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16. Abstract

This report evaluates the operation of the Houston freeway high-occupancy vehicle (HOV) lane system through calendar year 1990. As of the end of 1990, 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). Since 1988, an annual report has been prepared through this research project that summarizes the status and effectiveness of the HOV improvements.

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 and a comparison to control freeways are used as a means of assessing the impacts of the HOV facilities.

As of the end of 1990, 46.5 miles of barrier-separated HOV facilities were in operation. Over 67,000 daily person trips are served on the HOV lanes; this represents a 50% increase in usage compared to 1989. Sixty percent of total person trips on the HOV lanes are being served by carpools and vanpools, with the remaining 40% being served by buses.

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AN EVALUATION OF THE HOUSTON HIGH-OCCUPANCY VEHICLE LANE SYSTEM

By

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and

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Research Report 1146-4

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

Research Study 2-10-89/3-1146

Sponsored by
Texas State Department of Highways and Public Transportation
in cooperation with the
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Federal Highway Administration

Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843

June 1991

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
in	inches	2.54	centimetres	cm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km

AREA

Symbol	When You Know	Multiply By	To Find	Symbol
in^2	square inches	645.2	centimetres squared	cm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha

MASS (weight)

Symbol	When You Know	Multiply By	To Find	Symbol
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg

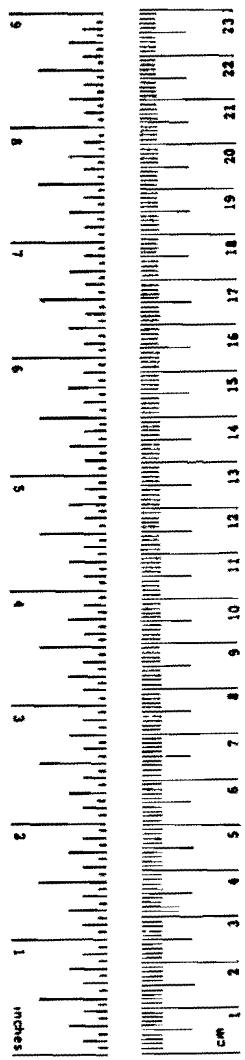
VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

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

TEMPERATURE (exact)

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



APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi

AREA

Symbol	When You Know	Multiply By	To Find	Symbol
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectores (10 000 m^2)	2.53	acres	ac

MASS (weight)

Symbol	When You Know	Multiply By	To Find	Symbol
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T

VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
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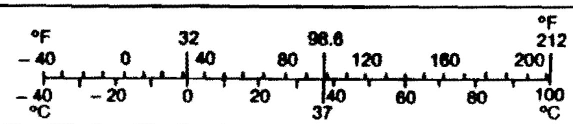

These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

ABSTRACT

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As of the end of 1990, 46.5 miles of barrier-separated HOV facilities were in operation. Over 67,000 daily person trips are served on the HOV lanes; this represents a 50% increase in usage compared to 1989. Sixty percent of total person trips on the HOV lanes are being served by carpools and vanpools, with the remaining 40% being served by buses.

Key Words: High-occupancy vehicle lanes, Transitways, Busways, Carpools, HOV Facilities, Authorized Vehicle Lanes, Priority Treatment for High-Occupancy Vehicles.

IMPLEMENTATION STATEMENT

This report was sponsored by the Texas State Department of Highways and Public 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 six committed freeway HOV lanes now being implemented in Houston, Texas.

The first of the completed HOV facilities opened on the Katy Freeway (I-10) in October 1984. In November 1984, the contraflow lane 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). No new HOV sections were completed in 1989; in 1990, extensions of the Katy, North and Northwest HOV lanes were completed, and carpool use of the North HOV lane began. High-occupancy vehicle lane construction continues in the Southwest Freeway (US 59) and Gulf Freeway (I-45) corridors.

This report presents data relating to the four operating HOV lanes and focuses on data collected during calendar year 1990. As of 1990 both the Gulf and Northwest HOV lanes were still relatively new. Thus, the data for the more mature facilities -- the North and the Katy -- is 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

SUMMARY

In response to congestion and related concerns, a variety of transportation actions are being taken in Houston. One of those actions involves the implementation on many of the urban freeways of a system of priority lanes for high-occupancy vehicles. Locally, these facilities are sometimes referred to as transitways, and they are being jointly developed by the Texas State Department of Highways and Public Transportation and the Metropolitan Transit Authority of Harris County. This report presents and evaluates data relative to transitway and freeway performance in Houston through calendar year 1990.

A commitment is in place to develop 95.5 miles of barrier-separated high-occupancy vehicle (HOV) lanes. The cost of the entire HOV lane system, including all support facilities, will be approximately $640 million.[1] As of the end of 1990, 46.5 miles of barrier-separated HOV lanes were in place, implemented at a cost of approximately $276 million[1]; HOV lanes were in operation in four corridors. As of that date, the Northwest and Gulf HOV lanes were still too new to have reached their potential. Thus, the data from the North and Katy HOV lanes is more relevant in assessing HOV lane effectiveness. While some sections of two-direction high-occupancy vehicle lane 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 1990, the HOV lane system served 67,367 person trips, a 50 percent increase over December 1989. At the end of 1990, 8,940 cars were parked in transitway corridor park-and-ride lots on a typical day. The HOV lanes have been successful in attracting young, educated, professional, white-collar patrons. These individuals are choosing to use the

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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.

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.

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 in Houston 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 the Houston HOV lanes 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 Houston transitways offer a travel time savings to users during the peak-hour; these savings range from three minutes on the Gulf HOV lane to 14 minutes on the Katy HOV lane. In an average, non-incident peak-hour, the 46.5-mile system offers 26.2 minutes of time savings, or about 0.6 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 in excess of 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 does increase the number of directional roadway lanes, for the high-occupancy vehicle lane to be effective it should at least increase person movement by an amount greater than the increase in lanes added to the roadway. The data show the Houston HOV lanes are helping to bring about a disproportionately large increase in person movement (Table S-1). During the peak-hour, the HOV lanes are moving 39 percent to 129 percent 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 and Katy Freeways has increased by over 20 percent. This type of increase has not been experienced on freeways not having 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, and those types of 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 more than doubled, increasing from 26 mph to 54 mph. The result has been significant decreases in bus schedule times. The reduction in revenue hours of service resulting because of the higher speeds on the HOV lanes results in an annual bus operating cost savings of approximately $4.8 million.

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 impact on the operation of the freeway general-purpose lanes that can be

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
Change in Roadway Person Movement				
% Increase in directional lanes due to HOV lane	33%	25%	—	33%
% Increase in a.m. person volume[1]	100%	101%	—	46%
Change in Average Vehicle Occupancy (persons/vehicle)[1]				
Occupancy before HOV lane	1.26	1.28	—	1.14
Occupancy in December 1990	1.56	1.59	—	1.30
% Change, Pre-HOV lane to current	+23.8%	+24.2%	—	+14.0%
% Change in 2+ Carpool Volume[1]	+132%	+127%	—	+183%
% of carpools formed due to transitway[2]	53%	46%	26%	47%
% Change in Bus Passengers (peak period)[1]	+355%	—	—	+108%
% New bus riders due to transitway[2]	47%	52%	33%	47%
% Change, Freeway Mainlane Volume per Lane[1,3]	+39%	+ 9%	+8%	—
% Change, Freeway Mainlane Speed (Peak Hour)[1,3]	+43%	+65%	0%	—
% Change, Freeway Mainlane Accident Rate[4]	- 4.7%	+4.3%	+18.0%	-19.0%
% Change, Freeway Per Lane Efficiency[1,3,5]	+169%	+150%	—	+37%
Comparison, HOV Lane vs. Freeway Lane[6] (HOV lane improvement as a % of freeway improvement)				
Fuel consumption (gallons)	82%	—	—	—
Air quality (kg of CO)	61%	—	—	—
Annual Value of Travel Time Saved on HOV Lane[7] ($ millions)	$10.9	$4.9	$0.6	$2.5
Travel time saved as a % of construction cost[8]	43.4%	8.9%	2.0%	4.0%
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.
[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 (accidents per 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 (1990) value of time saved by users of the HOV lane.
[8]This is the estimated annual value of 1990 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	1.56	+23.8%
North	1.28	1.59	+24.2%
Northwest	1.14	1.30	+14.0%
Freeway Without HOV Lane	1.29	1.31	+ 1.6%
Peak-Hour Peak-Direction 2+ Carpool Volume			
Freeways With HOV Lanes			
Katy (5-6 p.m.)	763	1627	+132.4%
North (7-8 a.m.)	490	1385	+182.7%
Northwest (7-8 a.m.)	700	1587	+126.7%
Freeway Without HOV Lane (7-8 a.m.)	595	743	+ 25.9%
A.M. Peak-Period Bus Ridership (3.5 hours)			
Freeways With HOV Lanes			
Katy	900	4095	+355.0
North	0	5195	—
Northwest	605	1260	+108.3
Freeway Without HOV Lane[1]	2230	2100	- 5.8%
Cars Parked at Park-and-Ride Lots			
Freeways With HOV Lanes			
Katy	575	2057	+257.8%
North	0	4159	—
Gulf	1115	1349	+ 21.0%
Northwest	430	1286	+199.1%
Freeway Without HOV Lane[1]	1675	1665	- 0.6%

[1] "Current" data is 1989. The 1990 data are not comparable due to diversion of bus service to the Katy HOV lane.

Note: The freeway without an HOV lane data are from the Southwest (US 59) Freeway.

attributed to implementation of the transitways (Table S-1). Per lane volumes on the general-purpose lanes are higher today than they were prior to HOV implementation. In reviewing accident data for the four 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 times the speed at which that volume is moved (a weighted average for the freeway and the HOV lane). This efficiency has increased (Table S-1) since the HOV lanes have been implemented, and a part of that increase is the result of the transitway 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 1990), 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 an 18 percent reduction in fuel consumed and a 39 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 just be more cost effective if all benefits were quantified. Based on this analysis, the two more mature HOV lanes -- Katy and North -- are cost effective. The Northwest is only marginally cost effective based on this single benefit, but the value of time saved on the Northwest HOV lane in 1990 was 317 percent greater than it was in 1989; thus, benefits are increasing rapidly on this facility. The Gulf HOV lane will need to have the next phase completed before it will generate significant benefits; that will not happen for at least a year.

If some of the additional benefits referred to previously are considered, the benefit-cost ratio increases markedly. For example, with this type of analysis, in 1990 the benefit-cost ratio for the Katy HOV project was in excess of 4.0 (see Table 28 in text). For that facility, the value of all quantified benefits was five 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 the HOV lane program by the public is high and has been increasing over time. Based on 1990 surveys, over 70 percent of the motorists in the freeway general-purpose lanes (not HOV lane users) viewed these project as being good transportation improvements. Fewer than 15 percent stated the projects were not good improvements.

Comparison to Other Fixed-Guideway Projects

The Houston HOV facilities are relatively inexpensive and move a large volume of persons during the congested peak hour. Their public operating costs are low. Rail projects tend to move more persons on a daily basis. Selected data are summarized in Table S-3.

Conclusions

This report identified the objectives associated with developing high-occupancy vehicle lanes in Houston. The report reviews and analyzes data collected through calendar year 1990 to assess the performance of the priority lanes in meeting their objectives.

Table S-3. Comparison of the Houston High-Occupancy Vehicle Lanes With Other Fixed-Guideway Improvements

Comparative Factor	Type of Fixed-Guideway Improvement		
	Houston HOV Lanes[1]	Heavy Rail	Light Rail
Capital Cost per Mile (millions)	$ 5.9	$57.1[2]	$12.4[3]
Operating Cost per Passenger Mile (cents)	13	31[4]	24[5]
Ridership (person trips)			
Maximum Peak-Hour, Peak-Direction	3900	6,700[6]	1,900[3]
Daily	16,800	55,000[2]	21,100[3]

[1]The average value for the four operating Houston high-occupancy vehicle lanes. 1990 dollars.
[2]Miami. Year of construction dollars.
[3]Average for light rail in Portland, Sacramento, San Diego (San Ysidro line) and San Jose. Year of construction dollars.
[4]Average for heavy rail in Miami, Atlanta, and Washington, D.C.
[5]Average for light rail in Buffalo, Portland, Sacramento, and San Diego.
[6]Average for Miami and Atlanta.

Some of the relevant data associated with these analyses is shown in Tables S-1 through S-3. A review of these performance measures leads to several general observations. The performance measures suggest that both the Katy and North HOV lanes are fulfilling their intended purpose; these are the two more mature priority lanes. The Northwest HOV lane is marginal at this time, while the Gulf HOV lane has yet to generate significant benefits. Both of these facilities have been operating less than three years. 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, and the section that is offers only minimal benefits; it will not be extended for two more years. Nevertheless, daily usage of the Northwest HOV lane increased by 56 percent during 1990, while usage of the Gulf increased by 23 percent during 1990.

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

TABLE OF CONTENTS

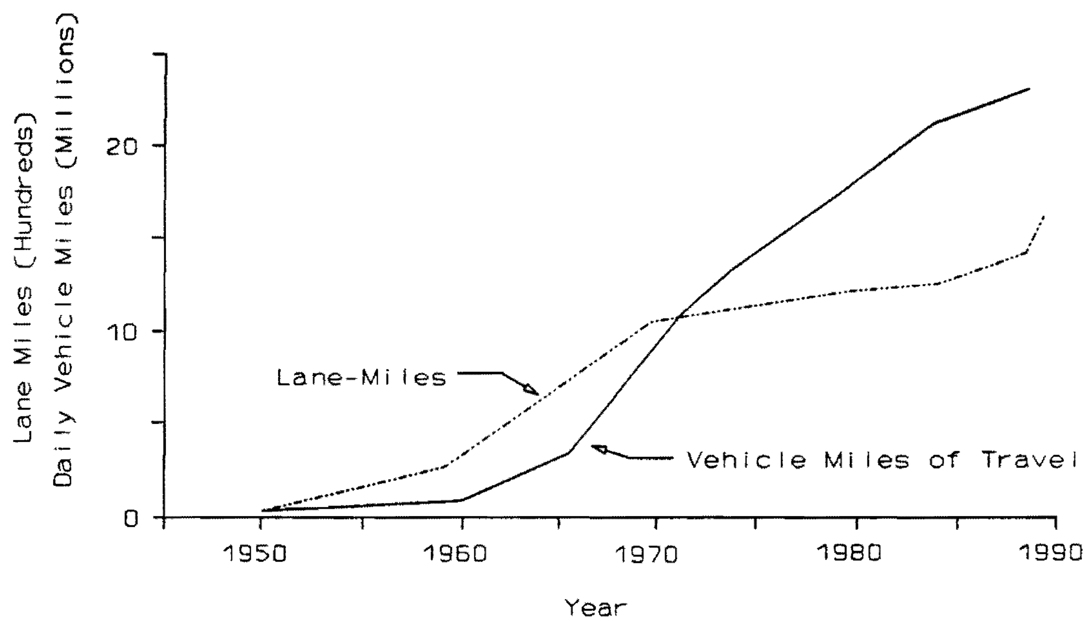
Page

TABLE OF CONTENTS (continued)

Page

I. INTRODUCTION

Beginning in the early 1970's, 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[3] indicated that Houston had some of the most, if not the most, congested freeway facilities in the nation.



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, Harris County

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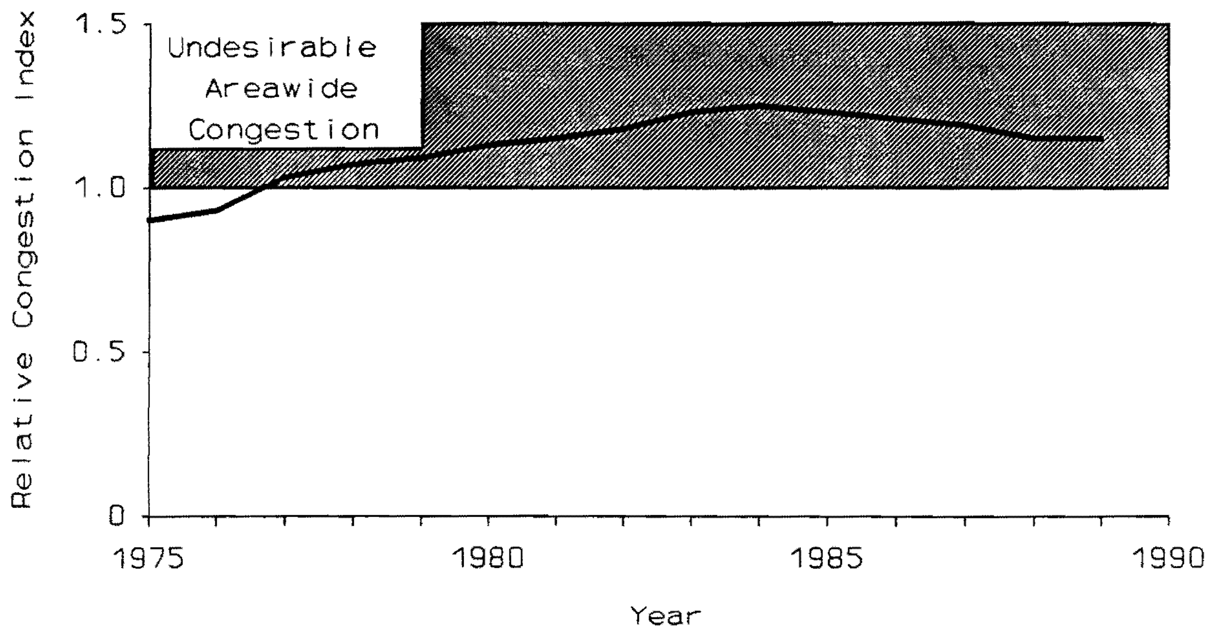
[2] Texas Transportation Institute Research Report 431-1F.

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

Monitoring of overall urban congestion in major cities clearly indicated that mobility in Houston deteriorated until the mid 1980s. Areawide congestion levels in Houston increased by 39 percent between 1975 and 1984.[4] However, as the result of an aggressive multimodal effort to restore mobility in Houston, congestion in the area has been moderating in recent years (Figure 2). Between 1984 and 1989, the congestion index in Houston actually declined by eight percent, even though vehicle-miles of travel increased by over nine percent during that time period. Nevertheless, Houston remains a relatively congested city (Table 1).



Note: 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: "Regional Mobility Plan for the Houston Area, 1989" and Texas Transportation Institute Research

Figure 2. Relative Houston Area Mobility Level, 1975-1989

In response to the congestion problem, a variety of actions are being taken. One of these actions involves the implementation on the urban freeways of a system of priority lanes for high-occupancy vehicles. These facilities, sometimes referred to locally as transitways, are being

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

jointly developed by the Texas State Department of Highways and Public Transportation (SDHPT) and the Metropolitan Transit Authority of Harris County (Metro).

Table 1. Relative Mobility Levels in Major United States Cities, 1989

Urban Area	Relative Mobility Index[1]	Urban Area	Relative Mobility Index[1]
1. Los Angeles	1.54	6. Chicago	1.21
2. Washington, D.C.	1.36	7. San Diego	1.18
3. San Francisco-Oakland	1.36	8. HOUSTON	1.15
4. Miami	1.25	9. Atlanta	1.14
5. Seattle	1.21	10. New Orleans	1.13

[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 Study No. 2-10-90-1131 (Preliminary).

Through this research effort, a comprehensive evaluation of the HOV lanes is being performed; an objective of the 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 through December 1990. Data are presented for all four of the operating transitways.

Organization of the Report

The following section of this report provides an overview description of the entire Houston high-occupancy vehicle facility system. 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 the Houston HOV lanes and more detailed data on each of the HOV lane projects are also included.

II. OVERVIEW OF THE HOUSTON HIGH-OCCUPANCY VEHICLE SYSTEM

Historical Background

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 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 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.

The Committed System

A commitment is in place in the Houston area to develop approximately 96 miles of high-occupancy vehicle lanes (Figure 3). As of December 1990, four separate HOV facilities were in operation (Table 2). A total of 46.5 miles of barrier-separated, high-occupancy vehicle lanes were operating, representing an increase from the 36.6 miles that operated at the end of 1989. During 1990, extensions to the Katy, North, and Northwest HOV lanes were completed. Also, during 1990 carpool use of the North Freeway HOV lane was allowed. The Katy and Gulf HOV lanes were opened to weekend use in 1989; in 1990, both the North and Northwest HOV lanes also opened to weekend use. Construction is continuing in the Southwest and Gulf corridors.

Table 2. Status of the High-Occupancy Vehicle Lane System, December 1990

HOV Facility	Date First Phase Opened	Miles in Operation	Ultimate System Miles	Vehicles Allowed to Use HOV Lane	Hours of Weekday[1] Operation
Katy (I-10)	October 1984	13.0	13.0	3+ vehicles from 6:45 to 8:00 a.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[4]	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[5]	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 1990	—	13.8[6]	—	—
Eastex (US 59)	Not open in 1990	—	15.5-20.0[3]	—	—
Total		46.5	91.0-95.5[3]		

[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. Further data on weekend use are presented subsequently in this report.
[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]A firm commitment is in place to develop 15.5 miles of the HOV lane from the CBD to Will Clayton Drive, scheduled completion is in 1996. Implementation of the 4.5 miles from Will Clayton to Kingwood Drive has not yet been scheduled.
[4]Scheduled for completion in 1996.
[5]Scheduled for completion in 1994.
[6]Scheduled for completion in 1994.

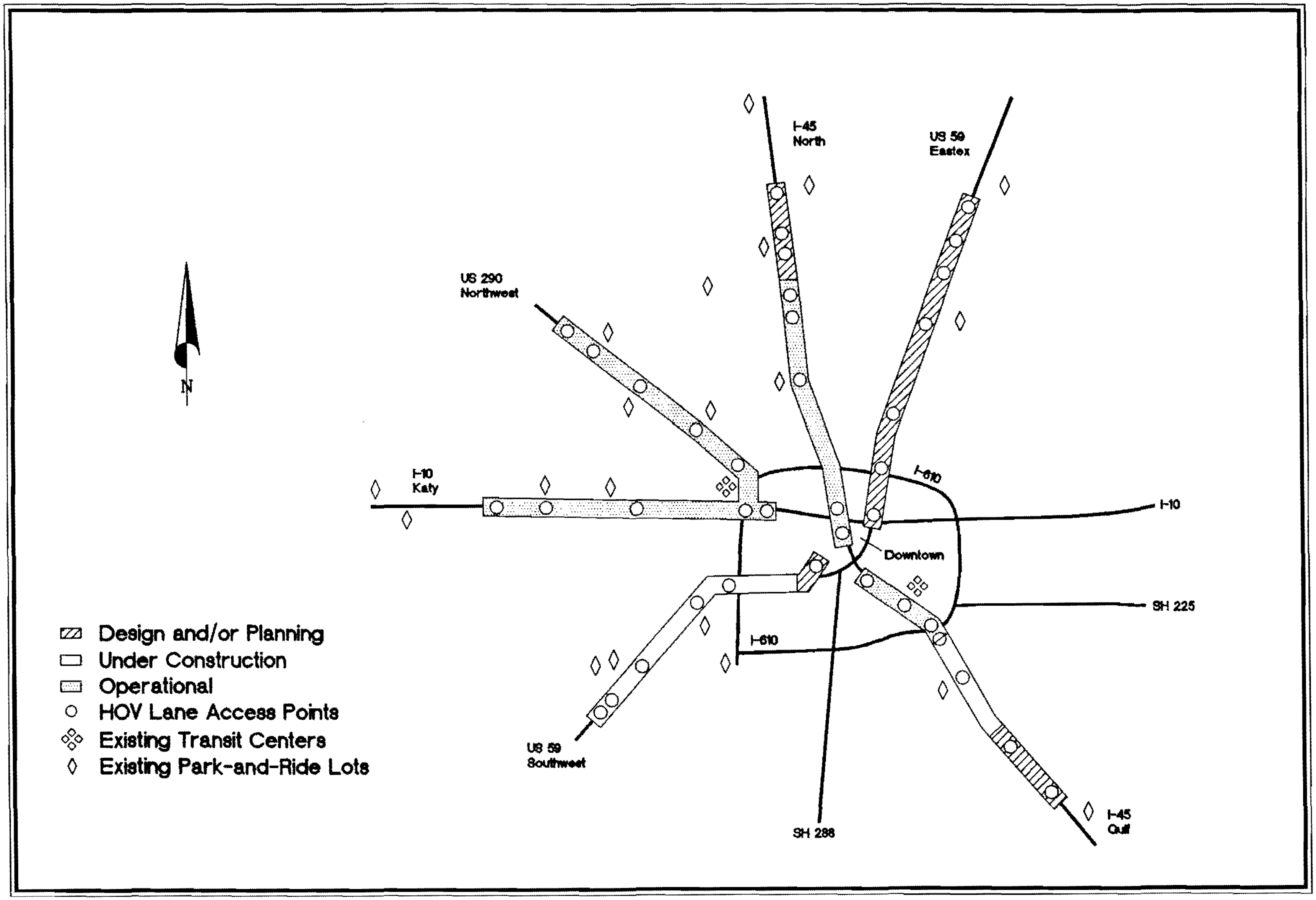


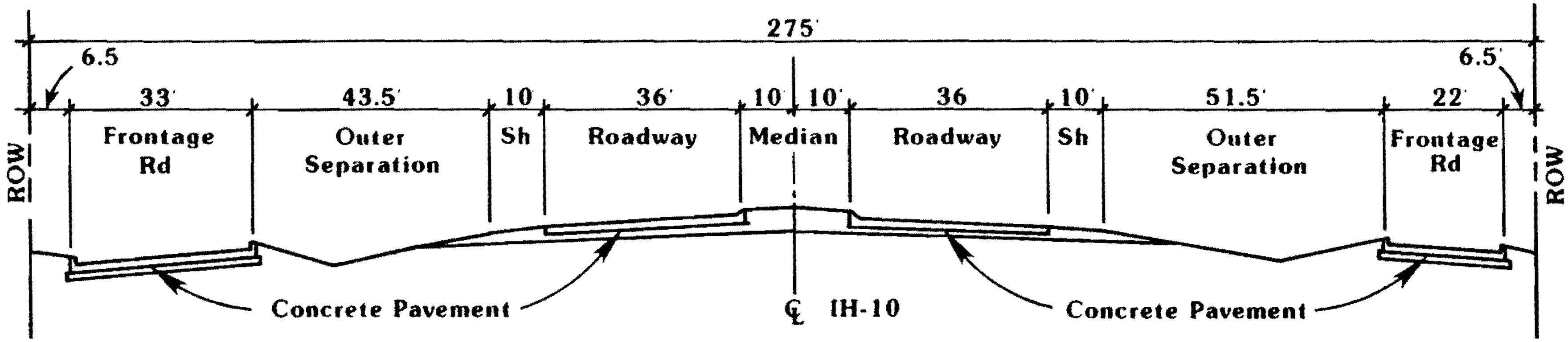
Figure 3. Status of Transitway Development, September 1990

Physical Description of the High-Occupancy Vehicle Lanes

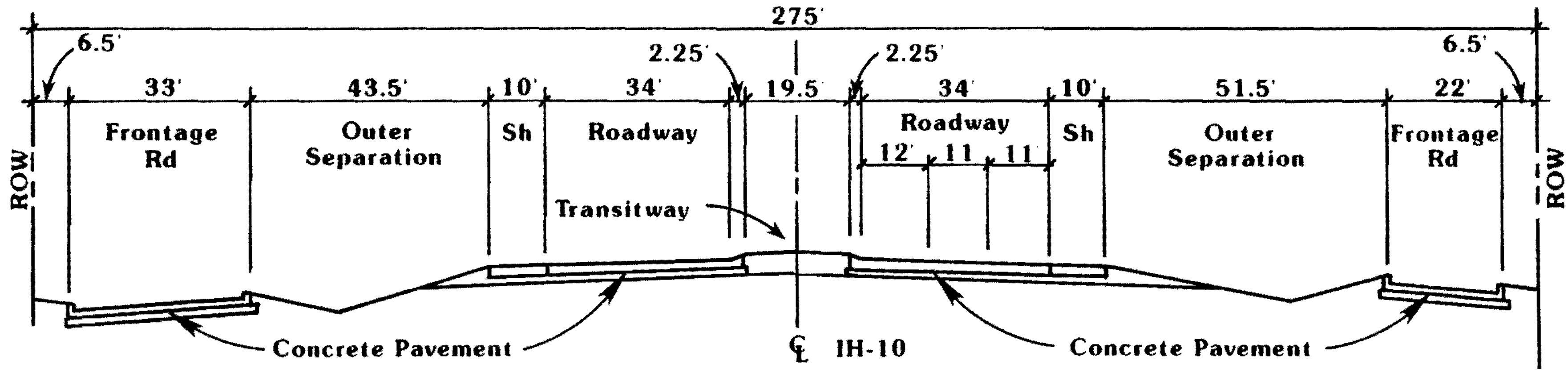
While some sections of two-direction HOV facility are being developed, the typical Houston HOV lane is located in the freeway median, is approximately 20-feet wide, is reversible, and is separated from the general-purpose freeway mainlanes by concrete median barriers (Figure 4). In some locations, implementation of the HOV lane was accomplished by narrowing freeway lanes to 11 feet and reducing inside shoulder widths. A typical section is shown in Figure 5.

Figure 4. Transitway in Median of Katy Freeway

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



Typical Section Before Transitway Construction



Typical Section After Transitway Construction

Figure 5. Typical Sections, Before and After Transitway Construction, Katy Freeway Transitway

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.

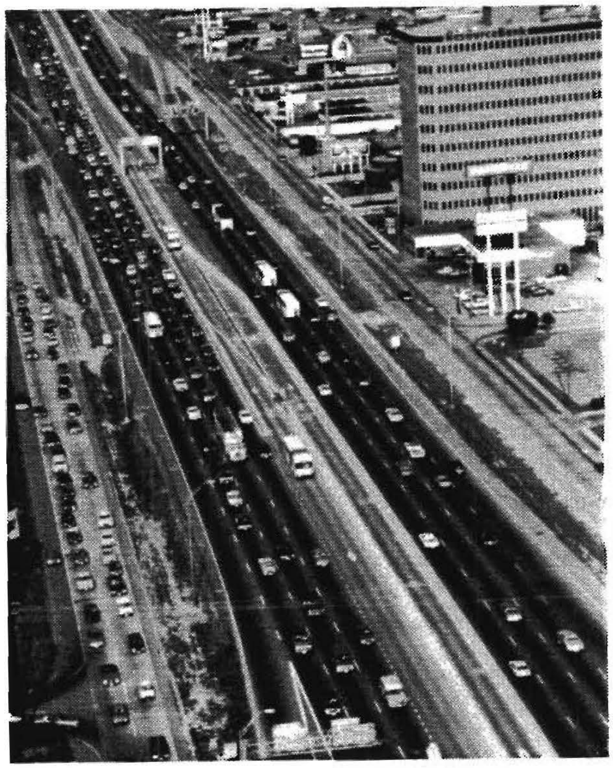


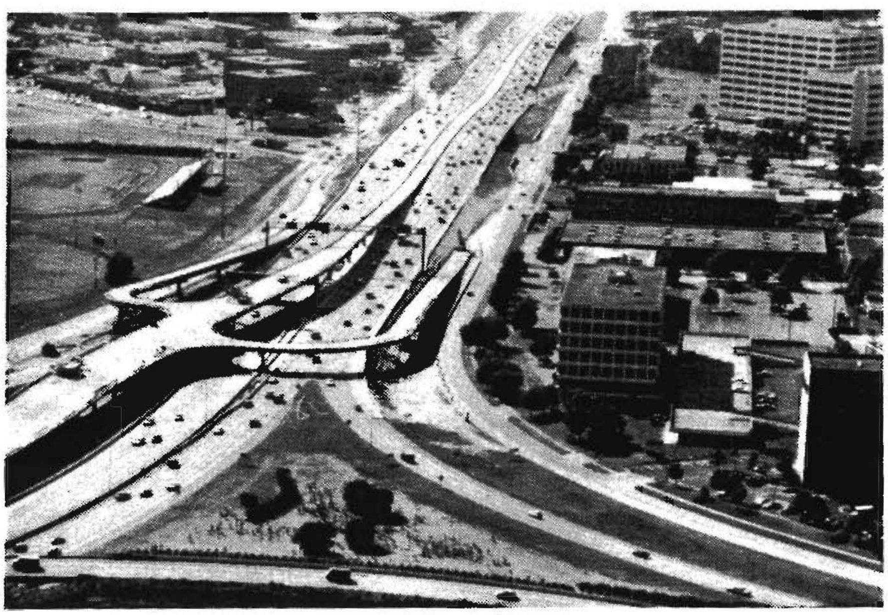
Figure 6. Slip Ramp for Transitway Access/Egress on Katy Freeway

<u>Estimated Capital Cost</u>

Since the HOV lanes have generally been constructed as part of freeway reconstruction projects, it is difficult to determine precisely the capital cost of the priority lanes. Information provided by both Metro and SDHPT 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 a cost of less than $4 million per mile (Table 3). An extensive system of support facilities -- park-and-ride lots, park-and-pool lots, and bus transfer facilities -- also have been provided in each corridor. Some of these facilities would have been provided even if there were no HOV

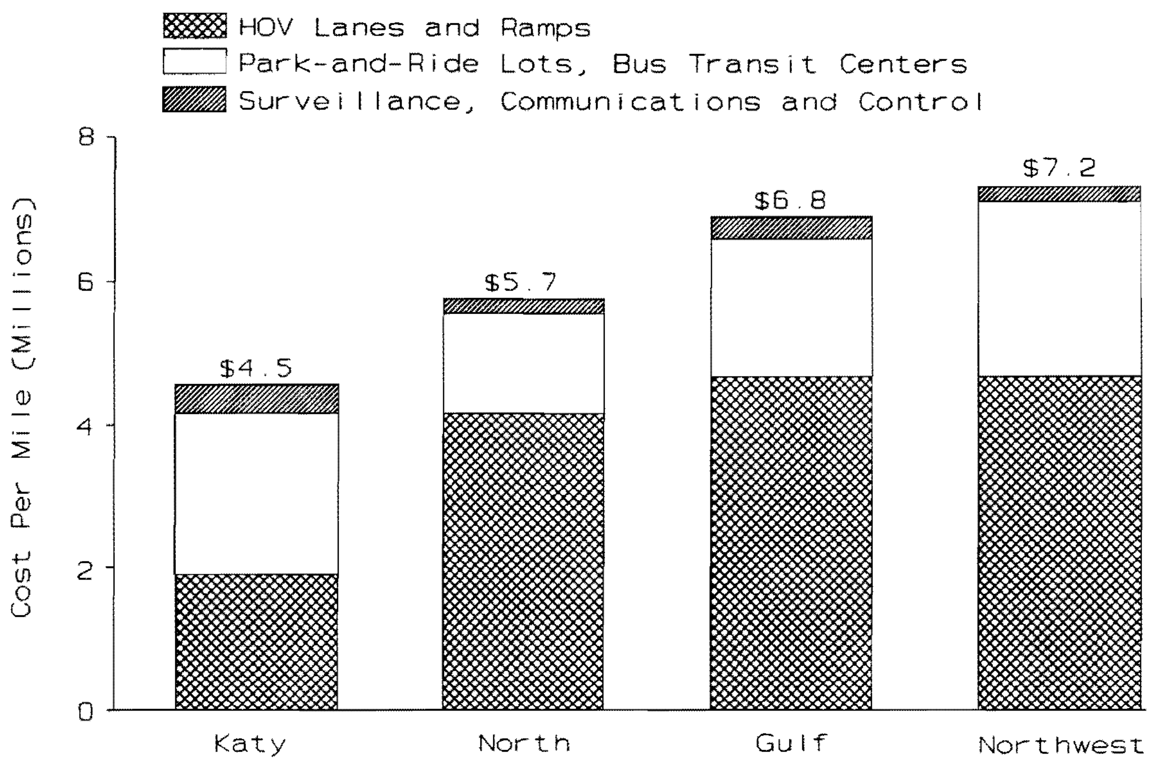
Direct Ramp to Eastwood Bus Transit Center, Gulf Transitway



Transitway Ramps to Frontage Roads, Northwest Transitway

Figure 7. Examples of Grade Separated Transitway Interchanges

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 HOV lanes at a typical cost of $200,000 to $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 8 summarizes current capital expenditures in the Houston HOV system.



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

Figure 8. Capital Cost Per Mile (1990 dollars) of the Operating Houston HOV Facilities

Approximately half of the ultimate HOV lane system was operating in 1990. Table 4 provides an estimate of the cost of the completed system. The ultimate capital cost (1990 dollars) for the HOV lanes and ramps will be approximately $5.0 million per mile. The HOV support facilities -- park-and-ride lots, park-and-pool lots, and bus transfer facilities -- will cost

Table 3. Estimated Capital Cost[1] of the Operational Houston HOV Lane System, 1990

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)	$1.4 ($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)	$32.6 ($32.0)	$2.4 ($2.4)	$2.9 ($2.9)	$0.2 ($0.2)	$98.2 ($96.9)	$7.3 ($7.2)
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 SDHPT. An additional cost breakdown is included in the appendices.

an additional $2.0 million per mile. The entire completed system will cost approximately $642 million, or about $7.1 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.

Table 4. Estimated Cost[1] of the Completed 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	$2.2	$ 4.7	$0.4	$59.1	$4.5
North (I-45)	19.7	$104.0	$5.3	$34.0	$1.7	$ 4.1	$0.2	$140.6	$7.1
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	$32.0	$2.4	$ 2.9	$0.2	$ 96.9	$7.2
Southwest (US 59)	13.8	$ 84.8	$6.1	$39.2	$2.8	$ 4.5	$0.3	$128.5	$9.3
Eastex (US 59)	15.5[6]	$ 73.9	$4.8	$17.8	$1.1	$ 3.9	$0.3	$ 95.6	$6.2
Total	91.0	$439.2	$4.8	$180.7	$2.0	$23.4	$0.3	$641.8	$7.1

[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.
[6]Ultimately, this will be a 20-mile HOV lane. A firm commitment to a date for developing the final 4.5 miles does not yet exist. Thus, costs are shown only for 15.5 miles.

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

Facility Operating and Enforcement Cost

The daily operation and enforcement of the HOV lanes is the responsibility of the Metropolitan Transit Authority. On average, this is costing just over $250,000 per HOV lane per year (Table 5). This is equivalent to less than one cent per passenger-mile.[5]

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 $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.

[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 5. Estimated Annual Cost of Operating and Enforcing the Operating Houston HOV Lanes

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

Thus, the total annual public operating costs for the HOV lanes is approximately $19 million; one million is for operations and enforcement, and $18 million is for bus operating subsidies. Figure 9 provides a summary of operating cost data. More detail on those costs is provided subsequently in this report.

General Trends in HOV System Utilization

This section briefly overviews systemwide data that help describe the usage of the Houston HOV lanes. A more detailed evaluation of these data is included in a subsequent section of this report, and additional data are included in the appendices.

Trends in Systemwide HOV Usage

Annual vehicle-miles of travel on the HOV lanes and annual passenger-miles traveled are depicted in Figures 10 and 11. 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.

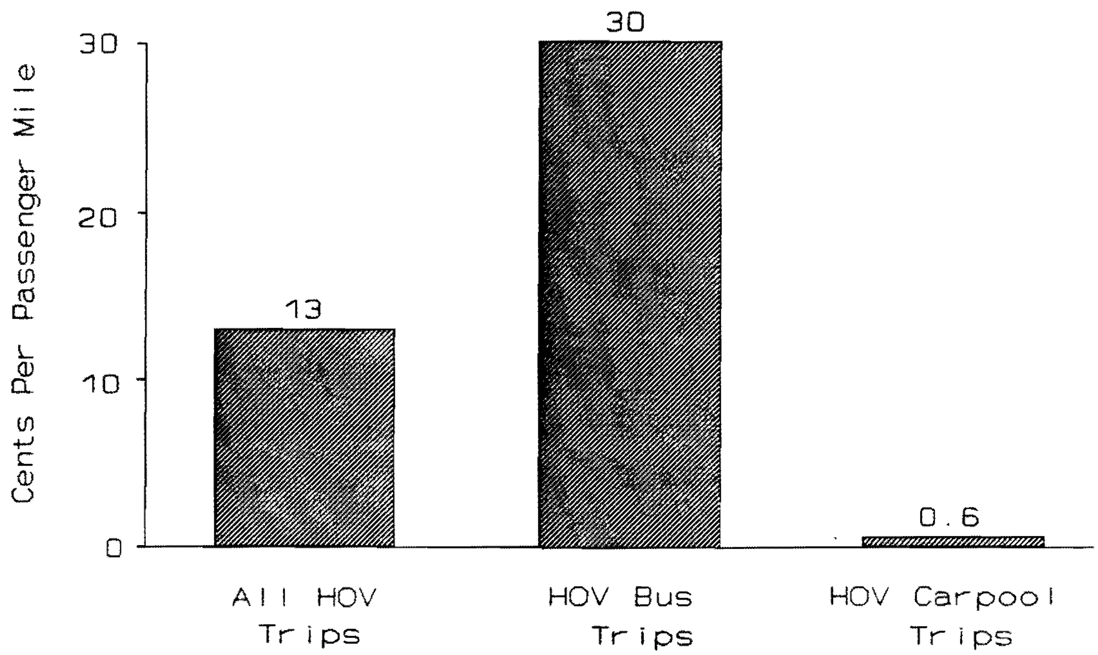


Figure 9. Operating Cost Per Passenger-Mile for the Operating Houston HOV Facilities

Figure 12 depicts total daily systemwide HOV usage in Houston. Daily person trips in December 1990 totalled 67,367[6], a 49.7 percent increase over the ridership level in December 1989. The increase between 1989 and 1990 is surprisingly great. On average, HOV ridership grew at a compound rate of 3.4 percent per month during 1990. That increase has been so great that it may be unreasonable to expect significant ridership increases to take place 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 13).

[6] This number is somewhat inflated since approximately 1,200 peak period bus riders have been routed from the Southwest Freeway to the Katy HOV lane due to construction in the Southwest corridor.

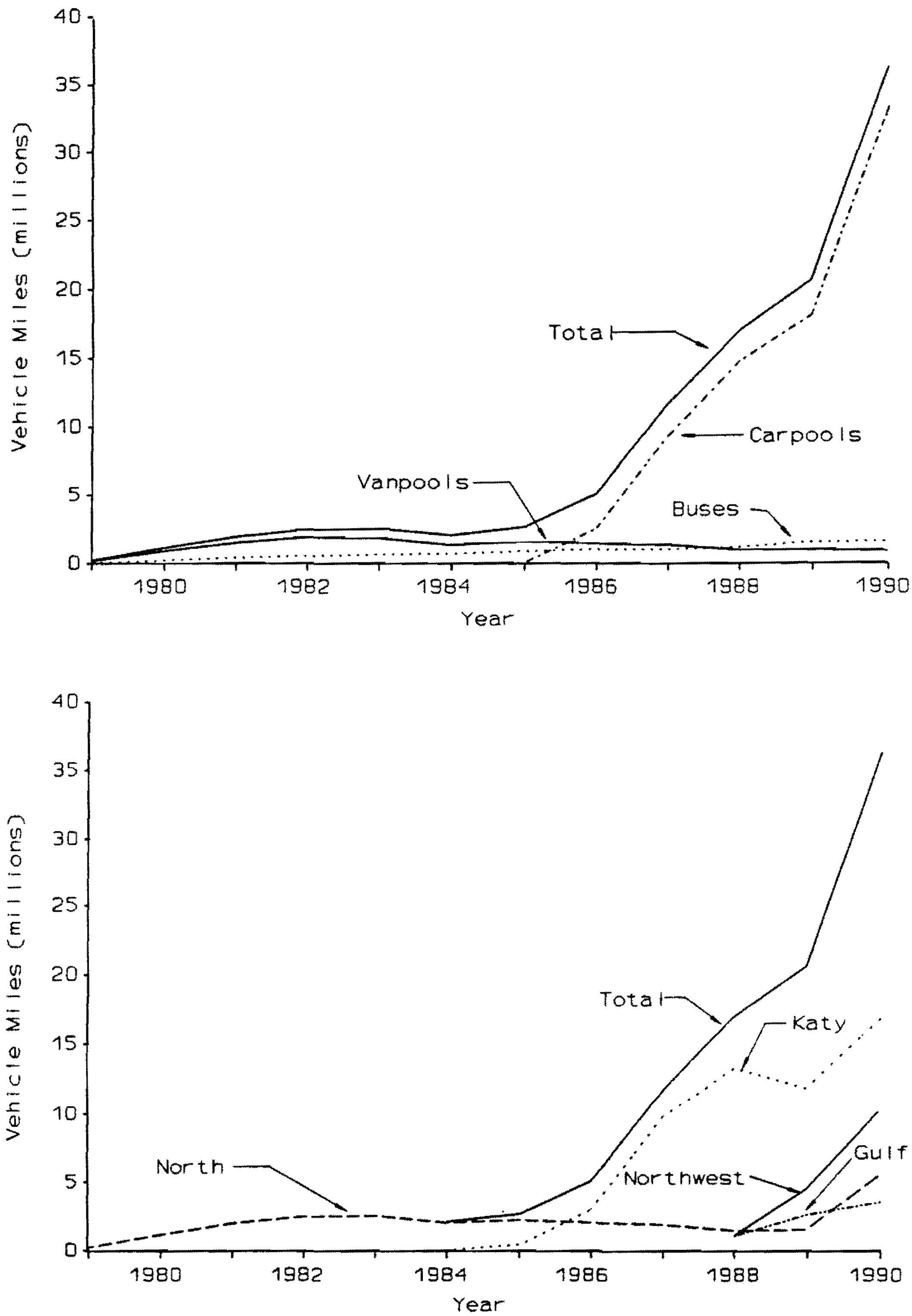


Figure 10. Trends in Annual Vehicle-Miles of Travel on Houston Transitways

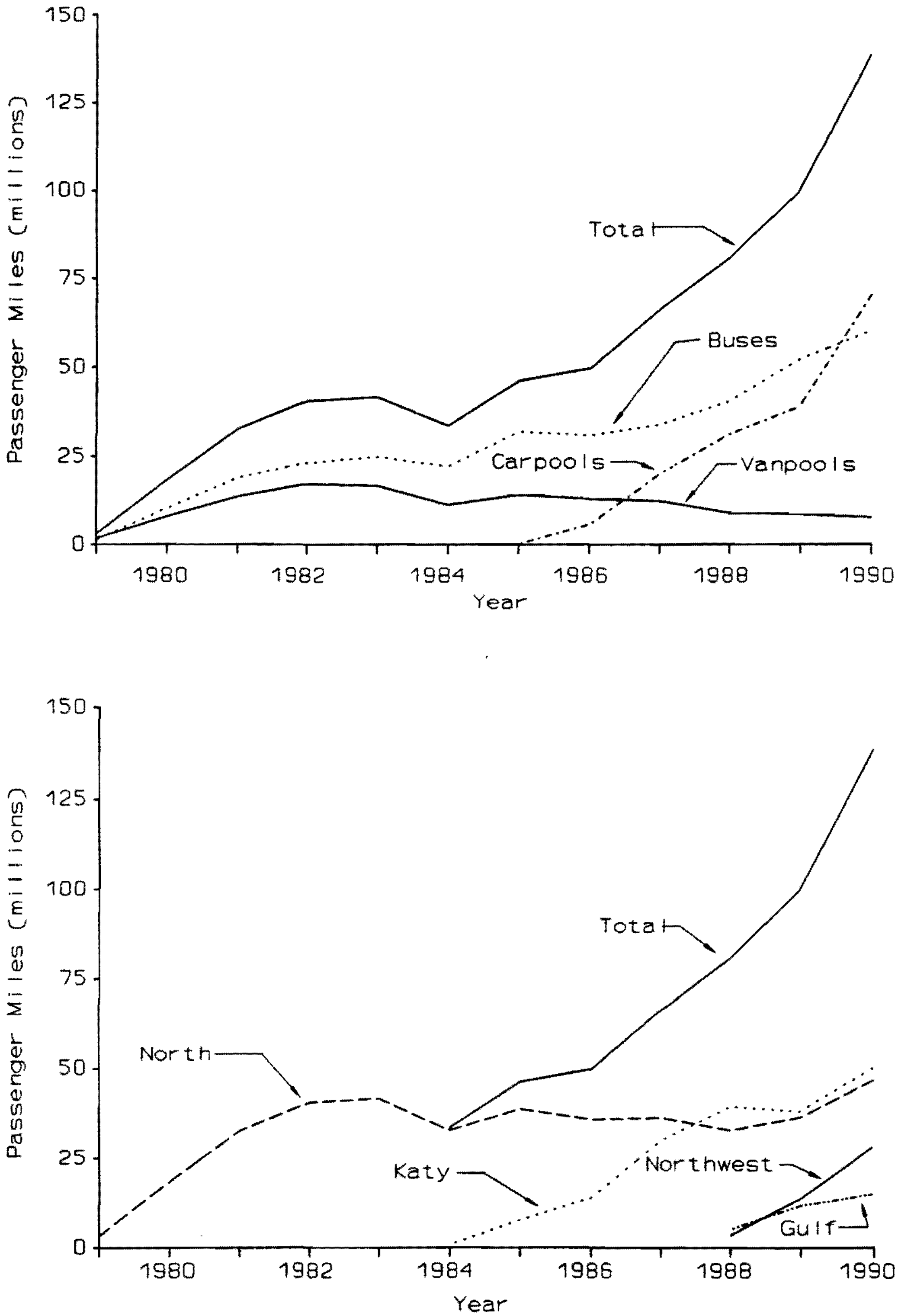
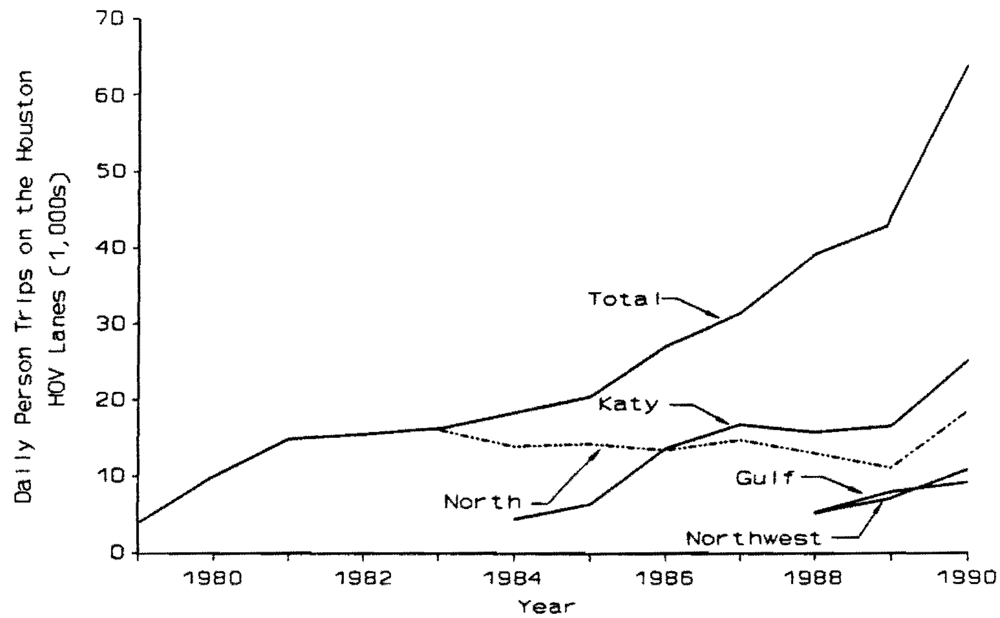


Figure 11. Trends in Annual Passenger-Miles of Travel on the Houston HOV Lanes



Source: See data in appendices.

Figure 12. Trends in Daily Person Trips on Houston Transitways

Between 1985 and 1990, the miles of operating HOV facility have increased by 194 percent. During that same time period, daily person trips on the HOV lanes have increased by 227 percent.

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 67,000 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 14) is not intended to lead to a conclusion that either of the projects is necessarily good or bad.

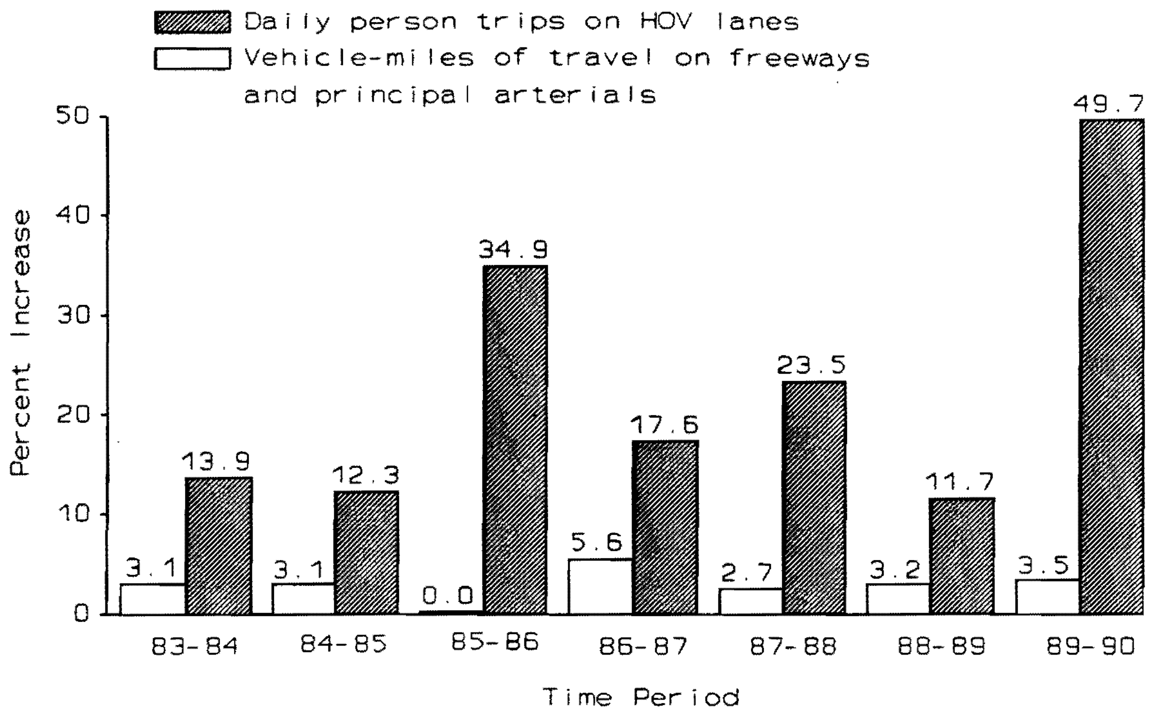


Figure 13. Annual Percentage Increase in HOV Person Trips and in Vehicle-Miles of Travel on Freeways and Principal Arterials

Table 6 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 7 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.

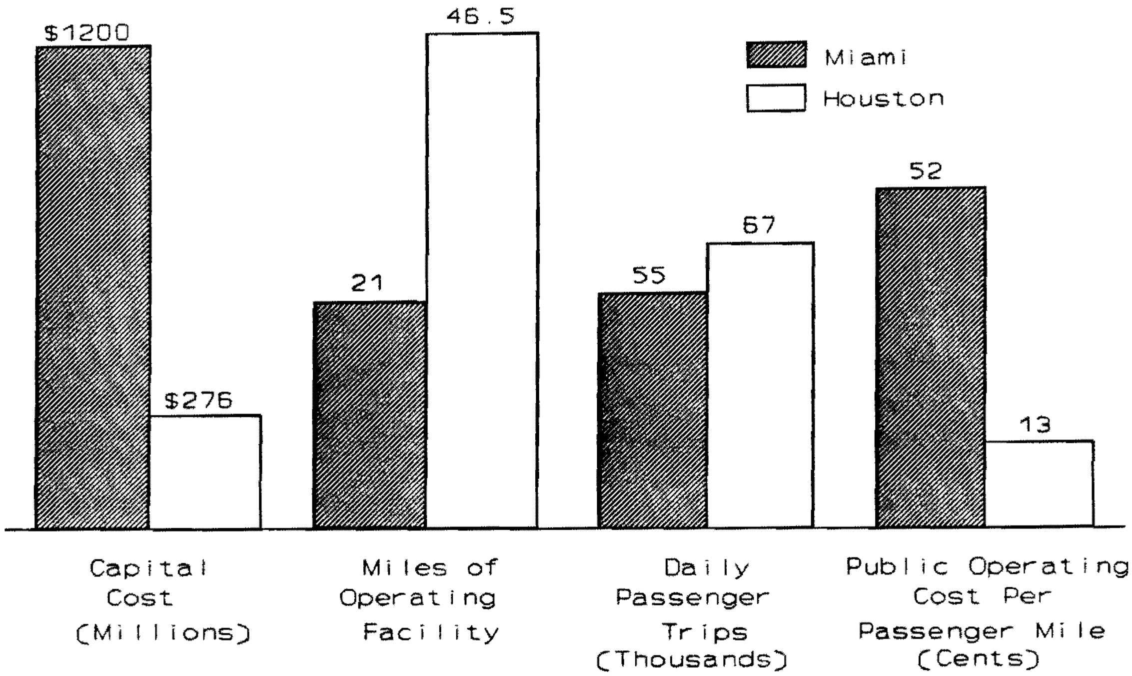


Figure 14. Comparative Data for the Operating Houston Transitways and the Miami Rail Transit System, 1990

Table 6. 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	26,960	5,198
North (I-45)	13.5	$5.6	19,033	4,476
Gulf (I-45)	6.5	$6.8	10,025	2,809
Northwest (US 290)	13.5	$7.2	11,349	2,960
Average	11.6	$5.9	16,840	3,860
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 3. Houston costs in 1990 dollars, rail costs in year of construction dollars.
[2]Houston HOV data for December 1990.

Source: Texas Transportation Institute and respective transit agencies.

Table 7. 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, 1988		
Unweighted Average	27	
Atlanta		16
Buffalo		50
Miami		52
Portland		19
Sacramento (1987)		17
San Diego		10
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.

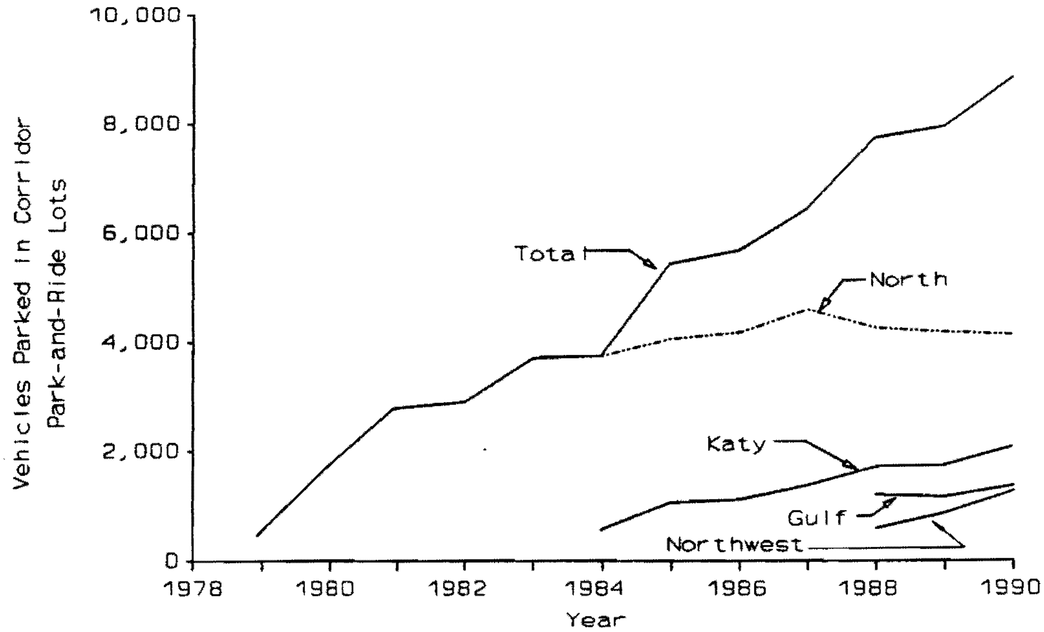
Source: Metropolitan Transit Authority of Harris County; "Rail Research Project Comparative City Data Base", prepared by Metropolitan Transit Authority and Texas Transportation Institute, and UMTA Section 18 data.

Park-and-Ride Usage

Between December 1989 and December 1990, there has been an increase of 12.5 percent in the use of park-and-ride lots in the corridors served by HOV lanes (Figure 15). In December 1990, approximately 8,940 cars were parked at park-and-ride lots; in December 1989 that number was 7,940, and in December 1988, 7,730 vehicles were parked in those lots. Parking at the park-and-ride lots is free.

Summary of HOV Usage Data

Selected HOV operating data are presented in Table 8. 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. With the exception of the Katy HOV lane, weekend use of the lanes is low.



Source: See data in appendices

Figure 15. Trends in Usage of Park-and-Ride Lots in Transitway Corridors

Table 8. Selected HOV Lane Operating Statistics, December 1990

Time Period and Operating Data	HOV Lane			
	Katy	North	Gulf	Northwest
Weekday Operations				
HOV Lane Person Volume				
A.M. Peak Hour	4,406	4,429	2,809	2,960
Daily	26,960[3]	19,033	10,025	11,349
HOV Lane Vehicle Volume				
A.M. Peak Hour	1,034	810	882	1,117
Daily	8,830	3,921	2,994	4,117
Percent of Total A.M. Peak-Hour, Peak-Direction Person Volume HOV Lane[1]	43%	35%	29%	33%
Vehicles Parked in Corridor Park-and-Ride Lots	2,057	4,157	1,349	1,286
Weekend Operations[2]				
Daily Saturday Vehicles	2,370	203	32	29
Daily Sunday Vehicles	3,266	388	135	65

[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.
[3]This value has increased significantly since 1989 in part due to a routing of approximately 1,200 peak-period bus patrons from the Southwest Freeway to the Katy HOV lane.

Note: See appendices for more detailed data.

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,[7] are highlighted herein.

Transit Surveys

Selected data are summarized in Table 9. The HOV facilities have attracted to transit young, educated, white-collar professionals. The bus is being used to serve long-distance commute trips, primarily to downtown. These individuals are using the HOV lanes primarily to save time, avoid having to drive in congested traffic, have time to relax, and have a reliable trip time. The bus patrons are transit users by choice, with over 85 percent having an auto available for the trip. Over 60 percent of the bus passengers have all or part of their bus fare paid by their employer. Interestingly, on the two HOV facilities surveyed in 1990 that have been open to carpool use for at least two years (Katy and Northwest), about half of the bus riders have at some time carpooled or vanpooled on the HOV lane.

Carpool and Vanpool Surveys

Carpoolers also tend to be young, educated, white-collar professionals (Table 10). 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.

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

Table 9. 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.

Table 10. 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 Houston. The commitment to developing these priority lanes is extensive, and the projects are unlike anything that has 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 State Department of Highways and Public 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, 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 corridors. However, demand is expected to continue to increase into the indefinite future at rates of around 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[8] 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 Houston, 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.

Thus, it is assumed that the primary goal of the Houston HOV lanes 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.

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

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

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 times speed of movement, should increase due to the implementation of the transitways.

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, desirably, show that support for these improvements exists.

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

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

Subsequent sections of the report analyze the data from the Houston research effort 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 1990, the oldest of the Houston HOV lanes had been in operation for just over five 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 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

In December 1990, 67,367 daily person trips were counted on the Houston HOV lane system. This represents a 50 percent increase over utilization in 1989. In addition to the fact that ridership has increased in general over time, four major events occurred during 1990 that helped create the increase in usage: 1) the 1.5-mile eastern extension of the Katy HOV lane was completed; 2) the final 4.0 miles of the Northwest HOV lane were completed; 3) an additional 4.4 miles of the North HOV lane were completed; and 4) carpool usage of the North HOV lane was allowed. Daily riders per mile of HOV lane was 1,449, a 17.9 percent increase over the December 1989 value.

As would be expected, the HOV lanes move a relatively high percentage of total roadway person volume in a relatively low percentage of total vehicles (Figure 16). 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.

Table 11 presents selected usage and time savings data related to the Houston HOV facilities for 1989 and 1990. Usage on all four of the operating HOV facilities has increased during 1990. Travel time savings increased, although only modestly, on all of the HOV lanes except the Gulf.

Table 11. Summary of Selected Data Relating to Usage and Travel Time Savings on the Houston HOV Lanes

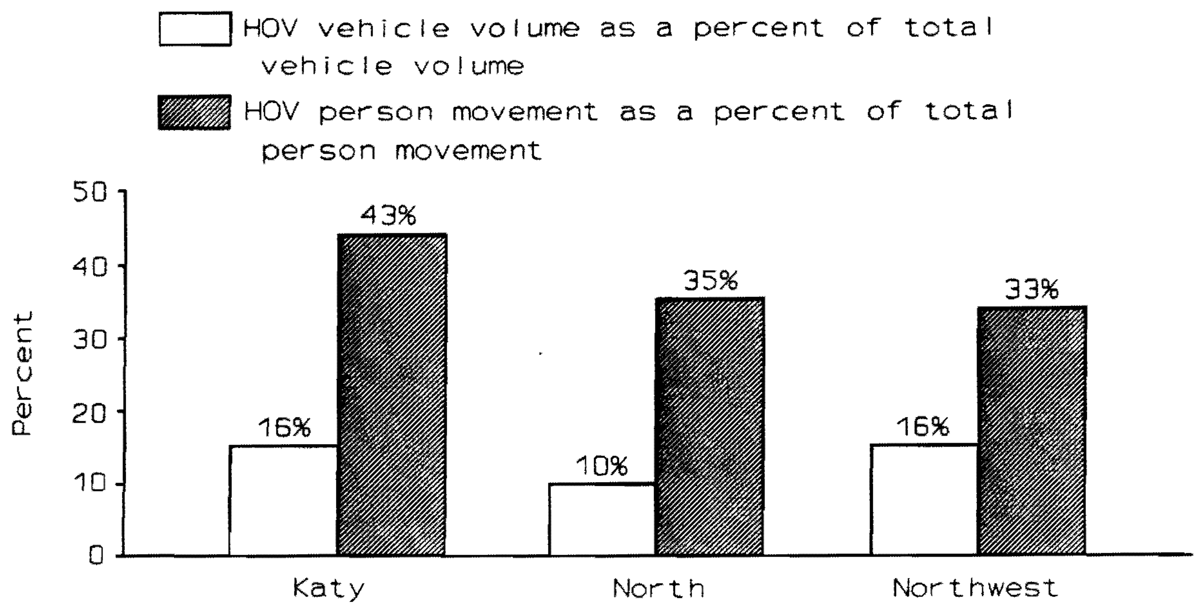
Data	Katy			North			Northwest			Gulf			Total, 4 Transitways		
	12/89	12/90	% Change	12/89	12/90	% Change	12/89	12/90	% Change	12/89	12/90	% Change	12/89	12/90	% Change
Miles of HOV Lane	11.5	13.0	13.0	9.1	13.5	48.4	9.5	13.5	42.1	6.5	6.5	0.0	36.6	46.5	27.0
HOV Lane Person Volume															
Daily	18352	26960	46.9	11226	19033	69.5	7275	11349	56.0	8139	10025	23.2	44992	67367	49.7
A.M. Peak Hour	3316	4406	32.9	3514	4429	26.0	2439	2960	21.4	2923	2809	-3.9	12192	14604	19.8
A.M. Peak Period	7523	11445	15.2	5633	9089	61.3	4089	5201	27.2	4300	5117	19.0	21545	30852	43.2
P.M. Peak Hour	4352	5198	19.4	3313	4476	35.1	1564	2776	77.5	2102	2332	10.9	11331	14782	30.5
P.M. Peak Period	9321	12739	36.7	5593	9340	67.0	3003	5600	86.5	3693	4404	19.3	21610	32083	48.5
HOV Lane Vehicle Volume															
Daily	5915	8830	49.3	488	3921	703.5	2439	4117	68.8	2154	2994	39.0	10996	19862	80.6
A.M. Peak Hour	950	1034	8.8	139	810	482.7	841	1117	32.8	878	882	0.5	2758	3843	39.3
A.M. Peak Period	2155	3386	57.1	239	1773	641.8	1427	1943	36.2	1227	1519	23.8	5048	8621	70.8
P.M. Peak Hour	1290	1419	10.0	129	809	527.1	448	920	105.4	482	705	46.3	2345	3853	64.3
P.M. Peak Period	3010	4056	34.8	249	1846	641.4	934	1900	103.4	858	1248	45.5	5051	9050	79.2
Avg. HOV Lane Vehicle Occupancy, A.M. Peak Hour	3.49	4.26	22.1	25.3	5.47	-78.4[2]	2.90	2.64	-9.0	3.33	3.18	-4.5	4.42	3.89	-12.0
HOV Lane Travel Time Savings, Avg. Peak Hour (min)[1]	13.8	14.0	1.4	5.3	5.7	7.5	2.4	4.7	95.8	2.8	1.8	-35.7	24.3	26.2	7.8

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.

[1]Travel time data can vary significantly due to normal variations in traffic flow. Time shown is 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 difference in the range of 2 minutes or less have little significance.

[2]During 1990 carpools were allowed to begin using the North HOV lane.

Source: Texas Transportation Institute. See appendices for more detail.



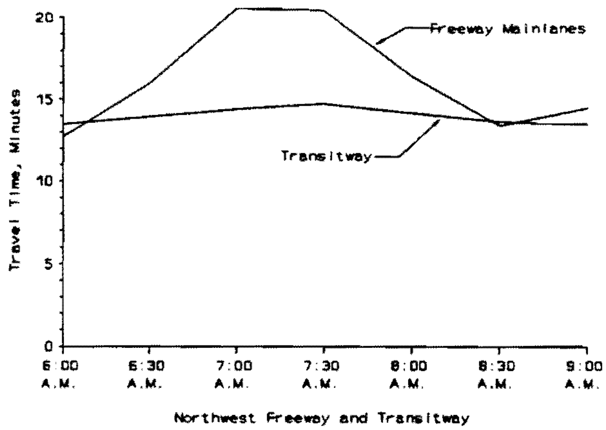
Source: See data in appendices.

Figure 16. HOV Vehicle and Person Volumes as a Percent of Total (HOV plus Freeway) Volumes, A.M. Peak-Hour, Peak-Direction

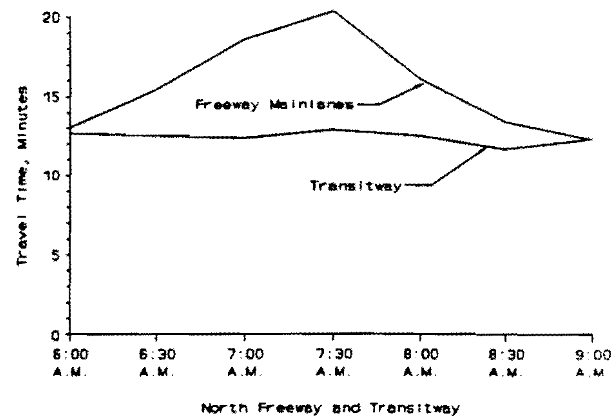
Travel Time Savings

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 17.

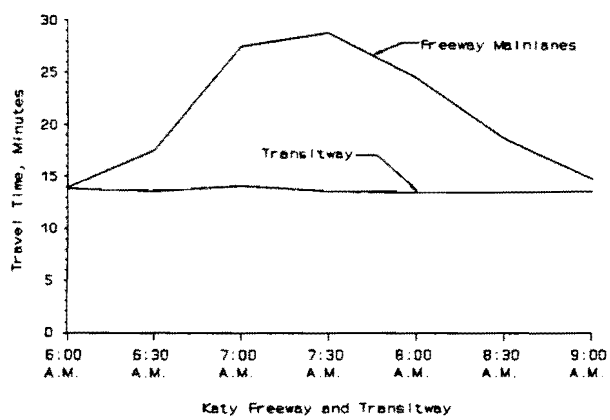
The data in Table 11 show the average peak-hour travel time savings measured on the HOV lanes. It should be noted that variability exists in travel times on a daily basis, plus there is some error in the measurement of travel times. As a result, differences or changes of only two to three minutes have little significance. It is interesting to note that the surveys show that the users of the HOV lanes perceive a much greater time savings than is actually realized (Table 12).



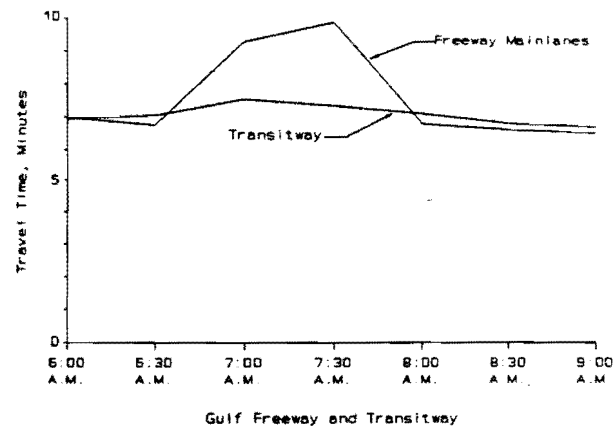
Note: Travel times are from Senate to the S.P. Railroad



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

Source: See data in appendices.

Figure 17. A.M. Peak Period Travel Time, Houston Freeways and Transitways

Table 12. Comparison of Actual and Perceived Travel Time Savings 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	14.2	13.8	17	19	19	19
North	6.9	4.5	15	19	15	19
Gulf[1]	2.1	1.5	10	15	12	15
Northwest	7.3	2.1	18	18	19	19

[1]Perceived travel time savings are 1989 data.

Source: Texas Transportation Institute surveys and data collection.

Factors Influencing High-Occupancy Vehicle Lane Utilization

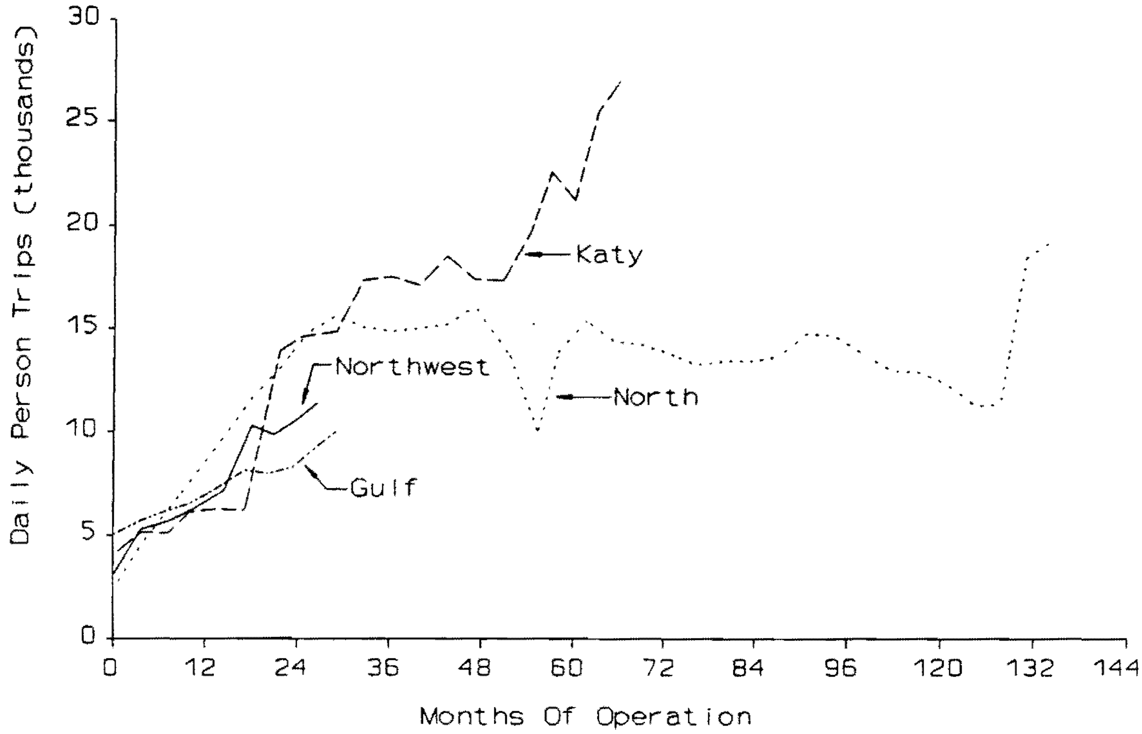
It is evident that a number of factors influence both bus ridership and carpooling on an HOV lane. Some of those factors, such as parking cost, are the ones used in traditional mode split models. A review of the Houston data suggests that at least three factors appear to be significant in helping to 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.[9] 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 the Houston HOV facilities (Figure 18). Both the North and Katy HOV lanes have been in operation long enough to have experienced this early year growth surge. The same is not yet true for the Gulf and Northwest HOV lanes which opened in 1988.

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

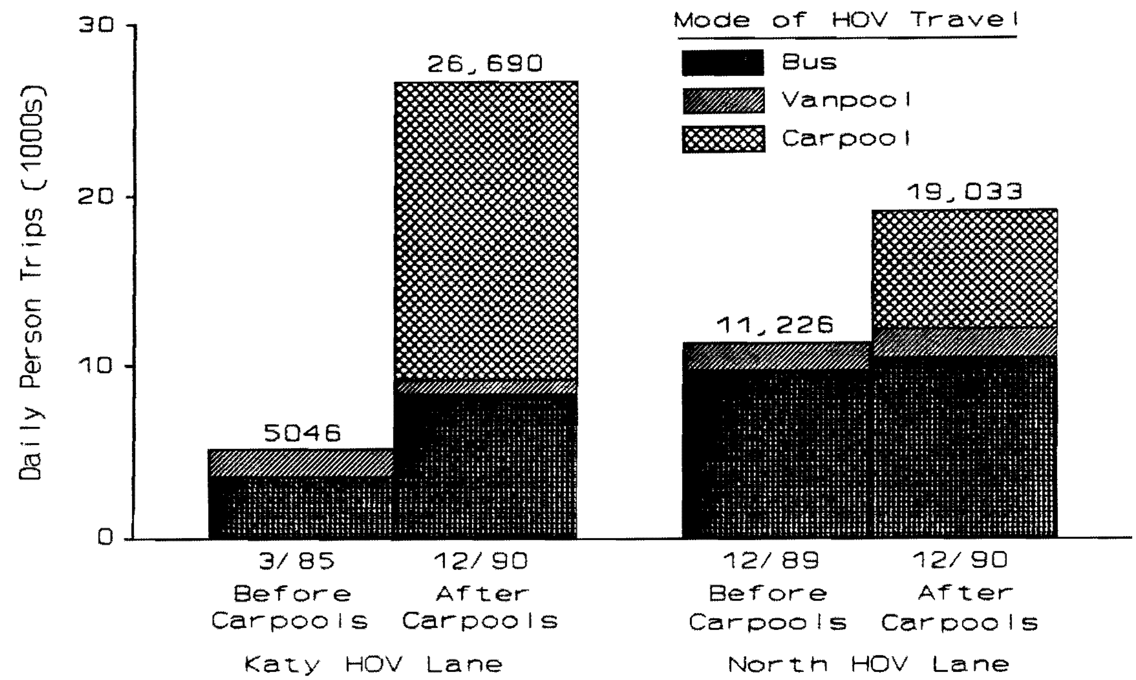


Source: See data in appendices.

Figure 18. Daily Ridership by Months of Operation, Houston Transitways

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 are in carpools or vanpools.

Figure 19 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 19. Impacts of Carpool Usage on Daily HOV Lane Person Trips, Katy and North HOV Facilities

The HOV Lane Must Offer Meaningful Travel Time Savings

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.[10]

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

The historical data from the Houston HOV evaluations provide a rough relationship between HOV lane usage and travel time savings (Figure 20). Those data suggest that HOV usage does not start to increase rapidly until travel time savings begin to exceed five minutes. While the relationship depicted in Figure 20 exhibits considerable data scatter, an explanation exists for most of the outlying data points.

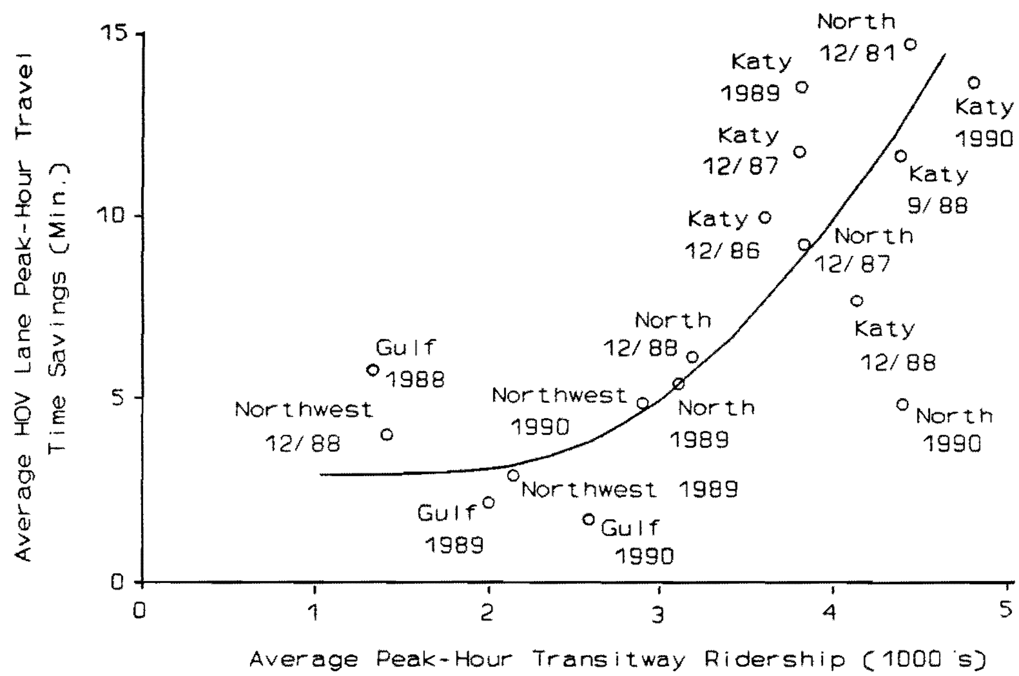
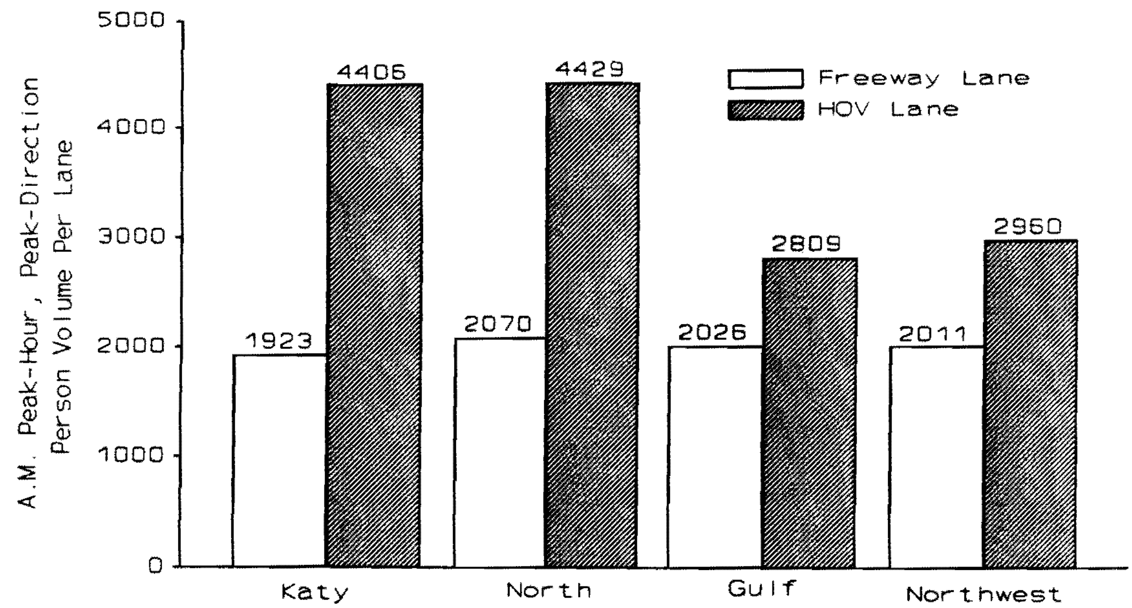


Figure 20. Relationship Between Peak-Hour HOV Lane Ridership and Peak-Hour HOV Lane Travel Time Savings

The relationship depicted in Figure 20 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

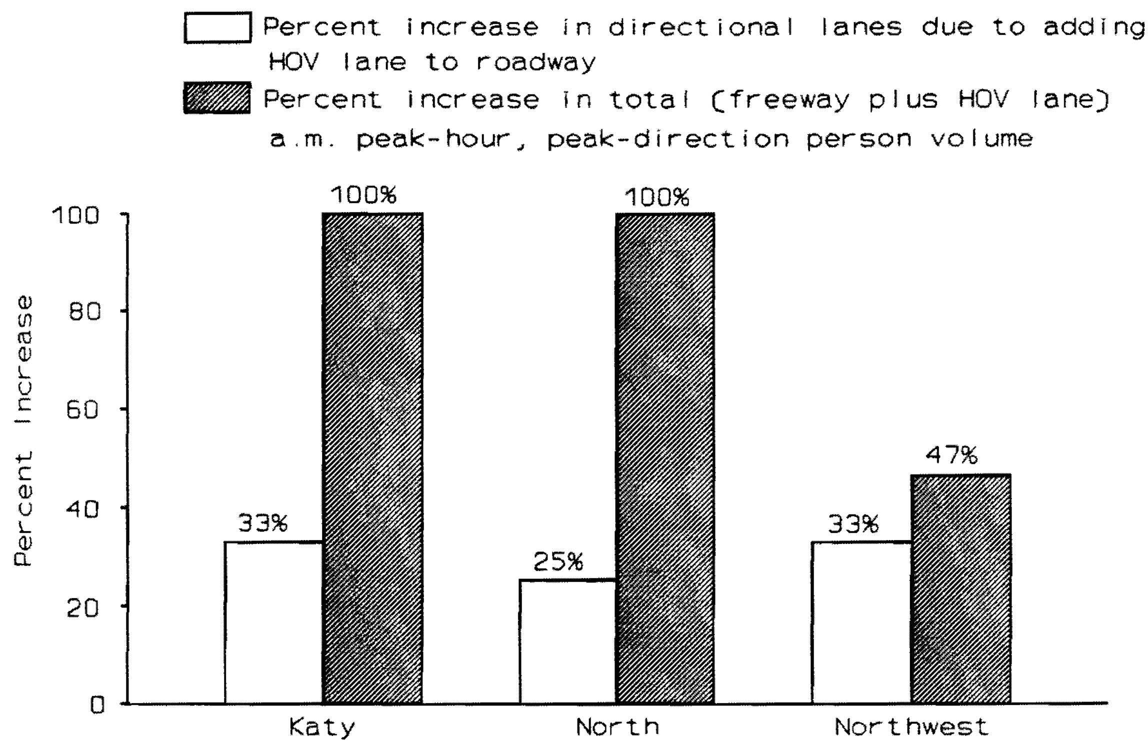
A major reason for implementing high-occupancy vehicle lanes is to increase the effective person-movement capacity of a roadway. There is at least an implicit recognition that emphasis needs to begin to be focused on moving people rather than vehicles. The HOV facilities are intended to be an incentive 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 21). During the peak hour, the HOV lanes are moving 39 percent to 129 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 21. Peak-Hour, Peak-Direction Person Volumes Per Lane on Houston Freeways and HOV Lanes

Since implementation of the HOV lane does increase the number of directional lanes, for the priority lane to be effective it should at least increase person movement by an amount greater than the increase in lanes added to the roadway due to implementing an HOV lane. If this is not the case, the effectiveness of the HOV lane might be called into question. The data show that the Houston HOV lanes are helping to result in a substantial increase in person movement (Figure 22). In all instances where data are available, the increase in person movement exceeds the increase in lanes provided.



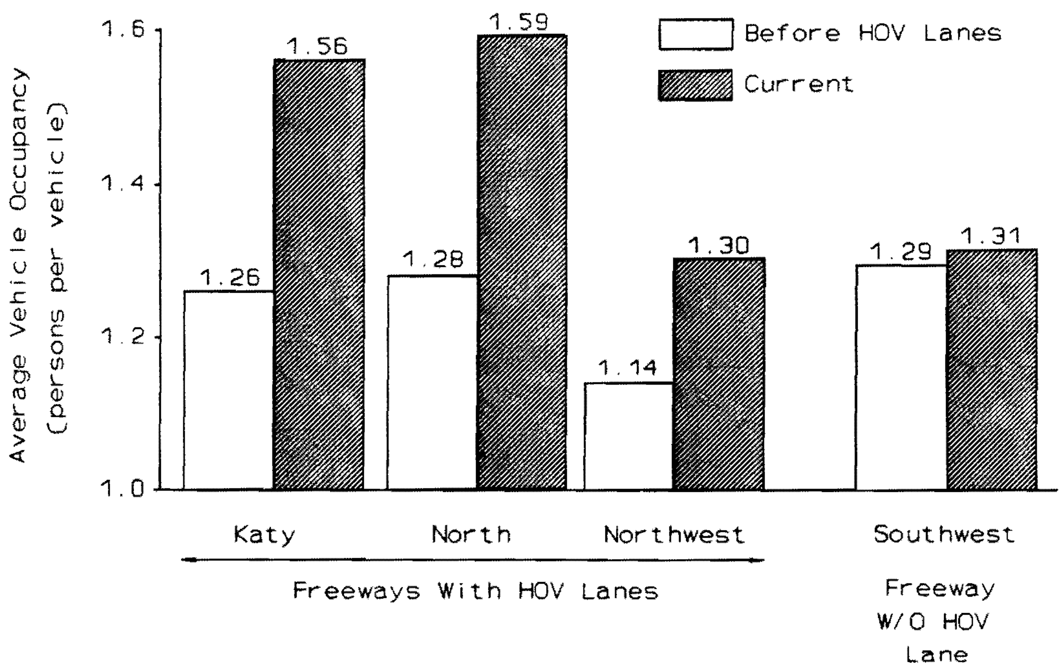
Source: See data in appendices

Figure 22. 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 22, 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 currently unusually high for Texas (or other southwestern states) freeways, being in excess of 1.5 persons per vehicle (Figure 23). These occupancies are the combined average of all freeway mainlane plus all transitway traffic.

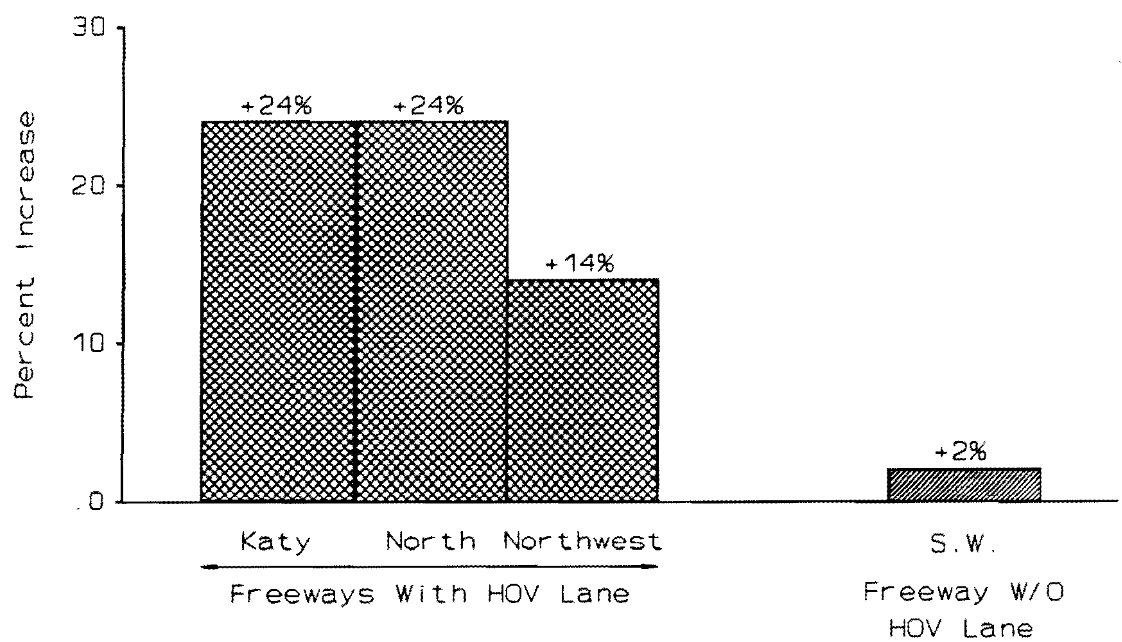


Source: See data in appendices.

Figure 23. 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 24).

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 14 to 24 percent. Over the same time period, occupancy on a freeway without an HOV lane has remained basically unchanged.



Source: See data in appendices.

Figure 24. Percentage Change (Pre-HOV Lane to Present) in Average Vehicle Occupancy, A.M. Peak-Hour, Peak-Direction, Freeways With and Without HOV Lanes

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

Changes in Carpooling

Survey data suggest that relatively few carpools now using the HOV lanes were existing carpools that diverted to the HOV lane from parallel routes (Table 13). This indicates that the increases that occurred in average vehicle occupancy were primarily from factors other than this diversion.

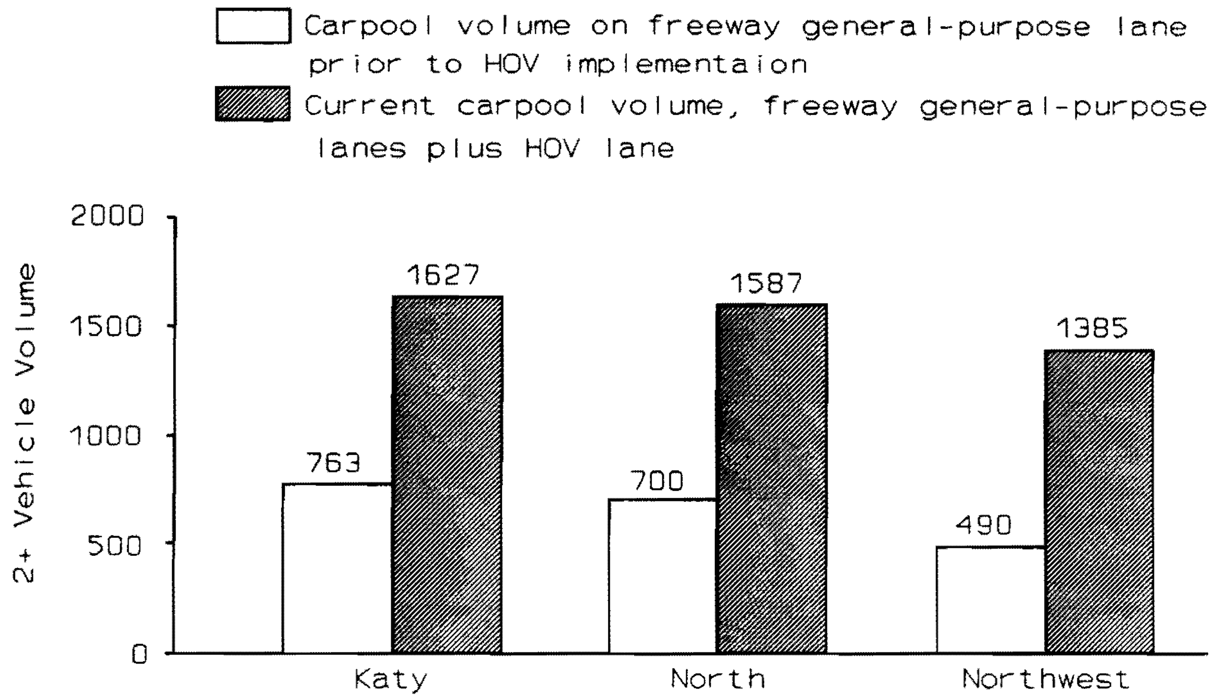
Table 13. Carpools That Diverted to the HOV Facility From Parallel Routes

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 25). Increases in excess of 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 those priority lanes.



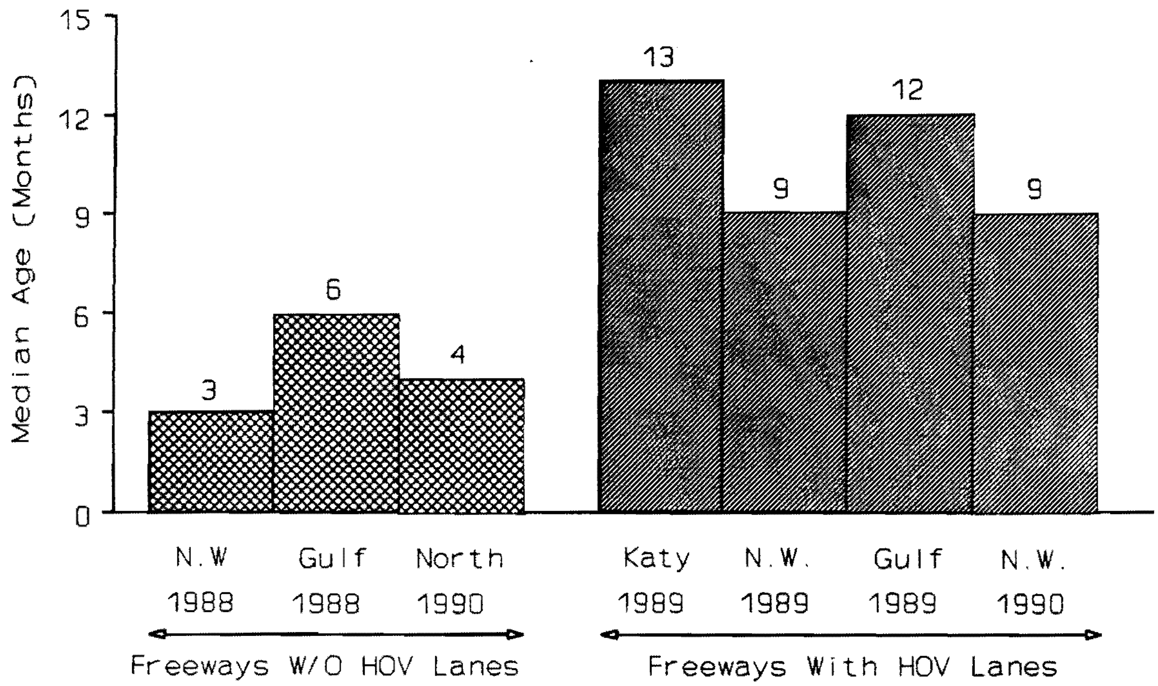
Note: Katy HOV data for p.m. peak hour due to 3+ requirement in a.m.

Source: See data in appendices

Figure 25. Volume of 2+ Carpools (Freeway Plus HOV Lane), A.M. Peak-Hour, Peak-Direction, Pre-HOV Lane and Current

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.

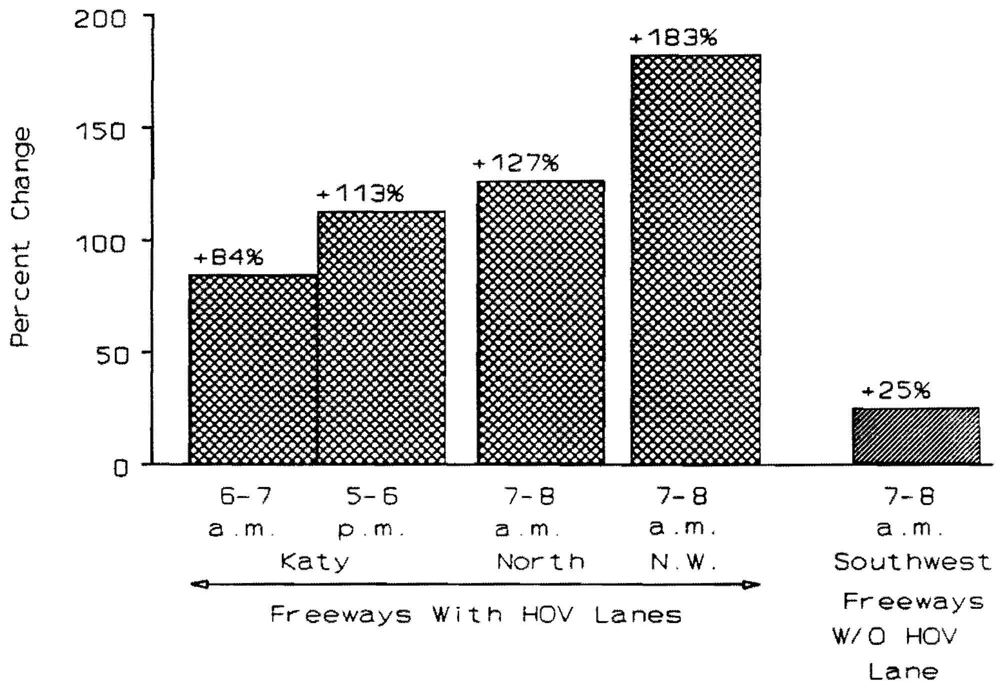
Available data suggest that carpools in corridors with HOV lanes do remain in existence longer than carpools in corridors without HOV lanes (Figure 26). The median age of a carpool on an HOV facility is over two times greater than the median carpool age on a non-HOV facility. It appears that the presence of an HOV lane is causing carpools to remain in existence longer.



Source: Texas Transportation Institute surveys

Figure 26. Median Age of a Carpool in Corridors With and Without High-Occupancy Vehicle Lanes

Comparing what has occurred on freeways with HOV lanes to what has taken place over the same time period on freeways without HOV lanes helps to isolate the impacts of the HOV facilities (Figure 27). The magnitude of increase that has occurred on the freeways with priority lanes simply has not taken place in the corridor without a transitway.[11] 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.



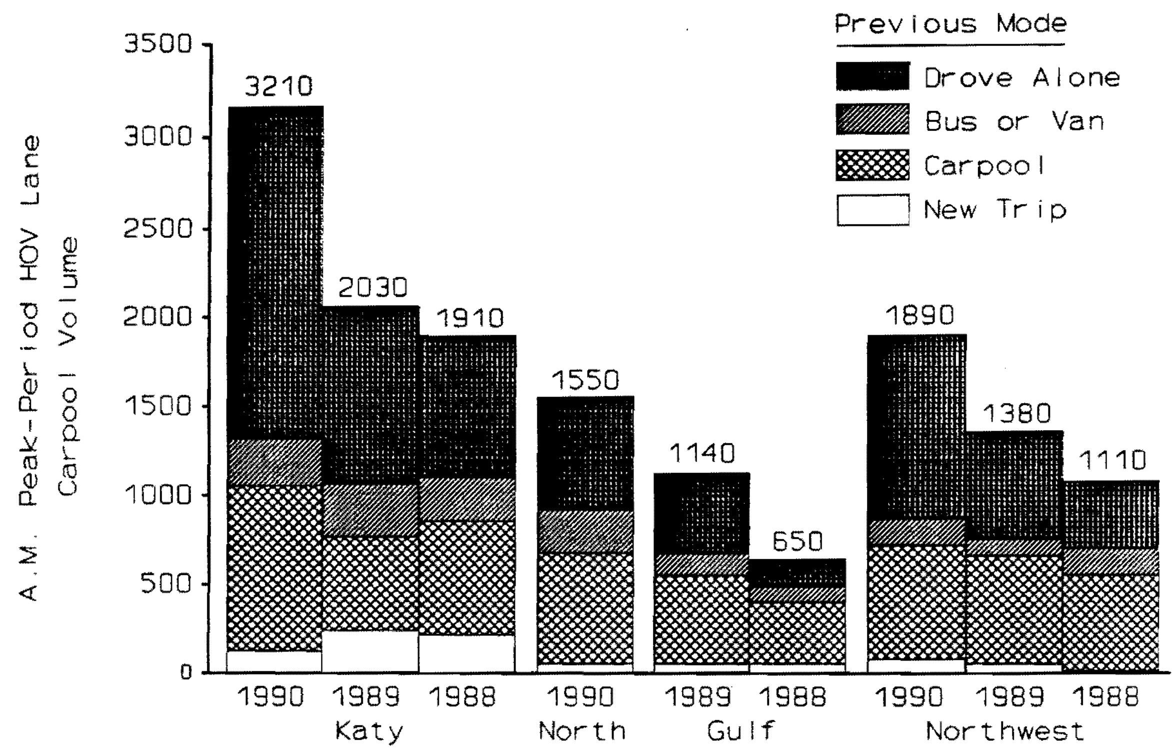
Source: See data in appendices.

Figure 27. 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 28). Those data

[11] It is worth noting that, until 1990, there had been no increase in carpool volumes on the Southwest Freeway since 1984. Part of the increase in 1990 may be the result of the construction now taking place in that corridor.

indicate that somewhere between 40 percent and 60 percent of current carpoolers on the HOV lanes 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 28. Previous Mode of Travel for HOV Lane Carpoolers

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.[12] To try to identify this portion of carpool demand, carpoolers using the transitway 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 14) 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 14. 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 15). In the 1990 surveys, over half the respondents said "no" or "not sure".

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

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

HOV carpoolers previously drove alone and formed a carpool as a result of the HOV facility (Table 16).

Table 15. 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.

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.

Table 16. 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 15.
[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.

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[13] 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. 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.[14]

Travel to Locations Other Than Downtown

As was shown previously in this report (see Table 9), 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 10), and implementing the HOV lanes has greatly increased the volume of carpools traveling to the other three major activity centers

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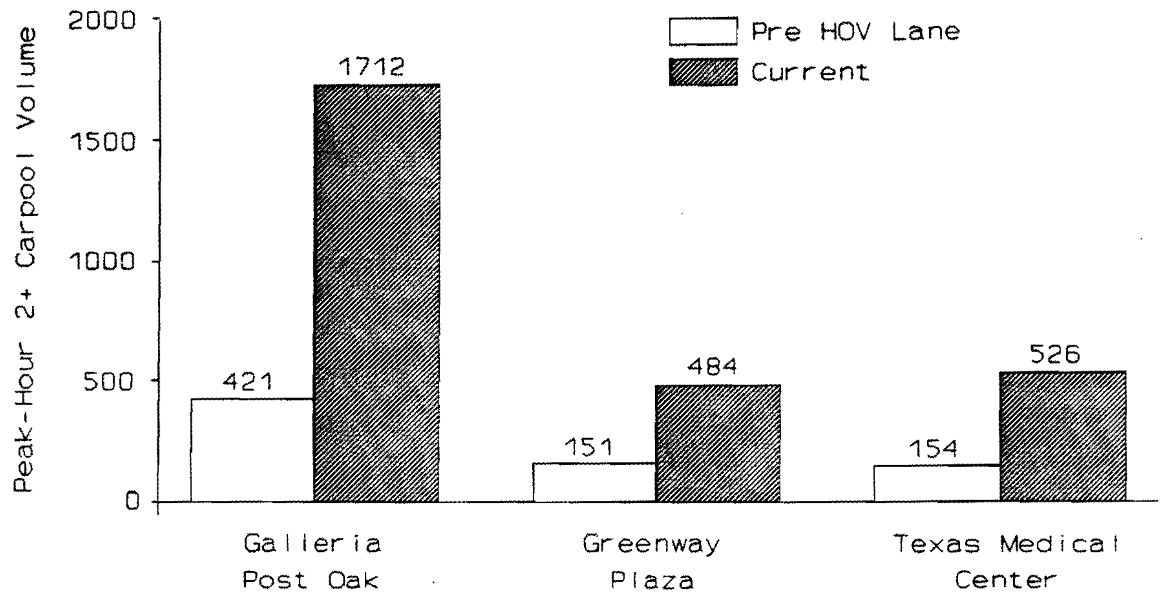
[13] Texas Transportation Institute Research Report 484-10.

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

(Table 17). That volume has more than tripled (Figure 29). Being able to help serve these dispersed trips contributes to the effectiveness of the HOV lanes.



Source: Texas Transportation Institute data collection.

Figure 29. Increase (Pre-HOV to Present) in Peak-Hour 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 5), the public operation cost for carpools is considerably less than one cent per passenger-mile (see Table 7), which helps make the HOV lanes alternative transportation im-

Table 17. 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	1990 Volume	Pre-HOV Volume	1990 Volume	Pre-HOV Volume	1990 Volume
Katy	170	535	49	201	43	223
% increase	—	+215%	—	+310%	—	+419%
North	169	509	75	153	56	173
% increase	—	+202%	—	+104%	—	+209%
Northwest	82	668	27	131	55	130
% increase	—	+715%	—	+385%	—	+136%
TOTAL	421	1712	151	484	154	526
% increase	—	+307%	—	+221%	—	+242%

Note: Volumes shown in carpool vehicles per hour. 1990 volumes include both freeway general-purpose lane and HOV lane carpools.

Source: Texas Transportation Institute data collection.

provements. 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).

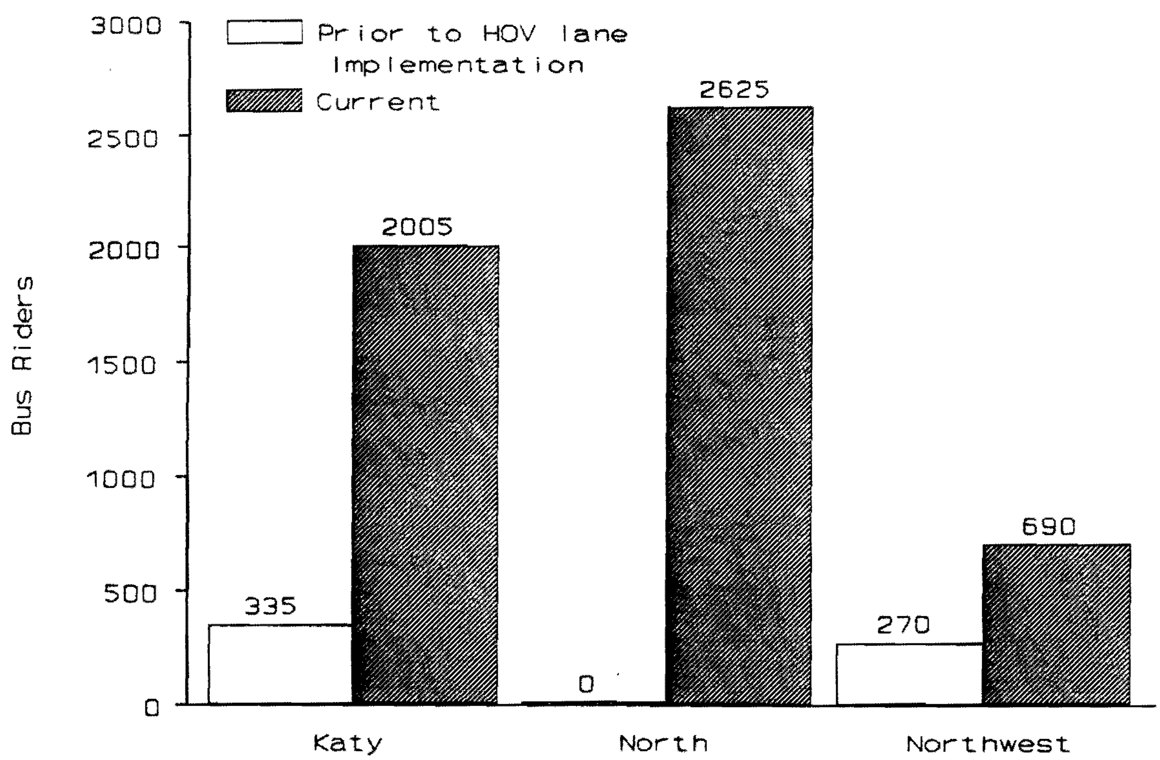
Bus Transit Operations

Data shown previously (see Table 9) 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.

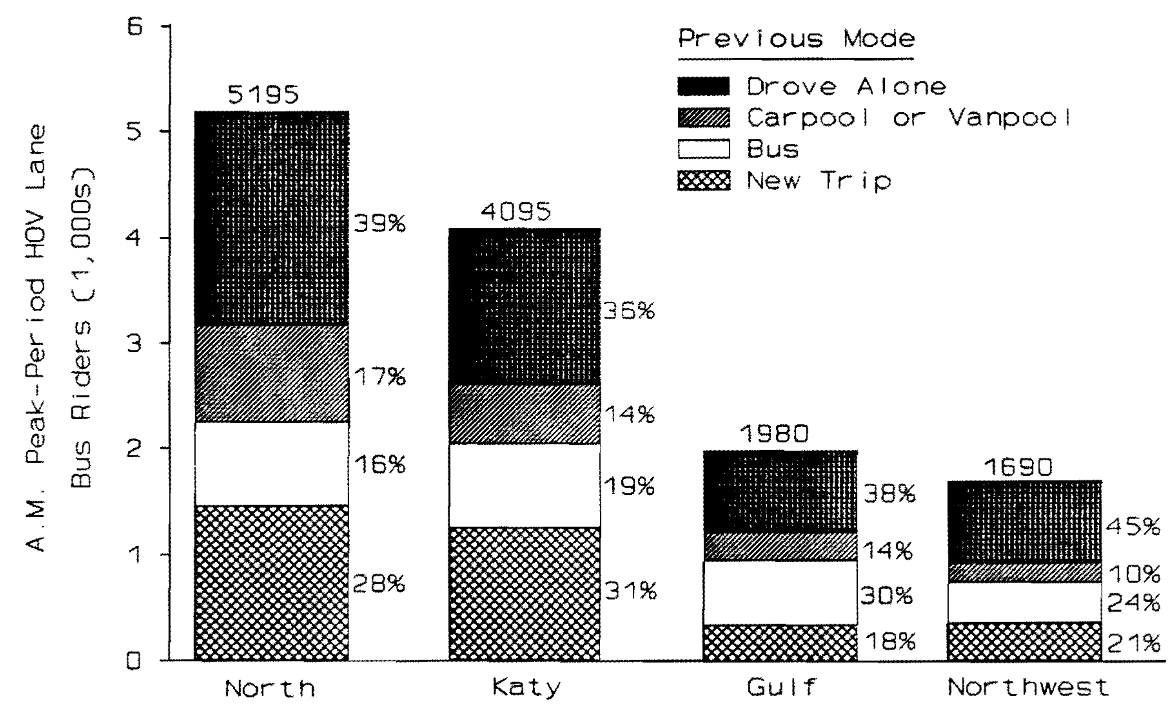
With the opening of the HOV lanes, significant increases in bus ridership have been realized (Figure 30). In the North Freeway corridor, there was essentially no bus service prior to the opening of the contraflow lane in 1979. It appears that the HOV lanes have been a meaningful factor in generating the ridership increases that have been observed.



Source: See data in appendices

Figure 30. 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 31). 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.



[1]Volume data are for 1990, previous mode percentages from 1989 survey.

Source: See data in appendices.

Figure 31. Previous Mode of Travel for HOV Lane Bus Riders, 1990

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 18). The HOV lane has been an unimportant consideration for fewer than 10 percent of the riders surveyed in 1990. Over time, the importance of the HOV lane in attracting riders appears to be increasing.

Table 18. 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 19). 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. The responses to the question from the Katy surveys have been consistent for the past several years.

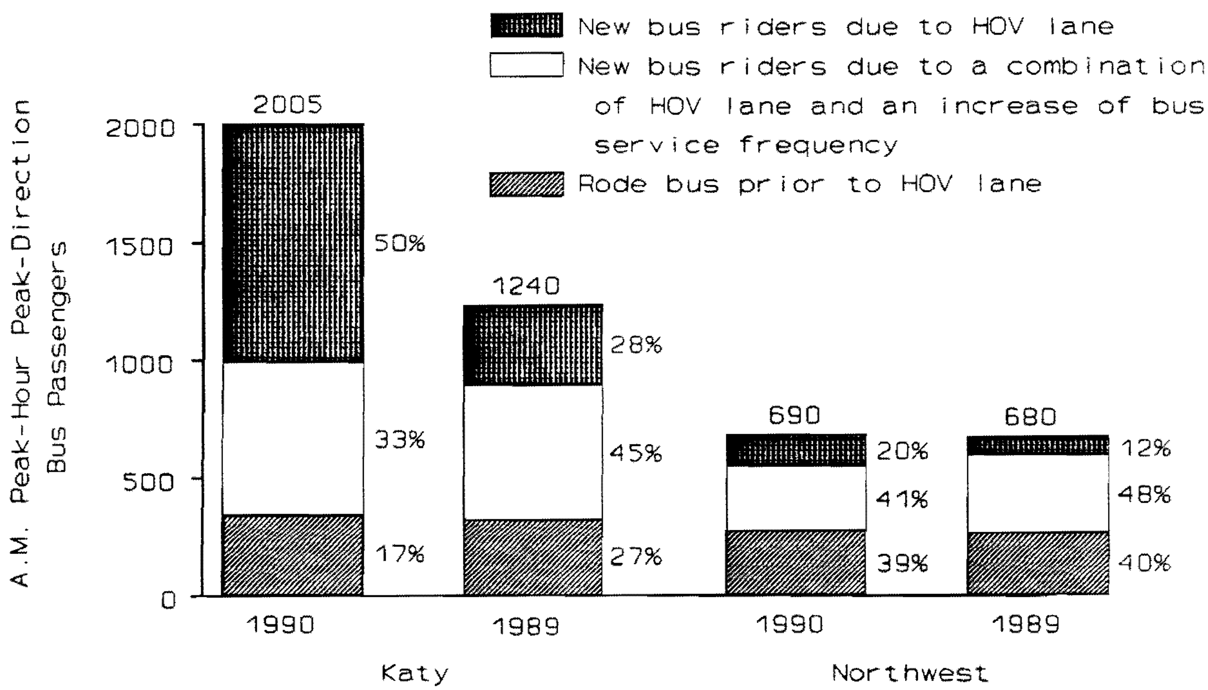
Table 19. Response to Question "If the Transitway Had Not Opened, Would You be Riding a Bus Now?"

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.

With the implementation of the HOV lanes, at least two factors are working to increase bus ridership. First, the HOV lane offers the bus riders numerous advantages, such as a faster trip and a more reliable trip time. However, with the opening of the HOV lanes, Metro has also increased the frequency of the bus service in the corridors (these increases were, however, generally in response to ridership increases). This increased frequency of bus service, by itself, would have resulted in increases in transit ridership. A general "rule of thumb" is that a ten percent increase in bus frequency will result in a five to six percent increase in bus ridership.[15] As indicated in the footnote, the results shown in Figure 32 significantly overstate the impacts of increases in bus frequency and, as a result, understate the impacts of the HOV lane. Nevertheless, it is clear that the presence of the HOV lane must be a major explanatory variable in accounting for increases in transit usage in the corridors.

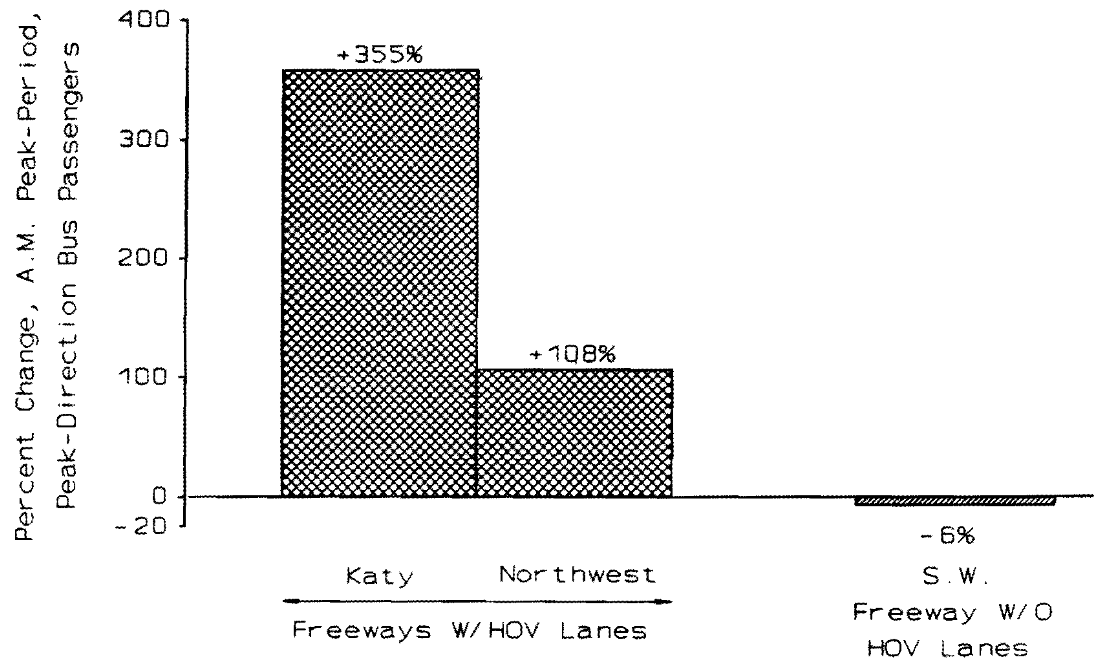


Source: See data in apprendices.

Figure 32. Estimated Percentage of HOV Bus Riders Riding the Bus Because of the HOV Facility

[15] This elasticity is generally applied to relatively small increases in bus service. Applying it to the large increases that have occurred on the HOV facilities probably significantly overstates the impact of service frequency on bus ridership.

Bus ridership has also increased more rapidly in corridors having HOV lanes than it has in a corridor without an HOV lane (Figure 33). 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 over 100 percent in the corridors with HOV lanes; the increases in peak-hour ridership have been even greater than the peak-period increases.



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 220%.

[2]1989 data for the Southwest Freeway are used instead of 1990 data to develop this change. This is due to the diversion of Southwest buses to the Katy HOV lane during 1990.

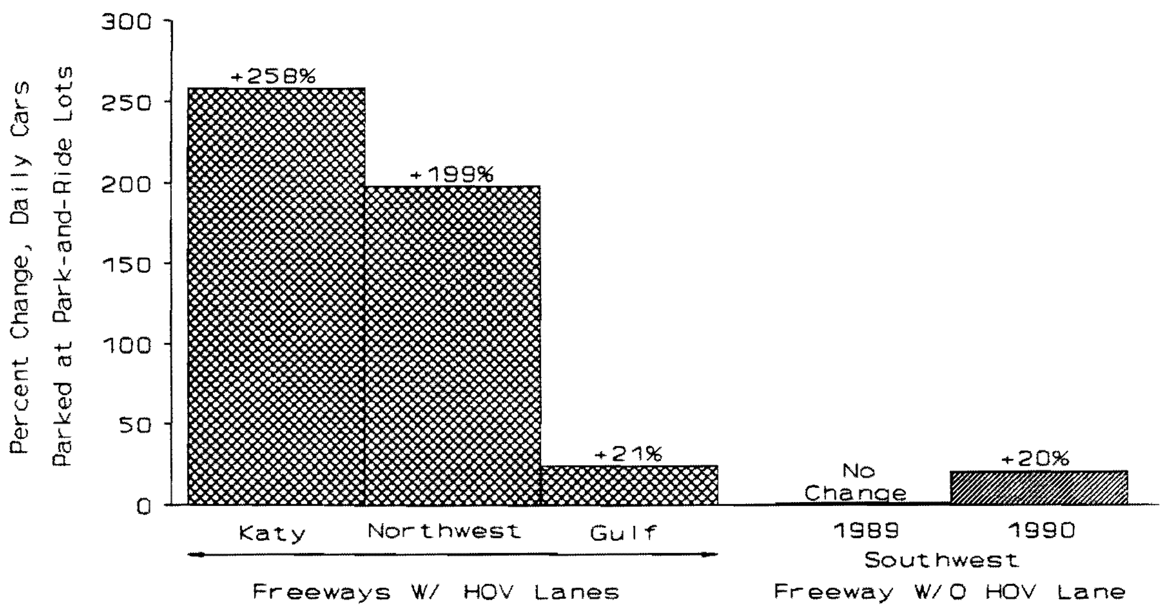
Source: See data in appendices.

Figure 33. Change (Pre-HOV Lane to Present) in A.M. Peak-Period, Peak-Direction Bus Ridership, Freeways With and Without HOV Lanes

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 at least double transit ridership.

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 34). In both the Northwest and the Katy corridors, nearly a 200 percent or greater increase 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 only a small change in park-and-ride usage during the same period of time.



Note: For the Southwest Freeway, the 1989 data may be the more relevant. During 1990 some transit service was routed from the Southwest Freeway to the Katy HOV lane. Also, construction in the corridor may be partly responsible for increases in bus use.

Source: See data in appendices.

Figure 34. Percent Change (Pre-HOV lane to present) in Daily Vehicles Parked in Corridor Park-and-Ride Lots

Enhancement of Bus Service

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

Compared to conditions that existed prior to HOV lane implementation, average bus operating speeds have increased dramatically (Table 20). On average, peak-hour bus operating speeds have more than doubled, increasing from 26 mph to 54 mph. Also, previous research[16] 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 35 provides an indication of the impacts that the HOV lanes can have on bus schedules during the peak hour. Due to the increase in bus operating speeds, schedule times have been cut significantly.

Table 20. Average A.M. Peak-Hour Bus Operating Speeds, Before HOV Implementation and Current

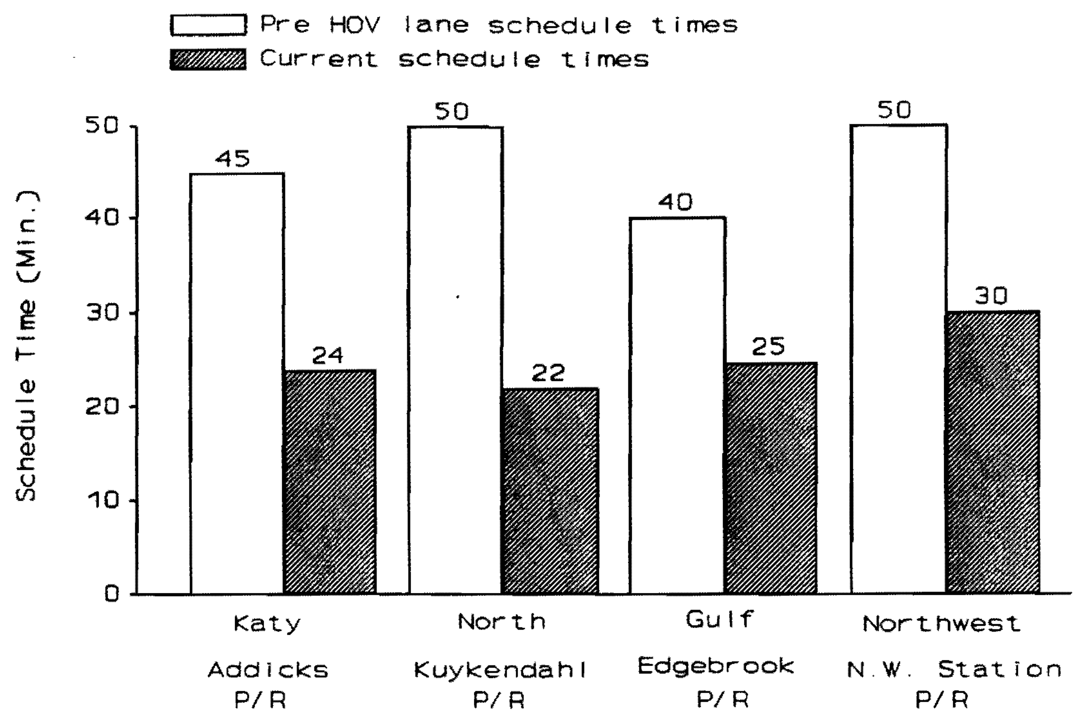
Freeway	Bus Operating Speed (mph)		
	Before HOV	Current	Percent Increase
Katy	23	53	130%
North	20	56	180%
Gulf	31	50	61%
Northwest	29	57	97%
Unweighted Average	26	54	108%

Source: See data in appendices.

Metro[17] has performed operational analyses of some of the recent enhancements to the HOV facility system. Analyses were performed for improvements to the Northwest, Katy, and North HOV lanes. The following modest improvements were analyzed by Metro.

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

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



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

- 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 21.

Table 21. 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.

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[18]

On a systemwide basis, Metro recovers about 23 percent of operating costs from the fare box (Table 22). 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.

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

Table 22. Revenue-Cost Ratios and Subsidy Per Passenger, Metro Bus Service, Average Weekday

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
Systemwide	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 23 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.

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 23. Selected Characteristics of Bus Service on the High-Occupancy Vehicle Lanes

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.

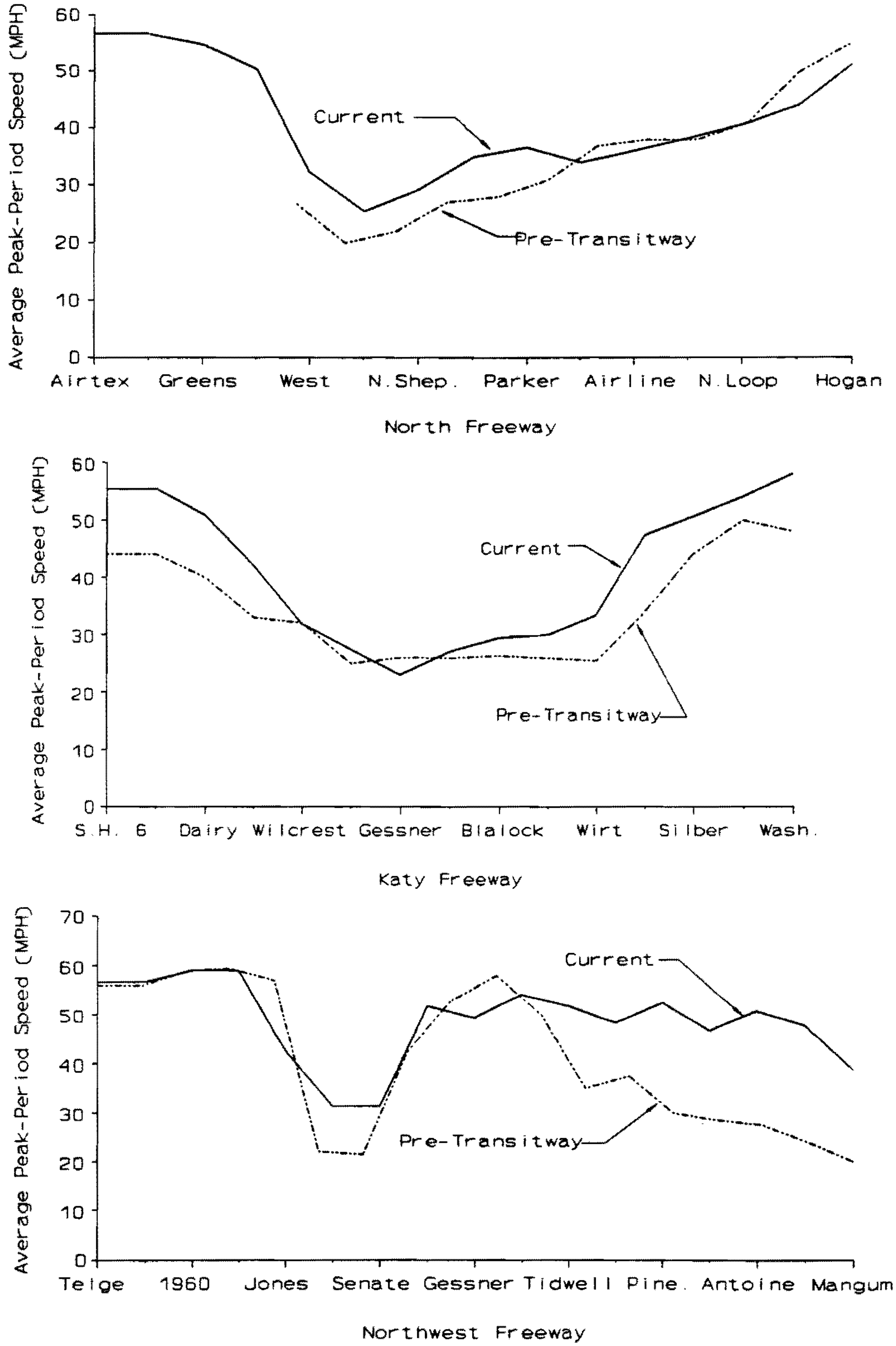
V. HOV LANE IMPACTS ON FREEWAY GENERAL-PURPOSE LANE OPERATIONS

Data presented previously have shown that the HOV lanes have increased the overall average vehicle occupancy characteristic of the roadways. 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 HOV facilities, to be "successful", 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 that being used in Houston, 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 24). Current per lane volumes on the North and Northwest freeways are within ten percent of what they were prior to HOV lane implementation; that is the same basic conclusion that was reached in 1989. 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 36.



Source: See data in appendices

Figure 36. Freeway Peak-Period Speeds on Mainlanes, Pre-Transitway and Current

Table 24. Freeway General-Purpose Lane Operation, Prior to HOV and Current

Freeway General-Purpose Lane Data	HOV Facility or Freeway							
	Katy		North		Northwest		Gulf	
	Pre-HOV	Current	Pre-HOV	Current	Pre-HOV	Current	Pre-HOV	Current
Vehicle Volume/Hour/Lane[1]								
A.M. Peak Hour	1320	1835	1650	1795	1790	1940	—	—
A.M. Peak Period	1250	1605	—	—	1460	1570	—	—
Freeway Peak-Hour Speed[2], mph	23	33	20	33	28	28	—	—
Accidents per MVM[3]	1.34	1.28	1.82	1.90	0.61	0.72	1.79	1.45

[1]Peak-period speeds are for 3.5 hour period.
[2]Many factors other than HOV implementation have had a more significant impact on freeway operating speeds.
[3]Accident rate expressed as accidents per 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.).

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. Due to the ongoing construction that has occurred in many of the corridors (e.g., interchanges with Beltway 8 on Katy and Northwest Freeways), it is difficult to establish meaningful roadway segments for comparing pre-HOV lane and current conditions. Table 24 presents the most relevant data. Accident rates are slightly higher on some roadways and slightly lower on others; the unweighted average accident rate has declined from 1.39 accidents per MVM prior to the HOV lanes to 1.34 accidents per 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 travelled 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.

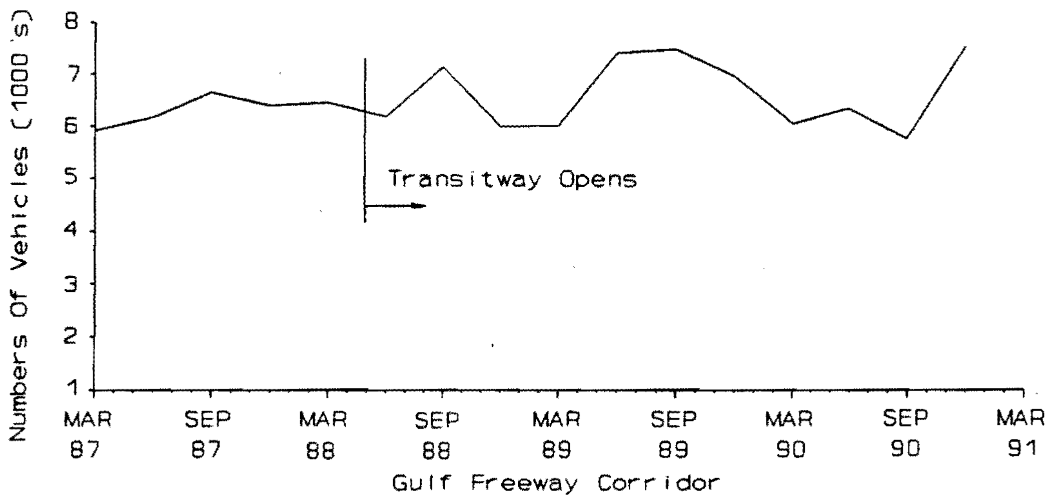
The survey data from the HOV carpool surveys are summarized in Table 25. It appears that between 10 percent and 20 percent of HOV lane carpoolers previously traveled on a parallel roadway. Given typical carpool volumes on the HOV lanes, this would equate to roughly 75 to 150 vehicles in the peak hour.

Table 25. HOV Lane Carpooler Responses to the Question "Prior to Carpooling on the Transitway, How Did you Normally Make the Trip?"

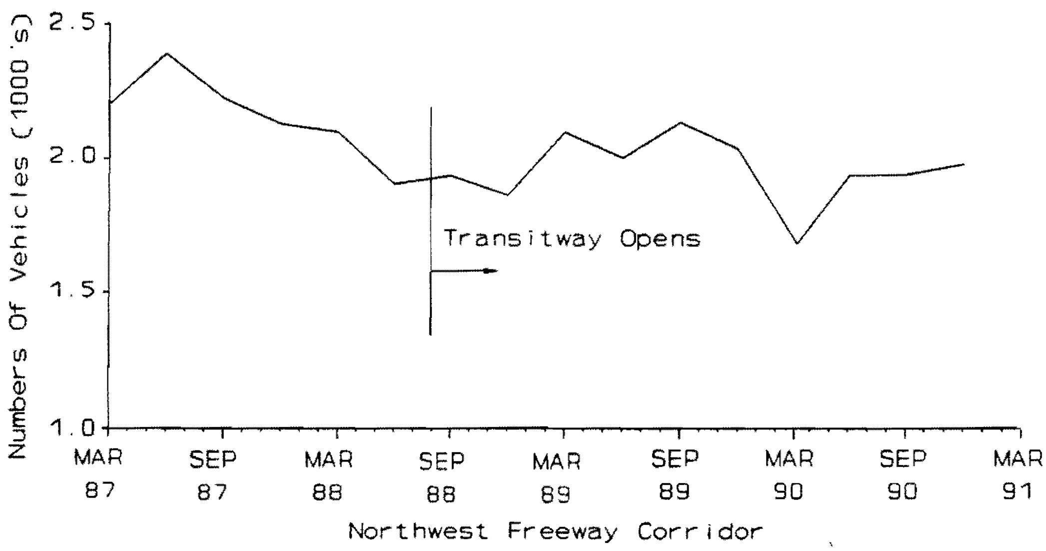
Response	HOV Lane							
	Katy		North		Gulf		Northwest	
	1989	1990	1989	1990	1989	1990	1989	1990
On the transitway (bus or van)	16%	15%	—	22%	17%	—	17%	14%
On the freeway general-purpose lanes	64%	68%	—	58%	68%	—	68%	67%
On a parallel street or highway	9%	13%	—	19%	10%	—	10%	15%
Did not make this trip	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 37. 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.



Note: Parallel routes are Old Galveston Road and Telephone Road



Note: Parallel route is Hempstead Highway

Figure 37. A.M. Peak-Period (6-9:30), Peak-Direction Vehicle Volumes on Parallel Routes in the Gulf and Northwest Freeway Corridors

Impacts on Overall Roadway Efficiency

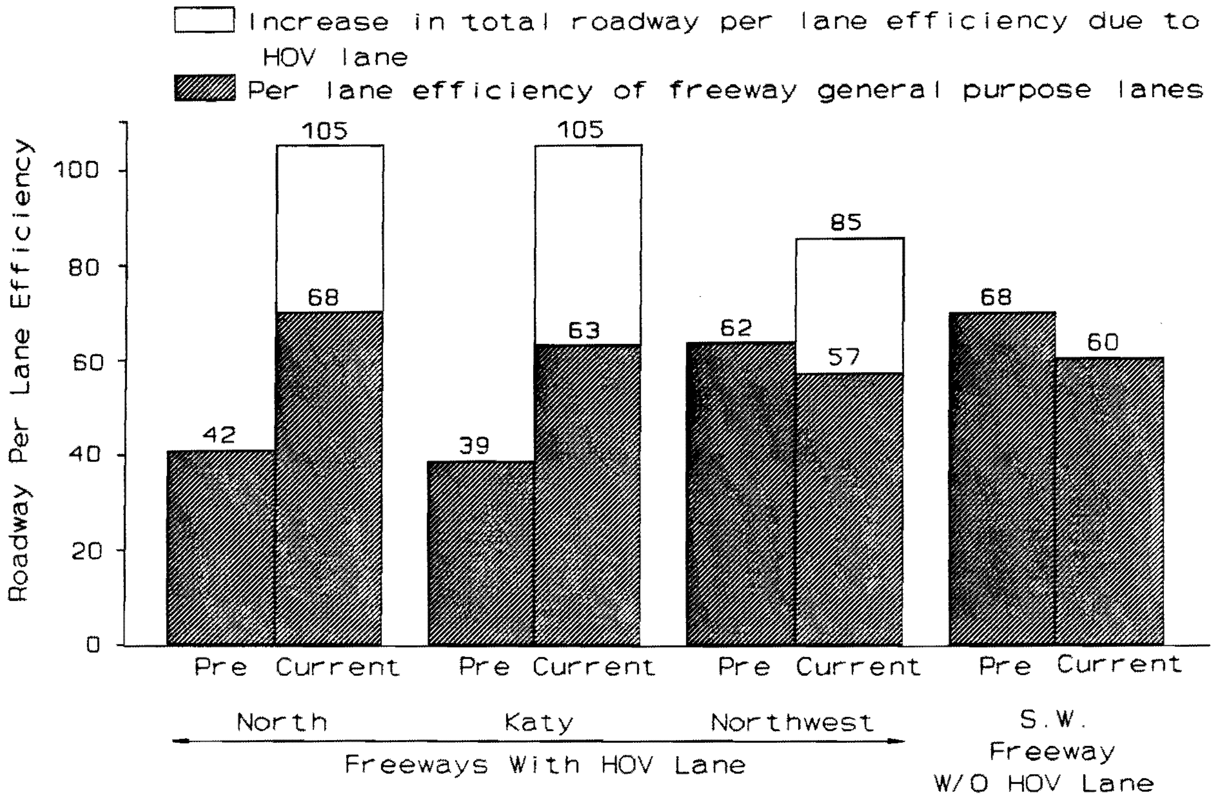
The HOV facilities are intended to move substantial volumes of commuters at relatively fast speeds. As such, successful HOV lane implementation should improve the overall efficiency of a freeway. For purposes of this study, the peak-hour efficiency of the freeway is expressed as the multiple of the peak-hour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

In all cases for which data are available, the implementation of the HOV lane has increased the overall efficiency of the facility (Table 26). 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, and Northwest Transitways. These increases in efficiency have been larger than those experienced on a freeway that does not have an HOV lane (Figure 38).

Table 26. 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	42	68	248	105	37
Katy	39	63	231	105	42
Northwest	62	57	168	85	28
Southwest[3] (w/o transitway)	68	60	—	60	—

[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 (2).
[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.



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

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[19] 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 and the current deliberations pertaining to new federal surface transportation legislation 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 significantly 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.

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

This analysis allows the impacts of doing nothing to be quantified. It also provides data that help to answer the question that, if one lane is to be added to a freeway, should that lane be designated as a reversible HOV lane, or should it be designated as an additional general-purpose traffic lane.[20]

The analysis presented in this section of the report utilized a freeway simulation model (FREQ) and applies that model to the Katy Freeway and Transitway. Operation on both the freeway mainlanes and the transitway, based on 1990 travel volumes, has been simulated. The demand, expressed as passenger-miles, that existed in 1990 is held constant in comparing alternatives. Average vehicle occupancy is adjusted between alternatives as necessary to reflect the observed impacts of the HOV facility on vehicle occupancy.

The following three alternatives have been 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.

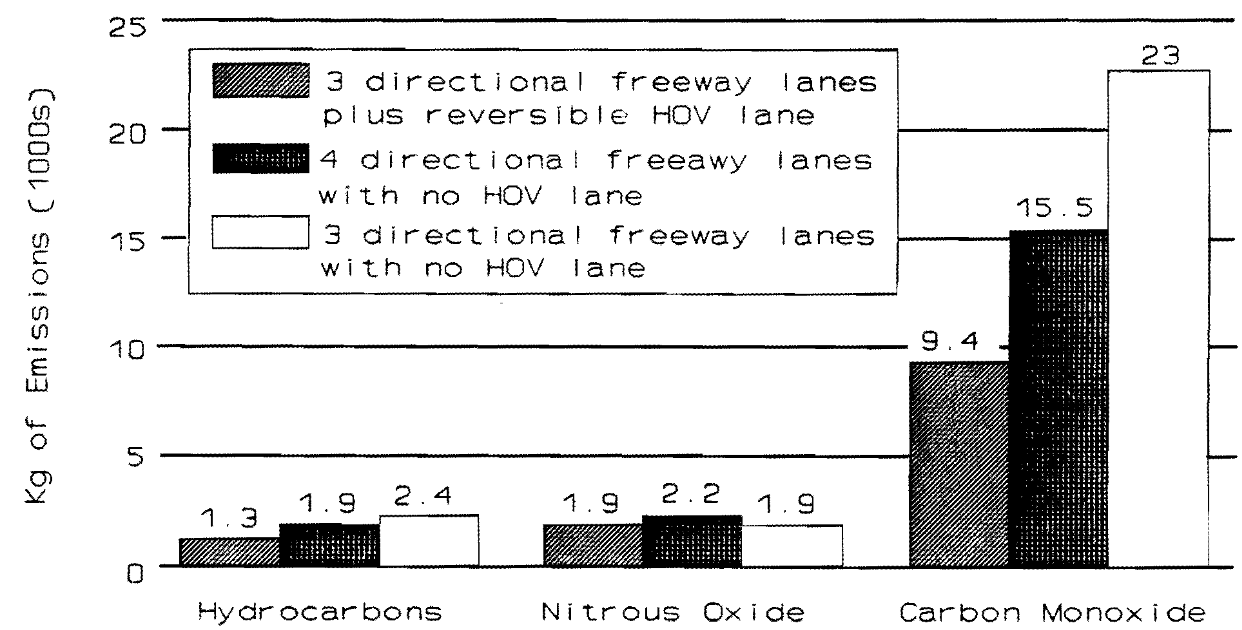
3. **Add an HOV lane.** This is the improvement that was implemented. A reversible HOV lane was added to the freeway. Three directional general-purpose freeway lanes remain.

The results of this analysis are shown in Figures 39 and 40. And 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 1990 and are unable

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

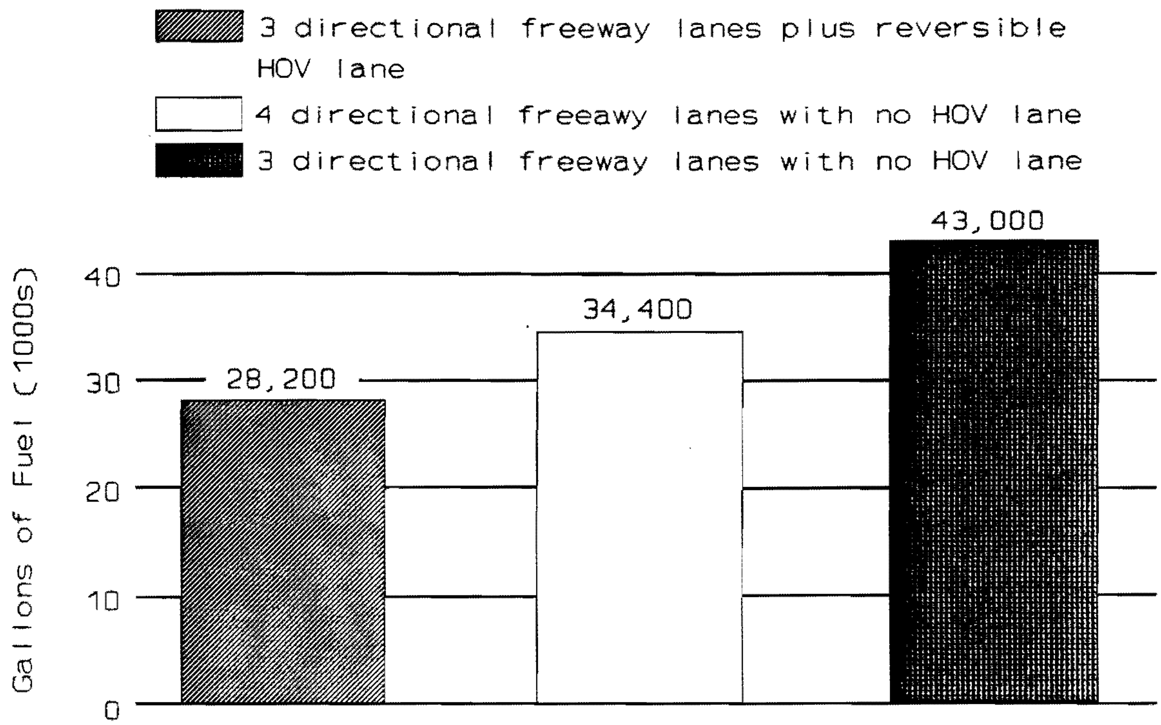
to serve higher volumes. It is recognized that this analysis has limitations (e.g., it does not consider the benefits that would accrue from having an additional mixed-flow lane available to serve off-peak and off-peak direction travel). However, it is clear that, to serve the passenger-mile demand in 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.

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, 1990 demand levels.

Figure 39. Estimated Impacts of HOV Improvements on Air Quality, Katy Freeway and HOV Lane



Source: Texas Transportation Institute simulation analysis, 6 a.m. to noon, peak direction, 1990 demand levels

Figure 40. 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 39 and 40) 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.[21] 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 10 percent of the construction cost of the project, the transitway project will be cost effective.[22]

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[21] 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.

[22] 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 $9.25/hour value of time, the present worth factor would be 13.6. Thus, if operating and maintenance costs are not included (they are relatively small), a benefit/cost ratio of approximately 1.4 would result if the annual benefit stream equalled 10% of the initial construction cost.

For reasons cited in the footnote, the average annual value of time saved over the life of the project should be greater than the amount saved in the early years of the project. Previous discussions in this report have identified specific reasons why time savings should be expected to increase on all of the Houston transitways. 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 27 summarizes this analysis. The value of time saved in 1990 is 52 percent greater than it was in 1989.

Table 27. Annual Value of Time Saved by HOV Lane Users as a 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	$10.9	$25.1	$54.4	43.4%	20.0%
North	$ 4.9	$54.8	$73.3	8.9%	6.7%
Gulf	$ 0.6	$29.9	$42.3	2.0%	1.4%
Northwest	$ 2.5	$62.0	$94.0	4.0%	2.7%
Total	$18.9	$171.8	$264.0	11.0%	7.2%

[1]Based on 1990 time savings for HOV lane users. Does not include any time savings by motorists in the freeway mainlanes.
[2]See Table 3 and appendices.

Based on this simplistic analysis, under 1990 operating conditions, the Katy HOV facility is clearly effective, and the North HOV is marginally effective. This conclusion, based on this type of analysis, does not presently apply to the Northwest or Gulf HOV lanes. When all four operating HOV lanes are combined, under 1990 conditions the overall system is 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 27 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 28 was prepared. Based on the costs and benefits listed in that table, and based on usage levels in 1990, the Katy HOV facility had a benefit-cost ratio of more than 4.0. The actual benefits quantified in that table are nearly five times greater than the value of the time saved by HOV lane users (that value of time is the only benefit considered in Table 27).

Table 28. Estimated Costs and Benefits of the Katy HOV Lane, 1990

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]	$10.9	
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		$52.8
Benefit/Cost Ratio		4.1

[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 23).
[4]The value of the time saved by users of the HOV facility (see Table 27).
[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 not 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 about four percent. This translates to a annual cost of congestion of approximately $115 million on an areawide basis.

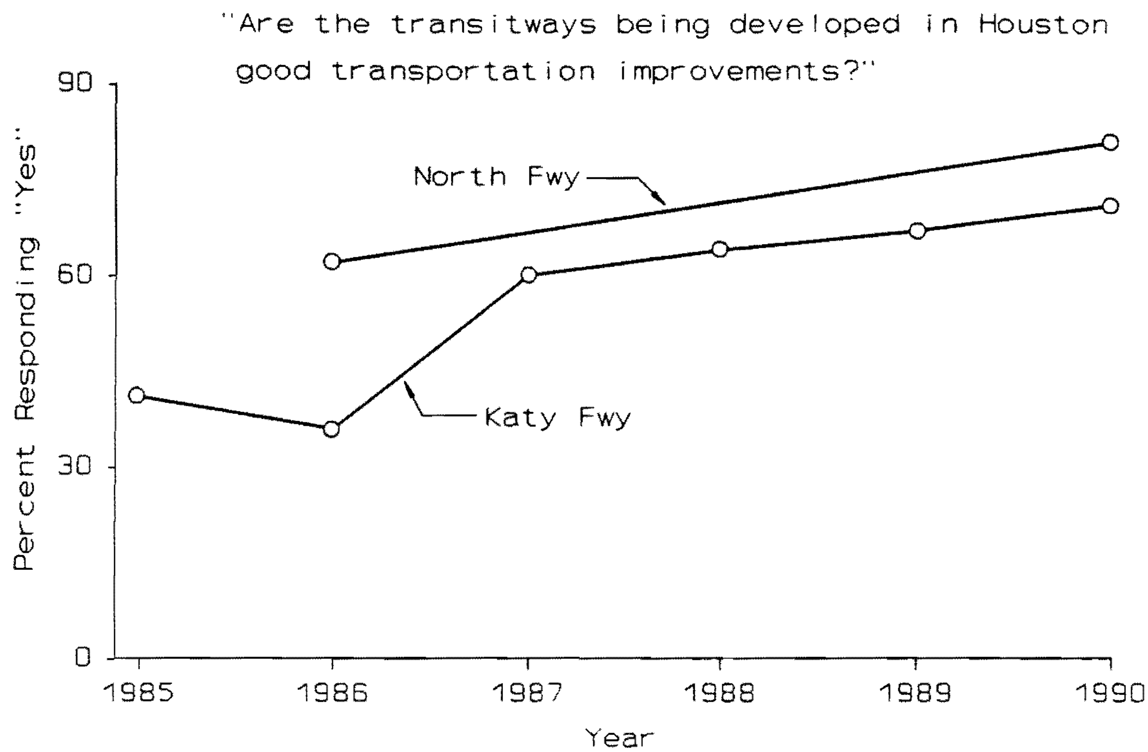
VIII. DOES THE HOV LANE PROGRAM HAVE PUBLIC SUPPORT?

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 over $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.

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 29), over 70 percent of the motorists in the freeway mainlanes (not HOV lane users) viewed these projects favorably. Of those motorists surveyed, fewer than 15 percent felt the 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 41.



Source: Texas Transportation Institute surveys

Figure 41. Trends in Public Attitudes Concerning HOV Lane Development

The responses shown in Table 29 and Figure 41 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.

Table 29. 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.

Are the HOV Lanes Sufficiently Utilized?

While the responses in Table 29 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 30 and 31). 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 program.

Table 30. 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.

Table 31. 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.

Over 75 percent of those who use the HOV lanes feel that those facilities are sufficiently utilized (Table 30). This percentage has generally been increasing over time.

However, the motorists using the general-purpose mainlanes do not feel that the HOV lanes are sufficiently utilized (Table 31). 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, nevertheless, this is an issue that will need to continue to be addressed in the formulation of strategies for operating the HOV facilities.

IX. CONCLUSIONS

A 95.5-mile system of freeway HOV lanes is being developed in Houston. As of the end of 1990, 46.5 miles of that barrier-separated system were operational, with priority facilities operating in four different freeway corridors.

In this report, it is assumed that the primary goal of the Houston 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 1990 to assess the extent to which these objectives are being attained (Table 32). 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.

Table 32. 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 (12/90)	26,960	19,033	10,025	11,349	NA
Percent Increase over 12/89	46.9%	69.5%	23.2%	56.0%	NA
% Change in Number of Lanes[4]	+33%	+25%	NA	+33%	NA
% Change in Person Volume[5]	+100%	+101%	NA	+47%	- 5%
% Change in Average Vehicle Occupancy[5] (persons/vehicle)	+24%	+24%	NA	+14%	- 2%
% Change in 2+ Carpool Volumes[5]	+113%[11]	+127%	NA	+183%	+25%
% New Carpools Due to HOV Lane[6]	53%	46%	26%	47%	NA
% Change in Peak-Period Bus Riders	+355%	NA	NA	+108%	- 6%
% New Bus Riders Due to HOV Lane[7]	47%	52%	33%	47%	NA
% Change in Peak-Hour Bus Speeds	+130%	+180%	+61%	+97%	-11%
Annual Savings in Bus Operating Costs Due to HOV Lane (millions)	$4.8	—	—	—	—
% Change in Vehicles at Park-and-Ride Lots	+258%	NA	+21%	+199%	+20%
% Change, Freeway Volumes Per Lane[8]	+39%	+ 9%	NA	+ 8%	- 2%
% Change, Roadway Efficiency[9]	+169%	+150%	NA	+37%	-12%
HOV Travel Time Savings as a % of Construction Cost[10]	43.4%	8.9%	2.0%	4.0%	—

[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 12/90.
[3]This freeway does not have an HOV lane and represents a basis of comparison to the freeways with HOV lanes. Some of the data are for 1989 since in 1990 some Southwest Freeway buses were diverted 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.
[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 1990 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 1990.
[11]P.M. peak-hour volume due to the 3+ a.m. requirement.

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 leads to several general observations (Table 33). The performance measures suggest that, at today's level of usage, both the Katy and North HOV lanes are fulfilling their intended purpose; these are the two more mature priority lanes. The Northwest HOV lane is marginal at this time, while the Gulf HOV lane has yet to generate significant benefits. Both of these facilities have been operating less than three years. 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 minimal benefits; the Gulf facility will not be extended for at least another year. Nevertheless, daily usage of the Northwest HOV lane increased by 56 percent during 1990, while usage of the Gulf HOV lane increased by 23 percent during 1990.

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

Table 33. Comparison of HOV Lane Objectives and HOV Lane Performance

Objective, Measure of Effectiveness	HOV Facility			
	Katy	North	Gulf	Northwest
Increase Person Movement				
• Is daily ridership greater than 10,000	Yes	Yes	Yes	Yes
• Is daily ridership greater than 15,000	Yes	Yes	No	No
• Has the increase in a.m. peak-hour person volume exceeded the increase in lanes due to the transitway	Yes	Yes	NA	Yes
• Has a.m. peak-hour occupancy increased by more than 15%	Yes	Yes	NA	No
• Are more than 25% of the transitway carpools new due to the transitway	Yes	Yes	Yes	Yes
• Are more than 25% of the transitway bus riders new due to the transitway	Yes	Yes	Yes	Yes
Don't Unduly Impact Freeway General-Purpose Lane Operations				
• Has mainlane congestion increased due to the transitway	No	No	No	No
• Has the mainlane accident rate increased significantly due to the transitway	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
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
Enhance Bus Operations				
• Peak-hour bus speeds increase by at least 50%	Yes	Yes	Yes	Yes
• HOV lane accident rate less than general-purpose lanes	No	Yes	Yes	No
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	Yes	No	No
HOV Lanes Should Have Public Support				
• Do most of the persons responding to surveys indicate support for transitway development	Yes	Yes	Yes	Yes
Overall Assessment, Is HOV Facility Effective?	Effective	Effective	Not Effective	Marginally Effective

NA = Either not available or not applicable.

APPENDIX A

KATY FREEWAY AND HOV LANE DATA

KATY FREEWAY (IH 10) AND HOV LANE, HOUSTON

Summary of A.M. Peak-Period, Peak-Direction Katy Freeway and Transitway Data, December 1990
Prepared by Texas Transportation Institute

Type of Data Phase 1 of Transitway Became Operational 10/29/84	"Representative" Pre-Transitway	"Representative" Current Value	% Change
Transitway Data			
Transitway Length (miles)		13.0	
Transitway Cost (millions of 1990 dollars)		$59.1	
Person-Movement			
Peak Hour (7-8 a.m.)		4,406	—
Peak Period (6-9:30 a.m.)		11,445	—
Total Daily		26,960	—
Vehicle Volumes			
Peak Hour	—	1,034	—
Peak Period	—	3,386	—
Vehicle Occupancy, Peak Hour (persons/veh)	—	4.26	—
Accident Rate (Accidents/MVM), 11/84-12/90	—	1.37	—
Vehicle Breakdowns (VMT/Breakdown), 11/84-12/90	—	35,424	—
Violation Rate (6-9:30 a.m.)	—	19%	
Peak Hour Lane Efficiency[1] (1000's)	—	232	—
Annual Value of User Time Saved (millions)[7]	—	$5.5 to $10.9	—
Freeway Mainlane Data (see note)			
Person Movement			
Peak Hour	5,100	5,769	+13/1%
Peak Period (6-9:30 a.m.)	15,655	18,129	+15.8%
Vehicle Volume			
Peak Hour	4,045	5,505	+36.1%
Peak Period	12,750	16,869	+32.3%
Vehicle Occupancy, Peak Hour (persons/veh)	1.26	1.05	-16.7%
Accident Rate (Accidents/MVM)[2]	1.34	1.28	- 4.5%
Avg. Operating Speed[3]			
Peak Hour	23	32.6	+41.7%
Peak Period	33	35.2	+ 6.7%
Peak Hour lane Efficiency[1] (1000's)	38	68	+78.9%
Combined Freeway Mainland and Transitway Data			
Total Person Movement			
Peak Hour	5,100	10,175	+99.5%
Peak Period	15,655	29,574	+88.9%
Vehicle Volume			
Peak Hour	4,045	6,539	+61.7%
Peak Period	12,750	20,255	+58.9%
Vehicle Occupancy			
Peak Hour	1.26	1.56	+23.8%
Peak Period	1.23	1.46	+18.7%
Carpool Volumes[8]			
2+, 6 a.m. to 7 a.m.	505	927	+83.6%
3+, 7 a.m. to 8 a.m.	45	308	+584.4%
2+, 5 p.m. to 6 p.m.	763	1627	+113.2%
Travel Time (minutes)[3]			
Peak Hour	33.9[4]	13.9[5]	-59.0%
Peak Period	23.1[4]	13.7[5]	-40.7%
Peak Hour Lane Efficiency[1] (1000's)	38	105	+169.2%

Footnotes on page A-3

Summary of P.M. Peak-Period, Peak-Direction Katy Freeway and Transitway Data, December 1990 Continued

Type of Data	"Representative" Pre-Transitway Value	"Representative" Current Value	% Change
Transit Data			
Bus Vehicle Trips			
Peak Hour	11	56	+409.1%
Peak-Period	32	123	+284.4%
Bus Passenger Trips			
Peak Hour	355	2005	+498.5%
Peak Period	900	4095	+355.0%
Bus Occupancy (persons/bus)			
Peak Hour	30.5	35.8	+ 17.4%
Peak Period	28.1	33.3	+ 18.5%
Vehicles Parked in Corridor Park & Ride Lots	575	2057	+257.7%
Bus Operating Speed (mph)[3]			
Peak Hour	22.6[4]	52.6[5]	+132.7%
Peak Period	33.2[4]	53.5[5]	+ 60.5%

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

Footnotes on following page.

Comparison of Measures of Effectiveness, Freeway With (Katy, I-10W) and Freeway Without (Southwest US 59) Transitway, Houston[6]

Measure of Effectiveness	"Representative" Pre-Transitway Value	"Representative" 12/90 Value	% Change
Average P.M. Peak-Hour Vehicle Occupancy			
Freeway w/transitway	1.26	1.56	+23.8%
Freeway w/o transitway	1.34	1.31	- 2.2%
Peak-Hour 2+ Carpool Volume			
Freeway w/transitway (5-6 p.m.)	763	1627	+113.2%
Freeway w/o transitway	600	743	+ 23.8%
Bus Passengers, Peak Period			
Freeway w/transitway	900	4095	+355.0%
Freeway w/o transitway	2,185	2100	- 3.9%
Cars Parked at Park-and-Ride Lots			
Freeway w/transitway	575	2057	+257.7%
Freeway w/o transitway[1]	1660	1665	+ 0.3%
Facility Per Lane Efficiency[1]			
Freeway w/transitway	39	105	+169.2%
Freeway w/o transitway	49	60	+ 22.4%

Footnotes on following page

Footnotes

[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.
[2]Accidents analyzed between Gessner and Post Oak, a distance of approximately 4.7 miles. This corresponds to Phase 1 of the transitway. "Before" data are for the period 1/82 through 10/84. "After" data are for the period from 11/84 to 9/90. Only officer-reported accidents are included in current files. 1990 freeway volumes estimated by TTI.
[3]From SH 6 to Washington, a distance of 12.18 miles. The transitway is in place over this section.
[4]Data pertains to operation in the freeway mainlanes.
[5]Data pertains to operation in the transitway.
[6]Data for freeways without transitways are a composite of data collected on the Gulf Freeway during the time in which no transitway existed on that facility (6/83 thru 4/88) and on the Southwest Freeway (9/86 to present).
[7]Based on time savings for transitway users in 1989 and transitway volumes in 1990, an annual estimate of travel time savings to transitway users is developed. A value of time of $9.25/hour is used based on the value applied in the Highway Economic Evaluation Model.
[8]Carpool counts are adjusted in an effort to compensate for under counting of occupancies in the field.

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

TRANSITWAY DATA

Description

- Phase 1 (4.7 miles) of the transitway opened October 29, 1984.
- The transitway is now complete with 13.0 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
    - 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.

KATY HOV LANE
Estimated Capital Costs (millions)

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 SDHPT

Person Movement

- In December 1990, 26,960 person trips per day were served on the HOV lane.
- A.M. Peak Hour, 4,406 persons/hour.
    - 2005 (46%) by bus, 203 (5%) by vanpool, 2198 (49%) by carpool (Figure 1).
    - Average transitway vehicle occupancy = 4.26 persons/vehicle.
- A.M. Peak Period, 11,445 persons.
    - 4,095 (36%) by bus, 427 (4%) by vanpool, by carpool 6,923 (60%) (Figure 2).

Vehicle Movement

- A.M. Peak Hour, 1,034 vph
    - 56 (5%) bus, 22 (2%) vans, by carpool 956 (93%) (Figure 3).
- A.M. Peak Period, 3,386 vehicles
    - 123 (4%) bus, 50 (1%) vans, carpool 3,213 (95%) (Figure 4).

Accident Rate

- For the period from November 1984 through September 1990, the transitway accident rate was 1.37 accidents per million vehicle miles.

Vehicle Breakdown Rates

- As measured for 11/84 to 12/90, the following rates have been observed.
    - Buses; 1 breakdown per 16,932 vehicle-miles of travel (VMT).
    - Vanpools; 1 breakdown per 96,316 VMT.
    - Carpools; 1 breakdown per 36,231 VMT.
    - The weighted average for all vehicle types is 1 breakdown per 35,242 VMT.

Violation Rate

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

- For the overall a.m. peak period it is 19%.
- For the period from 7:00 a.m. to 8:15 a.m. (the 3+ operating time) it averaged 50% for 1990 and was 56% in December.
- For the p.m. peak period, the violation rate is 1.6%.

Peak Hour Lane Efficiency

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. For the transitway lane, this value (expressed in 1000's) is approximately 232 (4406 passengers at 52.6 mph).

Travel Time Savings

- The users of the transitway experience a travel time savings (Figure 5).

- The tables on the following page indicate that, on a typical non-incident day, travel time savings of approximately 2,362 hours (141,736 min.) are realized. Assuming 250 days of operation, annual saving would be 590,500 hours. At $9.25/hour, this equates to $5.46 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 transitway users are conservatively estimated to be in the range of $5.46 to $10.92 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 13.1% (Figure 6).

- In the a.m. peak period, person movement has increased by 15.8% (Figure 7).

Eastbound A.M. Travel Time Savings for Katy Transitway
(Average of 4 Quarterly Travel Time Surveys Conducted in 1990)

Time of Day	Measured Travel Time			Transitway 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	6.96	7.10	-0.14	331	76	181	588	-79.59
6:30	8.90	7.02	1.88	1,226	87	725	2,038	3,831.95
7:00	11.36	7.14	4.23	1,004	94	961	2,059	8,698.22
7:30	12.06	7.03	5.03	868	38	950	1,856	9,343.13
8:00	10.77	6.83	3.93	894	32	486	1,411	5,549.93
8:30	8.79	6.92	1.87	775	17	241	1,032	1,928.55
9:00	7.79	7.03	0.76	452	20	87	558	423.34
Peak Period Total				5,550	362	3,630	9,542	29,695.52
Section From Gessner Interchange to Washington								
6:00	7.03	6.86	0.17	457	50	135	641	110.88
6:30	8.52	6.68	1.84	1,061	64	327	1,451	2,672.26
7:00	16.08	6.94	9.14	413	36	493	942	8,613.41
7:30	16.72	6.70	10.01	317	39	418	774	7,751.29
8:00	13.59	6.68	6.91	485	20	135	640	4,424.39
8:30	9.86	6.59	3.27	260	6	49	315	1,029.99
9:00	7.02	6.58	0.44	155	7	10	172	75.72
Peak Period Total				3,147	222	1,567	4,935	24,677.94
Westbound PM Travel Time Savings for Katy Transitway								
Section from Washington to Gessner Interchange								
1530	8.14	7.30	0.83	507	47	108	662	550.08
1600	9.62	7.64	1.99	835	142	441	1,418	2,818.71
1630	13.14	7.98	5.16	1,123	72	621	1,816	9,364.95
1700	17.75	8.52	9.23	1,448	58	893	2,398	22,126.55
1730	21.30	8.63	12.67	1,404	68	914	2,385	30,210.00
1800	18.68	8.13	10.54	915	23	415	1,353	14,263.06
1830	8.57	7.11	1.47	557	10	144	711	1,042.43
Peak Period				6,788	419	3,536	10,742	80,375.84
Section from Gessner Interchange to SH 6								
1530	6.92	6.49	43	208	6	10	224	96.60
1600	6.87	6.38	49	344	58	135	537	263.28
1630	7.42	6.51	1	569	76	245	890	808.42
1700	8.71	6.62	2.10	669	26	308	1,002	2,102.64
1730	8.75	6.58	2.17	772	28	550	1,349	2,923.38
1800	7.64	6.97	0.68	640	13	263	916	620.38
1830	6.81	6.48	3	407	6	113	525	171.80
Peak Period				609	212	1,624	5,444	6,986.49

Vehicle Volume

- In the a.m. peak hour, vehicle volume has increased by 36.1% (Figure 6).

- In the a.m. peak period, vehicle volume has increased by 32.3% (Figure 7).

Vehicle Occupancy

- In the a.m. peak hour, mainlane occupancy has decreased by 16.7%.

- In the a.m. peak period, mainlane occupancy has decreased by 12.5%, from 1.23 to 1.07.

Accident Rate

- Implementation of the transitway 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 transitway was 1.34 accidents per million vehicle miles (MVM). For the period from 11/84 to 9/90, the freeway accident rate was 1.28 accidents/MVM. These statistics do not include driver reported accidents; only officer reported accidents are included in current accident files. TTI estimated 1990 freeway volumes to compute accident rates.

Average Operating Speed

- In comparison to pre-transitway conditions, mainlane operating speeds have increased by 42% in the peak hour and 7% in the peak period (Figure 8).

Peak Hour Lane Efficiency

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

- For the freeway mainlanes, an increase in per lane efficiency of 79% has occurred.

COMBINED FREEWAY MAINLANE AND TRANSITWAY DATA

Total Person Movement

- Percent by transitway, a.m. peak hour.
  - At Bunker Hill, the transitway is moving 43% of peak-hour person movement (transitway = 4,406; freeway = 5,769) and 39% of peak-period (transitway = 11,445; freeway = 18,129) person movement.
- Increase in a.m. person movement at Bunker Hill.
  - Provision of the transitway increased total directional lanes by 33%.
  - Total peak-hour person movement has increased by 99.5% from 5,100 to 10,175 (Figure 9). Peak-period person movement has increased by 88.9% from 15,655 to 29,574 (Figure 10).

Vehicle Occupancy

- The combined occupancy for the freeway and transitway in the peak hour is 1.56, a 23.8% increase over the pre-transitway occupancy (Figure 11). Occupancy in the peak period is greater than pre-transitway levels (Figure 12), increasing from 1.23 to 1.46.
- While the occupancy on the Katy Freeway has increased, on freeways which do not have a transitway, occupancy has decreased (Figure 13).

Carpool Volumes

- In the a.m. peak hour, the total number of 2+ carpools (freeway plus transitway) has increased by 83.6% compared to pre-transitway levels (Figure 14).
- Between 7 and 8 a.m., prior to the HOV lane, the 3+ carpool volume was 45 vehicles. Now it is over 300 vehicles (Figure 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 transitway lane) has increased by 169% since the implementation of the transitway

(Figure 16). This large of an increase has not occurred on freeways not having transitways (Figure 17).

BUS TRANSIT DATA

Bus Vehicle and Passenger Trips

- In the a.m. peak hour, bus vehicle trips have been increased by 409% since the transitway opened, and a 499% increase in bus ridership has also resulted (Figure 18). In the peak period, a 284% increase has occurred in bus trips and a 355% increase in bus ridership has resulted (Figure 19).

- While bus trips have increased significantly in the Katy Freeway corridor, in the corridors which do not have a transitway this has not occurred (Figure 20).

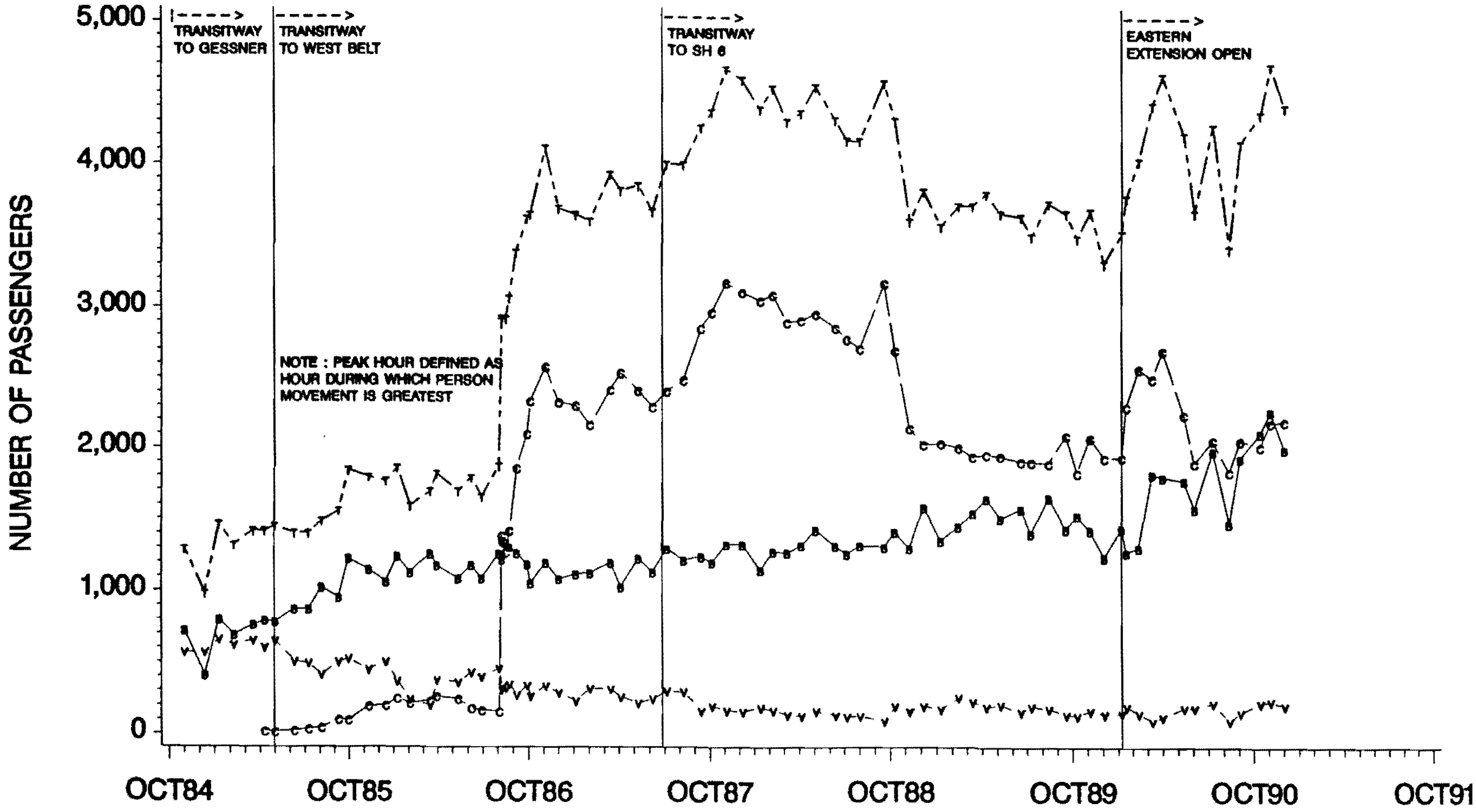
Park-and-Ride

- Prior to opening the transitway, approximately 575 vehicles were parked in corridor park-and-ride lots. This has increased 258% to a current level of 2,057 (Figure 21).

- The increase in cars parked in the Katy corridor has not been realized in the freeway corridors that do not have transitways (Figure 22).

FIGURE A-1

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

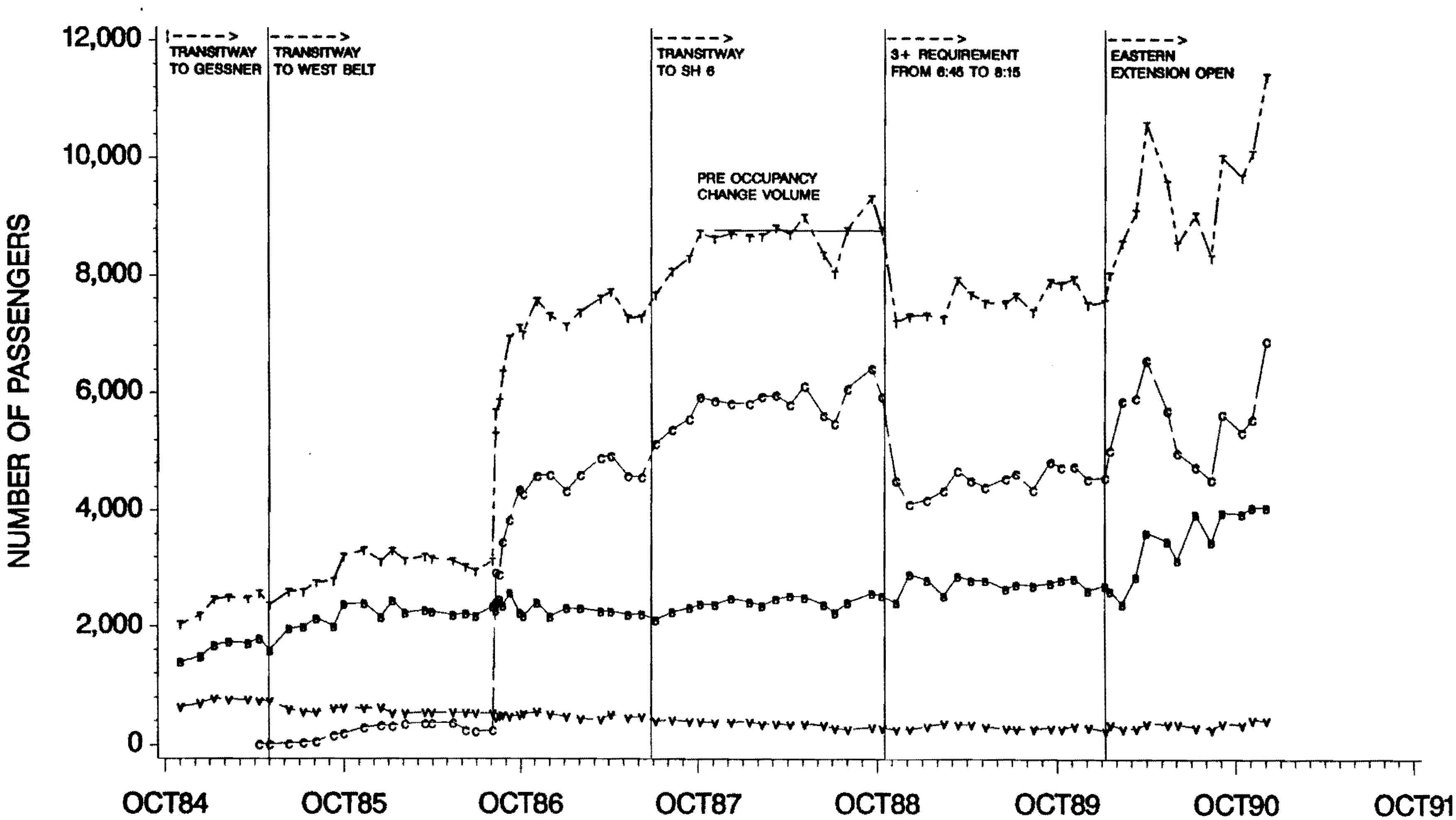


KATY TRANSITWAY PHASE 1, POST OAK TO GESSNER (4.7 MI.), OPENED OCTOBER 29, 1984
TRANSITWAY EXTENSION FROM GESSNER TO WEST BELT (1.7 MI.) OPENED MAY 2, 1985
OFF-PEAK, UNAUTHORIZED & 2+ CARPOOL OPERATION BEGAN AUGUST 11, 1986
TRANSITWAY EXTENSION FROM WEST BELT TO SH 6 (5.0 MI.) OPENED JUNE 29,1987
3+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

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



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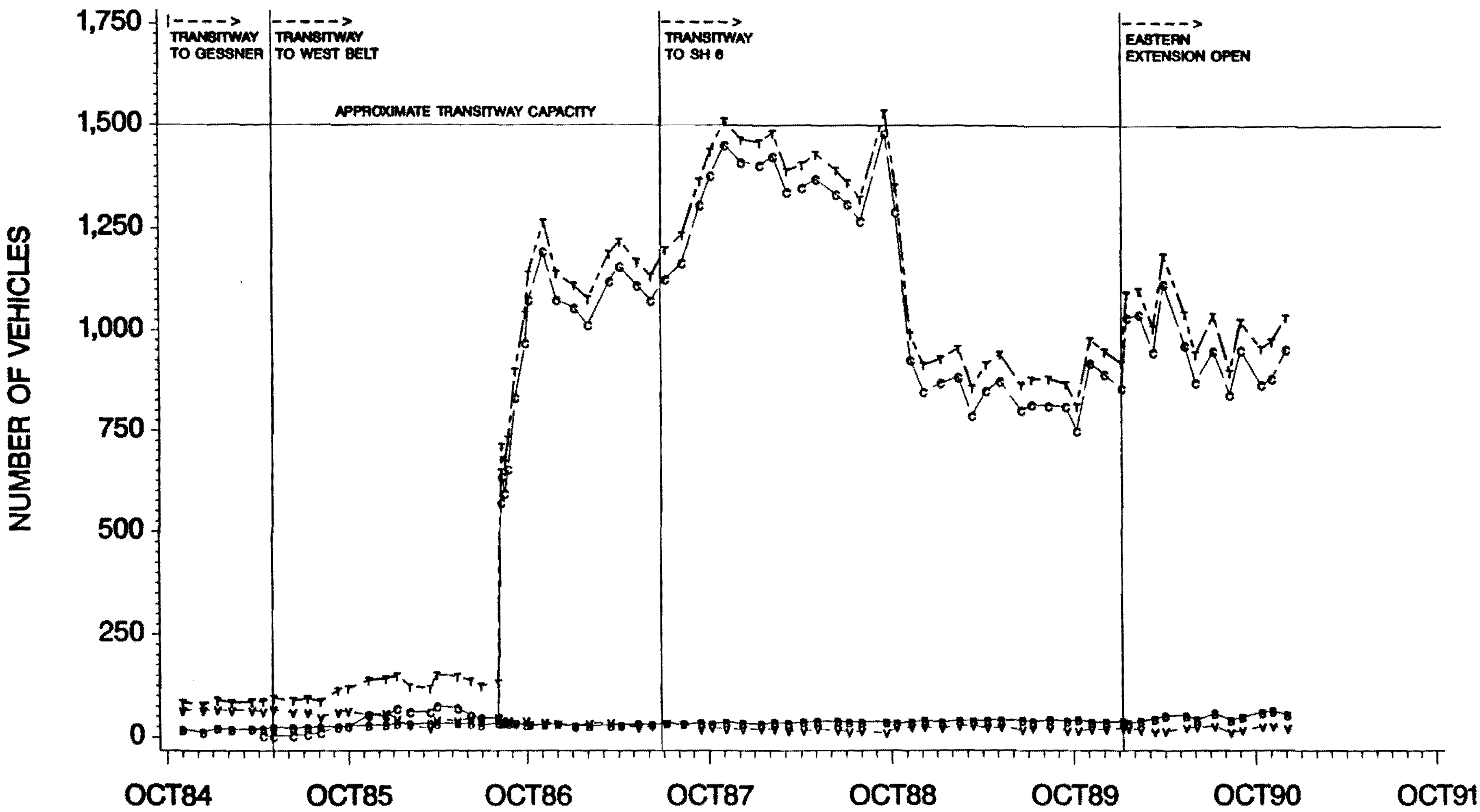
PEAK PERIOD IS 6:00 – 9:30 A.M.
DATA COLLECTED BETWEEN GESSNER AND POST OAK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE A-3

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



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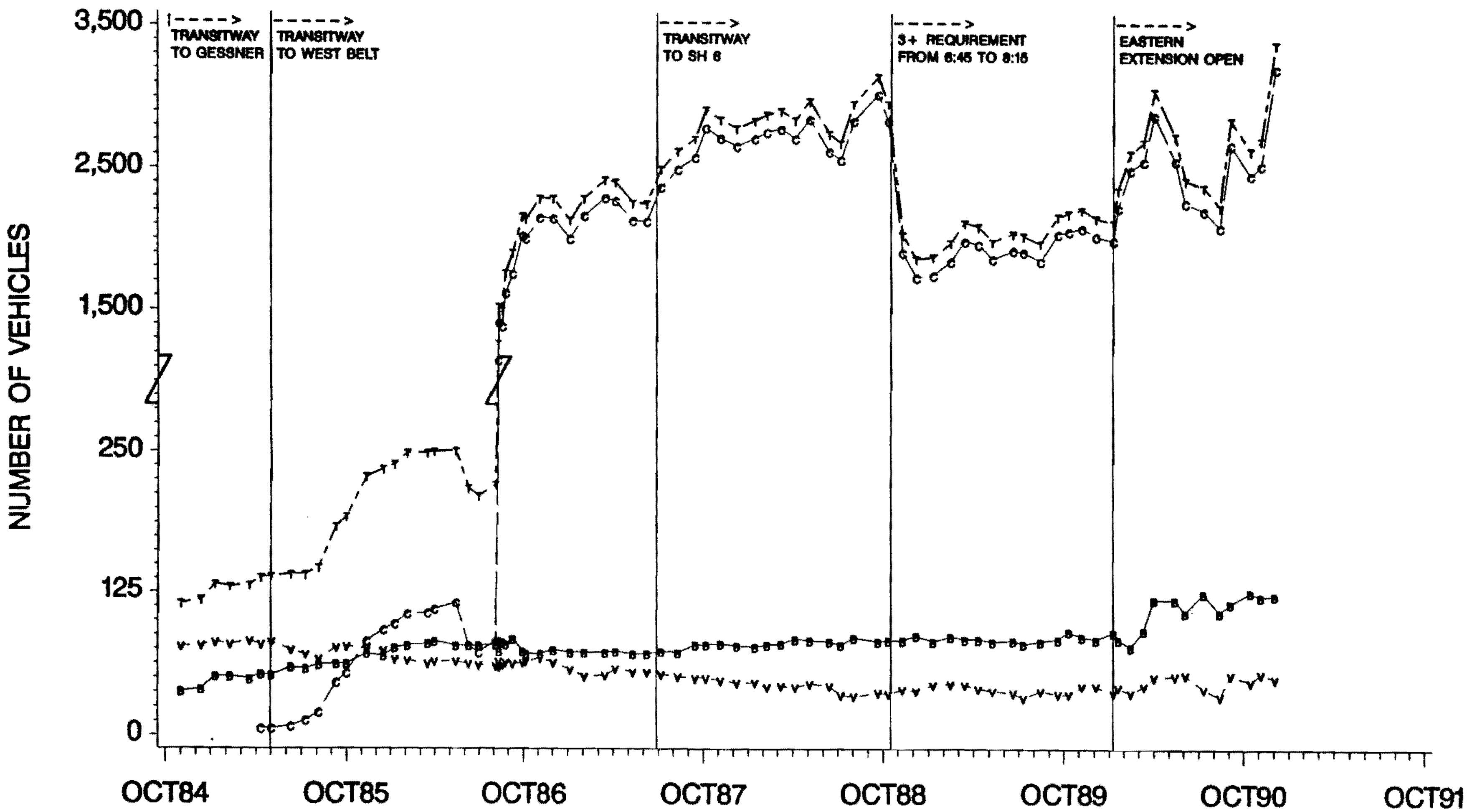
TRANSITWAY EASTERN EXTENSION (1.17 MI.) OPENED JANUARY 9, 1990
PEAK PERIOD IS 6:00 – 9:30 A.M.
DATA COLLECTED BETWEEN GESSNER AND POST OAK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE A-4

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



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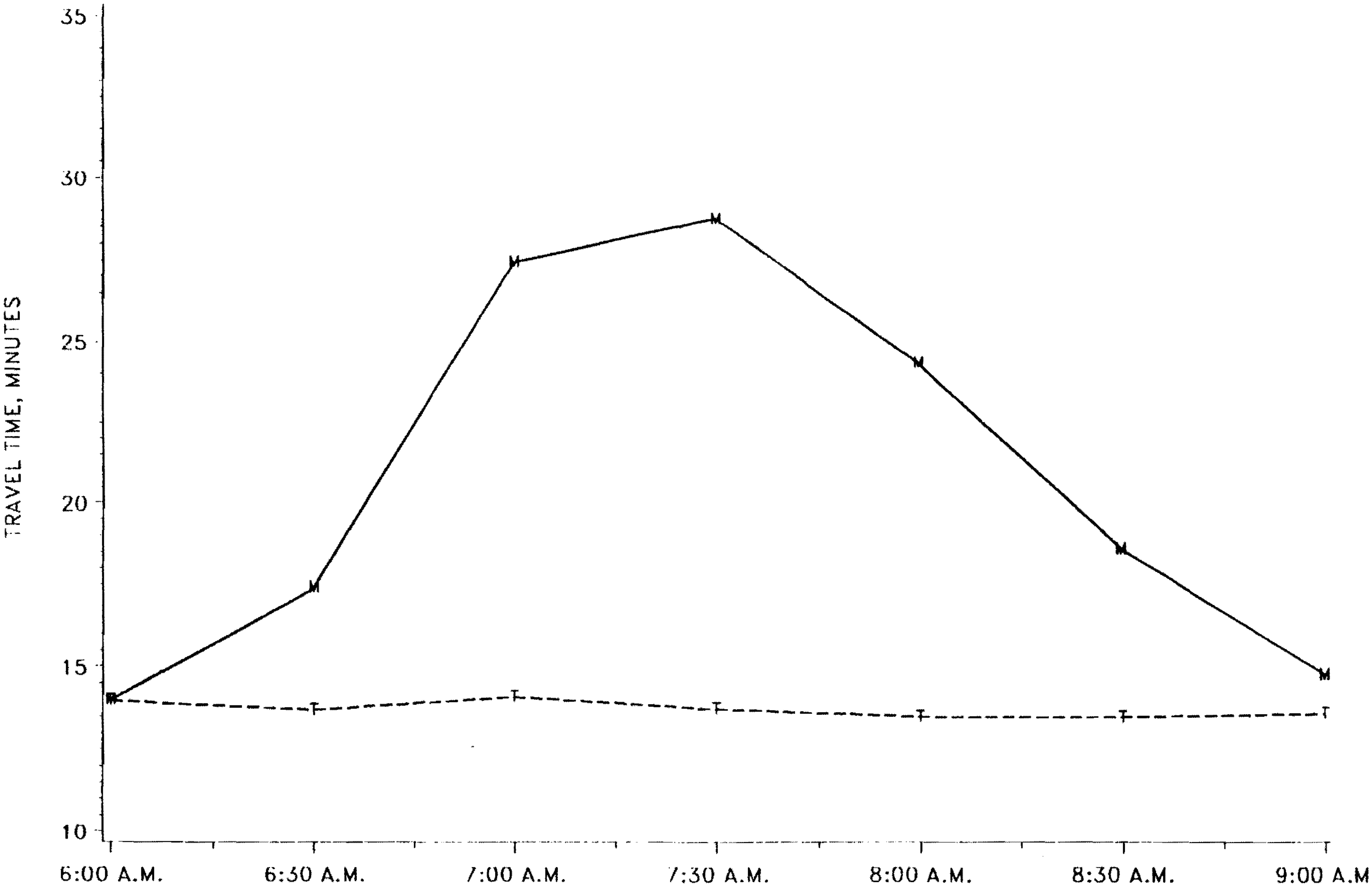
3+ CARPOOL REQUIREMENT FROM 6:45 TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
TRANSITWAY EASTERN EXTENSION (1.17 MI.) OPENED JANUARY 8, 1990
PEAK PERIOD IS 6:00 – 9:30 A.M.
DATA COLLECTED BETWEEN GESSNER AND POST OAK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE A-5

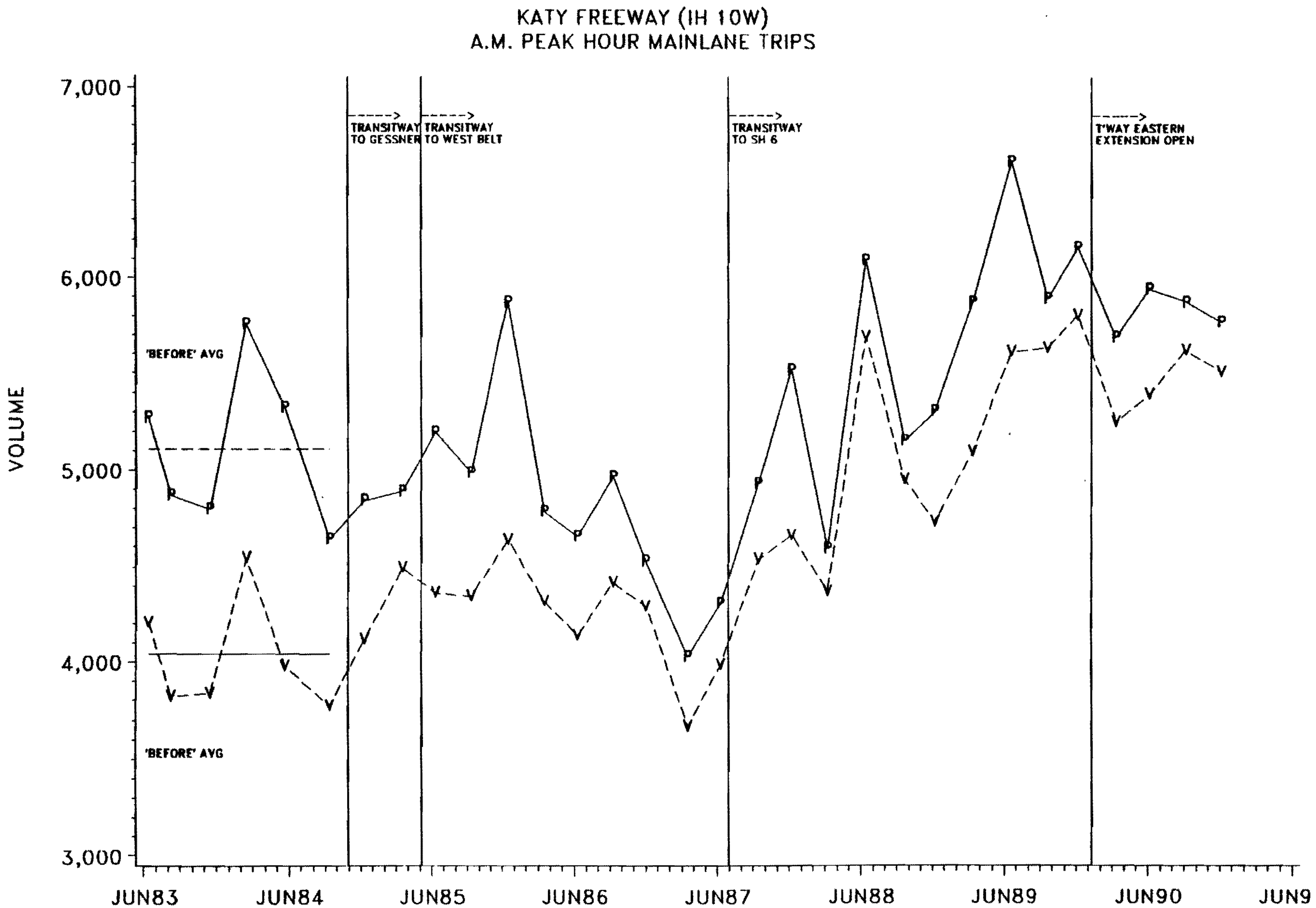
KATY FREEWAY (IH 10W) MAINLANES AND TRANSITWAY A.M. TRAVEL TIME



TRAVEL TIMES ARE FROM THE WESTERN TRANSITWAY TERMINUS TO THE S.P. RAILROAD OVERPASS
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : M – MAINLANE TRAVEL TIME
T – TRANSITWAY TRAVEL TIME

FIGURE A-6

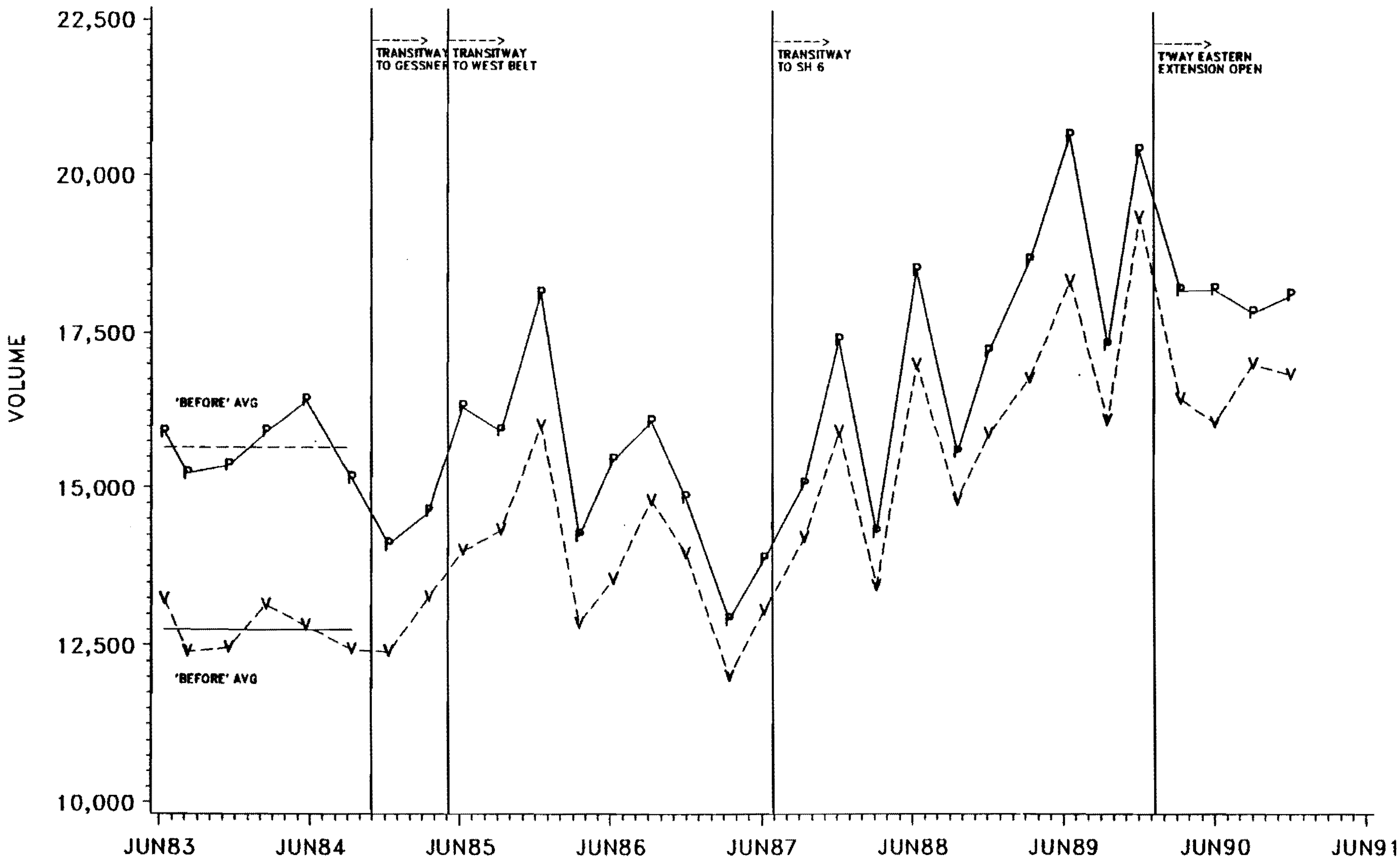


DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = MAINLANE PERSONS
V = MAINLANE VEHICLES

FIGURE A-7

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

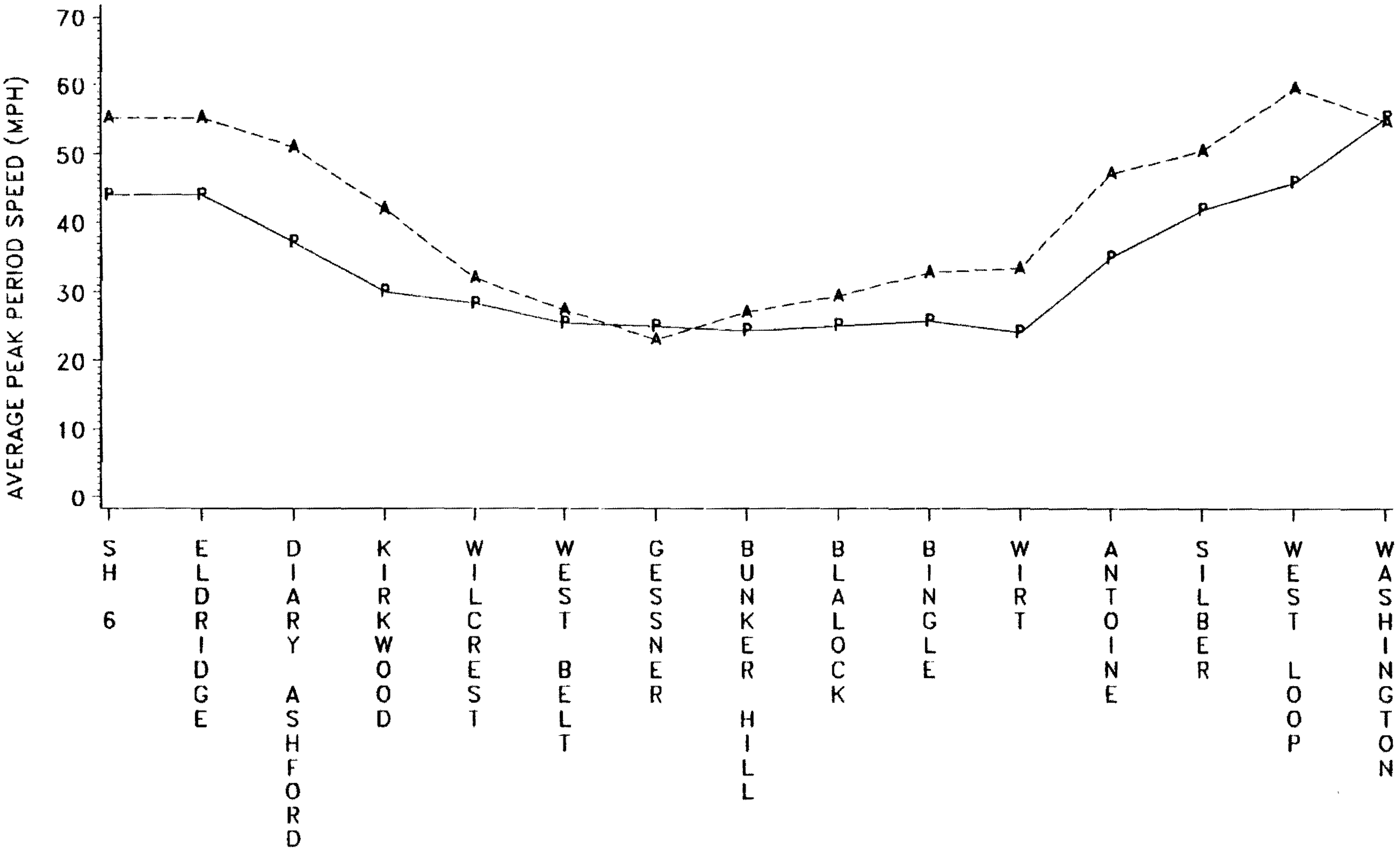


A.M. PEAK PERIOD DEFINED AS FROM 6:00 TO 9:30 A.M.
DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = MAINLANE PERSONS
V = MAINLANE VEHICLES

FIGURE A-8

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

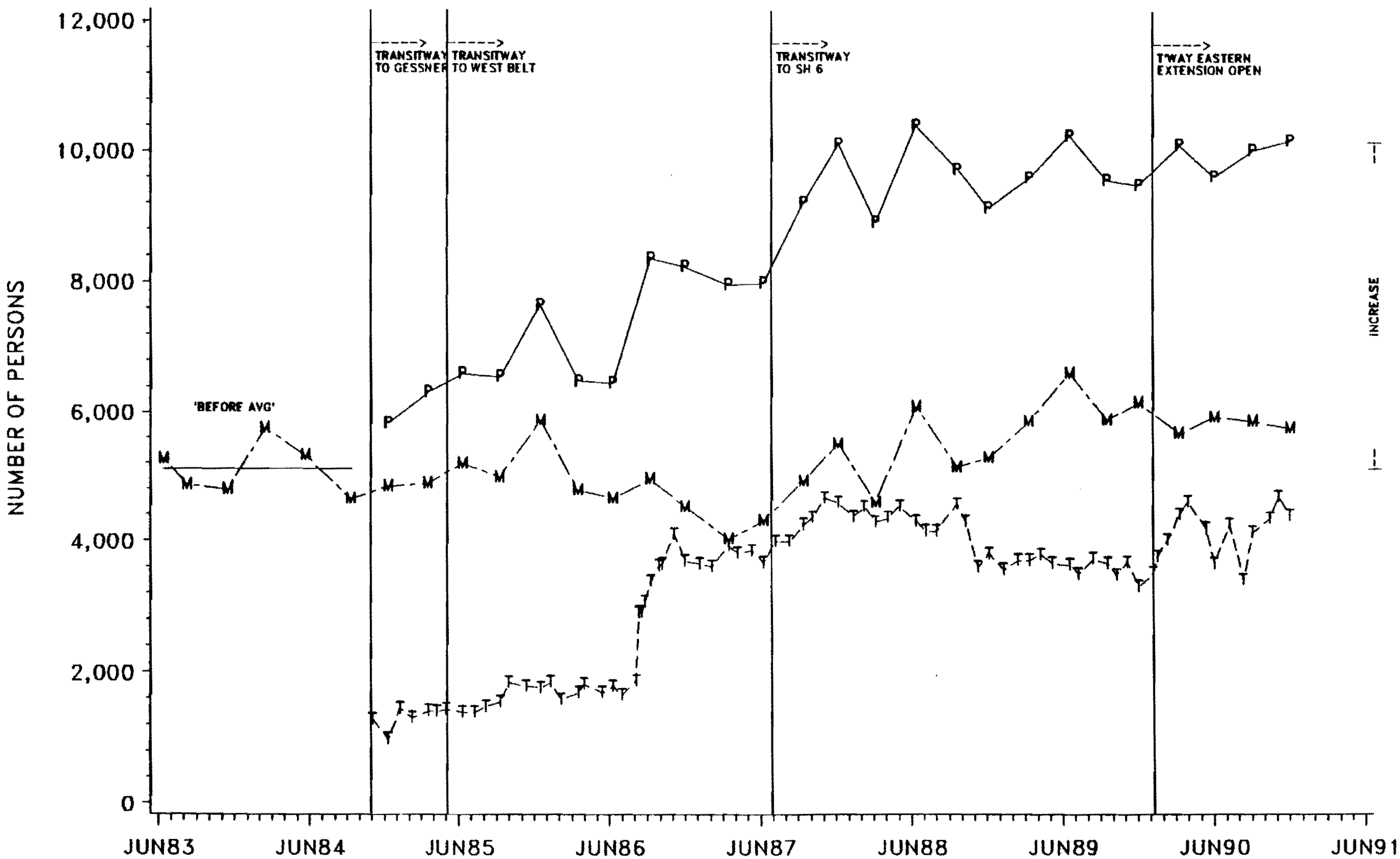


DATA COLLECTED 6:00 TO 9:30 A.M.
DATA COLLECTED FROM JUNE, 1983 TO DECEMBER, 1990
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE A-9

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

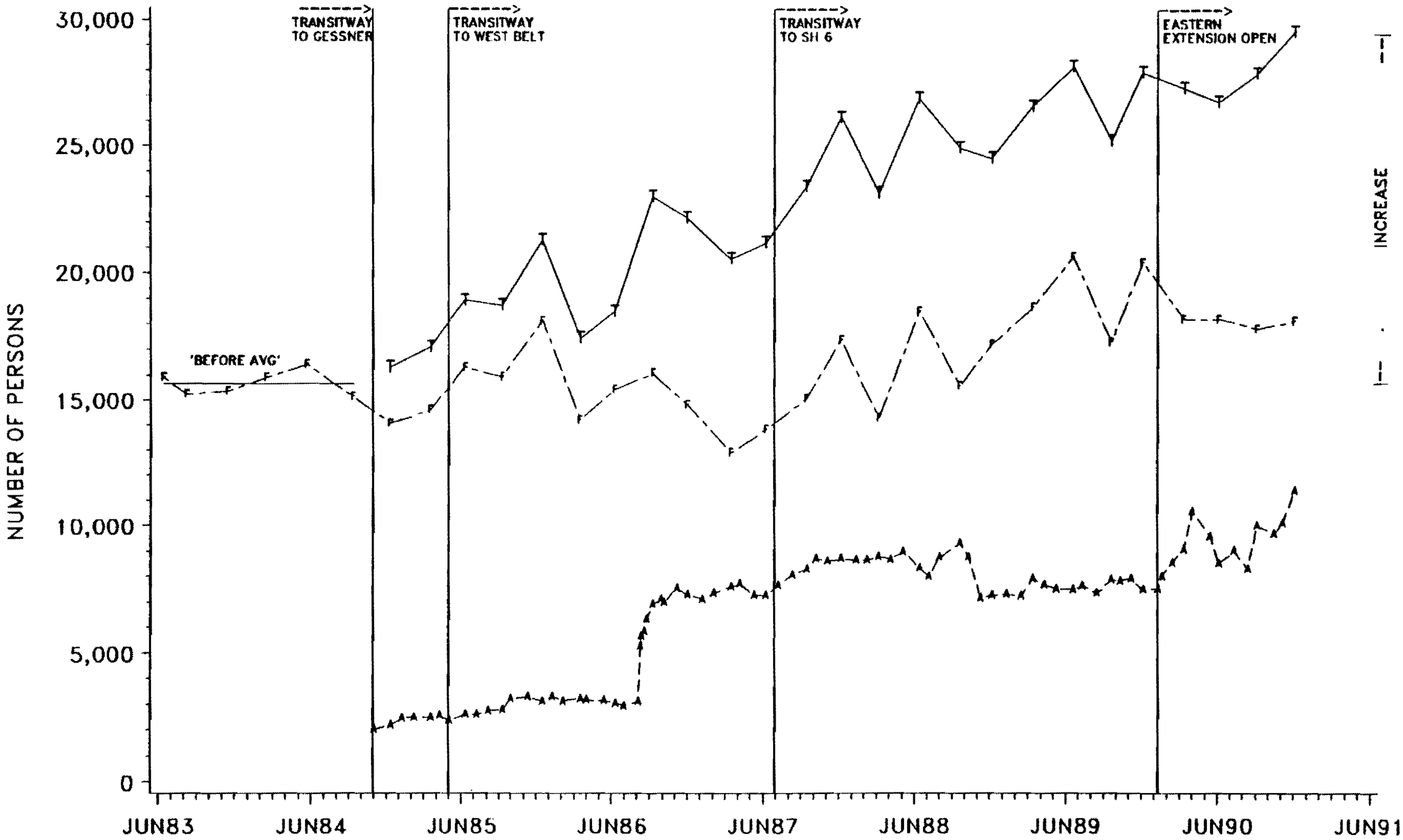


DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
3+ REQUIREMENT FROM 6:45 A.M. TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = TOTAL PERSONS
M = MAINLANE PERSONS
T = TRANSITWAY PERSONS

FIGURE A-10

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

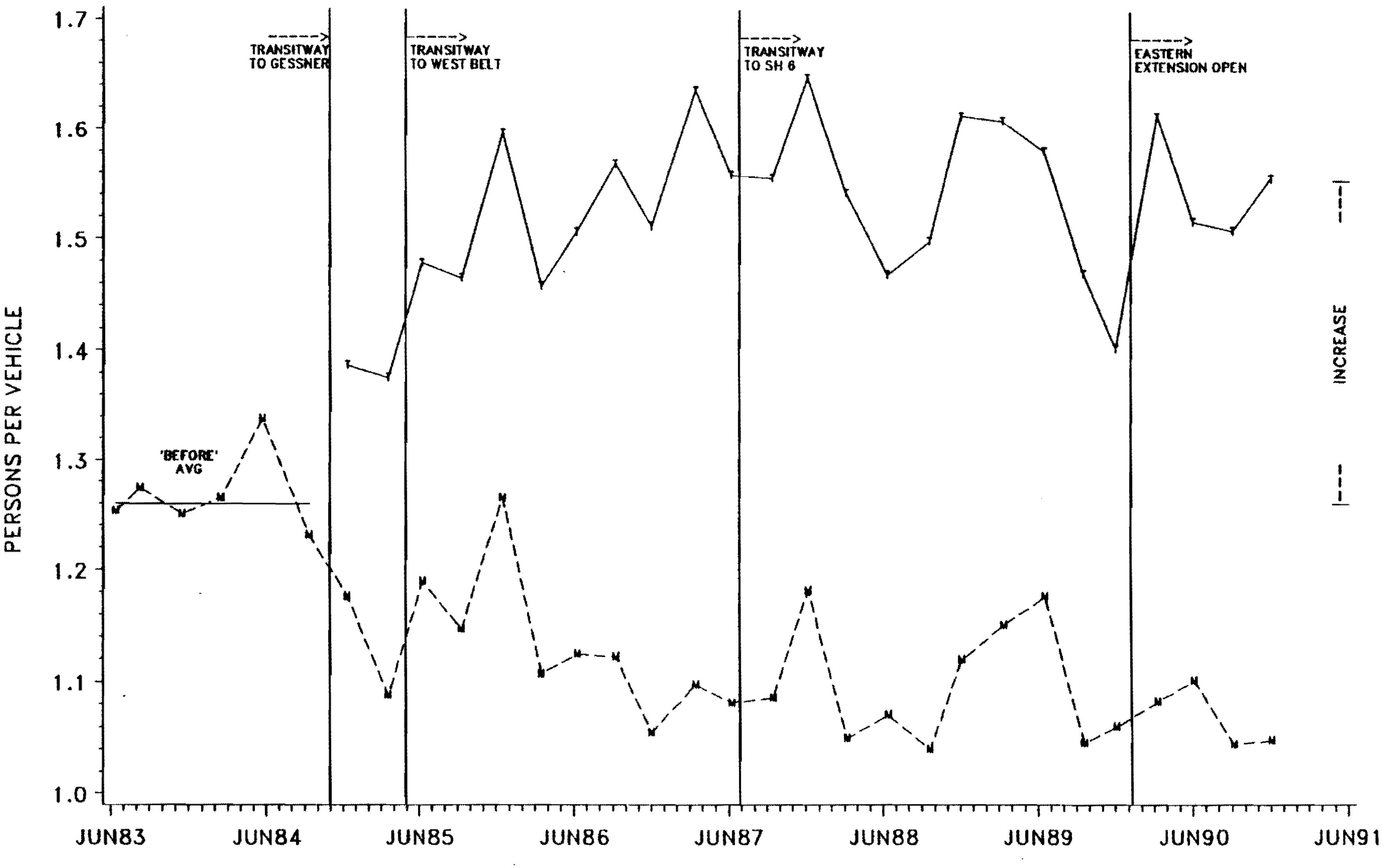


A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M
DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
3+ REQUIREMENT FROM 6:45 A.M. TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL PERSONS
F = MAINLANE PERSONS
A = TRANSITWAY PERSONS

FIGURE A-11

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



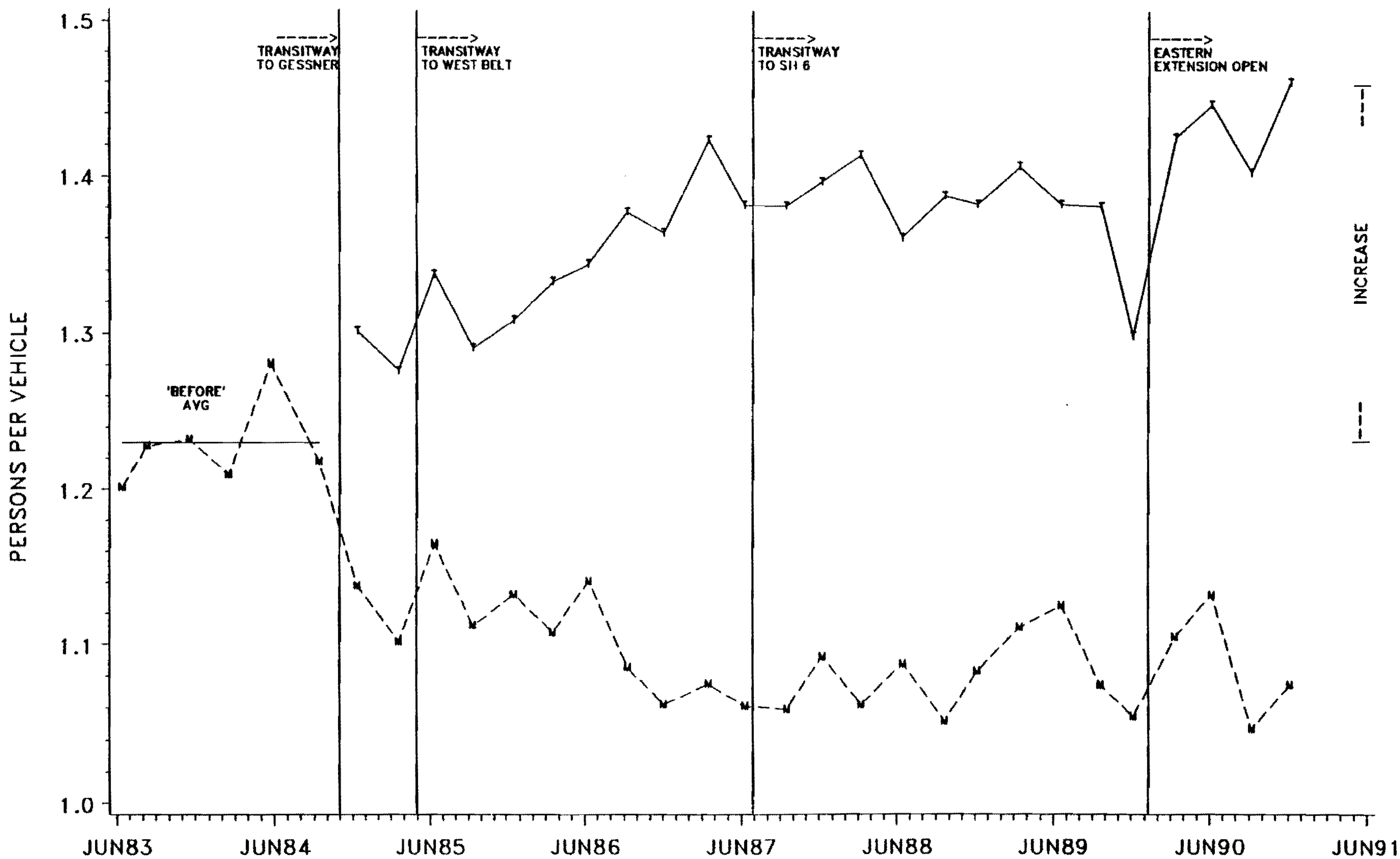
DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION

LEGEND : M = MAINLANE OCCUPANCY
T = TOTAL OCCUPANCY
(MAINLANE PLUS TRANSITWAY)

SOURCE : TEXAS TRANSPORTATION INSTITUTE

FIGURE A-12

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

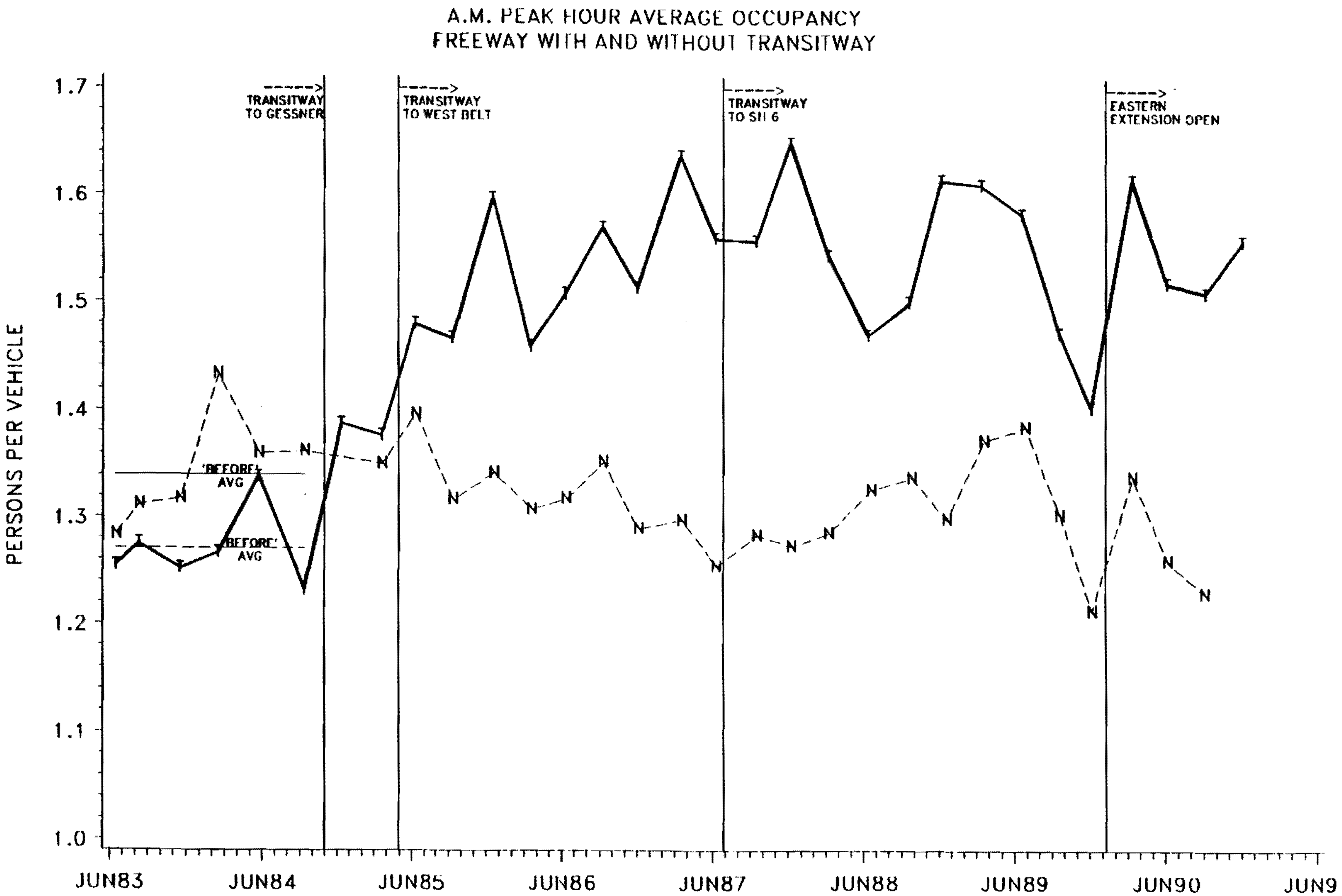


DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION

SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : M = MAINLANE OCCUPANCY
T = TOTAL OCCUPANCY
(MAINLANE PLUS TRANSITWAY)

FIGURE A-13

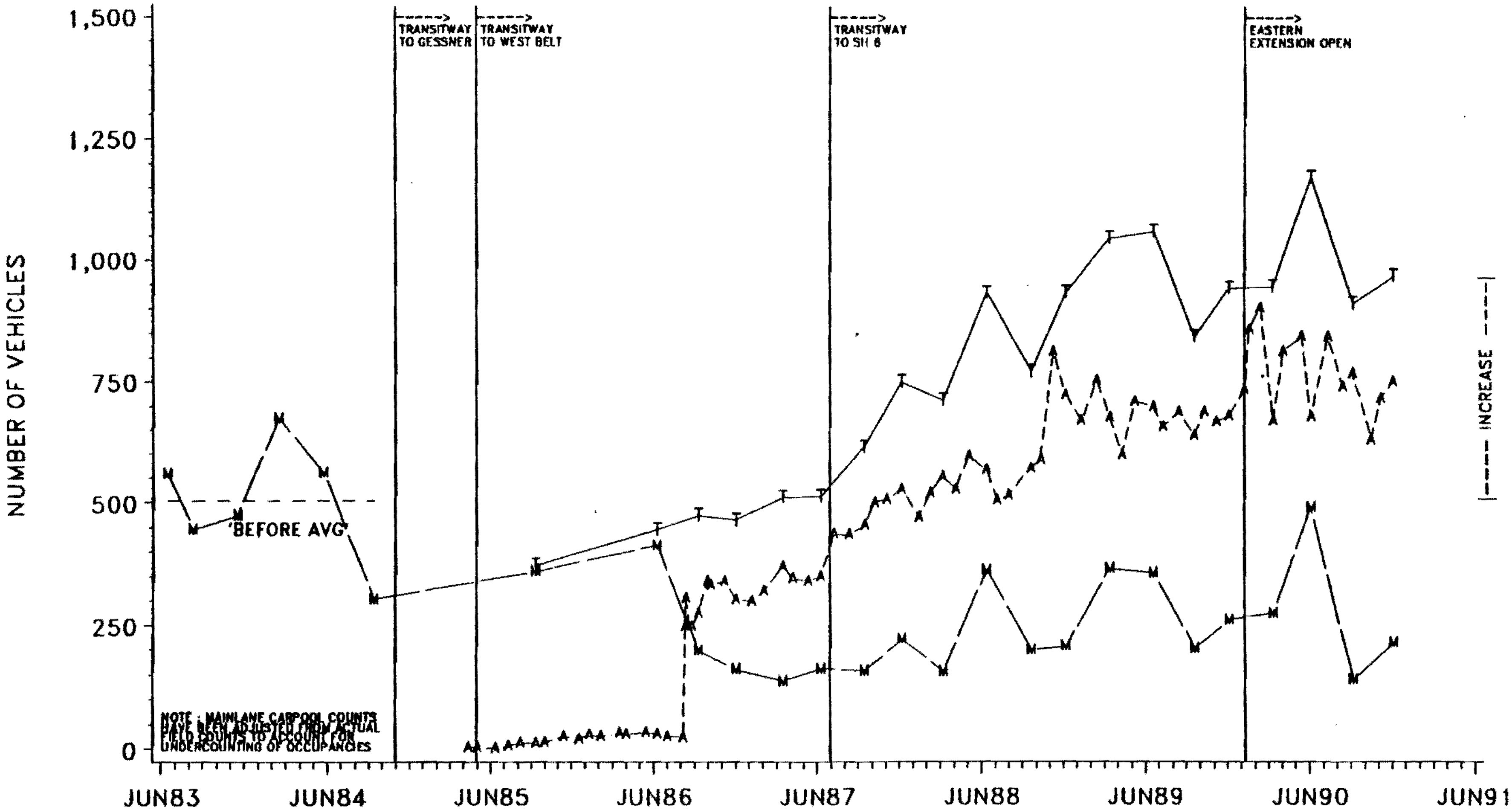


DATA FOR FREEWAYS WITHOUT TRANSITWAYS ARE A COMPOSITE OF
GULF FWY (6/83 – 4/88) AND SOUTHWEST FWY (9/86 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = KATY FREEWAY AT BUNKER HILL (WITH TRANSITWAY)
N = FREEWAYS WITHOUT TRANSITWAY

FIGURE A-14

KATY FREEWAY (IH 10W) MAINLANE AND TRANSITWAY
6:00 A.M. TO 7:00 A.M. 2+ CARPOOL UTILIZATION
DATA COLLECTED EASTBOUND OVER BUNKER HILL

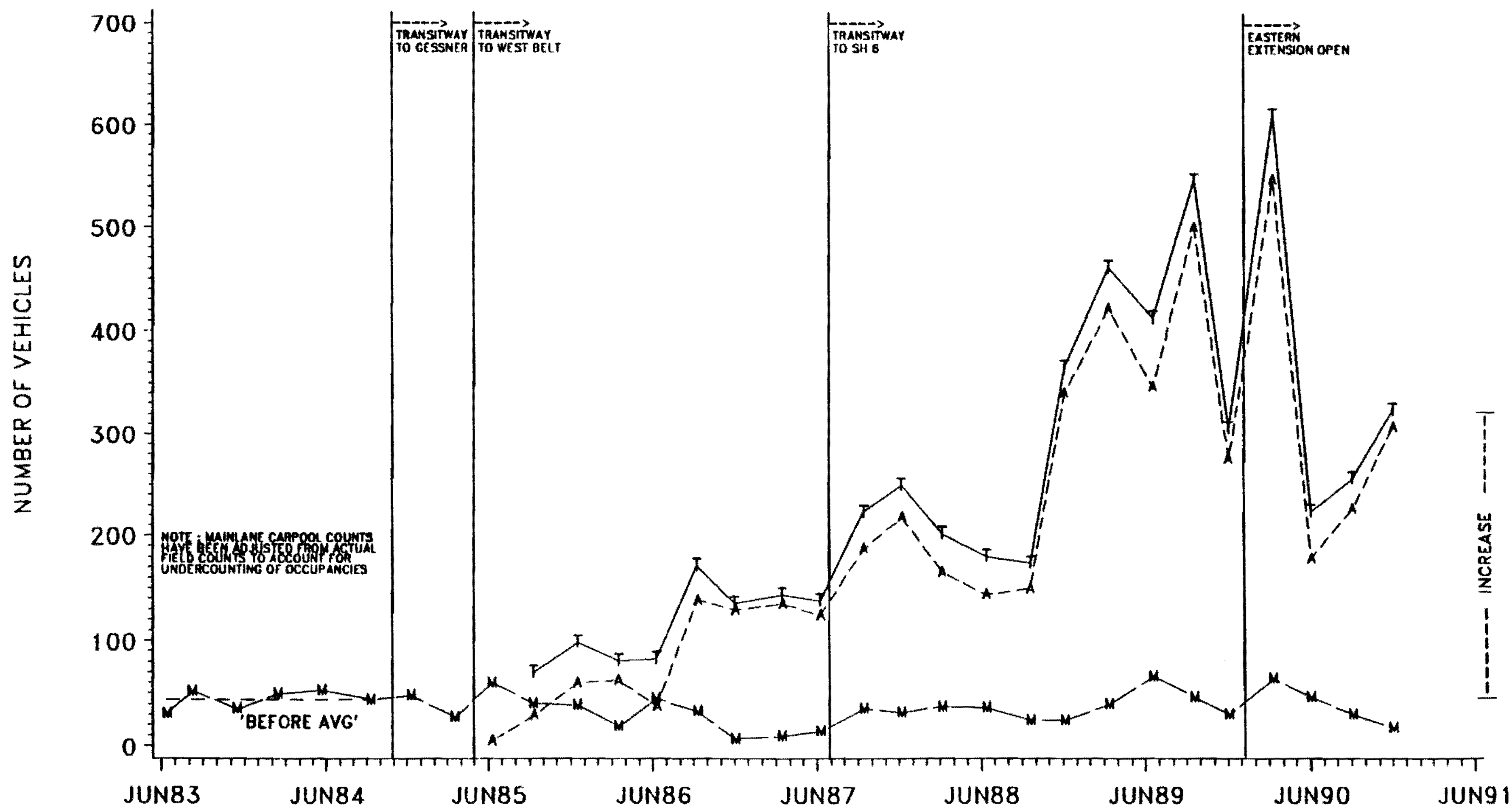


KATY TRANSITWAY PHASE 1, POST OAK TO GESSNER (4.7 MI.), OPENED OCTOBER 29, 1984
TRANSITWAY EXTENSION FROM GESSNER TO WEST BELT (1.7 MI.) OPENED MAY 2, 1985
OFF-PEAK, UNAUTHORIZED & 2+ CARPOOL OPERATION BEGAN AUGUST 11, 1986
TRANSITWAY EXTENSION FROM WEST BELT TO SH 6 (5.0 MI.) OPENED JUNE 29,1987
TRANSITWAY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

LEGEND : T = TOTAL 2+ CARPOOLS
A = TOTAL TRANSITWAY 2+ CARPOOLS
M = TOTAL MAINLANE 2+ CARPOOLS

FIGURE A-15

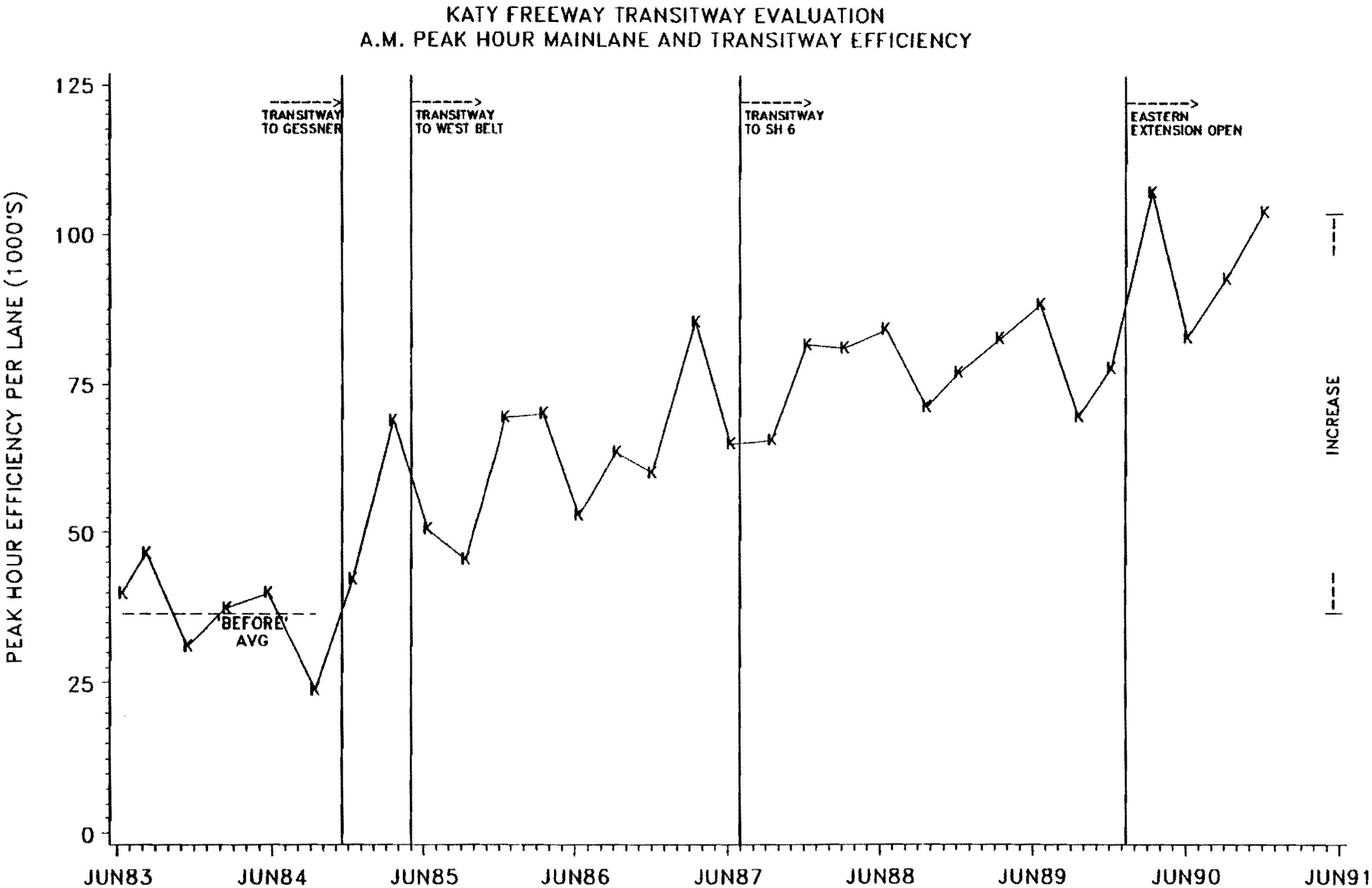
KATY FREEWAY (IH 10W) MAINLANE AND TRANSITWAY
7:00 A.M. TO 8:00 A.M. 3+ CARPOOL UTILIZATION
DATA COLLECTED EASTBOUND OVER BUNKER HILL



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

LEGEND : T = TOTAL 3+ CARPOOLS
A = TOTAL TRANSITWAY 3+ CARPOOLS
M = TOTAL MAINLANE 3+ CARPOOLS

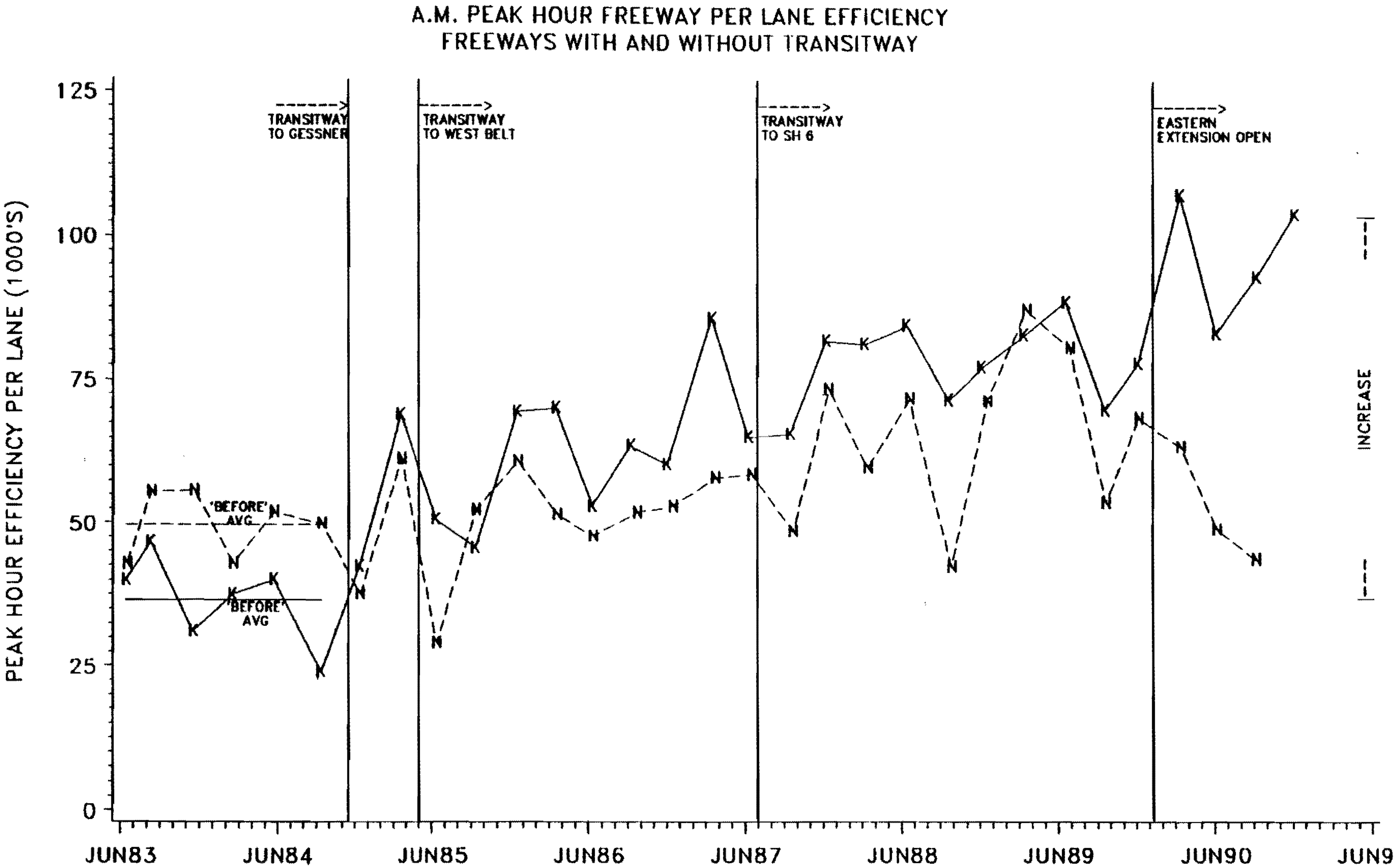
FIGURE A-16



PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE TRANSITWAY, IT REPRESENTS TOTAL PERSONS (FREEWAY + TRANSITWAY) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 4 LANES
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : K = KATY FREEWAY EFFICIENCY

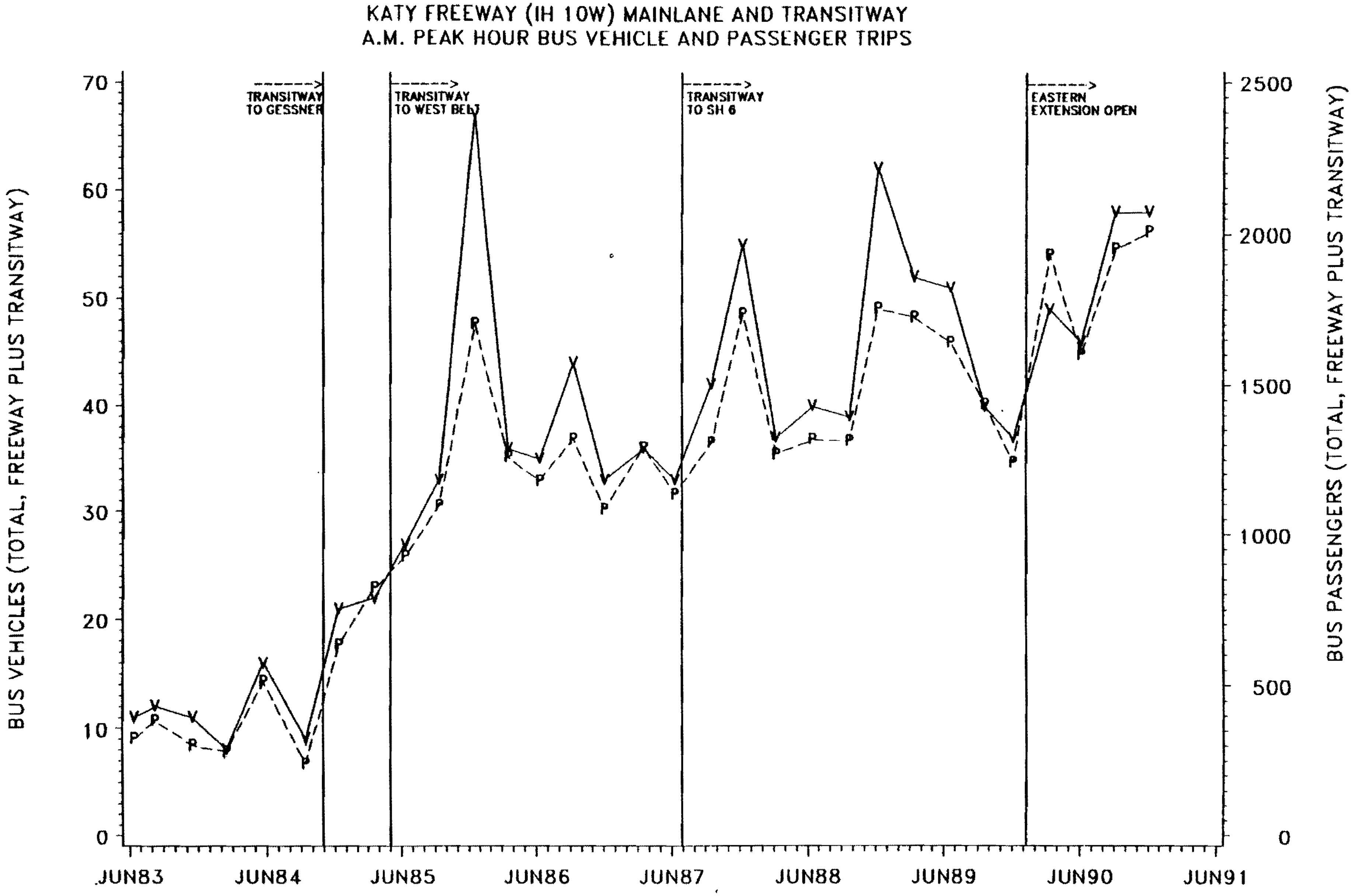
FIGURE A-17



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 TRANSITWAY, IT REPRESENTS TOTAL PERSONS (FREEWAY + TRANSITWAY) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 4 LANES
DATA FOR FREEWAYS WITHOUT TRANSITWAYS ARE A COMPOSITE OF
GULF FWY (6/83 – 4/88) AND SOUTHWEST FWY (6/86 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : K = KATY FREEWAY EFFICIENCY
N = FREEWAYS WITHOUT TRANSITWAY

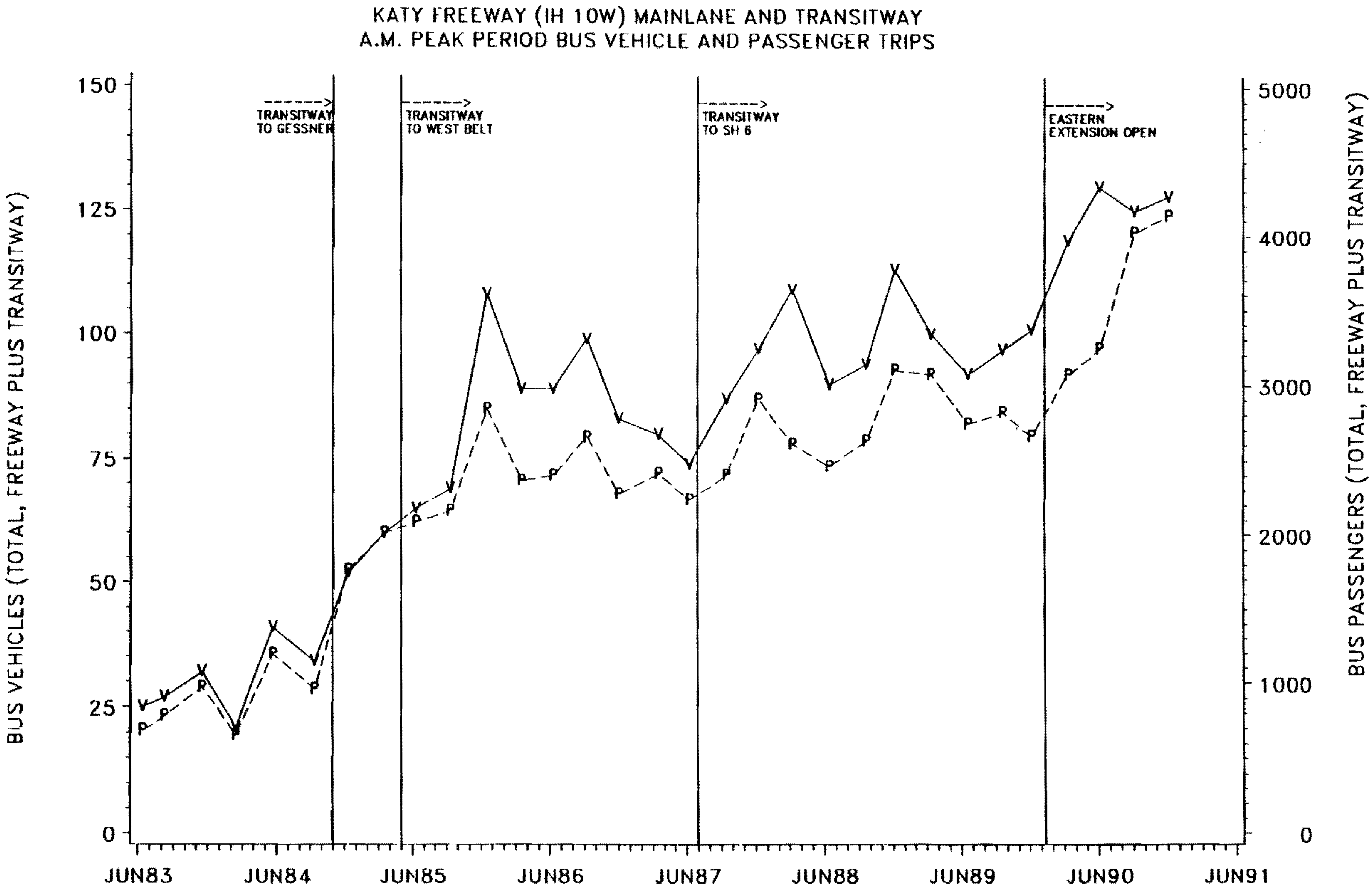
FIGURE A-18



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

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

FIGURE A-19

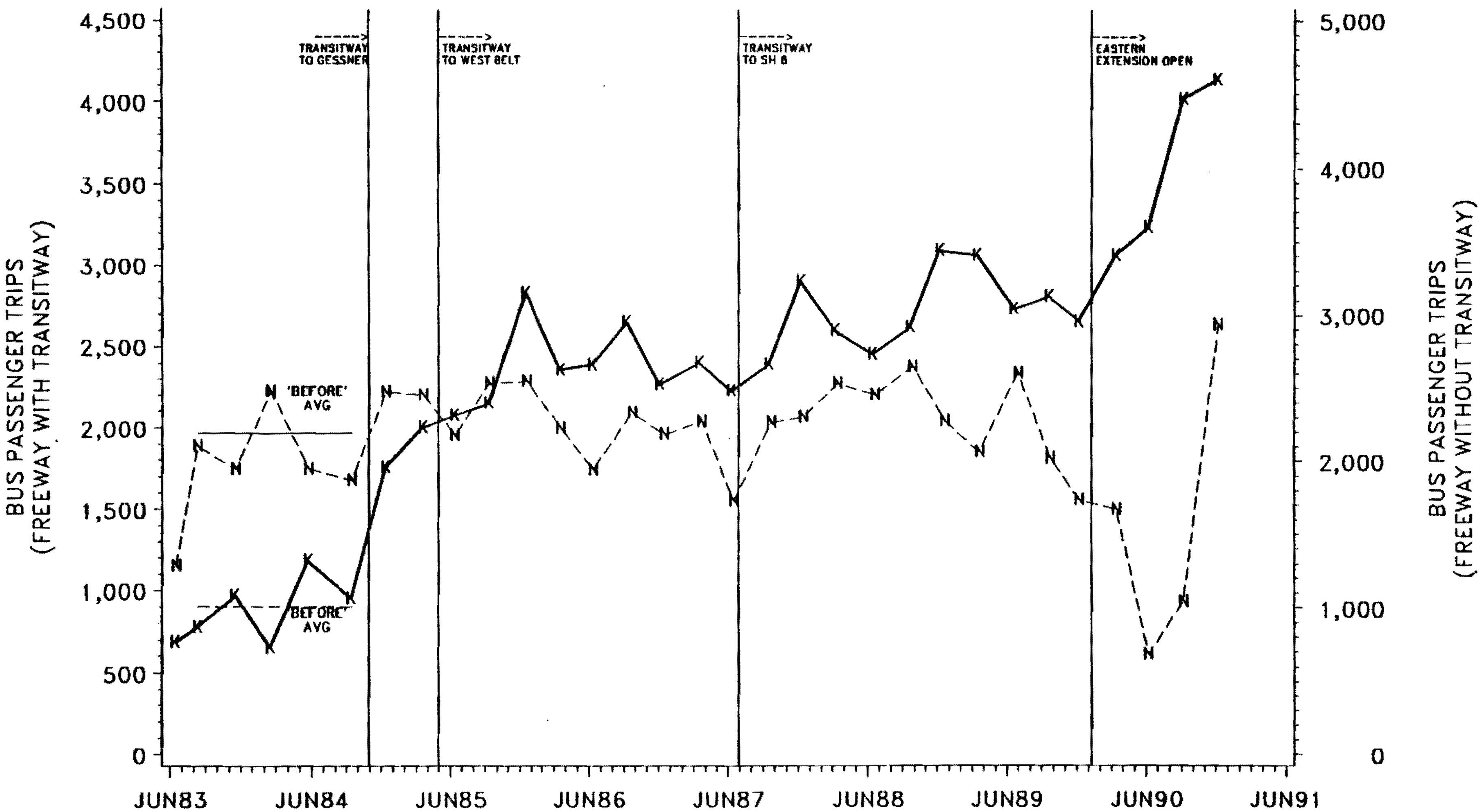


A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE A-20

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

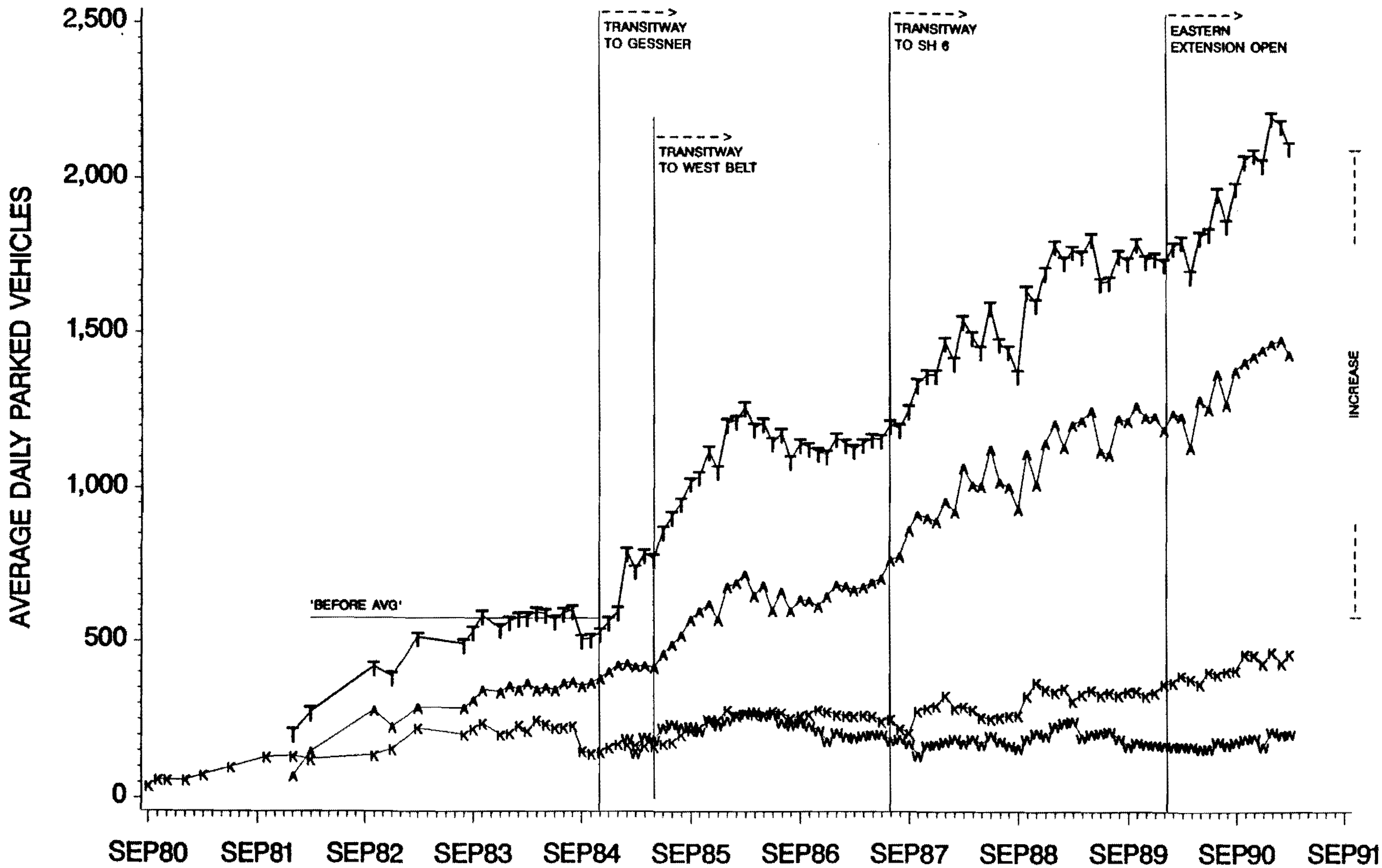


A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA FOR FREEWAYS WITHOUT TRANSITWAYS ARE A COMPOSITE OF
GULF FWY (6/83 – 4/88) AND SOUTHWEST FWY (9/86 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE A-21

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



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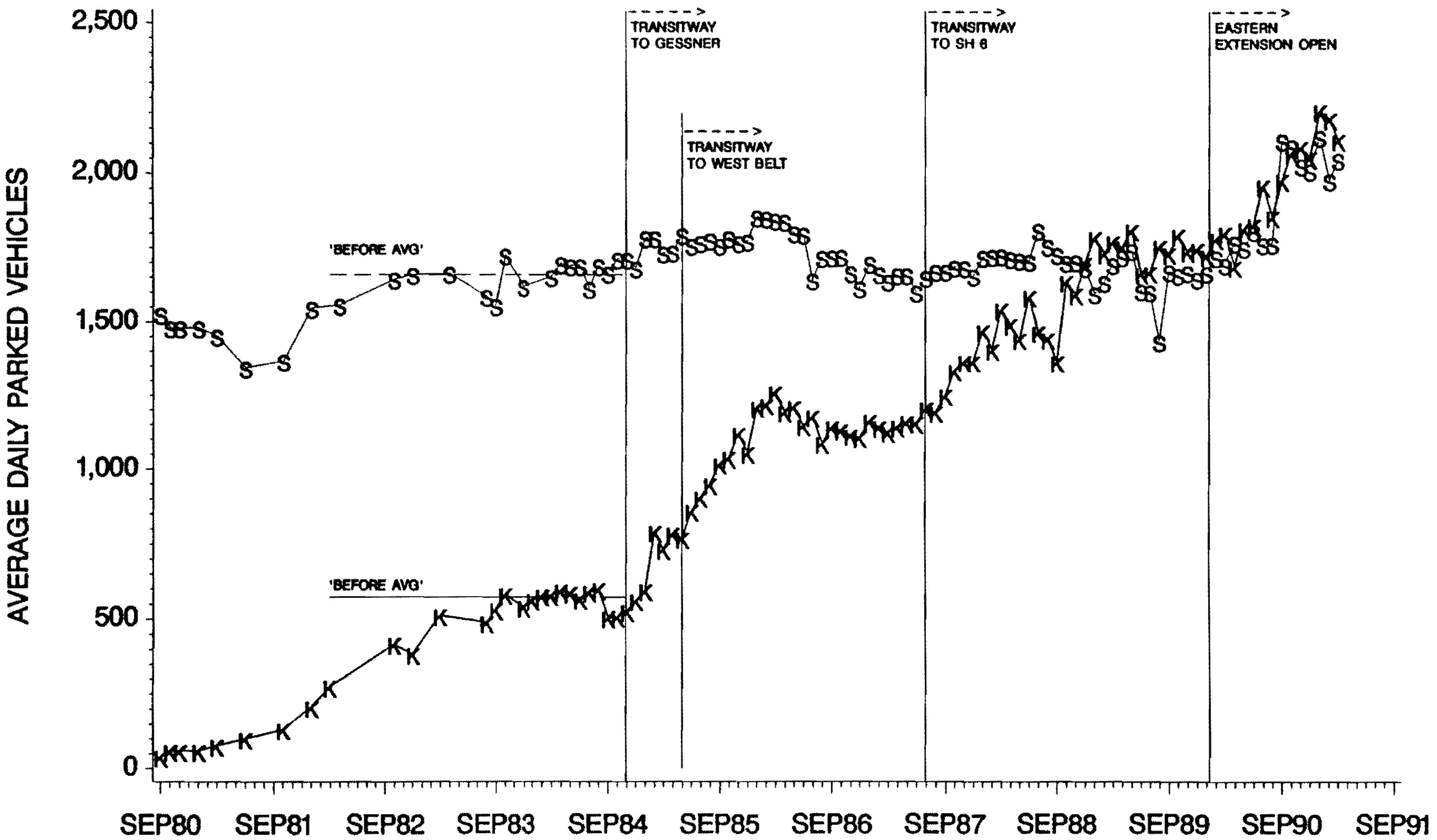
TRANSITWAY EXTENSION FROM WEST BELT TO SH 6 (5.0 MI.) OPENED JUNE 29, 1987
TRANSITWAY EASTERN EXTENSION (1.17 MI.) OPENED JANUARY 9, 1990
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL PARKED VEHICLES
K = KINGSLAND LOT (1326 SPACES)
W = WEST BELT LOT (1111 SPACES)
A = ADDICKS LOT (1155 SPACES)

FIGURE A-22

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



KATY TRANSITWAY PHASE 1, POST OAK TO GESSNER (4.7 MI.), OPENED OCTOBER 29, 1984
TRANSITWAY EXTENSION FROM GESSNER TO WEST BELT (1.7 MI.) OPENED MAY 2, 1985
TRANSITWAY EXTENSION FROM WEST BELT TO SH 6 (5.0 MI.) OPENED JUNE 29, 1987
TRANSITWAY EASTERN EXTENSION (1.17 MI.) OPENED JANUARY 9, 1990
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : K - KATY FREEWAY
S - FREEWAY WITHOUT TRANSITWAY (SOUTHWEST)

APPENDIX B

NORTH FREEWAY AND HOV LANE DATA

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

Summary of A.M. Peak-Period, Peak-Direction Katy Freeway and Transitway Data, December 1990
Prepared by Texas Transportation Institute

Type of Data Phase 1 of Transitway Became Operational 8/29/88 Contraflow Lane Became Operational 8/79	"Representative" Pre-Contraflow Value[7]	"Representative" Current Value	% Change
Transitway Data			
Transitway Length (miles)		13.5	
Transitway Cost (millions of 1990 dollars)		$75.9	
Person-Movement			
Peak Hour (7-8 a.m.)	—	4,429	—
Peak Period (6-9:30 a.m.)	—	9,089	—
Total Daily	—	19,033	—
Vehicle Volumes			
Peak Hour	—	810	—
Peak Period	—	1,773	—
Vehicle Occupancy, Peak Hour (persons/veh)	—	5.47	—
Accident Rate (Accidents/MVM), 4/84-12/90	—	1.28	—
Vehicle Breakdowns (VMT/Breakdown), 4/84-12/90	—	34,313	—
Violation Rate (6-9:30 a.m.)		1.5%	
Peak Hour Lane Efficiency[1] (1000's)	—	248	—
Annual Value of User Time Saved (millions)[7]	—	$2.5 to $4.9	—
Freeway Mainlane Data (see note)			
Person Movement	6,335	8,280	+30.7%
Peak Hour	—	24,484	—
Peak Period (6-9:30 a.m.)			
Vehicle Volume	4,950	7,181	+45.1%
Peak Hour	—	21,684	—
Peak Period	1.28	1.15	-10.2%
Vehicle Occupancy, Peak Hour (persons/veh)	1.28	1.13	-11.7%
Accident Rate (Accidents/MVM)[2]	1.82	1.90	+ 4.4%
Avg. Operating Speed[3]			
Peak Hour	20	33.2	+66.0%
Peak Period	30	43.6	+45.3%
Peak Hour lane Efficiency[1] (1000's)	41	68	+65.8%
Combined Freeway Mainland and Transitway Data			
Total Person Movement			
Peak Hour	6,335	12,709	+100.6%
Peak Period	—	33,573	—
Vehicle Volume			
Peak Hour	4,950	7,991	+61.4%
Peak Period	—	23,457	—
Vehicle Occupancy			
Peak Hour	1.28	1.59	+24.2%
Peak Period	1.28	1.43	+11.7%
2+ Carpool Volumes			
Peak Hour	700	1,587	+126.7%
Travel Time (minutes)[3]			
Peak Hour	23.2[4]	8.3[5]	-64.2%
Peak Period	15.5[4]	8.0[5]	-48.4%
Peak Hour Lane Efficiency[1] (1000's)	41	105	+156.1%

Footnotes on page B-3

Summary of P.M. Peak-Period, Peak-Direction Katy Freeway and Transitway Data, 1990 Continued

Type of Data	"Representative" Current Value
Transit Data	
Bus Vehicle Trips	
Peak Hour	63
Peak-Period	137
Bus Passenger Trips	
Peak Hour	2,625
Peak Period	5,195
Bus Occupancy (persons/bus)	
Peak Hour	41.7
Peak Period	37.9
Vehicles Parked in Corridor Park & Ride Lots	4,157
Bus Operating Speed (mph)[5]	
Peak Hour	56.0[4]
Peak Period	58.1[4]

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

Footnotes on following page.

Comparison of Measures of Effectiveness, Freeway With (Katy, I-10W) and Freeway Without (Southwest US 59) Transitway, Houston[6]

Measure of Effectiveness	North Freeway	Southwest Freeway
Average P.M. Peak-Hour Vehicle Occupancy		
Bus Passengers, Peak Period	1.59*	1.31
Cars Parked at Park-and-Ride Lots	5,195	2,100
Facility Per Lane Efficiency	4,157	1,665
	105**	60

* 1978 pre-contraflow occupancy estimated at 1.28 persons per vehicle
** 1978 pre-contraflow per lane efficiency estimated to be 41.

Footnotes on following page

Footnotes

[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.
[2]Accidents analyzed between North Shepherd and Hogan, a distance of approximately 7.75 miles. This corresponds to Phase 1 of the transitway. "Before" data are for the period 1/82 through 11/84. "After" accident rate shown is for the time period from 12/84 to 9/90. Only officer reported accidents are included in files. 1990 freeway volumes estimated by TTI to compute rates.
[3]From North Shepherd to Hogan, a distance of 7.75 miles.
[4]Data pertains to operation in the freeway mainlanes.
[5]Data pertains to operation in the transitway.
[6]Based on time savings for transitway users in 1990, an annual estimate of travel time savings to transitway users is developed. A value of time of $9.25/hour is used based on the value applied in the Highway Economic Evaluation Model.
[7]Pre-transitway 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 transitway in November 1984. Pre-contraflow data are for 1978.

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

TRANSITWAY DATA

Description

- The contraflow lane operation began 8/28/79
- Phase 1 and 2 of transitway 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 transitway (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 Transitway HOV replaces contraflow
  - 4/2/90 Transitway extended to Beltway 8 (13.5 miles)
  - 6/26/90 carpools allowed on HOV
  - 6/30/90 weekend operations begin

Person Movement

- In December 1990, 19,033 person trips per day were served on the HOV lane.
- A.M. Peak Hour, 4,429 persons/hour.

  - 2,625 (59%) by bus, 366 (8%) by vanpool, 1,438 (33%) by carpool, (Figure 1).
  - Average transitway vehicle occupancy = 5.47 persons/vehicle.

- A.M. Peak Period, 9,089 persons.

NORTH HOV LANE OPERATING SEGMENT
Estimated Capital Cost, (millions)

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 Exapnsion (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 SDHPT

NORTH HOV LANE, FUTURE SEGMENTS
Estimated Capital Cost, (millions)

Cost Component	Year of Construction Cost		Factor	Estimated Cost 1990 Dollars	
HOV Lane and Ramps					
Beltway 8 to Airtex		$14.2	1.00		$14.2
Airtex to FM 1960		10.5	1.00		10.5
Kuykendahl Interchange		10.7	1.00		10.7
FM 1960 Interchange		13.8	1.00		13.8
SUB-TOTAL	$49.2			$49.2	
Per Mile		$7.9			$7.9
Surveillance, Communication and Control	$1.5			$1.5	
Support Facilitites					
Kuykendahl P/R Expansion		$7.4	1.00		$7.4
Stuebner-Airline P/R		$8.1	1.00		8.1
SUB-TOTAL	$15.5			$15.5	
Per Mile		$2.5			$2.5
TOTAL COST	$66.2			$66.2	
COST PER MILE (6.2 miles)	$10.4			$10.4	

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

- 5,195 (57%) by bus, 741 (8%) by vanpool, 3,153 (35%) by carpool (Figure 2).

<u>Vehicle Movement</u>

- A.M. Peak Hour, 810 vph
  - 63 (8%) bus, 44 (5%) vans, 703 cars (87%) (Figure 3).

- A.M. Peak Period, 1773 vehicles.
  - 137 (8%) bus, 87 (5%) vans, 1549 (87%) cars (Figure 4).

<u>Accident Rate</u>

- For the period from November 1984 through September 1990, the transitway accident rate was 1.28 accidents per million vehicle miles.

<u>Vehicle Breakdown Rates</u>

- The following vehicle breakdown rates were observed between December, 1984 and December 1990.

  - Buses; 1 breakdown per 27,354 vehicle-miles of travel (VMT).
  - Vanpools; 1 breakdown per 92,727 VMT.
  - Carpools; 1 breakdown per 39,046 VMT.
  - Overall weighted average; 1 breakdown per 34,313 VMT.

<u>Violation Rate</u>

- The observed violation rate (vehicles on the transitway not eligible to use the transitway) is approximately 1.5%.

<u>Peak Hour Lane Efficiency</u>

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. For the transitway lane, this value (expressed in 1000's) is approximately 248.0.

<u>Travel Time Savings</u>

- The users of the transitway experience a travel time savings (Figure 5).

- The tables on the following page indicate that, on a typical non-incident day, travel time savings of approximately 1,057 hours (63,422 min.) are realized. Assuming 250 days of operation, annual savings would be 264,250 hours. At $9.25/hour, this equates to $2.447 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 transitway users are estimated to be in the range of $2.44 to $4.88 million per year.

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 8,280 persons in the peak hour (Figure 6). Prior to contraflow implementation, limited data suggest this value was 6,335.

- A.M. peak period mainlane person trips are shown in Figure 7.

Vehicle Volume

- In the a.m. peak hour, 7,181 vehicles use the mainlanes (Figure 6). Prior to contraflow implementation, limited data suggest this value was 4,950.

- In the a.m. peak period, 21,684 vehicles use the mainlanes (Figure 7).

Southbound A.M. Travel Time Savings for North Transitway
(Average of 4 Quarterly Travel Time Surveys Conducted in 1990)

Time of Day	Measured Travel Time			Transitway 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	4.76	4.61	0.15	181	227	520	927	136.44
6:30	5.30	4.56	0.75	377	346	947	1,669	1,249.24
7:00	5.28	4.35	0.93	536	213	1,176	1,925	1,788.41
7:30	5.70	4.43	1.28	430	30	1,086	1,546	1,972.66
8:00	4.62	4.45	0.17	201	7	676	884	151.02
8:30	4.52	4.32	0.20	77	6	180	263	52.28
9:00	4.47	4.47	-0.01	21	4	0	25	-0.14
Peak Period Total				1,822	832	4,584	7,238	5,349.92
Section From N. Shepherd to the Hogan Overpass								
6:00	8.26	8.14	0.12	210	227	726	1,163	143.76
6:30	10.14	8.04	2.10	348	463	1,629	2,440	5,119.56
7:00	13.29	8.02	5.27	520	329	2,031	2,880	15,164.00
7:30	14.72	8.48	6.23	505	110	1,860	2,475	15,425.94
8:00	11.46	8.00	3.46	222	20	941	1,183	4,090.34
8:30	8.95	7.50	1.45	102	1	344	447	648.15
9:00	7.82	7.86	-0.04	35	0	28	63	-2.78
Peak Period Total				1,942	1,151	7,557	10,650	40,588.98
Northbound PM Travel Time Savings for North Transitway								
Section from Sam Houston Parkway to N. Shepherd								
15:30	4.40	4.37	0.03	51	14	189	245	8.12
16:00	4.86	4.57	0.29	169	257	532	958	276.09
16:30	4.62	4.62	0.00	239	128	463	831	0.00
17:00	6.15	5.15	1.00	375	215	1,345	1,935	1,942.81
17:30	10.67	5.09	5.58	314	122	1,104	1,541	8,596.85
18:00	5.57	5.56	0.02	252	1	653	907	17.63
18:30	4.93	4.62	.31	116	3	133	252	78.50
Peak Period Total				1,516	741	4,420	6,678	10,920.00
Section from N. Shepherd to the Hogan Overpass								
15:30	7.79	7.98	-0.19	61	46	403	510	-94.92
16:30	8.70	8.48	0.21	195	306	947	1,448	310.66
16:30	8.41	8.59	-0.18	249	191	916	1,355	-240.95
17:00	9.70	8.63	1.07	489	355	2,149	2,992	3,191.20
17:30	9.99	8.73	1.25	437	165	1,713	2,315	2,903.08
18:00	8.83	8.26	0.57	236	23	755	1,014	578.12
18:30	7.96	8.02	-0.07	110	20	378	508	-33.84
Peak Period				1,776	1,104	7,261	10,141	6,613.36

Vehicle Occupancy

- In the a.m. peak hour, mainlane occupancy is approximately 1.15.
- In the a.m. peak period, mainlane occupancy is approximately 1.13.

Accident Rate

- Implementation of the transitway resulted in narrower shoulders and no inside emergency shoulder.
- Prior to opening the transitway, a contraflow lane was in operation. For the period (1/82 to 11/84) prior to opening the transitway, the freeway accident rate was 1.82 accidents per million vehicle miles (MVM). From 12/84 through 9/90, since the transitway opened, the accident rate has been 1.90. Only officer reported accidents are included. 1990 freeway volumes estimated by TTI to obtain rates.

Average Operating Speed

- Average operating speed on the mainlanes has increased since the transitway opened (Figure 8).

Peak Hour Lane Efficiency

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of per lane efficiency.
- For the freeway mainlanes, the current peak hour per lane efficiency is 68.7.

COMBINED FREEWAY AND TRANSITWAY DATA

Total Person Movement

- Percent by transitway, a.m. peak.
  - At Little York, the transitway is carrying 35% of the total peak-hour person movement (Figure 9). In the peak period, the transitway carries 27% of the a.m. peak period person trips (Figure 10). Compared to pre-contraflow conditions, peak-hour person movement has increased by 100.6%.

Vehicle Occupancy

- The combined occupancy for the freeway and transitway in the peak hour is 1.59, versus 1.15 occupants per vehicle for the mainlanes (Figure 11). Occupancy in the peak period has also increased with the opening of the transitway (Figure 12). 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 transitway lane since 1979, has consistently been higher than the occupancy of freeways without transitways (Figure 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 104.6 (Figure 14). Prior to contraflow lane implementation, in 1978 the per lane efficiency was estimated to be 41. Freeway corridors without transitways experience lower efficiencies (Figure 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 16) and about 5,000 passengers per peak period (Figure 17). Likewise, the bus vehicle trips for the peak period have also remained consistent, with about 150 bus trips per peak period (Figure 17).

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

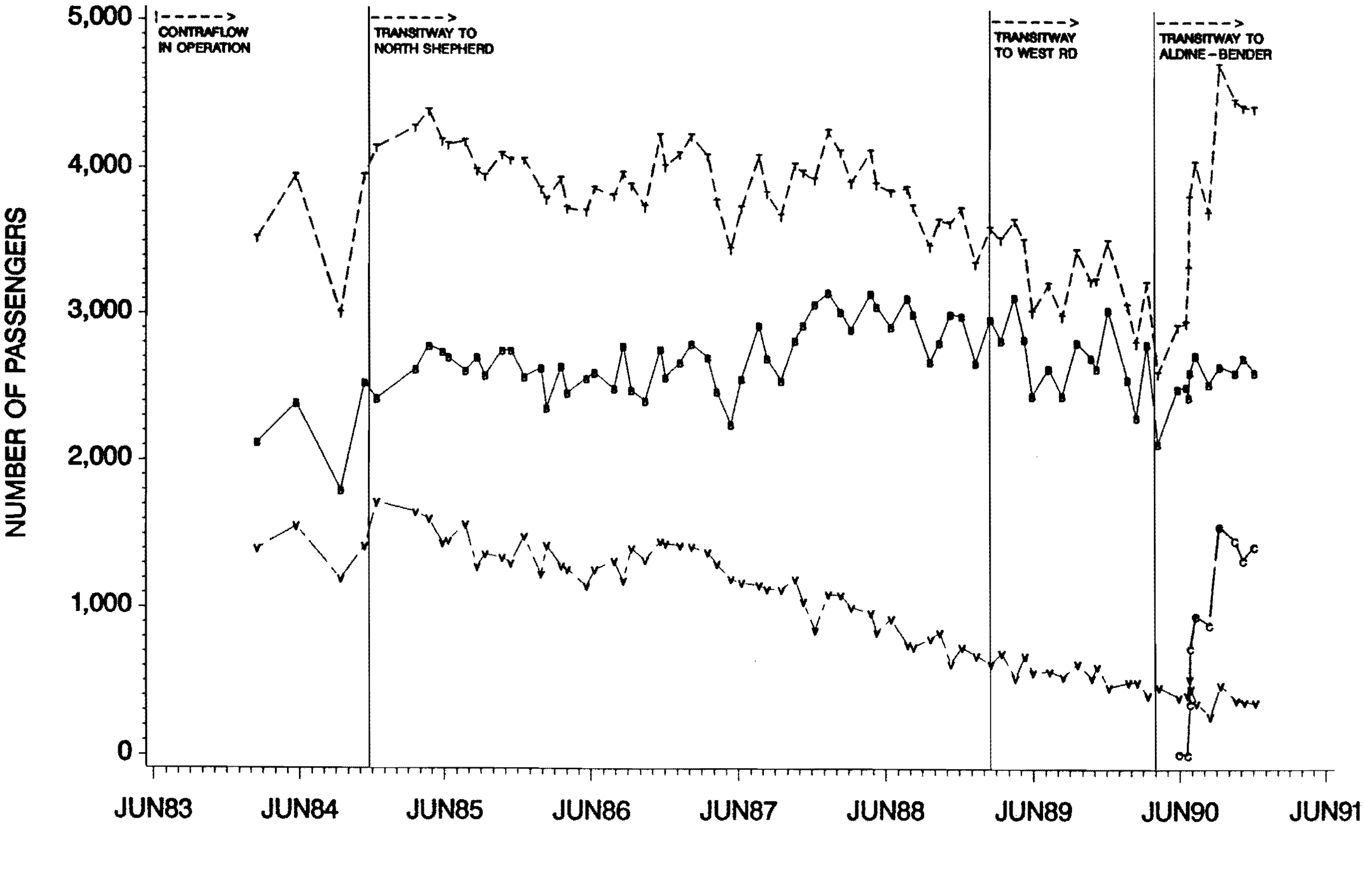
Park-and-Ride

- Currently, 4,157 vehicles are parked in the corridor park-and-ride lots. Approximately 59% of the 7,017 parking spaces are utilized (Figure 19).

- The Southwest Freeway, which does not have a transitway, has less than half the number of park-and-ride patrons as North Transitway. Southwest Freeway park-and-ride lots are operating at only 40% capacity as opposed to 59% on North Freeway (Figure 20).

FIGURE B-1

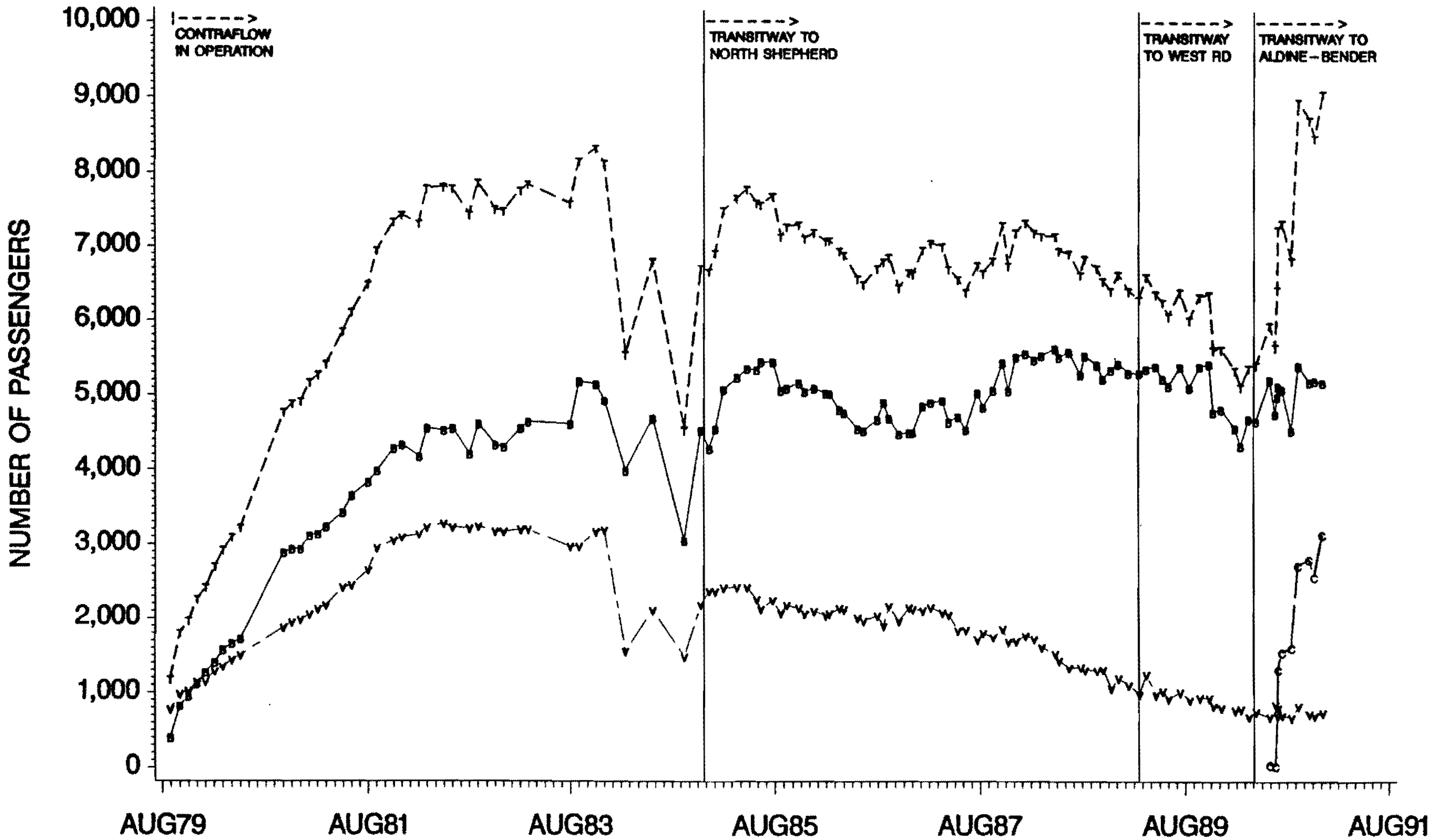
NORTH FREEWAY (IH 45N) TRANSITWAY
A.M. PEAK HOUR TRANSITWAY PERSON MOVEMENT



2+ CARPOOL AND OFF-PEAK OPERATION BEGAN JUNE 26, 1990
DATA COLLECTED SOUTHBOUND AT LITTLE YORK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

FIGURE B-2

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

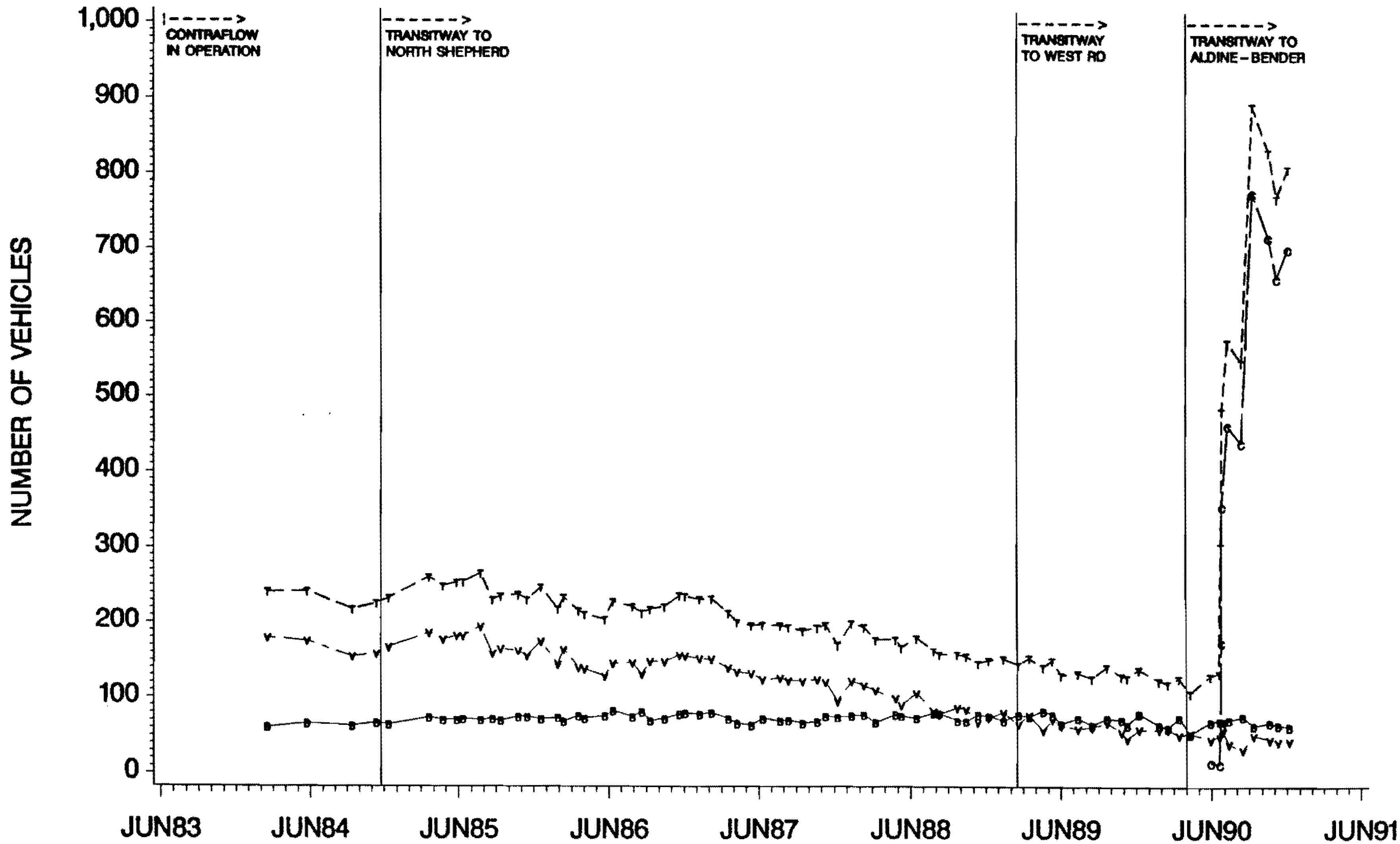


THE A.M. PEAK PERIOD IS 6:00 TO 8:45 A.M. FROM AUGUST 1979 THROUGH JUNE 1990
SINCE JUNE 1990 THE A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M
2+ CARPOOL AND OFF-PEAK OPERATION BEGAN JUNE 26, 1990
DATA COLLECTED SOUTHBOUND AT LITTLE YORK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE B-3

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

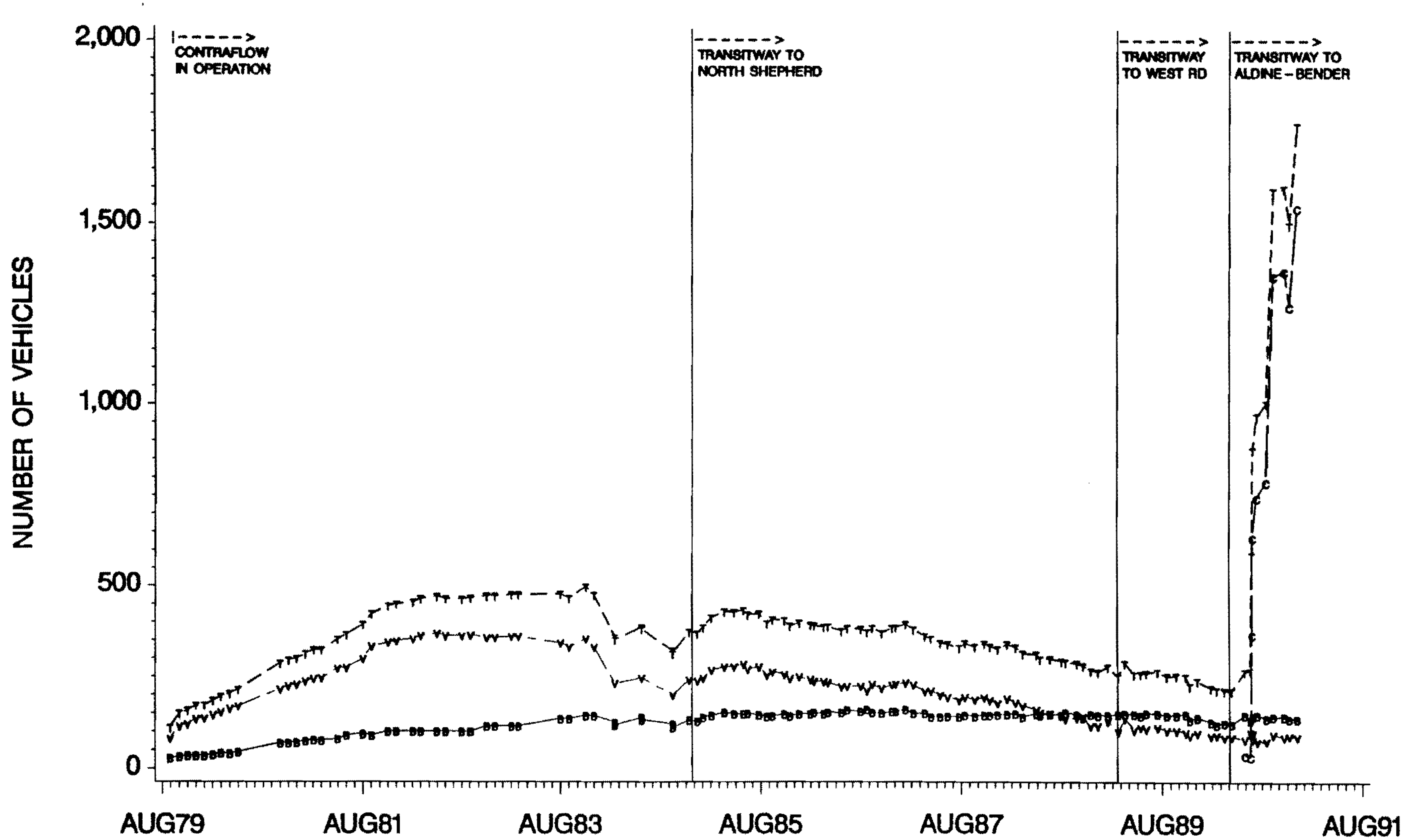


2+ CARPOOL AND OFF-PEAK OPERATION BEGAN JUNE 26, 1990
DATA COLLECTED SOUTHBOUND AT LITTLE YORK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE B-4

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

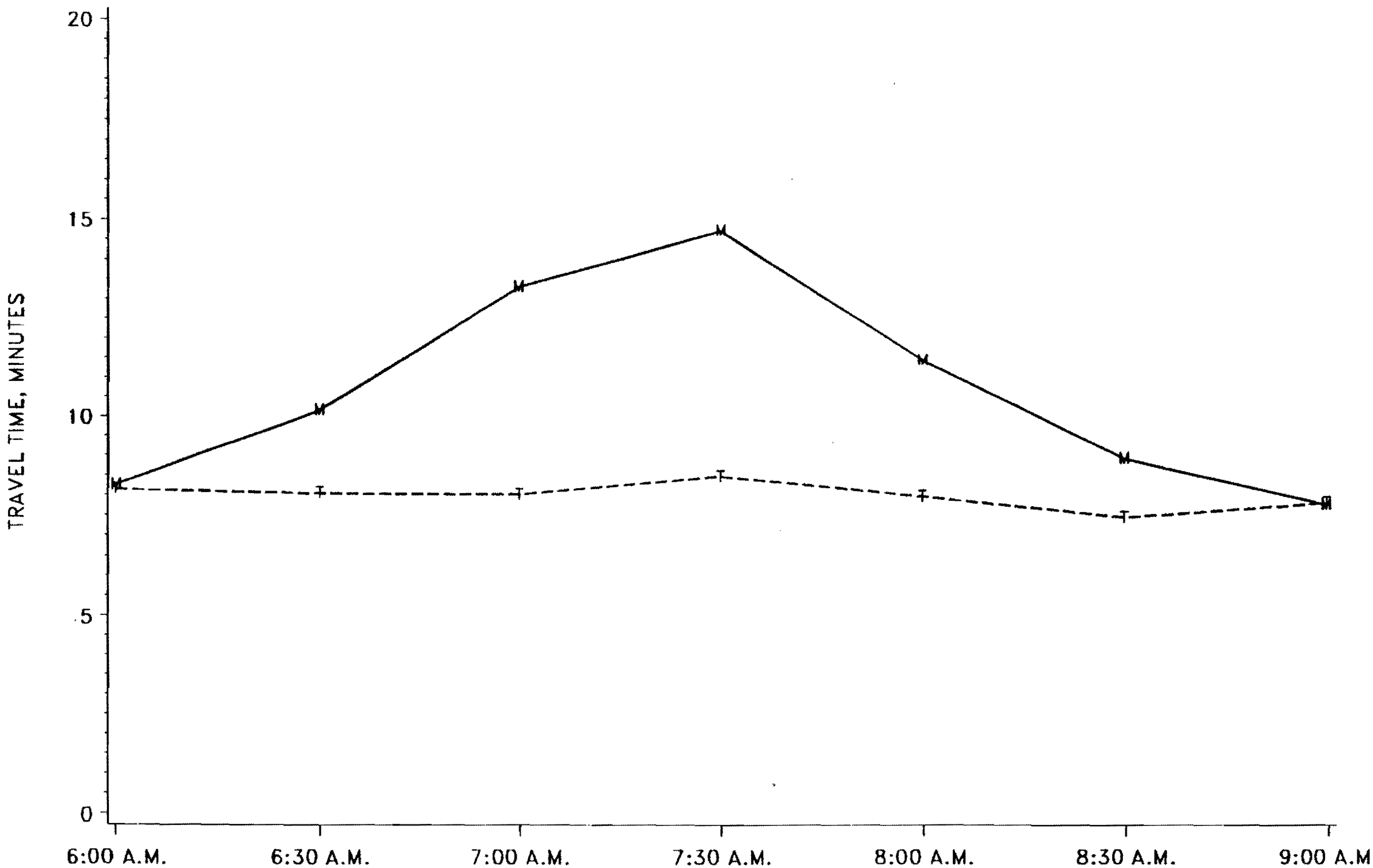


THE A.M. PEAK PERIOD IS 6:00 TO 8:45 A.M. FROM AUGUST 1979 THROUGH JUNE 1990
SINCE JUNE 1990 THE A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M
2+ CARPOOL AND OFF-PEAK OPERATION BEGAN JUNE 26, 1990
DATA COLLECTED SOUTHBOUND AT LITTLE YORK
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE B-5

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

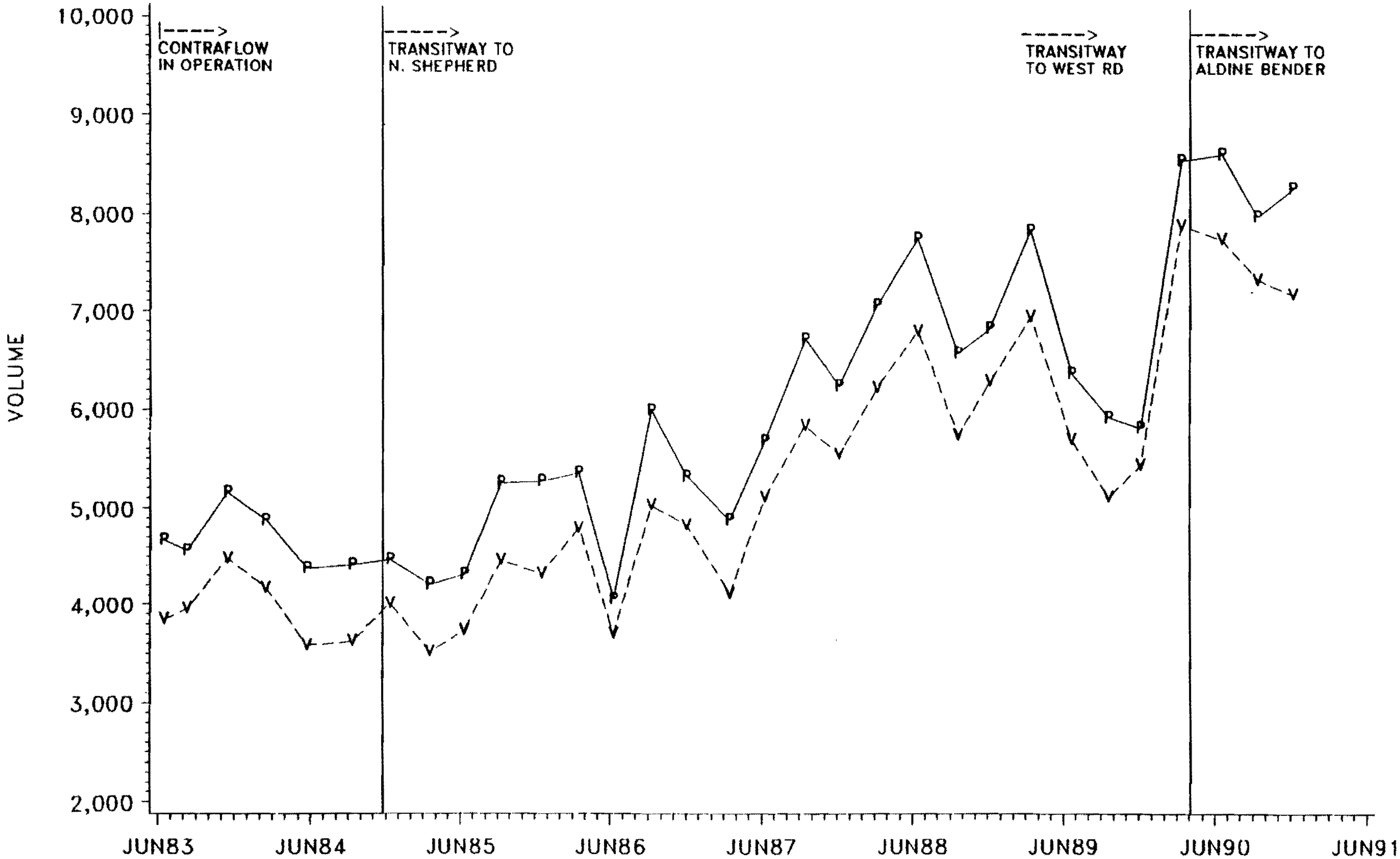


TRAVEL TIMES ARE FROM NORTH SHEPHERD TO HOGAN
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : M – MAINLANE TRAVEL TIME
T – TRANSITWAY TRAVEL TIME

FIGURE B-6

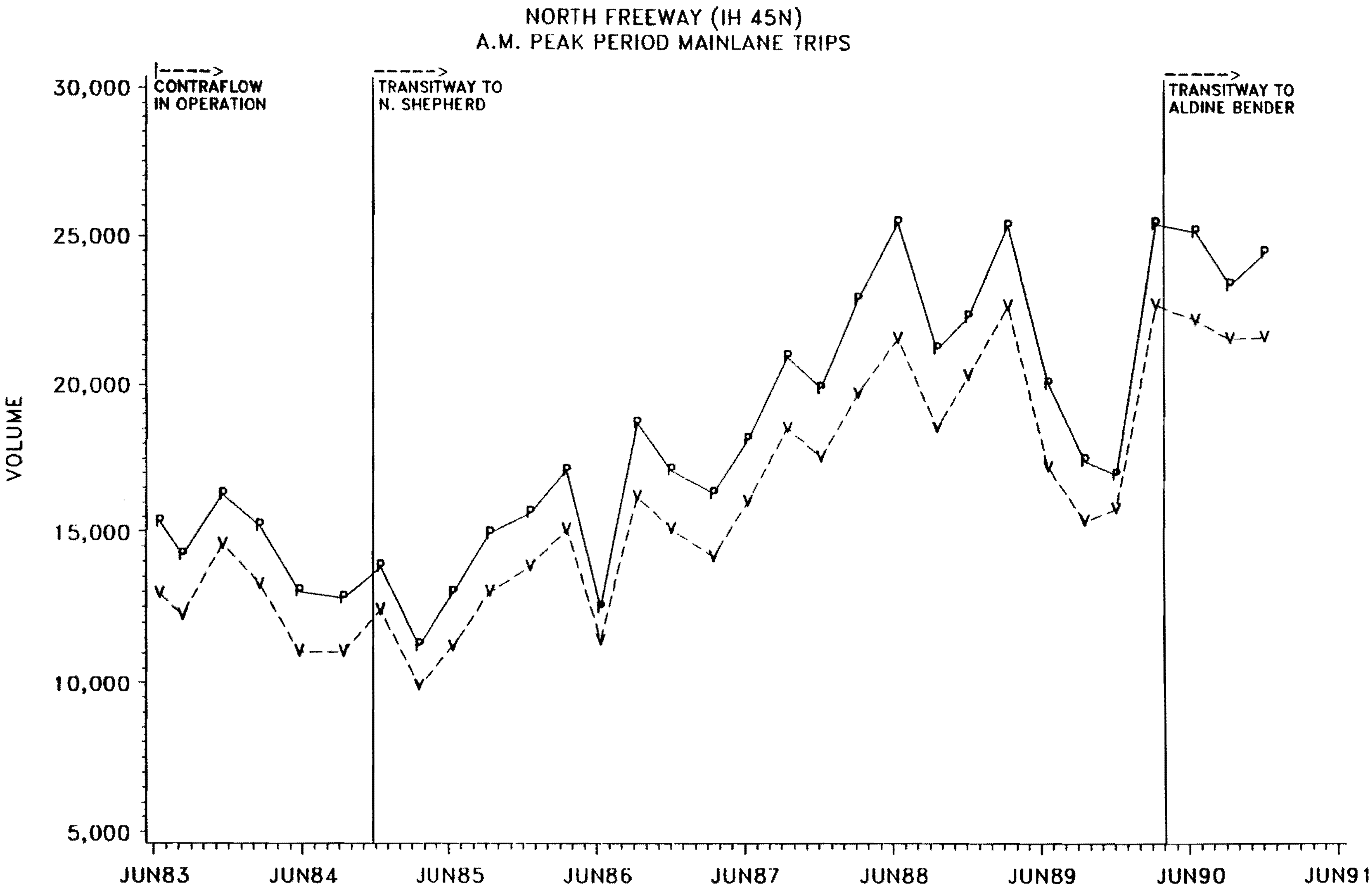
NORTH FREEWAY (IH 45N)
A.M. PEAK HOUR MAINLANE TRIPS



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

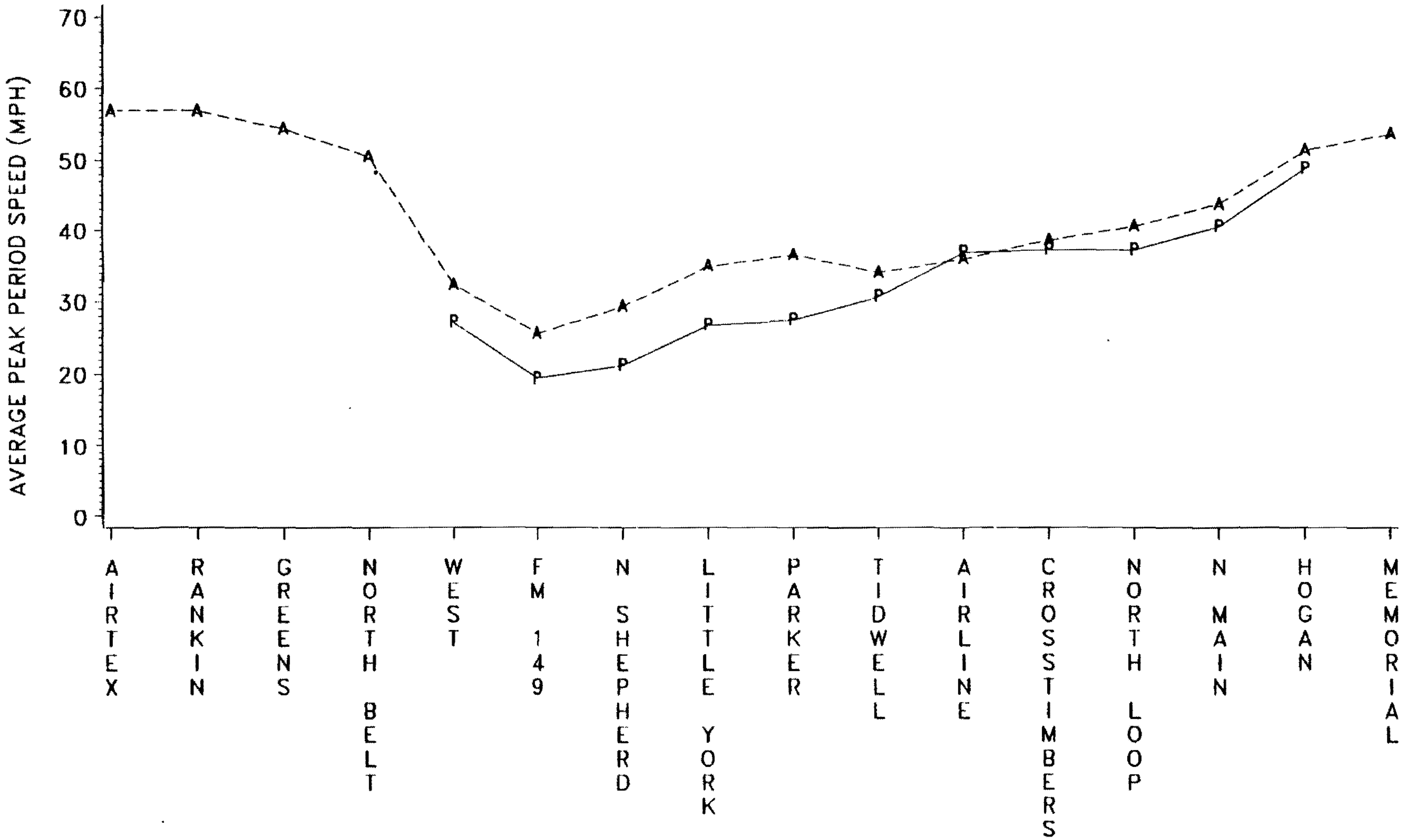


A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA COLLECTED SOUTHBOUND AT LITTLE YORK
SOUTHBOUND CROSS SECTION AT LITTLE YORK EXPANDED FROM 3 TO 4 LANES IN JUNE,
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = MAINLANE PERSONS
V = MAINLANE VEHICLES

FIGURE B-8

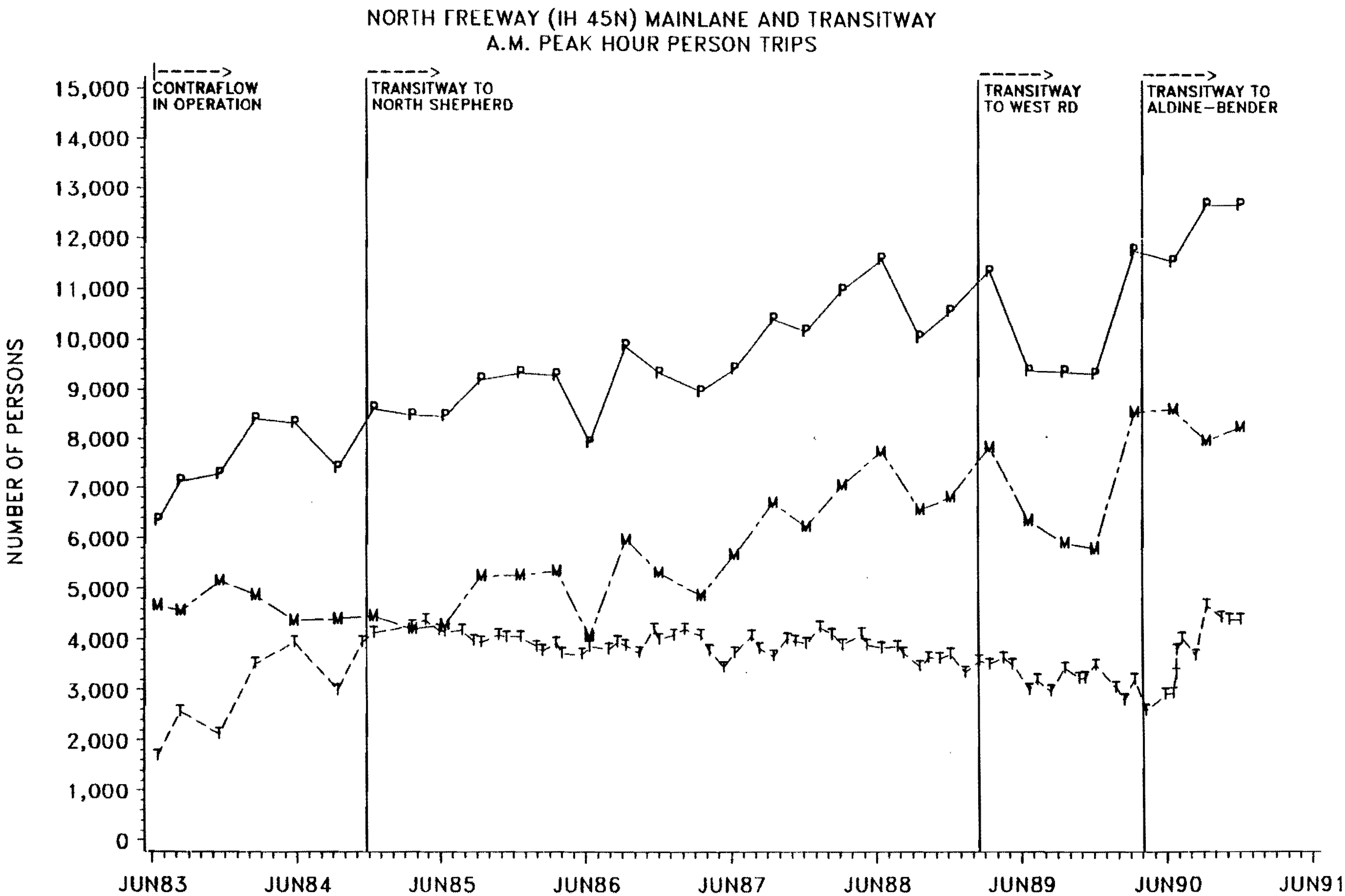
NORTH FREEWAY (IH 45N) MAINLANE TRAVEL TIME AND SPEED SURVEY
SOUTHBOUND, AIRTEX TO MEMORIAL
A.M. PEAK PERIOD



DATA COLLECTED 6:00 TO 9:30 A.M.
DATA COLLECTED FROM JUNE, 1983 TO DECEMBER, 1990
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

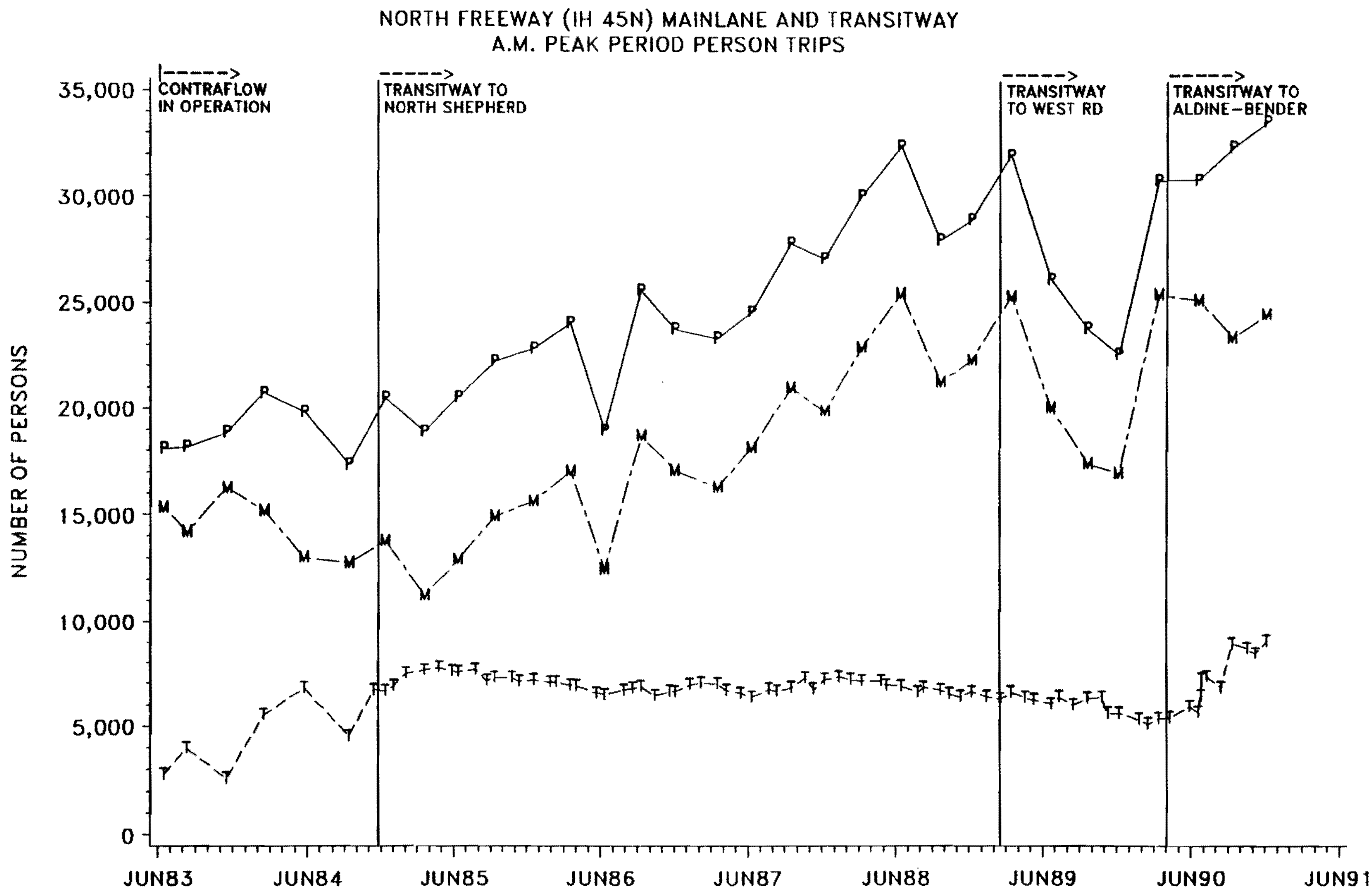
FIGURE B-9



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

LEGEND : P = TOTAL PERSONS
M = MAINLANE PERSONS
T = TRANSITWAY PERSONS

FIGURE B-10

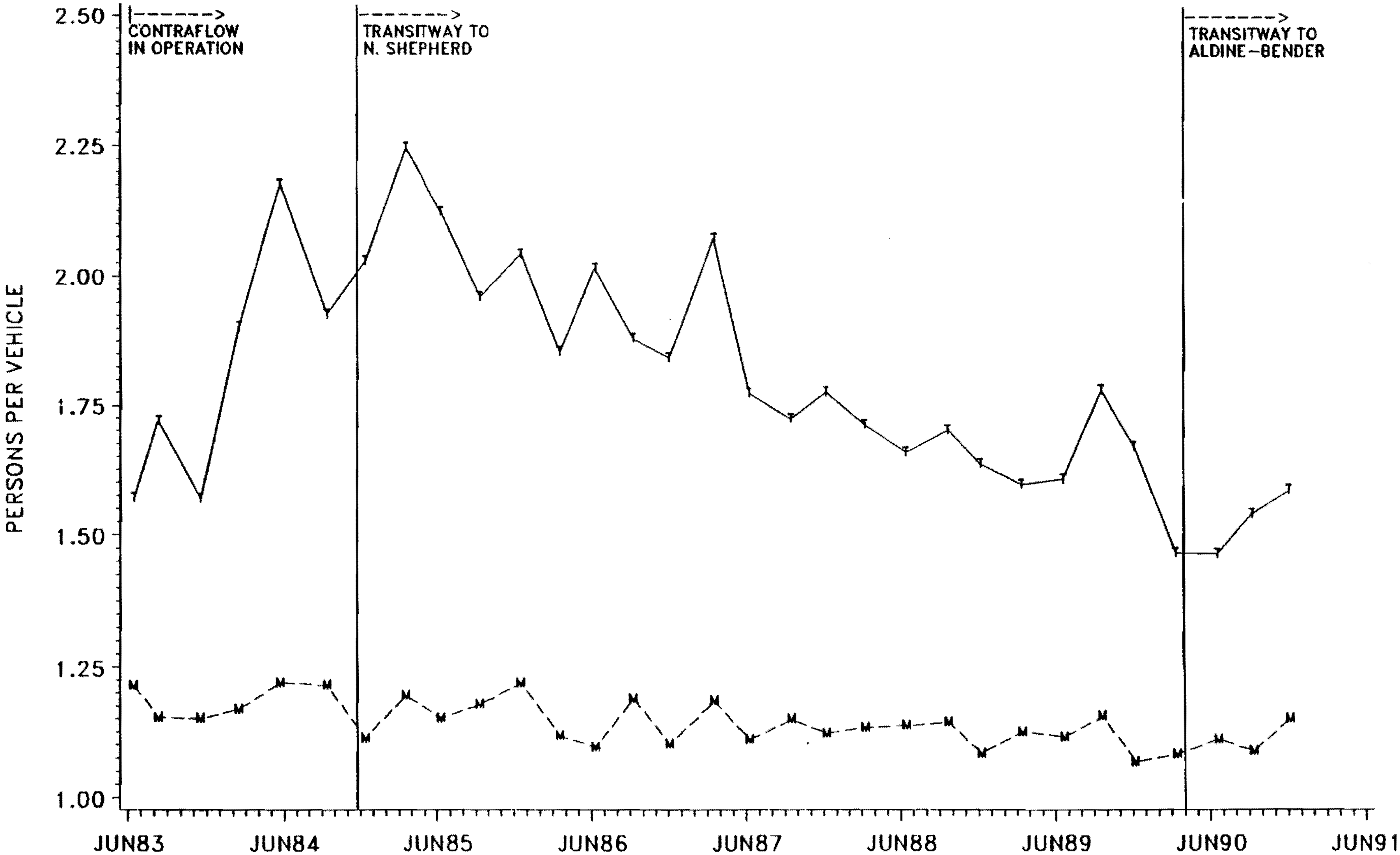


A.M. PEAK PERIOD DEFINED AS FROM 6:00 TO 9:30 A.M., TRANSITWAY ONLY OPERATES TO 8:45 A.M.
DATA COLLECTED SOUTHBOUND AT LITTLE YORK, 4 LANE SECTION
SOUTHBOUND FREEWAY CROSS SECTION INCREASED FROM 3 TO 4 LANES IN JUNE, 1987
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = TOTAL PERSONS
M = MAINLANE PERSONS
T = TRANSITWAY PERSONS

FIGURE B-11

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

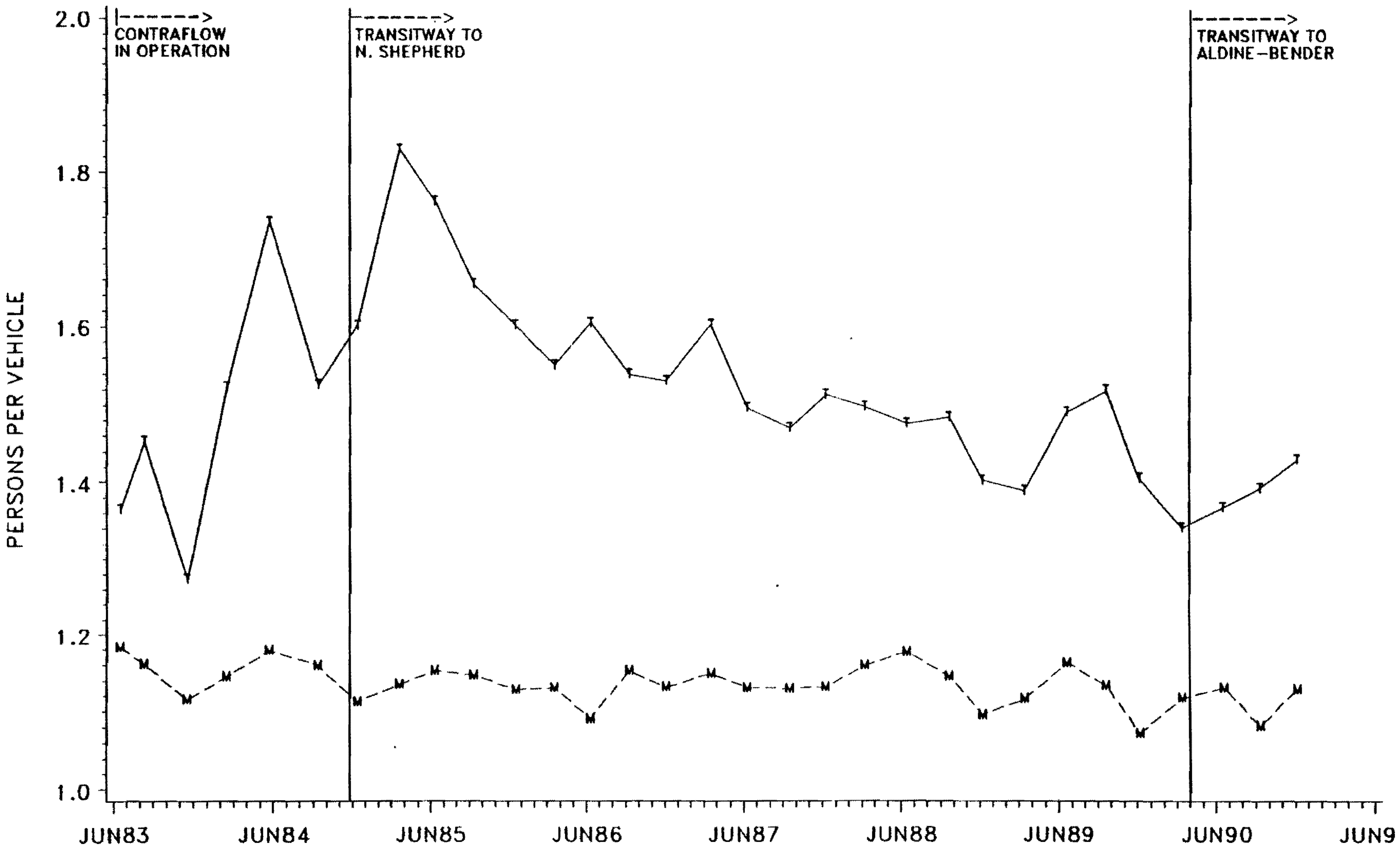


DATA COLLECTED SOUTHBOUND AT LITTLE YORK
SOUTHBOUND FREEWAY CROSS SECTION INCREASED FROM 3 TO 4 LANES IN JUNE, 1987
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE B-12

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

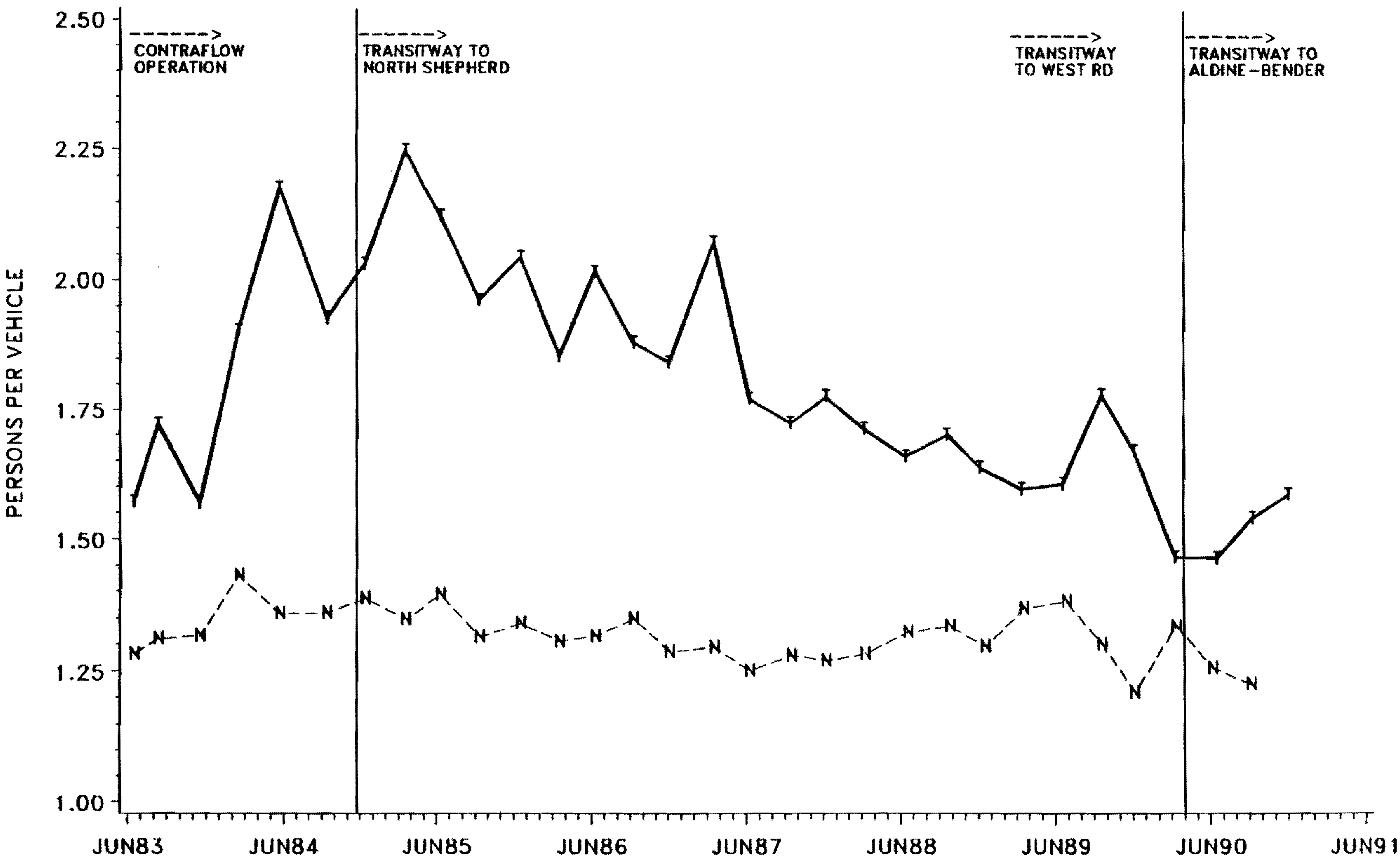


DATA COLLECTED SOUTHBOUND AT LITTLE YORK
PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
SOUTHBOUND FREEWAY CROSS SECTION INCREASED FROM 3 TO 4 LANES IN JUNE, 1987
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE B-13

A.M. PEAK HOUR AVERAGE OCCUPANCY
FREEWAY WITH AND WITHOUT TRANSITWAY

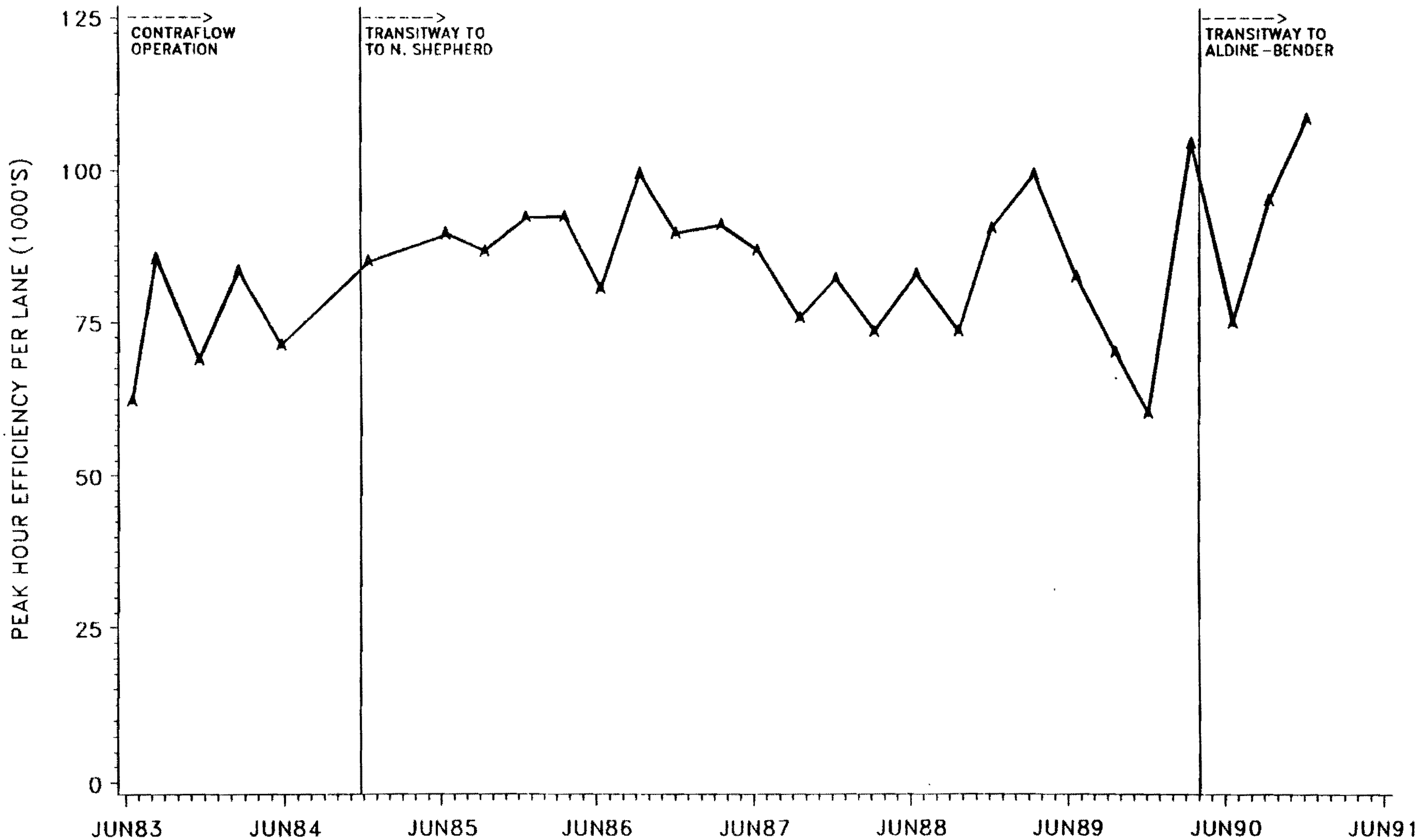


DATA FOR FREEWAYS WITHOUT TRANSITWAYS ARE A COMPOSITE OF
GULF FWY (6/83 - 4/88) AND SOUTHWEST FWY (9/86 - PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = NORTH FREEWAY AT LITTLE YORK
(WITH TRANSITWAY)
N = FREEWAYS WITHOUT TRANSITWAY

FIGURE B-14

NORTH FREEWAY TRANSITWAY EVALUATION
A.M. PEAK HOUR MAINLANE AND TRANSITWAY EFFICIENCY



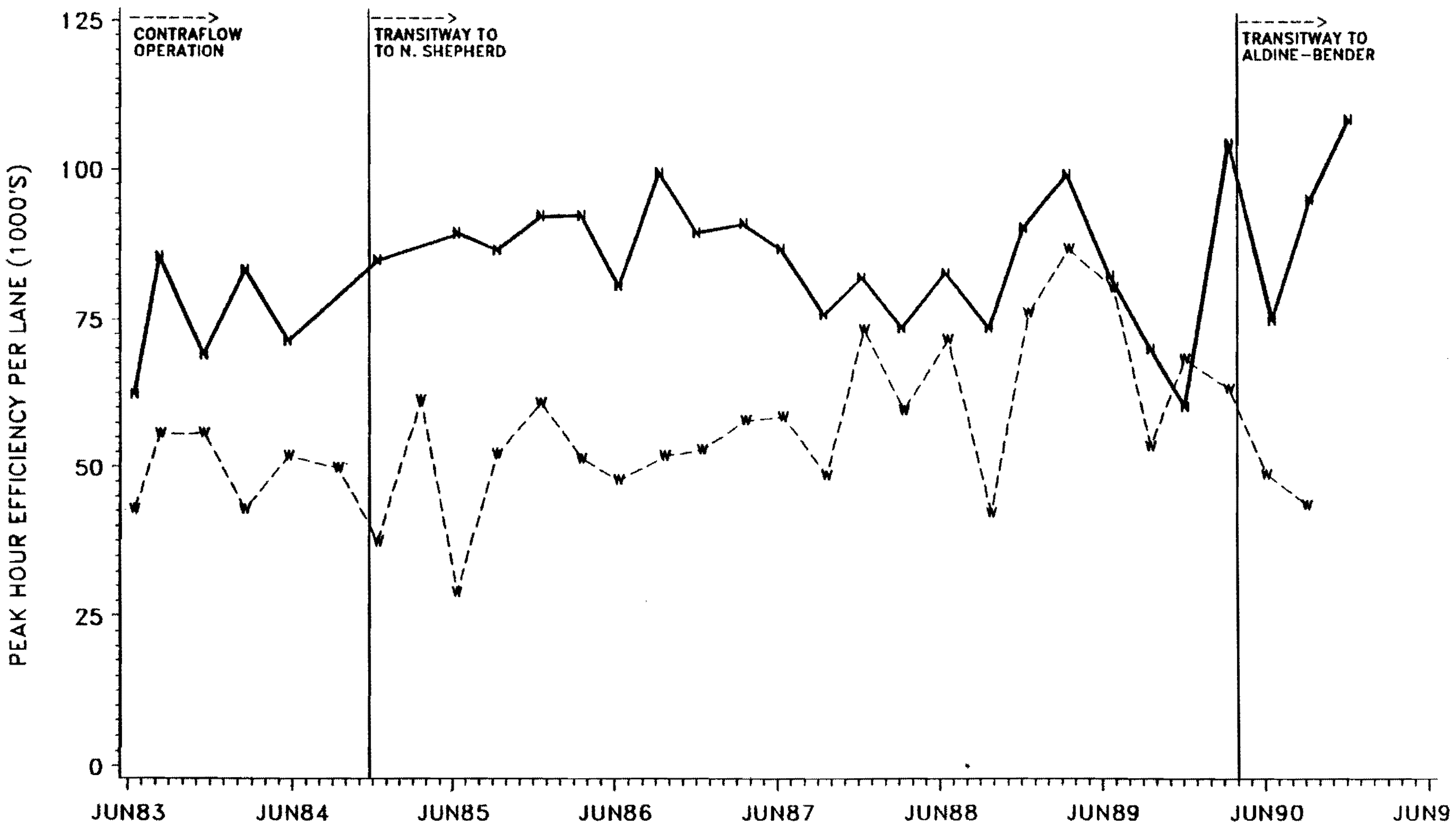
PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE TRANSITWAY, IT REPRESENTS TOTAL PERSONS (FREEWAY + TRANSITWAY) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 5 LANES

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 TRANSITWAY

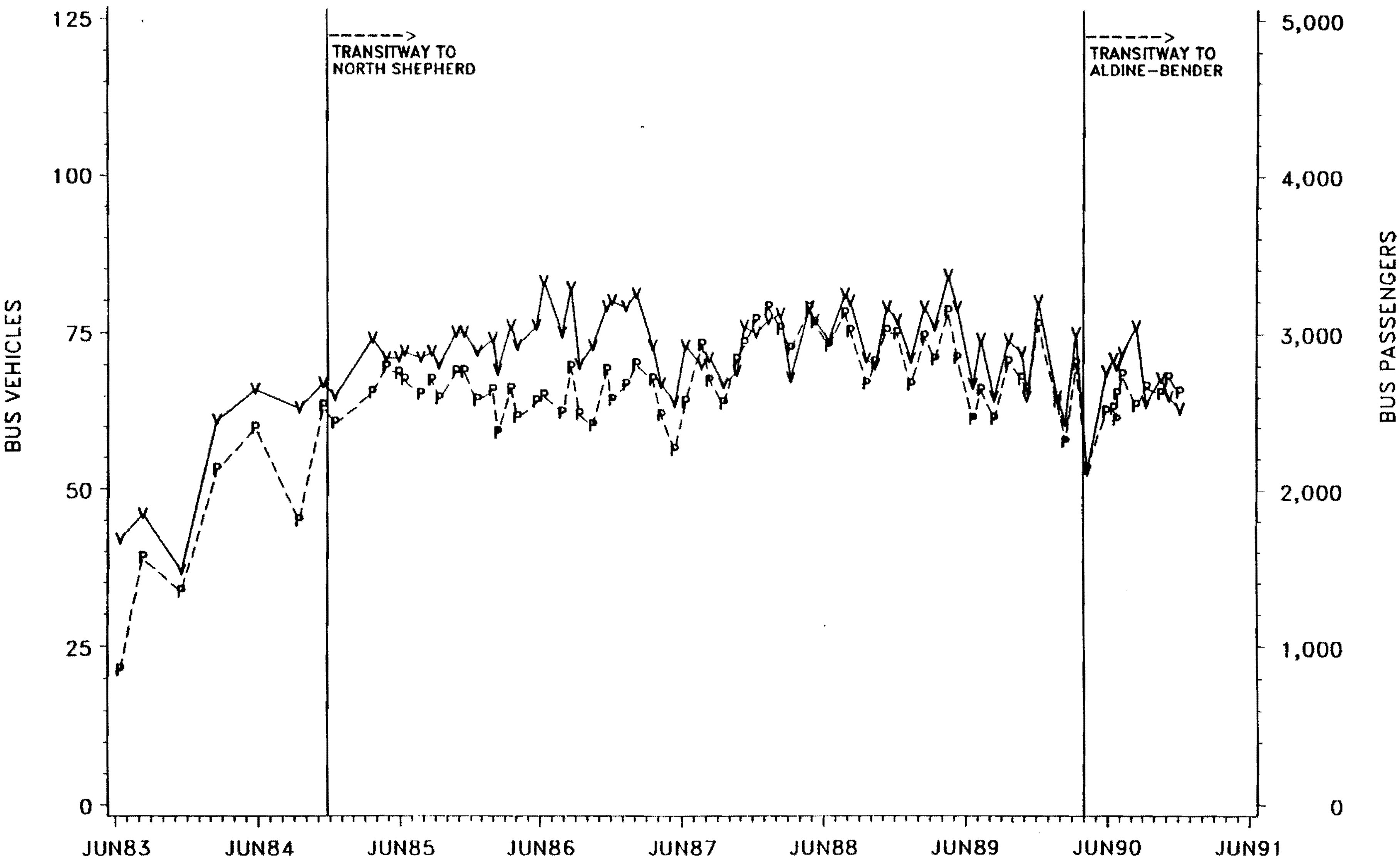


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE TRANSITWAY, IT REPRESENTS TOTAL PERSONS (FREEWAY + TRANSITWAY) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 4 LANES
DATA FOR FREEWAYS WITHOUT TRANSITWAYS ARE A COMPOSITE OF
GULF FWY (6/83 – 4/88) AND SOUTHWEST FWY (6/86 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : N = NORTH FREEWAY EFFICIENCY
W = FREEWAYS WITHOUT TRANSITWAY

FIGURE B-16

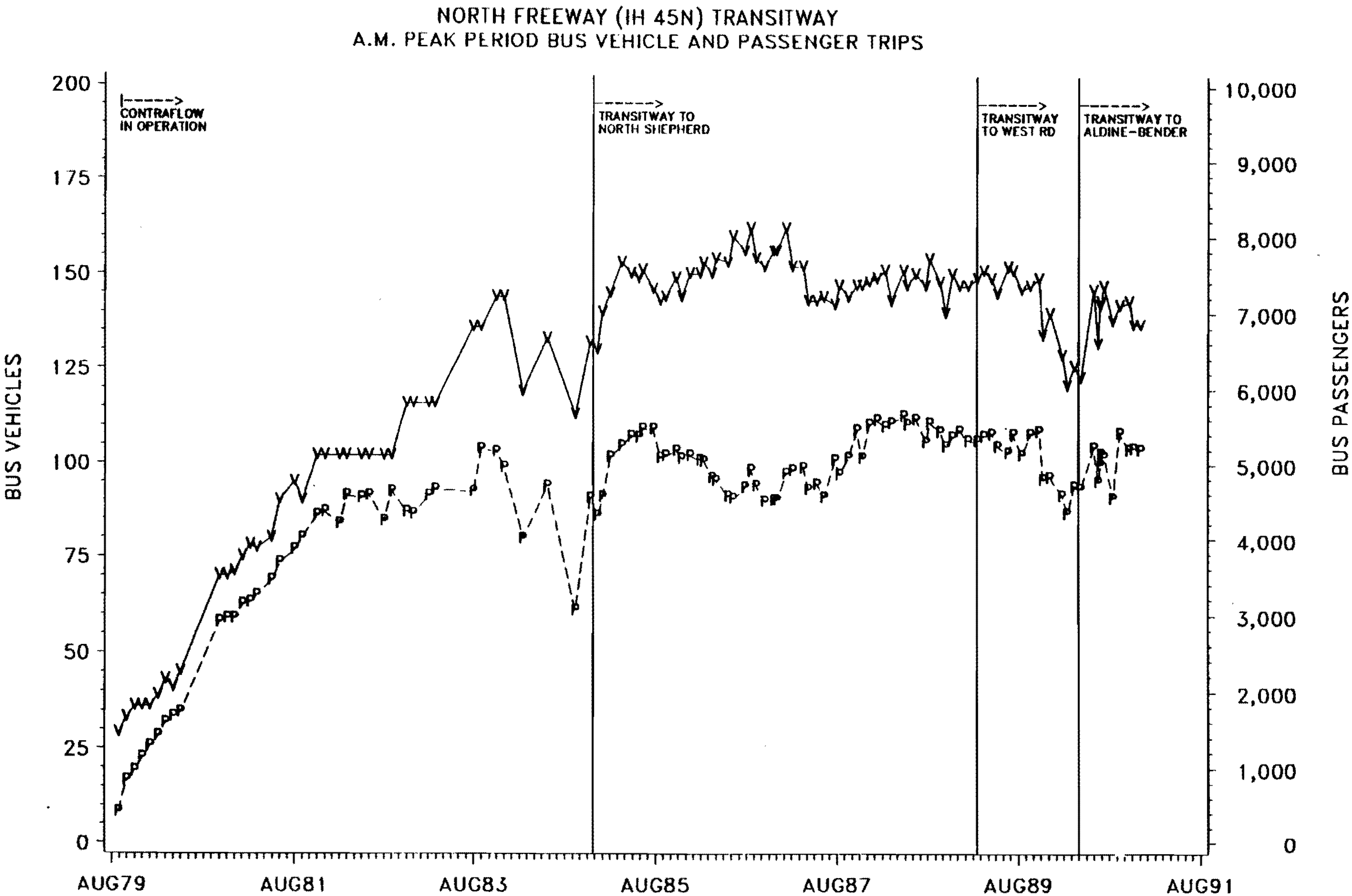
NORTH FREEWAY (IH 45N) TRANSITWAY
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS



NORTH TRANSITWAY OPERATES FROM 5:45 TO 8:45 A.M.
SOURCE : TEXAS TRANSPORTATION INSTITUTE & METRO

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

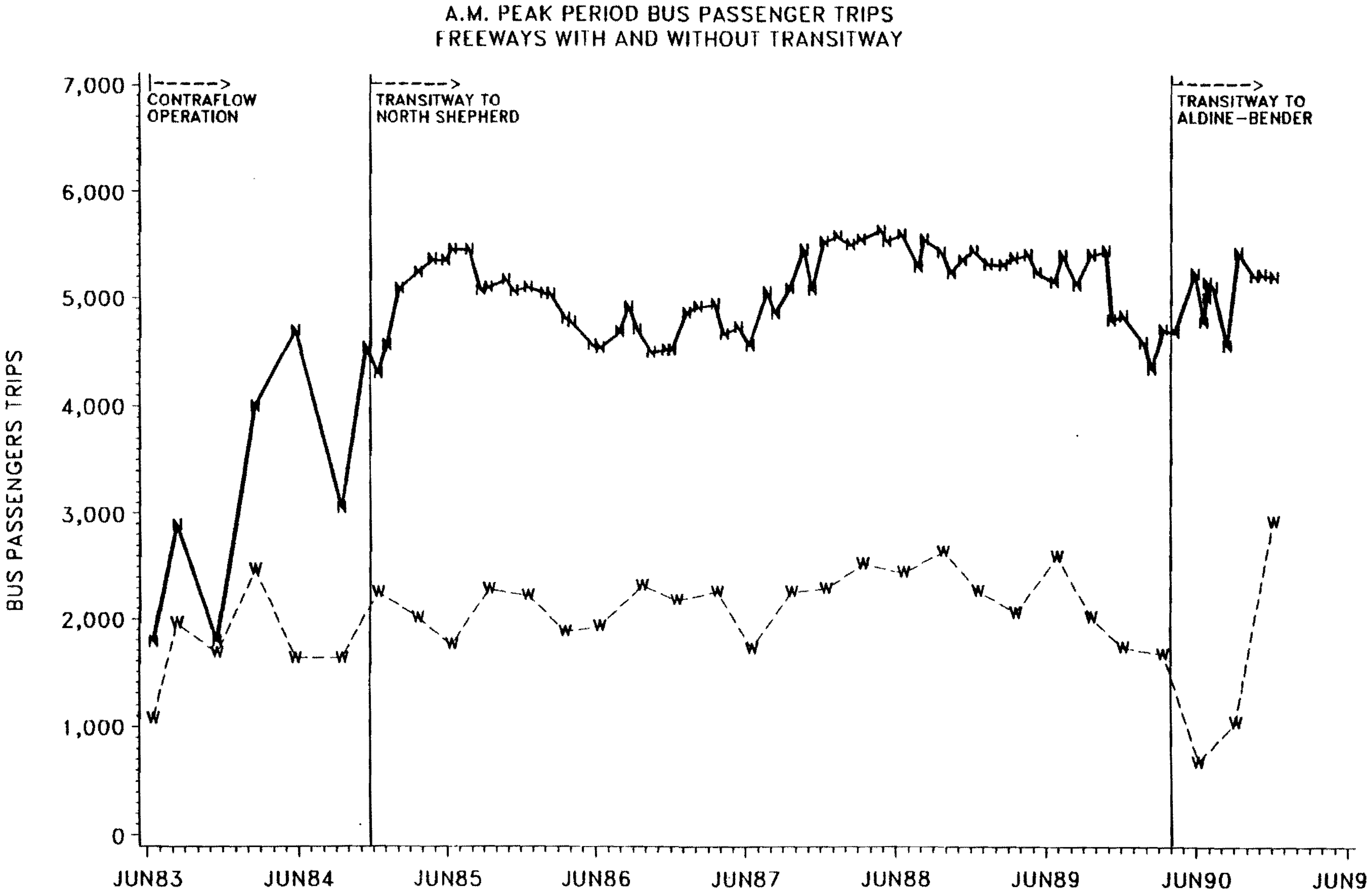
FIGURE B-17



NORTH TRANSITWAY OPERATES FROM 5:45 TO 8:45 A.M.
SOURCE : TEXAS TRANSPORTATION INSTITUTE & METRO

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

FIGURE B-18

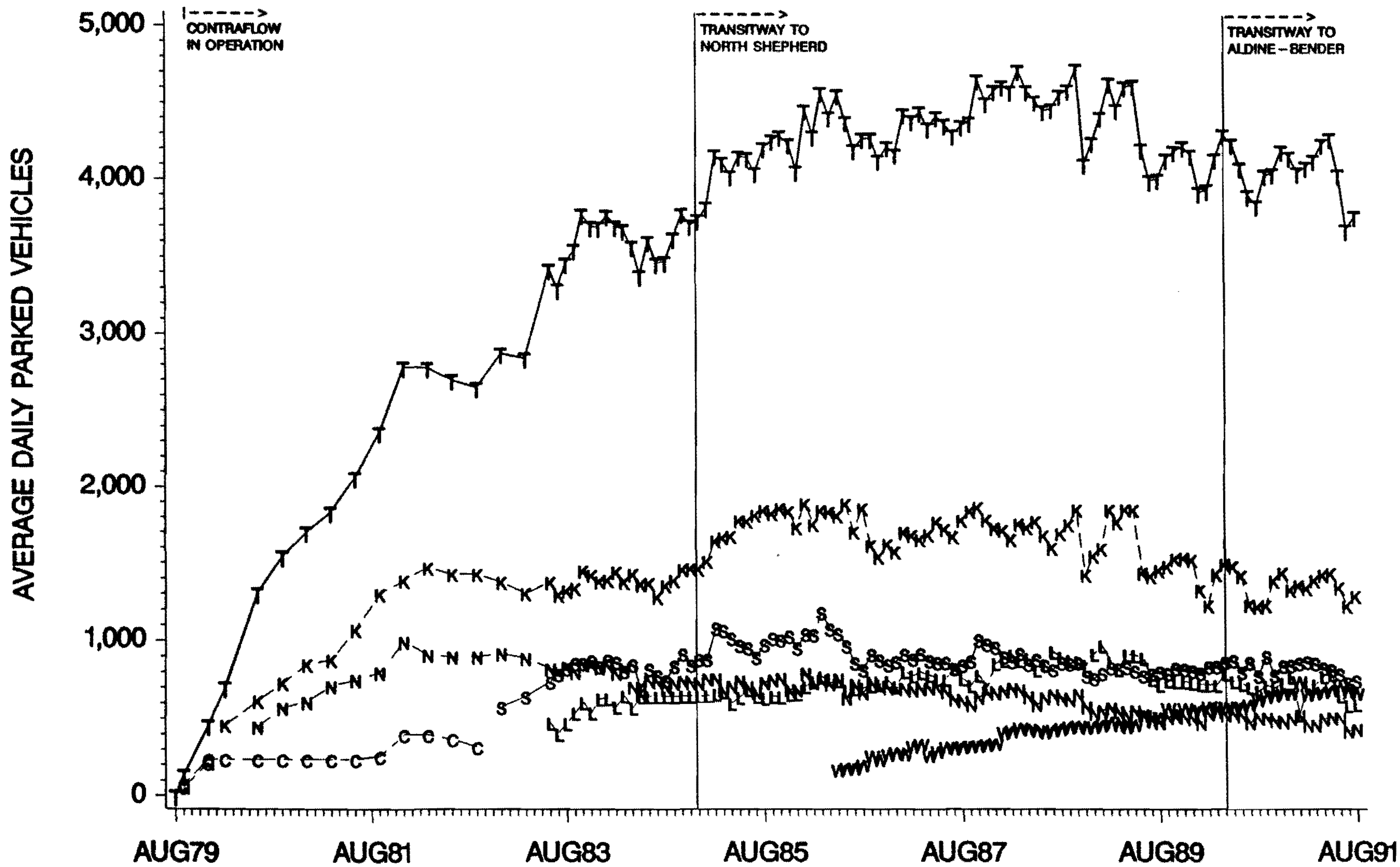


PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA FOR FREEWAYS WITHOUT TRANSITWAYS ARE A COMPOSITE OF GULF FWY (6/83 – 4/88) AND SOUTHWEST FWY (9/86 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE B-19

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

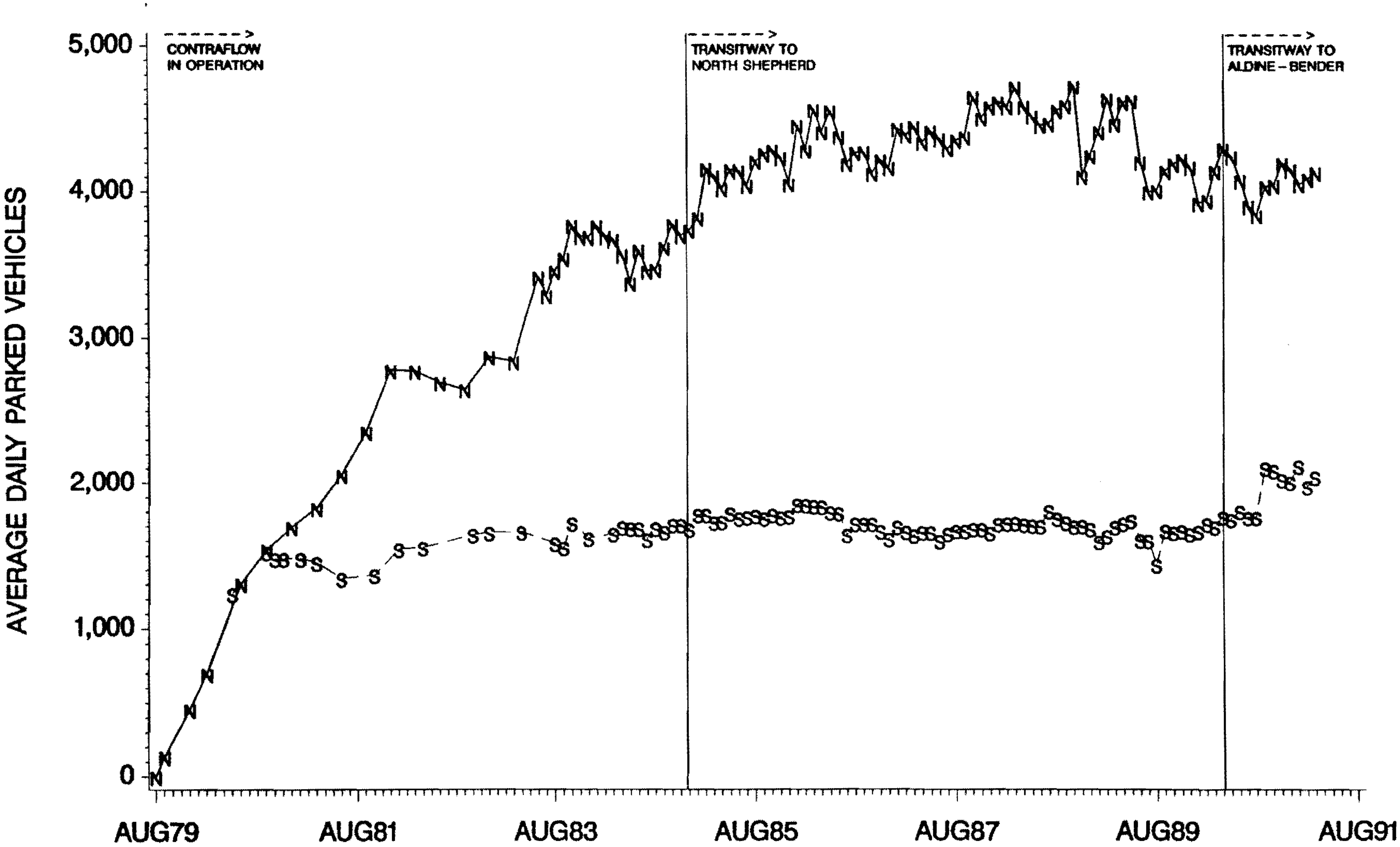


NORTH CFL FROM DOWNTOWN TO NORTH SHEPHERD (9.6 MI.) OPENED AUGUST, 1979
CONCURRENT FLOW LANE (A.M. ONLY) FROM NORTH SHEPHERD TO WEST RD (3.3 MI.) OPENED MARCH, 1981
NORTH TRANSITWAY FROM DOWNTOWN TO NORTH SHEPHERD (9.6 MI.) OPENED NOVEMBER, 1984
TRANSITWAY EXTENSION FROM NORTH SHEPHERD TO ALDINE-BENDER (4.3 MI.) OPENED APRIL, 1990
CURRENT TOTAL CORRIDOR PARKING CAPACITY = 7017 SPACES
CHAMPIONS (C) AND GREENSPOINT (G) LOTS WERE TEMPORARY LOTS
SOURCE : TEXAS TRANSPORTATION INSTITUTE & METRO

LEGEND : T = TOTAL PARKED VEHICLES
K = KUYKENDAHL LOT (2246 SPACES)
L = SETON LAKE LOT (1286 SPACES)
N = NORTH SHEPHERD LOT (1605 SPACES)
S = SPRING LOT (1280 SPACES)
W = THE WOODLANDS LOT (600 SPACES)

FIGURE B-20

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



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 TRANSITWAY FROM DOWNTOWN TO NORTH SHEPHERD (9.6 MI.) OPENED NOVEMBER, 1984
TRANSITWAY EXTENSION FROM NORTH SHEPHERD TO ALDINE-BENDER (4.3 MI.) OPENED APRIL, 1990
SOURCE : TEXAS TRANSPORTATION INSTITUTE & METRO

LEGEND : N - NORTH FREEWAY
S - FREEWAY WITHOUT TRANSITWAY (SOUTHWEST)

APPENDIX C

GULF FREEWAY AND HOV LANE DATA

GULF FREEWAY (I 45) AND HOV LANE, HOUSTON

Summary of A.M. Peak-Period, Peak-Direction Katy Freeway and Transitway Data, December 1990
Prepared by Texas Transportation Institute

Type of Data[7] Phase 1 of Transitway Became Operational 5/16/88	"Representative" Pre-Transitway Value	"Representative" Current Value	% Change
Transitway Data			
Transitway Length (miles)		6.5	
Transitway Cost (millions of 1990 dollars)		$44.2	
Person-Movement			
Peak Hour (7-8 a.m.)		2,809	—
Peak Period (6-9:30 a.m.)		5,117	—
Total Daily		10,025	—
Vehicle Volumes			
Peak Hour	—	882	—
Peak Period	—	1,519	—
Vehicle Occupancy, Peak Hour (persons/veh)	—	3.18	—
Accident Rate (Accidents/MVM), 11/84-12/90	—	1.35	—
Vehicle Breakdowns (VMT/Breakdown), 11/84-12/90	—	43,982	—
Violation Rate (6-9:30 a.m.)	—	2.1%	
Peak Hour Lane Efficiency[1] (1000's)	—	142	—
Annual Value of User Time Saved (millions)[7]	—	$0.3 to $0.6	—
Freeway Mainlane Data (see note)			
Person Movement			
Peak Hour	6,972	—	—
Peak Period (6-9:30 a.m.)	21,259	—	—
Vehicle Volume			
Peak Hour	5,628	—	—
Peak Period	17,414	—	—
Vehicle Occupancy, Peak Hour (persons/veh)	1.24	—	—
Accident Rate (Accidents/MVM)[2]	1.79	1.45	-19.0%
Avg. Operating Speed[3]			
Peak Hour	39.6	—	—
Peak Period	43.0	—	—
Peak Hour lane Efficiency[1] (1000's)	92	—	—
Combined Freeway Mainland and Transitway 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	—	—	—
Peak Period	—	—	—
Travel Time (minutes)[3]			
Peak Hour	9.6[4]	7.5[5]	-21.9%
Peak Period	7.5[4]	7.1[5]	- 5.3%
Peak Hour Lane Efficiency[1] (1000's)	—	—	—

Footnotes on page C-3

Summary of P.M. Peak-Period, Peak-Direction Katy Freeway and Transitway Data, December 1990 Continued

Type of Data	"Representative" Pre-Transitway Value	"Representative" Current Value	% Change
<u>Transit Data</u>			
Bus Vehicle Trips			
Peak Hour	23	—	—
Peak-Period	41*	—	—
Bus Passenger Trips			
Peak Hour	800*	—	—
Peak Period	1,310*	—	—
Bus Occupancy (persons/bus)			
Peak Hour	34.8	—	—
Peak Period	32.0	—	—
Vehicles Parked in Corridor Park & Ride Lots	1,115	1,349	+21.0%
Bus Operating Speed (mph)[3]			
Peak Hour	30.7[4]	50.4[5]	+ 63.2%
Peak Period	41.7[4]	53.2[5]	+ 28.8%

*Data collected at Monroe, not Telephone.

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.

Footnotes on following page.

Comparison of Measures of Effectiveness, Freeway With (Gulf, I-45) and Freeway Without (Southwest US 59) Transitway, Houston[7,8]

Measure of Effectiveness	"Representative" Pre-Transitway Value	"Representative" 12/90 Value	% Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/transitway	1.29	—	—
Freeway w/o transitway	1.26	1.31	+ 4.0%
A.M. Peak Hour, 2+ Carpool Volume Change			
Freeway w/transitway	475	—	—
Freeway w/o transitway	595	743	+24.9%
Bus Passengers, Peak Period			
Freeway w/transitway	1,310	—	—
Freeway w/o transitway	2,255	2,100	- 6.9%
Cars Parked at Park-and-Ride Lots			
Freeway w/transitway	1,115	1,349	+21.0%
Freeway w/o transitway	1,680	1,665	- 0.9%
Facility Per Lane Efficiency[1]			
Freeway w/transitway	—	—	—
Freeway w/o transitway	76	60	- 21.1%

Footnotes on following page

Footnotes

[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.
[2]Accidents analyzed between Broadway and downtown, a distance of approximately 6.5 miles, which corresponds to Phase 1 of the transitway. Pre-transitway includes 4 years of mainlane accident data from 5/16/84 to 5/15/88. Current value is from 5/16/88 to 9/90.
[3]From Braodway to Dowling a distance of 6.3 miles.
[4]Data pertains to operation in the freeway mainlanes.
[5]Data pertains to operation in the transitway.
[6]Based on time savings for transitway users in 1990, an annual estimate of travel time savings to transitway users is developed. A value of time of $9.25/hour is used based on the value applied in the Highway Economic Evaluation Model.
[7]Transitway data are collected at Telephone Road and freeway data are collected at Monroe. Since the transitway does not yet extend to Monroe, it is not possible at this time to combine and/or compare freeway and transitway data.
[8]Data for freeways without transitways are a composite of data collected on the Gulf Freeway during the time in which no transitway existed on that facility (6/83 thru 4/88) and on the Southwest Freeway (9/86 to present).

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

TRANSITWAY 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.

- Key dates are noted on the capital cost sheets.

Person Movement

- In December 1990, 10,025 person trips per day were served on the HOV lane.

- A.M. Peak Hour, 2,809 persons/hour.

  - 930 (33%) by bus, 171 (6%) by vanpool, 1,708 (61%) by carpool (Figure 1).
  - Average transitway vehicle occupancy = 3.18 persons/vehicle.

- A.M. Peak Period, 5,117 persons.

  - 1,980 (39%) by bus, 224 (4%) by vanpool, 2,913 (57%) by carpool (Figure 2).

Vehicle Movement

- A.M. Peak Hour, 882 vph

GULF HOV LANE OPERATING SEGMENT
Estimated Capital Cost, (millions)

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.

GULF HOV LANE, FUTURE SEGMENTS
Estimated Capital Cost, (millions)

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

    - 30 (3%) bus, 17 (2%) vans, 835 (95%) carpools (Figure 3).

- A.M. Peak Period, 1,519 vehicles.
    - 70 (4%) bus, 24 (2%) vans, 1,425 (94%) carpools (Figure 4).

<u>Vehicle Breakdown Rates</u>

- As measured from September 1, 1988 through December 1990, the following rates have been observed.

    - Buses; 1 breakdown per 59,687 vehicle-miles of travel (VMT).
    - Vanpools; 0 breakdowns.
    - Carpools; 1 breakdown per 41,850 VMT.
    - Weighted average; 1 breakdown per 43,982 VMT.

<u>Peak Hour Lane Efficiency</u>

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. For the transitway lane, this value (expressed in 1000's) is approximately 141.6.

<u>Travel Time Savings</u>

- The users of the transitway experience a travel time savings (Figure 5).

- The tables on the following page indicate that, on a typical non-incident day, travel time savings of approximately 123 hours (7,378 min.) are realized. Assuming 250 days of operation, annual savings would be 30,750 hours. At $9.25/hour, this equates to $284,000 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 transitway users are estimated to be in the range of $0.3 to $0.6 million per year.

Northbound A.M. Travel Time Savings for Gulf Transitway
(Average of 4 Quarterly Travel Time Surveys Conducted in 1990)

Time of Day	Measured Travel Time			Transitway 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	6.98	6.93	0.05	55	9	133	197	9.82
6:30	6.75	7.06	-0.31	176	19	315	510	-159.45
7:00	9.25	7.54	1.71	564	115	503	1,181	2,022.46
7:30	9.86	7.36	2.50	883	50	465	1,399	3,490.42
8:00	6.82	7.08	-0.26	380	21	333	734	-192.54
8:30	6.60	6.83	-0.23	137	7	121	265	-60.67
9:00	6.50	6.71	-0.21	68	7	15	90	-19.02
Peak Period Total				2,263	227	1,884	4,374	5,091.02
Southbound PM Travel Time Savings for Gulf Transitway								
Section from Park Place to Dowling								
3:30	6.67	6.64	0.03	70	9	85	164	5.47
4:00	6.87	7.80	-0.92	137	36	203	375	-347.11
4:30	6.85	7.34	-0.49	274	38	308	620	-302.01
5:00	8.67	8.12	0.55	500	64	508	1,071	584.45
5:30	9.87	7.33	2.54	456	30	383	869	2,208.71
6:00	7.61	7.16	0.45	195	18	195	408	183.49
6:30	6.63	6.97	-0.35	67	5	60	132	-45.56
Peak Period				1,697	200	1,741	3,638	2,287.45

FREEWAY DATA

Note

- For the freeway data which have been collected in the Gulf corridor since 1983 have been, for a variety of reasons, collected at Monroe. The transitway does not yet extend to Monroe. As a result, the freeway data are not at this time comparable to the transitway data. As a result, the freeway data are generally shown as being "Pre-Transitway" in the summary sheet.

Person Movement

- In the a.m. peak hour, the average person volume is 6,972 (Figure 6).

- The a.m. peak period, person volume is approximately 21,259 (Figure 7).

Vehicle Volume

- In the a.m. peak hour, vehicle volume is 5,628 vph (Figure 6).
- In the a.m. peak period, vehicle volume is 17,414 (Figure 7).

Vehicle Occupancy

- In the a.m. peak hour, mainlane occupancy is 1.24 persons per vehicle.
- In the a.m. peak period, mainlane occupancy is 1.22 persons per vehicle.

Accident Rate

- Implementation of the transitway 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 1.79 accidents per million vehicle miles (MVM). "After transitway" accident rate for the mainlanes is 1.45 accidents per MVM and includes the period 5/88 to 9/90. Only officer-reported accidents are included in current accident files. 1990 volumes estimated by TTI to compute rates.

Average Operating Speed

- In comparison to pre-transitway 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 transitway. Speeds have dropped outside South Loop 610, where the transitway has yet to be implemented (Figure 8).

Peak Hour Lane Efficiency

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of per lane efficiency.
- The freeway efficiency as measured at Monroe is 92.0 (Figure 9).

COMBINED FREEWAY AND TRANSITWAY DATA

Note

- The freeway data collected at Monroe (the transitway is not yet completed to Monroe) cannot be combined or compared to the transitway 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

- In the a.m. peak hour, the total number of 2+ carpools measured on the freeway at Monroe is approximately 858 vph (Figure 10). The peak-period volume is shown in Figure 11.

Peak Hour Lane Efficiency (see note)

BUS TRANSIT DATA

Note

- Transitway data are routinely collected at Telephone Road and freeway data at Monroe. Until the transitway is completed to Monroe, it is not appropriate to combine or compare freeway and transitway data.

Bus Vehicle and Passenger Trips

- Bus vehicle and passenger trips as counted on the freeway mainlanes at Monroe show: 23 peak-hour bus vehicle trips and 800 peak-hour bus passenger trips; and 41 peak-period bus trips and 1,310 peak-period bus passenger trips.

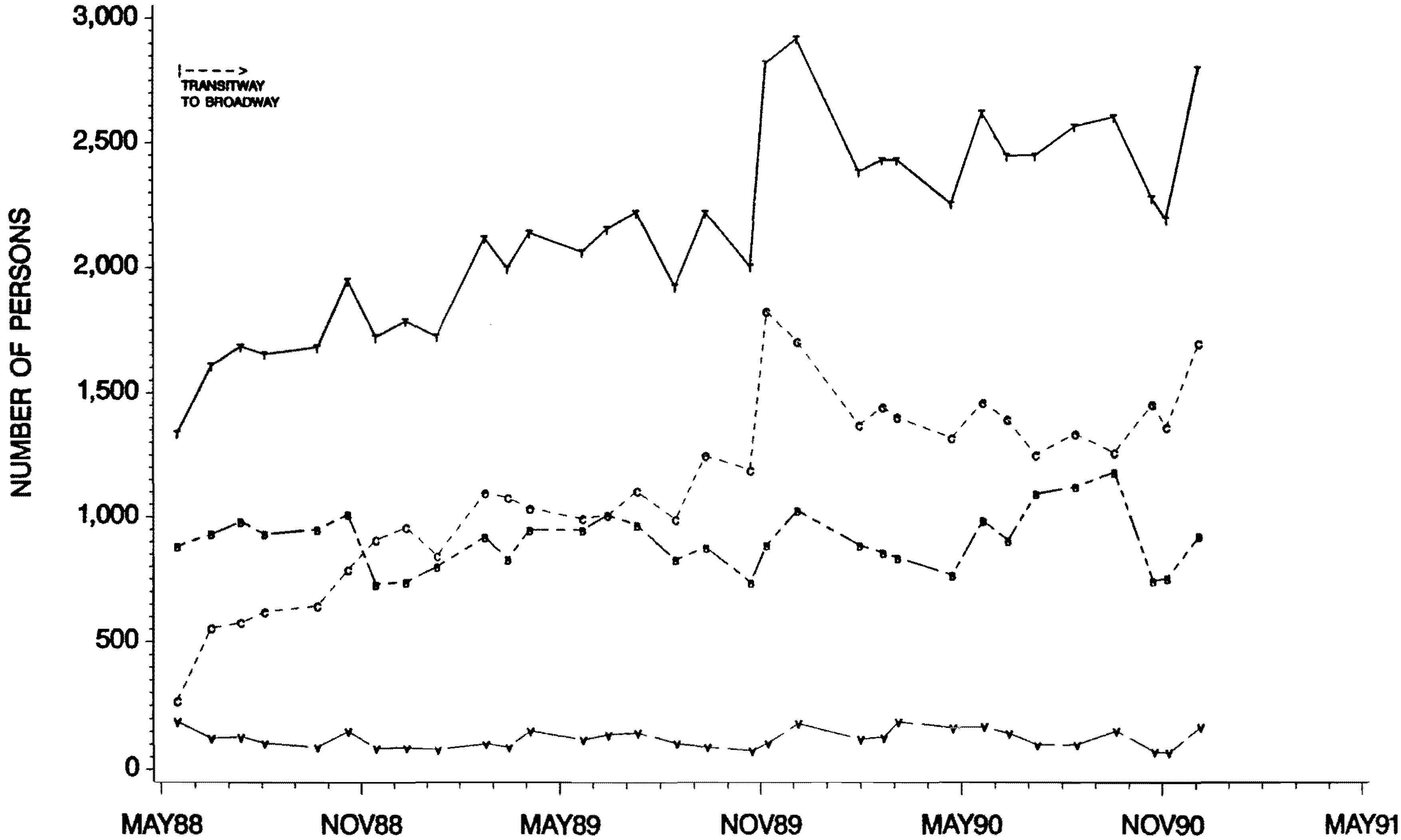
Park-and-Ride

- Prior to opening the transitway, approximately 1,115 vehicles were parked in corridor park-and-ride lots. This has increased 21.0% to a current level of 1,349 (Figure 12).

- Comparison of Southwest Freeway and Gulf Freeway park-and-ride utilization is shown in Figure 13.

FIGURE C-1

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



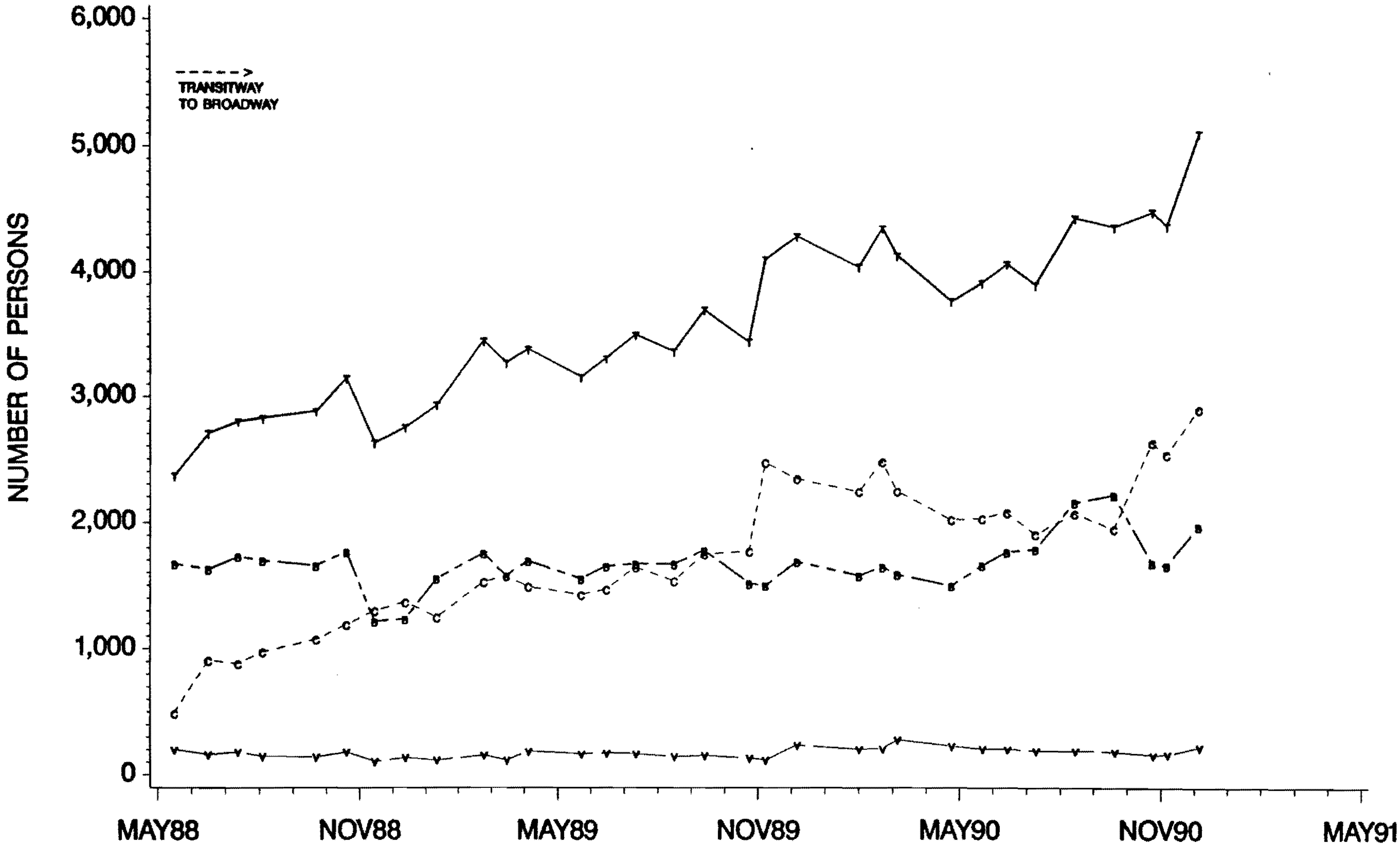
GULF TRANSITWAY, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988

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) TRANSITWAY
A.M. PEAK PERIOD TRANSITWAY PERSON MOVEMENT



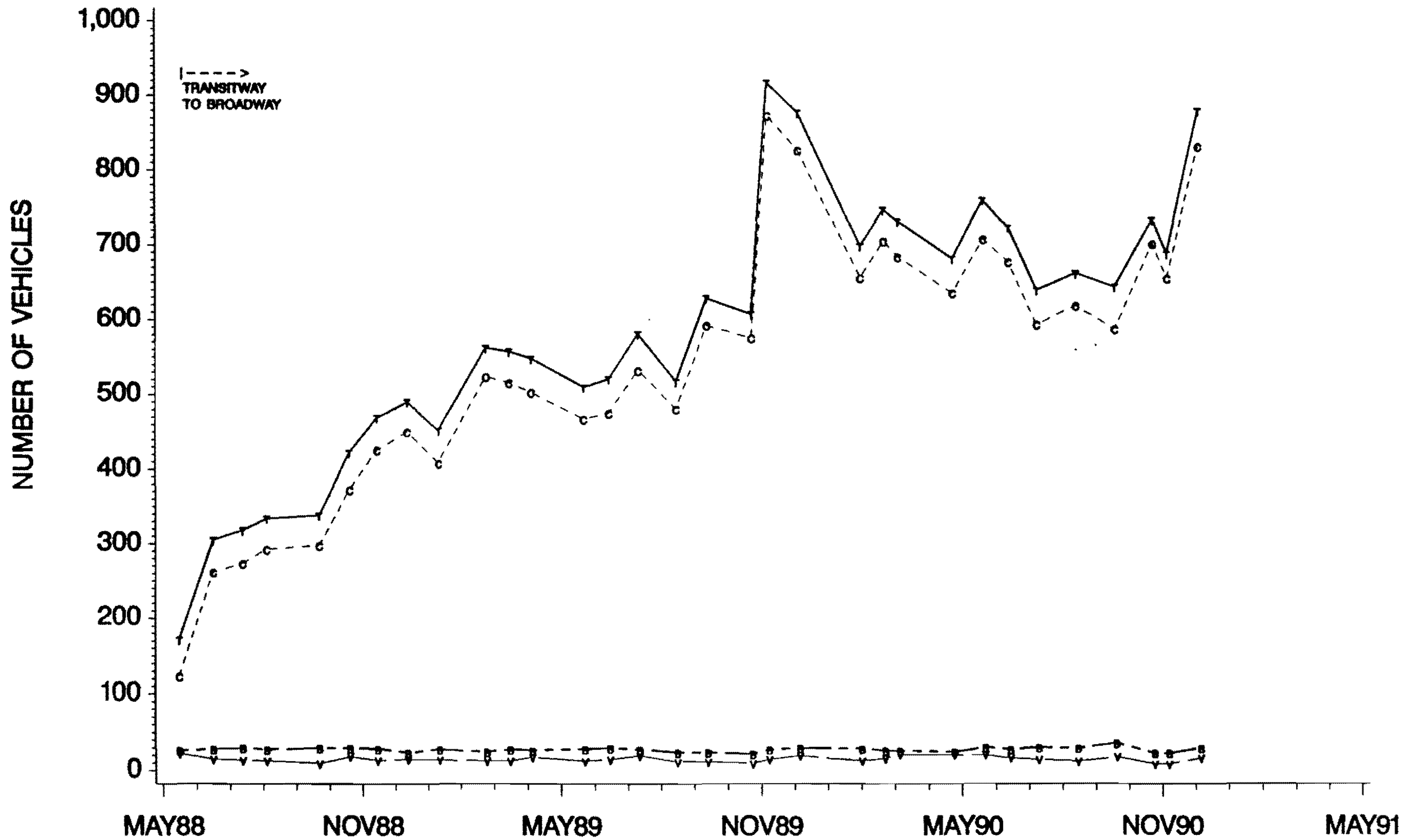
GULF TRANSITWAY, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988
PEAK PERIOD IS FROM 6:00 – 8:30 A.M.

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) TRANSITWAY
A.M. PEAK HOUR TRANSITWAY VEHICLE UTILIZATION



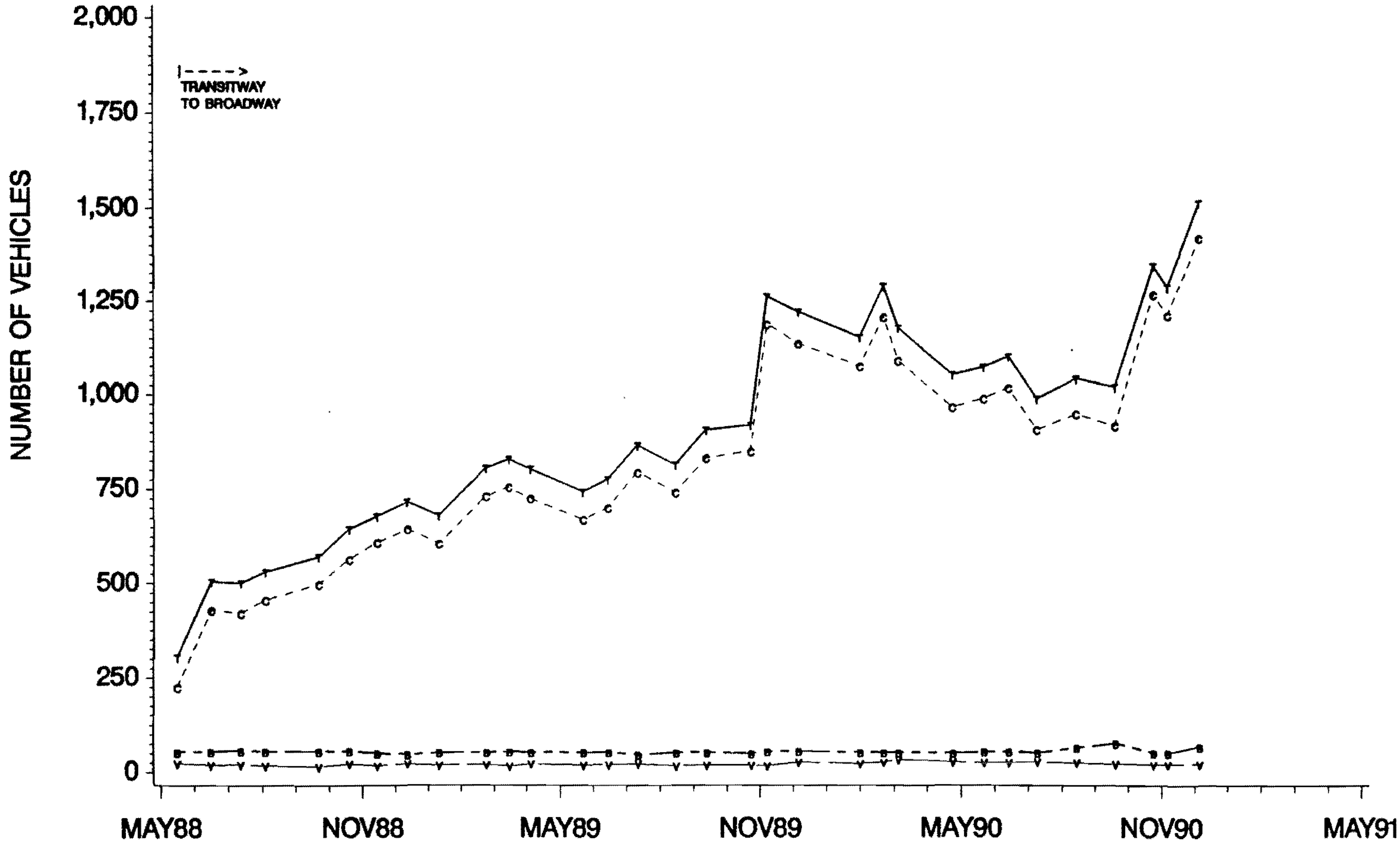
GULF TRANSITWAY, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988

SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE 1

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



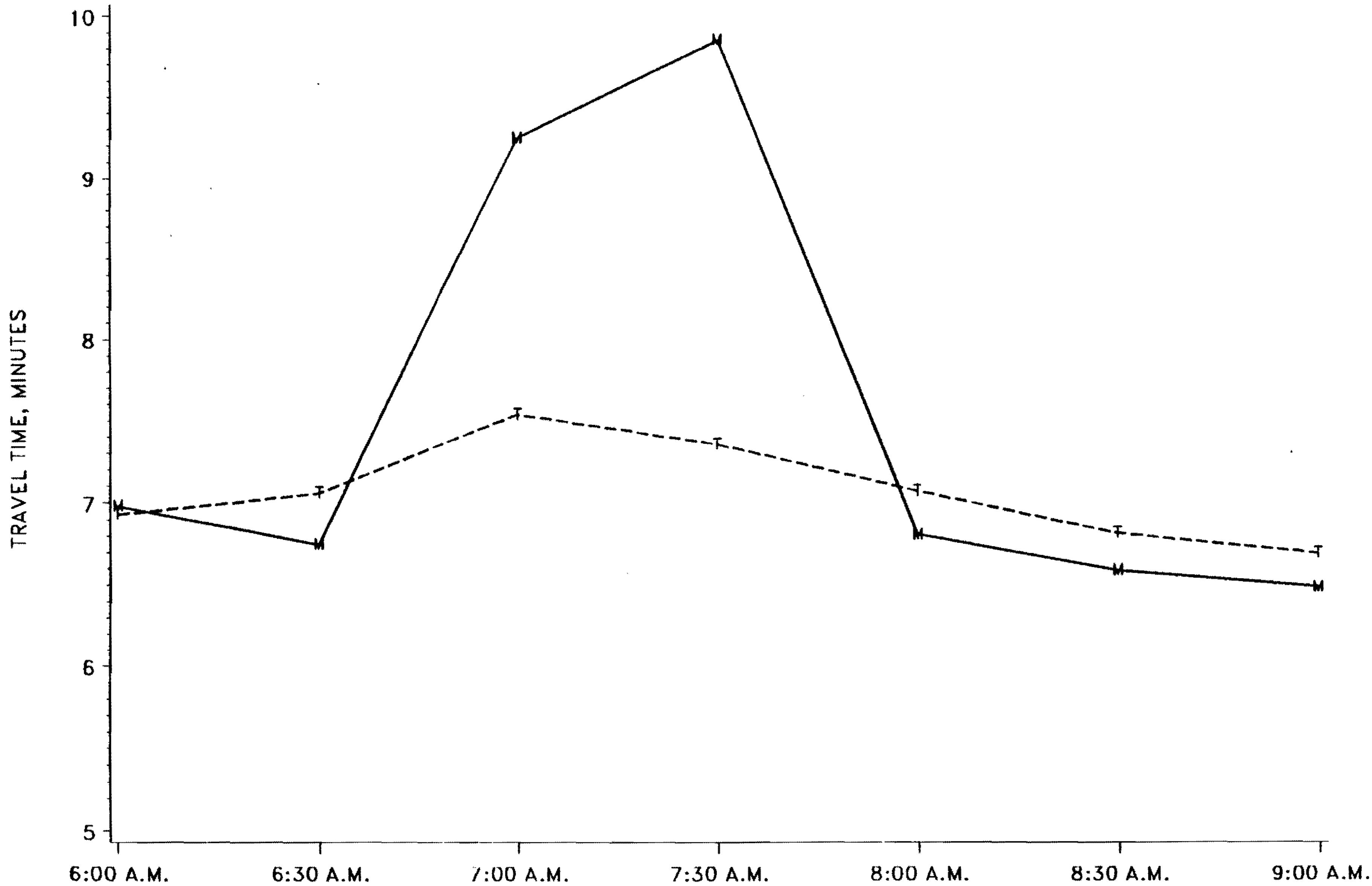
GULF TRANSITWAY, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988
PEAK PERIOD IS FROM 6:00 – 9:30 A.M.

SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE C-5

GULF FREEWAY MAINLANE AND TRANSITWAY A.M. TRAVEL TIME

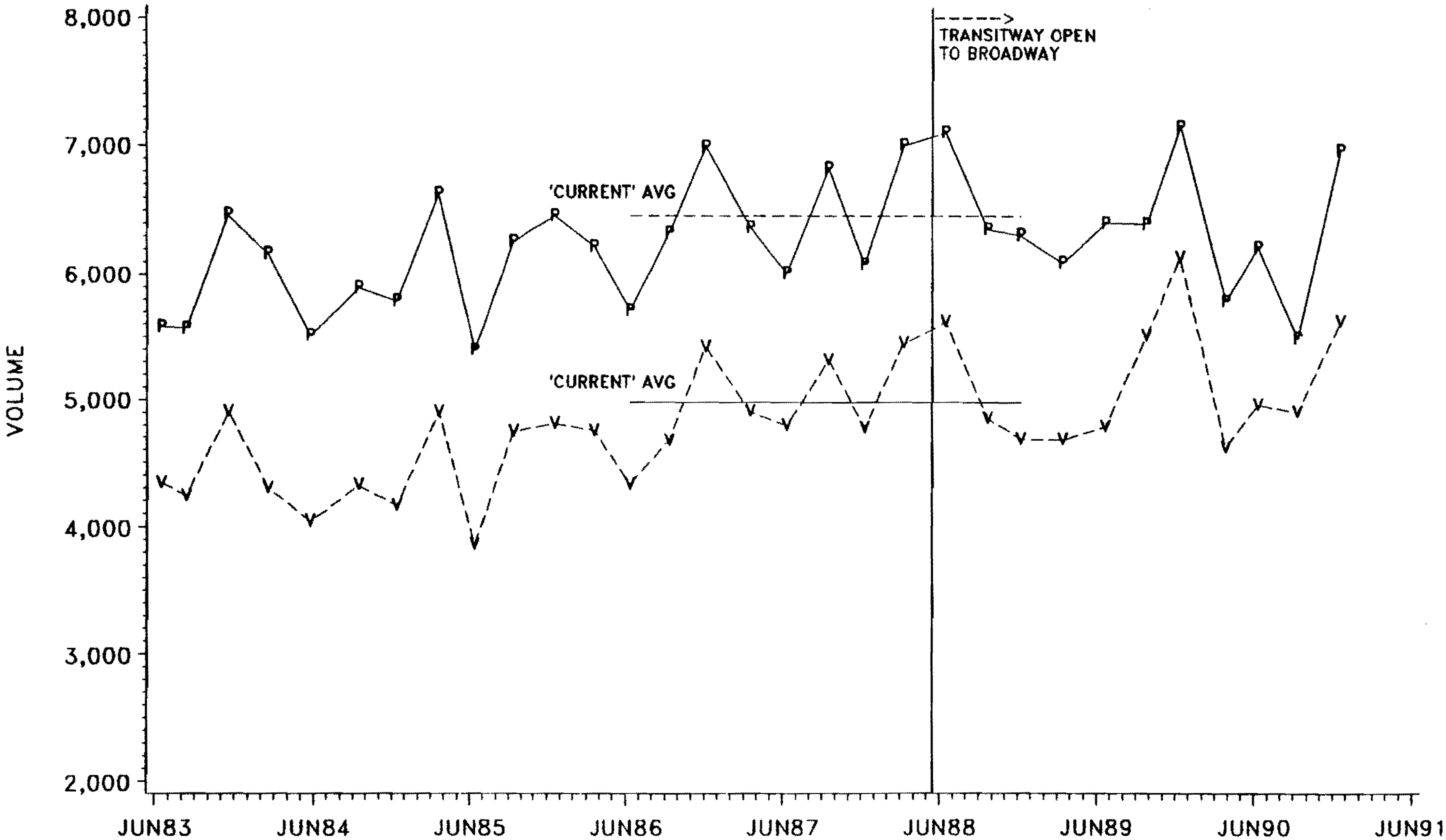


TRAVEL TIMES ARE FROM PARK PLACE TO DOWLING
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : M – MAINLANE TRAVEL TIME
T – TRANSITWAY TRAVEL TIME

FIGURE C-6

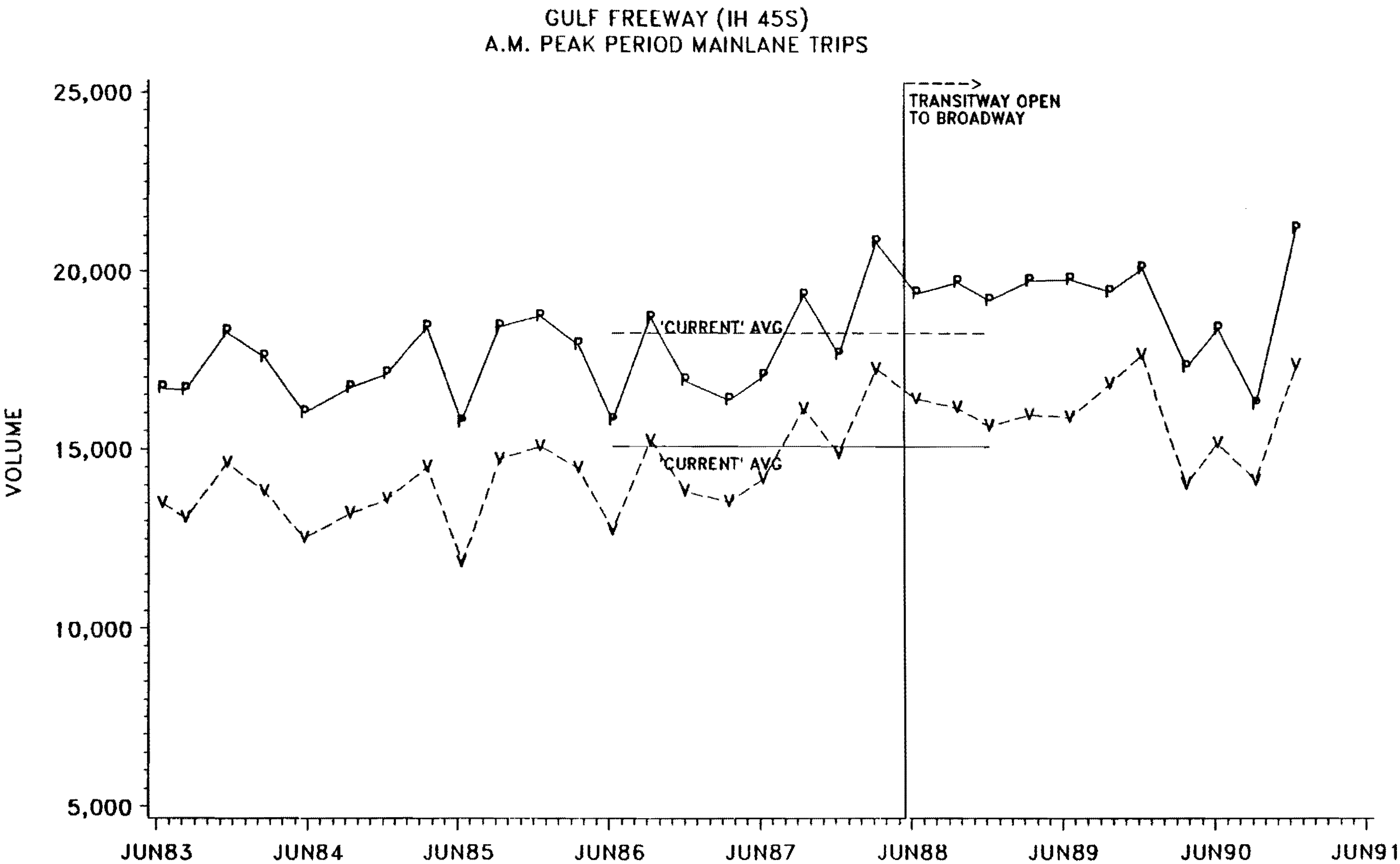
GULF FREEWAY (IH 45S)
A.M. PEAK HOUR MAINLANE TRIPS



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

LEGEND : P = MAINLANE PERSONS
V = MAINLANE VEHICLES

FIGURE C-7

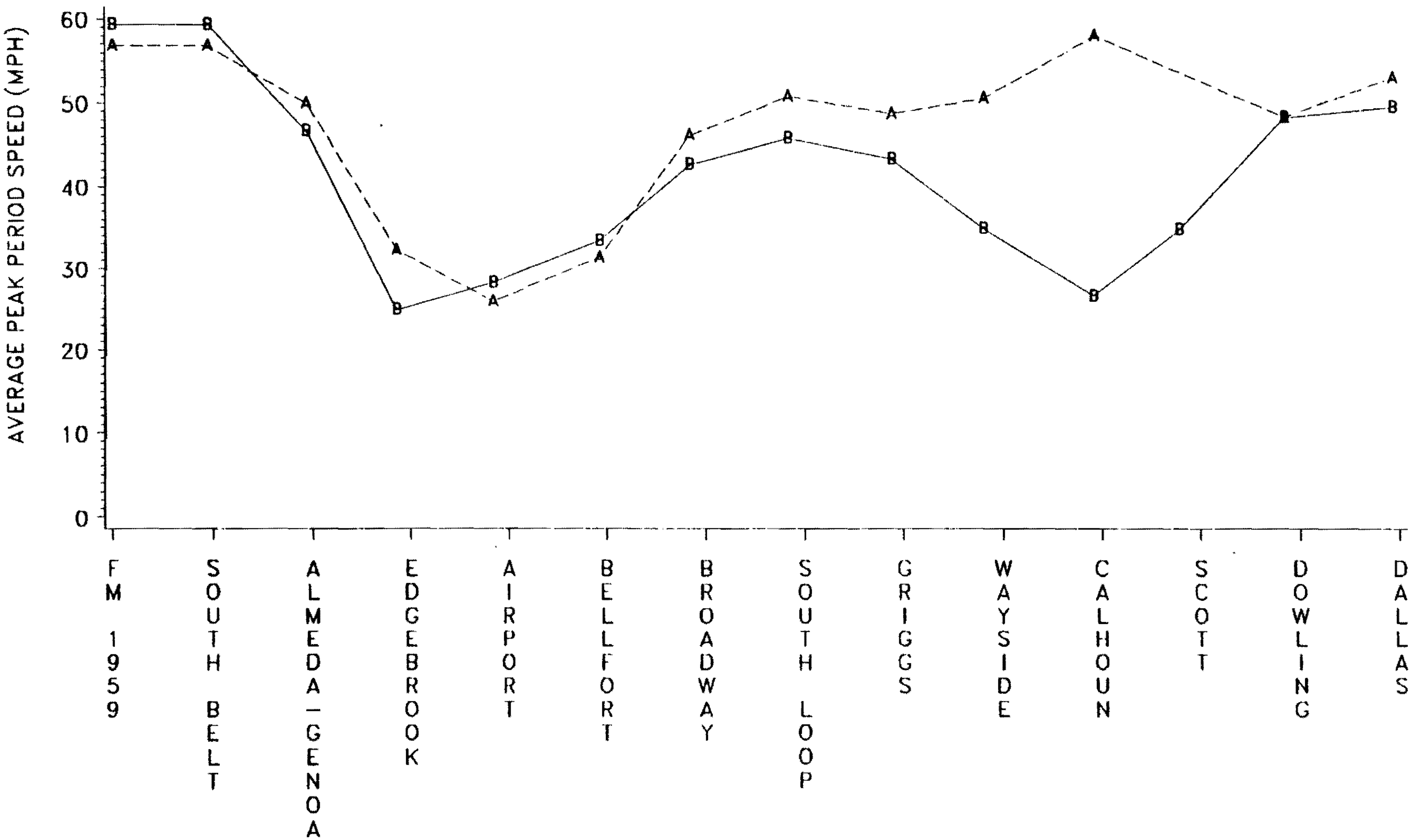


A.M. PEAK PERIOD DEFINED AS FROM 6:00 TO 9:30 A.M.
DATA COLLECTED AT MONROE
TRANSITWAY NOT YET COMPLETED TO MONROE; FREEWAY DATA NOT DIRECTLY COMPARABLE WITH TRANSITWAY DATA AT THIS TIME
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = MAINLANE PERSONS
V = MAINLANE VEHICLES

FIGURE C-8

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

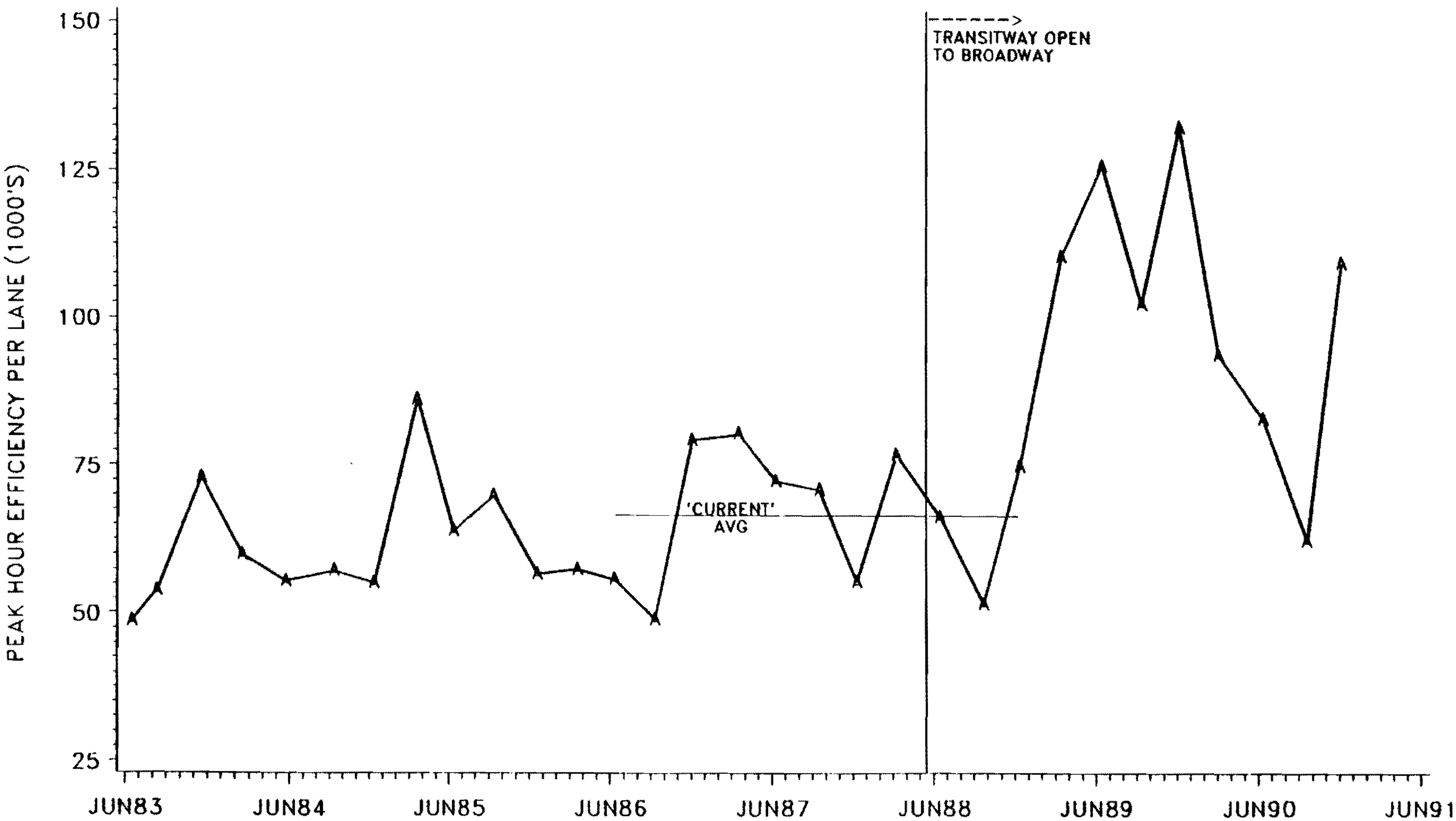


GULF TRANSITWAY, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988
DATA COLLECTED 6:00 TO 9:30 A.M.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : B = AVERAGE SPEEDS BEFORE TRANSITWAY OPENED
A = AVERAGE SPEEDS AFTER TRANSITWAY OPENED

FIGURE C-9

GULF FREEWAY TRANSITWAY EVALUATION
A.M. PEAK HOUR MAINLANE EFFICIENCY

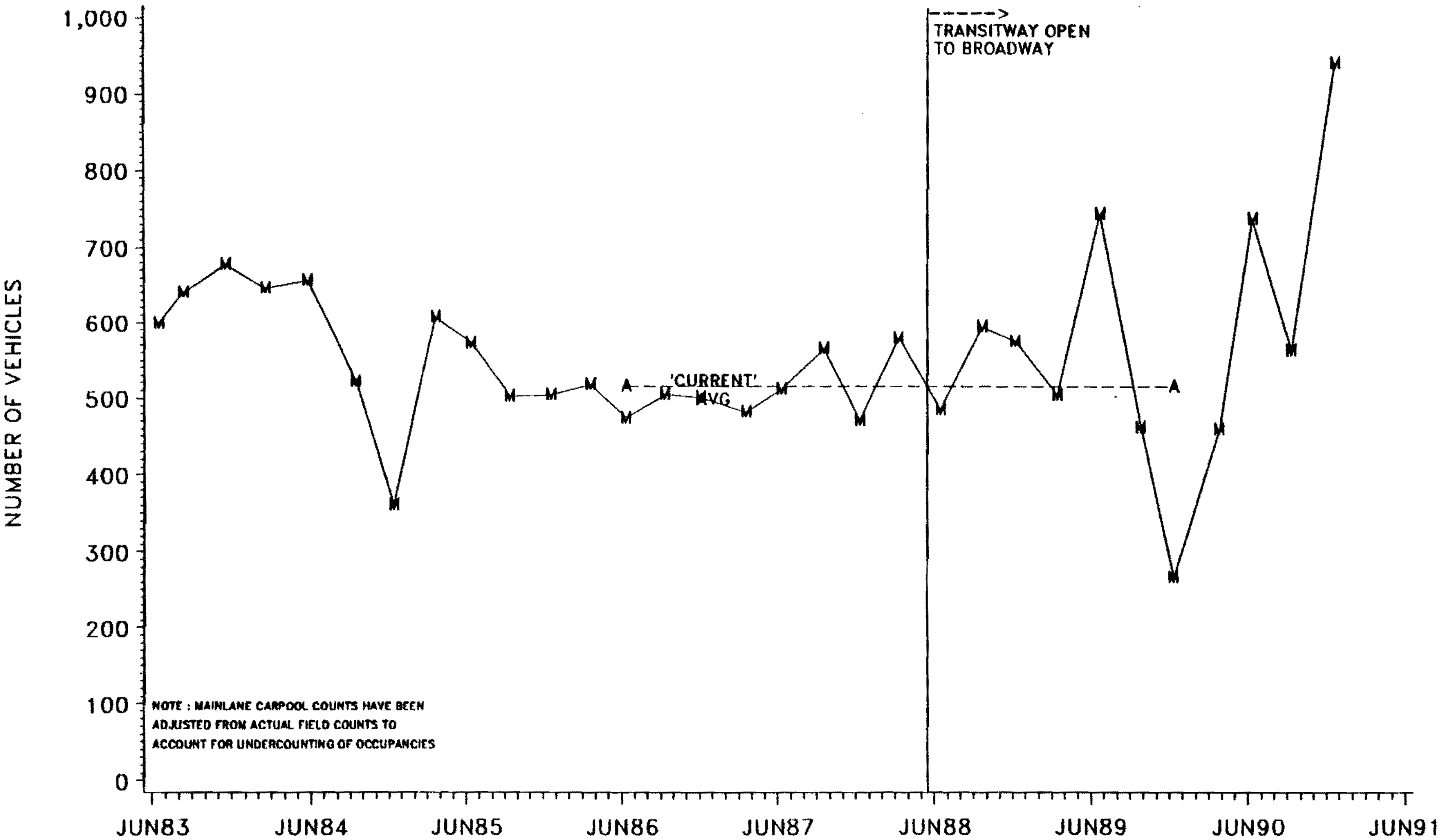


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE
OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED
DATA COLLECTED AT MONROE
TRANSITWAY NOT YET COMPLETED TO MONROE; FREEWAY DATA ARE NOT
COMPARABLE WITH TRANSITWAY DATA AT THIS TIME
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : A = A.M. PEAK HOUR EFFICIENCY

FIGURE C-10

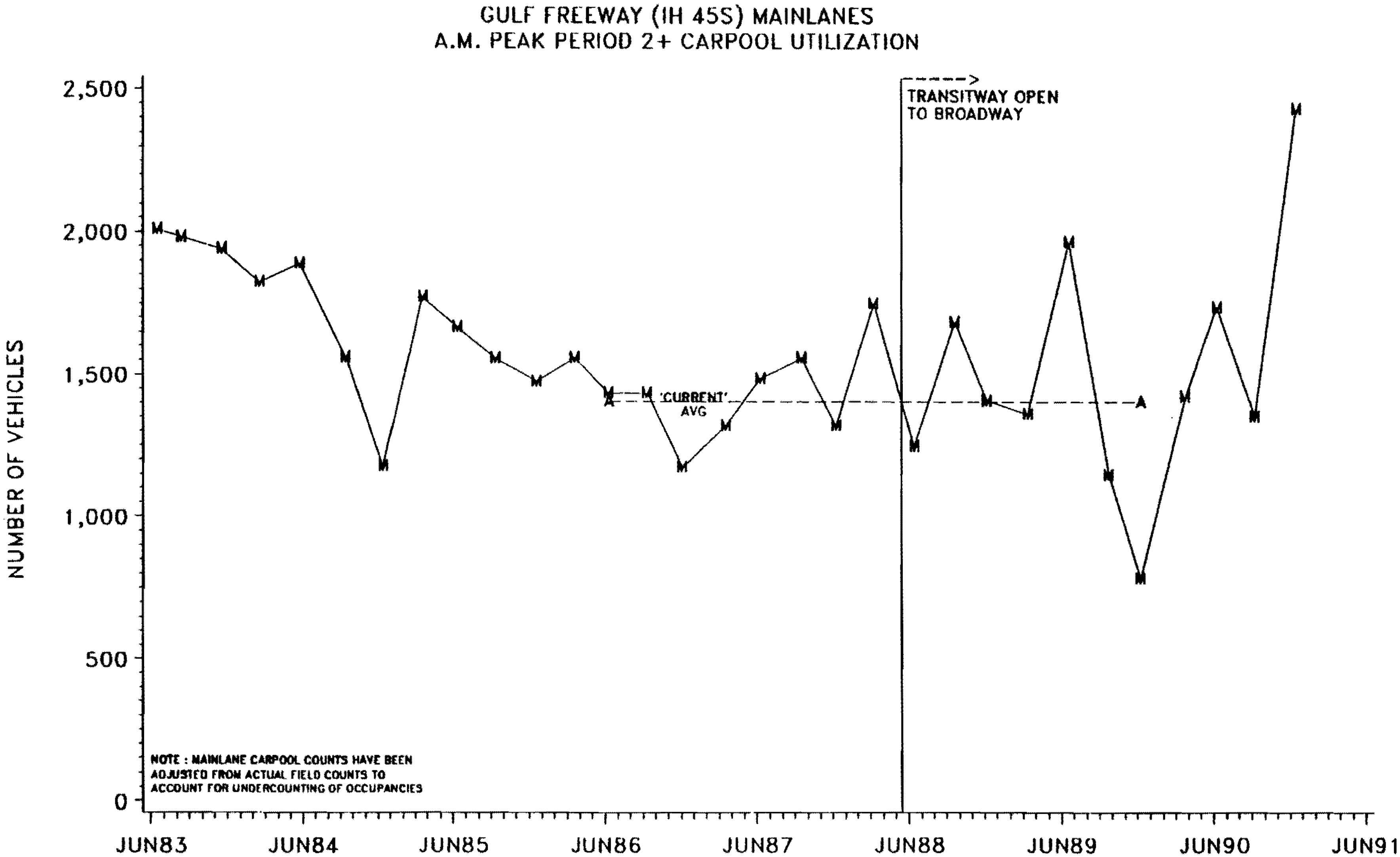
GULF FREEWAY (IH 45S) MAINLANES
A.M. PEAK HOUR 2+ CARPOOL UTILIZATION



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

LEGEND : T = TOTAL 2+ CARPOOLS
A = TOTAL TRANSITWAY 2+ CARPOOLS
M = TOTAL MAINLANE 2+ CARPOOLS

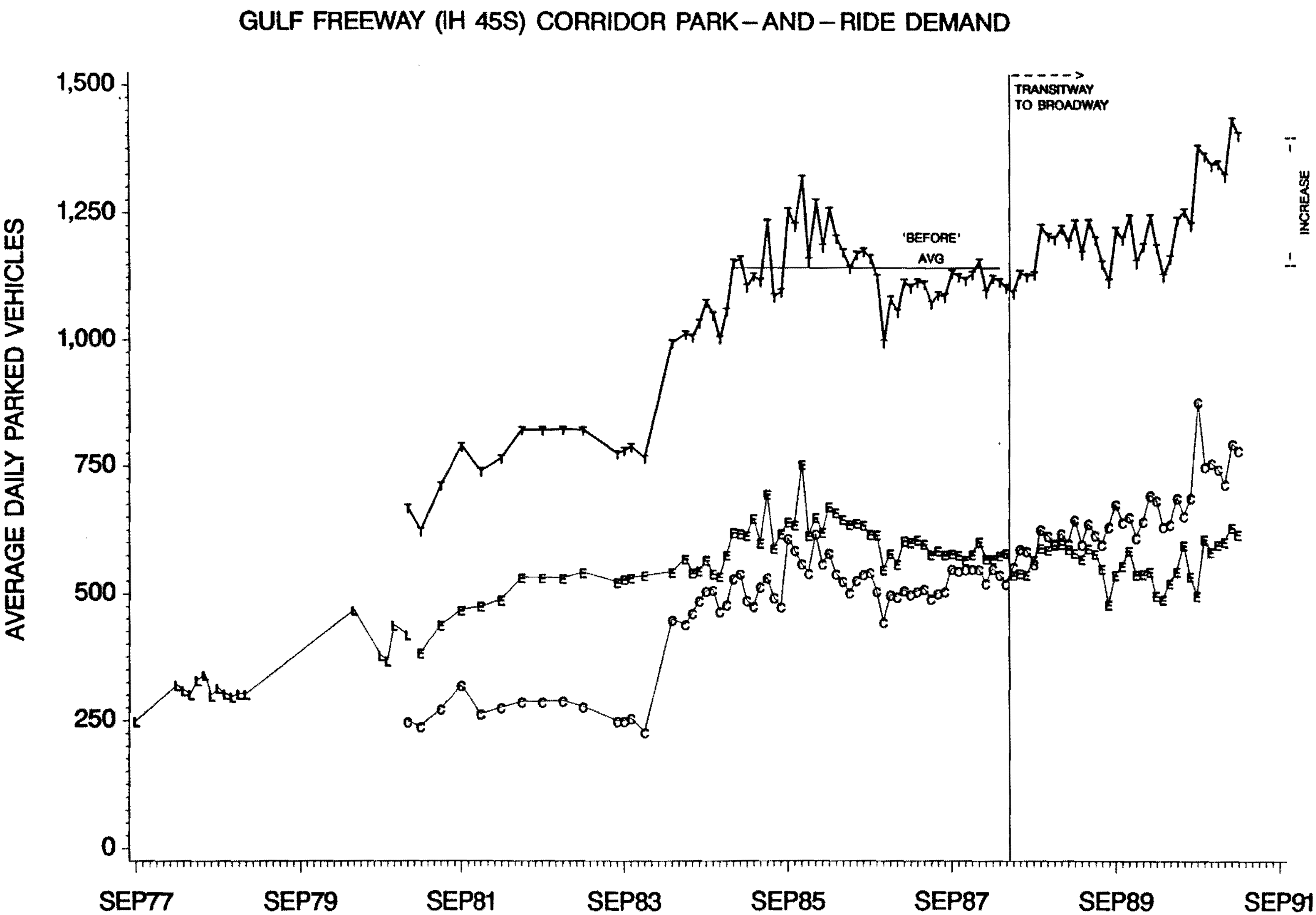
FIGURE C-11



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

LEGEND : T = TOTAL 2+ CARPOOLS
A = TOTAL TRANSITWAY 2+ CARPOOLS
M = TOTAL MAINLANE 2+ CARPOOLS

FIGURE C-12



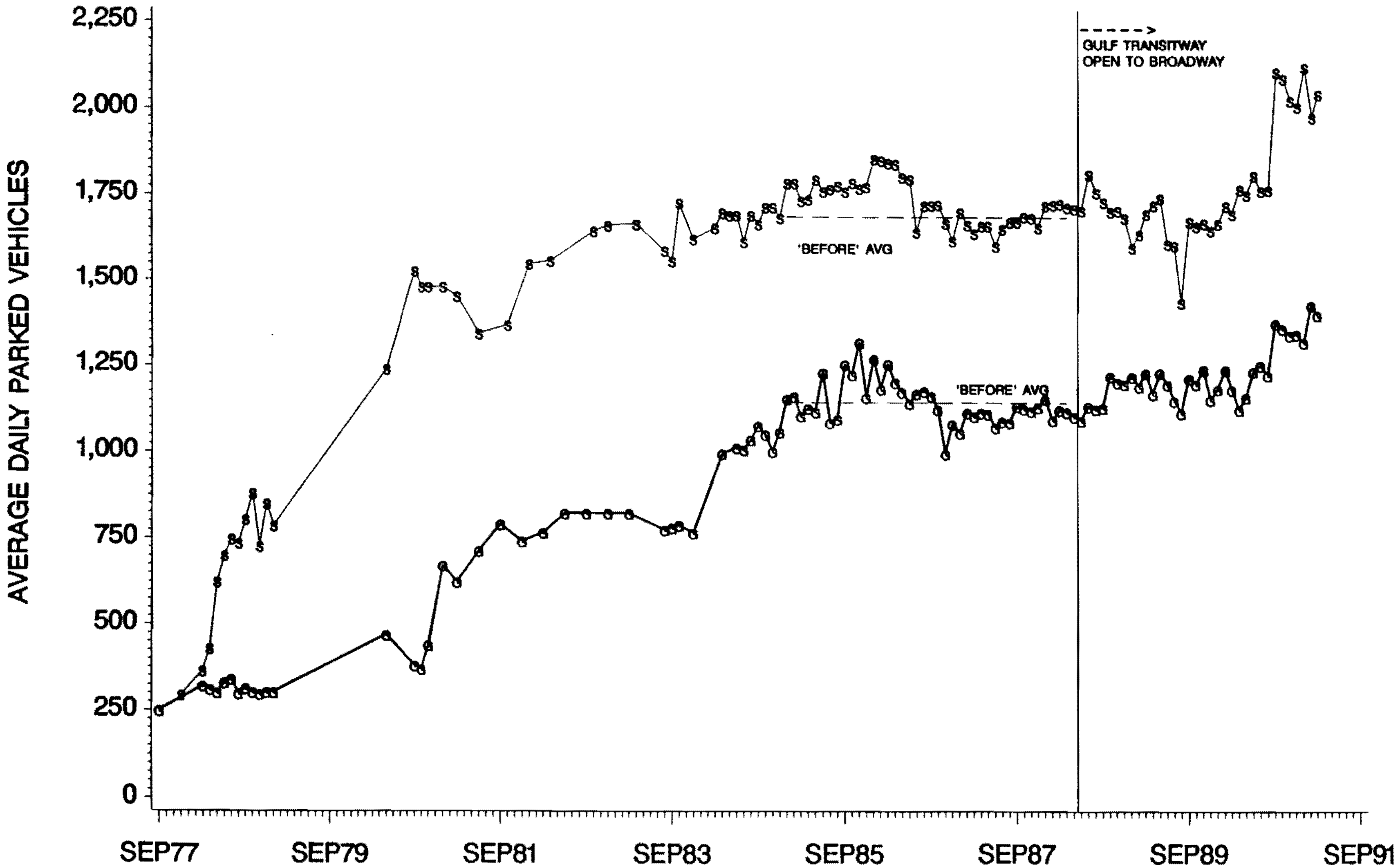
GULF TRANSITWAY, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988
CURRENT TOTAL CORRIDOR PARKING CAPACITY = 2165 SPACES

SOURCE : TEXAS TRANSPORTATION INSTITUTE & METRO

LEGEND : T = TOTAL PARKED VEHICLES
E = EDGEBROOK LOT (1000 SPACES)
C = CLEAR LAKE LOT (1165 SPACES)
L = LEASED LOTS

FIGURE C-13

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



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

LEGEND : G = GULF FREEWAY
S = FREEWAY WITHOUT TRANSITWAY (SOUTHWEST)

APPENDIX D

NORTHWEST FREEWAY AND HOV LANE

NORTHWEST FREEWAY (US 290) AND HOV LANE, HOUSTON

Summary of A.M. Peak-Period, Peak-Direction Northwest Freeway and Transitway Data, December 1990
Prepared by Texas Transportation Institute

Type of Data Phase 1 of Transitway Became Operational 8/29/88	"Representative" Pre-Transitway Value	"Representative" Current Value	% Change
Transitway Data			
Transitway Length (miles)		13.5	
Transitway Cost (millions of 1990 dollars)		$96.9	
Person-Movement			
Peak Hour (7-8 a.m.)		2,960	—
Peak Period (6-9:30 a.m.)		5,201	—
Total Daily		11,349	—
Vehicle Volumes			
Peak Hour	—	1,117	—
Peak Period	—	1,943	—
Vehicle Occupancy, Peak Hour (persons/veh)	—	2.65	—
Accident Rate (Accidents/MVM), 11/84-12/90	—	0.95	—
Vehicle Breakdowns (VMT/Breakdown), 11/84-12/90	—	55,733	—
Violation Rate (6-9:30 a.m.)	—	4.6%	—
Peak Hour Lane Efficiency[1] (1000's)	—	168	—
Annual Value of User Time Saved (millions)[7]	—	$1.3 to $2.5	—
Freeway Mainlane Data (see note)			
Person Movement			
Peak Hour	6,140	6,034	- 1.7%
Peak Period (6-9:30 a.m.)	17,450	17,455	+ 1.8%
Vehicle Volume			
Peak Hour	5,370	5,823	+ 8.4%
Peak Period	15,295	16,472	+ 7.7%
Vehicle Occupancy, Peak Hour (persons/veh)	1.14	1.04	- 8.8%
Accident Rate (Accidents/MVM)[2]	0.61	0.72	+18.0%
Avg. Operating Speed[3]			
Peak Hour	28	28.3	+ 1.1%
Peak Period	40	41.6	+ 4.0%
Peak Hour lane Efficiency[1] (1000's)	62	57	- 8.2%
Combined Freeway Mainland and Transitway Data			
Total Person Movement			
Peak Hour	6,140	8,994	+46.5%
Peak Period	17,450	22,656	+29.8%
Vehicle Volume			
Peak Hour	5,370	6,940	+29.2%
Peak Period	15,295	18,415	+20.4%
Vehicle Occupancy			
Peak Hour	1.14	1.30	+14.0%
Peak Period	1.14	1.23	+ 7.9%
2+ Carpool Volumes			
Peak Hour	490	1,389	+182.7%
Peak Period	1,365	2,609	+ 91.1%
Travel Time (minutes)[3]			
Peak Hour	16.2[4]	8.0[5]	-50.6%
Peak Period	11.4[4]	7.9[5]	-30.7%
Peak Hour Lane Efficiency[1] (1000's)	62	85	+37.1%

Footnotes on page D-3

Summary of P.M. Peak-Period, Peak-Direction Katy Freeway and Transitway Data, December 1990 Continued

Type of Data	"Representative" Pre-Transitway Value	"Representative" Current Value	% Change
<u>Transit Data</u>			
Bus Vehicle Trips			
Peak Hour	7	22	+214.3%
Peak-Period	17	45	+164.7%
Bus Passenger Trips			
Peak Hour	270	690	+155.6%
Peak Period	605	1,260	+108.3%
Bus Occupancy (persons/bus)			
Peak Hour	39	31.4	- 19.5%
Peak Period	36	28.0	- 22.2%
Vehicles Parked in Corridor Park & Ride Lots	430	1,286	+199.1%
Bus Operating Speed (mph)[3]			
Peak Hour	29.2[4]	56.9[5]	+ 94.9%
Peak Period	49.2[4]	62.5[5]	+ 27.0%

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.

Footnotes on following page.

Comparison of Measures of Effectiveness, Freeway With (Northwest US 290) and Freeway Without (Southwest US 59) Transitway, Houston[7,8]

Measure of Effectiveness	"Representative" Pre-Transitway Value	"Representative" 12/90 Value	% Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/transitway	1.14	1.30	+ 15.8%
Freeway w/o transitway	1.26	1.31	+ 4.8%
A.M. Peak Hour, 2+ Carpool Volume Change			
Freeway w/transitway	490	1,385	+156.1%
Freeway w/o transitway	595	743	+ 24.9%
Bus Passengers, Peak Period			
Freeway w/transitway	605	1,260	+108.3%
Freeway w/o transitway	2,255	2,100	- 6.9%
Cars Parked at Park-and-Ride Lots			
Freeway w/transitway	430	1,286	+199.1%
Freeway w/o transitway	1,685	1,665	- 1.2%
Facility Per Lane Efficiency[1]			
Freeway w/transitway	62	85	+ 37.1%
Freeway w/o transitway	76	60	- 23.1%

Footnotes on following page

Footnotes

[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.
[2]Accidents analyzed between Little York and IH 610, a distance of approximately 7.7 miles. This corresponds to Phase 1 of the transitway. "Before" data are for the period from 1/82 to 8/88. "Current" accident data are for the period 9/88 to 9/90. 1990 freeway volumes estimated by TTI to compute rates.
[3]From Little York to IH 510, a distance of 7.70 miles. The remaining 1.8 miles of transitway is inside IH 610.
[4]Data pertains to operation in the freeway mainlanes.
[5]Data pertains to operation in the transitway.
[6]Data for freeway without a transitway is from the Southwest Freeway (9/86 to 12/89).
[7]Based on time savings from transitway users in 1990, an annual estimate of travel time savings to transitway users is developed. A value of time of $9.25/hour is used based on the value applied in the Highway Economic Evaluation Model.
[8]The carpool volumes are adjusted in an effort to account for undercounting of carpool vehicles.

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

TRANSITWAY DATA

Description

- Phase 1 (9.5 miles) of the transitway opened August 29, 1988.
- The transitway is now complete with 13.5 miles in operation.
- The capital cost (incl. all support facilities) for the completed facility in 1990 dollars was $96.9 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.
  - 10/1/89 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

Person Movement

- In December 1990, 11,349 person trips per day were served on the HOV lane.
- A.M. Peak Hour, 2,960 persons/hour.
  - 690 (23%) bus, 8 (1%) vanpool, 2262 (76%) carpool (Figure 1).
  - Average transitway vehicle occupancy = 2.65 persons/vehicle.
- A.M. Peak Period, 5,201 persons.

NORTHWEST HOV LANE
Estimated Capital Cost (millions)

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
SUB-TOTAL	$32.6			$32.0	
Per Mile		$2.4			$2.4
TOTAL COST	$98.2			$96.9	
COST PER MILE (13.5 miles)	$7.3			$ 7.2	

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

- 1,260 (24%) bus, 95 (2%) vanpool, 3,846 (74%) carpool (Figure 2).

Vehicle Movement

- A.M. Peak Hour, 1117 vph
  - o 22 (2%) bus, 1 (<1%) vans, 1094 (98%) carpools (Figure 3).

- A.M. Peak Period, 1943 vehicles.
  - o 45 (2%) bus, 15 (1%) vans, 1883 (97%) carpools (Figure 4).

Accident Rate

- For the period 8/88 thru 12/90, the transitway accident rate was 0.95 accidents per million vehicle miles.

Vehicle Breakdown Rates

- As measured from September 1, 1988 through December 1990, the following rates have been observed.

  - Buses; 1 breakdown per 40,236 vehicle-miles of travel (VMT).
  - Vanpools; no breakdowns to date.
  - Carpools; 1 breakdown per 55,851 VMT.
  - The weighted average for all vehicle types is 1 breakdown per 55,733 VMT.

Violation Rate

- The observed violation rate (vehicles on the transitway not eligible to use the transitway) is approximately 4.6%.

Peak Hour Lane Efficiency

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. For the transitway lane, this value (expressed in 1000's) is approximately 168.4.

Travel Time Savings

- The users of the transitway experience a travel time savings in the a.m. (Figure 5).

- The tables on the following page below indicate that, on a typical non-incident day, travel time savings of approximately 32,653 minutes, or 544 hours, are realized. Assuming 250 days of operation and a value of time of $9.25/hour, this equates to $1.3 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 transitway users are estimated to be in the range of $1.3 to $2.5 million per year.

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 am. peak hour, compared to pre HOV conditions person movement has decreased by 1.7% (Figure 6).

- The a.m. peak period, compared to pre HOV conditions person movement has increased by 1.8% (Figure 7).

Vehicle Volume

- In the a.m. peak hour, vehicle volume has increased by 8.4% (Figure 6).

- In the a.m. peak period, vehicle volume has increased by 7.7% (Figure 7).

Southbound A.M. Travel Time Savings for Northwest Transitway
(Average of 4 Quarterly Travel Time Surveys Conducted in 1990)

Time of Day	Measured Travel Time			Transitway 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	4.48	4.08	0.40	259	20	95	374	149.60
6:30	4.24	4.07	0.17	634	21	180	835	142.65
7:00	4.82	4.04	0.78	872	0	268	1,139	886.08
7:30	4.65	4.05	0.61	566	2	170	738	447.77
8:00	4.47	3.98	0.48	268	0	73	340	164.33
8:30	4.07	3.96	0.11	78	0	0	78	8.45
9:00	4.08	3.97	0.11	36	0	7	43	4.86
Peak Period Total				2,712	43	792	3,547	1,803.75
Section From Senate to S.P. Railroad								
6:00	12.87	13.66	-0.79	167	16	80	263	-207.48
6:30	16.00	14.01	1.98	644	66	263	973	1,931.13
7:00	21.52	14.52	6.99	1,249	18	368	1,634	11,427.17
7:30	21.28	14.82	6.46	1,365	9	345	1,719	11,103.42
8:00	16.47	14.19	2.28	650	1	140	791	1,802.25
8:30	13.53	13.74	-0.22	223	0	15	238	-51.24
9:00	14.59	13.57	1.02	74	0	13	87	88.69
Peak Period Total				4,370	110	1224	5,704	26,093.96
Northbound PM Travel Time Savings for Northwest Transitway								
Section from Senate to Eldridge								
15:30	4.42	4.35	0.08	45	3	20	67	5.14
16:00	4.25	4.42	-0.18	157	15	30	202	-35.35
16:30	4.36	4.32	0.04	249	8	103	359	13.46
17:00	4.29	4.33	-0.04	454	8	245	706	-28.45
17:30	4.51	4.51	0.00	587	2	295	884	3.68
18:00	4.35	4.31	0.04	372	3	95	470	18.28
18:30	4.33	4.29	0.04	170	0	50	220	9.78
Peak Period Total				2,032	39	838	2,908	-13.46
Section from the S.P. Railroad to Senate								
15:30	13.01	13.98	-0.97	84	0	30	114	-110.27
16:00	13.17	14.56	-1.39	234	43	98	375	-520.66
16:30	14.49	14.04	0.45	450	23	253	725	325.36
17:00	15.43	14.38	1.06	765	10	315	1,090	1,152.07
17:30	17.97	14.88	3.09	778	6	375	1,159	3,584.91
18:00	15.01	14.51	0.50	411	1	213	625	314.24
18:30	12.98	13.79	-0.82	152	0	63	214	-174.77
Peak Period Total				2,873	83	1,345	4,301	4,570.87

Vehicle Occupancy

- In the a.m. peak hour, compared to pre HOV conditions mainlane occupancy has declined by 8.8%.
- In the a.m. peak period, compared to pre HOV conditions mainlane occupancy has declined by 5.4%.

Accident Rate

- Implementation of the transitway 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 transitway was 0.61 accidents per million vehicle miles (MVM). The accident data available for the period (9/88-9/90) after the transitway opened indicates an accident rate of 0.72 accidents/MVM. 1990 freeway volumes estimated by TTI to compute rates.

Average Operating Speed

- In comparison to pre-transitway conditions, mainlane operating speeds have decreased in the peak hour, but show improvement in the peak period. The data in Figure 8 show the average of all travel time runs made both before and after the transitway 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 8.2%.

COMBINED FREEWAY AND TRANSITWAY DATA

Total Person Movement

- Percent by transitway, a.m. peak.

- At Pinemont, the transitway is moving 33% of peak-hour person movement (transitway = 2,960; freeway = 6,034) and 23% of peak-period (transitway = 5,201; freeway = 17,455) person movement (Figure 9).

- Increase in a.m. Person Movement at Pinemont

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

  - Total peak-hour person movement has increased by 46.5%, from 6,140 to 8,994 (Figure 9). Peak-period person movement has increased by 29.8%, from 17,450 to 22,656 (Figure 10).

<u>Vehicle Occupancy</u>

- The combined occupancy for the freeway and transitway in the peak hour is 1.30, an 14.0% increase over the pre-transitway occupancy (Figure 11). Occupancy in the peak period is 7.9% greater than pre-transitway levels (Figure 12).

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

<u>Carpool Volumes</u>

- In the a.m. peak hour, the total number of 2+ carpools (freeway plus transitway) has increased by 182.7% compared to pre-transitway levels (Figure 14). In the a.m. peak period, the increase has been 91.1% (Figure 15). These increases have not been experienced on freeways not having transitways (Figure 16).

- Carpools using the transitway were surveyed in November 1987. Of the carpools surveyed: 34% previously drove alone; 1% are making new trips; 52% previously carpooled, and 13% rode a bus or van.

<u>Peak Hour Lane Efficiency</u>

- 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 transitway lane) has increased by 37% since the implementation of the transitway (Figure 17). Currently, no discernable trend in efficiency is evident when the Northwest Freeway is compared with freeways that have no transitway (Figure 18).

BUS TRANSIT DATA

Bus Vehicle and Passenger Trips

- In the a.m. peak hour, bus trips have been increased by 214% since the transitway opened, and a 156% increase in bus ridership has resulted (Figure 19). In the peak period, a 165% increase has occurred in bus trips, and a 108% increase in bus ridership has resulted (Figure 20).

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

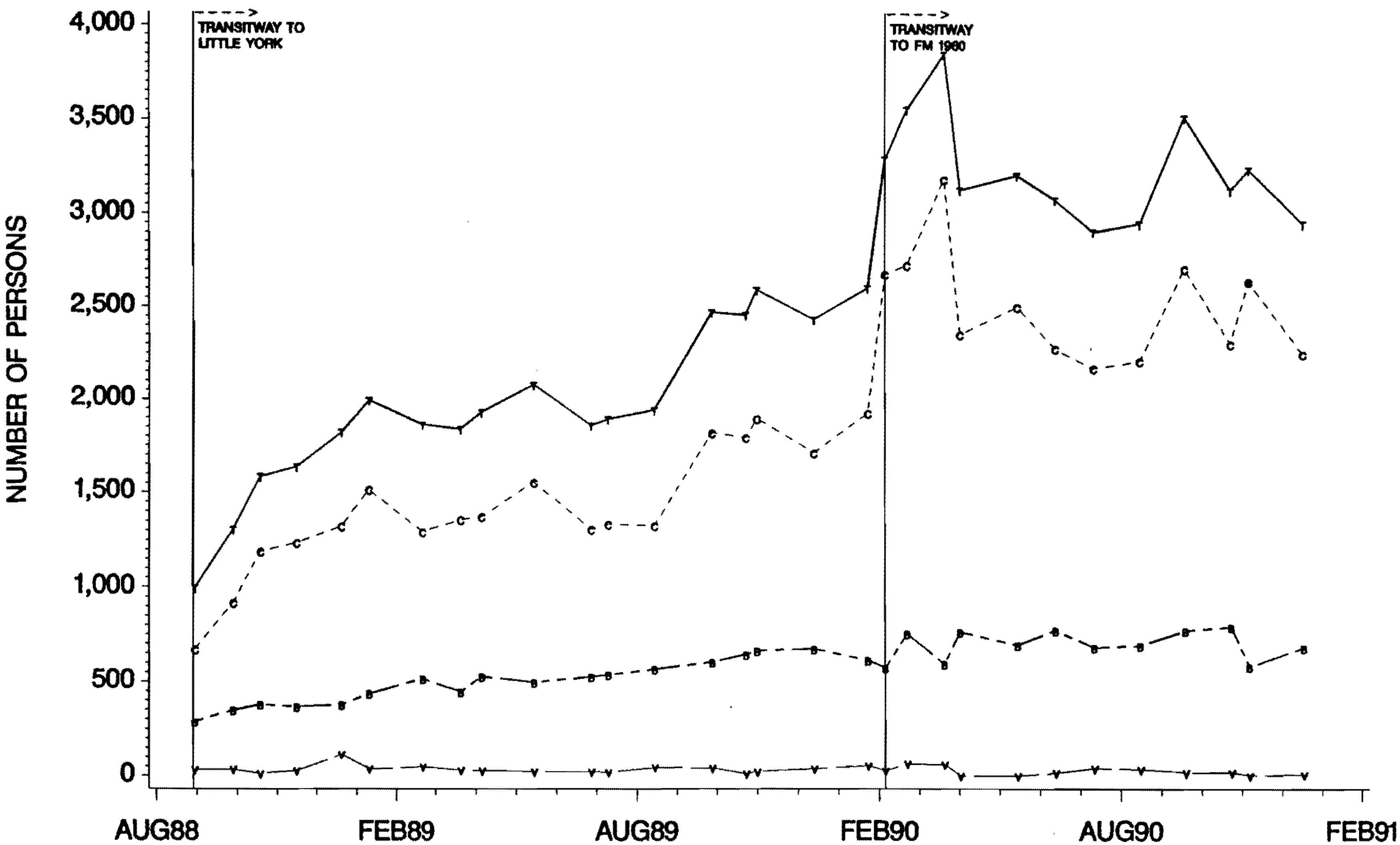
Park-and-Ride

- Prior to opening the transitway, approximately 430 vehicles were parked in corridor park-and-ride lots. This has increased 199% to a current level of 1286 (Figure 22).

- The increase in cars parked in the Northwest corridor has not occurred in the freeway corridor that does not have a transitway (Figure 23).

FIGURE D-1

NORTHWEST FREEWAY (US 290) TRANSITWAY
A.M. PEAK HOUR TRANSITWAY PERSON MOVEMENT

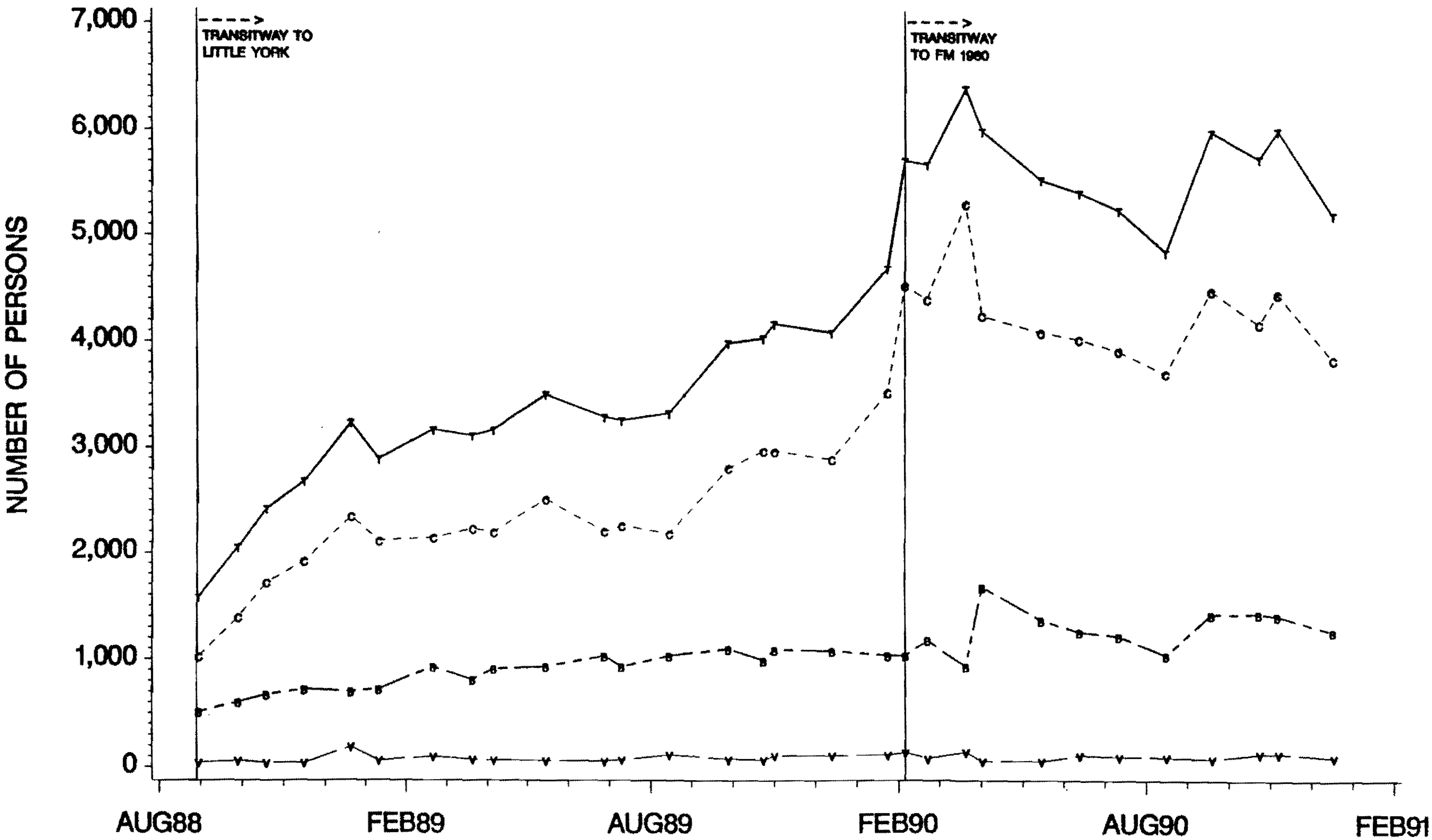


NORTHWEST TRANSITWAY PHASE 1, NORTHWEST TRANSIT CENTER TO
LITTLE YORK (9.5 MI.), OPENED AUGUST 29, 1988
NORTHWEST TRANSITWAY PHASE 2, LITTLE YORK TO FM 1960 (3.9 MI.), OPENED FEBRUARY 6, 1990
DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-2

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

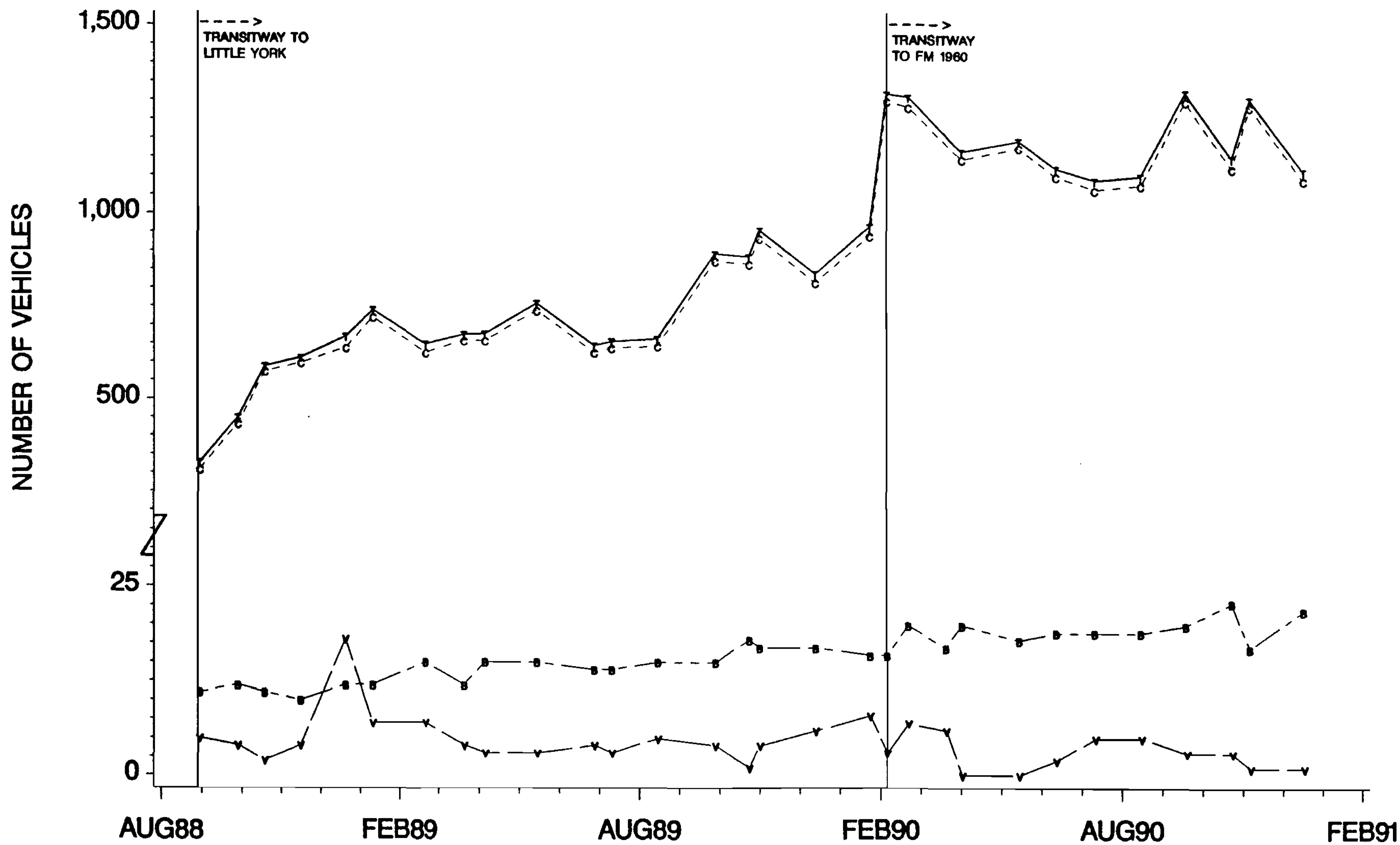


NORTHWEST TRANSITWAY PHASE 1, NORTHWEST TRANSIT CENTER TO
LITTLE YORK (9.5 MI), OPENED AUGUST 29, 1988
NORTHWEST TRANSITWAY PHASE 2, LITTLE YORK TO FM 1960 (3.9 MI.), OPENED FEBRUARY 6, 1990
PEAK PERIOD IS 6:00 – 9:30 A.M.
DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-3

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

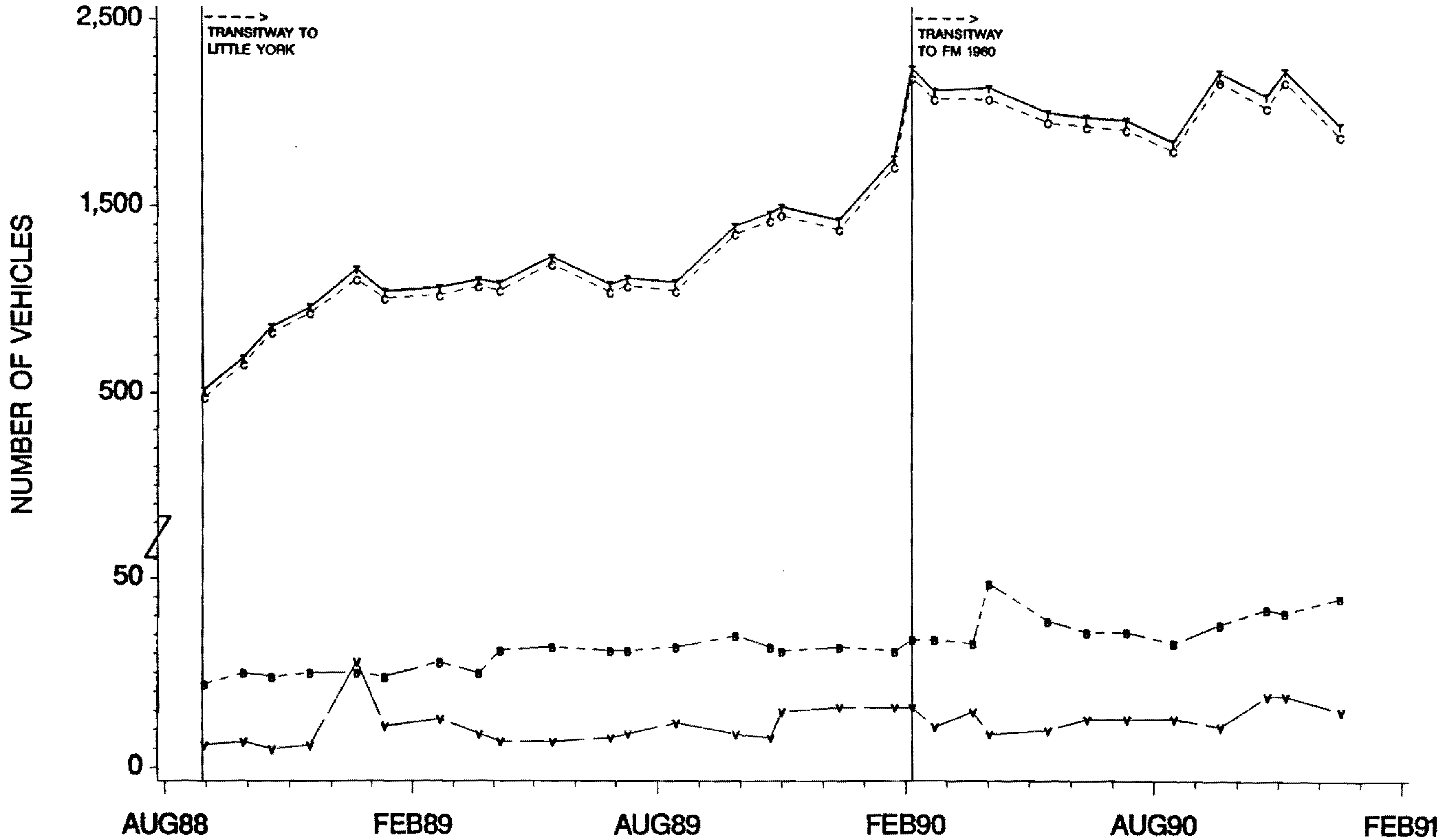


NORTHWEST TRANSITWAY PHASE 1, NORTHWEST TRANSIT CENTER TO
LITTLE YORK (9.5 MI), OPENED AUGUST 29,1988
NORTHWEST TRANSITWAY PHASE 2, LITTLE YORK TO FM 1960 (3.9 MI.), OPENED FEBRUARY 6, 1990
DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-4

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

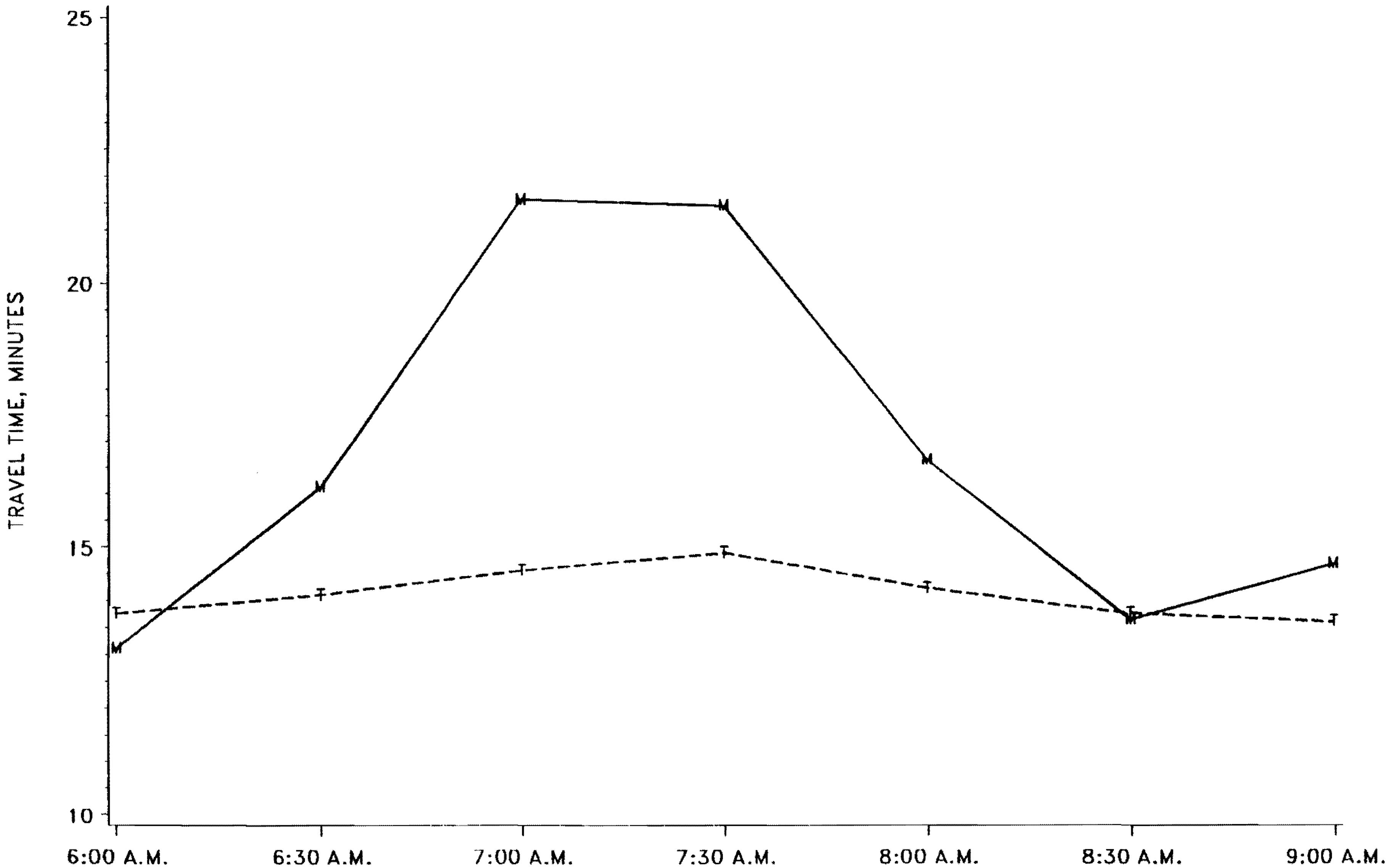


NORTHWEST TRANSITWAY PHASE 1, NORTHWEST TRANSIT CENTER TO
LITTLE YORK (9.5 MI.), OPENED AUGUST 29, 1988
NORTHWEST TRANSITWAY PHASE 2, LITTLE YORK TO FM 1960 (3.9 MI.), OPENED FEBRUARY 8, 1990
PEAK PERIOD IS 6:00 – 9:30 A.M.
DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-5

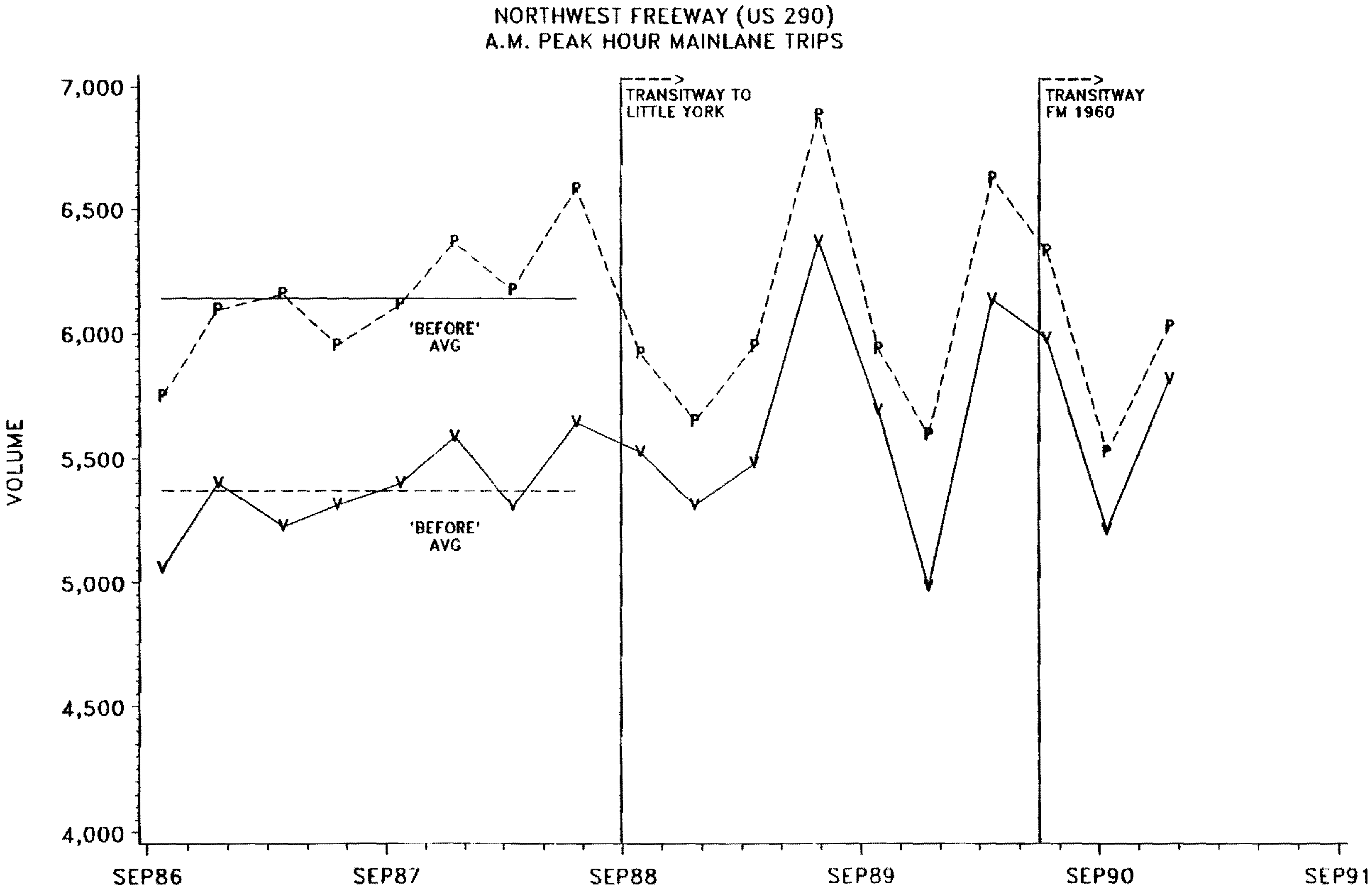
NORTHWEST FREEWAY (US 290)
MAINLANE AND TRANSITWAY A.M. TRAVEL TIME



TRAVEL TIMES ARE FROM TELGE TO S.P.R.R. @ KATY FREEWAY
SOURCE : TEXAS TRANSPORTATION INSTITUTE

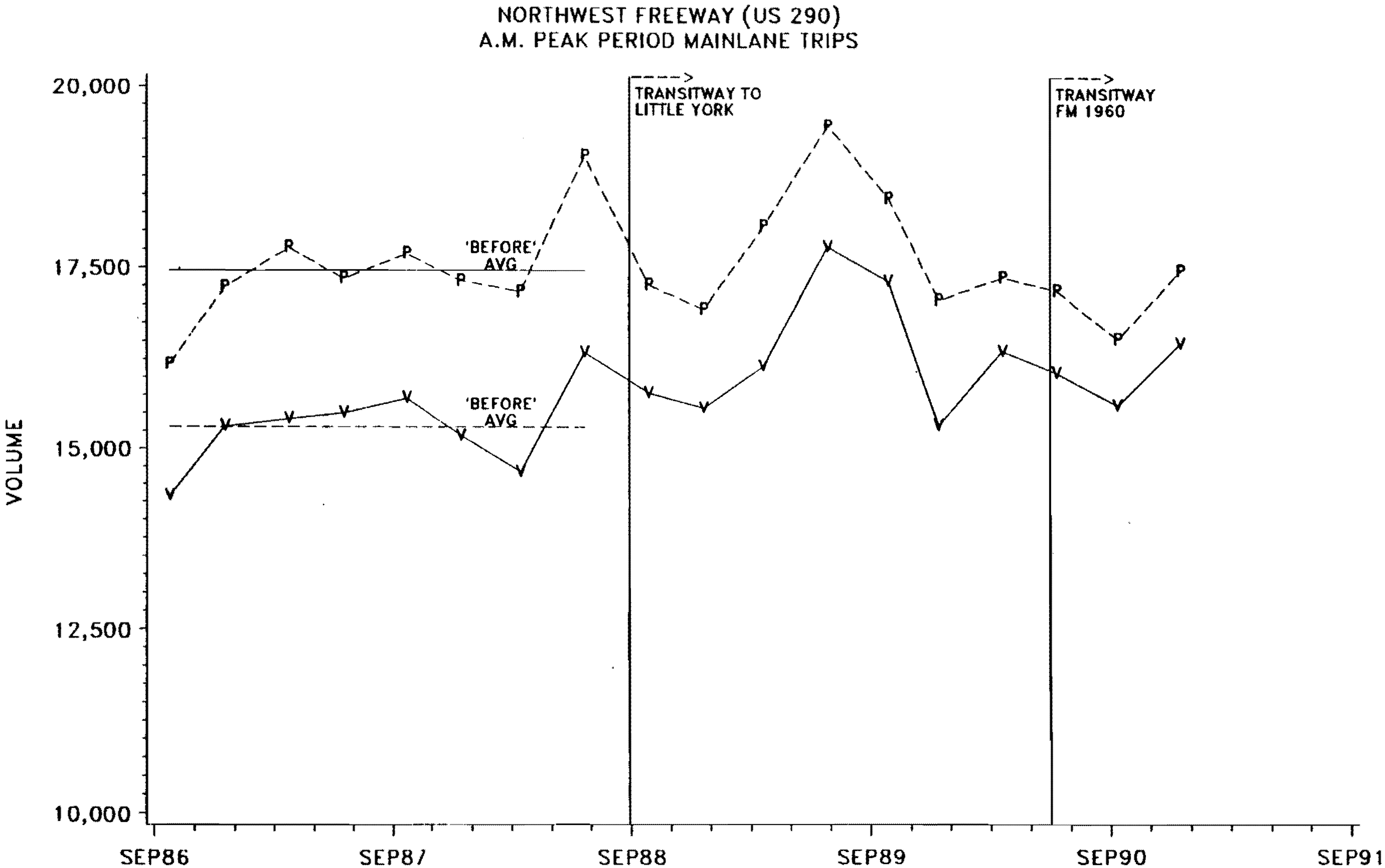
LEGEND : M – MAINLANE TRAVEL TIME
T – TRANSITWAY TRAVEL TIME

FIGURE D-6



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

FIGURE D-7

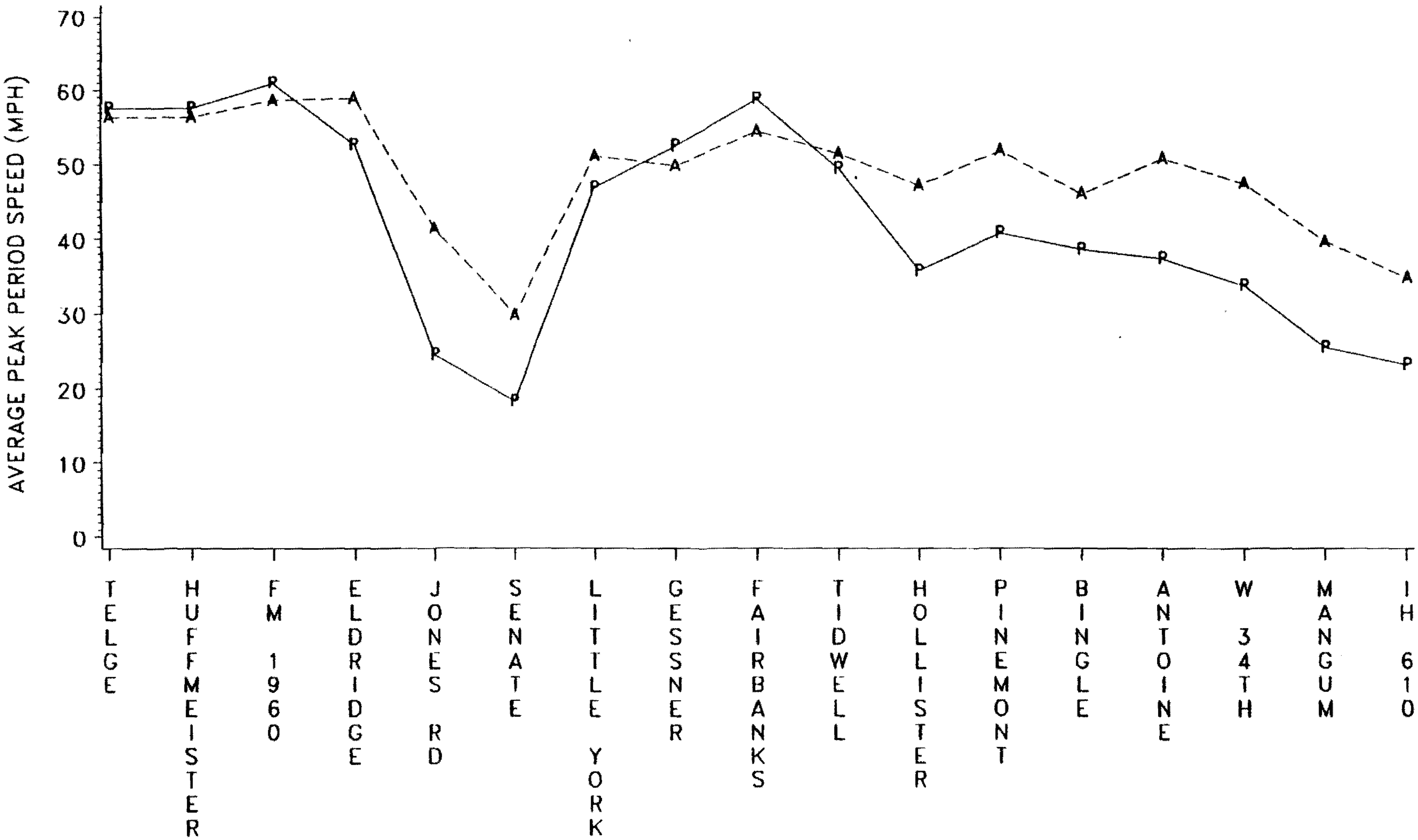


NORTHWEST TRANSITWAY PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (9.5 MI), OPENED AUGUST 29,1988
PEAK PERIOD IS 6:00 TO 9:30 A.M.
DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-8

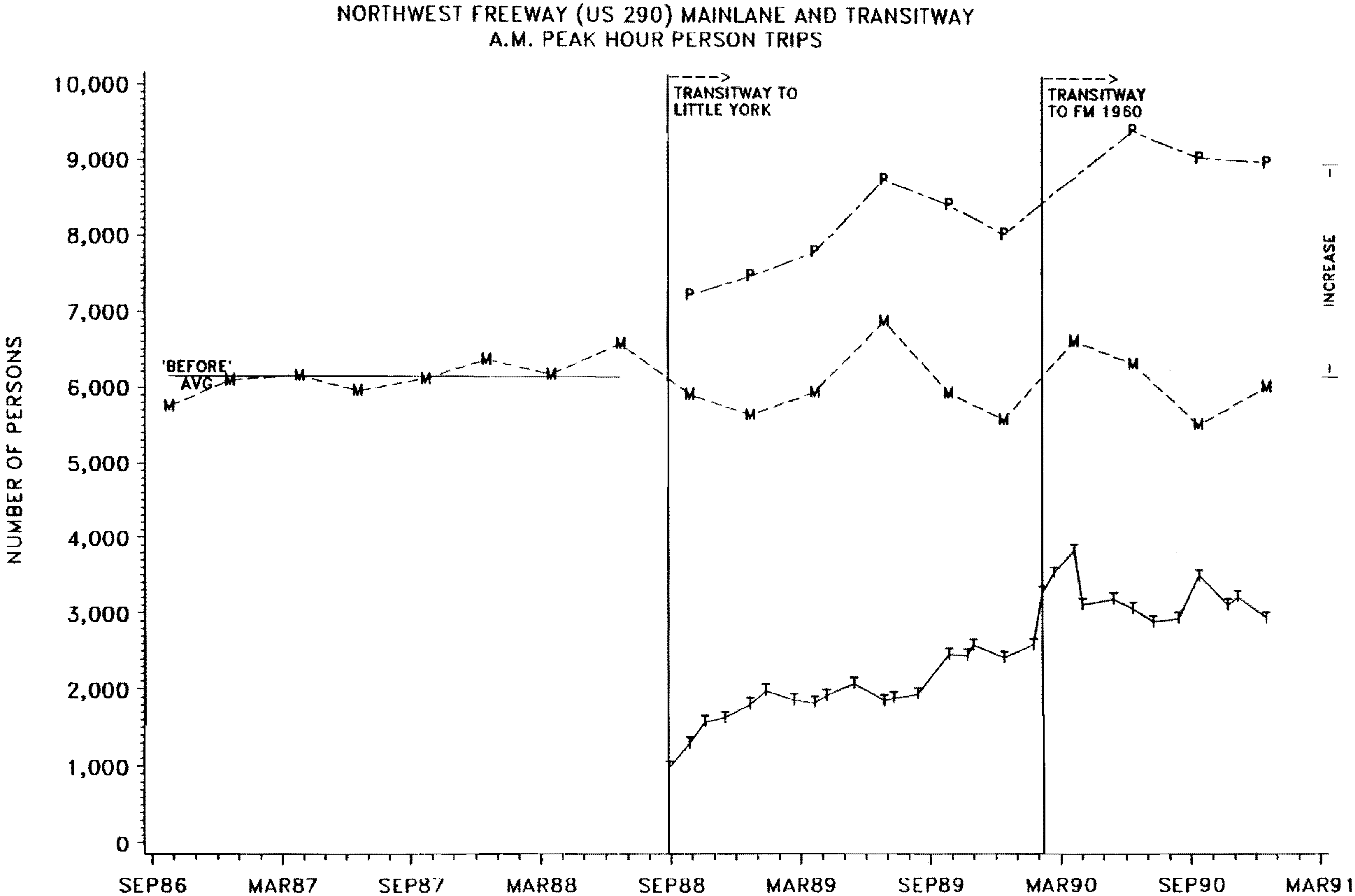
NORTHWEST FREEWAY (US 290) MAINLANE TRAVEL TIME AND SPEED SURVEY
SOUTHBOUND, TELGE TO IH 610
A.M. PEAK PERIOD



DATA COLLECTED 6:00 TO 9:30 A.M.
DATA COLLECTED FROM SEPTEMBER, 1986 TO DECEMBER, 1990
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-9

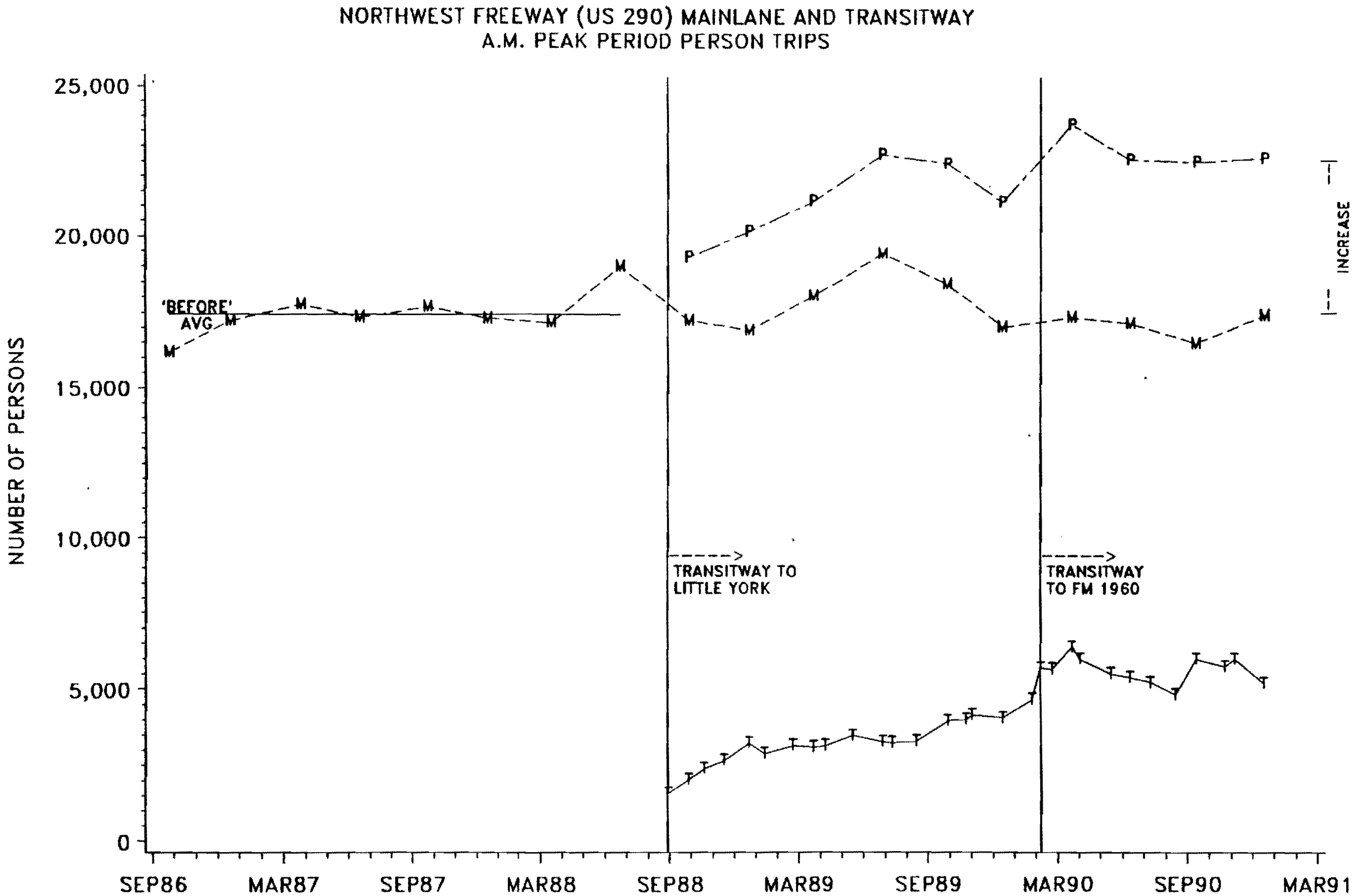


DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION

SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = TOTAL PERSONS
M = MAINLANE PERSONS
T = TRANSITWAY PERSONS

FIGURE D-10

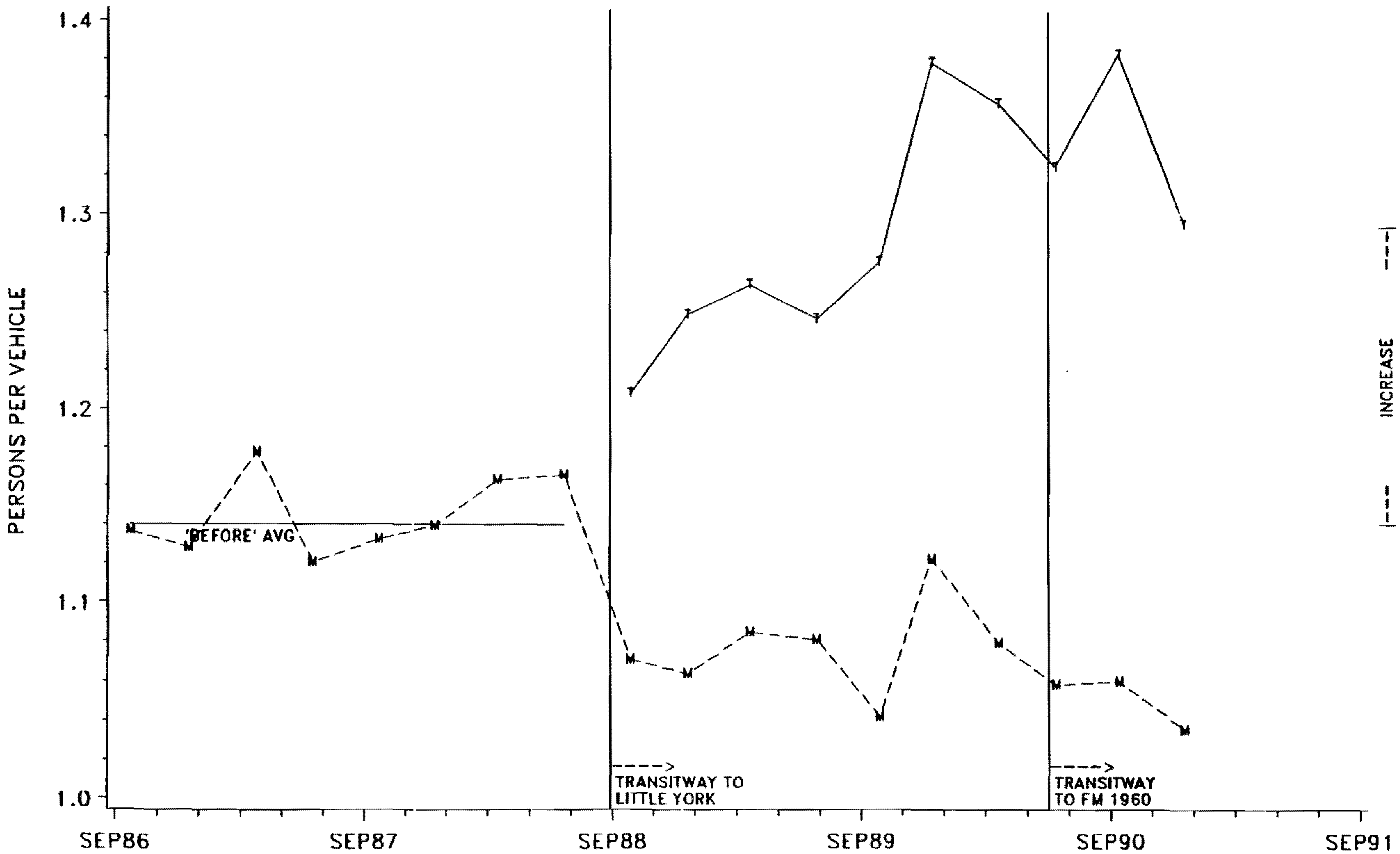


DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION
PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = TOTAL PERSONS
M = MAINLANE PERSONS
T = TRANSITWAY PERSONS

FIGURE D-11

NORTHWEST FREEWAY (US 290) MAINLANE AND TRANSITWAY
A.M. PEAK HOUR AVERAGE OCCUPANCY

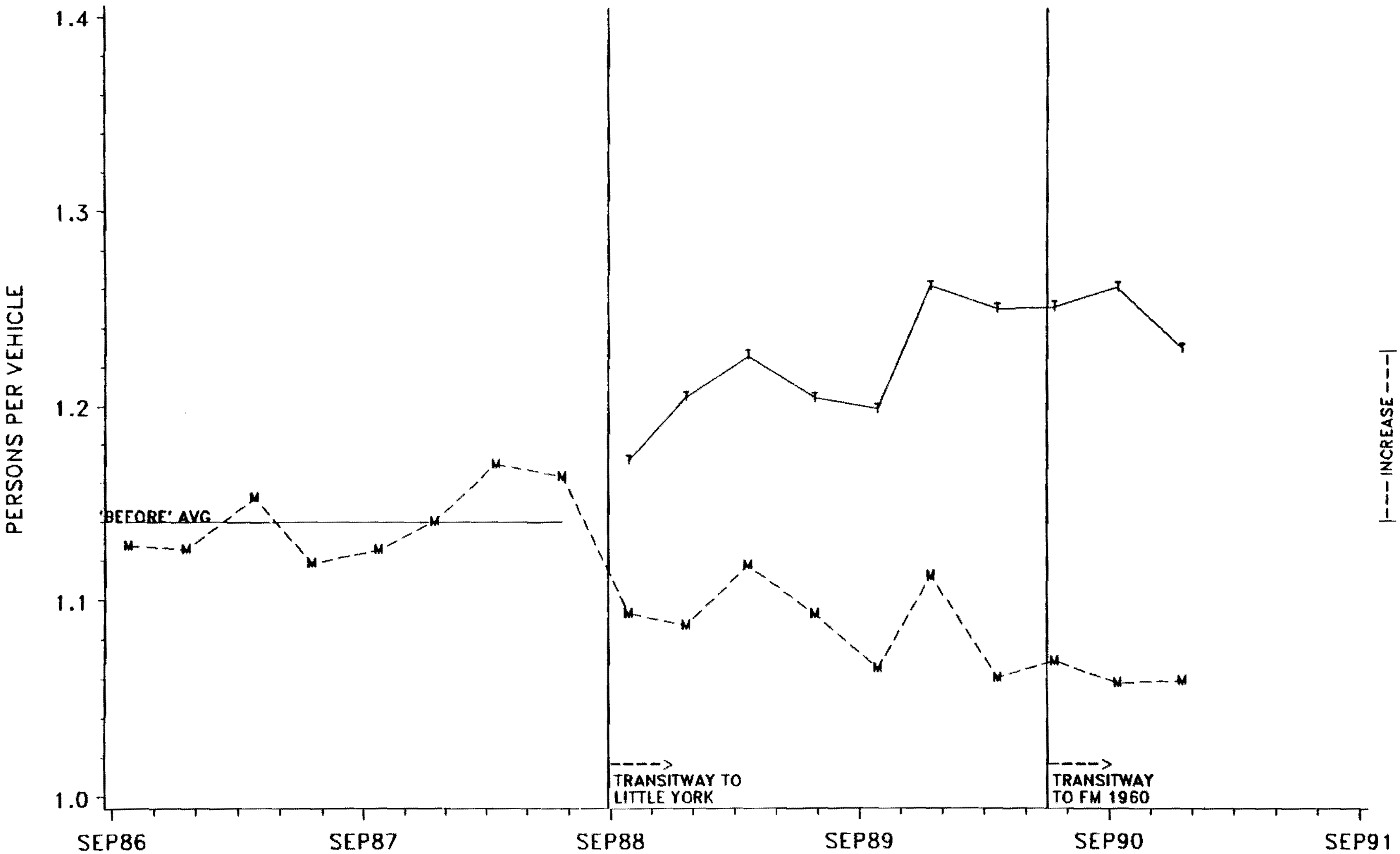


DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-12

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

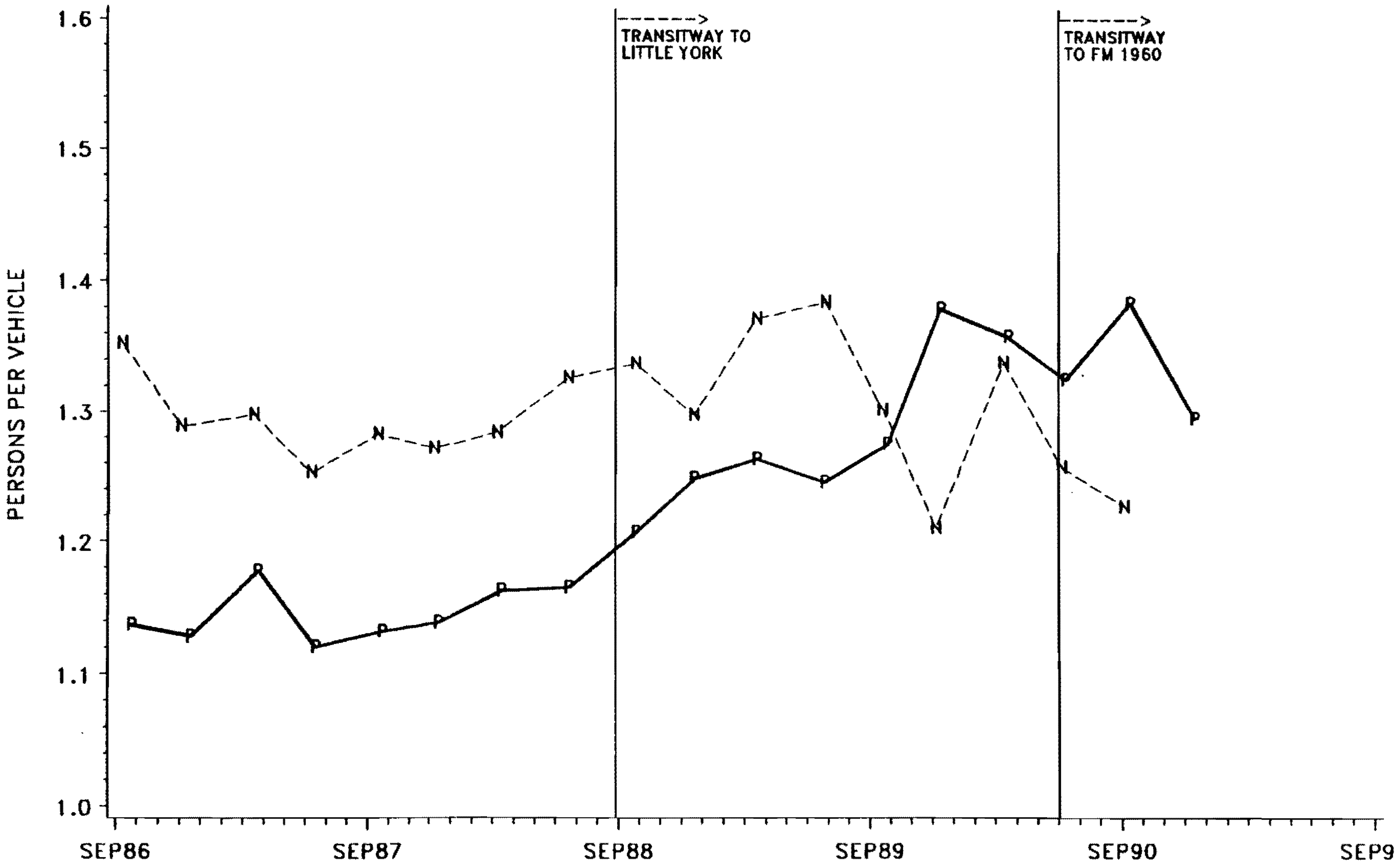


DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION
PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-13

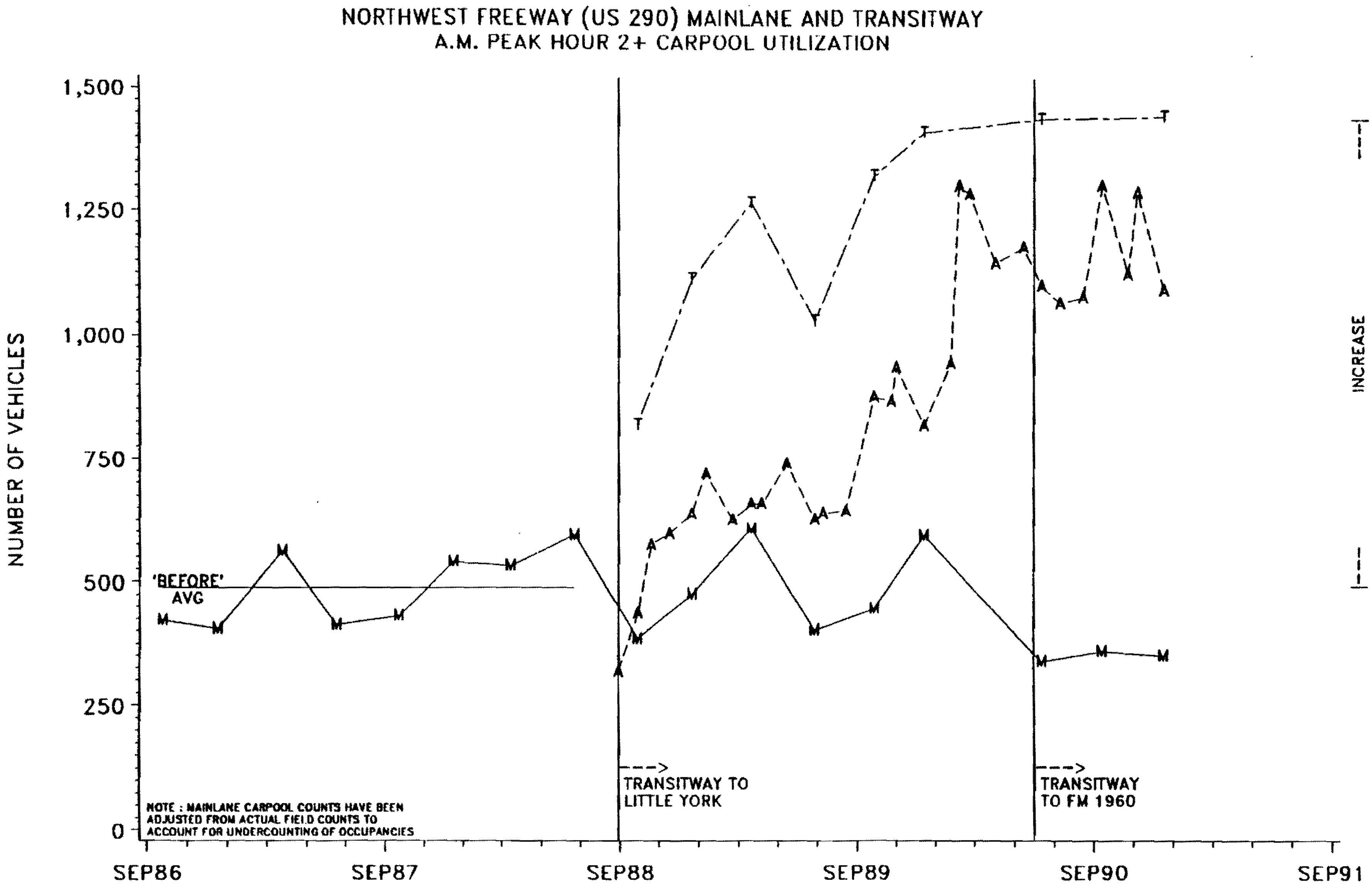
A.M. PEAK HOUR AVERAGE OCCUPANCY
FREEWAY WITH AND WITHOUT TRANSITWAY



DATA FOR FREEWAYS WITHOUT TRANSITWAYS 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 TRANSITWAY)
N = FREEWAYS WITHOUT TRANSITWAY

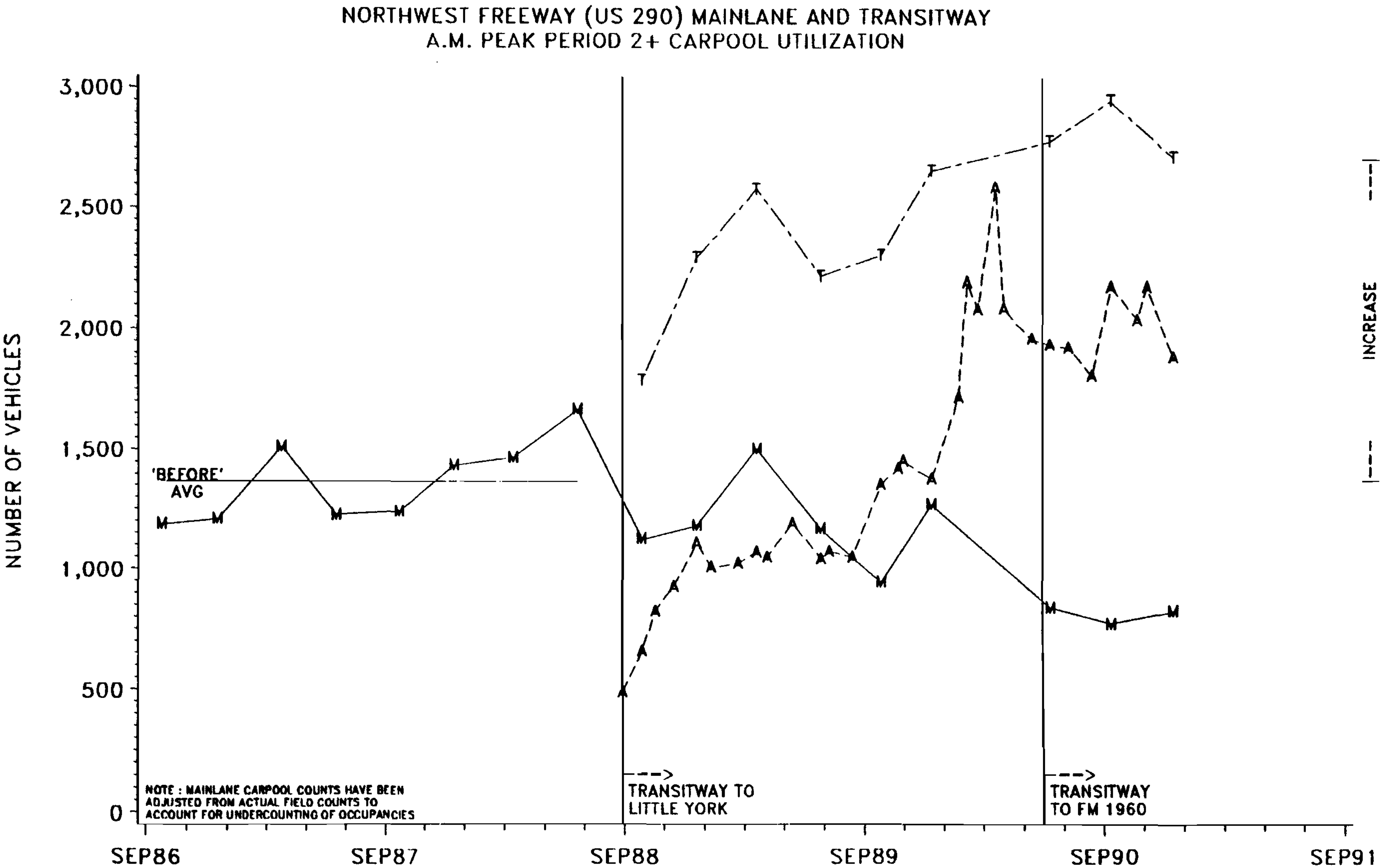
FIGURE D-14



NORTHWEST TRANSITWAY 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
A = TOTAL TRANSITWAY 2+ CARPOOLS
M = TOTAL MAINLANE 2+ CARPOOLS

FIGURE D-15

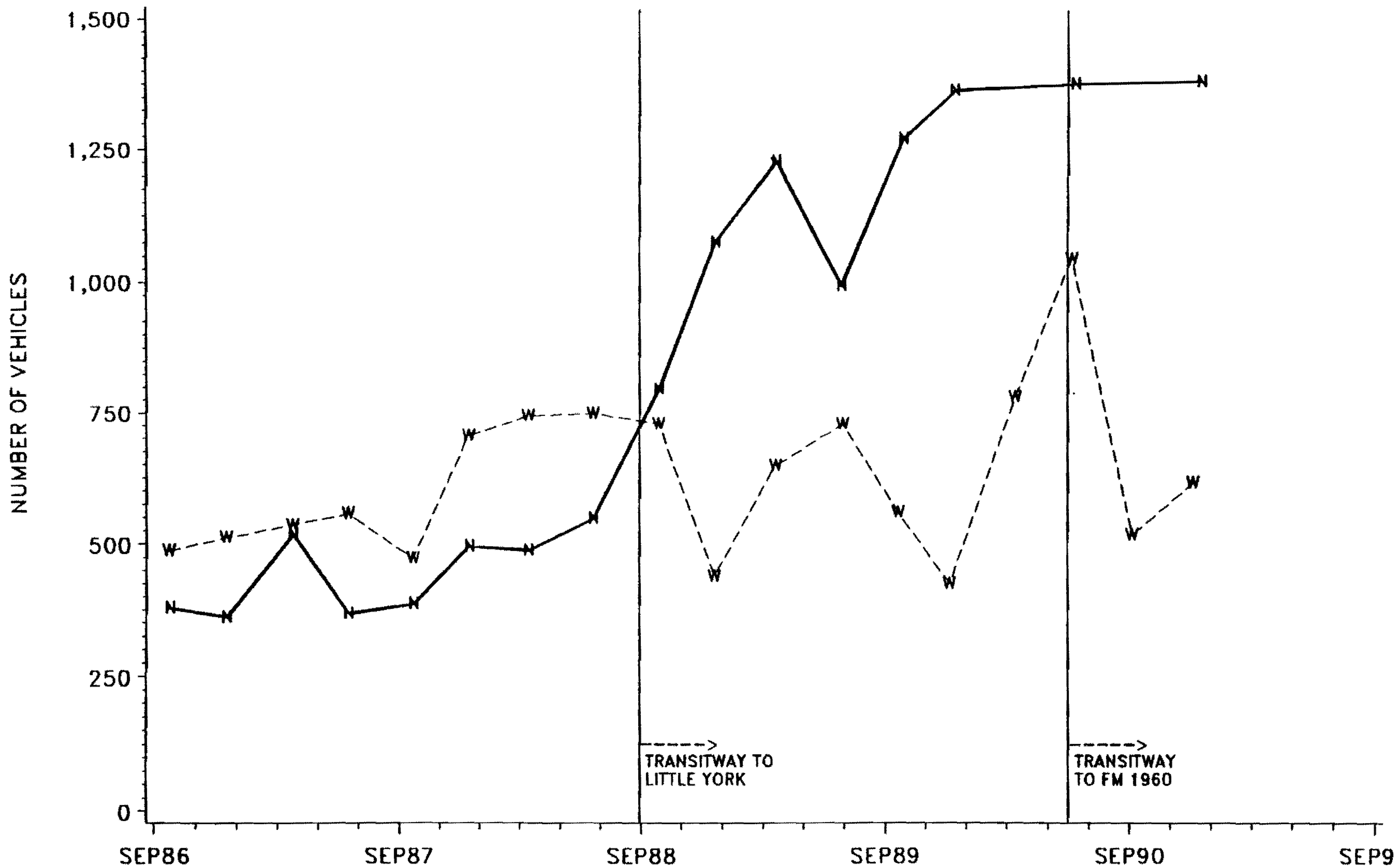


NORTHWEST TRANSITWAY PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (9.5 MI), OPENED AUGUST 29, 1988
PEAK PERIOD IS 6:00 – 9:30 A.M.
DATA COLLECTED SOUTHBOUND UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL 2+ CARPOOLS
A = TOTAL TRANSITWAY 2+ CARPOOLS
M = TOTAL MAINLANE 2+ CARPOOLS

FIGURE D-16

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

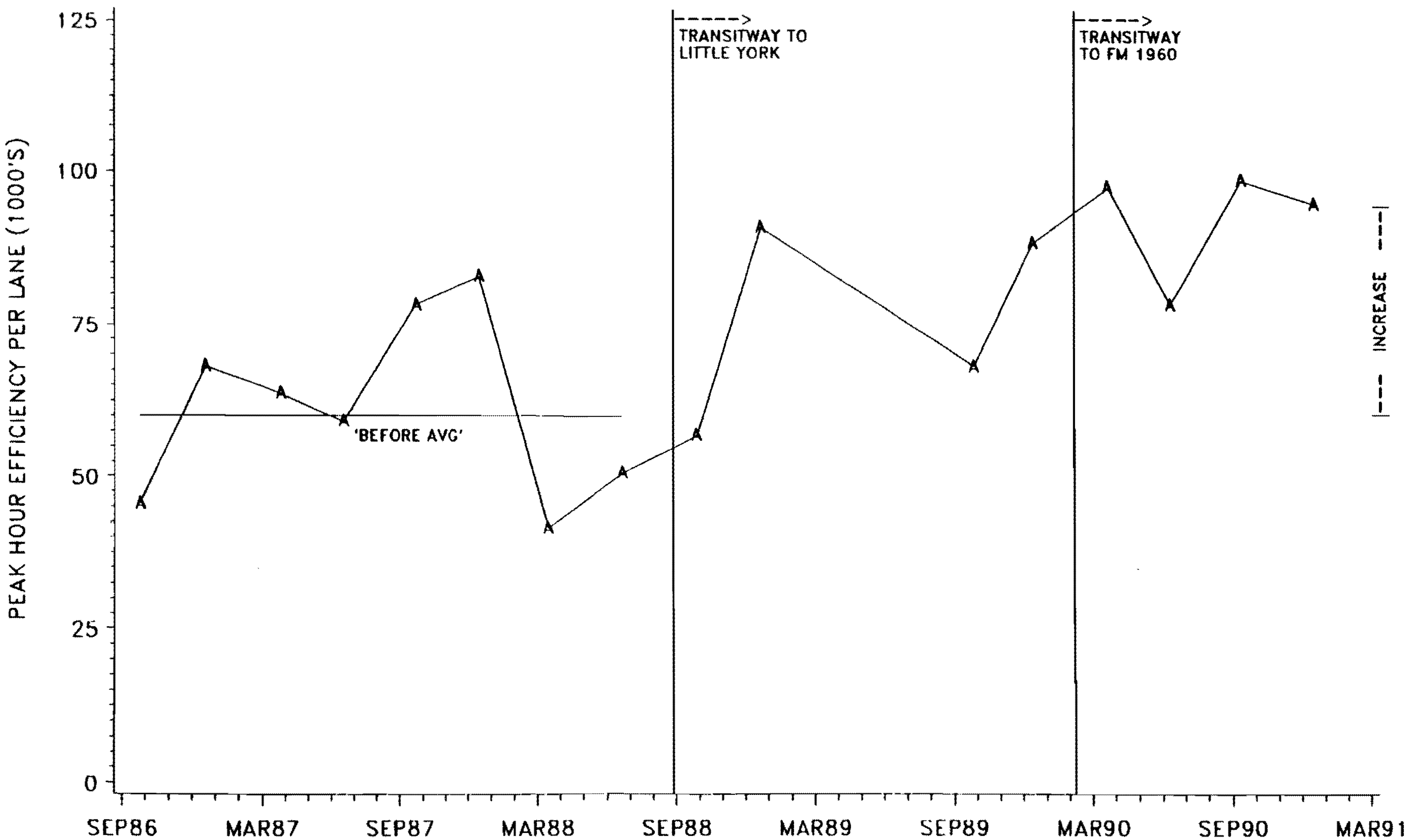


DATA FOR FREEWAYS WITHOUT TRANSITWAYS ARE A COMPOSITE OF
GULF FWY (6/83 – 4/88) AND SOUTHWEST FWY (6/86 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-17

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

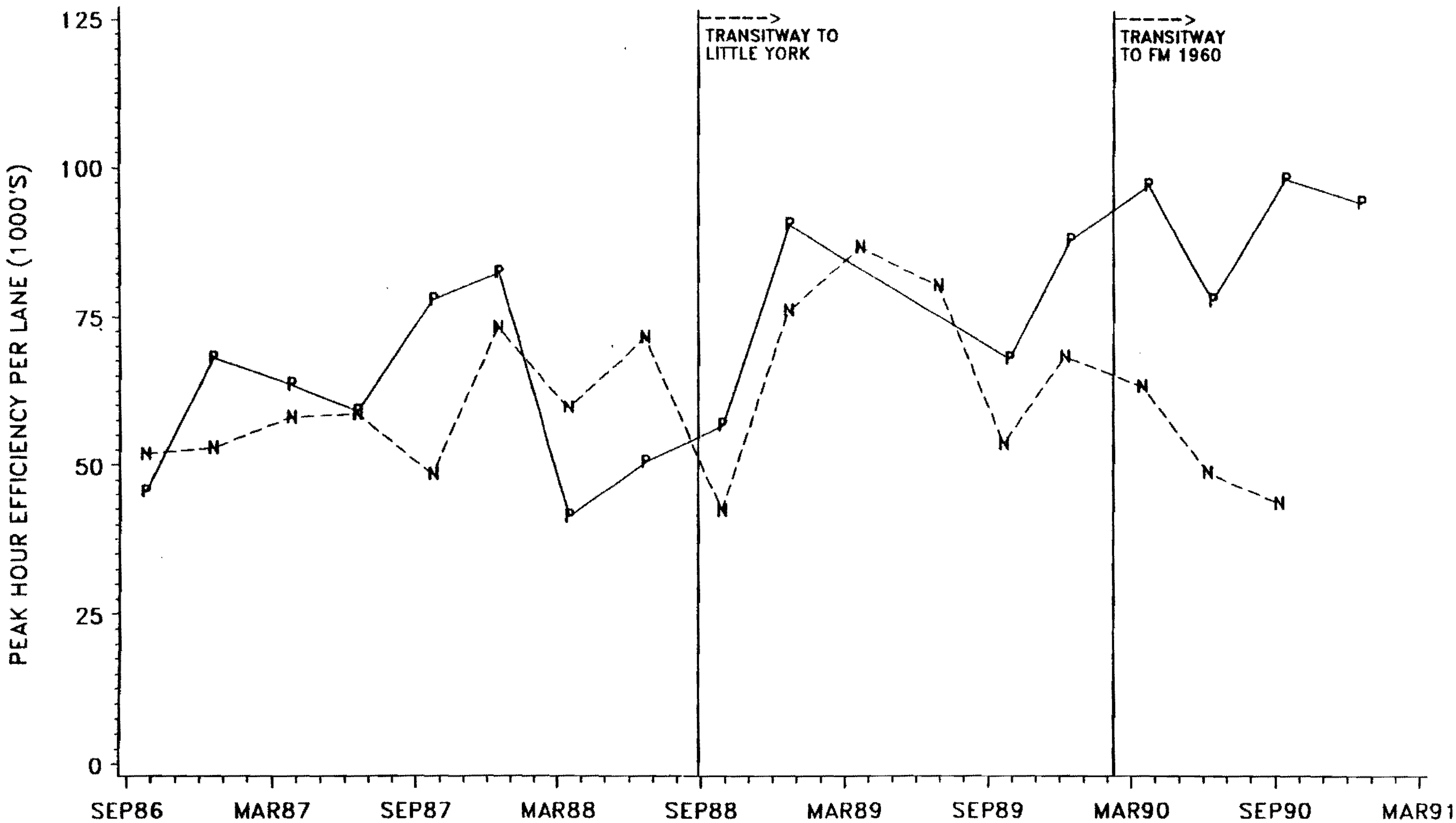


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE TRANSITWAY, IT REPRESENTS TOTAL PERSONS (FREEWAY + TRANSITWAY) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 4 LANES
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : A = A.M. PEAK HOUR EFFICIENCY

FIGURE D-18

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

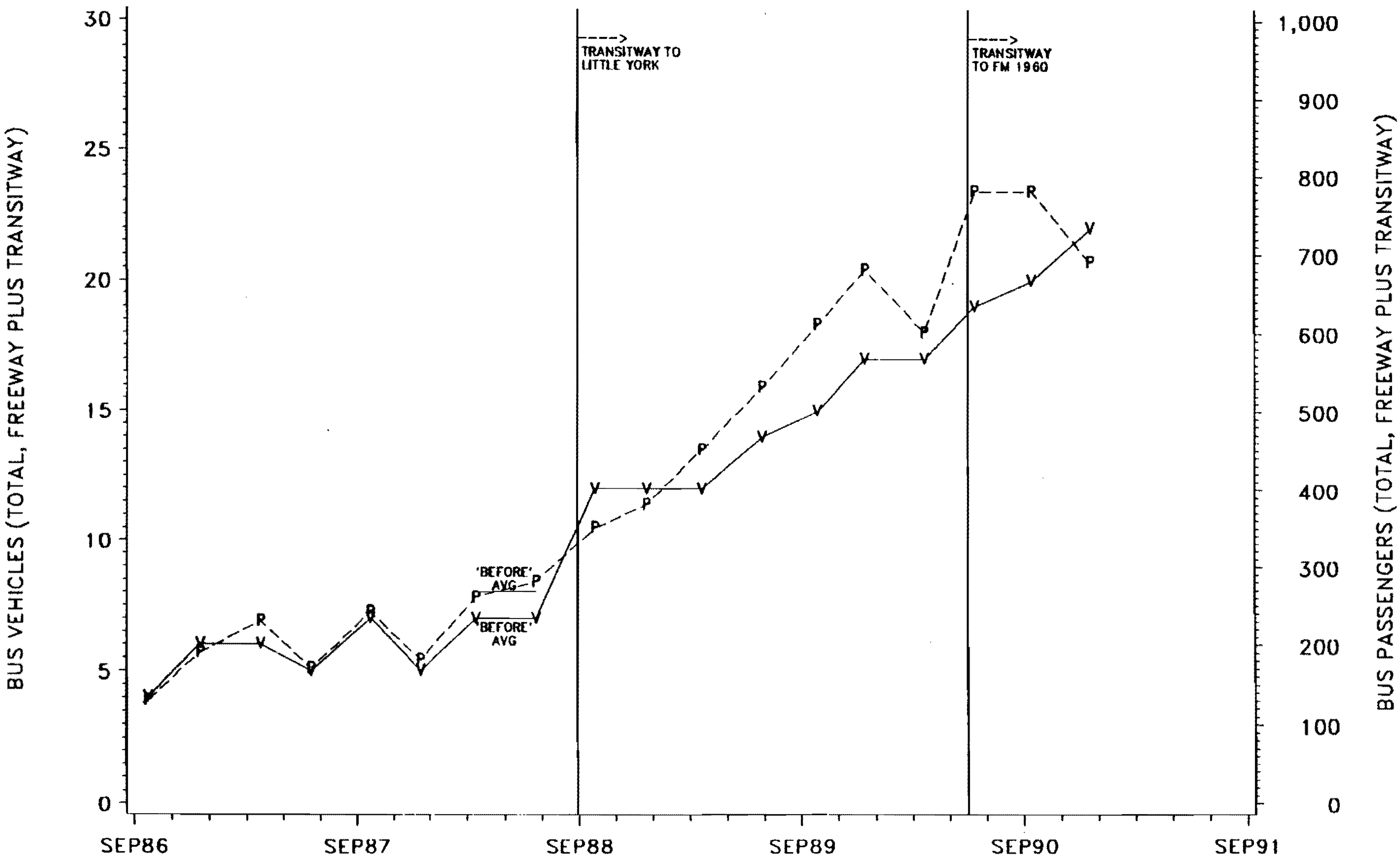


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE TRANSITWAY, IT REPRESENTS TOTAL PERSONS (FREEWAY + TRANSITWAY) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 4 LANES
DATA FOR FREEWAYS WITHOUT TRANSITWAYS ARE A COMPOSITE OF
GULF FWY (6/83 – 4/88) AND SOUTHWEST FWY (6/86 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = NORTHWEST FREEWAY EFFICIENCY
N = FREEWAYS WITHOUT TRANSITWAY

FIGURE D-19

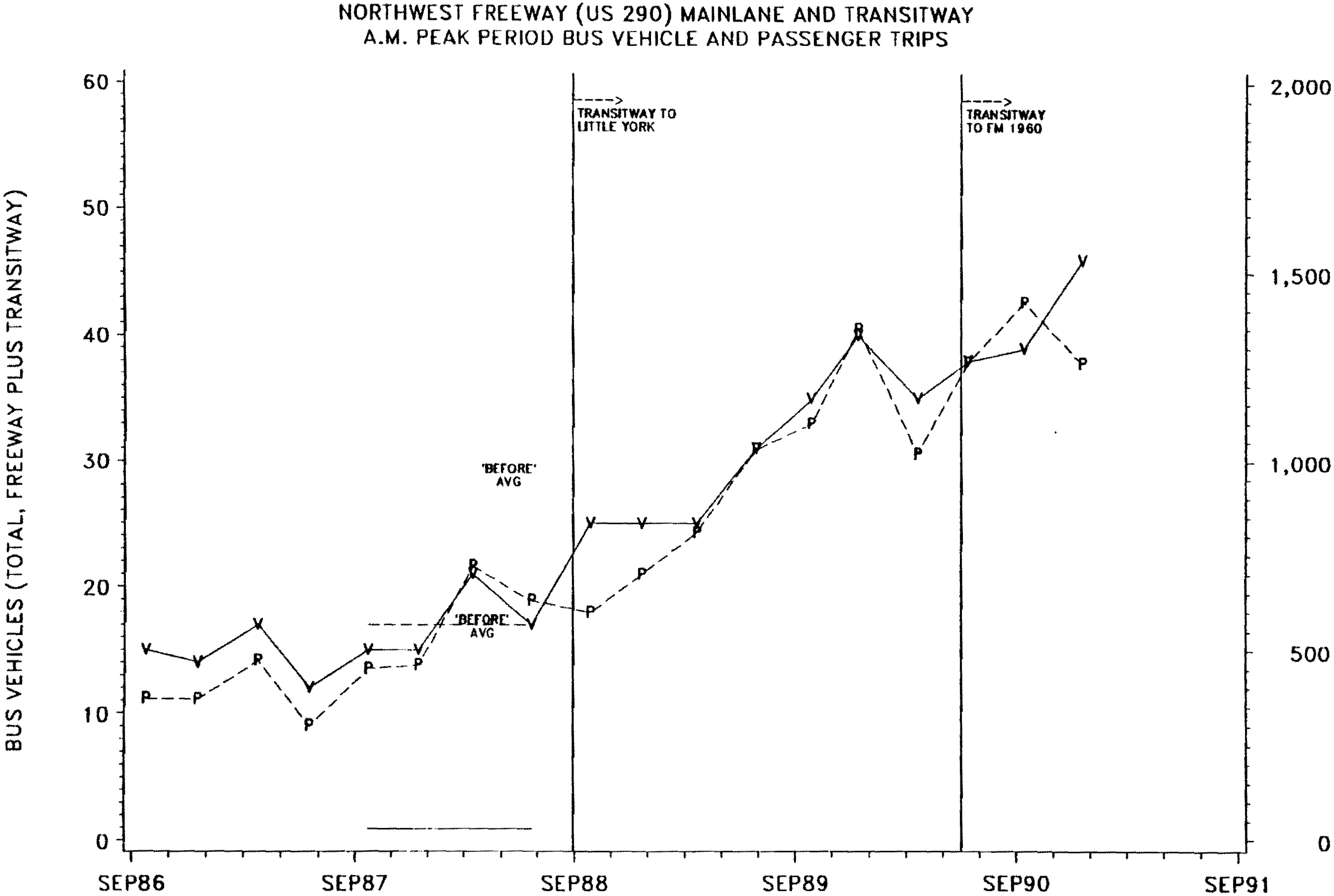
NORTHWEST FREEWAY (US 290) MAINLANE AND TRANSITWAY
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS



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

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

FIGURE D-20

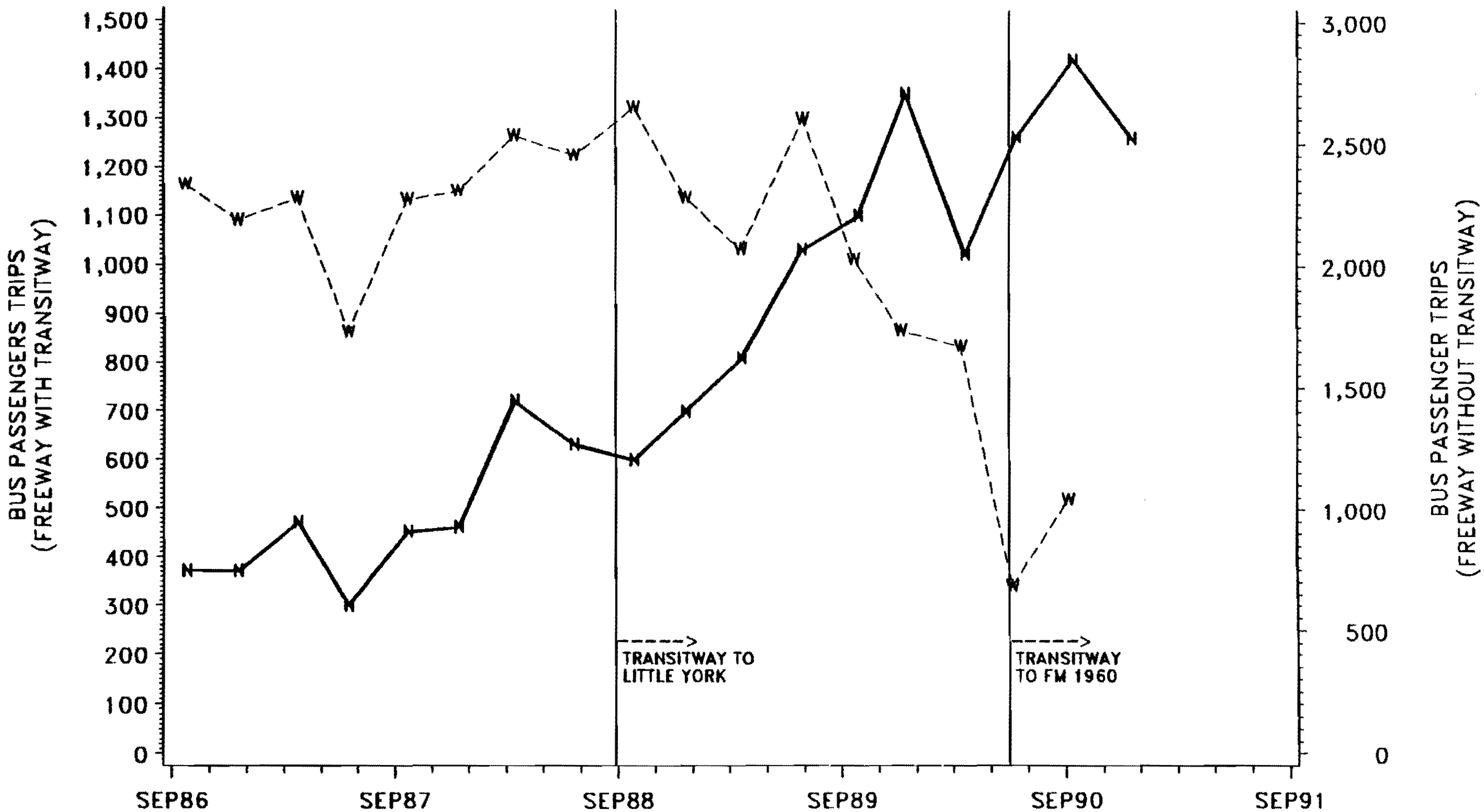


DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION
PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
SOURCE ; TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-21

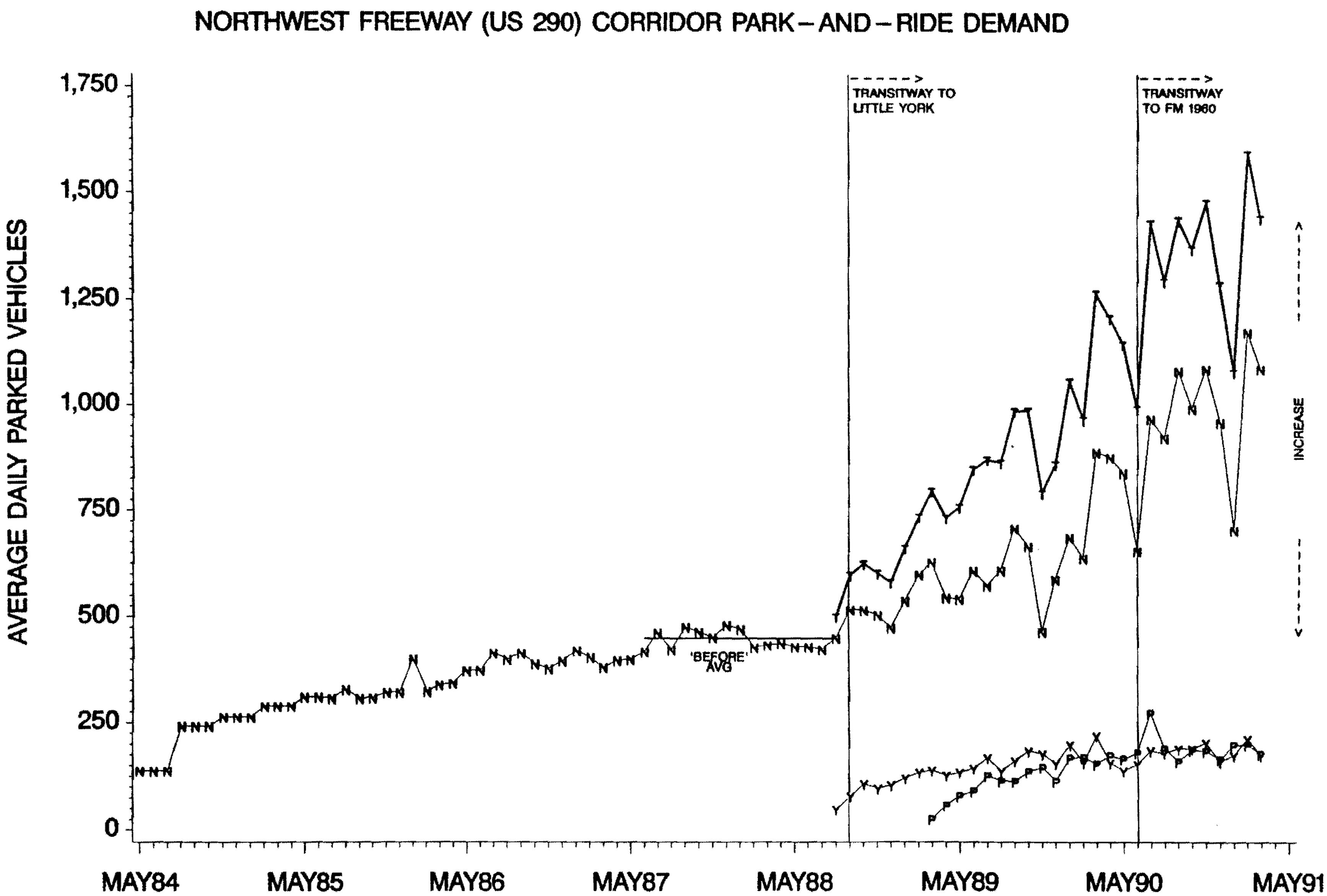
A.M. PEAK PERIOD BUS PASSENGER TRIPS
TOTAL, FREEWAY PLUS TRANSITWAY VOLUMES
FREEWAYS WITH AND WITHOUT TRANSITWAY



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

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

FIGURE D-22

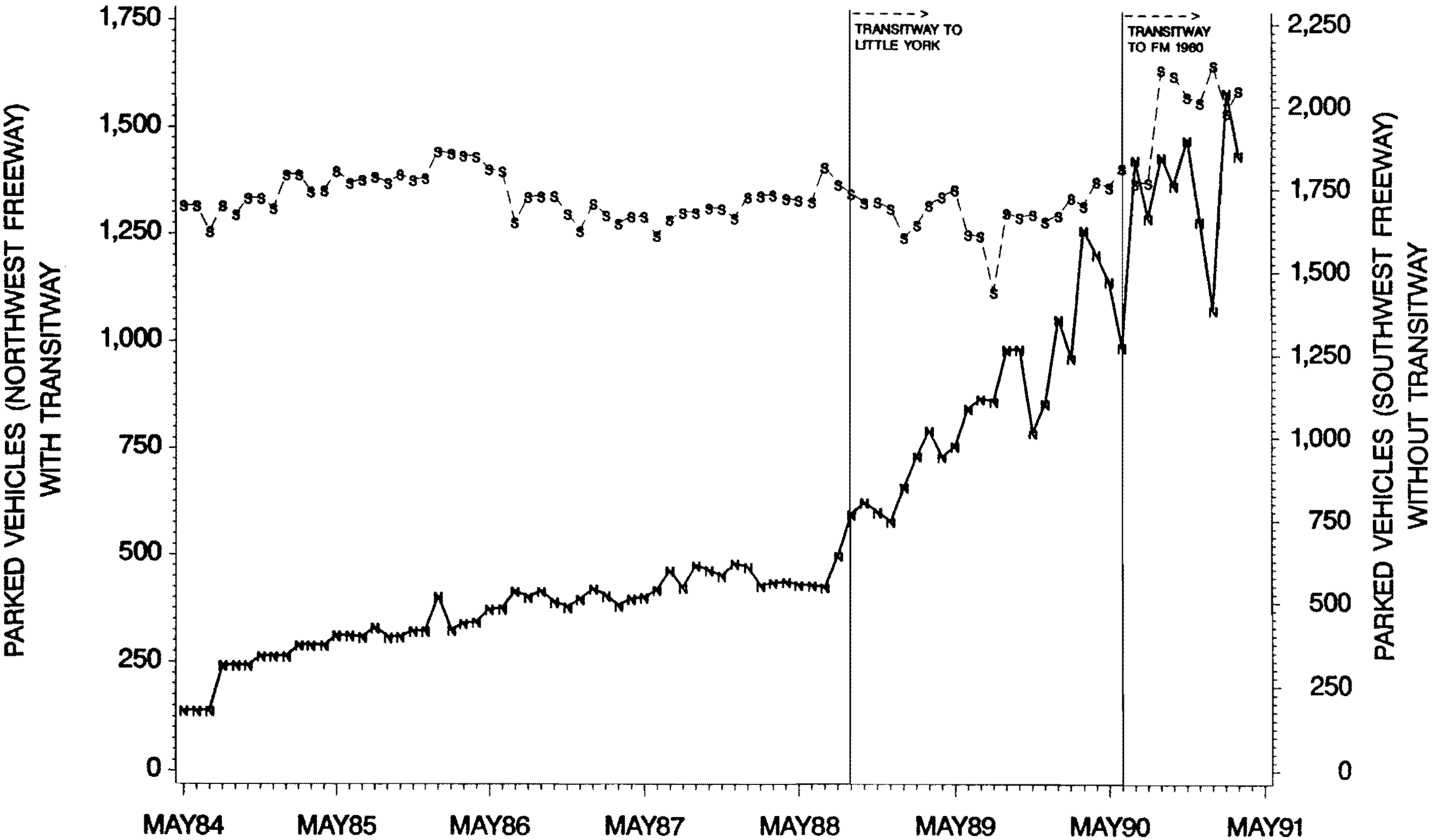


NORTHWEST TRANSITWAY PHASE 1, NORTHWEST TRANSIT CENTER
TO LITTLE YORK (9.5 MI), OPENED AUGUST 29, 1988
CURRENT TOTAL CORRIDOR PARKING CAPACITY = 3130 SPACES
TRANSITWAY EXTENSION FROM LITTLE YORK TO FM 1960 (3.9 MI.) OPENED JUNE 2, 1990
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL PARKED VEHICLES
N = NORTHWEST STATION (945 SPACES)
Y = LITTLE YORK LOT (1265 SPACES)
P = PINEMONT LOT (920 SPACES)

FIGURE D-23

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



NORTHWEST TRANSITWAY PHASE 1, NORTHWEST TRANSIT CENTER
TO LITTLE YORK (9.5 MI), OPENED AUGUST 29, 1988
TRANSITWAY 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 TRANSITWAY (SOUTHWEST)