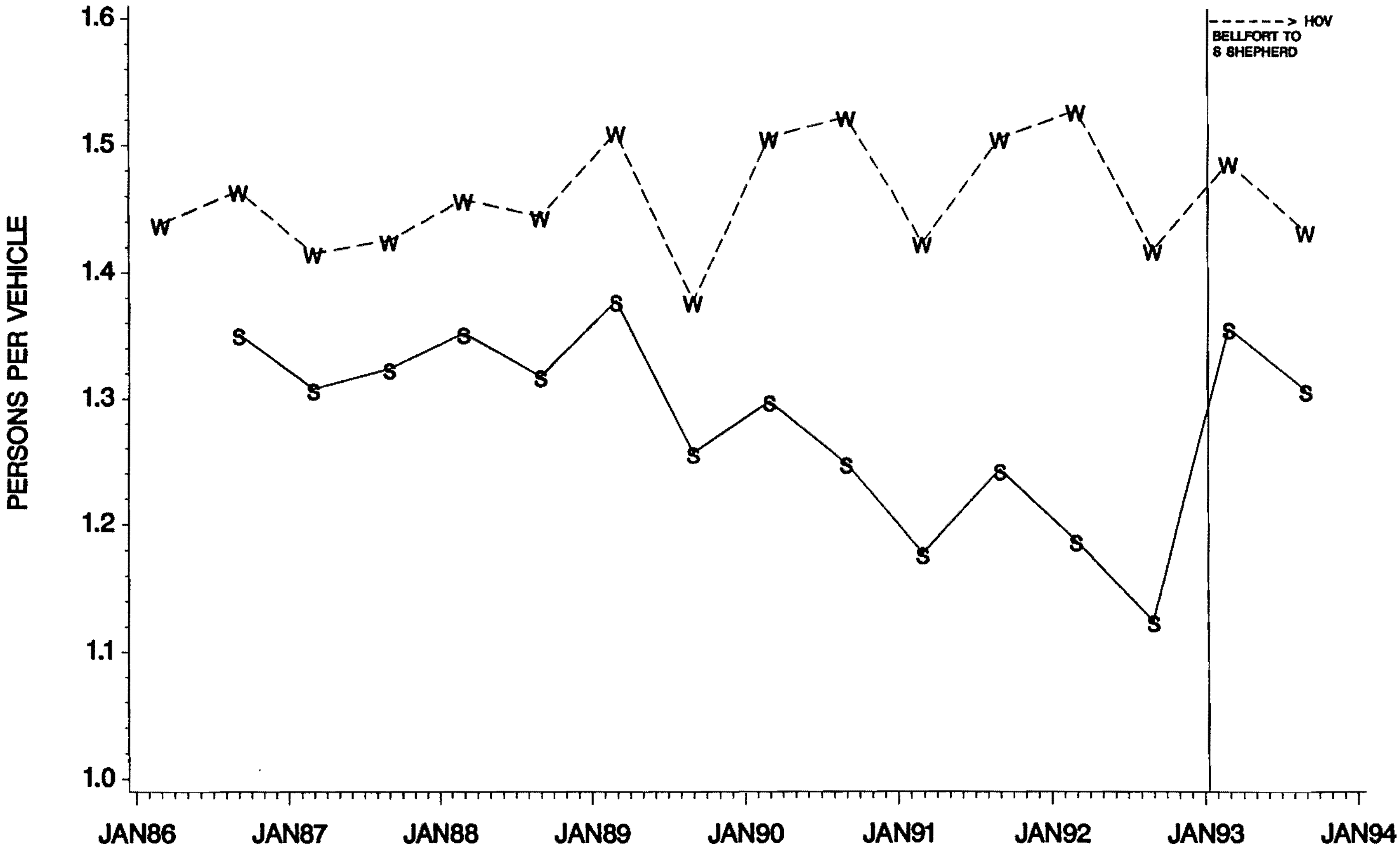


SOUTHWEST HOV LANE, BELLFORT TO SHEPHERD (18.66 KM [11.6 MI]), OPENED JANUARY 11, 1993
DATA COLLECTED OVER WESTPARK
PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : M = MAINLANE OCCUPANCY
T = TOTAL OCCUPANCY
(FREEWAY PLUS HOV LANE)

FIGURE E-13

A.M. PEAK HOUR AVERAGE OCCUPANCY
SOUTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

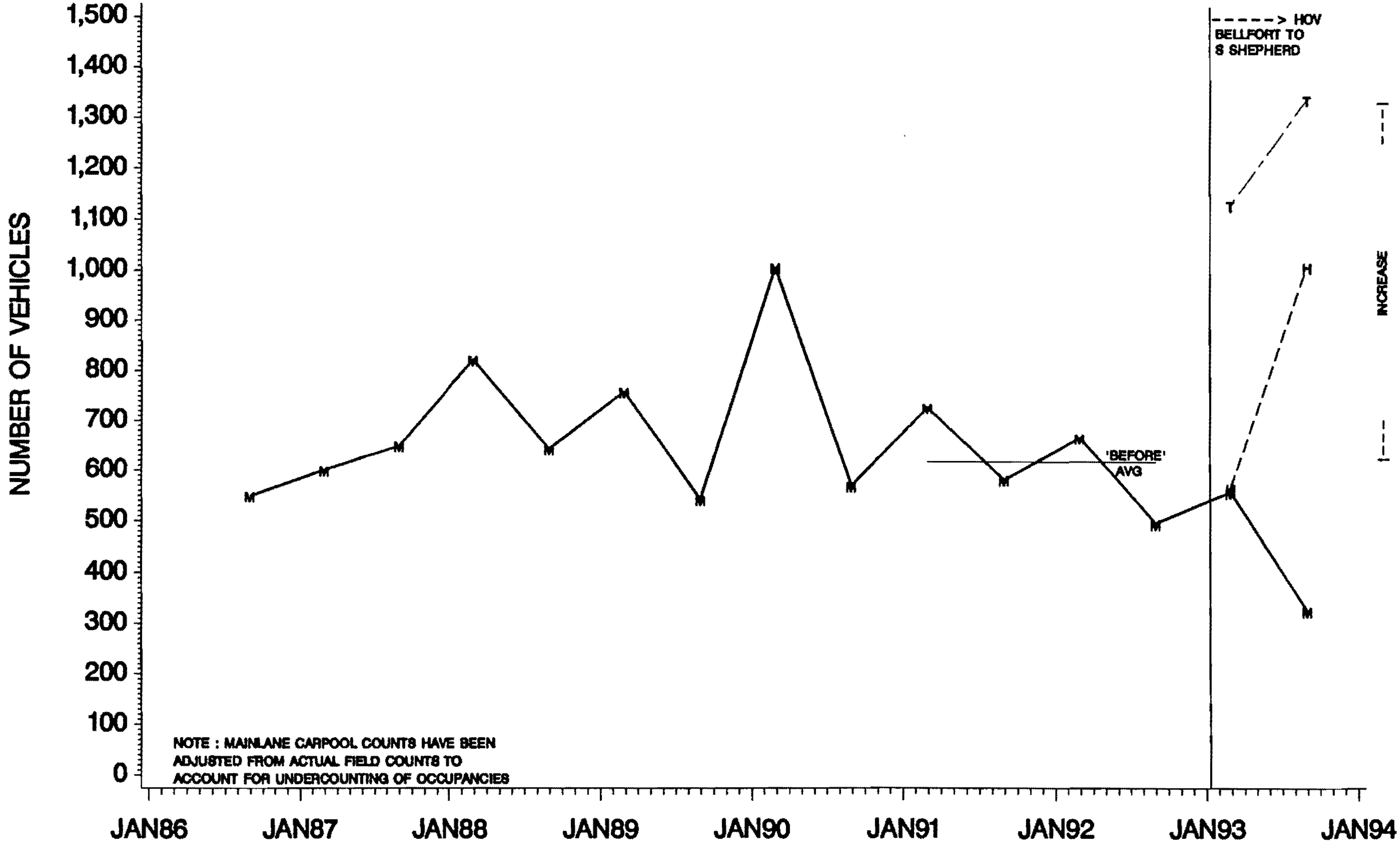


DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF
THE SOUTHWEST FWY (9/86 – 12/92) AND EASTEX FWY (1/93 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : S = SOUTHWEST FREEWAY OVER WESTPARK
(WITH HOV LANE)
W = FREEWAYS WITHOUT HOV LANE

FIGURE E-14

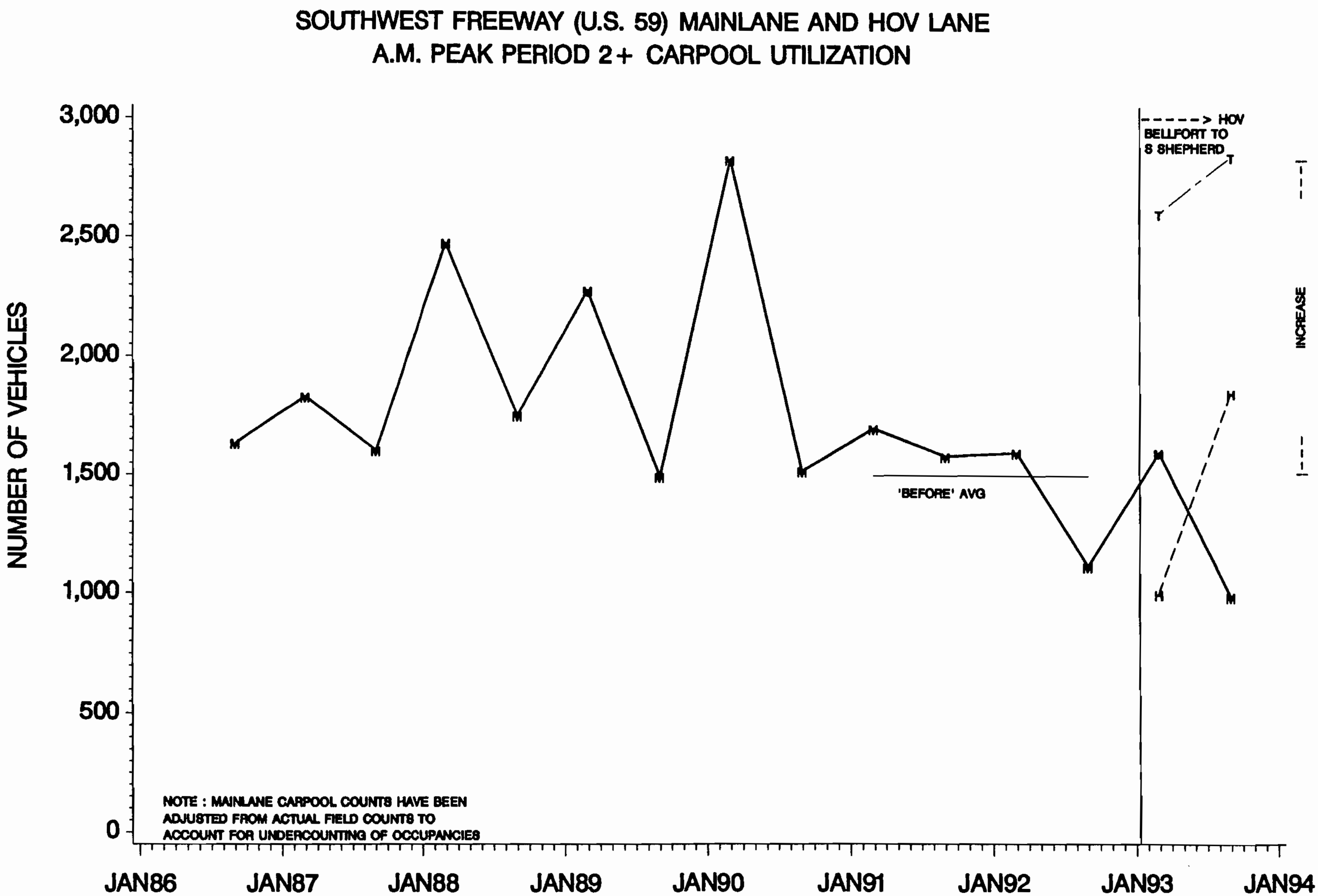
SOUTHWEST FREEWAY (U.S. 59) MAINLANE AND HOV LANE A.M. PEAK HOUR 2+ CARPOOL UTILIZATION



SOUTHWEST HOV LANE, BELLFORT TO S. SHEPHERD (18.68 KM [11.6 MI]), OPENED JANUARY 11, 1993
DATA COLLECTED OVER WESTPARK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL 2+ CARPOOLS
H = TOTAL HOV LANE 2+ CARPOOLS
M = TOTAL MAINLANE 2+ CARPOOLS

FIGURE E-15

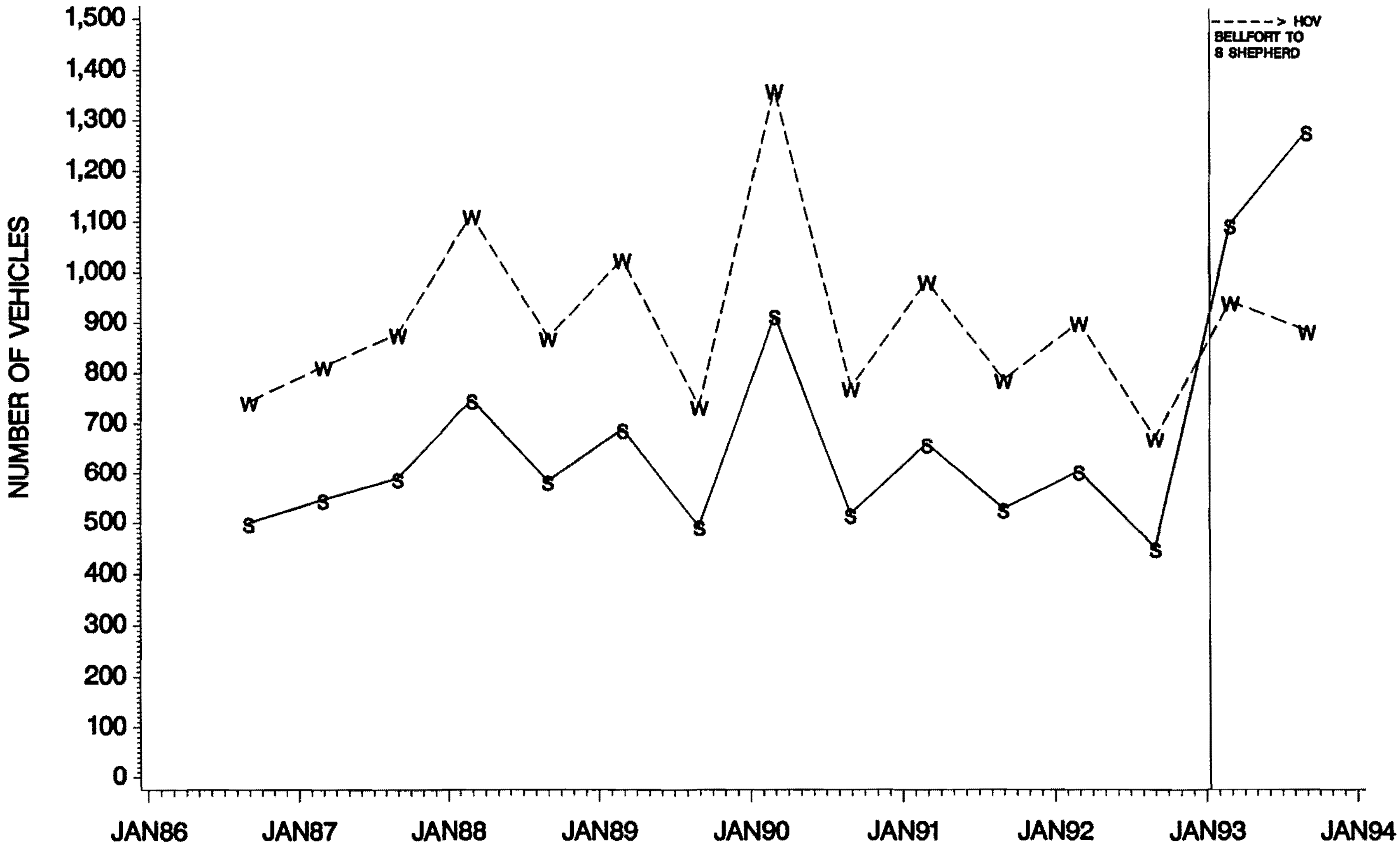


SOUTHWEST HOV LANE, BELLFORT TO S. SHEPHERD (18.66 KM [11.6 MI]), OPENED JANUARY 11, 1993
PEAK PERIOD IS 6:00 – 9:30 A.M.
DATA COLLECTED OVER WESTPARK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL 2+ CARPOOLS
H = TOTAL HOV LANE 2+ CARPOOLS
M = TOTAL MAINLANE 2+ CARPOOLS

FIGURE E-16

A.M. PEAK HOUR 2+ CARPOOL VOLUMES
SOUTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

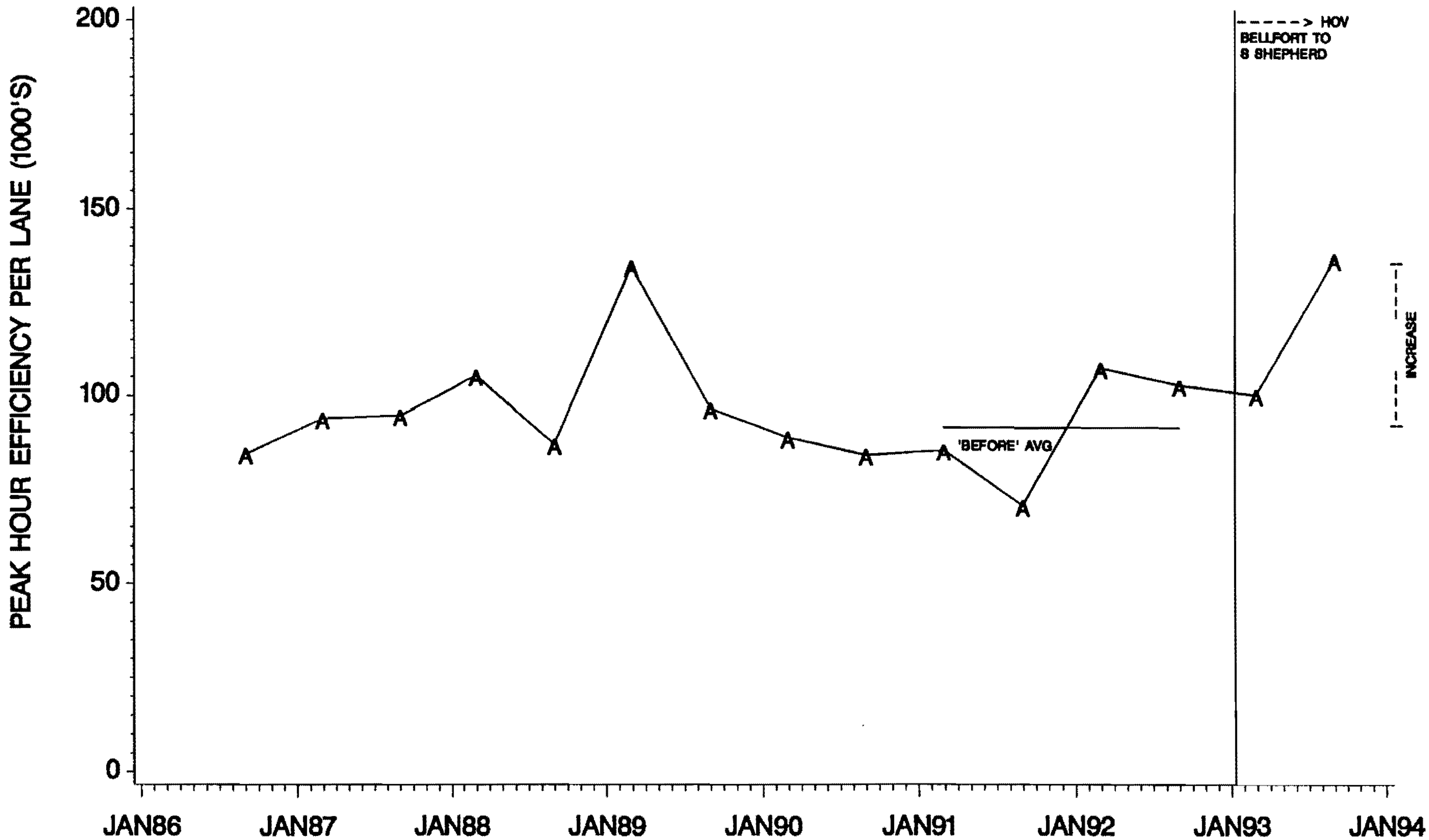


DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF
GULF FWY (6/83 – 4/86), SOUTHWEST FWY (6/86 – 12/92) AND EASTEX FWY (1/93 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : S = SOUTHWEST FREEWAY 2+ CARPOOLS
W = FREEWAYS WITHOUT HOV LANE

FIGURE E-17

SOUTHWEST FREEWAY (U.S. 59S) EVALUATION
A.M. PEAK HOUR MAINLANE AND HOV LANE EFFICIENCY

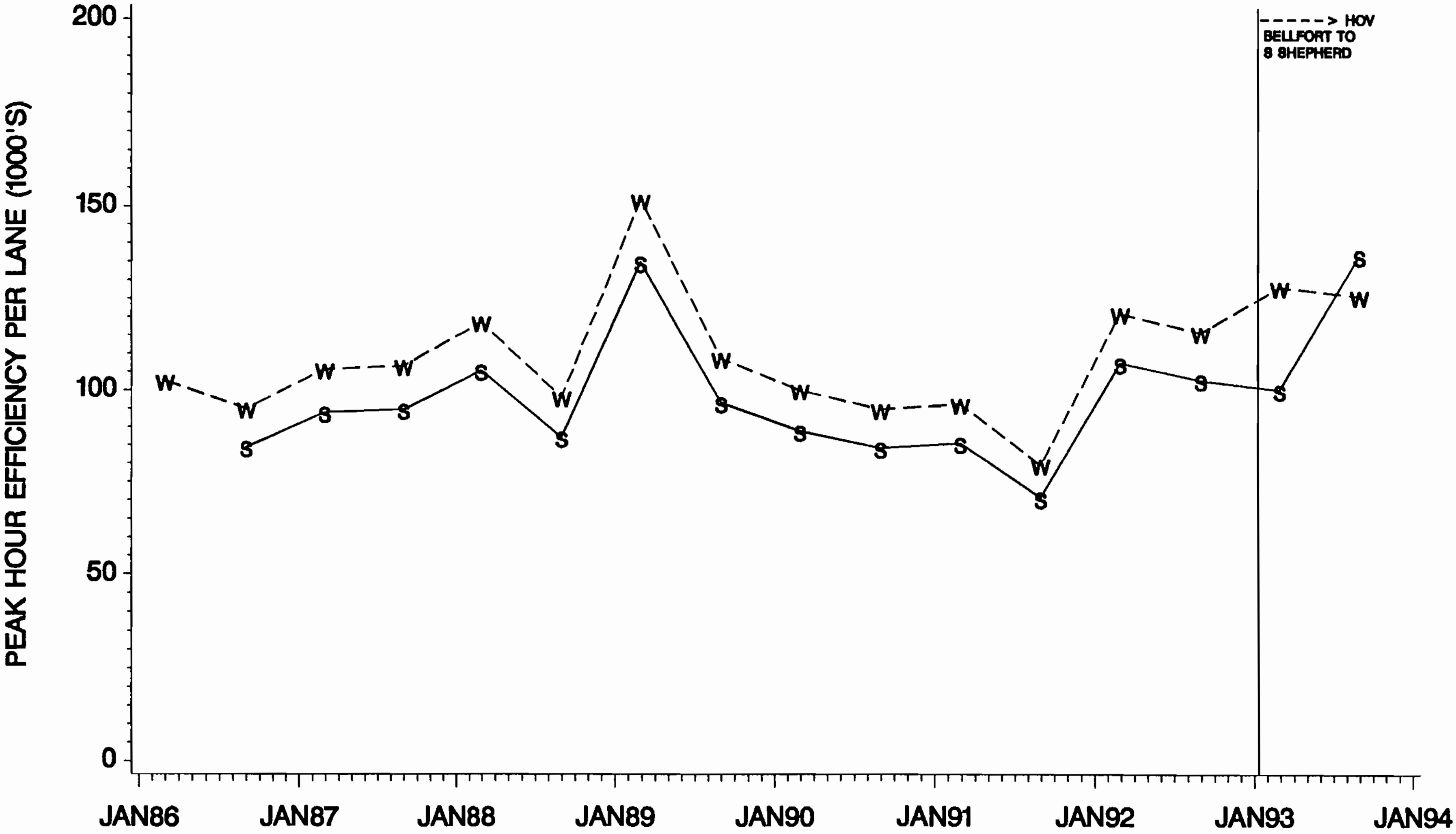


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE HOV LANE, IT REPRESENTS TOTAL PERSONS (FREEWAY + HOV LANE) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 4 LANES
TO CONVERT EFFICIENCY FROM METRIC TO ENGLISH UNITS MULTIPLY BY 0.62
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : A = A.M. PEAK HOUR EFFICIENCY

FIGURE E-18

A.M. PEAK HOUR FREEWAY PER LANE EFFICIENCY
SOUTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

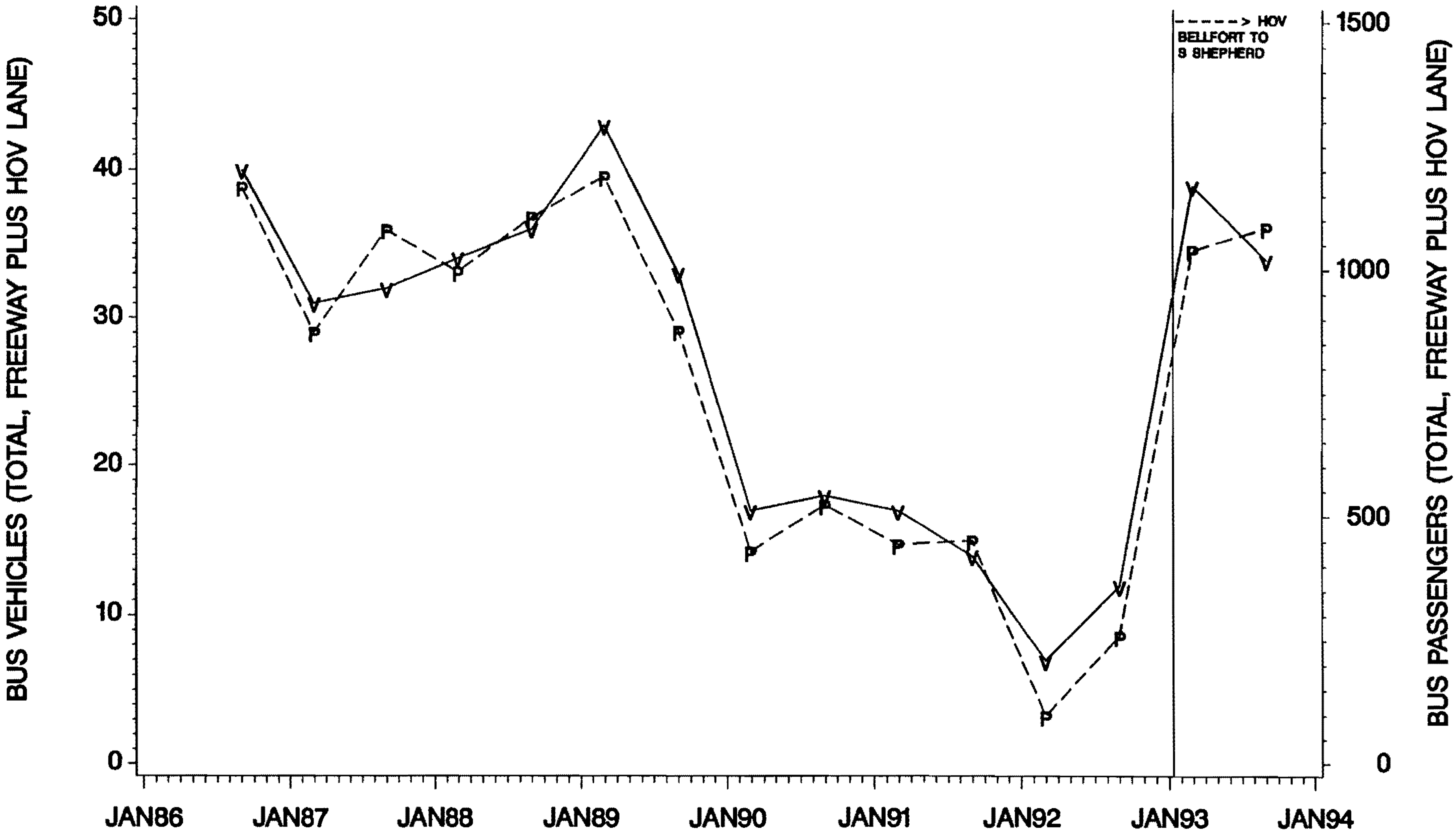


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE HOV LANE, IT REPRESENTS TOTAL PERSONS (FREEWAY + HOV LANE) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 4 LANES
DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF
GULF FWY (6/83 – 4/86), SOUTHWEST FWY (6/86 – 12/92) AND EASTEX FWY (1/93 – PRESENT) DATA
TO CONVERT EFFICIENCIES FROM METRIC TO ENGLISH UNITS MULTIPLY BY 0.62
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : S = SOUTHWEST FREEWAY EFFICIENCY
W = FREEWAYS WITHOUT HOV LANE

FIGURE E-19

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



SOUTHWEST HOV LANE, BELLFORT TO SHEPHERD (18.68 KM [11.6 MI]), OPENED JANUARY 11, 1993
DATA COLLECTED OVER WESTPARK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = BUS PASSENGER VOLUME
V = BUS VEHICLE VOLUME

FIGURE E-20

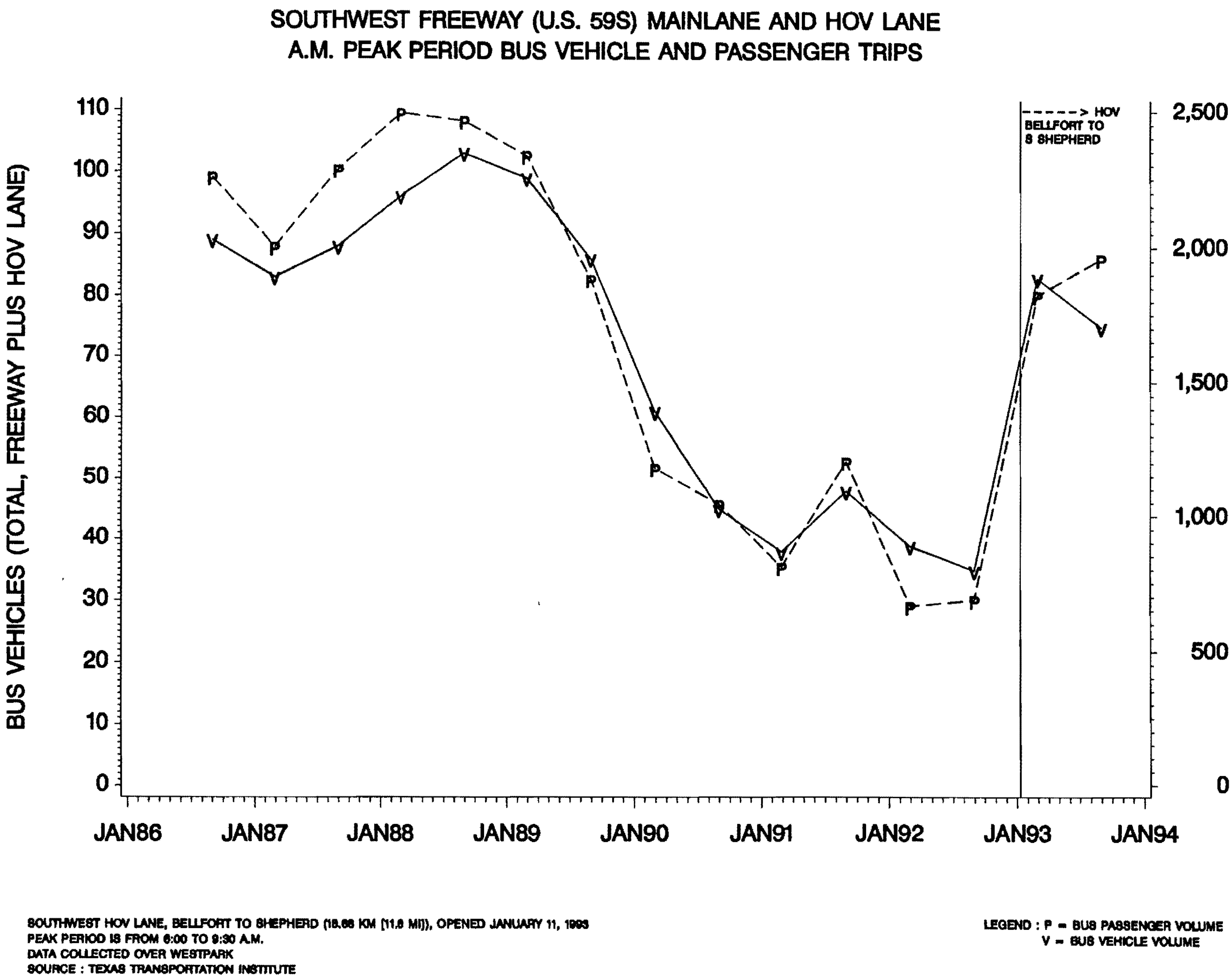
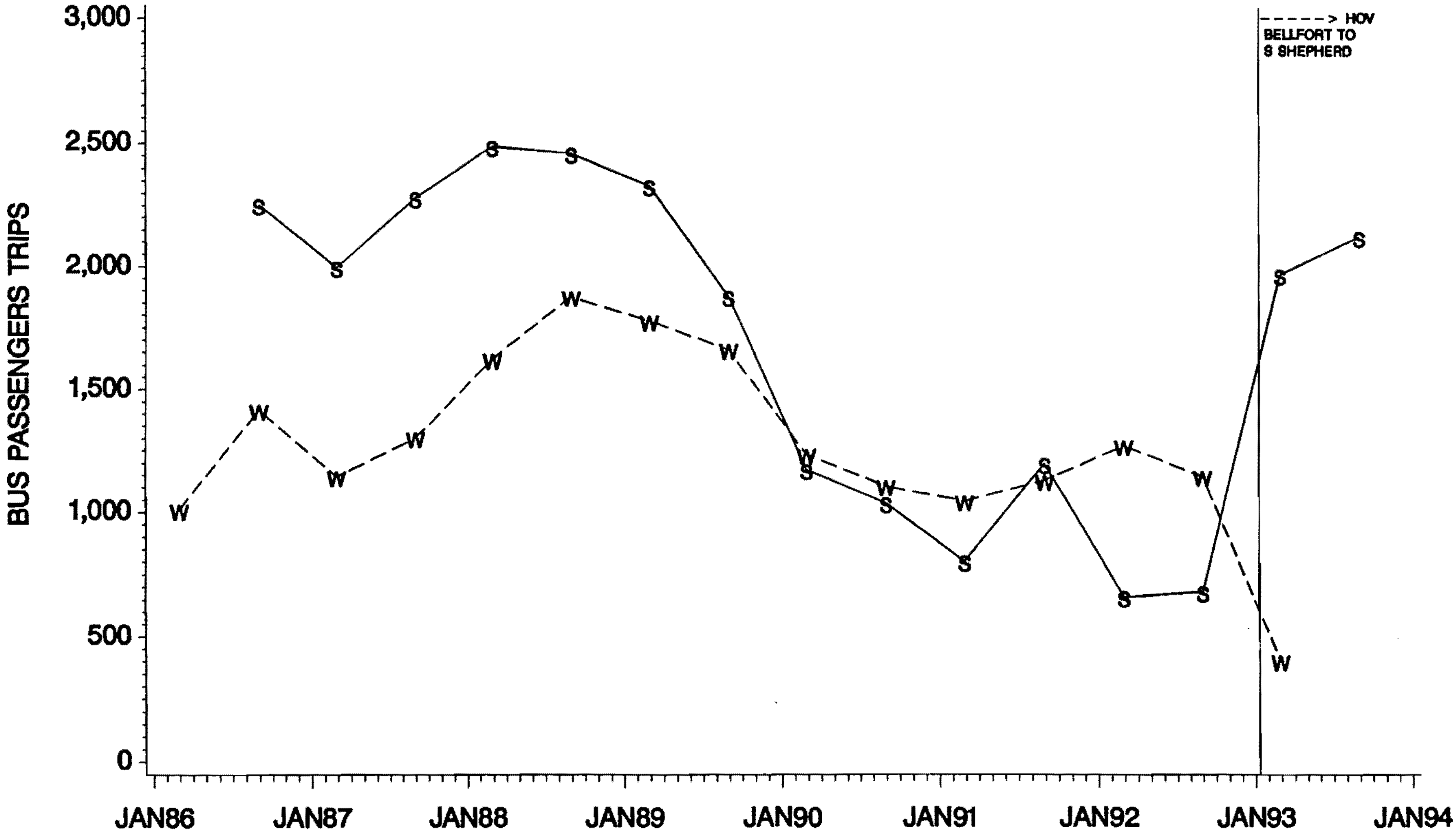

SOUTHWEST FREEWAY (U.S. 59S) MAINLANE AND HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS
BUS VEHICLES (TOTAL, FREEWAY PLUS HOV LANE)
BUS PASSENGERS (TOTAL, FREEWAY PLUS HOV LANE)
----> HOV BELLFORT TO S SHEPHERD
JAN86
JAN87
JAN88
JAN89
JAN90
JAN91
JAN92
JAN93
JAN94
SOUTHWEST HOV LANE, BELLFORT TO SHEPHERD (18.66 KM (11.6 MI)), OPENED JANUARY 11, 1993
PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA COLLECTED OVER WESTPARK
SOURCE : TEXAS TRANSPORTATION INSTITUTE
LEGEND : P = BUS PASSENGER VOLUME
V = BUS VEHICLE VOLUME

FIGURE E-21

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

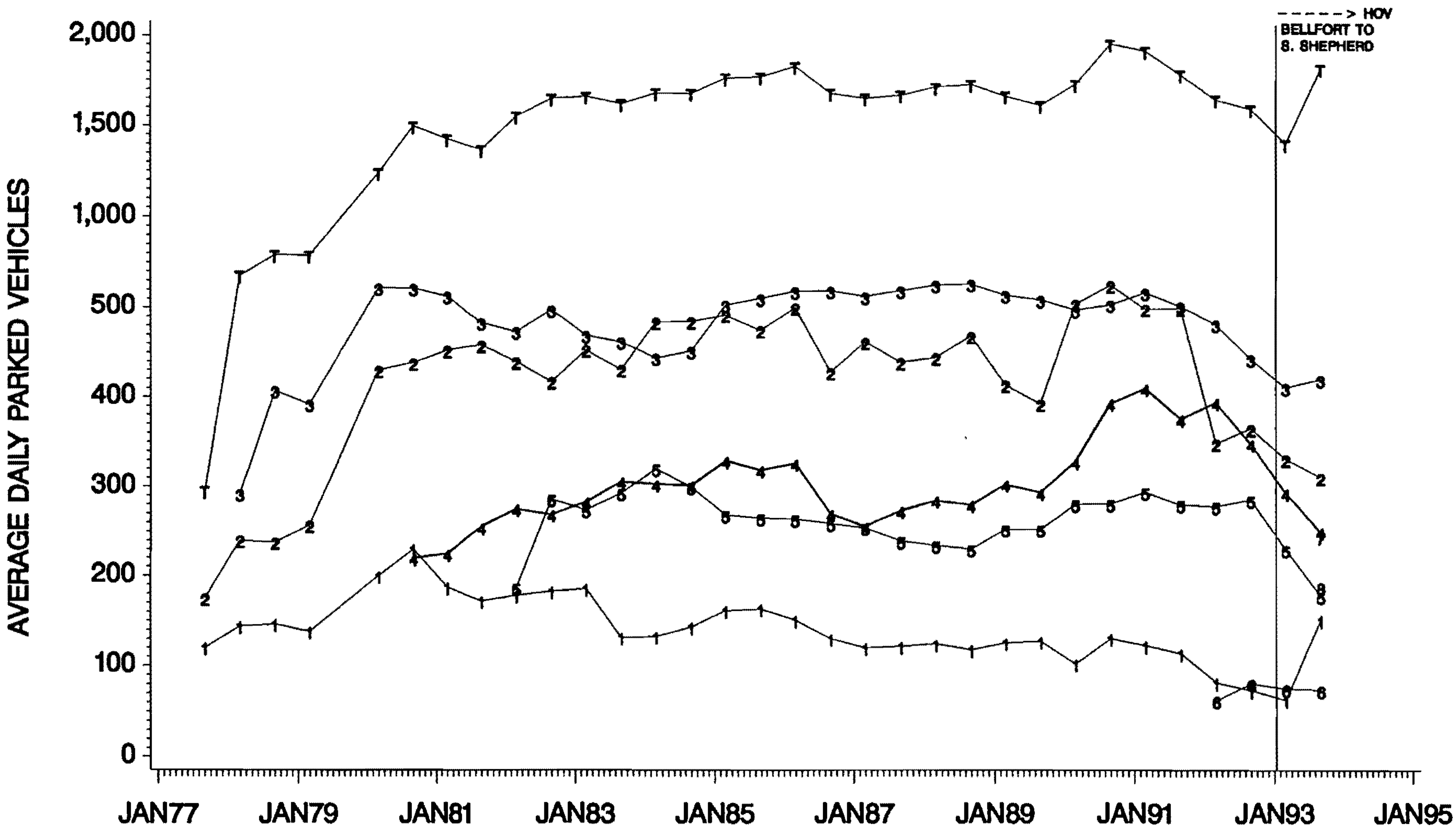


PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF
SOUTHWEST FWY (9/86 – 8/89) AND EASTEX FWY (9/89 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : S = SOUTHWEST FREEWAY OVER WESTPARK
(WITH HOV LANE)
W = FREEWAYS WITHOUT HOV LANE

FIGURE E-22

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



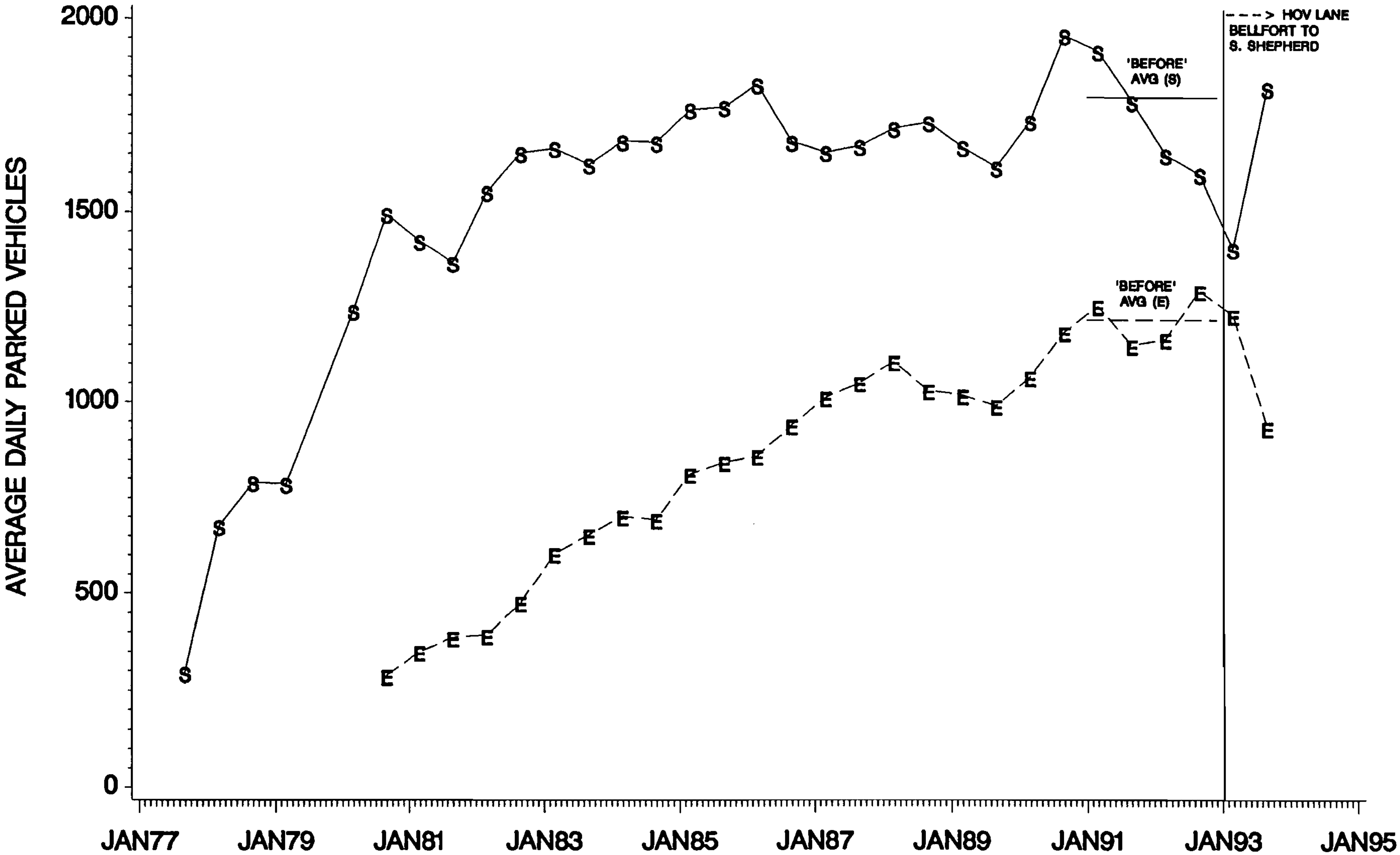
SOUTHWEST HOV LANE, BELLFORT TO S. SHEPHERD (18.68 KM [11.6 MI]), OPENED JANUARY 11, 1993
CURRENT TOTAL CORRIDOR PARKING CAPACITY = 7,022 SPACES

SOURCE : TEXAS TRANSPORTATION INSTITUTE & METRO

LEGEND : T = TOTAL PARKED VEHICLES
1 = SHARPSTOWN LOT (135 SPACES)
2 = WEST LOOP LOT (978 SPACES)
3 = WESTWOOD LOT (800 SPACES)
4 = ALIEF LOT (1,373 SPACES)
5 = MISSOURI CITY LOT (779 SPACES)
6 = MISSION BEND LOT (862 SPACES)
7 = W. BELLFORT LOT (1,200 SPACES)
8 = HILLCROFT TRANSIT CENTER (895 SPACES)

FIGURE E-23

AVERAGE DAILY VEHICLES PARKED AT PARK-AND-RIDE LOTS
SOUTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE



SOUTHWEST HOV LANE, BELLFORT TO S. SHEPHERD (18.68 KM [11.6 MI]), OPENED JANUARY 11, 1993
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : S - SOUTHWEST FREEWAY
E - FREEWAY WITHOUT HOV LANE (EASTEX)

APPENDIX F

EAST R. L. THORNTON FREEWAY AND HOV LANE DATA

EAST R. L. THORNTON FREEWAY (IH 30E) & HOV LANE, DALLAS

Table F-1. Summary of A.M. Peak-Direction East R. L. Thornton Freeway and HOV Lane Data, December 1993

Type of Data HOV Lane Became Operational 9/23/91	"Representative" Pre-HOV Lane	"Representative" Current Value	Percent Change
<u>HOV Lane Data</u>			
HOV Lane Length kilometers (miles)			
Morning		8.4 (5.2)	---
Evening		5.3 (3.3)	---
HOV Lane Cost (millions of 1990 dollars)		$12.7	---
Person-Movement			
Peak Hour (7:00-8:00 a.m.)	---	3,640	---
Peak Period (6:00-9:00 a.m.)	---	7,276	---
Total Daily	---	14,017	---
Vehicle Volumes			
Peak Hour	---	1,243	---
Peak Period	---	2,507	---
Vehicle Occupancy, Peak Hour (persons/veh)	---	2.93	---
Accident Rate (i.e. Injury accidents/100 MVK [/100 MVM]), 10/91-12/93[1]	---	10.4 (16.7)	---
Vehicle Breakdowns (VMK/Breakdown [VMT/Breakdown]), 10/91-12/93	---	43,068 (26,750)	---
Violation Rate (6:00-9:00 a.m.)	---	1.8%	---
Peak Hour Lane Efficiency (1000's)[2]	---	261 (162)	---
Annual Value of User Time Saved (millions)[3]	---	$1.4 to $2.8	---
<u>Freeway Mainlane Data (see note)</u>			
Person Movement			
Peak Hour	7,689	7,235	-6%
Peak Period (6:00-9:00 a.m.)	23,030	20,349	-12%
Vehicle Volume			
Peak Hour	5,692	6,880	+21%
Peak Period	17,946	19,086	+6%
Vehicle Occupancy, Peak Hour (persons/veh)	1.35	1.05	-22%
Accident Rate (i.e. Injury accidents/100 MVK [/100 MVM])[1]	14.0 (22.6)	13.5 (21.8)	-4%
Avg. Operating Speed[4] (kph [mph])			
Peak Hour	34 (21)	46 (29)	+34%
Peak Period	48 (30)	66 (41)	+37%
Peak Hour Lane Efficiency (1000's)[2]	66 (41)	83 (52)	+26%

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

[1]In order to directly compare accidents to Houston, only injury accidents are included in this analysis. Accidents were analyzed between Pearl/Central Expressway and Jim Miller Road, a distance of approximately 8.4 kilometers (5.2 miles). "Before" data are for the period 9/90 through 9/91. "After" data are for the period from 10/91 to 12/93. Only officer-reported accidents are included in current files. 1993 freeway volumes estimated by TTI.

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

[3]Based on time savings for HOV lane users in 1993 and HOV lane volumes in 1993, an annual estimate of travel time savings to HOV lane users is developed. A value of time of $10.78/hour is used based on the value applied in the Highway Economic Evaluation Model.

[4]From Jim Miller to Central Expressway, the distance is 8.4 kilometers (5.2 miles). The morning HOV lane is in place over this section.

Table F-1. Summary of A.M. Peak-Direction East R. L. Thornton Freeway and HOV Lane Data, December 1993 (Continued)

Type of Data HOV Lane Became Operational 9/23/91	"Representative" Pre-HOV Lane	"Representative" Current Value	Percent Change
Combined Freeway Mainlane and HOV Lane Data			
Total Person Movement			
Peak Hour	7,689	10,875	+41%
Peak Period	23,030	27,625	+20%
Vehicle Volume			
Peak Hour	5,692	8,123	+43%
Peak Period	17,946	21,593	+20%
Vehicle Occupancy			
Peak Hour	1.35	1.34	-1%
Peak Period	1.26	1.28	+2%
2+ Carpool Volumes[1]			
Peak Hour	596	1,463	+145%
Peak Period	1,903	3,322	+75%
Travel Time (minutes)			
Peak Hour	14.7[2]	11.6[3]	-21%
Peak Period	10.6[2]	8.0[3]	-25%
Peak Hour Lane Efficiency (1000's)[4]	66 (41)	119 (74)	+80%
Transit Data			
Bus Vehicle Trips			
Peak Hour	41	62	+51%
Peak Period	103	121	+17%
Bus Passenger Trips			
Peak Hour	1,283	1,470	+15%
Peak Period	2,819	2,790	-1%
Bus Occupancy (persons/bus)			
Peak Hour	31.3	23.7	-24%
Peak Period	27.4	23.1	-16%
Vehicles Parked in Corridor Park & Ride Lots	847	841	-1%
Bus Operating Speed[5] (kph [mph])			
Peak Hour	34 (21)[2]	71 (44)[3]	+109%
Peak Period	48 (30)[2]	86 (54)[3]	+79%

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

[1]Carpool counts are adjusted in an effort to compensate for under counting of occupancies in the field.
[2]Data pertain to operation in the freeway mainlanes.
[3]Data pertain to operation in the HOV lane.
[4]This represents the multiple of peak-hour passengers and average speed (passengers x kilometers/hour [passengers x miles/hour]). It is used as a measure of per lane efficiency.
[5]From Jim Miller to Central Expressway, the distance is 8.4 kilometers (5.2 miles). The HOV lane is in place over this section.

Table F-2. Comparison of Measures of Effectiveness, Freeway With (East Thornton, IH 30E) and Freeway Without (South Thornton, IH 35E) HOV Lane, Dallas

Measure of Effectiveness	"Representative" Pre-HOV Lane Value	"Representative" 12/93 Value	Percent Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/HOV lane	1.35	1.34	-1%
Freeway w/o HOV lane	1.25	1.21	-3%
Peak-Hour 2+ Carpool Volume			
Freeway w/HOV lane	596	1,463	+145%
Freeway w/o HOV lane	802	766	-4%
Bus Passengers, Peak Period			
Freeway w/HOV lane	2,819	2,285	-19%
Freeway w/o HOV lane	2,540	2,225	-12%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	847	841	-1%
Freeway w/o HOV lane	425	392	-8%
Facility Per Lane Efficiency[1]			
Freeway w/HOV lane	66 (41)	119 (74)	+80%
Freeway w/o HOV lane	108 (67)	100 (62)	-8%

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

HOV LANE DATA

DESCRIPTION

- The evening operation (5.3 kilometers [3.3 miles]) opened September 23, 1991.
- The morning operation (5.3 kilometers [3.3 miles]) opened September 30, 1991.
- The morning operation (8.4 kilometers [5.2 miles]) extended November 4, 1991.
- The capital cost for the completed facility in 1990 dollars was $12.7 million. A more detailed cost breakdown (including dates) is provided on the following page.
- Selected milestone dates are listed below. Other dates are shown in the capital cost table.
- 9/23/91 Evening lane opens Central Expressway to Dolphin Road (5.3 kilometers [3.3 miles]), used by buses and vans.
- 9/30/91 Morning lane opens Dolphin Road to Central Expressway (5.3 kilometers [3.3 miles]), used by buses and vans.

- 10/7/91 3+ carpools allowed onto HOV lane.
- 10/21/91 2+ carpools allowed onto HOV lane.
- 11/04/91 Morning operation extended to begin at Jim Miller (8.4 kilometers [5.2 miles, total]).
- 11/25/91 DART adds bus service to existing routes.

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

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1990 dollars
HOV Lane and Ramps (1990)			
Barrier	$6.0	1.00	$6.0
Barrier Machine(s)	0.9	1.00	0.9
Contraflow Lane	5.6	1.00	5.6
Support Vehicles	0.2	1.00	0.2
TOTAL COST	$12.7		$12.7
COST PER KILOMETER (8.4 kilometers [5.2 miles])	$1.5 ($2.4)		$1.5 ($2.4)

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

PERSON MOVEMENT

- In December 1993, 14,017 person trips per day were served on the HOV lane.
- A.M. Peak Hour, 3,640 persons/hour.
  - 1,110 (31%) by bus, 88 (2%) by vanpool, 2,442 (67%) by carpool (Figure F-1).
  - Average HOV lane vehicle occupancy = 2.93 persons/vehicle.
- A.M. Peak Period, 7,276 persons.
  - 2,285 (31%) by bus, 115 (2%) by vanpool, by carpool 4,876 (67%) (Figure F-2).

VEHICLE MOVEMENT

- A.M. Peak Hour, 1,243 vph
  - 43 (4%) buses, 11 (1%) vans, 1,186 (95%) carpools (Figure F-3).
- A.M. Peak Period, 2,507 vehicles
  - 102 (4%) buses, 18 (1%) vans, 2,387 (95%) carpools (Figure F-4).

ACCIDENT RATE

- For the period from October 1991 through December 1993, the HOV lane accident rate was 10.4 injury accidents per 100 million vehicle kilometers of travel (16.7 injury accidents per 100 million vehicle miles).

VEHICLE BREAKDOWN RATES

- As measured for 1/93 to 12/93, the following rate has been observed.
  - The weighted average for all vehicle types is one breakdown per 43,068 VKT (26,750 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 1.8%.
  - For the p.m. peak period, the violation rate is 1.5%.

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 262 (3,640 passengers at 72 kph) or 160 (3,640 passengers at 44 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane experienced an average travel time savings of 8.6 minutes during the morning peak hour in 1993 (Figure F-5).

- The tables on the following page indicate that, on a typical non-incident day, travel time savings of approximately 523 hours (31,406 min.) are realized. Assuming 250 days of operation, annual savings would be 130,859 hours. At $10.78/hour, this equates to $1.41 million per year. This is extremely conservative since it does not consider travel time savings due to incidents on the freeway. Data from Houston suggest that increasing this value by 100% to account for incidents would be reasonable. Thus, travel time savings to HOV lane users are conservatively estimated to be in the range of $1.41 to $2.82 million per year.

FREEWAY DATA

NOTES

- For purposes of safety and visibility, freeway volumes are counted near Dolphin Road between an entrance ramp and an exit ramp. This location is not necessarily the highest traffic volume section; however, the location gives reasonable estimates of traffic volumes which can be used for monitoring trends.

PERSON MOVEMENT

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

- In the a.m. peak period, person movement has decreased by 12% relative to pre-HOV conditions (Figure F-7).

VEHICLE VOLUME

- In the a.m. peak hour, vehicle volume has increased by 21% relative to pre-HOV conditions (Figure F-6).

- In the a.m. peak period, vehicle volume has increased by 6% relative to pre-HOV conditions (Figure F-7).

VEHICLE OCCUPANCY

- In the a.m. peak hour, mainlane occupancy has decreased by 22% relative to pre-HOV conditions (from 1.35 to 1.03).

- In the a.m. peak period, mainlane occupancy has decreased by 18%, relative to pre-HOV conditions (from 1.28 to 1.05).

ACCIDENT RATE

- Implementation of the HOV lane resulted in narrower freeway lanes and no inside emergency shoulder in the off-peak direction during HOV lane operation.

- The accident data shown are for the section between Pearl/Central Expressway and Jim Miller Road. The accident rate for the period (10/90-9/91) preceding Phase 1 of the HOV lane was 14.0 accidents per 100 million vehicle kilometers (100 MVK) (22.6 accidents per 100 million vehicle miles [100 MVM]). For the period from 10/91 to 9/93, the freeway accident rate was 13.5 accidents/100 MVK (21.8 accidents/100 MVM). These statistics do not include driver reported accidents; only officer reported accidents are included in current accident files. TTI estimated 1993 freeway volumes to compute accident rates.

AVERAGE OPERATING SPEED

- In comparison to pre-HOV lane conditions, mainlane operating speeds have increased by 34% in the peak hour and 37% in the peak period (Figures F-8 and F-9).

PEAK HOUR LANE EFFICIENCY

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

- For the freeway mainlanes, an increase in per lane efficiency of 26% has occurred.

COMBINED FREEWAY MAINLANE AND HOV LANE DATA

TOTAL PERSON MOVEMENT

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

    - The HOV lane is responsible for 36% of peak-hour person movement (HOV lane = 3,640; freeway = 7,235) and 28% of peak-period (HOV lane = 7,276; freeway = 19,086) person movement.

- Increase in a.m. person movement at Dolphin Road relative to pre-HOV lane operations.

    - Provision of the HOV lane increased total directional lanes by 25% in the peak period.

    - Total peak-hour person movement has increased by 41% from 7,689 to 10,875 (Figure F-10). Peak-period person movement has increased by 20% from 23,030 to 27,625 (Figure F-11).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.34 -- a 2% increase over the pre-HOV lane occupancy (Figure F-12). Occupancy in the peak period is greater than pre-HOV lane levels (Figure F-13), increasing from 1.26 to 1.28 (2%).

- 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-14).

CARPOOL VOLUMES

- In the a.m. peak hour, the total number of 2+ carpools (freeway plus HOV lane) has increased by 145% compared to pre-HOV lane levels (Figure F-15).

Table F-4. Westbound A.M. Travel Time Savings for Thornton HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1993)

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 Jim Miller to Central Expressway								
6:00	5.66	5.39	0.27	48	1	75	125	34
6:15	6.18	5.70	0.48	211	1	156	368	176
6:30	7.32	6.19	1.14	403	6	273	682	775
6:45	9.09	6.31	2.78	499	6	234	739	2,053
7:00	9.58	6.48	3.10	604	11	323	938	2,905
7:15	11.80	6.70	5.11	739	24	345	1,109	5,664
7:30	11.38	7.86	3.53	721	42	334	1,098	3,870
7:45	10.93	7.00	3.93	648	11	325	985	3,874
8:00	7.61	6.01	1.60	446	5	170	621	996
8:15	7.33	5.96	1.37	401	10	145	556	763
8:30	5.83	5.60	0.22	298	2	115	415	93
8:45	5.93	5.63	0.31	200	2	35	238	73
9:00	5.39	5.18	0.21	80	7	15	102	22
Peak Period Total				5,297	125	2,544	7,973	21,298
Eastbound P.M. Travel Time Savings for Thornton HOV Lane								
Section from Central Expressway to Dolphin								
4:00	4.00	3.90	0.10	305	3	175	483	50
4:15	4.00	3.84	0.17	349	10	223	582	97
4:30	3.85	3.66	0.19	467	16	238	721	135
4:45	5.12	4.62	0.49	547	15	318	879	432
5:00	5.95	4.49	1.46	585	59	413	1,057	1,546
5:15	7.62	5.18	2.44	585	7	423	1,016	2,477
5:30	8.90	5.74	3.16	495	9	293	796	2,517
5:45	8.28	4.78	3.50	415	4	188	608	2,128
6:00	6.11	3.93	2.18	268	1	120	389	849
6:15	3.73	3.93	-0.20	192	1	85	279	-55
6:30	3.36	3.63	-0.27	140	3	55	199	-55
6:45	3.47	3.55	-0.08	126	3	38	167	-12
Peak Period Total				4,472	131	2,565	7,173	10,109

PEAK HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. The average efficiency of a lane on the freeway (4 freeway lanes plus 1 HOV lane) has increased by 80% since the implementation of the HOV lane (Figure F-16). The per-lane efficiency has decreased during this same time period on freeways not having HOV lanes (Figure F-17).

BUS TRANSIT DATA

BUS VEHICLE AND PASSENGER TRIPS

- In the a.m. peak hour, bus vehicle trips have been increased by 12% since the HOV lane opened, and a 13% decrease in bus ridership has also resulted (Figure F-18). In the peak period, a 5% decrease has occurred in bus trips and a 19% decrease in bus ridership has resulted (Figure F-19).

- While bus passenger trips have increased significantly in the East Thornton Freeway corridor, this has not occurred in the corridors which do not have HOV lanes (Figure E-20).

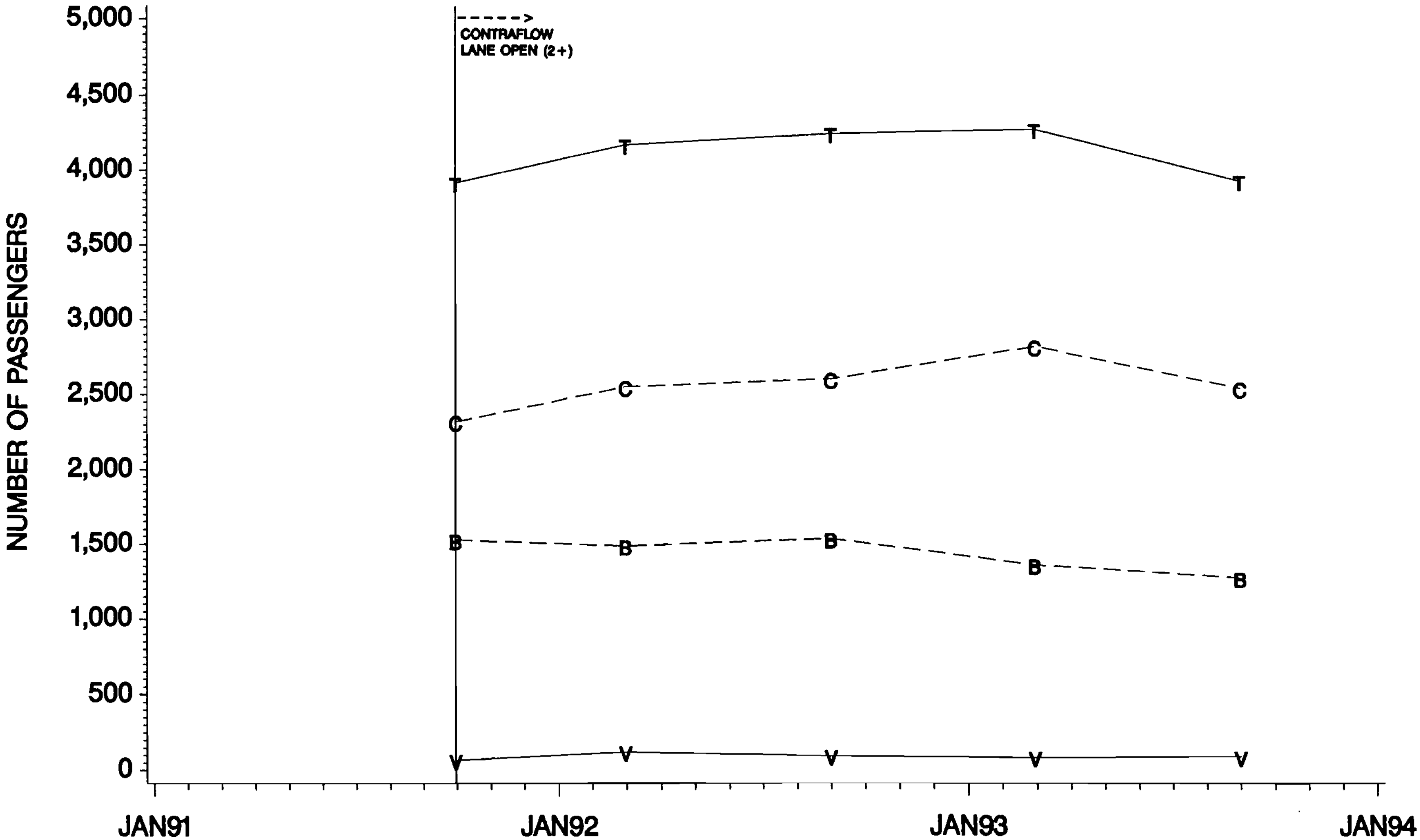
PARK-AND-RIDE

- Prior to opening the HOV lane, approximately 847 vehicles were parked in corridor park-and-ride lots; this has decreased 1% to a current level of 841 (Figure F-21).

- The number of parked vehicles in the representative freeway corridor without an HOV lane (South R.L. Thornton Freeway) has also increased slightly (Figure F-22).

FIGURE F-1

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

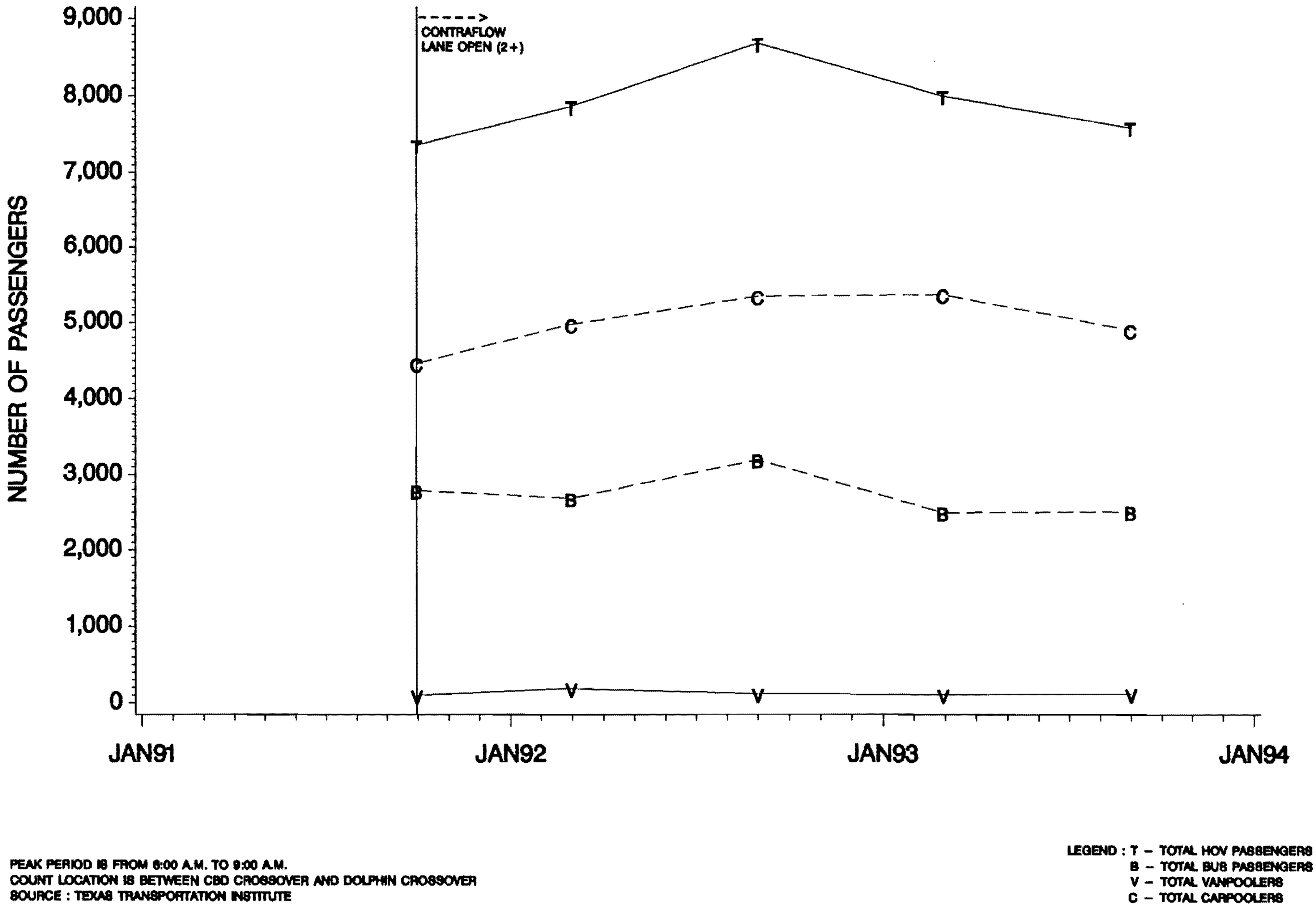


COUNT LOCATION IS BETWEEN CBD CROSSOVER AND DOLPHIN CROSSOVER
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T - TOTAL HOV PASSENGERS
B - TOTAL BUS PASSENGERS
V - TOTAL VANPOOLERS
C - TOTAL CARPOOLERS

FIGURE F-2

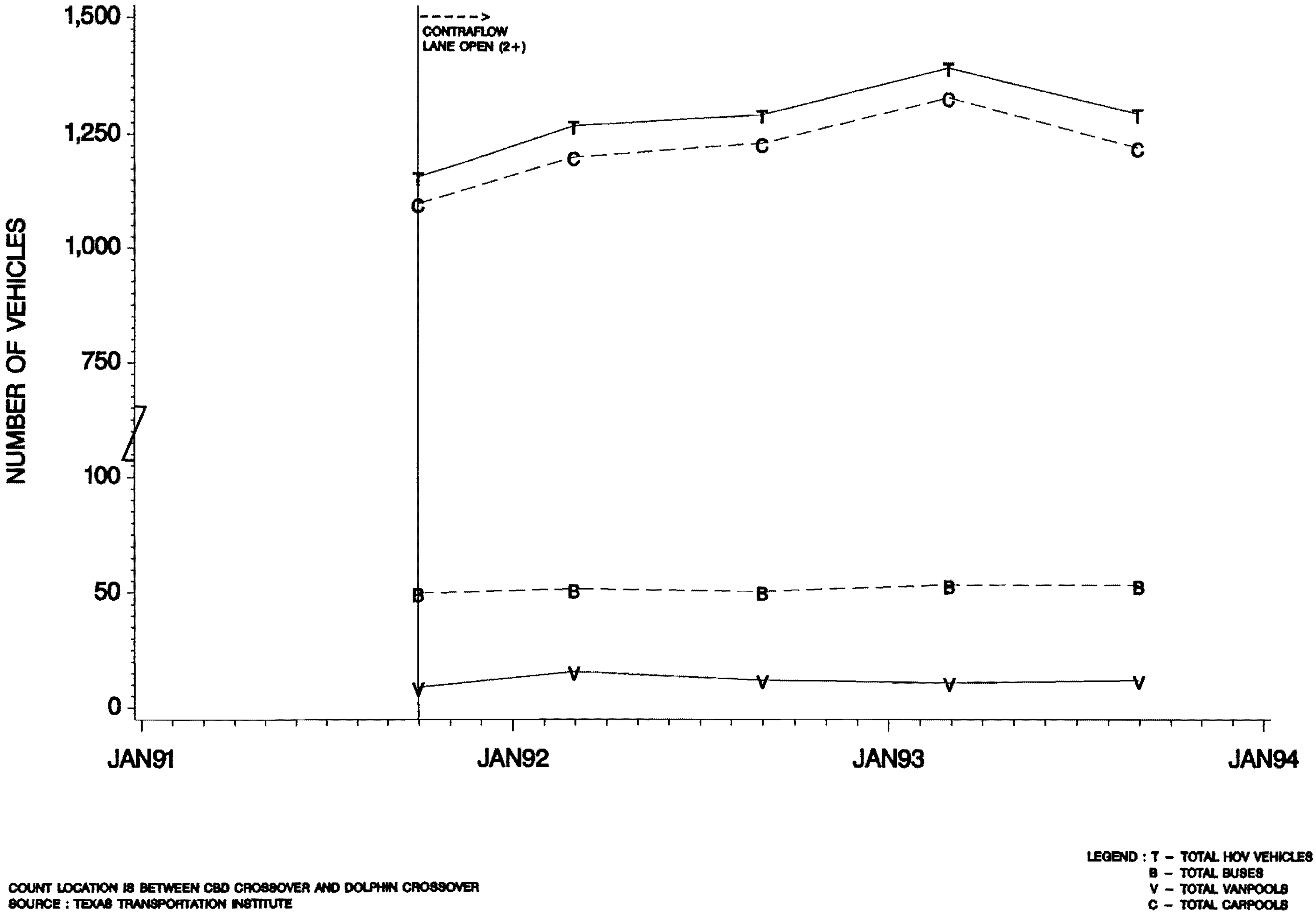
EAST R.L. THORNTON FREEWAY (IH 30E) HOV LANE
A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT



PEAK PERIOD IS FROM 6:00 A.M. TO 9:00 A.M.
COUNT LOCATION IS BETWEEN CBD CROSSOVER AND DOLPHIN CROSSOVER
SOURCE : TEXAS TRANSPORTATION INSTITUTE

FIGURE F-3

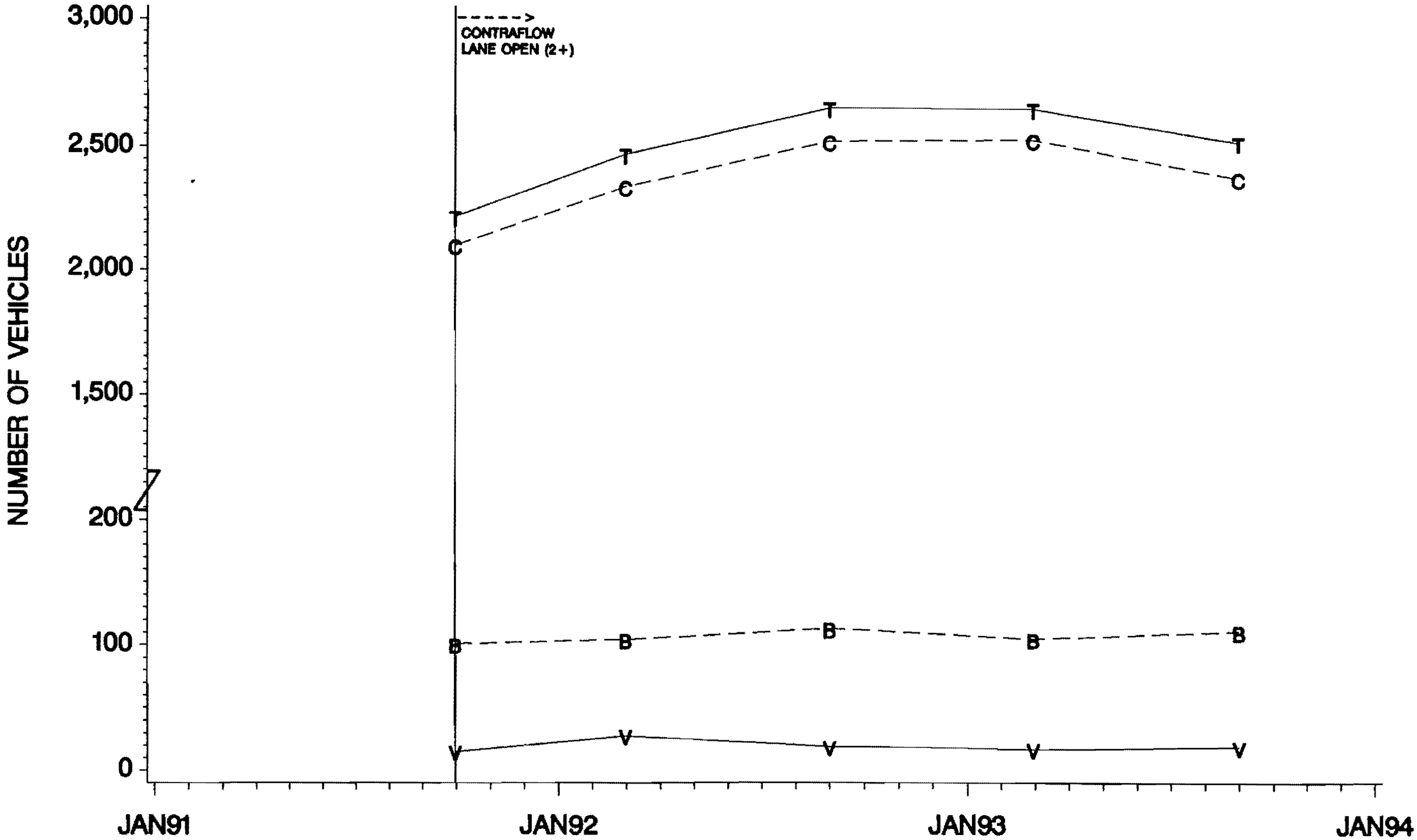
EAST R.L. THORNTON FREEWAY (IH 30E) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION



COUNT LOCATION IS BETWEEN CBD CROSSOVER AND DOLPHIN CROSSOVER
SOURCE : TEXAS TRANSPORTATION INSTITUTE

FIGURE F-4

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

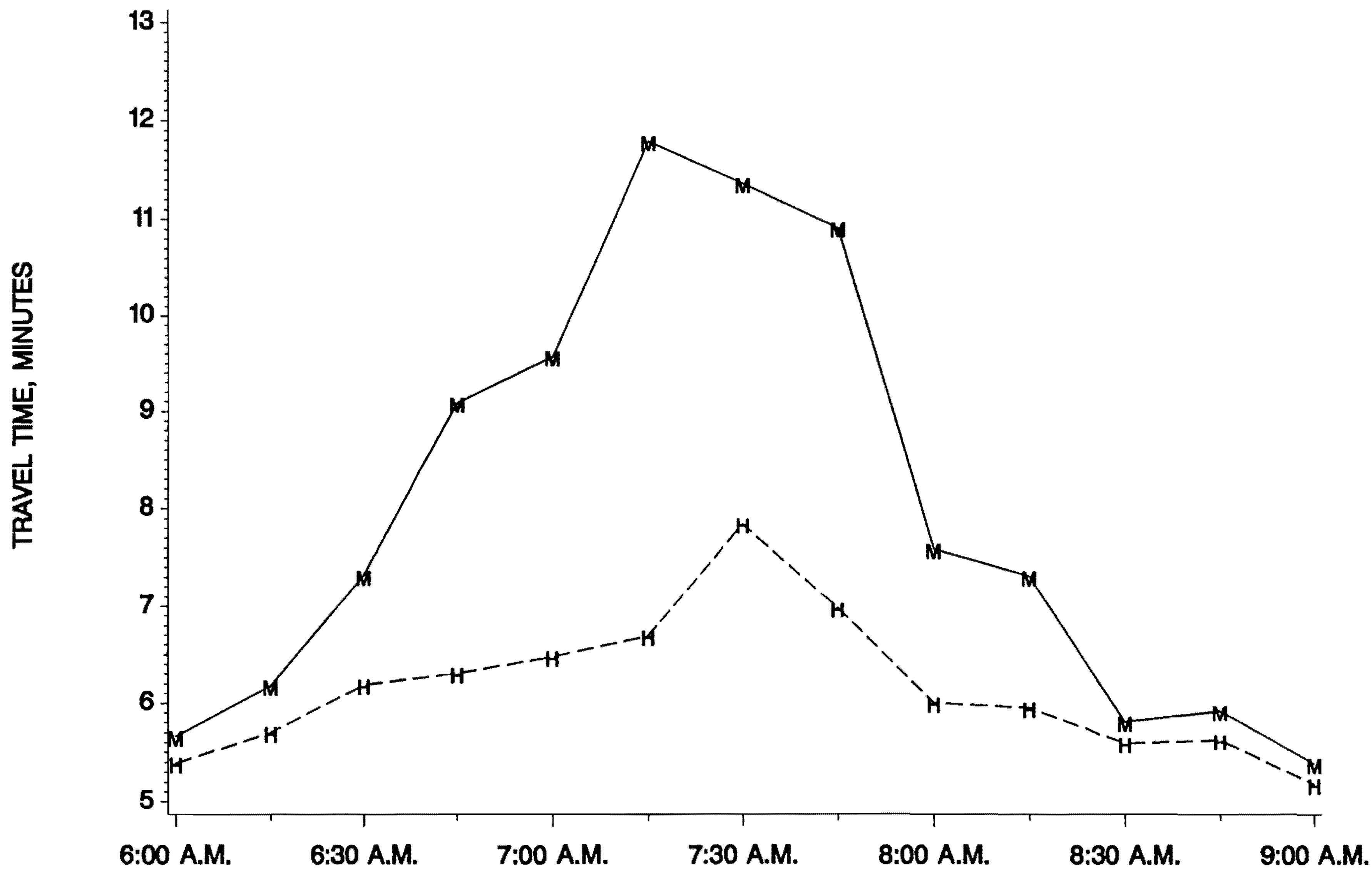


PEAK PERIOD IS FROM 6:00 A.M. TO 9:00 A.M.
COUNT LOCATION IS BETWEEN CBD CROSSOVER AND DOLPHIN CROSSOVER
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T – TOTAL HOV VEHICLES
B – TOTAL BUSES
V – TOTAL VANPOOLS
C – TOTAL CARPOOLS

FIGURE F-5

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

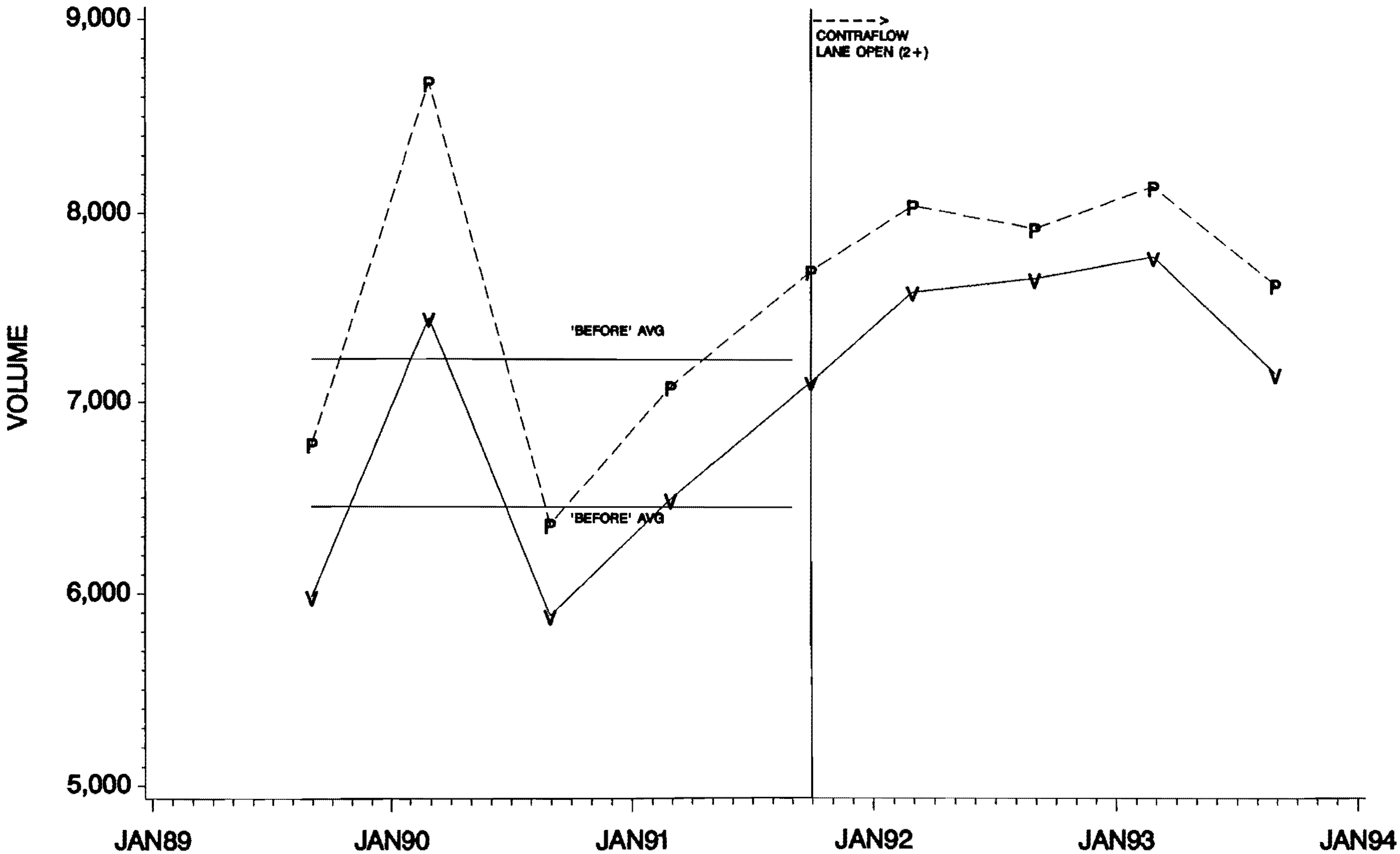


TRAVEL TIMES ARE AN AVERAGE OF 4 QUARTERLY TRAVEL TIME SURVEYS CONDUCTED IN 1993
TRAVEL TIMES ARE FROM JIM MILLER TO CENTRAL EXPRESSWAY
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : M -- MAINLANE TRAVEL TIME
H -- HOV LANE TRAVEL TIME

FIGURE F-6

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

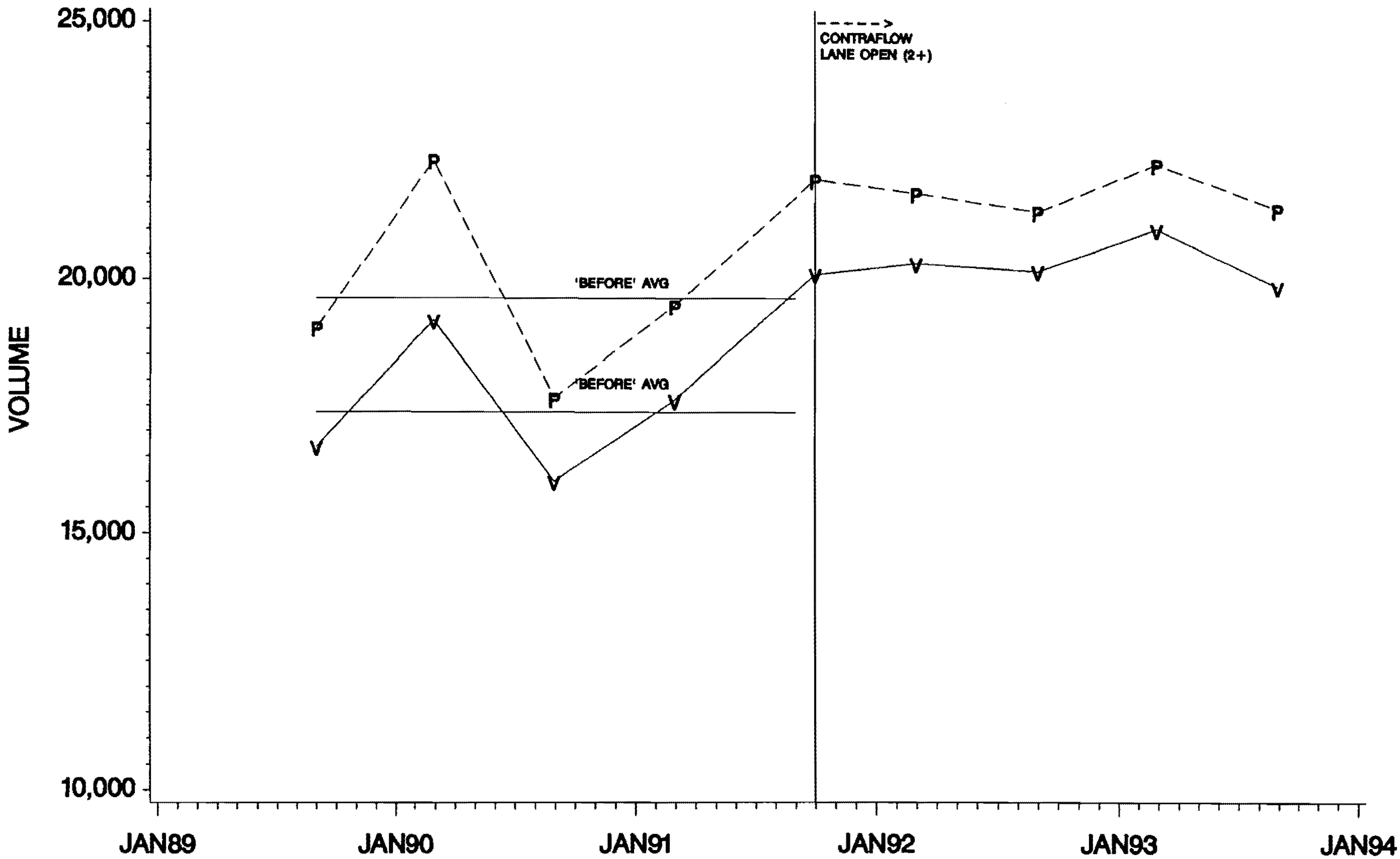


COUNT LOCATION IS WEST OF DOLPHIN ROAD ENTRANCE.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : V - TOTAL VEHICLE TRIPS
P - TOTAL PERSON TRIPS

FIGURE F-7

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

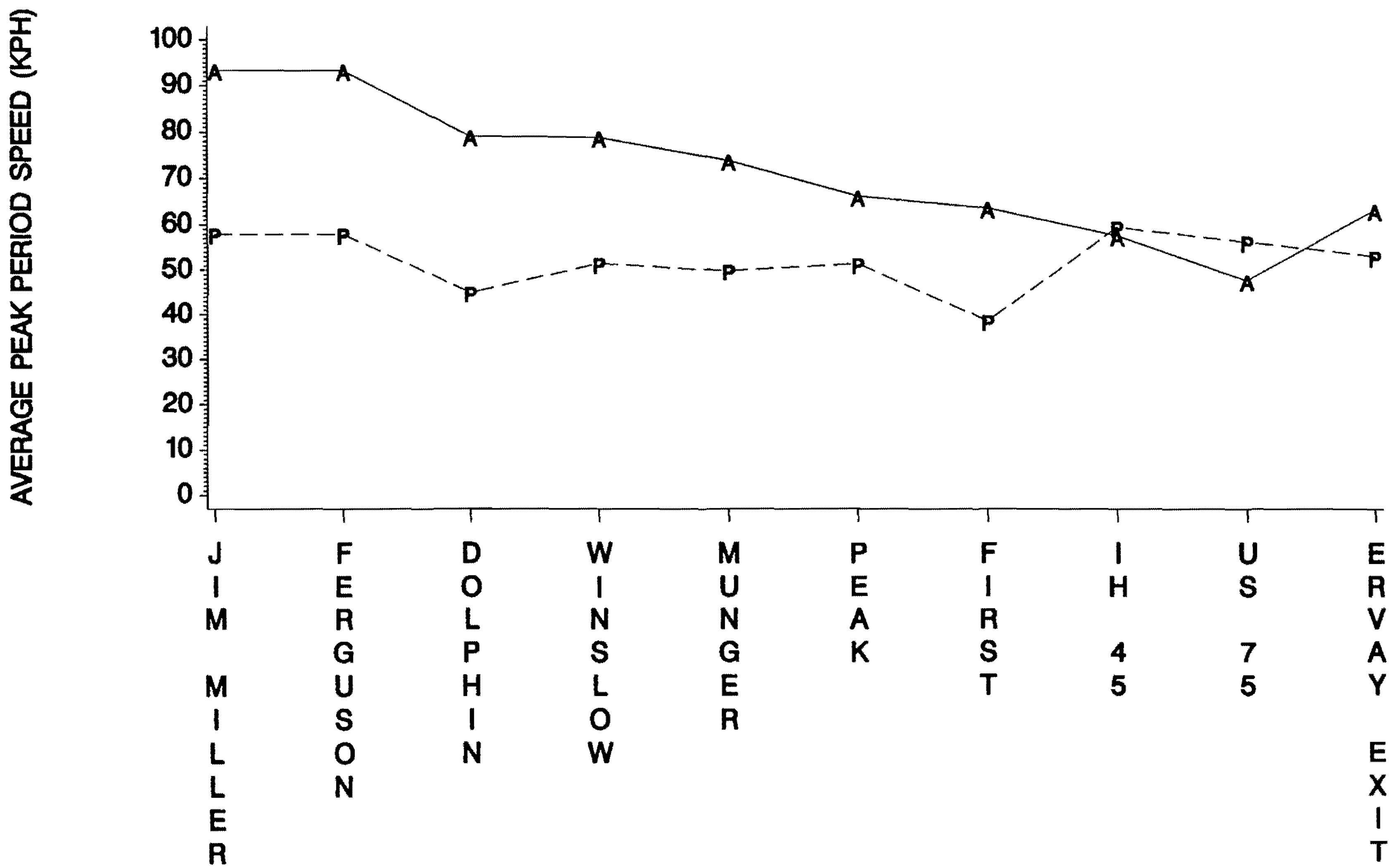


COUNT LOCATION IS WEST OF DOLPHIN ROAD ENTRANCE.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : V - TOTAL VEHICLE TRIPS
P - TOTAL PERSON 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

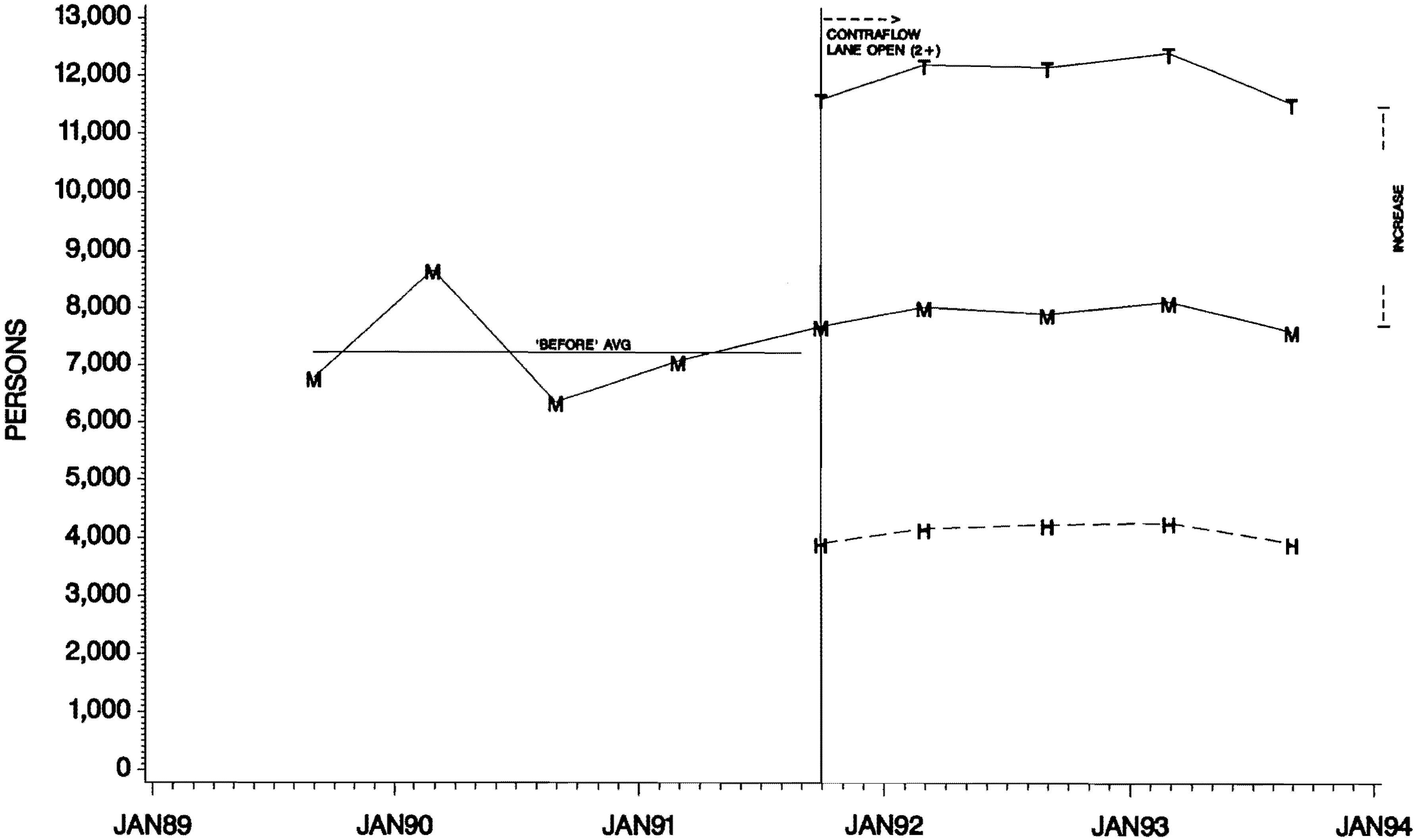


NOTE : TO CONVERT SPEEDS FROM METRIC TO ENGLISH UNITS MULTIPLY KPH BY 0.62
DATA COLLECTED 6:00 TO 9:30 A.M.
DATA COLLECTED FROM OCTOBER, 1989 TO DECEMBER, 1993
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = AVERAGE SPEED PRIOR TO OPENING HOV LANE
A = AVERAGE SPEED SINCE HOV LANE OPEN (10/91)

FIGURE F-9

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

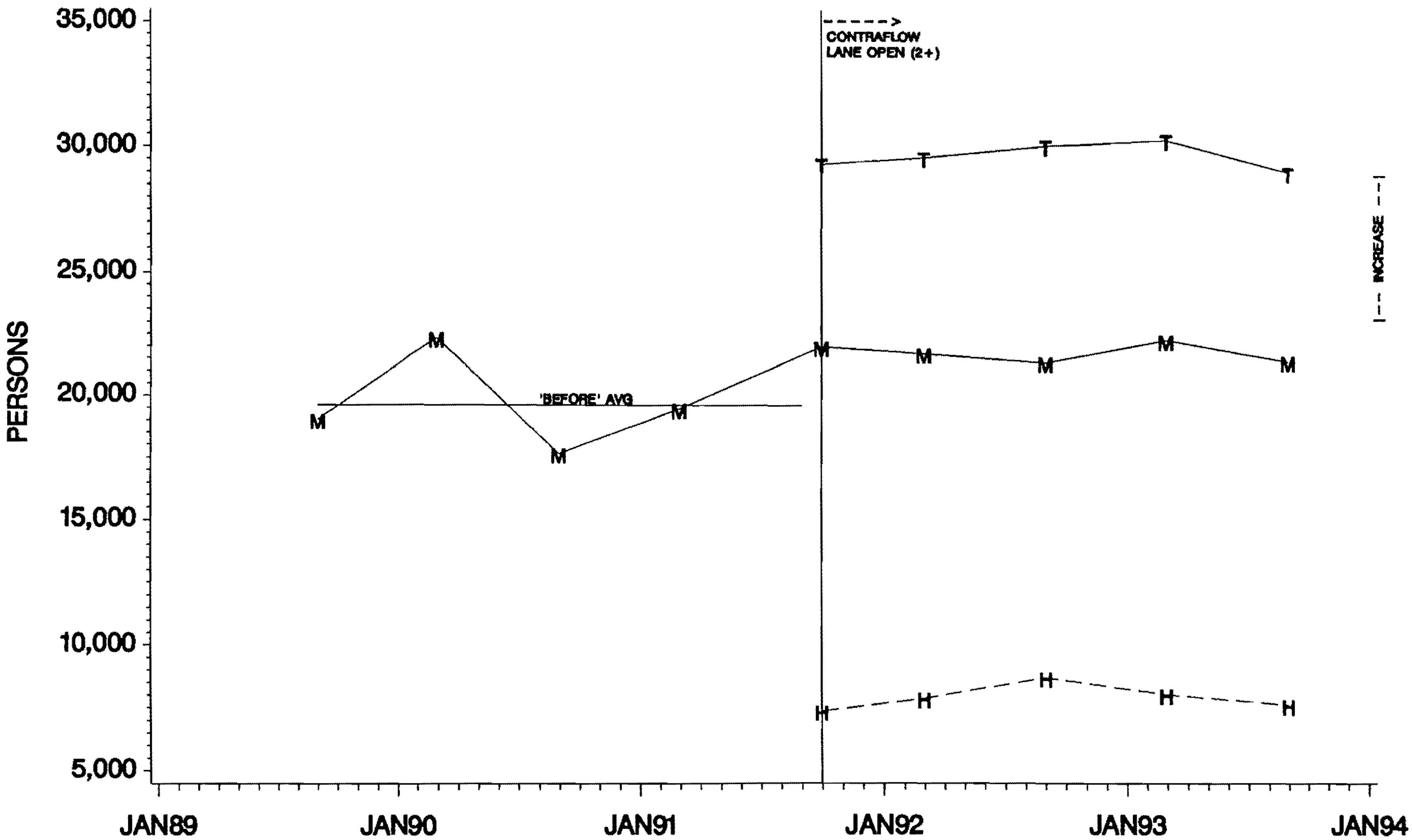


COUNT LOCATION IS WEST OF DOLPHIN ROAD ENTRANCE.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T – TOTAL PERSONS
M – MAINLANE PERSONS
H – HOV LANE PERSONS

FIGURE F-10

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

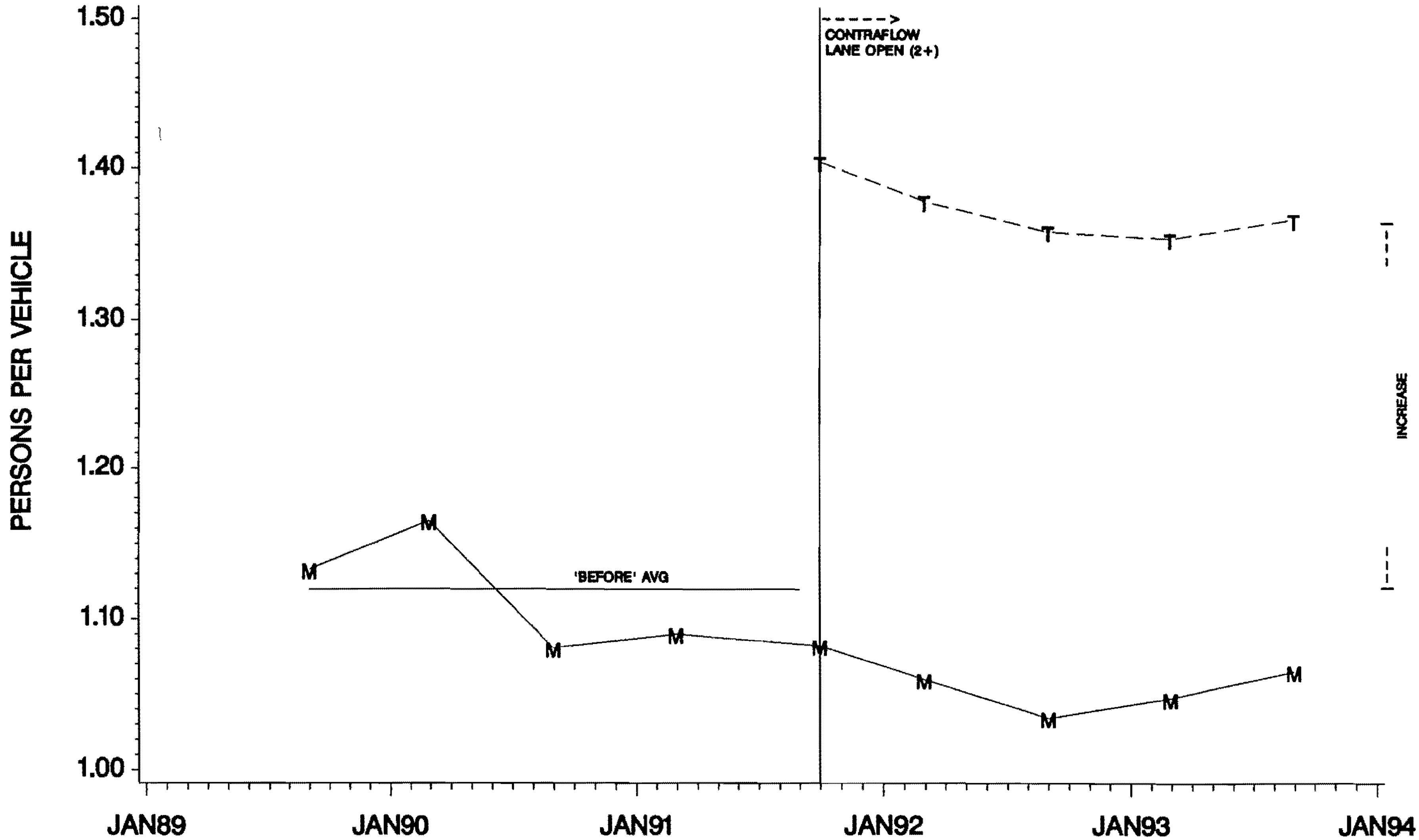


PEAK PERIOD IS FROM 6:00 A.M. TO 9:00 A.M.
COUNT LOCATION IS WEST OF DOLPHIN ROAD ENTRANCE.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T – TOTAL PERSONS
M – MAINLANE PERSONS
H – HOV LANE PERSONS

FIGURE F-11

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

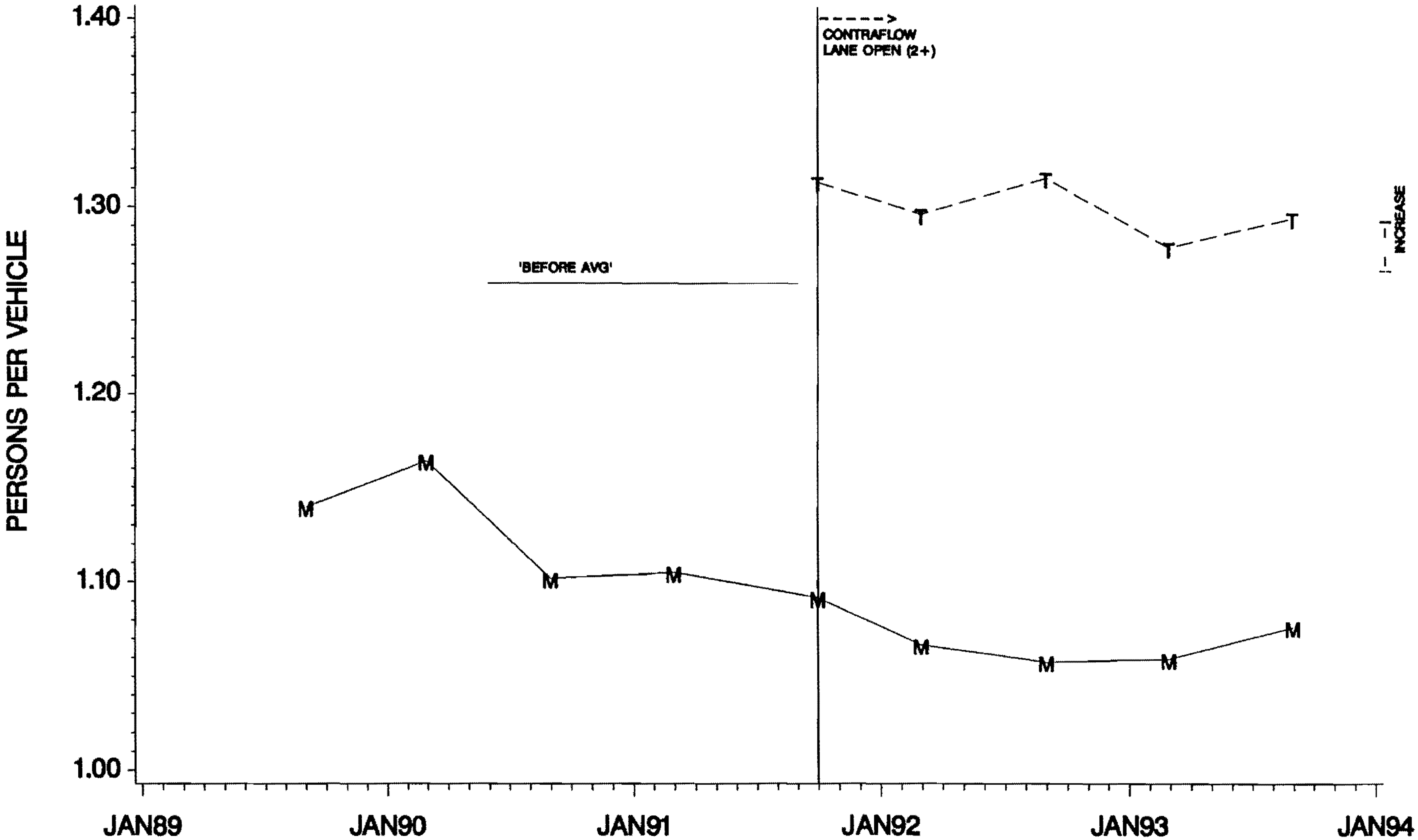


COUNT LOCATION IS WEST OF DOLPHIN ROAD ENTRANCE.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : M – MAINLANE OCCUPANCY
T – TOTAL OCCUPANCY
(FREEWAY PLUS HOV LANE)

FIGURE F-12

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

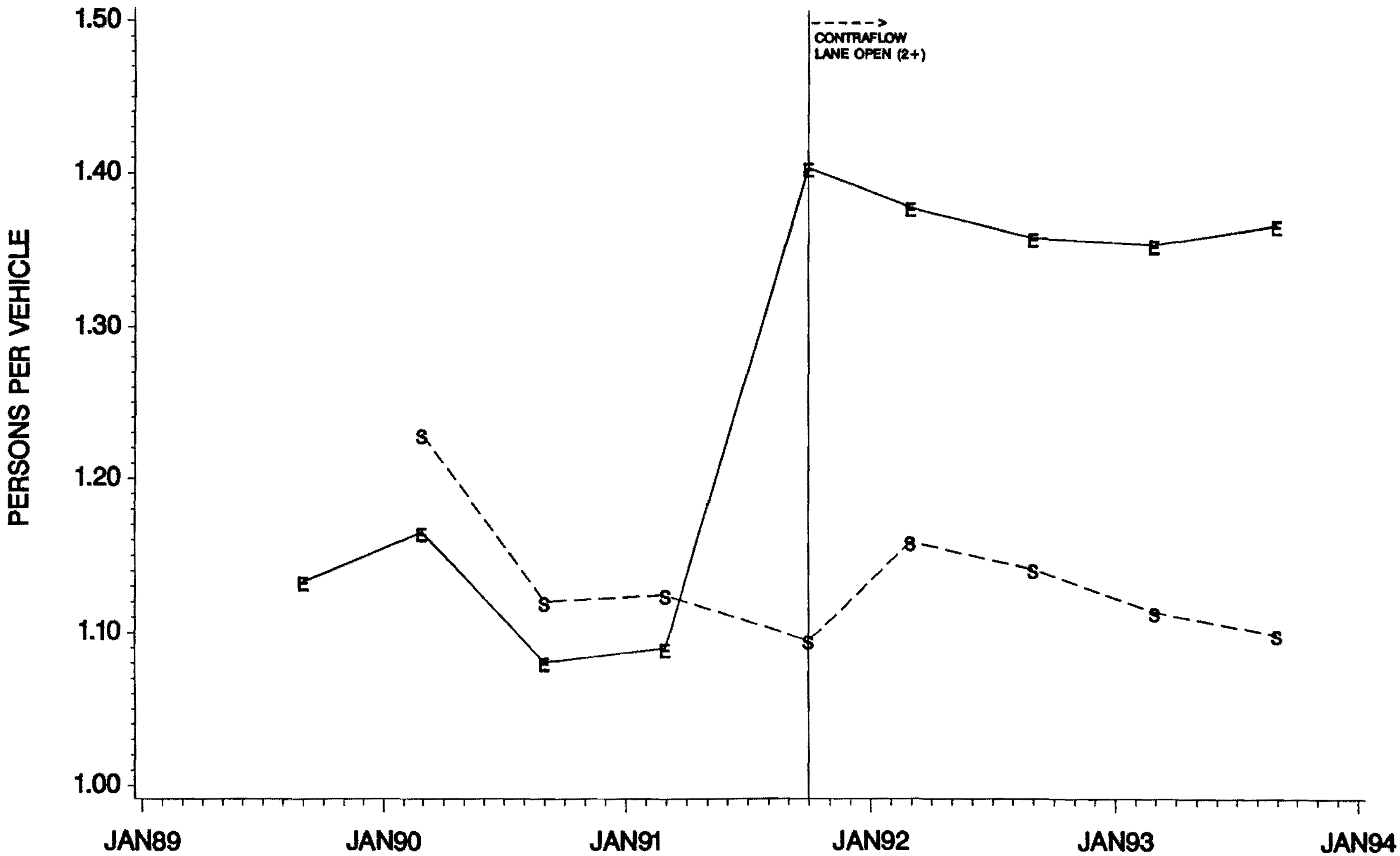


PEAK PERIOD IS FROM 6:00 A.M. TO 9:00 A.M.
COUNT LOCATION IS WEST OF DOLPHIN ROAD ENTRANCE.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : M - MAINLANE OCCUPANCY
T - TOTAL OCCUPANCY
(FREEWAY PLUS HOV LANE)

FIGURE F-13

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

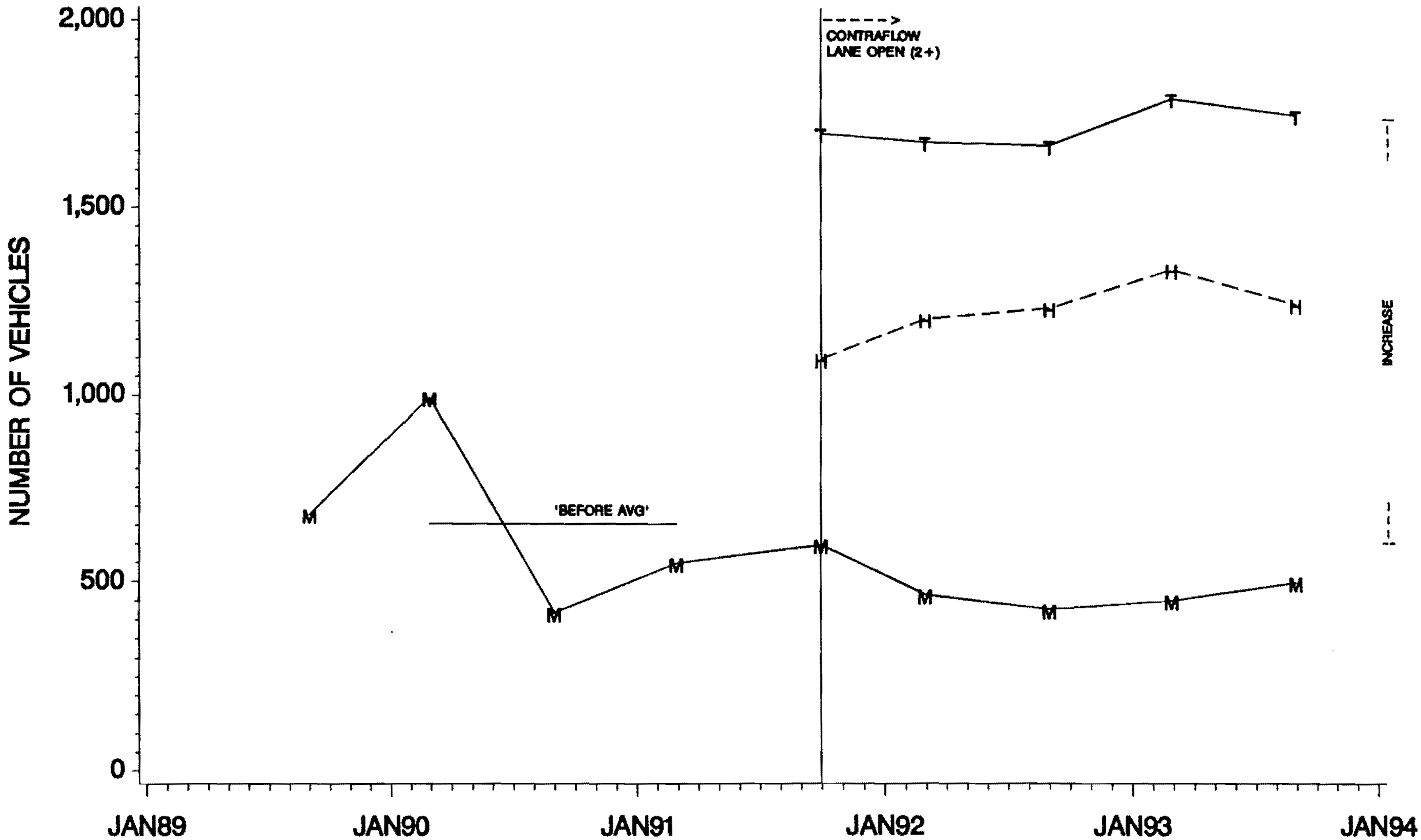


SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : E – EAST R.L. THORNTON FREEWAY (WITH HOV LANE)
S – SOUTH R.L. THORNTON FREEWAY (WITHOUT HOV LANE)

FIGURE F-14

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

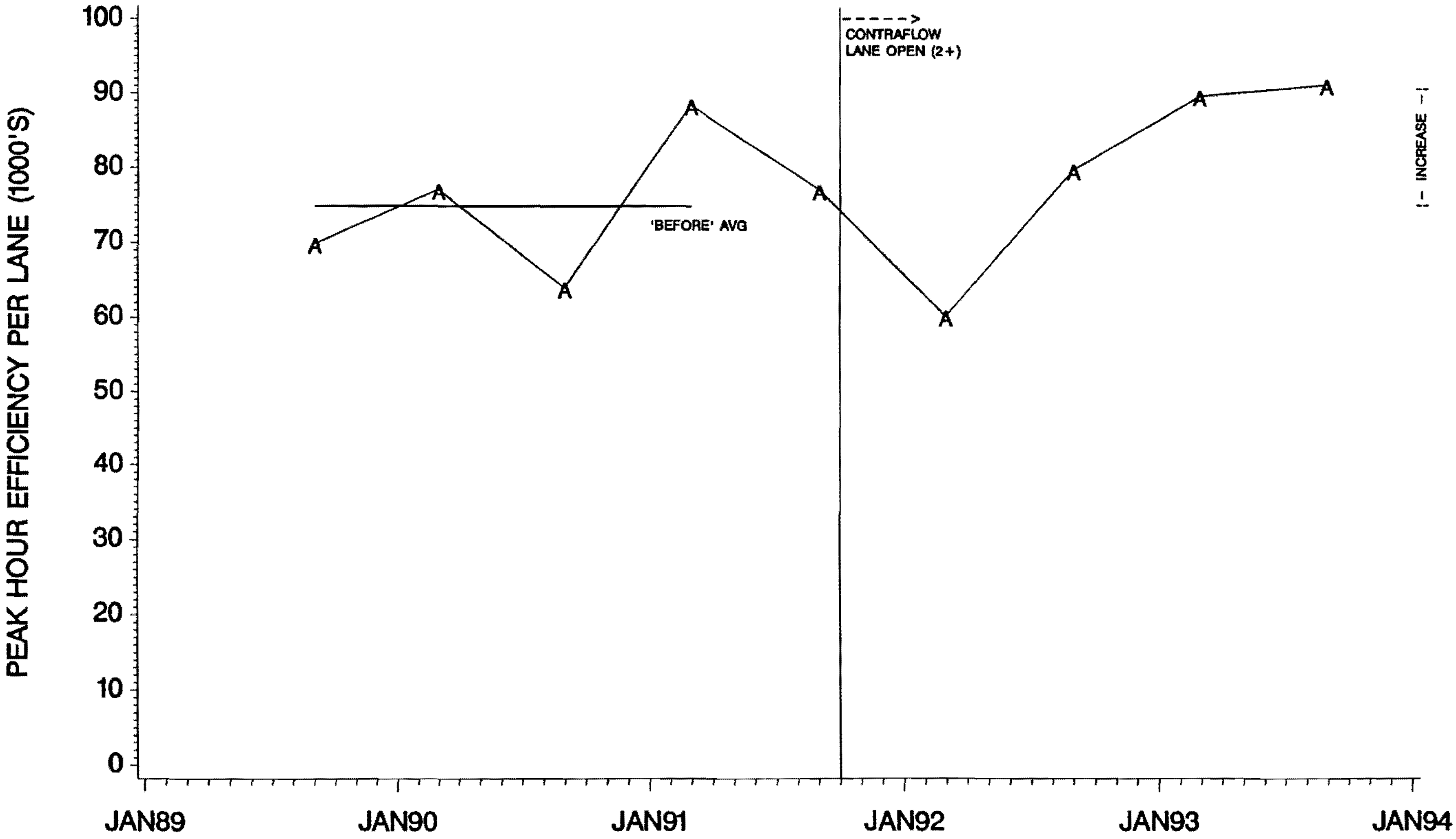


EAST R.L. THORNTON HOV LANE, DOLPHIN TO CENTRAL EXPRESSWAY, OPENED SEPTEMBER 23, 1991
COUNT LOCATION IS WEST OF DOLPHIN ROAD ENTRANCE
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T – TOTAL 2+ CARPOOLS
H – TOTAL HOV LANE 2+ CARPOOLS
M – TOTAL MAINLANE 2+ CARPOOLS

FIGURE F-15

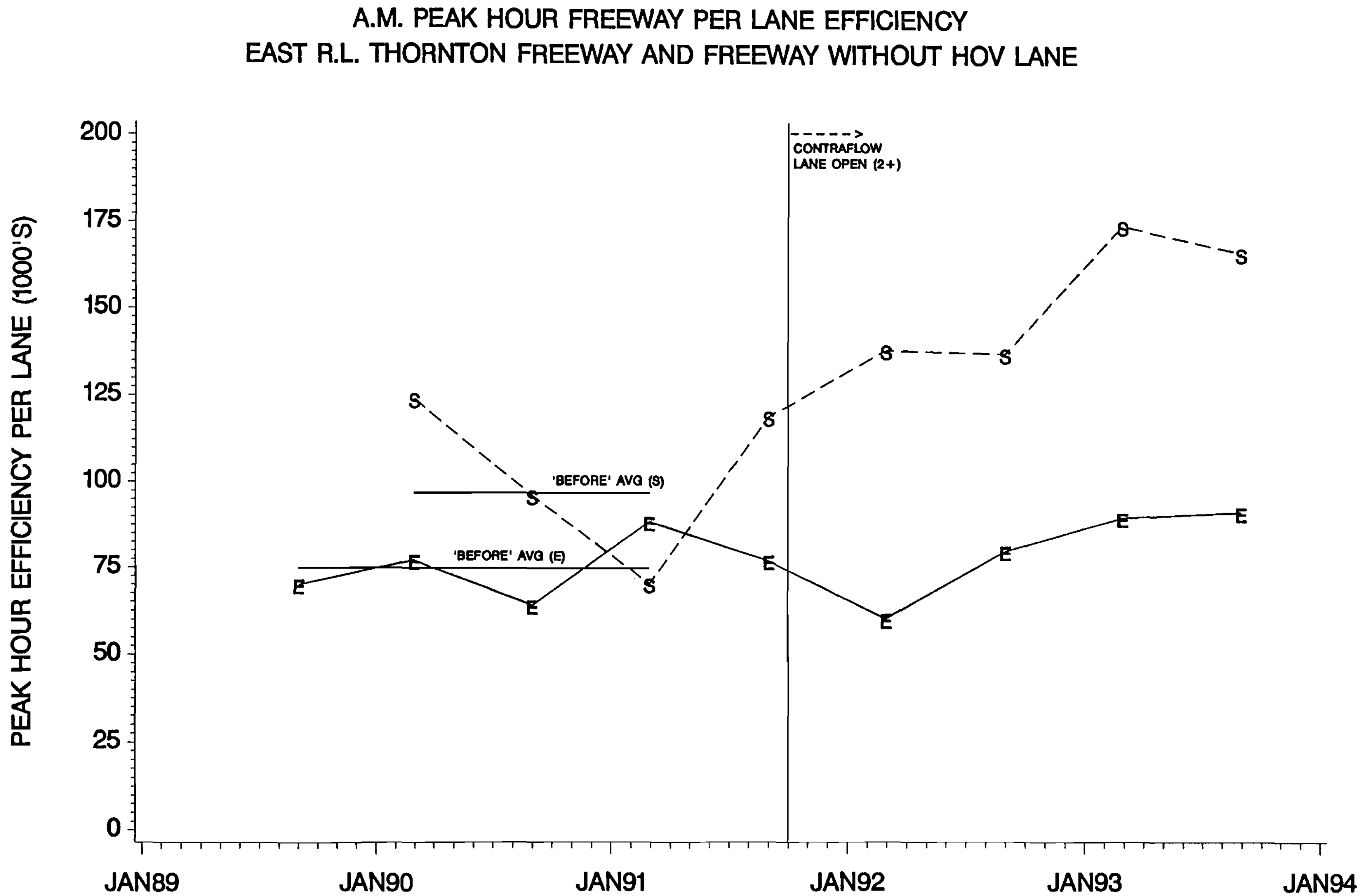
EAST R.L. THORNTON FREEWAY (IH 30E) EVALUATION
A.M. PEAK HOUR COMBINED MAINLANE AND HOV LANE EFFICIENCY



PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE HOV LANE, IT REPRESENTS TOTAL PERSONS (FREEWAY + HOV LANE) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 5 LANES
TO CONVERT EFFIENCIES FROM METRIC TO ENGLISH UNITS MULTIPLY BY 0.62
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : A – A.M. PEAK HOUR EFFICIENCY

FIGURE F-16

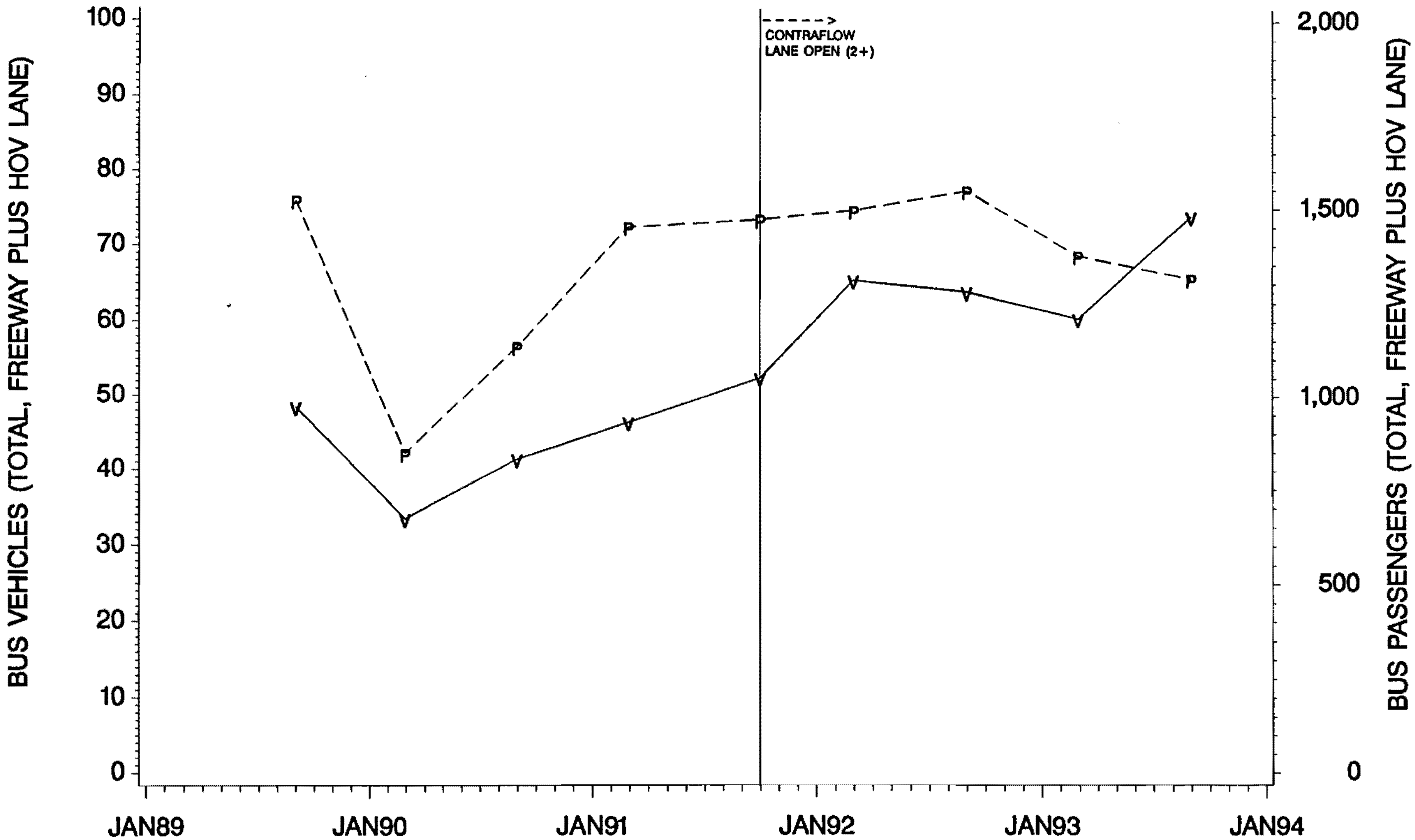


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE HOV LANE, IT REPRESENTS TOTAL PERSONS (FREEWAY + HOV LANE) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 5 LANES
TO CONVERT EFFIENCIES FROM METRIC TO ENGLISH UNITS MULTIPLY BY 0.62
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : E – EAST R.L. THORNTON (IH 30E) EFFICIENCY (WITH HOV LANE)
S – SOUTH R.L. THORNTON (IH 35E) EFFICIENCY (WITHOUT HOV LANE)

FIGURE F-17

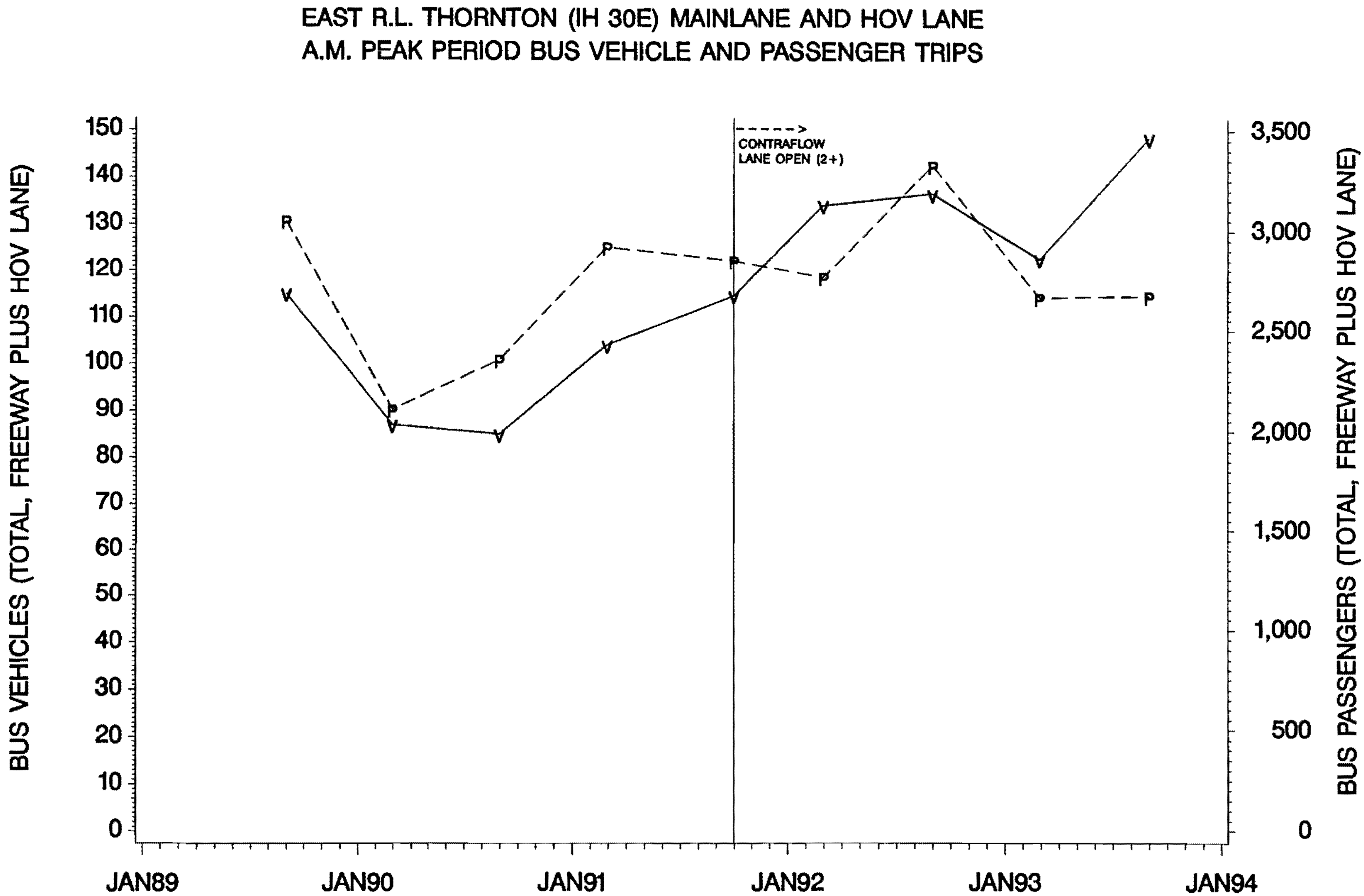
EAST R.L. THORNTON (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS



COUNT LOCATION IS BETWEEN CBD CROSSOVER AND DOLPHIN CROSSOVER
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P – BUS PASSENGER VOLUME
V – BUS VEHICLE VOLUME

FIGURE F-18

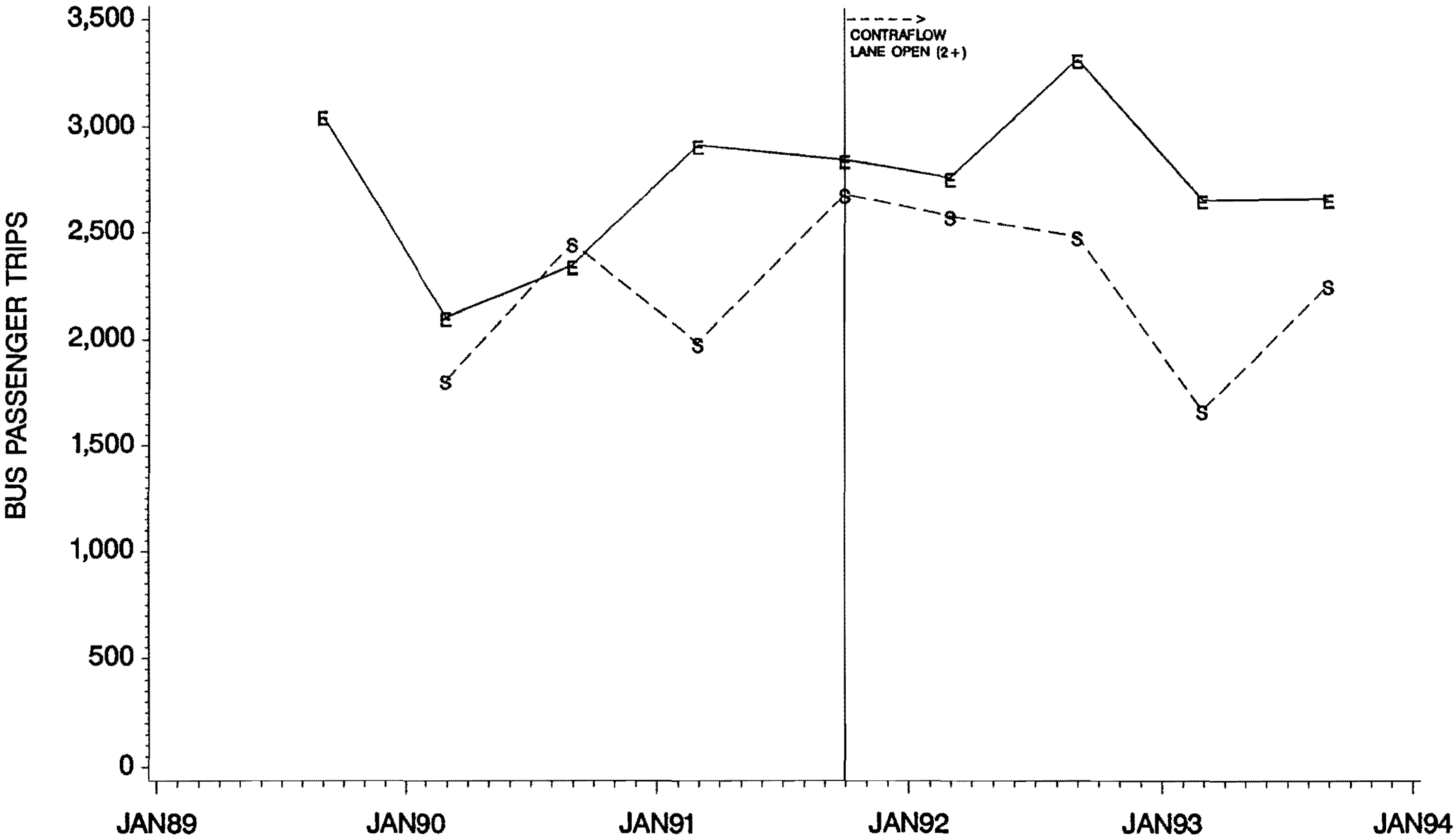


PEAK PERIOD IS FROM 6:00 A.M. TO 9:00 A.M.
COUNT LOCATION IS BETWEEN CBD CROSSOVER AND DOLPHIN CROSSOVER
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P – BUS PASSENGER VOLUME
V – BUS VEHICLE VOLUME

FIGURE F-19

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

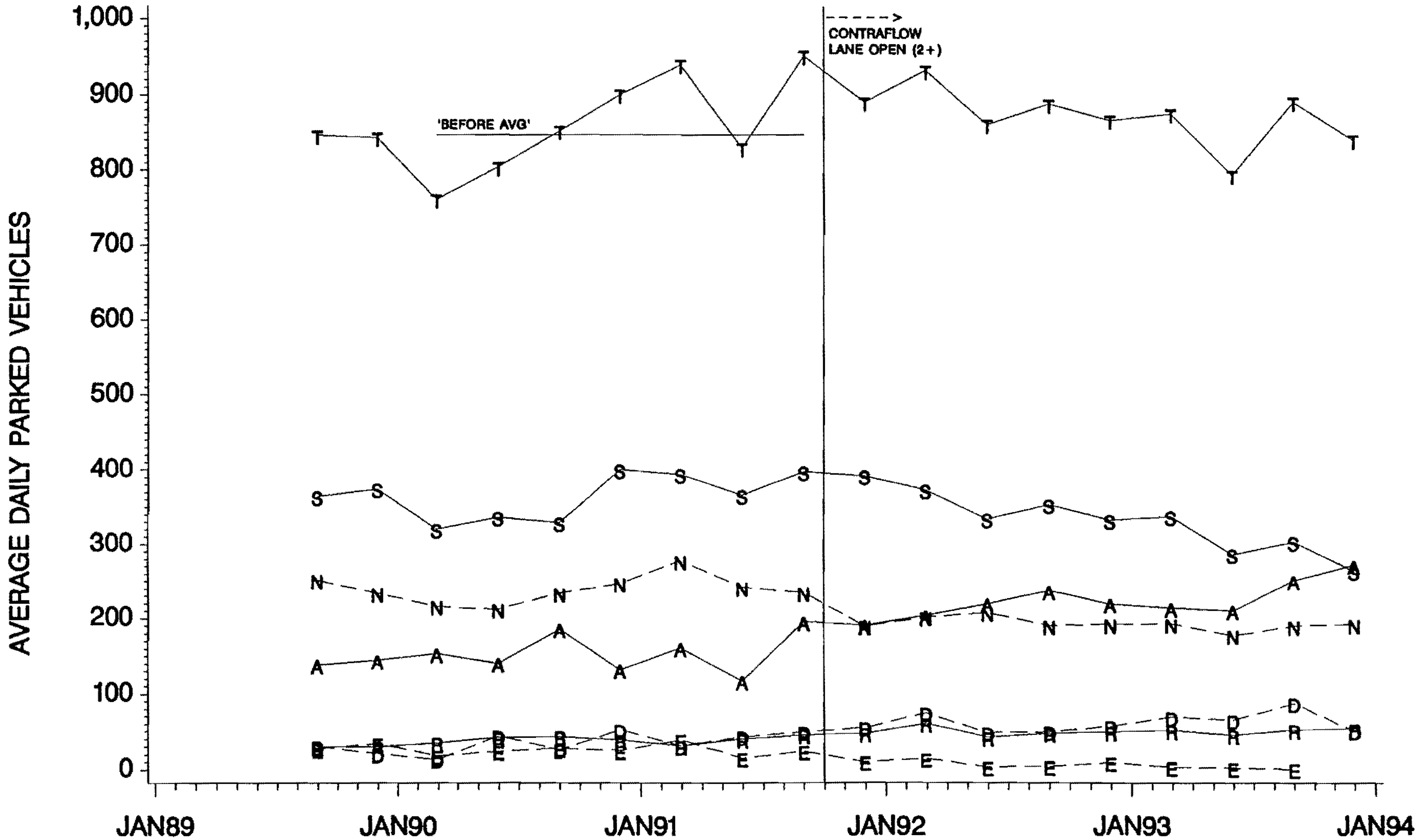


PEAK PERIOD IS FROM 6:00 A.M. TO 9:00 A.M.
COUNT LOCATION IS BETWEEN CBD CROSSOVER AND DOLPHIN CROSSOVER
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : E – EAST R.L. THORNTON FREEWAY (WITH HOV LANE)
S – SOUTH R.L. THORNTON FREEWAY (WITHOUT HOV LANE)

FIGURE F-20

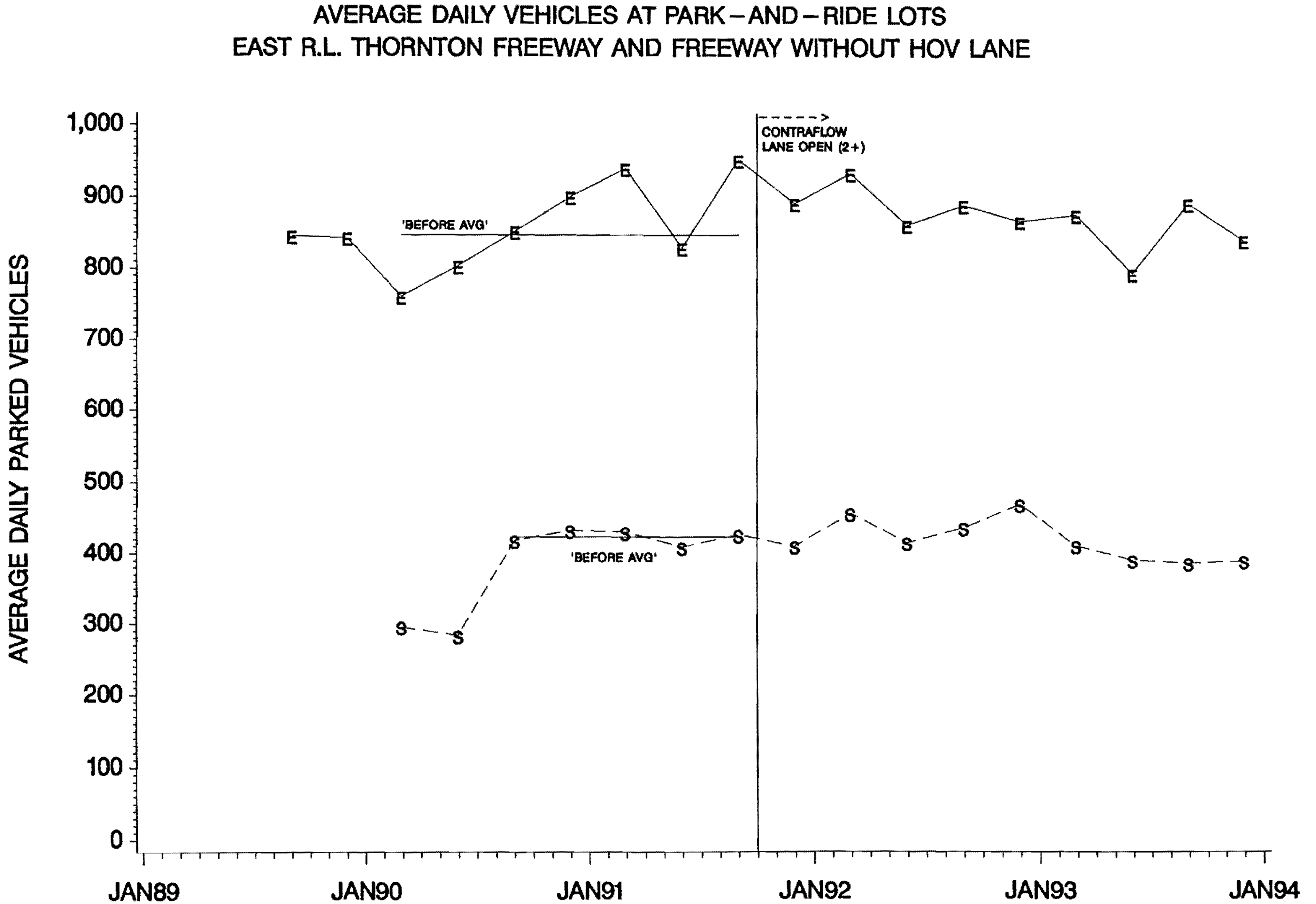
EAST R.L. THORNTON FREEWAY (IH 30E) CORRIDOR PARK-AND-RIDE DEMAND



LEGEND : T - TOTAL PARKED VEHICLES
N - NORTH GARLAND (298 SPACES)
S - SOUTH GARLAND (503 SPACES)
E - EAST GARLAND (84 SPACES)
R - ROWLETT (58 SPACES)
D - DALROCK CHURCH (80 SPACES)
A - AUDOBON PARK (200 SPACES)

EAST R.L. THORNTON HOV LANE, DOLPHIN TO CENTRAL EXPRESSWAY, OPENED SEPTEMBER 23, 1991
CURRENT TOTAL CORRIDOR PARKING CAPACITY = 1223 SPACES
SOURCE : TEXAS TRANSPORTATION INSTITUTE

FIGURE F-21

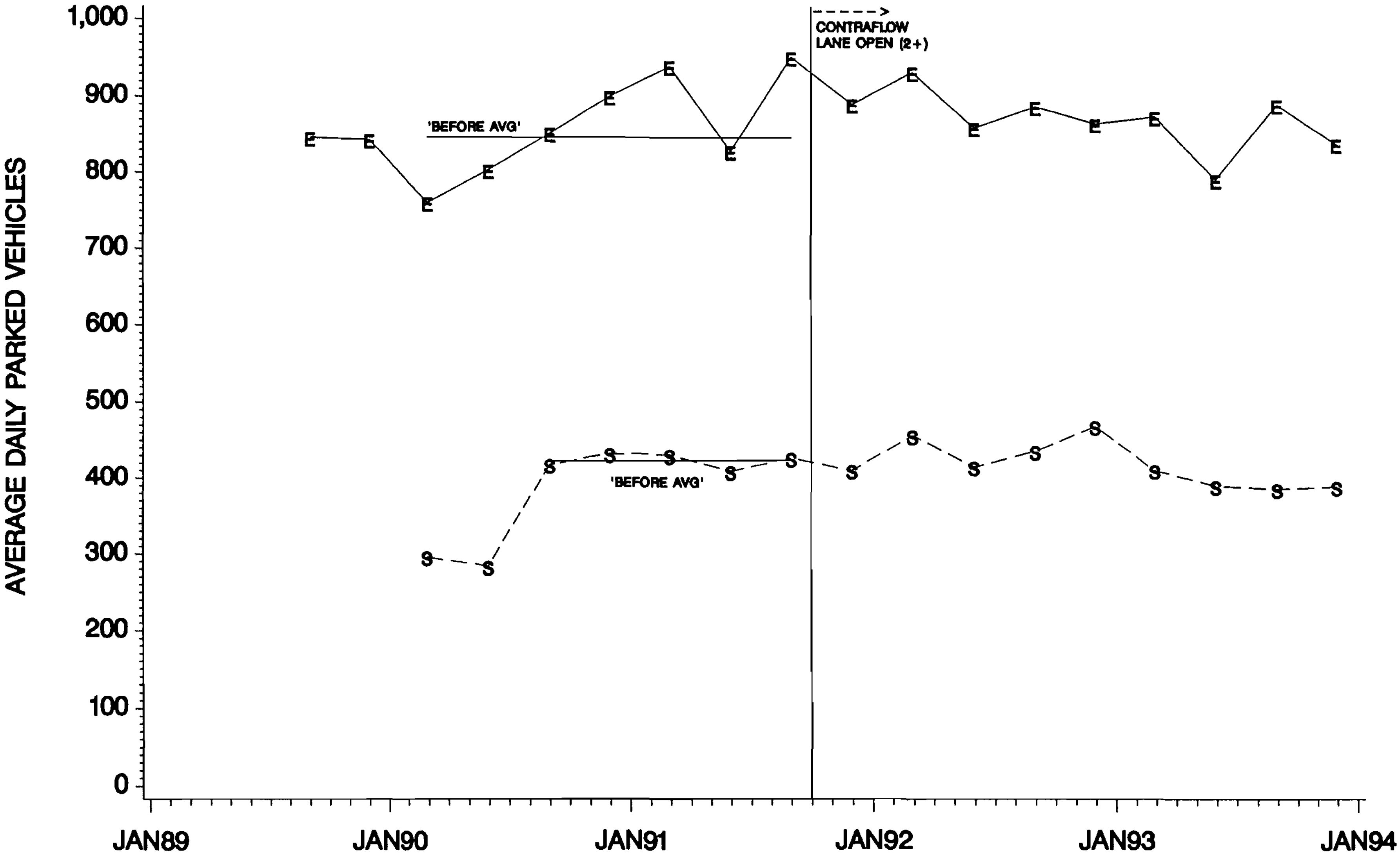


EAST R.L. THORNTON HOV LANE, DOLPHIN TO CENTRAL EXPRESSWAY, OPENED SEPTEMBER 23, 1991
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : E - EAST R.L. THORNTON FREEWAY (WITH HOV LANE)
S - SOUTH R.L. THORNTON FREEWAY (WITHOUT HOV LANE)

FIGURE F-23

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

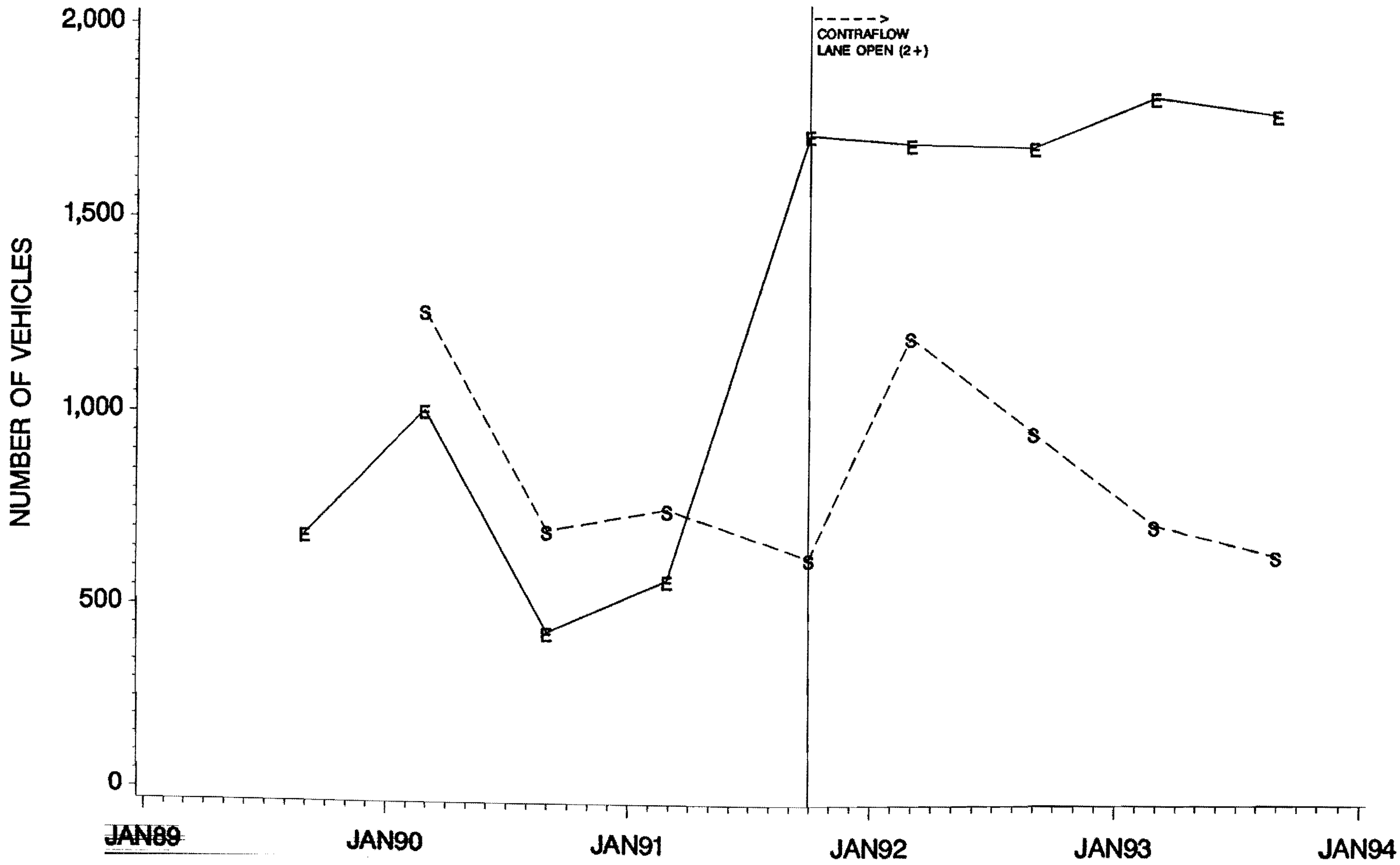


EAST R.L. THORNTON HOV LANE, DOLPHIN TO CENTRAL EXPRESSWAY, OPENED SEPTEMBER 23, 1991
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : E - EAST R.L. THORNTON FREEWAY (WITH HOV LANE)
S - SOUTH R.L. THORNTON FREEWAY (WITHOUT HOV LANE)

FIGURE F-22

A.M. PEAK HOUR 2+ CARPOOL UTILIZATION
EAST R.L. THORNTON FREEWAY AND FREEWAY WITHOUT HOV LANE



SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : E – EAST R L THORNTON (IH 30E) CARPOOLS
S – SOUTH R L THORNTON (IH 35E) CARPOOLS