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16. Abstract

This report evaluates the operation of freeway high-occupancy vehicle (HOV) lanes in Houston and Dallas through calendar year 1992. As of the end of 1992, HOV lanes were in operation on four Houston freeways: Katy Freeway (I-10); North Freeway (I-45); Northwest Freeway (US 290); and Gulf Freeway (I-45). The only HOV facility in operation in Dallas as of the end of 1992 was on the East R.L. Thornton Freeway (I-30E). Since 1988, an annual report has been prepared through this research project that summarizes the status and effectiveness of freeway HOV improvements in the State of Texas.

This research report provides an analysis of data related to: 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 the end of 1992, 46.5 miles of barrier-separated HOV facilities were in operation in Houston, while 5.2 miles were in operation in Dallas. Approximately 70,000 daily person trips are served on the Houston HOV lane system. Sixty percent of total person trips on the Houston HOV lanes are being served by carpools and vanpools, with the remaining 40 percent being served by buses. The East R.L. Thornton HOV lane in Dallas serves approximately 16,500 daily person trips. Sixty-four percent of these trips are being served by carpools and vanpools, with the remaining 36 percent being served by buses.

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AN EVALUATION OF
HIGH-OCCUPANCY VEHICLE LANES IN TEXAS

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Research Report 1146-6F

Research Study Number 0-1146

Study Title: A "Before" and "After" Evaluation of the Committed High-Occupancy Vehicle Transitway Projects

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in Cooperation with the
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TEXAS TRANSPORTATION INSTITUTE
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IMPLEMENTATION STATEMENT

This report was sponsored by the Texas Department of Transportation as part of an overall effort entitled "A 'Before' and 'After' Evaluation of the Committed High-Occupancy Vehicle Transitway Projects." 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-10) in October 1984. In November 1984, the contraflow lane (which was implemented in 1979) on the North Freeway (I-45) was converted to a barrier-separated HOV lane, and, in 1988, transitways were opened on both the Northwest Freeway (US 290) and the Gulf Freeway (I-45). 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 (US 59) facility was initiated. High-occupancy vehicle lane construction continues in the Southwest Freeway (US 59), Gulf Freeway (I-45), and Eastex Freeway (US 59) corridors.

The first completed HOV facility in Dallas opened on the East R.L. Thornton (East RLT) Freeway (I-30E) in September 1991. This facility is currently operating as a barrier-separated contraflow lane—1992 marked the first full year of its operation. An extension of the contraflow lane is planned within the next two years.

This report presents data relating to the five operating HOV lanes in Texas and focuses on data collected during calendar year 1992. As of 1992, the Gulf, Northwest, and East RLT HOV lanes were still relatively new. Thus, the data for the more mature facilities (i.e., the North and the Katy) are more meaningful. The results of this research have helped the implementing agencies to learn from the early experience with HOV lanes in order to allow future projects to be developed more effectively.

DISCLAIMER

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

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METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

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

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

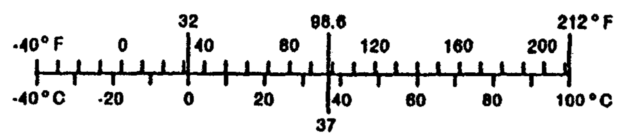
Symbol	When You Know	Multiply By	To Find	Symbol
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

These factors conform to the requirement of FHWA Order 5190.1A

*SI is the symbol for the International System of Measurements

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
yd	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
yd^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.53	acres	ac
		MASS (weight)		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME		
mL	millimeters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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 on freeways in Houston and Dallas. Locally, these facilities are sometimes referred to as high-occupancy vehicle (HOV) lanes or transitways. 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 transitway and freeway performance in Houston and Dallas through calendar year 1992.

A commitment is in place to develop 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 $669 million.[1] As of the end of 1992, 46.5 miles of barrier-separated HOV lanes were in place and operational in four corridors, implemented at a cost of approximately $276 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 20-feet wide, is reversible, and is separated from the freeway general-purpose mainlanes by concrete median barriers. Most access/egress to the transitways is provided by grade-separated ramps.

In December 1992, the Houston HOV lane system served 69,956 daily person trips—a 16 percent increase compared to December 1991. At the end of 1992, 8,625 cars were parked in Houston transitway 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.

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[1]These costs include the HOV lanes, HOV lane access and egress ramps, all park-and-ride lots, park-and-pool lots and bus transfer centers, and the HOV surveillance, communication and control system. The costs are in 1990 dollars.

The Dallas HOV system is in its relative infancy. A plan is, however, currently in place in Dallas to construct approximately 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 1992, a 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. This contraflow lane was constructed at a cost of $12.7 million.

In December of 1992, the East RLT HOV lane served 16,472 daily person trips. By the end of 1992, 865 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 being 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, however, is 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 eight minutes on the Gulf HOV lane to 15 minutes on the Katy HOV lane, while the East RLT HOV lane in Dallas saves its users approximately five minutes. In an average, non-incident morning peak hour, the 46.5-mile system in Houston offers 43 minutes of time savings, or about 0.9 minutes per mile. The 5.2-mile East RLT HOV lane in Dallas offers a time savings of approximately 1.0 minutes per mile. It is of interest to note, however, that the time savings perceived by the users is 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 (to be considered effective) 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 a significant increase in person movement (Table S-1). During the peak hour, the HOV lanes are moving 96 percent (Gulf) to 228 percent (Katy) more persons per lane than are the freeway general-purpose lanes.

Changes in Average Vehicle Occupancy

For the priority HOV lanes to generate substantial 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 1.5 persons per vehicle (Tables S-1 and S-2). Compared to pre-HOV lane conditions, average vehicle occupancy on the North, Katy, and Northwest Freeways has increased by over 20 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 26 mph to 49 mph. The result has been significant decreases in bus 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	East RLT
Change in Roadway Person Movement					
% Increase in directional lanes due to HOV lane	33%	25%	---	33%	25%
% Increase in a.m. person volume[1]	96%	105%	---	53%	48%
Change in Average Vehicle Occupancy (persons/vehicle)[1]					
Occupancy before HOV lane	1.26	1.28	---	1.14	1.31
Occupancy in December 1992	1.57	1.57	---	1.40	1.36
% Change, Pre-HOV lane to current	+25%	+22%	---	+23%	+4%
% Change in 2+ Carpool Volume[1]	+94%	+66%	---	+199%	+126%
% of carpools formed due to HOV lane[2] (1990)	53%	46%	26%	47%	---
% Change in Bus Passengers (peak period)[1]	+420%	---	---	+176%	+15%
% New bus riders due to HOV lane[2] (1990)	47%	52%	33%	47%	---
% Change, Freeway Mainlane Vehicle Volume per Lane[1,3]	+34%	+6%	---	-3%	+25%
% Change, Freeway Mainlane Speed (Peak Hour)[1,3]	+17%	+73%	---	+ 4%	+32%
% Change, Freeway Mainlane Accident Rate[4]	+5%	-14%	-20%	- 6%	+17%
% Change, Freeway Per Lane Efficiency[1,5]	+150%	+185%	---	+53%	+88%
Comparison, HOV Lane vs. Freeway Lane[6] (HOV lane improvement as a % of freeway improvement)					
Fuel consumption (gallons)	84%	---	---	---	---
Air quality (kg of CO)	69%	---	---	---	---
Annual Value of Travel Time Saved on HOV Lane[7] ($ millions)	$8.3	$4.9	$2.7	$4.2	$2.8
Travel time saved as a % of construction cost[8]	33%	9%	9%	7%	13%
Are HOV Lanes Good Improvements[9]					
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]Data for the freeway general-purpose mainlanes.
[4]Percentage change in accident rate (injury accidents per 100 million vehicle miles) from pre-HOV to current.
[5]Freeway per lane efficiency is expressed as the multiple of persons moved times average speed. Analysis combines freeway general-purpose lane performance with HOV lane performance.
[6]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 transitway. The values of fuel consumption and air quality (CO emissions) are those characteristic of the transitway 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.
[7]This is an estimate of the annual value of time saved by users of the HOV lane.
[8]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. A simplistic analysis suggests that, if this value exceeds 10%, the project is cost effective.
[9]Responses from motorists in the general-purpose freeway lanes to the question "Do you feel the transitways 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	1.57	+25%
North	1.28	1.57	+22%
Northwest	1.14	1.40	+23%
East RLT	1.35	1.36	+1%
Freeway Without HOV Lane	1.34	1.30	-3%
Peak-Hour Peak-Direction 2+ Carpool Volume			
Freeways With HOV Lanes			
Katy (5-6 p.m.)	763	1,480[1]	+94%
North (7-8 a.m.)	700	1,165	+66%
Northwest (7-8 a.m.)	490	1,465	+199%
East RLT (7-8 a.m.)	596	1,346	+126%
Freeway Without HOV Lane (7-8 a.m.)	600	531	-11.5%
A.M. Peak-Period Bus Ridership (3.5 hours)			
Freeways With HOV Lanes			
Katy	900	4,680	+420%
North	0	5,950	—
Northwest	605	1,670	+176%
Freeway Without HOV Lane[2]	2,185	2,174	-1%
Cars Parked at Park-and-Ride Lots			
Freeways With HOV Lanes			
Katy	575	2,122	+269%
North	—	3,614	—
Gulf	1,115	1,331	+ 19%
Northwest	430	1,558	+262%
Freeway Without HOV Lane	1,680	1,522	-13%

[1]The most current peak-hour 2+ carpool volume is from 1991. On 9/16/91, the vehicle occupancy requirement from 5-6 p.m. was changed to 3+ for the Katy HOV lane; thus, resulting in the absence of 1992 2+ carpool volume data for the Katy HOV lane.

[2]The bus ridership data have been adjusted to compensate for the diversion of bus service from Southwest Freeway to the Katy HOV lane due to construction on Southwest Freeway.

Note: The freeway without an HOV lane data are from the Southwest (US 59) 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 facilities (Table S-1). Per-lane volumes on the general-purpose lanes are often higher today than they were prior to HOV implementation. In reviewing accident data for the five freeways with HOV lanes, in aggregate there has not been a noticeable change in those rates.

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). This efficiency has generally increased (Table S-1) since the HOV lanes have been implemented, and a part of that increase is the result of their 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 1992), 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.

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 Katy corridor it would be necessary to construct four to five 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.

However, if an HOV project is even marginally cost effective based on the single travel time savings benefit, that project would simply be even more cost effective if all benefits were quantified. Based on this analysis (using 1992 data), the Katy and East RLT HOV lanes are clearly cost effective, while the Gulf, North, and Northwest HOV are marginally 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 1992 the benefit-cost ratio for the Katy HOV project was in excess of 3.8 (see Table 32, p. 86). 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, it is estimated that the 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 $115 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

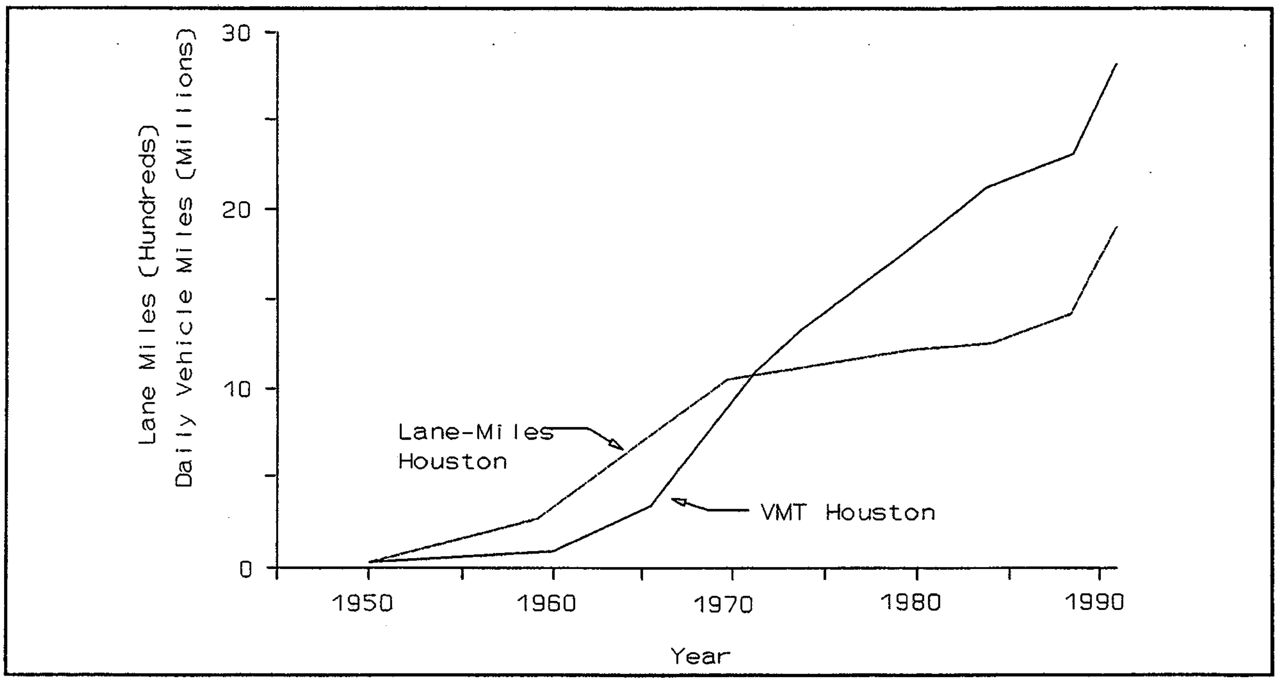
This report identified the objectives associated with developing high-occupancy vehicle lanes in Texas. The report reviews and analyzes data collected through calendar year 1992 to assess the performance of the priority lanes in meeting their objectives.

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 and East RLT HOV lanes are fulfilling their intended purpose. The Gulf, North, and Northwest HOV lanes are marginal at this time. The Northwest HOV lane was completed in final form during 1990. Less than half the length of the ultimate Gulf HOV lane is now operating; the remainder of this facility will open in 1993.

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

I. INTRODUCTION

Beginning in the early 1970s, increases in travel demand, expressed as freeway vehicle-miles of travel (VMT), in Houston began to exceed increases in roadway supply, expressed as lane-miles of freeway (Figure 1). Between 1970 and 1985, VMT per freeway lane-mile 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-Miles of Travel and Lane-Miles of Freeway, Houston

Monitoring of overall urban congestion in major cities clearly indicated that mobility in Houston and Dallas deteriorated significantly during the late 1970s and early 1980s. Areawide congestion levels increased by 39 percent between 1975 and 1984 in Houston and by 24 percent

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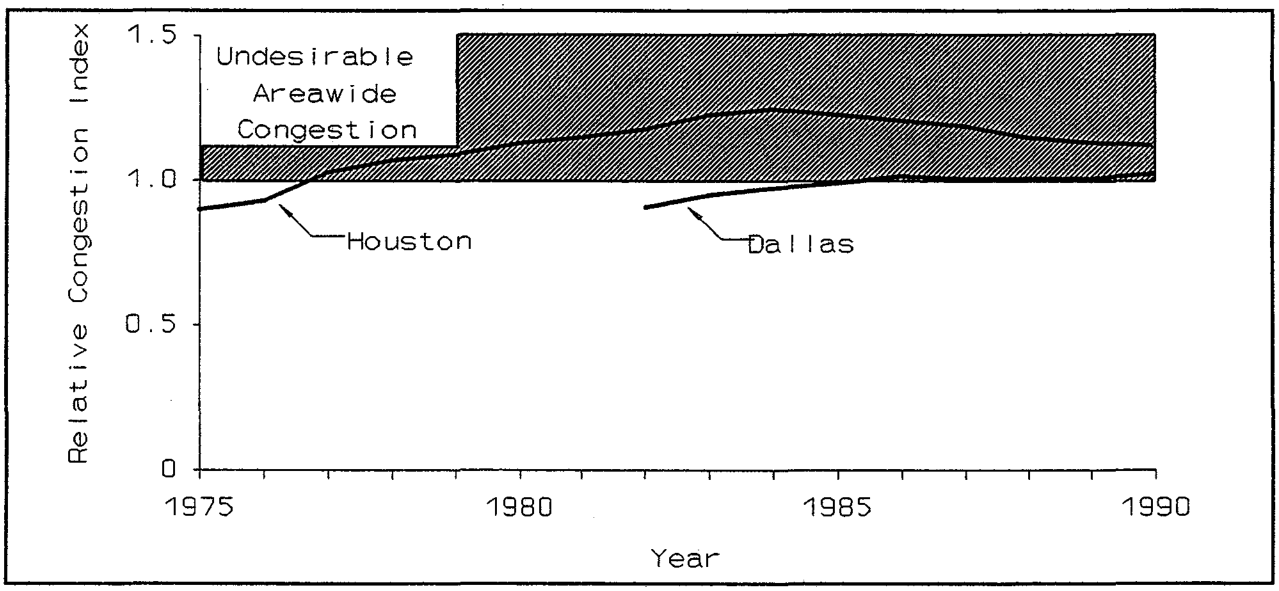
[2]Texas Transportation Institute Research Report 431-1F.

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

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 1990, 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 remained steady between 1986 and 1990. 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-miles of travel and lane-miles of roadway for both freeways and principal arterials.

Figure 2. Relative Mobility Levels for Houston and Dallas, 1975-1990

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, sometimes referred to locally as transitways or HOV lanes, 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, 1990

Urban Area	Relative Mobility Index[1]	Urban Area	Relative Mobility Index[1]
1. Los Angeles	1.55	7. Seattle	1.20
2. Washington, D.C.	1.37	8. San Bernardino	1.19
3. San Francisco-Oakland	1.35	9. New York	1.14
4. Miami	1.26	10. HOUSTON	1.12
5. Chicago	1.25	10. New Orleans	1.12
6. San Diego	1.22	17. DALLAS	1.05

[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-miles of travel and lane-miles 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 being 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 being collected on freeways that do not have an HOV lane. These "control" corridors help to 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 1992. Data are presented for all five of the operational transitways.

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, in the mid 1970s a joint decision was made by the City of Houston and the Texas Department of Transportation (then the Texas Highway Department) to test the high-occupancy vehicle lane concept in Houston. Accordingly, these two agencies developed and operated a 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 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 congestion problems in the late 1980s. Influenced by the success of HOV lanes in Houston (as well as other areas of the nation), a joint decision was made between TxDOT and Dallas Area Rapid Transit (DART) to test the high-occupancy vehicle lane concept in Dallas. A 5.2-mile barrier-separated contraflow lane was consequently developed and opened for operation on East R.L Thornton Freeway (I-30E/East RLT). 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 great success. After having been opened for less than one year, the contraflow lane was already serving 16,000 daily person trips and saving its users approximately 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 96 miles of high-occupancy vehicle lanes (Figure 3). As of December 1992, four separate HOV facilities were in operation (Table 2). A total of 46.5 miles of barrier-separated, high-occupancy vehicle lanes were operating. No extensions of operating HOV segments occurred during 1992; the Katy HOV lane continued to operate on weekends, and motorcycles were allowed to use any of the HOV lanes in Houston (regardless of the number of persons riding the motorcycle). Construction is continuing in the Southwest, Gulf, and Eastex corridors. The first phase of the Southwest HOV lane opened in January 1993. Another major segment of the Gulf HOV lane should be completed in late 1993.

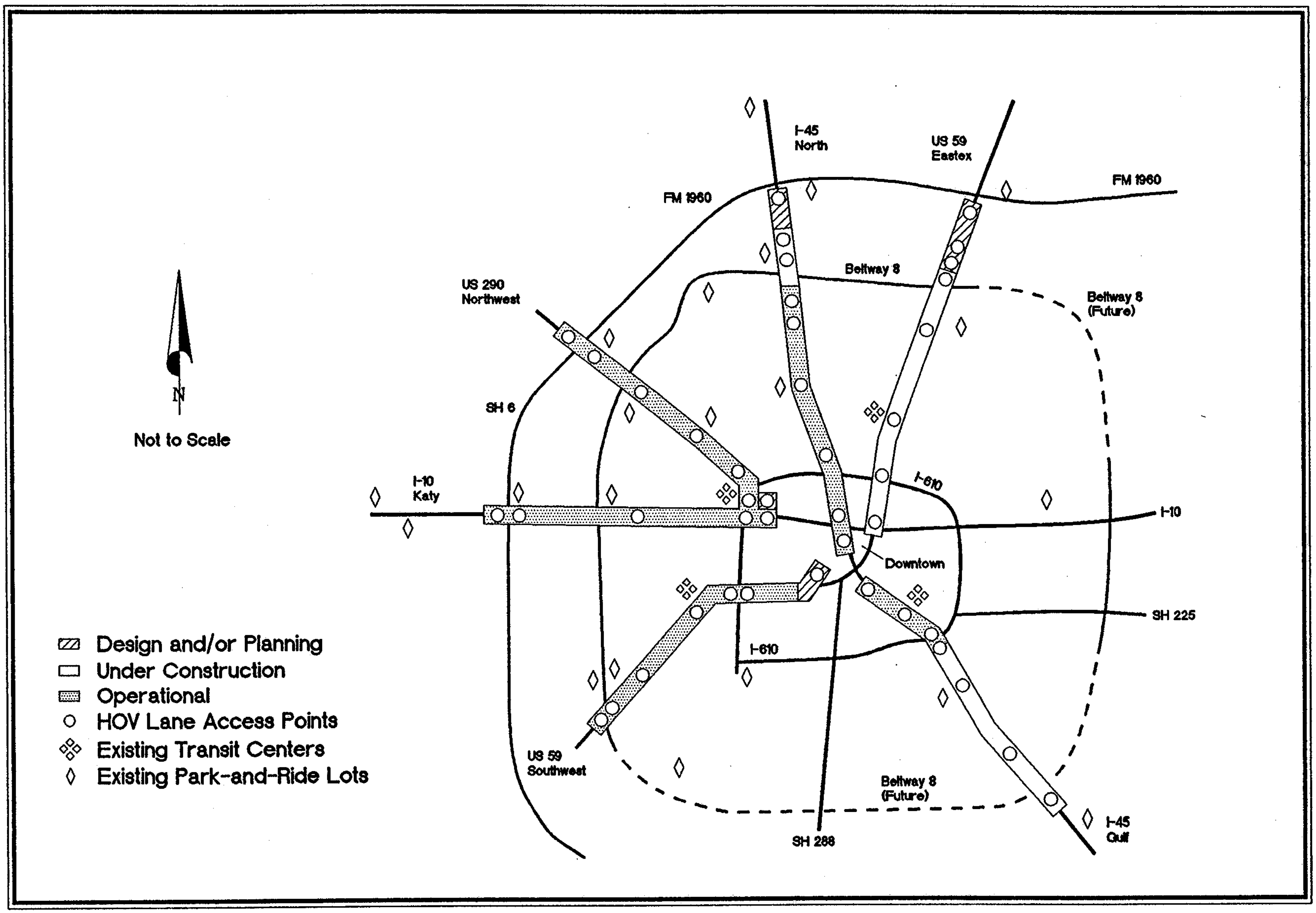


Figure 3. Status of Houston HOV Lane System, December 1992

Table 2. Status of the Houston High-Occupancy Vehicle Lane System, December 1992

HOV Facility	Date First Phase Opened	Miles in Operation	Ultimate System Miles (Current Plan)	Vehicles Allowed to Use HOV Lane	Hours of Weekday Operation[1]
Katy (I-10)	October 1984	13.0	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-45)	November 1984[2]	13.5	19.7[3]	2+ vehicles	4 a.m. to 1 p.m. inbound 2 p.m. to 10 p.m. outbound
Gulf (I-45)	May 1988	6.5	15.5[4]	2+ vehicles	4 a.m. to 1 p.m. inbound 2 p.m. to 10 p.m. outbound
Northwest (US 290)	August 1988	13.5	13.5	2+ vehicles	4 a.m. to 1 p.m. inbound 2 p.m. to 10 p.m. outbound
Southwest (US 59)	Not open in 1992	—	13.8[4]	—	—
Eastex (US 59)	Not open in 1992	—	20.0	—	—
Total		46.5	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 1993.

Dallas

Compared to Houston, the Dallas HOV lane system is in its relative infancy. A plan is, however, currently in place to construct approximately 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 1992, 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 1994, while additional HOV facilities are in the planning and design stage for five other Dallas freeways.

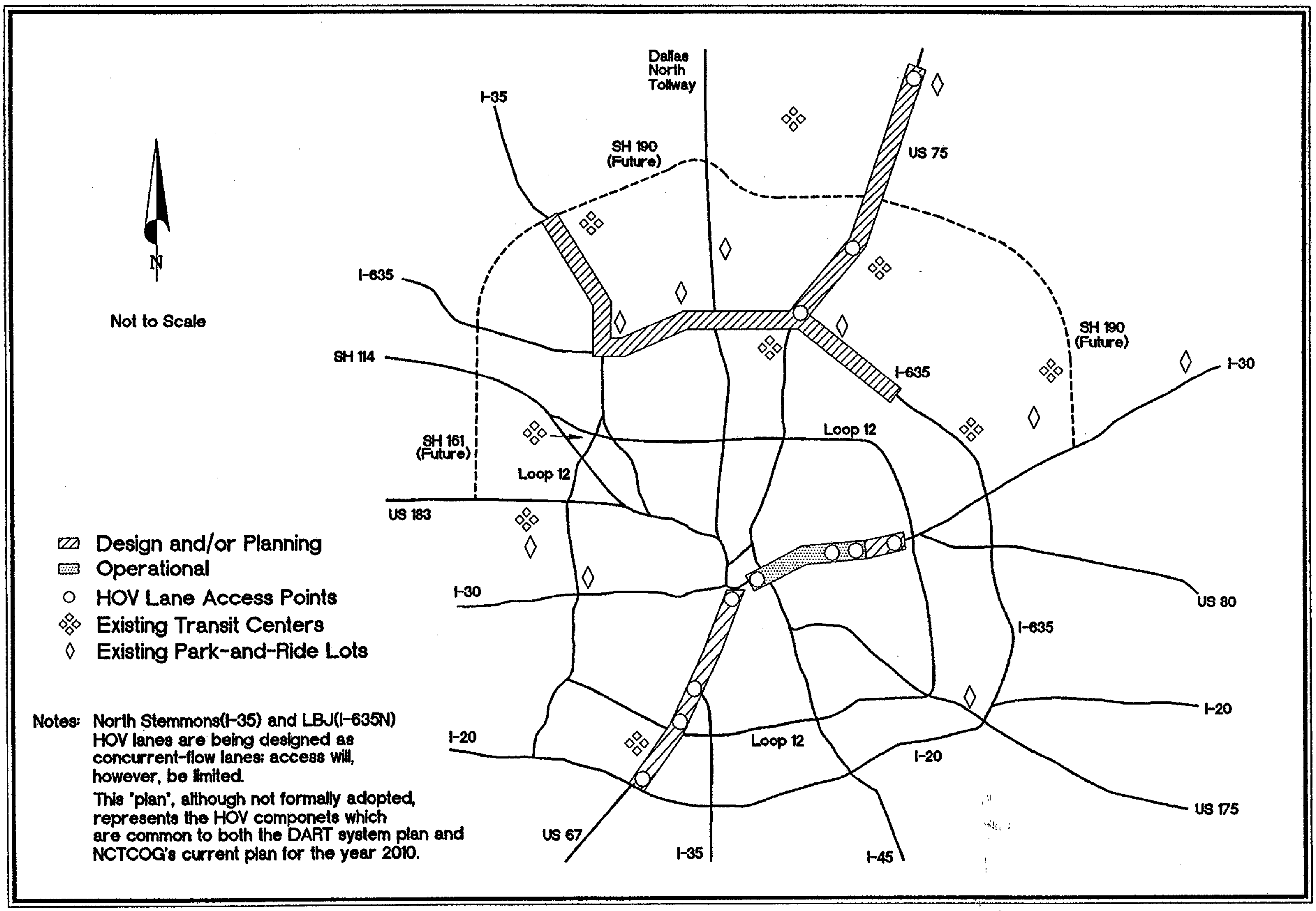


Figure 4. Status of Dallas HOV Lane System, December 1992

Table 3. Status of the Dallas High-Occupancy Vehicle Lane System, December 1992

HOV Facility	Date First Phase Opened	Miles in Operation	Ultimate Miles	Vehicles Allowed to Use HOV Lane	Hours of Weekday Operation
East R.L. Thornton (I-30)	September 1991[1]	5.2 inbound 3.3 outbound	5.2 inbound 5.2 outbound [2]	2+ vehicles	6 a.m. to 9 a.m. inbound 4 p.m. to 7 p.m. outbound
North Stemmons (I-35E)	Not open in 1992	—	9.7[3]	—	—
South R.L. Thornton (I-35E)	Not open in 1992	—	9.0[4]	—	—
Marvin D. Love (US 67)	Not open in 1992	—	6.2[4]	—	—
LBJ (I-635)	Not open in 1992	—	6.5[5]	—	—
North Central Expwy. (US 75)	Not open in 1992	—	—[6]	—	—

[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 1994; the current outbound length is 3.3 miles.
[3]Concurrent flow lane scheduled for completion in 1994.
[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 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, most access to the median HOV lanes is provided by grade-separated interchanges of various designs (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 3- to 5-mile intervals.

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

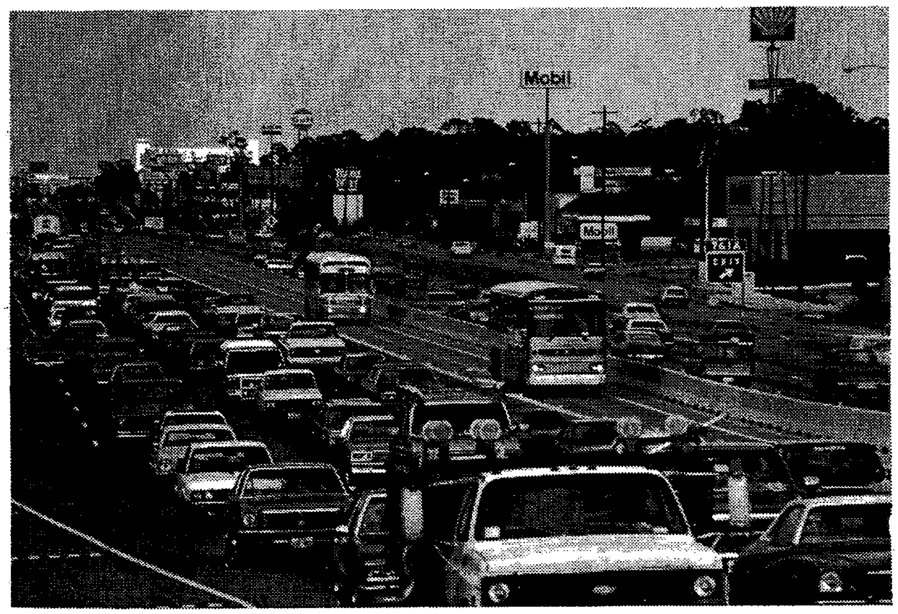


Figure 5. Transitway in Median of Katy Freeway

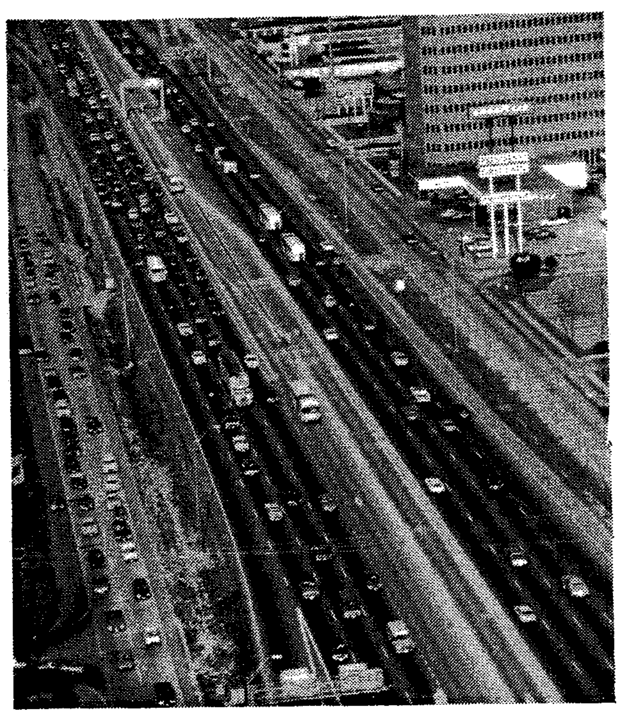
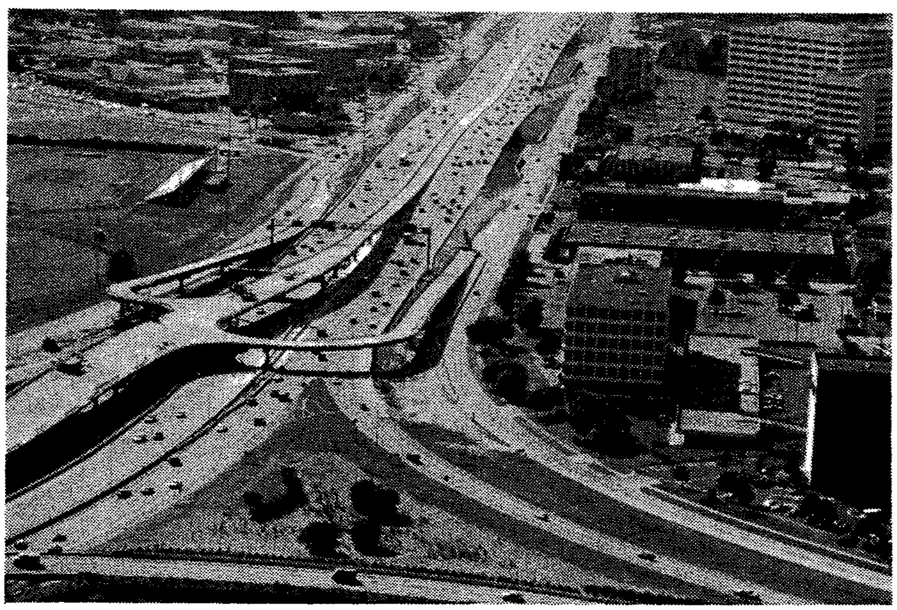


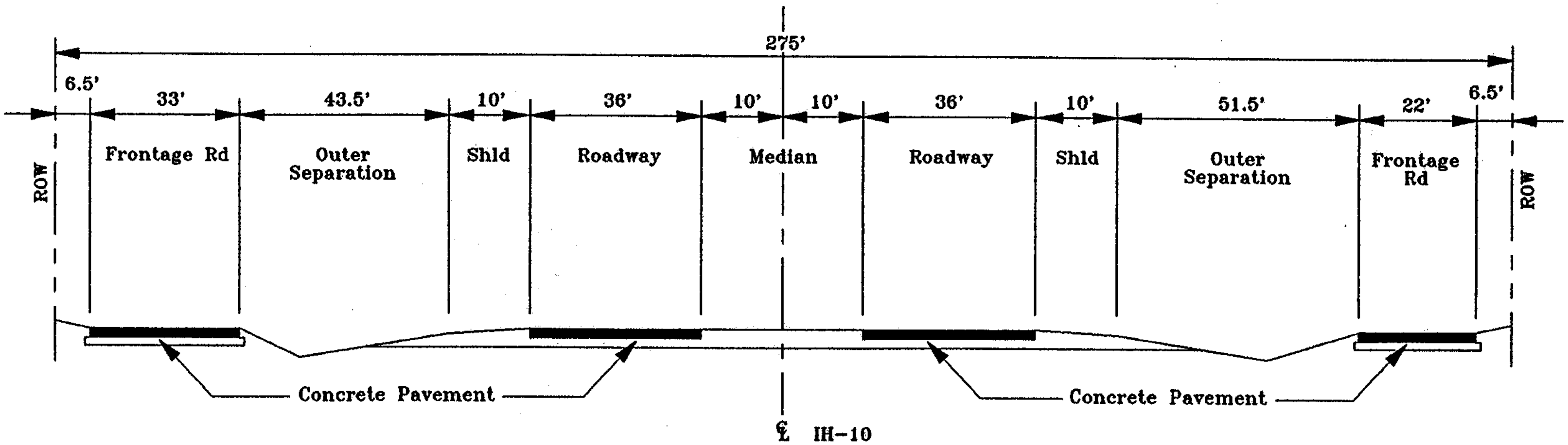
Figure 6. Slip Ramp for Transitway Access/Egress on Katy Freeway

Direct Ramp to Eastwood Bus Transit Center, Gulf Transitway

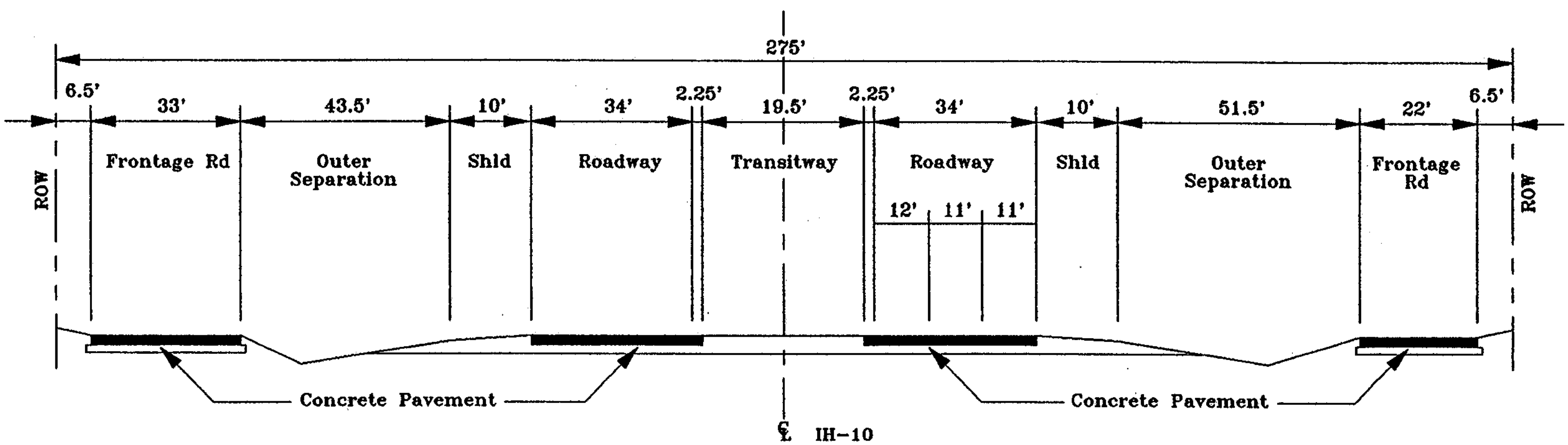


Transitway Ramps to Frontage Roads, Northwest Transitway

Figure 7. Examples of Grade-Separated Transitway Interchanges



Typical Section Before Transitway Construction



Typical Section After Transitway Construction

Figure 8. Typical Sections, Before and After Katy Transitway 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 20-foot wide HOV lane, consists of three-foot concrete segments joined together by pins. The flexibility created by these pins allows the barrier machine (Figure 9) to shift the barrier 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 11 feet and reducing the inside shoulder of the freeway in some locations (Figure 10). Access to, and egress from, the East RLT HOV lane is provided by slip ramps such as the one shown in Figure 11.

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

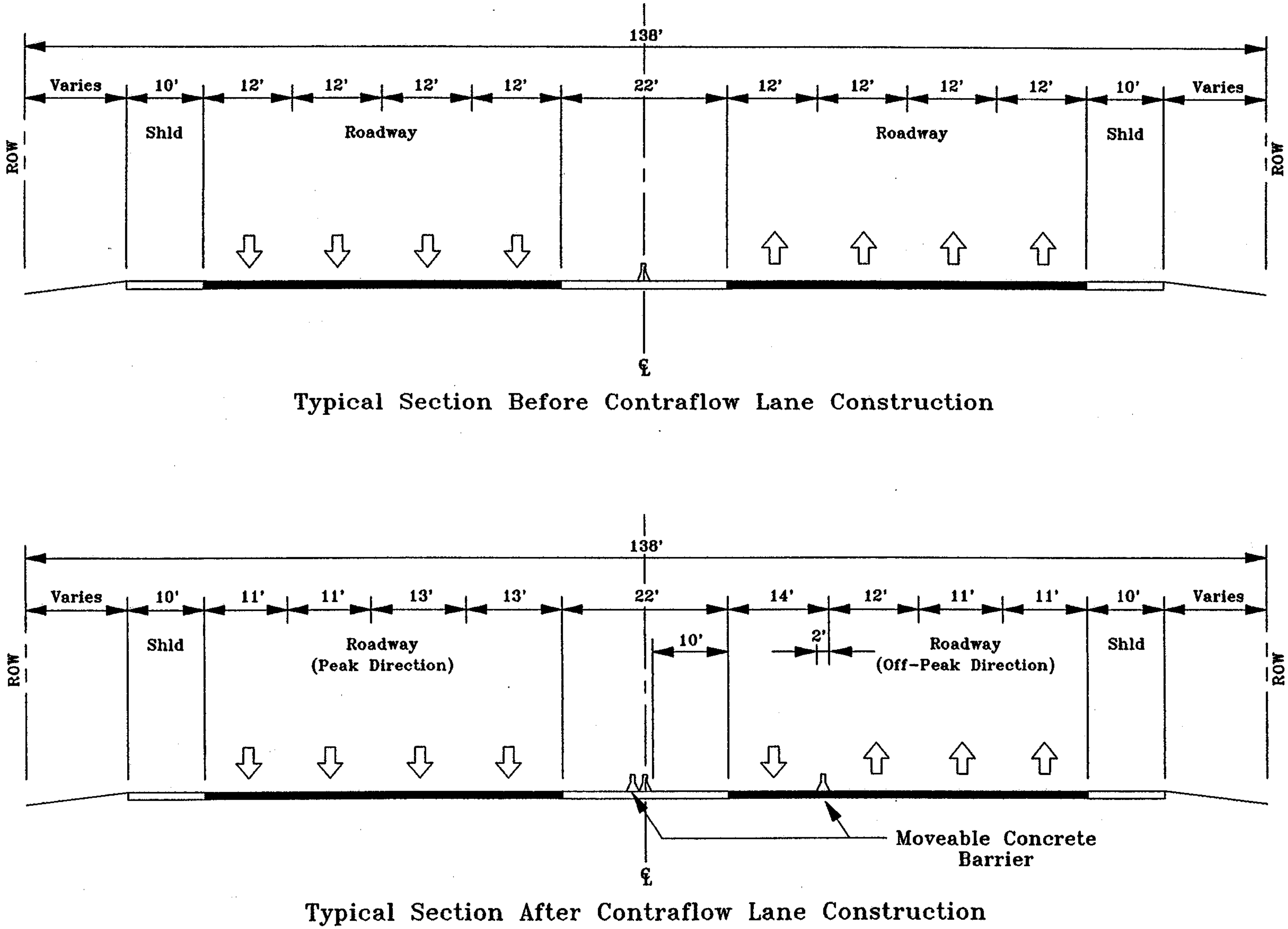


Figure 10. Typical Sections, Before and After East RLT Contraflow Lane Construction

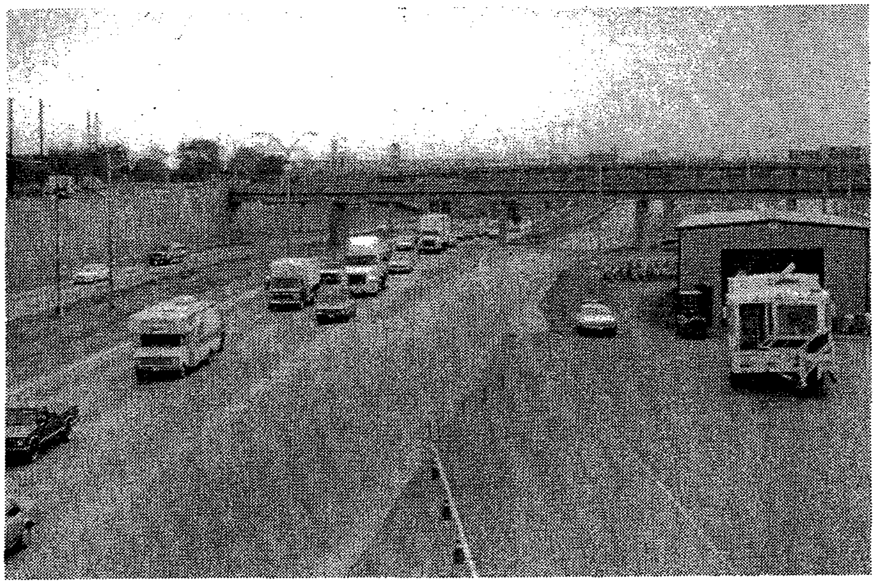


Figure 11. Example of Access Point on East R.L. Thornton HOV Lane

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. More detailed cost breakdowns are included in the appendices.

The HOV lanes in operation today, including all access ramps, have typically been built at an average cost of less than $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 $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 $300,000 per mile. The total cost for all project elements is in the range of $6 million per mile. Total capital expenditures (1990 dollars) for the operating segments have been approximately $276 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, 1992

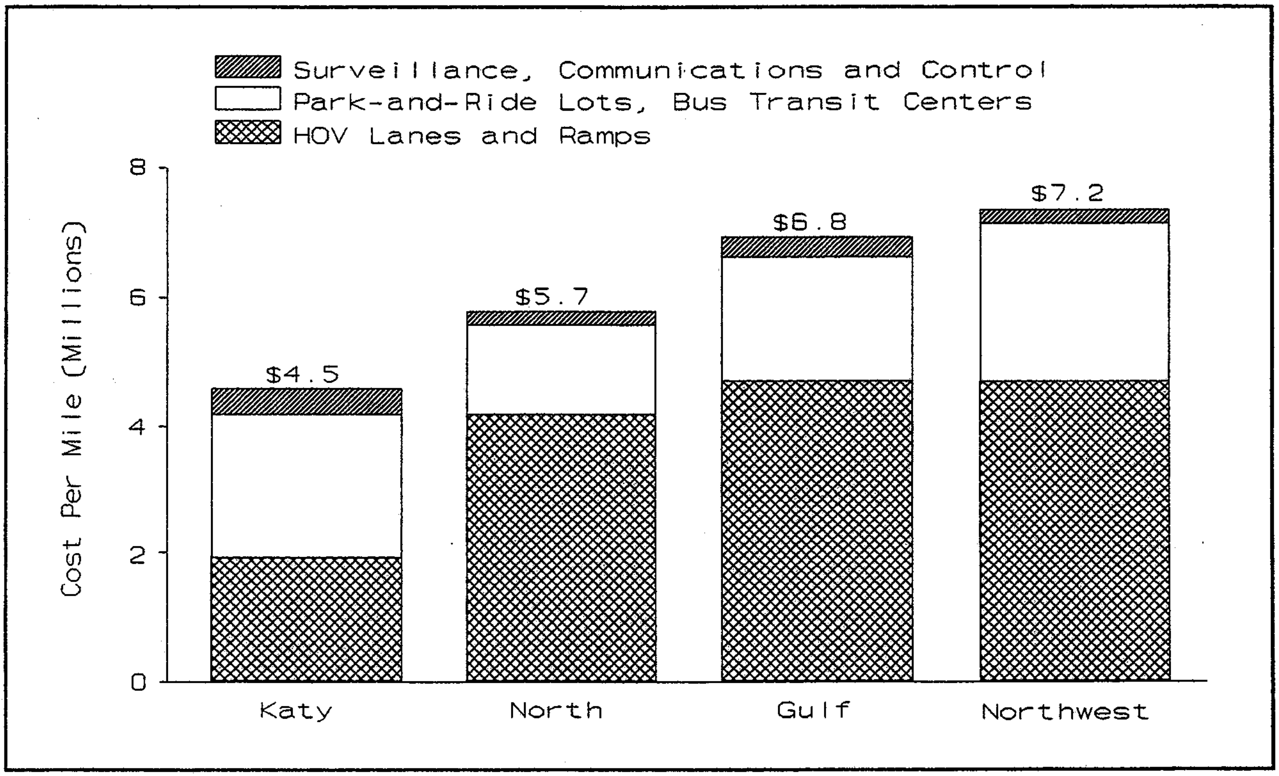
HOV Lane	Miles in Operation	Estimated Capital Cost, Millions[1,2]							
		HOV Lane Plus Ramps[3]		Support Facilities[4]		Surveillance, Communication and Control[5]		Total	
		Total	Per Mile	Total	Per Mile	Total	Per Mile	Total	Per Mile
Katy (I-10)	13.0	$27.5 ($25.1)	$2.1 ($1.9)	$30.0 ($29.3)	$2.3 ($2.2)	$5.5 ($4.7)	$0.4 ($0.4)	$63.0 ($59.1)	$4.8 ($4.5)
North (I-45)	13.5	$57.8 ($54.8)	$4.3 ($4.1)	$18.2 ($18.5)	$1.3 ($1.4)	$2.6 ($2.6)	$0.2 ($0.2)	$78.6 ($75.9)	$5.8 ($5.6)
Northwest (US 290)	13.5	$62.7 ($62.0)	$4.6 ($4.6)	$33.8 ($33.2)	$2.5 ($2.5)	$2.9 ($2.9)	$0.2 ($0.2)	$99.4 ($98.1)	$7.4 ($7.3)
Gulf (I-45)	6.5	$30.5 ($29.9)	$4.7 ($4.6)	$12.6 ($12.4)	$1.9 ($1.9)	$1.9 ($1.9)	$0.3 ($0.3)	$45.0 ($44.2)	$6.9 ($6.8)
Total	46.5	$178.5 ($171.8)	$3.8 ($3.7)	$93.4 ($92.2)	$2.0 ($2.0)	$12.9 ($12.1)	$0.3 ($0.3)	$284.8 ($276.1)	$6.1 ($5.9)

[1]Numbers in parentheses are in 1990 dollars. Numbers not in parentheses are in year of construction dollars. Highway construction costs in 1990 are generally lower than those that existed in the 1980s.
[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 half of the ultimate HOV lane system in Houston was operating in 1992. An estimate of the cost of the completed system is provided in Table 5. The ultimate capital cost (1990 dollars) for the HOV lanes and ramps will be approximately $5.0 million per mile. The HOV support facilities will cost an additional $1.6 million per mile. The entire completed system will cost approximately $669 million, or about $7.0 million per mile (1990 dollars).

Each of the HOV projects has been funded differently, 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 Mile (1990 Dollars) of the Operating Houston HOV Facilities

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

HOV Lane	Ultimate System Miles	Estimated Capital Cost, Millions[1,2]							
		HOV Lane Plus Ramps[3]		Support Facilities[4]		Surveillance, Communication and Control[5]		Total	
		Total	Per Mile	Total	Per Mile	Total	Per Mile	Total	Per Mile
Katy (I-10)	13.0	$ 25.1	$1.9	$29.3	$2.3	$ 4.7	$0.4	$59.1	$4.6
North (I-45)	19.7	$104.8	$5.3	$26.6	$1.4	$ 4.1	$0.2	$135.5	$6.9
Gulf (I-45)	15.5	$ 89.4	$5.8	$28.4	$1.8	$ 3.3	$0.2	$121.1	$7.8
Northwest (US 290)	13.5	$ 62.0	$4.6	$33.2	$2.5	$ 2.9	$0.2	$ 98.1	$7.3
Southwest (US 59)	13.8	$ 84.4	$6.1	$24.6	$1.8	$ 4.5	$0.3	$113.5	$8.2
Eastex (US 59)	20.0	$119.3	$6.0	$15.0	$0.8	$ 7.3	$0.4	$141.6	$7.1
Total	95.5	$485.0	$5.1	$157.1	$1.6	$26.8	$0.3	$668.9	$7.0

[1]Estimated costs are in 1990 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 (1990 dollars) 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

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

[1]Estimated costs are in 1990 dollars.
[2]Costs do not include the value of the existing freeway rights-of-way in which the HOV lane is located. The costs of any additional buses required to provide HOV service and any associated increases in bus maintenance costs are not included.
[3]Includes the cost of any structural upgrades of pavement for the HOV lane and the access/egress ramps serving the lane.
[4]Includes the cost of the movable concrete barriers and the machines required to move those barriers.
[5]No new support facilities (e.g., park-and-ride lots and bus transfer centers) have been provided as part of this project.
[6]The East RLT HOV lane operates 5.2 miles inbound and 3.3 outbound. The HOV lane will eventually operate 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 $265,000 per HOV lane per year (Table 7). This is equivalent to less than one cent per passenger-mile.[5]

[5]In 1990, approximately 140 million passenger-miles were served on the Houston HOV facilities. At $1,060,000 per year for operations and enforcement, this equates to 0.8 cents per passenger mile.

Table 7. Estimated Annual Cost of Operating and Enforcing the Operating Houston HOV Lanes, 1990

Type of Cost	Annual Budget
Daily Operations	$ 660,000
Enforcement	$ 400,000
Total	$1,060,000
Average Per HOV Lane (unweighted)	$ 265,000

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 $3.00 is required for each bus passenger using the HOV facilities. This equates to an annual subsidy of approximately $18 million to provide the bus service on the HOV facilities.

Thus, the total annual public operating costs for the HOV lanes is approximately $19 million; $1 million is for operations and enforcement, and $18 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.

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 $450,000 per year in 1990 dollars (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-mile are unavailable at this time.

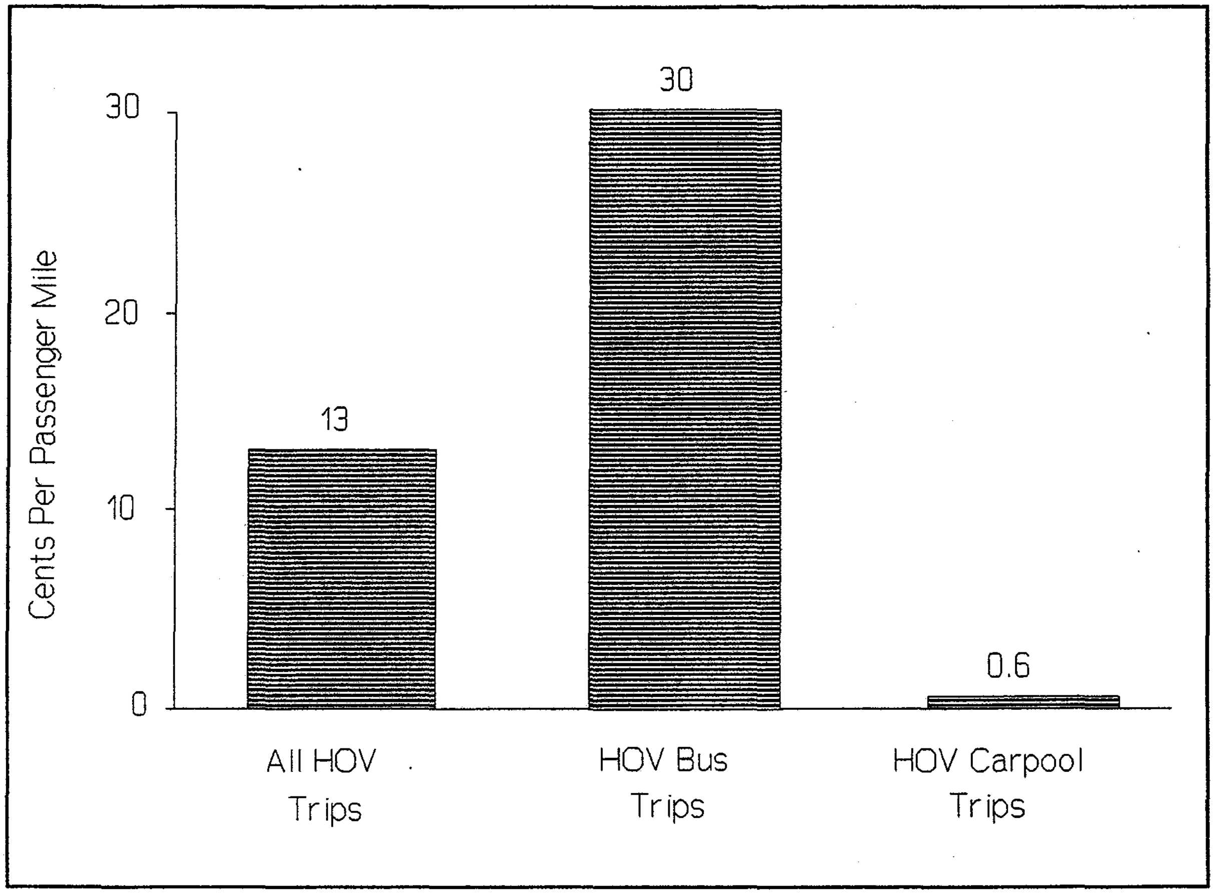


Figure 13. Operating Cost Per Passenger-Mile for the Operating Houston HOV Facilities, 1990

Table 8. Estimated Annual Cost of Operating and Enforcing the East RLT HOV Lane, 1990

Type of Cost	Annual Budget
Daily Operations	$ 370,000
Enforcement	$ 80,000
Total	$ 450,000

[1]The operating and enforcement costs are in 1990 dollars. Cost figures from 1992 were used, in conjunction with the Consumer Price Index (CPI), to arrive at these estimates.

Source: Dallas Area Rapid Transit

GENERAL TRENDS IN HOUSTON HOV SYSTEM UTILIZATION

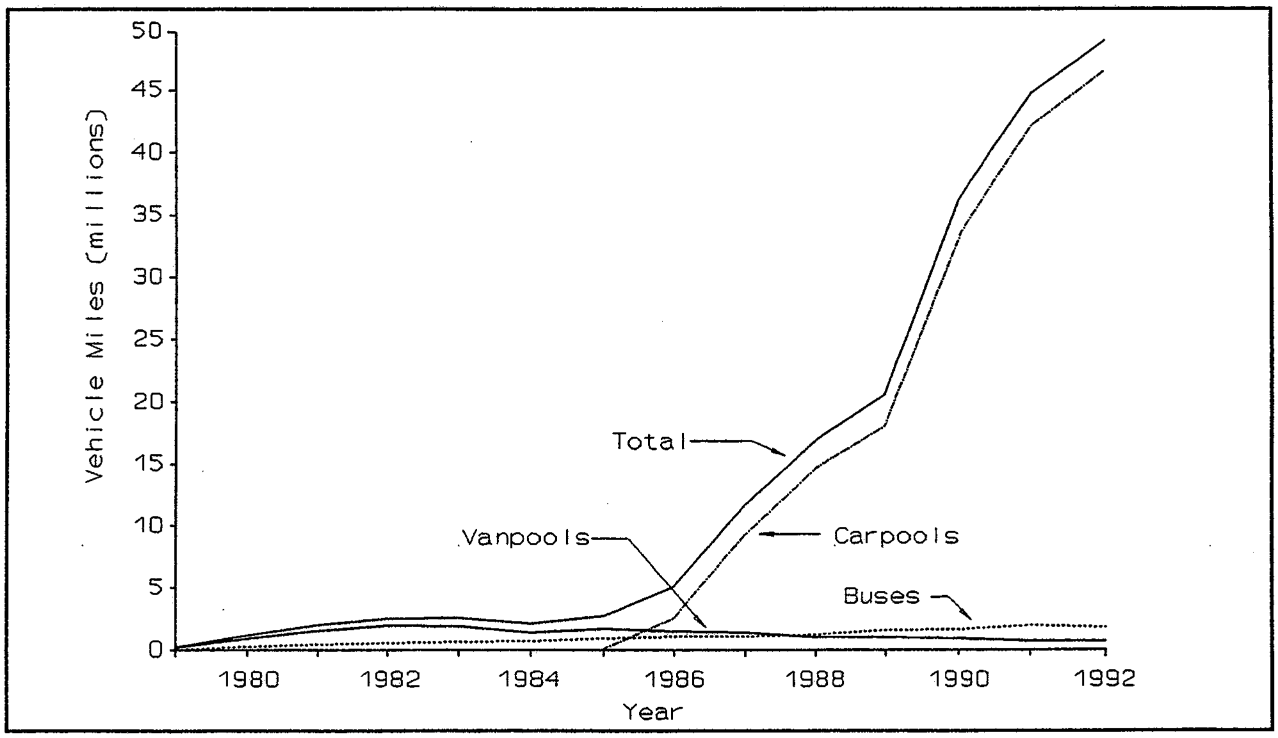
This section briefly overviews system-wide data that help describe the usage of the Houston HOV lanes over time. A more detailed evaluation of these data is included in a subsequent section of this report. Additional data for both the Houston and Dallas HOV lanes are included in the appendices.

Trends in System-wide HOV Usage

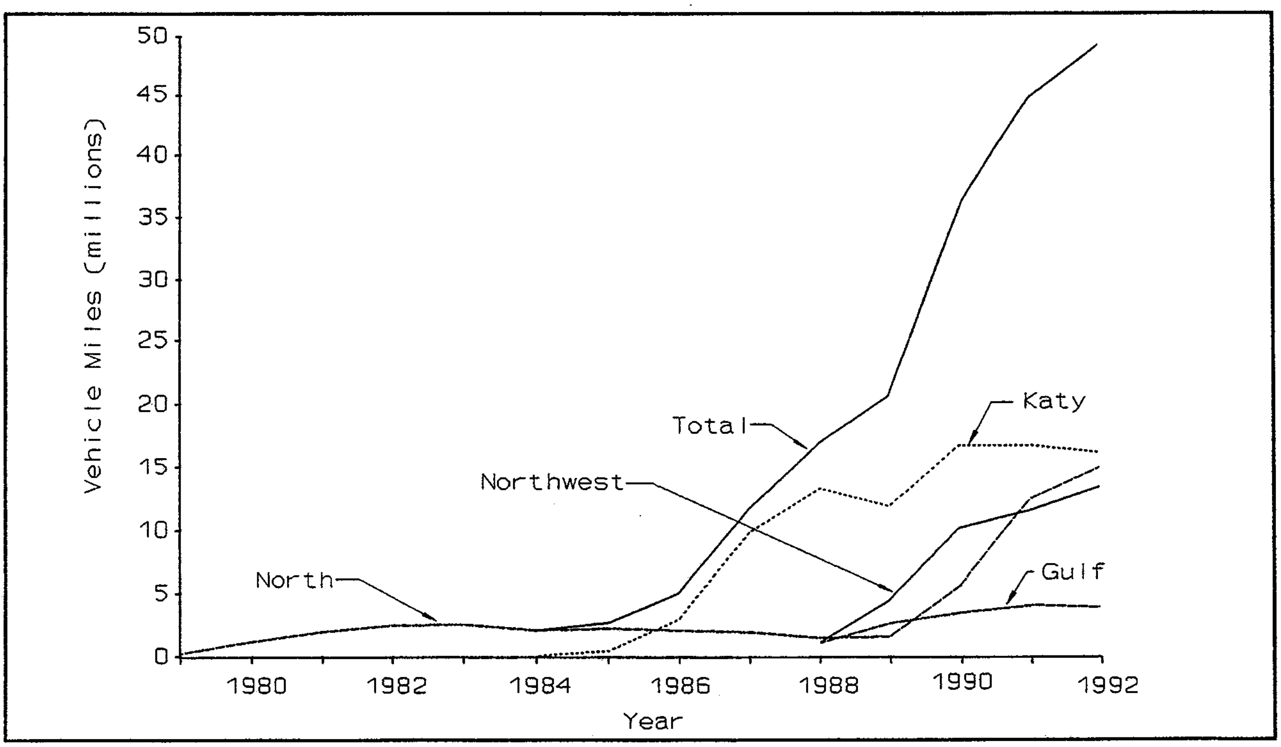
Annual vehicle-miles of travel on the HOV lanes and annual passenger-miles traveled are depicted in Figures 14 and 15. Since carpools were first allowed to use the HOV lanes in 1985, vehicle-miles of transitway usage have increased rapidly. With this carpool use and the continued opening of HOV lanes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

Figure 16 depicts total daily system-wide HOV usage in Houston. Daily person trips in December 1992 totaled 69,956—a 16 percent increase over the ridership level in December 1991. While this is a substantial annual increase in ridership, it is important to note that there was a decrease in HOV lane ridership during 1991.

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 1992, the miles of operating HOV facility have increased by 188 percent. During that same time period, daily person trips on the HOV lanes have increased by 230 percent. Person trips have, thus, been increasing at a rate greater than that of the expansion of the HOV lane system.

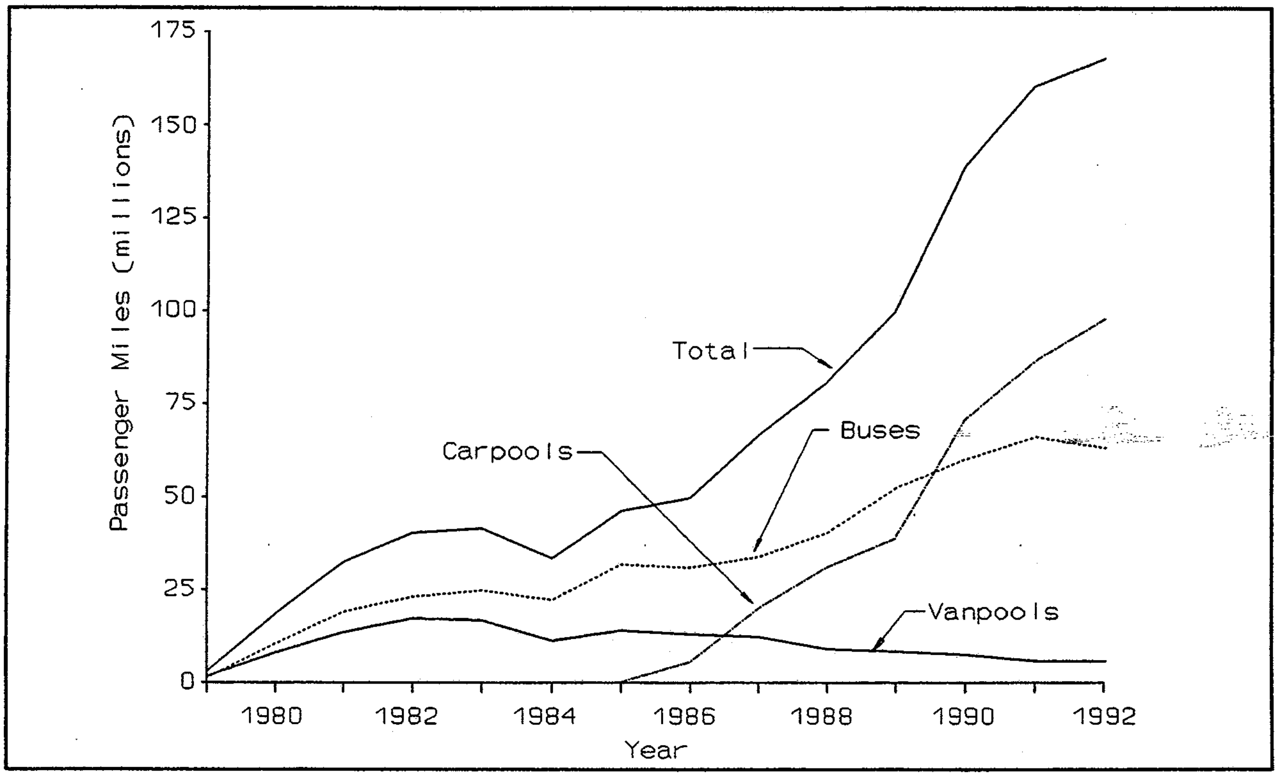


Source: See data in appendices.

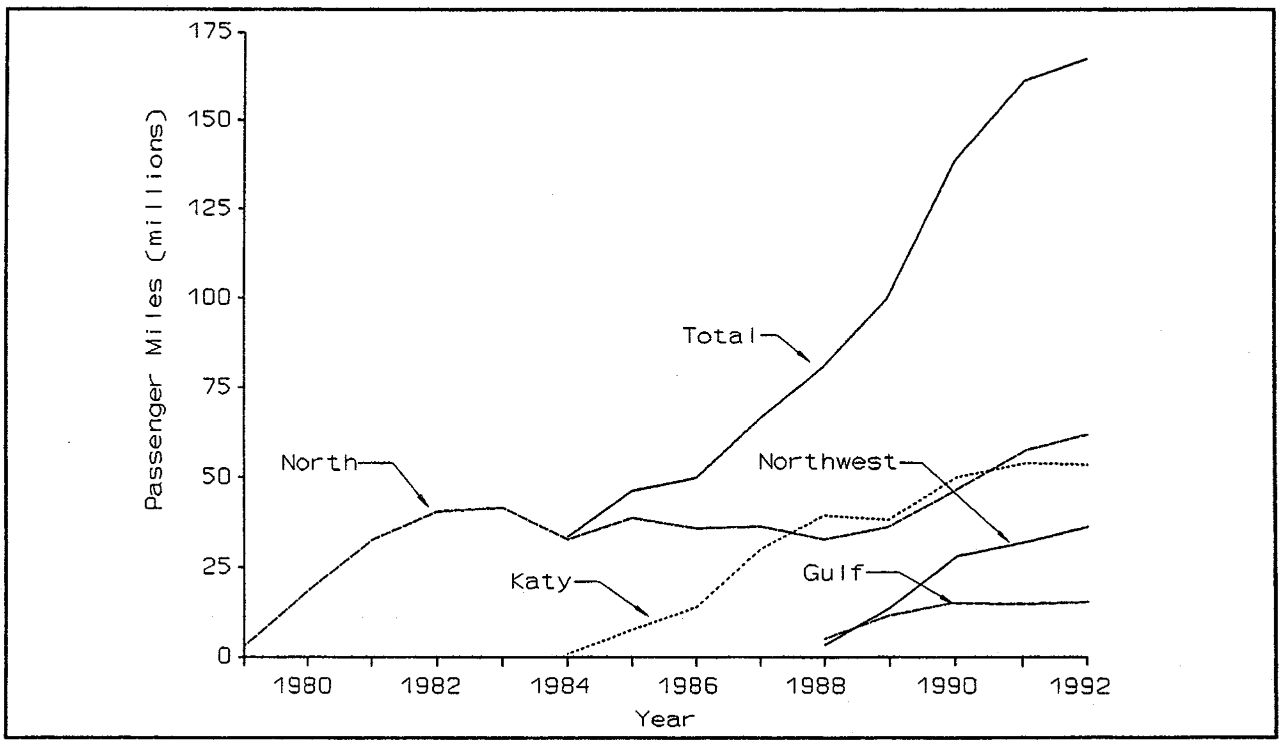


Source: See data in appendices.

Figure 14. Trends in Annual Vehicle-Miles of Travel on Houston Transitways

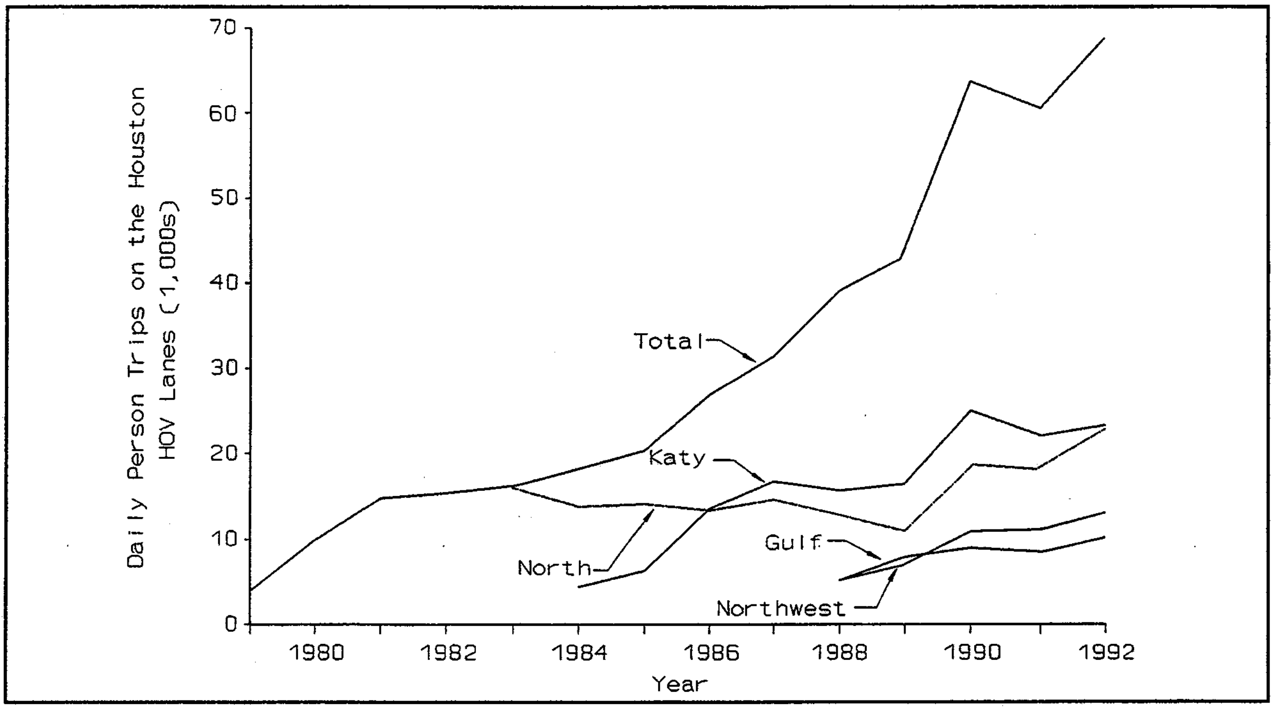


Source: See data in appendices.



Source: See data in appendices.

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



Source: See data in appendices.

Figure 16. Trends in Daily Person Trips on Houston Transitways

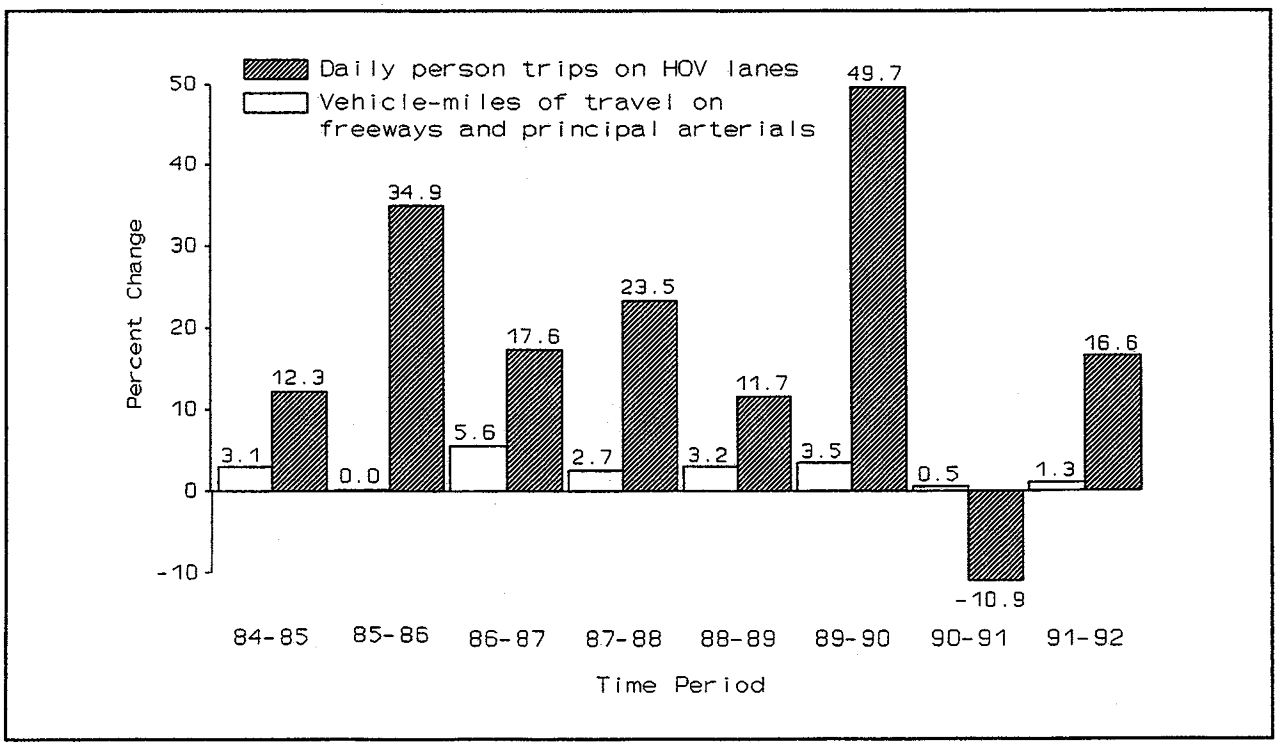


Figure 17. Annual Percentage Increase in HOV Person Trips and in Vehicle-Miles of Travel on Freeways and Principal Arterials

Comparison to Other Fixed-Guideway Projects

Simply as a basis of comparison, the operating Houston HOV lane system (46.5 miles) has been constructed for a capital cost of approximately $276 million, and this system serves approximately 70,000 person trips per day. The public operating cost per passenger-mile is roughly 13 cents. The Miami heavy rail system (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-mile on that system is 52 cents. 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.

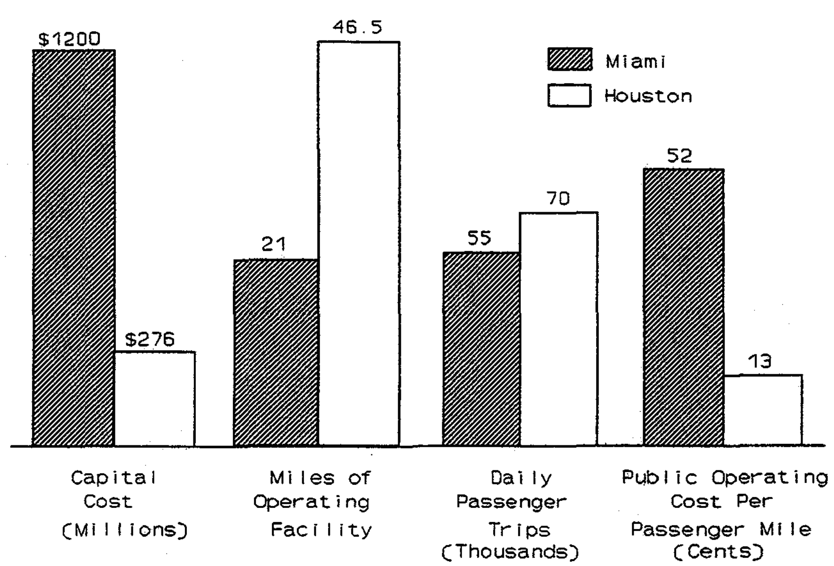


Figure 18. Comparative Data for the Operating Houston HOV Lanes and the Miami Rail Transit System

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 (Miles)	Capital Cost Per Mile[1] (millions)	Average Weekday Person Trips[2]	Maximum Ridership, Peak-Hour, Peak-Direction
Houston HOV Lanes				
Katy (I-10)	13.0	$4.5	23,434	4,524
North (I-45)	13.5	$5.7	23,030	5,560
Gulf (I-45)	6.5	$6.8	10,196	3,218
Northwest (US 290)	13.5	$7.2	13,296	3,969
Average	11.6	$5.9	17,489	4,318
U.S. Light Rail Lines				
Portland	15.1	$14.1	22,000	2,200
Sacramento	18.3	$ 9.6	21,000	2,500
San Diego (San Ysidro)	15.9	$ 7.3	31,900	2,300
San Jose	10.0	$18.8	9,400	500
Average	14.8	$12.4	21,100	1,900

[1]HOV capital costs from Table 5. Houston costs in 1990 dollars, rail costs in year of construction dollars.
[2]Houston HOV data for December 1992. LRT ridership data for 1990.

Source: Texas Transportation Institute and respective transit agencies.

Table 10 compares public operating cost per passenger-mile 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-Mile for Selected Fixed-Guideway Facilities

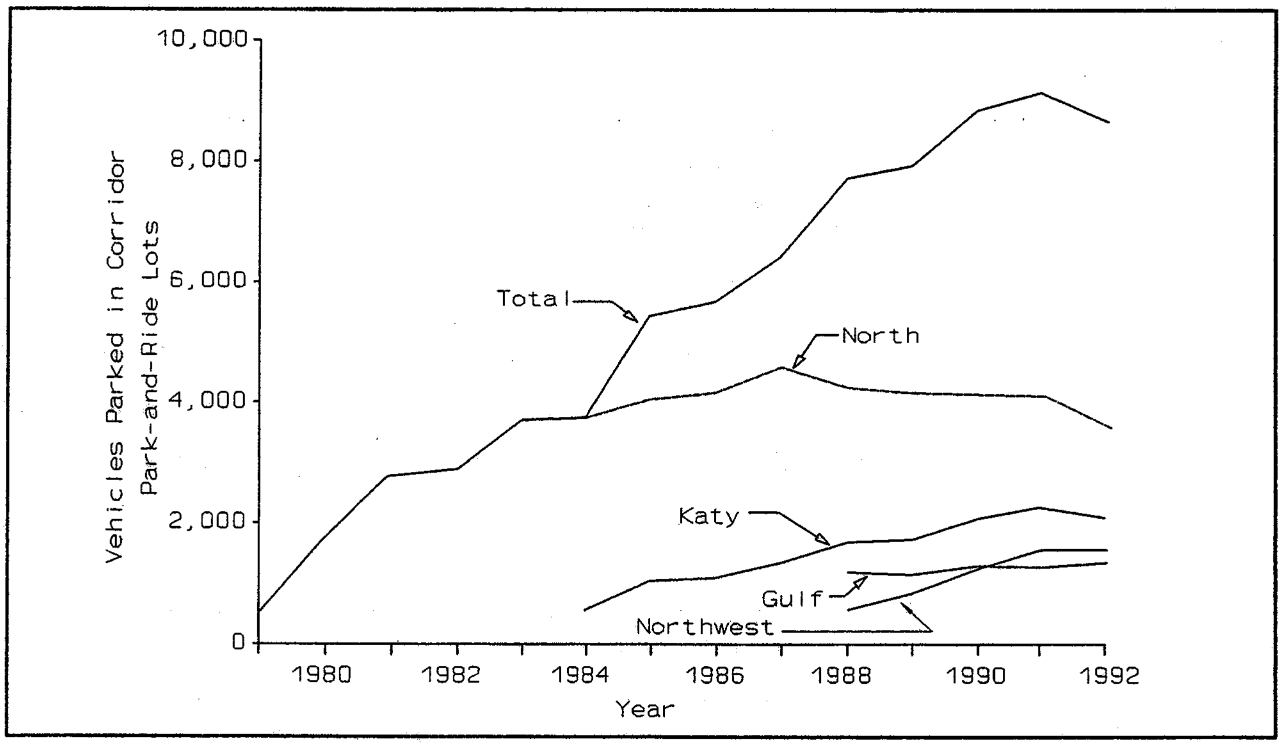
Fixed Guideway	Operating Cost Per Passenger-Mile (cents)
Houston HOV System[1], 1990	13
Rail Transit Systems, 1990	
Unweighted Average	29
Atlanta	17
Buffalo	57
Miami	43
Portland	24
Sacramento	27
San Diego	12
Washington, D.C.	25

[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 $18 million, and the costs of operating and enforcing the priority lanes was about $1 million.

Source: Metropolitan Transit Authority of Harris County; "Rail Research Project Comparative City Data Base," prepared by Metropolitan Transit Authority and Texas Transportation Institute, and FTA Section 15 data.

Park-and-Ride Usage

Between December 1991 and December 1992, there has been a decrease of 6.0 percent in the use of park-and-ride lots in the corridors served by HOV lanes (Figure 19). In December 1992, approximately 8,625 cars were parked at park-and-ride lots; in December 1991 that number was 9,171. On an areawide basis, park-and-ride patronage in Houston has been declining over this same time period.



Source: See data in appendices.

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

Summary of HOV Usage Data

Selected HOV operating data are presented in Table 11. 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 about 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 1992

Time Period and Operating Data	HOV Lane			
	Katy	North	Gulf	Northwest
Weekday Operations				
HOV Lane Person Volume				
A.M. Peak Hour	4,524	5,560	3,218	3,969
Daily	23,434	23,030	10,196	13,296
HOV Lane Vehicle Volume				
A.M. Peak Hour	977	1,256	1,013	1,504
Daily	6,829	4,892	3,018	4,928
Percent of Total A.M. Peak-Hour, Peak-Direction Person Volume on HOV Lane[1]	45%	43%	—[3]	42%
Vehicles Parked in Corridor Park-and-Ride Lots	2,122	3,614	1,331	1,558
Weekend Operations[2]				
Daily Saturday Vehicles	2,471	—	—	—
Daily Sunday Vehicles	2,940	—	—	—

[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.

Transit Surveys

Selected data are summarized in Table 12. The HOV facilities have attracted young, educated, white-collar professionals to ride transit. The bus is being used to serve long-distance

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

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.

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 Transitway[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.

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 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 Transitways[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 $5 to $10 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 recent 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. A discussion of these issues is presented in this section; actual data collection and analyses are presented in subsequent sections of this report.

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

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

Measure. *The percentage increase in the peak-hour, peak-direction person volume resulting from HOV lane implementation should at least be greater than the percentage increase in directional lanes added to the roadway.* This will be accomplished by increasing the average number of persons per vehicle on a roadway; the increase in average vehicle occupancy should be the result of creating *new* carpoolers and *new* bus transit riders. Unless 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.

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 and 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 transitway, 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% 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 over 10 years without yet being fully 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 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 1992, the oldest HOV lanes in Texas (the Katy and North HOV lanes in Houston) had been in operation for just over seven 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). In this section of the report, data are presented that address these issues. Transit operating data are also documented.

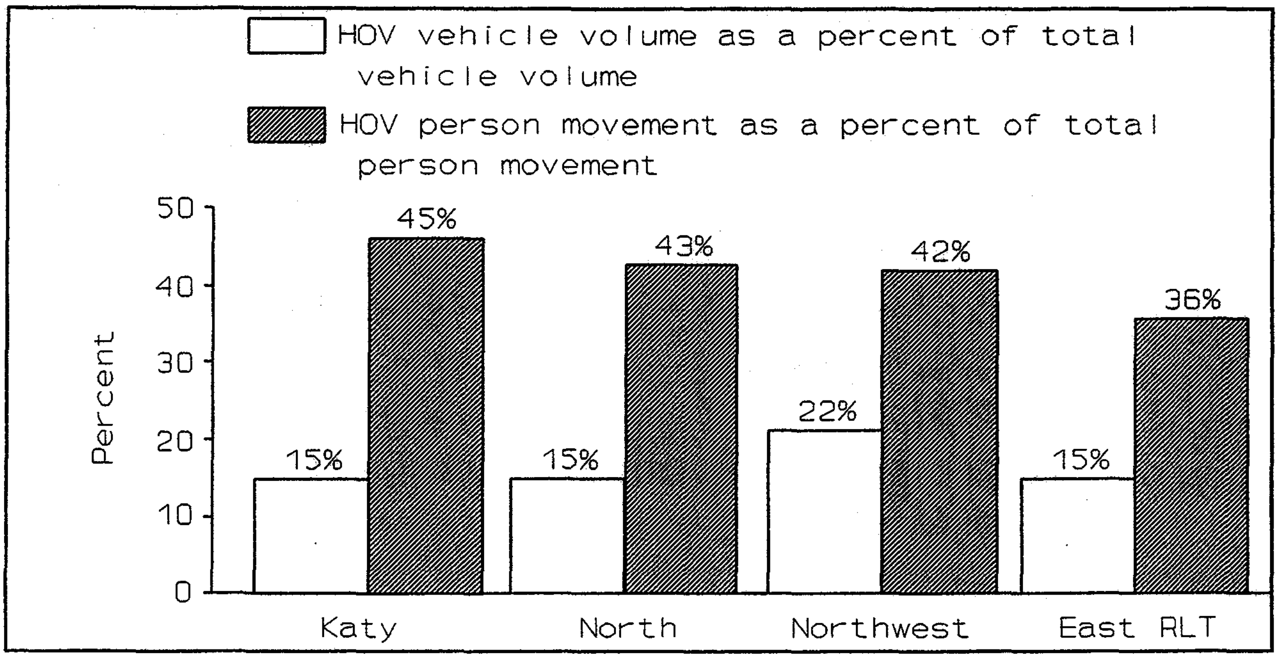
HIGH-OCCUPANCY VEHICLE LANE UTILIZATION AND TIME SAVINGS

HOV Lane Utilization

In December 1992, 69,956 daily person trips were counted on the Houston HOV lane system. This level of ridership represents a 16 percent increase in comparison to 1991; however, 1991 usage was about 11 percent lower than 1990 usage. Daily riders per mile of HOV lane in 1992 was 1,505. The comparable number in 1991 was 1,318.

The East RLT HOV lane in Dallas served 16,472 daily person trips in December 1992. By comparison, this facility served 15,200 daily person trips in December 1991. Daily riders per mile of HOV lane has grown from 2,764 in 1991 to 2,995 in 1992 (8 percent).

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.



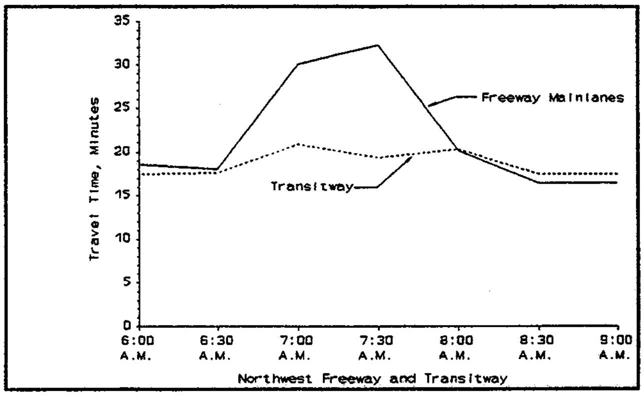
Source: See data in appendices.

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

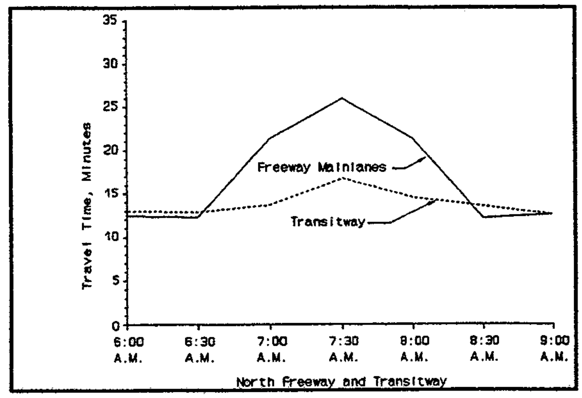
Travel Time Savings

A major purpose of the high-occupancy vehicle lanes is to offer HOV users a savings in travel time. 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 21.

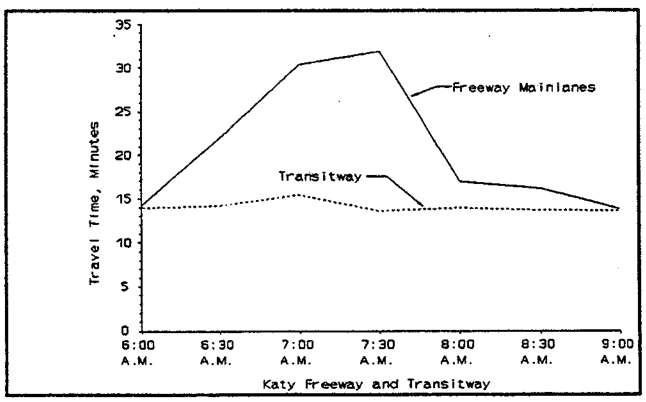
Table 14 presents selected usage and time savings data related to the Houston HOV facilities for 1991 and 1992. Statistics indicate an increase in usage of the HOV facilities during 1992. The increase in travel time savings at least partly explains the increase in usage of the HOV lanes.



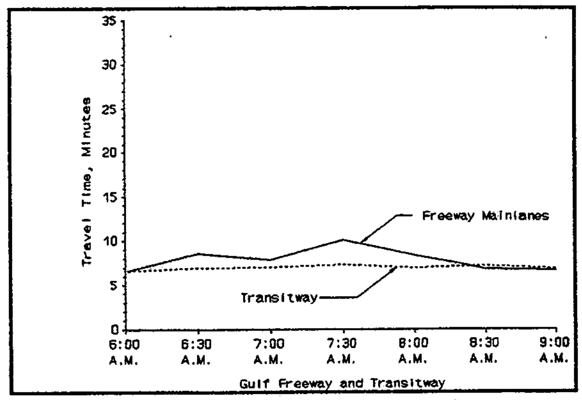
Note: Travel times are from Senate to the S.P. Railroad.



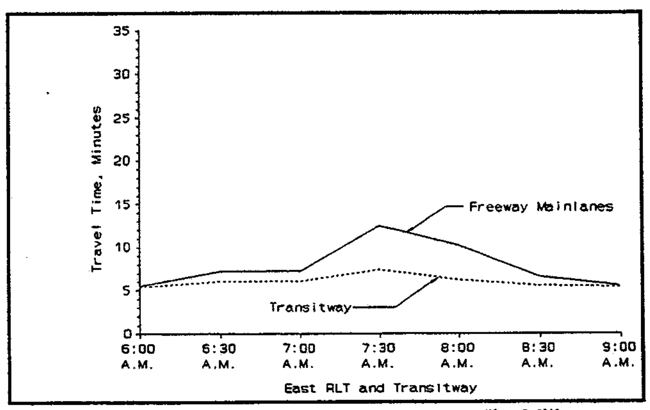
Note: Travel times are from Beltway 8 to Hogan.



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



Note: Travel times are from Park Place to Dowling.



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

Figure 21. 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 Transitways		
	12/91	12/92	% Change	12/91	12/92	% Change	12/91	12/92	% Change	12/91	12/92	% Change	12/91	12/92	% 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	22,284	23,434	+5.2	18,252	23,030	+26.2	11,041	13,296	+20.4	8,564	10,196	+19.1	60,141	69,956	+16.3
A.M. Peak Hour	3,966	4,524	+14.1	4,520	5,560	+23.0	3,055	3,969	+29.9	2,209	3,218	+45.7	13,750	17,271	+25.6
A.M. Peak Period	8,760	10,702	+22.2	8,501	10,994	+29.3	5,270	7,049	+33.8	4,224	5,165	+22.3	26,755	33,910	+26.7
P.M. Peak Hour	4,300	4,535	+5.5	4,632	5,403	+16.6	2,842	2,979	+4.8	2,364	2,627	+11.1	14,138	15,544	+9.9
P.M. Peak Period	10,472	9,950	-5.0	9,117	11,278	+23.7	5,485	5,785	+5.5	4,034	4,529	+12.3	29,108	31,542	+8.4
HOV Lane Vehicle Volume															
Daily	6,539	6,829	+4.4	3,929	4,892	+24.5	3,905	4,928	+26.2	2,475	3,018	+21.9	16,848	19,667	+16.7
A.M. Peak Hour	838	977	+16.6	1,081	1,256	+16.2	1,095	1,504	+37.4	613	1,013	+65.3	3,627	4,750	+31.0
A.M. Peak Period	2,349	2,755	+17.3	1,874	2,345	+25.1	1,857	2,685	+44.6	1,168	1,544	+32.2	7,248	9,329	+28.7
P.M. Peak Hour	788	1,072	+36.0	986	1,049	+6.4	1,015	1,058	+4.2	671	653	-2.7	3,460	3,832	+10.8
P.M. Peak Period	2,664	2,683	+0.7	1,738	2,168	+24.7	1,905	2,012	+5.6	1,154	1,223	+6.0	7,461	8,086	+8.4
Avg. HOV Lane Vehicle Occupancy, A.M. Peak Hour	4.73	4.63	-2.0	4.2	4.4	+4.8	2.79	2.64	-5.4	3.6	3.2	-11.1	3.57	3.56	-0.2
HOV Lane Travel Time Savings, Avg. Peak Hour (min)[1]	15.0	14.5	-3.3	5.0	5.9	+18.0	7.9	7.8	-1.3	4.4	5.4	+22.7	32.3	33.6	+4.0

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 3.5 hour time period. See Appendices A through D 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 or differences in the range of 2 minutes or less have little significance.

Source: Texas Transportation Institute.

Selected usage and time savings data for the East RLT HOV facility are also included in Table 15. These statistics indicate a moderate increase in usage of the facility and a decrease 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	12/91	12/92	% Change
Miles of HOV Lane			
Morning	5.2	5.2	0
Evening	3.3	3.3	0
HOV Lane Person Volume			
Daily	15,200	16,472	+8.4
A.M. Peak Hour	4,360	4,043	-7.3
A.M. Peak Period	7,960	8,932	+12.2
P.M. Peak Hour	3,880	4,140	+6.7
P.M. Peak Period	7,260	7,540	+3.9
HOV Lane Vehicle Volume			
Daily			
A.M. Peak Hour	1,274	1,222	-4.1
A.M. Peak Period	2,477	2,717	+9.7
P.M. Peak Hour	1,106	1,171	+5.9
P.M. Peak Period	2,248	2,326	+3.5
Avg. HOV Lane Vehicle Occupancy, A.M. Peak Hour	3.42	3.31	-3.2
HOV Lane Travel Time Savings, Avg. Peak Hour (min)[1]	3.3	2.5	-24.2

Notes: Peak hour is defined as the hour in which person movement is the highest. As a result, it is not always the same hour. The peak period is a 3.0 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 (1992) and Perceived Travel Time Savings[1] on the HOV Lanes

HOV Facility	Measured Peak-Hour Travel Time Savings (min)		Perceived HOV Travel Time Savings (min.)			
			Transit Riders		Carpoolers	
	AM	PM	AM	PM	AM	PM
Katy	18.6	10.4	17	19	19	19
North	9.0	2.7	15	19	15	19
Gulf[1]	2.8	8.0	10	15	12	15
Northwest	13.1	2.5	18	18	19	19

[1]Perceived travel time savings are 1990 data.

Source: Texas Transportation Institute surveys and data collection.

FACTORS INFLUENCING HIGH-OCCUPANCY VEHICLE LANE UTILIZATION

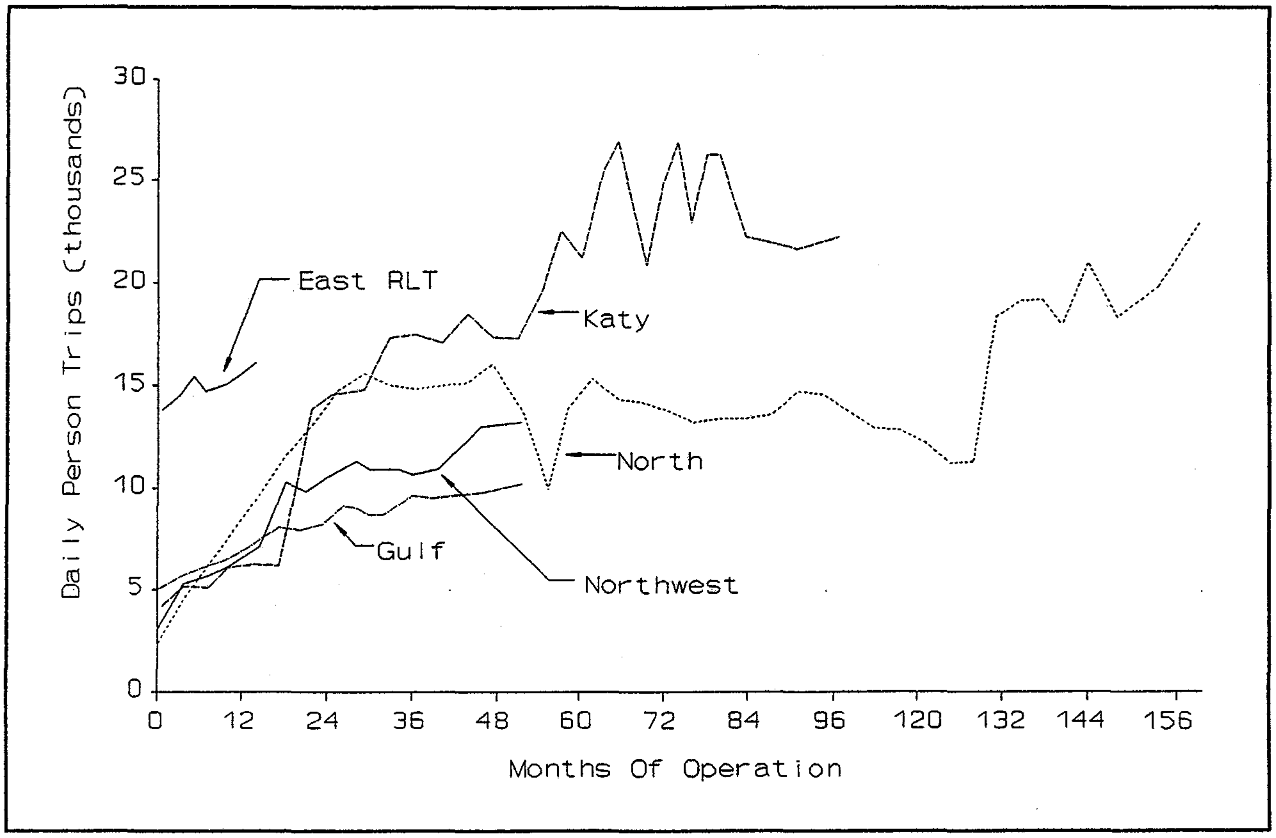
It is evident that a number of factors influence both bus ridership and carpooling on an HOV lane. Some of those factors, such as parking cost, are the ones used in traditional mode split models. A review of the Houston data suggests that at least three factors appear to be significant in helping to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

This occurrence of rapid growth in usage during the early years of operation has been observed on both the Houston and Dallas HOV facilities (Figure 22). 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 East RLT HOV lane has experienced significant growth since its opening in 1991, but has, by comparison, been open a relatively short period of time.

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



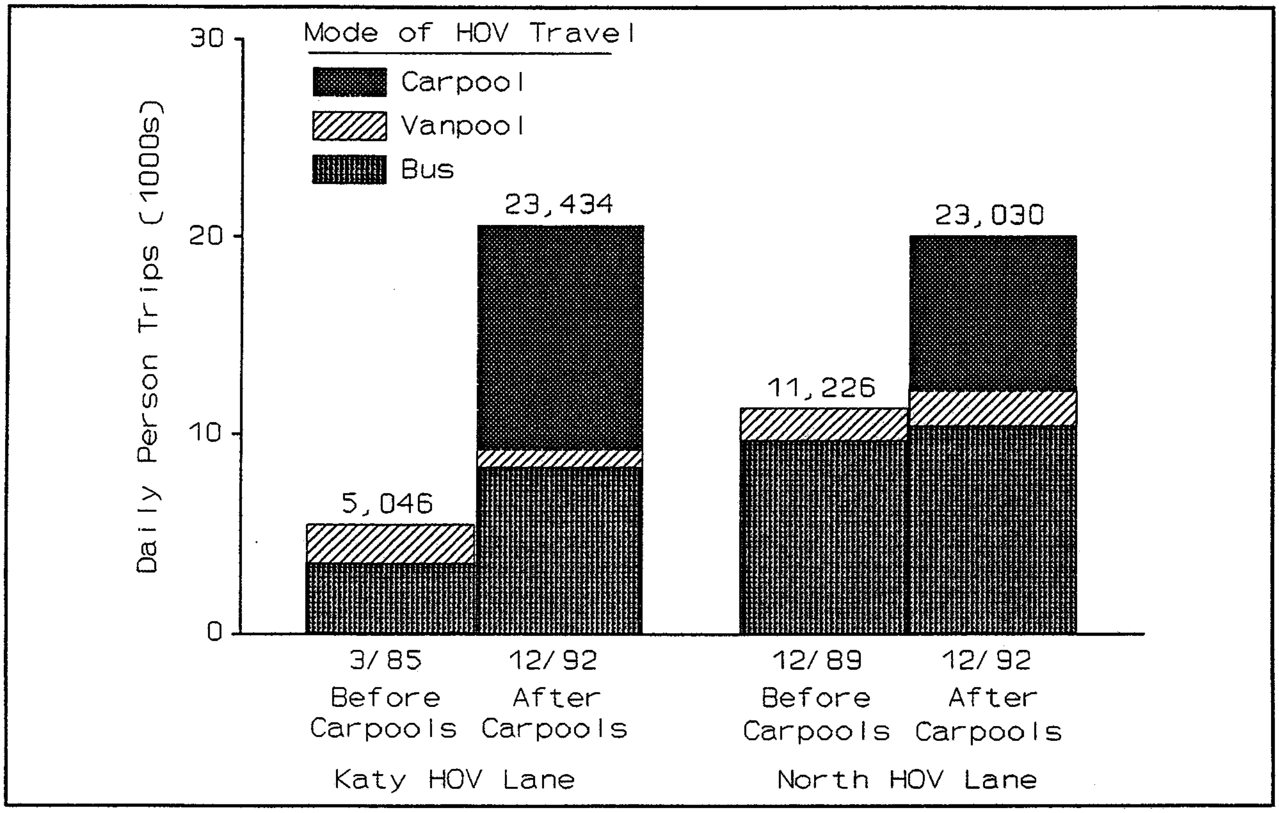
Source: See data in appendices.

Figure 22. Daily Ridership by Months of Operation, Houston and Dallas Transitways

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 60 percent of total HOV person trips on the Houston HOV lanes and 64 percent of HOV person trips on the East RLT HOV lane are in carpools or vanpools.

Figure 23 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 23. Impacts of Carpool Usage on Daily HOV Lane Person Trips, Katy and North HOV Facilities

Travel Time Savings 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 one minute of travel time savings per mile of lane to be successful.[9]

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

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

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.

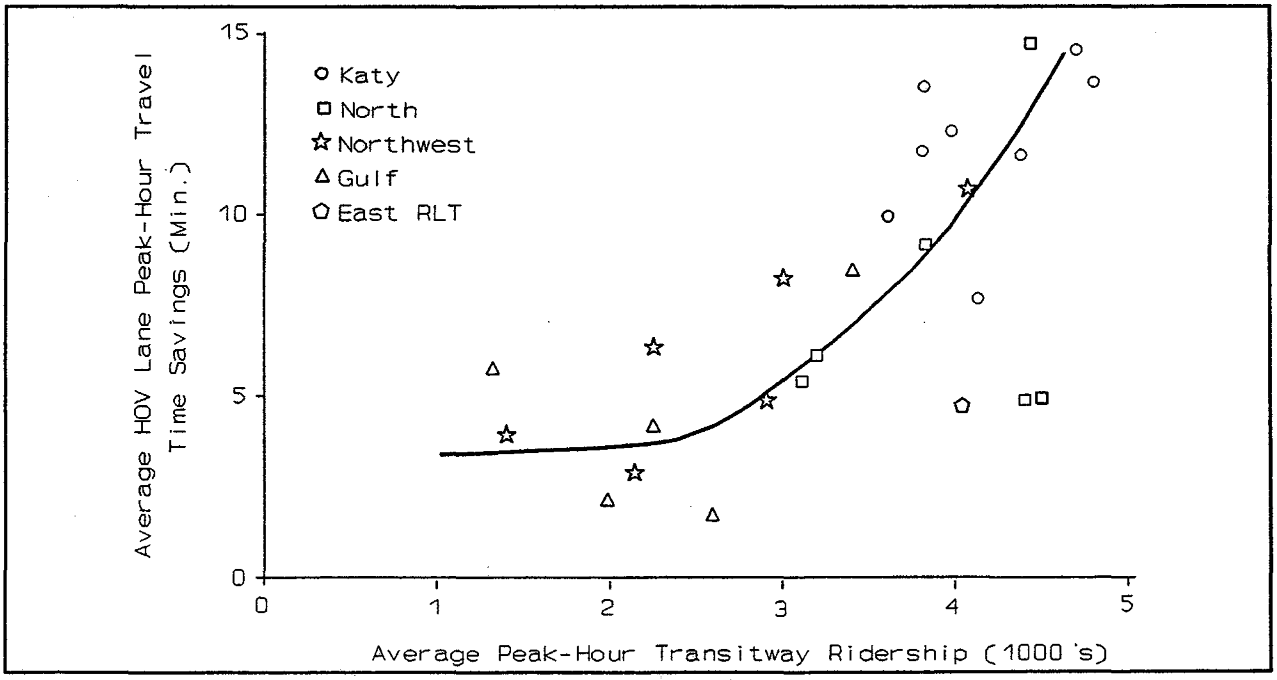
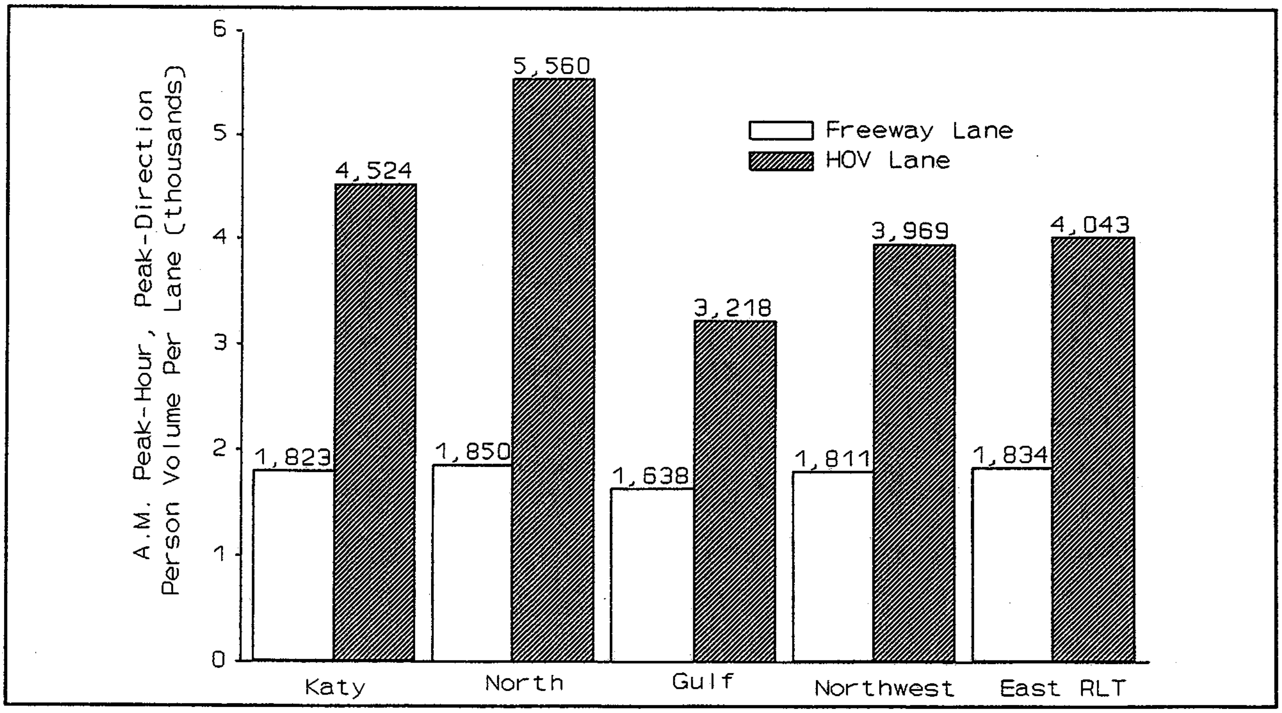


Figure 24. Relationship Between Peak-Hour HOV Lane Ridership and Peak-Hour HOV Lane Travel Time Savings

The relationship depicted 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.

CHANGES IN ROADWAY PERSON MOVEMENT

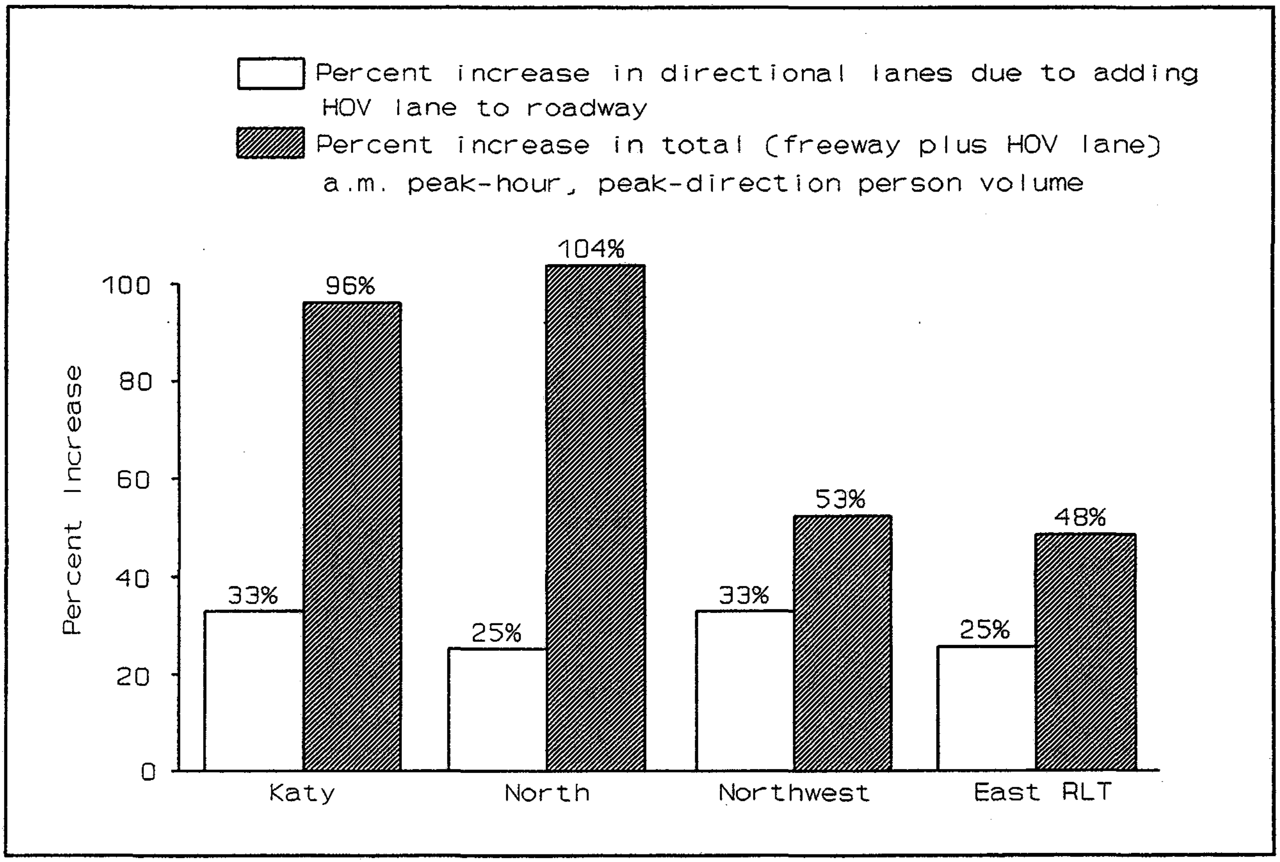
A major reason for implementing high-occupancy vehicle lanes is to increase the effective person-movement capacity of a roadway. There is at least an implicit recognition that emphasis needs to begin to be focused on moving people rather than vehicles. The HOV facilities are intended to be an incentive 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 25). During the peak hour, the HOV lanes are moving 96 percent to 200 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 25. 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 <u>at least</u> 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 might be called into question. The data show that the HOV lanes in Texas are helping to result in a substantial increase in person movement (Figure 26). In all instances where data are available, the increase in person movement exceeds the increase in lanes provided.



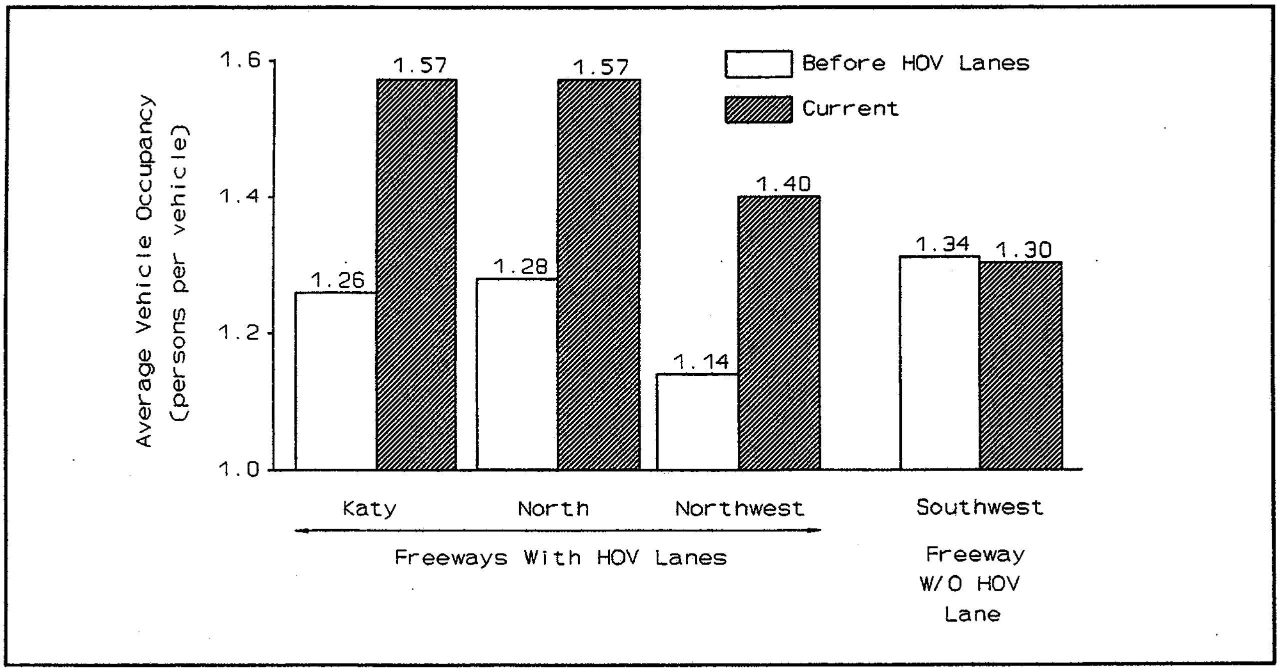
Source: See data in appendices.

Figure 26. 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 26, 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 more than 1.5 persons per vehicle (Figure 27). These occupancies are the combined average of all freeway mainlane plus all transitway traffic.

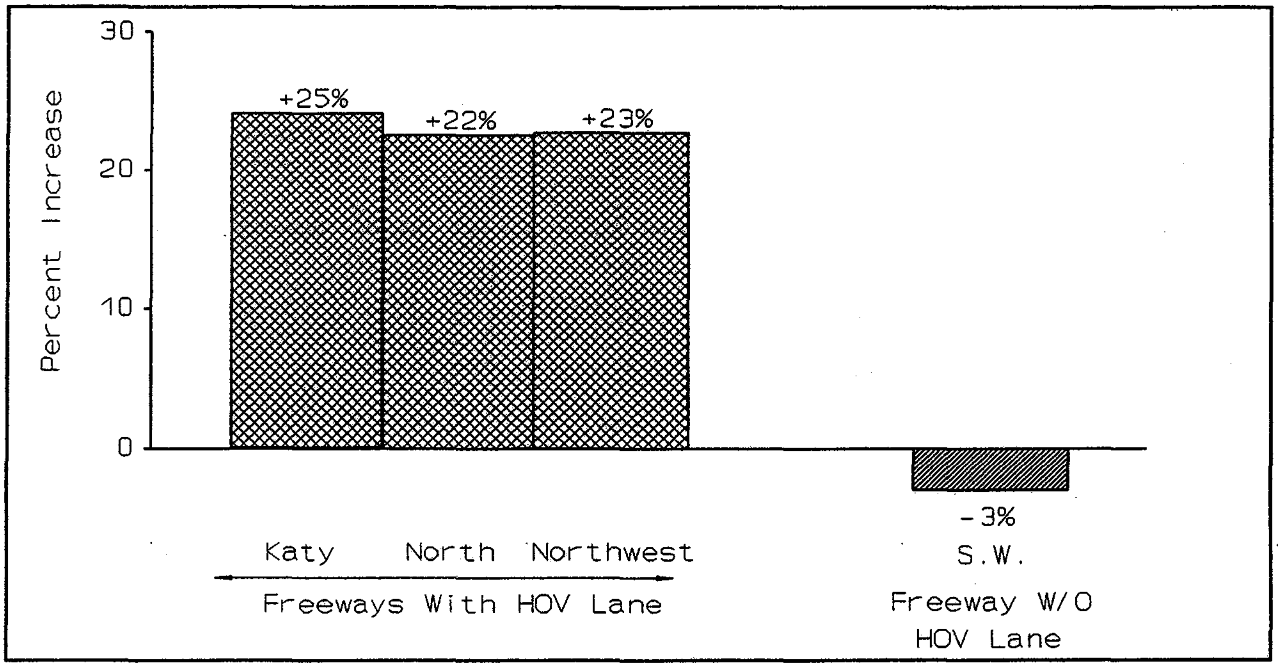


Source: See data in appendices.

Figure 27. 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 28).

The data clearly show that the presence of the HOV lane has resulted in a meaningful increase in average vehicle occupancy. On the freeways with HOV lanes, in comparison to pre-HOV lane conditions, the average peak-hour, peak-direction vehicle occupancy has increased by 22 to 25 percent. Over the same time period, occupancy on a freeway without an HOV lane has experienced a three percent decrease in average vehicle occupancy.



Source: See data in appendices.

Figure 28. 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 significantly 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 17). This indicates that the increases that occurred in average vehicle occupancy were primarily from factors other than this diversion.

Table 17. Carpools That Diverted to the HOV Facility From Parallel Routes

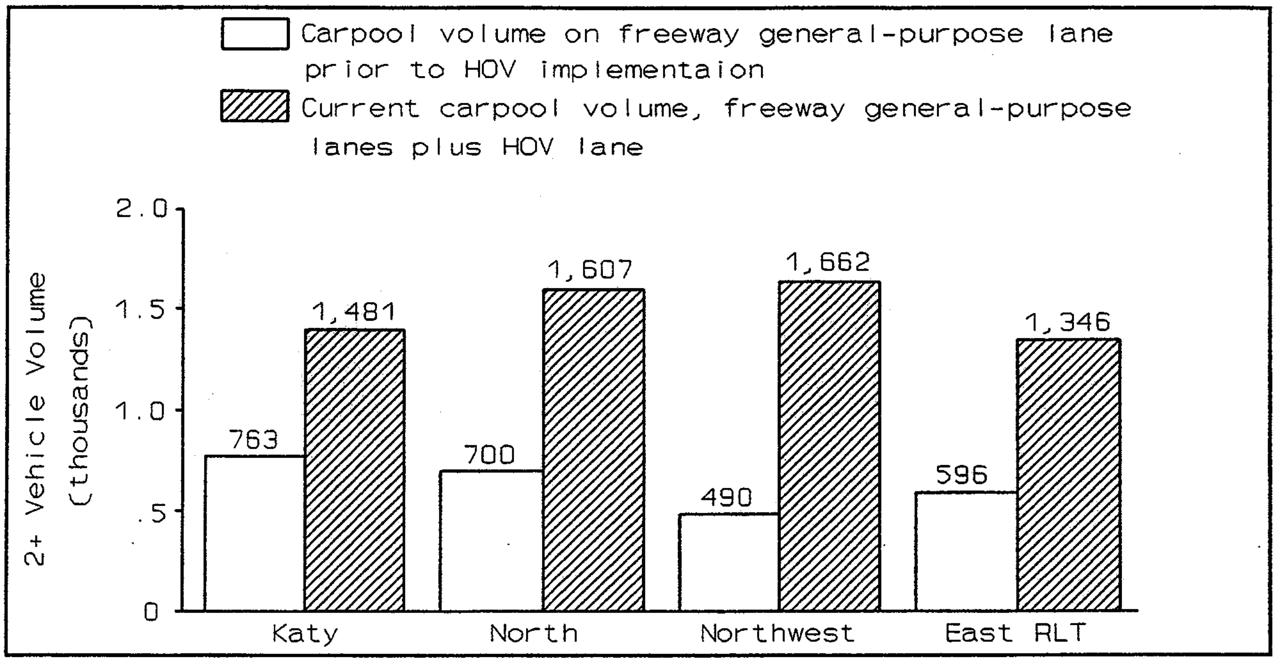
HOV Facility	Percent of HOV Carpoolers Whose Previous Mode Was Carpooling[1]		Percent of Those Carpoolers Who Previously Used a Parallel Route[2]	
	1989	1990	1989	1990
Katy	26%	29%	15%	13%
North	—	40%	—	19%
Gulf	44%	—	14%	—
Northwest	46%	33%	11%	15%
Unweighted Average	39%	34%	13%	16%

[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 29). 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.

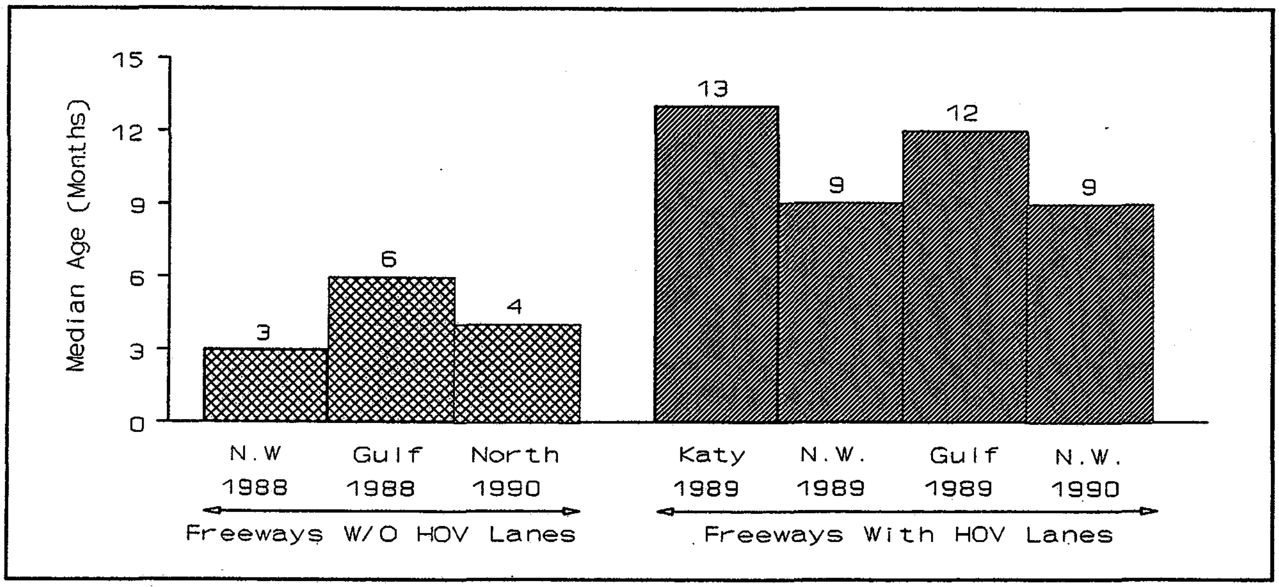


Note: Katy HOV data from p.m. peak hour (5-6 p.m.) during 1991 due to the 3+ occupancy requirement now in effect during the a.m. and p.m. peak hours on the Katy HOV lane.
Source: See data in appendices.

Figure 29. Volume of 2+ Carpools (Freeway Plus HOV Lane), A.M. Peak-Hour, Peak-Direction, Pre-HOV Lane and Current

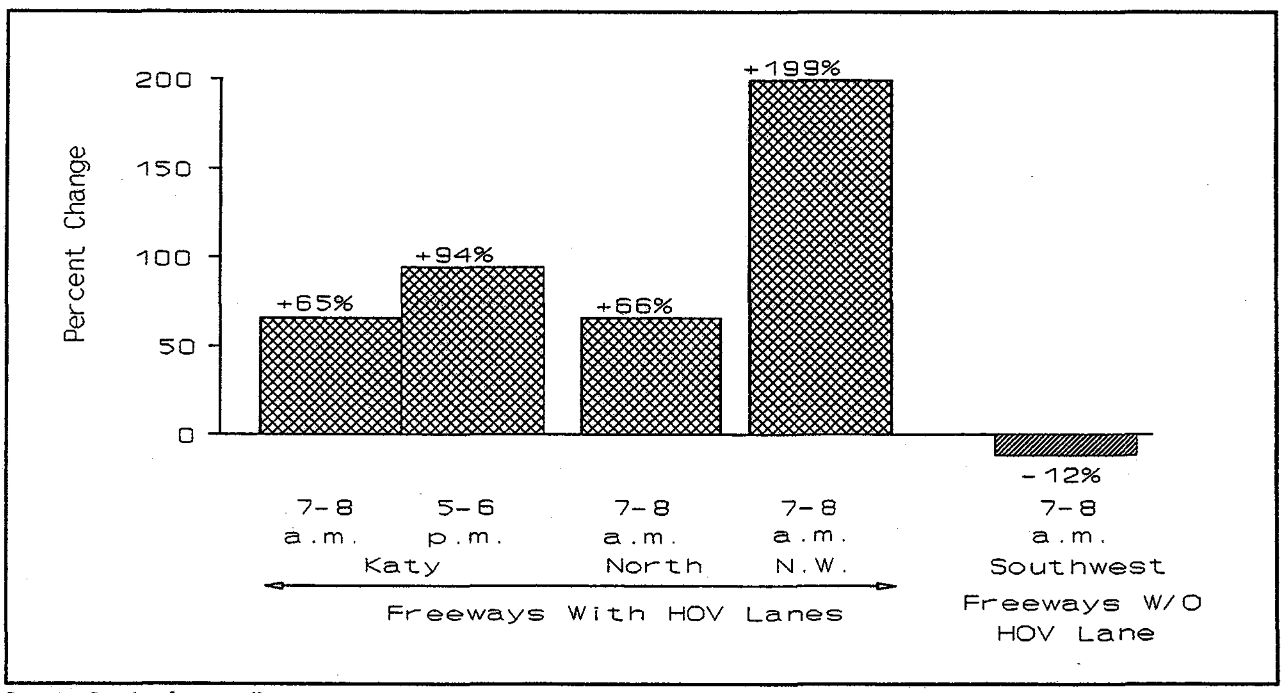
Available data suggest that carpools in corridors with HOV lanes do remain in existence longer than carpools in corridors without HOV lanes (Figure 30). The median age of a carpool on an HOV facility is over two times greater than the median carpool age on a non-HOV facility. It appears that the presence 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 31). The magnitude of increase that has occurred on the freeways with priority lanes simply has not taken place in the corridor without a transitway. The increase in carpools on the freeways with transitways 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.

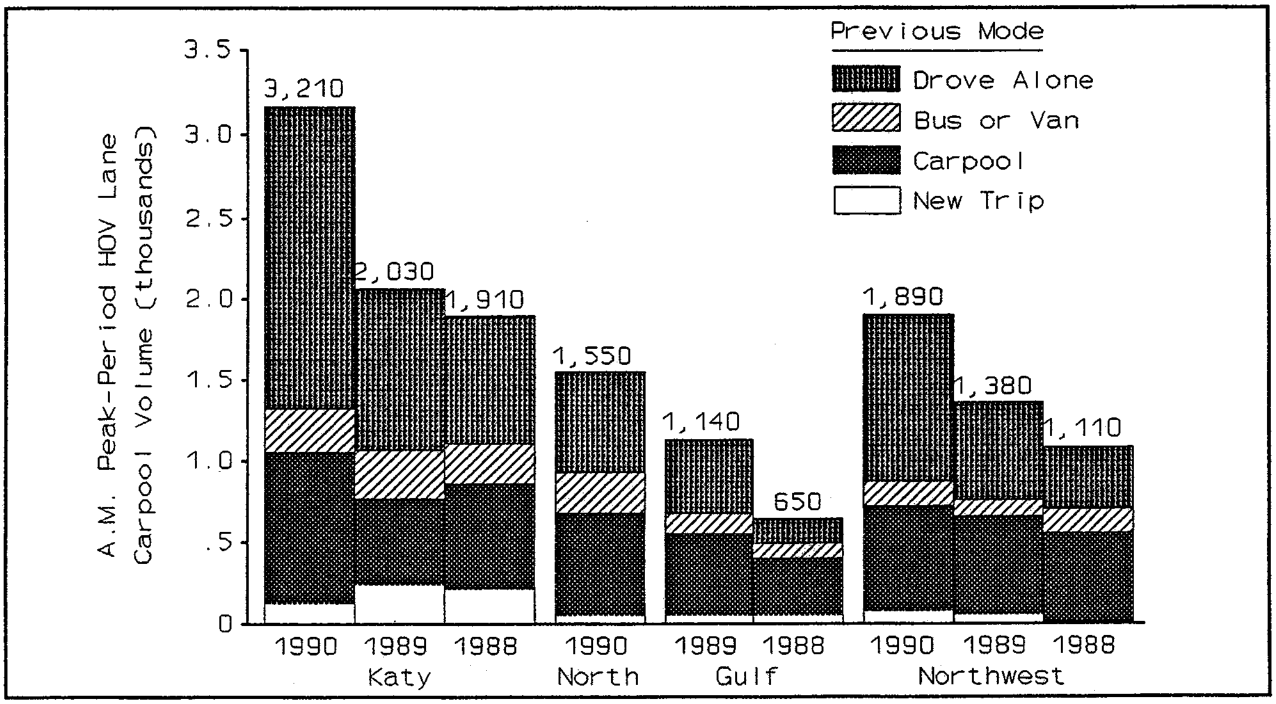
Figure 30. Median Age of a Carpool in Corridors With and Without High-Occupancy Vehicle Lanes



Source: See data in appendices.

Figure 31. 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 32). 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 32. 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 transitway in your decision to carpool?" The responses (Table 18) 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 18. Responses to Question "How Important Was the Transitway 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 transitway (Table 19). In the 1990 surveys, over half the respondents said "no" or "not sure."

Table 19. Response to Question "If the Transitway 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 20).

Table 20. Estimated Impact of HOV Lanes in Forming New Carpools

HOV Facility	Apparent % New Carpools Based on Previous Mode[1]		Would You Carpool if No Transitway[2]						Est. % of 1990 Transitway Carpools Formed Due to Transitway
			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 19.
[3]It is assumed that the sum of "no" responses plus one-half of the "not sure" responses equals the percentage of total transitway carpools that were formed due to implementing the transitway. 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 to be 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]

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 the 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 21). That volume has almost tripled (Figure 33). Being able to help serve these dispersed trips contributes to the effectiveness of the HOV lanes.

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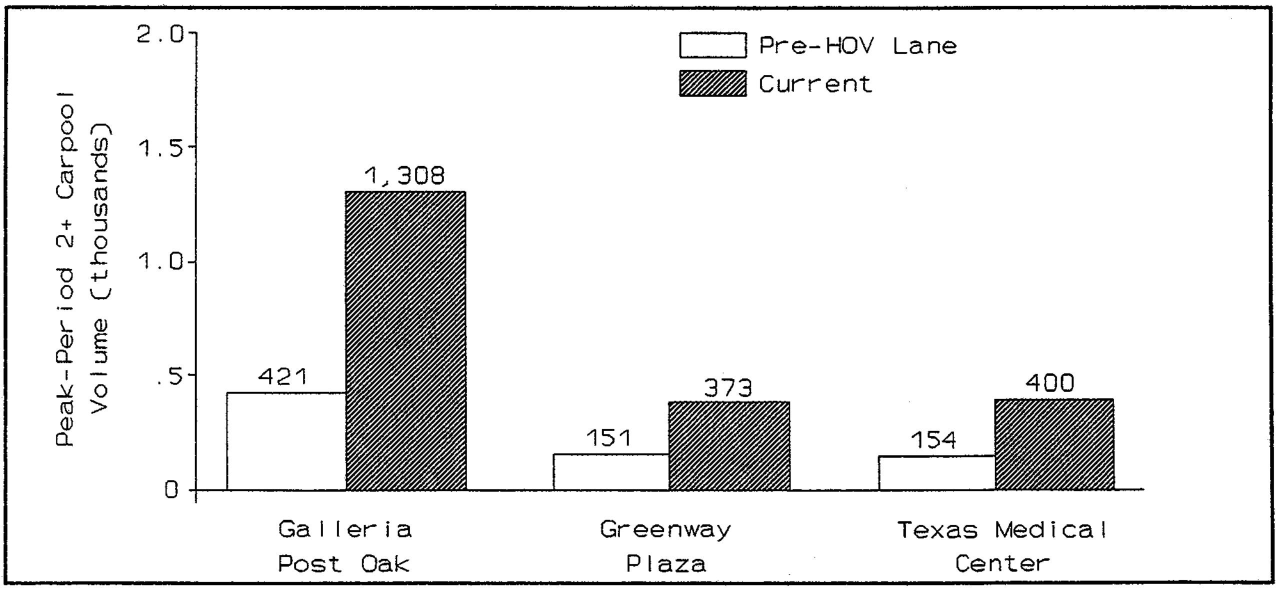
[11]Texas Transportation Institute Research Report 484-10.

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

Table 21. 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 33. 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 considerably less than one cent per passenger-mile (see Table 10), 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 9).

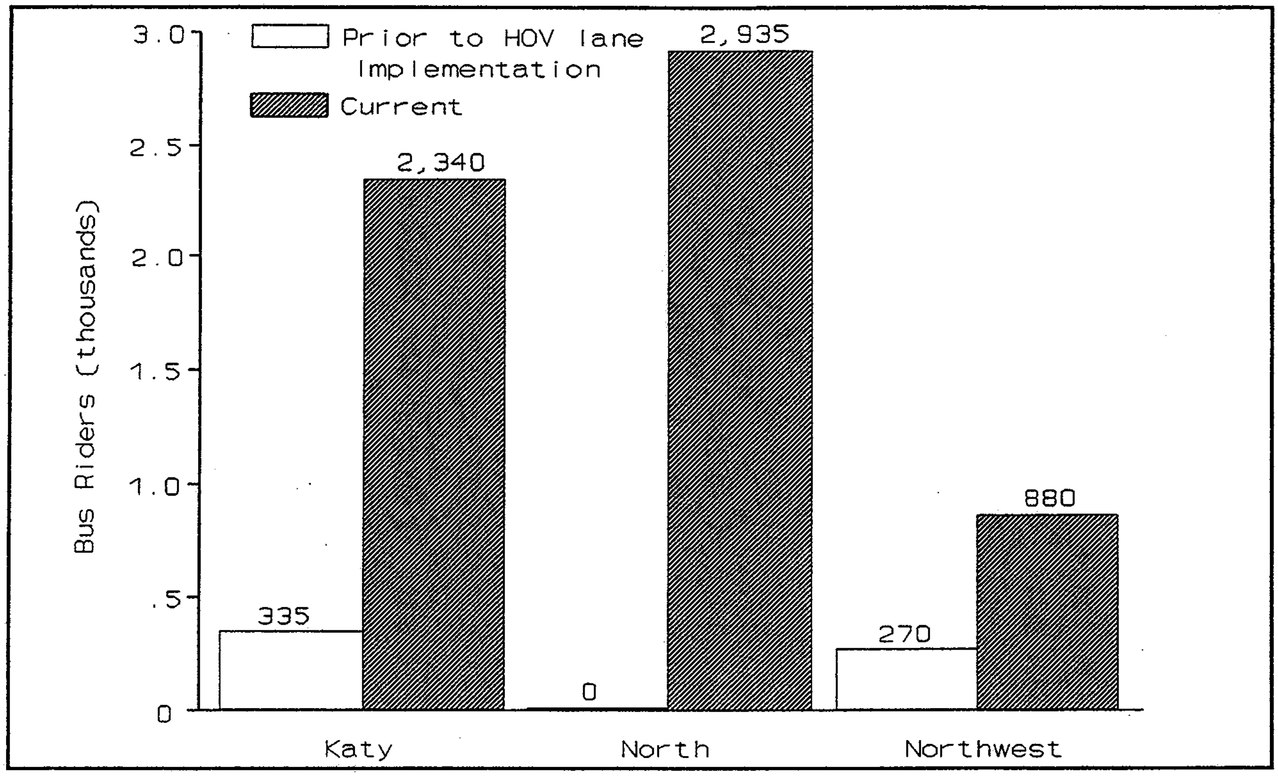
BUS TRANSIT OPERATIONS

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 significant increases in bus ridership.

With the opening of the HOV lanes, significant increases in bus ridership have been realized (Figure 34). 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.

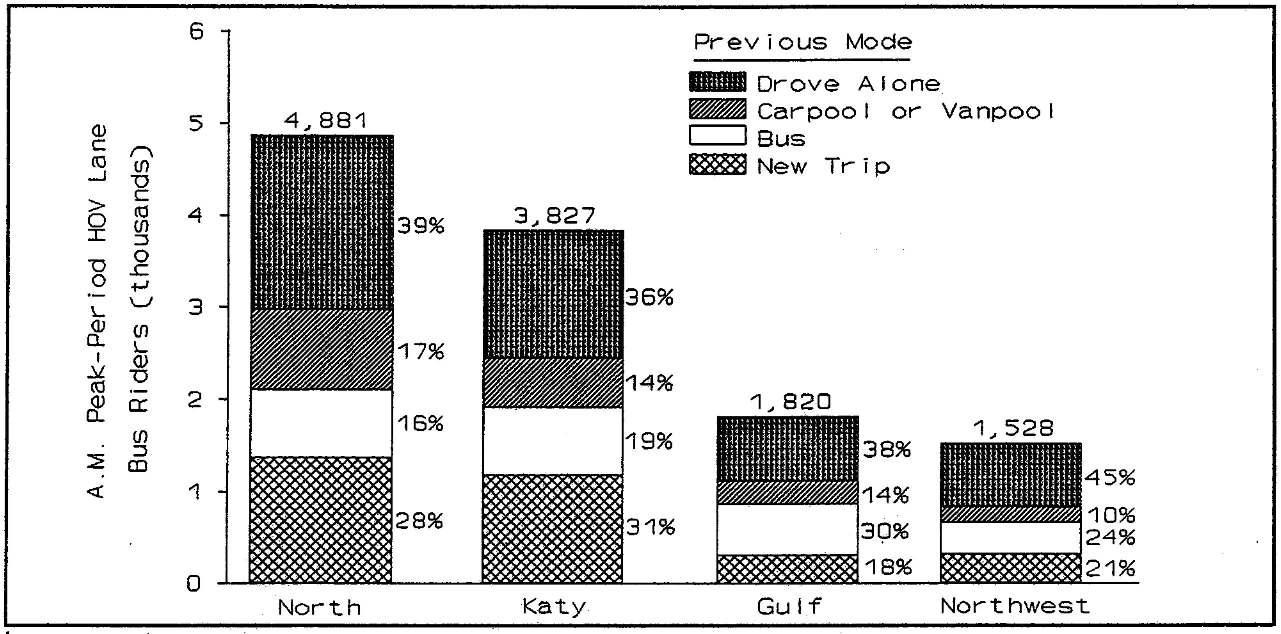


Source: See data in appendices.

Figure 34. 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 35). 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 22). 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 35. Previous Mode of Travel for HOV Lane Bus Riders, 1990

Table 22. Response to Question "How Important Was the Opening of the Transitway 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 23). 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 23. Response to Question "If the Transitway Had Not Opened, Would You be Riding a Bus Now?"

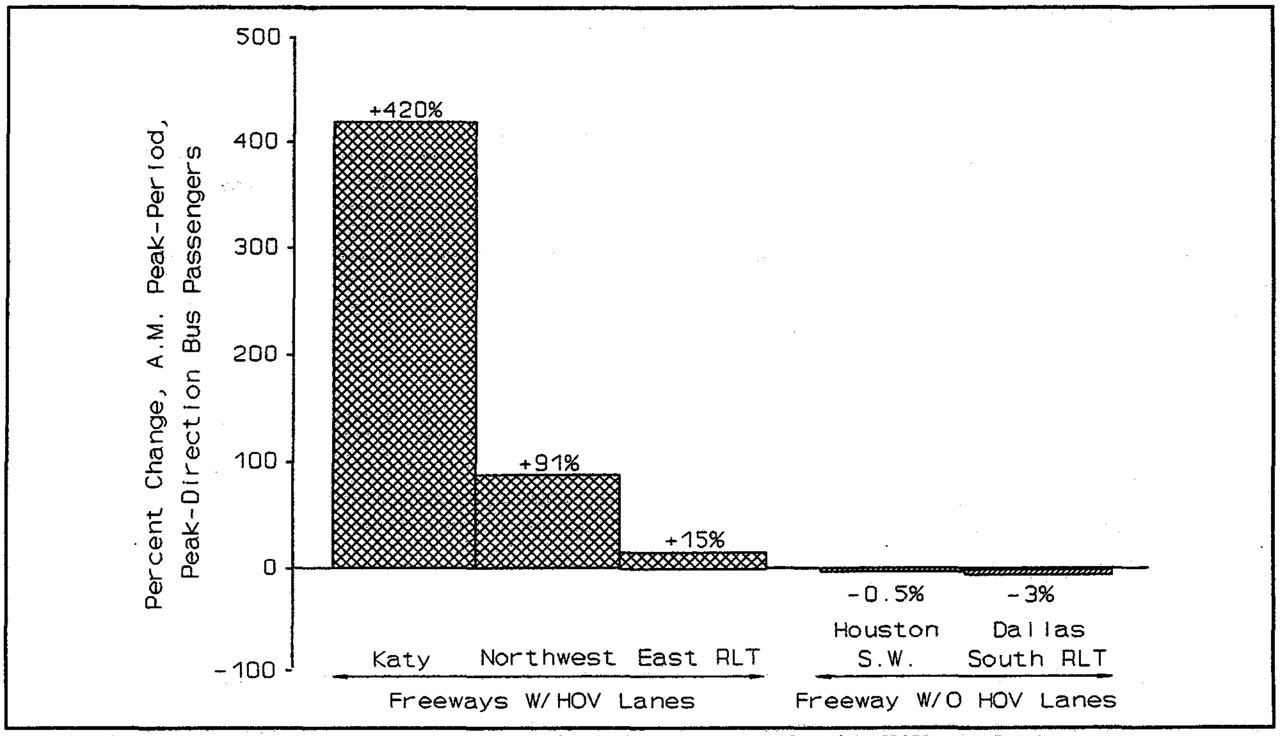
HOV Facility	Apparent % New 1990 Bus Riders Based on Previous Mode[1]	Response to Question (percent)						Est. % of 1990 Bus Ridership Formed Due to HOV Lane[2]
		Yes		No		Not Sure		
		1989	1990	1989	1990	1989	1990	
Katy	52	32	35	36	31	32	33	47%
North	52	—	33	—	37	—	30	52%
Gulf	47	56	—	22	—	22	—	33%[3]
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 36). 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 90 to 420 percent in the corridors with HOV lanes in Houston; the increases in peak-hour ridership have been even greater than the peak-period increases.

Bus ridership on the East RLT HOV lane in Dallas has not increased as significantly as has ridership on the Houston HOV lanes (Figure 36). Compared to the Houston freeway corridors in which HOV facilities have been implemented, however, the East RLT Freeway had a much higher base (pre-HOV) level of bus ridership. For instance, bus ridership on the Katy Freeway prior to HOV lane implementation was 900 persons, while pre-HOV bus ridership on the East RLT Freeway was 2,819 persons. In addition (as alluded to previously), the East RLT HOV lane is still relatively new and continues to experience growth in bus ridership. During this same time period, bus ridership has declined by 3 percent on the Dallas freeways without HOV facilities.

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 not shown since no bus service existed prior to implementation of the HOV contraflow lane.

[1]The Katy increase is overstated due to a diversion of Southwest Freeway buses to the Katy HOV lane. Without that diversion, the Katy increase would be 291%.

Source: See data in appendices.

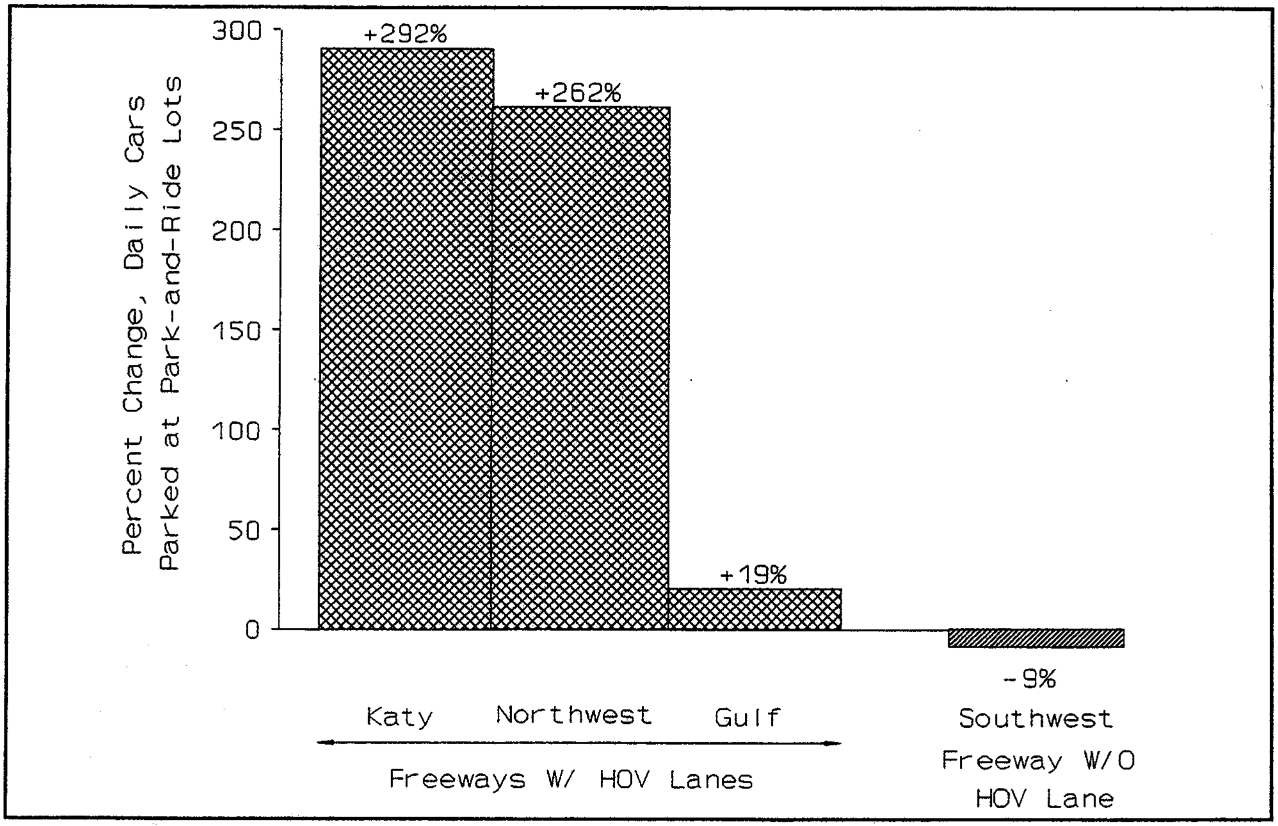
Figure 36. Change (Pre-HOV Lane to Present) in A.M. Peak-Period, Peak-Direction Bus Ridership, Freeways With and Without HOV Lanes

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 37). In both the Northwest and the Katy corridors, an increase of greater than 260 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.

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.



Source: See data in appendices.

Figure 37. Percent Change (Pre-HOV Lane to Present) in Daily Vehicles Parked in Corridor Park-and-Ride Lots

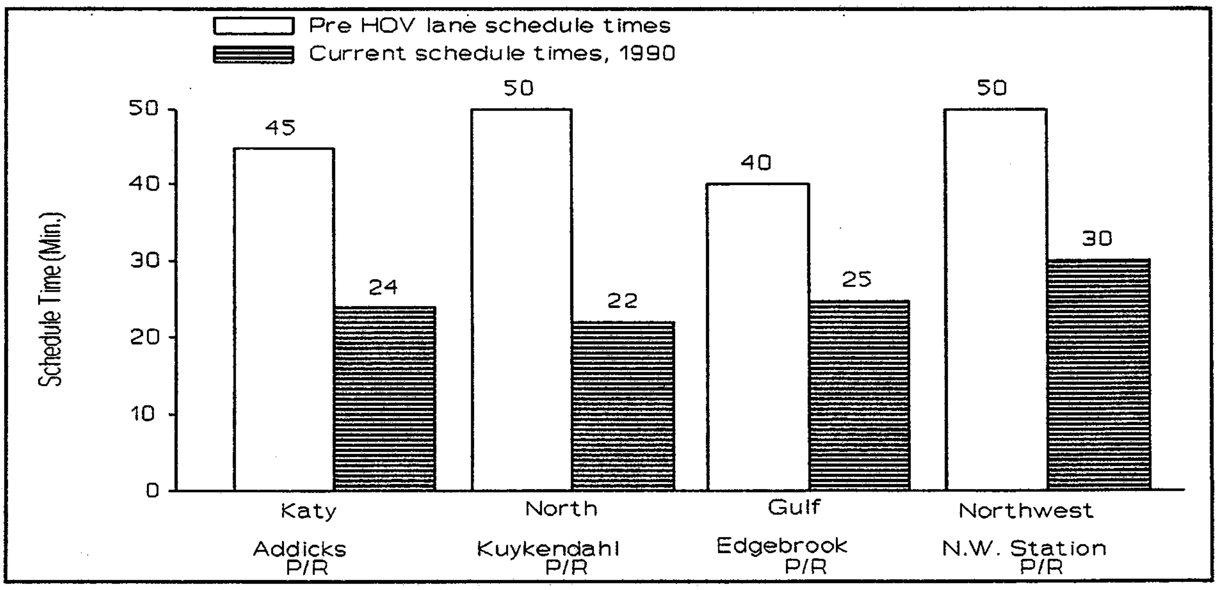
Compared to conditions that existed prior to HOV lane implementation, average bus operating speeds have increased dramatically (Table 24). On average, peak-hour bus operating speeds have doubled, increasing from 25 mph to 51 mph. Also, previous research[13] has illustrated that, based on a comparison of standard deviations, travel times in the HOV lanes are much more reliable and consistent than are travel times on the freeway mainlanes. Figure 38 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.

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

Table 24. Average A.M. Peak-Hour Bus Operating Speeds, Before HOV Implementation and Current

Freeway	Bus Operating Speed (mph)		
	Before HOV	Current	Percent Increase
Katy	23	52	126%
North	20	50	150%
Gulf	31	52	68%
Northwest	29	56	93%
East RLT	21	44	110%
Unweighted Average	25	51	104%

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 38. 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 recent enhancements to the HOV facility system.[14] Analyses were performed for improvements to the Northwest, Katy, and North HOV lanes. The following modest improvements were analyzed by Metro.

- Northwest HOV Lane. In April 1990, the direct ramp from the Northwest Station park-and-ride lot to the transitway was opened.
- North Freeway. For construction purposes, the 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 1.5-mile eastern extension of the 11.5-mile Katy HOV lane opened in January 1990.

A summary of the impacts of these improvements is presented in Table 25.

Table 25. 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 ramp from the park-and-ride lot to the HOV lane.
[2]The improvement is re-opening a 3.8-mile section of the HOV lane.
[3]The improvement is a 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 23 percent of operating costs from the fare box (Table 26). 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 26. Revenue-Cost Ratios and Subsidy Per Passenger, Metro Bus Service, Average Weekday, 1990

Type of Service	Passenger Boardings	Revenue/Cost	Subsidy Per Passenger
Local	263,680	19.6%	$1.52
Commuter[1]	24,206	34.6%	$3.29
System-wide	287,886	22.6%	$1.67

[1]Commuter service includes all park-and-ride service, not just the park-and-ride that uses HOV facilities. See Table 23.

Source: Metropolitan Transit Authority of Harris County.

Thus, providing the commuter bus service on the HOV lanes requires an operating subsidy. Table 27 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 39 percent of operating costs from fare box revenue.

[15]From "Quarterly Ridership and Route Performance Report, June 1990." Metropolitan Transit Authority.

In general, an operating subsidy of $3.00 is required for each passenger trip using the HOV lanes on a bus. Data suggest that, in 1990, approximately 5.85 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 $18 million in 1990.

Table 27. Selected Characteristics of Bus Service on the High-Occupancy Vehicle Lanes, 1990

HOV Lane and Bus Route[1]	Avg. Weekday Passenger-Trips	Subsidy Per Passenger Trip	Revenue/Cost	Estimated Annual Subsidy[2] (1000s)
Katy				
West Belt (210)	381	$4.22	25%	$ 402
Addicks (228)	2,378	$3.57	33%	$ 2,122
Kingsland (221)	797	$5.36	30%	$ 1,068
Sub-total	3,566	$4.03	31%	$ 3,592
North[3]				
N. Shepherd (201)	1,088	$3.32	27%	$ 903
Kuykendahl (202)	3,129	$2.90	38%	$ 2,268
Seton Lake (212)	1,664	$2.25	44%	$ 936
Spring (204)	1,716	$1.46	59%	$ 626
FM 1960 (207)	470	$3.83	35%	$ 450
Sub-Total	8,067	$2.57	42%	$ 5,183
Gulf				
Edgebrook (245)	1,237	$4.29	26%	$ 1,327
Bay Area (246)	1,605	$1.66	55%	$ 666
Sub-Total	2,842	$2.81	42%	$ 1,993
Northwest				
W. Little York (216)	290	$2.76	39%	$ 200
Pinemont (218)	338	$2.00	42%	$ 169
N.W. Station (214)	1,755	$3.39	34%	$ 1,487
Sub-Total	2,383	$3.12	36%	$ 1,856
Total HOV System	16,858	$3.00	39%	$12,624

[1]Only data for routes serving downtown are shown. This is virtually all of the service.
[2]Daily subsidy multiplied by 250.
[3]Data from Woodlands lot, which is not a Metro operated lot, are not shown.

Source: Metropolitan Transit Authority.

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 the transitways are moving several thousand persons in the peak hour (Table 28). Current per lane volumes on the North and Northwest freeways are within ten percent of what they were prior to HOV lane implementation, while volumes have increased significantly (25 to 36 percent) on the East RLT and Katy Freeways. 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 transitway implementation, this is largely attributable to factors other than the transitway implementation. Plots of freeway travel speeds, prior to HOV lane implementation and current, are shown in Figure 39.

Table 28. Freeway General-Purpose Lane Operation, Prior to HOV and Current

Freeway General-Purpose Lane Data	HOV Facility or Freeway									
	Katy		North		Northwest		Gulf		East RLT	
	Pre-HOV	Current	Pre-HOV	Current	Pre-HOV	Current	Pre-HOV	Current	Pre-HOV	Current
Vehicle Volume/Hour/Lane[1]										
A.M. Peak Hour	1,320	1,800	1,650	1,750	1,790	1,740	---	---	1,420	1,780
A.M. Peak Period	1,250	1,400	---	1,500	1,460	1,430	---	---	1,500	1,650
Freeway Peak-Hour Speed[2], mph	23	27	20	35	28	29	---	---	21	28
Injury Accidents per 100 MVM[3]	20.0	21.0	30.3	26.0	11.7	11.0	29.8	24.0	33.7	39.5

[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 miles. Accidents were evaluated for the following roadway sections: Katy, Gessner to Post Oak (4.7 mi.); North, N. Shepherd to Hogan (7.8 mi.); Northwest, Little York to I-610 (7.7 mi.); and Gulf, Broadway to Dowling (6.3 mi.); and East RLT, Central Expressway to Jim Miller (5.2 mil).

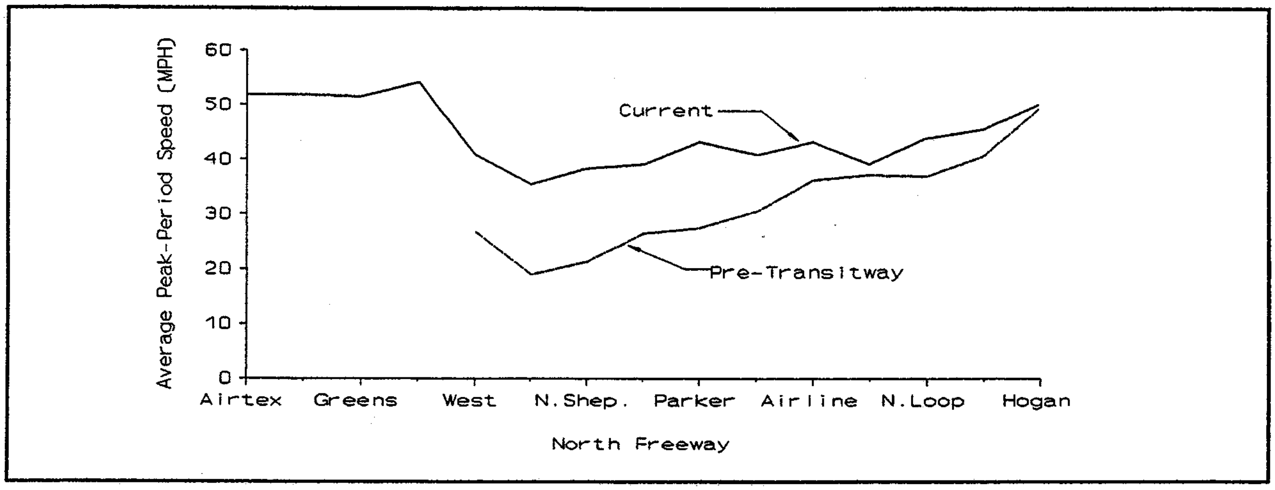
Source: See data in appendices.

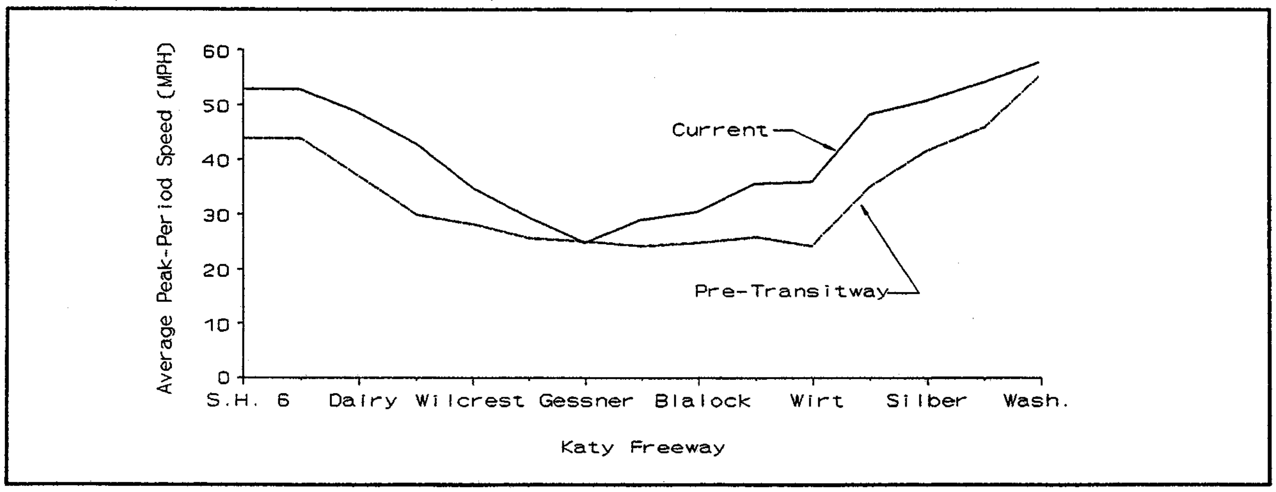
Implementation of some of the HOV lanes has involved narrowing traffic lanes and inside shoulders. As a result, potential accident impacts have been a concern. Relevant data are presented in Table 28. Accident rates are slightly higher on some roadways and slightly lower on others; the unweighted average accident rate has declined from 25 injury accidents per 100 MVM prior to the HOV lanes to 24 accidents per 100 MVM currently. It appears that HOV lane implementation has not significantly impacted freeway accident rates.

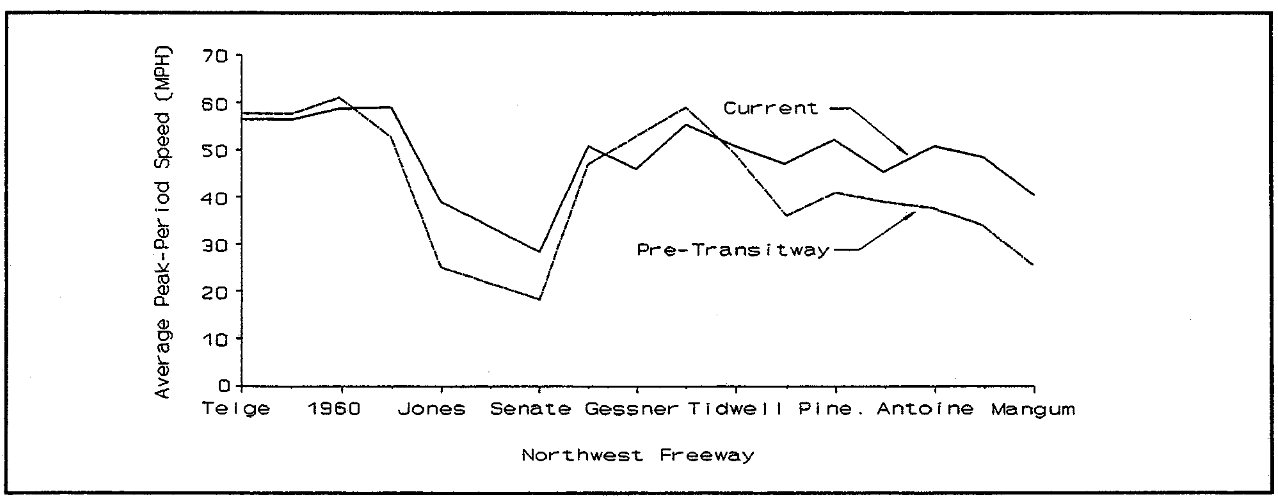
Parallel Route Volumes

It is commonly postulated that, as a result of implementing a transitway, significant rideshare volumes of travel divert to the HOV 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, transitway carpoolers have been asked which route they traveled prior to using the transitway. 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 39. Freeway Peak-Period Speeds on Mainlanes, Pre-Transitway and Current

The survey data from the HOV carpool surveys are summarized in Table 29. 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 29. HOV Lane Carpooler Responses to the Question "Prior to Carpooling on the Transitway, How Did you Normally Make the Trip?"

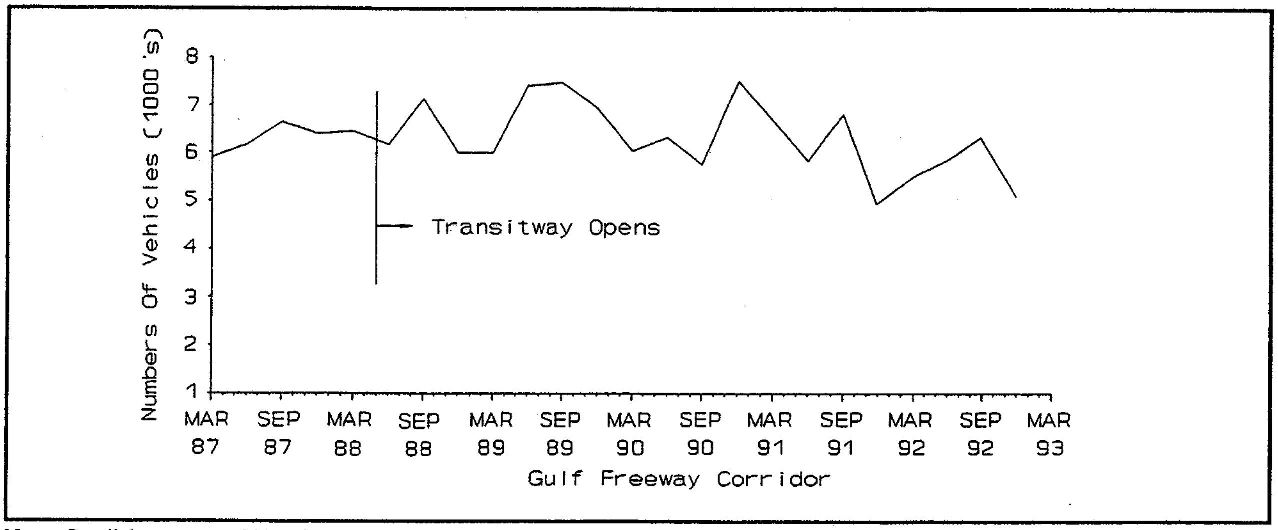
Response	HOV Lane							
	Katy		North		Gulf		Northwest	
	1989	1990	1989	1990	1989	1990	1989	1990
On the transitway (bus or van)	16%	15%	—	22%	17%	—	17%	14%
On the freeway general-purpose lanes	64%	68%	—	58%	68%	—	68%	67%
On a parallel street or highway	9%	13%	—	19%	10%	—	10%	15%
Did not make this trip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

Source: Texas Transportation Institute surveys.

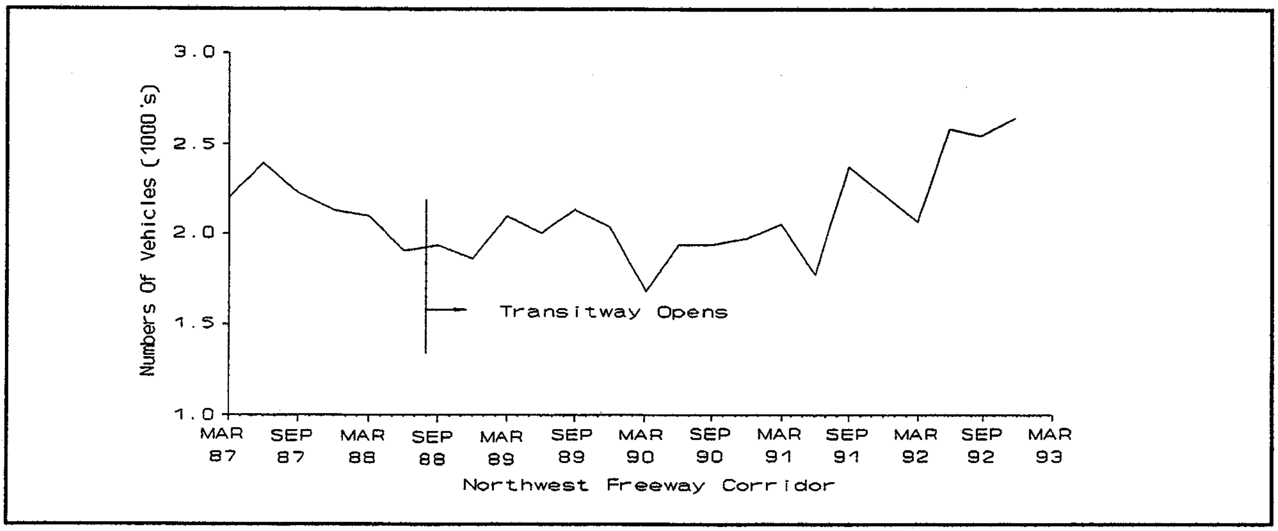
In two of the corridors, volume counts have been conducted on parallel routes. These data are depicted in Figure 40. There is no reason to conclude from these data that the opening of the transitways brought about a significant decrease in parallel route volumes, although a small decline may have occurred. Rather than reducing peak vehicle volumes, the transitways 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.

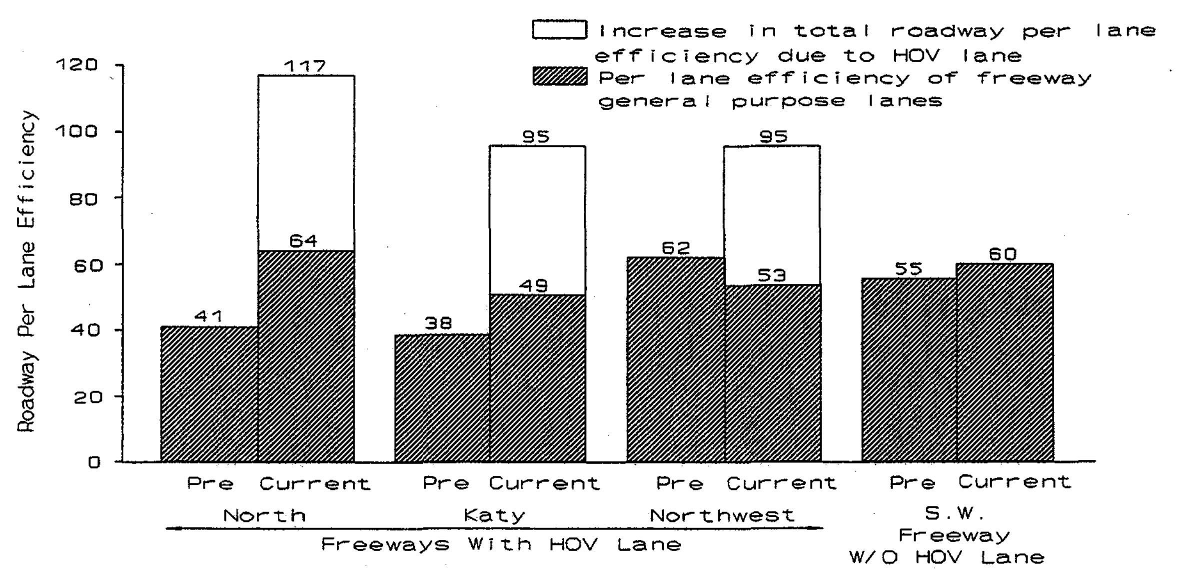
Figure 40. A.M. Peak-Period (6-9:30), Peak-Direction Vehicle Volumes on Parallel Routes in the Gulf and Northwest Freeway Corridors

In all cases for which data are available, the implementation of the HOV lane has increased the overall efficiency of the facility (Table 30). It appears that, on a facility with a mature HOV lane, the priority lane should increase the per lane efficiency, compared to pre-transitway conditions, by an absolute value of at least 20; this level of increase has been attained on the North, Katy, Northwest and East RLT Transitways. These increases in efficiency have been larger than those experienced on freeways that do not have an HOV lane (Figures 41 and 42).

Table 30. Estimated Change in A.M. Peak-Hour, Peak-Direction Per Lane Efficiency[1], "Before" and "After" HOV Lane Implementation

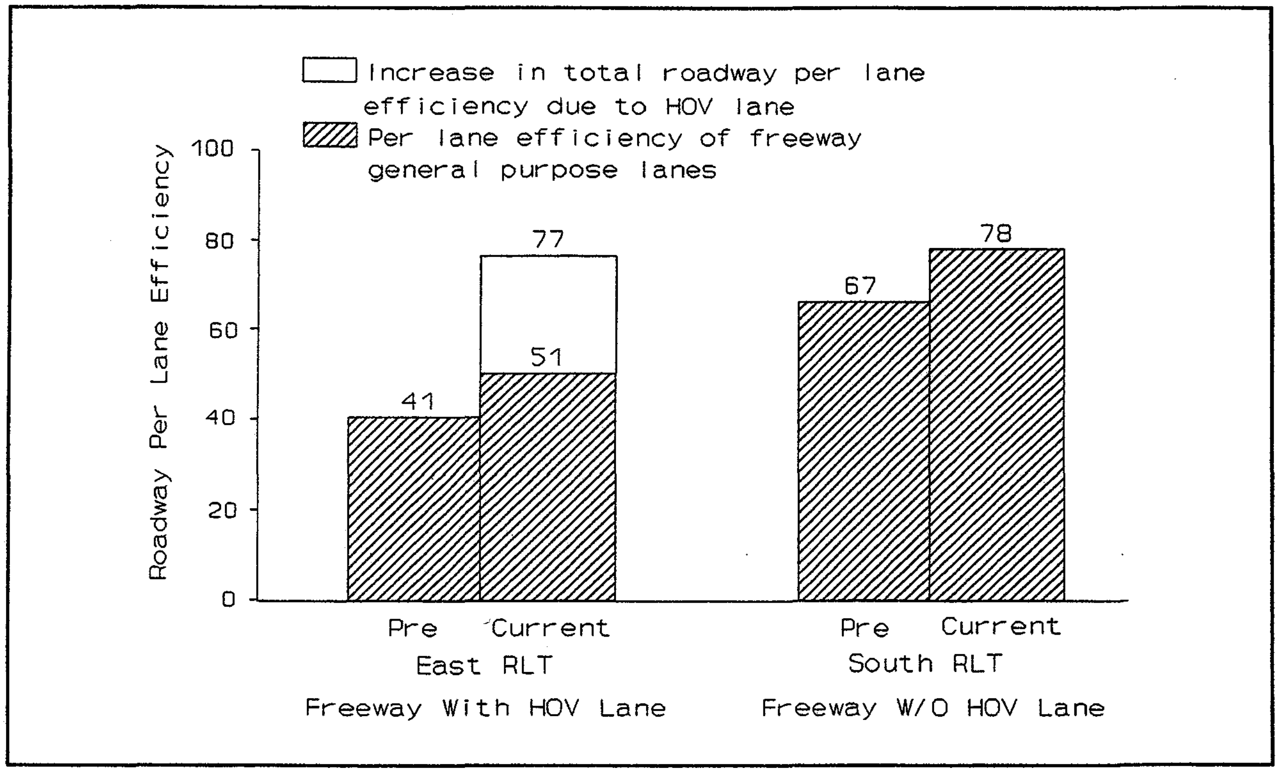
Freeway	Pre-HOV Lane Per Lane Freeway Efficiency (1)	Current Per Lane Efficiency			Absolute Increase in Per Lane Efficiency Due to HOV Lane[2] (5)
		Freeway (2)	HOV Lane (3)	Combined Freeway & HOV Lane (4)	
North	41	64	276	117	76
Katy	38	49	233	95	57
Northwest	62	53	221	95	33
East RLT	41	51	178	77	36
Southwest[3] (w/o transitway, Houston)	55	60	NA	60	5
South RLT[4] (w/o transitway, Dallas)	67	78	NA	78	11

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 a transitway. The pre-transitway value is the average of conditions on the Southwest Freeway prior to implementation of the Katy, the Northwest, and the Gulf Transitways.
[4]For comparison to East RLT, this is a freeway without a transitway 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 41. 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 42. 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 a transitway. 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-miles of travel compared to what existed prior to constructing the priority lane. Consequently, in comparison to pre-transitway conditions, implementing an HOV lane may well increase the total vehicle-miles 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.

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

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

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 Transitway. Operation on both the freeway mainlanes and the transitway, based on 1992 travel volumes, were simulated. The demand, expressed as passenger-miles, that existed in 1992 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 3 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.

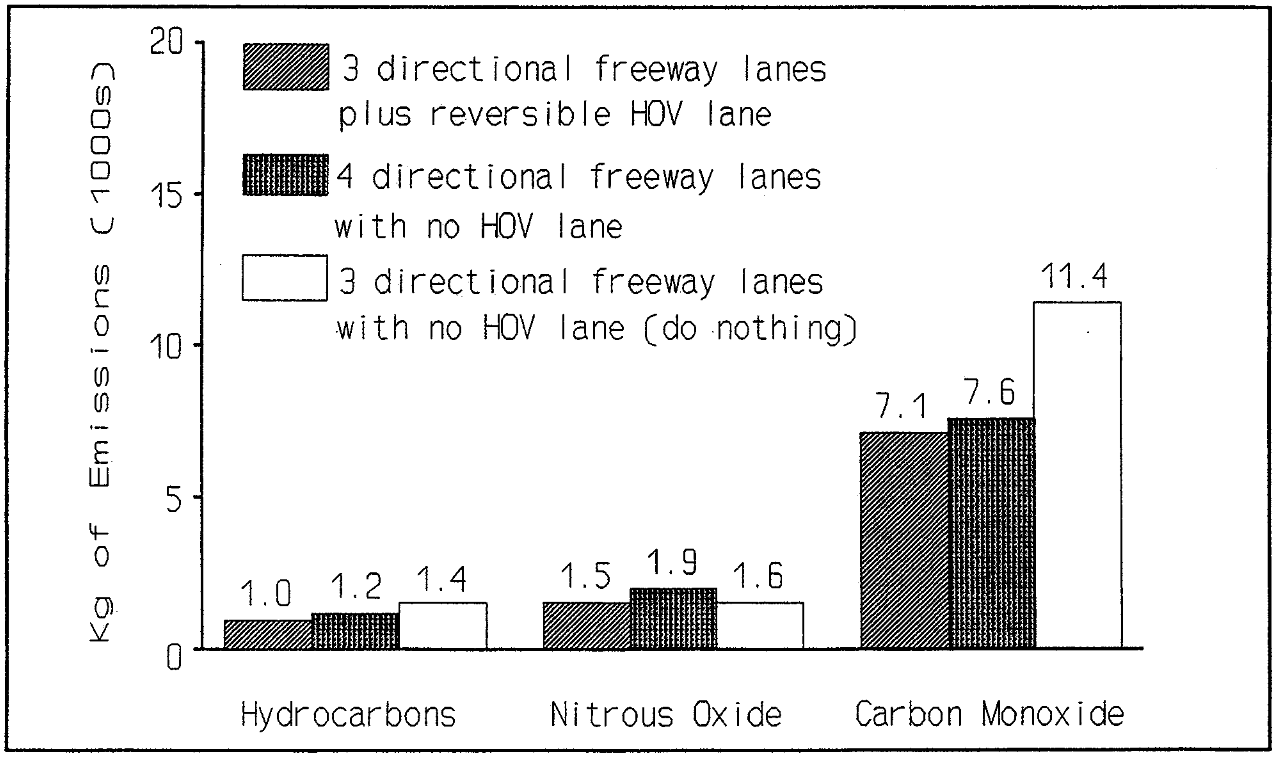
2. **Add a general-purpose freeway lane.** This would result in four general-purpose freeway lanes in each direction with no HOV facility. It is the condition that would have resulted had an additional freeway general-purpose lane been added to the freeway instead of an HOV lane.

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.

The results of this analysis are shown in Figures 43 and 44. 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 1992 and are unable to 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

[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.

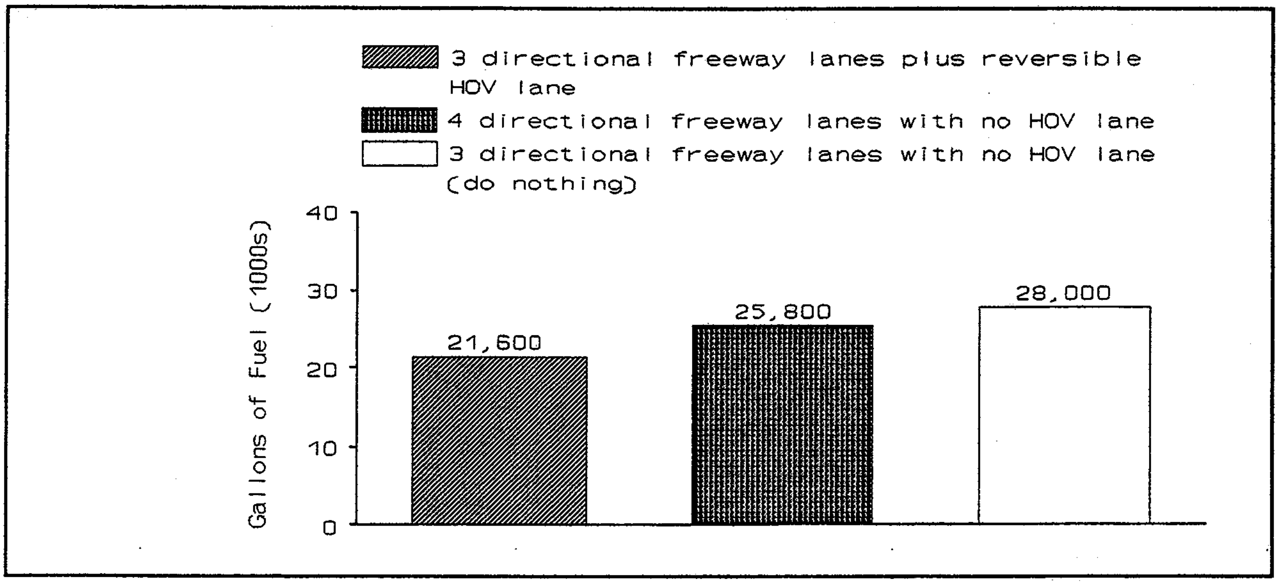
issues). However, it is clear that, to serve the passenger-mile demand in the peak direction that is occurring today on this particular facility, the HOV lane alternative is superior in terms of air quality and energy conservation benefits.



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

Figure 43. 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, 1991 demand levels.

Figure 44. 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 43 and 44) 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 four to five 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 transitway project will be cost effective.[19]

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

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[18]An argument that has some merit and has not yet been fully resolved is what would happen to overall travel time if the new lane added was a mixed-flow lane and not an HOV lane. Experience would suggest that expansion of freeway capacity will not, other than possibly in the very short term, significantly improve freeway operating speeds during peak periods. This does not mean that freeway projects aren't necessary and cost effective, it simply suggests they will not eliminate peak-period congestion. Also, as shown previously, moving several thousand persons per hour on the Houston transitways 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 $10.47/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.

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 transitway use increases. Table 31 summarizes this analysis.

Table 31. 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, 1990 dollars)		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	$ 8.3	$25.1	$54.4	33.1%	15.3%
North	$ 4.9	$54.8	$73.3	8.9%	6.7%
Gulf	$ 2.7	$29.9	$42.3	9.0%	6.4%
Northwest	$ 4.2	$62.0	$94.0	6.8%	4.5%
East RLT	$ 2.8	$12.7	$12.7	13.1%[3]	13.1%[3]
Total	$22.9	$184.5	$276.7	11.8%[3]	7.9%[3]

[1]Based on 1992 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 1992 operating conditions, the Katy and East RLT HOV facilities are clearly effective, and the other HOV lanes are marginally effective. When all five operating HOV lanes are combined, under 1992 conditions, the HOV lanes in Texas are cost effective (based on the cost to construct the HOV lane and ramps) based on this single benefit. Again, this simple benefit is not representative of total benefits.

However, the analysis shown in Table 31 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 32 was prepared. Based on the costs and benefits listed in that table, and based on usage levels in 1992, the Katy HOV facility had a benefit-cost ratio of 3.9. 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 31).

Table 32. Estimated Costs and Benefits of the Katy HOV Lane, 1992

Cost or Benefit Category	Dollars (millions)	
Cost		
Capital Cost[1]	$5.5	
Operating Cost		
Enforcement and Operations[2]	0.3	
Bus Subsidy[3]	7.2	
TOTAL COST		$13.0
Benefits		
HOV User Travel Time Savings[4]	$8.3	
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]	4.3	
TOTAL Benefits		$50.2
Benefit/Cost Ratio		3.9

[1]10 percent of HOV capital cost, assumed to be the annualized cost.
[2]Based on $250,000 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 27).
[4]The value of the time saved by users of the HOV facility (see Table 31).
[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-mile assumed to be $4 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.

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 $140 million in Houston.

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 $700 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. It is envisioned that similar surveys will be conducted in both Houston and Dallas during the 1994 calendar year.

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 33), over 70 percent of the motorists in the freeway mainlanes (<u>not</u> HOV lane users) viewed these projects favorably. Of those motorists surveyed, fewer than 15 percent felt the transitways were not good transportation improvements; this is similar to what was found in a 1988 survey on a freeway (Eastex) that does not have a transitway. The trend of increasing acceptance of the HOV lanes over time is reflected in Figure 45.

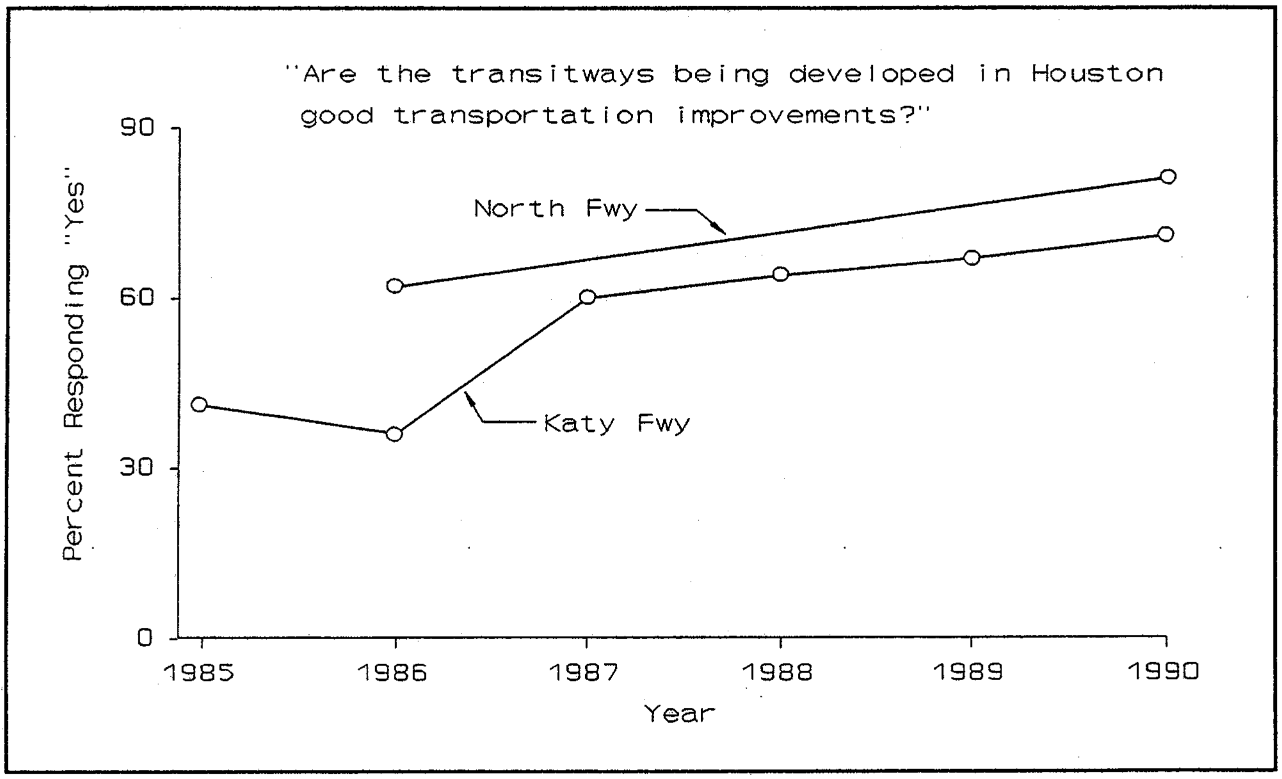


Figure 45. Trends in Public Attitudes Concerning HOV Lane Development

The responses shown in Table 33 and Figure 45 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 LANES SUFFICIENTLY UTILIZED?

While the responses in Table 33 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 34 and 35). 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 33. Responses to the Question "Do You Feel the Transitways 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 Transitways						
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 Transitway						
Eastex Freeway						
Yes	—	—	—	58%	—	—
No	—	—	—	15%	—	—
Not Sure	—	—	—	27%	—	—

[1]The original North Freeway contraflow lane opened in 1979; the North Transitway opened in 1984.
[2]The Katy Transitway opened in October 1984.
[3]The Northwest Transitway opened in August 1988.
[4]The Gulf Transitway 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 34). This percentage has generally been increasing over time.

Table 34. Responses from Users of the Transitway to the Question "Is the Transitway Sufficiently Utilized?"[1]

Survey Location and Group Responses to Question	Year of Survey					
	1985	1986	1987	1988	1989	1990
Katy Transitway 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 Transitway 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 Transitway 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 Transitway 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 transitway 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 35). The plurality of responses in the three corridors in which surveys were conducted in 1990 was that the transitways 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 35. Response from Non-Users of the Transitway to the Question "Is the Transitway 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 transitway was changed from 2+ to 3+ between 6:45 and 8:15 a.m.

Source: Texas Transportation Institute surveys.

IX. CONCLUSIONS

A 95.5-mile system of freeway HOV lanes is being developed in Houston. As of the end of 1992, 46.5 miles of that barrier-separated system were operational, with priority facilities operating in four different freeway corridors. The Dallas HOV lane system is currently planned to consist of approximately 37 miles of HOV facilities. As of December 1992, a 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 1992 to assess the extent to which these objectives are being attained (Tables 36 and 37). 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 20 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 20.

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 38). 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, and Gulf HOV lanes are considered to be marginally effective at this time. The Northwest HOV lane was completed in final form in 1990. 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 not be extended for at least another year.

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

Table 36. 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[3] w/o HOV Lane
Daily HOV Lane Person Trips (12/92)	23,434	23,030	10,196	13,296	NA
Percent Change over 12/91	+5%	+26%	+19%	+20%	NA
% Change in Number of Lanes[4]	+33%	+25%	NA	33%	NA
% Change in Person Volume[5]	+96%	+105%	NA	+53%	-21 %
% Change in Average Vehicle Occupancy[5] (persons/vehicle)	+25%	+22%	NA	+23%	-3%
% Change in 2+ Carpool Volumes[5]	+94%[11]	+66%	NA	+199%	-12%
% New Carpools Due to HOV Lane[6] (1990)	53%	46%	26%	47%	NA
% Change in Peak-Period Bus Riders	+420%	NA	NA	+176%	-1%
% New Bus Riders Due to HOV Lane[7]	47%	52%	33%	47%	NA
% Change in Peak-Hour Bus Speeds	+128%	NA	+70%	+91%	-11%
Annual Savings in Bus Operating Costs Due to HOV Lane (millions) (1990)	$4.8	—	—	—	—
% Change in Vehicles at Park-and-Ride Lots	+269%	NA	+18%	+262%	-10%
% Change, Freeway Vehicle Volumes Per Lane[8]	+34%	+6%	NA	-3%	- 7%
% Change, Roadway Efficiency[9]	+150%	+185%	NA	+53%	-21%
HOV Travel Time Savings as a % of Construction Cost[10]	33%	9%	9%	7%	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 12/92.
[3]This freeway does not have an HOV lane and represents a basis of comparison to the freeways with HOV lanes. Adjustments have been made to some of the data to account for the diversion of bus service from Southwest Freeway to the Katy HOV lane.
[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 transitway that are new carpools created as a result of the transitway.
[7]This is an estimate of the percent of total bus riders using the transitway that are new bus riders created as a result of the transitway.
[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 1992 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 1992.
[11]P.M. peak-hour volume from 1991 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 37. 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 (12/92)	16,472	NA
Percent Change over 12/91	+8%	NA
% Change in Number of Lanes[4]	+25%	NA
% Change in Person Volume[5]	+48%	-1%
% Change in Average Vehicle Occupancy[5] (persons/vehicle)	+4%	+2%
% Change in 2+ Carpool Volumes	+126%	+1%
% Change in Peak-Period Bus Riders	+15%	-3%
% Change in Peak-Hour Bus Speeds	+107%	-19%
% Change in Vehicles at Park-and-Ride Lots	+2%	+11%
% Change, Freeway Vehicle Volumes Per Lane[6]	+25%	-6%
% Change, Roadway Efficiency[7]	+88%	+16%
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]These freeways have operating HOV lanes as of 12/92.
[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 1992 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 1992.

Table 38. Comparison of HOV Lane Objectives and HOV Lane Performance, 1992

Objective, Measure of Effectiveness	HOV Facility				
	Katy	North	Gulf	Northwest	East RLT
Increase Person Movement					
• Is daily ridership greater than 10,000	Yes	Yes	Yes	Yes	Yes
• Is daily ridership greater than 15,000	Yes	Yes	No	No	Yes
• Has the increase in a.m. peak-hour person volume exceeded the increase in lanes due to the transitway	Yes	Yes	NA	Yes	Yes
• Has a.m. peak-hour occupancy increased by more than 15%	Yes	Yes	NA	No	No
• Are more than 25% of the transitway carpools new due to the transitway	Yes	Yes	Yes	Yes	NA
• Are more than 25% of the transitway bus riders new due to the transitway	Yes	Yes	Yes	Yes	NA
Don't Unduly Impact Freeway General-Purpose Lane Operations					
• Has mainlane congestion increased due to the transitway	No	No	No	No	No
• Has the mainlane accident rate increased significantly due to the transitway	No	No	No	No	No
Increase the Overall Efficiency of the Roadway					
• Has the roadway per lane efficiency increased by more than 20 due to the HOV lane	Yes	Yes	NA	Yes	Yes
HOV Lane Should Have Favorable Air Quality & Energy Impacts					
• Has adding a transitway lane been more effective than adding a general purpose freeway lane would have been	Yes	NA	NA	NA	NA
Enhance Bus Operations					
• Peak-hour bus speeds increase by at least 50%	Yes	NA	Yes	Yes	Yes
• HOV lane accident rate less than general-purpose lanes	No	No	Yes	No	Yes
The HOV Lane Should be Cost Effective					
• Is the annual value of time saved by transitway users greater than 10% of the transitway capital cost	Yes	No	No	No	Yes
HOV Lanes Should Have Public Support					
• Do most of the persons responding to surveys indicate support for transitway development	Yes	Yes	Yes	Yes	NA
Overall Assessment, Is HOV Facility Effective?	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-Period, Peak-Direction Katy Freeway and HOV Lane Data, December 1992

Type of Data Phase 1 of HOV Lane Became Operational 10/29/84	"Representative" Pre-HOV Lane	"Representative" Current Value	% Change
HOV Lane Data			
HOV Lane Length (miles)		13.0	
HOV Lane Cost (millions of 1990 dollars)		$59.1	
Person-Movement			
Peak Hour (7-8 a.m.)		4,524	—
Peak Period (6-9:30 a.m.)		10,702	—
Total Daily		23,434	—
Vehicle Volumes			
Peak Hour	—	977	—
Peak Period	—	2,755	—
Vehicle Occupancy, Peak Hour (persons/veh)	—	4.63	—
Accident Rate (i.e. Injury accidents/100 MVM), 11/84-12/92[1]	—	20.3	—
Vehicle Breakdowns (VMT/Breakdown), 11/84-12/92	—	40,500	—
Violation Rate (6-9:30 a.m.)	—	16%	
Peak Hour Lane Efficiency (1000's)[2]	—	233	—
Annual Value of User Time Saved (millions)[3]	—	$4.2 to $8.3	—
Freeway Mainlane Data (see note)			
Person Movement			
Peak Hour	5,100	5,467	+7.2%
Peak Period (6-9:30 a.m.)	15,655	15,579	-0.5%
Vehicle Volume			
Peak Hour	4,045	5,407	+33.7%
Peak Period	12,750	14,672	+15.1%
Vehicle Occupancy, Peak Hour (persons/veh)	1.26	1.01	-19.8%
Accident Rate (i.e. Injury accidents/100 MVM)[1]	20.0	21.0	+5.0%
Avg. Operating Speed[4]			
Peak Hour	23.0	27.0	+17.4%
Peak Period	33.0	36.4	+10.3%
Peak Hour lane Efficiency (1000's)[2]	38.0	49	+28.9%

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 Gessner and Post Oak, a distance of approximately 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 8/92. Only officer-reported accidents are included in current files. 1992 freeway volumes estimated by TTI.

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

[3]Based on time savings for HOV lane users in 1992 and HOV lane volumes in 1992, an annual estimate of travel time savings to HOV lane users is developed. A value of time of $10.47/hour is used based on the value applied in the Highway Economic Evaluation Model.

[4]From SH 6 to Washington, a distance of 12.2 miles. The HOV lane is in place over this section.

KATY FREEWAY (IH 10) AND HOV LANE, HOUSTON

Table A-2. Summary of Katy Freeway and HOV Lane Data, December 1992

Type of Data Phase 1 of HOV Lane Became Operational 10/29/84	"Representative" Pre-HOV Lane	"Representative" Current Value	% Change
Combined Freeway Mainlane and HOV Lane Data			
Total Person Movement			
Peak Hour	5,100	9,991	+95.9%
Peak Period	15,655	26,281	+67.9%
Vehicle Volume			
Peak Hour	4,045	6,384	+57.8%
Peak Period	12,750	17,427	+36.7%
Vehicle Occupancy			
Peak Hour	1.26	1.57	+24.6%
Peak Period	1.23	1.51	+22.7%
Carpool Volumes[1]			
2+, 6 a.m. to 7 a.m.	505	868	+71.9%
3+, 7 a.m. to 8 a.m.	45	400	+788.9%
3+, 5 p.m. to 6 p.m.	104	540	+419.2%
Travel Time (minutes)			
Peak Hour	33.9[2]	14.2[3]	-58.1%
Peak Period	23.1[2]	13.5[3]	-41.6%
Peak Hour Lane Efficiency (1000's)[4]	38	95	+150.0%
Transit Data			
Bus Vehicle Trips			
Peak Hour	11	57	+418.2%
Peak Period	32	129	+303.1%
Bus Passenger Trips			
Peak Hour	335	2,340	+598.5%
Peak Period	900	4,680	+420.0%
Bus Occupancy (persons/bus)			
Peak Hour	30.5	41.1	+ 34.8%
Peak Period	28.1	36.3	+ 29.2%
Vehicles Parked in Corridor Park & Ride Lots	575	2,122	+269.0%
Bus Operating Speed (mph)[5]			
Peak Hour	22.6[2]	51.5[3]	+127.9%
Peak Period	33.2[2]	54.2[3]	+ 63.3%

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 miles/hour). It is used as a measure of per lane efficiency.
[5]From SH 6 to Washington, a distance of 12.2 miles. The HOV lane is in place over this section.

Table A-3. Comparison of Measures of Effectiveness, Freeway With (Katy, I-10W) and Freeway Without (Southwest US 59) HOV Lane, Houston

Measure of Effectiveness	"Representative" Pre-HOV Lane Value	"Representative" 12/92 Value	% Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/HOV lane	1.26	1.57	+ 24.6%
Freeway w/o HOV lane	1.34	1.30	- 3.0%
Peak-Hour 2+ Carpool Volume			
Freeway w/HOV lane	763	1,481[1]	+ 94.0%
Freeway w/o HOV lane	600	531	- 11.5%
Bus Passengers, Peak Period			
Freeway w/HOV lane	900	4,680	+420.0%
Freeway w/o HOV lane	2,185	2,174	- 0.5%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	575	2,122	+269.0%
Freeway w/o HOV lane[1]	1,660	1,522	- 8.3%
Facility Per Lane Efficiency[2]			
Freeway w/HOV lane	38	95	+150.0%
Freeway w/o HOV lane	49	60	+ 22.4%

[1]The most current peak-hour 2+ carpool data are from 1991 during the p.m. peak hour (5-6 p.m.). On 9/16/91, the vehicle occupancy requirement from 5-6 p.m. was changed to 3+; thus, resulting in the absence of 1992 2+ carpool data for the Katy HOV lane.

[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 through 4/88) and on the Southwest Freeway (9/86 to present).

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

HOV LANE DATA

DESCRIPTION

- Phase 1 (4.7 miles) of the HOV lane opened October 29, 1984.
- The HOV lane is now complete with 12.3 miles in operation.
- The capital cost (incl. 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 (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 (6.4 miles)
- 11/4/85 3+ authorized carpools allowed onto HOV

- 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 (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 (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-4. 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 Mile	$2.1		$1.9
Surveillance, Communication & Control (1987)	$5.5	0.85	$4.7
SUB-TOTAL	$5.5		$4.7
Per Mile	$0.4		$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 Mile	$2.3		$2.2
TOTAL COST	$63.0		$59.1
COST PER MILE (13.0 miles)	$ 4.8		$ 4.5

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

PERSON MOVEMENT

- In December 1992, 23,434 person trips per day were served on the HOV lane.
- A.M. Peak Hour, 4,524 persons/hour.
  - 2,340 (52%) by bus, 106 (2%) by vanpool, 2,062 (46%) by carpool (Figure A-1).
  - Average HOV lane vehicle occupancy = 4.63 persons/vehicle.
- A.M. Peak Period, 10,702 persons.
  - 4,680 (44%) by bus, 307 (3%) by vanpool, by carpool 5,690 (53%) (Figure A-2).

VEHICLE MOVEMENT

- A.M. Peak Hour, 977 vph
  - 57 (6%) buses, 16 (2%) vans, 888 (92%) carpools (Figure A-3).
- A.M. Peak Period, 2,755 vehicles
  - 129 (5%) buses, 52 (2%) vans, 2,549 (93%) carpools (Figure A-4).

ACCIDENT RATE

- For the period from November 1984 through December 1992, the HOV lane accident rate was 20.3 injury accidents per 100 million vehicle miles.

VEHICLE BREAKDOWN RATES

- As measured for 11/84 to 12/92, the following rate has been observed.
  - The weighted average for all vehicle types is one breakdown per 40,500 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 16.0%.
  - For the period from 7:00 a.m. to 8:15 a.m. (the 3+ operating time) it averaged 45.1% for 1992 and was 41.4% in December.
  - For the p.m. peak period, the violation rate is 12.6%.
  - For the p.m. peak hour (the 3+ operating time), the violation rate is 36.0%.

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 233 (4,524 passengers at 51.5 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane experienced an average travel time savings of 16 minutes during the morning peak hour in 1992 (Figure A-5).

- The tables on the following page indicate that, on a typical non-incident day, travel time savings of approximately 1,589 hours (95,332 min.) are realized. Assuming 250 days of operation, annual savings would be 397,216 hours. At $10.47/hour, this equates to $4.16 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 $4.16 to $8.32 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 7.2% relative to pre-HOV conditions (Figure A-6).

- In the a.m. peak period, person movement has decreased by 0.5% relative to pre-HOV conditions (Figure A-7).

VEHICLE VOLUME

- In the a.m. peak hour, vehicle volume has increased by 33.7% relative to pre-HOV conditions (Figure A-8).

- In the a.m. peak period, vehicle volume has increased by 15.1% relative to pre-HOV conditions (Figure A-9).

VEHICLE OCCUPANCY

- In the a.m. peak hour, mainlane occupancy has decreased by 19.8% relative to pre-HOV conditions (Figure A-10).

- In the a.m. peak period, mainlane occupancy has decreased by 13.8%, 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 20.0 accidents per 100 million vehicle miles (100 MVM). For the period from 11/84 to 8/92, the freeway accident rate was 33.0 accidents/100 MVM. These statistics do not include driver reported accidents; only officer reported accidents are included in current accident files. TTI estimated 1992 freeway volumes to compute accident rates.

AVERAGE OPERATING SPEED

- In comparison to pre-HOV lane conditions, mainlane operating speeds have increased by 17% in the peak hour and 10% 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 28.9% has occurred.

Table A-5. Eastbound A.M. Travel Time Savings for Katy HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1992)

Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	T-Way (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section From SH 6 to Gessner Interchange								
6:00	7.01	6.81	0.20	530	50	185	764	152.83
6:30	9.48	7.03	2.45	1,060	49	320	1,429	3,501.66
7:00	18.29	7.49	10.79	484	33	493	1,009	10,890.92
7:30	19.90	6.70	13.19	417	16	410	843	11,117.28
8:00	7.94	6.83	1.11	658	12	145	815	903.58
8:30	8.45	6.48	1.97	316	9	33	358	706.06
9:00	6.95	6.69	0.25	160	4	0	165	41.87
Peak Period Total				3,624	173	1,586	5,383	27,314.21
Section From Gessner Interchange to Washington								
6:00	7.12	7.20	-0.08	404	52	382	838	-69.80
6:30	8.49	7.24	1.25	1,200	99	768	2,066	2,591.45
7:00	12.03	7.85	4.18	726	64	1,279	2,069	8,655.35
7:30	12.06	6.92	5.14	711	35	1,321	2,066	10,609.75
8:00	9.08	7.18	1.89	1,010	38	694	1,742	3,294.38
8:30	7.61	7.30	0.32	821	16	245	1,082	342.57
9:00	6.92	6.95	-0.03	458	19	52	528	-17.62
Peak Period Total				5,330	322	4,739	10,390	25,406.09
Westbound P.M. Travel Time Savings for Katy HOV Lane								
Section from Washington to Gessner Interchange								
3:30	7.98	7.54	0.43	471	25	95	590	255.77
4:00	10.48	8.53	1.94	875	77	391	1,343	2,607.66
4:30	12.35	8.37	3.98	1,265	75	584	1,923	7,652.98
5:00	14.62	7.86	6.76	870	81	1,057	2,007	13,573.98
5:30	11.78	7.60	4.19	653	28	1,055	1,736	7,268.47
6:00	9.82	8.34	1.47	1,087	23	558	1,667	2,454.59
6:30	7.02	7.14	-0.12	481	18	229	728	-87.96
Peak Period				5,700	327	3,968	9,995	33,725.50
Section from Gessner Interchange to SH 6								
3:30	6.85	6.53	0.32	222	14	35	271	85.65
4:00	6.95	6.75	0.21	359	39	141	539	112.29
4:30	7.49	6.73	0.76	599	33	240	872	661.28
5:00	10.60	6.97	3.63	667	48	383	1,097	3,981.18
5:30	10.02	6.50	3.52	374	18	553	944	3,319.76
6:00	7.68	6.74	0.94	548	23	226	797	748.96
6:30	6.77	6.82	-0.05	383	6	105	493	-22.60
Peak Period				3,151	179	1,683	5,012	8,886.52

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 45% of peak-hour person movement (HOV lane = 4,524; freeway = 5,467) and 41% of peak-period (HOV lane = 10,702; freeway = 15,579) 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 95.9% from 5,100 to 9,991 (Figure A-6). Peak-period person movement has increased by 67.9% from 15,655 to 26,281 (Figure A-7).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.57, a 24.6% 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 1.51 (18.9%).
- While the occupancy on the Katy Freeway has increased, freeways which do not have HOV lanes have experienced a decrease in occupancy (Figure A-13).

CARPOOL VOLUMES

- In the a.m. peak hour, the total number of 2+ carpools (freeway plus HOV lane) has increased by 59.4% compared to pre-HOV lane levels (Figure A-14).
- Prior to the HOV lane, the peak hour (7 to 8 a.m.) 3+ carpool volume was 45 vehicles -- now it is nearly 400 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 150% 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 418% since the HOV lane opened, and a 599% increase in bus ridership has also resulted (Figure A-18). In the peak period, a 303% increase has occurred in bus trips and a 420% 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).

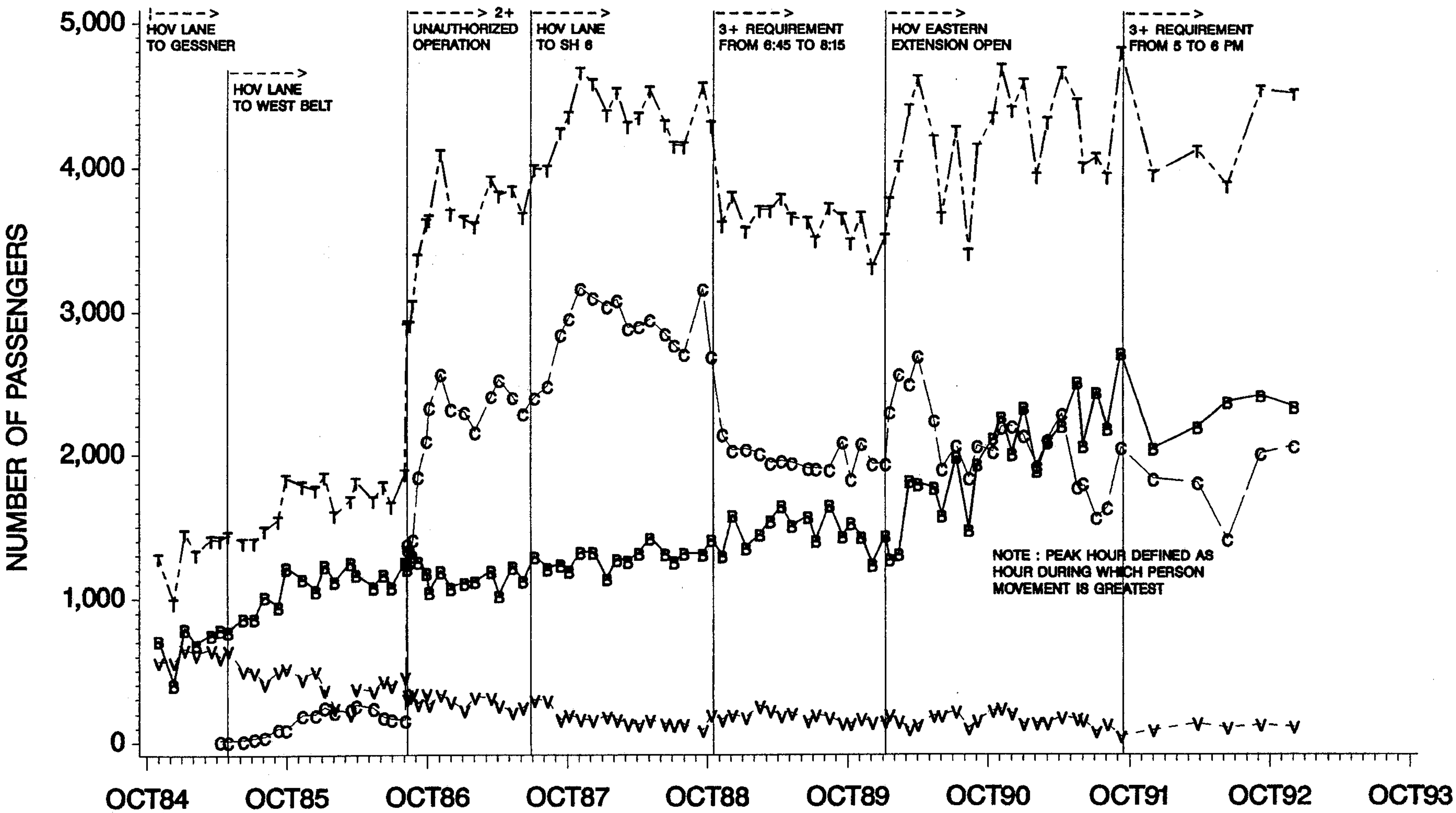
PARK-AND-RIDE

- Prior to opening the HOV lane, approximately 575 vehicles were parked in corridor park-and-ride lots. This has increased 269% to a current level of 2,122 (Figure A-21).

- The 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

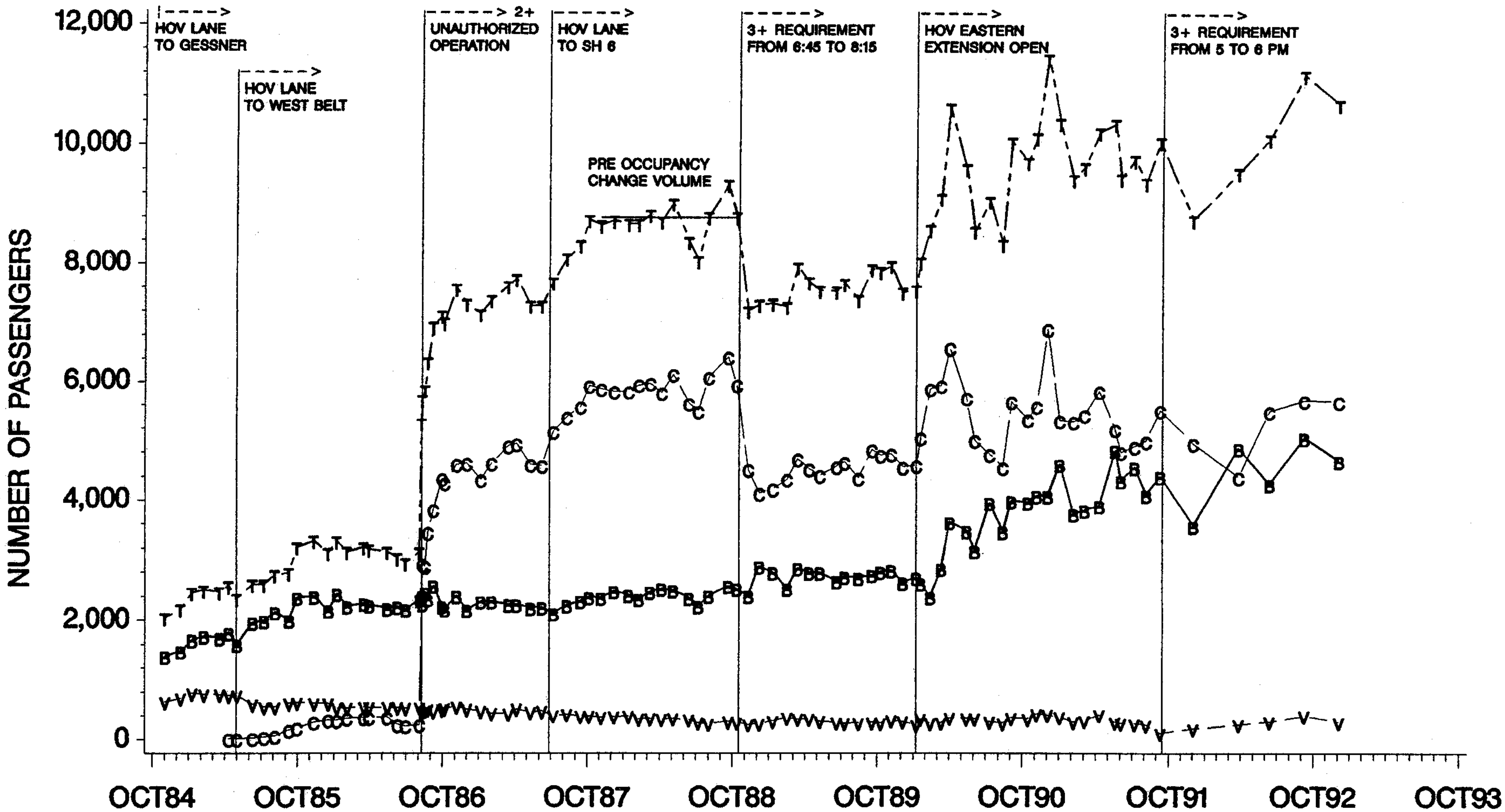


KATY HOV LANE PHASE 1, POST OAK TO GESSNER (4.7 MI.), OPENED OCTOBER 29, 1984
HOV LANE EXTENSION FROM GESSNER TO WEST BELT (1.7 MI.) OPENED MAY 2, 1985
OFF-PEAK, UNAUTHORIZED & 2+ CARPOOL OPERATION BEGAN AUGUST 11, 1986
HOV LANE EXTENSION FROM WEST BELT TO SH 6 (5.0 MI.) OPENED JUNE 29, 1987
3+ CARPOOL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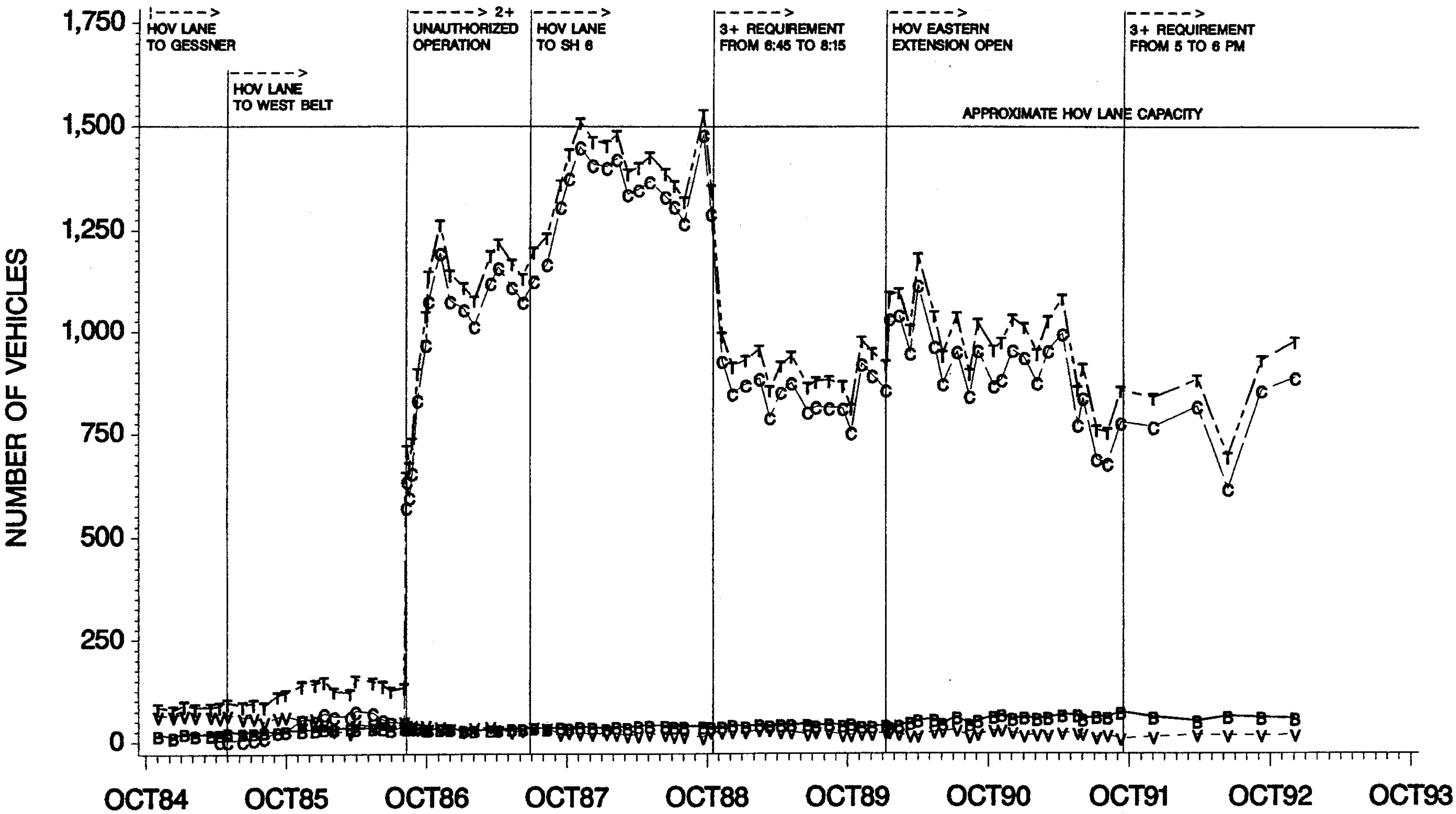
3+ CARPOOL REQUIREMENT FROM 6:45 TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
HOV LANE EASTERN EXTENSION (1.17 MI.) OPENED JANUARY 9, 1990
PEAK PERIOD IS 6:00 – 9:30 A.M.
DATA COLLECTED BETWEEN GESSNER AND POST OAK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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 (4.7 MI.), OPENED OCTOBER 29, 1984
HOV LANE EXTENSION FROM GESSNER TO WEST BELT (1.7 MI.) OPENED MAY 2, 1985
OFF-PEAK, UNAUTHORIZED & 2+ CARPOOL OPERATION BEGAN AUGUST 11, 1986
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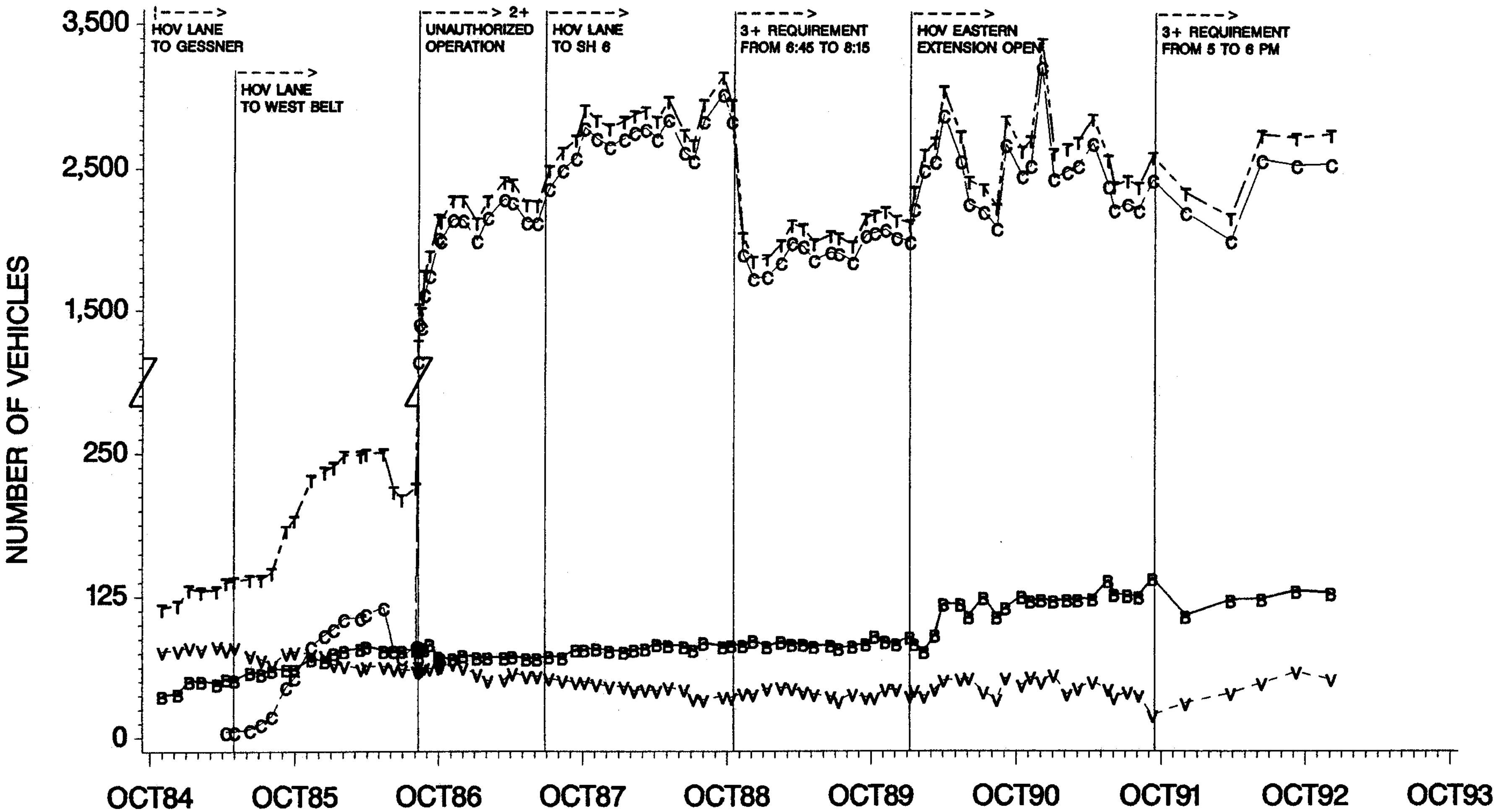
HOV LANE EASTERN EXTENSION (1.17 MI.) OPENED JANUARY 9, 1990
DATA COLLECTED BETWEEN GESSNER AND POST OAK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

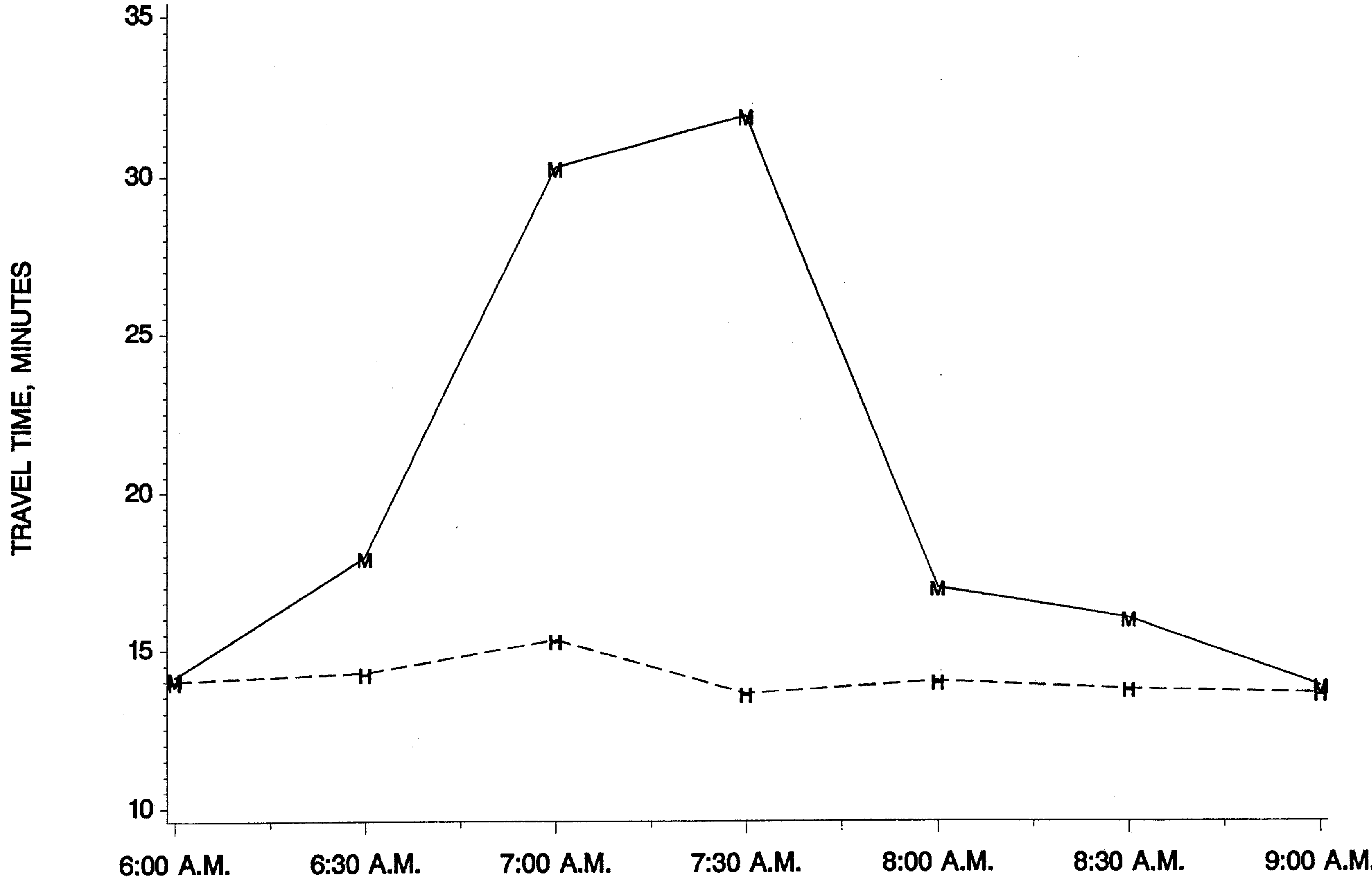


KATY HOV LANE PHASE 1, POST OAK TO GESSNER (4.7 MI.), OPENED OCTOBER 29, 1984
HOV LANE EXTENSION FROM GESSNER TO WEST BELT (1.7 MI.) OPENED MAY 2, 1985
OFF-PEAK, UNAUTHORIZED & 2+ CARPOOL OPERATION BEGAN AUGUST 11, 1986
HOV LANE EXTENSION FROM WEST BELT TO SH 6 (5.0 MI.) OPENED JUNE 29, 1987
3+ CARPOOL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

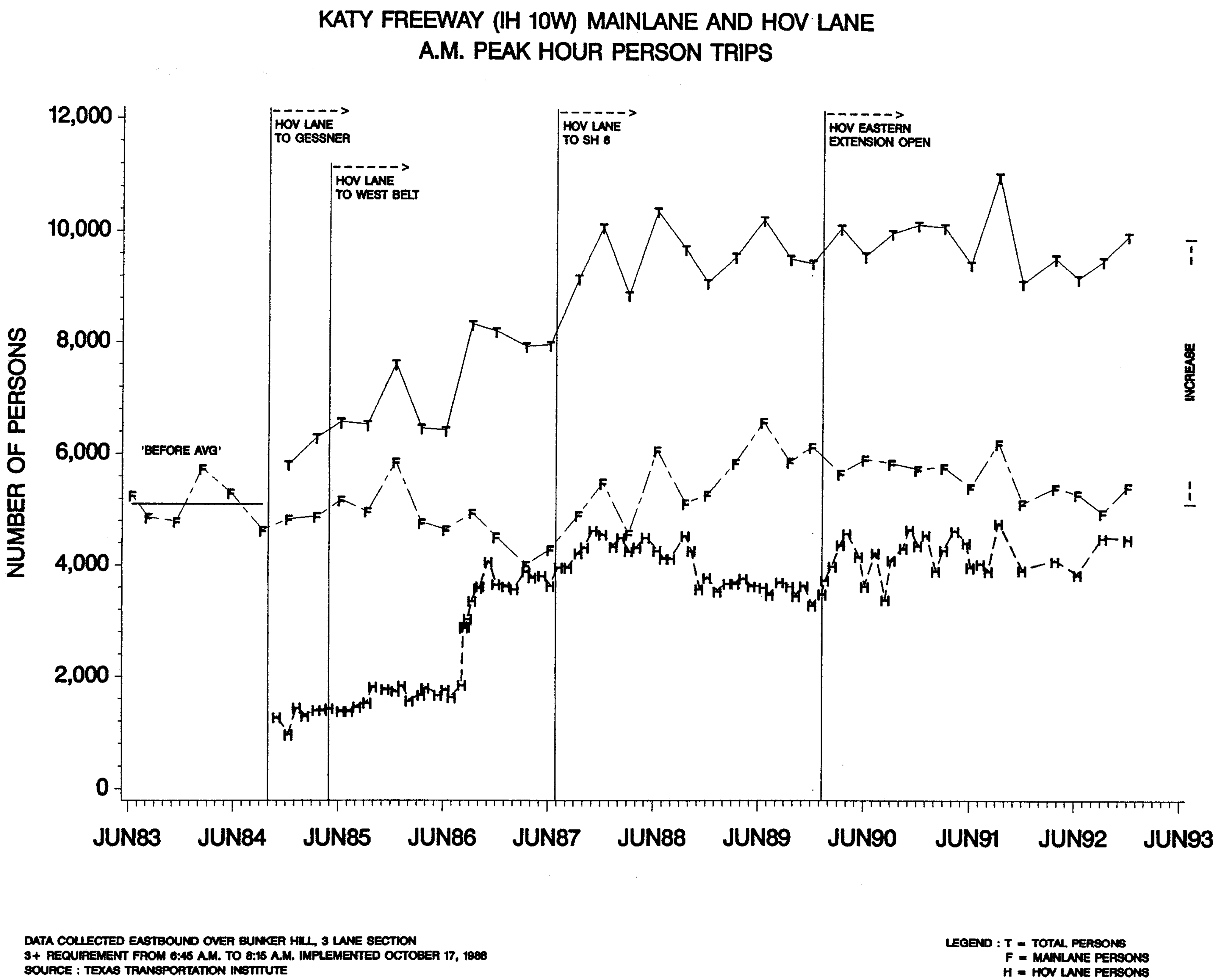
KATY FREEWAY (IH 10W) MAINLANES AND HOV LANE A.M. TRAVEL TIME



TRAVEL TIMES ARE AN AVERAGE OF 4 QUARTERLY TRAVEL TIME SURVEYS CONDUCTED IN 1992
TRAVEL TIMES ARE FROM THE WESTERN HOV LANE TERMINUS TO THE S.P. RAILROAD OVERPASS
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

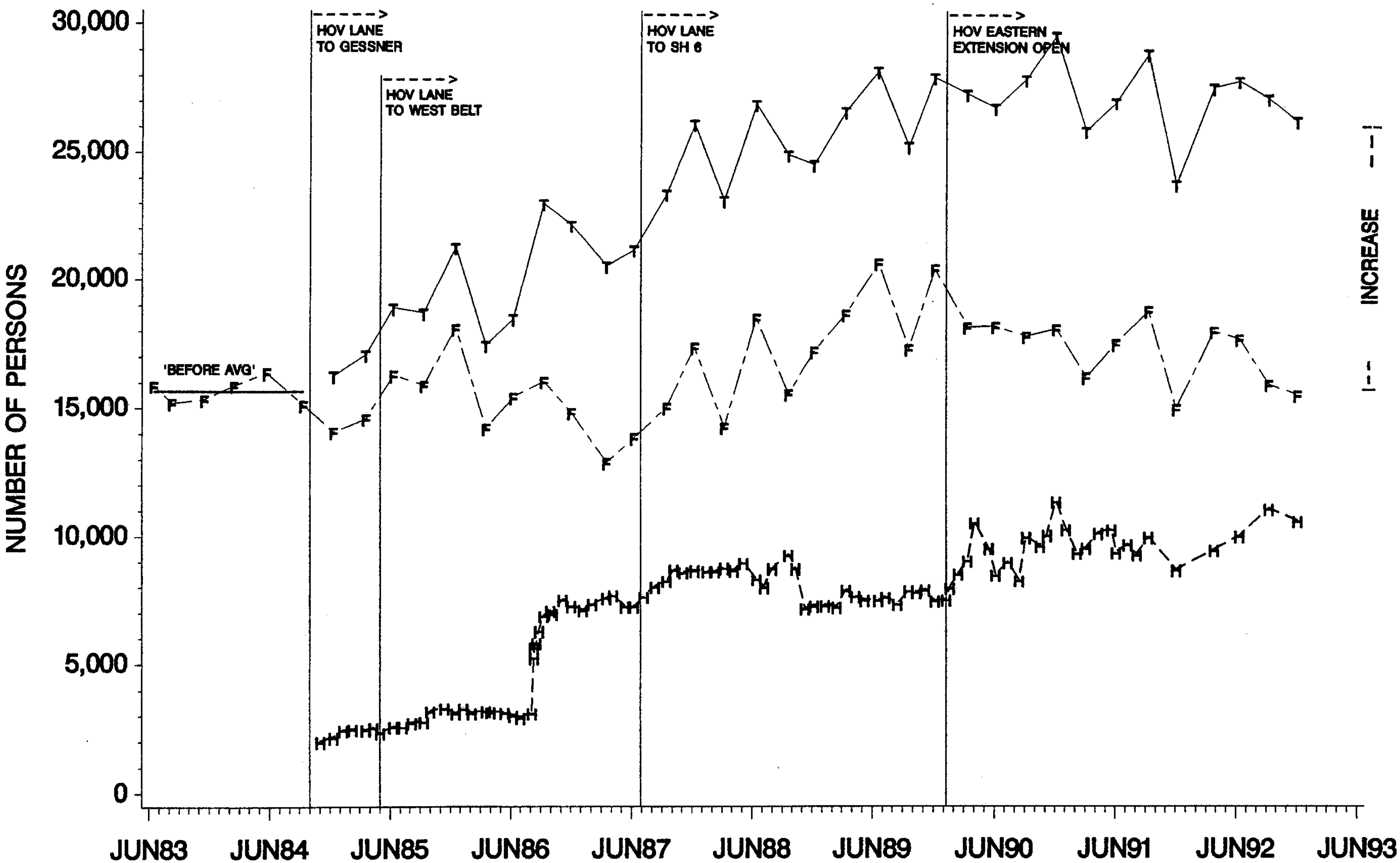
FIGURE A-6



KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK HOUR PERSON TRIPS
NUMBER OF PERSONS
12,000
10,000
8,000
6,000
4,000
2,000
0
'BEFORE AVG'
HOV LANE
TO GESSNER
HOV LANE
TO WEST BELT
HOV LANE
TO SH 6
HOV EASTERN
EXTENSION OPEN
INCREASE
JUN83
JUN84
JUN85
JUN86
JUN87
JUN88
JUN89
JUN90
JUN91
JUN92
JUN93
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

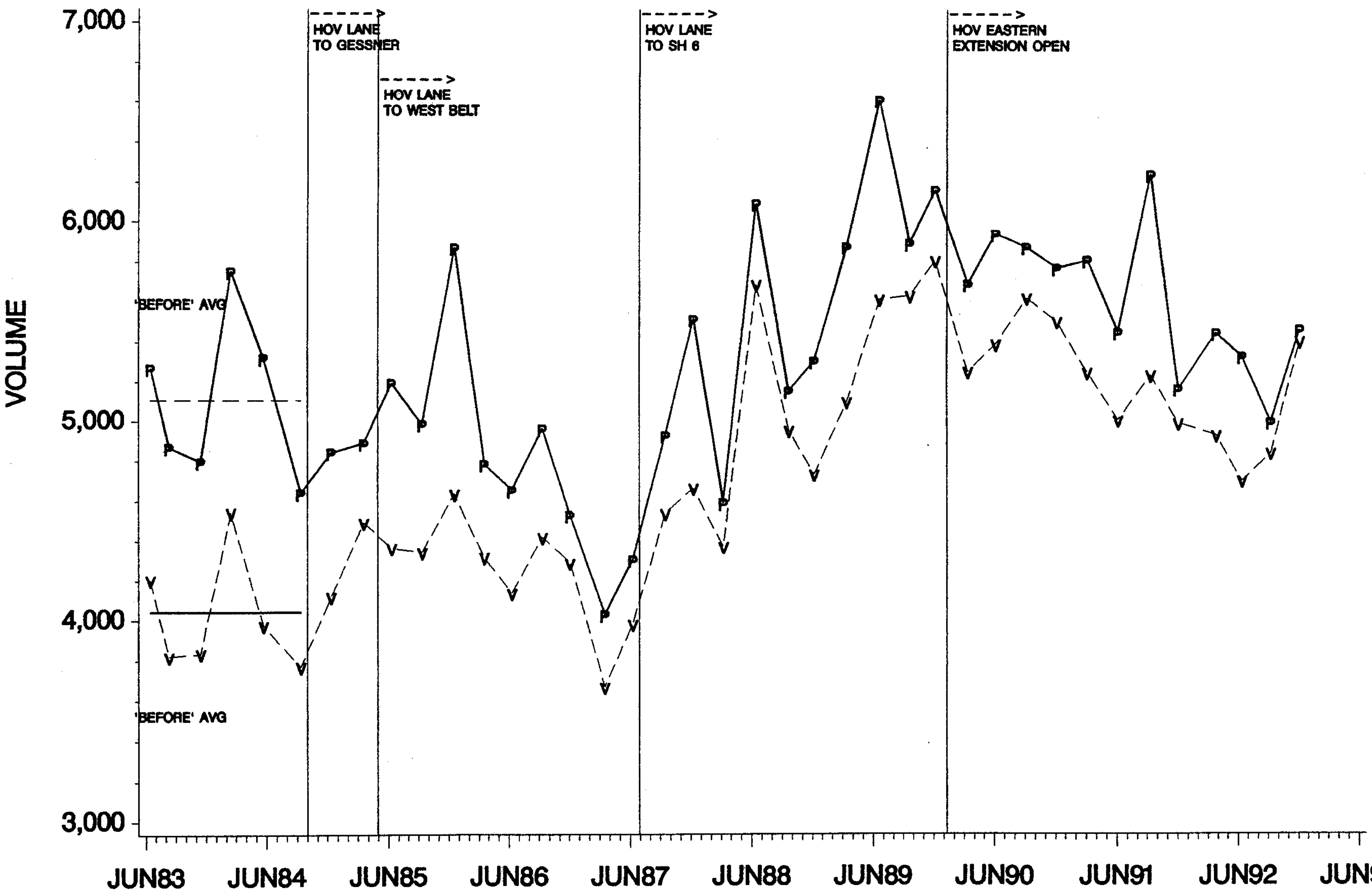


A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M
DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
3+ REQUIREMENT FROM 6:45 A.M. TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE A-8

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

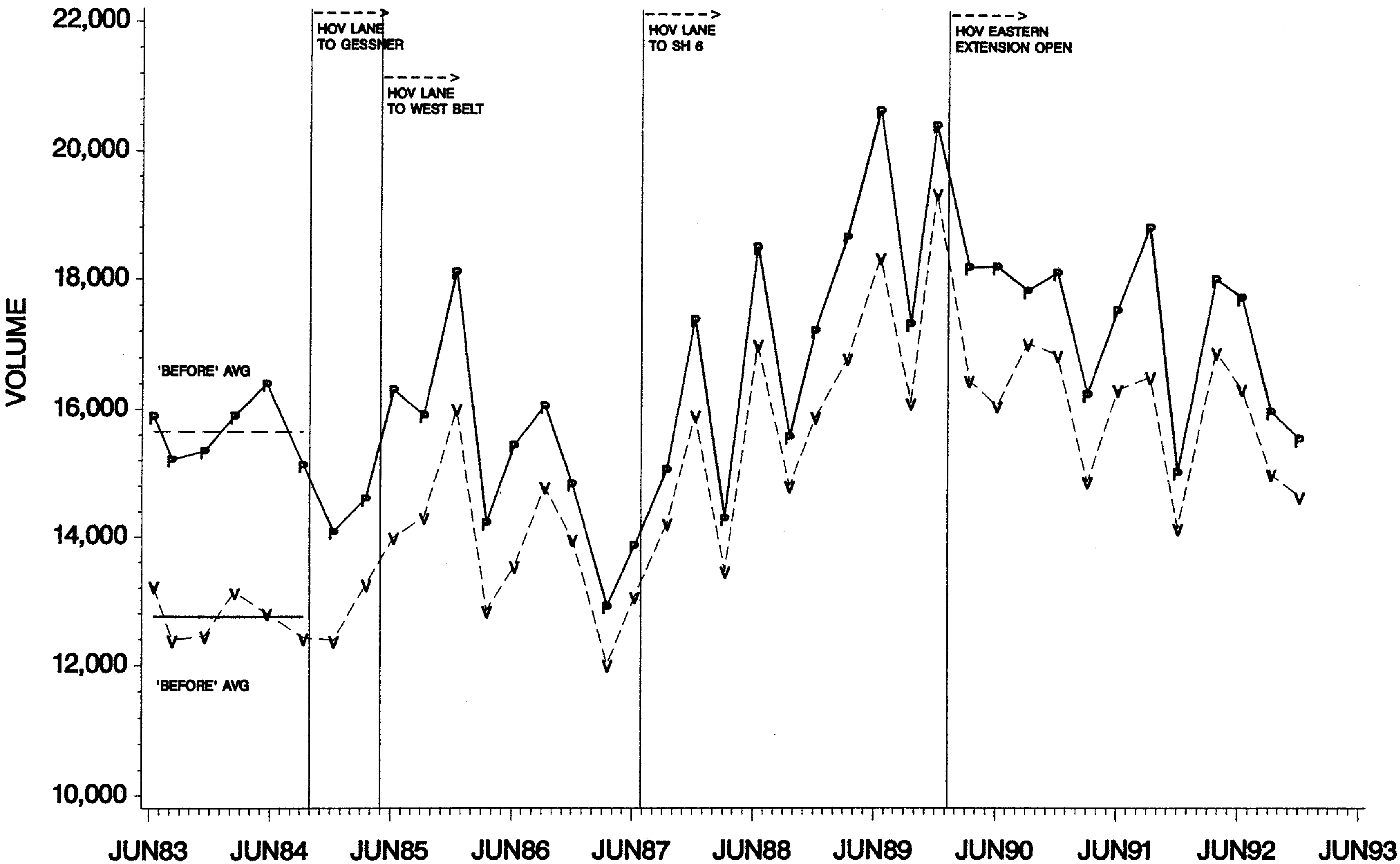


DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = MAINLANE PERSONS
V = MAINLANE VEHICLES

FIGURE A-9

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

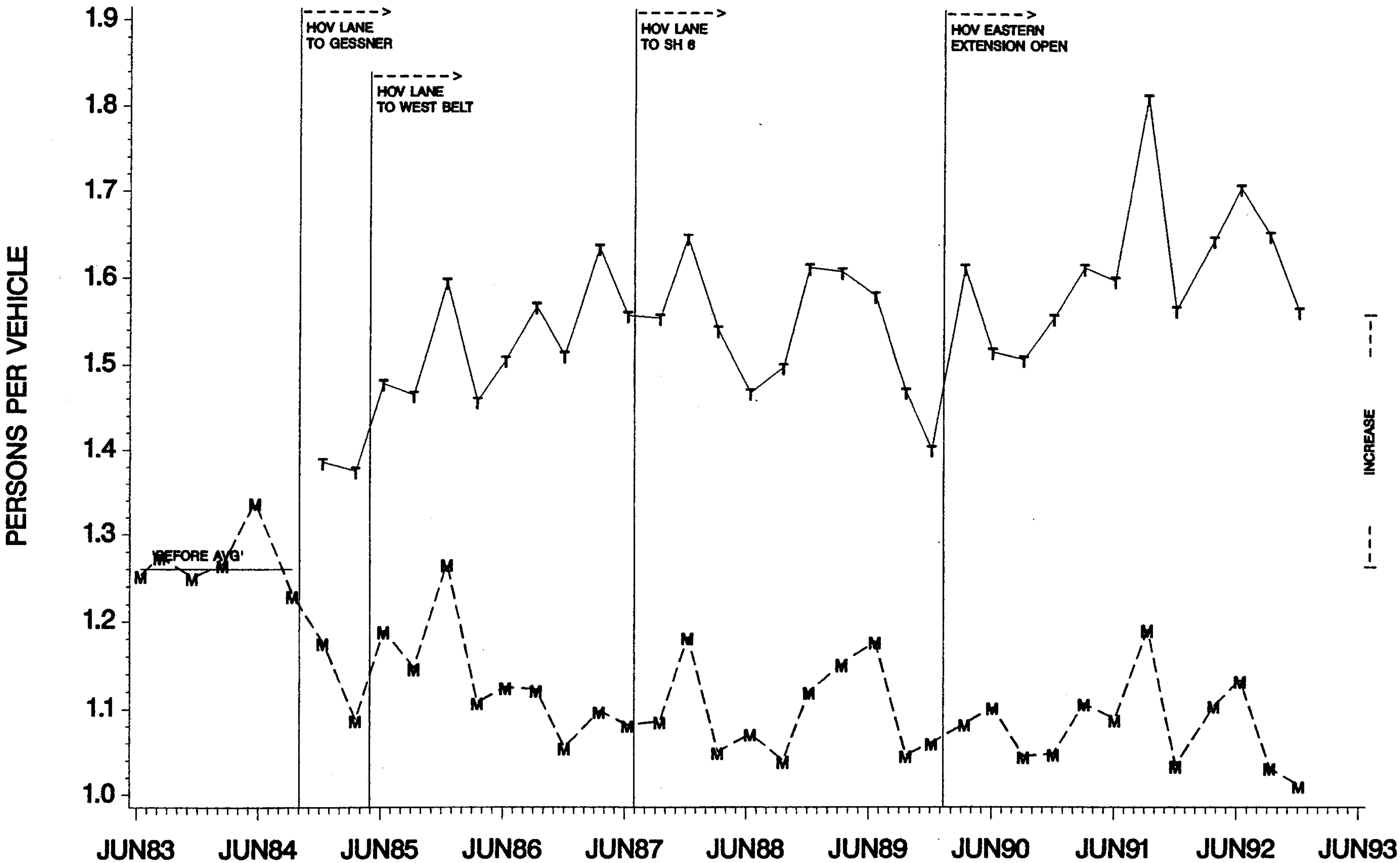


A.M. PEAK PERIOD DEFINED AS FROM 6:00 TO 9:30 A.M.
DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = MAINLANE PERSONS
V = MAINLANE VEHICLES

FIGURE A-10

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

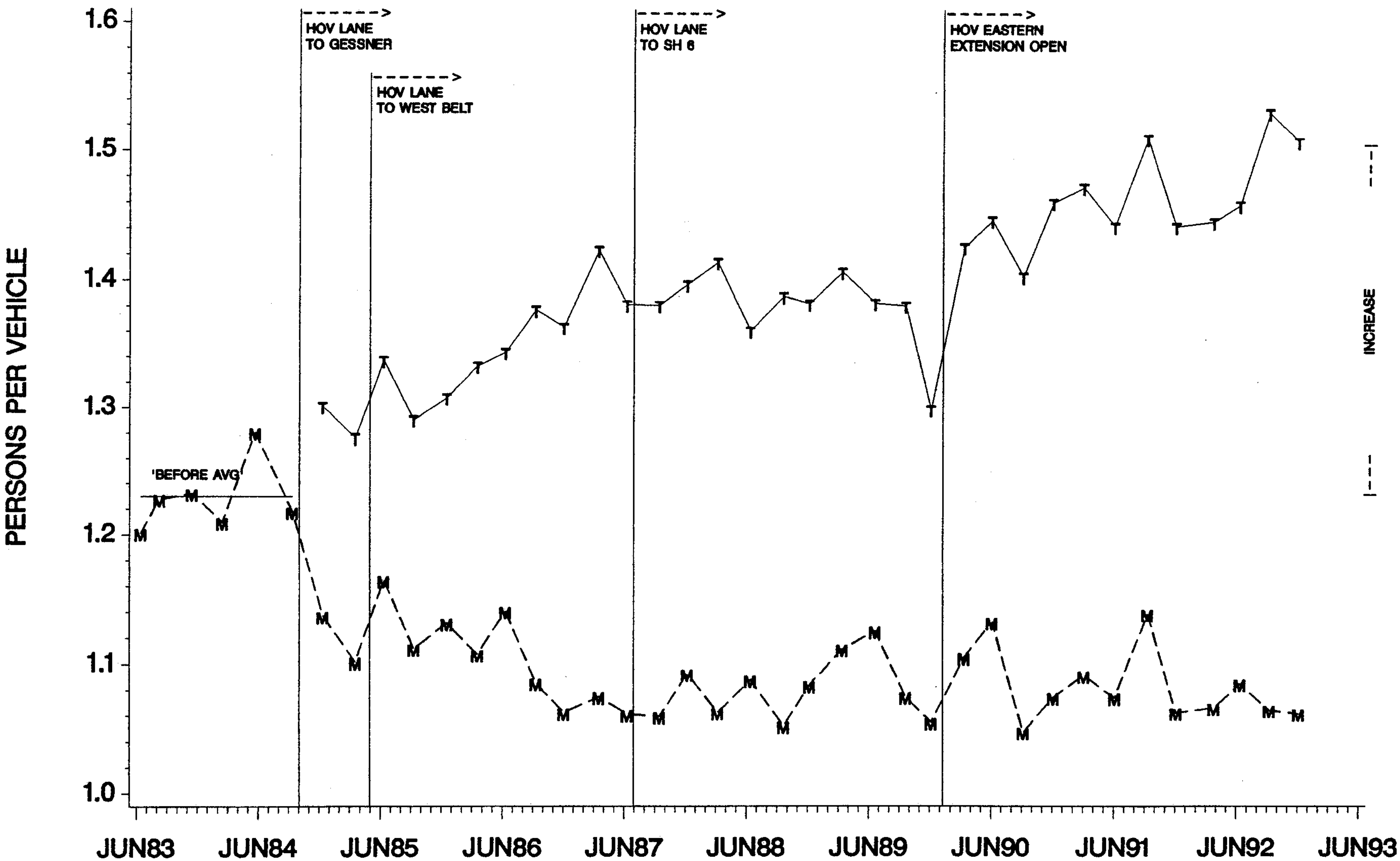


DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
3+ REQUIREMENT FROM 6:45 A.M. TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE A-11

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

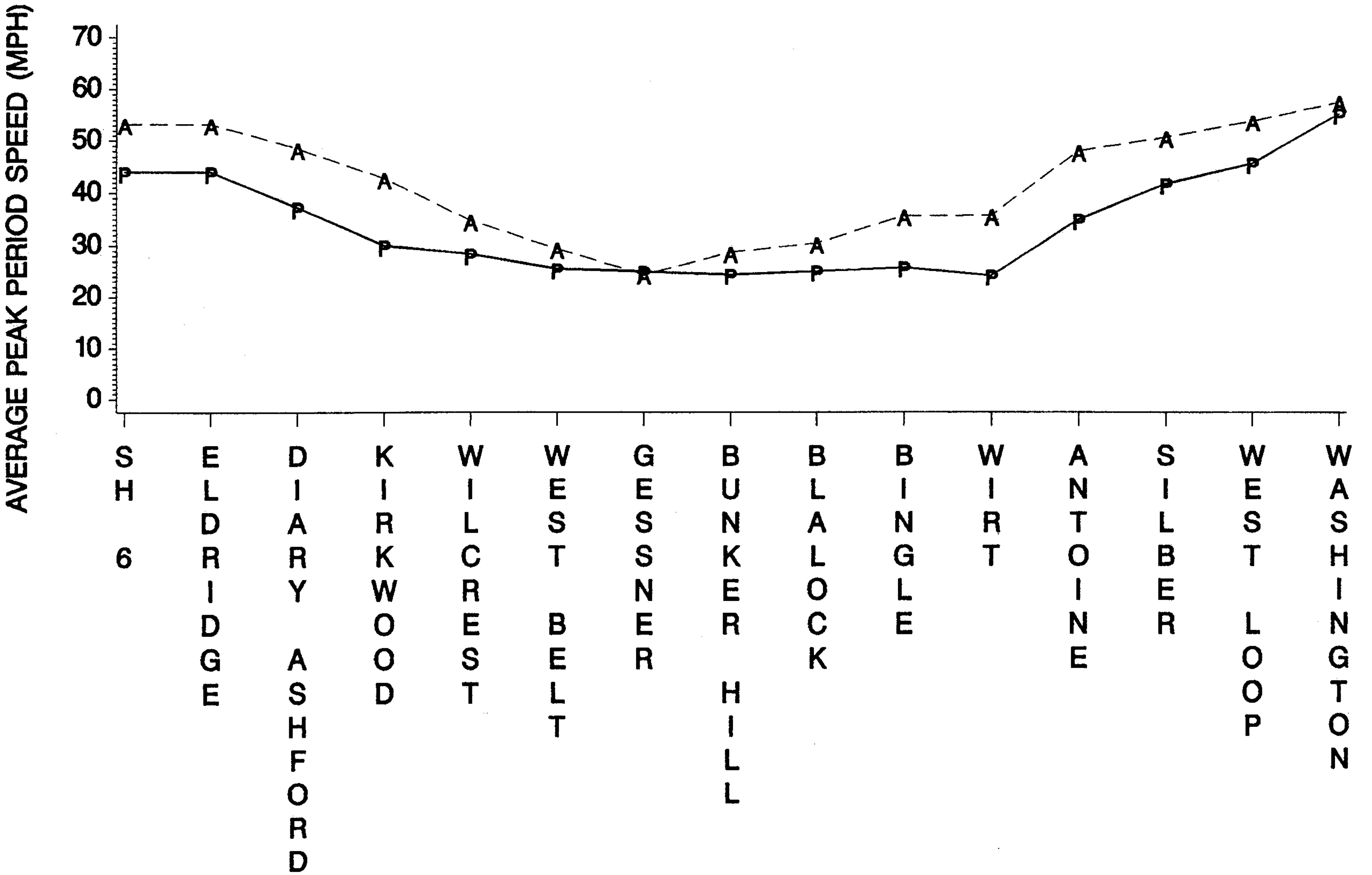


A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M
DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
3+ REQUIREMENT FROM 6:45 A.M. TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

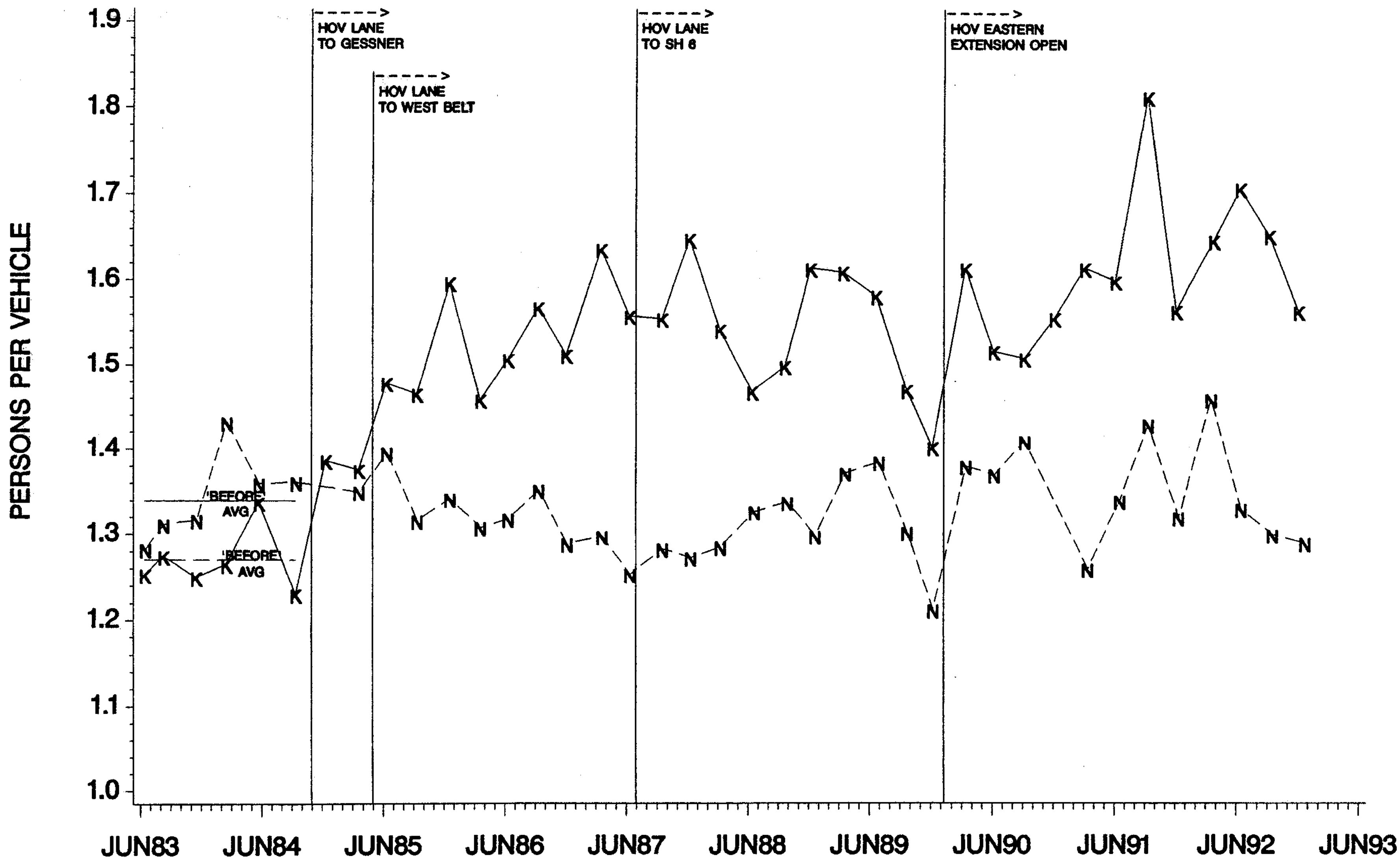


DATA COLLECTED 6:00 TO 9:30 A.M.
DATA COLLECTED FROM JUNE, 1983 TO DECEMBER, 1992
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE A-13

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

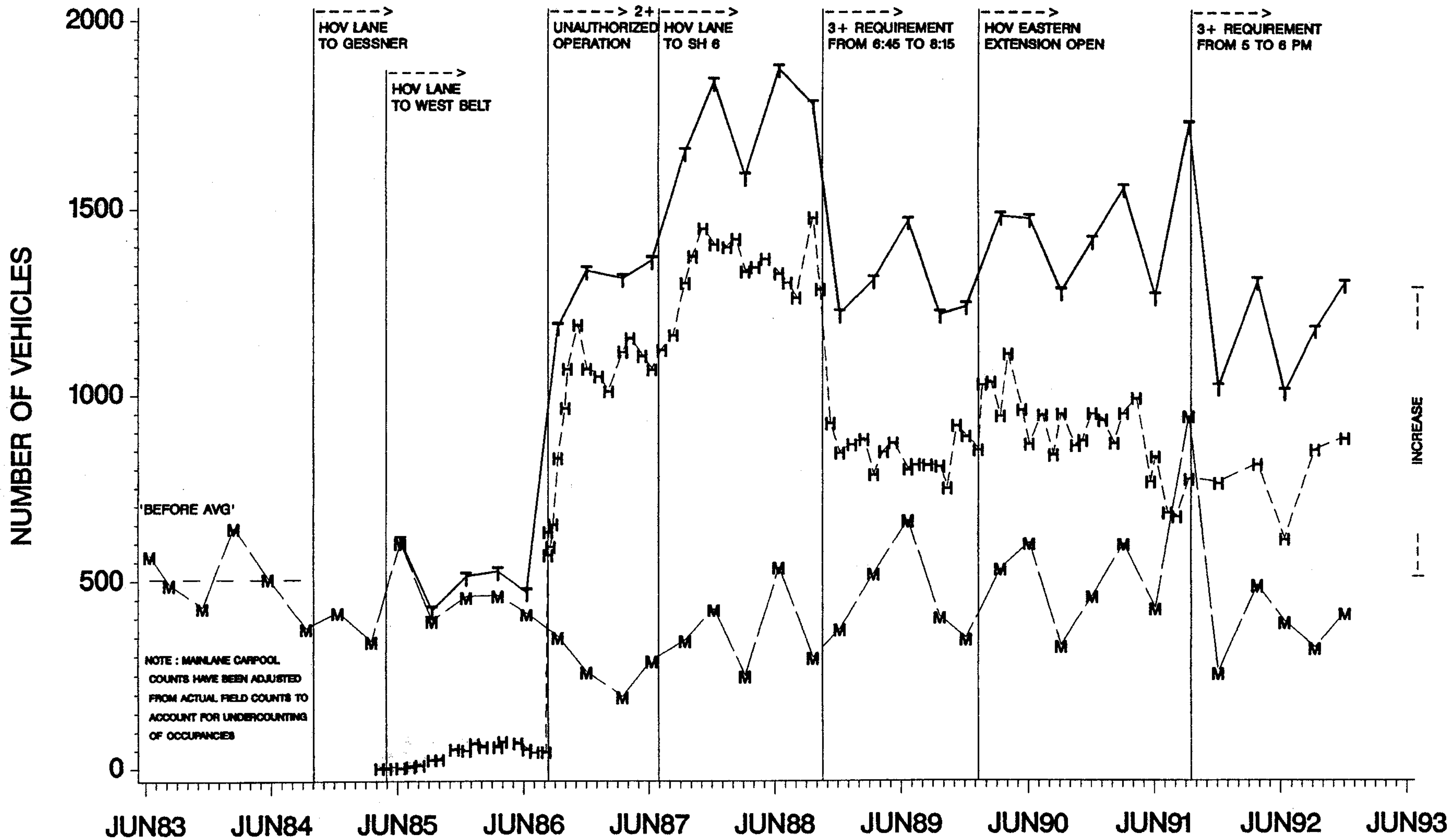


DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF GULF FWY (6/83 – 4/86) AND SOUTHWEST FWY (9/86 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

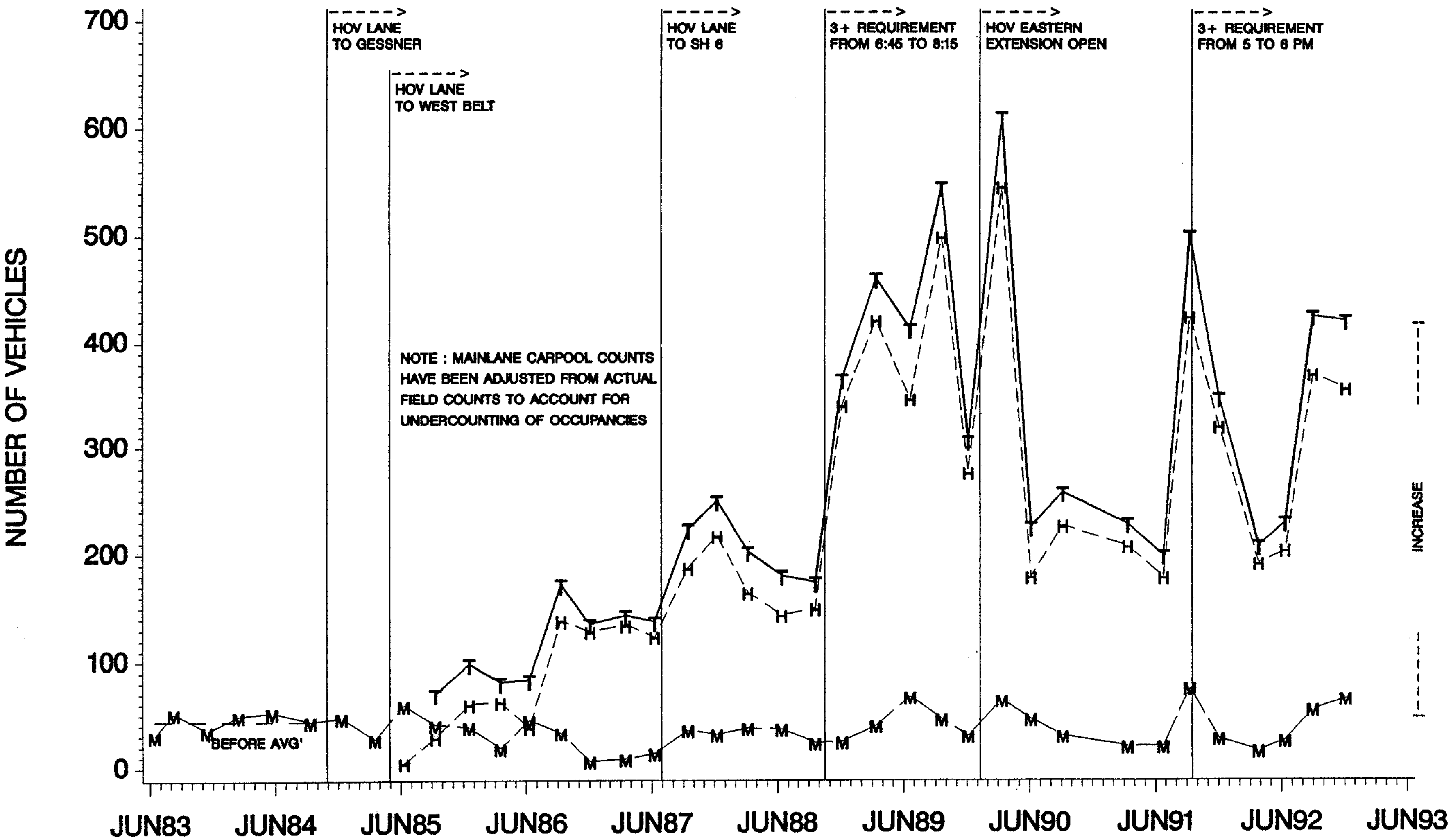


KATY HOV LANE PHASE 1, POST OAK TO GESSNER (4.7 MI) OPENED OCTOBER 29,1986
HOV LANE EXTENSION FROM GESSNER TO WEST BELT (1.7 MI) OPENED MAY 2, 1985
OFF-PEAK, UNAUTHORIZED & 2+ CARPOOL OPERATION BEGAN AUGUST 11, 1986
HOV LANE EXTENSION FROM WEST BELT TO SH 6 (5.0 MI) OPENED JUNE 29, 1987
3+ CARPOOL REQUIREMENT FROM 6:45 TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
HOV LANE EASTERN EXTENSION (1.17 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 FREEWAY (IH 10W) MAINLANE AND HOV LANE
7:00 A.M. TO 8:00 A.M. 3+ CARPOOL UTILIZATION

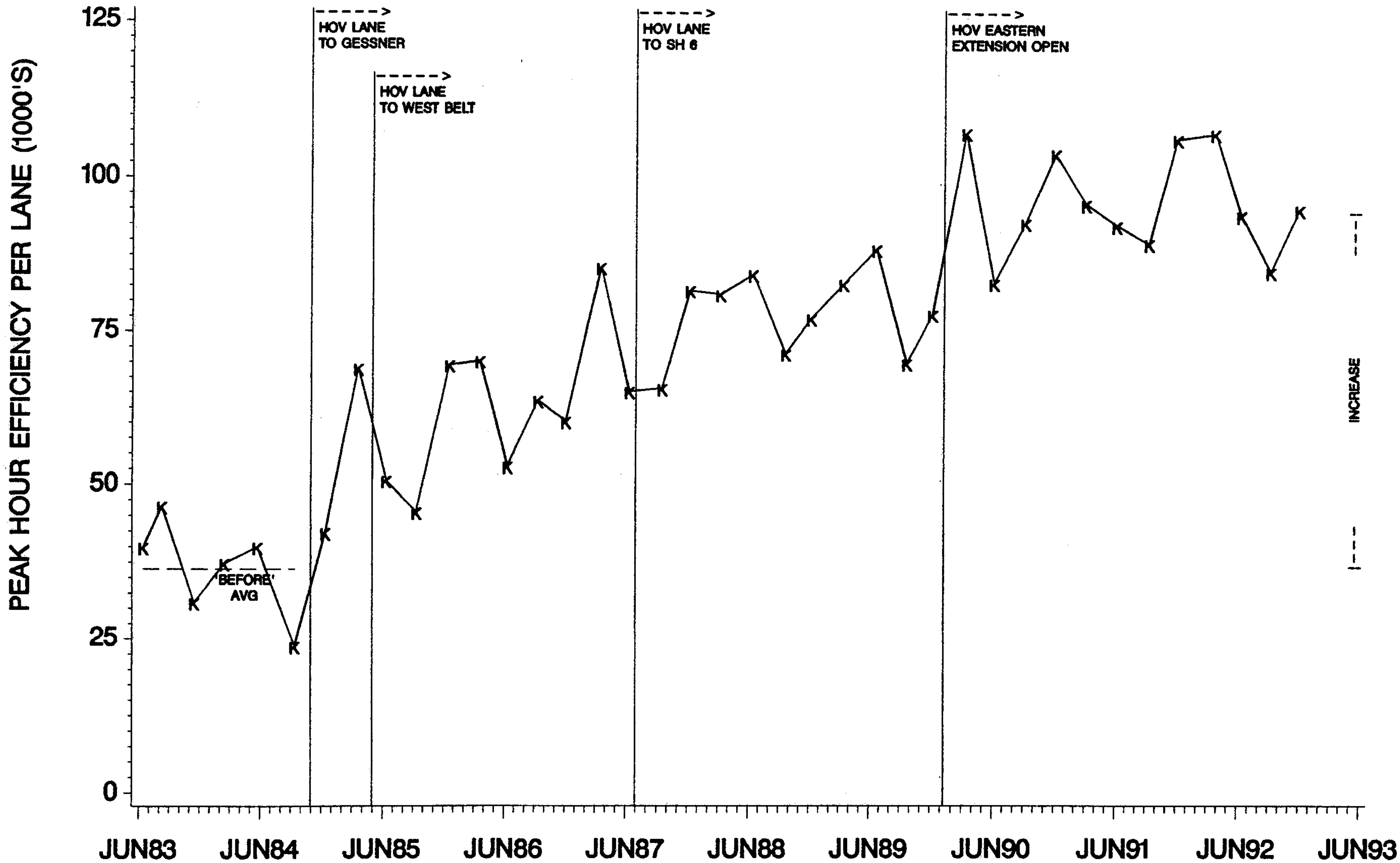


KATY HOV LANE PHASE 1, POST OAK TO GESSNER (4.7 MI.), OPENED OCTOBER 29, 1984
HOV LANE EXTENSION FROM GESSNER TO WEST BELT (1.7 MI.) OPENED MAY2, 1985
OFF-PEAK, UNAUTHORIZED & 2+ CARPOOL OPERATION BEGAN AUGUST 11, 1986
HOV LANE EXTENSION FROM WEST BELT TO SH 6 (5.0 MI.) OPENED JUNE 29, 1987
HOV LANE EASTERN EXTENSION (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

KATY FREEWAY HOV LANE EVALUATION
A.M. PEAK HOUR MAINLANE AND HOV LANE EFFICIENCY

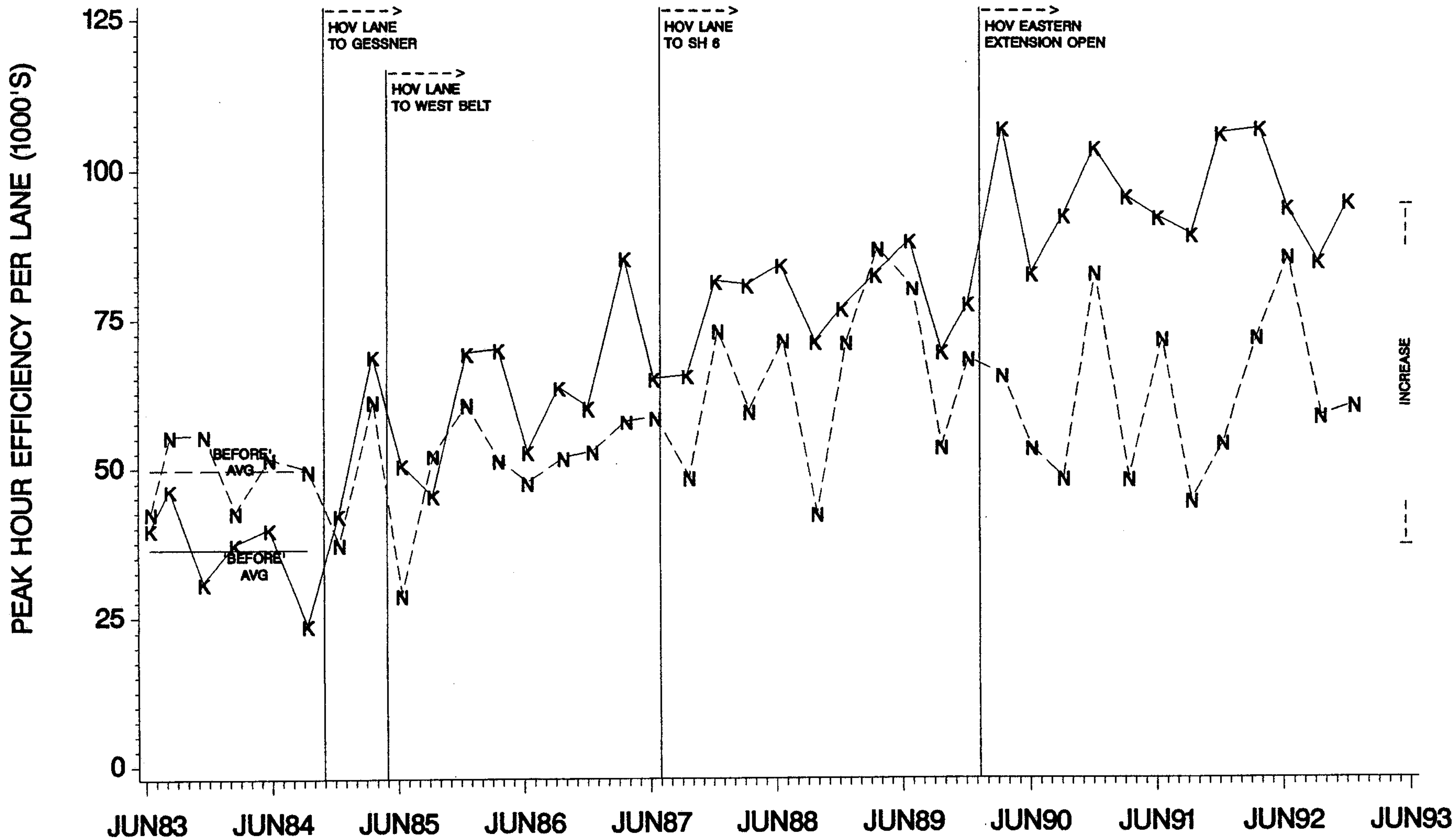


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE HOV LANE, IT REPRESENTS TOTAL PERSONS (FREEWAY + HOV LANE)
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : K = KATY FREEWAY EFFICIENCY

FIGURE A-17

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

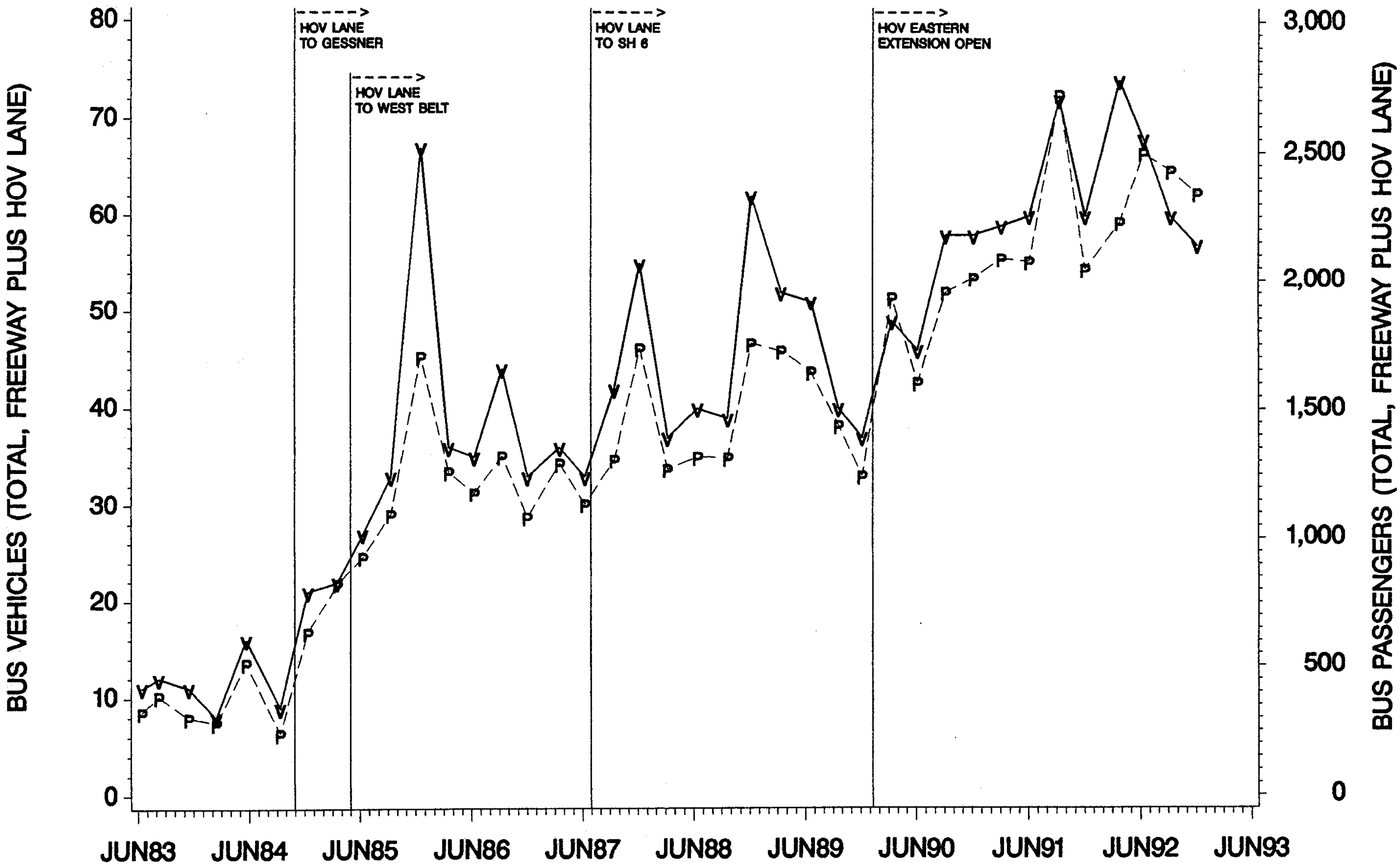


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE HOV LANE, IT REPRESENTS TOTAL PERSONS (FREEWAY + HOV LANE) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 4 LANES
DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF GULF FWY (6/83 – 4/86) AND SOUTHWEST FWY (6/86 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE A-18

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

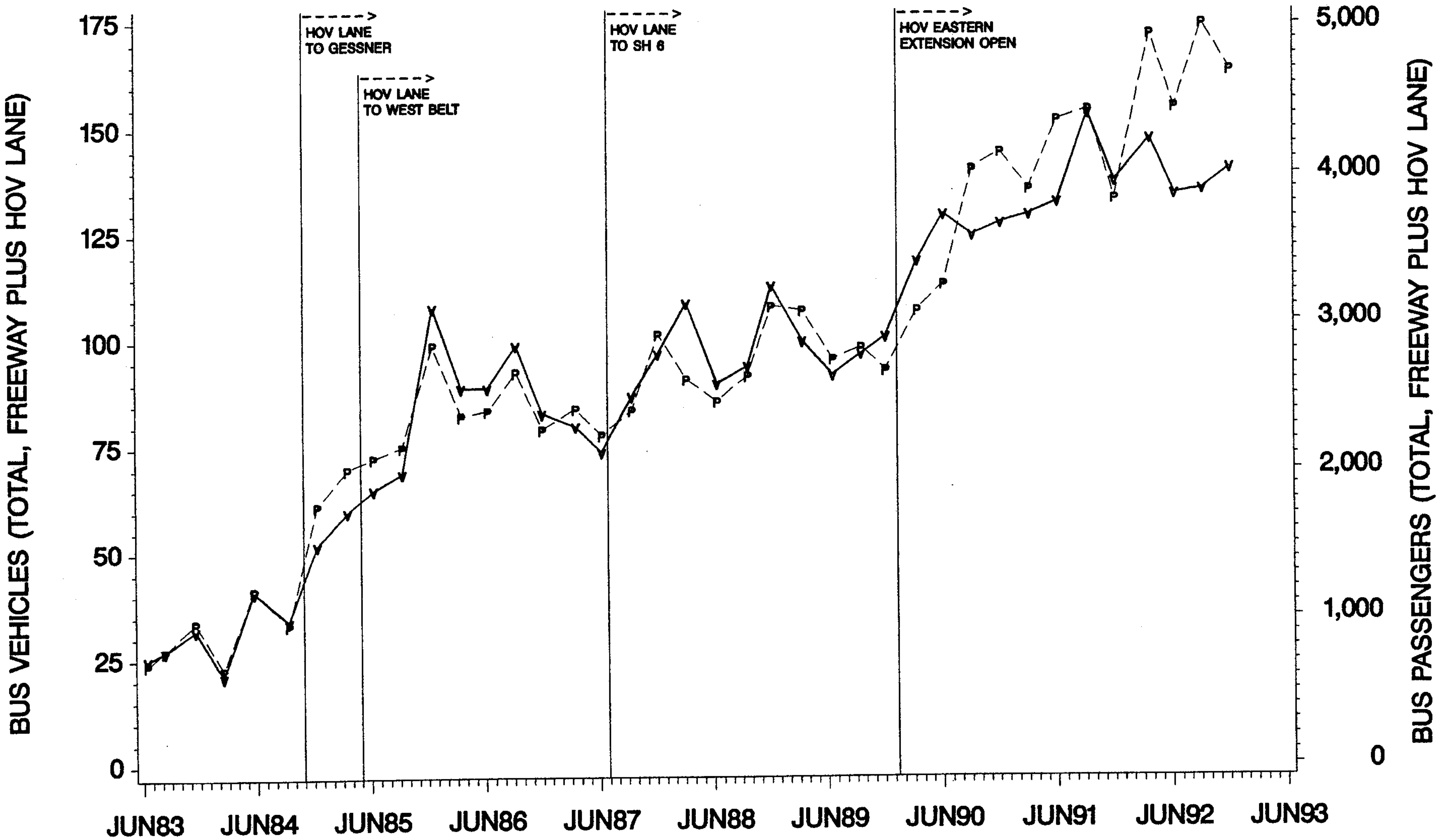


DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE A-19

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

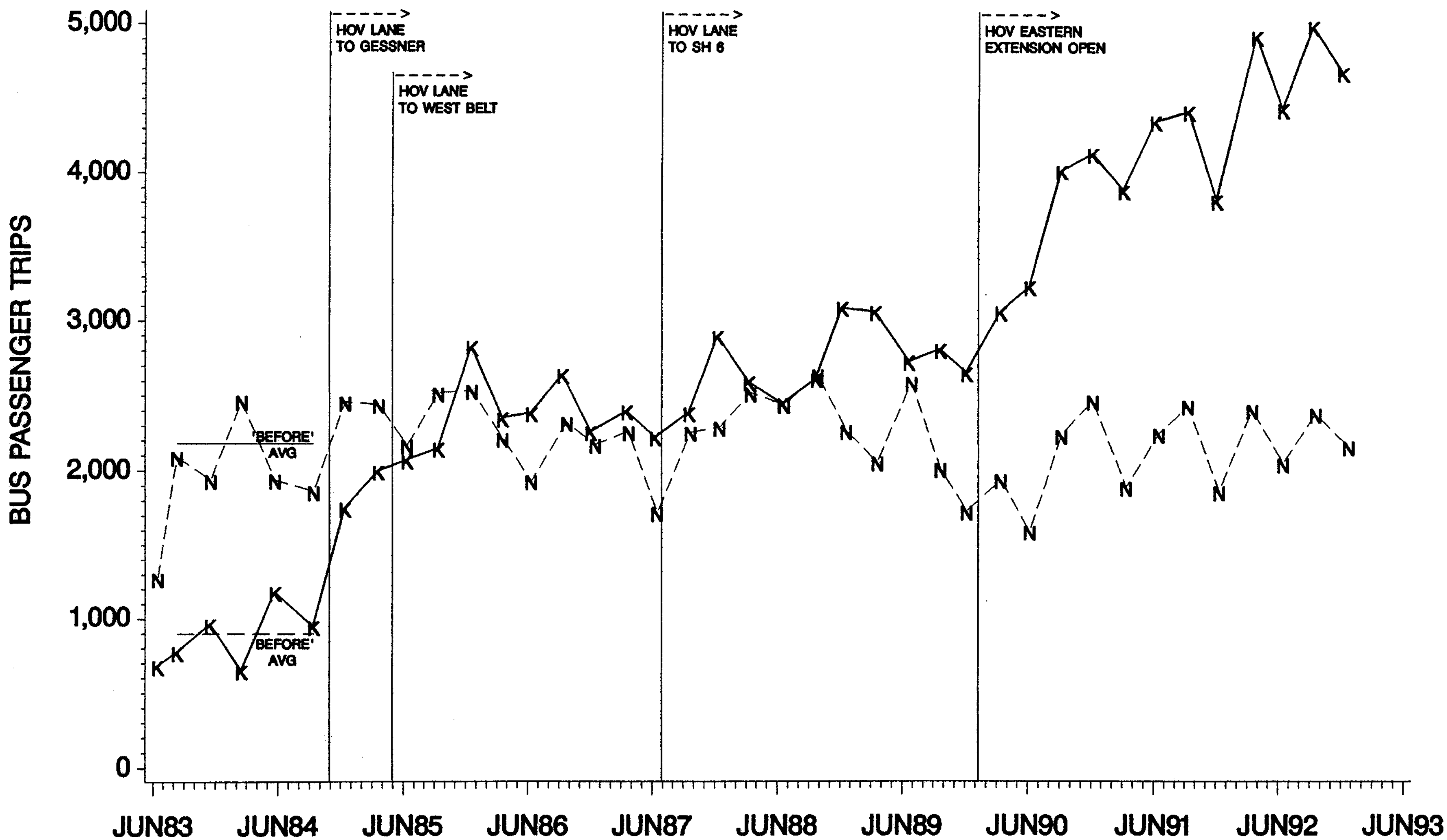


A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE A-20

A.M. PEAK PERIOD BUS PASSENGER TRIPS TOTAL, MAINLANES PLUS HOV LANE VOLUMES FREEWAYS WITH AND WITHOUT HOV LANE

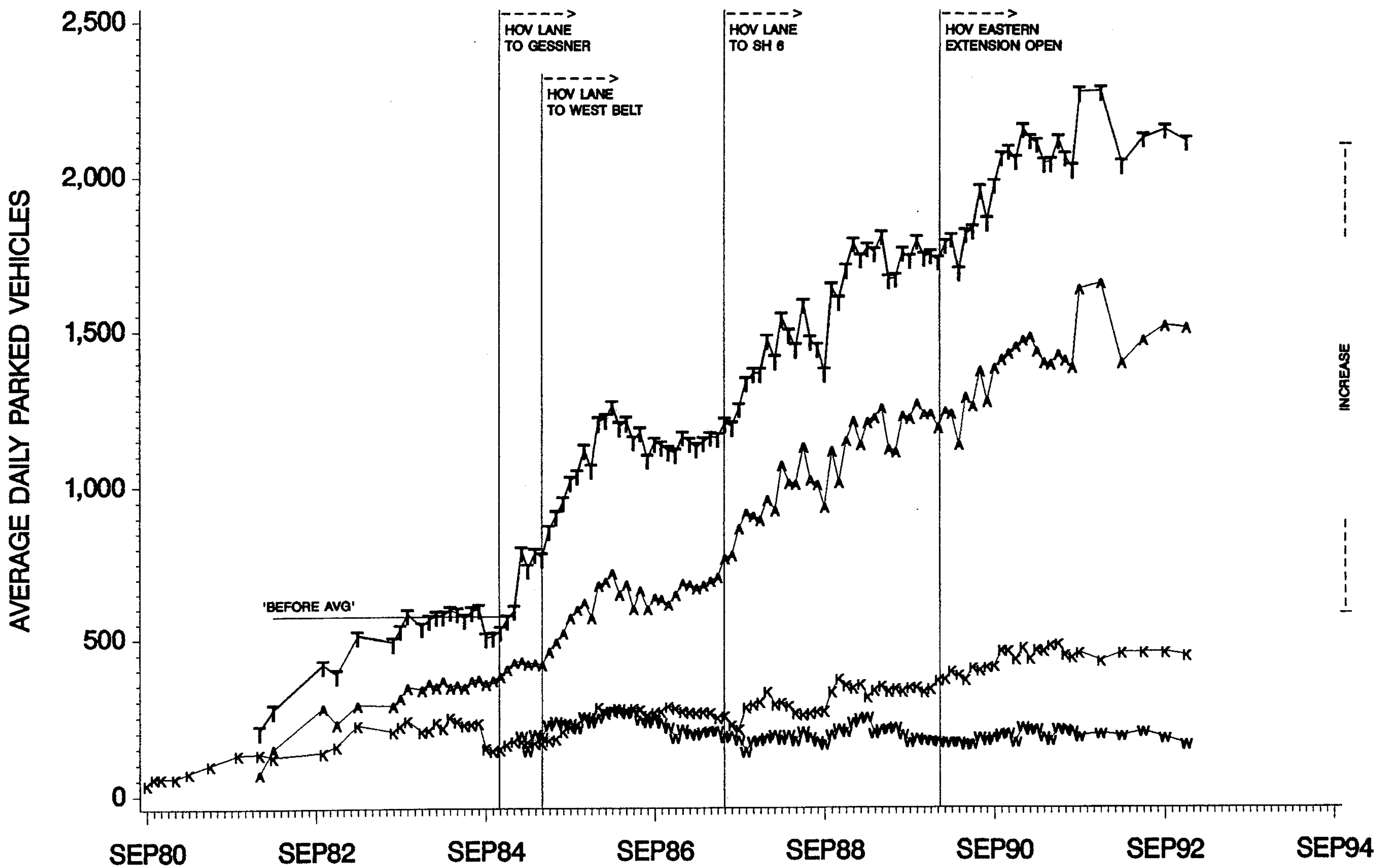


A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF GULF FWY (6/83 – 4/86) AND SOUTHWEST FWY (9/86 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE A-21

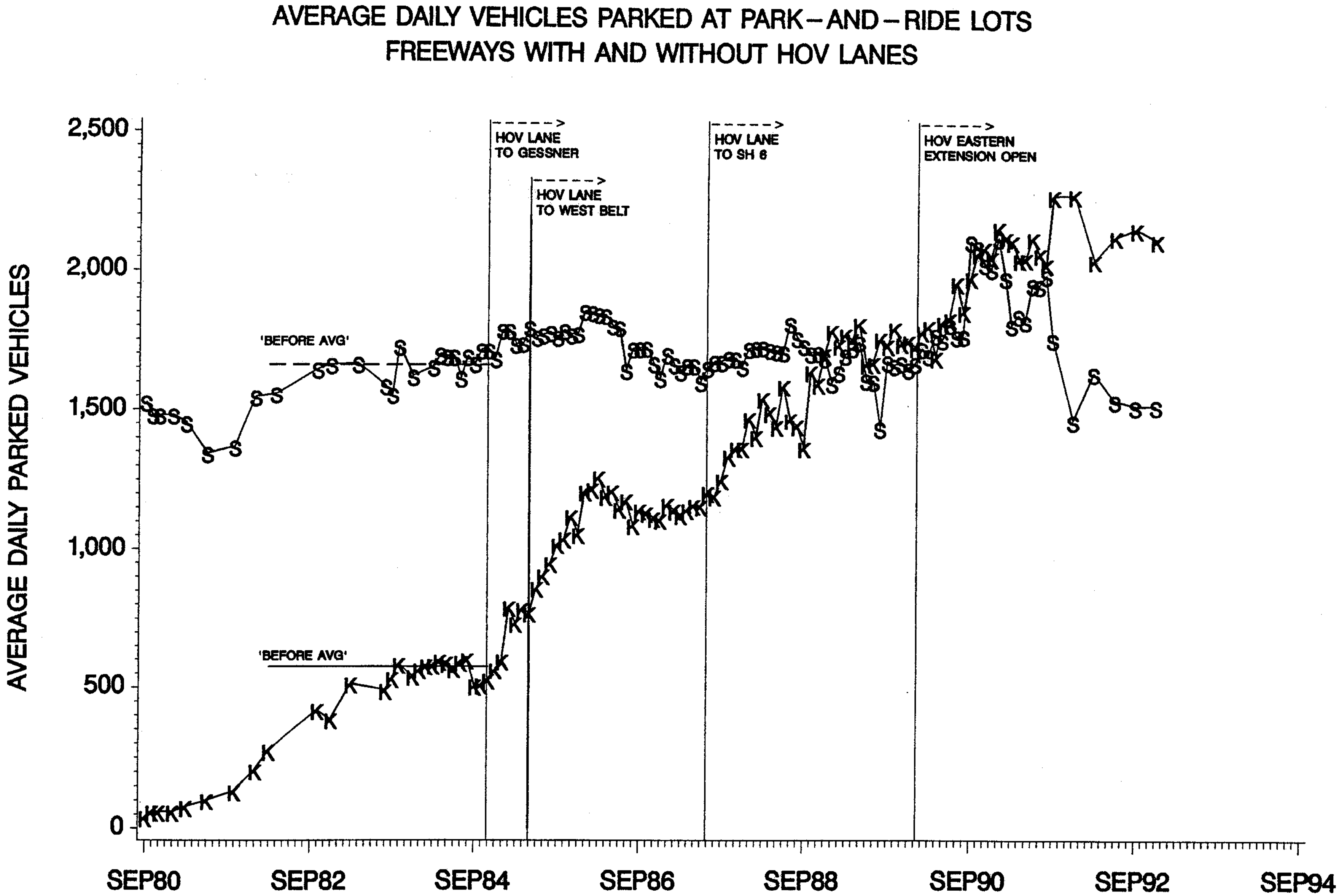
KATY FREEWAY (IH 10W) CORRIDOR PARK-AND-RIDE DEMAND



KATY HOV LANE PHASE 1, POST OAK TO GESSNER (4.7 MI.), OPENED OCTOBER 29, 1984
HOV LANE EXTENSION FROM GESSNER TO WEST BELT (1,.7 MI.) OPENED MAY 2, 1985
HOV LANE EXTENSION FROM WEST BELT TO SH 6 (5.0 MI.) OPENED JUNE 29, 1987
HOV LANE EASTERN EXTENSION (1,.17 MI.) OPENED JANUARY 9, 1990
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL PARKED VEHICLES
K = KINGSLAND LOT (1,326 SPACES)
W = WEST BELT LOT (1,111 SPACES)
A = ADDICKS LOT (1,156 SPACES)

FIGURE A-22



KATY HOV LANE PHASE 1, POST OAK TO GESSNER (4.7 MI.), OPENED OCTOBER 29, 1984
HOV LANE EXTENSION FROM GESSNER TO WEST BELT (1,.7 MI.) OPENED MAY 2, 1985
HOV LANE EXTENSION FROM WEST BELT TO SH 6 (5.0 MI.) OPENED JUNE 29, 1987
HOV LANE EASTERN EXTENSION (1,.17 MI.) OPENED JANUARY 9, 1990
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : K – KATY FREEWAY
S – FREEWAY WITHOUT HOV LANE (SOUTHWEST)

APPENDIX B

NORTH FREEWAY AND HOV LANE DATA

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

Table B-1. Summary of A.M. Peak-Period, Peak-Direction North Freeway and HOV Lane Data, December 1992

Type of Data Phase 1 of HOV Lane Became Operational 8/29/88 Contraflow Lane Became Operational 8/79	"Representative" Pre-Contraflow Value[1]	"Representative" Current Value	% Change
HOV Lane Data			
HOV Lane Length (miles)		13.5	
HOV Lane Cost (millions of 1990 dollars)		$75.9	
Person-Movement			
Peak Hour (7-8 a.m.)	—	5,560	—
Peak Period (6-9:30 a.m.)	—	10,994	—
Total Daily	—	23,030	—
Vehicle Volumes			
Peak Hour	—	1,256	—
Peak Period	—	2,345	—
Vehicle Occupancy, Peak Hour (persons/veh)	—	4.43	—
Accident Rate (i.e., Injury accidents/100 MVM), 4/84-12/92[2]	—	49.6	—
Vehicle Breakdowns (VMT/Breakdown), 4/84-12/92	—	47,200	—
Violation Rate (6-9:30 a.m.)		3.8%	
Peak Hour Lane Efficiency (1000's)[3]	—	276	—
Annual Value of User Time Saved (millions)[4]	—	$2.4 to $4.9	—
Freeway Mainlane Data (see note)			
Person Movement			
Peak Hour	6,335	7,398	+16.8%
Peak Period (6-9:30 a.m.)	—	22,727	—
Vehicle Volume			
Peak Hour	4,950	7,015	+41.7%
Peak Period	—	21,052	—
Vehicle Occupancy, Peak Hour (persons/veh)	1.28	1.05	-18.0%
Accident Rate (i.e., Injury accidents/100 MVM)[2]	30.3	26.0	-14.2%
Avg. Operating Speed[5]			
Peak Hour	20.0	34.5	+72.5%
Peak Period	30.0	46.3	+54.3%
Peak Hour Lane Efficiency (1000's)[3]	41	64	+56.1%

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 between North Shepherd and Hogan, a distance of approximately 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 8/92. Only officer reported accidents are included in files. 1992 freeway volumes estimated by TTI to compute rates.

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

[4] Based on time savings for HOV lane users in 1992, an annual estimate of travel time savings to HOV lane users is developed. A value of time of $10.47/hour is used based on the value applied in the Highway Economic Evaluation Model.

[5] From North Shepherd to Hogan, a distance of 7.8 miles.

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

Table B-2. Summary of North Freeway and HOV Lane Data, December 1992

Type of Data Phase 1 of HOV Lane Became Operational 8/29/88 Contraflow Lane Became Operational 8/79	"Representative" Pre-Contraflow Value[1]	"Representative" Current Value	% Change
Combined Freeway Mainlane and HOV Lane Data			
Total Person Movement			
Peak Hour	6,335	12,958	+104.5%
Peak Period	—	33,721	—
Vehicle Volume			
Peak Hour	4,950	8,271	+67.1%
Peak Period	—	23,397	—
Vehicle Occupancy			
Peak Hour	1.28	1.57	+22.4%
Peak Period	1.28	1.44	+12.5%
2+ Carpool Volumes			
Peak Hour	700	1,607	+129.6%
Travel Time (minutes)[2]			
Peak Hour	23.2[3]	9.4[4]	-59.5%
Peak Period	15.5[3]	8.7[4]	-43.9%
Peak Hour Lane Efficiency (1000's)[5]	41	117	+185.4%
Transit Data[6]			
Bus Vehicle Trips			
Peak Hour	—	67	—
Peak-Period	—	139	—
Bus Passenger Trips			
Peak Hour	—	2,935	—
Peak Period	—	5,950	—
Bus Occupancy (persons/bus)			
Peak Hour	—	43.8	—
Peak Period	—	42.8	—
Vehicles Parked in Corridor Park & Ride Lots	—	3,614	—
Bus Operating Speed (mph)[2]			
Peak Hour	—	49.7[4]	—
Peak Period	—	53.7[4]	—

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] From North Shepherd to Hogan, a distance of 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 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-3. Comparison of Measures of Effectiveness, Freeway With (North, I-45N) and Freeway Without (Southwest US 59) HOV Lane, Houston

Measure of Effectiveness	North Freeway	Southwest Freeway
Average A.M. Peak-Hour Vehicle Occupancy	1.57[1]	1.14
Bus Passengers, Peak Period	5,950	2,174
Cars Parked at Park-and-Ride Lots	3,614	1,522
Facility Per Lane Efficiency	117[2]	60

[1] 1978 pre-contraflow occupancy estimated at 1.28 persons per vehicle
[2] 1978 pre-contraflow per lane efficiency estimated to be 41.

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 (incl. all existing support facilities) in 1990 dollars was $75.9 million. The total cost for the completed HOV lane (1990 dollars) will be $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 (9.1 miles)
  - 3/31/81 a.m. concurrent flow lane to West Road opens (12.9 miles)
  - 11/23/84 HOV Lane HOV replaces contraflow
  - 4/2/90 HOV Lane extended to Beltway 8 (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 1992, 23,030 person trips per day were served on the HOV lane.
- A.M. Peak Hour, 5,560 persons/hour.

  - 2,935 (53%) by bus, 221 (4%) by vanpool, and 2,401 (43%) by carpool, (Figure B-1).
  - Average HOV lane vehicle occupancy = 4.4 persons/vehicle.

- A.M. Peak Period, 10,994 persons.
  - 5,950 (54%) by bus, 639 (6%) by vanpool, and 4,399 (40%) by carpool (Figure B-2).

Table B-4. 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 Mile		$4.3			$4.1
Surveillance, Communication and Control (1990)		$2.6	1.00		$2.6
SUB-TOTAL	$2.6			$2.6	
Per Mile		$0.2			$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 Mile		$1.3			$1.4
TOTAL COST	$78.6			$75.9	
COST PER MILE (13.5 miles)	$5.8			$5.6	

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

Table B-5. 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	14.6
SUB-TOTAL	$49.2		$50.0
Per Mile	$7.9		$8.1
Surveillance, Communication and Control	$1.5		$1.5
Support Facilities			
Kuykendahl P/R Expansion	$7.4	1.00	$8.1
SUB-TOTAL	$15.5		$ 8.1
Per Mile	$2.5		$1.3
TOTAL COST	$66.2		$59.6
COST PER MILE (6.2 miles)	$10.4		$ 9.6

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

VEHICLE MOVEMENT

- A.M. Peak Hour, 1,256 vph
  - 67 (5%) buses, 21 (2%) vans, and 1,165 (93%) carpools (Figure B-3).

- A.M. Peak Period, 2,345 vehicles.
  - 139 (6%) buses, 61 (3%) vans, and 2,139 (91%) carpools (Figure B-4).

ACCIDENT RATE

- For the period from November 1984 through December 1992, the HOV lane accident rate was 49.6 injury accidents per 100 million vehicle miles.

VEHICLE BREAKDOWN RATES

- The following vehicle breakdown rates was observed between December, 1984 and December 1992.

  - Overall weighted average; 1 breakdown per 47,200 VMT.

VIOLATION RATE

- The observed violation rate (vehicles on the HOV lane not eligible to use the HOV lane) for December 1992 was approximately 3.8%.

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 276.

TRAVEL TIME SAVINGS

- The users of the HOV lane experienced a travel time savings of 8 minutes during the morning peak hour in 1992 (Figure B-5).

- The tables on the following page indicate that, on a typical non-incident day, travel time savings of approximately 930 hours (55,814 min.) are realized. Assuming 250 days of operation, annual savings would be 232,557 hours. At $10.47/hour, this equates to $2.44 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 $2.44 to $4.87 million per year.

Table B-6. Southbound A.M. Travel Time Savings for North HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1992)

Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	T-Way (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section from Sam Houston Parkway to N. Shepherd								
6:00	4.83	4.55	0.28	249	137	348	734	204.77
6:30	5.15	4.66	0.49	644	104	713	1,460	711.87
7:00	5.43	4.85	0.58	1,048	111	900	2,059	1,200.81
7:30	7.19	4.86	2.33	918	21	792	1,730	4,032.65
8:00	4.62	4.67	-0.05	473	18	518	1,009	-54.65
8:30	4.48	4.62	-0.14	180	8	127	316	-44.73
9:00	4.52	4.63	-0.11	78	3	36	117	-12.68
Peak Period Total				3,612	432	3,418	7,462	6,038.05
Section From N. Shepherd to the Hogan Overpass								
6:00	8.20	8.33	-0.13	285	184	591	1,060	-141.29
6:30	8.26	8.35	-0.09	764	157	1,073	1,994	-174.45
7:00	16.92	10.18	6.74	1,177	102	1,217	2,496	16,830.67
7:30	18.76	10.45	8.32	1,139	37	1,168	2,344	19,491.08
8:00	12.73	9.23	3.49	547	7	748	1,302	4,547.03
8:30	8.18	8.88	-0.70	242	3	211	455	-320.58
9:00	8.07	8.56	-0.49	76	1	43	120	-59.00
Peak Period Total				4,250	512	5,189	9,950	40,173.47
Northbound P.M. Travel Time Savings for North HOV Lane								
Section from Sam Houston Parkway to N. Shepherd								
3:30	4.50	4.55	-0.05	103	12	84	198	-9.91
4:00	4.85	4.99	-0.15	296	137	419	852	-126.60
4:30	5.79	5.59	0.20	436	98	566	1,100	215.37
5:00	7.18	5.38	1.80	752	113	811	1,676	3,015.95
5:30	8.27	6.45	1.82	901	91	827	1,819	3,311.65
6:00	4.81	5.74	-0.93	524	20	558	1,102	-1,023.71
6:30	4.50	4.59	-0.09	238	2	275	515	-45.08
Peak Period Total				3,249	472	3,540	7,261	5,337.68
Section from N. Shepherd to the Hogan Overpass								
3:30	7.96	8.19	-0.23	194	35	211	439	-102.39
4:30	8.85	8.47	0.38	427	198	683	1,308	501.40
4:30	8.88	8.88	-0.01	577	121	806	1,503	-12.46
5:00	10.61	8.89	1.72	998	127	1,197	2,321	3,984.89
5:30	10.35	10.27	0.08	1,000	126	1,316	2,442	193.35
6:00	8.35	8.51	-0.17	531	10	695	1,236	-206.01
6:30	8.03	8.25	-0.22	170	0	254	424	-94.21
Peak Period				3,895	616	5,161	9,673	4,264.56

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 7,398 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 7,015 vehicles used the mainlanes during 1992 (Figure B-6). Prior to contraflow implementation, limited data suggest this value was 4,950.

- In the a.m. peak period, an average of 21,052 vehicles used the mainlanes (Figure B-7).

VEHICLE OCCUPANCY

- In the a.m. peak hour, mainlane occupancy is approximately 1.05 (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 30.3 injury accidents per 100 million vehicle miles (100 MVM). From 12/84 through 8/92, (since the barrier-separated HOV lane opened) the accident rate has been 26.0 injury accidents/100 MVM. Only officer reported accidents are included. 1992 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 64.

COMBINED FREEWAY AND HOV LANE DATA

TOTAL PERSON MOVEMENT

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

    - At Little York, the HOV lane is carrying 43% of the total peak-hour person movement (Figure B-11). In the peak period, the HOV lane carries 33% of the a.m. peak period person trips (Figure B-12). Compared to pre-contraflow conditions, peak-hour person movement has increased by 104.5%.

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.57 versus 1.05 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 117 (Figure B-14). Prior to contraflow lane implementation in 1978, the per lane efficiency was estimated to be 41. 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 3,000 passengers per peak hour (Figure B-16) and about 5,000 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).

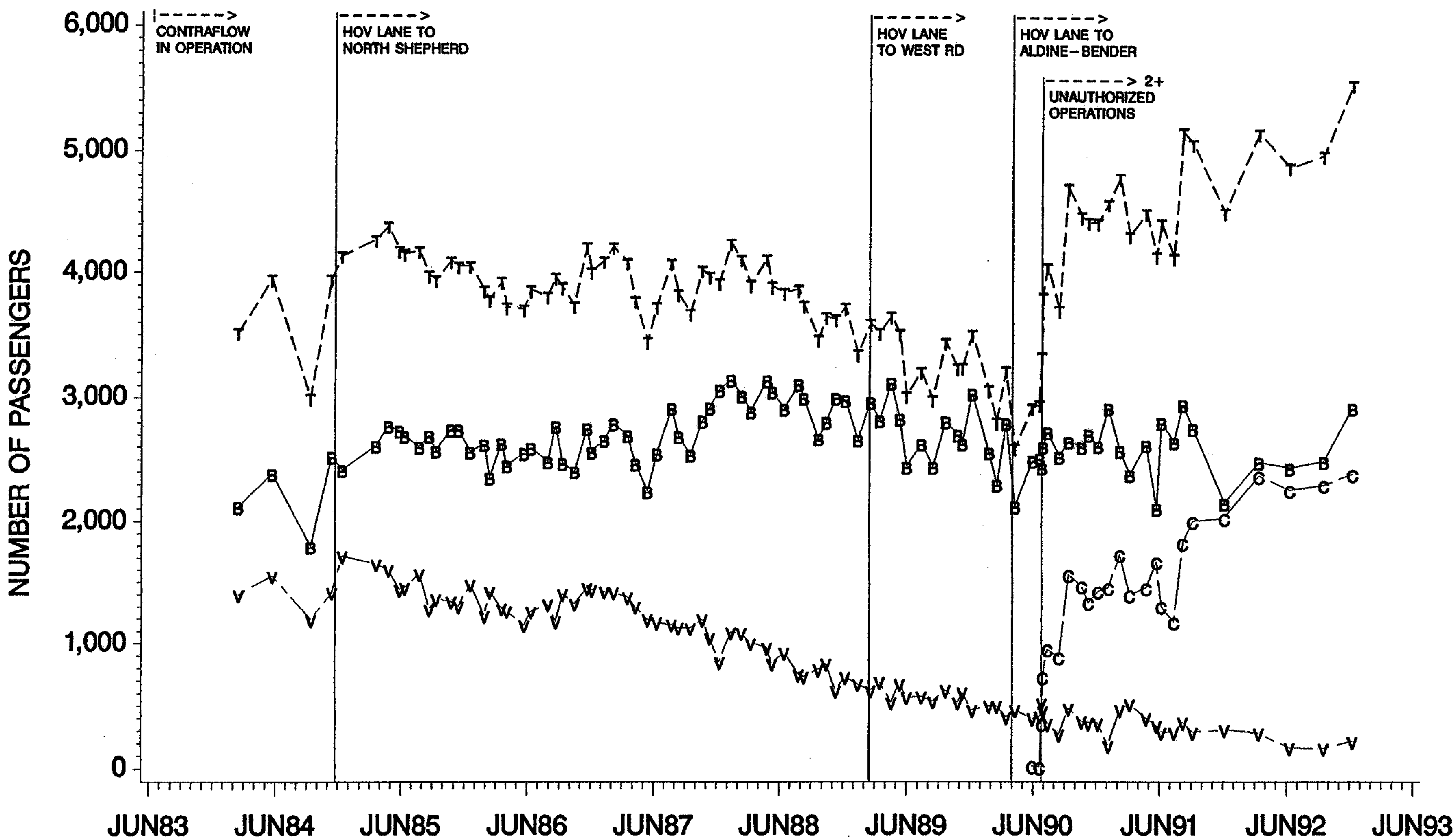
PARK-AND-RIDE

- Currently, 3,614 vehicles are parked in the corridor park-and-ride lots. Approximately 52% of the 7,017 parking spaces are utilized (Figure B-19).

- The Southwest Freeway corridor (which does not have a HOV lane) has less than half the number of park-and-ride patrons as the North Freeway corridor. Southwest Freeway park-and-ride lots are operating at only 40% capacity as opposed to 52% on North Freeway (Figure B-20).

FIGURE B-1

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

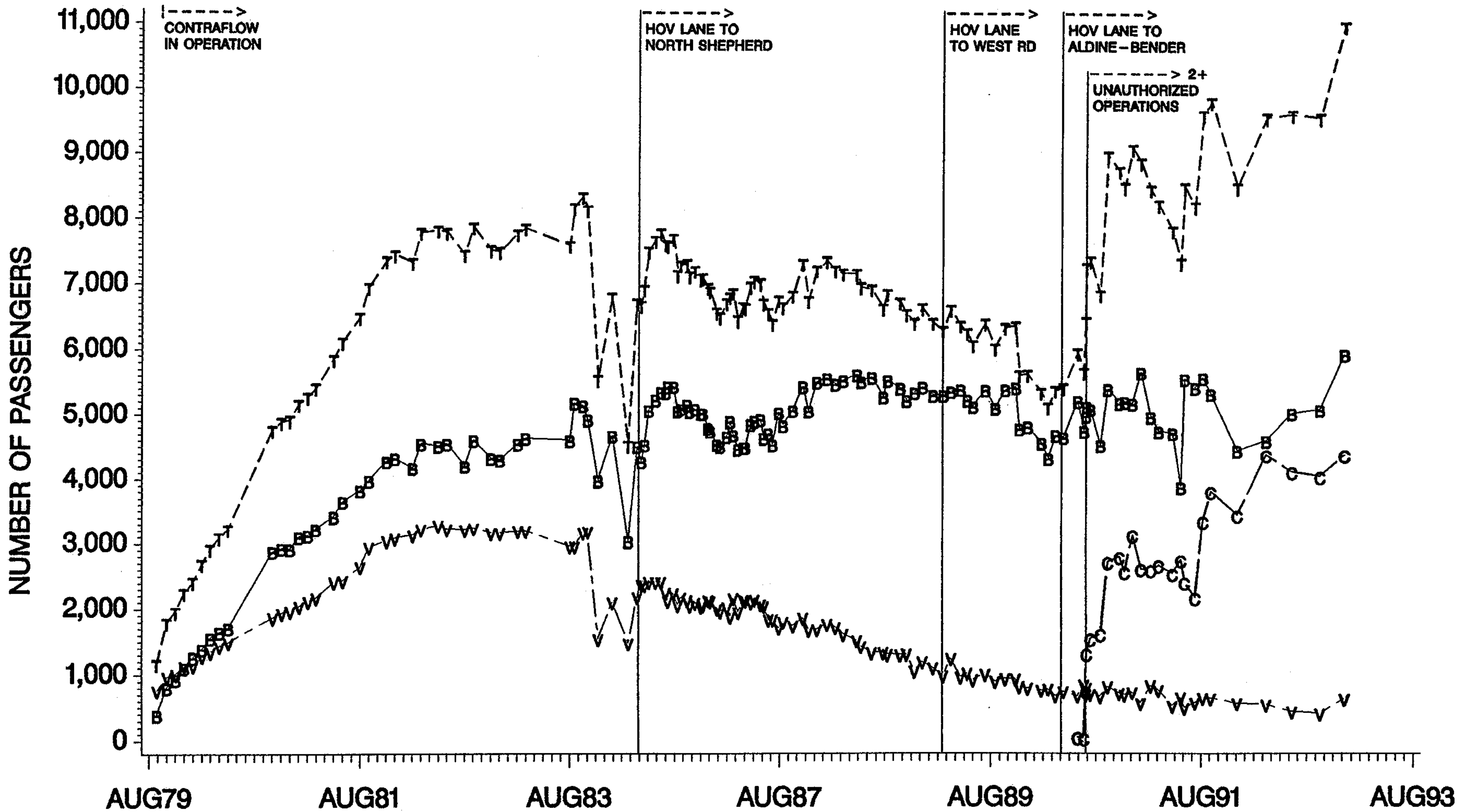


CONTRAFLOW OPERATION, CBD TO N SHEPHERD (9.1 MI), BEGAN AUGUST 28, 1979
HOV LANE OPERATION, CBD TO N SHEPHERD (9.1 MI), BEGAN NOVEMBER 23, 1984
HOV LANE EXTENSION, N SHEPHERD TO ALDINE-BENDER (4.29 MI.), OPENED APRIL 2, 1990
2+ CARPOOL AND OFF-PEAK OPERATION BEGAN JUNE 26, 1990
DATA COLLECTED SOUTHBOUND AT LITTLE YORK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL HOV 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

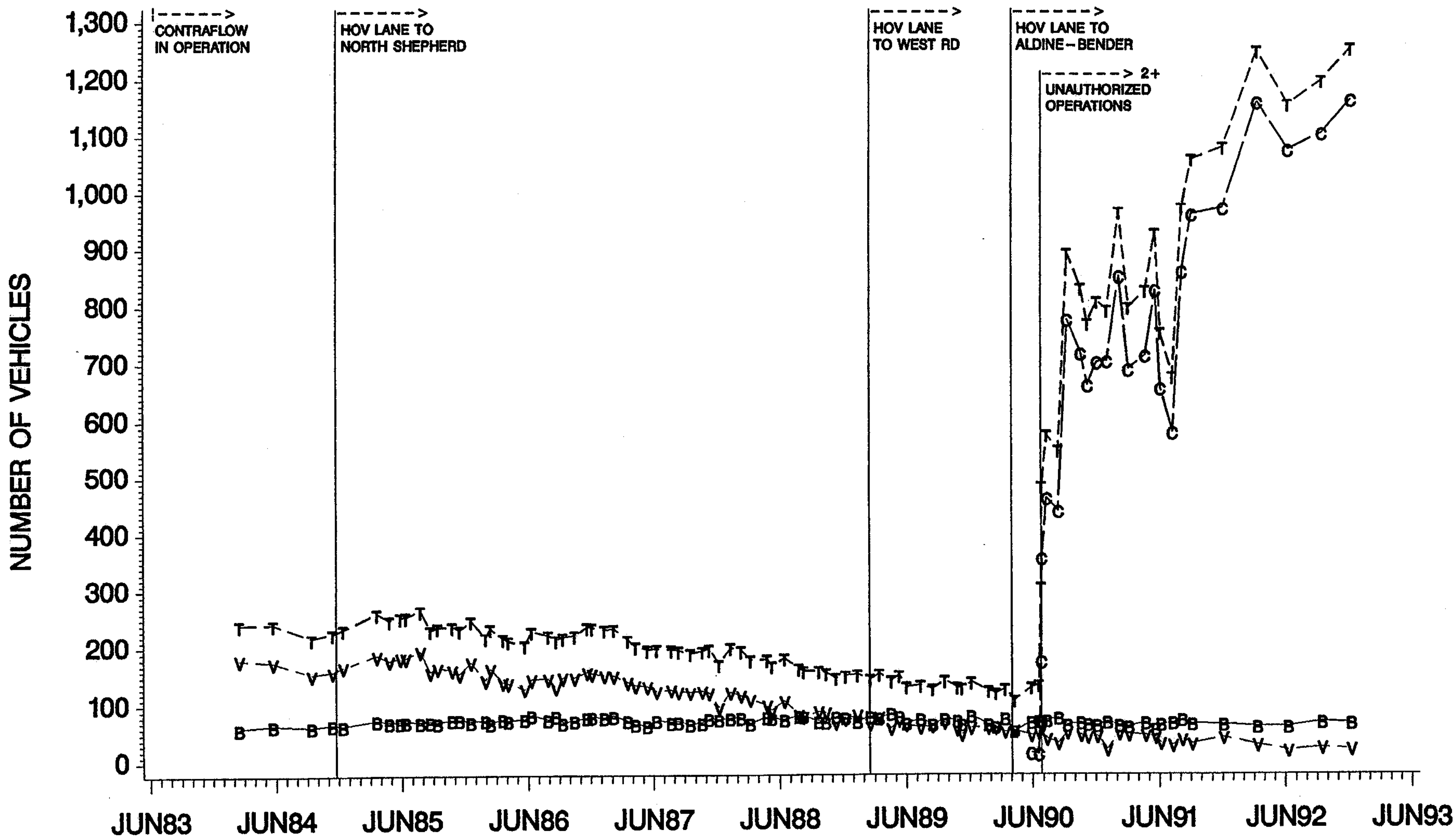


THE A.M. PEAK PERIOD IS 6:00 TO 8:45 A.M. FROM AUGUST 1979 THROUGH JUNE 1990
SINCE JUNE 1990 THE A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M
CONTRAFLOW OPERATION, CBD TO N SHEPHERD (9.1 MI), BEGAN AUGUST 28, 1979
HOV LANE OPERATION, CBD TO N SHEPHERD (9.1 MI), BEGAN NOVEMBER 23, 1984
HOV LANE EXTENSION, N SHEPHERD TO ALDINE-BENDER (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 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

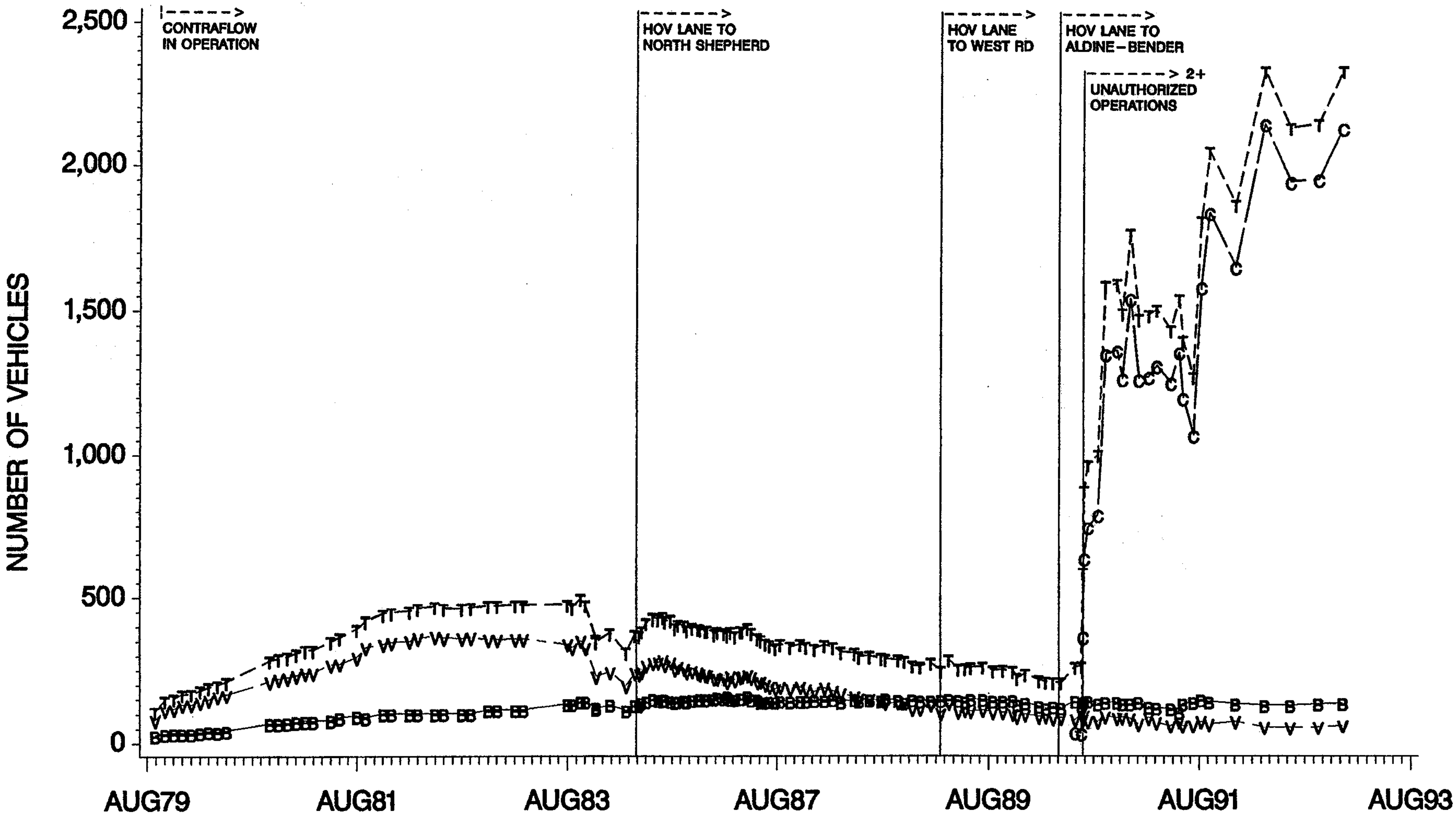


CONTRAFLOW OPERATION, CBD TO N SHEPHERD (9.1 MI), BEGAN AUGUST 28, 1979
HOV LANE OPERATION, CBD TO N SHEPHERD (9.1 MI), BEGAN NOVEMBER 23, 1984
HOV LANE EXTENSION, N SHEPHERD TO ALDINE-BENDER (4.29 MI.), OPENED APRIL 2, 1990
2+ CARPOOL AND OFF-PEAK OPERATION BEGAN JUNE 26, 1990
DATA COLLECTED SOUTHBOUND 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

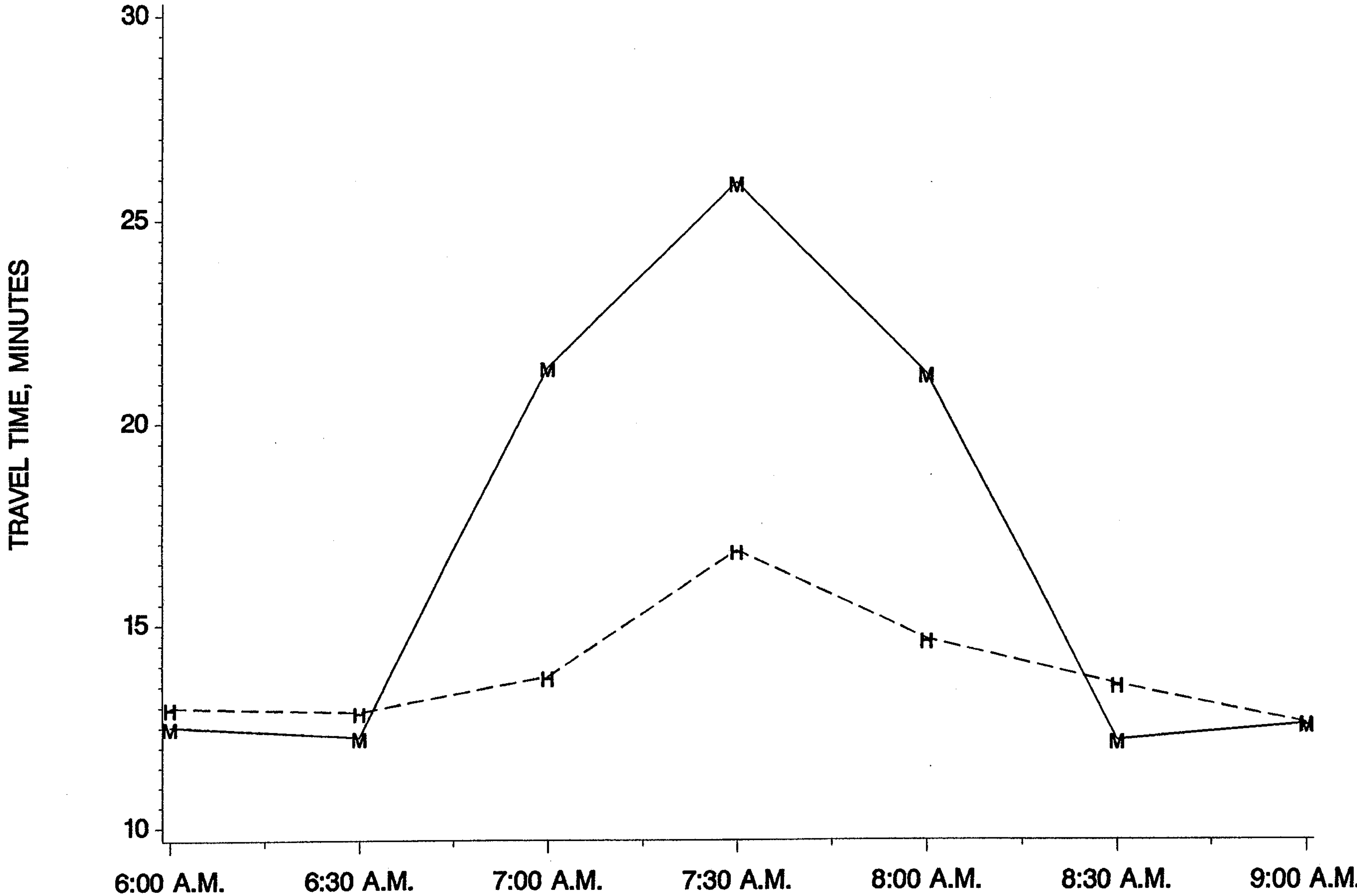


THE A.M. PEAK PERIOD IS 6:00 TO 8:45 A.M. FROM AUGUST 1979 THROUGH JUNE 1990
SINCE JUNE 1990 THE A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M
CONTRAFLOW OPERATION, CBD TO N SHEPHERD (9.1 MI), BEGAN AUGUST 28, 1979
HOV LANE OPERATION, CBD TO N SHEPHERD (9.1 MI), BEGAN NOVEMBER 23, 1984
HOV LANE EXTENSION, N SHEPHERD TO ALDINE-BENDER (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

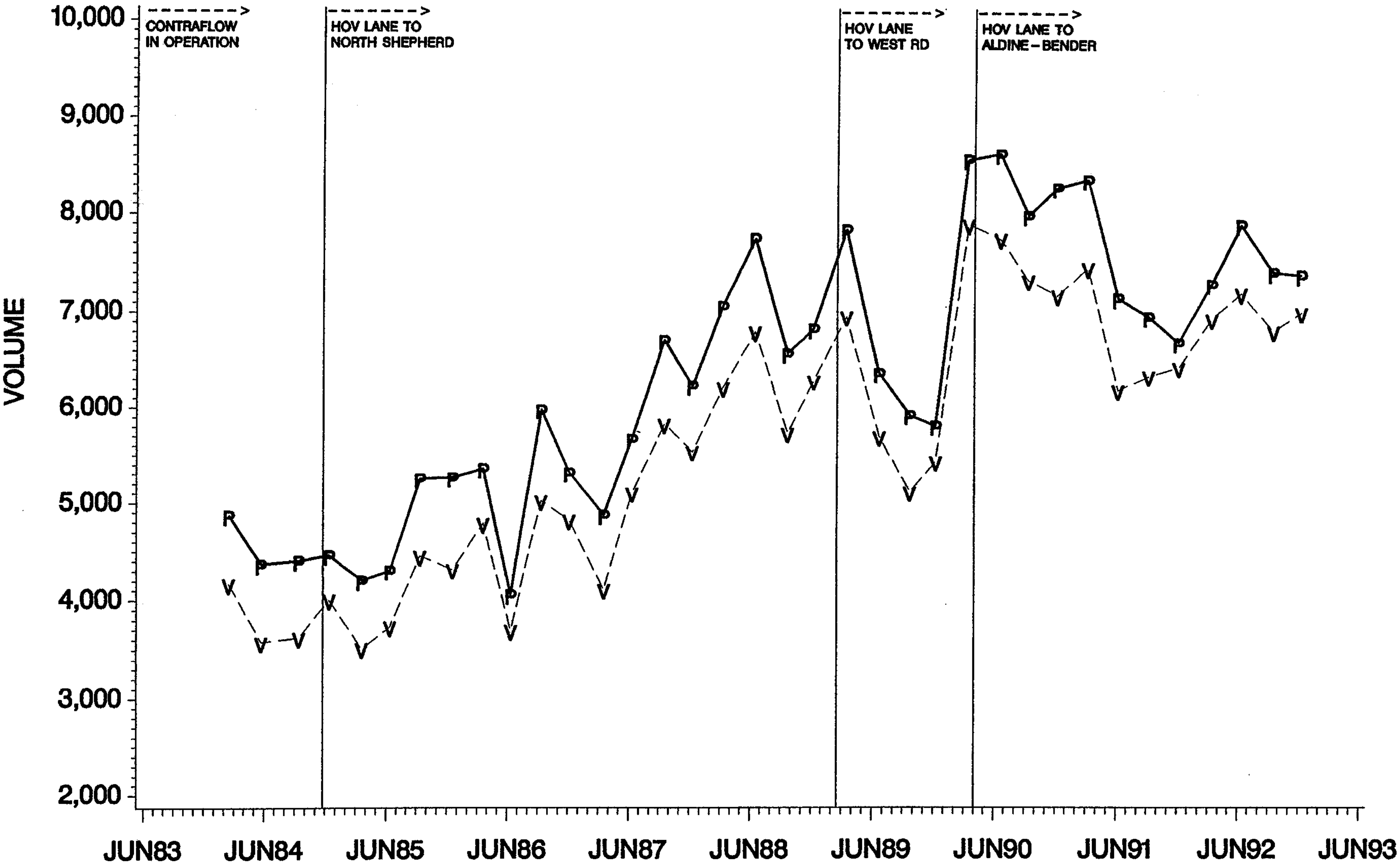


TRAVEL TIMES ARE FROM NORTH SAM HOUSTON PARKWAY TO HOGAN
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE B-6

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

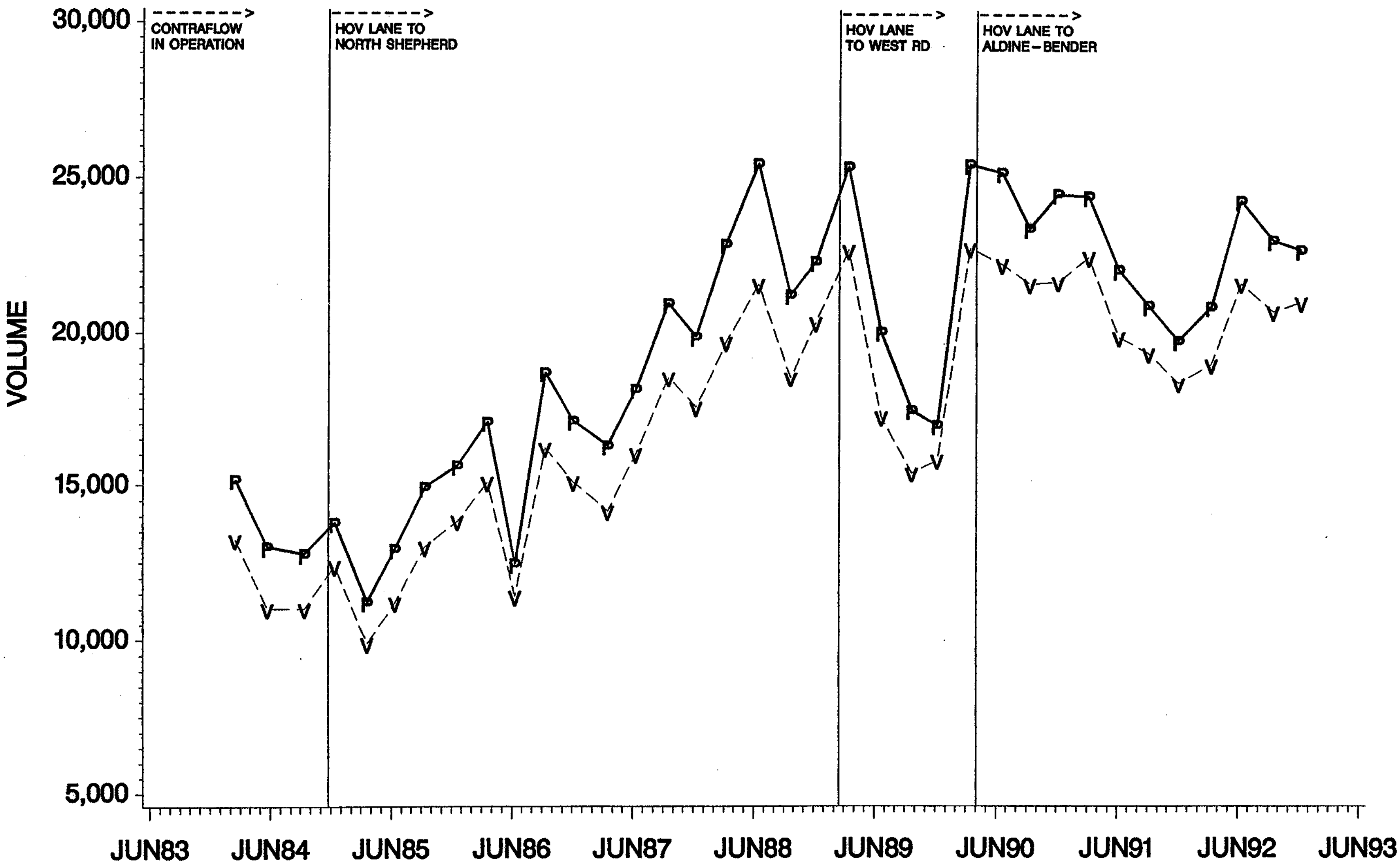


DATA COLLECTED SOUTHBOUND AT LITTLE YORK
SOUTHBOUND CROSS SECTION AT LITTLE YORK EXPANDED FROM 3 TO 4 LANES IN JUNE, 1987
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = MAINLANE PERSONS
V = MAINLANE VEHICLES

FIGURE B-7

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

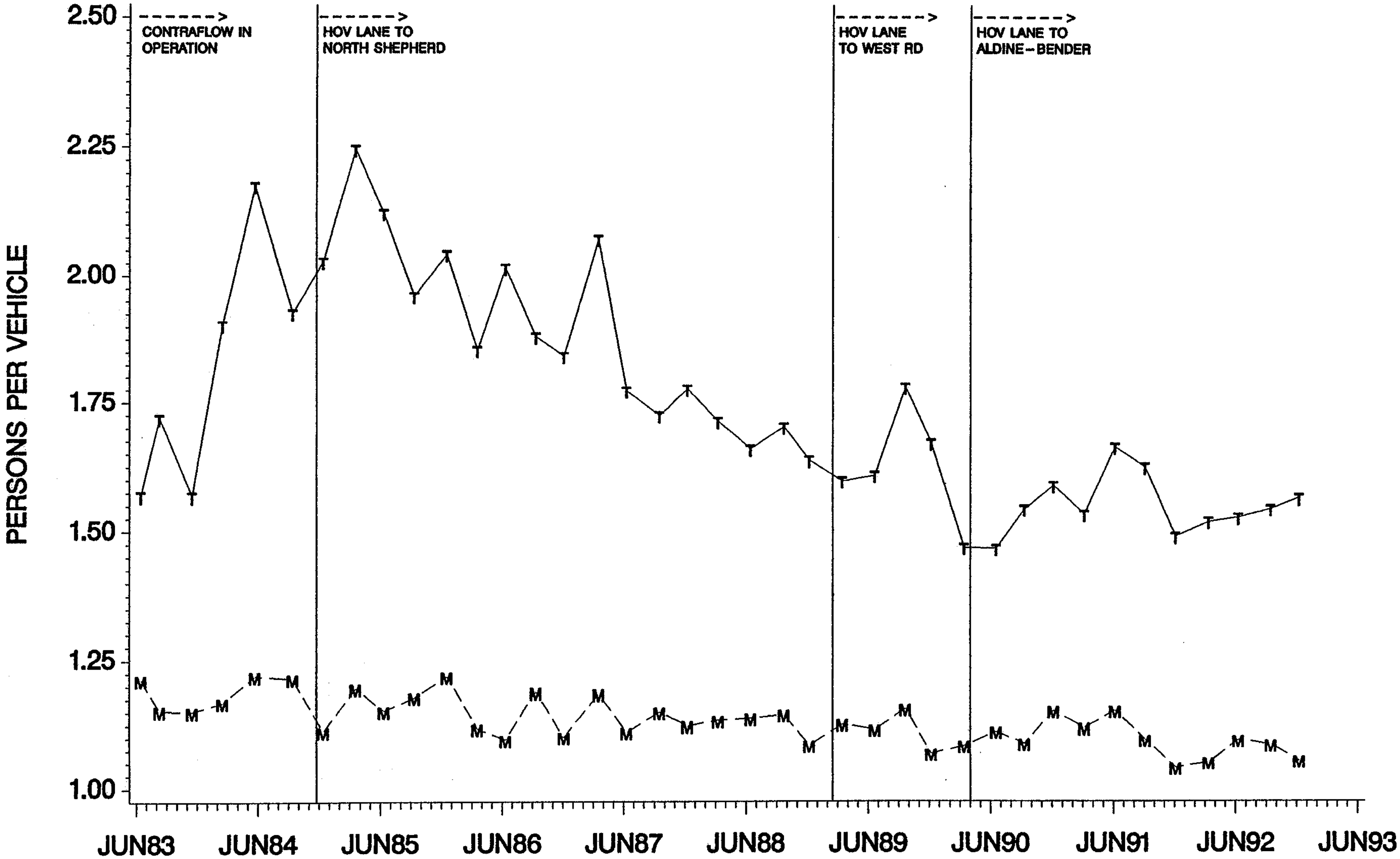


A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA COLLECTED SOUTHBOUND AT LITTLE YORK
SOUTHBOUND CROSS SECTION AT LITTLE YORK EXPANDED FROM 3 TO 4 LANES IN JUNE, 1987
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = MAINLANE PERSONS
V = MAINLANE VEHICLES

FIGURE B-8

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

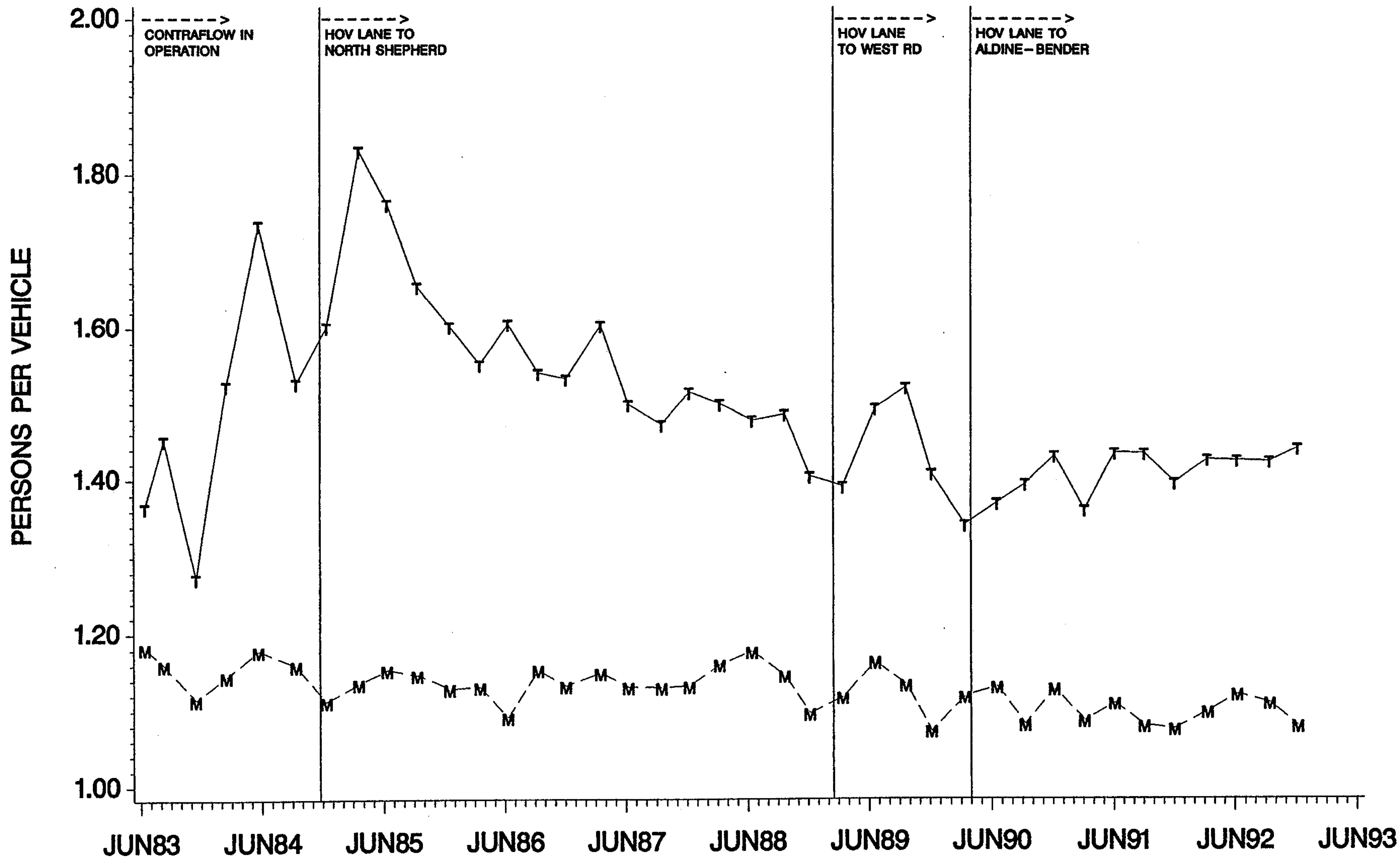


DATA COLLECTED SOUTHBOUND AT LITTLE YORK
SOUTHBOUND FREEWAY CROSS SECTION INCREASED FROM 3 TO 4 LANES IN JUNE 1987
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

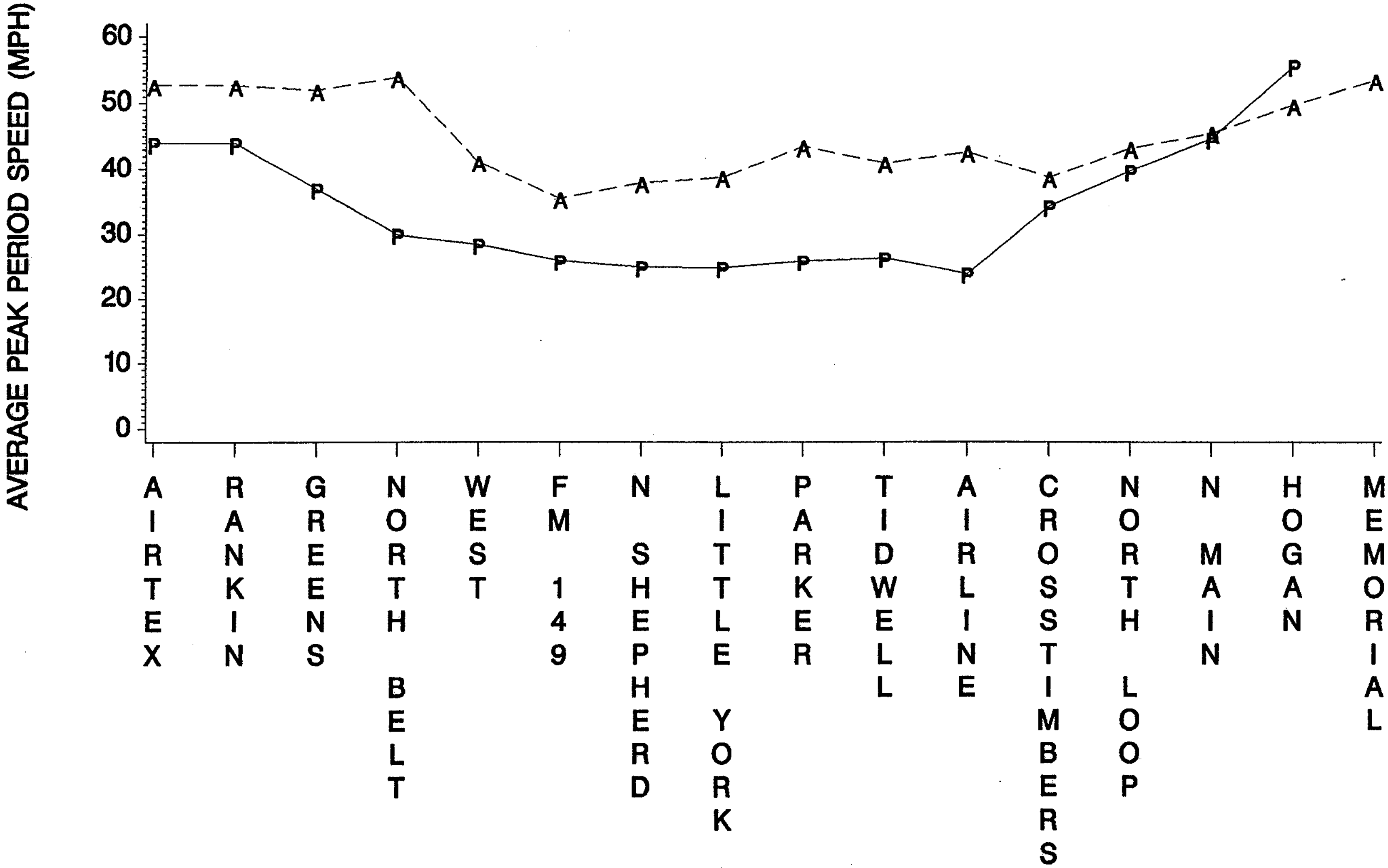


DATA COLLECTED SOUTHBOUND AT LITTLE YORK
PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
SOUTHBOUND FREEWAY CROSS SECTION INCREASED FROM 3 TO 4 LANES IN JUNE 1987
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

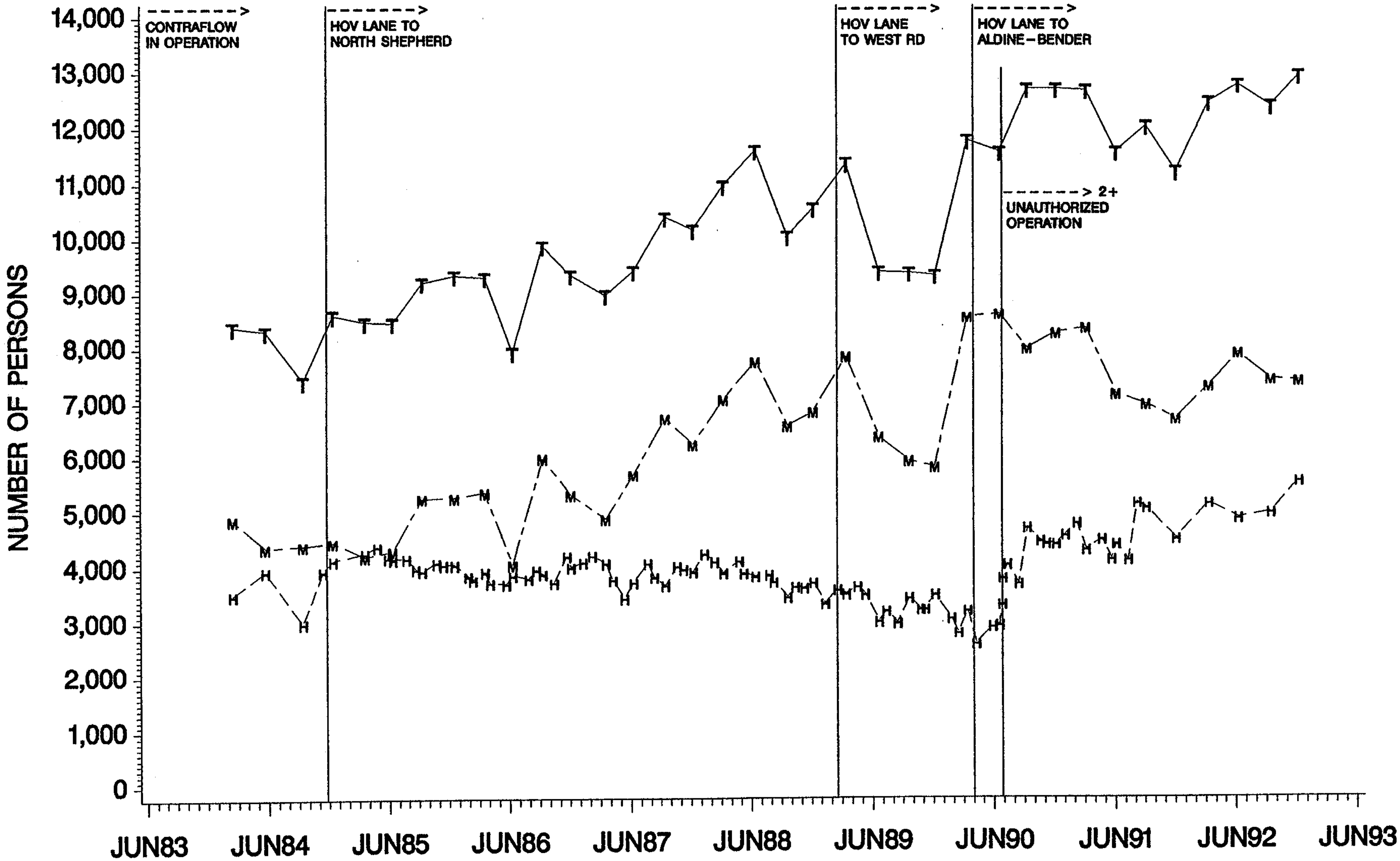


DATA COLLECTED 6:00 TO 9:30 A.M.
DATA COLLECTED FROM JUNE, 1983 TO DECEMBER, 1992
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE B-11

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

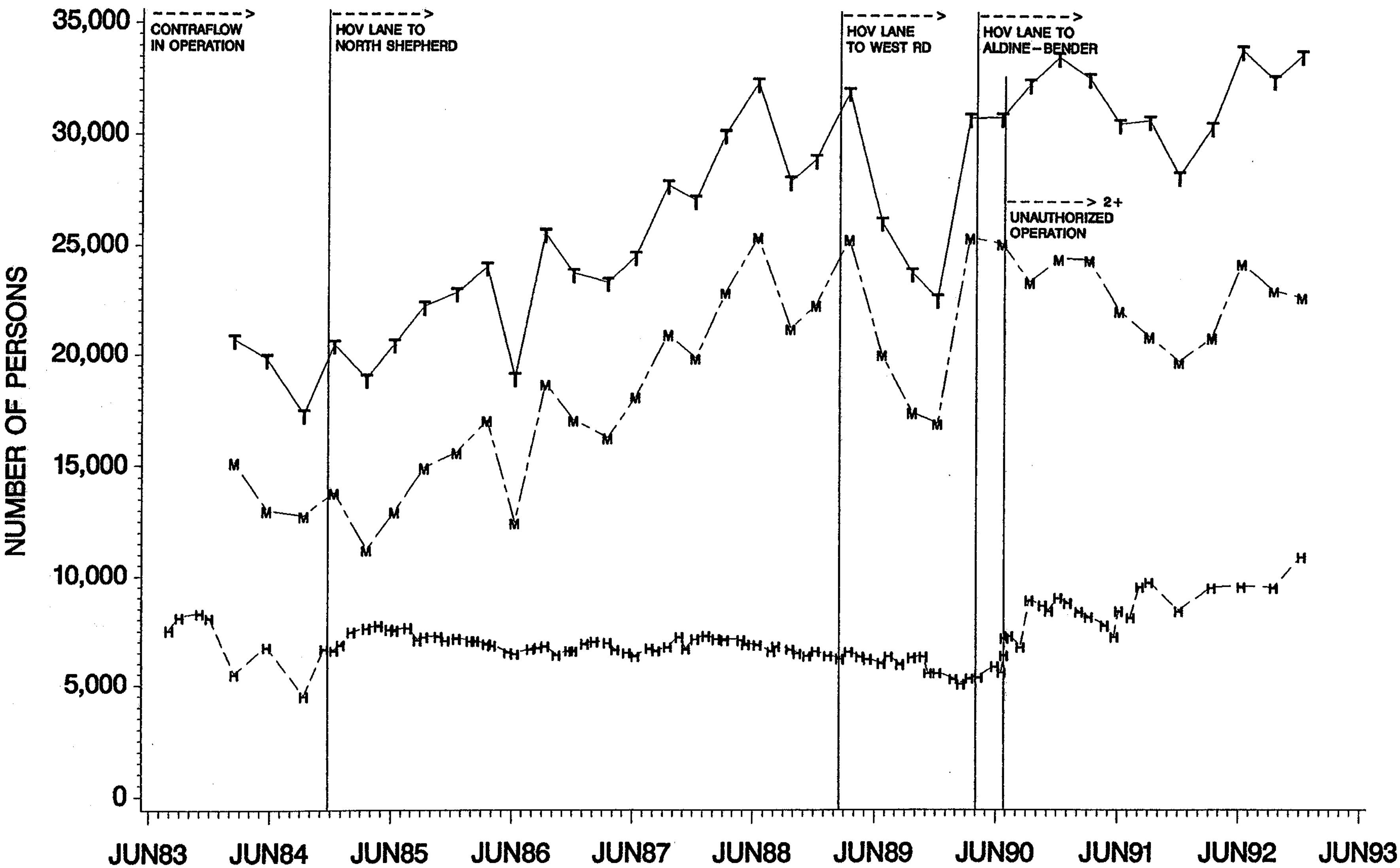


DATA COLLECTED SOUTHBOUND AT LITTLE YORK, 4 LANE SECTION
SOUTHBOUND CROSS SECTION AT LITTLE YORK EXPANDED FROM 3 TO 4 LANES IN JUNE, 1987
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

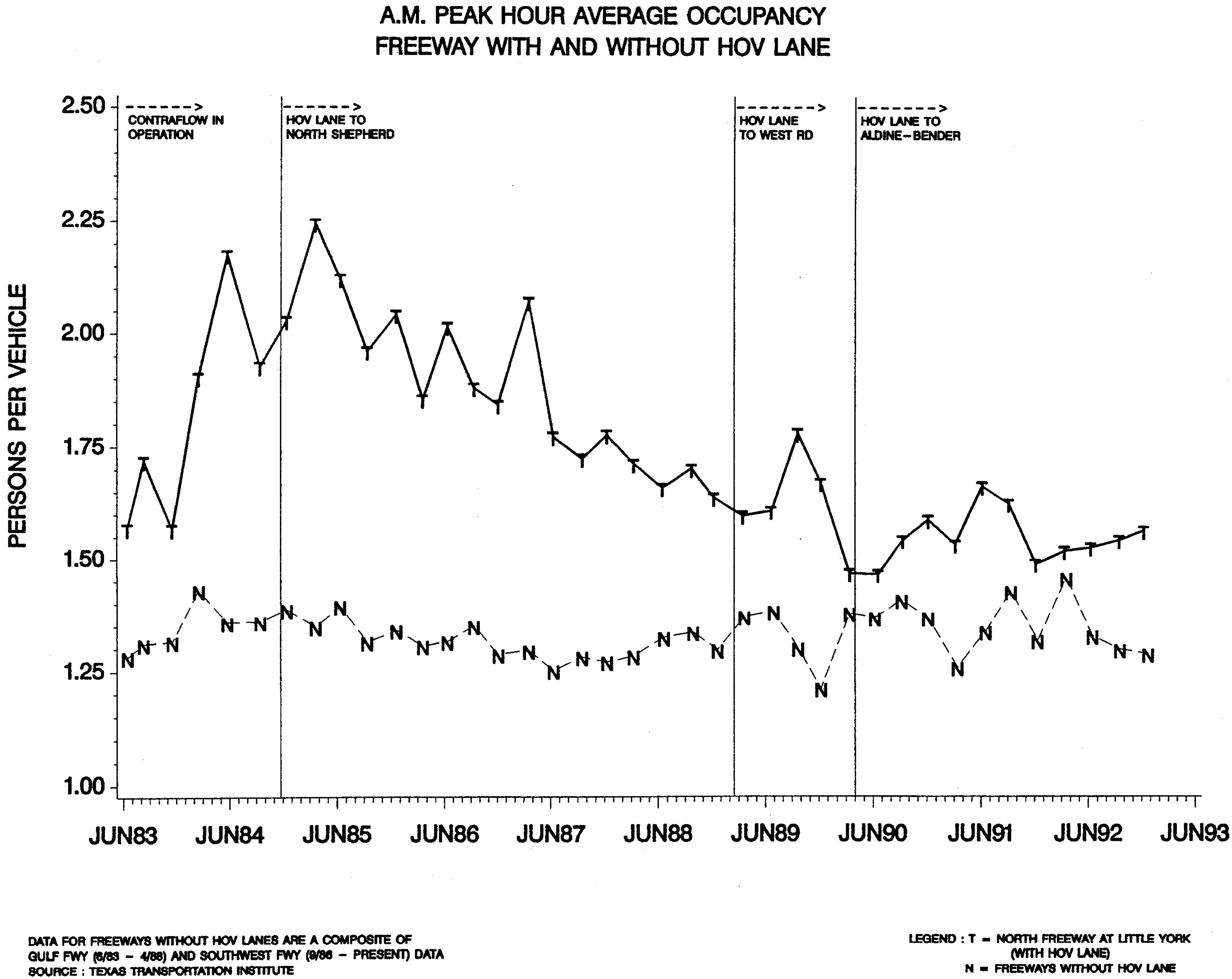
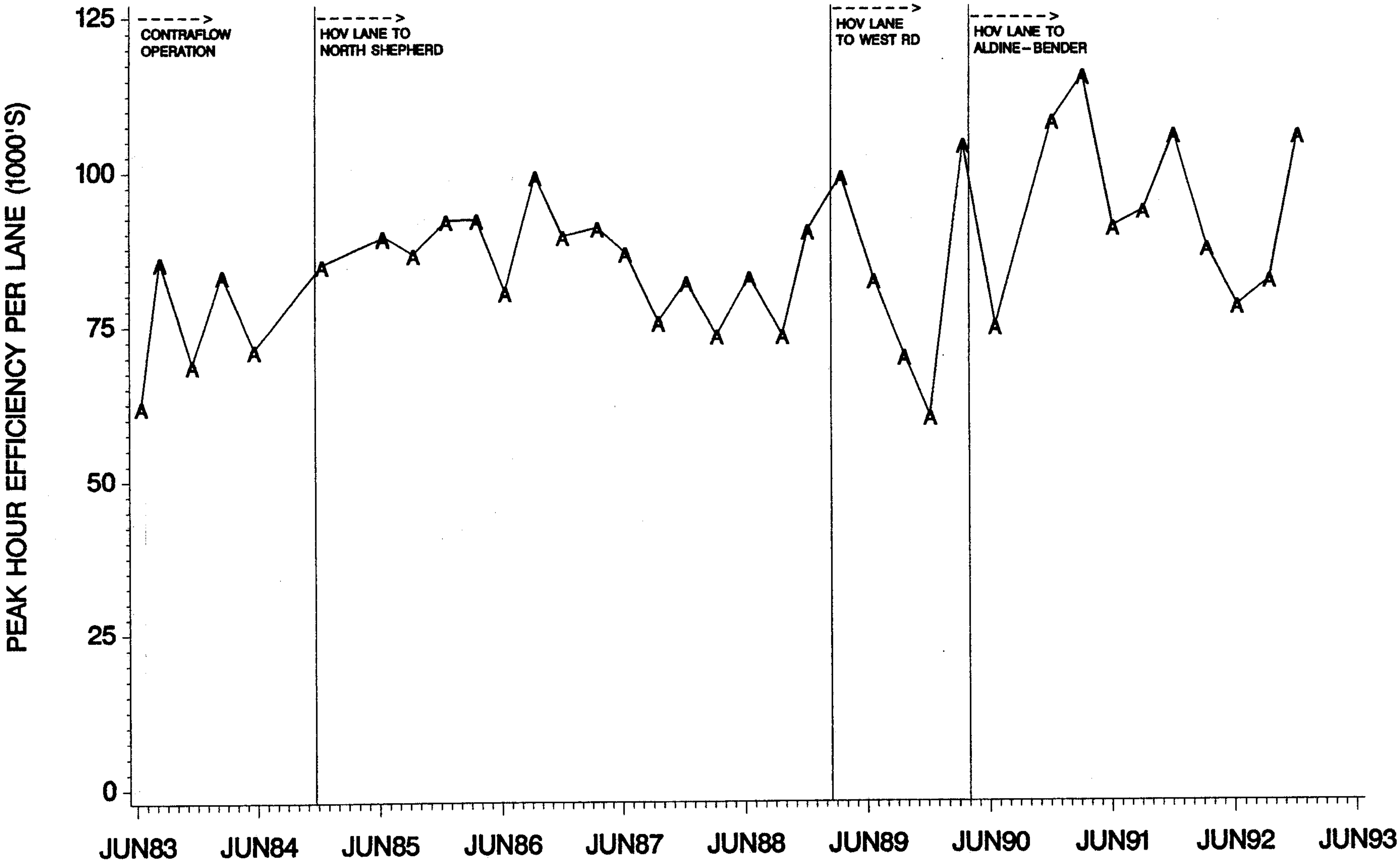

A.M. PEAK HOUR AVERAGE OCCUPANCY
FREEWAY WITH AND WITHOUT HOV LANE
PERSONS PER VEHICLE
2.50
2.25
2.00
1.75
1.50
1.25
1.00
-------> CONTRAFLOW IN OPERATION
-------> HOV LANE TO NORTH SHEPHERD
-------> HOV LANE TO WEST RD
-------> HOV LANE TO ALDINE-BENDER
JUN83
JUN84
JUN85
JUN86
JUN87
JUN88
JUN89
JUN90
JUN91
JUN92
JUN93
DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF
GULF FWY (6/83 - 4/86) AND SOUTHWEST FWY (9/86 - PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE
LEGEND : T = NORTH FREEWAY AT LITTLE YORK (WITH HOV LANE)
N = FREEWAYS WITHOUT HOV LANE

FIGURE B-14

NORTH FREEWAY HOV LANE EVALUATION
A.M. PEAK HOUR MAINLANE AND HOV LANE EFFICIENCY



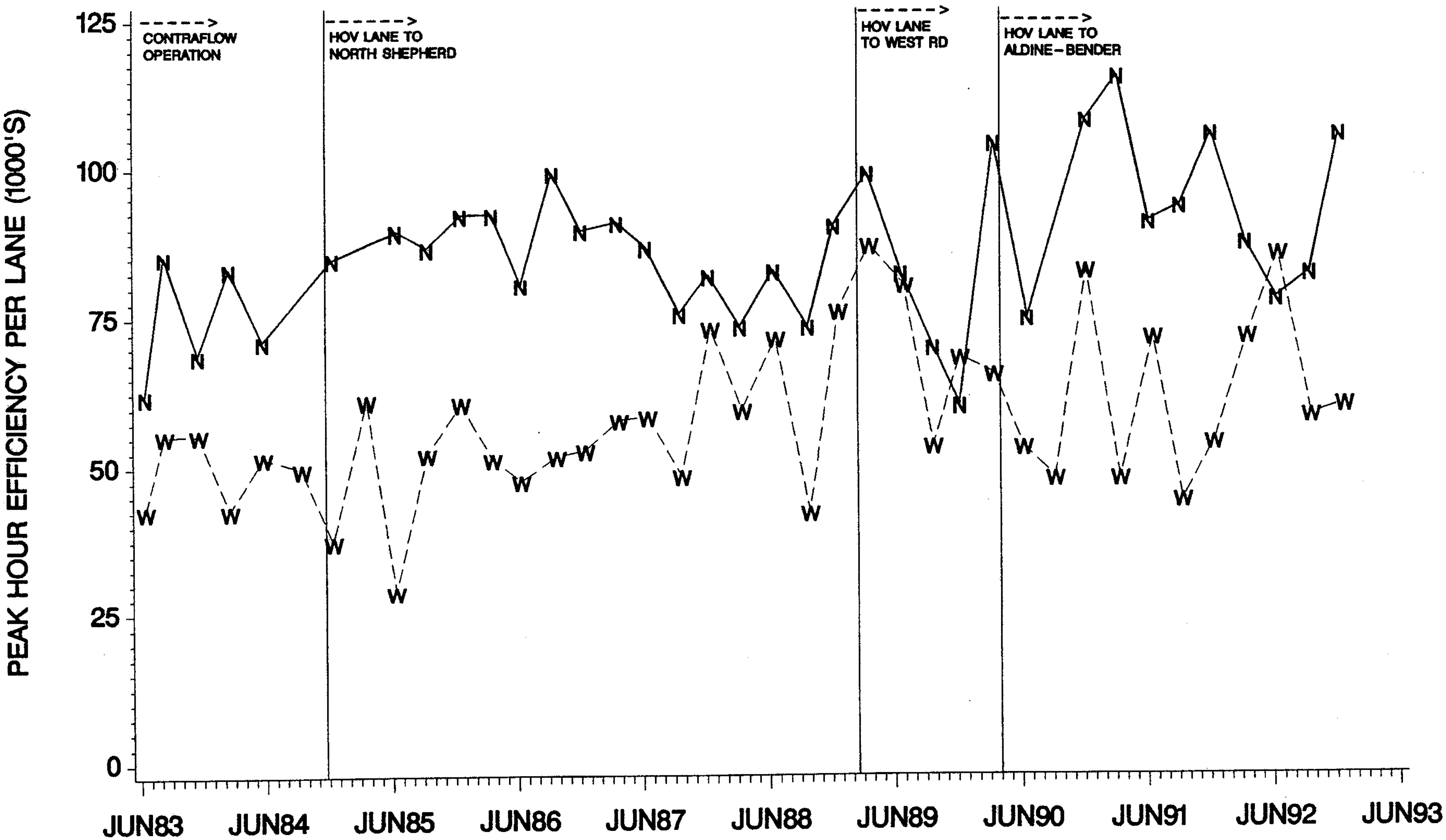
PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE HOV LANE, IT REPRESENTS TOTAL PERSONS (FREEWAY + HOV LANE) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 5 LANES

SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : A = A.M. PEAK HOUR EFFICIENCY

FIGURE B-15

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

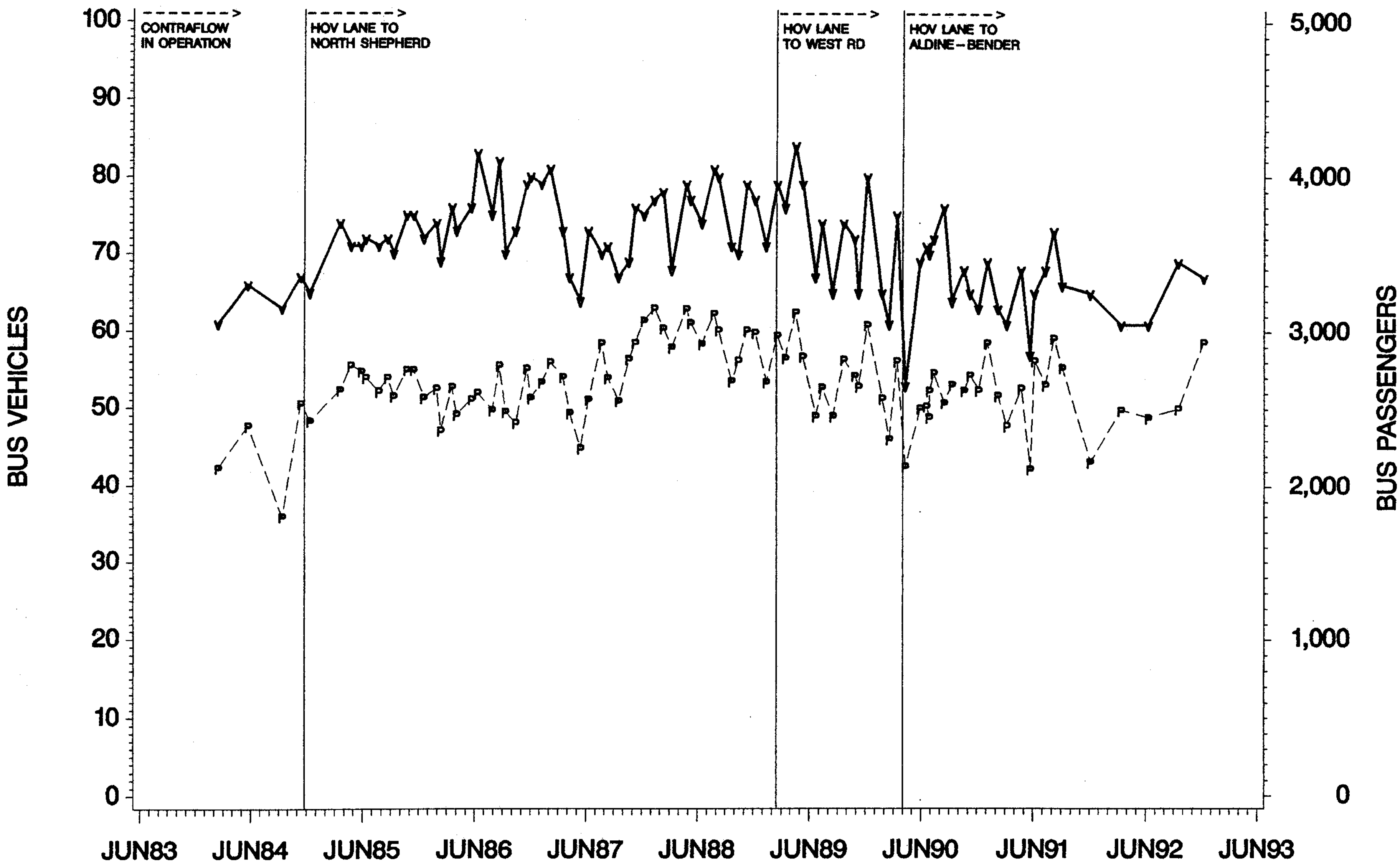


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE HOV LANE, IT REPRESENTS TOTAL PERSONS (FREEWAY + HOV LANE) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 4 LANES
DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF
GULF FWY (6/83 – 4/86) AND SOUTHWEST FWY (6/86 – PRESENT) DATA
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

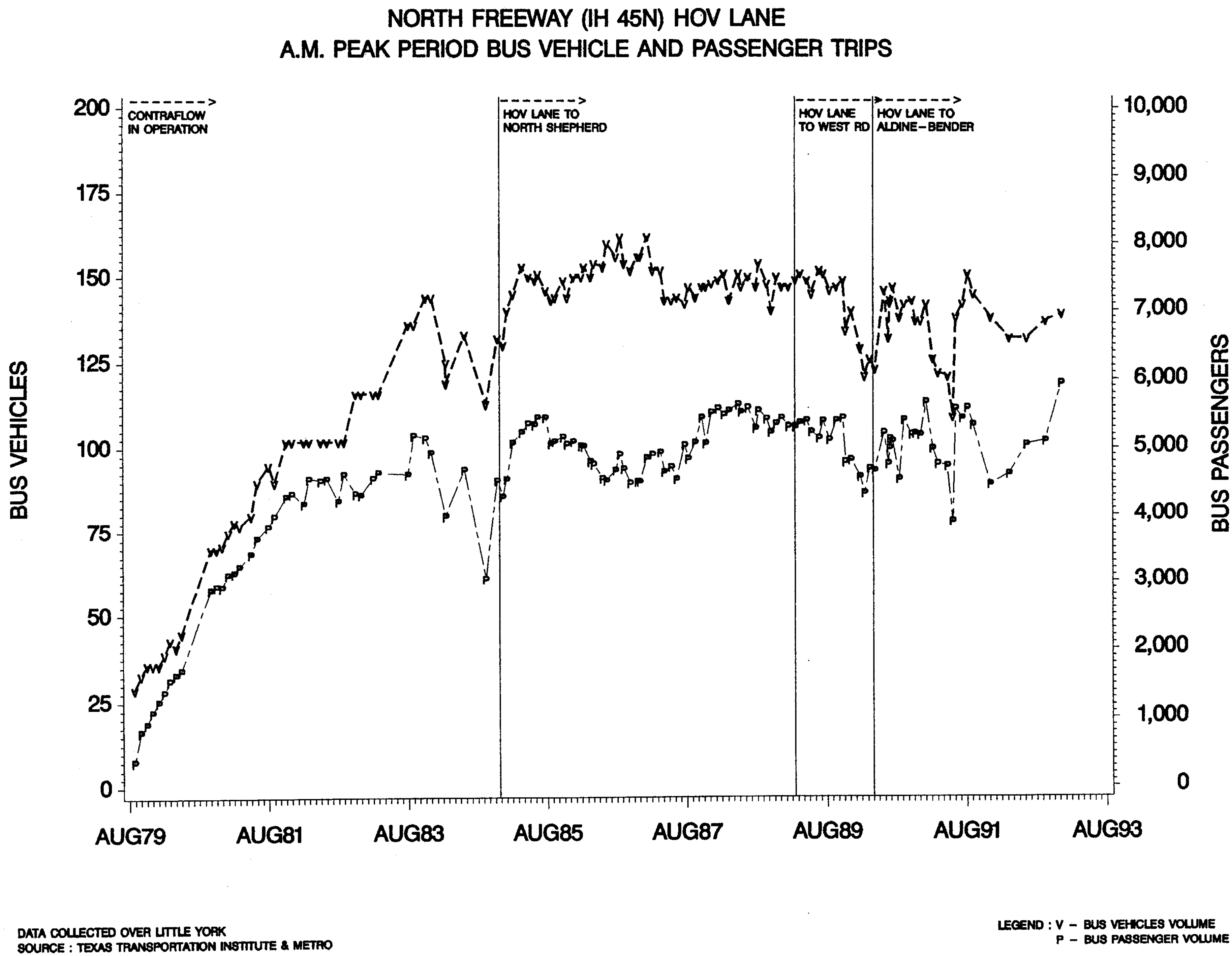
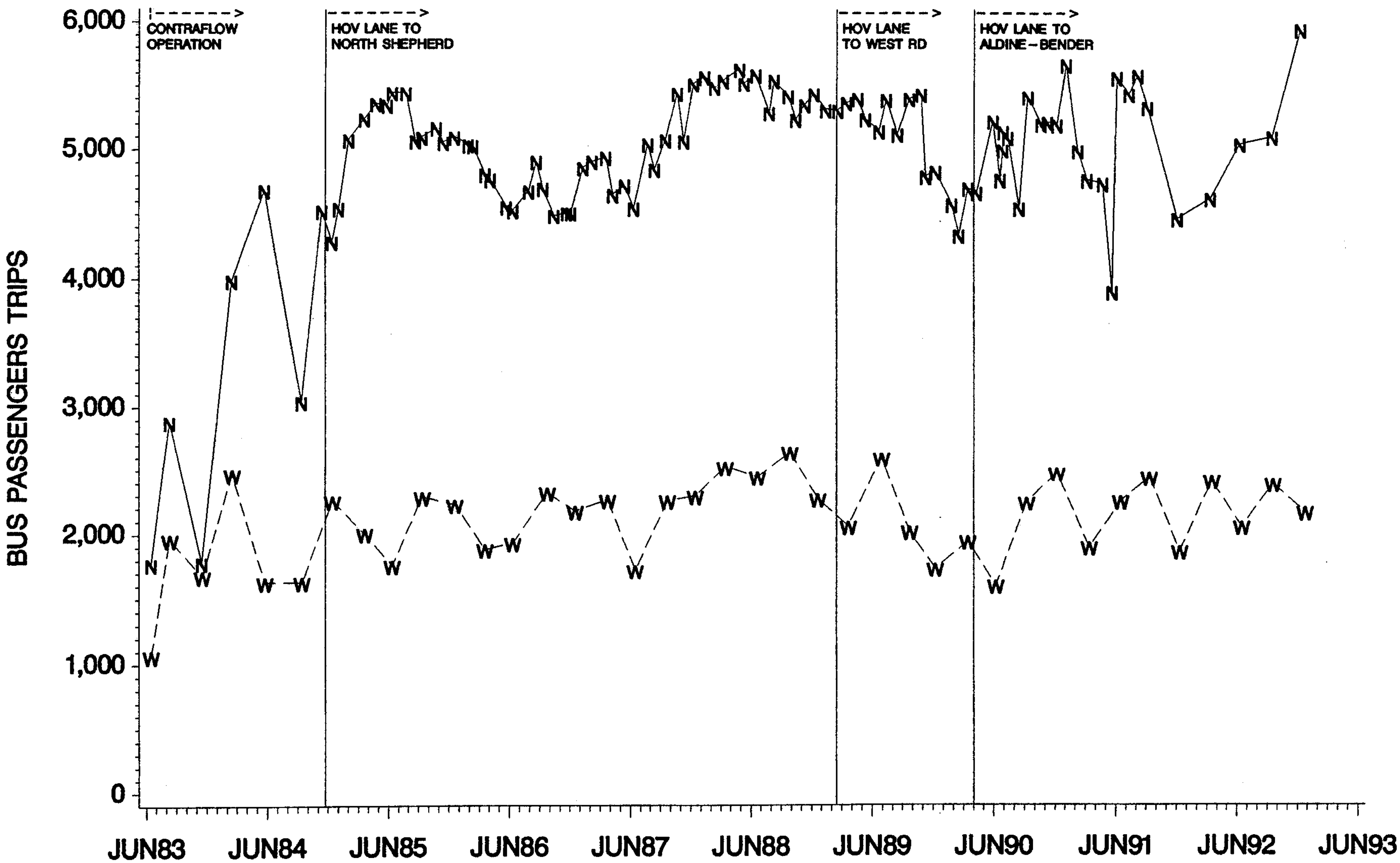

NORTH FREEWAY (IH 45N) HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS
CONTRAFLOW IN OPERATION
HOV LANE TO NORTH SHEPHERD
HOV LANE TO WEST RD
HOV LANE TO ALDINE-BENDER
BUS VEHICLES
BUS PASSENGERS
0
25
50
75
100
125
150
175
200
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
AUG79
AUG81
AUG83
AUG85
AUG87
AUG89
AUG91
AUG93
DATA COLLECTED OVER LITTLE YORK
SOURCE : TEXAS TRANSPORTATION INSTITUTE & METRO
LEGEND : V - BUS VEHICLES VOLUME
P - BUS PASSENGER VOLUME

FIGURE B-18

A.M. PEAK PERIOD BUS PASSENGER TRIPS
FREEWAYS WITH AND WITHOUT HOV LANE

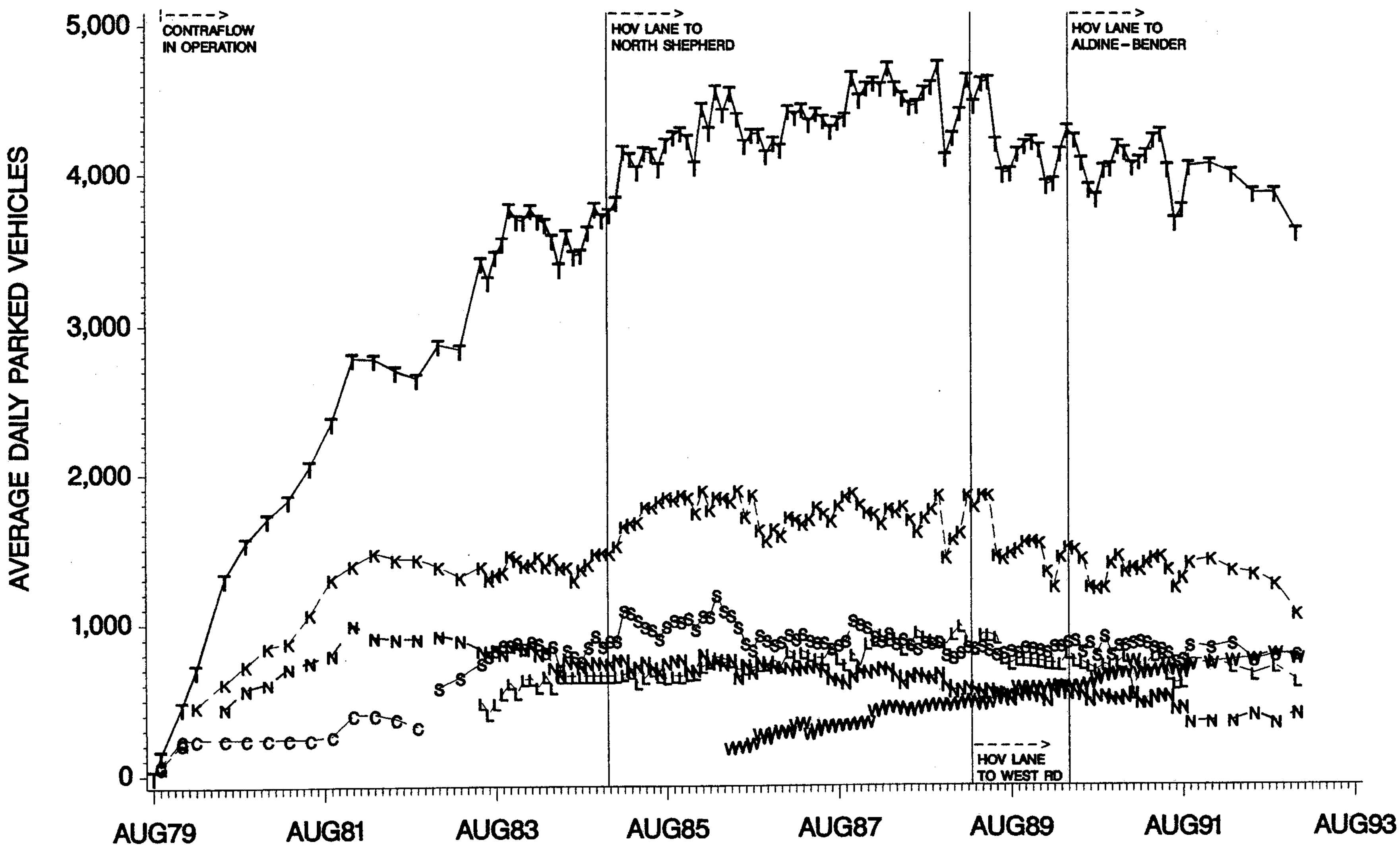


PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF
GULF FWY (6/83 – 4/86) AND SOUTHWEST FWY (9/86 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

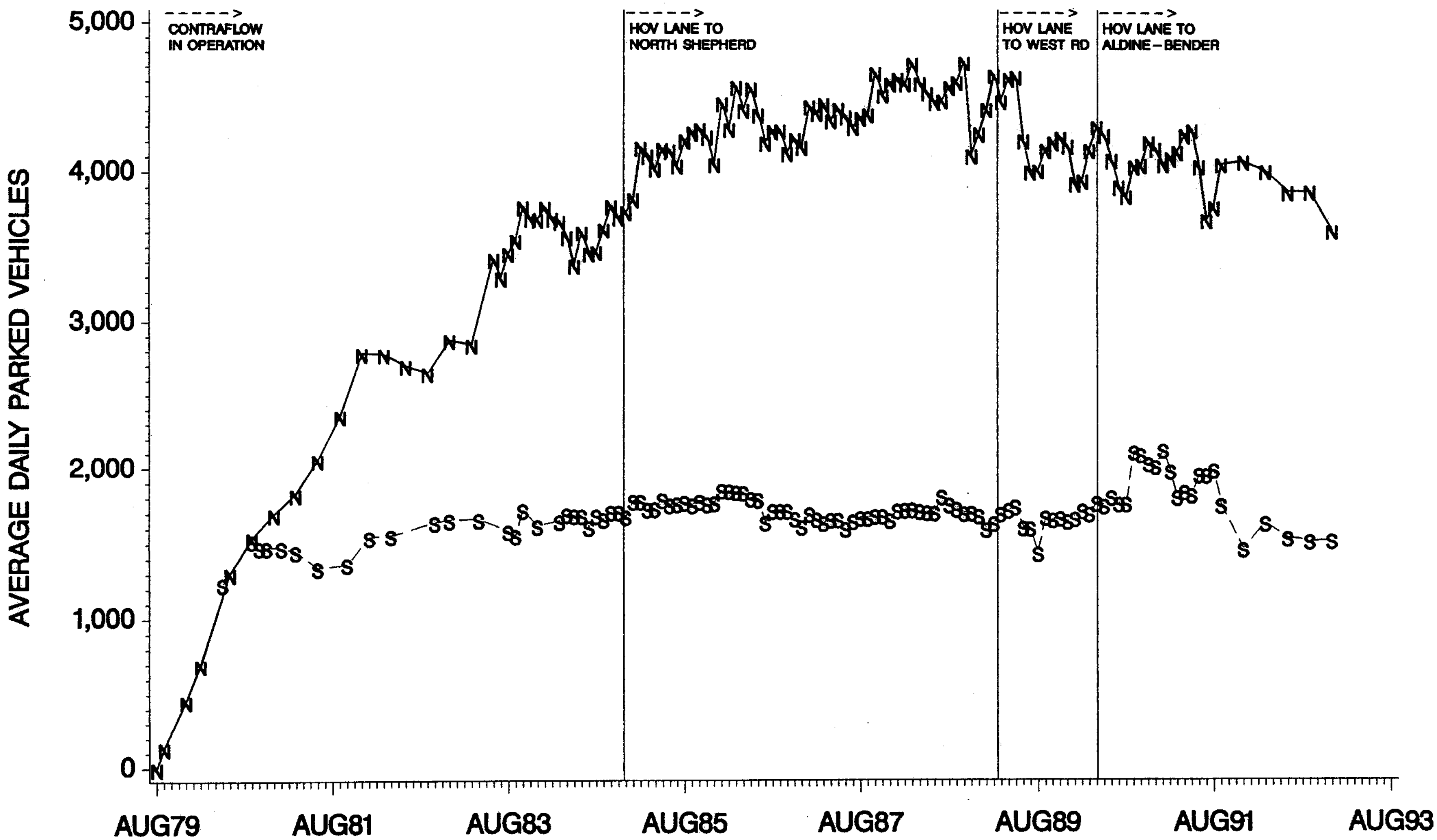


NORTH CFL FROM DOWNTOWN TO NORTH SHEPHERD (9.6 MI.) OPENED AUGUST, 1979
CONCURRENT FLOW LANE (A.M. ONLY) FROM NORTH SHEPHERD TO WEST RD (3.3 MI.) OPENED MARCH, 1981
NORTH HOV LANE FROM DOWNTOWN TO NORTH SHEPHERD (9.6 MI.) OPENED NOVEMBER, 1984
HOV LANE EXTENSION FROM NORTH SHEPHERD TO ALDINE–BENDER (4.3 MI.) OPENED APRIL, 1990
CURRENT TOTAL CORRIDOR PARKING CAPACITY = 7,017 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 (2,246 SPACES)
L = SETON LAKE LOT (1,286 SPACES)
N = NORTH SHEPHERD LOT (1,605 SPACES)
S = SPRING LOT (1,260 SPACES)
W = THE WOODLANDS LOT (600 SPACES)

FIGURE B-20

AVERAGE DAILY VEHICLES PARKED AT PARK-AND-RIDE LOTS
FREEWAYS WITH AND WITHOUT HOV LANES



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

LEGEND : N - NORTH FREEWAY
S - FREEWAY WITHOUT HOV LANE (SOUTHWEST)

APPENDIX C

GULF FREEWAY AND HOV LANE DATA

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

Table C-1. Summary of A.M. Peak-Period, Peak-Direction Gulf Freeway and HOV Lane Data, December 1992

Type of Data[1] Phase 1 of HOV Lane Became Operational 5/16/88	"Representative" Pre-HOV Lane Value	"Representative" Current Value	% Change
HOV Lane Data			
HOV Lane Length (miles)		6.5	
HOV Lane Cost (millions of 1990 dollars)		$44.2	
Person-Movement			
Peak Hour (7-8 a.m.)		3,218	—
Peak Period (6-9:30 a.m.)		5,165	—
Total Daily		10,196	—
Vehicle Volumes			
Peak Hour	—	1,013	—
Peak Period	—	1,544	—
Vehicle Occupancy, Peak Hour (persons/veh)	—	3.18	—
Accident Rate (Injury accidents/100 MVM), 11/84-12/92[2]	—	12.6	—
Vehicle Breakdowns (VMT/Breakdown), 11/84-12/92	—	63,800	—
Violation Rate (6-9:30 a.m.)	—	2.9%	
Peak Hour Lane Efficiency (1000's)[3]	—	168	—
Annual Value of User Time Saved (millions)[4]	—	$1.4 to $2.7	—
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 MVM)[2]	29.8	24.0	-19.5%
Avg. Operating Speed[5]			
Peak Hour	30.8	—	—
Peak Period	36.3	—	—
Peak Hour Lane Efficiency (1000's)[3]	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 analyzed between Broadway and Dowling, a distance of approximately 6.5 miles, which corresponds to Phase 1 of the HOV lane. Pre-HOV lane includes 4 years of mainlane accident data from 5/16/84 to 5/15/88. Current value is from 5/16/88 to 8/92.

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

[4] Based on time savings for HOV lane users in 1992, an annual estimate of travel time savings to HOV lane users is developed. A value of time of $10.47/hour is used based on the value applied in the Highway Economic Evaluation Model.

[5] From Broadway to Dowling a distance of 6.3 miles.

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

Table C-2. Summary of Gulf Freeway and HOV Lane Data, December 1992

Type of Data	"Representative" Pre-HOV Lane Value	"Representative" Current Value	% 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]	7.2[3]	-25.8%
Peak Period	8.1[2]	6.9[3]	-14.8%
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	1,331	+19.4%
Bus Operating Speed (mph)[1]			
Peak Hour	30.8[2]	52.2[3]	+ 69.5%
Peak Period	36.3[2]	54.4[3]	+ 49.9%

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 6.3 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 miles/hour). It is used as a measure of per lane efficiency.
[5] Data collected at Monroe.

Table C-3. Comparison of Measures of Effectiveness, Freeway With (Gulf, I-45) and Freeway Without (Southwest US 59) HOV Lane, Houston[1,2]

Measure of Effectiveness	"Representative" Pre-HOV Lane Value	"Representative" 12/92 Value	% Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/HOV lane	1.29	—	—
Freeway w/o HOV lane	1.34	1.30	-3.0%
A.M. Peak Hour, 2+ Carpool Volume			
Freeway w/HOV lane	475	—	—
Freeway w/o HOV lane	600	531	-11.5%
Bus Passengers, Peak Period			
Freeway w/HOV lane	1,230	—	—
Freeway w/o HOV lane	2,185	2,174	-0.5%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	1,115	1,331	+19.4%
Freeway w/o HOV lane	1,680	1,522	-9.4%
Facility Per Lane Efficiency[3]			
Freeway w/HOV lane	66	—	—
Freeway w/o HOV lane	76	60	-21.1%

[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) and on the Southwest Freeway (9/86 to present).

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

HOV LANE DATA

DESCRIPTION

- Phase 1 (6.5 miles) of the HOV lane opened 5/16/88. Weekend operation began 10/1/89. The capital cost for the operating segment (incl. 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 (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 1992, 10,196 person trips per day were served on the HOV lane.
- A.M. peak hour, 3,218 persons/hour.
  - 940 (29%) by bus, 177 (6%) by vanpool, and 2,101 (65%) by carpool (Figure C-1).
  - Average HOV lane vehicle occupancy = 3.18 persons/vehicle.
- A.M. peak period, 5,165 persons.
  - 1,820 (35%) by bus, 208 (4%) by vanpool, and 3,133 (61%) by carpool (Figure C-2).

Table C-4. 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 Mile	$4.7		$4.6
Surveillance, Communication and Control	$1.9	1.00	$1.9
SUB-TOTAL	$1.9		$1.9
Per Mile	$0.3		$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 Mile	$1.9		$1.9
TOTAL COST	$45.0		$44.2
COST PER MILE (6.5 miles)	$6.9		$6.8

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

Table C-5. 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 Mile		$6.6			$6.6
Surveillance, Communication and Control		$1.4	1.00		$1.4
SUB-TOTAL	$1.4			$1.4	
Per Mile		$0.2			$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 Mile		$1.8			$1.8
TOTAL COST	$76.9			$76.9	
COST PER MILE (9.0 miles)	$8.5			$8.5	

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

VEHICLE MOVEMENT

- A.M. Peak Hour, 1,013 vph
  - 31 (3%) buses, 18 (2%) vans, and 964 (95%) carpools (Figure C-3).

- A.M. Peak Period, 1,544 vehicles.
  - 60 (4%) buses, 23 (2%) vans, and 1,457 (94%) carpools (Figure C-4).

VEHICLE BREAKDOWN RATES

- As measured from September 1, 1988 through December 1992, the following rate has been observed.

  - Weighted average; 1 breakdown per 63,800 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 168.

TRAVEL TIME SAVINGS

- The users of the HOV lane experience an average travel time savings of 2 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 525 hours (31,472 min.) are realized. Assuming 250 days of operation, annual savings would be 131,133 hours. At $10.47/hour, this equates to $1.37 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 $1.37 to $2.74 million per year.

Table C-6. Northbound A.M. Travel Time Savings for Gulf HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1992)

Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	T-Way (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section From Park Place to Dowling								
6:00	6.57	6.58	-0.01	44	5	123	172	-1.43
6:30	8.60	6.97	1.62	254	31	350	635	1,032.27
7:00	7.91	7.08	0.83	560	84	440	1,084	903.14
7:30	10.07	7.25	2.82	1,052	54	508	1,613	4,542.59
8:00	8.28	6.97	1.30	576	18	260	854	1,113.11
8:30	6.86	7.17	-0.31	209	2	125	336	-104.99
9:00	6.63	6.91	-0.28	80	0	13	93	-26.28
Peak Period Total				2,774	194	1,818	4,786	7,458.41
Southbound PM Travel Time Savings for Gulf HOV Lane								
Section from Park Place to Dowling								
3:30	7.34	6.67	0.68	105	9	28	142	95.68
4:00	8.66	7.39	1.27	249	33	215	497	631.59
4:30	10.14	7.18	2.96	394	57	348	799	2,365.56
5:00	14.62	7.34	7.27	739	74	623	1,435	10,439.59
5:30	15.31	7.25	8.06	566	41	581	1,188	9,574.19
6:00	9.40	8.20	1.20	271	4	173	447	534.53
6:30	8.92	6.94	1.98	102	4	83	188	372.08
Peak Period				2,425	222	2,049	4,695	24,013.22

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 comparable to the HOV lane data at this time. 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 29.8 accidents per 100 million vehicle miles (100 MVM). The "after HOV lane" accident rate for the mainlanes is 24.0 accidents per 100 MVM and includes the period 5/88 to 12/92. Only officer-reported accidents are included in current accident files. 1992 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 66 (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.

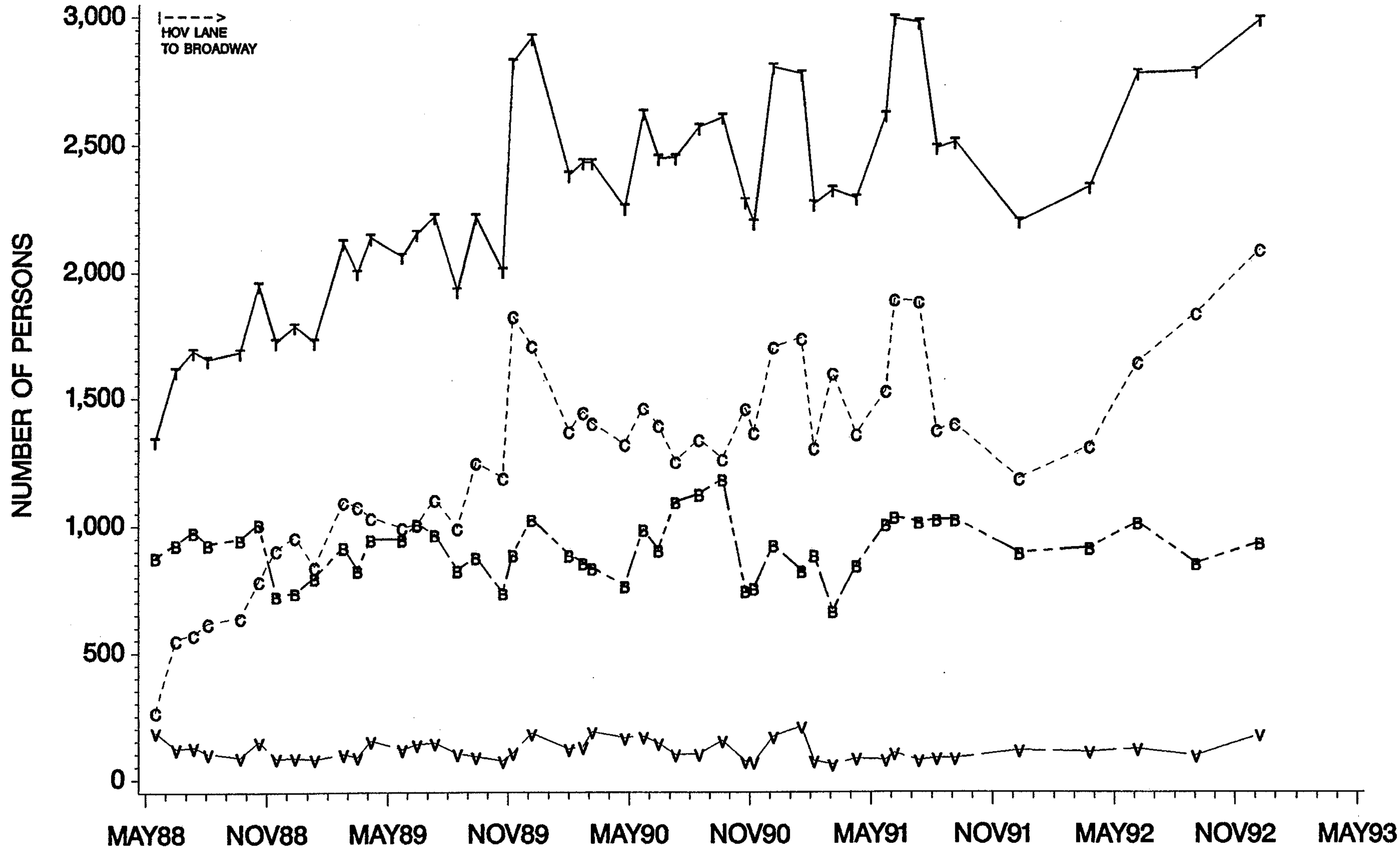
PARK-AND-RIDE

- Prior to opening the HOV lane, approximately 1,115 vehicles were parked in corridor park-and-ride lots. This has increased 19.4% to a current level of 1,331 (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



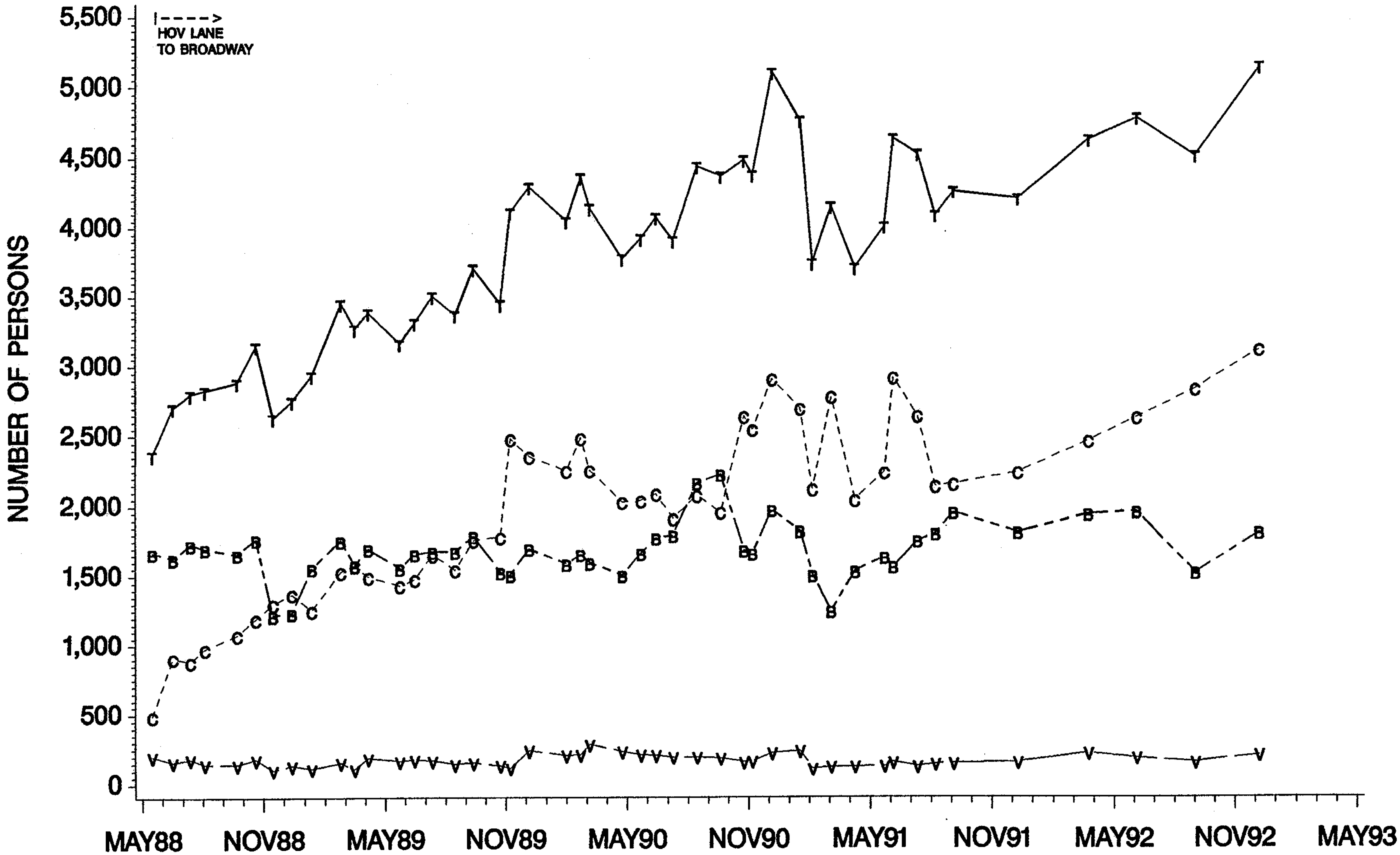
GULF HOV LANE, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988

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



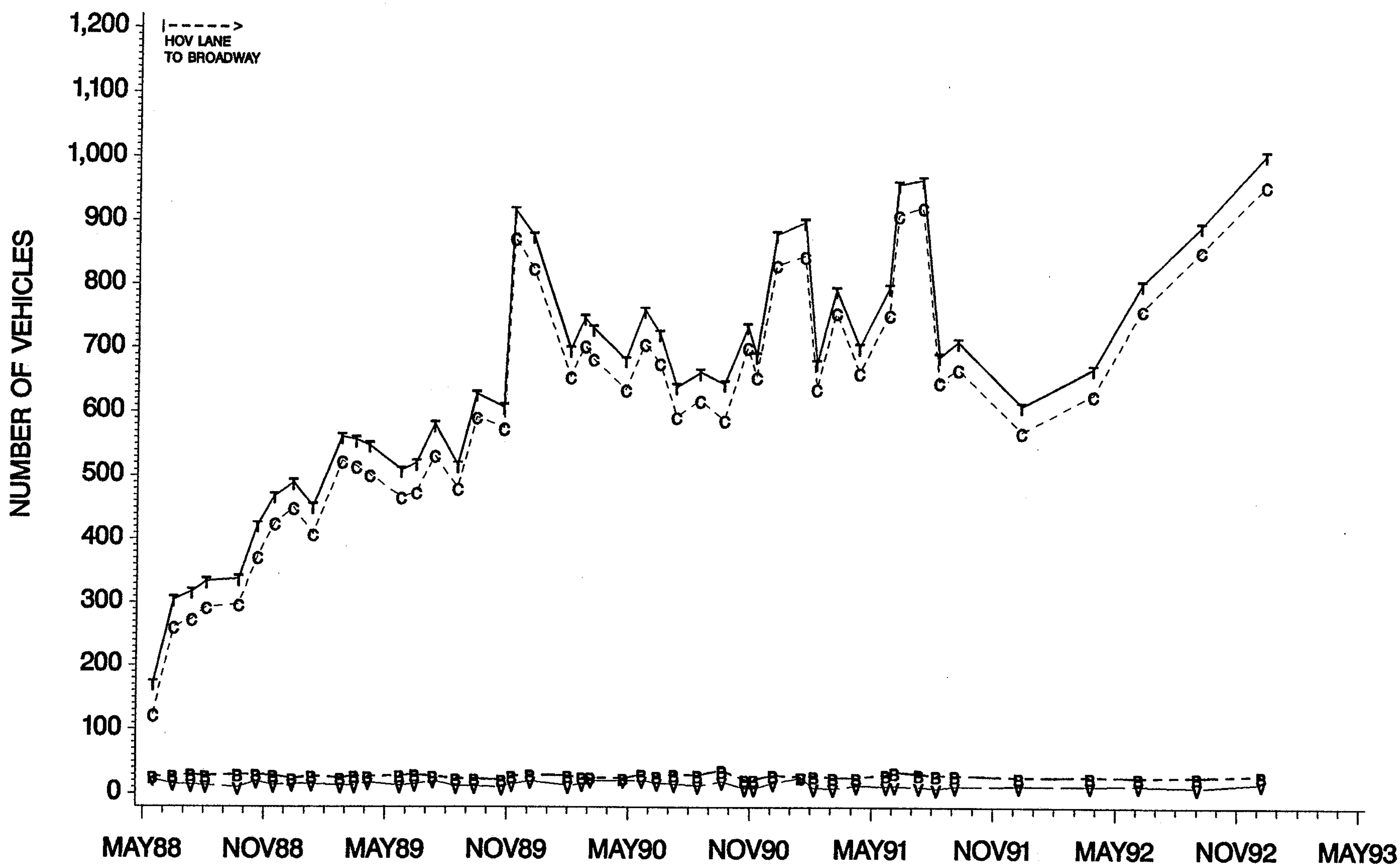
GULF HOV LANE, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988
PEAK PERIOD IS FROM 6:00 – 9:30 A.M.

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



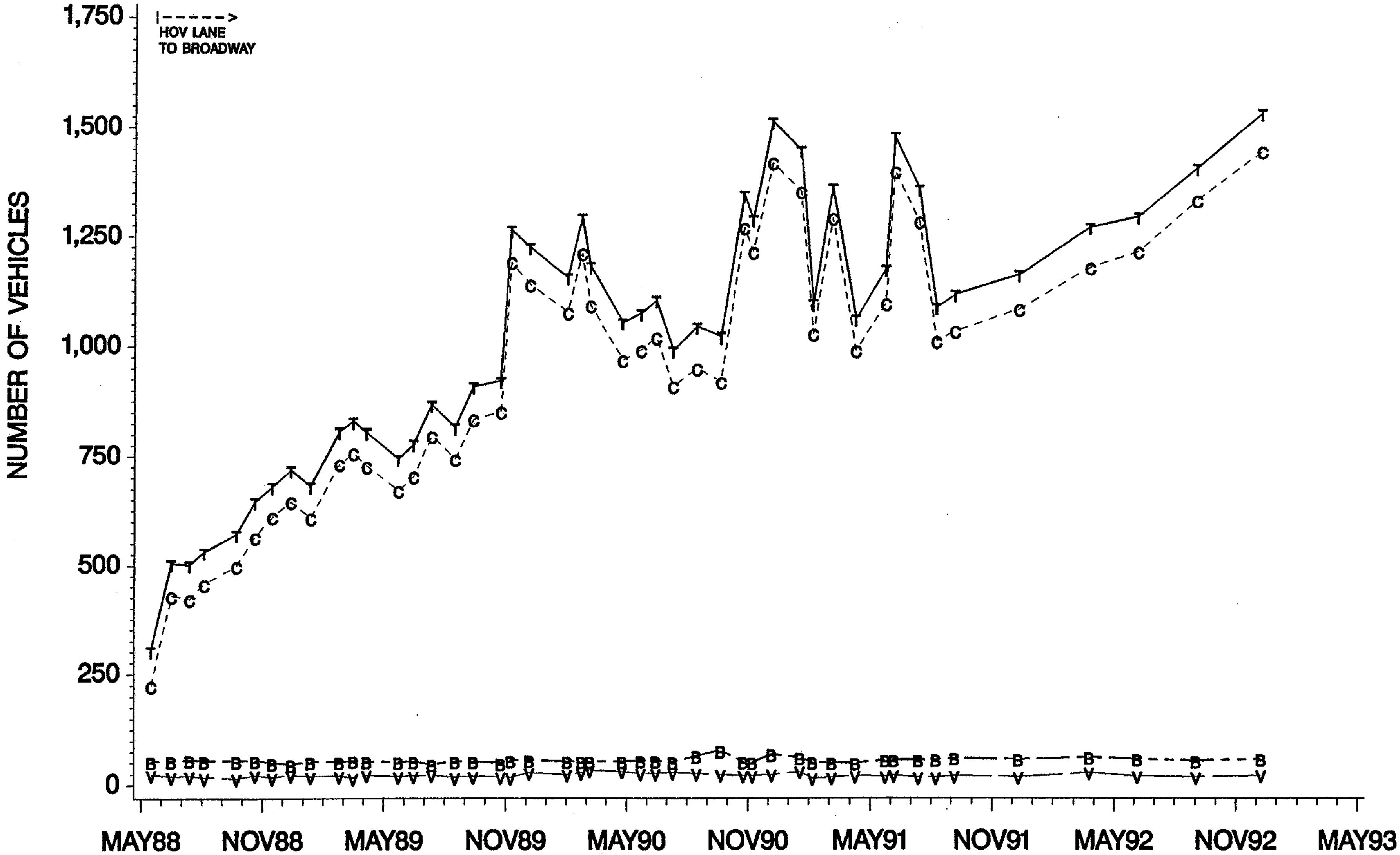
GULF HOV LANE, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988

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



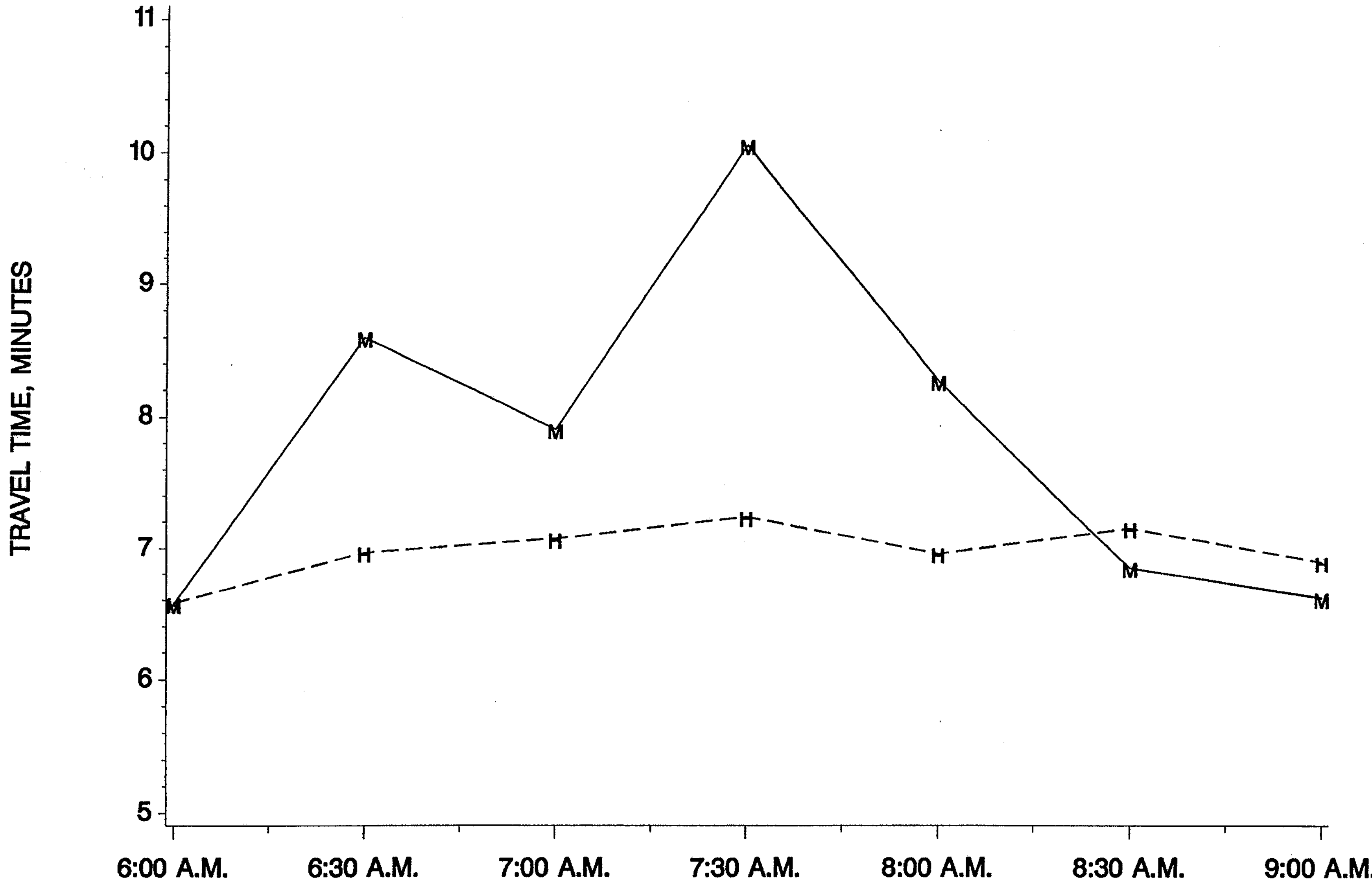
GULF HOV LANE, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988
PEAK PERIOD IS FROM 6:00 – 9:30 A.M.

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

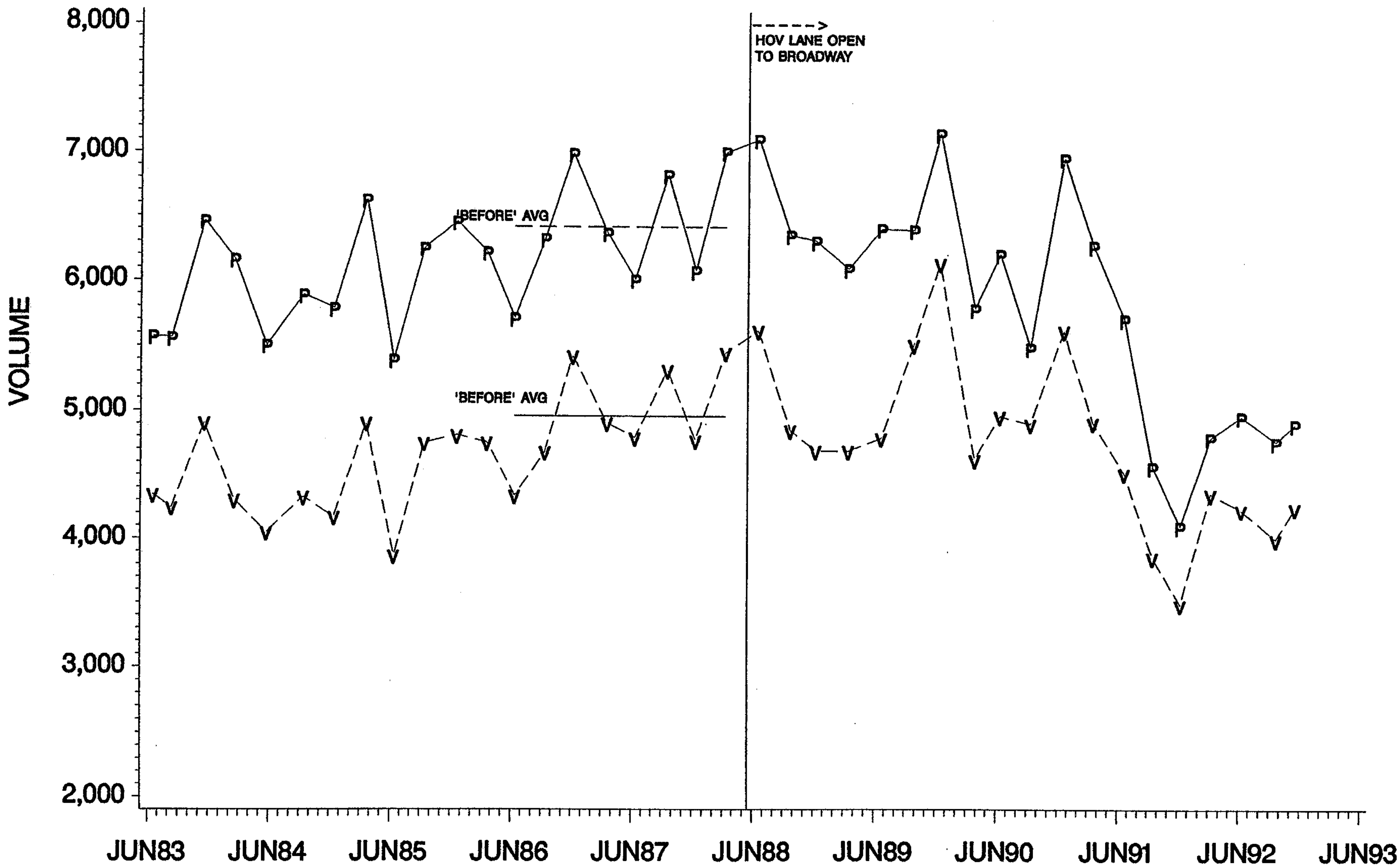


TRAVEL TIMES ARE AN AVERAGE OF 4 QUARTERLY TRAVEL TIME SURVEYS CONDUCTED IN 1992
TRAVEL TIMES ARE FROM PARK PLACE TO DOWLING
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE C-6

GULF FREEWAY (IH 45S)
A.M. PEAK HOUR MAINLANE TRIPS

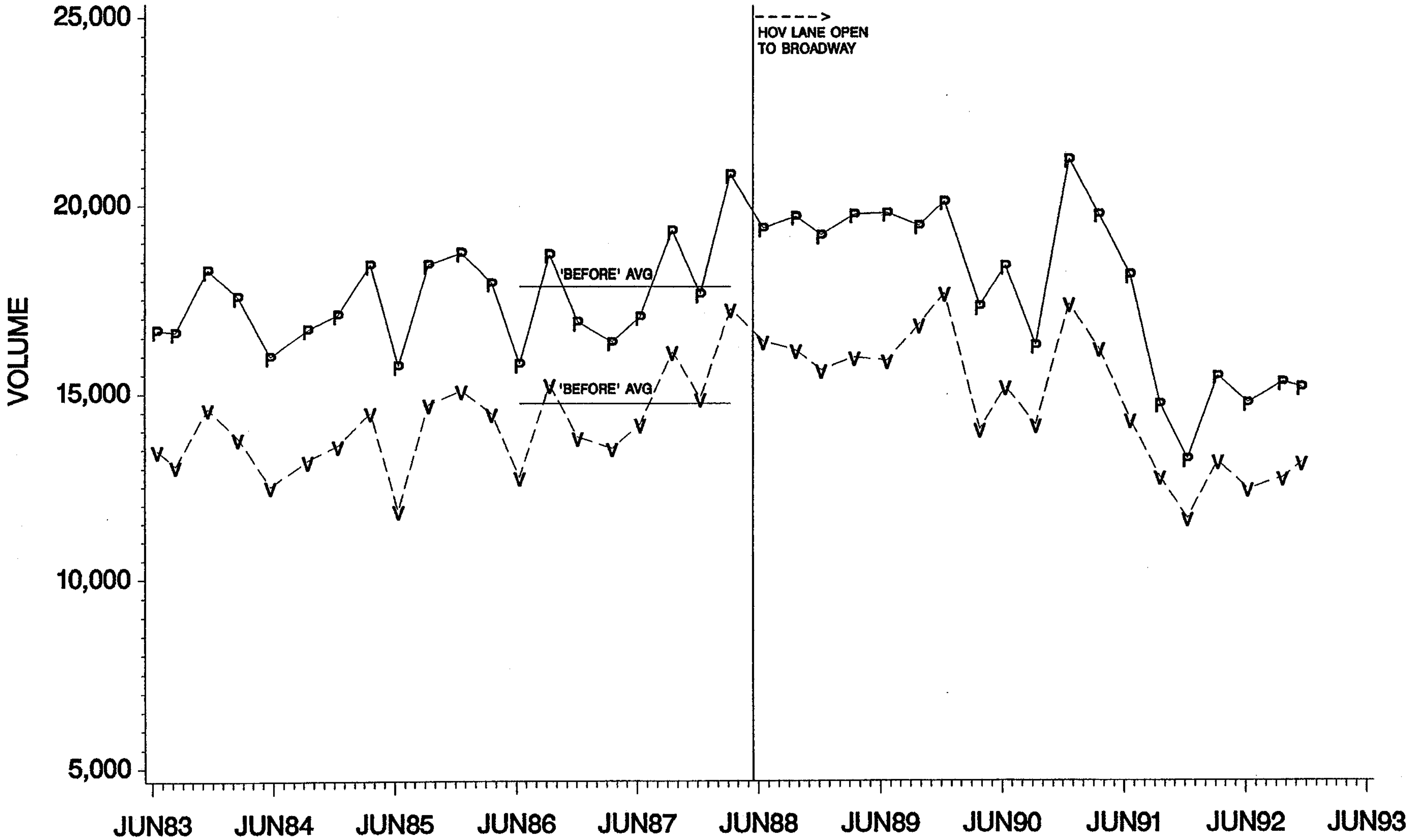


DATA COLLECTED AT MONROE
HOV LANE NOT YET COMPLETED TO MONROE; FREEWAY DATA NOT
DIRECTLY COMPARABLE WITH HOV LANE DATA AT THIS TIME
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = MAINLANE PERSONS
V = MAINLANE VEHICLES

FIGURE C-7

GULF FREEWAY (IH 45S)
A.M. PEAK PERIOD MAINLANE TRIPS

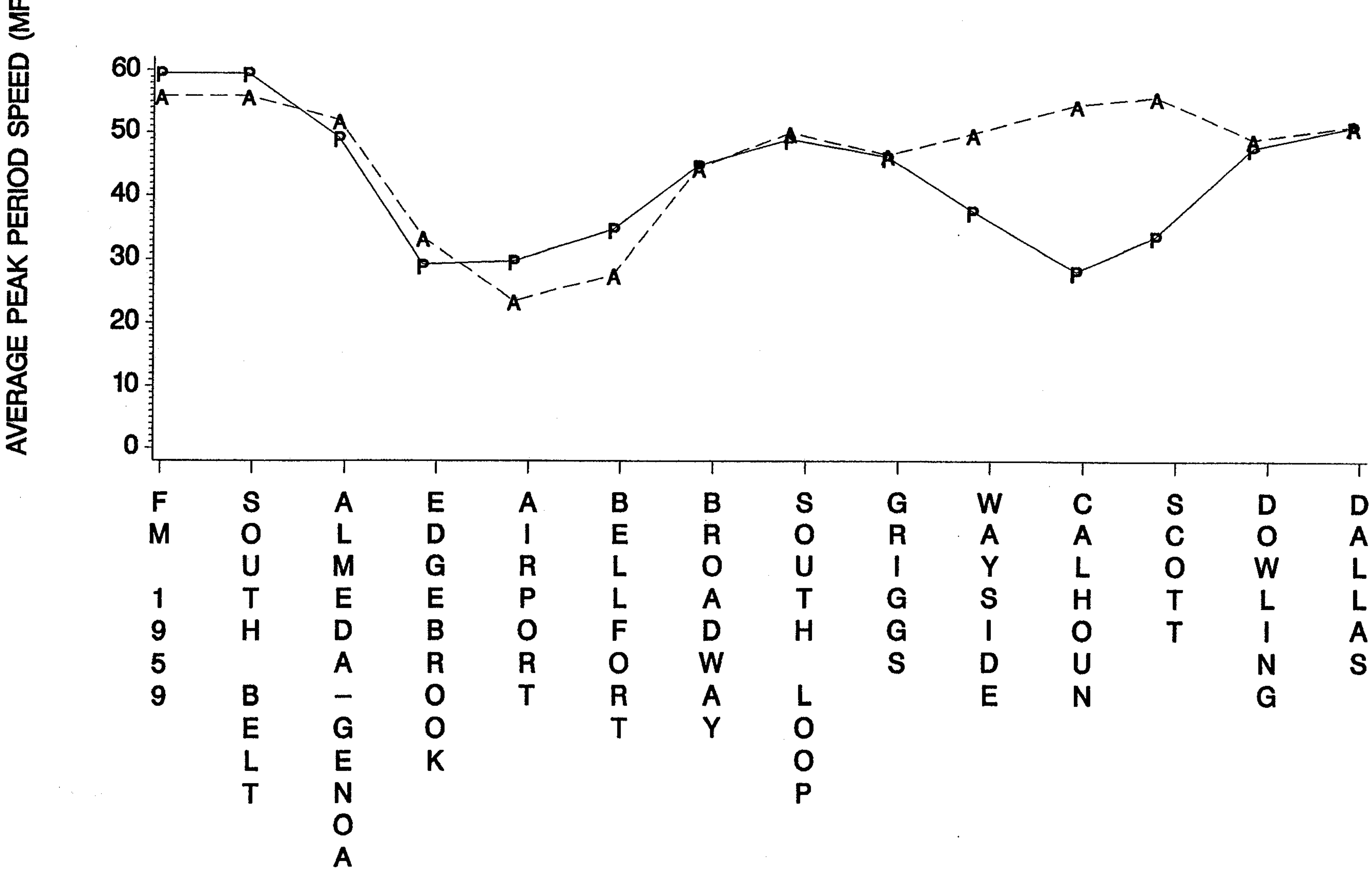


A.M. PEAK PERIOD DEFINED AS FROM 6:00 TO 9:30 A.M.
DATA COLLECTED AT MONROE
HOV LANE NOT YET COMPLETED TO MONROE; FREEWAY DATA NOT
DIRECTLY COMPARABLE WITH HOV LANE DATA AT THIS TIME
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = MAINLANE PERSONS
V = MAINLANE VEHICLES

FIGURE C-8

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

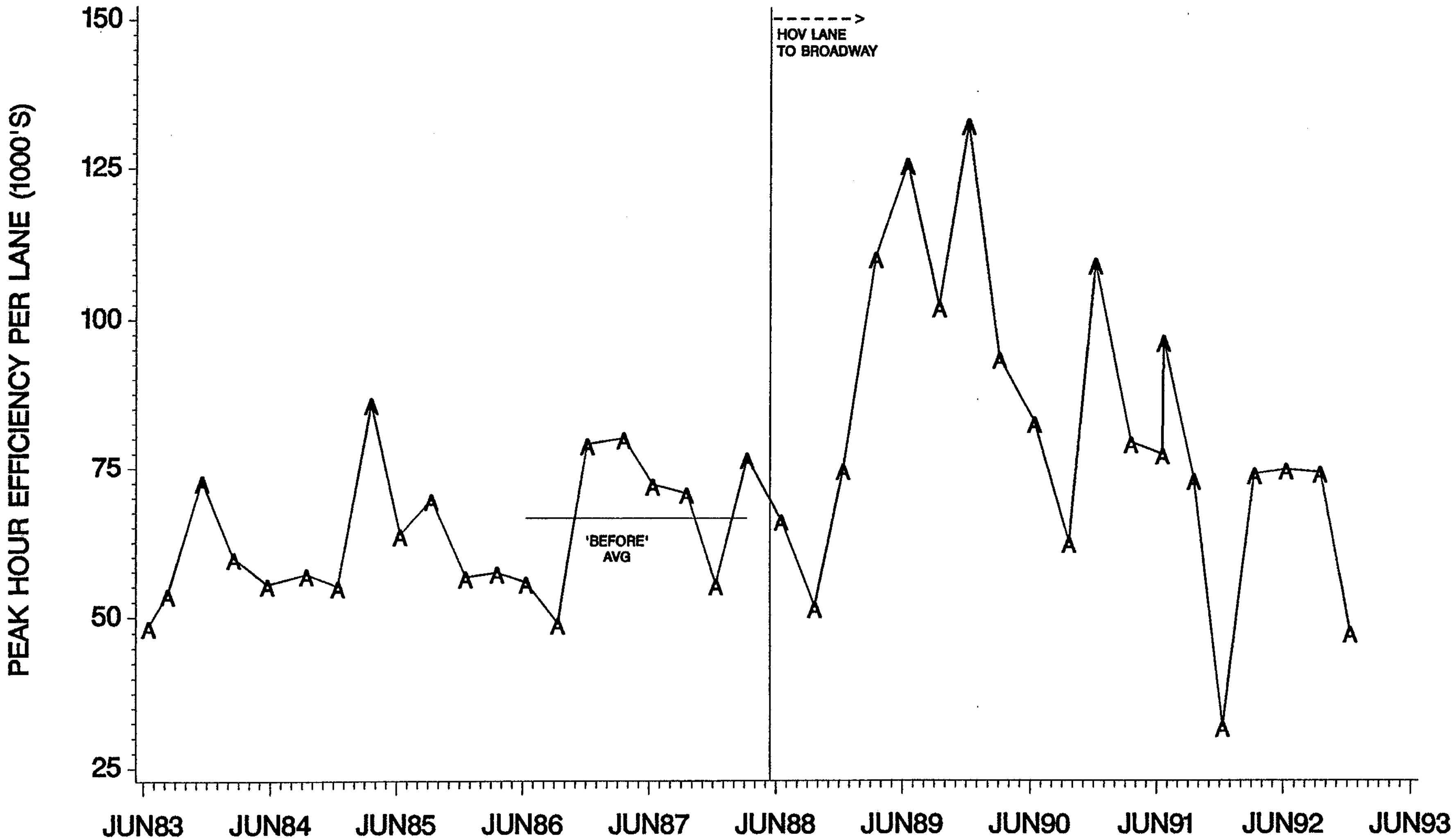


GULF TRANSITWAY, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988
DATA COLLECTED 6:00 TO 9:30 A.M.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE C-9

GULF FREEWAY HOV LANE EVALUATION
A.M. PEAK HOUR MAINLANE EFFICIENCY

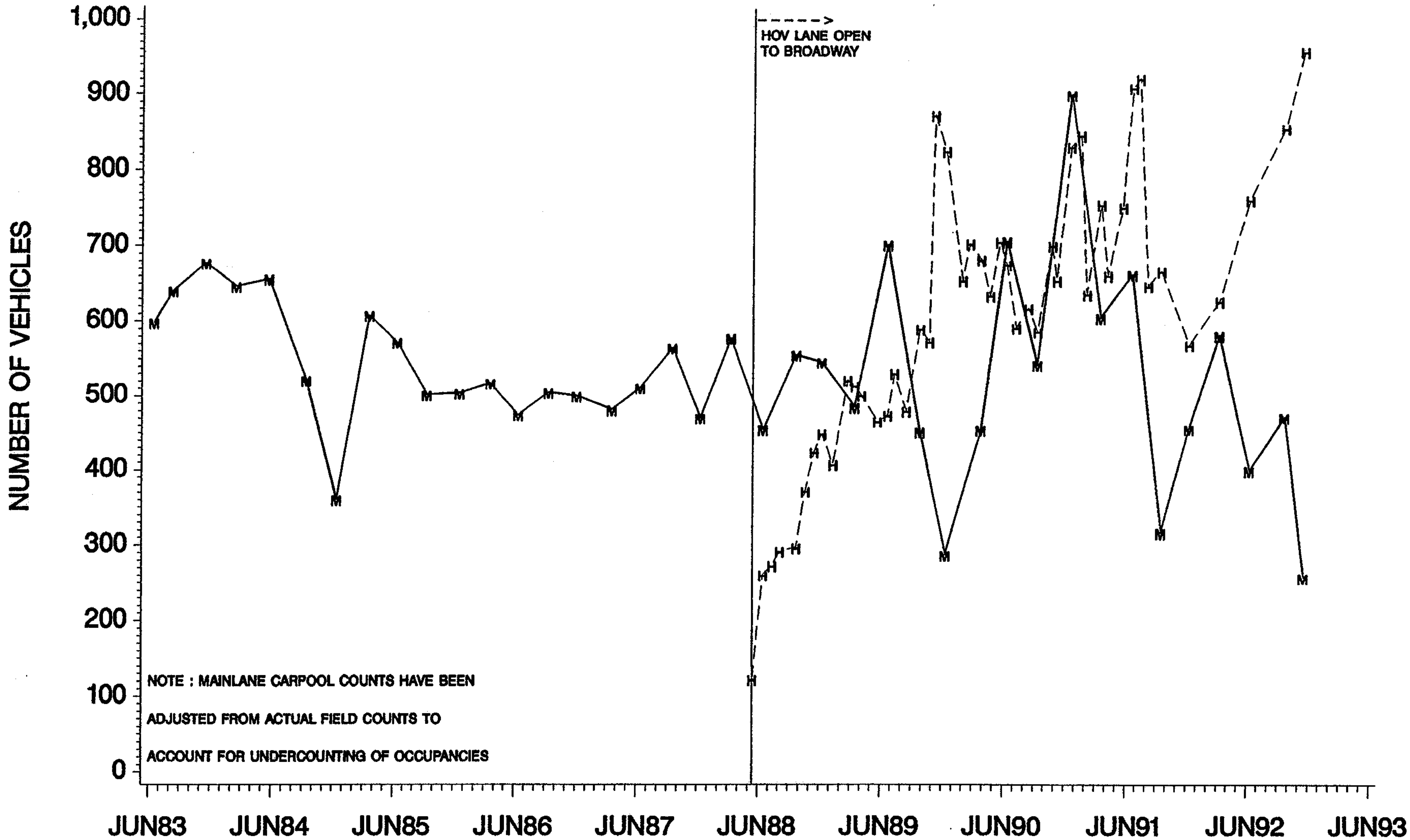


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE
OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED
DATA COLLECTED AT MONROE
HOV LANE NOT YET COMPLETED TO MONROE; FREEWAY DATA ARE NOT
COMPARABLE WITH HOV LANE DATA AT THIS TIME
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : A = A.M. PEAK HOUR EFFICIENCY

FIGURE C-10

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

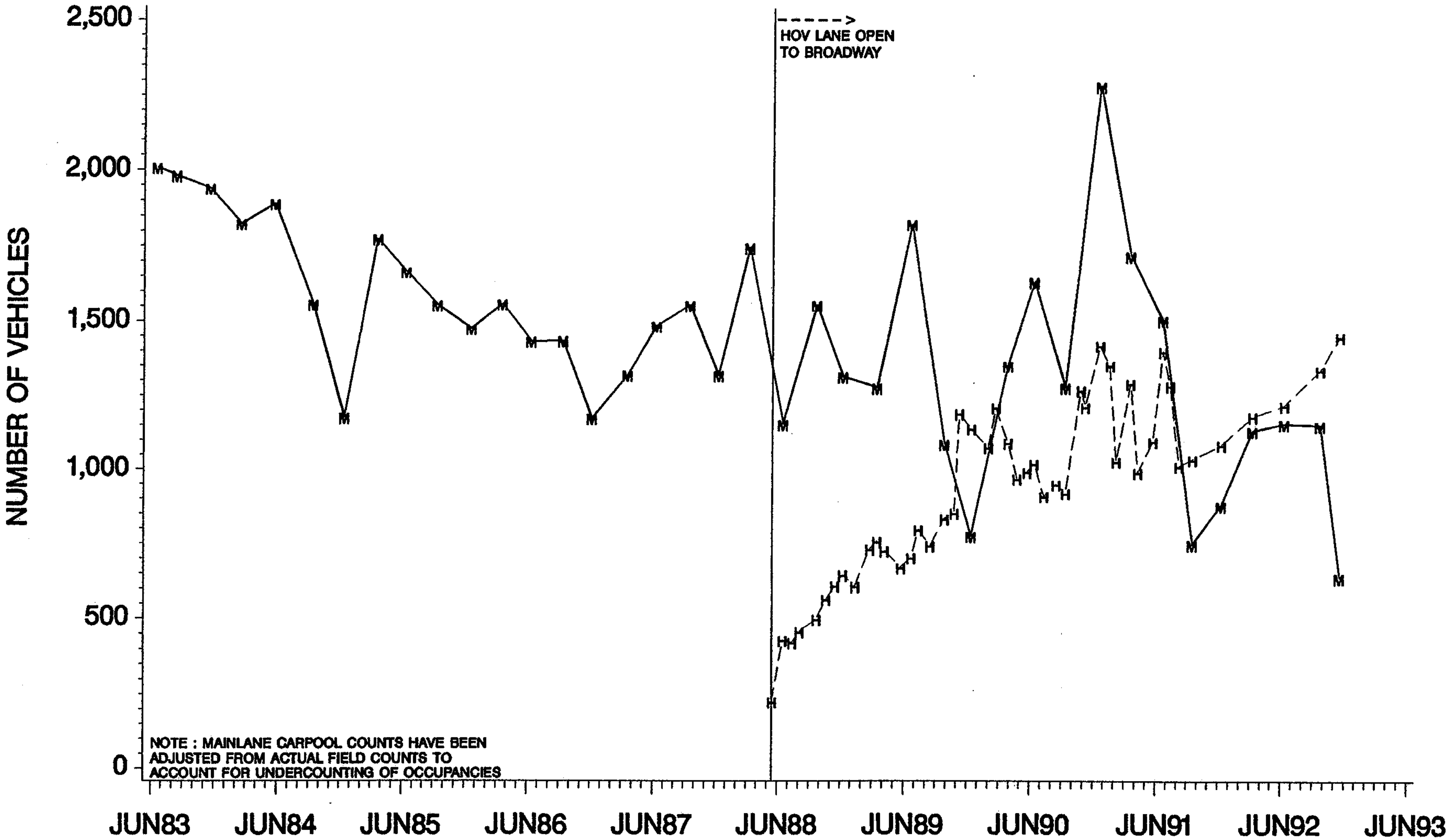


GULF HOV LANE, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988
DATA COLLECTED AT MONROE
HOV LANE NOT YET COMPLETED TO MONROE; FREEWAY DATA ARE NOT DIRECTLY COMPARABLE TO HOV LANE DATA AT THIS TIME
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

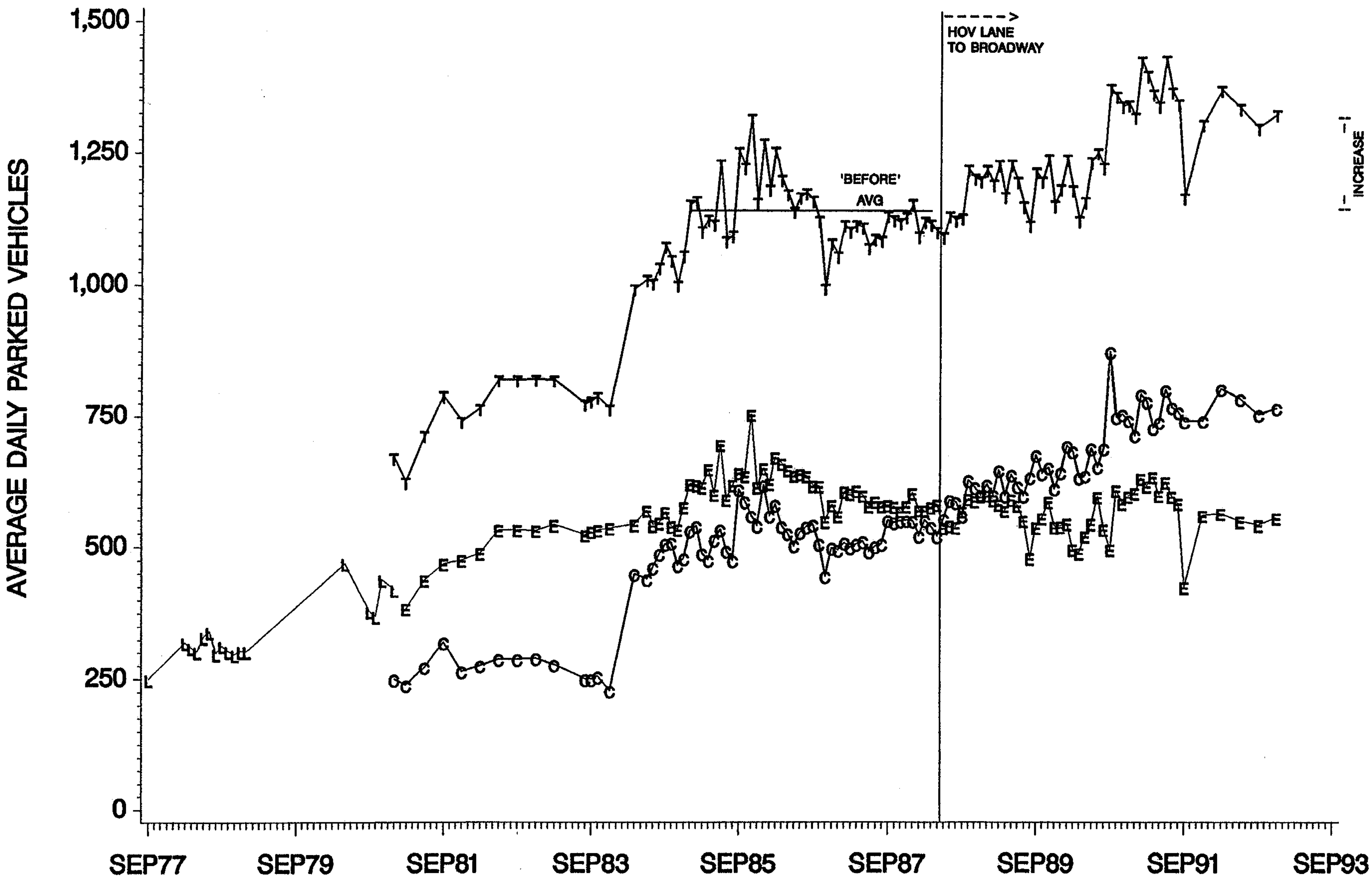


GULF HOV LANE, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988
DATA COLLECTED AT MONROE
HOV LANE NOT YET COMPLETED TO MONROE; FREEWAY DATA ARE NOT DIRECTLY COMPARABLE TO HOV LANE DATA AT THIS TIME
PEAK PERIOD IS 6:00 – 9:30 A.M.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE C-12

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



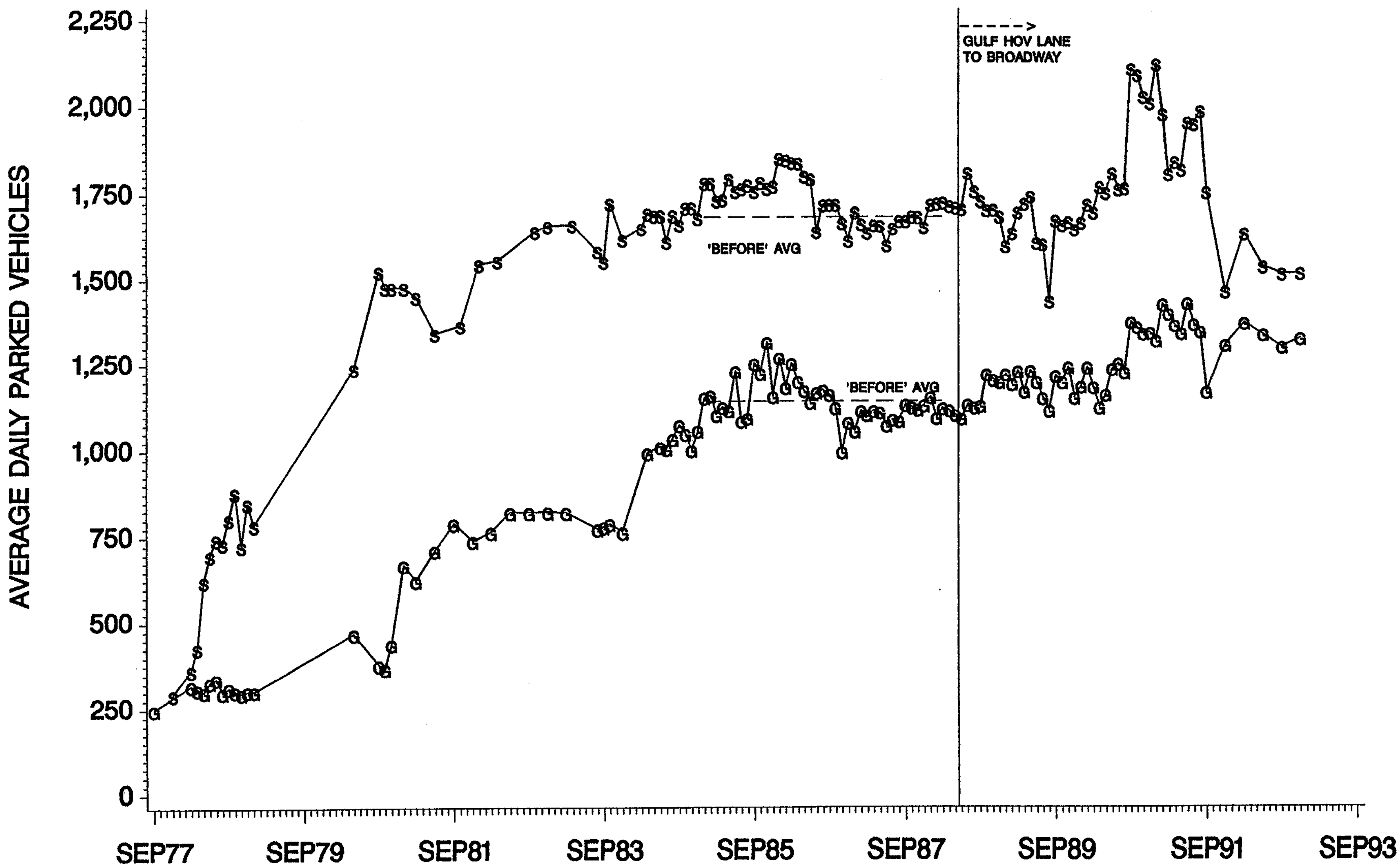
GULF HOV LANE, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988
CURRENT TOTAL CORRIDOR PARKING CAPACITY = 2,165 SPACES

SOURCE : TEXAS TRANSPORTATION INSTITUTE & METRO

LEGEND : T = TOTAL PARKED VEHICLES
E = EDGEBROOK LOT (1,000 SPACES)
C = CLEAR LAKE LOT (1,165 SPACES)
L = LEASED LOTS

FIGURE C-13

AVERAGE DAILY VEHICLES PARKED AT PARK–AND–RIDE LOTS
FREEWAYS WITH AND WITHOUT HOV LANES



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

LEGEND : G = GULF FREEWAY
S = FREEWAY WITHOUT HOV LANE (SOUTHWEST)

APPENDIX D

NORTHWEST FREEWAY AND HOV LANE

NORTHWEST FREEWAY (US 290) AND HOV LANE, HOUSTON

Table D-1. Summary of A.M. Peak-Period, Peak-Direction Northwest Freeway and HOV Lane Data, December 1992

Type of Data Phase 1 of HOV Lane Became Operational 8/29/88	"Representative" Pre-HOV Lane Value	"Representative" Current Value	% Change
HOV Lane Data			
HOV Lane Length (miles)		13.5	
HOV Lane Cost (millions of 1990 dollars)		$98.1	
Person-Movement			
Peak Hour (7-8 a.m.)		3,969	—
Peak Period (6-9:30 a.m.)		7,049	—
Total Daily		13,296	—
Vehicle Volumes			
Peak Hour	—	1,504	—
Peak Period	—	2,685	—
Vehicle Occupancy, Peak Hour (persons/veh)	—	2.64	—
Accident Rate (i.e., Injury accidents/100 MVM), 11/84-12/92[1]	—	12.8	—
Vehicle Breakdowns (VMT/Breakdown), 11/84-12/92	—	72,300	—
Violation Rate (6-9:30 a.m.)	—	6.1%	
Peak Hour Lane Efficiency (1000's)[2]	—	221	—
Annual Value of User Time Saved (millions)[3]	—	$2.1 to $4.2	—
Freeway Mainlane Data (see note)			
Person Movement			
Peak Hour	6,140	5,433	-11.5%
Peak Period (6-9:30 a.m.)	17,450	15,982	- 8.4%
Vehicle Volume			
Peak Hour	5,370	5,222	- 2.8%
Peak Period	15,295	14,990	- 2.0%
Vehicle Occupancy, Peak Hour (persons/veh)	1.14	1.04	- 8.8%
Accident Rate (i.e., Injury accidents/100 MVM)[1]	11.7	11.0	-6.0%
Avg. Operating Speed[4]			
Peak Hour	28	29.2	+4.3%
Peak Period	40	46.1	+15.3%
Peak Hour Lane Efficiency (1000's)[2]	62	53	-14.5%

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 Little York and IH 610, a distance of approximately 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 8/92. 1992 freeway volumes estimated by TTI to compute rates.

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

[3] Based on time savings from HOV lane users in 1992, an annual estimate of travel time savings to HOV lane users is developed. A value of time of $10.47/hour is used based on the value applied in the Highway Economic Evaluation Model.

[4] From Little York to IH 610, a distance of 7.70 miles. The remaining 1.8 miles of HOV lane is inside IH 610.

NORTHWEST FREEWAY (US 290) AND HOV LANE, HOUSTON

Table D-2. Summary of Northwest Freeway and HOV Lane Data, December 1992

Type of Data	"Representative" Pre-HOV Lane Value	"Representative" Current Value	% Change
Combined Freeway Mainlane and HOV Lane Data			
Total Person Movement			
Peak Hour	6,140	9,402	+53.1%
Peak Period	17,450	23,031	+32.0%
Vehicle Volume			
Peak Hour	5,370	6,726	+25.3%
Peak Period	15,295	17,675	+15.6%
Vehicle Occupancy			
Peak Hour	1.14	1.40	+22.8%
Peak Period	1.14	1.30	+14.0%
2+ Carpool Volumes			
Peak Hour	490	1,465	+199.0%
Peak Period	1,365	2,611	+ 91.3%
Travel Time (minutes)[1]			
Peak Hour	16.2[2]	12.4[3]	-23.5%
Peak Period	11.4[2]	9.1[3]	-20.2%
Peak Hour Lane Efficiency (1000's)[4]	62	95	+53.2%
Transit Data			
Bus Vehicle Trips			
Peak Hour	7	22	+214.3%
Peak-Period	17	45	+164.7%
Bus Passenger Trips			
Peak Hour	270	880	+225.9%
Peak Period	605	1,670	+176.0%
Bus Occupancy (persons/bus)			
Peak Hour	39	40.0	+2.6%
Peak Period	36	37.1	+3.1%
Vehicles Parked in Corridor Park & Ride Lots	430	1,558	+262.3%
Bus Operating Speed (mph)[1]			
Peak Hour	29.2[2]	55.7[3]	+90.8%
Peak Period	49.2[2]	57.1[3]	+16.1%

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 Little York to IH 610, a distance of 7.70 miles. The remaining 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 miles/hour). It is used as a measure of per lane efficiency.

Table D-3. Comparison of Measures of Effectiveness, Freeway With (Northwest US 290) and Freeway Without (Southwest US 59) HOV Lane, Houston[1]

Measure of Effectiveness	"Representative" Pre-HOV Lane Value	"Representative" 12/92 Value	% Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/HOV lane	1.14	1.40	+ 22.8%
Freeway w/o HOV lane	1.34	1.30	- 3.0%
A.M. Peak Hour, 2+ Carpool Volume Change			
Freeway w/HOV lane	490	1,465	+199.0%
Freeway w/o HOV lane	600	531	- 11.5%
Bus Passengers, Peak Period			
Freeway w/HOV lane	605	1,670	+176.0%
Freeway w/o HOV lane	2,185	2,174	- 0.5%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	430	1,558	+262.3%
Freeway w/o HOV lane	1,685	1,522	- 9.7%
Facility Per Lane Efficiency[2]			
Freeway w/HOV lane	62	56	- 9.7%
Freeway w/o HOV lane	76	60	-21.1%

[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) and on the Southwest Freeway (9/86 to present).

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

HOV LANE DATA

DESCRIPTION

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

- The HOV lane is now complete with 13.5 miles in operation.

- The capital cost (incl. 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 (9.5 miles)
  - 2/6/90 HOV extended to FM 1960 (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 1992, 13,296 person trips per day were served on the HOV lane.

- A.M. peak hour, 3,969 persons/hour.
  - 880 (22%) by bus, 103 (3%) by vanpool, and 2,982 (75%) by carpool (Figure D-1).
  - Average HOV lane vehicle occupancy = 2.64 persons/vehicle.

- A.M. peak period, 7,049 persons.

  - 1,670 (24%) by bus, 145 (2%) by vanpool, and 5,224 (74%) by carpool (Figure D-2).

Table D-4. 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 Mile		$4.6			$4.6
Surveillance, Communication & Control (1990)		$2.9	1.00		$2.9
SUB-TOTAL	$2.9			$2.9	
Per Mile		$0.2			$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 (1992)		1.2	1.00		1.2
SUB-TOTAL	$33.8			$33.2	
Per Mile		$2.4			$2.5
TOTAL COST	$99.4			$98.1	
COST PER MILE (13.5 miles)	$7.4			$ 7.3	

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

VEHICLE MOVEMENT

- A.M. peak hour, 1,504 vph
  - 22 (1%) buses, 13 (1%) vans, and 1,465 (98%) carpools (Figure D-3).

- A.M. peak period, 2,685 vehicles.
  - 45 (2%) buses, 19 (1%) vans, and 2,611 (97%) carpools (Figure D-4).

ACCIDENT RATE

- For the period 8/88 through 12/92, the HOV lane accident rate was 0.74 accidents per million vehicle miles.

VEHICLE BREAKDOWN RATES

- As measured from September 1, 1988 through December 1992, the following rate has been observed.
    - The weighted average for all vehicle types is 1 breakdown per 76,100 VMT. Bus breakdowns occurred once every 41,400 VMT, while cars broke down once every 77,800 VMT.

VIOLATION RATE

- The observed violation rate (vehicles on the HOV lane not eligible to use the HOV lane) is approximately 6.1%.

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 146.

TRAVEL TIME SAVINGS

- The users of the HOV lane experience an average travel time savings of 11 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 48,236 minutes, or 804 hours, are realized. Assuming 250 days of operation and a value of time of $10.47/hour, this equates to $2.1 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 $2.1 to $4.2 million per year.

Table D-5. Southbound A.M. Travel Time Savings for Northwest HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1992)

Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	T-Way (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section from Eldridge to Senate								
6:00	4.18	3.97	0.22	243	18	140	401	86.94
6:30	4.01	3.98	0.03	777	48	230	1,055	35.17
7:00	5.71	5.06	0.65	1,184	9	278	1,470	957.18
7:30	5.92	4.08	1.85	792	1	243	1,036	1,911.81
8:00	4.02	4.10	-0.08	409	0	120	529	-43.35
8:30	4.05	4.03	0.03	166	0	0	166	4.16
9:00	4.06	4.03	0.03	45	0	0	45	1.24
Peak Period Total				3,616	75	1,010	4,701	2,953.16
Section From Senate to S.P. Railroad								
6:00	14.42	13.63	0.80	175	12	111	298	236.96
6:30	14.00	13.68	0.31	795	56	293	1,144	357.50
7:00	24.35	15.84	8.51	1,415	31	438	1,883	16,013.79
7:30	26.39	15.12	11.27	1,528	17	421	1,966	22,150.28
8:00	16.11	14.83	1.29	844	2	281	1,127	1,449.41
8:30	12.49	13.63	-1.14	317	1	18	335	-381.34
9:00	12.47	13.62	-1.15	99	0	0	99	-114.26
Peak Period Total				5,173	119	1,560	6,852	39,712.34
Northbound P.M. Travel Time Savings for Northwest HOV Lane								
Section from Senate to Eldridge								
3:30	4.27	4.37	-0.11	116	1	8	87	-9.42
4:00	4.34	4.38	-0.04	208	8	69	316	-11.84
4:30	4.16	4.25	-0.09	438	31	200	716	-66.64
5:00	4.39	4.33	0.07	806	68	324	1,231	82.09
5:30	4.74	4.37	0.37	1,048	13	332	1,447	530.58
6:00	4.45	4.33	0.12	626	2	194	845	98.53
6:30	5.22	4.92	0.30	203	0	55	268	80.40
Peak Period Total				3,444	123	1,181	4,909	703.69
Section from the S.P. Railroad to Senate								
3:30	12.45	14.25	-1.79	120	0	38	158	-238.08
4:00	12.62	14.17	-1.55	292	22	104	417	-646.73
4:30	12.21	14.13	-1.91	648	59	355	1,062	-2,032.56
5:00	16.67	14.49	2.17	965	13	523	1,502	3,262.59
5:30	17.89	15.75	2.14	1,060	4	445	1,509	3,231.25
6:00	17.08	15.05	2.03	541	4	225	770	1,561.96
6:30	13.60	14.12	-0.52	180	0	113	292	-150.99
Peak Period Total				3,806	101	1,803	5,710	4,942.44

FREEWAY DATA

NOTE

- For purposes of safety and visibility, freeway volumes are counted at 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 11.5% (Figure D-6).

- In the a.m. peak period, compared to pre-HOV conditions, person movement has decreased by 8.4% (Figure D-7).

VEHICLE VOLUME

- In the a.m. peak hour, vehicle volume has decreased by 2.8% (Figure D-6).

- In the a.m. peak period, vehicle volume has decreased by 2.0% (Figure D-7).

VEHICLE OCCUPANCY

- In the a.m. peak hour, compared to pre-HOV conditions, mainlane occupancy has declined by 8.8% (Figure D-11).

- In the a.m. peak period, compared to pre-HOV conditions, mainlane occupancy has declined by 6.1% (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 11.7 accidents per 100 million vehicle miles (100 MVM). The accident data available for the period (9/88-8/92) after the HOV lane opened indicate an accident rate of 8.0 accidents/100 MVM. 1992 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, decreased peak hour person movement has resulted in a decrease in per lane efficiency of 58.1%.

COMBINED FREEWAY AND HOV LANE DATA

TOTAL PERSON MOVEMENT

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

  - At Pinemont, the HOV lane is responsible for 42% of peak-hour person movement (HOV lane = 3,969; freeway = 5,433) and 31% of peak-period (HOV lane = 7,049; freeway = 15,982) 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 53.1%, from 6,140 to 9,402 (Figure D-9). Peak-period person movement has increased by 32.0%, from 17,450 to 23,031 (Figure D-10).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.40, a 22.8% increase over the pre-HOV lane occupancy (Figure D-11). Occupancy in the peak period is 14.0% 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 199.0% compared to pre-HOV lane levels (Figure D-14). In the a.m. peak period, the increase has been 91.3% (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 decreased by 9.7% 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 PASSENGER TRIPS

- In the a.m. peak hour, bus vehicle trips have been increased by 214% since the HOV lane opened, and a 226% increase in bus ridership has resulted (Figure D-19). In the peak period, a 165% increase has occurred in bus vehicle trips, and a 176% 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).

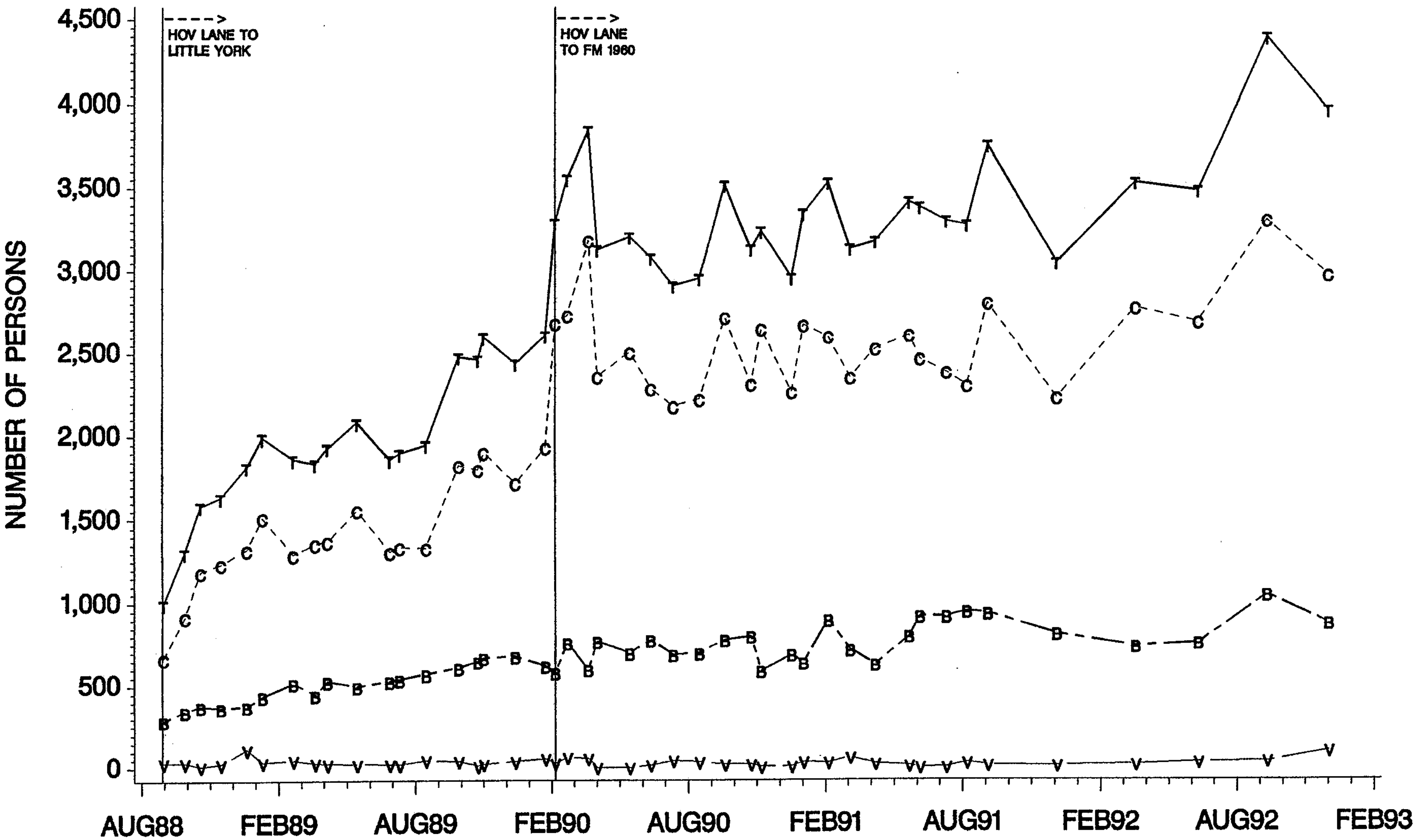
PARK-AND-RIDE

- Prior to opening the HOV lane, approximately 430 vehicles were parked in corridor park-and-ride lots. This has increased 262% to a current level of 1,558 (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 (US 290) HOV LANE
A.M. PEAK HOUR HOV LANE PERSON MOVEMENT

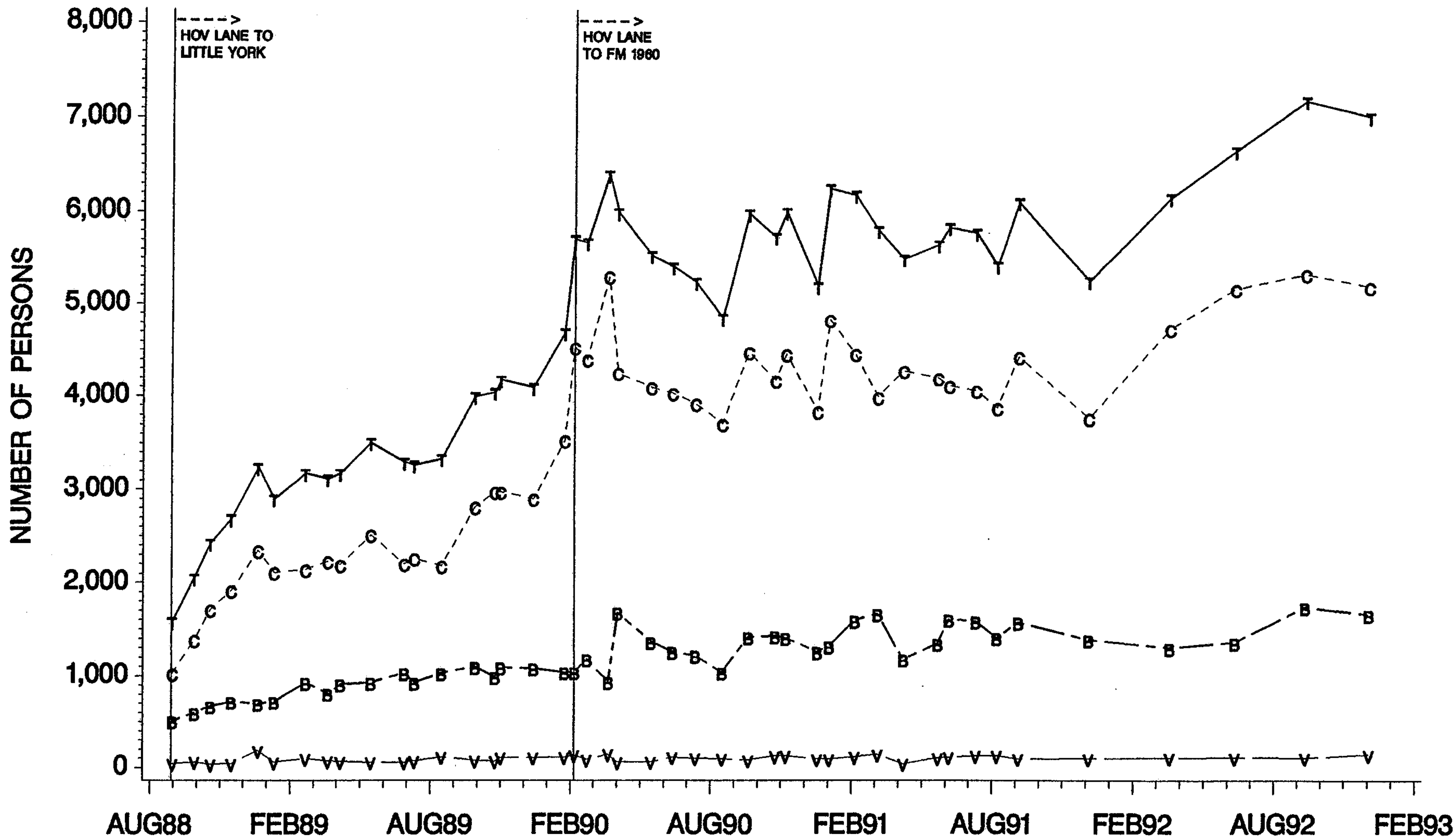


NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (9.5 MI), OPENED AUGUST 29, 1988
NORTHWEST HOV LANE PHASE 2, LITTLE YORK TO FM 1960 (3.9 MI.), OPENED FEBRUARY 6, 1990
DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-2

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

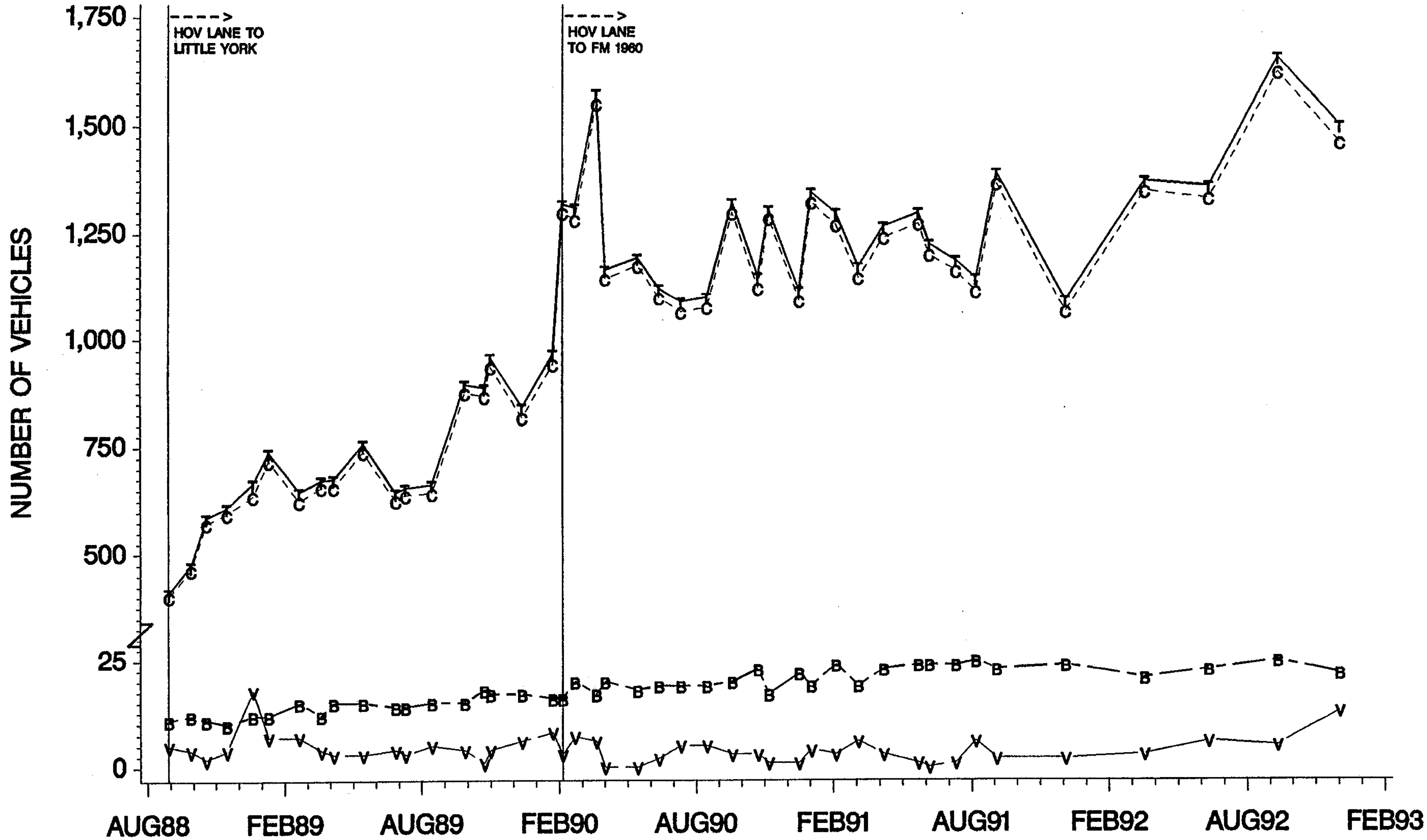


NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (9.5 MI), OPENED AUGUST 29, 1988
NORTHWEST HOV LANE PHASE 2, LITTLE YORK TO FM 1960 (3.9 MI.), OPENED FEBRUARY 6, 1990
PEAK PERIOD IS 6:00 – 9:30 A.M.
DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-3

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

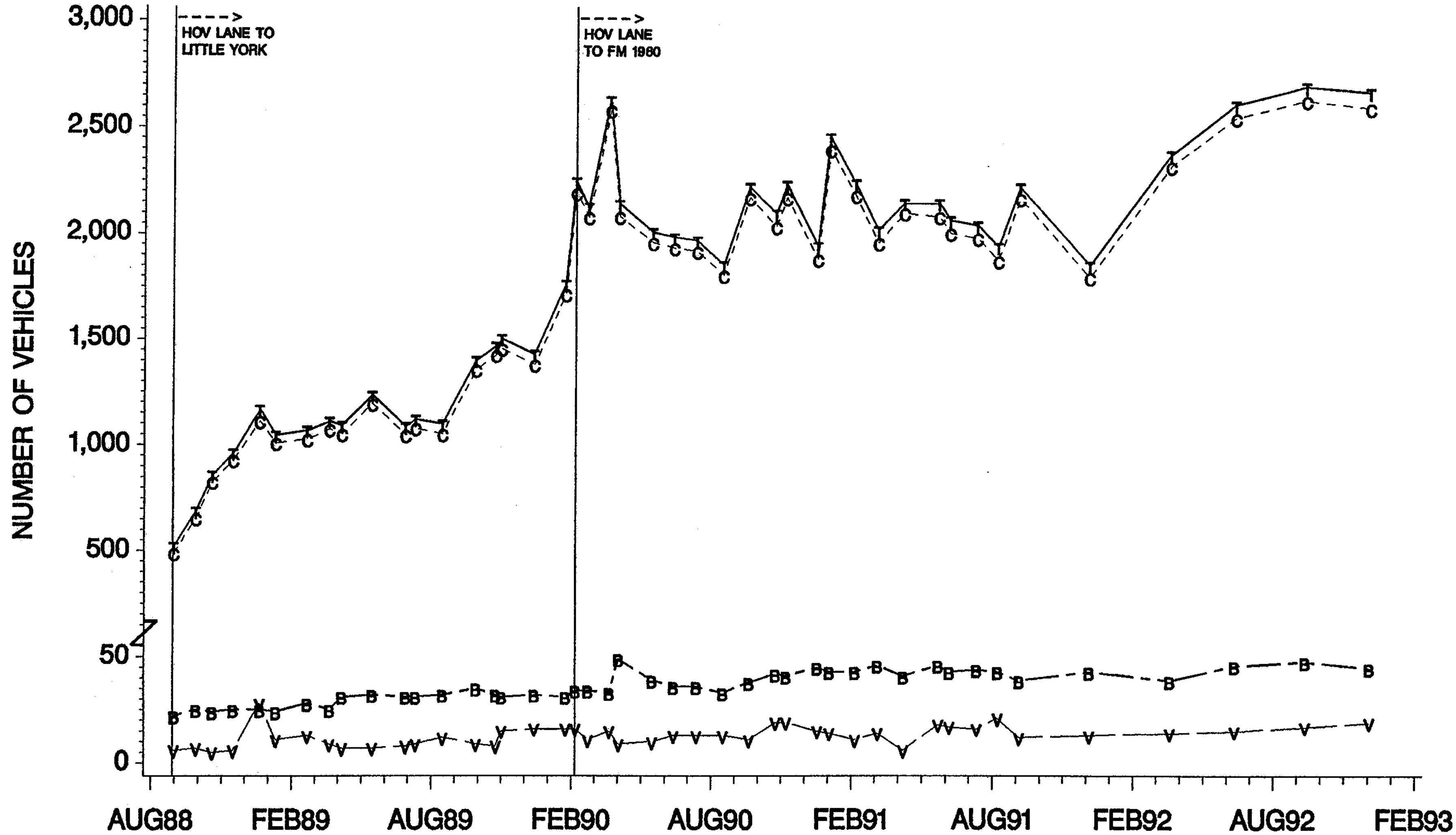


NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (9.5 MI), OPENED AUGUST 29,1988
NORTHWEST HOV LANE PHASE 2, LITTLE YORK TO FM 1960 (3.9 MI.), OPENED FEBRUARY 6, 1990
DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-4

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

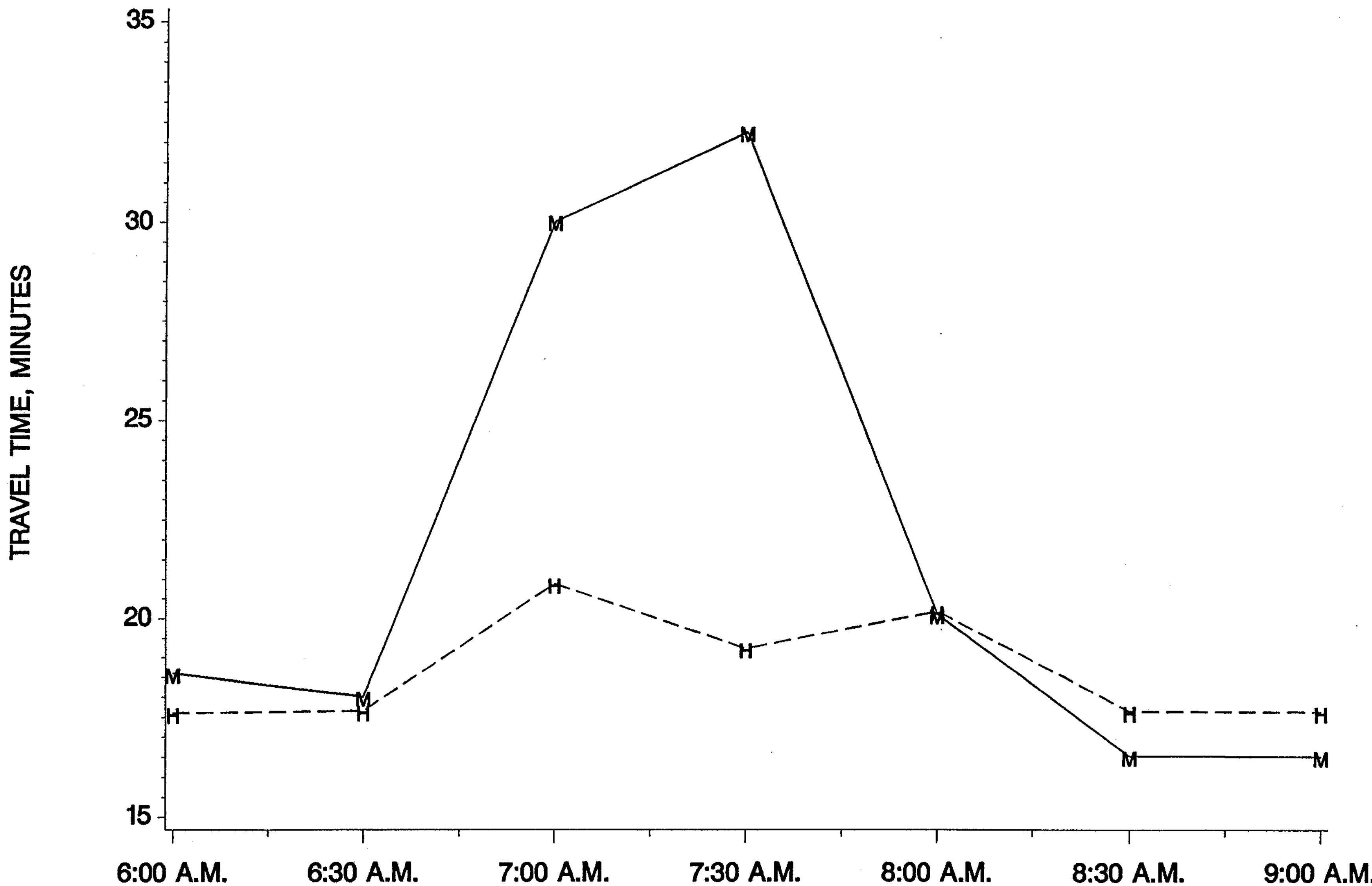


NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER TO
LITTLE YORK (9.5 MI), OPENED AUGUST 29, 1988
NORTHWEST HOV LANE PHASE 2, LITTLE YORK TO FM 1960 (3.9 MI.), OPENED FEBRUARY 6, 1990
PEAK PERIOD IS 6:00 – 9:30 A.M.
DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-5

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

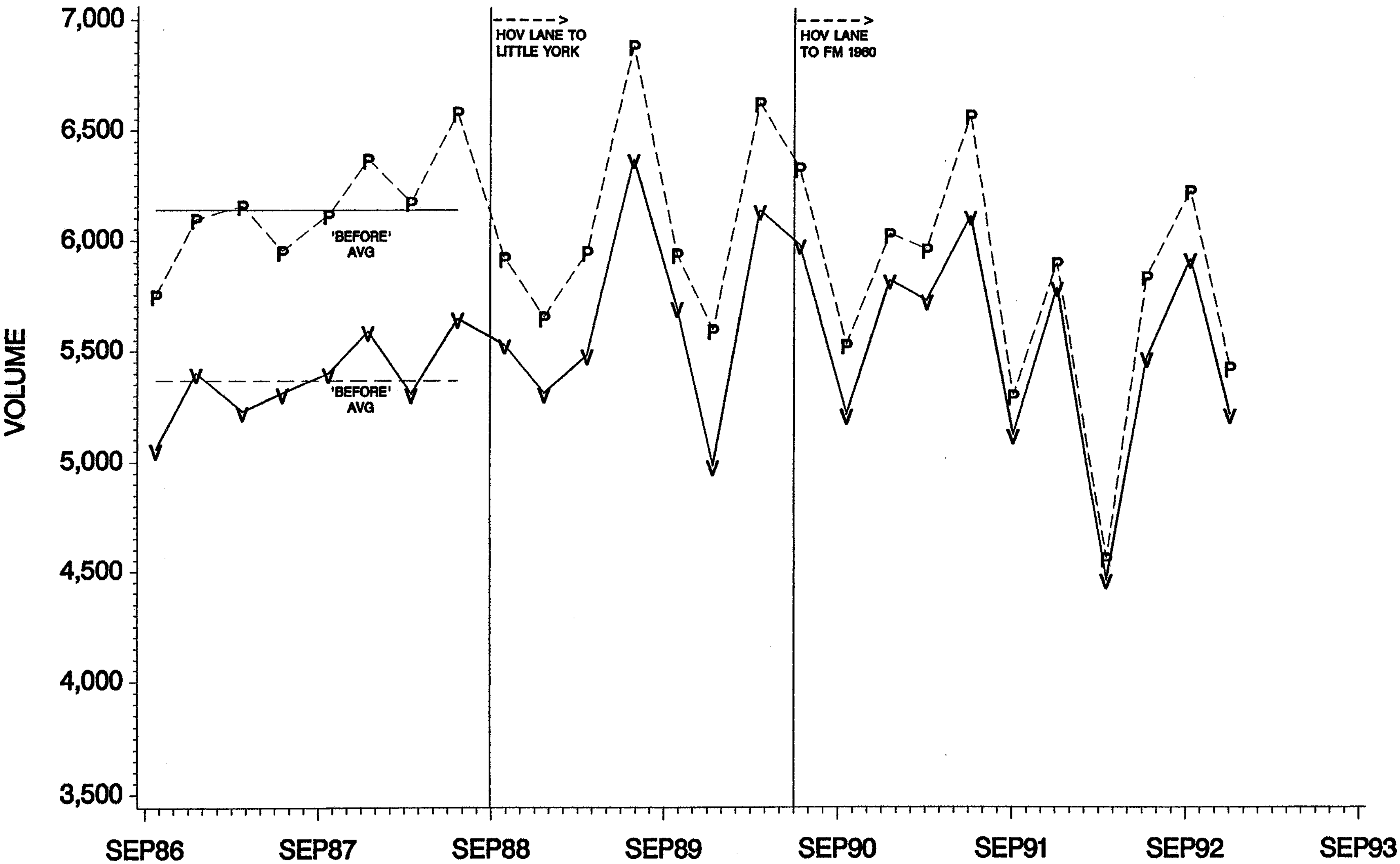


TRAVEL TIMES ARE AN AVERAGE OF 4 QUARTERLY TRAVEL TIME SURVEYS CONDUCTED IN 1992
TRAVEL TIMES ARE FROM TELGE TO S.P.R.R. @ KATY FREEWAY
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-6

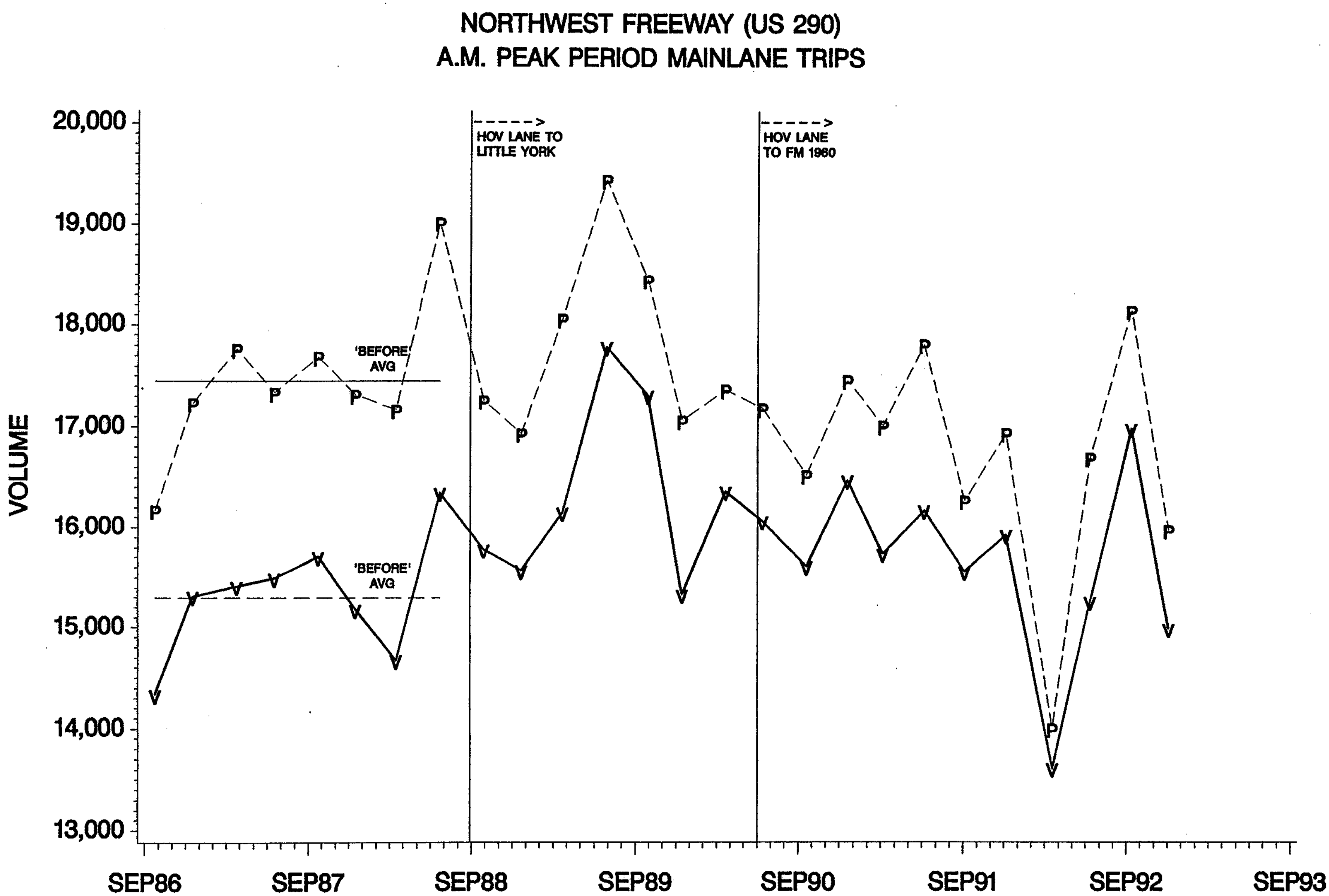
NORTHWEST FREEWAY (US 290)
A.M. PEAK HOUR MAINLANE TRIPS



NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (9.5 MI), OPENED AUGUST 29,1988
DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-7

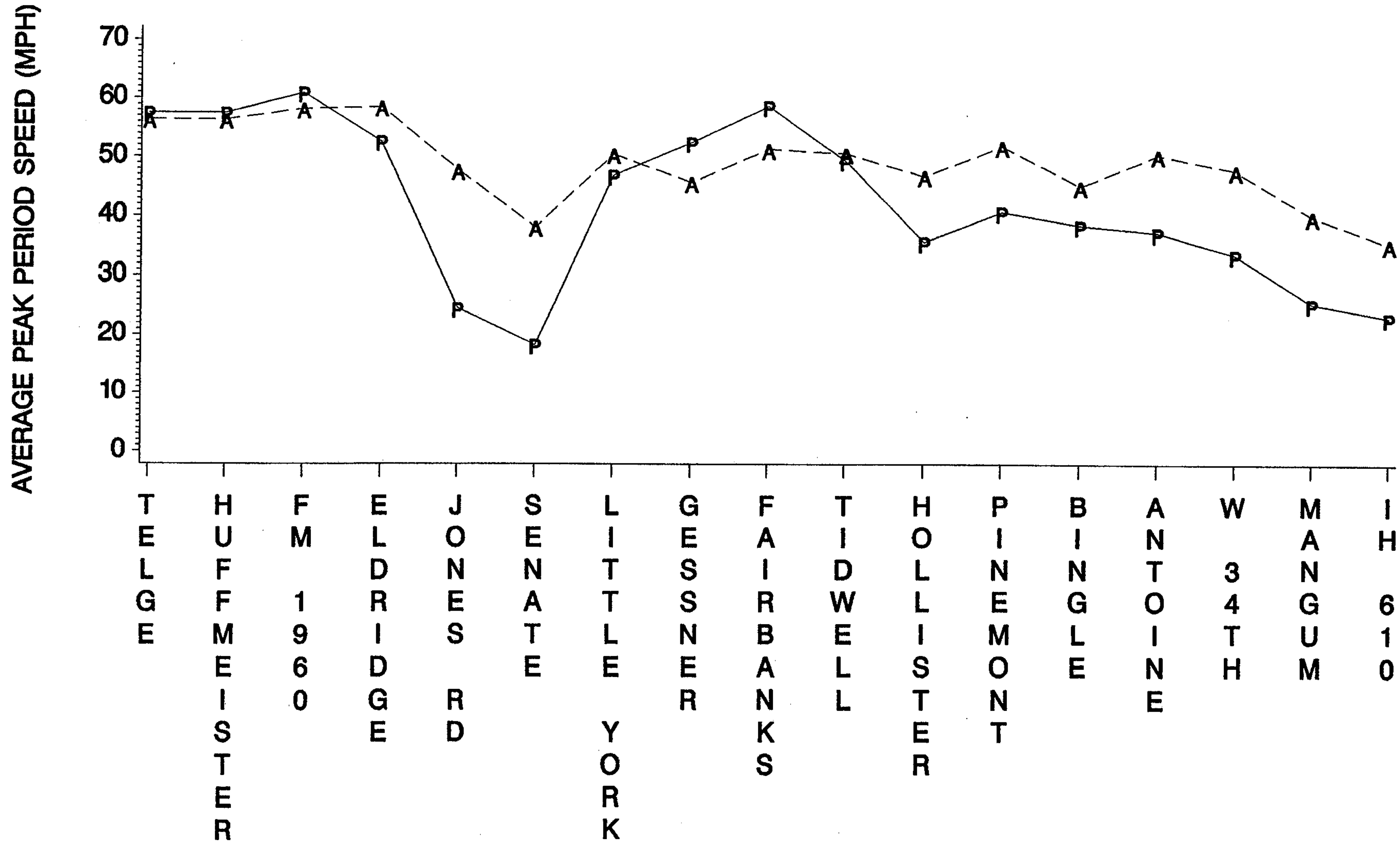


NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (9.5 MI), OPENED AUGUST 29,1988
PEAK PERIOD IS 6:00 TO 9:30 A.M.
DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-8

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



DATA COLLECTED 6:00 TO 9:30 A.M.
DATA COLLECTED FROM SEPTEMBER, 1986 TO DECEMBER, 1992
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-9

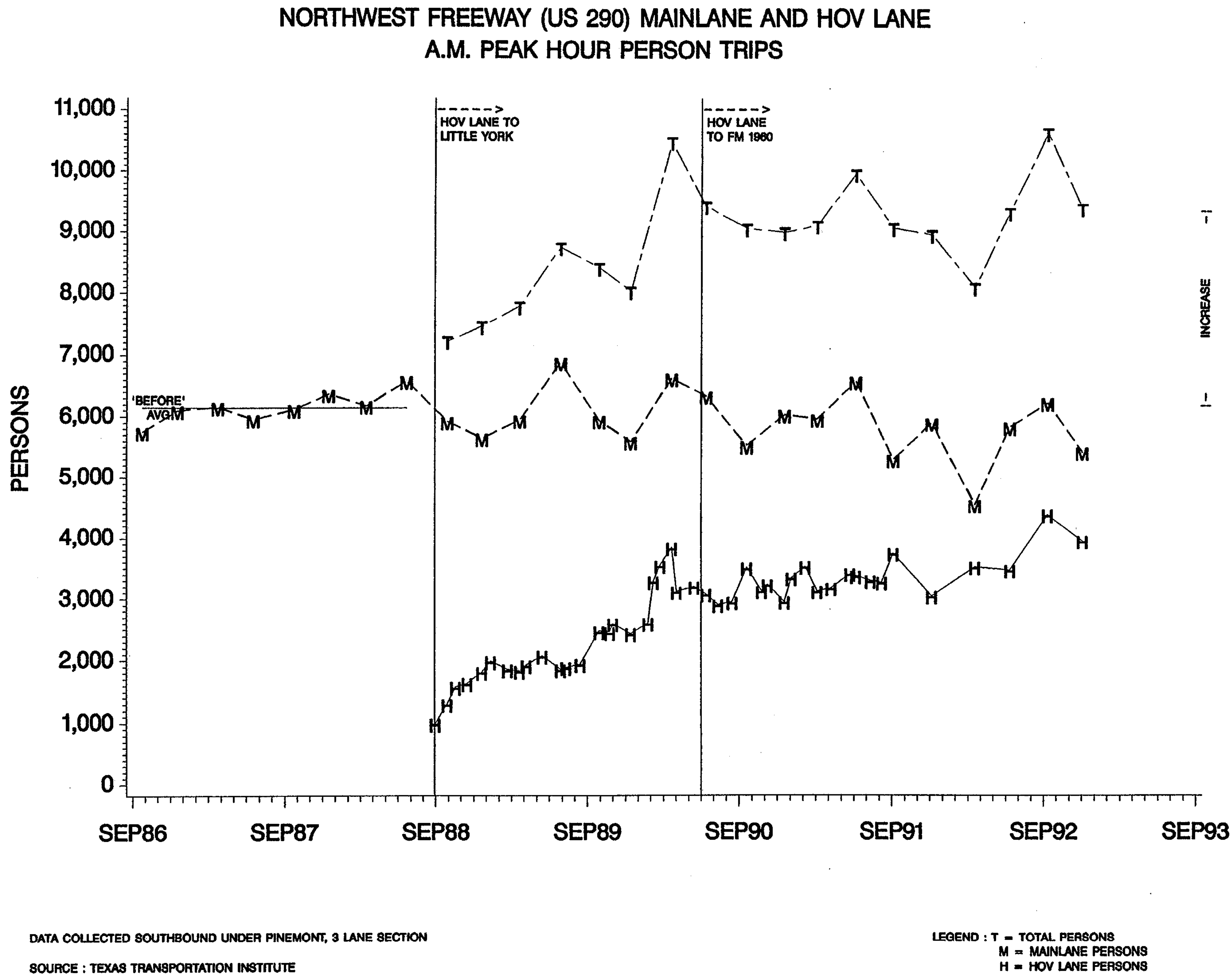
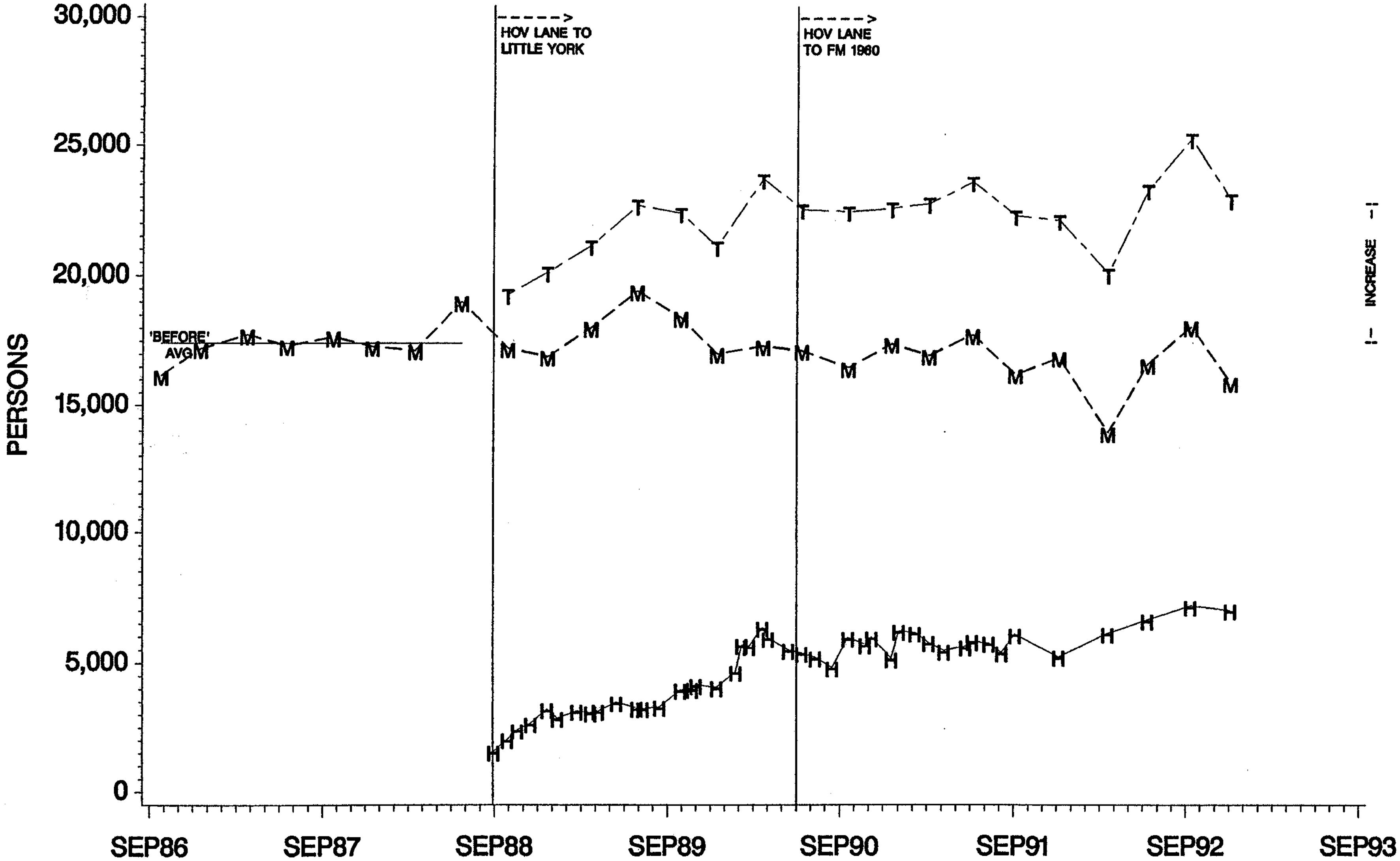

NORTHWEST FREEWAY (US 290) MAINLANE AND HOV LANE
A.M. PEAK HOUR PERSON TRIPS
PERSONS
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
SEP86
SEP87
SEP88
SEP89
SEP90
SEP91
SEP92
SEP93
'BEFORE' AVG
HOV LANE TO LITTLE YORK
HOV LANE TO FM 1960
INCREASE
DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE
LEGEND : T = TOTAL PERSONS
M = MAINLANE PERSONS
H = HOV LANE PERSONS

FIGURE D-10

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



DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION
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 D-11

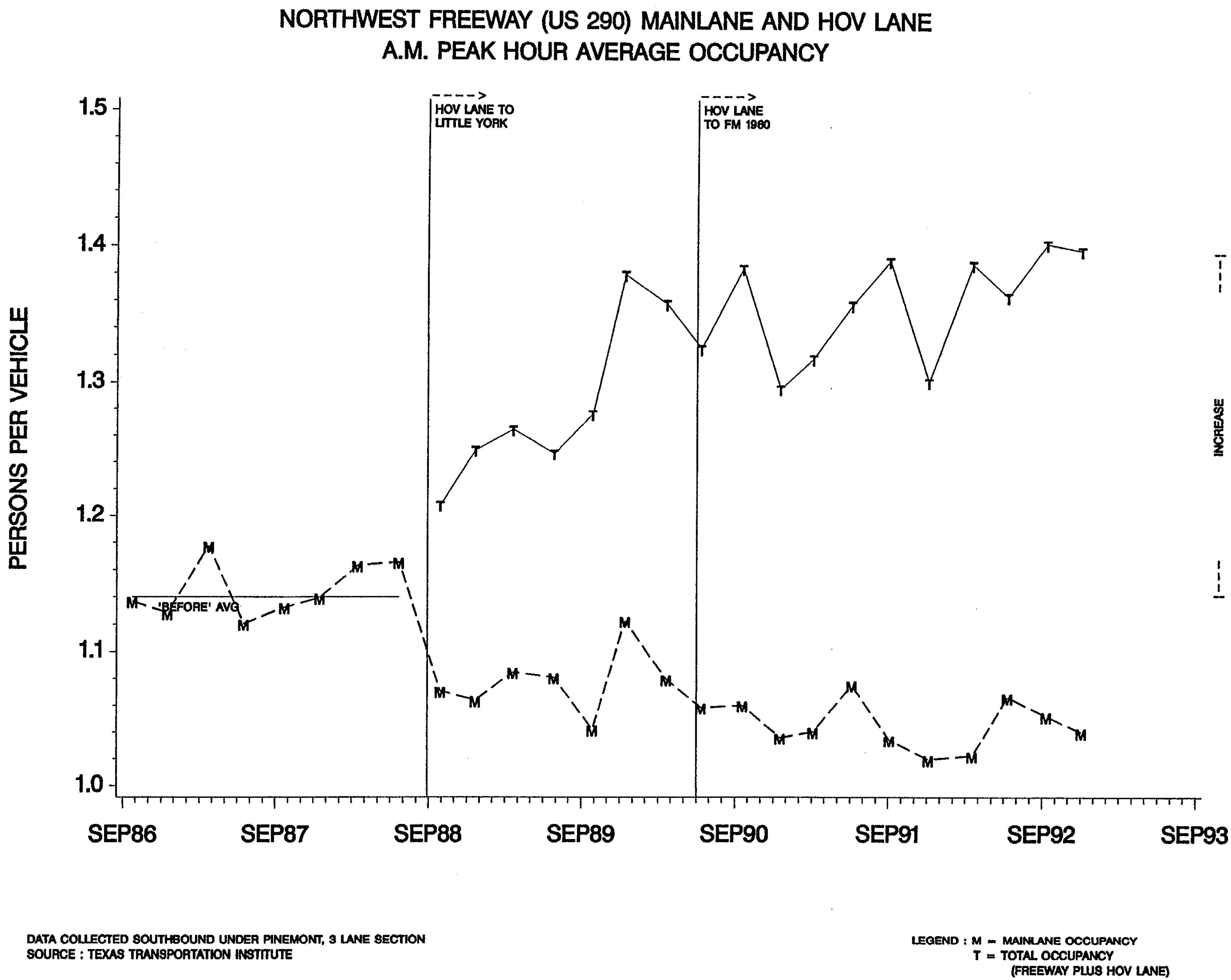
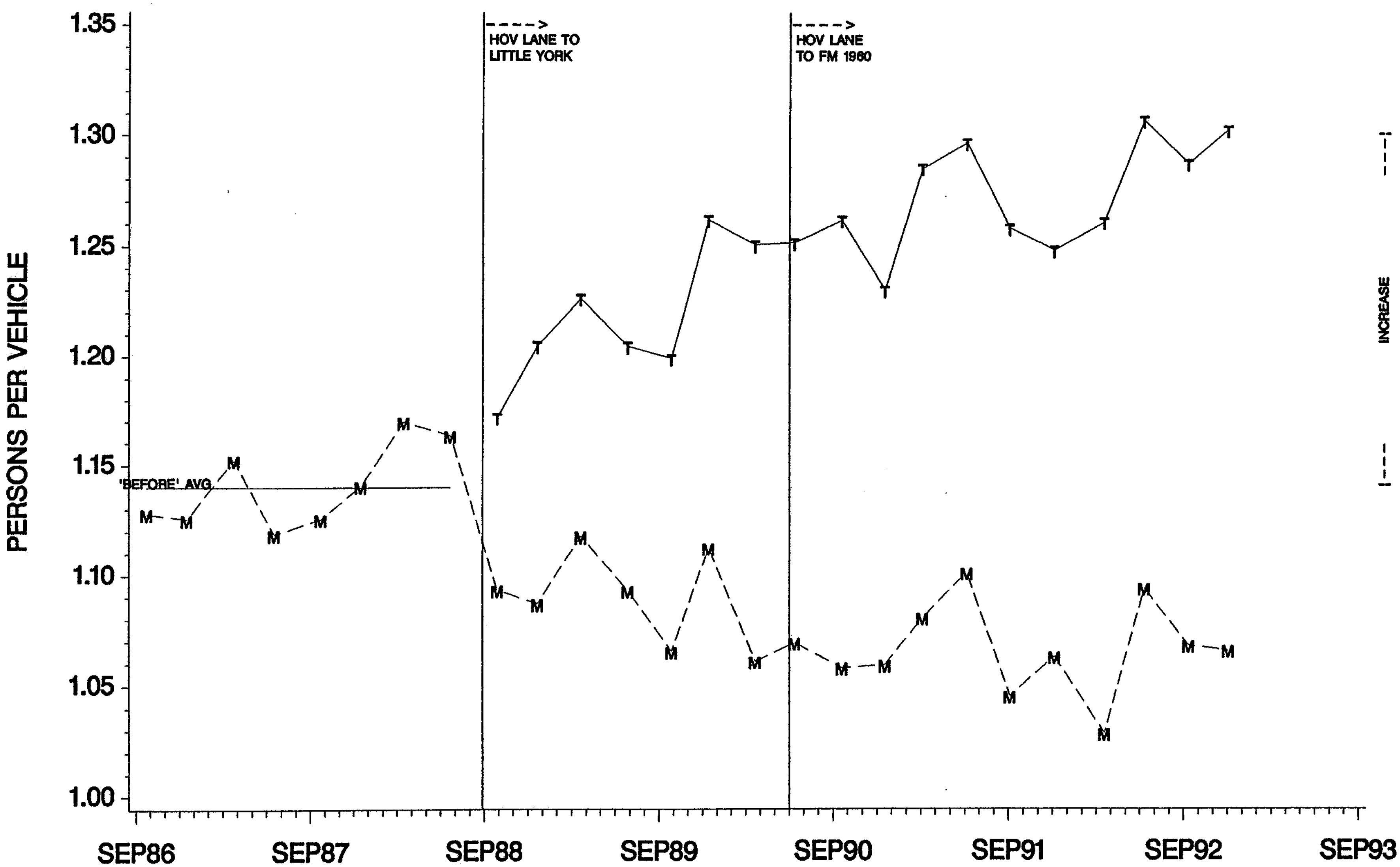

NORTHWEST FREEWAY (US 290) MAINLANE AND HOV LANE
A.M. PEAK HOUR AVERAGE OCCUPANCY
PERSONS PER VEHICLE
1.5
1.4
1.3
1.2
1.1
1.0
HOV LANE TO LITTLE YORK
HOV LANE TO FM 1960
'BEFORE' AVG
INCREASE
SEP86
SEP87
SEP88
SEP89
SEP90
SEP91
SEP92
SEP93
DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE
LEGEND : M = MAINLANE OCCUPANCY
T = TOTAL OCCUPANCY
(FREEWAY PLUS HOV LANE)

FIGURE D-12

NORTHWEST FREEWAY (US 290) MAINLANE AND HOV LANE
A.M. PEAK PERIOD AVERAGE OCCUPANCY



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

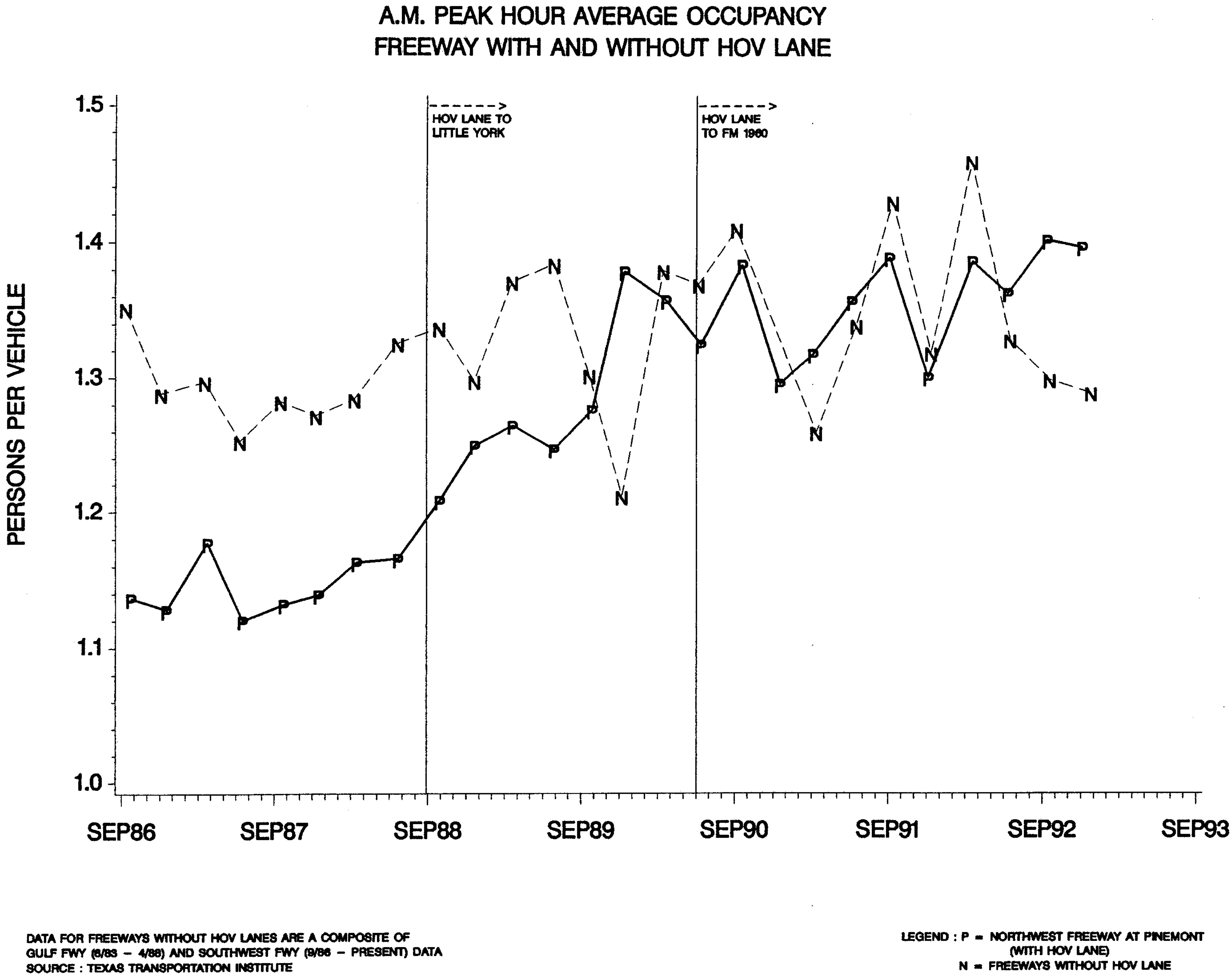
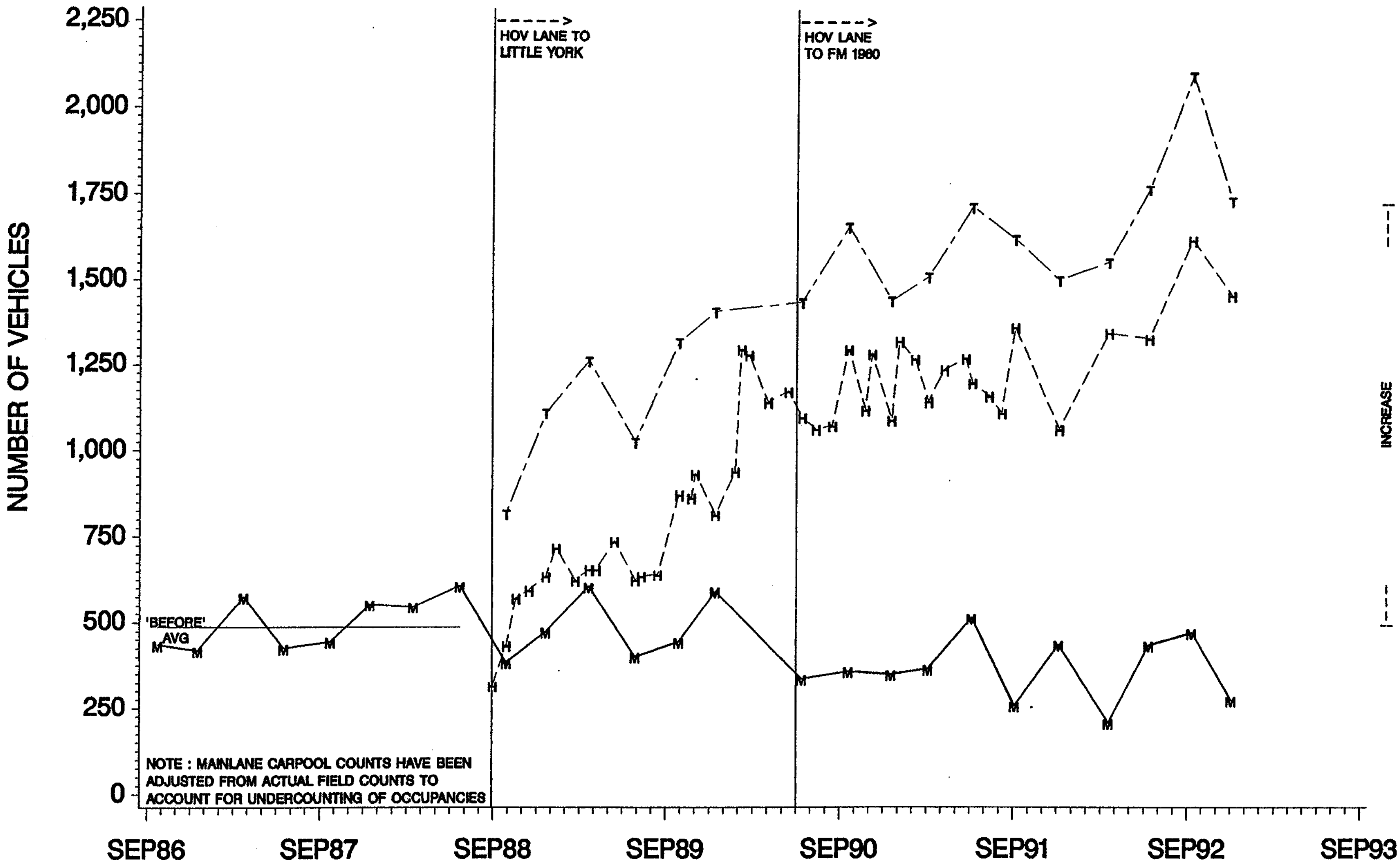

A.M. PEAK HOUR AVERAGE OCCUPANCY
FREEWAY WITH AND WITHOUT HOV LANE
PERSONS PER VEHICLE
1.5
1.4
1.3
1.2
1.1
1.0
HOV LANE TO LITTLE YORK
HOV LANE TO FM 1960
SEP86
SEP87
SEP88
SEP89
SEP90
SEP91
SEP92
SEP93
DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF
GULF FWY (6/83 - 4/88) AND SOUTHWEST FWY (9/86 - PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE
LEGEND : P = NORTHWEST FREEWAY AT PINEMONT (WITH HOV LANE)
N = FREEWAYS WITHOUT HOV LANE

FIGURE D-14

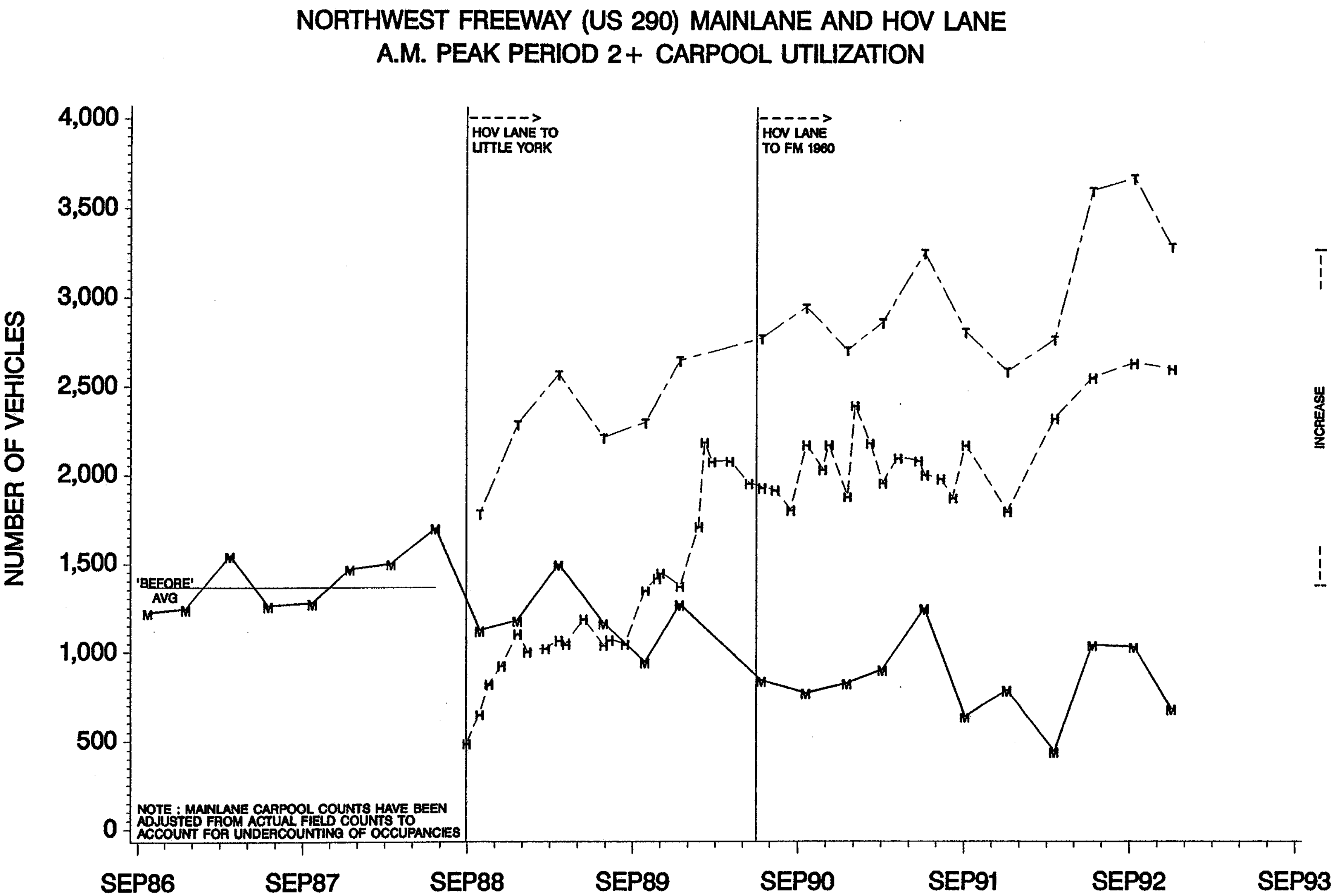
NORTHWEST FREEWAY (US 290) MAINLANE AND HOV LANE
A.M. PEAK HOUR 2+ CARPOOL UTILIZATION



NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (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

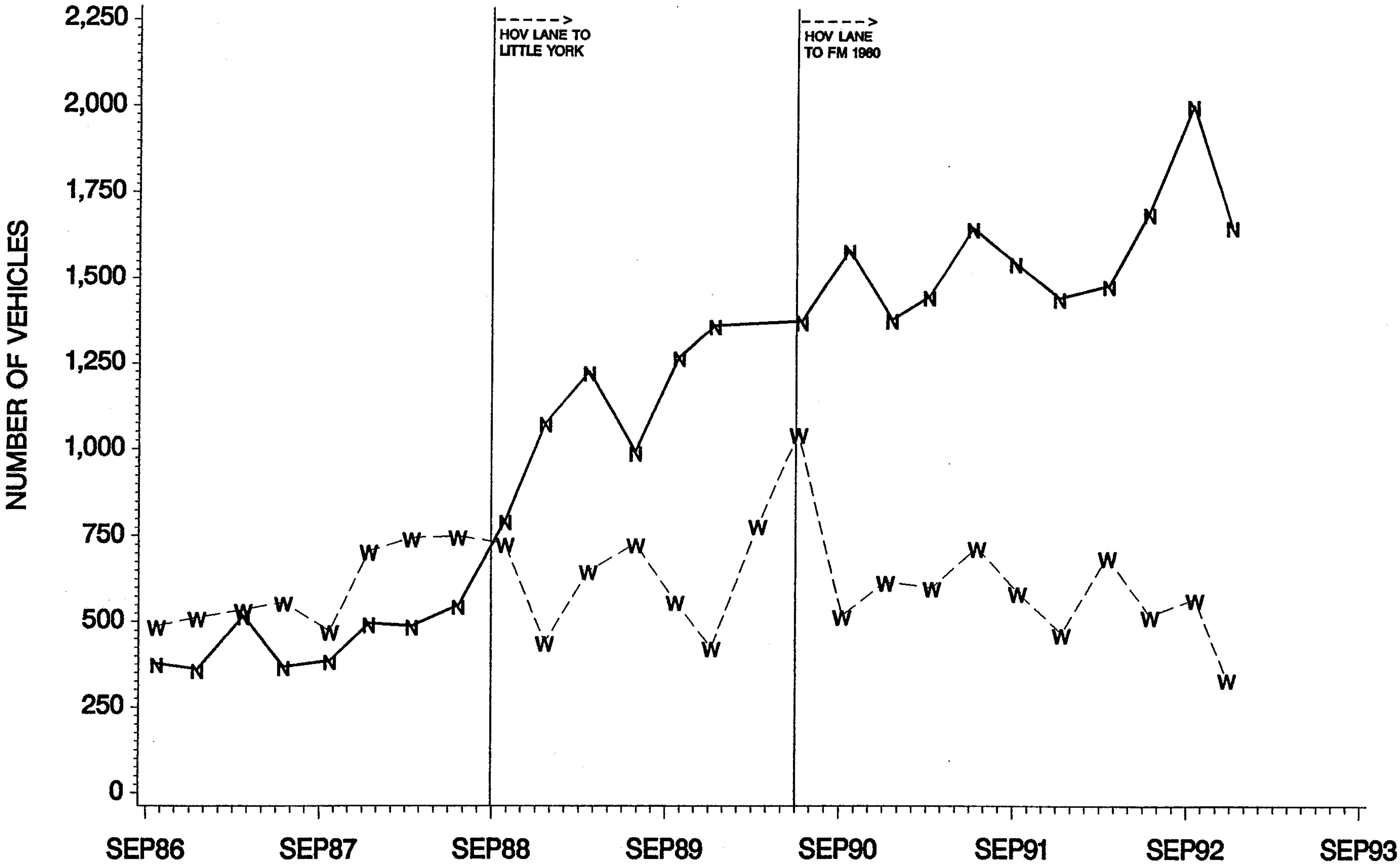


NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (9.5 MI), OPENED AUGUST 29, 1988
PEAK PERIOD IS 6:00 ~ 9:30 A.M.
DATA COLLECTED SOUTHBOUND UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-16

A.M. PEAK HOUR 2+ CARPOOL VOLUMES FREEWAYS WITH AND WITHOUT HOV LANE

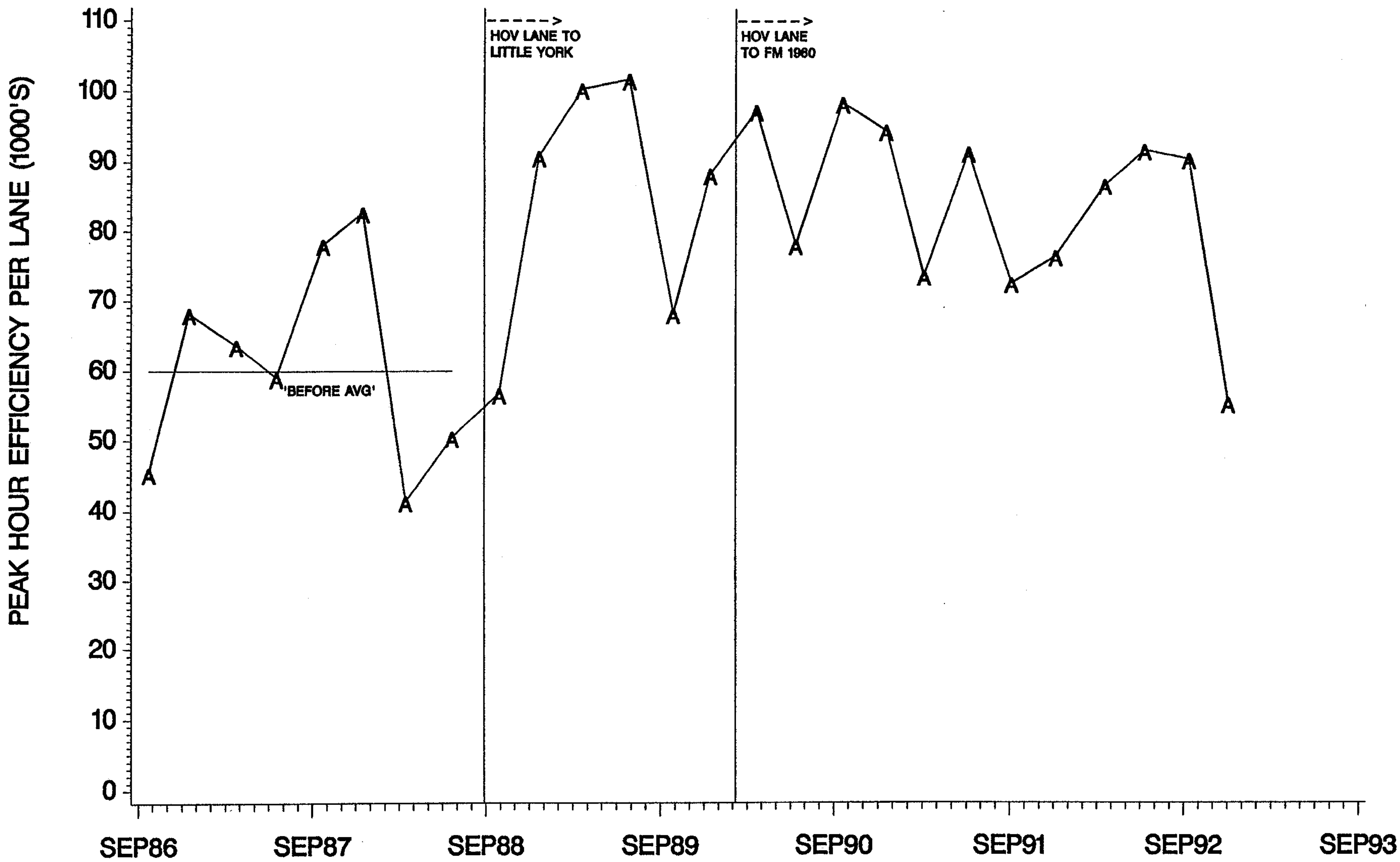


DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF GULF FWY (6/83 – 4/88) AND SOUTHWEST FWY (6/88 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : N = NORTHWEST FREEWAY 2+ CARPOOLS
W = FREEWAYS WITHOUT HOV LANE

FIGURE D-17

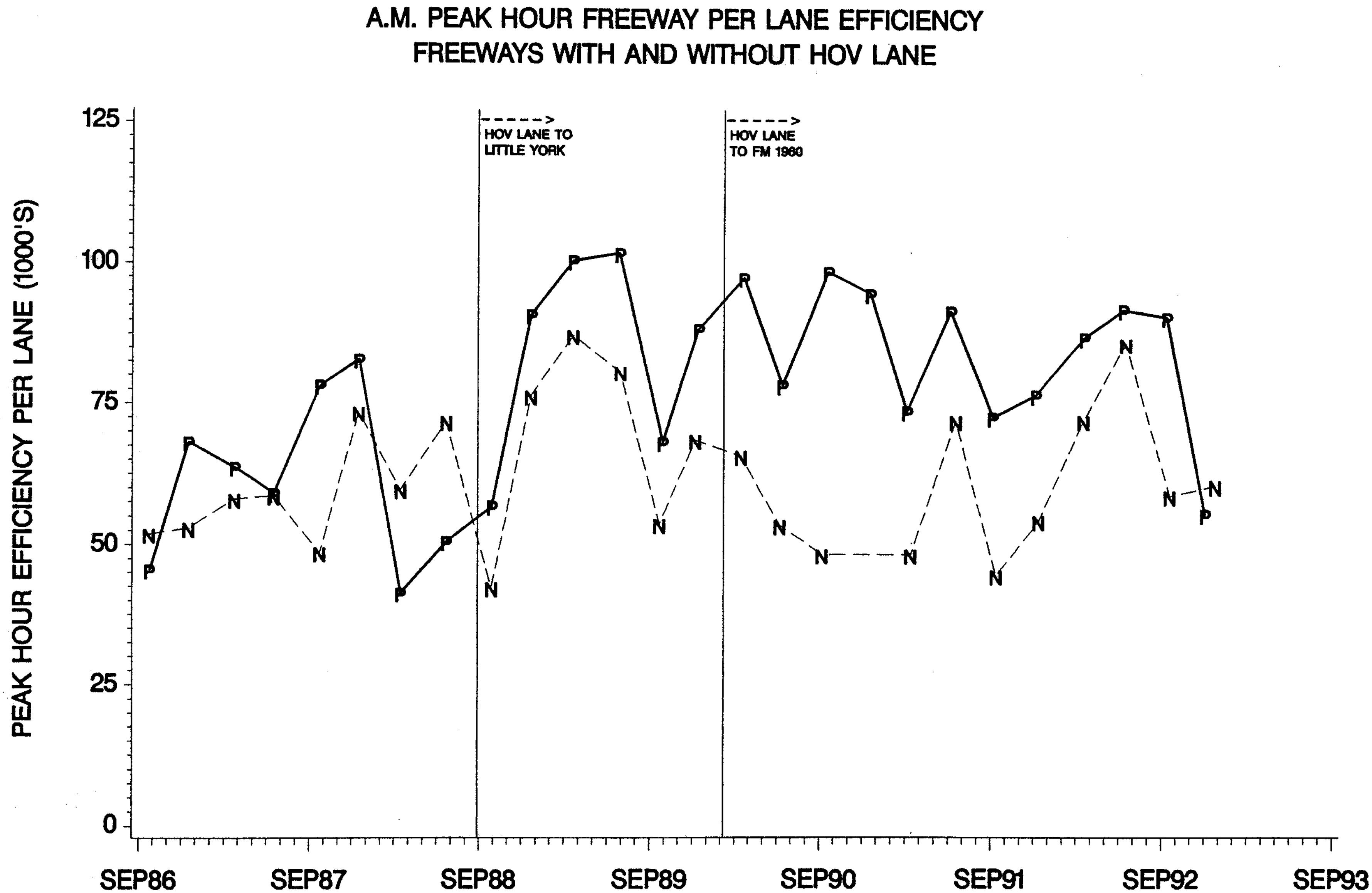
NORTHWEST FREEWAY (US 290) EVALUATION
A.M. PEAK HOUR COMBINED MAINLANE AND HOV LANE EFFICIENCY



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 4 LANES
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : A = A.M. PEAK HOUR EFFICIENCY

FIGURE D-18

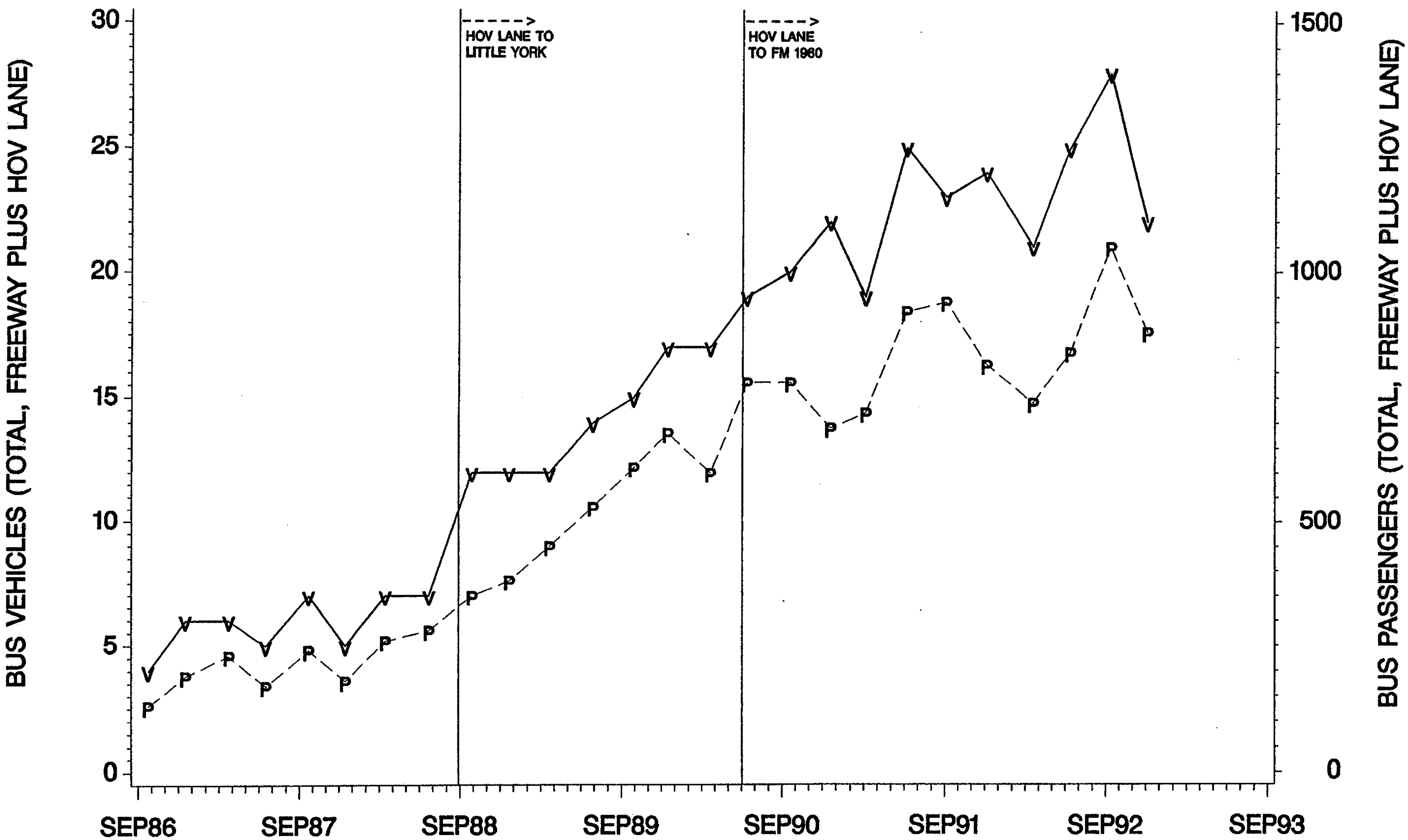


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE HOV LANE, IT REPRESENTS TOTAL PERSONS (FREEWAY + HOV LANE) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 4 LANES
DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF GULF FWY (6/83 – 4/86) AND SOUTHWEST FWY (6/86 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = NORTHWEST FREEWAY EFFICIENCY
N = FREEWAYS WITHOUT HOV LANE

FIGURE D-19

NORTHWEST FREEWAY (US 290) MAINLANE AND HOV LANE
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS

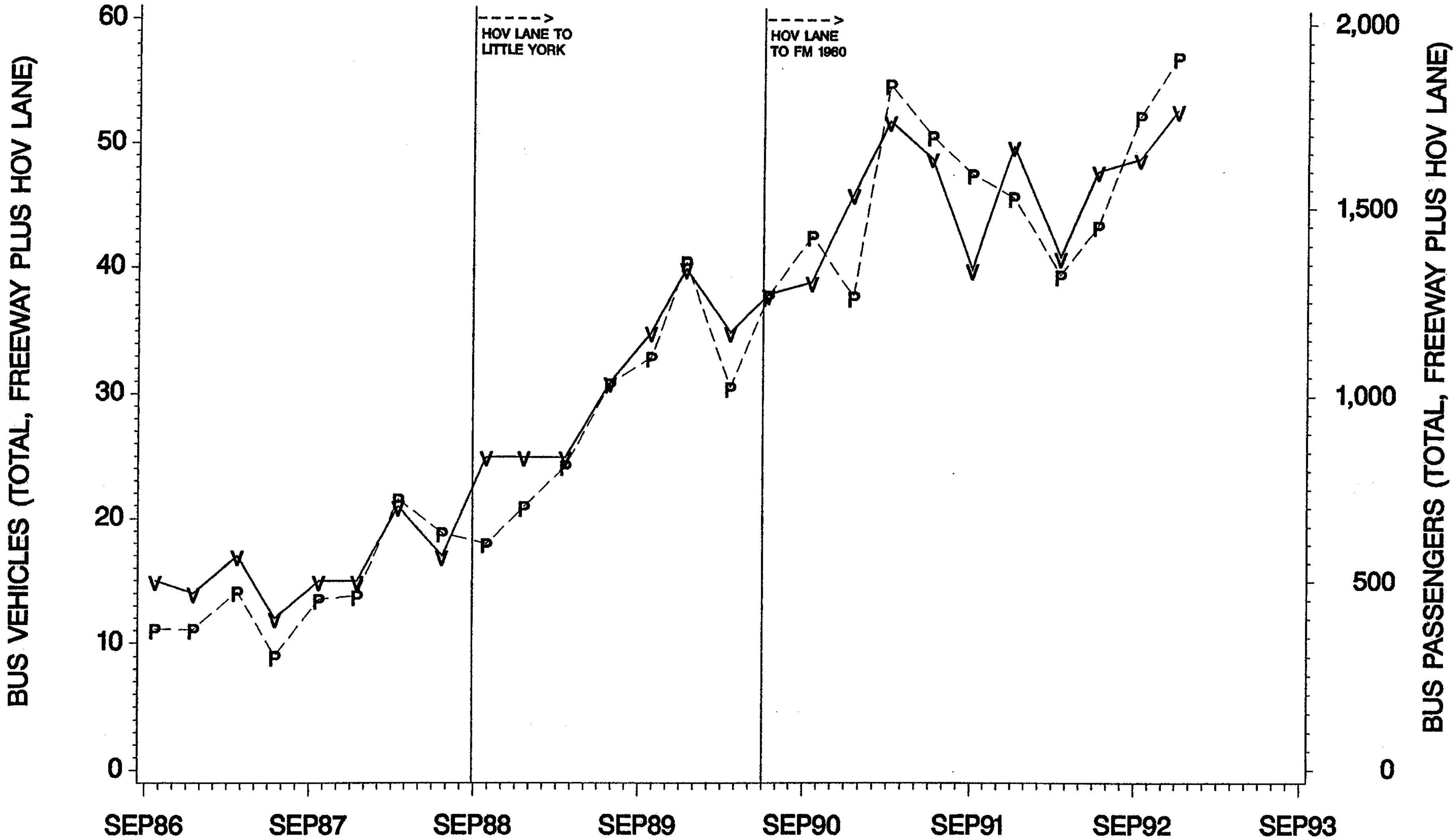


DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-20

NORTHWEST FREEWAY (US 290) MAINLANE AND HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS

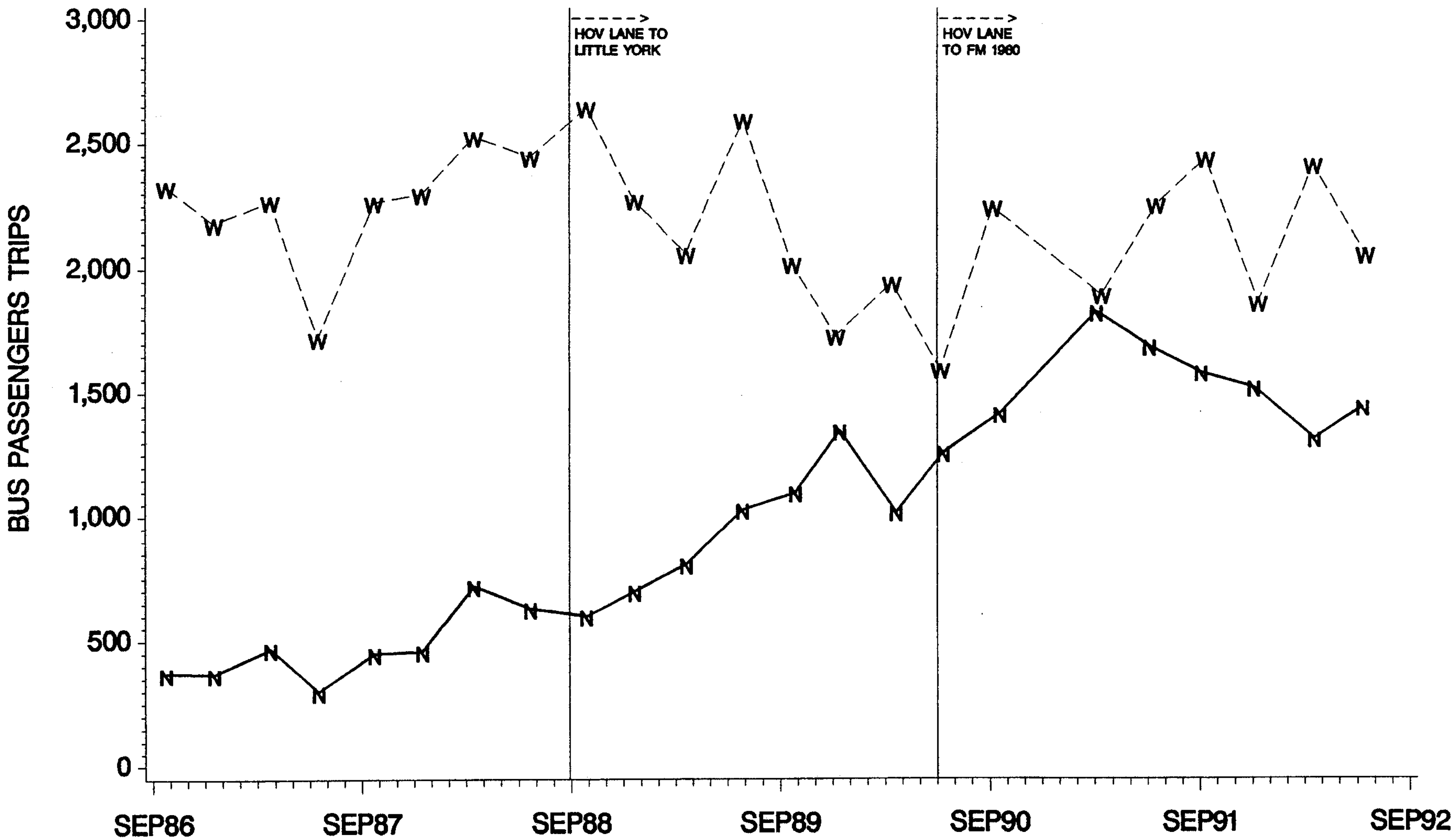


PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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
FREEWAYS WITH AND WITHOUT HOV LANE

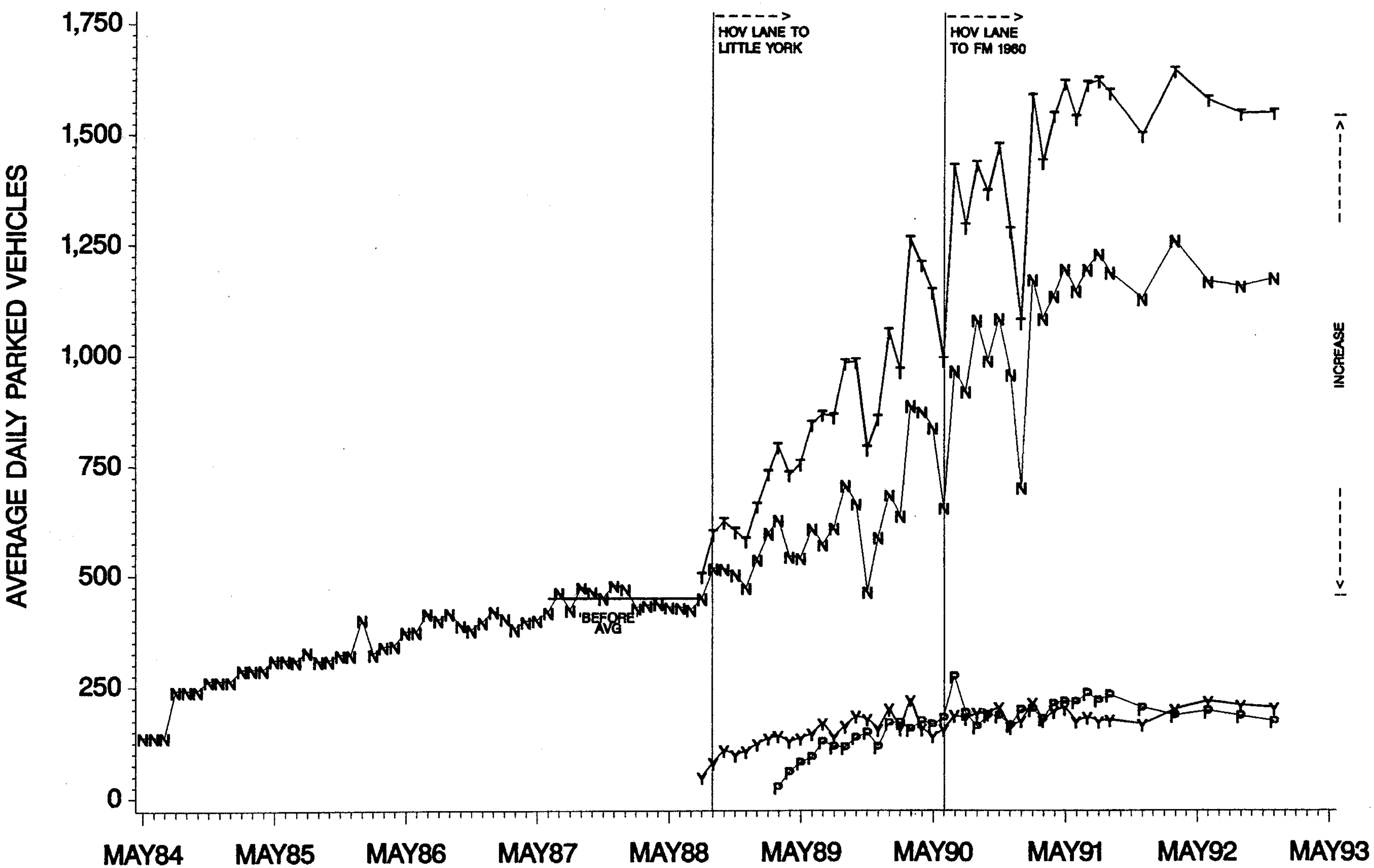


PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA FOR FREEWAYS WITHOUT HOV LANES ARE A COMPOSITE OF
GULF FWY (6/83 – 4/88) AND SOUTHWEST FWY (9/88 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : N = NORTHWEST FREEWAY AT PINEMONT (WITH HOV LANE)
W = FREEWAYS WITHOUT HOV LANE

FIGURE D-22

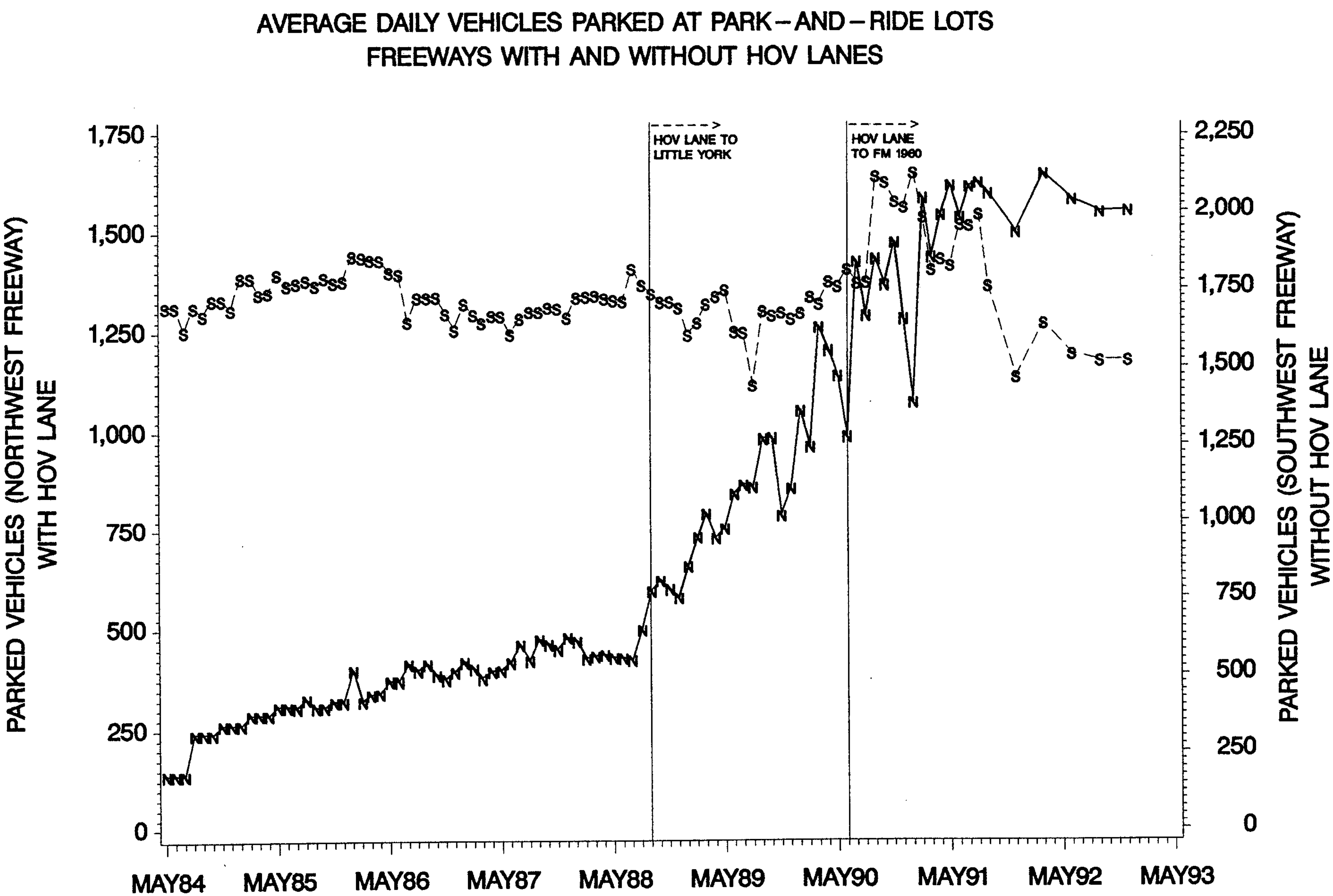
NORTHWEST FREEWAY (US 290) CORRIDOR PARK-AND-RIDE DEMAND



NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (9.5 MI), OPENED AUGUST 29, 1988
CURRENT TOTAL CORRIDOR PARKING CAPACITY = 3,130 SPACES
HOV LANE EXTENSION FROM LITTLE YORK TO FM 1960 (3.9 MI.) OPENED JUNE 2, 1990
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL PARKED VEHICLES
N = NORTHWEST STATION (945 SPACES)
Y = LITTLE YORK LOT (1,265 SPACES)
P = PINEMONT LOT (920 SPACES)

FIGURE D-23



NORTHWEST HOV LANE PHASE 1, NORTHWEST TRANSIT CENTER
TO LITTLE YORK (9.5 MI), OPENED AUGUST 29, 1988
HOV LANE EXTENSION FROM LITTLE YORK TO FM 1960 (3.9 MI.) OPENED JUNE 2, 1990
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : N = NORTHWEST FREEWAY
S = FREEWAY WITHOUT HOV LANE (SOUTHWEST)

APPENDIX E

EAST R. L. THORNTON FREEWAY AND HOV LANE DATA

EAST R. L. THORNTON FREEWAY (IH 30E) AND HOV LANE, DALLAS

Table E-1. Summary of A.M. Peak-Period, Peak-Direction East R. L. Thornton Freeway and HOV Lane Data, December 1992

Type of Data HOV Lane Became Operational 9/23/91	"Representative" Pre-HOV Lane	"Representative" Current Value	% Change
HOV Lane Data			
HOV Lane Length (miles)			
Morning		5.2	
Evening		3.3	
HOV Lane Cost (millions of 1990 dollars)		$12.7	
Person-Movement			
Peak Hour (7:00-8:00 a.m.)		4,043	—
Peak Period (6:00-9:00 a.m.)		8,932	—
Total Daily		16,472	—
Vehicle Volumes			
Peak Hour	—	1,222	—
Peak Period	—	2,717	—
Vehicle Occupancy, Peak Hour (persons/veh)	—	3.31	—
Accident Rate (i.e. Injury accidents/100 MVM), 10/91-12/92[1]	—	14.6	—
Vehicle Breakdowns (VMT/Breakdown), 1/92-12/92	—	27,800	—
Violation Rate (6:00-9:00 a.m.)	—	0.5%	
Peak Hour Lane Efficiency (1000's)[2]	—	178	—
Annual Value of User Time Saved (millions)[3]	—	$1.4 to $2.8	—
Freeway Mainlane Data (see note)			
Person Movement			
Peak Hour	7,689	7,337	-4.6%
Peak Period (6:00-9:00 a.m.)	23,030	20,841	-9.5%
Vehicle Volume			
Peak Hour	5,692	7,128	+25.2%
Peak Period	17,946	19,839	+10.6%
Vehicle Occupancy, Peak Hour (persons/veh)	1.35	1.03	-23.7%
Accident Rate (i.e. Injury accidents/100 MVM)[1]	33.7	39.5	+17.2%
Avg. Operating Speed[4]			
Peak Hour	21.2	28.0	+32.1%
Peak Period	30.0	38.0	+26.7%
Peak Hour Lane Efficiency (1000's)[2]	41	51	+24.4%

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 analyzed between Pearl/Central Expressway and Jim Miller Road, a distance of approximately 5.2 miles. "Before" data are for the period 9/90 through 9/91. "After" data are for the period from 10/91 to 12/92. Only officer-reported accidents are included in current files. 1992 freeway volumes estimated by TTI.

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

[3] Based on time savings for HOV lane users in 1992 and HOV lane volumes in 1992, an annual estimate of travel time savings to HOV lane users is developed. A value of time of $10.47/hour is used based on the value applied in the Highway Economic Evaluation Model.

[4] From Jim Miller to Central Expressway, a distance of 5.2 miles. The morning HOV lane is in place over this section.

EAST R. L. THORNTON FREEWAY (IH 30E) AND HOV LANE, DALLAS

Table E-2. Summary of East R. L. Thornton Freeway and HOV Lane Data, December 1992

Type of Data HOV Lane Became Operational 9/23/91	"Representative" Pre-HOV Lane	"Representative" Current Value	% Change
Combined Freeway Mainlane and HOV Lane Data			
Total Person Movement			
Peak Hour	7,689	11,380	+48.0%
Peak Period	23,030	29,773	+29.3%
Vehicle Volume			
Peak Hour	5,692	8,350	+46.7%
Peak Period	17,946	22,556	+25.7%
Vehicle Occupancy			
Peak Hour	1.31	1.36	+3.8%
Peak Period	1.26	1.32	+4.8%
2+ Carpool Volumes[1]			
Peak Hour	596	1,346	+125.8%
Peak Period	1,903	3,366	+76.9%
Travel Time (minutes)			
Peak Hour	14.7[2]	7.1[3]	-51.7%
Peak Period	10.6[2]	6.3[3]	-40.6%
Peak Hour Lane Efficiency (1000's)[4]	41	77	+87.8%
Transit Data			
Bus Vehicle Trips			
Peak Hour	41	43	+4.9%
Peak Period	103	112	+8.7%
Bus Passenger Trips			
Peak Hour	1,283	1,450	+13.0%
Peak Period	2,819	3,240	+14.9%
Bus Occupancy (persons/bus)			
Peak Hour	31.3	33.7	+7.7%
Peak Period	27.4	28.9	+5.5%
Vehicles Parked in Corridor Park & Ride Lots	847	865	+2.1%
Bus Operating Speed (mph)[5]			
Peak Hour	21.2[2]	43.9[3]	+107.1%
Peak Period	30.0[2]	49.5[3]	+ 65.1%

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 miles/hour). It is used as a measure of per lane efficiency.

[5] From Jim Miller to Central Expressway, a distance of 5.2 miles. The HOV lane is in place over this section.

Table E-3. 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" 12/92 Value	% Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/HOV lane	1.35	1.36	+0.7%
Freeway w/o HOV lane	1.25	1.27	+1.6%
Peak-Hour 2+ Carpool Volume			
Freeway w/HOV lane	596	1,346	+125.8%
Freeway w/o HOV lane	802	804	+0.2%
Bus Passengers, Peak Period			
Freeway w/HOV lane	2,819	3,240	+14.9%
Freeway w/o HOV lane	2,540	2,470	- 2.8%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	847	865	+2.1%
Freeway w/o HOV lane	425	471	+10.8%
Facility Per Lane Efficiency[1]			
Freeway w/HOV lane	41	77	+87.8%
Freeway w/o HOV lane	67	78	+16.4%

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

HOV LANE DATA

DESCRIPTION

- The evening operation (3.3 miles) opened September 23, 1991.
- The morning operation (3.3 miles) opened September 30, 1991.
- The morning operation (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 (3.3 miles), used by buses and vans.
- 9/30/91 Morning lane opens Dolphin Road to Central Expressway (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 (5.2 miles, total).
- 11/25/91 DART adds bus service to existing routes.

Table E-4. 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 MILE (5.2 miles)	$ 2.4		$2.4

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

PERSON MOVEMENT

- In December 1992, 16,472 person trips per day were served on the HOV lane.
- A.M. Peak Hour, 4,043 persons/hour.
  - 1,450 (36%) by bus, 102 (2%) by vanpool, 2,491 (62%) by carpool (Figure E-1).
  - Average HOV lane vehicle occupancy = 3.31 persons/vehicle.
- A.M. Peak Period, 8,932 persons.
  - 3,240 (36%) by bus, 159 (2%) by vanpool, by carpool 5,533 (62%) (Figure E-2).

VEHICLE MOVEMENT

- A.M. Peak Hour, 1,222 vph
  - 43 (4%) buses, 11 (1%) vans, 1,168 (95%) carpools (Figure E-3).
- A.M. Peak Period, 2,717 vehicles
  - 112 (4%) buses, 18 (1%) vans, 2,587 (95%) carpools (Figure E-4).

ACCIDENT RATE

- For the period from October 1991 through December 1992, the HOV lane accident rate was 14.6 injury accidents per 100 million vehicle miles of travel.

VEHICLE BREAKDOWN RATES

- As measured for 1/92 to 12/92, the following rate has been observed.
  - The weighted average for all vehicle types is one breakdown per 27,800 VMT.

VIOLATION RATE

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

  - For the overall a.m. peak period it is 0.5%.
  - 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 178 (4,043 passengers at 43.9 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane experienced an average travel time savings of 4.1 minutes during the morning peak hour in 1992 (Figure E-5).

- The tables on the following page indicate that, on a typical non-incident day, travel time savings of approximately 531 hours (31,855 min.) are realized. Assuming 250 days of operation, annual savings would be 132,750 hours. At $10.47/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 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 $1.39 to $2.78 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 4.6% relative to pre-HOV conditions (Figure E-6).
- In the a.m. peak period, person movement has decreased by 9.5% relative to pre-HOV conditions (Figure E-7).

VEHICLE VOLUME

- In the a.m. peak hour, vehicle volume has increased by 25.2% relative to pre-HOV conditions (Figure E-6).
- In the a.m. peak period, vehicle volume has increased by 10.6% relative to pre-HOV conditions (Figure E-7).

VEHICLE OCCUPANCY

- In the a.m. peak hour, mainlane occupancy has decreased by 23.7% relative to pre-HOV conditions (from 1.35 to 1.03).
- In the a.m. peak period, mainlane occupancy has decreased by 18.0%, 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 33.7 accidents per 100 million vehicle miles (100 MVM). For the period from 10/91 to 9/92, the freeway accident rate was 39.5 accidents/100 MVM. These statistics do not include driver reported accidents; only officer reported accidents are included in current accident files. TTI estimated 1992 freeway volumes to compute accident rates.

AVERAGE OPERATING SPEED

- In comparison to pre-HOV lane conditions, mainlane operating speeds have increased by 32.1% in the peak hour and 26.7% in the peak period (Figures E-8 and E-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 24.4% 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 = 4,043; freeway = 7,337) and 30% of peak-period (HOV lane = 8,932; freeway = 20,841) 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 48.0% from 7,689 to 11,380 (Figure E-10). Peak-period person movement has increased by 29.3% from 23,030 to 29,773 (Figure E-11).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.36 -- a 3.8% increase over the pre-HOV lane occupancy (Figure E-12). Occupancy in the peak period is greater than pre-HOV lane levels (Figure E-13), increasing from 1.26 to 1.32 (4.8%).
- While the occupancy on the East Thornton Freeway has increased, freeways which do not have HOV lanes have experienced a decrease in occupancy (Figure E-14).

CARPOOL VOLUMES

- In the a.m. peak hour, the total number of 2+ carpools (freeway plus HOV lane) has increased by 125.8% compared to pre-HOV lane levels (Figure E-15).

Table E-5. Westbound A.M. Travel Time Savings for Thornton HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1992)

Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	T-Way (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section from Jim Miller to Central Expressway								
6:00	5.53	5.55	-0.02	32	0	60	92	-1.84
6:15	5.50	5.88	-0.38	174	1	158	333	-126.54
6:30	7.22	6.13	1.10	367	5	323	695	764.50
6:45	8.06	6.06	2.00	482	1	229	712	1,424.00
7:00	7.21	6.14	1.08	552	19	375	946	1,021.68
7:15	10.30	6.46	3.83	705	32	395	1,132	4,335.56
7:30	12.44	7.56	4.88	761	23	399	1,183	5,773.04
7:45	12.15	8.24	3.90	670	8	340	1,018	3,970.20
8:00	10.05	6.27	3.78	503	9	302	814	3,076.92
8:15	7.82	5.83	1.99	466	8	196	670	1,333.30
8:30	6.76	5.52	1.24	319	4	145	468	580.32
8:45	5.58	5.66	-0.08	226	1	68	295	-23.60
9:00	5.49	5.47	0.02	112	1	10	123	2.46
Peak Period Total				5,369	112	3,000	8,481	22,130.00
Eastbound P.M. Travel Time Savings for Thornton HOV Lane								
Section from Central Expressway to Dolphin								
4:00	3.66	4.12	-0.46	326	1	200	527	-242.42
4:15	4.35	3.96	0.40	342	7	178	527	210.80
4:30	3.92	3.80	0.12	517	16	245	778	93.36
4:45	5.35	4.28	1.07	596	23	404	1,023	1,094.61
5:00	6.62	4.25	2.37	607	64	347	1,018	2,412.66
5:15	8.12	5.92	2.20	652	19	501	1,172	2,578.40
5:30	8.99	6.86	2.13	488	9	225	722	1,537.86
5:45	7.24	4.72	2.52	392	10	191	593	1,494.36
6:00	5.23	3.68	1.55	307	0	105	412	638.60
6:15	3.46	3.56	-0.10	202	0	68	270	-27.00
6:30	3.45	3.75	-0.31	144	1	38	183	-56.73
6:45	3.44	3.54	-0.10	94	0	3	97	-9.70
Peak Period Total				4,667	150	2,505	7,322	9,724.80

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 87.8% since the implementation of the HOV lane (Figure E-16). This large an increase has not occurred on freeways not having HOV lanes (Figure E-17).

BUS TRANSIT DATA

BUS VEHICLE AND PASSENGER TRIPS

- In the a.m. peak hour, bus vehicle trips have been increased by 4.9% since the HOV lane opened, and a 13.0% increase in bus ridership has also resulted (Figure E-18). In the peak period, a 8.7% increase has occurred in bus trips and a 14.9% increase in bus ridership has resulted (Figure E-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).

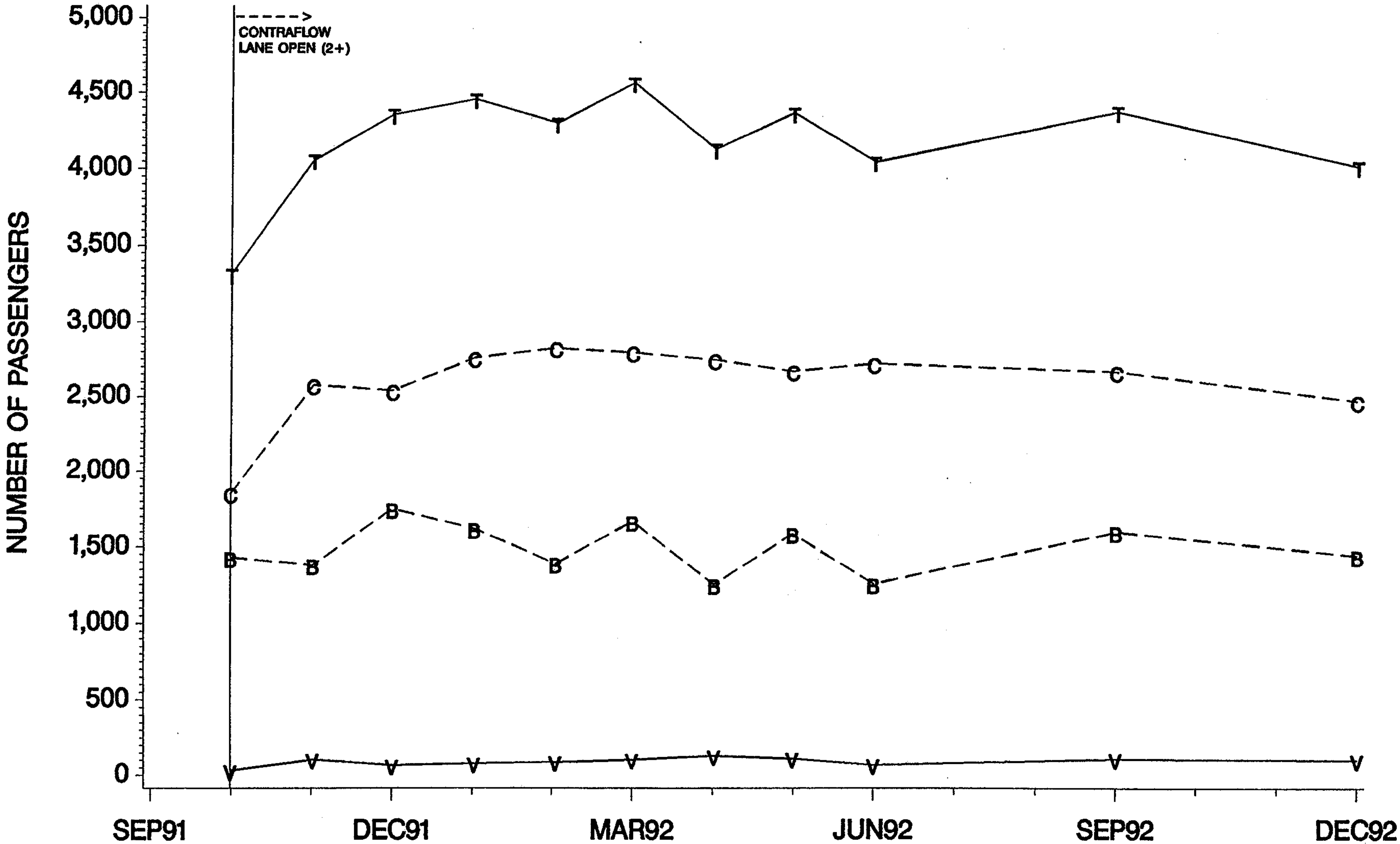
PARK-AND-RIDE

- Prior to opening the HOV lane, approximately 847 vehicles were parked in corridor park-and-ride lots; this has increased 2.1% to a current level of 865 (Figure E-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 E-22).

FIGURE E-1

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

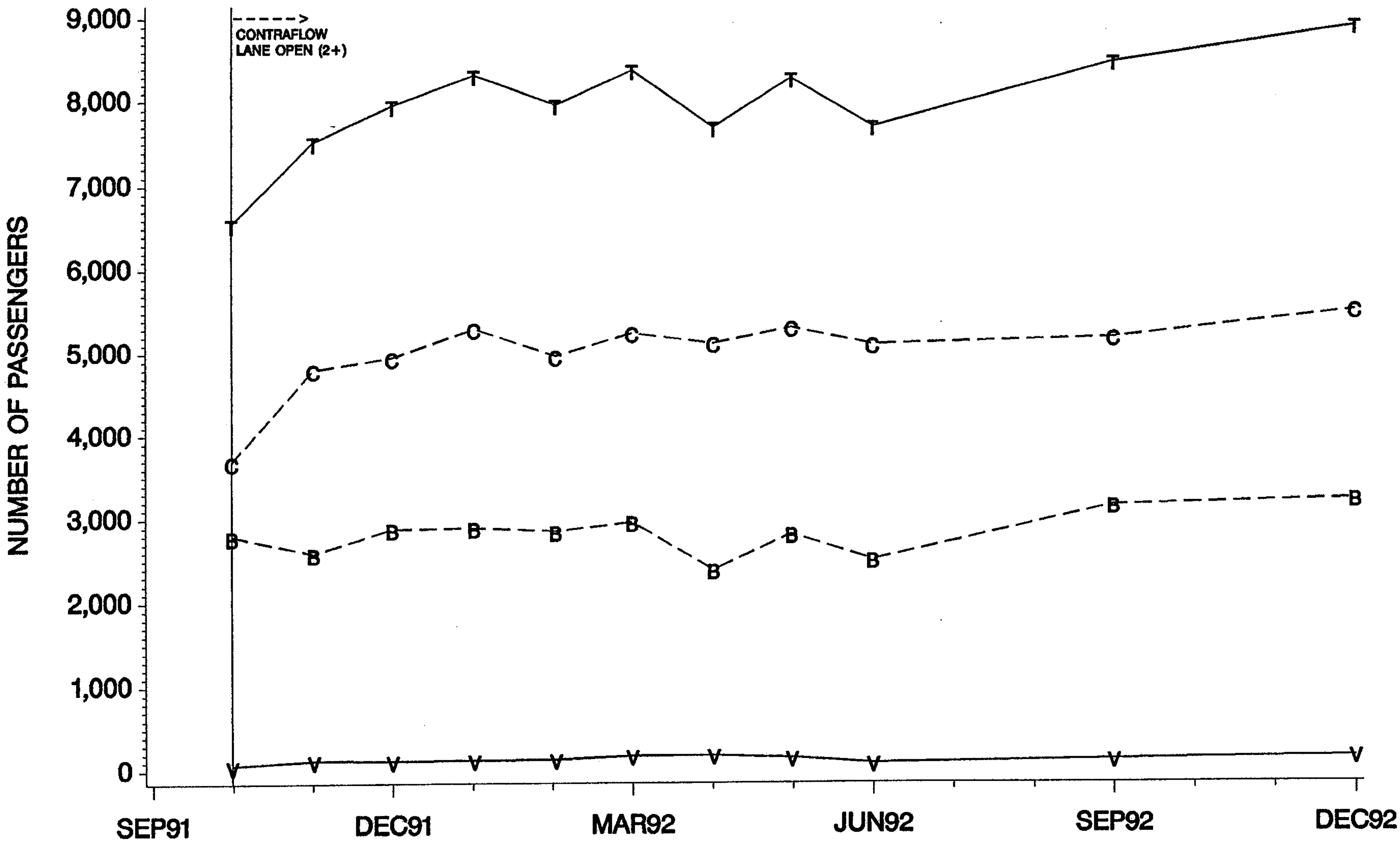


COUNT LOCATION IS BETWEEN CBD CROSSOVER AND DOLPHIN CROSSOVER
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-2

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

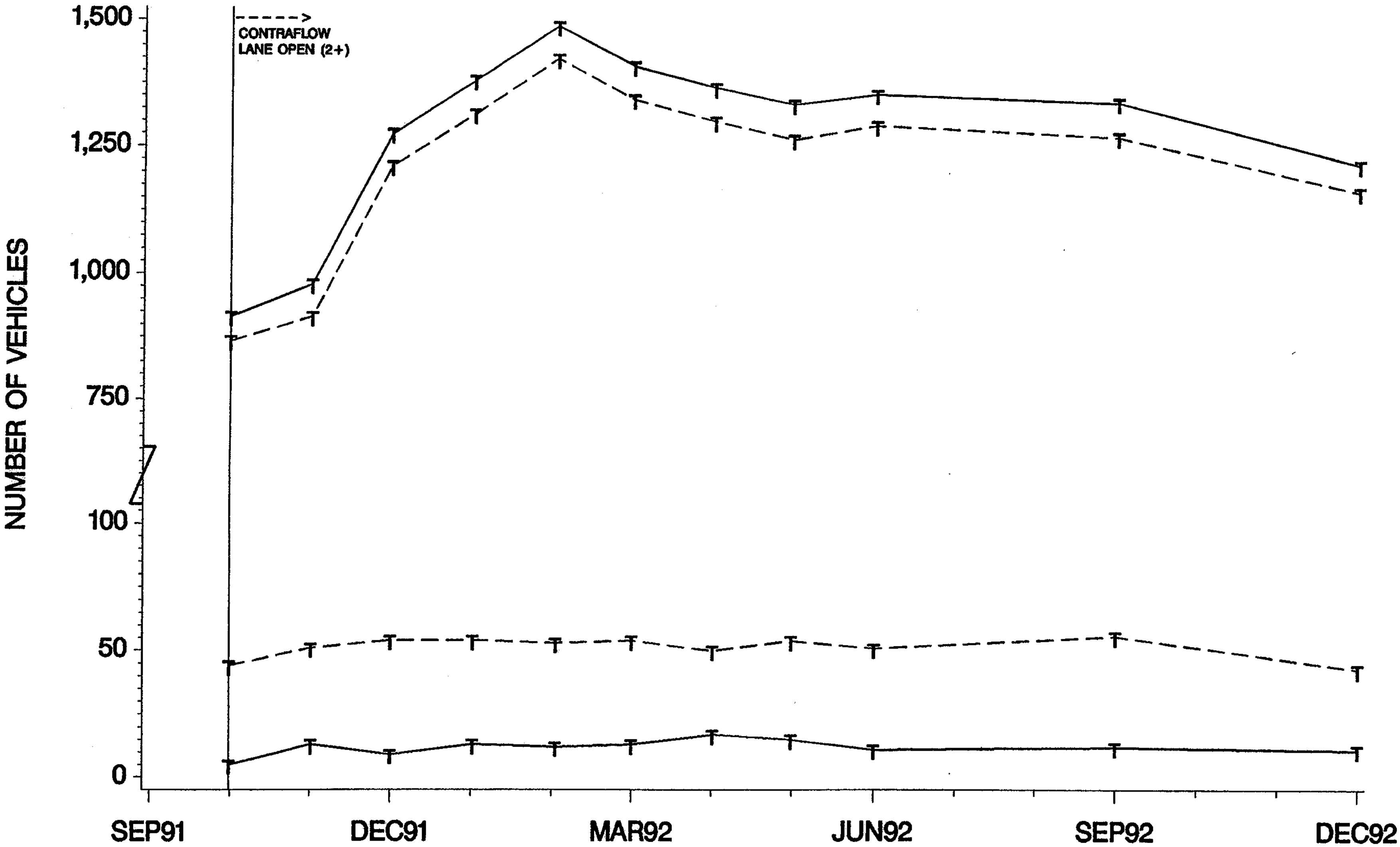


PEAK PERIOD IS FROM 6:00 A.M. TO 9:00 A.M.
COUNT LOCATION IS BETWEEN CBD CROSSOVER AND DOLPHIN CROSSOVER
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-3

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

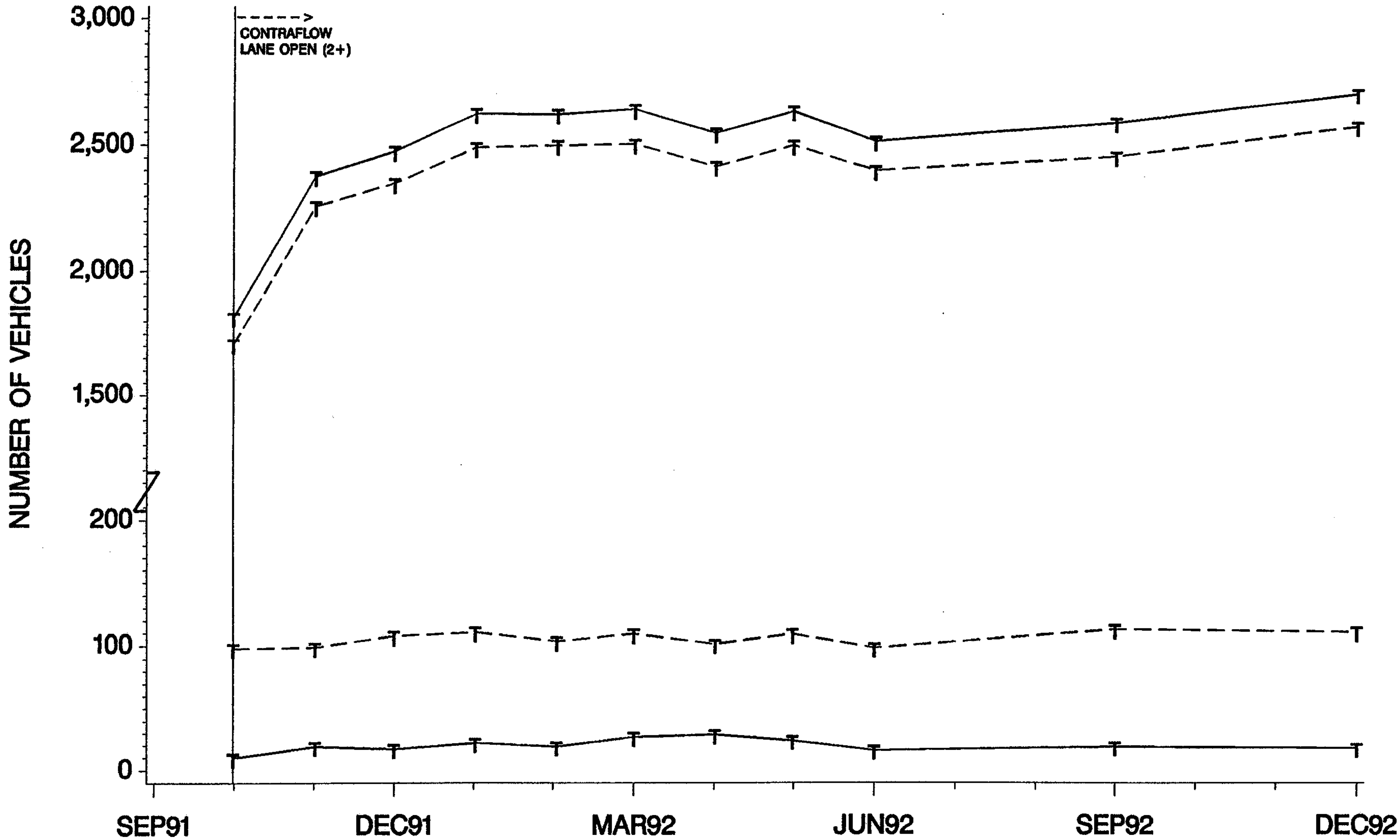


COUNT LOCATION IS BETWEEN CBD CROSSOVER AND DOLPHIN CROSSOVER
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-4

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

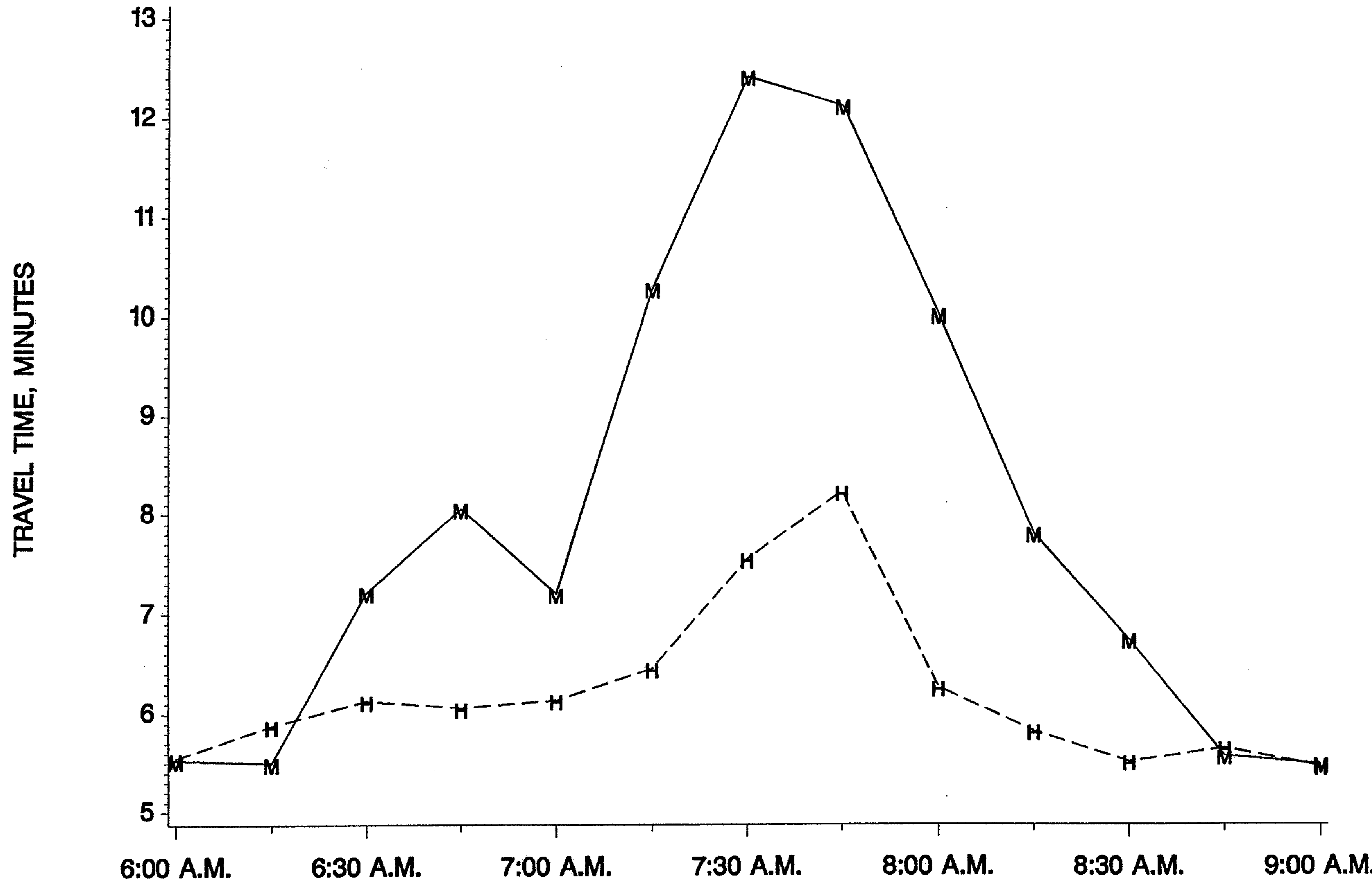


PEAK PERIOD IS FROM 6:00 A.M. TO 9:00 A.M.
COUNT LOCATION IS BETWEEN CBD CROSSOVER AND DOLPHIN CROSSOVER
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-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 1992
TRAVEL TIMES ARE FROM JIM MILLER TO CENTRAL EXPRESSWAY
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-6

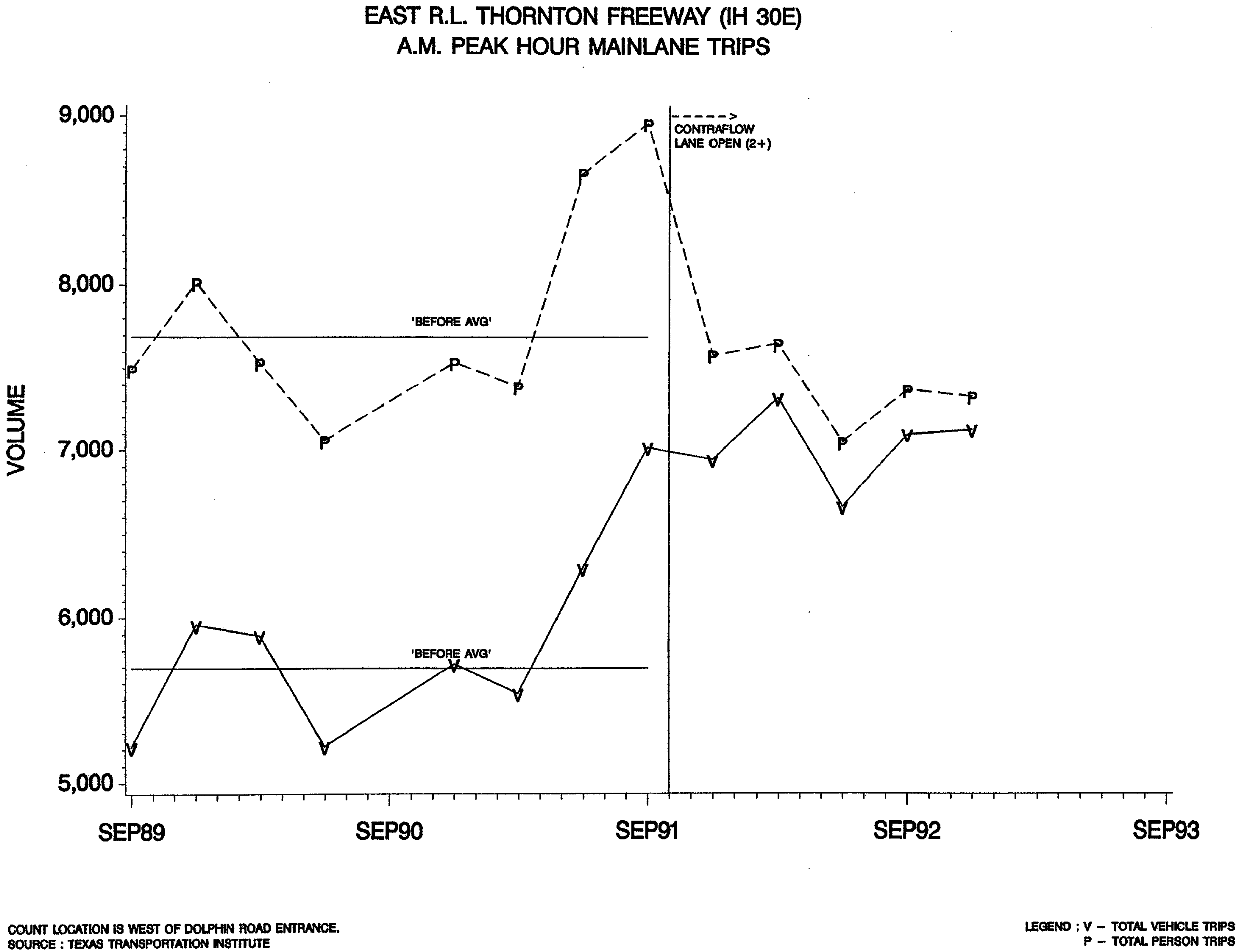
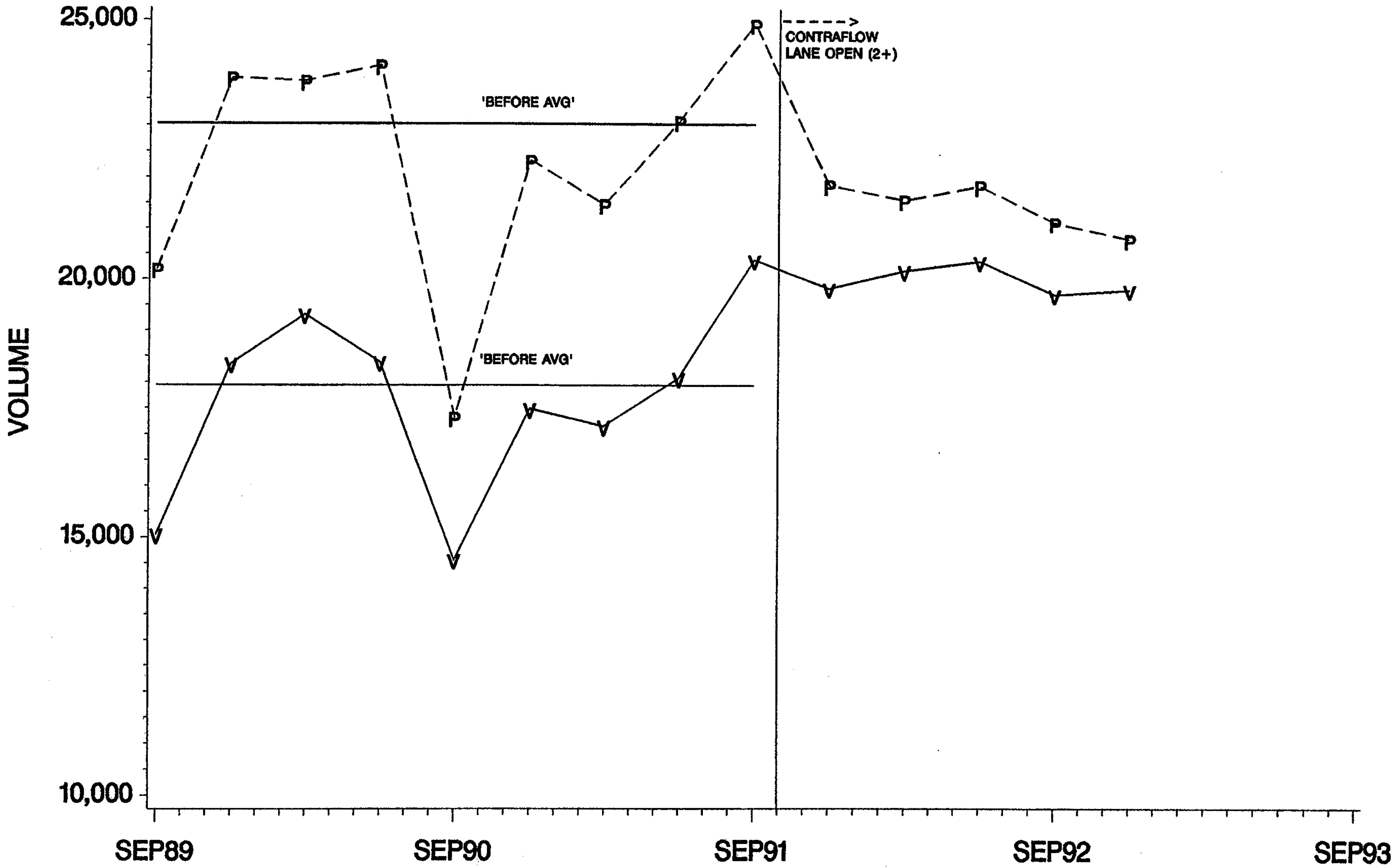

EAST R.L. THORNTON FREEWAY (IH 30E)
A.M. PEAK HOUR MAINLANE TRIPS
VOLUME
9,000
8,000
7,000
6,000
5,000
SEP89
SEP90
SEP91
SEP92
SEP93
'BEFORE AVG'
'BEFORE AVG'
CONTRAFLOW
LANE OPEN (2+)
COUNT LOCATION IS WEST OF DOLPHIN ROAD ENTRANCE.
SOURCE : TEXAS TRANSPORTATION INSTITUTE
LEGEND : V – TOTAL VEHICLE TRIPS
P – TOTAL PERSON TRIPS

FIGURE E-7

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

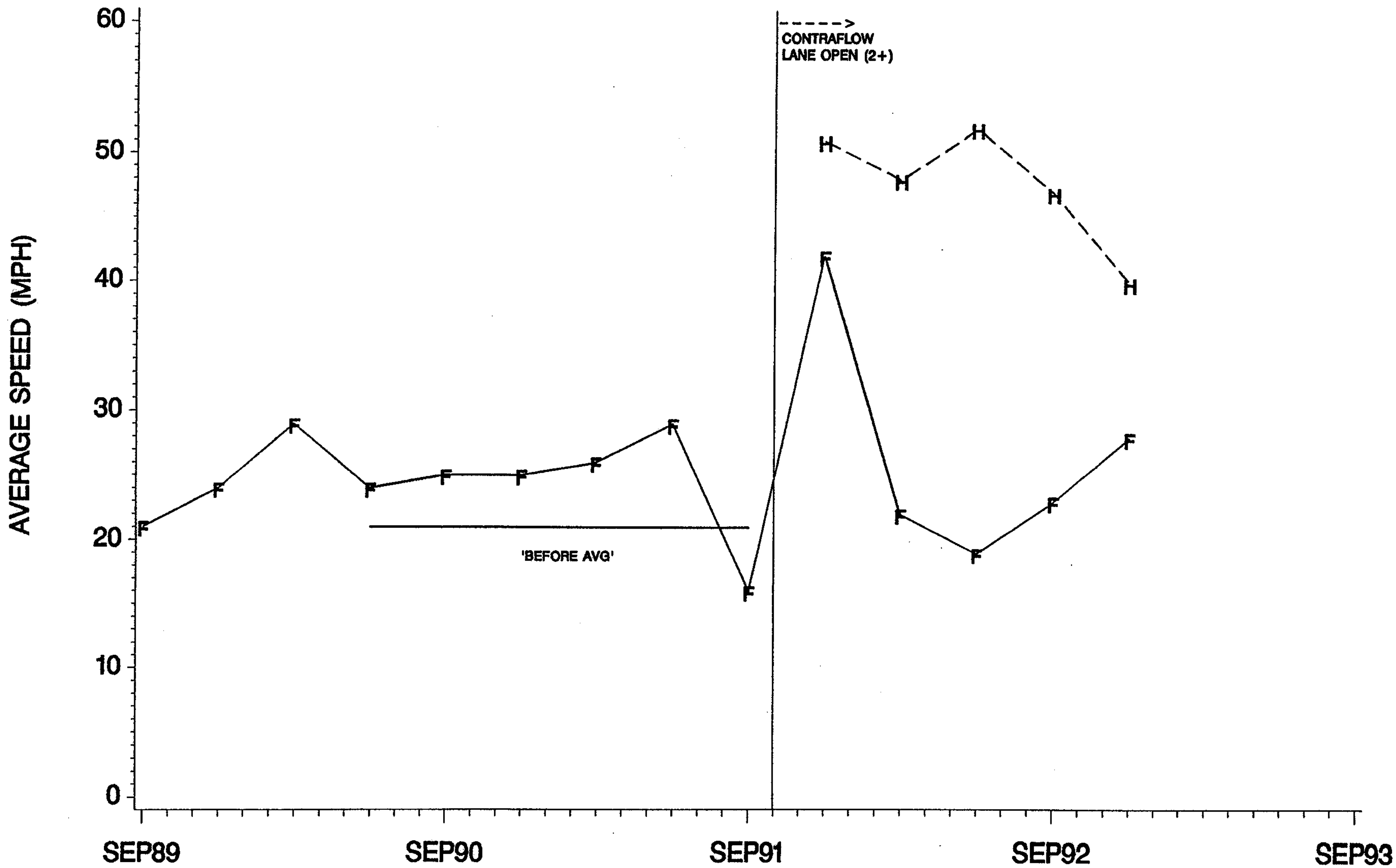


COUNT LOCATION IS WEST OF DOLPHIN ROAD ENTRANCE.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-8

EAST R.L. THORNTON (IH 30E) FREEWAY
A.M. PEAK HOUR AVERAGE SPEEDS



PEAK HOUR IS BASED ON THE HIGHEST AVERAGE HOURLY TRAVEL TIME
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : F – FREEWAY SPEEDS
H – HOV LANE SPEEDS

FIGURE E-9

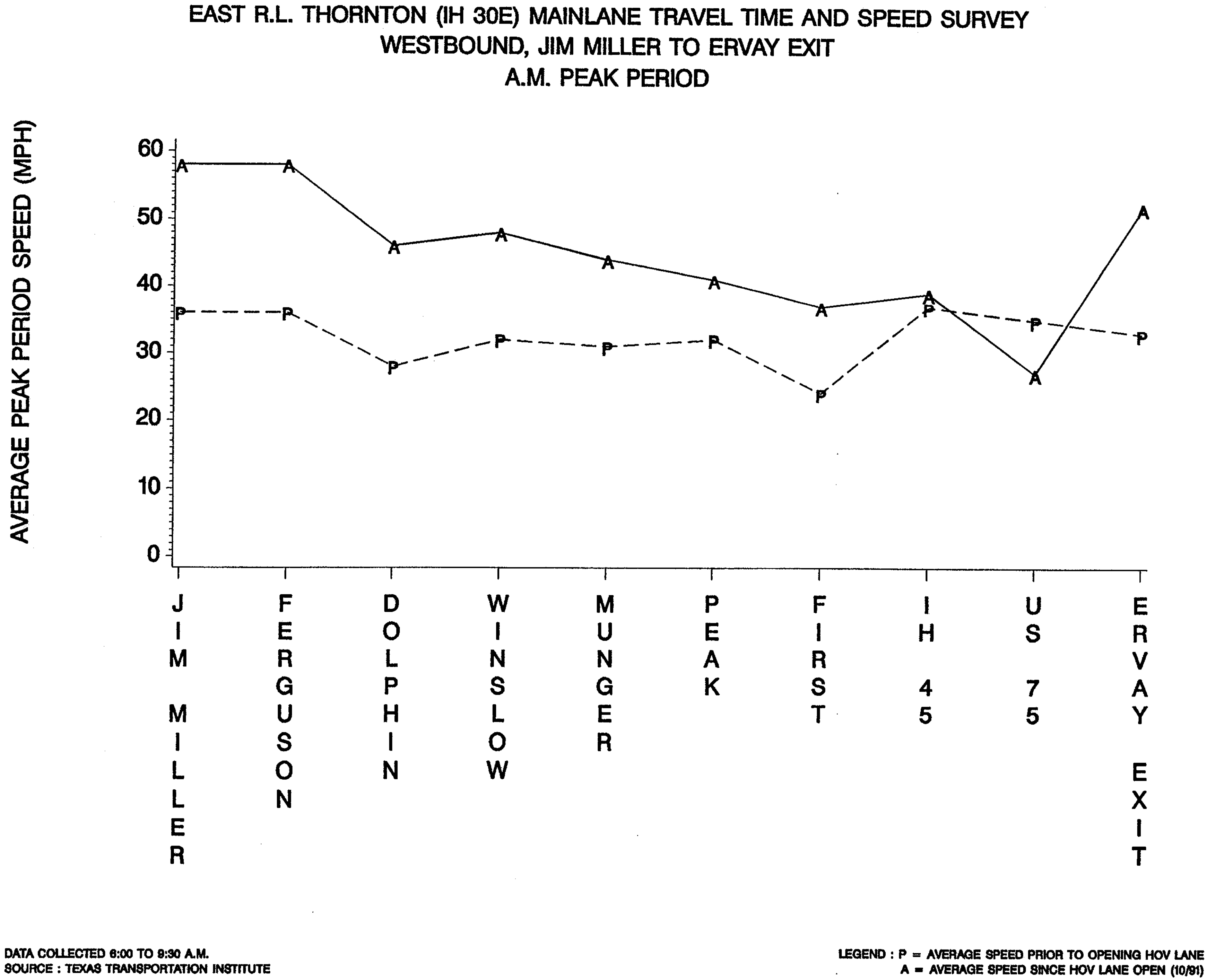
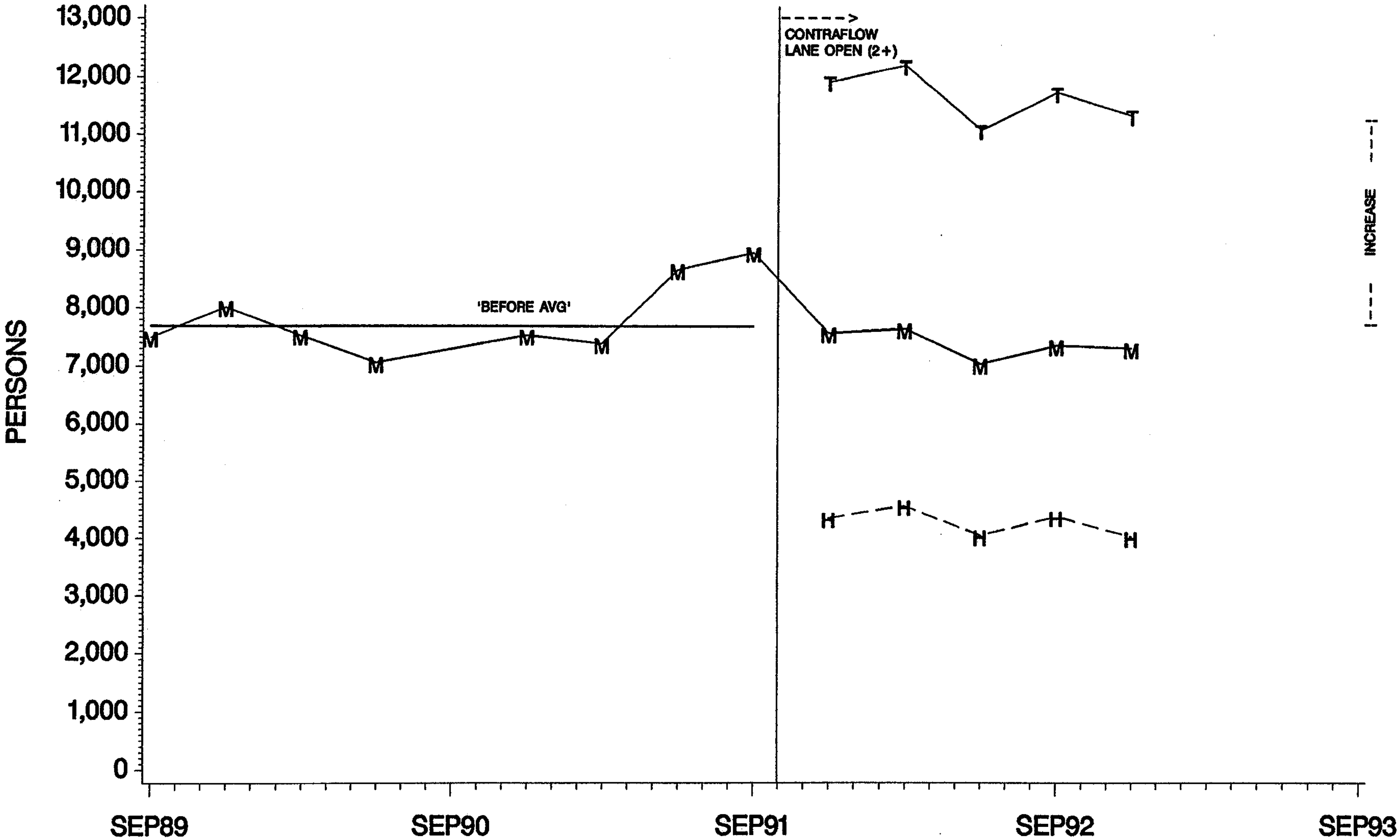

EAST R.L. THORNTON (IH 30E) MAINLANE TRAVEL TIME AND SPEED SURVEY
WESTBOUND, JIM MILLER TO ERVAY EXIT
A.M. PEAK PERIOD
AVERAGE PEAK PERIOD SPEED (MPH)
60
50
40
30
20
10
0
JIM MILLER
FERGUSON
DOLPHIN
WINSLOW
MUNGER
PEAK
FIRST
IH 45
US 75
ERVAY EXIT
DATA COLLECTED 6:00 TO 9:30 A.M.
SOURCE : TEXAS TRANSPORTATION INSTITUTE
LEGEND : P = AVERAGE SPEED PRIOR TO OPENING HOV LANE
A = AVERAGE SPEED SINCE HOV LANE OPEN (10/91)

FIGURE E-10

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

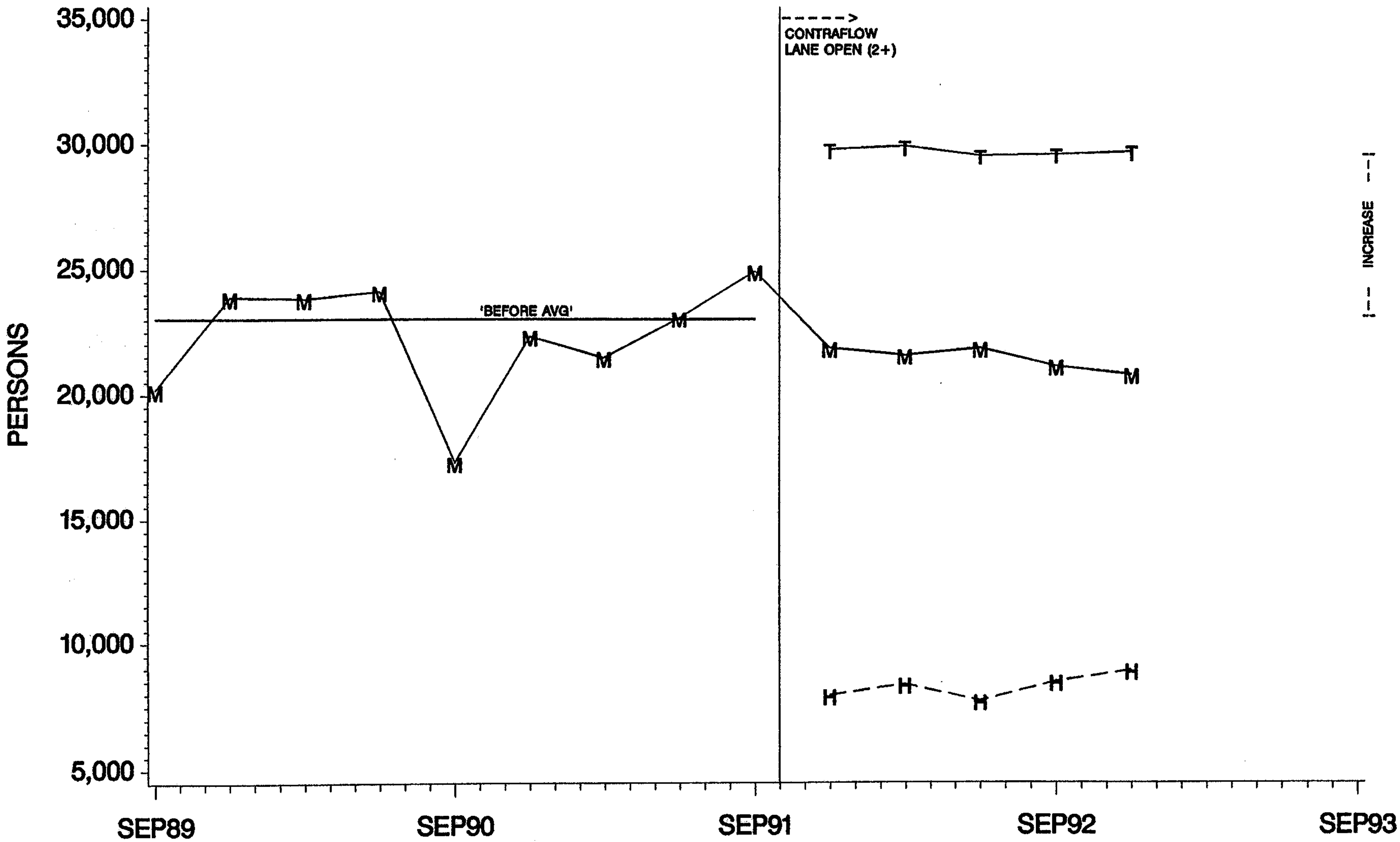


COUNT LOCATION IS WEST OF DOLPHIN ROAD ENTRANCE.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-11

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

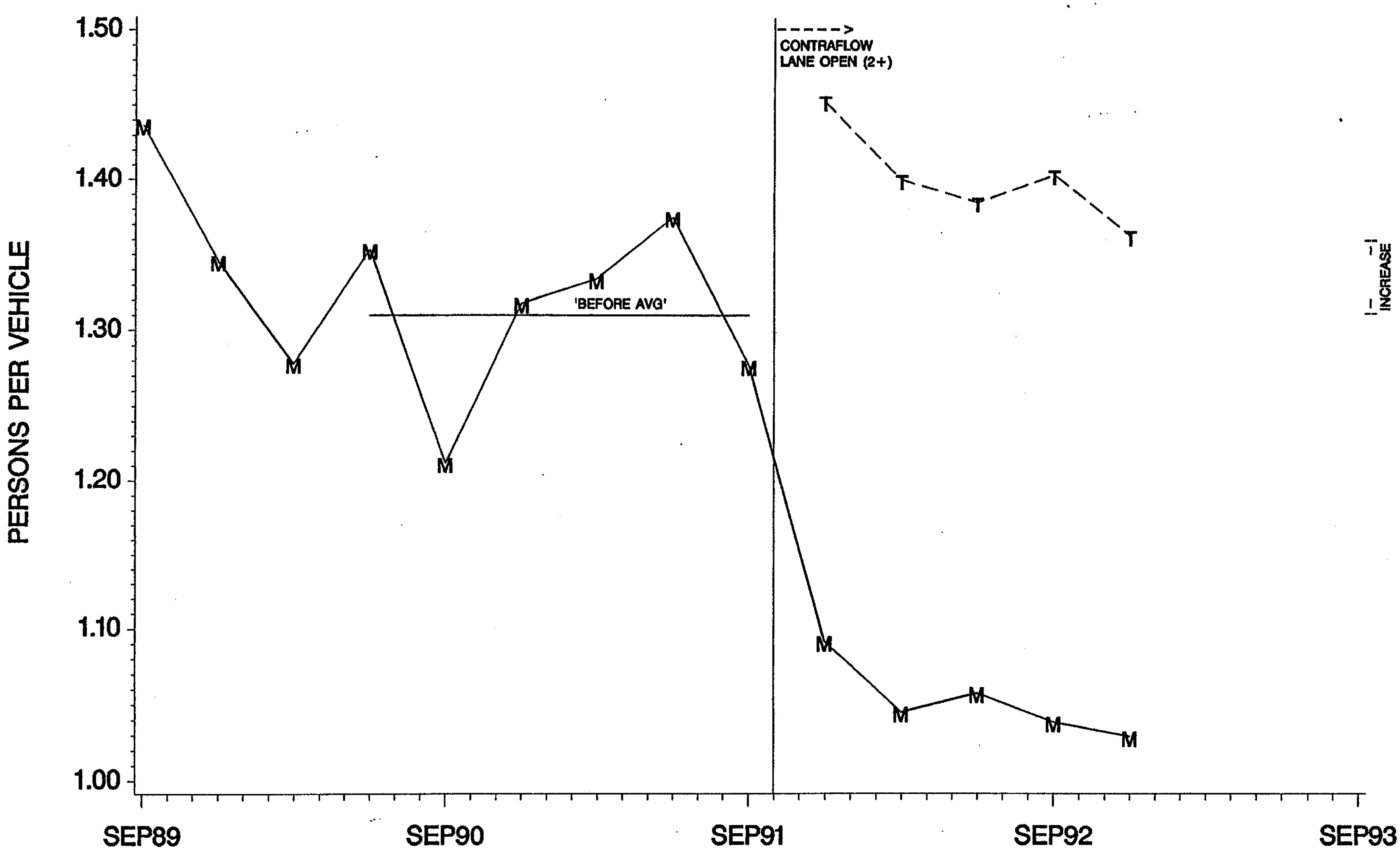


PEAK PERIOD IS FROM 6:00 A.M. TO 9:00 A.M.
COUNT LOCATION IS WEST OF DOLPHIN ROAD ENTRANCE.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-12

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

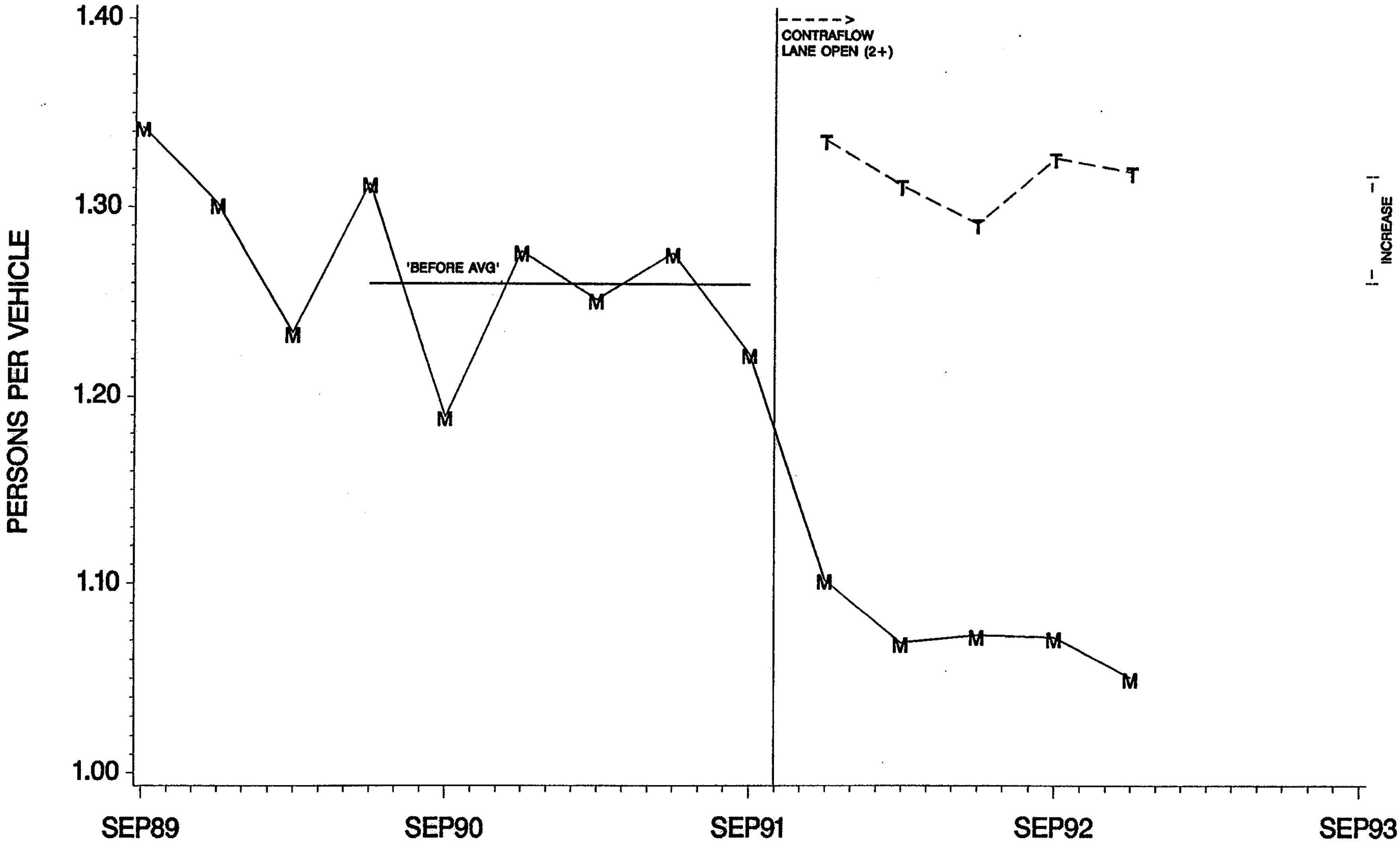


COUNT LOCATION IS WEST OF DOLPHIN ROAD ENTRANCE.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-13

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

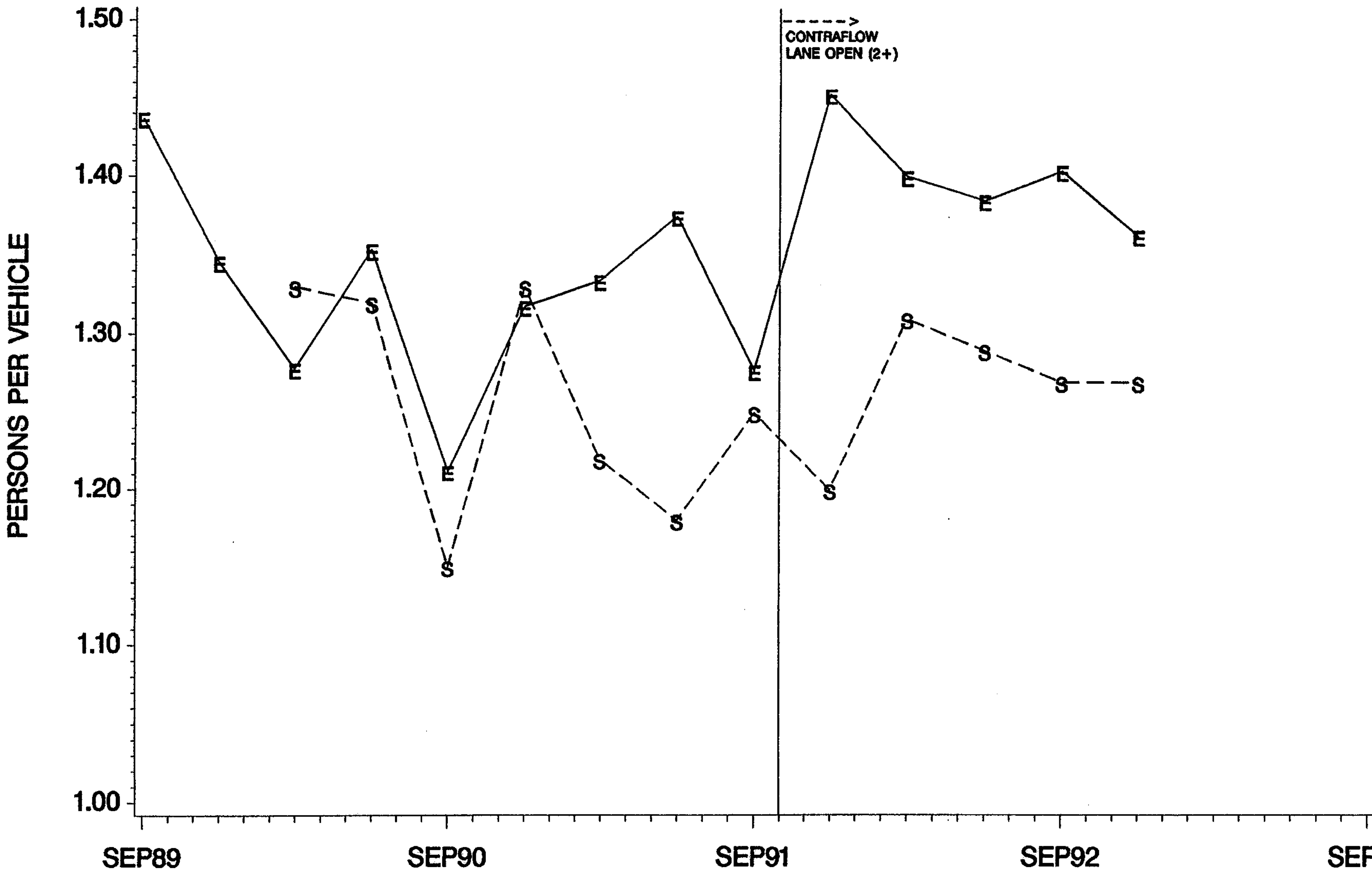


PEAK PERIOD IS FROM 6:00 A.M. TO 9:00 A.M.
COUNT LOCATION IS WEST OF DOLPHIN ROAD ENTRANCE.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-14

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

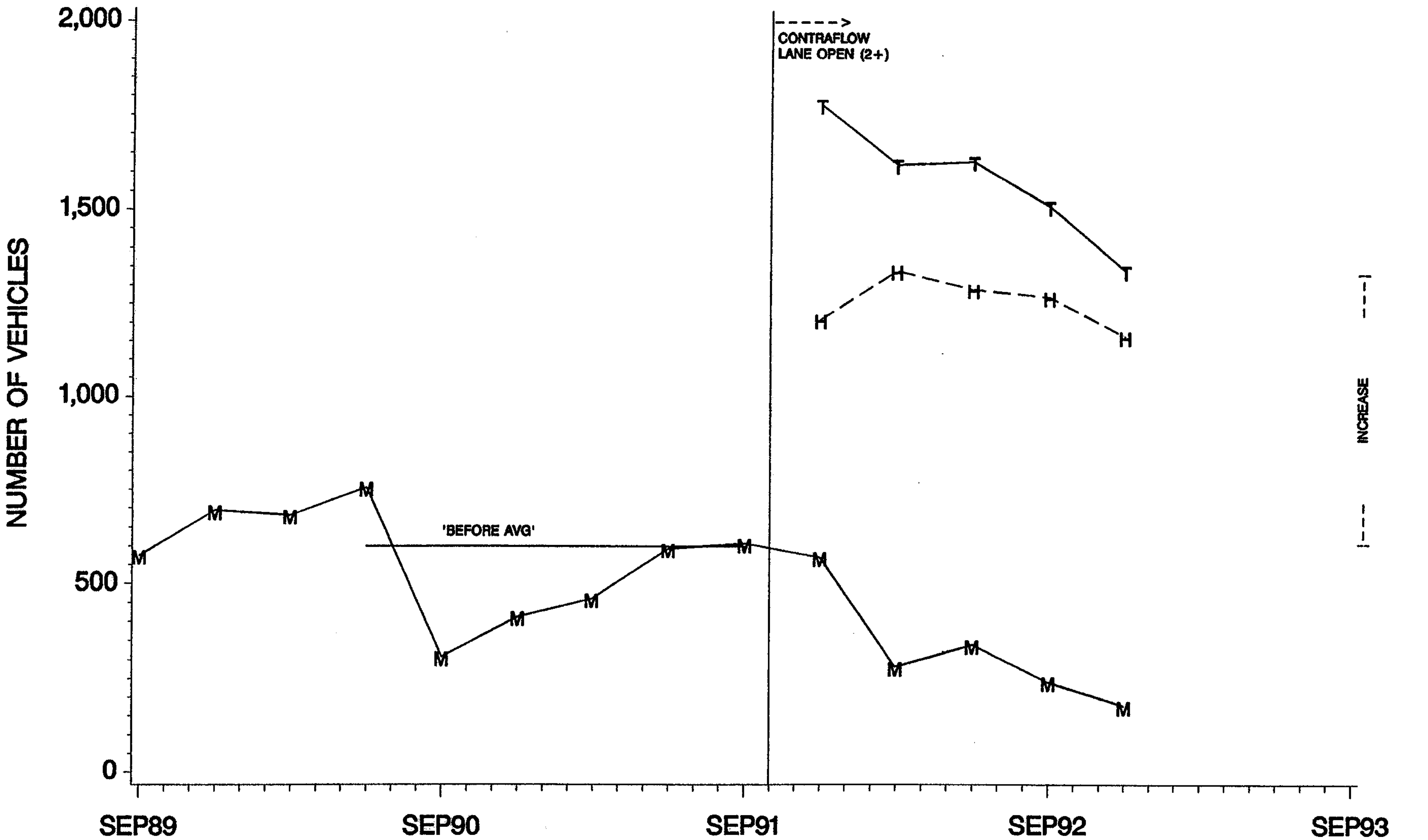


SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : E – EAST R.L. THORNTON FREEWAY (WITH HOV LANE)
S – SOUTH R.L. THORNTON FREEWAY (WITHOUT HOC LANE)

FIGURE E-15

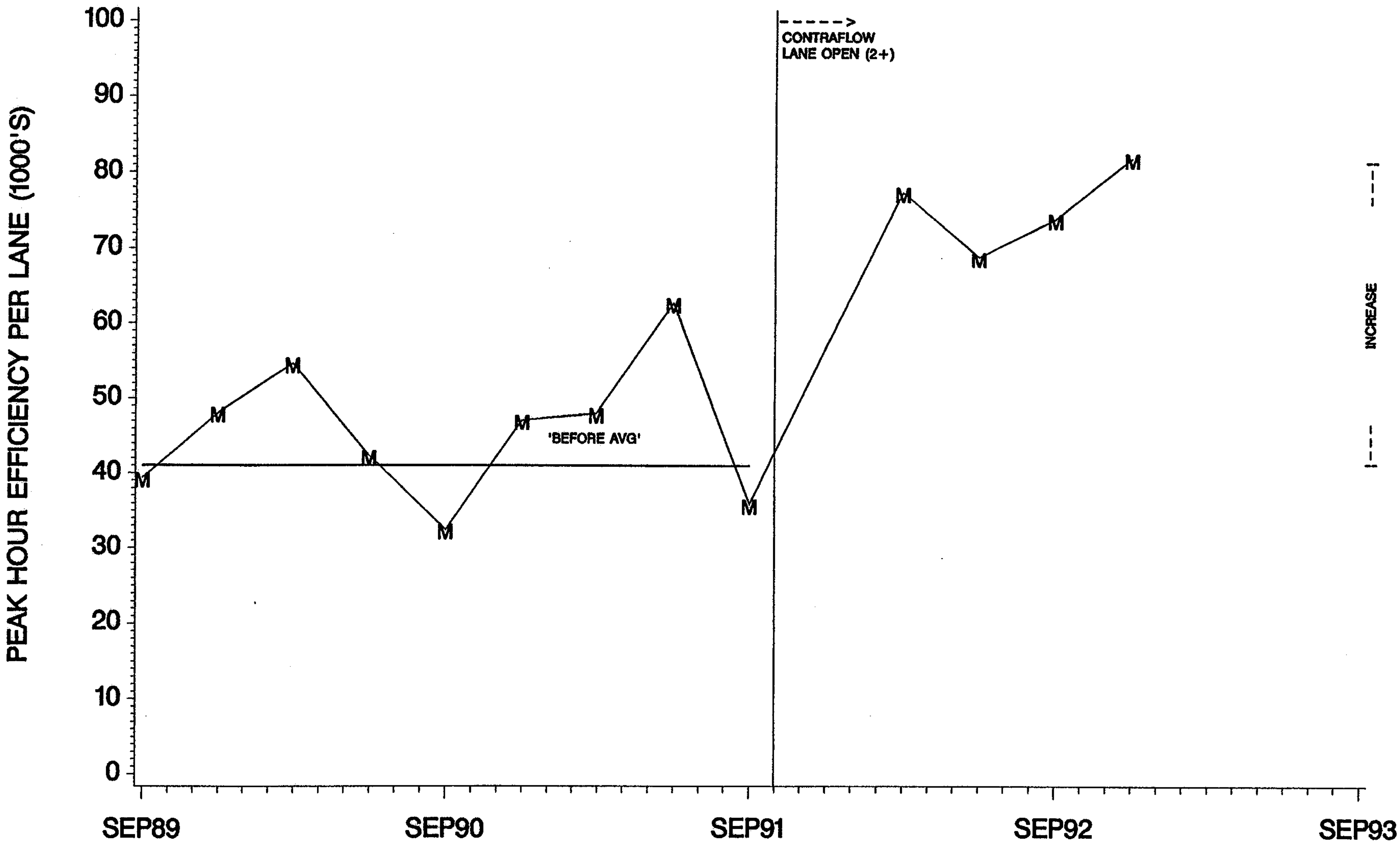
EAST R.L. THORNTON (IH 30E) MAINLANE AND HOV LANE A.M. PEAK HOUR 2+ CARPOOL UTILIZATION



COUNT LOCATION IS WEST OF DOLPHIN ROAD ENTRANCE
SOURCE : TEXAS TRANSPORTATION INSTITUTE

FIGURE E-16

EAST R.L. THORNTON FREEWAY (IH 30E) EVALUATION
A.M. PEAK HOUR COMBINED MAINLANE AND HOV LANE EFFICIENCY

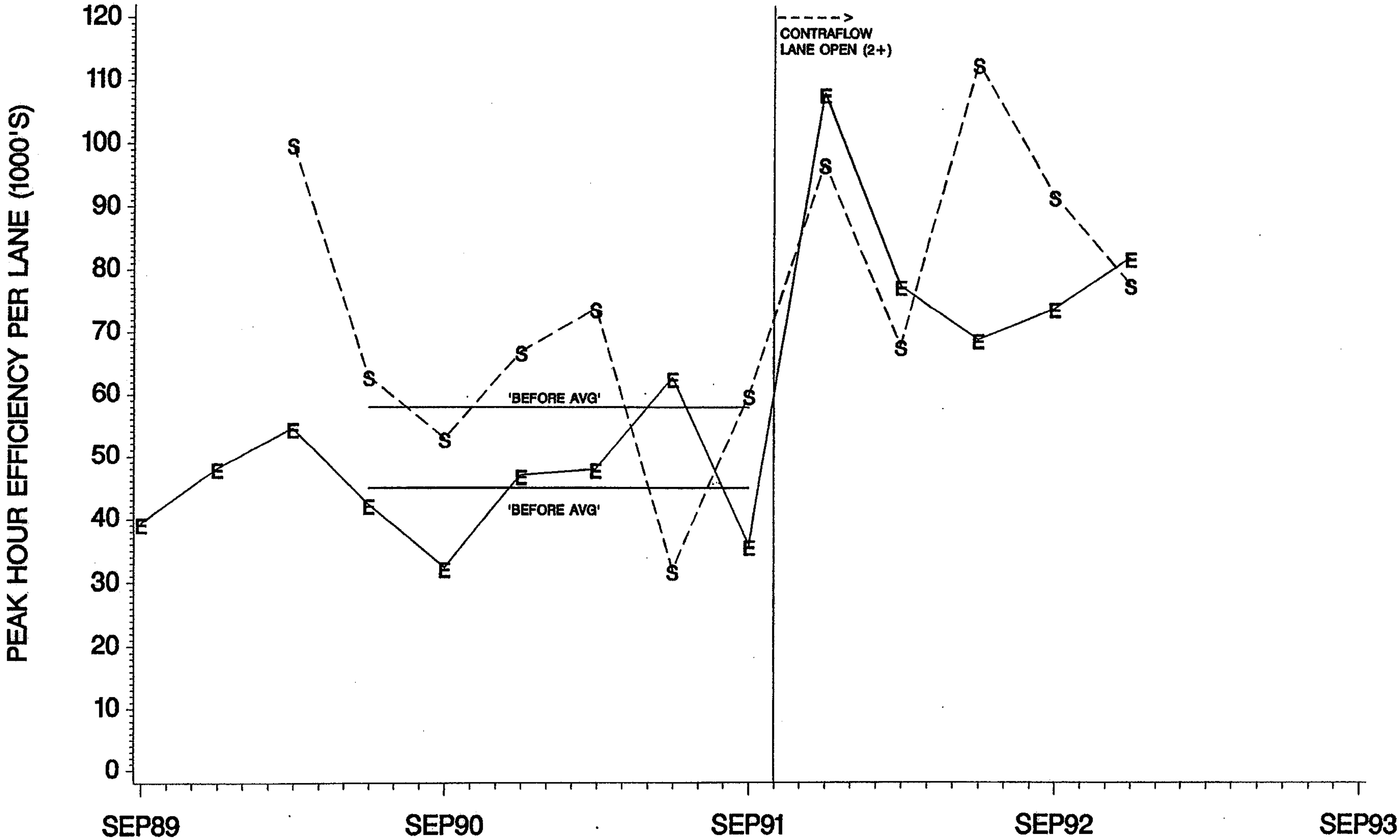


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENONG OF THE HOV LANE, IT REPRESENTS TOTAL PERSONS (FREEWAY + HOV LANE) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 5 LANES
SOURCE : TEXAS TRANSPORTATION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

LEGEND : A – A.M. PEAK HOUR EFFICIENCY

FIGURE E-17

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

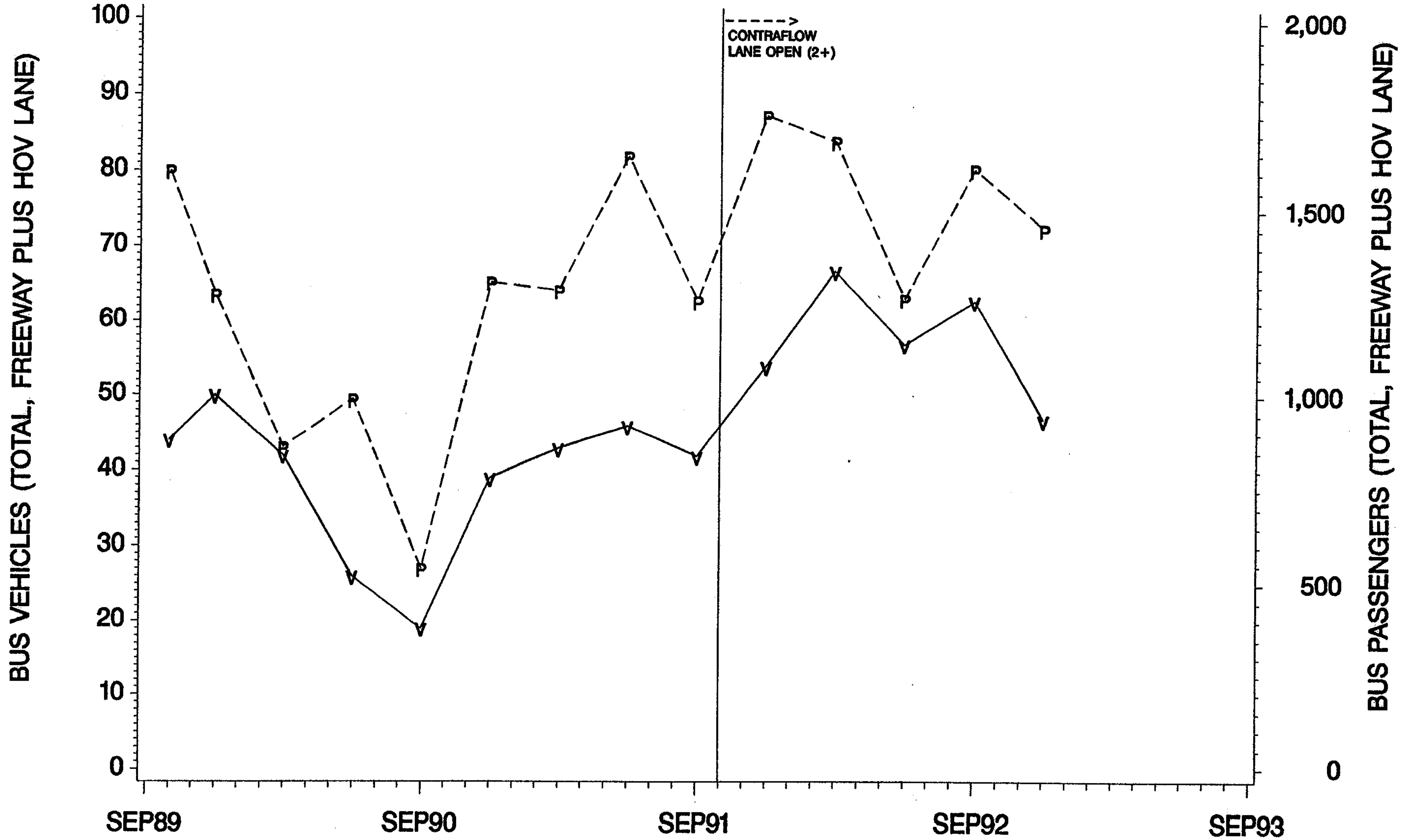


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENONG OF THE HOV LANE, IT REPRESENTS TOTAL PERSONS (FREEWAY + HOV LANE) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 5 LANES
SOURCE : TEXAS TRANSPORTATION 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 E-18

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

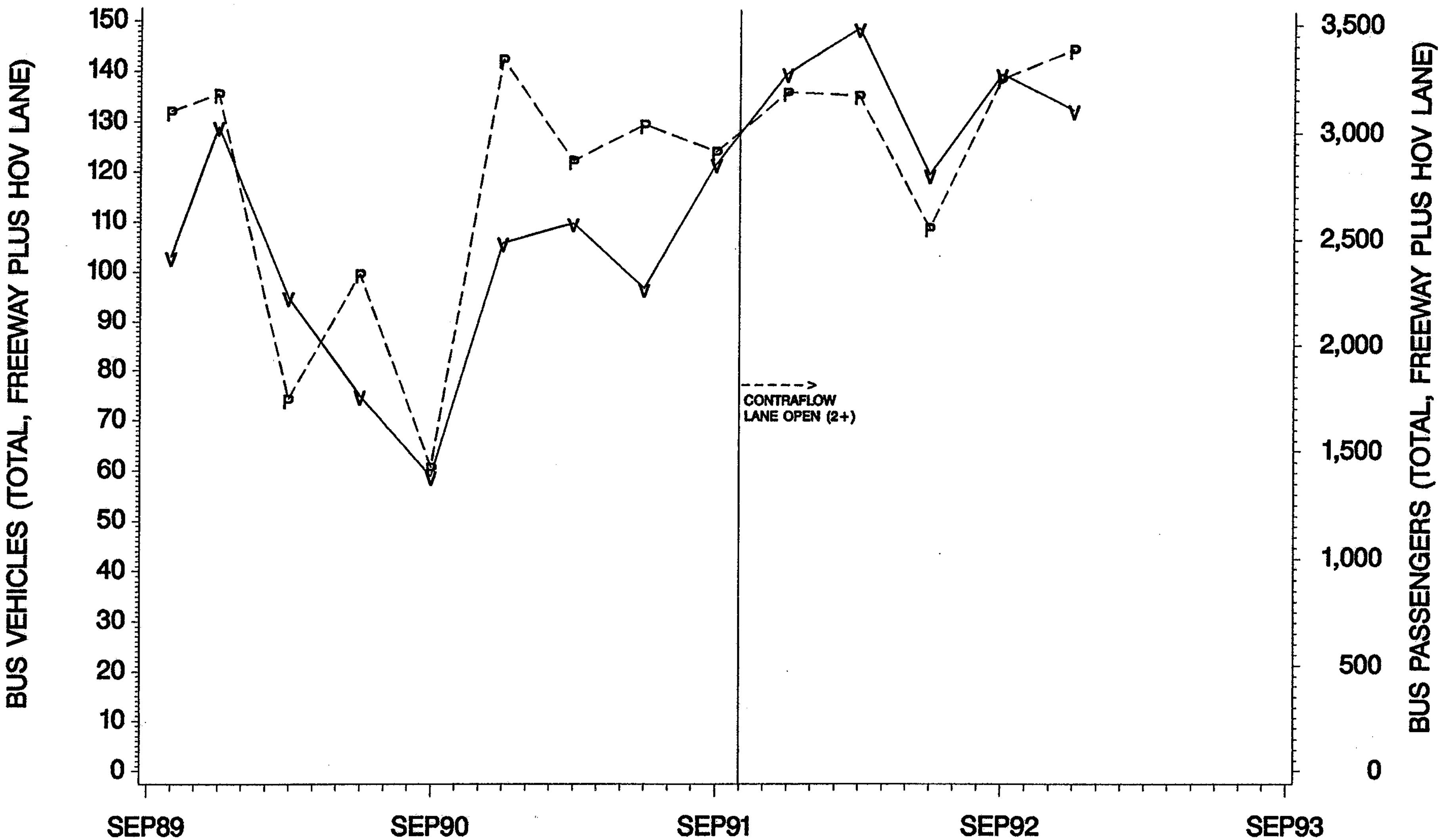


COUNT LOCATION IS BETWEEN CBD CROSSOVER AND DOLPHIN CROSSOVER
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-19

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

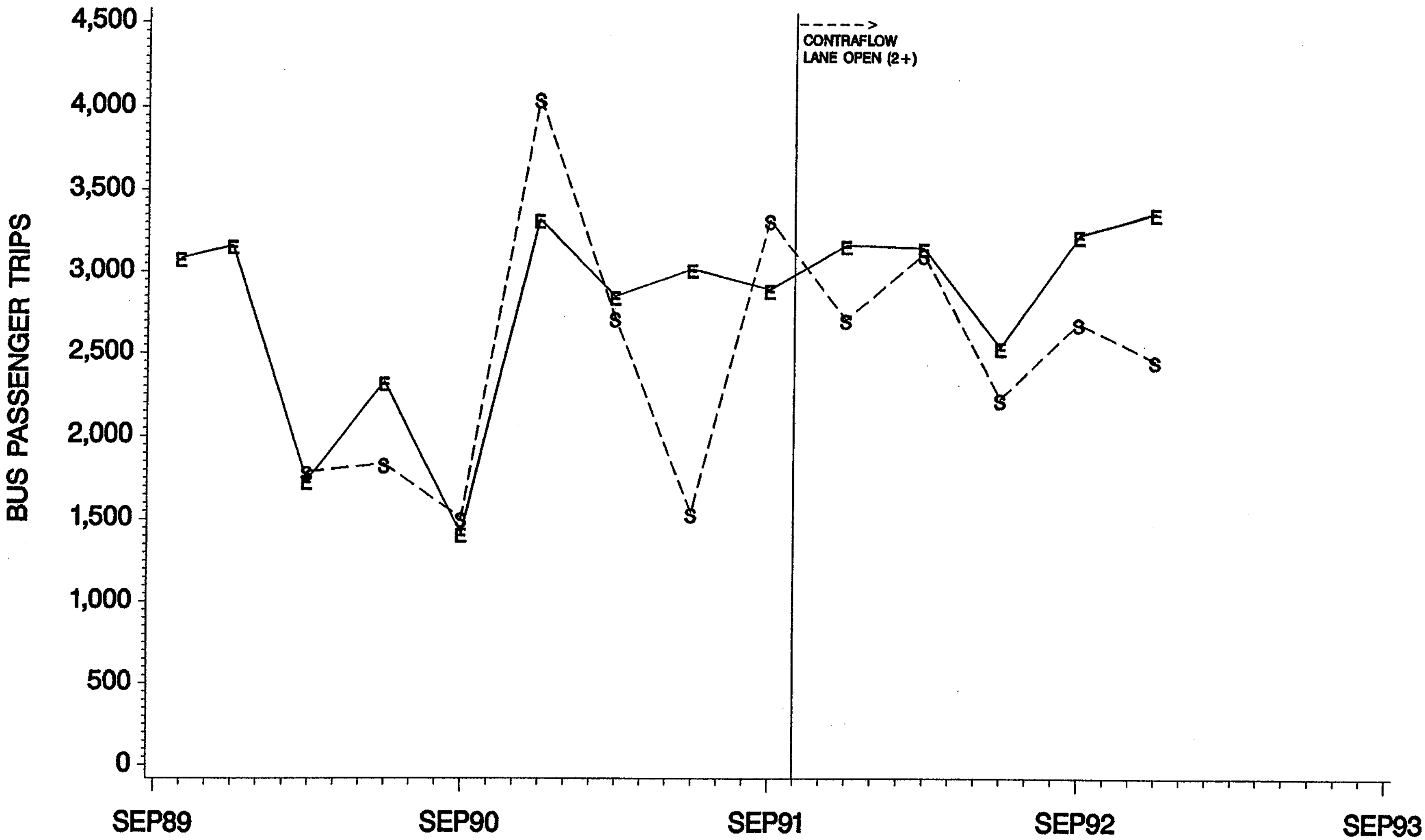


PEAK PERIOD IS FROM 6:00 A.M. TO 9:00 A.M.
COUNT LOCATION IS BETWEEN CBD CROSSOVER AND DOLPHIN CROSSOVER
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-20

A.M. PEAK PERIOD BUS PASSENGER TRIPS
TOTAL, FREEWAY PLUS HOV LANE
FREEWAYS WITH AND WITHOUT HOV LANE

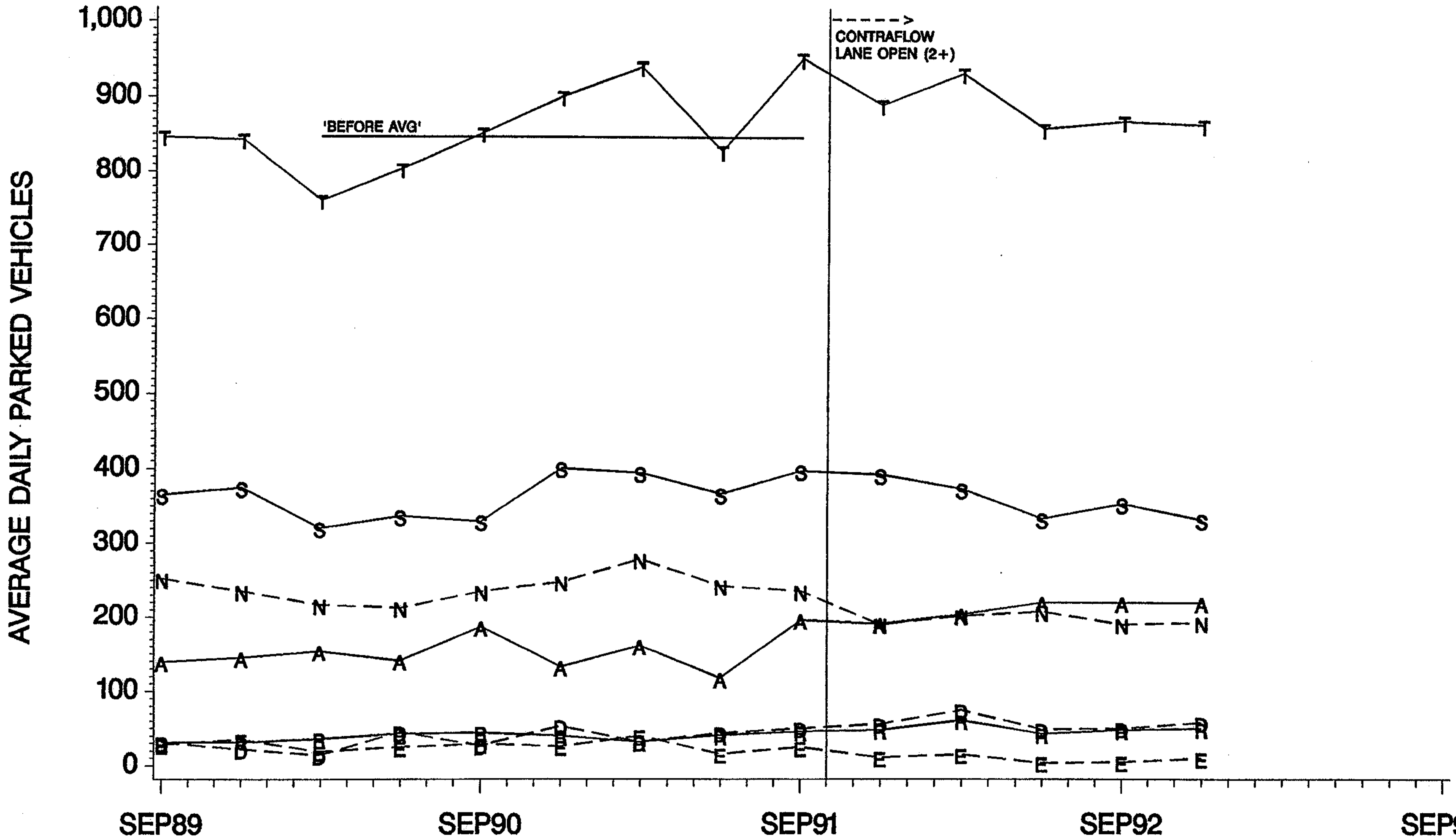


PEAK PERIOD IS FROM 6:00 A.M. TO 9:00 A.M.
COUNT LOCATION IS BETWEEN CBD CROSSOVER AND DOLPHIN CROSSOVER
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : E – EAST R.L. THORNTON FREEWAY (WITH HOV LANE)
S – SOUTH R.L. THORNTON FREEWAY (WITHOUT HOV LANE)

FIGURE E-21

EAST R.L. THORNTON (IH 30E) FREEWAY PARK–AND–RIDE LOT UTILIZATION

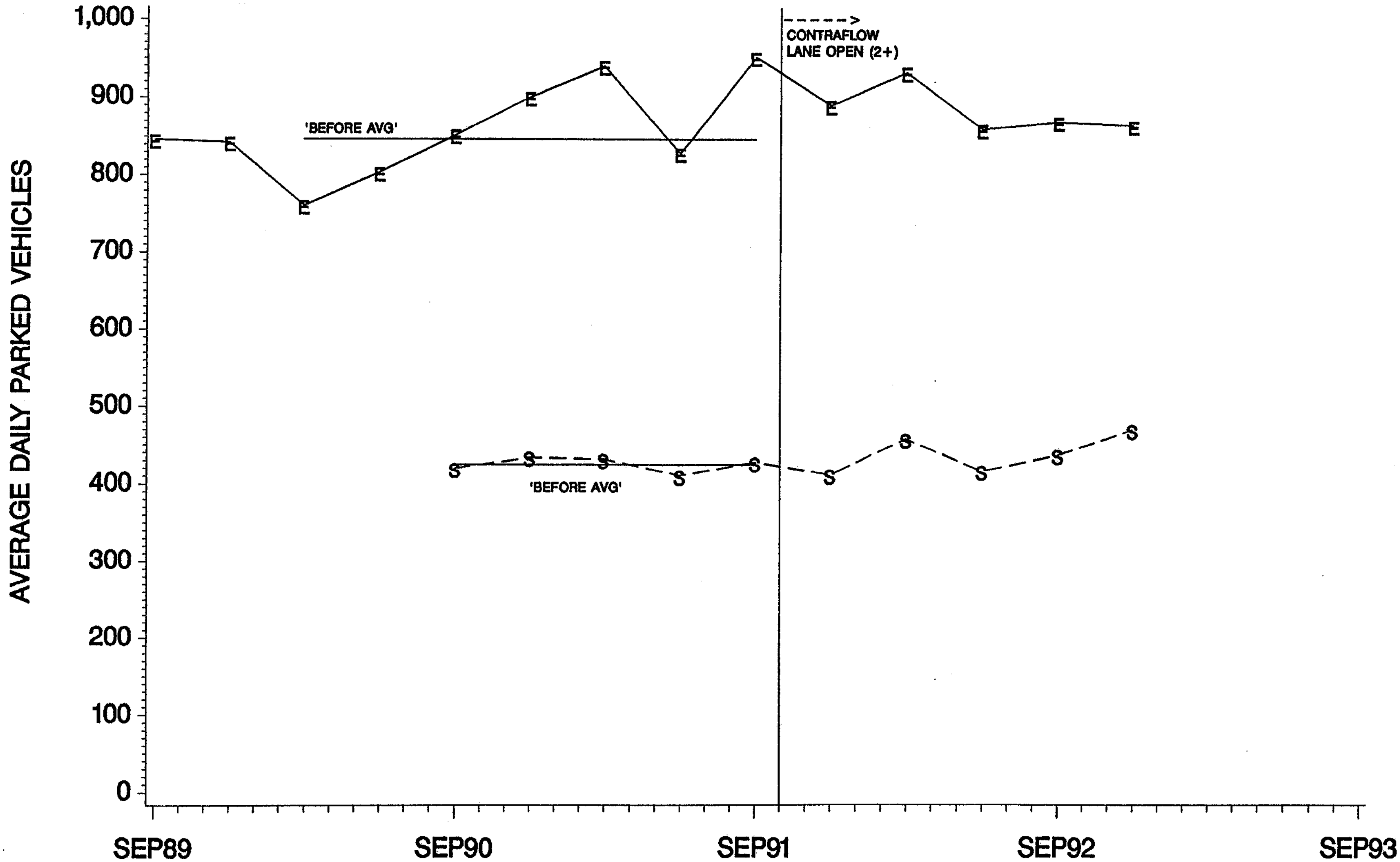


LEGEND : T – TOTAL (1223 SPACES)
N – NORTH GARLAND (298 SPACES)
S – SOUTH GARLAND (503 SPACES)
E – EAST GARLAND (84 SPACES)
R – ROWLETT (58 SPACES)
D – DALROCK CHURCH (80 SPACES)
A – AUDOBON PARK (200 SPACES)

SOURCE : TEXAS TRANSPORTATION INSTITUTE

FIGURE E-22

AVERAGE DAILY VEHICLES AT PARK–AND–RIDE LOTS FREEWAYS WITH AND WITHOUT HOV LANES

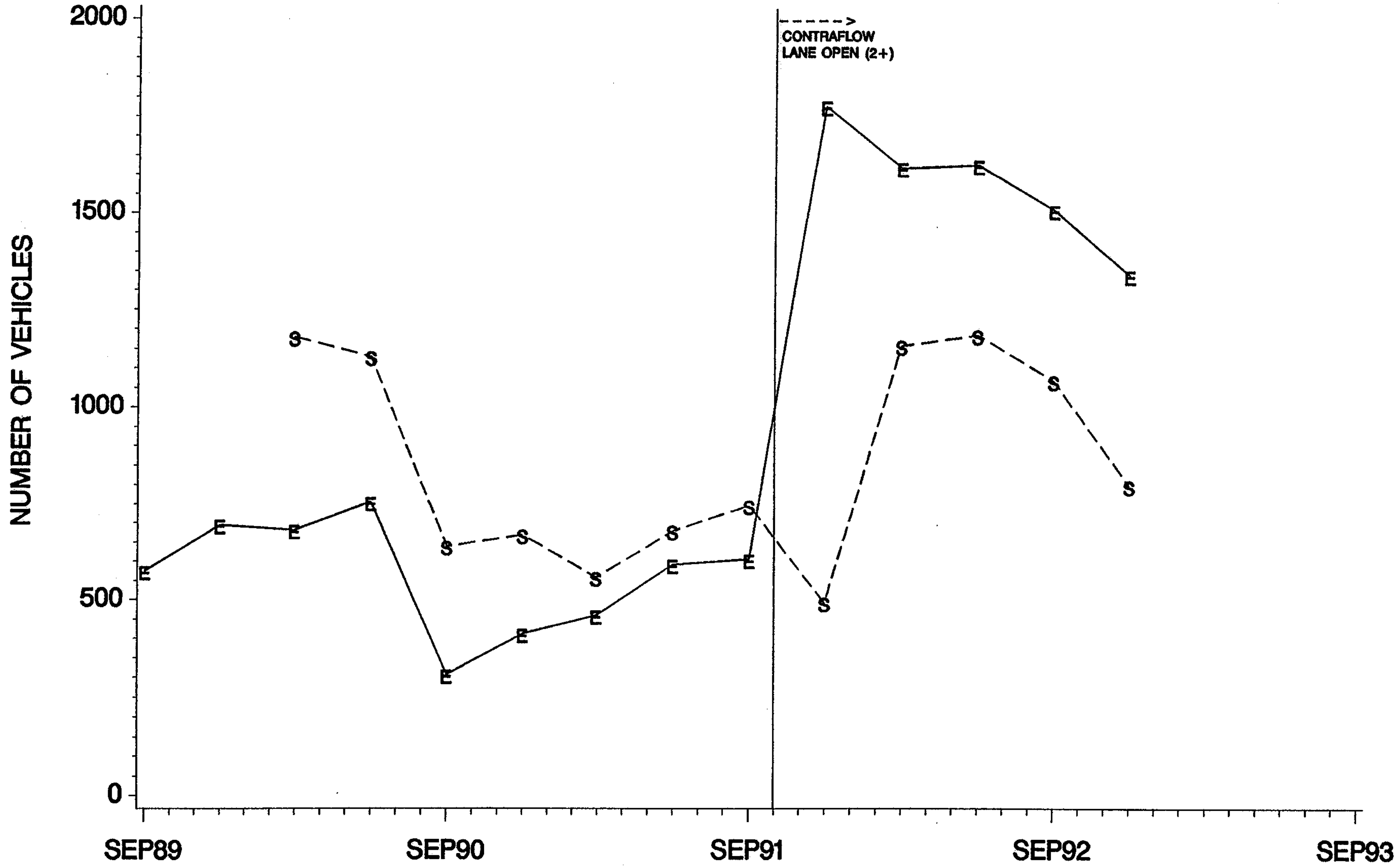


SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : E – EAST R.L. THORNTON FREEWAY (WITH HOV LANE)
S – SOUTH R.L. THORNTON FREEWAY (WITHOUT HOV LANE)

FIGURE E-23

A.M. PEAK HOUR 2+ CARPOOL UTILIZATION FREEWAYS WITH AND WITHOUT HOV LANE

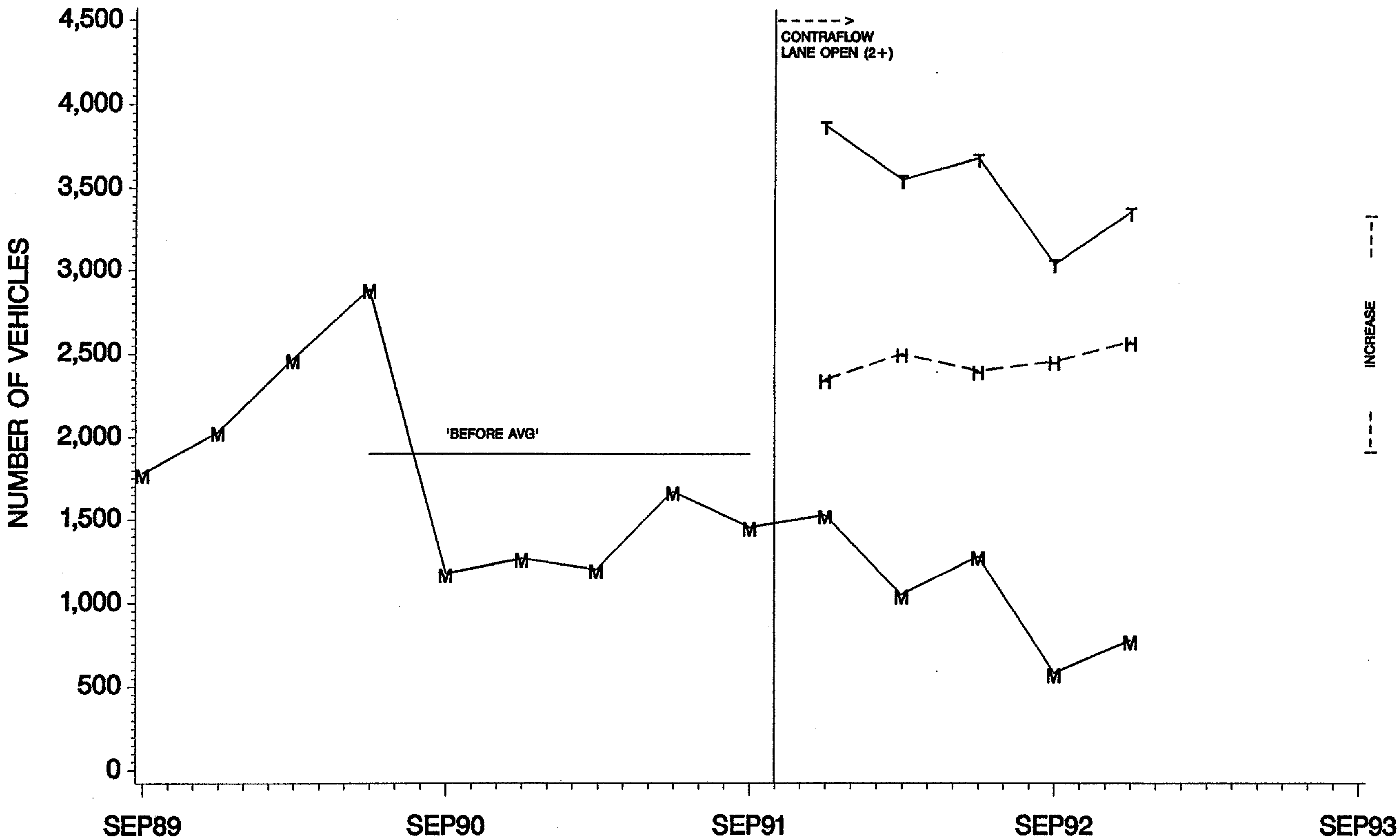


SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : E – EAST R L THORNTON (IH 30E) CARPOOLS
S – SOUTH R L THORNTON (IH 35E) CARPOOLS

FIGURE E-24

EAST R.L. THORNTON (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK PERIOD 2+ CARPOOL UTILIZATION



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