1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-89/3-1146-2		

4. Title and Subtitle	5. Report Date
The Status and Effectiveness of the Houston Transitway System, 1989	March 1990
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Dennis L. Christiansen and Daniel E. Morris	Research Report 1146-2

9. Performing Organization Name and Address	10. Work Unit No.
Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135	11. Contract or Grant No. Study No. 2-10-89/3-1146

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Texas State Department of Highways and Public Transportation P.O. Box 5051 Austin, Texas 78763	Interim - September 1988 March 1990
	14. Sponsoring Agency Code

15. Supplementary Notes

Research performed in cooperation with DOT, FHWA.
Research Study Title: A "Before" and "After" Evaluation of the Committed High-Occupancy Vehicle Transitway Projects

16. Abstract

This report evaluates the operation of the Houston freeway transitway system through calendar year 1989. As of the end of 1989, transitways were in operation on the following four Houston freeways: Katy Freeway (I-10); North Freeway (I-45); Northwest Freeway (US 290); and Gulf Freeway (I-45). Prior to 1988, individual research reports had been prepared on an annual basis for both the Katy and North Freeway transitways, which were the only transitways operating at that time. Beginning in 1988, an annual report has been prepared summarizing operations on all of the transitways.

This research report provides an analysis of trend data related to: 1) operation of the transitway; 2) operation of the freeway mainlanes; 3) combined transitway and freeway data; and 4) data relating to transit usage and operations. Both a "before" and "after" trend line analyses and a comparison to control freeways not having transitways are used as a means of evaluating the effectiveness of the transitway facilities.

As of the end of 1989, 36.6 miles of barrier-separated transitway were in operation. On a daily basis, nearly 45,000 person trips were served on the transitways; approximately 45% of those trips were served in buses, with the remaining 55% being served in carpools and vanpools.

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

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	242	

Form DOT F 1700.7 (8-69)

THE STATUS AND EFFECTIVENESS OF THE HOUSTON TRANSITWAY SYSTEM, 1989

by

Dennis L. Christiansen
Research Engineer

and

Daniel E. Morris
Research Associate

Research Report 1146-2

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
U.S. Department of Transportation
Federal Highway Administration

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

March 1990

ABSTRACT

This report evaluates the operation of the Houston freeway transitway system through calendar year 1989. As of the end of 1989, transitways were in operation on the following four Houston freeways: Katy Freeway (I-10); North Freeway (I-45); Northwest Freeway (US 290); and Gulf Freeway (I-45). Prior to 1988, individual research reports had been prepared on an annual basis for both the Katy and North Freeway transitways, which were the only transitways operating at that time. Beginning in 1988, an annual report has been prepared summarizing operations on all of the transitways.

This research report provides an analysis of trend data related to: 1) operation of the transitway; 2) operation of the freeway mainlanes; 3) combined transitway and freeway data; and 4) data relating to transit usage and operations. Both a "before" and "after" trend line analyses and a comparison to control freeways not having transitways are used as a means of evaluating the effectiveness of the transitway facilities.

As of the end of 1989, 36.6 miles of barrier-separated transitway were in operation. On a daily basis, nearly 45,000 person trips were served on the transitways; approximately 45% of those trips were served in buses, with the remaining 55% being served in carpools and vanpools.

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

IMPLEMENTATION STATEMENT

This study 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 study is to collect, analyze and interpret data that can be used to assess the performance and effectiveness of the six committed freeway transitways now being implemented in Houston, Texas.

The first of the completed transitways opened on the Katy Freeway (I-10) in Houston in October 1984. In November 1984, the contraflow lane on the North Freeway (I-45) was converted to a transitway, and in 1988 transitways were opened on both the Northwest Freeway (US 290) and the Gulf Freeway (I-45). While no new barrier-separated transitway sections opened in 1989, construction continued in several corridors, and transitway extensions in 3 corridors will open in early 1990. This report presents data relating to the four operating transitways and focuses on data collected during calendar year 1989.

DISCLAIMER

SUMMARY

In response to the congestion problem, a variety of actions are being taken in Houston. One of those actions involves the implementation on the urban freeways of a system of priority lanes for high-occupancy vehicles. Locally, these facilities are commonly referred to as transitways and 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 1989.

A commitment is in place to develop 95.5 miles of barrier-separated transitways at a total capital cost of approximately $689 million. As of the end of 1989, 36.6 miles of barrier-separated transitway were in operation on 4 separate freeways, built at a cost of approximately $132 million. While some sections of two-direction transitway have been developed, the typical Houston transitway 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 1989, the transitway system served 44,922 person trips, an 11.7% increase over December 1988. At the end of 1989, 7,940 cars were parked in transitway corridor park-and-ride lots on a typical day. The transitways have been successful in attracting young, educated, professional, white-collar patrons. These individuals are choosing to use the transitways 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 Transitway Effectiveness

In order to evaluate whether or not the transitways have been effective, it is necessary to identify the purpose(s) for which those facilities were provided. To a large extent, the decision to consider building transitways 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 travel demands during peak periods at 1.2 occupants per auto.

Accordingly, it is assumed that the primary objective of the Houston transitways is to increase the effective person-movement capacity of the freeway in a cost effective manner and to accomplish this without unduly impacting the operation of the freeway general purpose mixed-flow lanes; desirably these improvements will have public support. Secondary benefits include factors such as improved air quality and reduced fuel consumption.

This report presents data and analyses that help to determine whether these objectives are being attained. Two major evaluation approaches are used. First, "before" and "after" trend line data are being collected for each freeway on which a transitway is being developed. Second, similar data are being collected in control corridors that do not have transitways. These data collection efforts help to identify and isolate the impacts of the freeway transitways.

Changes in Person Movement and Vehicle Occupancy

The transitway lanes move a relatively high percentage of the total person movement in a relatively low percentage of total vehicles; this, however, certainly is expected and, by itself, does not measure or imply that the transitways are effective.

On a typical day, the Houston transitways offer users a time savings during the peak-hour of between 3 and 14 minutes. It is of interest to note that the time savings perceived by the users can be several times greater than the actual savings measured in the field.

Factors Influencing Transitway Utilization

This research effort has shown that the following factors significantly impact the level of utilization on a transitway: 1) the length of time the facility has been in operation; 2) the vehicle groups allowed to use the transitway; and 3) the travel time savings and trip time reliability provided by the transitway. This third factor is, perhaps, the most important single factor influencing transitway use. The data suggest that, unless the transitway offers a travel time savings relative to the general-purpose freeway lanes of at least 7 to 8 minutes during the peak hour, utilization of the transitway will be marginal.

Changes in Roadway Person Movement

A major reason for implementing transitway improvements is to increase the effective person-movement capacity of a roadway. Since implementation of the transitway does increase the number of directional lanes, for the transitway 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 that all of the Houston transitways are resulting in a disproportionately large increase in person movement (Table S-1). During the peak hour, the transitways are moving 20% to 116% more persons per lane than are the freeway mainlanes.

Changes in Average Vehicle Occupancy

For the transitways to generate disproportionate increases in person movement, it is necessary to increase average vehicle occupancy. This has happened. On the two freeways with the more mature transitways, peak-hour average vehicle occupancies are in the range of 1.4 to 1.7 persons per vehicle (Tables S-1 and S-2); compared to pre-transitway conditions, average vehicle occupancy has increased by 16% to 31%. These increases in average vehicle occupancy have not been experienced on the freeways without transitways.

Table S-1. Summary of Measures Used to Assess the Effectiveness of the Houston Transitways

Measure of Effectiveness	Transitway			
	North	Katy	Northwest	Gulf
Change in Roadway Person Movement				
% Inc. in directional lanes due to transitway	25%	33%	33%	--
% Inc. in a.m. person volume[1]	58%	85%	39%	--
Change in Average Vehicle Occupancy (persons/vehicle)[1]				
Occupancy before transitway	1.28	1.26	1.14	--
Occupancy in December 1989	1.68	1.46	1.32	--
% Change, Pre-transitway to current	+31.2%	+15.8%	+15.8%	--
% Change in 2+ Carpool Volume[1]	--	+92.9%	+156.1%	--
% of Carpools formed due to transitway[2]	--	50%	39%	26%
% Change in Bus Passengers (peak period)[1]	--	+194%	+79%	--
% New Bus Riders Due to Transitway[2]	59%	52%	49%	33%
% Change, Freeway Mainlane Volume Per Lane[1,3]	-11.8%	+39.8%	+0.6%	--
% Change, Freeway Mainlane Travel Time (Peak Hour)[1,3]	+60.0%	0.0%	+53.6%	--
% Change, Freeway Mainlane Accident Rate[4]	+ 1.1%	0.0%	+ 6.6%	-12.8%
% Change, Freeway Per Lane Efficiency[1,3,5]	+92.7%	+94.7%	+54.8%	--
Comparison, Transitway Lane vs. Freeway Lane[6] (Transitway Improvement as a % of Freeway Improvement)				
Fuel Consumption (gallons)	--	88.4%	--	--
Air Quality (kg of CO)	--	78.1%	--	--
Vehicle-Miles of Travel	--	91.6%	--	--
Annual Value of Travel Time Saved on Transitway[7] ($ millions)	$3.0	$7.7	$ 0.6	$1.1
Travel Time Saved as a % of Construction Cost[8]	10.3%	24.1%	1.4%	4.1%
Are Transitways Good Improvements[9]				
Yes	62%	67%	71%	63%
No	20%	19%	13%	21%
Not Sure	18%	14%	16%	16%

[1] A.M. peak-hour, peak-direction. Percentage change from pre-transitway conditions to current conditions.
[2] Estimated percent of total carpools or bus passengers using the transitway that have been created because of the transitway.
[3] Data for the freeway general purpose mainlanes.
[4] Percentage change in pre-transitway accident rate (accidents per million vehicle miles).
[5] Freeway per lane efficiency is expressed as the multiple of persons moved times average speed.
[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, air quality (CO emission), and vehicle-miles of travel 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 (1989) value of time saved by users of the transitway.
[8] This is the estimated annual value of 1989 travel time savings for transitway users expressed as a percent of the cost of constructing the operating segment of the transitway. 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?"

For average occupancy to increase, there needs to be an increase in transit use and carpooling. The transitways have resulted in the formation of new carpools and new transit riders (Table S-1). These increases in ridesharing have not been experienced on freeways not having transitways (Table S-2). It is estimated that about half of the people using transitways have chosen to rideshare because of the presence of the transitways.

Table S-2. Comparison of Experience on Freeways With and Without Transitways

Measure of Effectiveness	Representative Pre-Transitway Value	Representative Current Value	% Change
A.M. Peak-Hour, Peak-Direction Avg. Vehicle Occupancy			
Freeways With Transitways			
North	1.28	1.68	+ 31.2%
Katy	1.26	1.46	+ 15.9%
Northwest	1.14	1.32	+ 15.8%
Freeway Without Transitway	1.29	1.32	+ 2.3%
A.M. Peak-Hour, Peak-Direction 2+ Carpool Volume			
Freeways With Transitways			
Katy (6-7 a.m.)	505	975	+ 92.9%
Northwest (7-8 a.m.)	490	1255	+156.1%
Freeway Without Transitways	600	590	- 1.7%
A.M. Peak-Period Bus Ridership			
Freeways With Transitways			
North	0	4830	---
Katy	900	2645	+193.9%
Northwest	605	1080	+ 78.5%
Gulf	1780	1943	+ 9.2%
Freeway Without Transitway	2230	2100	- 5.8%
Cars Parked at Park-and-Ride Lots			
Freeways With Transitways			
North	0	4199	---
Katy	575	1873	+225.7%
Northwest	430	913	+112.3%
Gulf	1115	1200	+ 7.6%
Freeway Without Transitway	1675	1665	- 0.6%

Transitway Impacts on Freeway Mainlane Operations

Although the transitways are moving several thousand persons during the peak hour, there has been virtually no impact on freeway mainlane operations that can be attributed to the implementation of the transitways; mainlane volumes, operating speeds, and accident rates have not changed appreciably due to the transitways (Table S-1). Data also show that volumes on parallel routes have not changed due to the transitway.

Transitway implementation should increase the overall efficiency of a freeway. For purposes of this study, the per lane, peak-hour efficiency of the freeway is expressed as the multiple of peak-hour person volume times the speed at which that volume is moved. This efficiency has increased, and at least a part of that increase is due to transitway implementation (Table S-1); the increase has been more significant on the freeways with mature transitways.

Air Quality and Energy Considerations

A simulation analysis (a.m. inbound, 6 a.m. to noon) was undertaken on the Katy Freeway to compare the "add a transitway" alternative to an "add another mixed-flow freeway lane" alternative. If both alternatives serve the same total demand (expressed as passenger miles), the transitway alternative is more favorable in terms of reduction in vehicle miles of travel, energy consumption, and pollutants emitted (Table S-1). The transitway alternative, compared to the add another mainlane alternative, resulted in approximately: a 10% reduction in vehicle-miles of travel; just over a 10% reduction in gallons of fuel consumed; and a 10% to 20% reduction in kilograms of pollutants emitted. More of this type of analysis is needed to better understand the trade-offs between adding general purpose lanes as opposed to adding HOV lanes.

Transitway Project Cost Effectiveness

Many of the potential benefits associated with a transitway facility, while possibly significant, are difficult to quantify. However, one benefit that can be quantified relatively easily is the value of time saved by users of the transitway. 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.

As a simplified "rule of thumb", if the average annual value of the transitway user travel time savings is at least 10% of the construction cost of the project, the transitway project will be cost effective. In terms of this criterion, based on 1989 operations, the Katy and North Transitways can be considered cost effective. The same conclusion cannot yet be drawn for the Northwest and Gulf Transitways. The data suggest that, for a "Houston type" transitway to be cost effective, it needs to serve at least in excess of 10,000 daily person trips.

Public Support for the Transitway Program

Acceptance of the transitways by the public exists and has been growing over time. Based on recent surveys, 67% of the motorists in the freeway mainlanes (not transitway users) viewed those projects favorably. In general, fewer than 20% of those surveyed felt that the transitways were not good transportation improvements (Table S-1). A survey on a freeway that does not have a transitway (Eastex) found that only 15% of those respondents felt that the transitways being developed in Houston were not good transportation improvements.

Conclusions

This report has identified the objectives associated with developing transitways in Houston. The report reviews and analyzes data collected through calendar year 1989 to assess the performance of the transitways in meeting their objectives.

Some of the relevant data associated with these analyses is shown in Tables S-1 and S-2. A review of these performance measures leads to several general observations. All of the performance measures suggest that the Katy Transitway is fulfilling its intended purposes. The North Transitway, at present, is marginally effective; allowing carpools to use this facility as well as extending the transitway 4 miles, both of which are scheduled to occur in 1990, are expected to significantly improve the overall performance of this facility. As presently being operated, neither the Northwest nor the Gulf Transitway can be considered to be clearly effective. However, there is reason to believe that their performance will improve significantly. Both facilities have been in operation for less than two years and, as of the end of 1989, only the first phase of each facility was in operation. The Northwest Transitway will be completed in its final form in February 1990; that improvement should greatly enhance the benefits offered by the transitway. It appears, however, that the Gulf Transitway will not be extended for at least two more years, and its performance should not be expected to improve significantly until that time.

Continued monitoring of all the committed transitways will take place as part of this research project.

TABLE OF CONTENTS

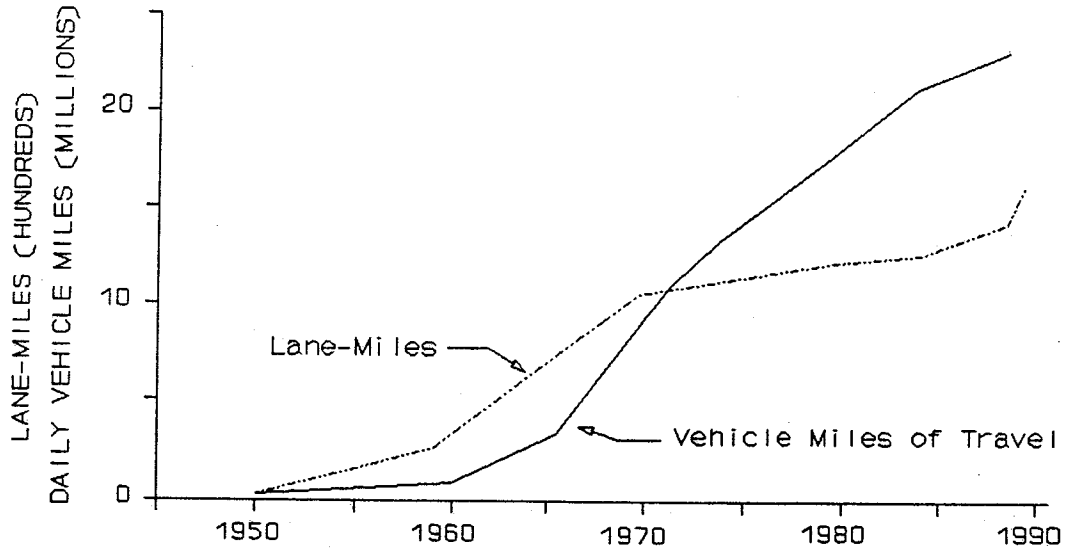
TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF FIGURES

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 has increased by 95%[1]. As a result, congestion also increased significantly; in fact, a 1984 Federal Highway Administration study[2] indicated that Houston had some of the most, if not the most, congested freeway facilities in the nation. Monitoring of overall urban congestion in major cities has clearly indicated that mobility levels in Houston have become undesirable; however, at the same time, as a result of an aggressive effort to restore acceptable mobility in Houston, congestion has been moderating the Houston area in recent years (Figure 2). Between 1984 and 1988, the congestion index in Houston actually declined by 9% even though vehicle-miles of travel increased by 6.3% during that same period. Nevertheless, Houston remains a relatively congested city (Table 1).

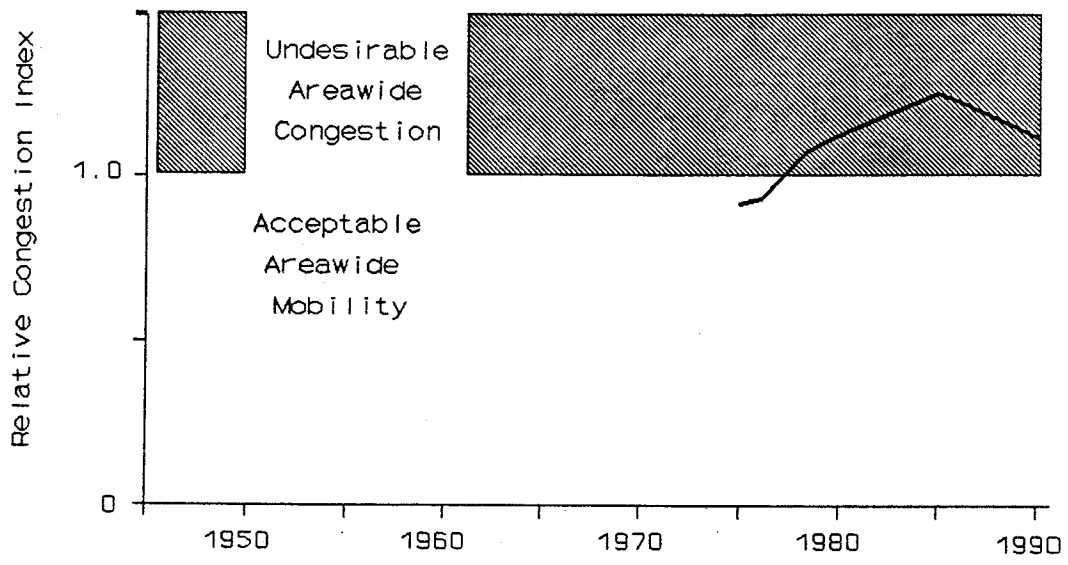


Source: "Regional Mobility Plan for the Houston Area, 1989" and TTI Research

Figure 1. Relationship Between Freeway Vehicle-Miles of Travel and Lane-Miles of Freeway, Harris County

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

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



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

Figure 2. Relative Houston Area Mobility Level, 1975-1990

Table 1. Relative Mobility Levels in Major United States Cities, 1987

Urban Area	Relative Mobility Index[1]	Urban Area	Relative Mobility Index[1]
1. Los Angeles	1.47	6. Atlanta	1.16
2. San Francisco-Oakland	1.31	7. Miami	1.14
3. Washington, D.C.	1.25	8. Seattle	1.14
4. Phoenix	1.23	9. Chicago	1.11
5. Houston	1.19	10. New York City	1.11

[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 facilities for both freeways and principal arterials.

Source: TTI Research Study 431 and "Regional Mobility Plan for the Houston Area, 1989".

In response to the congestion problem, a variety of actions are being taken. One of those actions involves the implementation on the urban freeways of a system of priority lanes for high-occupancy vehicles. Locally, these facilities are commonly referred to as transitways and are being jointly developed by the Texas State Department of Highways and Public Transportation (SDHPT) and the Metropolitan Transit Authority of Harris County (Metro).

Through this research effort, a comprehensive evaluation of these transitway facilities 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 transitways. The evaluations are being conducted using two approaches. First, "before" and "after" trend line data are being collected for each freeway on which a transitway is being developed; this provides a means for identifying changes that occur in those corridors. Second, similar data are being collected in corridors that do not have transitways. These "control" corridors help to isolate the specific impacts of the transitways.

This report presents and evaluates data relative to transitway and freeway operations in Houston through December 1989. 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 transitway system. The next six sections review the available data to determine the current effectiveness of the transitways. The last section of the main report presents the conclusions. A series of appendices are also included. The first of the appendices provides data relative to the increase in occupancy requirements that was initiated on the Katy Transitway in late 1988. The remaining four appendices provide more detailed data on each of the individual transitway projects.

II. OVERVIEW OF THE HOUSTON TRANSITWAY SYSTEM

A commitment is in place in the Houston area to develop approximately 96 miles of freeway transitway (Figure 3). As of December 1989, 4 separate transitway facilities were in operation; a total of 36.6 miles of barrier-separated transitway were in operation. The miles of operating barrier-separated transitway have not changed since December 1988; however, construction has been continuing and, in early 1990, extensions of the Katy, Northwest, and North Transitways will be opened. The daily operation and enforcement of these facilities is the responsibility of the Metropolitan Transit Authority (Metro). Selected characteristics of the operating transitways are shown in Table 2.

Table 2. Status of Operating Transitways, December 1989

Transitway	Date First Phase Opened	Miles in Operation	Vehicles Allowed to Use Transitway	Hours of Weekday[1] Operation
Katy (I-10)	October 1984	11.5	3+ vehicles from 6:45 to 8:15 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]	9.1	Authorized buses and vanpools[3]	5:45 to 8:45 a.m. inbound 3:30 to 7:00 p.m. outbound
Northwest (US 290)	August 1988	9.5	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	2+ vehicles	4 a.m. to 1 p.m. inbound 2 p.m. to 10 p.m. outbound
TOTAL		36.6		

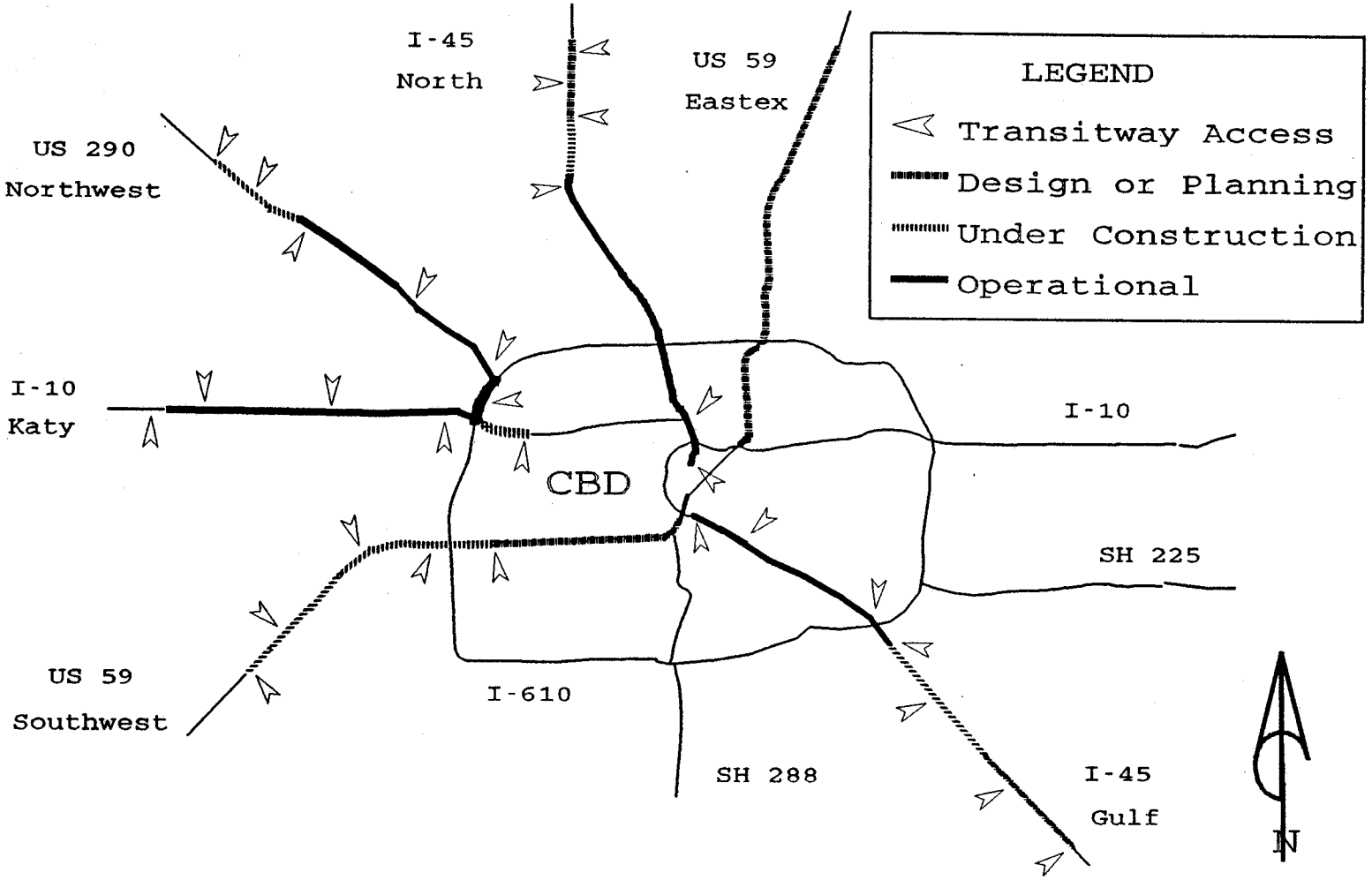
[1]Beginning in October 1989, the Katy and Gulf Transitways were opened to 2+ carpools on weekends; those facilities operate outbound on Saturday (4 a.m. to 10 p.m.) and inbound on Sundays (4 a.m. to 10 p.m.). Due to construction, weekend use of the North and Northwest Transitways was not allowed in 1989. Further data on weekend use is presented subsequently in this section.

[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]Due to construction in the corridor, only buses and vans authorized by Metro are presently allowed to use the transitway. In 1990, carpools will become eligible users of this facility.

Physical Description of Transitways

While some sections of two-direction transitway are being developed, the typical Houston transitway 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



Note: In early 1990, extensions of the Katy, Northwest and North Transitways are scheduled to open.

Figure 3. Status of Transitway Development, December 1989

barriers (Figure 4). In some locations, transitway implementation was accomplished by narrowing freeway mainlanes and inside shoulder width. A typical section is shown in Figure 5.

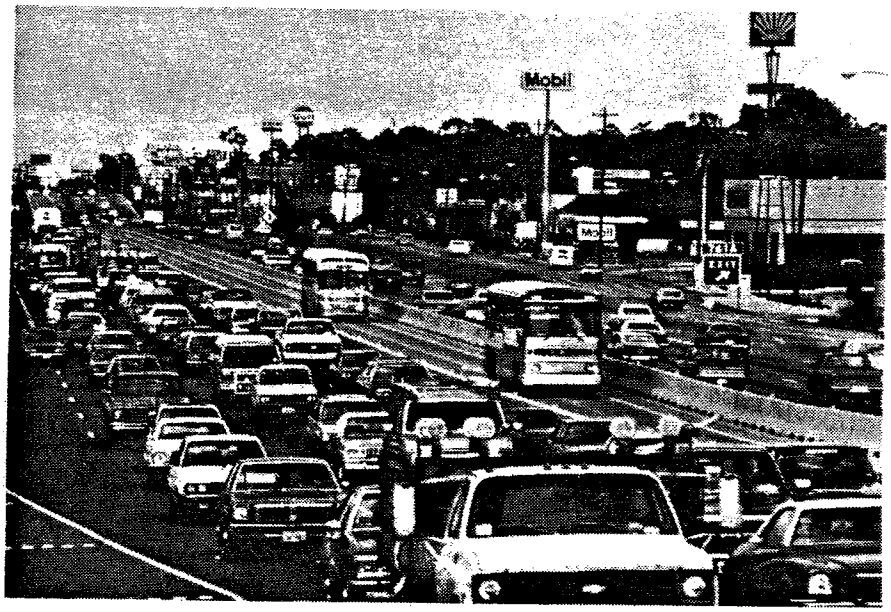
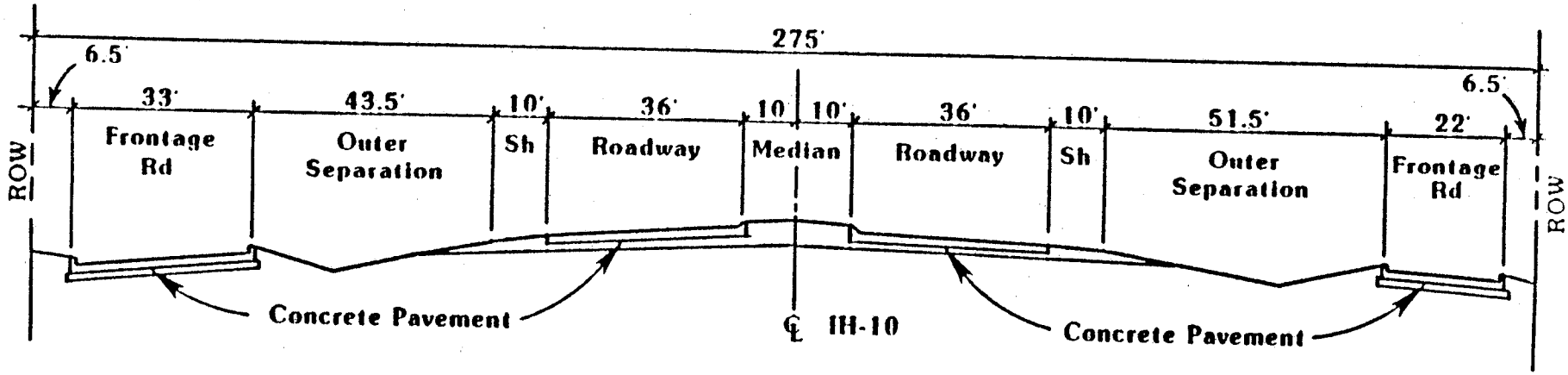
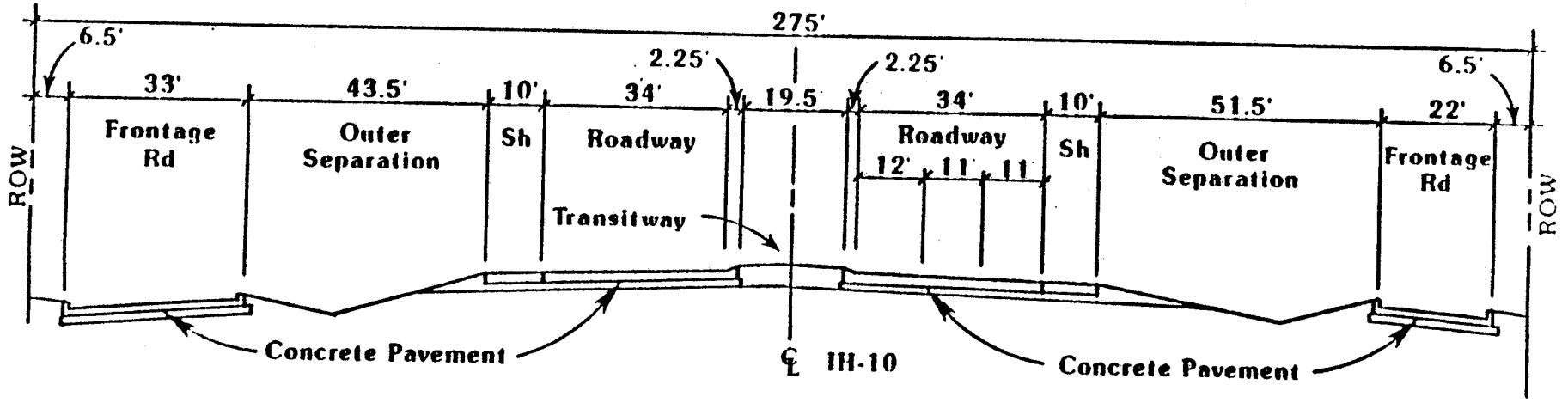


Figure 4. Transitway in Median of Katy Freeway

Access to the median transitways 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, they have associated with them a variety of operational disadvantages. As a consequence, most access to these median transitways is being provided by grade-separated interchanges of various designs (Figure 7). The transitway becomes elevated in the median, and ramps go over the freeway lanes to connect with streets or park-and-ride lots. These grade-separated interchanges are typically constructed at a cost in the range of $2 to $5 million each; transitway access/egress is typically provided at 3 to 5 mile intervals.



Typical Section Before Transitway Construction



Typical Section After Transitway Construction

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

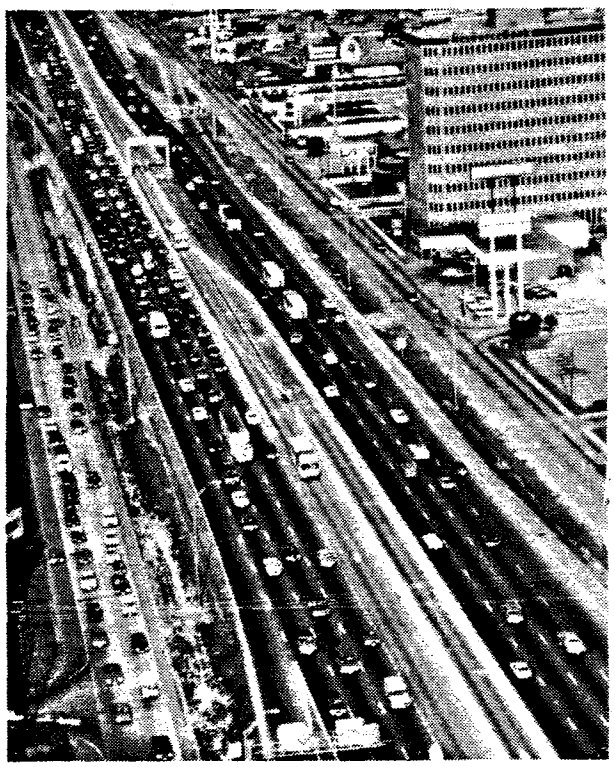


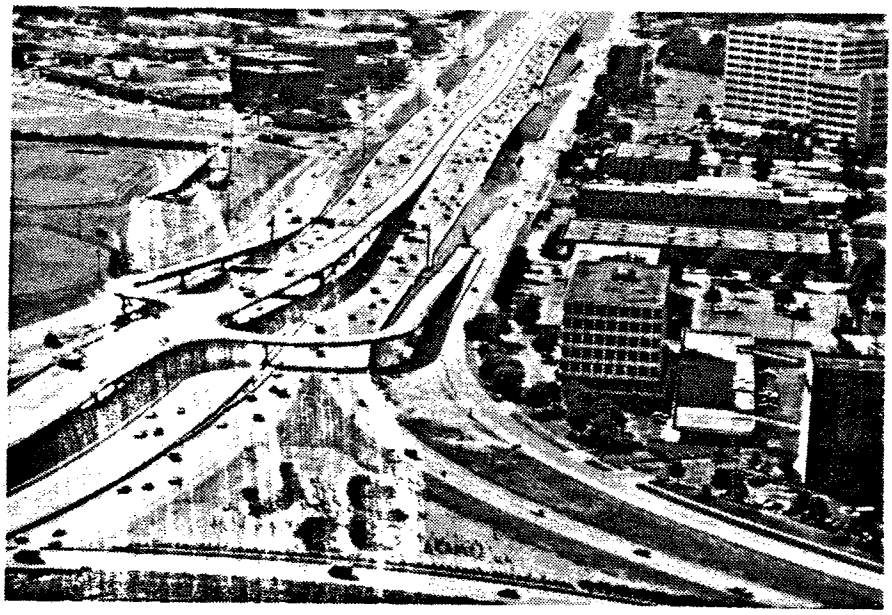
Figure 6. Slip Ramp for Transitway Access/Egress on Katy Freeway

Estimated Transitway System Cost

The estimated capital cost of the entire 95.5-mile system is approximately $689 million, or about $7.2 million per mile (Table 3). The 36.6 miles of barrier-separated facility that are actually in operation have been built for a construction cost of approximately $132 million, or $3.6 million per mile. For the committed transitways, it is anticipated that approximately 80% of the cost will be funded using transit dollars (Table 4); these are both federal and local transit monies.

The operation and enforcement of the transitways is a Metro responsibility. This is costing approximately $250,000 to $300,000 per year per transitway.

Direct Ramp to Eastwood Bus Transit Center, Gulf Transitway



Transitway Ramps to Frontage Roads, Northwest Transitway

Figure 7. Examples of Grade Separated Transitway Interchanges

Table 3. Estimated Capital Cost of The Houston Transitway System

Transitway	Ultimate System		Current System	
	Length (miles)	Est. Construction Cost (millions)	Length (miles)	Est. Construction Cost (millions)
North (I-45)	19.7	$141.2	9.1	$ 29
Katy (I-10)	13.0	55.7	11.5	32
Gulf (I-45)	15.5	100.2	6.5	27
Northwest (US 290)	13.5	117.3	9.5	44
Southwest (US 59)	13.8	98.3[1]	0.0	0
Eastex (US 59)	20.0	176.3	0.0	0
Total	95.5	$689.0	36.6	$132

[1]The final 4.2-mile segment near downtown is not included in this cost estimate.

Note: The estimated construction cost includes many of the associated park-and-ride lots and transit centers but does not include the value of the freeway right-of-way used for the transitway, nor is the cost of buses and bus support facilities (maintenance garages) included.

Source: Metropolitan Transit Authority of Harris County.

General Trends in Transitway System Utilization

This section briefly overviews systemwide data that help describe the usage of the Houston transitways. A more detailed evaluation of these data are included in a subsequent section of this report. Additional relevant data are provided in the appendices.

Annual vehicle-miles of travel on the transitways and annual passenger-miles travelled on the transitways are depicted in Figures 8 and 9. Since carpools were first allowed to use the transitways in 1985, vehicle-miles of transitway usage have increased rapidly. With this carpool use and the continued opening of more transitways, annual passenger-mile on the transitways have also been increasing. In 1989, passenger-miles (both bus and carpool) on the transitways represented approximately 20% of all the passenger-miles served by the Metropolitan Transit Authority of Harris County.

Figure 10 depicts total daily systemwide transitway usage in Houston. Total transitway usage (expressed as person trips) in December 1989 was 44,992, an 11.7% increase over the ridership level in December 1988. Simply as a basis for comparison, the operating Houston transitway system (36.6 miles) has been constructed at a cost of approximately $132 million

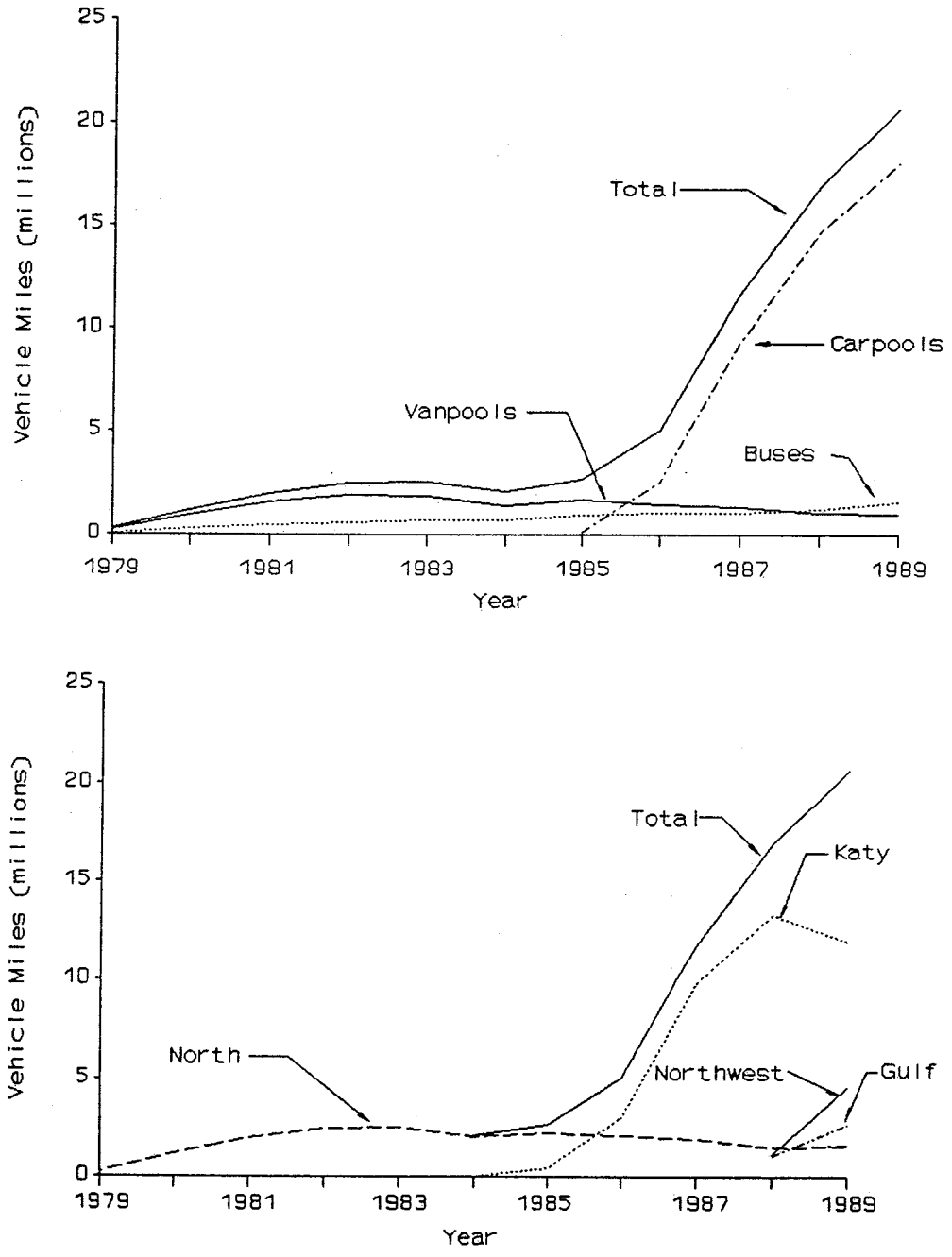


Figure 8. Trends in Annual Vehicle-Miles of Travel on Houston Transitways

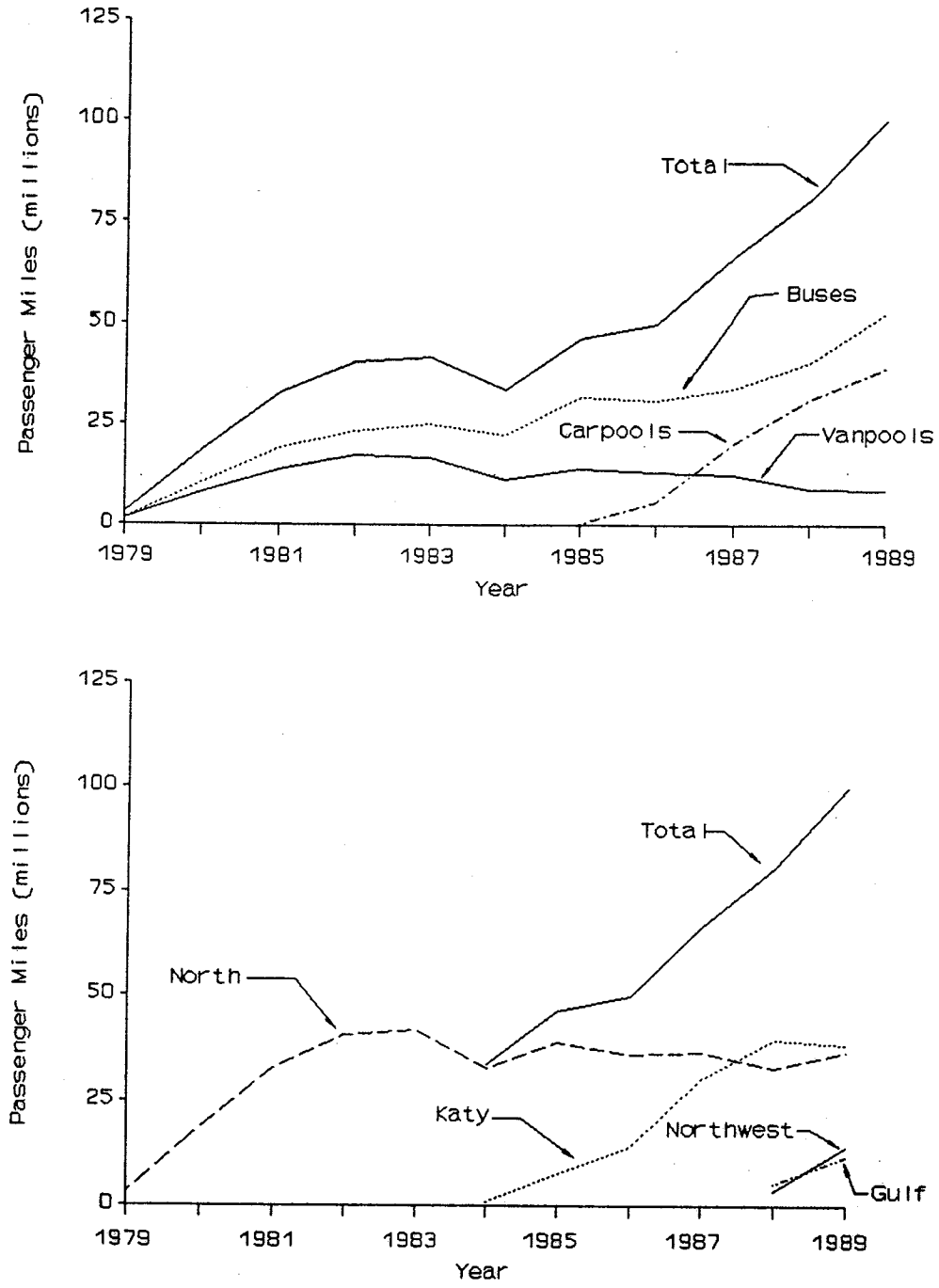
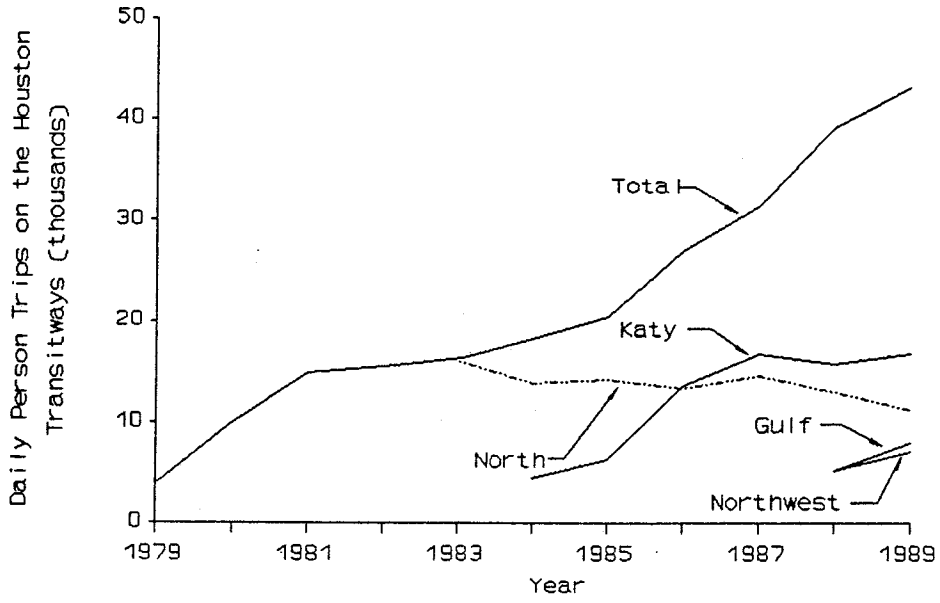


Figure 9. Trends in Annual Passenger-Miles of Travel on Houston Transitways



Source: See data in appendices.

Figure 10. Trends in Daily Person Trips on Houston Transitways

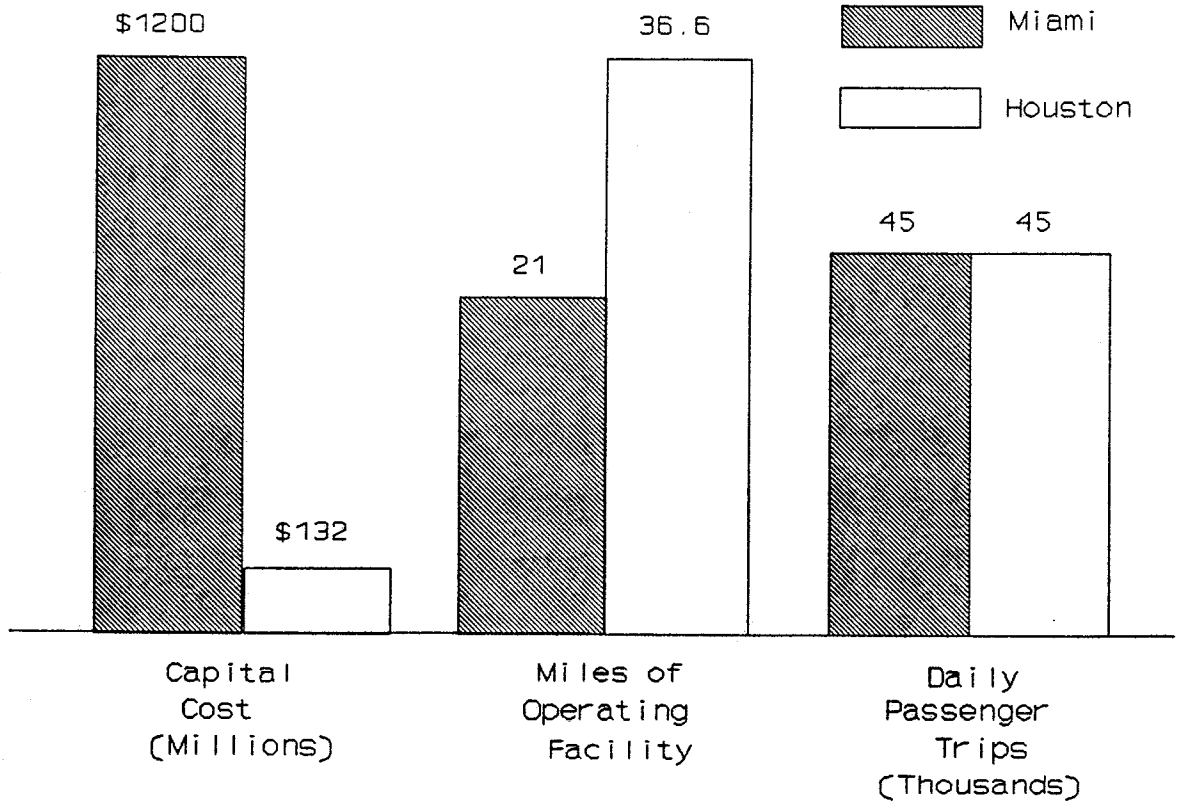
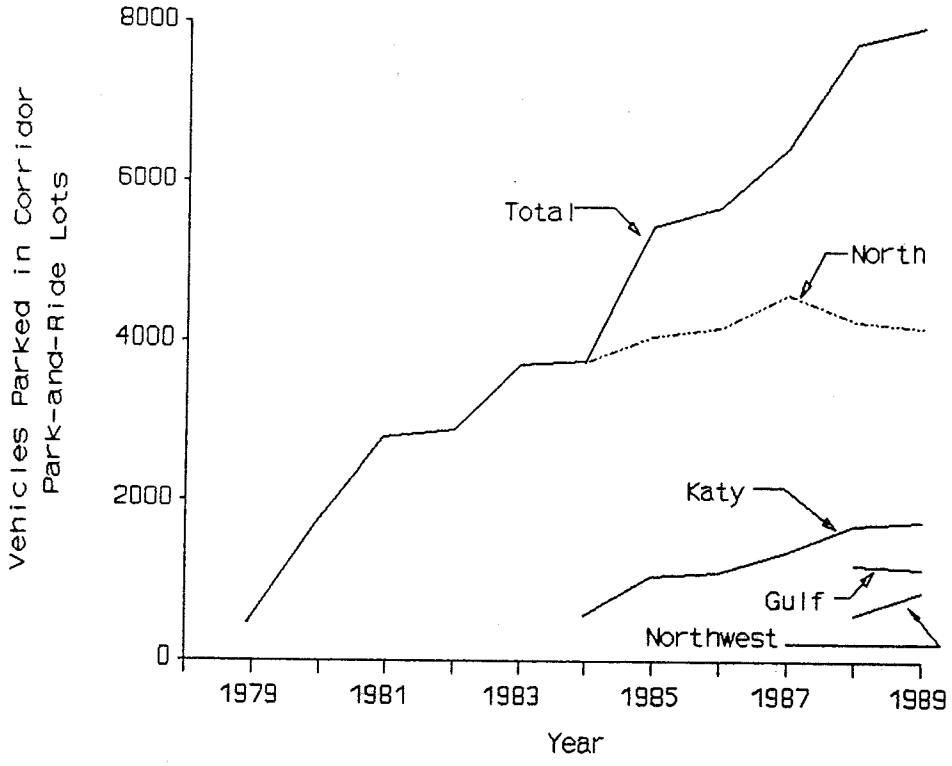


Figure 11. Comparative Data for the Operating Houston Transitways and the Miami Rail Transit System, 1989

and serves approximately 45,000 person trips per day; the Miami heavy rail system (21 miles) was constructed at a cost of approximately $1.2 billion and also serves approximately 45,000 daily person trips (Figure 11). This simplistic comparison, by itself, certainly does not lead to a conclusion that either of the projects are necessarily good or bad.

With the expansion of the transitway system, in the past year there has also been a 3% increase in the use of park-and-ride lots in the corridors served by transitways (Figure 12). In December 1989, approximately 7,940 cars used park-and-ride lots on a daily basis; in December 1988, approximately 7,730 vehicles were parked in those lots. Parking at these lots is free.



Source: See data in appendices.

Figure 12. Trends in Usage of Park-and-Ride Lots in Transitway Corridors

Selected transitway operating data are presented in Table 4. Except for the Katy Transitway during the period of 3+ operations, violations have not been a problem and have been less than 1%. The accident rates on the transitways have generally been less

than the freeway accident rates. More detailed data for each of the 4 operating transitways are included in the appendices.

Table 4. Selected Transitway Operating Statistics, December 1989

Operating Data	Transitway			
	Katy	North	Northwest	Gulf
Transitway Person Volume				
Daily	18,352	11,226	7,275	8,139
A.M. Peak Hour	3,316	3,514	2,439	2,923
Transitway Vehicle Volume				
Daily	5,915	488	2,439	2,154
A.M. Peak Hour	950	139	841	878
Percent of A.M. Peak-Hour, Peak Direction Person Volume on the Transitway	35%	35%	29%	30%
Vehicles Parked in Corridor Park-and-Ride Lots	1,750	4,173	860	1,157

Source: Texas Transportation Institute data collection, see appendices.

Beginning in October 1989, on a trial basis both the Gulf and Katy Transitways were opened to 2+ carpools on weekends. The facilities operated outbound on Saturday from 4 a.m. to 10 p.m. and inbound on Sundays during the same hours. While there is some intercity bus use of these facilities, no scheduled transit service uses the transitways on weekends. To date, carpool volumes have been relatively low, particularly on the Gulf Transitway. In December 1989, 772 carpools used the Katy Transitway on Saturday and 1206 used it on Sunday. On the Gulf Transitway, 28 carpools were counted on Saturday and 58 on Sunday.

The data presented in this section provide a general indication of the extent of use of the transitways and how that use has changed over time. These trends do not, however, by themselves, indicate whether the transitways have been effective. As a result, a more detailed discussion of the meaning and significance of the ridership data is presented subsequently in this report.

Characteristics of Transitway Users

On several occasions, TTI has surveyed both bus patrons and carpoolers using the transitways. Those data are thoroughly documented in other research reports (see Research Reports 484-8, 484-10 and 484-12).

Selected data are summarized in Tables 5 and 6. The transitways have been successful in attracting young, educated, professional white-collar patrons. These individuals are choosing to use the transitways primarily in order to save time, avoid having to drive in congested traffic, have time to relax, and to have a reliable trip time. They are choice riders in that an auto is available for the trip.

Table 5. Selected Characteristics of Transitway Bus Patrons, 1989

Characteristic	Transitway Corridor			
	Katy	North[1]	Northwest	Gulf
A.M. Trip Destination				
Downtown	94%	94%	97%	86%
City Post Oak	2%	1%	0%	1%
Greenway Plaza	0%	2%	0%	0%
Texas Medical Center	1%	1%	2%	5%
Trip Purpose (% work)	98%	---	98%	96%
Age, Years (50th Percentile)	35	34	34	34
Sex (% Male)	47%	44%	41%	30%
Education, Years (avg.)	15	15	14	14
Occupation				
Professional	51%	38%	36%	41%
Managerial	15%	23%	12%	16%
Clerical	26%	30%	40%	32%
Sales	3%	3%	5%	2%
Auto Available (% Yes)	90%	95%	92%	87%
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%	---	---

[1]Data from 1986 transit user surveys.

Source: Texas Transportation Institute Surveys.

Table 6. Selected Characteristics of Transitway Carpoolers and Vanpoolers, 1989

Characteristic	Transitway Corridor			
	Katy	North[1,2]	Northwest	Gulf
A.M. Trip Destination				
Downtown	40%	61%	41%	78%
City Post Oak	20%	7%	22%	6%
Greenway Plaza	5%	4%	4%	2%
Texas Medical Center	5%	8%	2%	4%
Trip Purpose (% Work)	84%	---	93%	98%
Age (50th Percentile)	38	39	36	38
Sex (% Male)	55%	55%	50%	41%
Education, Years (avg.)	15	15	15	14
Occupation				
Professional	45%	45%	44%	46%
Managerial	18%	24%	18%	15%
Clerical	14%	23%	18%	26%
Sales	6%	7%	9%	4%
Why Use Transitway[2]				
Freeway Too Congested	19%	20%	---	---
Saves Time	20%	20%	---	---
Time to Relax	14%	13%	---	---
Reliable Trip Time	12%	13%	---	---
Costs Less	14%	15%	---	---

[1]Data for the North Transitway are vanpool data only.
[2]Data from 1986 surveys.

Source: Texas Transportation Institute surveys

III. MEASURES OF TRANSITWAY EFFECTIVENESS

A major intent of this research project is to evaluate the effectiveness of the transitways being implemented in Houston. The commitment to developing transitways in Houston is extensive and somewhat unique. As a result, a high level of interest exists to determine whether the transitways are effective; in response to this interest, the State Department of Highways and Public Transportation has chosen to pursue a long-range evaluation of the transitway facilities.

To a large extent, the decision to consider building transitways came through the realization that it was simply not possible, either physically or economically, to provide enough street and highway lanes to indefinitely serve travel demands during peak periods at 1.2 occupants per auto. The current round of freeway expansion being pursued in Houston, which will be largely complete by the end of the 1990's, represents, to a significant extent, the last major capacity expansion that can be added to existing freeway corridors; however, demand is estimated to continue to increase at rates of 3% per year or more into the indefinite future.

In concept, if the transitways perform as intended, providing the high-occupancy vehicle lane will offer a means to help accommodate some of this future growth. If design year volumes of 7,500 to 10,000 persons per hour per lane are actually achieved on the transitways, in effect the person-movement capacity of the freeway will have been doubled at a cost of only $5 to $7 million per mile; and volumes for the foreseeable future could be served acceptably. However, this will only be the case if the transitways perform as intended. As a result, their performance is being closely monitored to assess the effectiveness of these improvements.

Potential Measures of Effectiveness

Prior to establishing measures of effectiveness by which to measure the performance of the transitways, it is necessary to identify the primary reason(s) those facilities were built. The effectiveness measures can then be developed to determine whether those objectives have been met.

Numerous potential objectives exist, some qualitative in nature and some that can be quantified. A 1985 survey[3] of North American high-occupancy vehicle lane (HOV) projects determined that increasing roadway capacity and reducing vehicle-miles of travel were the primary reasons for implementing HOV lanes nationwide.

It can be argued that, in Houston, the primary reason for transitway development has been to increase the effective roadway capacity. 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.

Thus, *it is assumed that the primary objective of the Houston transitways is to increase the effective person-movement capacity of the freeway in a cost effective manner and to accomplish this without unduly impacting the operation of the freeway general purpose mixed-flow lanes; desirably, these improvements will have public support. Secondary benefits include factors such as improved air quality and reduced fuel consumption.*

If these are accepted as the major reasons for implementing a transitway, the next question becomes what type of data needs to be collected and what analyses performed to assess whether these objectives are, indeed, being realized. A discussion of these issues is

---

[3]Institute of Transportation Engineers. "The Effectiveness of High-Occupancy Vehicle Facilities," 1988.

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 transitway implementation should at least be greater than the percentage increase in directional lanes added to the roadway.* In effect, this will be accomplished by increasing the average vehicle occupancy (persons per vehicle) on a roadway; much of 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. Transitway implementation should not unduly impact freeway mainlane operation.

Measure. *Operation on the mainlanes should not be degraded as a result of the transitway, and the per lane efficiency of the roadway should increase because of the transitway.* 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 transitway 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 transitway 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 transitway should be at least 10% of the total transitway construction cost.

Objective. Development of transitways desirably will have public support.

Measure. *Opinion surveys will show that public support exists for developing freeway transitways.* Experience has shown that major transportation projects -- whether freeway or transit -- that generate major public opposition in many instances will not continue to proceed forward. The on-going debate over rail transit development in Houston, which has now lasted over 10 years without yet being resolved, is an example of the difficulty encountered in developing major transportation projects without having clear public support. Monitoring of public attitudes regarding transitways will, desirably, show that strong negative feelings regarding these improvements do not exist.

Objective. Transitways should have favorable impacts on air quality and energy consumption.

Measure. *For the total demand being served on the facility, the transitway 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.

Subsequent sections of the report analyze the data from the Houston research effort to assess the effectiveness of the transitways at this point in time in regard to the objectives set forth above.

The Time Factor

The transitways in Houston have just begun to be implemented. As of the end of 1989, none of the transitways was completed in its final form. These facilities are being looked to as a means of helping to serve the growth in travel demands that is expected to occur over the next 10 to 20 years. Design year demand estimates are generally two to three times as great as current transitway volumes.

As a result, it would not be expected that the transitways would 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 transitways -- the Katy and the North transitways. 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 increases as is anticipated.

IV. CHANGES IN PERSON MOVEMENT AND VEHICLE OCCUPANCY

A primary objective of transitway implementation is to significantly increase the person-movement on a roadway. This will be accomplished if average vehicle occupancy is increased, and if that increase in average vehicle occupancy 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.

Transitway Utilization and Time Savings

In December 1989 the Houston transitway system served 44,992 person trips. During 1989, no additional miles of barrier-separated transitway opened. However, daily ridership, compared to December 1988, was up 11.7%. Daily riders per mile of transitway had been 1,583 in 1987, declined to 1,101 in 1988, and increased to 1,229 in 1989.

As would be expected, the transitways move a relatively high percentage of peak-hour person movement in a relatively small percentage of vehicles (Figure 13). However, this is the result that should occur if nearly all of the high-occupancy vehicles operate in a single lane. And, as a consequence, by itself, this is not necessarily a measure of effectiveness. Nevertheless, in all instances, the percentage increase in persons moved due to implementing the HOV lane is greater than the percentage increase in total lanes that resulted from adding the HOV lane.

Table 7 presents selected usage and time savings data related to the Houston transitways for 1988 and 1989. Usage on the Katy, Northwest and Gulf transitways has increased. Usage on the North Transitway has decreased; this would appear to be primarily the result of a general decline in vanpooling in the region; carpools are not yet allowed to use the North Transitway. Also, travel time savings provided by the transitway in this corridor have been decreasing in recent years.

Table 7. Summary of Selected Data Relating to Usage and Travel Time Savings on the Houston Transitways

Data	Katy			North[1]			Northwest[2]			Gulf[2]			Total, 4 Transitways		
	12/88	12/89	% Change	12/88	12/89	% Change	12/88	12/89	% Change	12/88	12/89	% Change	12/88	12/89	% Change
Miles of Transitway	11.5	11.5	0.0%	9.1	9.1	0.0%	9.5	9.5	0.0%	6.5	6.5	0.0%	36.6	36.6	0.0%
Transitway Person Volume															
Daily	16772	18352	+ 9.4%	12946	11226	-13.3%	5283	7275	+37.7%	5291	8139	+53.8%	40292	44992	+11.7%
A.M. Peak Hour	3881	3316	-14.6%	3732	3514	- 5.8%	1821	2439	+33.9%	1787	2923	+63.6%	11221	12192	+ 8.7%
A.M. Peak Period	7319	7523	+ 2.8%	6640	5633	-15.2%	3235	4089	+26.4%	2754	4300	+56.1%	19948	21545	+ 8.0%
P.M. Peak Hour	3750	4352	+16.1%	2725	3313	+21.6%	985	1564	+58.8%	780	2102	+169.5%	8240	11331	+37.5%
P.M. Peak Period	8429	9321	+10.6%	6306	5593	+11.3%	1960	3003	+53.2%	2469	3693	+49.6%	19164	21610	+12.8%
Transitway Vehicle Volume															
Daily	5079	5915	+16.5%	531	488	- 8.1%	1844	2439	+32.3%	1424	2154	+51.3%	8878	10996	+23.9%
A.M. Peak Hour	938	950	+ 1.3%	151	139	- 7.9%	668	841	+25.9%	490	878	+87.2%	2247	2758	+22.7%
A.M. Peak Period	1862	2155	+15.7%	265	239	- 9.8%	1164	1427	+22.6%	719	1227	+70.7%	4010	5048	+25.9%
P.M. Peak Hour	1122	1290	+15.0%	125	129	+ 3.2%	304	448	+47.4%	372	482	+29.6%	1923	2345	+21.9%
P.M. Peak Period	2723	3010	+10.5%	266	249	- 6.4%	636	934	+46.9%	632	858	+35.8%	4257	5051	+18.7%
Avg. Vehicle Occupancy, A.M. Peak Hour	4.14	3.49	-15.7%	24.7	25.3	+ 2.4%	2.73	2.90	+ 6.2%	3.65	3.33	- 8.8%	4.99	4.42	-11.4%
Transitway Travel Time Savings, Avg. Peak Hour (min)[3]	13.8	13.8	0.0%	6.2	5.3	-14.5%	4.3	2.4	-44.2%	5.3	2.8	-47.2%	29.6	24.3	-17.9%

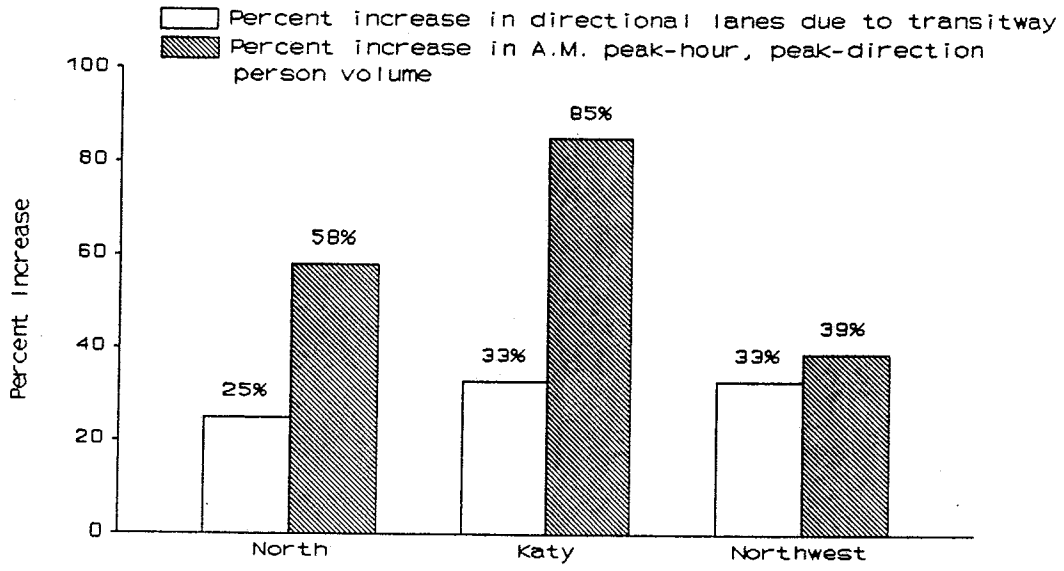
Notes: Peak hour is defined as the hour in which person movement is the highest. As a result, it is not always the same hour. The peak period is a 3.5 hour time period for all transitways except the North, where it is 3 hours in the a.m. and 3.5 hours in the p.m.

[1]The North Transitway, due to ongoing construction in the corridor, is used only by authorized buses and vanpools and operates for fewer hours per day than do the other transitways.

[2]The Gulf and Northwest Transitways opened during 1988.

[3]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. Due to these variations and the error associated with measuring these values, changes or differences in the range of 2 minutes or less have little significance.

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



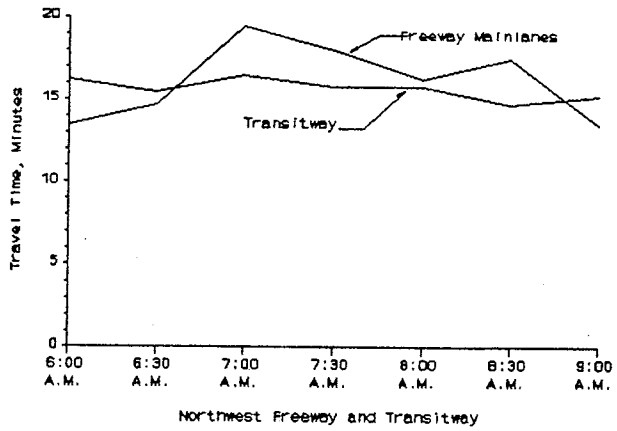
Source: See data in appendices.

Figure 13. Transitway Volumes as a Percent of Total (Freeway Plus Transitway) Peak-Hour, Peak-Direction Volumes

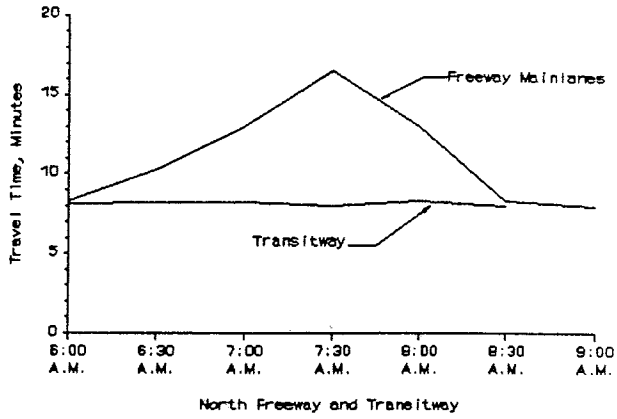
Travel Time Savings

A major purpose of the transitways is to offer users of high-occupancy vehicles a savings in travel time. On a quarterly basis, Texas Transportation Institute performs travel time surveys on both the transitway and the freeway. These data points, collected on 4 separate occasions, are averaged to estimate the time savings offered by the transitway. A plot of a.m. travel time savings by freeway is shown in Figure 14.

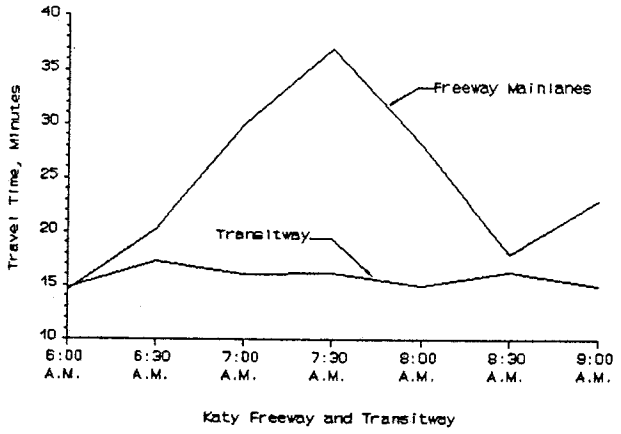
The data in Table 7 show the actual travel time savings measured on the transitway. It should be noted that variability exists in travel times on a daily basis, plus there is some error in measuring travel times. As a result, differences or changes of only 2 to 3 minutes have relatively little significance. It is interesting to note that surveys indicate that the users of the transitways perceive a much greater time savings than is actually realized (Table 8).



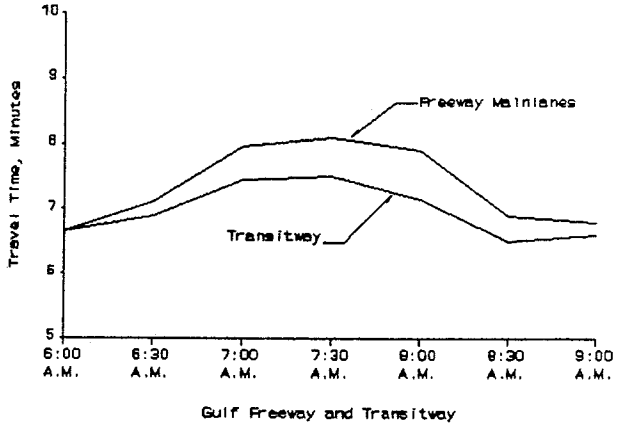
Note: Travel times are from Senate to the S.P. Railroad



Note: Travel times are from N. Shepherd to Hogan



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



Note: Travel times are from Park Place to Dowling

Source: See data in appendices.

Figure 14. A.M. Peak Period Travel Time, Houston Freeways and Transitways

Table 8. Comparison of Actual and Perceived Travel Time Savings on the Transitways

Transitway	Avg. Peak-Hour Time Savings (min.)[1]	Perceived Transitway Time Savings (min.)[2]			
		Transit Riders		Carpoolers & Vanpoolers	
		AM	PM	AM	PM
North[3]	5.3	20	25	20	30
Katy	13.8	20	20	20	20
Northwest	2.4	15	15	15	15
Gulf	2.8	10	15	12	15

[1]The average of the a.m. and p.m. peak-hour savings as measured in the field. See Table 7 and the appendices for more data.
[2]Responses of transitway users to the question "How many minutes, if any, do you believe you save by using the transitway instead of the regular freeway lanes?" Times shown are the median of the responses.
[3]The measured travel time savings for the North Freeway are 1989 data. The perceived travel times shown are from a 1986 survey. Travel times on the freeway have improved noticeably since 1986; thus, a meaningful comparison of these data is difficult.

Source: Texas Transportation Institute surveys.

Factors Influencing Transitway Utilization

It is evident that a number of factors influence both bus ridership and carpooling on a transitway facility. Some of those factors, such as parking cost, are the ones used in traditional mode split models. A review of the Houston data suggest that at least 3 factors appear to be significant in helping to explain current transitway ridership levels.

Length of Time the Transitway Has Been in Operation

Most "successful" transitway projects experience rapid growth during the first several years of operation. Trends in ridership on two of the more successful high-occupancy vehicle lane projects -- the Shirley Highway in Washington, D.C., and the San Bernardino Busway in Los Angeles -- are shown in Figure 15. While some of the increase in usage of those transitways has been the result of allowing additional user groups onto the facility (e.g., allowing carpools to use the facility), much of the increase is simply the result of the fact that mode choice changes continue to occur over a period of several years.

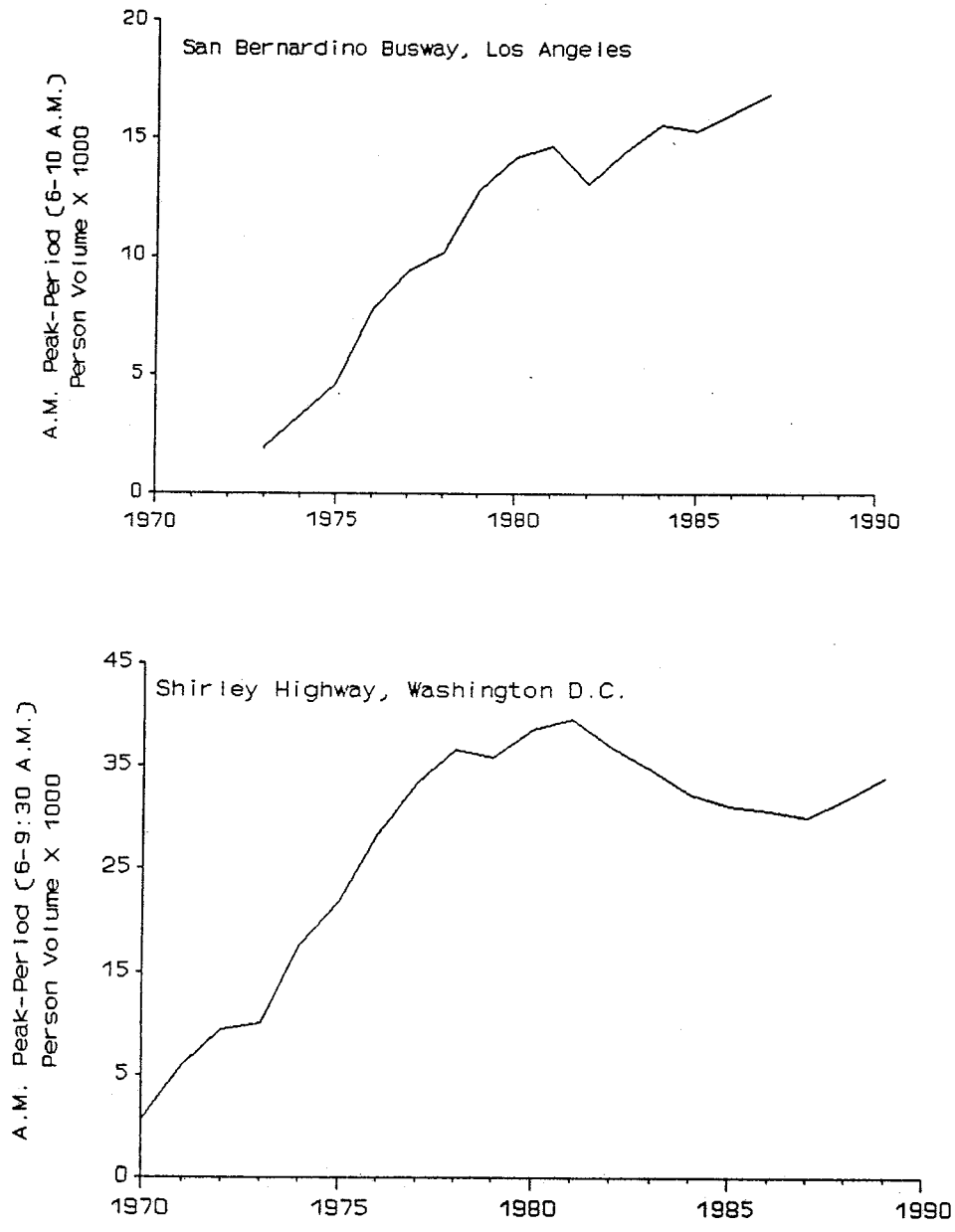
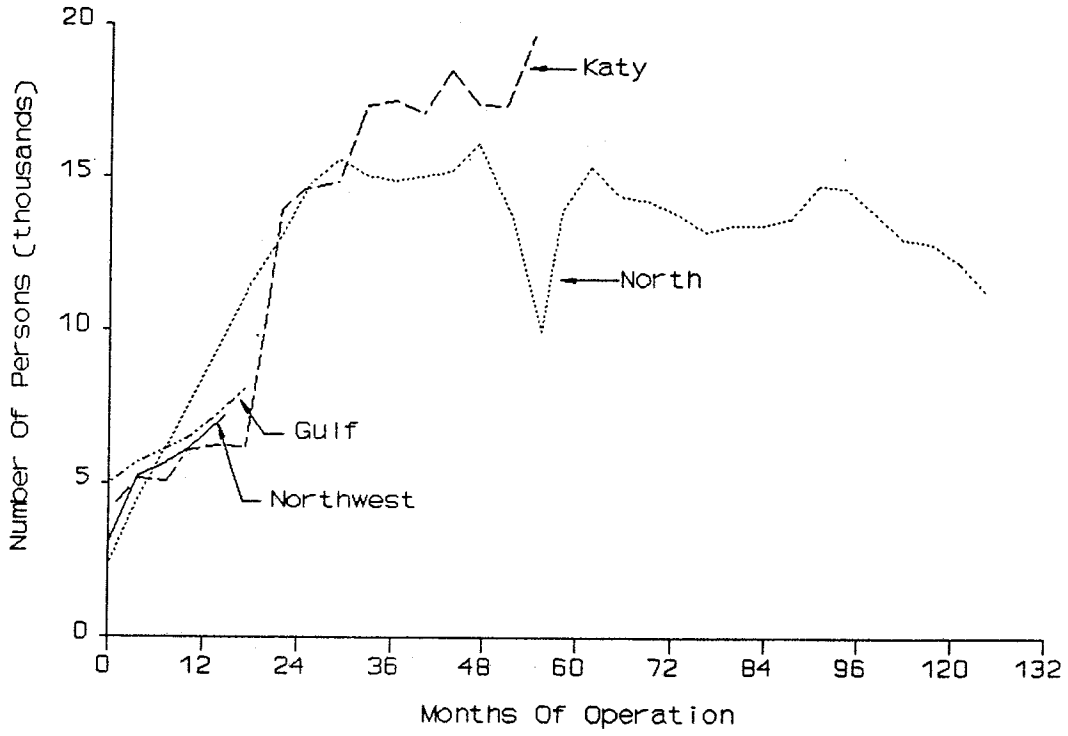


Figure 15. Historical Trends in Ridership on the Shirley Highway HOV Lanes and the San Bernardino Busway

This occurrence of rapid growth in usage during the early years of operation has also been observed on the Houston transitways (Figure 16). While both the North and Katy Transitways have been in existence sufficiently long to have experienced this early growth surge, the same is not true for the Northwest and Gulf transitways, which opened in 1988. Usage of those facilities is expected to increase in the near future as a result of this "early growth" trend.



Source: See data in appendices.

Figure 16. Daily Ridership by Months of Operation, Houston Transitways

Vehicle Groups Allowed to Use the Transitways

As would be expected, allowing carpools to use a transitway, or reducing carpool occupancy requirements, will result in an increase in transitway person volume (as long as the vehicular capacity of the transitway lane is not exceeded). This clearly helps to explain

the utilization trend on the North Transitway, which is used only by authorized buses and vanpools. Vanpooling in general has been declining in Houston, and that is reflected in the ridership trends on the North Transitway. The opening of this transitway to carpools (which is expected to occur in April 1990), should greatly increase North Transitway utilization. TTI estimates suggest that allowing usage of the North Transitway by 2+ carpools will increase the volume by about 6,000 daily trips, roughly a 50% increase in current usage.

A somewhat similar experience has occurred on the Katy Transitway. Prior to instituting the 3+ carpool requirement from 6:45 a.m. to 8:15 a.m. in October 1988, usage of that facility had increased throughout 1988 and exceeded 19,000 daily trips in September 1988. The change in the occupancy requirements, which was necessary to address a vehicular capacity problem on the transitway, caused an immediate drop in transitway usage. By December 1989, daily usage levels had increased to a level comparable to that which existed in September 1988.

The Transitway Must Offer Meaningful Travel Time Savings

Provision of travel time savings is, perhaps, the most important single factor influencing transitway use. Quite simply, unless severe freeway congestion exists, usage of transitways 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[4].

The 1988 evaluation of the Houston data suggested that, unless the transitway offers a travel time savings relative to the freeway mixed-flow lanes in excess of 7 to 8 minutes during the peak hour, utilization of the transitway will be somewhat marginal. The data collected during 1989 tend to also support that general relationship (Figure 17).

---

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

This conclusion currently impacts several of Houston freeway transitways. The completion of the North Freeway widening between I-610 and North Shepherd, combined with the opening of the Hardy Toll Road, have at least temporarily reduced transitway travel times savings in that corridor. When the contraflow lane first opened in 1979, 15-minute travel time savings to contraflow users were typical; the corresponding time savings

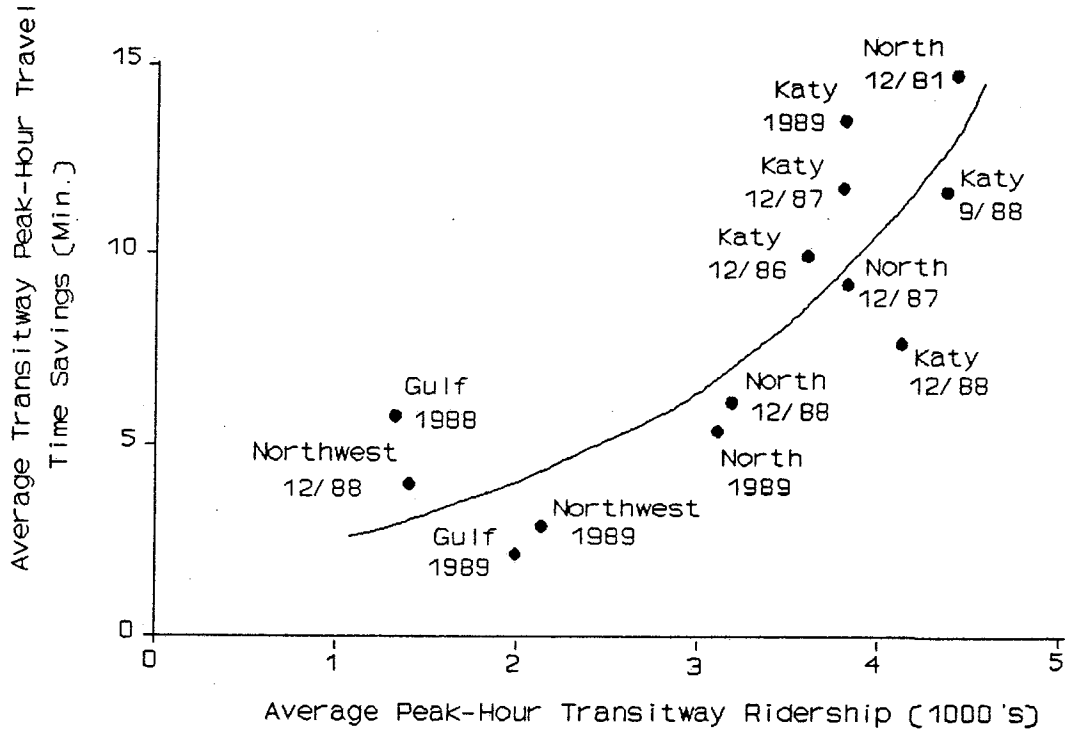


Figure 17. Relationship Between Peak-Hour Transitway Ridership and Peak-Hour Transitway Travel Time Savings, Houston Data

were closer to 6 minutes in 1988, and were roughly 5 minutes in 1989. The section of the Gulf Transitway currently in operation is located in a freeway segment that has recently been significantly expanded; the transitway currently offers peak-hour travel time savings of less than 5 minutes, and this marginal level of travel time savings will continue at least until the second phase of the transitway is completed. And, while 9.5 miles of the Northwest Transitway are operational, the geometrics and operations at the temporary

terminus of this lane at West Little York cause severe congestion for transitway users. In fact, in the afternoon, travel time savings generated on the transitway are essentially negated by the congestion experienced at the terminus of the transitway. Completion of this transitway, scheduled for February 1990, should eliminate this problem and result in an increase in transitway utilization; until that occurs, marginal average peak-hour travel time savings (less than 5 minutes) will continue to exist.

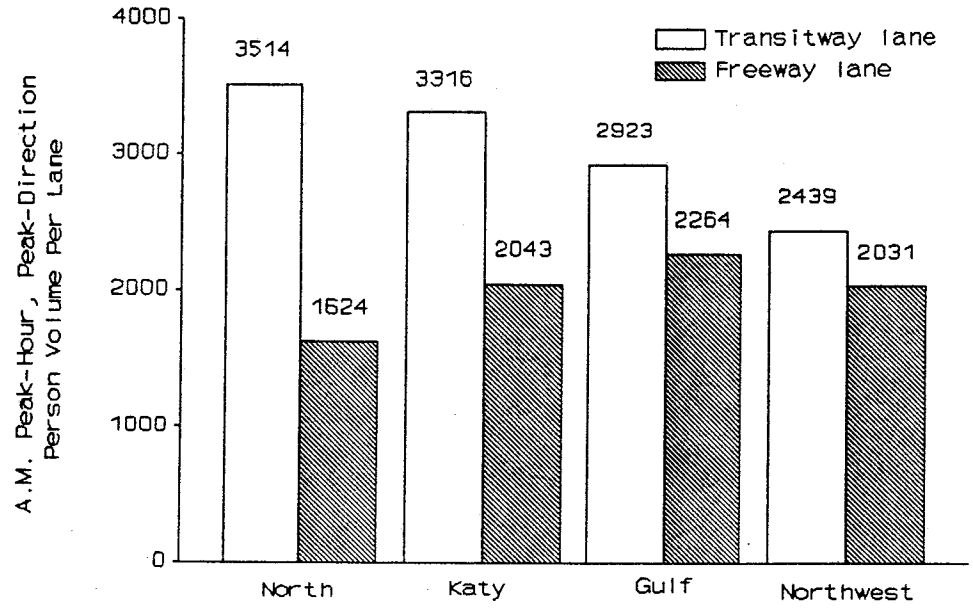
The relationship depicted in Figure 17 is critical in planning and justifying transitway improvements. The transitway is an appropriate improvement in freeway corridors that routinely experience intense congestion so that the transitway can offer, as a minimum, a 5 to 10 minute travel time savings compared to driving in the freeway mainlanes.

Changes in Roadway Person Movement

A major reason for implementing transitway improvements is to increase the effective person-movement capacity of a roadway. There is an implicit recognition that an emphasis needs to begin to be given to moving people rather than moving vehicles. The transitways are intended to be an incentive to bring about this increase in person movement.

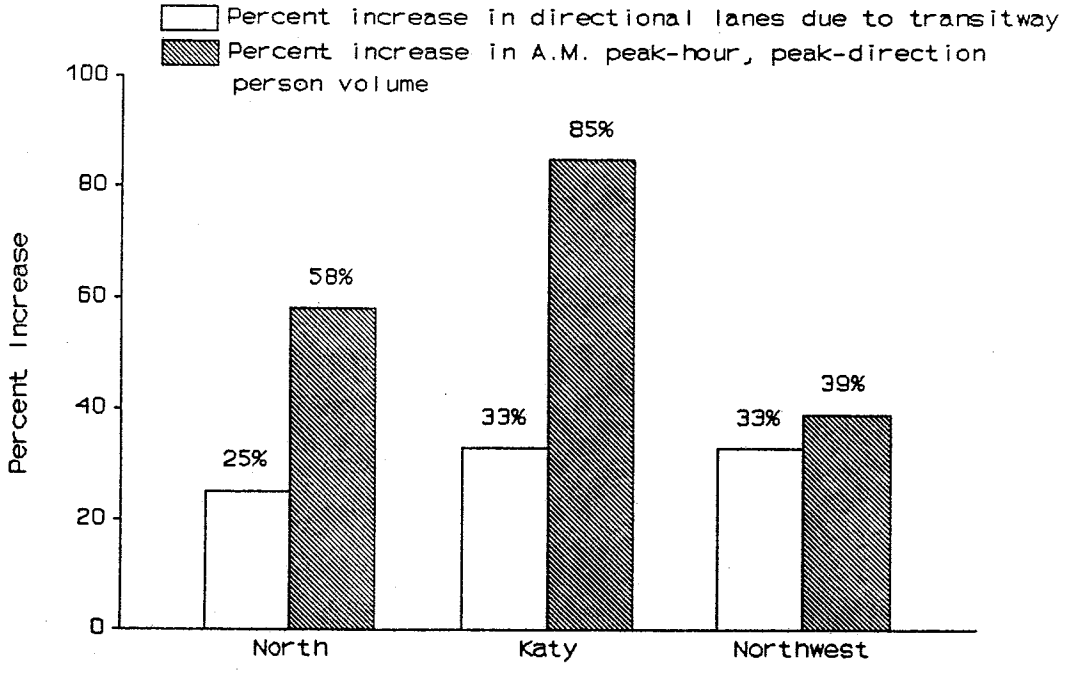
The transitway lanes do move a greater volume of persons than do the freeway lanes (Figure 18); in the peak hour, the transitways are moving 20% to 116% more persons per lane than are the freeway mainlanes. To a certain extent, however, this would be expected since the higher-occupancy vehicles have virtually all been put into one lane.

As a result, since implementation of the transitway does increase the number of directional lanes, for the transitway 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 transitway implementation; if this is not the case, it can be argued that, perhaps, the additional lane should have been designated for use by mixed-flow traffic.



Source: See data in appendices.

Figure 18. Peak-Hour, Peak-Direction Person Volumes on the Houston Freeways and Transitways, 1989



Source: See data in appendices.

Figure 19. Increase in Total (Freeway Plus Transitway) A.M. Peak-Hour, Peak-Direction Person Volume

Conclusion. The data show that the Houston transitways are resulting in a disproportionately large increase in person movement (Figure 19); in all instances, the increase in person movement exceeds the increase in lanes provided. This suggests that the transitways are being effective at meeting this objective.

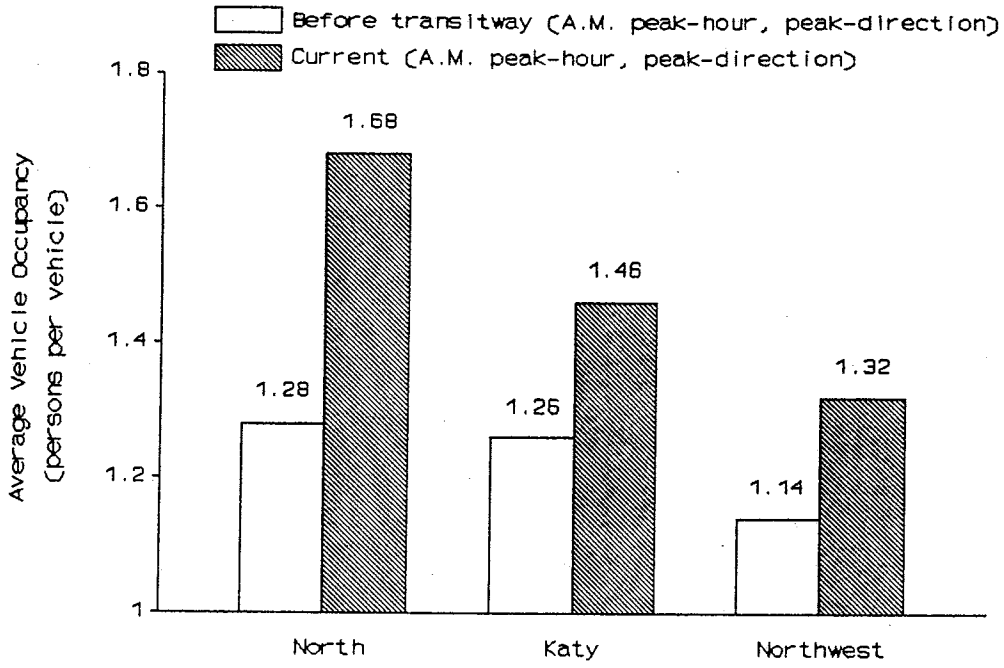
Changes in Average Vehicle Occupancy

For the transitways to generate the disproportionate increases in person movement reflected in Figure 19, it is necessary to increase the average vehicle occupancy (persons per vehicle) characteristic of the roadway. The transitway 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 transitways (North and Katy), peak-hour average vehicle occupancies (persons per vehicle) are currently unusually high for Texas (or other southwestern states) freeways, being in the range of 1.4 to 1.7 persons per vehicle (Figure 20). These occupancies are the combined average of all freeway mainlane plus transitway traffic. To date, the occupancy on the Northwest Freeway has not attained this impressive level; however, it is continuing to increase. In comparison to 1988, the occupancy for the Northwest Freeway has increased by 4.8%.

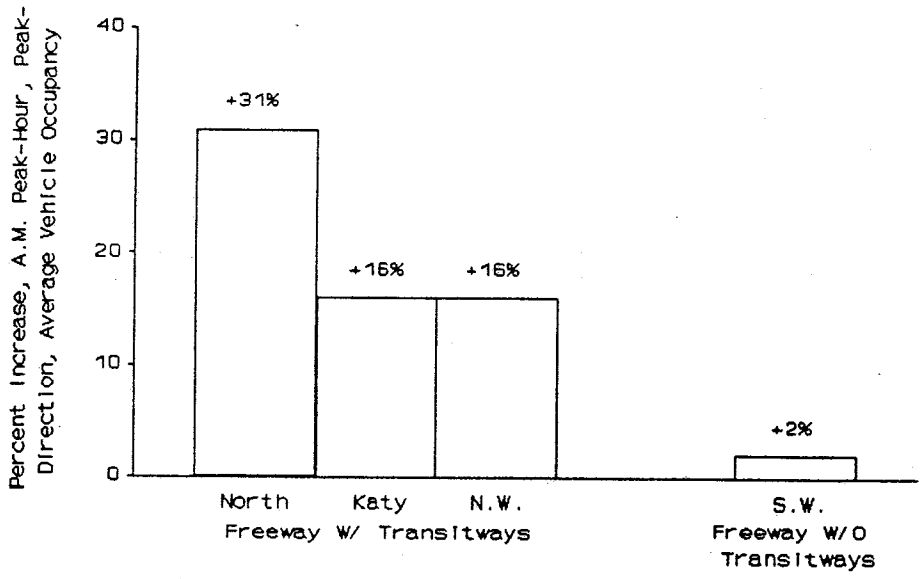
Comparing the experience on the freeways with transitways to what has occurred on the freeways not having transitways helps to isolate the impact of the transitway. In comparison to pre-transitway conditions, significant increases in the peak-hour average vehicle occupancy have been experienced on the freeways having transitways; this has not occurred on the freeway not having a transitway (Figure 21).

Conclusion. The data clearly show that the presence of a transitway has resulted in a meaningful increase in average vehicle occupancy. On the freeways with transitways, in comparison to pre-transitway conditions, average peak-hour, peak-direction vehicle



Source: See data in appendices.

Figure 20. Change in A.M. Peak-Hour, Peak-Direction Average Vehicle Occupancy, Freeway With Transitways



Source: See data in appendices

Figure 21. Changes (Pre-Transitway to Current) in Average Vehicle Occupancy, Freeways With and Without Transitways

occupancy has increased by 16% to 31%. Over the same time period, occupancy on the freeway without a transitway has increased by 2%.

Increase in Ridesharing Due to Transitways

Data shown previously indicate that significant increases have occurred in both person movement and average vehicle occupancy on the freeways that have transitways. However, it is important in assessing transitway effectiveness that much of this increase be the result of having created new rideshare patrons; the transitway should accomplish more than simply diverting existing buses and carpools to the transitway. This section of the report presents available data that can be used to estimate the increase, if any, resulting from transitway implementation that has occurred in both carpooling and bus usage.

Have the Transitways Caused an Increase in Carpooling

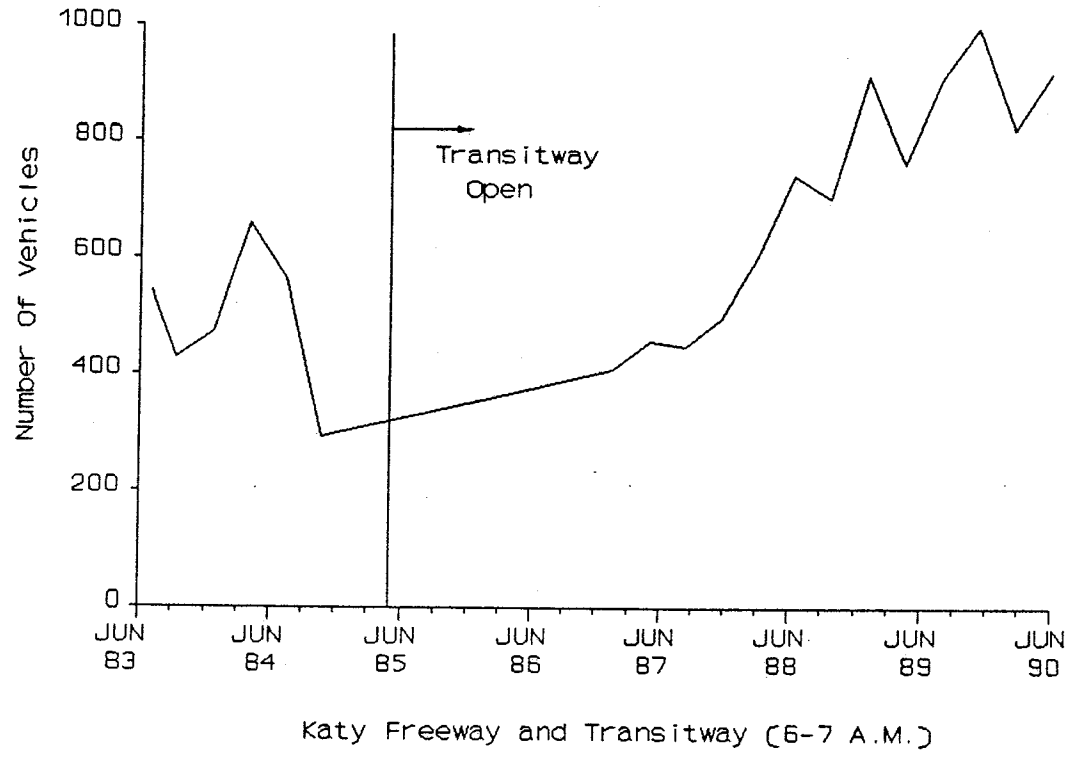
Survey data suggest that relatively few carpools using the transitway were diverted to that facility from parallel routes (Table 9). This indicates that increases that may have occurred in average vehicle occupancy on the roadway are primarily due to factors other than this diversion.

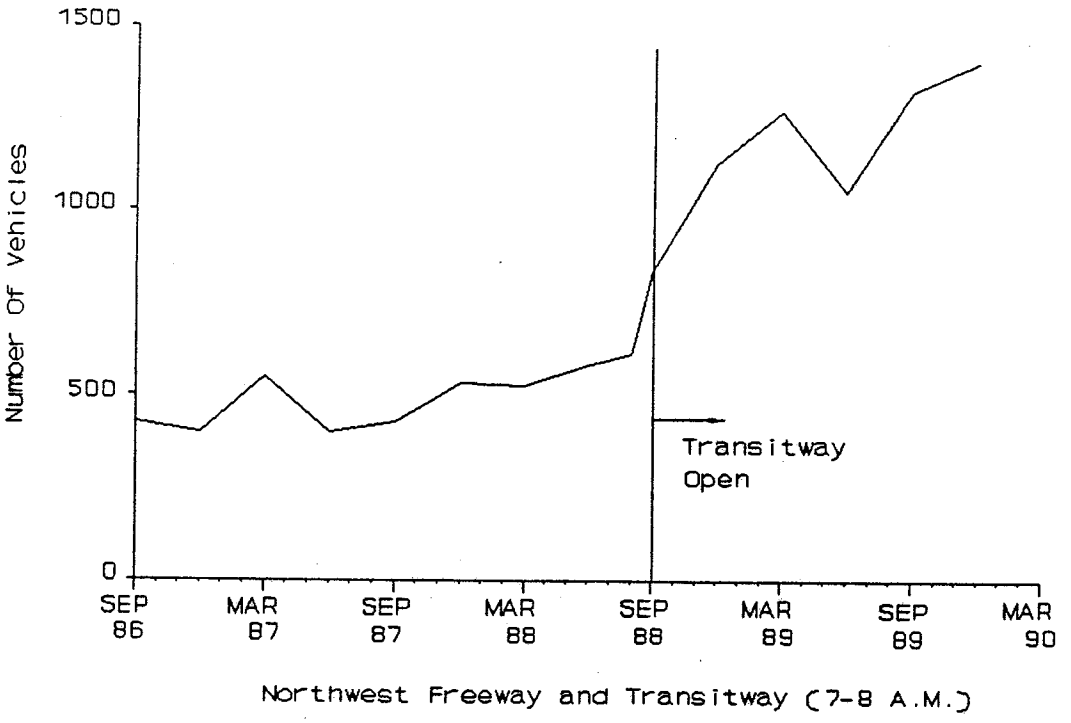
Table 9. Carpools Diverted to the Transitway From Parallel Routes

Transitway	Percent of Transitway Carpoolers Whose Previous Mode Was Carpooling[1]	Percent of Those Carpoolers Who Previously Used a Parallel Route
Katy	26%	15%[2]
Northwest	46%	11%
Gulf	44%	14%

[1]Mode of travel prior to carpooling on the transitway.
[2]As an example, 15% of 26%, or approximately 4%, of total carpools using the Katy Transitway are carpools that are diverted to the transitway from parallel routes.

Source: Texas Transportation Institute Surveys.



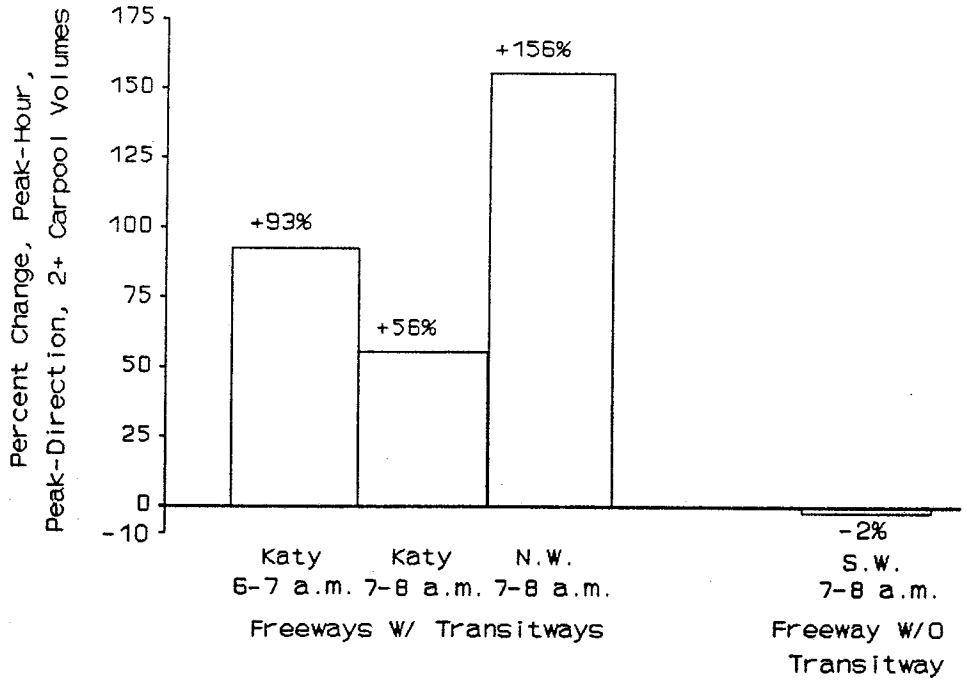


Source: See data in appendices.

Figure 22. Trends in 2+ Carpool Volumes, Freeways With Transitways

And there have been significant increases in carpool volumes since the transitway facilities have opened (Figure 22). To assess the effectiveness of the transitway, however, it is necessary to develop estimates of how many of the carpools using the transitways are new carpools formed primarily because of the presence of the transitways.

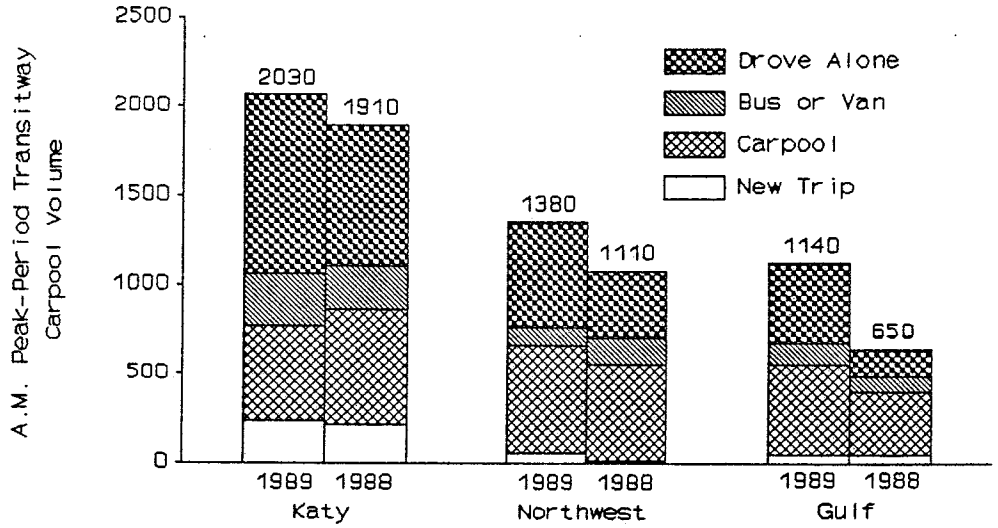
This estimate of new carpools is further complicated in that carpools naturally have relatively high turnover rates; just to keep the total carpool volume constant, many new carpools need to be formed to replace those that are disbanded. However, one approach for addressing this concern is to compare what has happened in those corridors with transitways to what has happened in a corridor that does not have a transitway (Figure 23). The type of increase in carpooling that has occurred in the transitway corridors simply has not taken place in the corridor without a transitway; in fact, while substantial increases in carpool volumes have been experienced in the transitway corridors, a slight decline has actually occurred on the freeway without a transitway. Since the major difference in the corridors being compared is the availability of a transitway, a conclusion appears to be that the transitway must be a significant factor in causing the increase in carpooling.



Source: See data in appendices.

Figure 23. Change (Pre-Transitway to Current) in 2+, A.M. Peak-Hour Peak-Direction Carpool Volumes (Freeway plus Transitway)

Other approaches exist for trying to identify that component of transitway carpooling that has been created as a result of the transitway. One indicator is the "previous mode" of travel for carpoolers; that is, prior to carpooling on the transitway, how was the trip made (Figure 24). Those data indicate that somewhere between 40% and 50% of current carpoolers on the transitway were previously in "drive alone" vehicles; as the transitways become more mature and carpool volumes increase, this percentage has also been increasing. The sum of "drive alone" plus "new trips", which is in the range of 45% to 60% of total carpools, could be considered as an initial indication of the volume of new carpools created as a result of the transitway.



Source: See data in appendices.

Figure 24. Previous Mode of Travel for Transitway 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 a transitway were in existence. To try to identify this portion of carpool demand, carpoolers using the transitway were surveyed in an effort to assess the importance of the transitway in their decision to carpool.

One question asked "how important was the transitway in your decision to carpool?" The responses (Table 10) suggest that the transitway was "somewhat important" or "very

important" in the decision to carpool to the overwhelming majority of carpoolers on the transitway. As might be expected, this percentage is highest on the most mature of the transitways -- the Katy -- which is also the transitway that presently offers the greatest travel time savings.

Table 10. Responses to Question "How Important Was the Transitway in Your Decision to Carpool?"

Transitway	Response		
	Very Important	Somewhat Important	Not Important
Katy	73%	14%	13%
Northwest	56%	20%	24%
Gulf	48%	19%	33%

Source: Texas Transportation Institute surveys.

A second question asked carpoolers if they would be carpooling if there were no transitway (Table 11). The percentage of carpoolers stating "no" or "not sure" has increased over the last year.

Table 11. Response to Question "If the Transitway Had Not Opened to Carpools, Would You be Carpooling Now?"

Transitway	Response					
	Yes		No		Not Sure	
	1989	1988	1989	1988	1989	1988
Katy	42%	53%	42%	35%	16%	11%
Northwest	52%	70%	30%	21%	18%	9%
Gulf	68%	75%	20%	14%	12%	11%

Source: Texas Transportation Institute surveys.

It is well documented that carpools have a high turnover rate. Data are beginning to suggest that carpools remain in existence longer as a result of the transitways. Surveys conducted on the Northwest and Gulf Freeways in 1988 (representative of pre-transitway conditions) found that the median age of a carpool was 3 months and 6 months, respectively. Surveys conducted in late 1989 on the Katy, Northwest, and Gulf Transitways (representative of transitway conditions) found the median age of a carpool to be: Katy Transitway, 13 months; Northwest Transitway, 9 months; and Gulf Transitway, 12 months.

The "representative" median age of a carpool on a freeway without a transitway is 4.5 months; the "representative" median age of a carpool on a transitway is 11.3 months.

Conclusion. Implementation of the transitways has clearly increased the volume of carpools; this type of increase simply has not taken place on freeways not having transitways.

Surveys indicate that the transitway is an important factor in the decision to carpool. It appears that, on the more mature Katy Transitway, approximately half of the current transitway carpoolers previously drove alone and formed a carpool as a result of the transitway (Table 12); this percentage has increased from 40% in 1988. On the less mature transitways, it appears that between 25% and 40% of the carpools using those facilities are new carpools created in response to the presence of a transitway. *Thus, on a freeway with a transitway that has operated several years and offers meaningful time savings, the presence of that transitway can be expected to essentially double carpooling.*

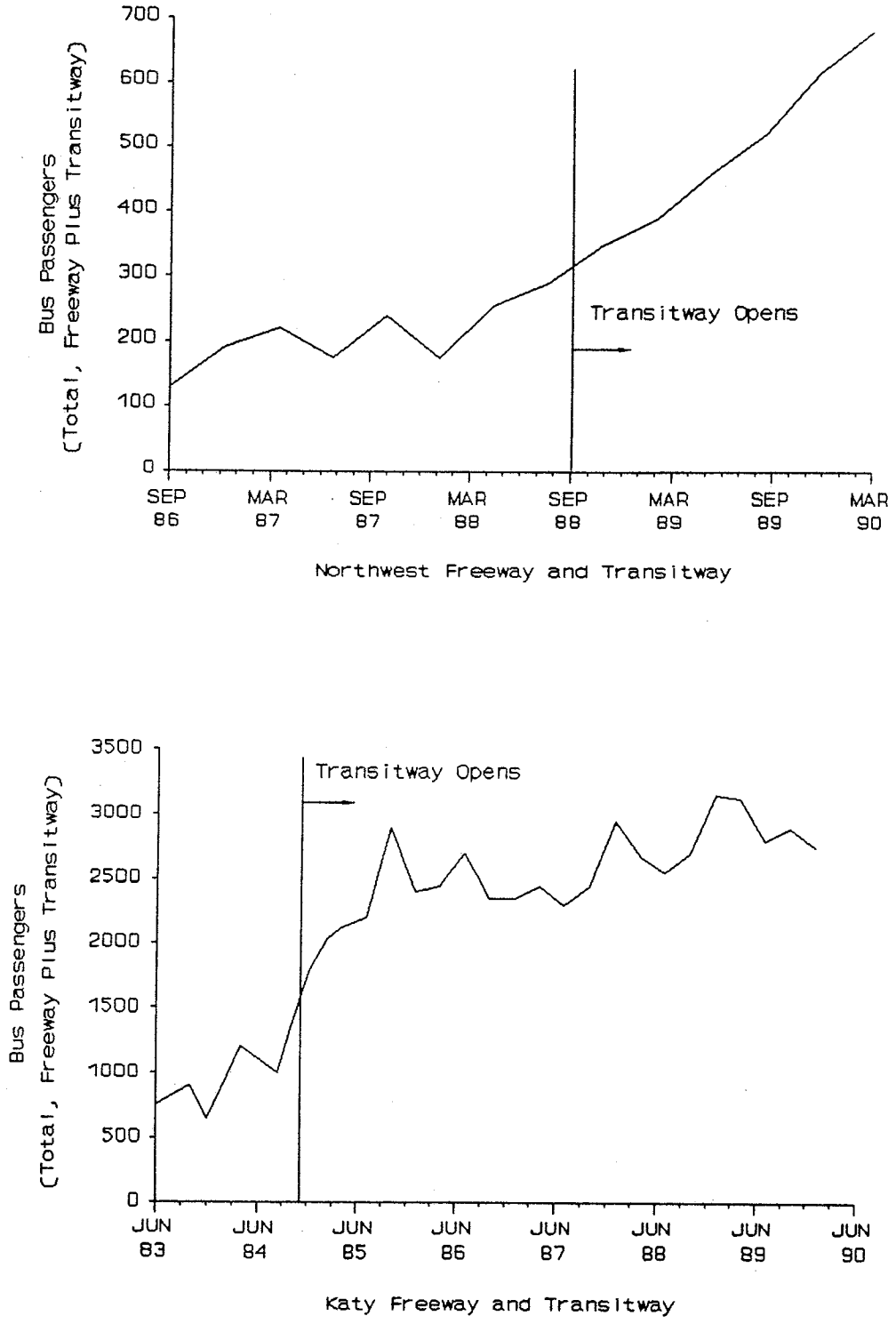
Table 12. Estimated Impact of Transitways in Forming New Carpools

Transitway	Apparent % New Carpools Based on Previous Mode[1]	Would You Carpool If No Transitway[2]			Est. % of Transitway Carpools Formed Due to Transitway[3]
		Yes	No	Not Sure	
Katy	61%	42%	42%	16%	50%
Northwest	48%	52%	30%	18%	39%
Gulf	45%	68%	20%	12%	26%

[1] From Figure 24, the sum of "drove alone" and "new trips".
[2] See Table 11.
[3] It is assumed that the sum of the "no" responses plus one-half of the "not sure" responses equals the percentage of total transitway carpools that were previously "drive alone" that formed a carpool as a result of the transitway. The previous mode response provides a logic check for this conclusion.

Have the Transitways Caused an Increase in Bus Ridership

The previous section determined that the transitways have been responsible for creating a significant volume of new carpools. The available data suggest that the transitways have also caused significant increases in bus ridership and park-and-ride lot utilization.

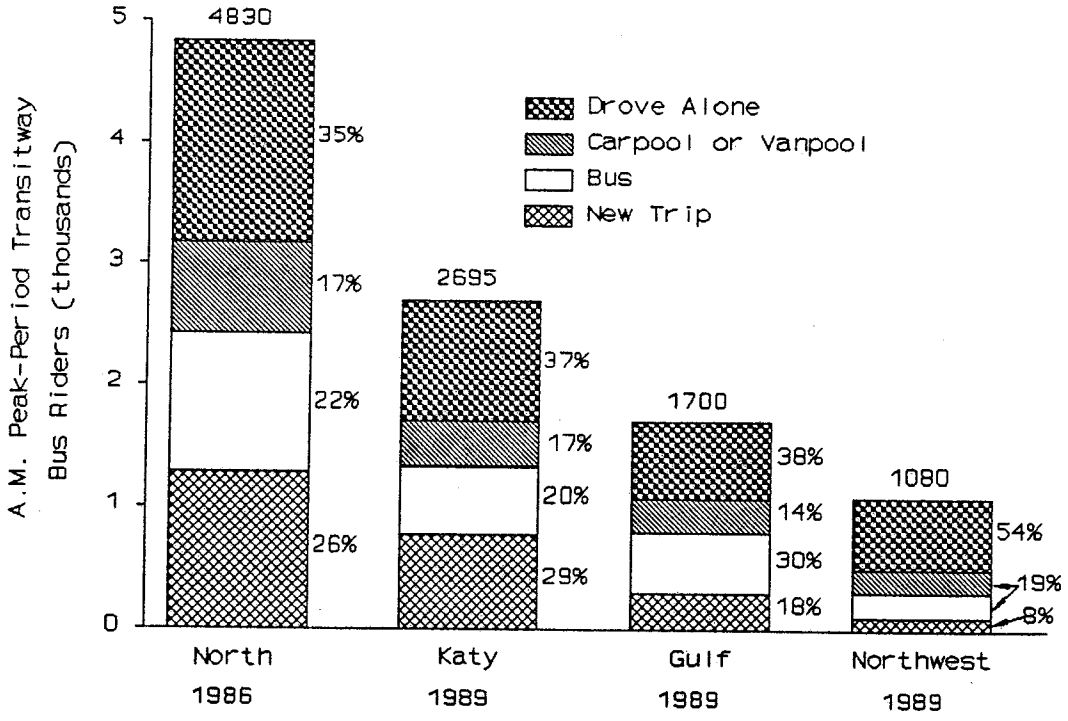


Source: See Data in appendices.

Figure 25. Trends in Bus Ridership, Freeways With Transitways

With the creation of the transitways, significant increases in bus ridership have resulted (Figure 25); 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 opening of the transitways has been a meaningful factor responsible for at least a portion of the increase in transit ridership.

An examination of the previous mode of travel for transitway bus riders provides a further indication that the transitways have created new bus riders (Figure 26). These data suggest that fewer than 30% of existing transitway bus riders rode a bus prior to being a transitway bus patron.



Source: See data in appendices.

Figure 26. Previous Mode of Travel for Transitway Bus Riders

Transitway bus riders were surveyed in an effort to determine the importance of the transitway in their decision to ride a bus. The data suggest that the availability of a

transitway has been an important consideration in deciding to ride a bus (Table 13). The transitway was not an important consideration for less than 25% of the transitway bus riders.

Table 13. Responses to Question "How Important Was the Opening of the Transitway in Your Decision to Ride a Bus?"

Transitway	Response		
	Very Important	Somewhat Important	Not Important
Katy	72%	17%	11%
Northwest	71%	21%	8%
Gulf	54%	22%	24%

Source: Texas Transportation Institute Surveys.

A second question asked bus riders if they would be riding the bus if there were no transitway (Table 14). For the more mature transitways (Katy and North), the plurality of responses was "no". The data suggest that, on these mature facilities, over half of total bus ridership would not be using transit were there no transitway.

With the implementation of the transitways, at least two factors are working to increase transit ridership. First, the transitway offers the bus rider numerous advantages, such as a faster trip and a more reliable trip time. However, with the opening of the transitways, Metro has also increased the frequency of bus service available in the corridors. The increased frequency of bus service, by itself, would have resulted in increases in transit ridership; a general "rule of thumb" is that a 10% increase in bus frequency will result in a 5% to 6% increase in bus ridership.[5] As indicated in the footnote below, the results shown in Figure 27 significantly overstate the impacts of increases in bus frequency and understate the impacts of the transitway; nevertheless, it is clear that the presence of the transitway has to be a major explanatory variable in accounting for the increases in transit usage in the corridors.

[5]It should be realized that this elasticity is generally applied to relatively small increases in bus service. Applying it to the large frequency increases on the transitways probably significantly overstates the impact of frequency increases on bus ridership.

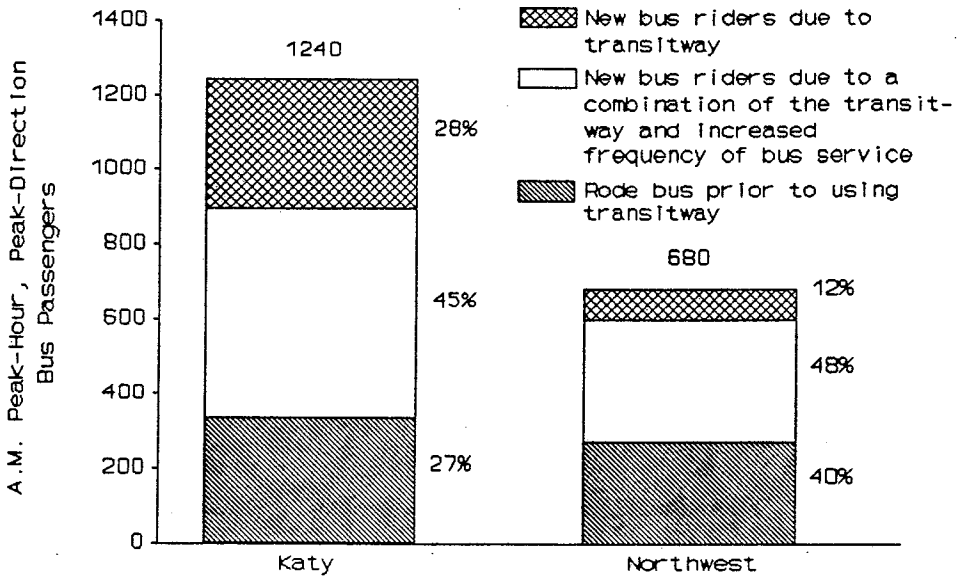


Figure 27. Estimated Percentage of Transitway Bus Patrons Using the Bus Because of Transitway

Table 14. Response to Question "If the Transitway Had Not Opened, Would You be Riding a Bus Now?"

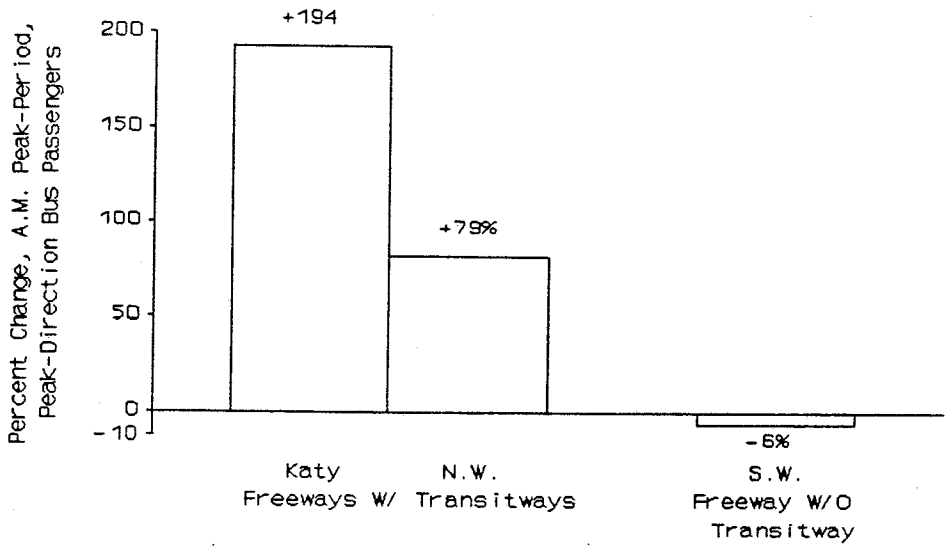
Transitway	Would You be Riding a Bus if No Transitway[1]			Est. % of New Bus Ridership Formed Due to Transitway[2]
	Yes	No	Not Sure	
North (1986)	23%	41%	36%	59%
Katy	32%	36%	32%	52%
Northwest	41%	39%	20%	49%
Gulf	56%	22%	22%	33%

[1]Transit rider response to the question "If the transitway had not opened, would you be riding a bus now?"

[2]It is assumed that the sum of "no" responses plus one-half of the "not sure" responses equals the percentage of total transitway bus riders that are riding a bus due to the availability of the transitways. The "previous mode" data provide a logic check for this conclusion.

Source: Texas Transportation Institute surveys.

Bus ridership has also increased much more rapidly in corridors having transitways than it has in corridors not having transitways (Figure 28). Again, it would appear that the



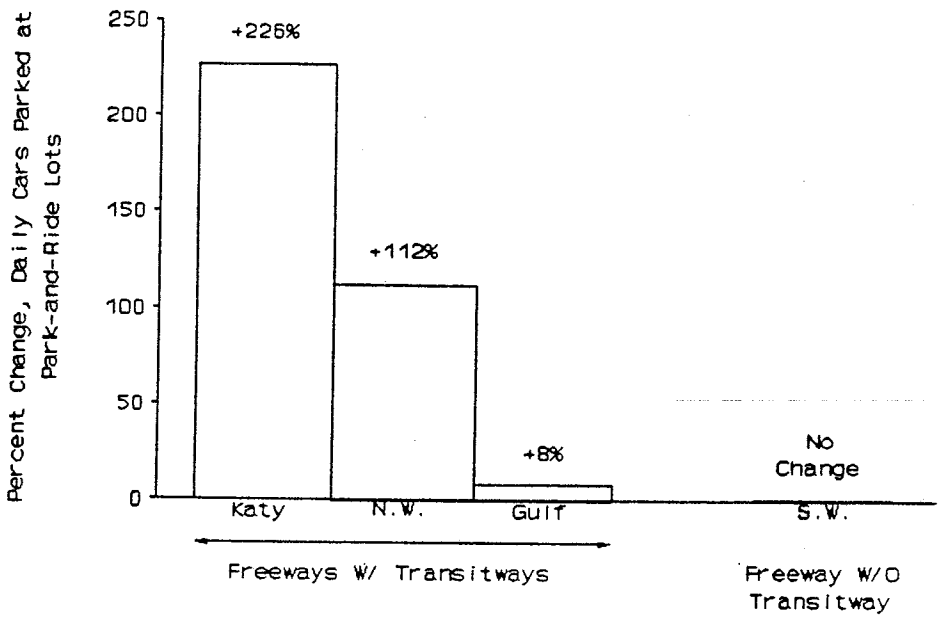
Source: See data in appendices.

Figure 28. Change (Pre-Transitway to Current) in A.M. Peak-Period Bus Ridership, Freeways With and Without Transitways

presence of the transitway is the primary driving force in increasing bus ridership. While peak-period bus ridership has increased by over 79% in the corridors with transitways, it has actually declined slightly in the corridor without a transitway. The same experience has occurred in observing the number of vehicles parked at bus park-and-ride lots in the corridor (Figure 29). Again, there has been over a 100% increase in the corridors that have transitways, and there has been a slight decline in park-and-ride usage in the corridor with a transitway.

Conclusion. Implementation of the transitways has clearly increased bus ridership; this type of increase has not occurred in freeway corridors not having transitways.

Surveys indicate that the presence of a transitway is an important factor in the decision to ride a bus. Many of the current bus riders previously "drove alone" and have indicated they would not be riding a bus were it not for the transitways. On the more mature transitways (North and Katy), it is estimated that over 50% of the total bus riders are using transit because of the transitway; *in effect, the implementation of the transitway has more than doubled transit ridership in those corridors with mature transitways.*



Source: See data in appendices

Figure 29. Change (Pre-Transitway to Current) in A.M. Peak-Period Bus Ridership, Freeways With and Without Transitways

V. TRANSITWAY IMPACTS ON FREEWAY MAINLANE OPERATIONS

Data presented previously have shown that the transitways have increased the overall average vehicle occupancy characteristic of the roadways. This has been accomplished largely by creating new carpools and new transit riders. However, desirably the implementation of a transitway, regardless of how much utilization it generates, will not unduly impact the operation of the freeway mainlanes; the transitway implementation should increase the overall peak-hour per lane efficiency.

Impacts on Freeway Mainlane Operations

It has been demonstrated previously that transitways, 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 transitway to be able to be successful in offering a significant travel time savings.

Available data suggest that the implementation of transitways, with a design similar to that being used in Houston, does not greatly affect the operation of the freeway mainlanes, either positively or negatively. The transitways have not greatly altered demand for the freeway mainlanes; while speeds on some freeways have actually increased since transitway implementation, this is largely attributable to factors other than the transitway implementation (Table 15). Plots of freeway travel speeds, prior to transitway implementation and current, are shown in Figure 30.

Compared to pre-transitway conditions, accident rates for the freeways shown in Table 15 have generally changed very little; statistically significant changes have not occurred. For the control freeway (Southwest Freeway) without a transitway, accident rates have also remained essentially unchanged for the comparable time periods. Since in several instances freeway mainlanes and inside shoulders were narrowed to provide the transitway, this accident impact has been an area of intense interest.

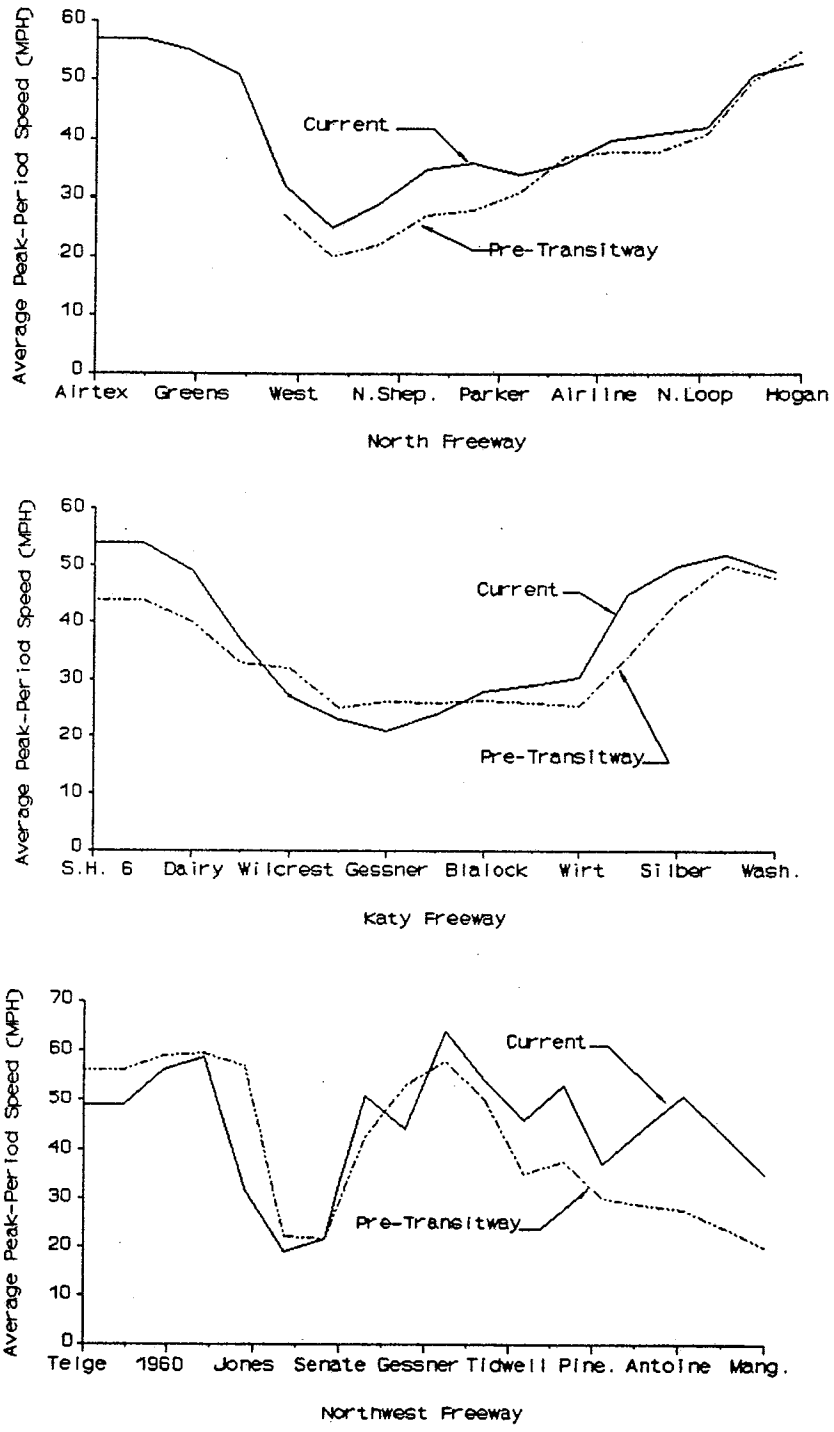


Figure 30. Freeway Peak-Period Speeds on Mainlanes, Pre-Transitway and Current

Table 15. Freeway Mainlane Operation, Prior to Transitway Implementation and Current

Freeway Mainlane Data	Transitway or Freeway					
	North[4]		Katy[5]		Northwest[6]	
	Pre-transitway	Current	Pre-Transitway	Current	Pre-transitway	Current
Volume Per Hour Per Lane[1]						
AM Peak Hour	1650	1455	1320	1845	1790	1800
AM Peak Period	----	----	1250	1680	1460	1585
Freeway Speed (mph)[2]	20	32	23	23	28	43
Accidents/MVM[3]	1.82	1.84	1.34	1.34	0.61	0.65

[1]In most instances, freeway volumes are counted between an exit ramp and an entrance ramp and, thus, may appear low. Peak-period data are total peak-period volumes divided by 3.5 hours. On the Katy Freeway, alleviating a downstream bottleneck has significantly increased volumes at the count location.
[2]Many factors other than transitway implementation have had a more significant impact on freeway operating speeds. Speed shown is a.m. peak hour, peak direction.
[3]Accident rate expressed as accidents per million vehicle miles of travel. The Southwest Freeway does not have a transitway. The accident rate in that corridor between 1982 and 1988 has remained between 1.55 and 1.50 accidents/MVM.
[4]Measured at West Little York. The number of mainlanes has increased by 1/direction since pre-transitway.
[5]Measured at Bunker Hill.
[6]Measured at Pinemont.

Source: See appendices.

It is apparent that the operation of the freeway mainlanes has not significantly deteriorated due to transitway implementation. What is, perhaps, of even greater interest is to note that, even though the transitways are moving several thousand persons in the peak hour, freeway mainlane volumes generally have not declined. This is indicative of the type of latent demand that apparently exists in corridors having sufficient congestion to justify transitway improvements. As was shown in Figure 26, many of the transitway trips being served are "new" trips.

Parallel Route Volumes

It is commonly postulated that, as a result of implementing a transitway, significant volumes of travel divert to the transitway 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 transitway users are summarized in Table 16. A relatively small percentage have indicated they previously travelled on a parallel roadway. The data suggest that, if anything, volumes on the freeway mainlanes should have decreased due to transitway implementation.

Table 16. Transitway Carpooler Response to the Question "Prior to Carpooling on the Transitway, How Did You Normally Make the Trip?"

Response	Transitway		
	Katy	Northwest	Gulf
On the transitway (bus or van)	16%	17%	17%
On the freeway general purpose lanes	64%	68%	68%
On a parallel street or highway	9%	10%	10%
Did not make this trip	11%	5%	5%

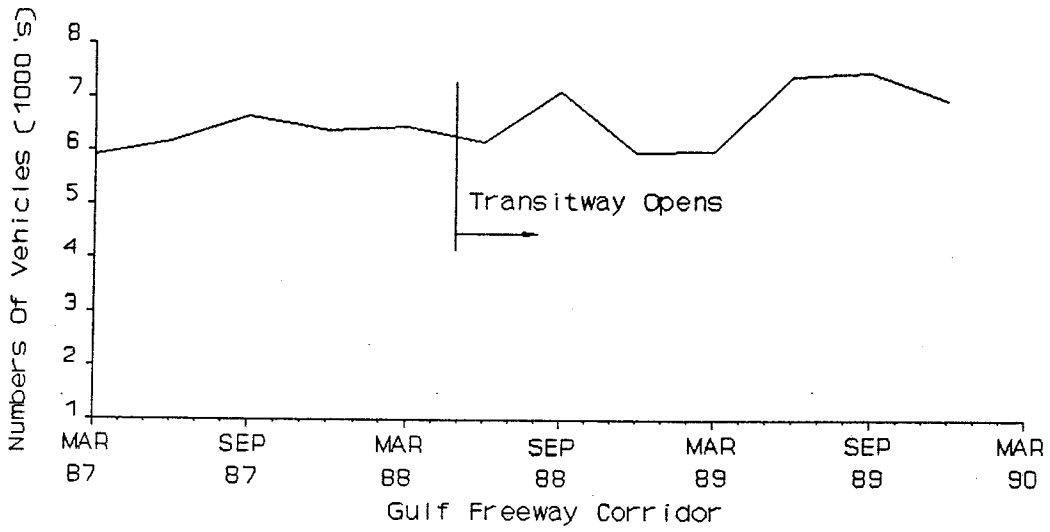
Source: Texas Transportation Institute surveys.

In two of the corridors, volume counts have been conducted on parallel routes. These data are depicted in Figure 31. There is no reason to conclude from these data that the opening of the transitways brought about a significant decrease in parallel route volumes. Rather than reducing peak vehicle volumes, the transitways appear to be a means of increasing person volume without a corresponding increase in vehicle volume.

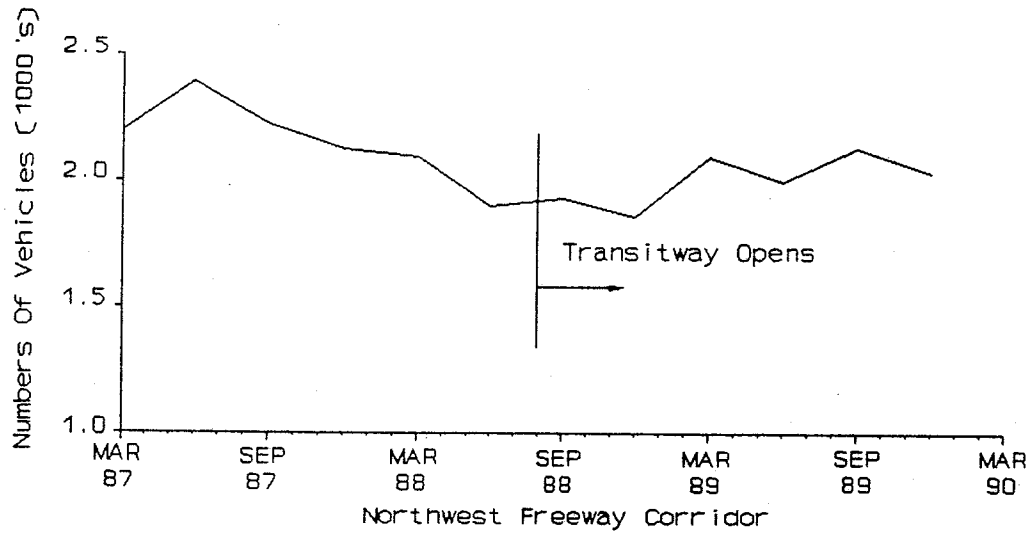
Impacts on Overall Roadway Efficiency

The transitways are intended to move substantial volumes of commuters at relatively fast speeds. As such, successful transitway 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 transitway has increased the overall efficiency of the facility (Table 17). It appears that, on a facility with



Note: Parallel routes are Old Galveston Road and Telephone Road



Source: Parallel route is Hempstead Highway

Figure 31. A.M. Peak-Period (6-9:30), Peak-Direction Vehicle Volumes on Parallel Routes in the Gulf and Northwest Freeway Corridors

a mature transitway, that transitway 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 and Katy Transitways. These increases in efficiency have been larger than those experienced on a freeway that does not have a transitway (Figure 32).

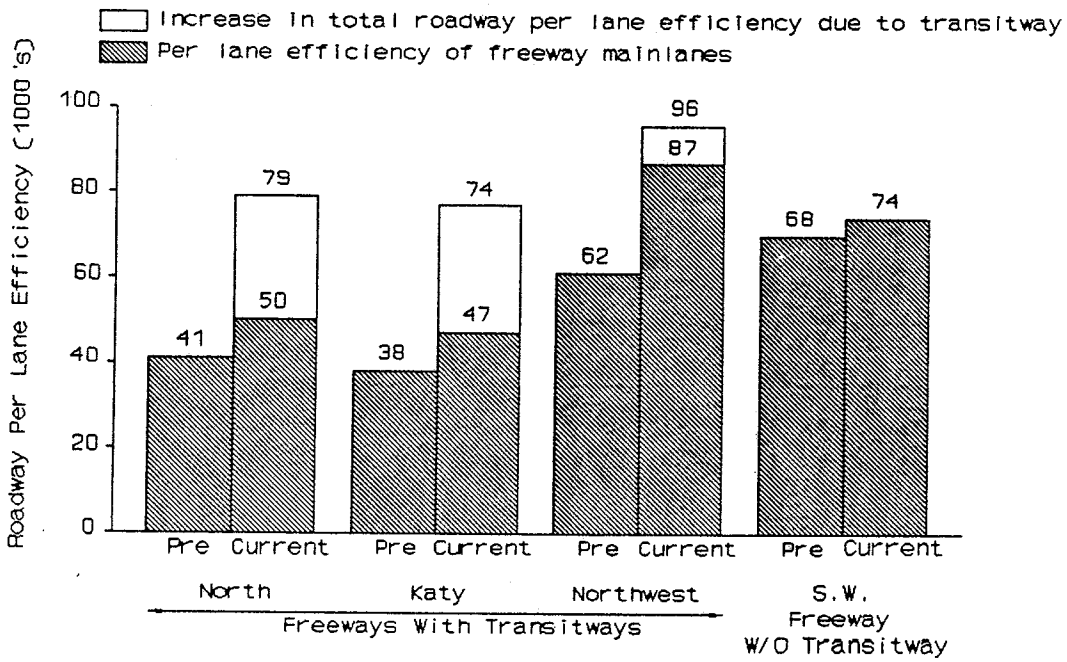
Table 17. Estimated Change in A.M. Peak-Hour, Peak-Direction Per Lane Efficiency[1], "Before" and "After" Transitway Implementation

Freeway	Pre-Transitway Per Lane Freeway Efficiency	Current Per Lane Efficiency			Absolute Inc. in Per Lane Efficiency Due to Transitway[2]
		Freeway	Transitway	Combined Freeway & Transitway	
	(1)	(2)	(3)	(4)	(5)
North	41	50	197	79	29
Katy	38	47	156	74	27
Northwest	62	87	124	96	9
Southwest[3] (w/o transitway)	68	74	---	74	---

[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.

Source: See data in appendices.

This criterion has weaknesses. While it can be used to show what the transitway 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; simulation of freeway operations is one means of addressing this issue. An example of this type of simulation analysis is presented subsequently in this report.



Source: See data in appendices.

Figure 32. Change (Pre-Transitway to Current) in A.M. Peak-Hour, Peak-Direction Roadway Efficiency, Freeways With and Without Transitways

VI. AIR QUALITY AND ENERGY CONSIDERATIONS

Surveys[6] have indicated that, while not the primary reasons for implementing high-occupancy vehicle facilities, air quality and energy consumption are secondary reasons for developing these projects. Evaluating the effectiveness of an HOV project regarding these issues is, however, somewhat difficult.

As has been shown in previous sections, implementing the high-occupancy vehicle lane does not noticeably reduce vehicle volumes on the freeway general purpose mainlanes. As a result, the travel that takes place in the extra lane which serves as the HOV facility is, in effect, an increase in vehicle-miles of travel compared to what existed prior to constructing the priority lane. Consequently, in comparison to the pre-transitway condition, implementing an HOV lane is likely to increase total vehicle-miles of travel which will also increase energy consumption and pollutants emitted.

Thus, a more appropriate comparison to help determine transitway impacts might be to compare the "add a transitway" alternative to an "add another mixed-flow traffic lane" alternative. In other words, if one lane is to be added to the freeway, would it be more effective to designate it as an HOV lane, or should it be designated as an additional general-purpose traffic lane. To make such a comparison, it is necessary to hold at least one variable constant; in the analysis developed in this section, total demand, expressed as passenger-miles, is held constant.

The analysis presented in this section of the report utilizes a freeway simulation model (FREQ) and is applied to the Katy Freeway and Transitway. Operation on both the mainlanes and the transitway, based on 1989 conditions, has been simulated. It is then assumed that the transitway does not exist; rather, an additional freeway mainlane has been provided in its place. The same demand is served, although it is served at the average vehicle occupancy (persons per vehicle) that existed on the Katy Freeway prior to the existence of the transitway. Thus, the actual conditions that exist today (with a transitway)

---

[6]Institute of Transportation Engineers. "The Effectiveness of High-Occupancy Vehicle Facilities." Informational Report IR-050, 1988.

can be compared to what would be occurring if 4 general-purpose mainlanes (one more than exist today) existed in each direction.

The results of this simulation are summarized in Table 18. 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 direction travel). However, it is clear that, to serve the same level of demand in the peak direction, the transitway alternative is superior in terms of reduction in total travel time, reduction in vehicle miles of travel, reduction in gallons of fuel consumed, and reduction in pollutants emitted. Vehicle miles are reduced by roughly 10%; gallons of fuel consumed are reduced by just over 10%; and kilograms of pollutants emitted are reduced by between 10% and 20%.

Table 18. Comparison of an "Add an HOV Lane" Alternative With an "Add an Additional Mixed-Flow Freeway Lane" Alternative, Katy Freeway, Houston

Alternative	Total Travel Time		Total Travel Distance		Avg. Speed (mph)	Fuel Consumption (gallons)	Emissions(kg)		
	Veh-Hr.	Pass-Hr.	Veh-Mi.	Pass-Mi.[3]			HC	CO	NO
1. 1989 Freeway (3 lanes)[1]	11,015	14,689	436,135	587,410	40	26,335	1268	8630	1836
1989 Transitway (1 lane)[1]	91	310	5,644	19,286	62	361	13	60	31
Total	11,106	15,179	441,779	606,696	41	26,696	1281	8690	1867
2. Freeway (4 lanes)[2]	13,821	17,378	482,532	606,696	38	30,198	1513	11120	2053
Alternative #1 as a % of Alternate #2	80.3%	87.3%	91.6%	100.0%	107.9%	88.4%	84.7%	78.1%	90.9%

Note: Analysis period is inbound, 6 a.m. to 12 noon, from Barker Cypress Road to the Southern Pacific Railroad (16 mi.). FREQ simulation model.

[1]Represents the freeway and transitway as they operated in December 1989. 1989 transitway volumes were used. 1985 base freeway volumes were increased by 2% per year to reflect 1989 conditions.

[2]Assumes there is no transitway. In its place, an additional general purpose lane has been added. The passenger-miles served under the first alternative are also served with this alternative, but at an average vehicle occupancy of 1.26 (occupancy on the Katy Freeway prior to transitway). Thus, both alternatives serve the same demand. One alternative serves that demand using both freeway lanes and an HOV lane. The other alternative serves all demand with an HOV lane.

[3]Due to difference in rounding as well as transitway access locations, passenger-miles between the two alternatives, as determined by the model, are not identical, but are within 5% of each other. The data shown in this table have been factored to eliminate this discrepancy.

Source: Texas Transportation Institute simulation analysis.

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; this work will be performed in future years of this project. However, at least in the Katy corridor, the HOV lane alternative relative to an additional freeway lane alternative reduces vehicle-miles of travel, which has associated with it other favorable impacts.

VII. TRANSITWAY PROJECT COST EFFECTIVENESS

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

Data presented previously in this report (Table 18) provided an indication of how an HOV lane project compares to a mixed-flow 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 mixed-flow highway lane. Since those are principal variables in determining cost effectiveness, it can be argued that, in at least the Katy Freeway corridor, the transitway 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, mainlane freeway improvements may be preferable to HOV lane implementation.

The analysis in this report focuses on the transitways that have been built and reviews available data to assess whether those projects are cost effective. Many of the potential benefits associated with a transitway facility, while possibly significant, are difficult to quantify without making numerous assumptions. 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 could, 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 transitway. 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.[7]

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 transitway 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 transitway user travel time savings is at least 10% of the construction cost of the project, the transitway project will be cost effective.[8]

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 significantly increase on all of the operating Houston transitways in the near future. 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. Based on data in Tables 3, 7, and in the appendices, Table 19 has been developed.

---

[7]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 mixed-flow freeway lanes.

[8]Assuming a constant stream of benefits over the life of the project (which is conservative since benefits should increase over time as transitway 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/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.

Table 19. Annual Value of Time Saved by Transitway Users as a Percent of Transitway Construction Cost

Transitway	Annual Value of Time Saved[1] ($ millions)	Est. Construction Cost for Section in Operation[2] ($ millions)	Annual Value of Time Saved as a % of Construction Cost[3]
North	$3.0	$29	10.3%
Katy	$ 7.7	$32	24.1%
Gulf	$ 1.1	$27	4.1%
Northwest	$ 0.6	$44	1.4%

[1]Based on 1989 time savings. See Table 7 and appendices. Does not include any time savings by motorists in the freeway mainlanes.
[2]See Table 3 and the appendices.
[3]As a "rule of thumb", this value should exceed 10% for the project to be cost effective.

Based on this analysis, under operating conditions existing in 1989, the Katy and North Transitways can be considered to be cost effective. This conclusion does not presently apply to either the Northwest or to the Gulf Transitway.

While the extent of data available as well as the sophistication of the analysis could be better, the procedure developed in this section can be used as a means of estimating what transitway ridership level must be attained on a "Houston type" transitway for the facility to be cost effective (Figure 33). In general, it appears that these facilities need to serve in excess of 10,000 daily person trips to have a favorable benefit/cost ratio. While the analysis supporting this conclusion is not definitive, this general finding is in agreement with previous research[9] pertaining to the cost effectiveness of barrier-separated transitways.

[9]"Guidelines for Estimating the Cost Effectiveness of High-Occupancy Vehicle Lanes." TTI Research Report 339-5, 1985.

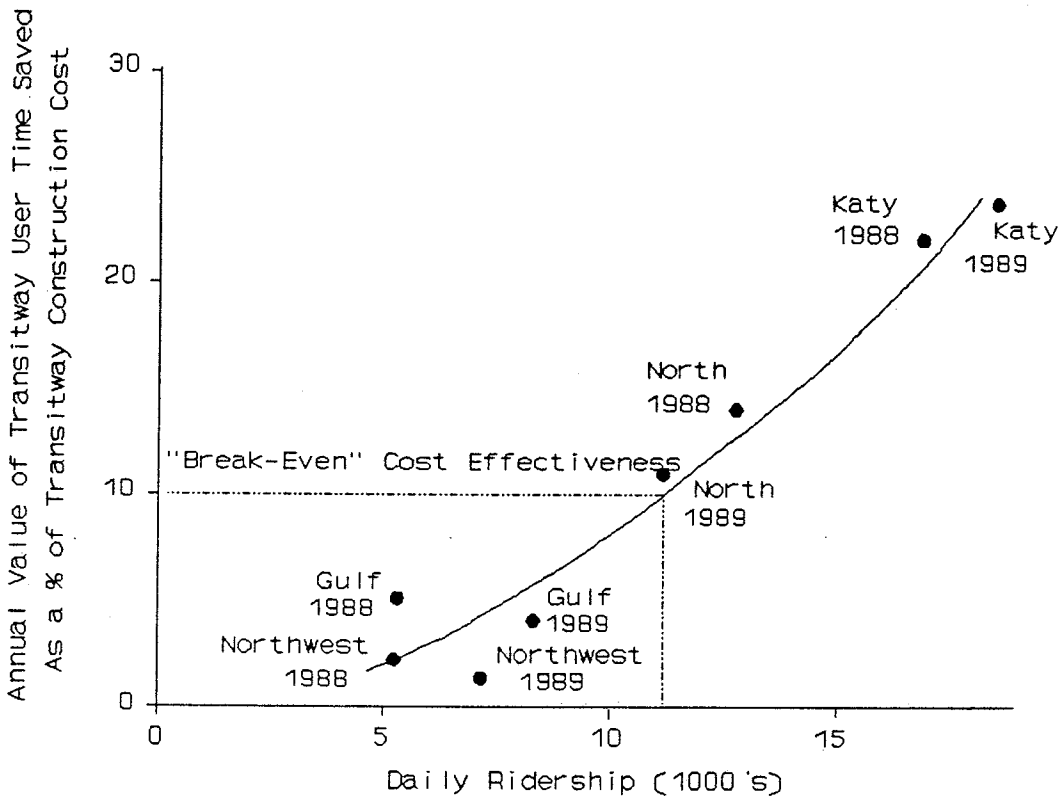


Figure 33. Estimated Daily Transitway Ridership Required for Transitway to be Cost Effective

VIII. DOES THE TRANSITWAY PROGRAM HAVE PUBLIC SUPPORT

Since the transitway system being developed in Houston is somewhat unique, is viewed as a major means for serving future travel demand growth, and involves the expenditure of approximately $700 million in tax monies, public attitudes pertaining to transitway development have been an area of continued interest. Desirably, if this program is to proceed, it should have public support.

Over the years, both individuals that use the transitways and individuals not using the transitways have been surveyed to identify their attitudes concerning these priority lane projects; surveys have been performed both on freeways that have transitways (Katy, North, Northwest and Gulf) and on a freeway (Eastex) that does not currently have a transitway. Two primary issues have been addressed: 1) are the transitways good transportation improvements?, and 2) are the transitways sufficiently utilized?

Are the Transitways Good Transportation Improvements?

Acceptance of the transitways as effective improvements appears to be growing over time. Based on data from the 1989 surveys (Table 20), 67% of the motorists in the freeway mainlanes (not transitway users) viewed these projects favorably. In general, fewer than 20% of those surveyed felt that the transitways were not good transportation improvements. A 1988 survey on a freeway (Eastex) that does not have a transitway found that only 15% of those respondents felt that the transitways being developed in Houston were not good transportation improvements.

It should be emphasized that the responses shown in Table 20 are those of the motorists using the highly-congested, mixed-flow freeway lanes. While these individuals may perceive that they are receiving relatively few direct benefits (e.g., freeway congestion has not noticeably been reduced) from the transitway development, nevertheless they indicate that, in their opinion, the transitways do represent good transportation improvements.

Table 20. 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
Motorists in Freeway Mainlanes Freeways With Transitways					
North Freeway[1]					
Yes	---	62%	---	---	---
No	---	20%	---	---	---
Not Sure	---	18%	---	---	---
Katy Freeway[2]					
Yes	41%	36%	60%[5]	64%	67%
No	35%	43%	24%	22%	19%
Not Sure	24%	21%	16%	14%	14%
Northwest Freeway[3]					
Yes	---	---	---	---	71%
No	---	---	---	---	13%
Not Sure	---	---	---	---	16%
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.

Thus, if a desirable objective of the transitway program is to develop and maintain public support for the transitways, that objective has been realized. If anything, public support for transitways appears to have been increasing over time.

Are the Transitways Sufficiently Utilized?

While the responses in Table 20 indicate that the transitways are accepted as worthwhile transportation improvements, there is less agreement as to whether the transitways are sufficiently utilized (Tables 21 and 22). The overwhelming majority of those who use the transitways feel those facilities are sufficiently utilized (Table 21).

Table 21. 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
Katy Transitway Users					
Bus Riders					
Yes	49%	66%	77%	72%	85%
No	33%	14%	7%	8%	5%
Not Sure	18%	20%	16%	20%	10%
Carpoolers & Vanpoolers[2]					
Yes	33%	43%	82%	45%	77%
No	46%	35%	9%	35%	14%
Not Sure	21%	22%	9%	20%	9%
North Transitway Users					
Bus Riders					
Yes	---	81%	---	---	---
No	---	6%	---	---	---
Not Sure	---	13%	---	---	---
Vanpoolers					
Yes	---	84%	---	---	---
No	---	7%	---	---	---
Not Sure	---	9%	---	---	---
Northwest Transitway					
Bus Riders					
Yes	---	---	---	---	72%
No	---	---	---	---	6%
Not Sure	---	---	---	---	22%
Carpoolers & Vanpoolers					
Yes	---	---	---	---	75%
No	---	---	---	---	12%
Not Sure	---	---	---	---	13%
Gulf Transitway					
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.

Source: Texas Transportation Institute surveys.

However, the same cannot be said for the motorists in the freeway mainlanes (Table 22). In all 3 corridors in which surveys of mainlane motorists were performed, over half of the respondents indicated they did not feel the transitways were being sufficiently utilized. This has been a consistent finding in all surveys conducted. It is apparent that this

Table 22. 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
Katy Freeway Mainlane Motorists					
Yes	3%	3%	40%[1]	31%[2]	31%
No	90%	92%	48%	55%	53%
Not Sure	7%	5%	12%	14%	16%
North Freeway Mainlane Motorists					
Yes	---	26%	---	---	---
No	---	56%	---	---	---
Not Sure	---	18%	---	---	---
Northwest Freeway Mainlane Motorists					
Yes	---	---	---	---	22%
No	---	---	---	---	58%
Not Sure	---	---	---	---	20%
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 transitway changed to 3+.

Source: Texas Transportation Institute surveys.

is an issue that will need to continue to be addressed in the formulation of strategies for operating the transitways.

IX. CONCLUSIONS

A 95.5-mile system of freeway transitways is being developed in Houston; as of the end of 1989, 36.6 miles of that barrier-separated system were operational, with facilities in operation in 4 different freeway corridors.

In this report, it is assumed that the primary objective of the Houston transitways is to increase the effective person-movement capacity of the freeway in a cost effective manner and to accomplish this without unduly impacting the operation of the freeway general purpose mixed-flow lanes; desirably, these improvements will have public support. Secondary benefits include factors such as improved air quality and reduced fuel consumption.

This report reviews and analyzes data collected through calendar year 1989 to assess the extent to which these objectives are being attained (Table 23). In assessing the performance of the transitways in meeting their objectives, the following quantitative values can be used as guides.

Objective: Increase Roadway Person Movement

1. Daily transitway ridership (measured in person trips) should be in excess of 10,000.
2. The transitway should increase peak-hour, peak-direction person volume by an amount greater than the increase in directional lanes added to the roadway due to transitway implementation.
3. The transitway should increase peak-hour, peak-direction average vehicle occupancy (persons per vehicle) for the roadway by at least 10% to 15%.

    - More than 25% of the total carpools using the transitway should be new carpools created because of the transitway.
    - More than 25% of the total bus riders using the transitway should be new bus riders created because of the transitway.

Table 23. Potential Performance Measures for the Houston Transitways, A.M. Peak-Hour, Peak-Direction

Performance Measure[1]	Freeway				
	North[2] w/ transitway	Katy[2] w/ transitway	Gulf[3] w/ transitway	Northwest[2] w/ transitway	Southwest[3] w/o transitway
Daily Transitway Person Trips (12/89)	11,226	18,352	8,139	7,275	NA
% Change in Number of Lanes[4]	+25%	+33%	NA	+33%	NA
% Change in Person Volume[5]	+58%	+85%	NA	+39%	- 5%
% Change in Avg. Vehicle Occupancy[5] (persons/vehicle)	+31%	+16%	NA	+16%	+ 2%
% Change in 2+ Carpools	NA	+93%	NA	+156%	- 2%
% New Carpools Due to Transitway[6]	NA	50%	26%	39%	NA
% Change in Bus Riders (Peak Period)	NA	+194%	NA	+79%	- 6%
% New Bus Riders Due to Transitway[7]	59%	52%	33%	49%	NA
% Change, Freeway Volume Per Lane[8]	-11.8%	+39.8%	NA	+0.6%	+1.9%
% Change in Per Lane Efficiency[9]	+92.7%	+94.7%	NA	+54.8%	+ 8.8%
Transitway Travel Time Savings as a % of Construction Cost[10]	10%	33%	4%	1%	NA

[1]The percent change is a comparison of current values with representative pre-transitway values.
[2]These freeways have operating transitways as of 12/89.
[3]This freeway does not have a transitway and represents a basis of comparison to the freeways with transitways.
[4]The transitway added one lane; this is the percent increase in the number of total lanes (freeway plus transitway) resulting from implementing the transitway.
[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 on the multiple of persons moved times average speed, a.m. peak-hour, peak-direction.
[10]This is the estimated annual value of 1989 travel time savings for transitway users expressed as a percent of the cost of constructing the segment of the transitway in operation in 1989.

Objective: Don't unduly impact freeway mainlane operations

1. A statistically significant increase should not occur in either freeway mainlane congestion or the freeway mainlane accident rate due to transitway implementation.
2. The absolute value of the total roadway (freeway plus transitway) peak-hour per lane efficiency (defined on the multiple of person volumes times speed of movement) should increase by at least 20 due to implementation of the transitway. Stated differently, the total roadway per lane efficiency should be greater than the freeway mainlane efficiency by an amount of at least 20.

Objective: The transitway should have favorable air quality and energy impacts.

1. Compared to the alternative of providing an additional mixed-flow lane rather than a transitway, the transitway implementation should result in significant reductions in energy consumption and pollutants emitted.

Objective: The transitway project should be cost effective

1. Conservatively, the project will have a benefit-cost ratio greater than one if the annual time saved by users of the transitway exceeds 10% of the initial construction cost of the transitway.

Objective: Development of the transitway should have public support

1. Opinion surveys should show that the plurality of people surveyed state that they believe the transitways are good improvements.

A review of these performance measures based on the transitway evaluation work performed in Houston leads to several general observations (Table 24). All of the performance measures suggest that the Katy Transitway is fulfilling its intended purposes. The North Transitway, at present, is marginally effective; allowing carpools to use this facility as well as extending the transitway 4 miles, both of which are scheduled to occur in 1990, are expected to significantly improve the overall performance of this facility. As presently being operated, neither the Northwest nor the Gulf Transitway can be considered to be clearly effective. However, there is reason to believe that their performance will improve significantly.[10] Both facilities have been in operation for less than two years and, as of the end of 1989, only the first phase of each facility was in operation. The Northwest Transitway will be completed in its final form in February 1990; however, it appears that the Gulf Transitway will not be extended for at least two more years.

Continued monitoring of all the committed transitways will take place as part of this research.

---

[10]Counts in early 1990 have already shown increases in carpool volumes on the Northwest Transitway of over 40% immediately after the 4.5-mile extension was opened.

Table 24. Comparison of Transitway Objectives and Transitway Performance

Objective, Measure of Effectiveness	Transitway			
	North	Katy	Northwest	Gulf
Increase Person Movement				
• Is daily ridership greater than 10,000	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	Yes	NA
• Has a.m. peak-hour occupancy increased by more than 15%	Yes	Yes	Yes	NA
• Are more than 25% of the transitway carpools new due to the transitway	NA	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 Mainlane Operations				
• Has mainlane congestion increased due to the transitway	No	No	No	No
• Has the mainlane accident rate increased due to the transitway	No	No	No	No
• Has the roadway per lane efficiency increased by more than 20 due to the transitway	Yes	Yes	No	NA
The Transitway 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
Transitways Should Have Public Support				
• Do most of the persons responding to surveys indicate support for transitway development	Yes	Yes	Yes	Yes
Transitways 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	NA	Yes	NA	NA
Overall Assessment, Is Transitway Effective?	Marginally Effective	Effective	Not Yet Effective	Not Yet Effective

NA = Either not available or not applicable.

APPENDIX A

THE IMPACTS OF INCREASING CARPOOL OCCUPANCY REQUIREMENTS ON THE KATY TRANSITWAY

APPENDIX A

THE IMPACTS OF INCREASING CARPOOL OCCUPANCY REQUIREMENTS ON THE KATY TRANSITWAY

December 1989

The Texas State Department of Highways and Public Transportation and the Metropolitan Transit Authority of Harris County are in the process of developing an extensive system of high-occupancy vehicle (HOV) lanes on the freeways in Houston, Texas. Locally, these HOV lanes are referred to as transitways. Today, over 36 miles of these facilities are in operation on 4 separate freeways. Ultimately, nearly 96-miles of transitways will be developed at a cost approaching $700 million. A more complete description of this transitway system is presented in the main text of this report.

Since the Houston commitment to developing transitways is somewhat unique and extensive, considerable effort is being given to identifying appropriate procedures for operating the transitways. The Katy Transitway, phase 1 of which opened in October 1984, was the first of the transitways to be completed in final form. Consequently, in many respects, it has been used as a laboratory in which different operating procedures could be tested.

One of the major operational decisions impacting the transitways is the decision regarding what vehicle groups will be allowed to use the transitway. In effect, a balancing act is required. On one hand, it is desirable to have a reasonably large volume of vehicles using the transitway so that it appears to be sufficiently utilized to those individuals not using the transitway. On the other hand, for the transitways to be successful, they need to offer a high travel speed and a reliable travel time. As a result, it is essential that volumes in the transitway be kept below capacity so that significant delay and congestion do not develop on the high-speed priority lane.

This balancing act is further complicated by two other factors. First, experience with HOV lanes in southwestern and western cities has shown that the 2+ carpool volume can be substantial. However, the 3+ carpool volume is generally quite small; using a 3+ rather than 2+ carpool designation can reduce carpool volume by 75%. And second, transitway facilities have exceedingly high peaking characteristics; generally the hourly vehicle volume on either side of the peak hour is about half of the peak-hour volume. Thus, the need exists to manage the peak hour volume without adversely affecting the volumes on either side of that peak hour.

ELIGIBLE KATY TRANSITWAY USER GROUPS

As part of the balancing act referred to above, the definition of who is allowed to use the Katy Transitway has changed on several occasions since its opening in October 1984.

- When the transitway opened in October 1984, based on previous experience in Houston on the North Freeway contraflow lane, only buses and vanpools formally authorized by the Metropolitan Transit Authority of Harris County (Metro) were allowed to use the Katy Transitway. Authorization involved many factors, including insurance requirements, driver training, and vehicle inspections. Drivers were issued licenses allowing them to operate in the priority lane, and vehicles in the lane displayed permits. With this approach, shortly after it opened, approximately 50 vehicles used the transitway in the peak hour. Surveys (referred to in the main body of this report) of motorists in the freeway mainlanes found that 97% of those individuals felt that the transitway was being underutilized.

- In April 1985, in order to increase use of the transitway, a decision was made to allow authorized 4+ carpools to begin using the transitway. It was found that few 4+ carpools existed in the Houston traffic stream, and it was also found that a carpool of that size was relatively unstable on a day-to-day basis

(due to at least one person not travelling to the place of work that day). As a result, the effects of this action were minimal; only about 10 vph were added to the peak-hour volume.

- In September 1985, 3+ authorized carpools were allowed onto the Katy Transitway. This action increased peak-hour volume to about 100 vph, but the transitways still appeared underutilized.

- In April 1986, 2+ carpools were allowed to use the transitway, and all authorization requirements were dropped. The peak-hour volume immediately increased to about 1200 vph, and for two years this approach worked relatively well. The volume of both persons and vehicles using the transitway was significant, and relatively high travel speeds continued to exist in the transitway.

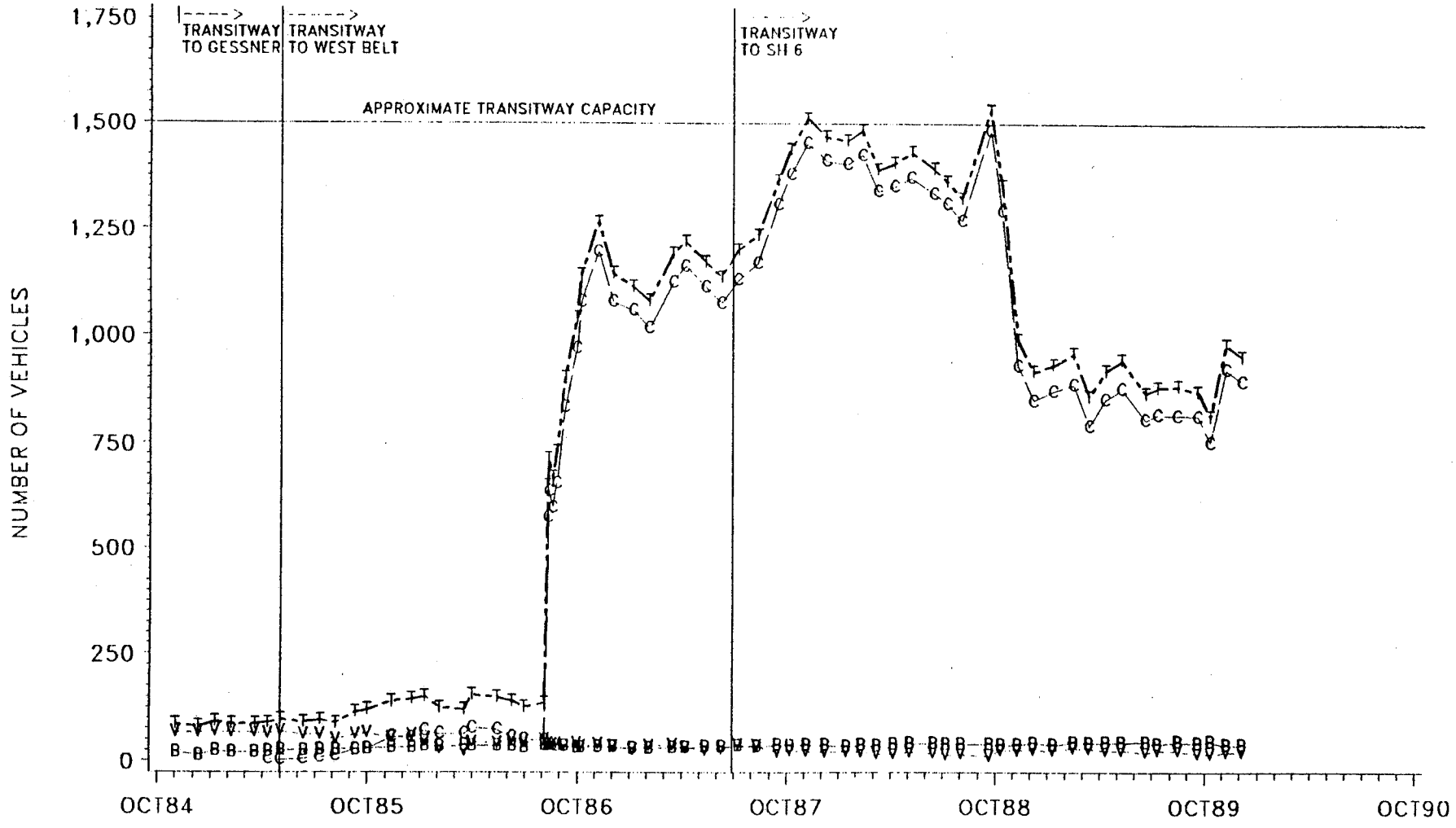
KATY TRANSITWAY VOLUME AND CAPACITY RELATIONSHIPS

In September 1988, with the economy in the Houston area beginning to rebound, volumes using both the freeway mainlanes and the transitway began to increase noticeably. Peak-hour volumes on the transitway frequently would approach or exceed 1500 vph (Figure A-1). Constraints on the a.m. capacity of the Katy Transitway include: 1) the merge at an a.m. access ramp from the inside freeway lane to the transitway in the vicinity at Bunker Hill; 2) the horizontal and vertical curvature on the structure approaching the eastern terminus of the transitway; and 3) the temporary eastern terminus of the transitway ending at a signalized intersection. Given these constraints, traffic analysis[1] showed that delays would begin to occur on the transitway as volumes exceeded about 1200 vph, and that 1500 vph effectively was the upper volume level that could be served with reasonably reliable

[1]Christiansen, Dennis and W.R. McCasland. "Options for Managing Speeds and Volumes on the Katy Transitway". Texas Transportation Institute Research Report 484-6, 1988.

FIGURE A-1

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



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
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

travel speeds; speeds during the peak of the peak hour were below 55 mph at these volumes.

As demands began to approach and exceed 1500 vph, the purpose of the transitway to provide travel time advantages began to be defeated. Considerable delay occurred on the transitway during the a.m. peak hour, and bus passengers began complaining to the transit authority.

In response to this problem, staff level studies of alternatives for managing demand were undertaken. Consideration was given to: 1) doing nothing; 2) requiring authorization for 2-person carpools desiring to use the transitway in the peak hour; 3) metering access to the transitway; and 4) increasing carpool occupancy requirements. All of the alternatives considered had problems; there was no obvious best alternative. A policy level decision was made to increase carpool occupancy requirements from 2+ to 3+ for the period of 6:45 a.m. to 8:15 a.m.; a 2+ policy remained in effect during all other operating hours. The decision was implemented in the field on 3 days notice with relatively little marketing and became effective October 17, 1988.

This decision represented an innovative approach for operating transitway facilities. It was the first time a carpool occupancy requirement had been increased on a high-occupancy vehicle facility, and it also was the first time that high-occupancy vehicle requirements were varied by time of day (some HOV facilities do revert from HOV lanes to regular mixed-flow freeway lanes during off-peak periods).

THE IMPACTS OF THE INCREASE IN OCCUPANCY REQUIREMENTS

The increase in carpool occupancy requirements between 6:45 a.m. and 8:15 a.m. was implemented with surprisingly little difficulty on October 17, 1988. The relatively unique design (barrier separated transitways with a limited number of access/egress locations) and regular, routine enforcement associated with the Houston transitways greatly enhanced the

feasibility of this demand management approach. Data are available through December 1989 to permit evaluation of at least the short-term impacts of this action. Data relevant to the analysis are summarized in Table A-1.

Table A-1. A.M. Travel Volumes Before and After Change in Occupancy Requirements, Katy Freeway Corridor

Travel Volumes	"Representative" Pre-Occupancy Change Value[1]	Value After Occupancy Change					
		11/88 and 12/88		3/89		12/89	
		Value[2]	% Change[3]	Value	% Change[3]	Value	% Change[3]
Daily Transitway Person Volume	18,880	16,595	- 12%	17,831	- 6%	18,352	- 3%
A.M. Peak-Period (6-9:30) Person Volume, Total	8,780	7,265	- 17%	7,945	- 10%	7,523	- 14%
2 Person Carpools	5,090	2,490	- 51%	2,800	- 45%	2,998	- 41%
3+ Person Carpools	935	1,835	+ 96%	1,905	+104%	1,569	+ 68%
Total, Carpool Riders	6,025	4,325	- 28%	4,705	- 22%	4,567	- 24%
Bus Patrons	2,450	2,670	+ 9%	2,885	+ 18%	2,645	+ 8%
Vanpool Riders	305	270	- 11%	335	+ 16%	311	+ 2%
7-8 A.M., Total Person Volume	4,320	2,915	- 33%	3,445	- 19%	3,079	- 28%
Carpools	2,885	1,315	- 54%	1,705	- 39%	1,557	- 46%
2 Person Carpools	2,410	230	- 90%	480	- 80%	670	- 72%
Bus Patrons	1,310	1,500	+ 15%	1,490	+ 14%	1,415	+ 8%
Vanpoolers	125	100	- 20%	205	+ 64%	107	- 14%
A.M. Peak Period Vehicle Volume, Total	2,900	1,950	- 33%	2,120	- 27%	2,155	- 26%
Carpools	2,780	1,820	- 34%	1,990	- 28%	1,971	- 29%
7-8 A.M., Total Vehicle Volume	1,400	510	- 64%	730	- 48%	688	- 51%
2+ Carpool Vehicles	1,365	455	- 67%	660	- 52%	611	- 55%
2 Person Carpools	1,205	115	- 90%	240	- 80%	335	- 72%
3+ Carpools	160	340	+112%	420	+162%	276	+ 72%
Carpool Vehicle Volume (6-7 and 8:15-9:30)	1,230	1,170	- 5%	1,295	+ 5%	1,360	+ 11%
Freeway Mainlane Volumes, 6-9:30 a.m.							
Vehicles	15,300	15,900	+ 4%	16,805	+ 10%	19,367	+ 27%
Total Persons	16,455	17,230	+ 5%	18,675	+ 13%	20,432	+ 24%
Average Vehicle Occupancy	1.075	1.084	+ 1%	1.111	+ 3%	1.055	- 2%

[1]This is the value representative of the trend line that existed prior to changing the occupancy requirement. It does not reflect the values for any particular month.
[2]These are representative of the average of the November and December 1988 data.
[3]The percent change in comparison to the representative pre-occupancy change value.

Source: Texas Transportation Institute data collection.

A.M. Transitway Operations

Data are presented both for the peak period and for the time period (7-8 a.m.) most affected by the change in occupancy requirements.

7:00 to 8:00 A.M. Transitway Travel

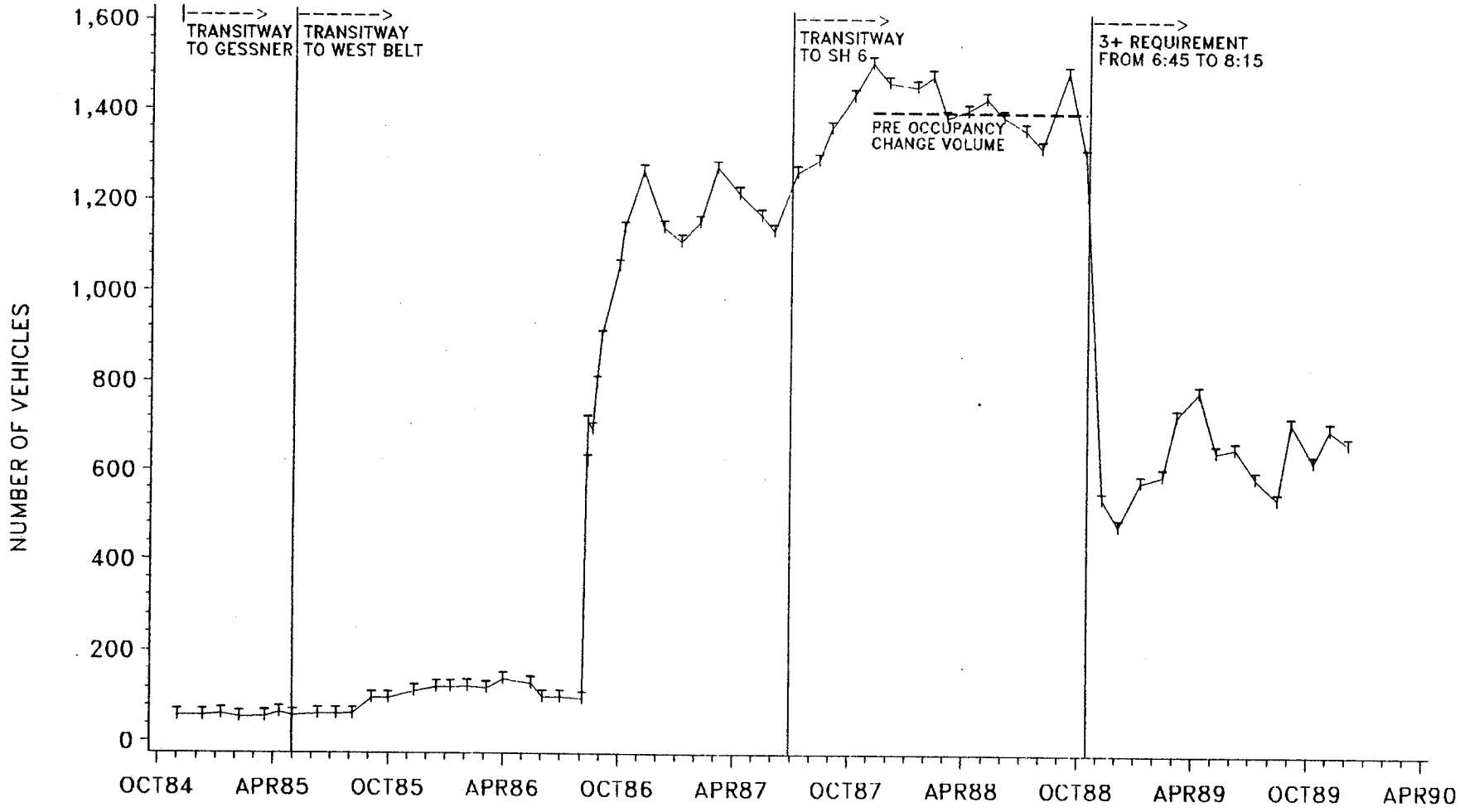
Between 7 and 8 a.m., the total peak-hour vehicle volume on the transitway immediately dropped by about 64%, from 1400 to 510 (Figure A-2, Table A-1). The travel time delays that had been experienced on the transitway prior to the occupancy change were immediately eliminated (Figure A-3). To that end, the change in occupancy requirements achieved its desired effect.

After the initial drop of about 33% in person volume on the transitway between 7 and 8 a.m., demand increased through March 1989. In March the person volume in that time period had increased to 3,445, 19% below the volume prior to the change but 18% above the November-December 1988 volume. However, the December 1989 volume was 11% less than the March 1989 volume.

Since the decline in vehicle volume was greater than the decline in person volume, average vehicle occupancy (persons per vehicle) on the transitway has increased. It was 3.1 prior to the occupancy change, increased to 4.7 in March 1989, and dropped to 4.5 in December 1989. The data in Table A-1 also indicate that a significant volume of 2-person carpools are in the transitway between 7 and 8 a.m., and this volume has continued to increase. Most of these are violators; some, however, appear to have legally entered the transitway prior to 6:45 a.m. at its western terminus and were still in the transitway at 7:00 a.m. when counted at the eastern terminus (Figure A-4).

FIGURE A-2

KATY FREEWAY (IH 10W) TRANSITWAY
7:00 A.M. TO 8:00 A.M. VEHICLE UTILIZATION

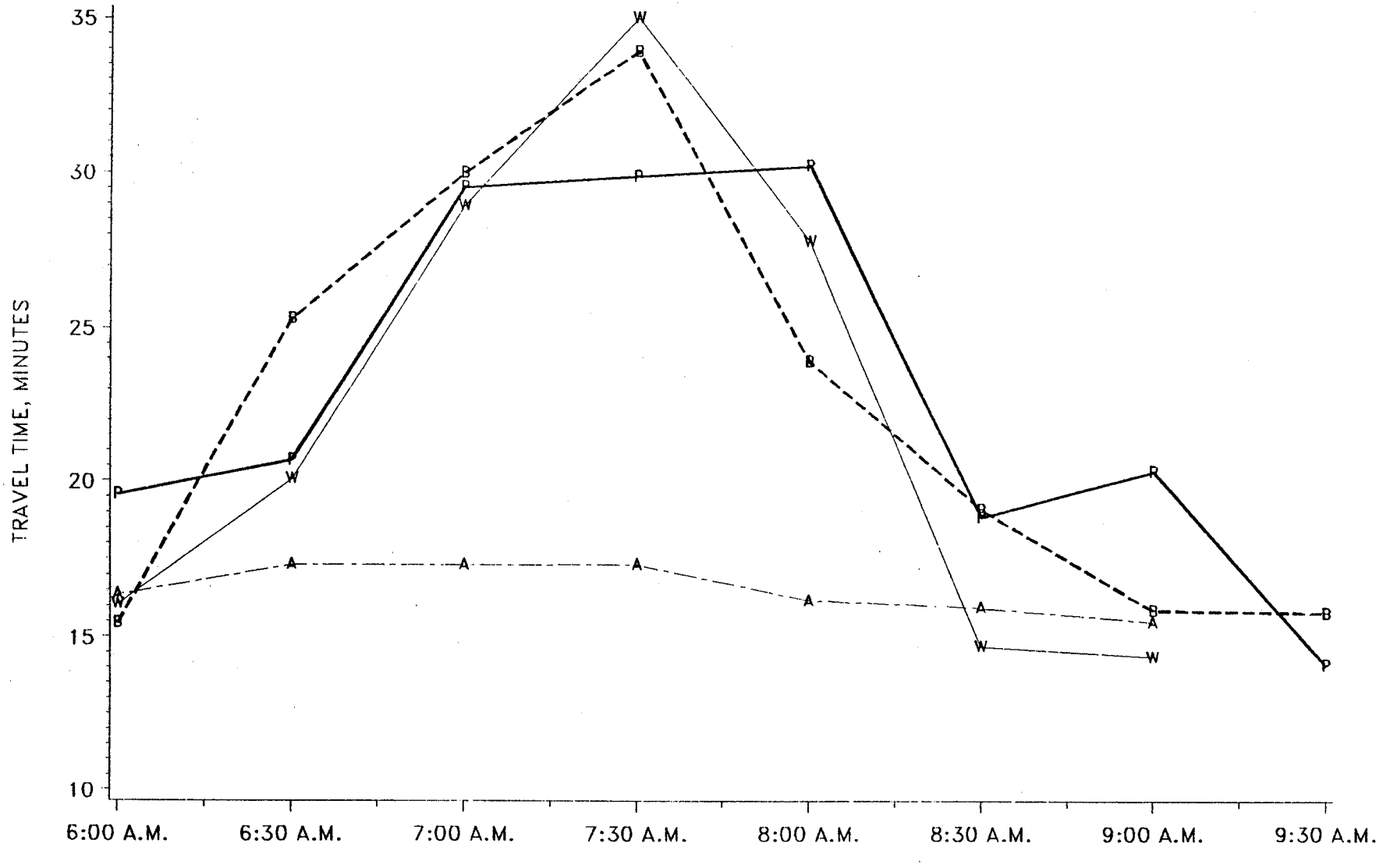


KATY TRANSITWAY PHASE 1, POST OAK TO GESSNER (4.7 MI.), OPENED OCTOBER 29, 1984
TRANSITWAY EXTENSION FROM GESSNER TO WEST BELT (1.7 MI.) OPENED MAY 2, 1985
OFF-PEAK, UNAUTHORIZED & 2+ CARPOOL OPERATION BEGAN AUGUST 11, 1986
TRANSITWAY EXTENSION FROM WEST BELT TO SH 6 (5.0 MI.) OPENED JUNE 29,1987
3+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

LEGEND : T = TOTAL HOV VEHICLES

FIGURE A-3

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



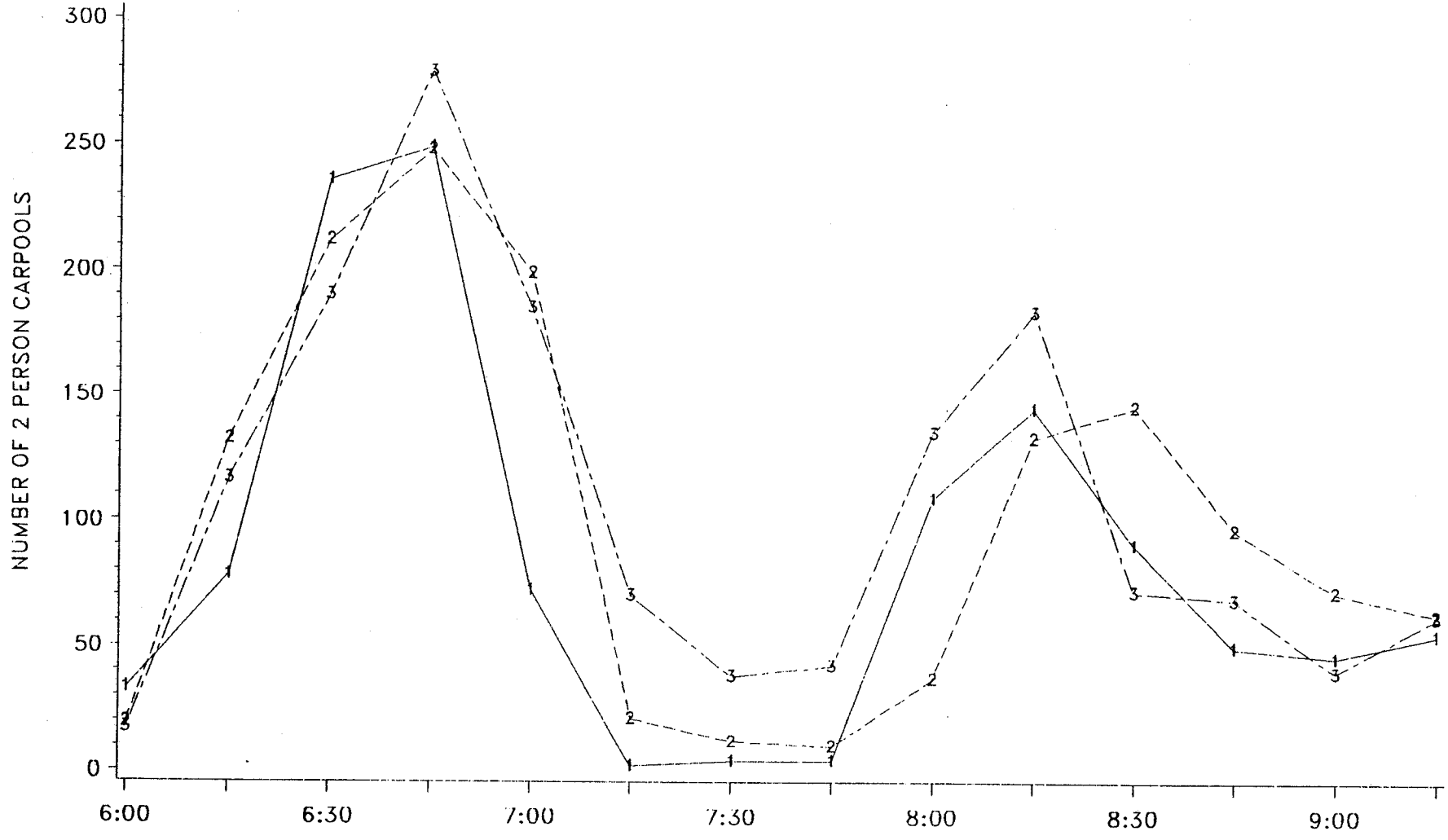
TRAVEL TIMES ARE FROM THE WESTERN TRANSITWAY TERMINUS TO THE S.P. RAILROAD
3+ CARPOOL REQUIREMENT FROM 6:45 TO 8:15 IMPLEMENTED OCTOBER 17, 1988

SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P – MAINLANE TRAVEL TIME BEFORE 3+ CHANGE (AVG. OF 3/88 & 6/88)
W – MAINLANE TRAVEL TIME AFTER 3+ CHANGE (AVG. OF 12/88 – 12/89)
B – TRANSITWAY TRAVEL TIME BEFORE 3+ REQUIREMENT
A – TRANSITWAY TRAVEL TIME AFTER 3+ REQUIREMENT

FIGURE A-4

KATY FREEWAY (IH 10W) TRANSITWAY
A.M. PEAK PERIOD 2 PERSON CARPOOL UTILIZATION



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

LEGEND : 1 = 12/88 2 PERSON CARPOOLS
2 = 3/89 2 PERSON CARPOOLS
3 = 12/89 2 PERSON CARPOOLS

6:00 to 9:30 A.M. Transitway Travel

During the a.m. peak period, person volume immediately dropped by 17%; it had been increasing and, in March 1989, was 10% below what it was prior to changing the occupancy requirement. However, between March and December, this volume declined by 5% (Figure A-5).

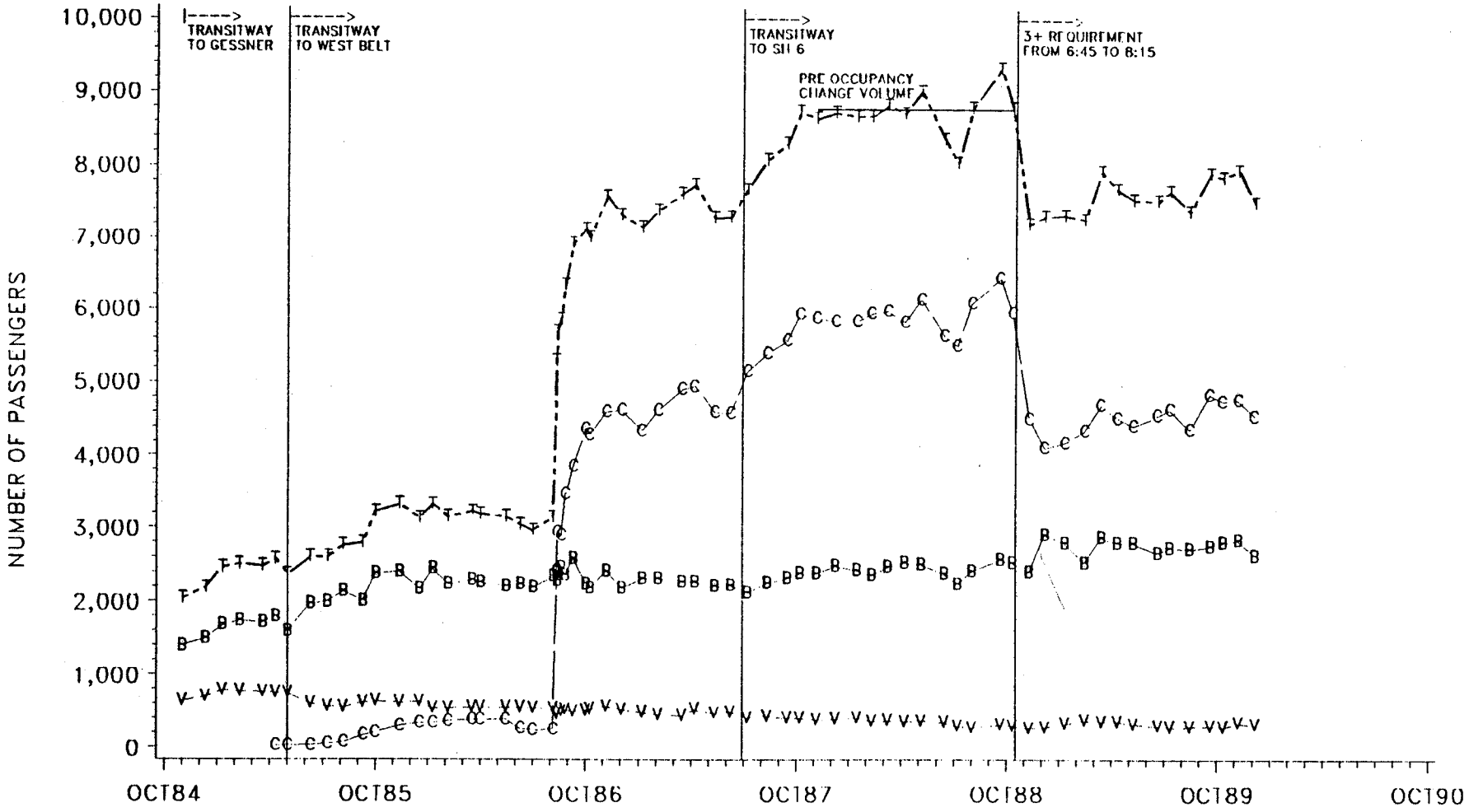
Components of the Change in Person Volumes. Prior to the change in occupancy requirements, approximately 5,090 persons used the transitway in 2-person carpools between 6 and 9:30 a.m. (Table A-1). This decreased to 2,490 in the November-December 1988 period, to 2,800 in March 1989, and to 2,998 in December 1989. Thus, if all the individuals in those 2-person carpools had ceased to use the transitway, the apparent loss in transitway ridership in November-December would have been 2,600 persons, it would have been 2,290 in March, and would have been 2,092 in December 1989. The actual declines in peak-period transitway ridership were 1,515, 835, and 1,257 for those periods, respectively. It is apparent that some changes have occurred in transitway travel patterns as a result of the changed occupancy requirement.

Table A-2 summarizes the changes that have occurred in peak-period transitway ridership since the change in occupancy requirements. One point is clear from that table; a significant volume of individuals have changed to a higher occupancy mode (either 3+ carpool or bus) in order to be able to keep using the transitway.

Through December 1989, a 68% increase in 3+ carpool person volumes had been realized: Most of that increase occurred almost immediately, although it has declined since March (Figure A-6). It is also of significance to note that bus ridership in the a.m. peak period had increased by nearly 8% through December, although that has also declined since March. It is apparent that there is some "modal overlap" and, if necessary, some individuals will choose a higher occupancy mode of travel.

FIGURE A-5

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

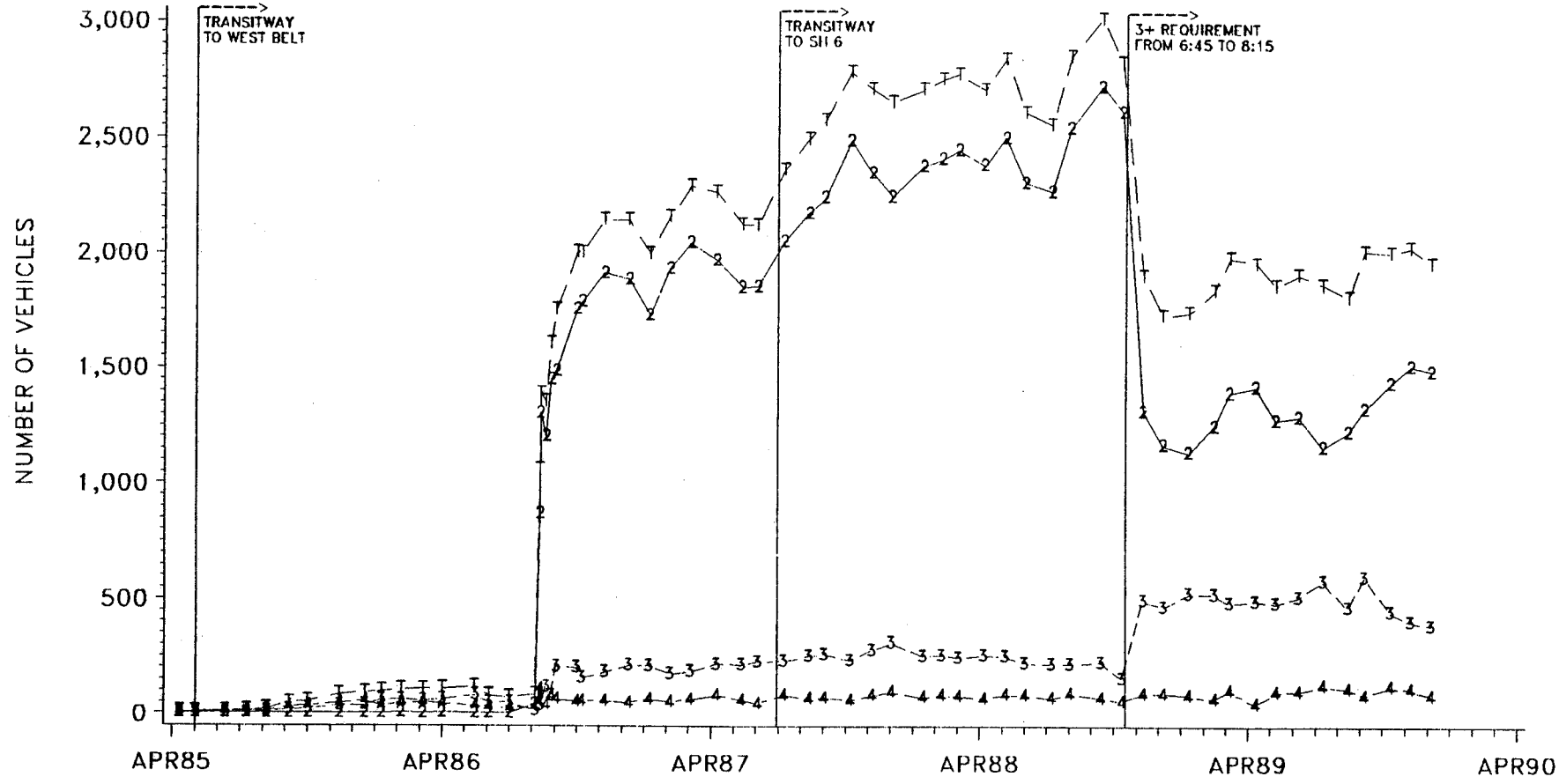


KATY TRANSITWAY PHASE 1, POST OAK TO GESSNER (4.7 MI.), OPENED OCTOBER 29, 1984
TRANSITWAY EXTENSION FROM GESSNER TO WEST BELT (1.7 MI.) OPENED MAY 2, 1985
OFF-PEAK, UNAUTHORIZED & 2+ CARPOOL OPERATION BEGAN AUGUST 11, 1986
TRANSITWAY EXTENSION FROM WEST BELT TO SH 6 (5.0 MI.) OPENED JUNE 29,1987
3+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

KATY FREEWAY (IH 10W) TRANSITWAY
A.M. PEAK PERIOD CARPOOL UTILIZATION
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
TRANSITWAY EXTENSION FROM WEST BELT TO SH 6 (5.0 MI.) OPENED JUNE 29, 1987
4+ AUTHORIZED CARPOOL OPERATION BEGAN APRIL 1, 1985
3+ AUTHORIZED CARPOOL OPERATION BEGAN SEPTEMBER 1985
OFF-PEAK, UNAUTHORIZED & 2+ CARPOOL OPERATION BEGAN AUGUST 11, 1986
3+ REQUIREMENT FROM 6:45 T 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL CARPOOLS
2 = TOTAL 2 PERSON CARPOOLS
3 = TOTAL 3 PERSON CARPOOLS
4 = TOTAL 4 PERSON CARPOOLS

Table 2. Summary of Changes in A.M. Peak-Period Person Travel on the Katy Transitway

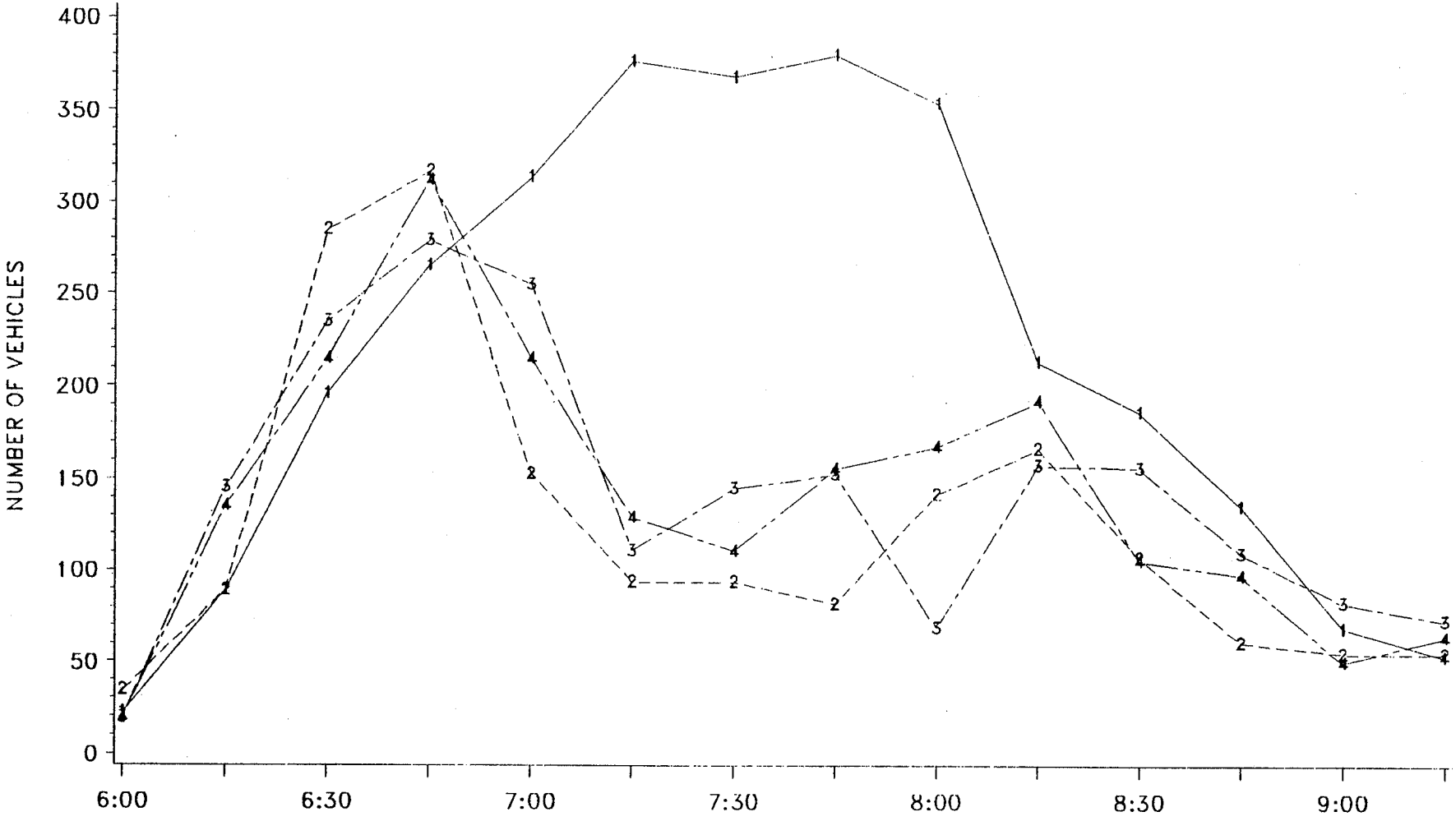
Component of Change From Base Ridership	November-December 1988 Time Period	March 1989 Time Period	December 1989 Time Period
Base Ridership (Pre-Occupancy Change)	8,780	8,780	8,780
Change Due to Vanpooling	- 35	+ 50	+ 6
Change in 2-Person Carpool Volume	- 2,600	- 2,290	-2,092
Change in 3+ Person Carpool Volume	+ 900	+ 900	+ 634
Change in Bus Patronage	+ 220	+ 220	+ 195
Resulting Peak Period Ridership	7,265	7,945	7,523

Changes in Time of Use of the Transitway. It would be expected that carpool volumes between 6:30 and 7:00 a.m. might have increased as a result of the change in occupancy requirements. Overall, carpool volumes do now peak earlier than they did prior to the occupancy change, but the absolute volume of carpools using the transitway between 6:00 and 7:00 a.m. is not that much different than it was prior to the occupancy change (Figure A-7). It is becoming evident, however, that the violation rate of the 3+ restriction is increasing and is significant. The increasing rate of violations could at least partly explain the decline in bus riders and 3+ carpools that has occurred since March.

Where Did the Remaining Volume Go?. While the decrease in overall transitway utilization was not as great as it might have been had not a meaningful number of commuters switched to a higher occupancy mode, nevertheless fewer people used the transitway during the peak period. In comparison to the conditions that existed prior to the occupancy change, in November-December 1988 that volume was 1515; in March it was 835; in December 1989 it was 1257.

FIGURE A-7

KATY FREEWAY (IH 10W) TRANSITWAY
A.M. PEAK PERIOD CARPOOL PEAKING CHARACTERISTICS



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

SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : 1 = 9/88 CARPOOLS (BEFORE OCCUPANCY CHANGE)
2 = 12/88 CARPOOLS (AFTER OCCUPANCY CHANGE)
3 = 3/89 CARPOOLS (AFTER OCCUPANCY CHANGE)
4 = 12/89 CARPOOLS (AFTER OCCUPANCY CHANGE)

It had been speculated that some portion of this volume may have diverted and begun to use the Northwest Transitway; this is a new transitway partially in the same corridor and still open to 2+ carpools during all operating hours. An analysis of trends in utilization on that transitway suggests that minor diversion to that transitway did take place. A survey of Northwest Transitway carpoolers conducted in October 1989 found that 14% of those carpoolers previously used the Katy Transitway.

It seems that most of the volume no longer using the Katy Transitway has diverted back to either using the Katy Freeway mainlanes or using other streets in the corridor. Indeed, freeway volumes have increased (Table A-1), although it is not possible to clearly identify the components of that increase. Essentially no change in freeway vehicle occupancy has occurred, suggesting few additional carpools are now in the freeway mainlanes.

However, surveys (described in the main body of this report) have clearly indicated that about half the carpools using the Katy Transitway were formed since that transitway opened and because the transitway opened. If those vehicles are forced back to using the freeway mainlanes, it is probable that some of those carpooling may choose to go back to driving alone.

P.M. Transitway Operations

During the p.m. peak period (3-6:30 p.m.), the transitway is still open to use by 2+ vehicles. As a result, it would be expected that meaningful changes in person volume should not occur; a decline in vehicle volume would be expected since there are more bus riders and more 3+ carpoolers due to the actions taken in the a.m. peak period.

In general, this has been the case (Table A-3, Figure A-8). By march and continuing through December 1989, the increasing trend in p.m. person movement was back in

evidence; compared to pre-occupancy change conditions, peak-period person volume in December was up 12%, with vehicle volume being up 7%.

Table A-3. P.M. Peak-Period (3:30-7 p.m.) Transitway Travel Volumes Before and After Change in Occupancy

Travel Volume	"Representative" Pre-Occupancy Change Value[1]	Value After Occupancy Change					
		11/88 and 12/88		3/89		12/89	
		Value[2]	% Change	Value	% Change[3]	Value	Change[3]
Peak Period Person Volume	8,325	8,180	- 2%	8,682	+ 4%	9321	+12%
Peak Person Vehicle Volume	2,825	2,665	- 6%	2,714	- 4%	3010	+ 7%

[1]This is the value of the trend line that existed prior to changing the occupancy requirement. It does not reflect the values for any particular month.
[2]These are representative of the average of November and December 1988 data.
[3]The percent change in comparison to the representative pre-occupancy change value.

Source: Texas Transportation Institute.

Daily Transitway Travel Volumes

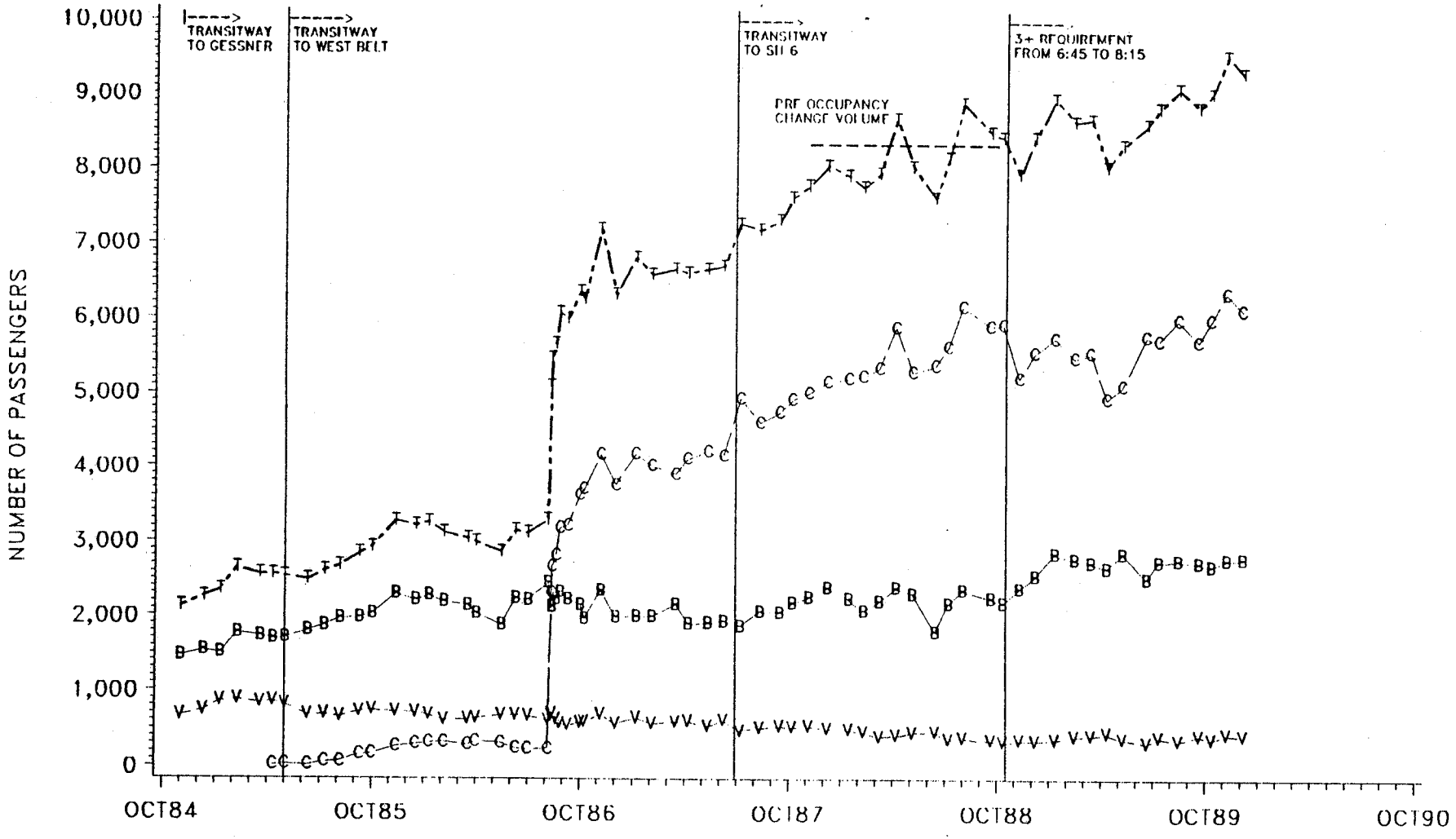
As would be expected, reducing the types of vehicles that can use the transitway during a portion of the a.m. peak would, at least in the short run, reduce total transitway utilization. Compared to the conditions that existed prior to changing the occupancy requirement, in the November-December 1988 period, daily travel dropped by 12%; demand has been increasing (Figure A-9), and in March 1989 the daily person volume on the transitway was 6% below what it was prior to changing the occupancy requirement (Table A-1). In December 1989, it was 3% below its level prior to the occupancy change.

Value of Transitway Travel Time Saved

Although person volumes on the transitway declined, the increase in travel time saved for the remaining transitway users was substantial. This is partly the result of eliminating delay on the transitway and partly the result of increased congestion on the freeway mainlanes (Figure A-3). Travel time savings by users of the transitway since the change in occupancy are essentially equal to what were prior to initiating the occupancy change

FIGURE A-8

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

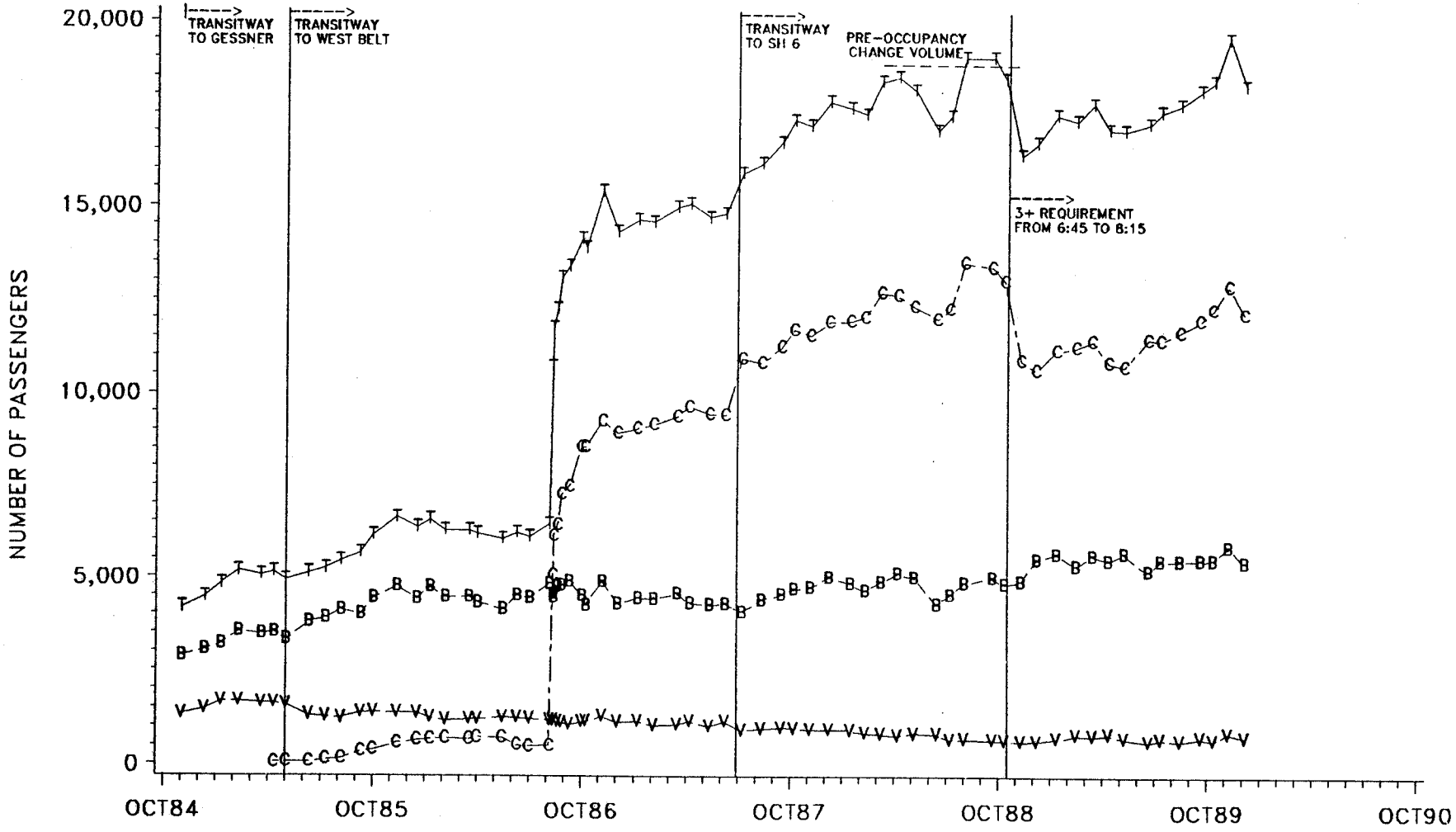


KATY TRANSITWAY PHASE 1, POST OAK TO GESSNER (4.7 MI.), OPENED OCTOBER 29, 1984
TRANSITWAY EXTENSION FROM GESSNER TO WEST BELT (1.7 MI.) OPENED MAY 2, 1985
OFF-PEAK, UNAUTHORIZED & 2+ CARPOOL OPERATION BEGAN AUGUST 11, 1986
TRANSITWAY EXTENSION FROM WEST BELT TO SH 6 (5.0 MI.) OPENED JUNE 29,1987
PEAK PERIOD IS 3:30 - 7:00 P.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-9

KATY FREEWAY (IH 10W) TRANSITWAY
TOTAL DAILY TRANSITWAY PERSON UTILIZATION



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 OPERATES FROM 4:00 A.M. TO 1:00 P.M. EASTBOUND AND 2:00 TO 10:00 P.M. WESTBOUND
DATA COLLECTED OVER BUNKER HILL
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

requirement (Table A-4). The a.m. time savings differences are largely the result of the occupancy change; the p.m. change is largely due to increased congestion on the freeway mainlanes.

Table A-4. Daily Person Hours of Time Saved by Users of the Katy Transitway

Time Period	Hours of Time Saved		
	Representative Value after Occupancy Change		
	Pre-Occupancy Change Value[1]	Value[2]	% Change[3]
A.M. Peak Period	833	805	- 3%
P.M. Peak Period	202	896	+343%
Total	1,035	1,701	+ 64%

[1]This is the average of travel time data collected 12/87, 3/88, and 6/88. Travel time saved due to incidents not included.
[2]This is the average of travel time data collected quarterly during 1989. Travel time saved due to incidents not included.
[3]The percent change in comparison to the pre-occupancy change value.

Source: Texas Transportation Institute.

CONCLUSIONS

In order to restore high speeds and reliable travel times on the Katy Transitway, occupancy requirements for carpools to be able to use the transitway between 6:45 and 8:15 a.m. were increased from 2+ to 3+ in October 1988. This had its intended effect of immediately eliminating congestion on the transitway lane.

This represented the first time carpool occupancy requirements had been increased on a high-occupancy vehicle facility. While considerable concern existed over whether this could be done, it was actually accomplished with relative ease. Given the design and enforcement associated with the Houston transitways, it should be possible to enforce this restriction, although violation rates have been increasing and are substantial. The change in occupancy requirements became a non-story within several days of being implemented. And, while this action directly impacted over 2,000 peak-hour commuters, fewer than 3-

dozen callas were received by the operating agencies complaining of the measures taken. Apparently those persons using the transitway realized that the value of that facility was being greatly reduced by the high vehicle volumes.

The action resulted in many individuals choosing to use a higher occupancy travel mode. By December 1989, peak-period bus ridership, compared to conditions before the occupancy change, had increased by 8% or, 195 riders; 3+ carpool person volume in the peak-period increased by 68%, or 634 persons. However, since March there has been a decline in both bus ridership and 3+ carpooling; this could be related to the increasing violation rate between 7 a.m. and 8 a.m.

By December 1989, daily person usage of the transitway had increased to within 3% of the volume that existed prior to the change. However, while person volume decreased, at least in the short run, the total value of time saved by users of the transitway has remained essentially unchanged due both to the elimination of congestion on the transitway and the increase in congestion on the freeway lanes.

The Houston transitways are intended to move a design year volume of 7,000 to 10,000 persons in the peak hour. This volume simply cannot be realistically attained with a 2+ occupancy requirement. As a result, it had been implicitly recognized that, at some point in time, peak-hour occupancy requirements would have to be increased. That action has now been taken, and it has been clearly demonstrated that this can be done successfully. This successful experiment has shown that, given the design and enforcement procedures associated with the Houston transitways, a very effective operating tool can be used to help manage transitway demand to assure that those facilities function as planned. In the future, in all likelihood this approach will be used on a fairly routine basis as needed to effectively operate other Houston transitways.

APPENDIX B

NORTH FREEWAY AND TRANSITWAY DATA

NORTH FREEWAY (I-45N) AND TRANSITWAY, HOUSTON

Summary of A.M. Peak-Period, Peak-Direction North Freeway and Transitway Data, December 1989
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)		9.1	
Transitway Cost (millions)		$29	
Person-Movement			
Peak Hour (7-8 a.m.)	---	3,514	---
Peak Period (6-9:30 a.m.)	---	5,633	---
Total Daily	---	11,226	---
Vehicle Volumes			
Peak Hour	---	139	---
Peak Period	---	239	---
Vehicle Occupancy, Peak Hour (persons/veh)	---	25.3	---
Accident Rate (Accidents/MVM), 4/84 to 12/89	---	1.84	---
Vehicle Breakdowns (VMT/Breakdown), 4/84-12/89	---	35,215	---
Violation Rate		1%	
Peak Hour Lane Efficiency[1](1000's)	---	197	---
Annual Value of User Time Saved (millions)[6]	---	$1.5 to $3.0	---
Freeway Mainlane Data (see note)			
Person Movement			
Peak Hour	6,335	6,495	+ 2.5%
Peak Period (6:00-9:30 a.m.)	---	19,970	---
Vehicle Volume			
Peak Hour	4,950	5,810	+17.4%
Peak Period	---	17,790	---
Vehicle Occupancy, Peak Hour (persons/veh)	1.28	1.12	-12.5%
Vehicle Occupancy, Peak Period	1.28	1.12	-12.5%
Accident Rate (Accidents/MVM)[2]	1.82	1.84	+ 1.1%
Avg. Operating Speed[3]			
Peak Hour	20	32	+60.0%
Peak Period	30	42	+40.0%
Peak Hour Lane Efficiency[1] (1000's)	41	51	+24.4%
Combined Freeway Mainlane and Transitway Data			
Total Person Movement			
Peak Hour	6,335	10,009	+58.0%
Peak Period	---	25,603	---
Vehicle Volume			
Peak Hour	4,950	5,949	+20.2%
Peak Period	---	18,029	---
Vehicle Occupancy			
Peak Hour	1.28	1.68	+31.2%
Peak Period	1.28	1.42	+10.9%
Travel Time (minutes)[3]			
Peak Hour	23.2	8.3[5]	-64.2%
Peak Period	15.5	8.1[5]	-47.7%
Peak Hour Lane Efficiency[1] (1000's)	41	79	+92.7%

Summary of A.M. Peak-Period, Peak-Direction Transitway Data, December 1989 Continued

Type of Data	"Representative" Current Value*
Transit Data	
Bus Vehicle Trips	
Peak Hour	80
Peak-Period	140
Bus Passenger Trips	
Peak Hour	3,045
Peak Period	4,830
Bus Occupancy (persons/bus)	
Peak Hour	38.1
Peak Period	34.5
Vehicles Parked in Corridor Park & Ride Lots	4,199
Bus Operating Speed (mph)[3]	
Peak Hour	56.2[4]
Peak Period	57.3[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 (North I-45N) and Freeway Without (Southwest US 59) Transitway, Houston

Measure of Effectiveness	North Freeway	Southwest Freeway
Average A.M. Peak-Hour Vehicle Occupancy	1.68*	1.32
Bus Passengers, Peak Period	4,830	2,100
Cars Parked at Park-and-Ride Lots	4,199	1,665
Facility Per Lane Efficiency (1000's)[1]	79**	74

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

Note: Southwest freeway data collected at Westpark.

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 8/89. Only officer reported accidents are included in files. 1989 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 1989 and transitway volumes in 1989, an annual estimate of travel time savings to transitway users is developed. A value of time of $9/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

- Phase 1-2 (9.1 miles) of the transitway opened November 23, 1984.
- The transitway operates on the North Freeway (I-45N) between North Shepherd and downtown. The transitway operates inbound toward downtown from 5:45 a.m. to 8:45 a.m. and outbound from 3:30 p.m. to 7 p.m.
- The transitway was constructed for approximately $29 million.
- In December 1989, 11,226 person trips per day were served on the transitway. The transitway is used only by buses and vanpools authorized by Metro.

Person Movement

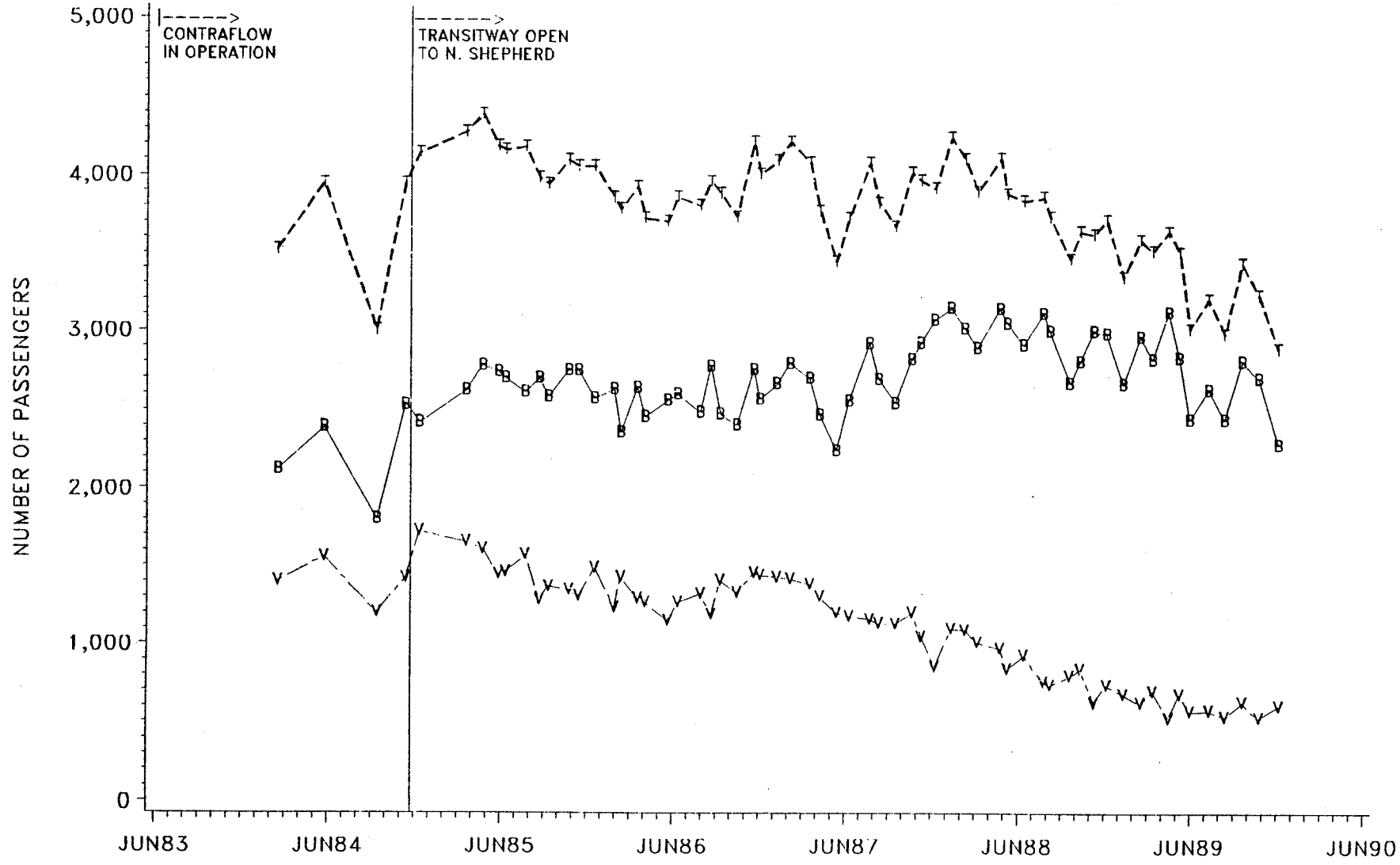
- A.M. Peak Hour (7-8 a.m.), 3,514 persons/hour.
  - 3,045 (87%) by bus, 469 (13%) by vanpool, (Figure B-1).
  - Average transitway vehicle occupancy = 25.3 persons/vehicle.
- A.M. Peak Period (6:00-8:45 a.m.), 5,633 persons.
  - 4,830 (86%) by bus, 803 (14%) by vanpool, (Figure B-2).

Vehicle Movement

- A.M. Peak Hour, 139 vph.
  - 80 (58%) bus, 59 (42%) vans, (Figure B-3).

FIGURE B-1

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

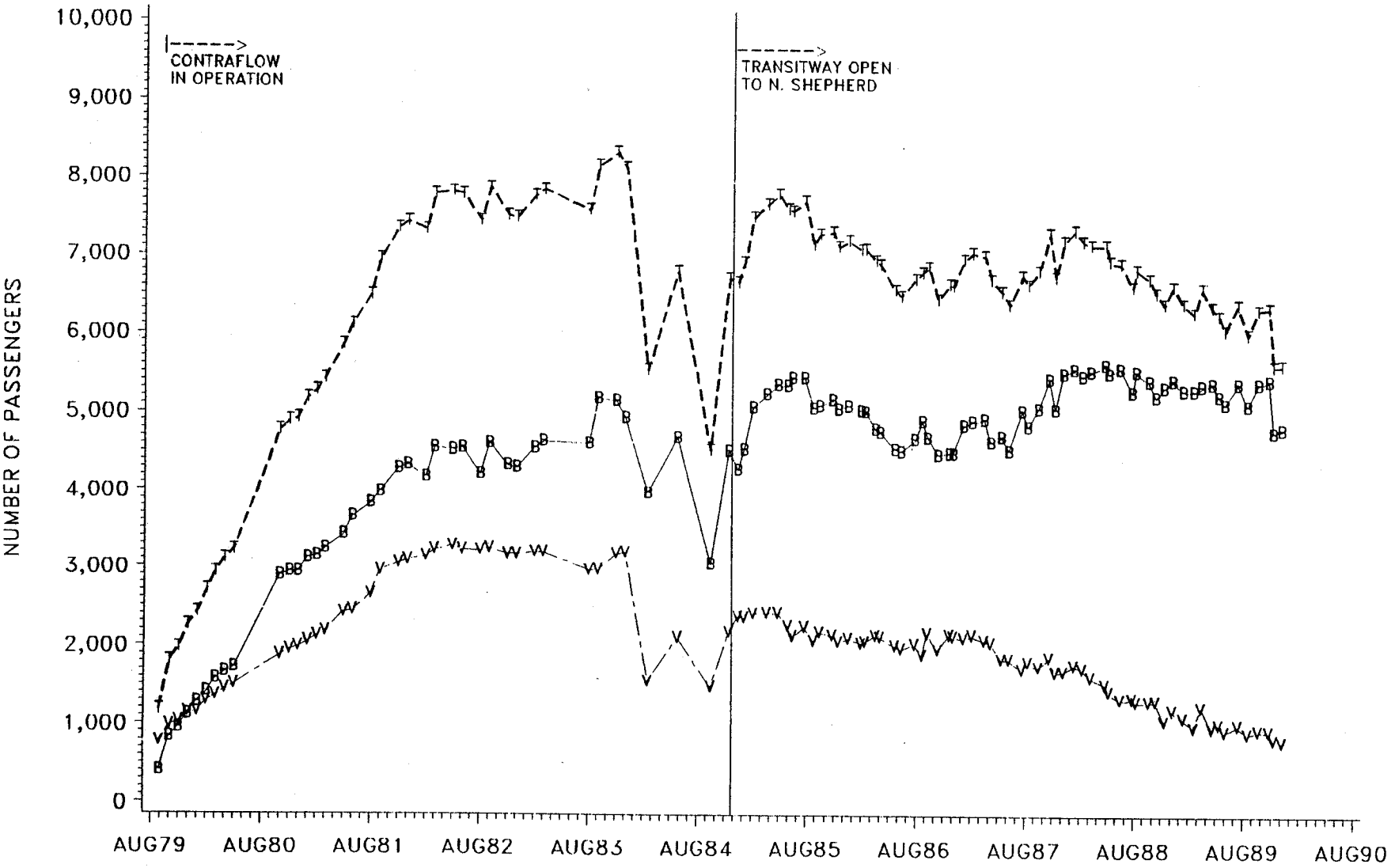


DATA COLLECTED SOUTHBOUND AT LITTLE YORK, 4 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : B = BUSES
V = VANPOOLS
T = TOTAL

FIGURE B-2

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



A.M. PEAK PERIOD DEFINED AS FROM 6:00 TO 8:45 A.M
DATA COLLECTED SOUTHBOUND AT LITTLE YORK, 4 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : B = BUSES
V = VANPOOLS
T = TOTAL

FIGURE B-3

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

DATA COLLECTED SOUTHBOUND AT LITTLE YORK, 4 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : B = BUSES
V = VANPOOLS
T = TOTAL

- A.M. Peak Period (6:00-8:45 a.m.), 239 vehicles.
  - 140 (59%) bus, 99 (41%) vans, (Figure B-4).

Accident Rate

- For the period from November 1984 through December 1989, the transitway accident rate was 1.84 accidents per million vehicle miles.

Vehicle Breakdown Rates

- The following vehicle breakdown rates were observed between April, 1984 and December 1989.
  - Buses; 1 breakdown per 22,771 vehicle-miles of travel (VMT).
  - Vanpools; 1 breakdown per 58,242 VMT.
  - Overall weighted average; 1 breakdown per 35,215 VMT.

Violation Rate

- The observed violation rate (vehicles on the transitway not eligible to use the transitway) has consistently been less than 1%.

Peak Hour Lane Efficiency

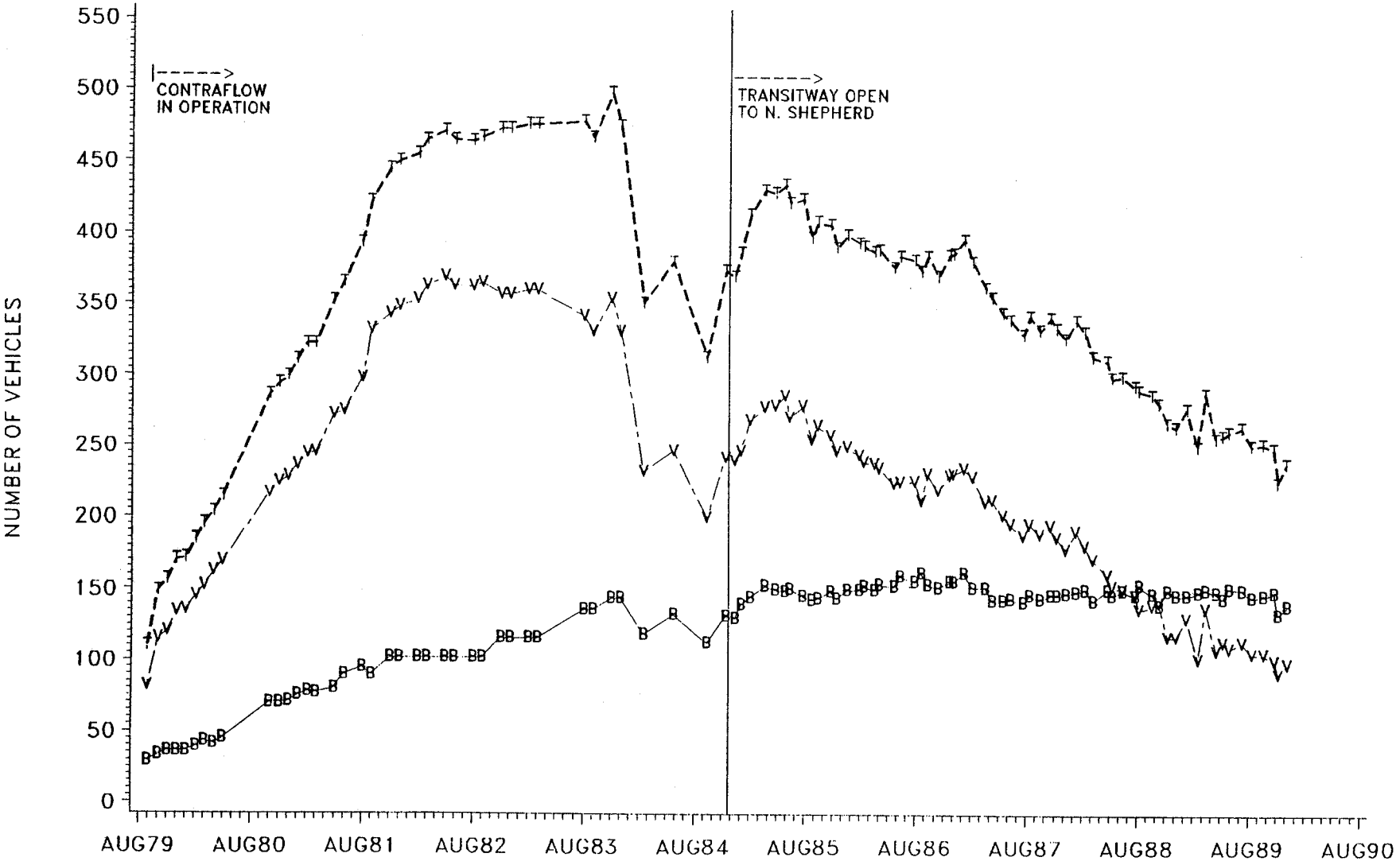
- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. For the transitway lane, this value (expressed in 1000's) is approximately 197 (3514 x 56.2 mph).

Travel Time Savings

- The users of the transitway experience a travel time savings (Figure B-5).
- The tables on the following page indicate that, on a typical non-incident day, travel time savings of approximately 675 hours (40,504 min.) are realized. Assuming 250 days of operation, annual savings would be 168,750 hours. At $9/hour, this equates to $1.52 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 $1.5 to $3 million per year.

FIGURE B-4

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

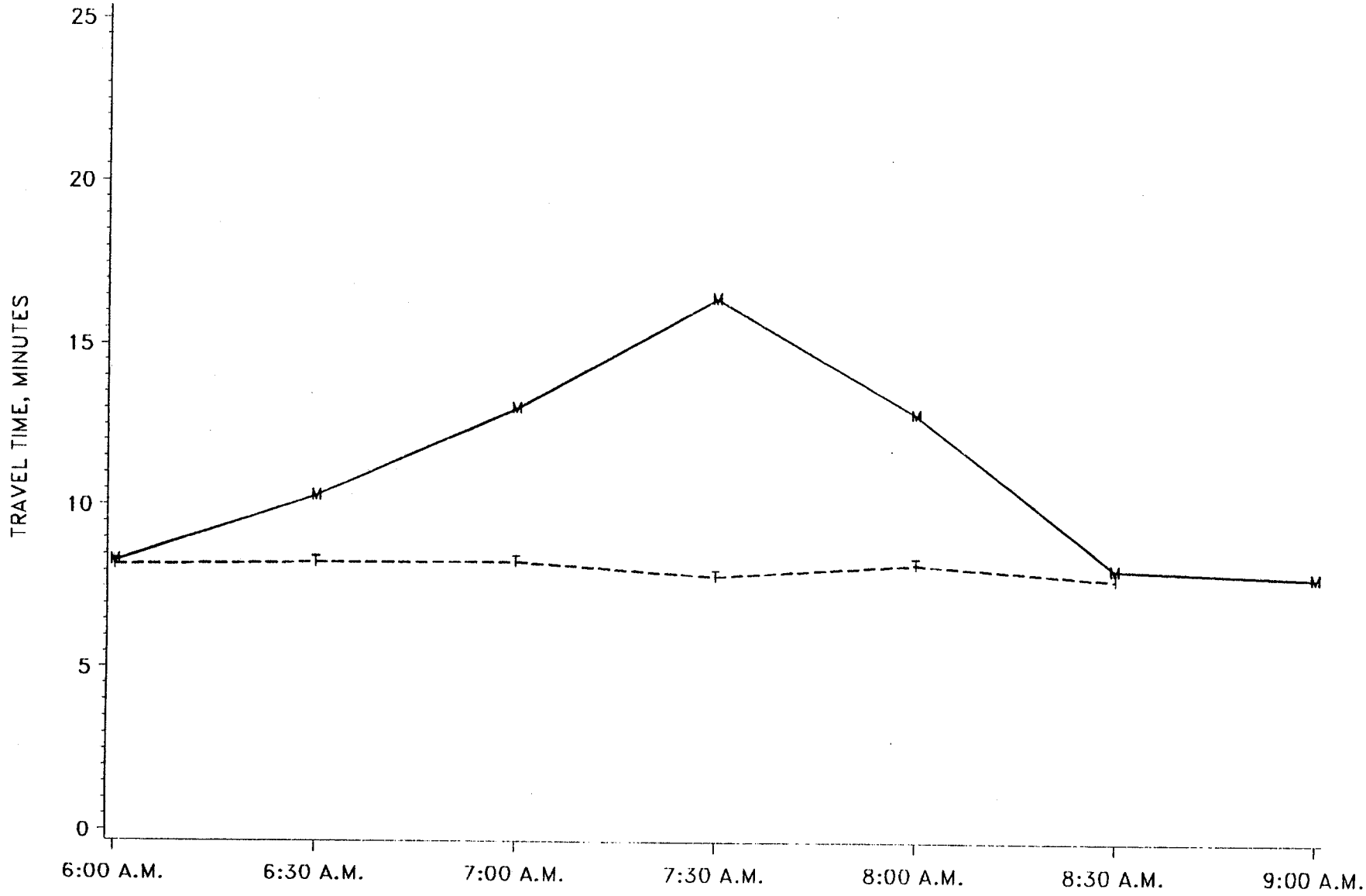


A.M. PEAK PERIOD DEFINED AS FROM 6:00 TO 8:45 A.M
DATA COLLECTED SOUTHBOUND AT LITTLE YORK, 4 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : B = BUSES
V = VANPOOLS
T = TOTAL

FIGURE B-5

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



TRAVEL TIMES ARE FROM N. SHEPHERD TO HOGAN OVERPASS
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

Southbound AM Travel Time Savings for North Transitway
Average of 4 Quarterly Travel Time Runs in 1989

Time of Day	Average Travel Time		Time Saved (minutes)	Transitway Person Volumes			Travel Time Saved (person minutes)
	Freeway (minutes)	Transitway (minutes)		Vans	Buses	Persons	
6:00	8.29	8.18	0.10	193	495	688	71.64
6:30	10.30	8.27	2.03	376	1093	1468	2985.44
7:00	13.02	8.29	4.72	303	1326	1628	7692.30
7:30	16.48	7.89	8.59	94	1435	1529	13138.81
8:00	12.89	8.27	4.63	11	649	660	3050.19
8:30	8.15	7.83	0.31	5	173	177	55.31
Peak Period				981	5188	6169	26,993.69

Northbound PM Travel Time Savings for North Transitway
Average of 4 Quarterly Travel Time Runs in 1989

Time of Day	Average Travel Time		Time Saved (minutes)	Transitway Person Volumes			Travel Time Saved (person minutes)
	Freeway (minutes)	Transitway (minutes)		Vans	Buses	Persons	
3:30	8.33	8.67	-0.34	32	234	266	- 90.88
4:00	9.17	9.24	-0.07	259	575	834	- 59.04
4:30	9.52	8.67	0.86	263	1031	1294	1110.68
5:00	12.18	8.72	3.45	239	1498	1737	5997.47
5:30	13.53	9.31	4.22	94	1177	1271	5368.92
6:00	11.37	9.23	2.14	16	519	535	1142.49
6:30	9.00	8.79	0.20	2	193	195	39.86
Peak Period				905	5227	6131	13,509.51

Note: The peak-hour volumes in these tables do not exactly agree with those presented in the summary table. The summary table was based on 15 minute volume data. The data for the analyses summarized in the above tables are based on 30-minute volume counts.

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 appear to be relatively 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 6,495 persons in the peak hour (Figure B-6). Prior to contraflow implementation, limited data suggest this value was 6,335.

- The a.m. peak period mainlane person trips have also been increasing. Between 6:00 a.m. and 9:30 a.m. the mainlanes are moving 19,970 persons (Figure B-7).

Vehicle Volume

- In the a.m. peak hour, 5,810 vehicles use the mainlanes (Figure B-6). Prior to contraflow implementation, limited data suggest this value was 4,950.

- In the a.m. peak period, 17,790 vehicle use the mainlanes (Figure B-7).

Vehicle Occupancy

- In the a.m. peak hour, mainlane occupancy is approximately 1.12.

- In the a.m. peak period, mainlane occupancy is approximately 1.12.

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 8/89, since the transitway opened, the accident rate has been 1.84 accidents per MVM. 1989 freeway volumes estimated by TTI to obtain rates.

Average Operating Speed

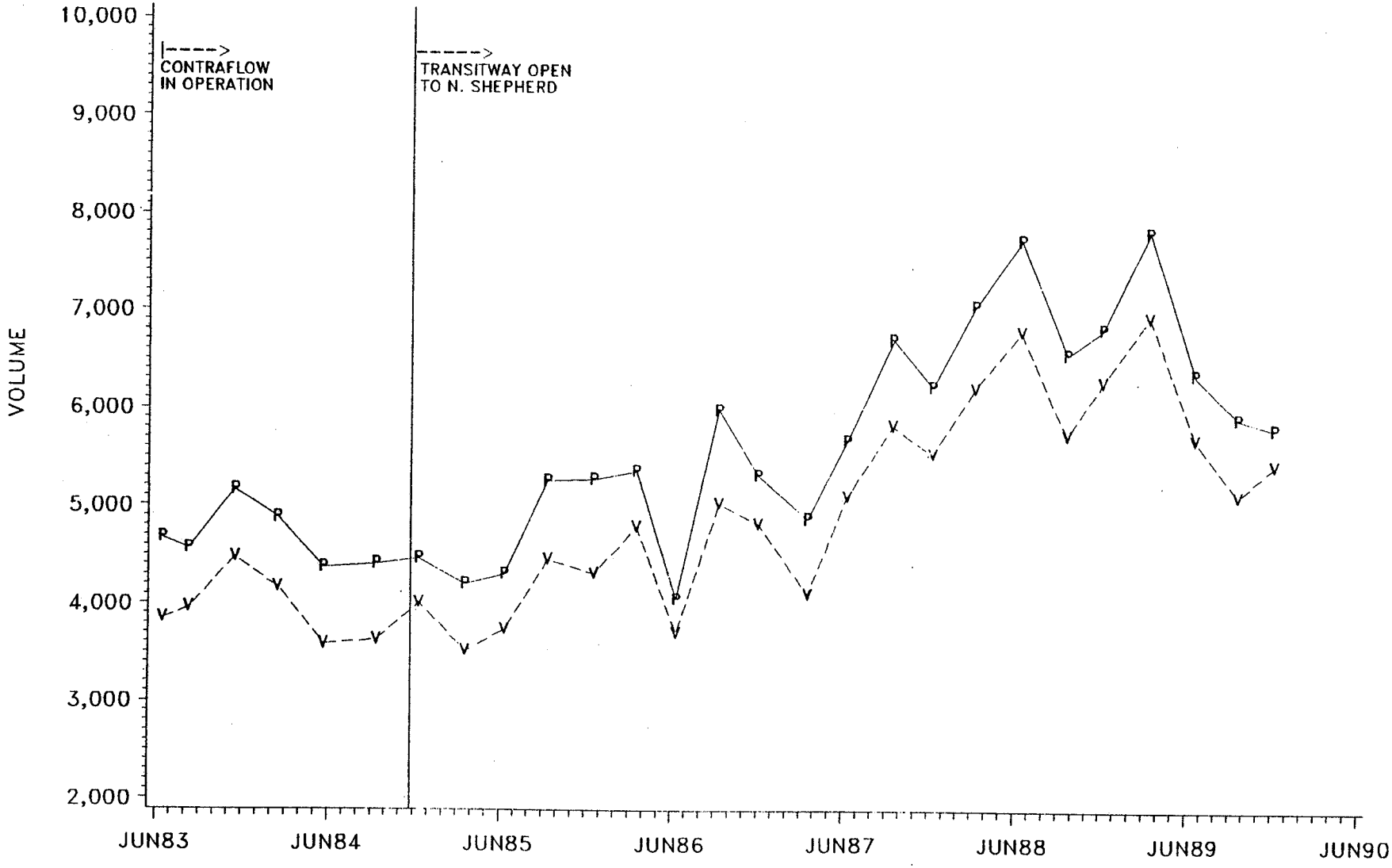
- Average operating speed on the mainlanes has increased since the transitway opened (Figure B-8).

Peak Hour Lane Efficiency

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

FIGURE B-6

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

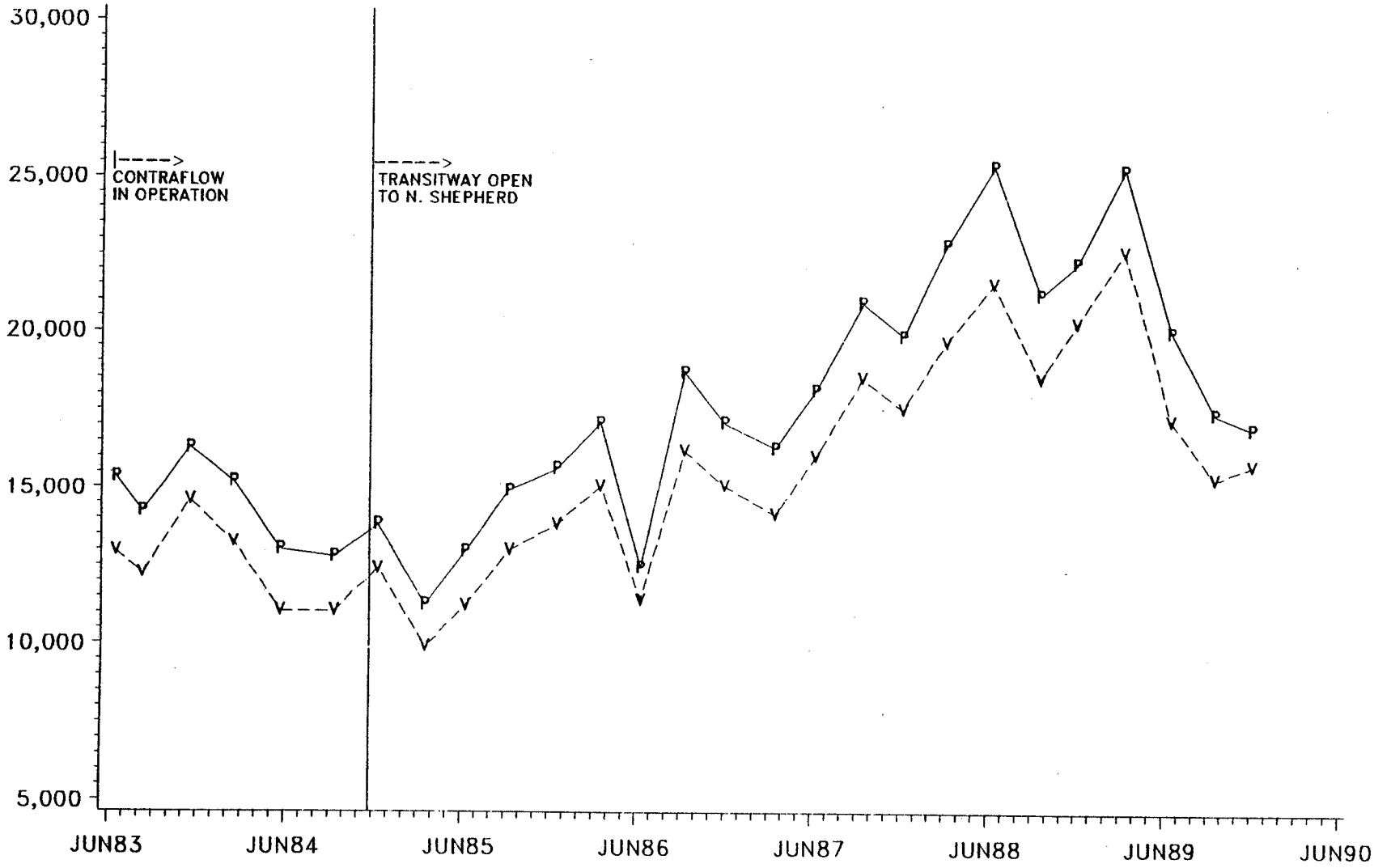


DATA COLLECTED SOUTHBOUND AT LITTLE YORK
SOUTHBOUND CROSS SECTION AT LITTLE YORK EXPANDED FROM 3 TO 4 LANES IN JUNE, 1987
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = MAINLANE PERSONS
V = MAINLANE VEHICLES

FIGURE B-7

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

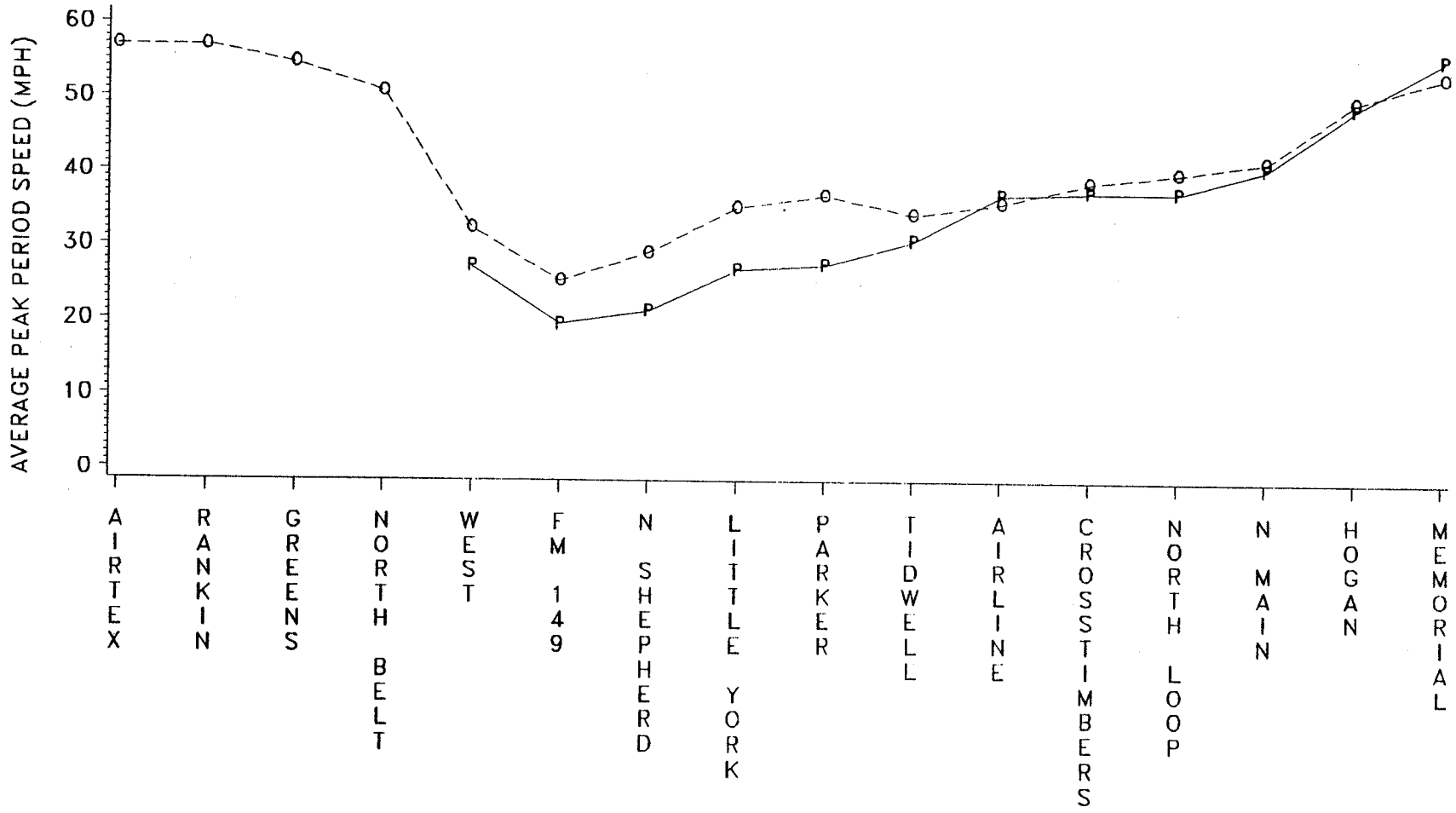


A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA COLLECTED SOUTHBOUND AT LITTLE YORK
SOUTHBOUND CROSS SECTION AT LITTLE YORK EXPANDED FROM 3 TO 4 LANES IN JUNE, 1987
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = MAINLANE PERSONS
V = MAINLANE VEHICLES

FIGURE B-8

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



TRANSITWAY OPENED NOVEMBER 23, 1984
DATA COLLECTED 6:00 TO 9:30 A.M.
TRANSITWAY OPERATES FROM N. SHEPHERD TO DOWNTOWN
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = FREEWAY SPEED PRIOR TO TWAY OPENING
O = FREEWAY SPEED SINCE TWAY OPENED

- For the freeway mainlanes, the current peak hour per lane efficiency is 51 (6,495 persons at 32 mph).

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 B-9). In the peak period, the transitway carries 22% of the a.m. peak period person trips (Figure B-10).

Vehicle Occupancy

- The combined occupancy for the freeway and transitway in the peak hour is 1.68 versus 1.12 occupants per vehicle for the mainlanes (Figure B-11). Occupancy in the peak period has also increased with the opening of the transitway (Figure B-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 B-13).

Peak Hour Lane Efficiency

- peak hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a freeway corridor. The efficiency for the North Corridor is 79 (Figure B-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 B-15).

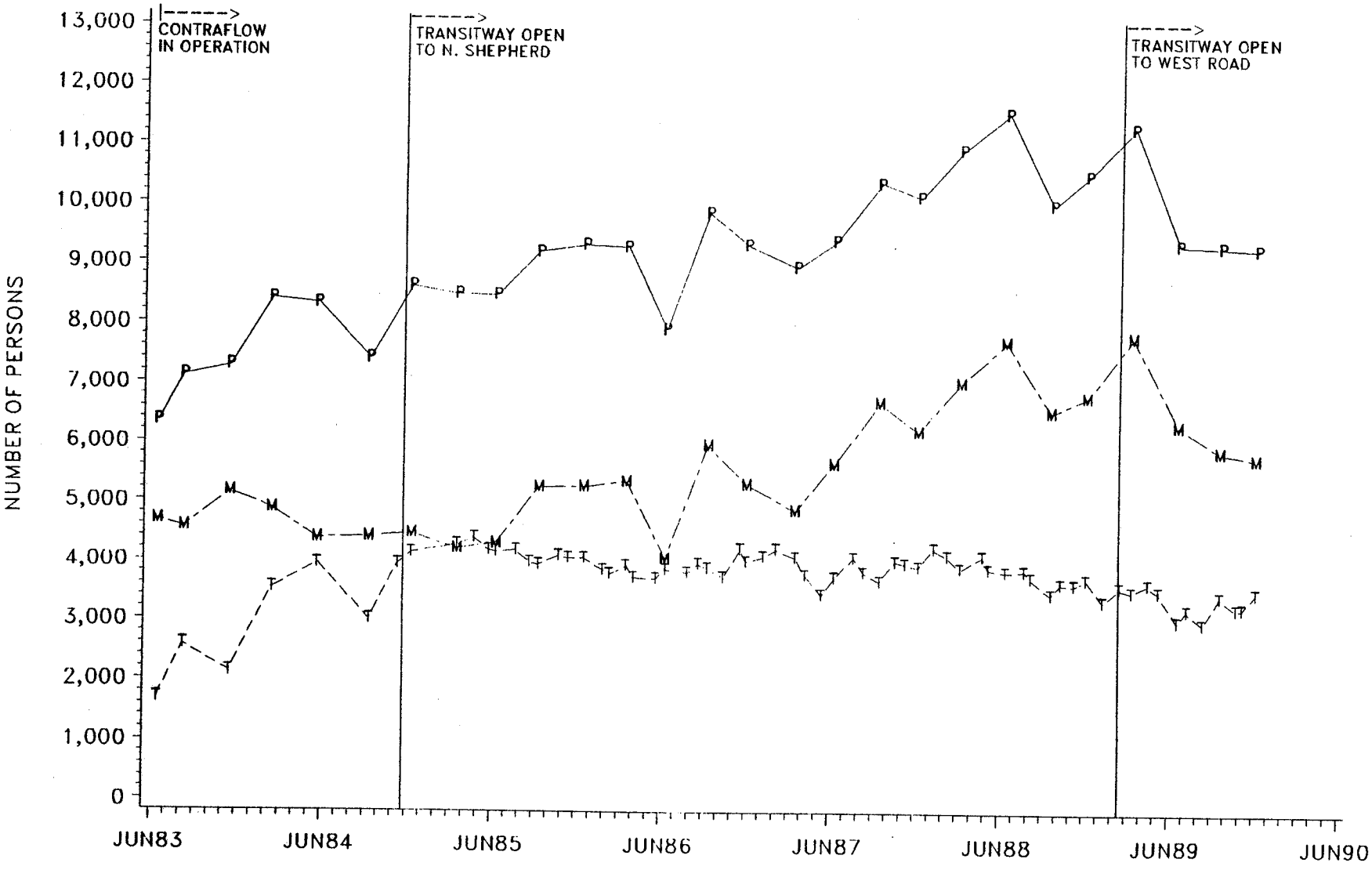
BUS TRANSIT DATA

Bus Vehicle and Passenger Trips

- Within the a.m. peak period, bus passenger trips have remained relatively consistent over the past three years, with about 3,000 passengers per peak hour (Figure B-16) and about 5,000 passengers per peak period (Figure B-17).

FIGURE B-9

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

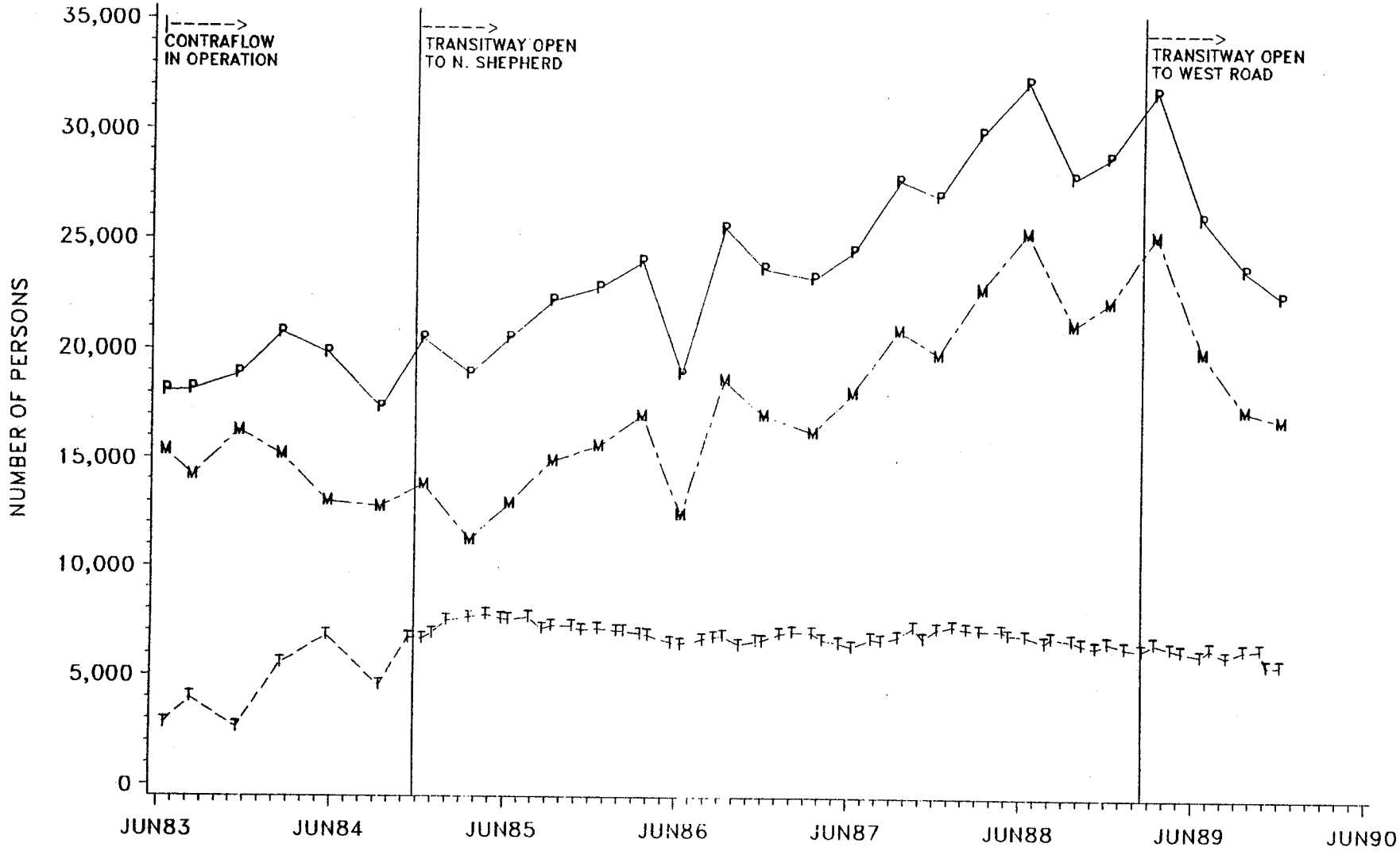


DATA COLLECTED SOUTHBOUND AT LITTLE YORK, 4 LANE SECTION
SOUTHBOUND FREEWAY CROSS SECTION INCREASED FROM 3 TO 4 LANES IN JUNE, 1987
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE B-10

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

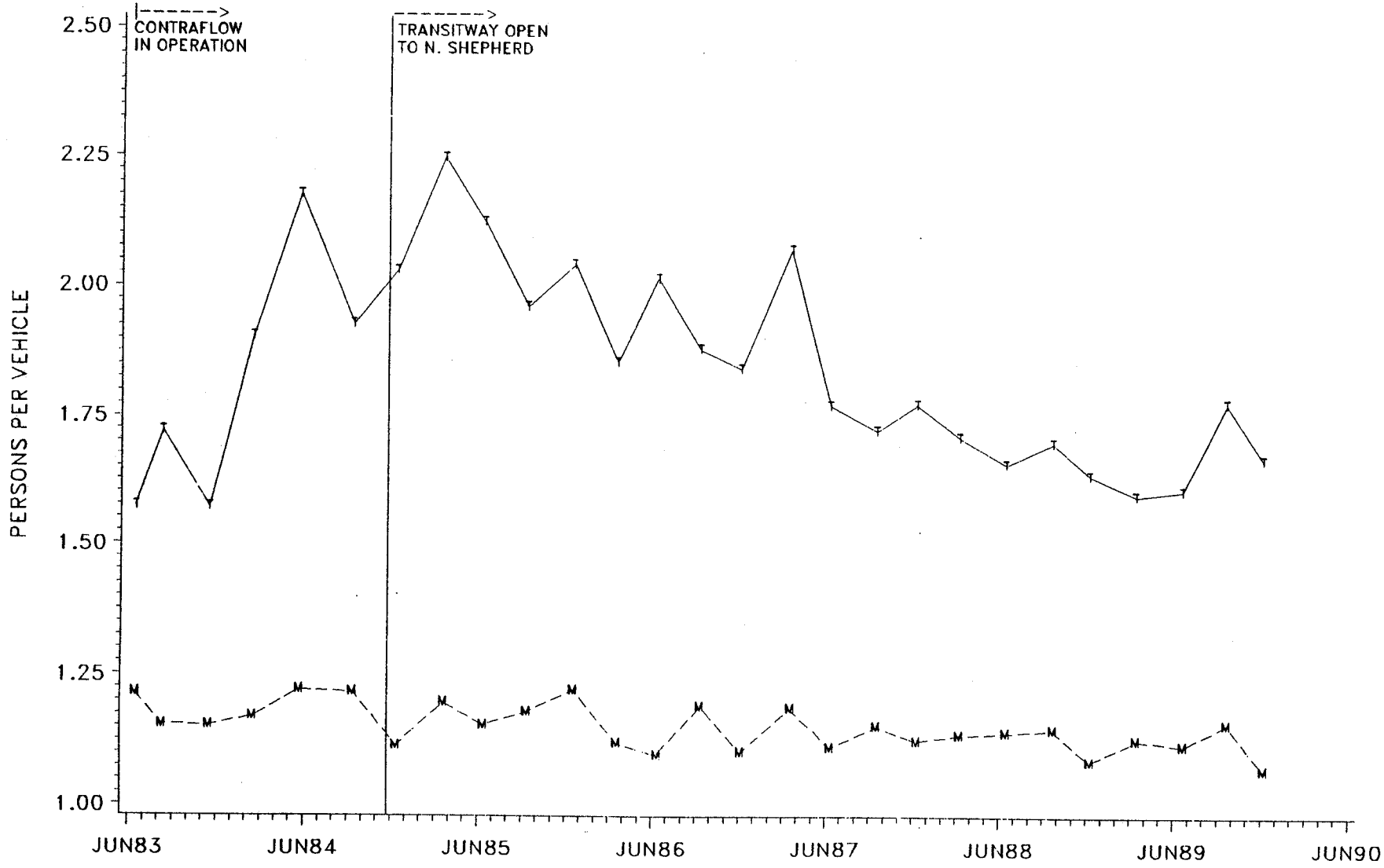


A.M. PEAK PERIOD DEFINED AS FROM 6:00 TO 9:30 A.M., TRANSITWAY ONLY OPERATES TO 8:45 A.M.
DATA COLLECTED SOUTHBOUND AT LITTLE YORK, 4 LANE SECTION
SOUTHBOUND FREEWAY CROSS SECTION INCREASED FROM 3 TO 4 LANES IN JUNE, 1987
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

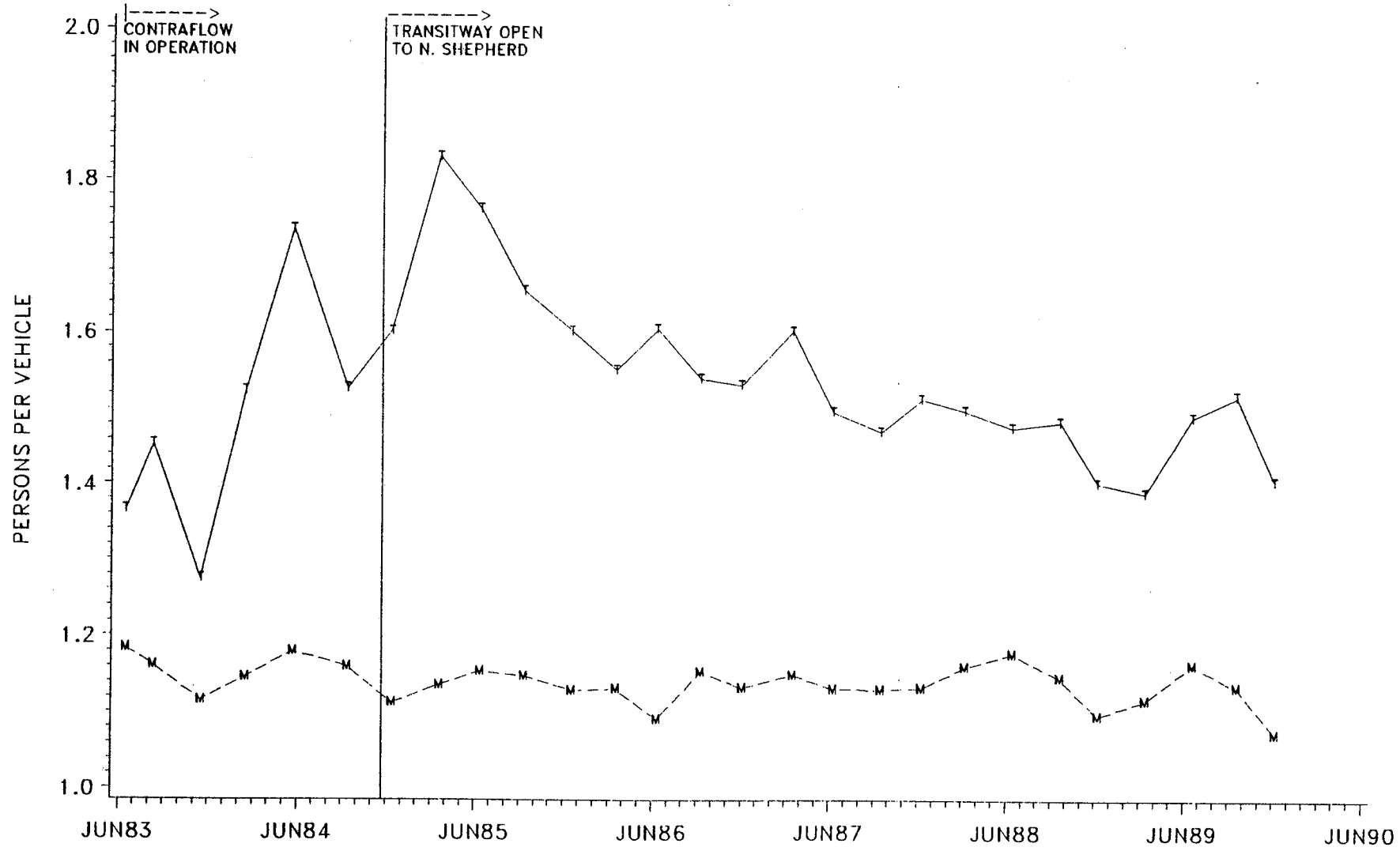


DATA COLLECTED SOUTHBOUND AT LITTLE YORK
SOUTHBOUND FREEWAY CROSS SECTION INCREASED FROM 3 TO 4 LANES IN JUNE, 1987
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

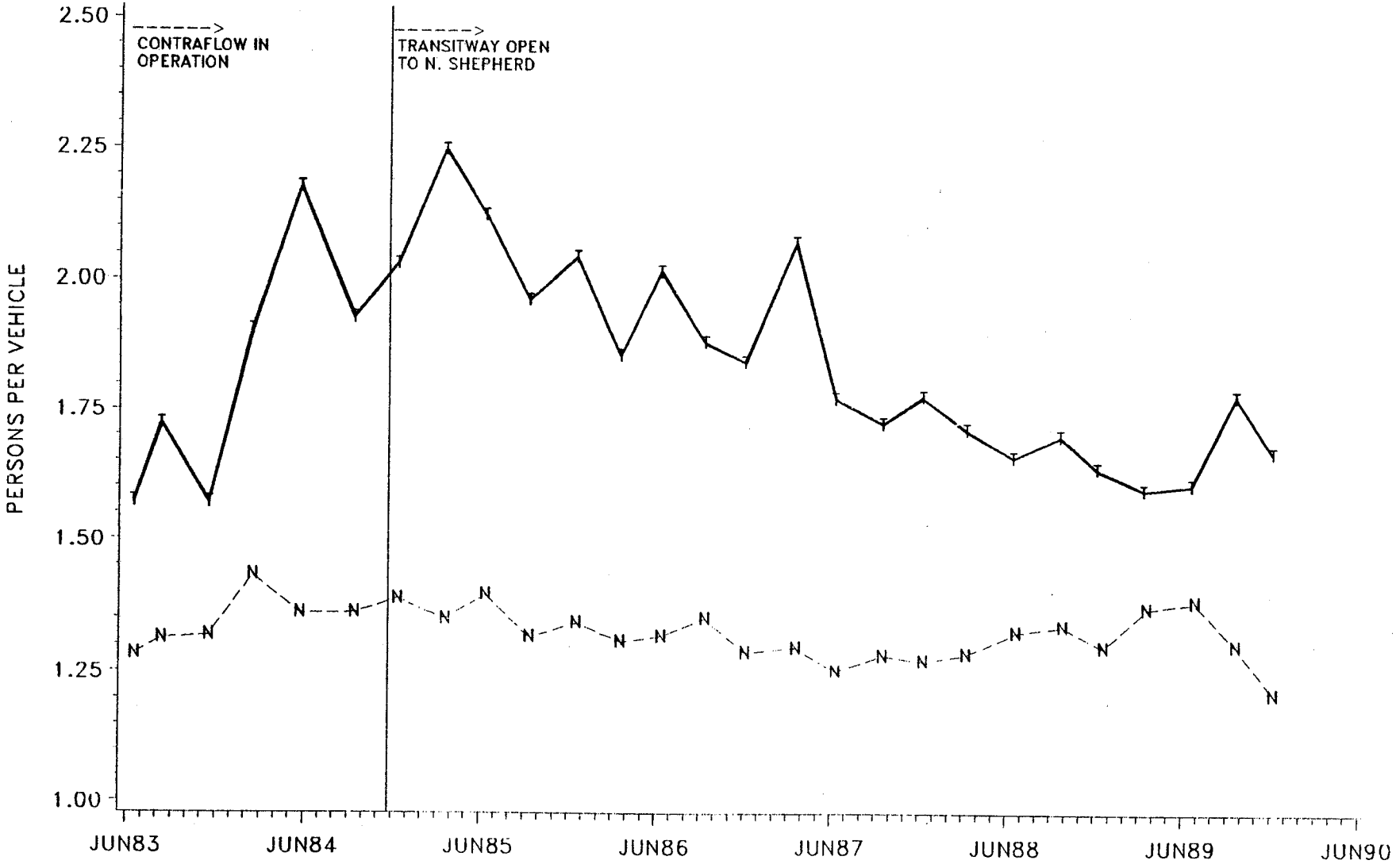


DATA COLLECTED SOUTHBOUND AT LITTLE YORK
PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
SOUTHBOUND FREEWAY CROSS SECTION INCREASED FROM 3 TO 4 LANES IN JUNE, 1987
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE B-13

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

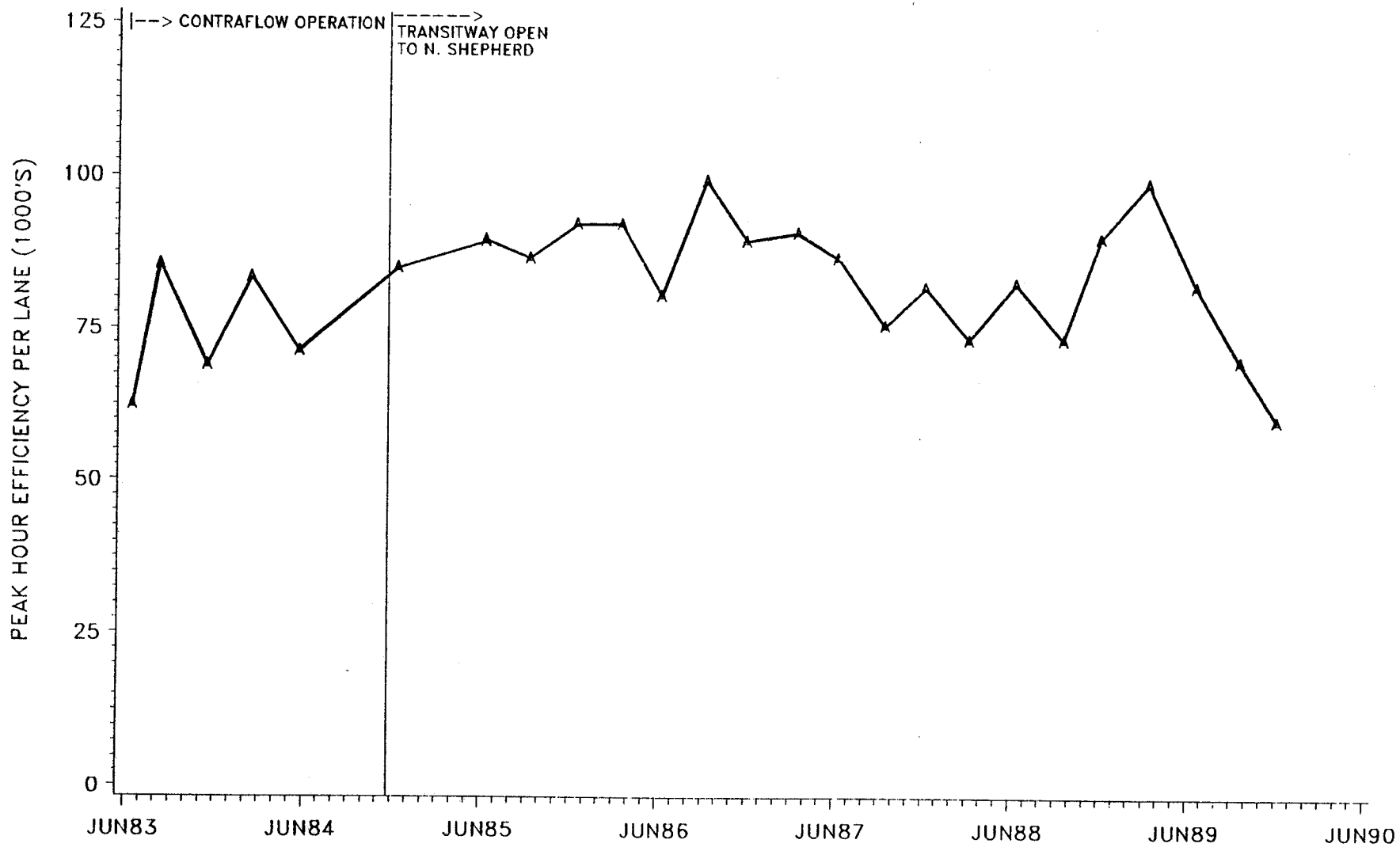


DATA FOR FREEWAYS WITHOUT TRANSITWAYS ARE A COMPOSITE OF
GULF FWY (6/83 – 4/88) AND SOUTHWEST FWY (9/86 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

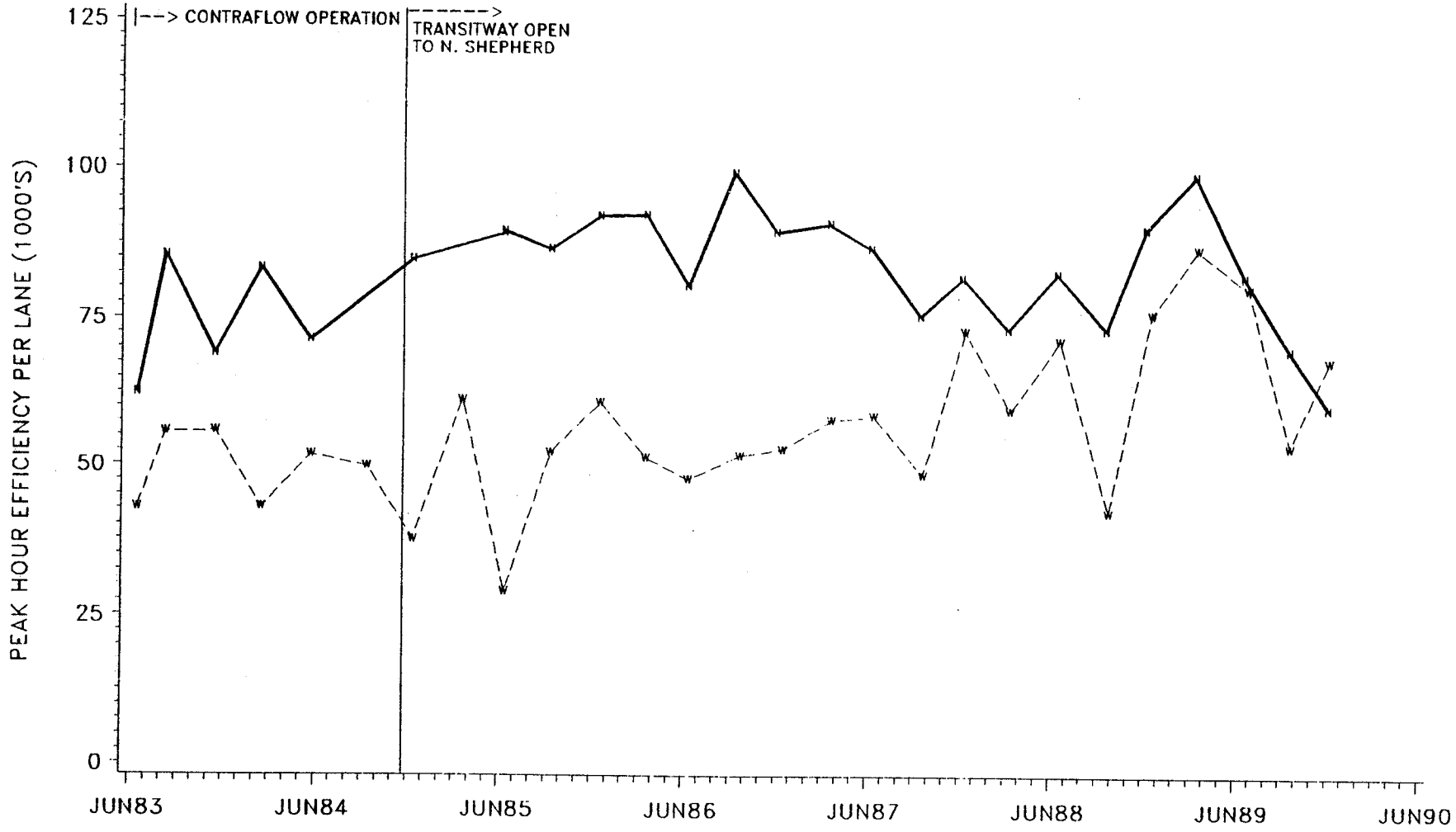


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE TRANSITWAY, IT REPRESENTS TOTAL PERSONS (FREEWAY + TRANSITWAY) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 5 LANES
SOURCE : TEXAS TRANSPORTATION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

LEGEND : A = A.M. PEAK HOUR EFFICIENCY

FIGURE B-15

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

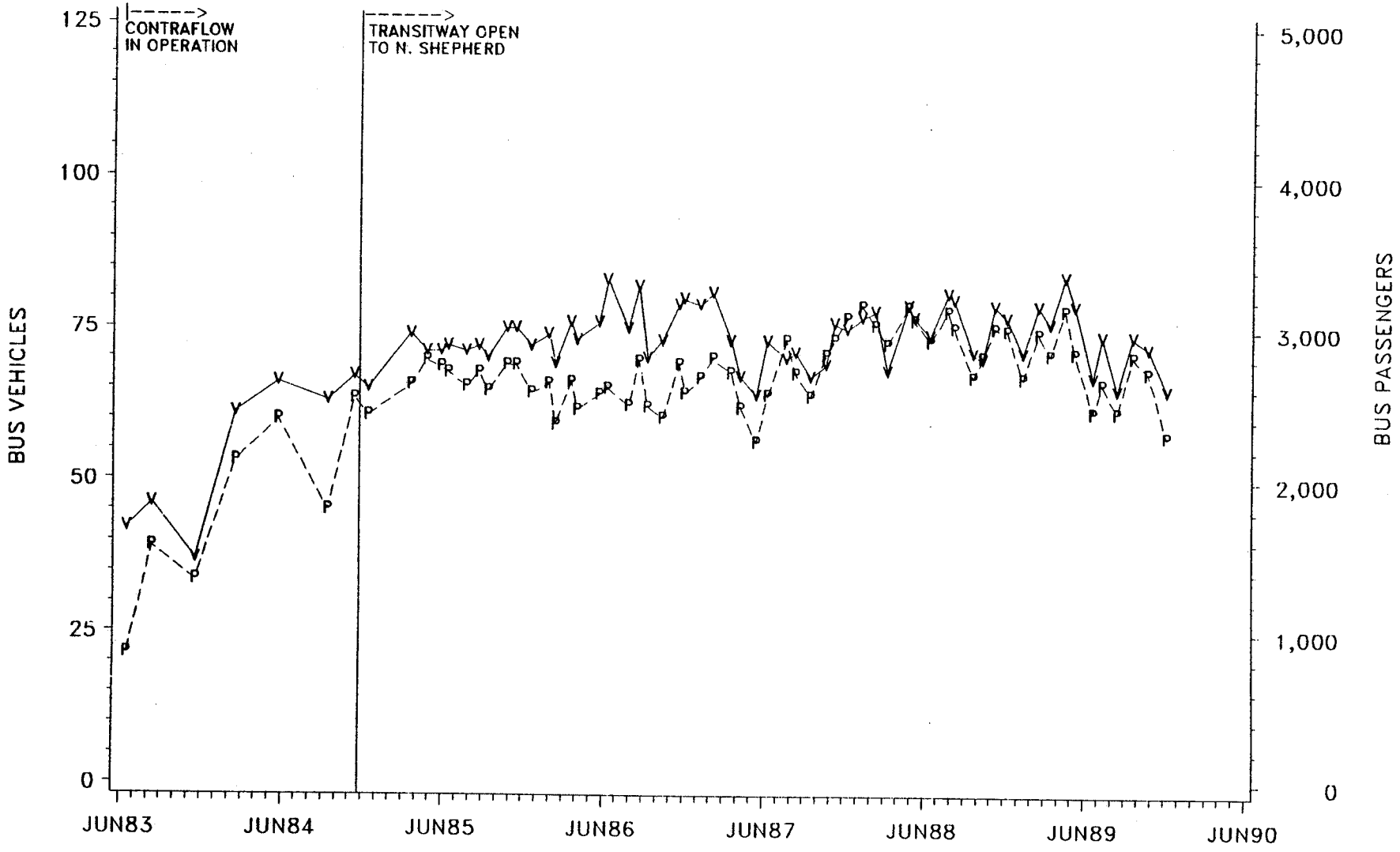


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE TRANSITWAY, IT REPRESENTS TOTAL PERSONS (FREEWAY + TRANSITWAY) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 4 LANES
DATA FOR FREEWAYS WITHOUT 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

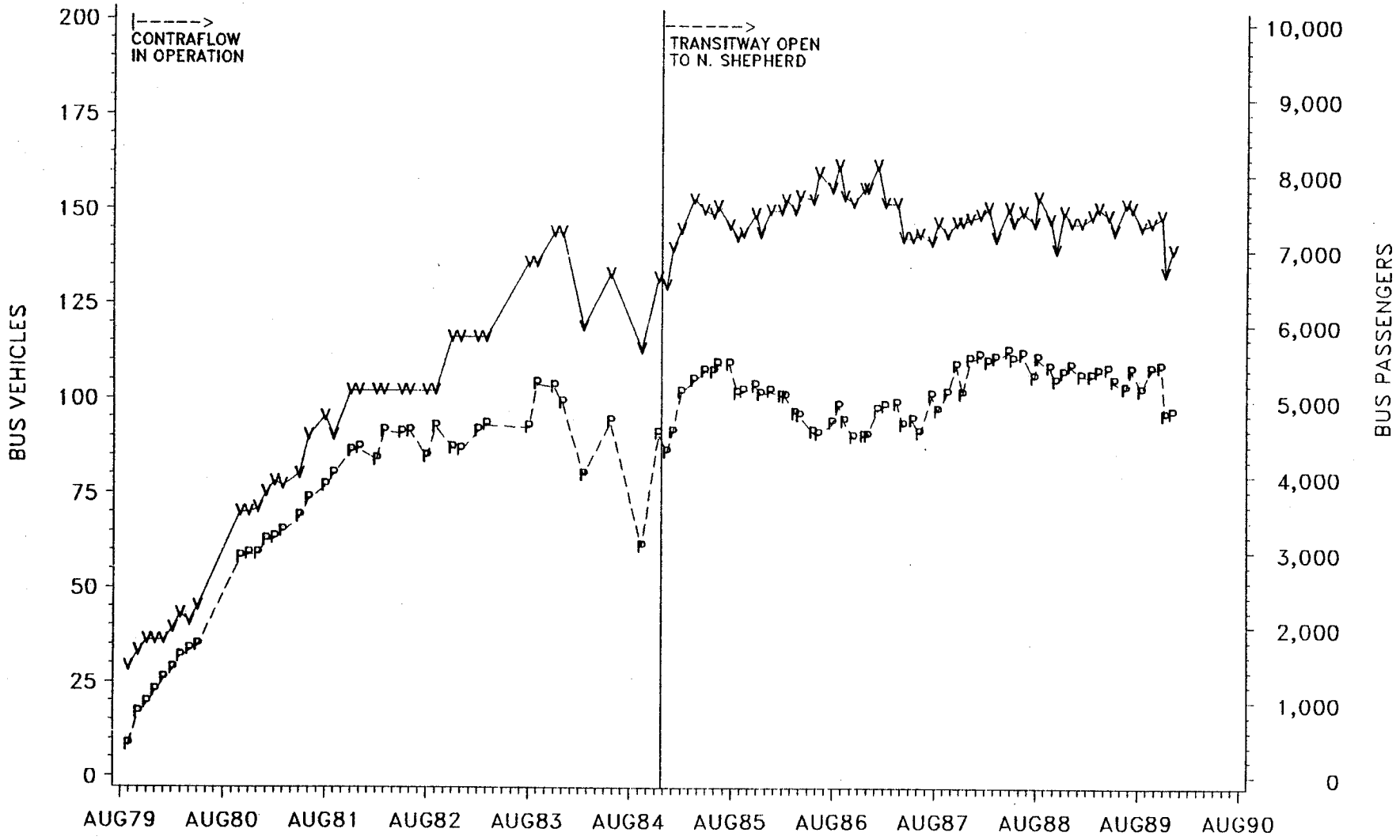


NORTH TRANSITWAY OPERATES FROM 5:45 TO 8:45 A.M.
SOURCE : TEXAS TRANSPORTATION INSTITUTE & METRO

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

FIGURE B-17

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

Likewise, the bus vehicle trips for the peak period have also remained consistent, with about 150 bus trips per peak period (Figure B-17).

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

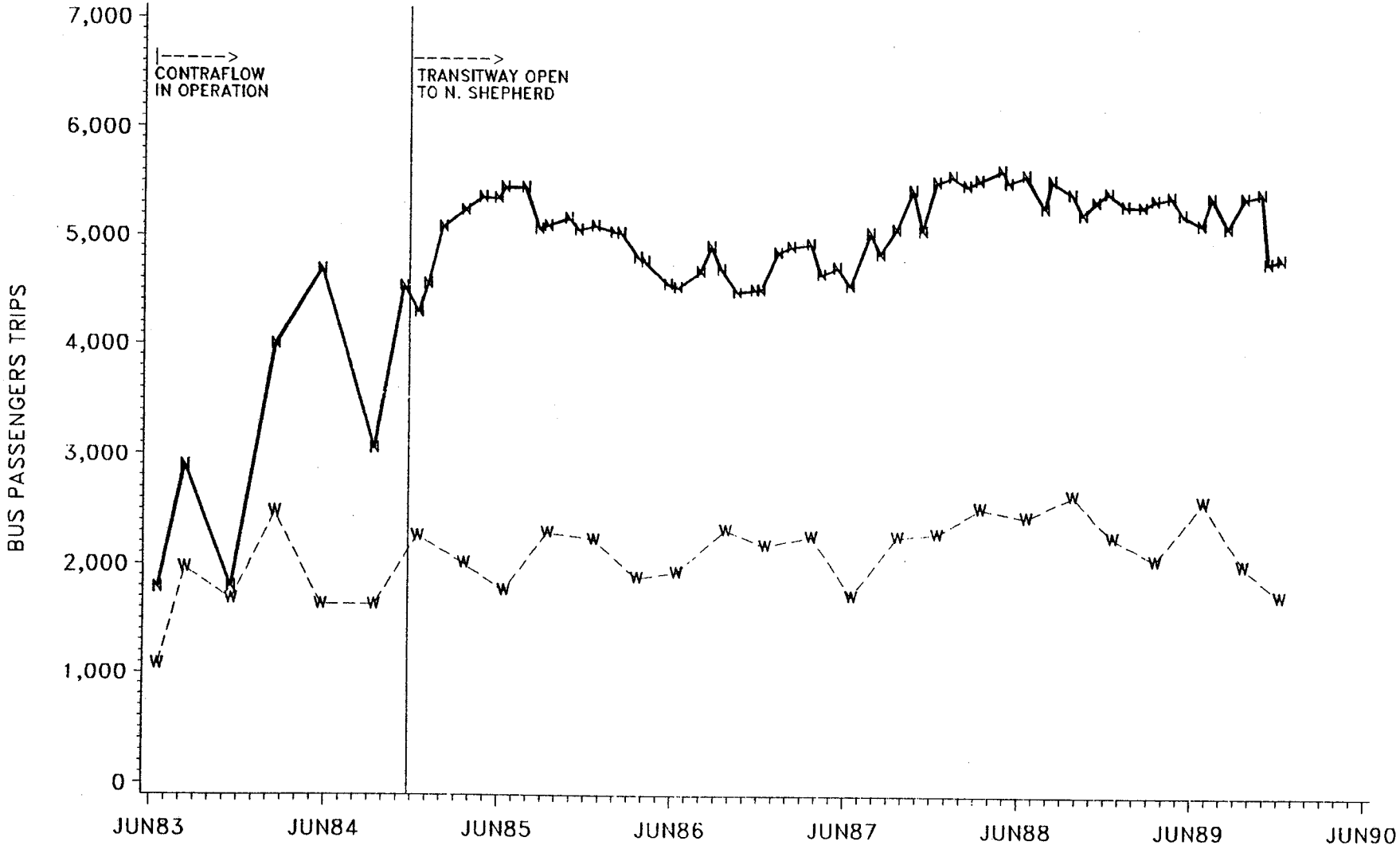
Park-and-Ride

- Currently, 4,199 vehicles are parked in the corridor park-and-ride lots. Approximately 60% of the 7,017 parking spaces are utilized (Figure B-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 41% capacity as opposed to 60% on North Freeway (Figure B-20).

FIGURE B-18

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

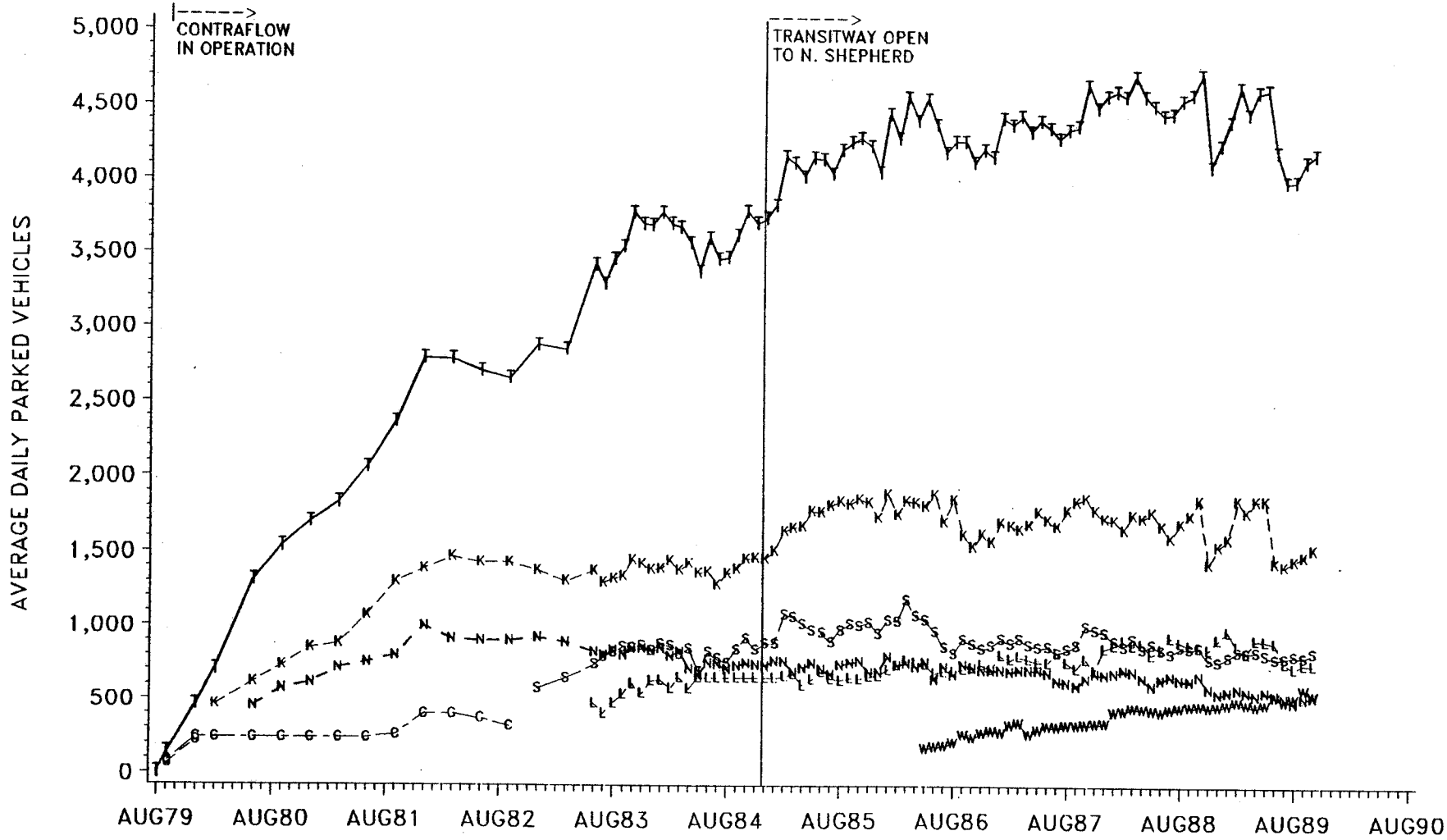


PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA FOR FREEWAYS WITHOUT TRANSITWAYS ARE A COMPOSITE OF GULF FWY (6/83 – 4/88) AND SOUTHWEST FWY (9/86 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE B-19

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

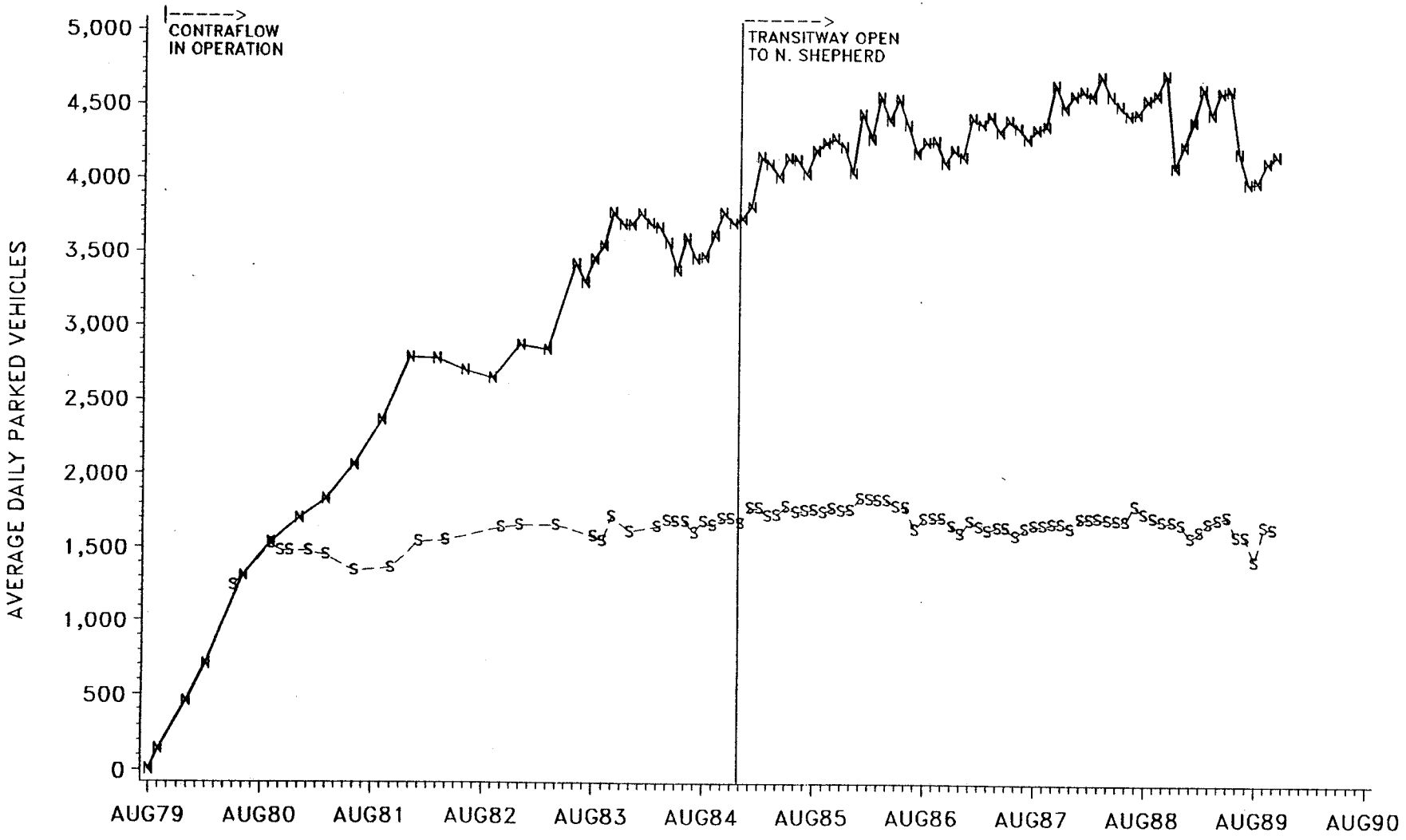


NORTH CFL FROM DOWNTOWN TO NORTH SHEPHERD (9.6 MI.) OPENED AUGUST, 1979
CONCURRENT FLOW LANE (A.M. ONLY) FROM NORTH SHEPHERD TO WEST RD (3.3 MI.) OPENED MARCH, 1981
NORTH TRANSITWAY FROM DOWNTOWN TO NORTH SHEPHERD (9.6 MI.) OPENED NOVEMBER, 1984
CURRENT TOTAL CORRIDOR PARKING CAPACITY = 7017 SPACES
CHAMPIONS (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
SOURCE : TEXAS TRANSPORTATION INSTITUTE & METRO

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

APPENDIX C

KATY FREEWAY AND TRANSITWAY DATA

KATY FREEWAY (I-10) AND TRANSITWAY, HOUSTON

Summary of A.M. Peak-Period, Peak-Direction Katy Freeway and Transitway Data, December 1989
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)		11.5	
Transitway Cost (millions)		$32	
Person-Movement			
Peak Hour (7-8 a.m.)	---	3,316	---
Peak Period (6-9:30 a.m.)	---	7,523	---
Total Daily	---	18,352	---
Vehicle Volumes			
Peak Hour	---	950	---
Peak Period	---	2,155	---
Vehicle Occupancy, Peak Hour (persons/veh)	---	3.49	---
Accident Rate (Accidents/MVM), 11/84 - 12/89	---	1.12	---
Vehicle Breakdowns (VMT/Breakdown), 11/84 - 12/89	---	34,253	---
Violation Rate (6-9:30 a.m.)		14%	
Peak Hour Lane Efficiency[1](1000's)	---	156	---
Annual Value of User Time Saved (millions)[7]	---	$3.8 to $7.7	---
Freeway Mainlane Data (see note)			
Person Movement			
Peak Hour	5,100	6,130	+20.2%
Peak Period (6:00-9:30 a.m.)	15,655	19,280	+23.2%
Vehicle Volume			
Peak Hour	4,045	5,540	+37.0%
Peak Period	12,750	17,660	+38.5%
Vehicle Occupancy, Peak Hour (persons/veh)	1.26	1.11	-11.9%
Accident Rate (Accidents/MVM)[2]	1.34	1.34	0.0%
Avg. Operating Speed[3]			
Peak Hour	23	23	0.0%
Peak Period	33	32	-3.0%
Peak Hour Lane Efficiency[1] (1000's)	38	47	+23.7%
Combined Freeway Mainlane and Transitway Data			
Total Person Movement			
Peak Hour	5,100	9,446	+85.2%
Peak Period	15,655	26,803	+71.2%
Vehicle Volume			
Peak Hour	4,045	6,490	+60.4%
Peak Period	12,750	19,815	+55.4%
Vehicle Occupancy			
Peak Hour	1.26	1.46	+15.8%
Peak Period	1.23	1.35	+ 9.8%
Carpool Volumes (vph)[8]			
2+, 6 a.m. to 7 a.m.	505	975	+93.1%
3+, 7 a.m. to 8 a.m.	45	430	+855.6
Total, 2+ and 3+, 6-8 a.m.	550	1,405	155.5%
Travel Time (minutes)[3]			-1.2%
Peak Hour	33.9[4]	33.5[5]	-5.6%
Peak Period	23.1[4]	24.4[5]	+94.7%
Peak Hour Lane Efficiency[1] (1000's)	38	74	

Summary of A.M. Peak-Period, Peak-Direction Transitway Data, December 1989 Continued

Type of Data	"Representative" Pre-Transitway Value	"Representative" Current Value	% Change
Transit Data			
Bus Vehicle Trips			
Peak Hour	11	37	+236.4%
Peak-Period	32	84	+162.5%
Bus Passenger Trips			
Peak Hour	335	1,240	+270.1%
Peak Period	900	2,645	+193.9%
Bus Occupancy (persons/bus)			
Peak Hour	30.5	33.5	+ 9.8%
Peak Period	28.1	31.5	+ 12.1%
Vehicles Parked in Corridor Park & Ride Lots	575	1,873	+225.7%
Bus Operating Speed (mph)[2]			
Peak Hour	22.6[4]	47.0[5]	+108.0%
Peak Period	33.2[4]	50.3[5]	+ 51.5%

Note: Site-specific data collected at Bunker Hill. For purposes of visibility and safety, the freeway 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 (Katy I-10) With and Freeway Without Transitways, Houston[6]

Measure of Effectiveness	"Representative" Pre-Transitway Value	"Representative" Current Value	% Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/transitway	1.26	1.46	+ 15.9%
Freeway w/o transitway	1.34	1.32	- 1.5%
A.M. Peak Hour, 2+ Carpool Volume Change			
Freeway w/transitway (6-7 a.m.)	505	975	+ 93.1%
Freeway w/o transitway	600	595	- 0.8%
Bus Passengers, Peak Period			
Freeway w/transitway	900	2,645	+193.9%
Freeway w/o transitway	2,185	2,100	- 3.9%
Cars Parked at Park-and-Ride Lots			
Freeway w/transitway	575	1,873	+225.7%
Freeway w/o transitway[6]	1,660	1,665	+ 0.3%
Facility Per Lane Efficiency[1]			
Freeway w/transitway	38	74	+ 94.7%
Freeway w/o transitway	49	74	+ 51.0%

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 8/89. Only officer-reported accidents are included in current files. 1989 freeway volumes estimated by TTI.
[3]From SH 6 to Washington, a distance of 12.18 miles. The transitway is in place over 11.5 miles of 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 1989, an annual estimate of travel time savings to transitway users is developed. A value of time of $9/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

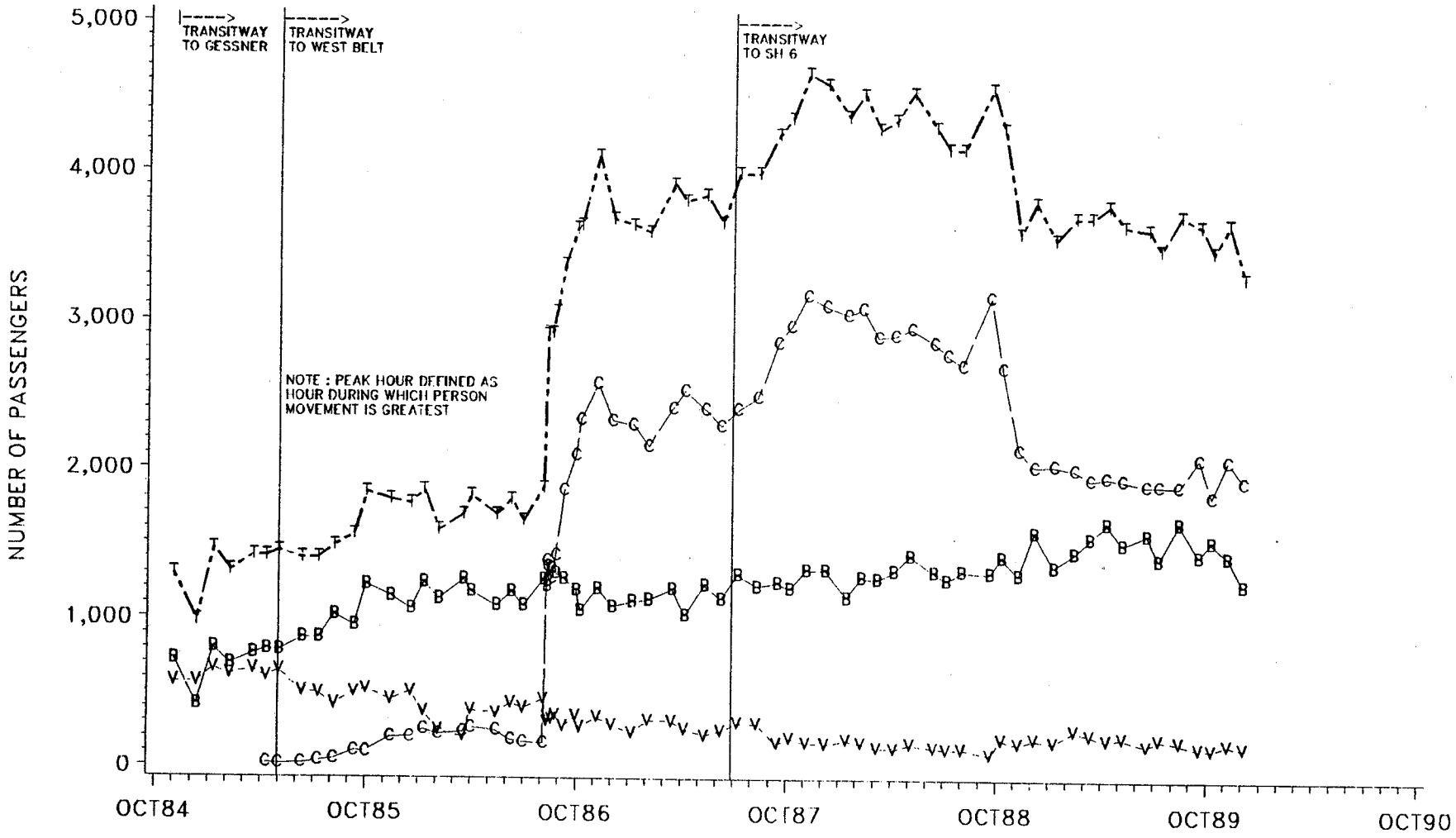
- Phase 1 (4.7 miles) of the transitway opened October 29, 1984.
- An 11.5 mile transitway operates on the Katy Freeway (I-10) between Post Oak Road and SH 6. The transitway operates inbound from 4:00 a.m. to 1:00 p.m. and outbound from 2:00 p.m. to 10:00 p.m. on weekdays. On Saturdays the facility operates outbound from 4 a.m. to 10:00 p.m., and on Sundays it operates inbound during the same hours.
- The transitway (11.5 miles) was constructed for approximately $32 million.
- Beginning in October 1988, the facility is used by 3+ vehicles between 6:45 a.m. and 8:15 a.m. It is used by 2+ vehicles during all other operating hours.
- In December 1989, 18,352 person trips per day were served on the transitway.

Person Movement

- A.M. Peak Hour (6:30-7:30 a.m.), 3,316 persons/hour.
  - 1,240 (37%) by bus, 140 (4%) by vanpool, 1,936 (58%) by carpool (Figure C-1).
  - Average transitway vehicle occupancy = 3.5 persons/vehicle.

FIGURE C-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
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

- A.M. Peak Period (6-9:30 a.m.), 7,523 persons.
    - 2,645 (35%) by bus, 311 (4%) by vanpool, 4,567 (61%) by carpool (Figure C-2).

Vehicle Movement

- A.M. Peak Hour, 950 vph.
    - 37 (4%) bus, 19 (2%) vans, 894 (94%) carpools (Figure C-3).
- A.M. Peak Period (6-9:30 a.m.), 2,155 vehicles.
    - 84 (4%) bus, 43 (2%) vans, 2,028 (94%) carpools (Figure C-4).

Accident Rate

- For the period from 11/84 to 12/89, the transitway accident rate was 1.12 accidents per million vehicle miles.

Vehicle Breakdown Rates

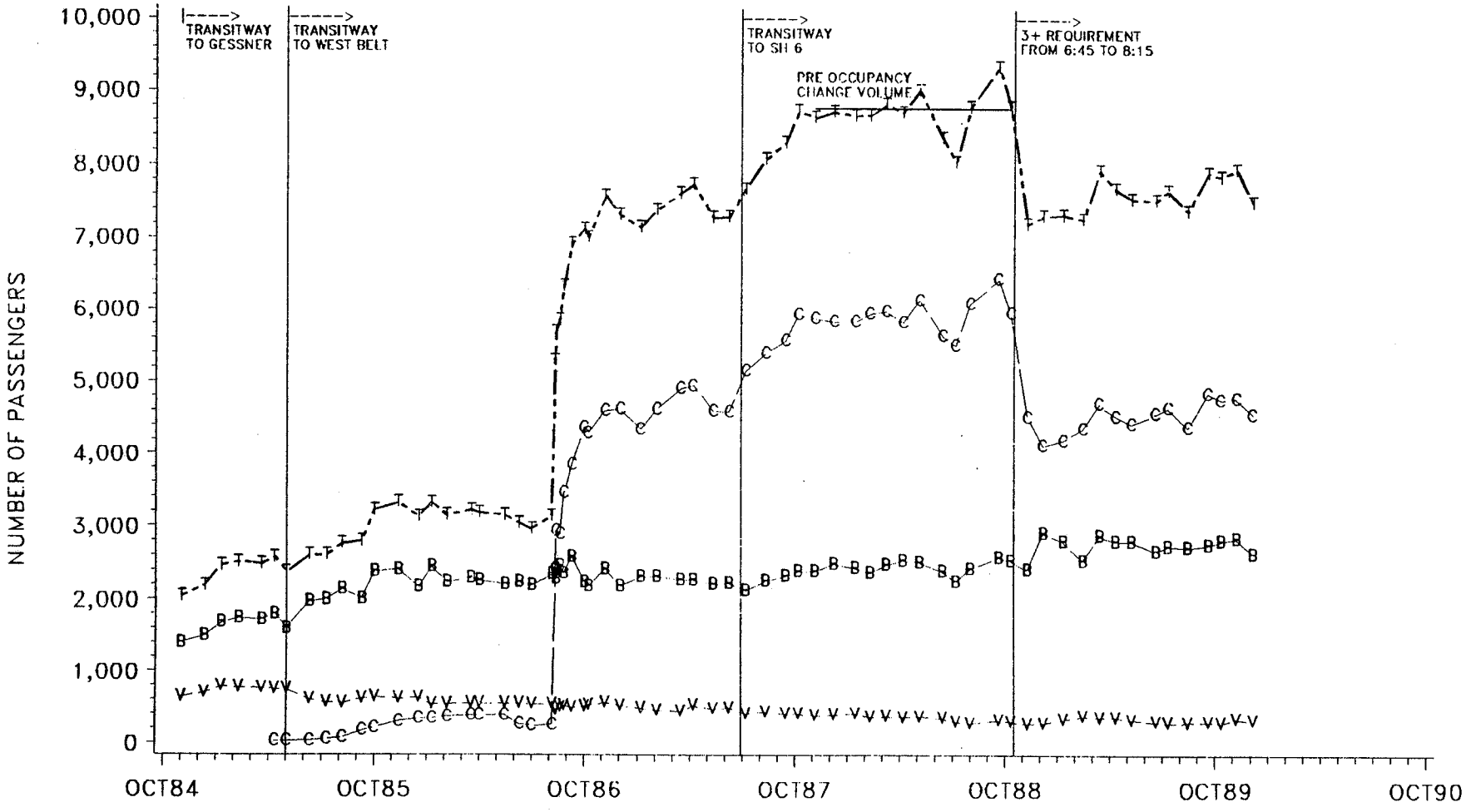
- As measured from 11/84 to 12/89, the following rates have been observed.
    - Buses; 1 breakdown per 16,702 vehicle-miles of travel (VMT).
    - Vanpools; 1 breakdown per 86,708 VMT.
    - Carpools; 1 breakdown per 34,989 VMT.
    - The weighted average for all vehicle types is 1 breakdown per 34,253 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 14%.
    - For the period from 7:00 a.m. to 8:15 a.m. (the 3+ operating time) it averaged 35% for 1989 and was 56% in December.
    - For the p.m. peak period, the violation rate is 0.7%.

FIGURE C-2

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

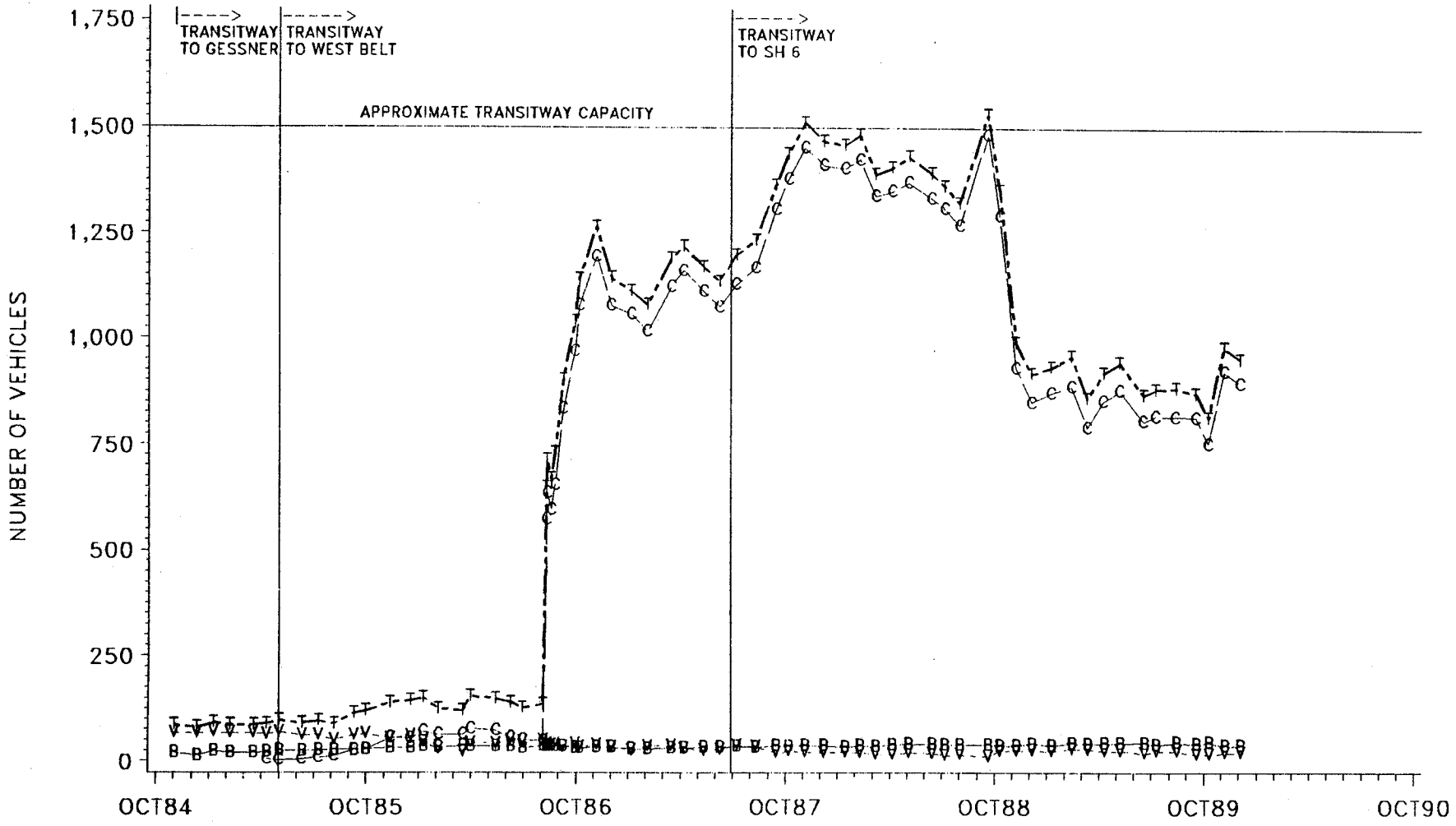


KATY TRANSITWAY PHASE 1, POST OAK TO GESSNER (4.7 MI.), OPENED OCTOBER 29, 1984
TRANSITWAY EXTENSION FROM GESSNER TO WEST BELT (1.7 MI.) OPENED MAY 2, 1985
OFF-PEAK, UNAUTHORIZED & 2+ CARPOOL OPERATION BEGAN AUGUST 11, 1986
TRANSITWAY EXTENSION FROM WEST BELT TO SH 6 (5.0 MI.) OPENED JUNE 29,1987
3+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

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

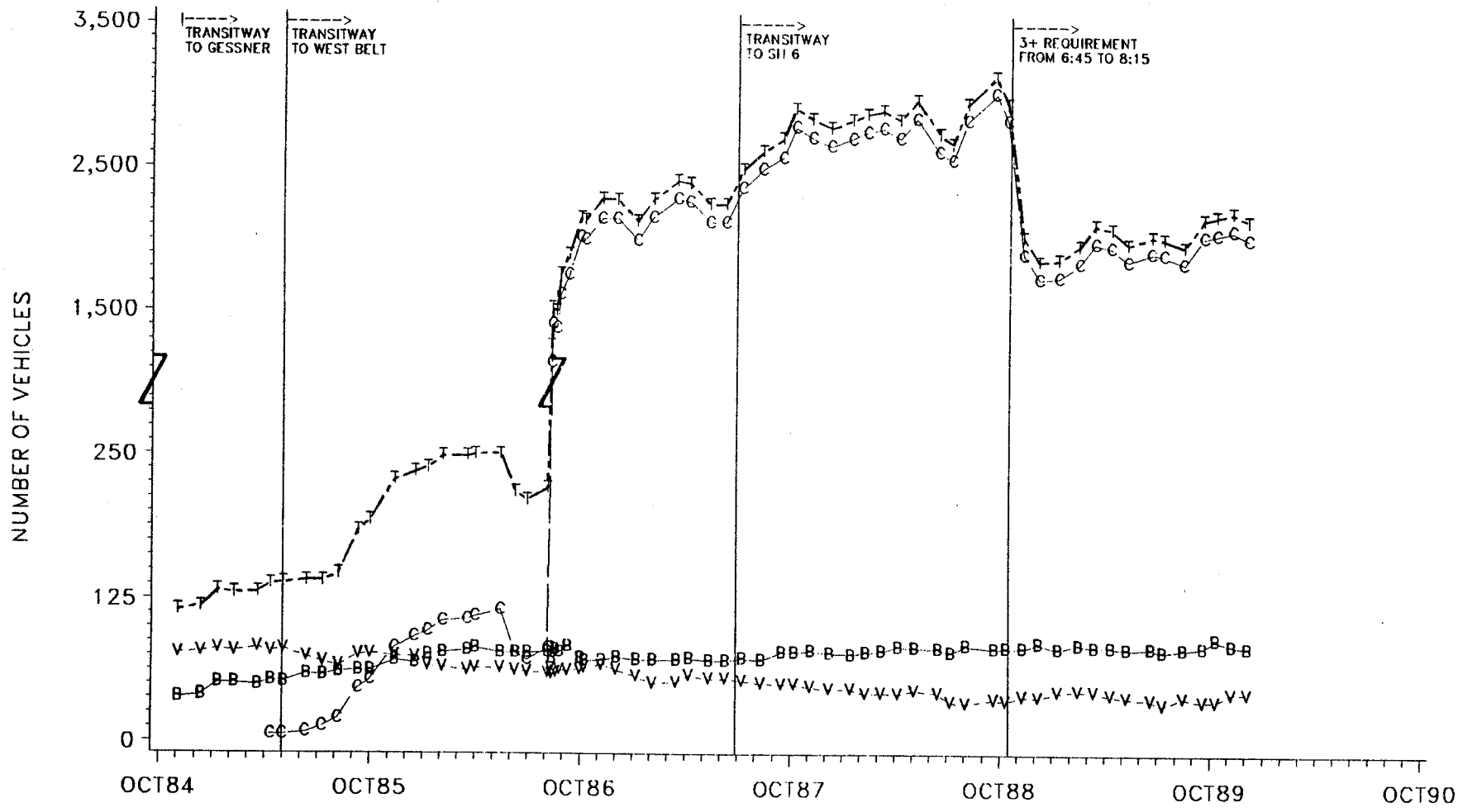


KATY TRANSITWAY PHASE 1, POST OAK TO GESSNER (4.7 MI.), OPENED OCTOBER 29, 1984
TRANSITWAY EXTENSION FROM GESSNER TO WEST BELT (1.7 MI.) OPENED MAY 2, 1985
OFF-PEAK, UNAUTHORIZED & 2+ CARPOOL OPERATION BEGAN AUGUST 11, 1986
TRANSITWAY EXTENSION FROM WEST BELT TO SH 6 (5.0 MI.) OPENED JUNE 29,1987
3+ CARPOOL REQUIREMENT FROM 6:45 TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
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 C-4

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



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
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

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 156 (3,316 passengers at 47 mph).

Travel Time Savings

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

- The tables below indicate that, on a typical non-incident day, travel time savings of approximately 1,701 hours (102,083 min.) are realized. Assuming 250 days of operation, annual saving would be 425,000 hours. At $9/hour, this equates to $3.83 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 $3.83 to $7.66 million per year.

FREEWAY DATA

Note

- For purposes of safety and visibility, freeway volumes are counted at Bunker Hill between an exit ramp and an entrance ramp. Thus, freeway volumes appear to be relatively 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.

Person Movement

- In the a.m. peak hour, person movement has increased by 20.2% (Figure C-6).

- In the a.m. peak period, person movement has increased by 23.2% (Figure C-7).

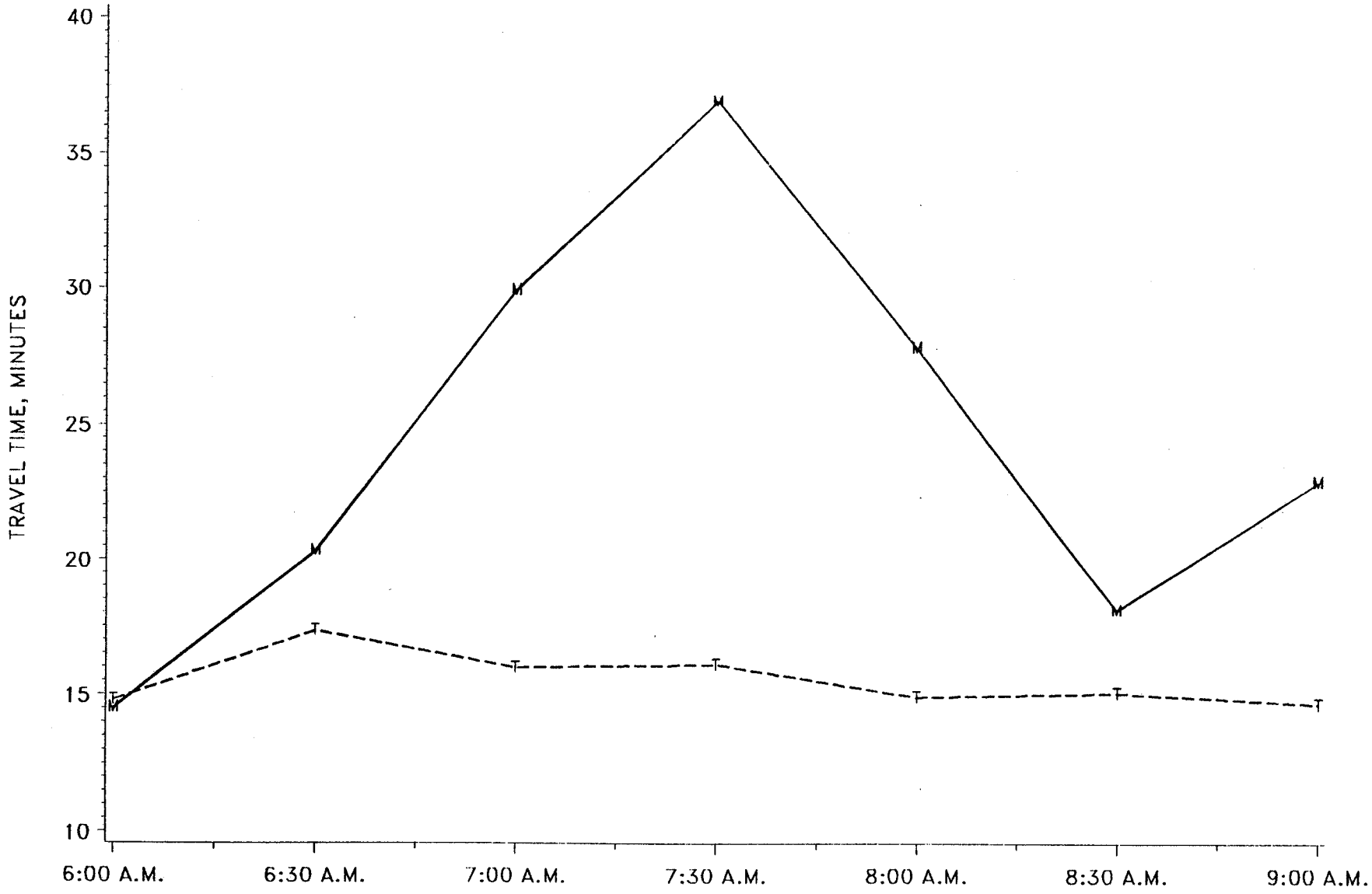
Vehicle Volume

- In the a.m. peak hour, vehicle volume has increased by 37.0% (Figure C-6).

- In the a.m. peak period, vehicle volume has increased by 38.5% (Figure C-7).

FIGURE C-5

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

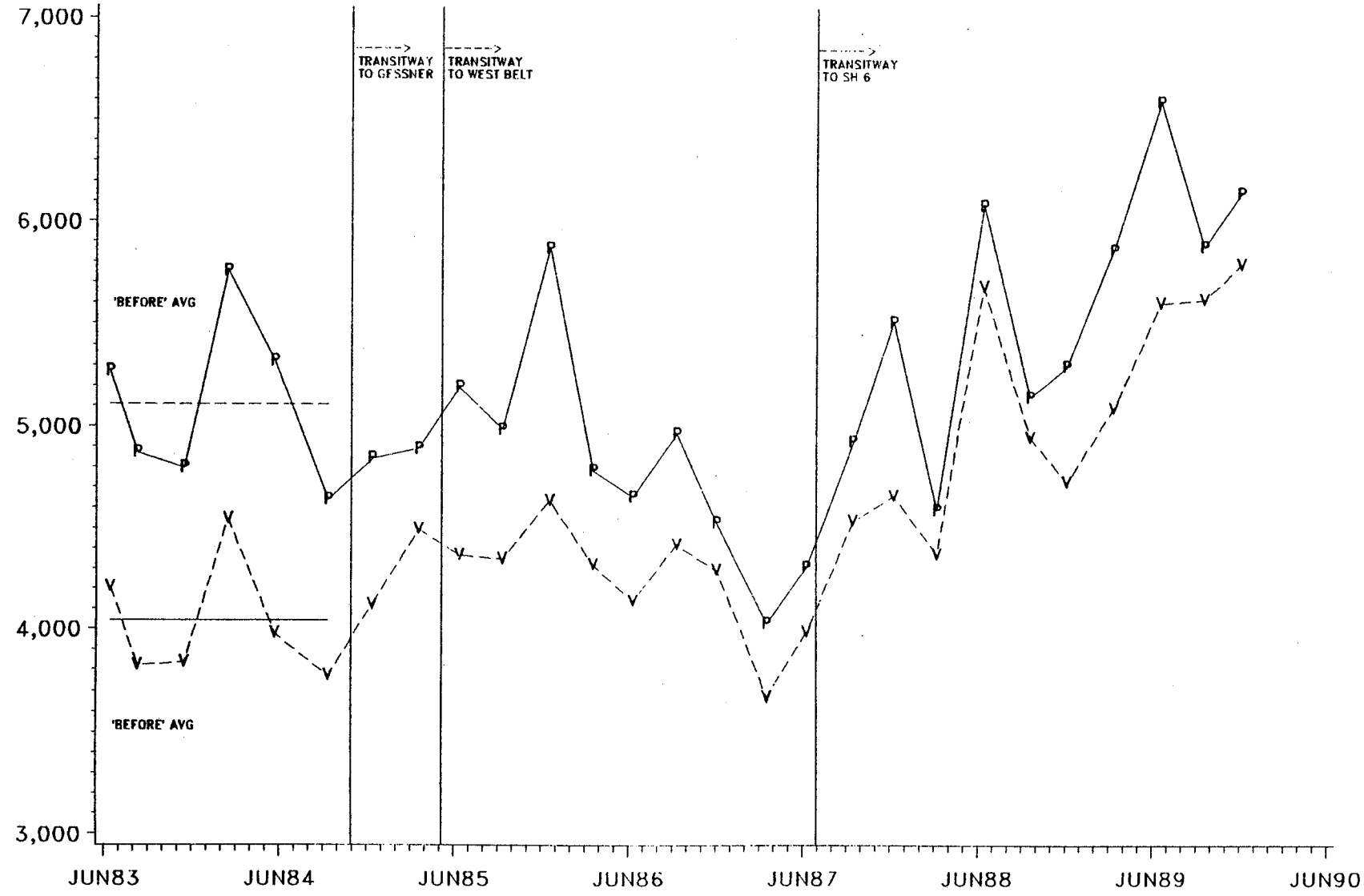


TRAVEL TIMES ARE FROM SH 6 TO WASHINGTON AVE.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE C-6

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

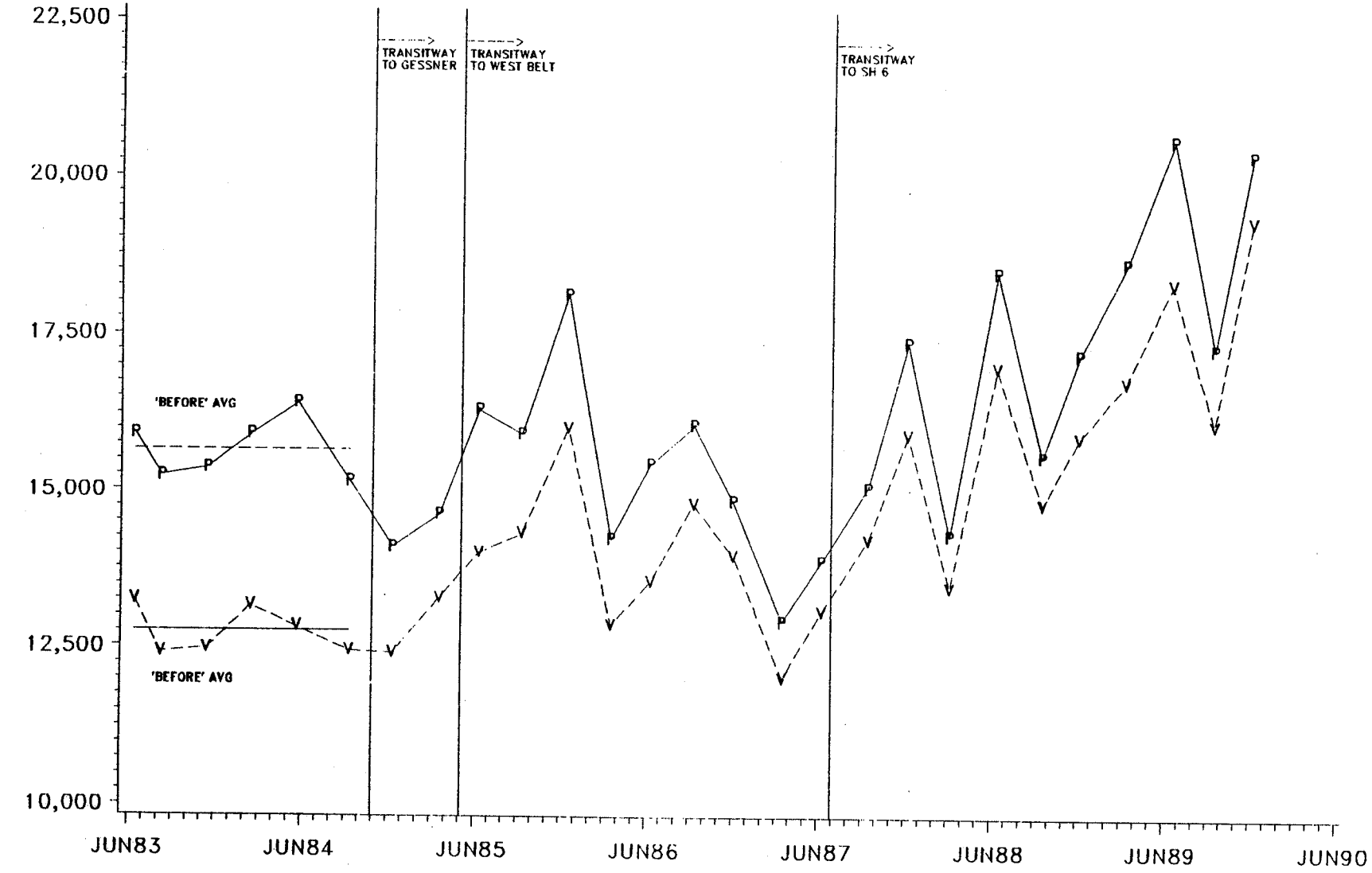


DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = MAINLANE PERSONS
V = MAINLANE VEHICLES

FIGURE C-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

Eastbound A.M. Travel Time Savings for Katy Transitway
(Average of 4 Quarterly Travel Time Surveys Conducted in 1989)

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	7.31	6.48	0.83	387	54	178	618	514.53
6:30	11.05	7.33	3.73	892	53	385	1,330	4,955.53
7:00	17.25	6.61	10.64	404	62	508	973	10,350.49
7:30	24.49	6.65	17.83	332	19	343	694	12,375.61
8:00	16.82	6.37	10.45	365	5	91	461	4,814.65
8:30	8.74	6.60	2.14	195	3	61	259	554.70
9:00	6.69	6.40	0.30	94	4	33	130	39.02
Peak Period Total				2,668	199	1,597	4,464	33,604.53
Section From Gessner Interchange to Washington								
6:00	7.20	8.32	-1.12	360	64	190	614	-690.62
6:30	9.29	10.01	-0.72	1,083	89	521	1,693	-1,215.61
7:00	12.68	9.38	3.30	890	92	849	1,832	6,047.38
7:30	12.49	9.45	3.04	841	44	623	1,507	4,586.17
8:00	11.05	8.56	2.49	701	24	388	1,113	2,767.97
8:30	9.43	8.50	0.93	527	0	123	650	601.70
9:00	16.34	8.32	8.02	275	2	51	328	2,631.17
								14,728.16
Peak Period Total				4,676	315	2,745	7,736	14,728.16
Westbound PM Travel Time Savings for Katy Transitway								
Section from Washington to Gessner Interchange								
1530	8.76	8.13	0.62	371	52	83	506	315.88
1600	11.15	8.80	2.35	771	124	197	1,091	2,568.85
1630	12.28	8.52	3.75	931	93	548	1,571	5,893.54
1700	14.93	9.42	5.51	1,252	61	769	2,082	11,478.83
1730	18.29	10.03	8.26	1,232	45	764	2,041	16,850.64
1800	15.86	8.56	7.29	792	9	259	1,060	7,732.48
1830	11.22	8.08	3.14	439	7	70	517	1,620.09
Peak Period				5,787	391	2,689	8,867	46,460.31
Section from Gessner Interchange to SH 6								
1530	6.71	6.48	0.22	156	3	33	191	42.51
1600	6.77	6.54	0.23	340	74	80	493	114.78
1630	7.46	6.51	0.94	484	64	260	808	762.48
1700	8.05	6.59	1.45	624	34	388	1,045	1,519.97
1730	9.73	6.67	3.06	700	36	434	1,170	3,583.01
1800	8.04	6.48	1.56	534	21	198	752	1,169.78
1830	6.74	6.42	0.32	240	5	61	305	98.30
Peak Period				3,076	235	1,453	4,764	7,290.83

Vehicle Occupancy

- In the a.m. peak hour, mainlane occupancy has decreased by 11.9%.
- In the a.m. peak period, mainlane occupancy has decreased by 11.4%, from 1.23 to 1.09.

Accident Rate

- Implementation of the transitway resulted in narrower freeway lanes and no inside emergency shoulder.
- The accident rate 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 8/89, the freeway accident rate was 1.34 accidents/MVM. These statistics do not include driver reported accidents; only officer reported accidents are included in current accident files. TTI estimated 1989 freeway volumes to compute accident rates.

Average Operating Speed

- In comparison to pre-transitway conditions, mainlane operating speeds have increased in both the peak hour and the peak period (Figure C-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 23.7% has occurred due to increased person volume.

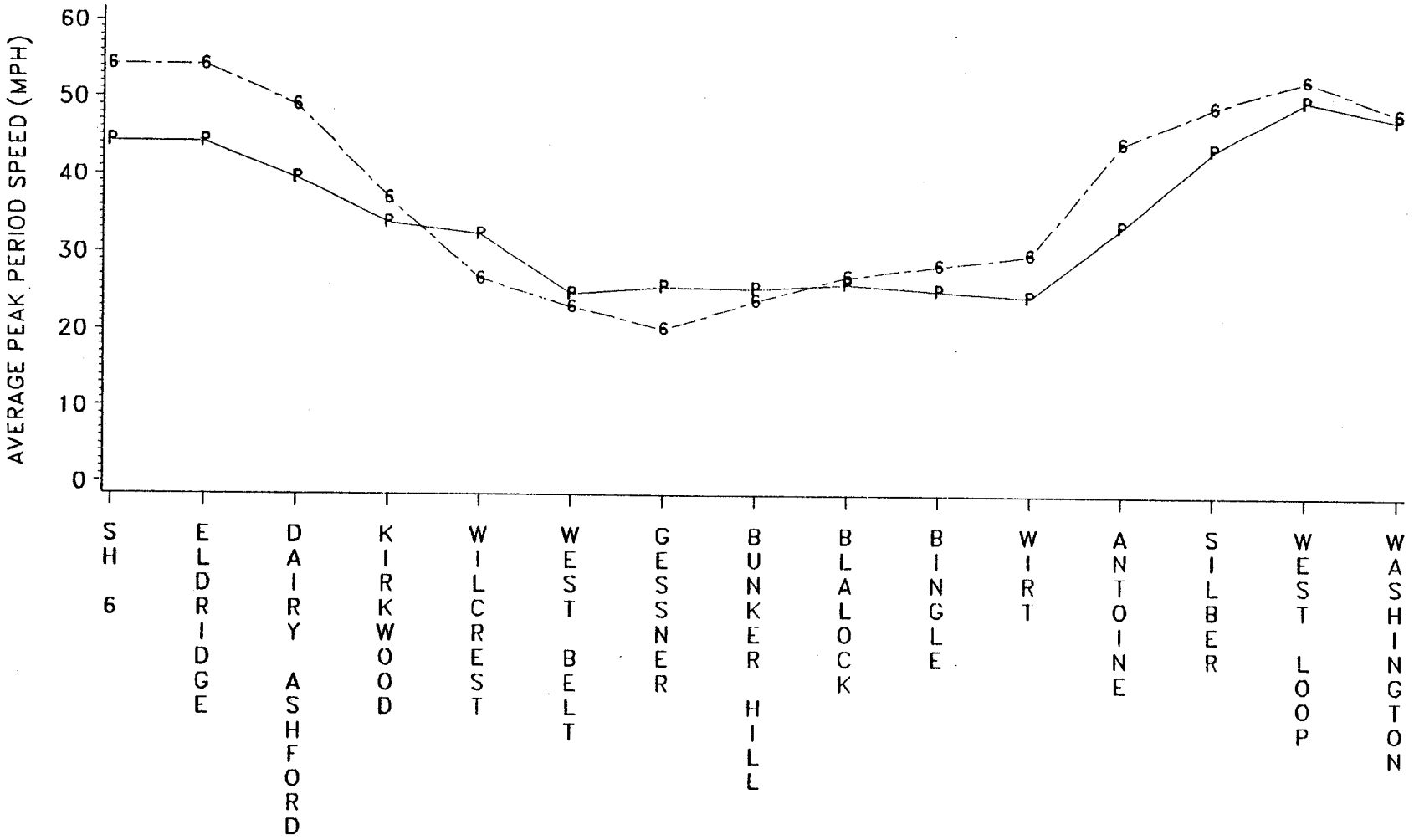
COMBINED FREEWAY MAINLANE AND TRANSITWAY DATA

Total Person Movement

- Percent by transitway, a.m. peak hour.

FIGURE C-8

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



TRANSITWAY OPENED OCTOBER 29,1984
DATA COLLECTED 6:00 TO 9:30 AM JUNE, 1983 TO DECEMBER, 1989
TRANSITWAY OPERATES FROM SH 6 TO WEST LOOP (11.5 MI.)
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : P = FREEWAY SPEEDS PRIOR TO OPENING TRANSITWAY
6 = FREEWAY SPEEDS SINCE TRANSITWAY OPEN TO SH 6 (6/87)

- At the Bunker Hill, the transitway is moving 35% of peak-hour person movement (transitway = 3,316; freeway = 6,130) and 28% of peak-period (transitway = 7,523; freeway = 19,280) 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 85.2% from 5,100 to 9,446 (Figure C-9). Peak-period person movement has increased by 71.2% from 15,655 to 26,803 (Figure C-10).

Vehicle Occupancy

- The combined occupancy for the freeway and transitway in the peak hour is 1.46, a 15.8% increase over the pre-transitway occupancy (Figure C-11). Occupancy in the peak period is 9.8% greater than pre-transitway levels (Figure C-12), increasing from 1.23 to 1.35.

- While the occupancy on the Katy Freeway has increased, on freeways which do not have a transitway, occupancy has decreased slightly (figure C-13).

Carpool Volumes

- In October 1988, carpool occupancy requirements on the transitway between 6:45 a.m. and 8:15 a.m. were increased to 3+. The transitway is used by 2+ carpools during all other operating periods.

- Between 6 a.m. and 7 a.m. (2+ carpools cannot currently enter the transitway between 6:45 a.m. and 7:00 a.m., but they can be in the transitway during that time if they entered prior to 6:45), compared to pre-transitway levels, the total 2+ carpool volume (freeway plus transitway) has increased by 93.1% (Figure C-14).

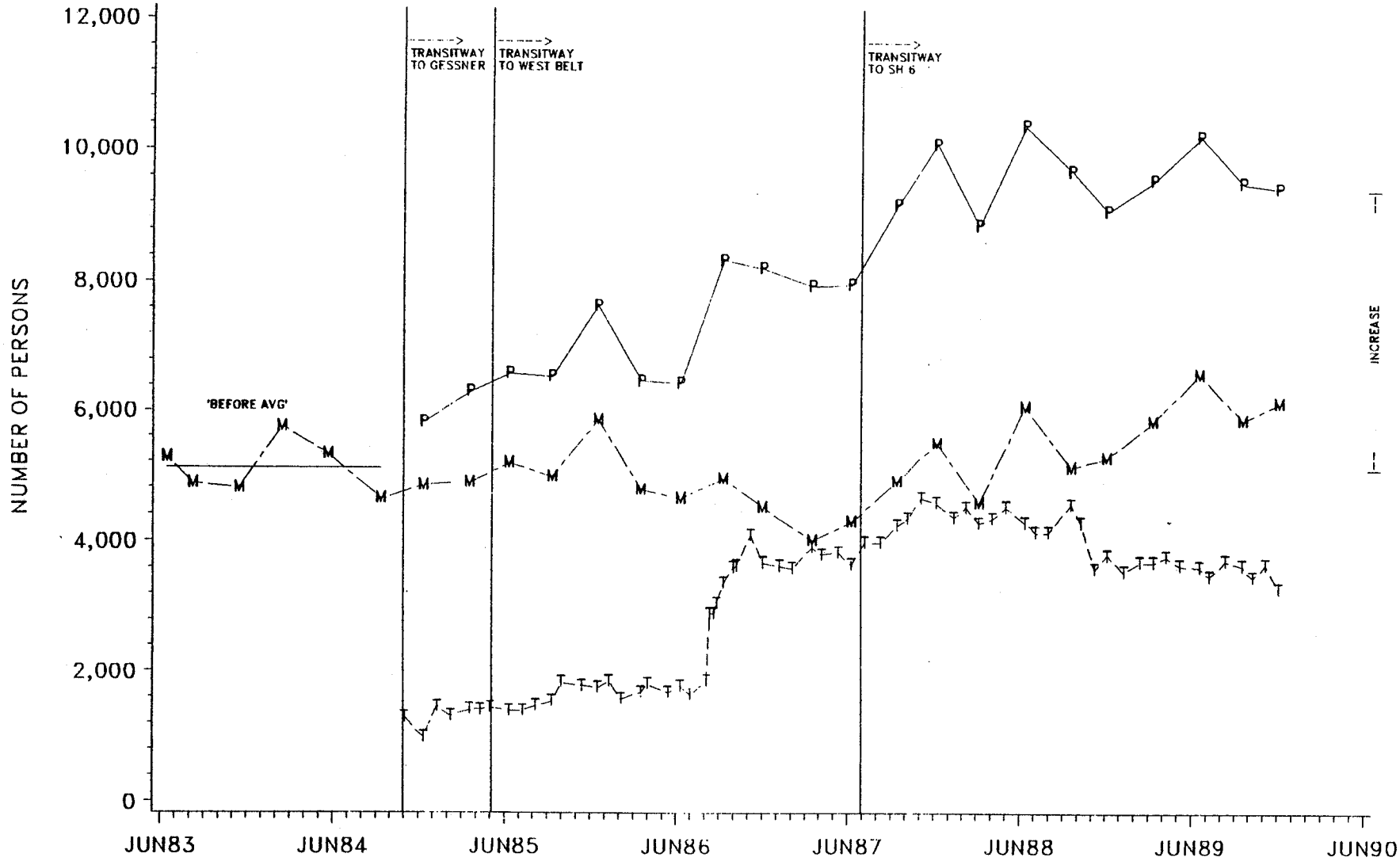
- Between 7 a.m. and 8 a.m., prior to implementing the transitway the 3+ carpool volume was 45 vehicles; in December 1989 that volume was 430 vehicles (total, freeway plus transitway), a 856% increase (Figure C-15). The high percentage increase is due to the relatively low base value.

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 94.7% since

FIGURE C-9

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

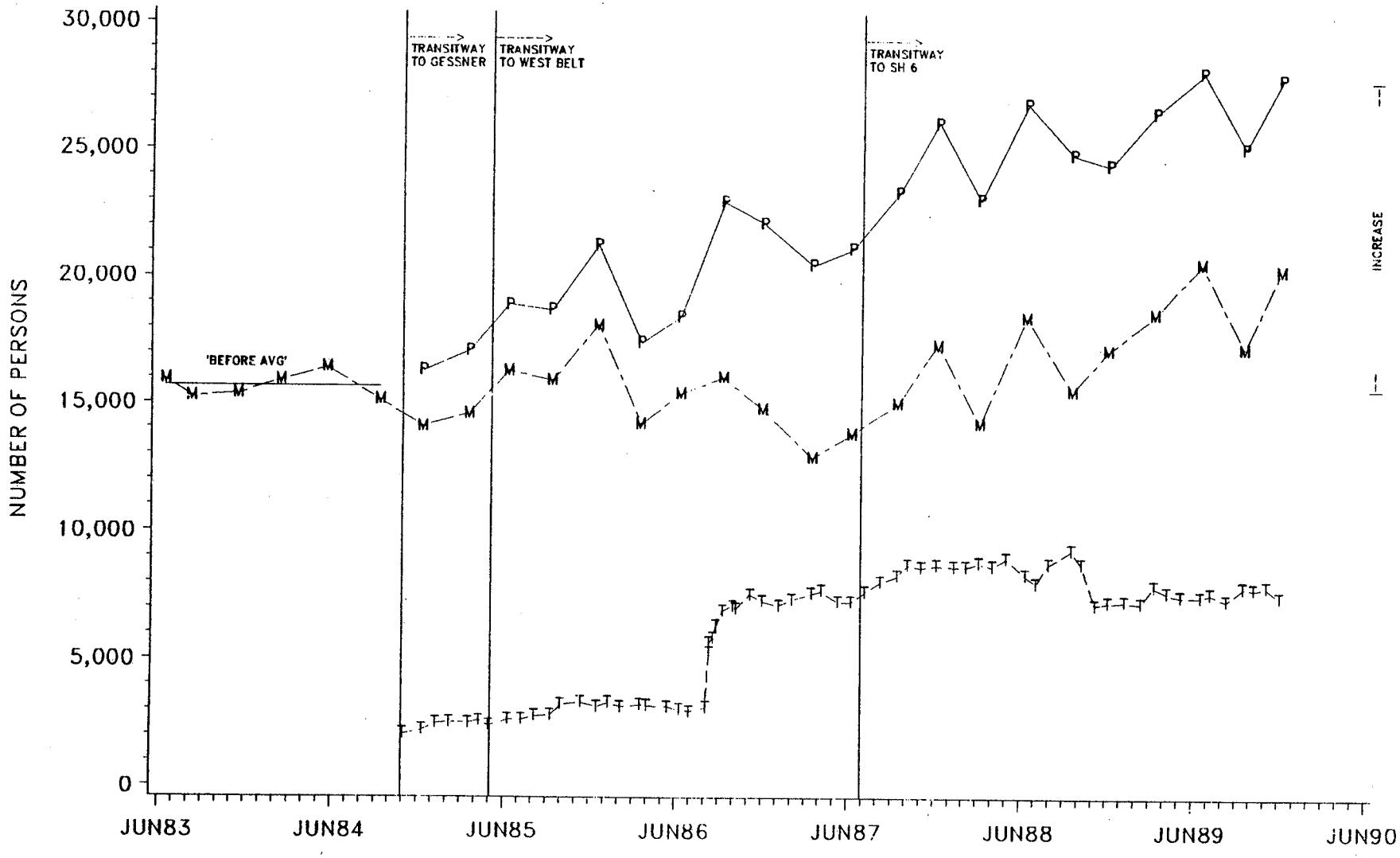


DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
3+ REQUIREMENT FROM 6:45 A.M. TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE C-10

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

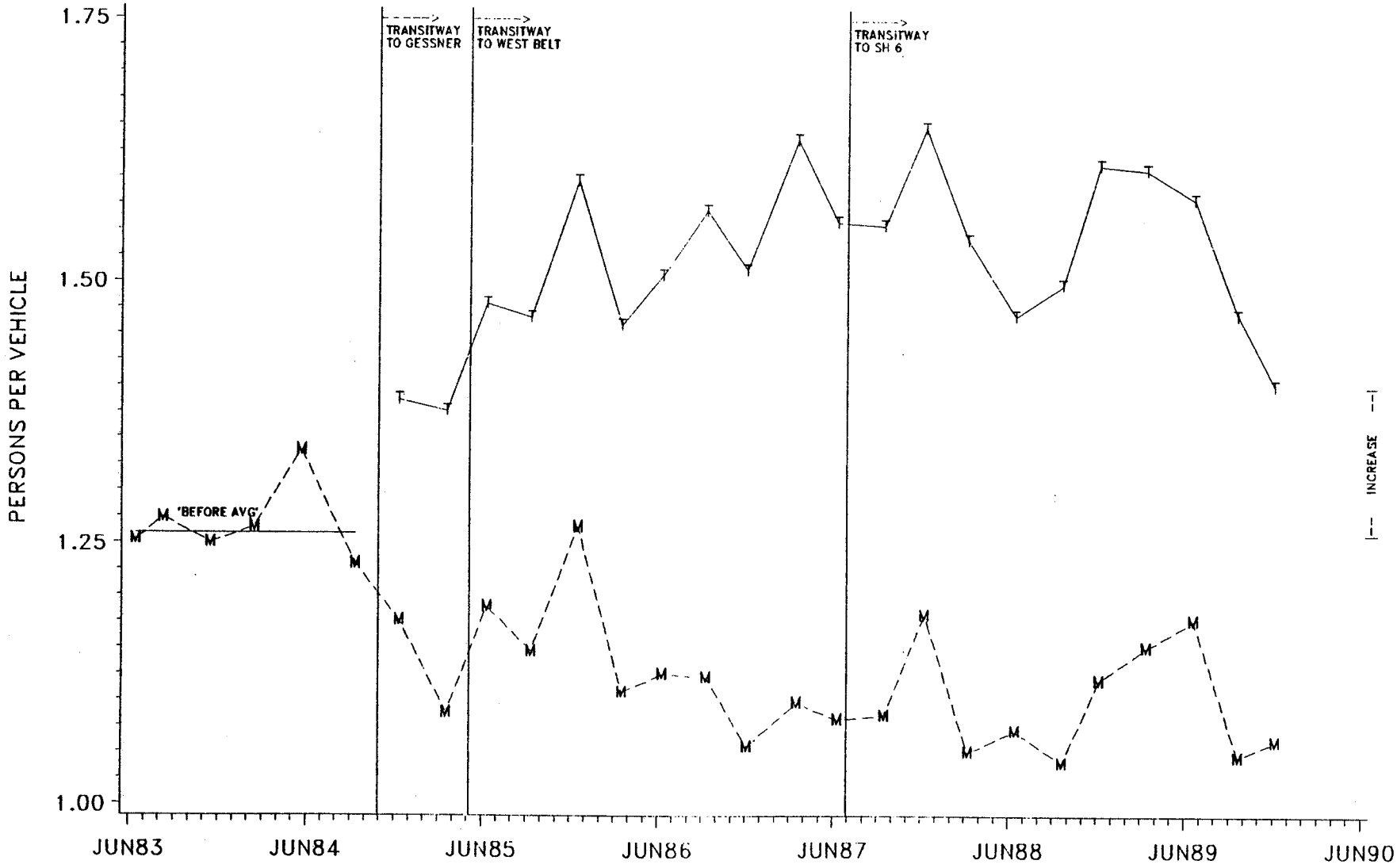


A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M
DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
3+ REQUIREMENT FROM 6:45 A.M. TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE C-11

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

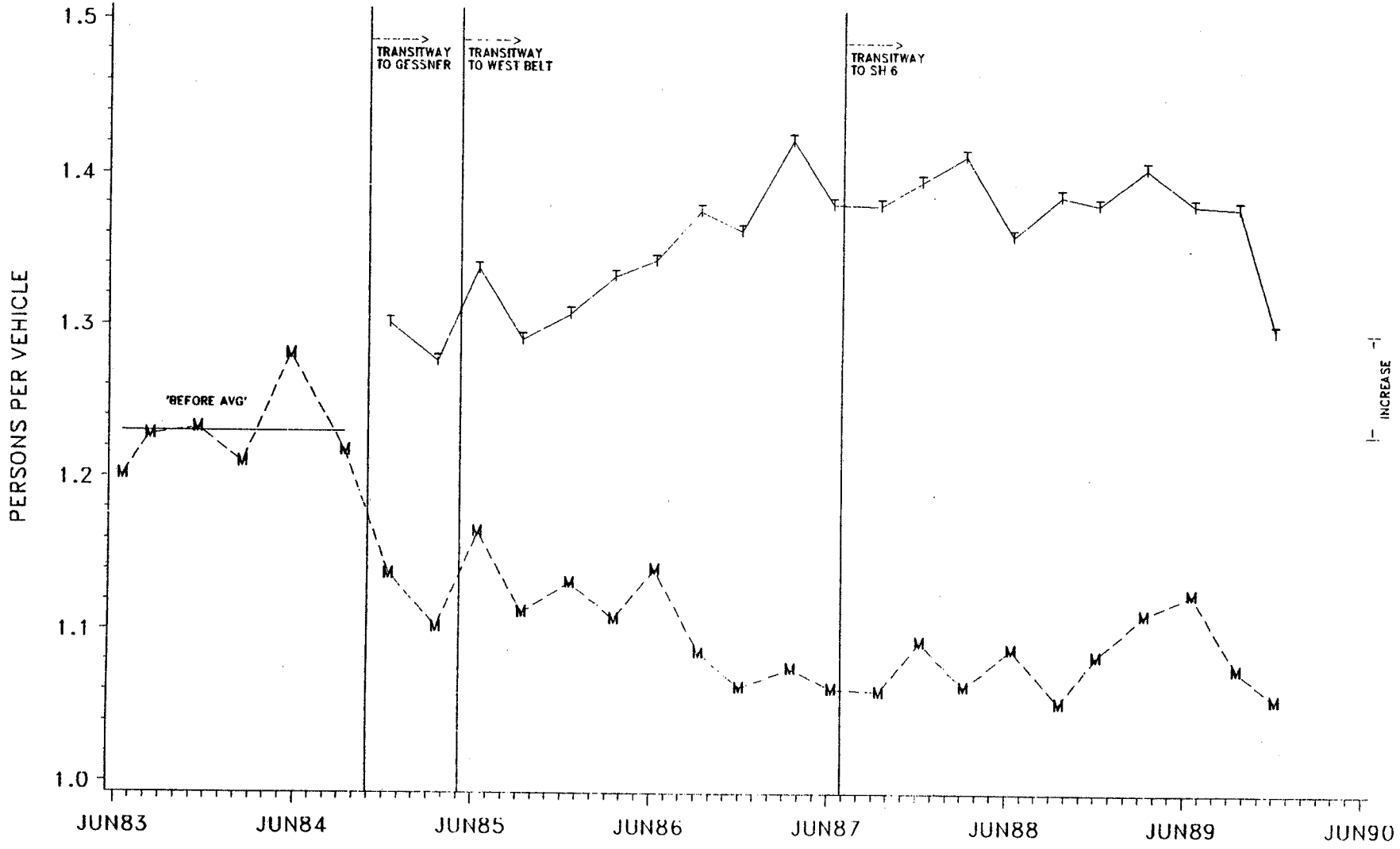


DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
3+ REQUIREMENT FROM 6:45 A.M. TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE C-12

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

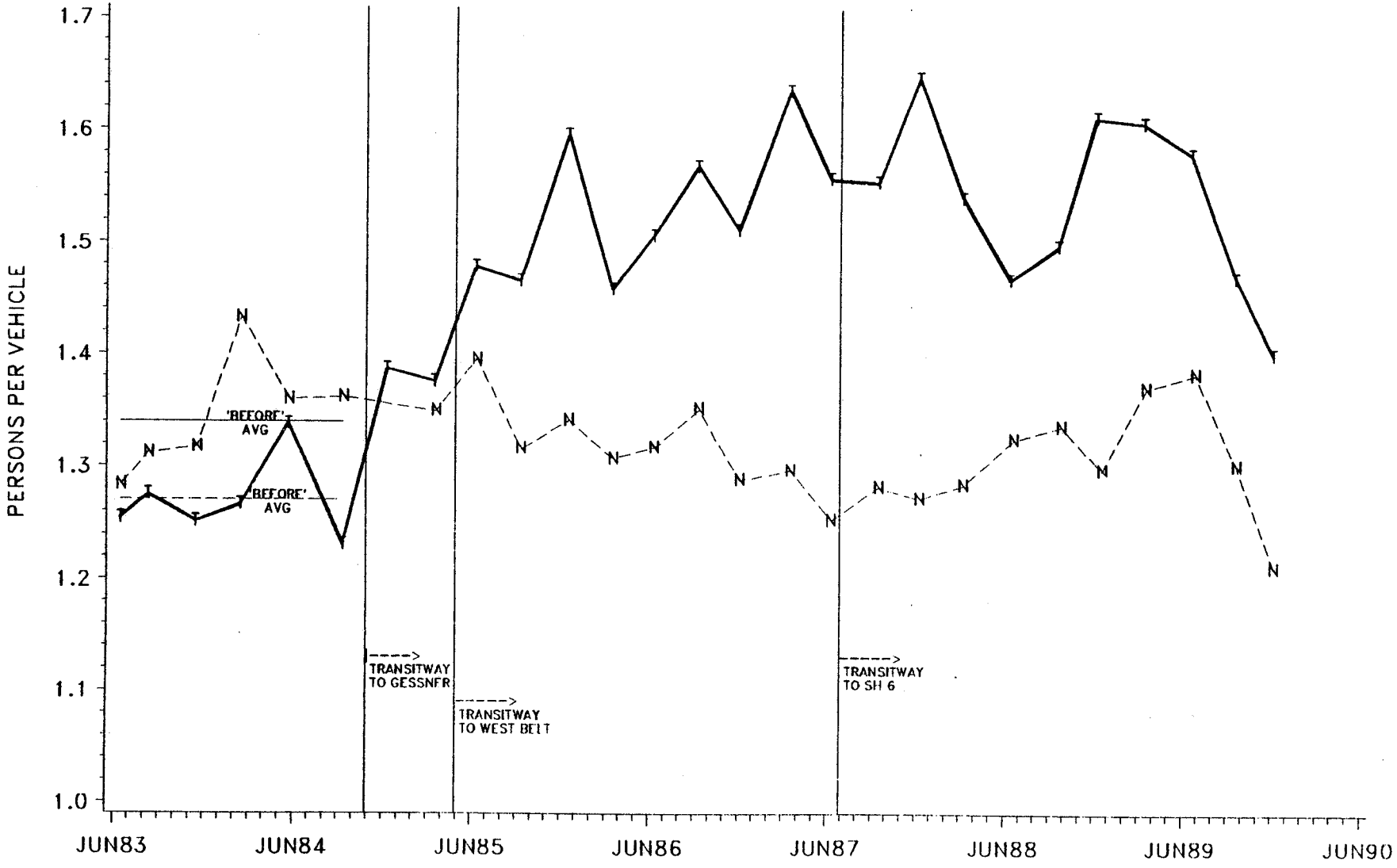


A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M
DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
3+ REQUIREMENT FROM 6:45 A.M. TO 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE C-13

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

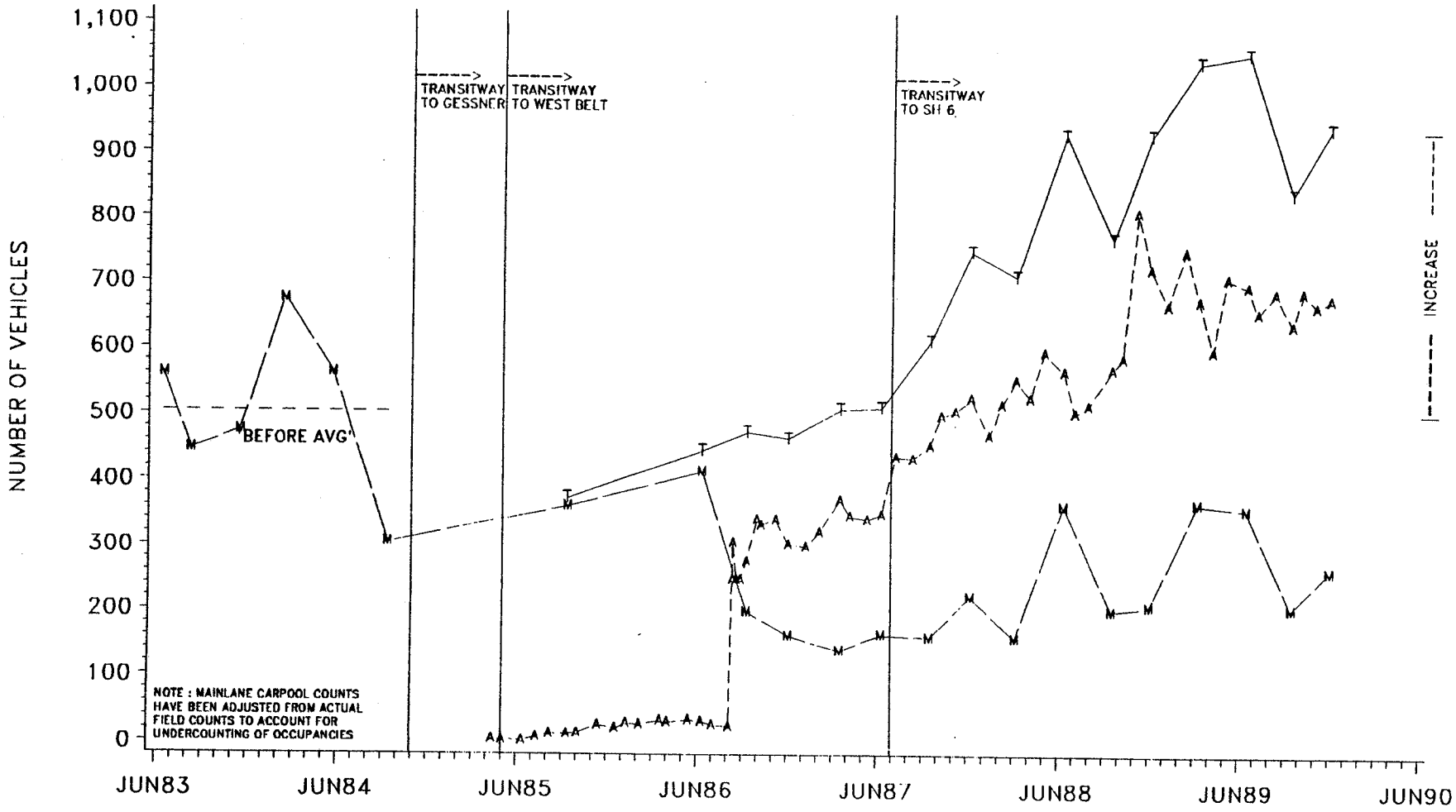


DATA FOR FREEWAYS WITHOUT TRANSITWAYS ARE A COMPOSITE OF GULF FWY (6/83 – 4/88) AND SOUTHWEST FWY (9/86 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE C-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

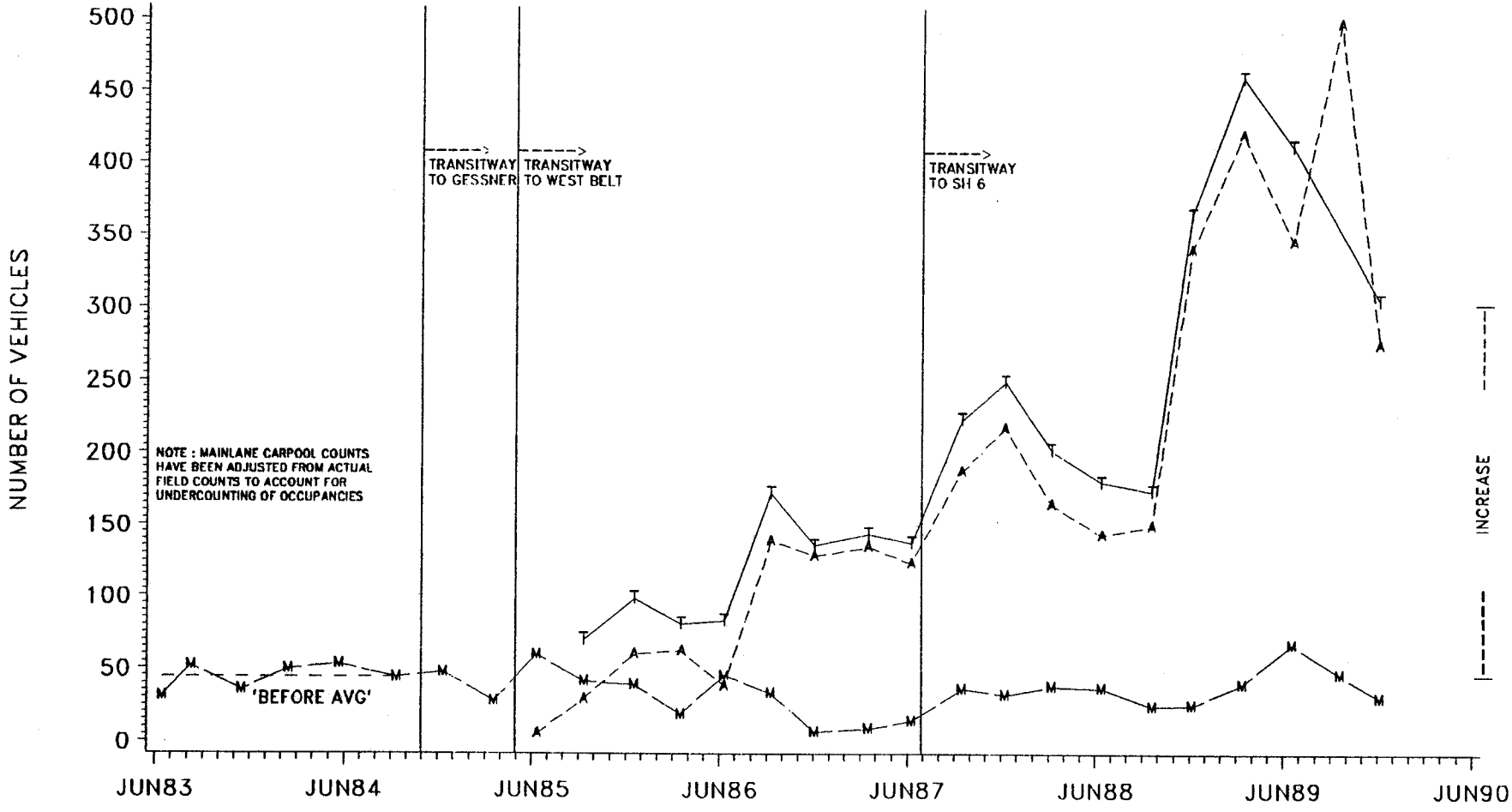


KATY TRANSITWAY PHASE 1, POST OAK TO GESSNER (4.7 MI.), OPENED OCTOBER 29, 1984
TRANSITWAY EXTENSION FROM GESSNER TO WEST BELT (1.7 MI.) OPENED MAY 2, 1985
OFF-PEAK, UNAUTHORIZED & 2+ CARPOOL OPERATION BEGAN AUGUST 11, 1986
TRANSITWAY EXTENSION FROM WEST BELT TO SH 6 (5.0 MI.) OPENED JUNE 29,1987
SOURCE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

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

FIGURE C-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
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

the implementation of the transitway (Figure C-16). This large of an increase has not occurred on freeways not having transitways (Figure C-17).

BUS TRANSIT DATA

Bus Vehicle and Passenger Trips

- In the a.m. peak hour, bus vehicle trips have been increased by 236% since the transitway opened, and a 270% increase in bus ridership has also resulted (Figure C-18). In the peak period, 162% increase has occurred in bus trips and a 194% increase in bus ridership has resulted (Figure C-19).

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

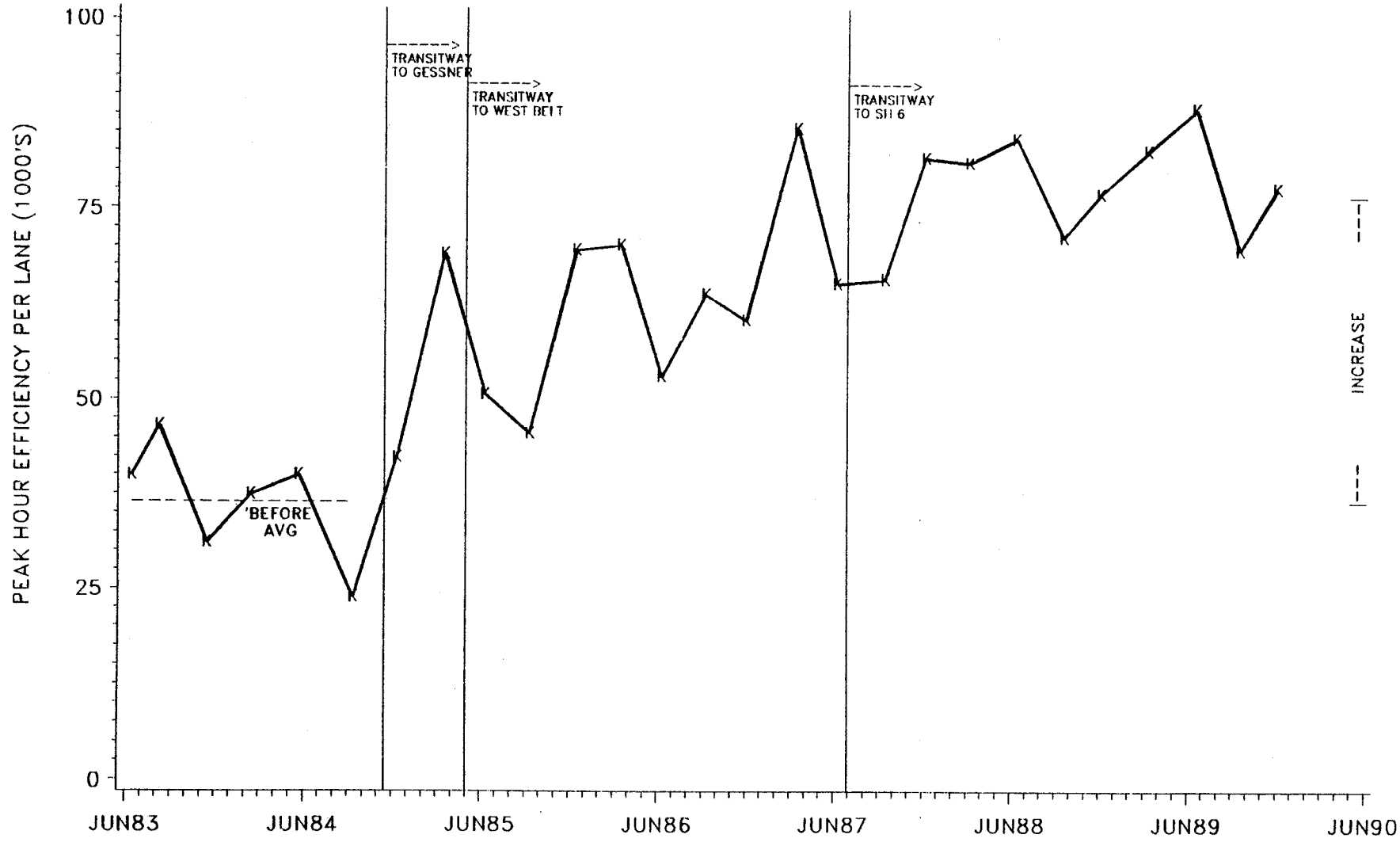
Park-and-Ride

- Prior to opening the transitway, approximately 575 vehicles were parked in corridor park-and-ride lots. This has increased 226% to a current level of 1,873 (Figure C-21).

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

FIGURE C-16

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

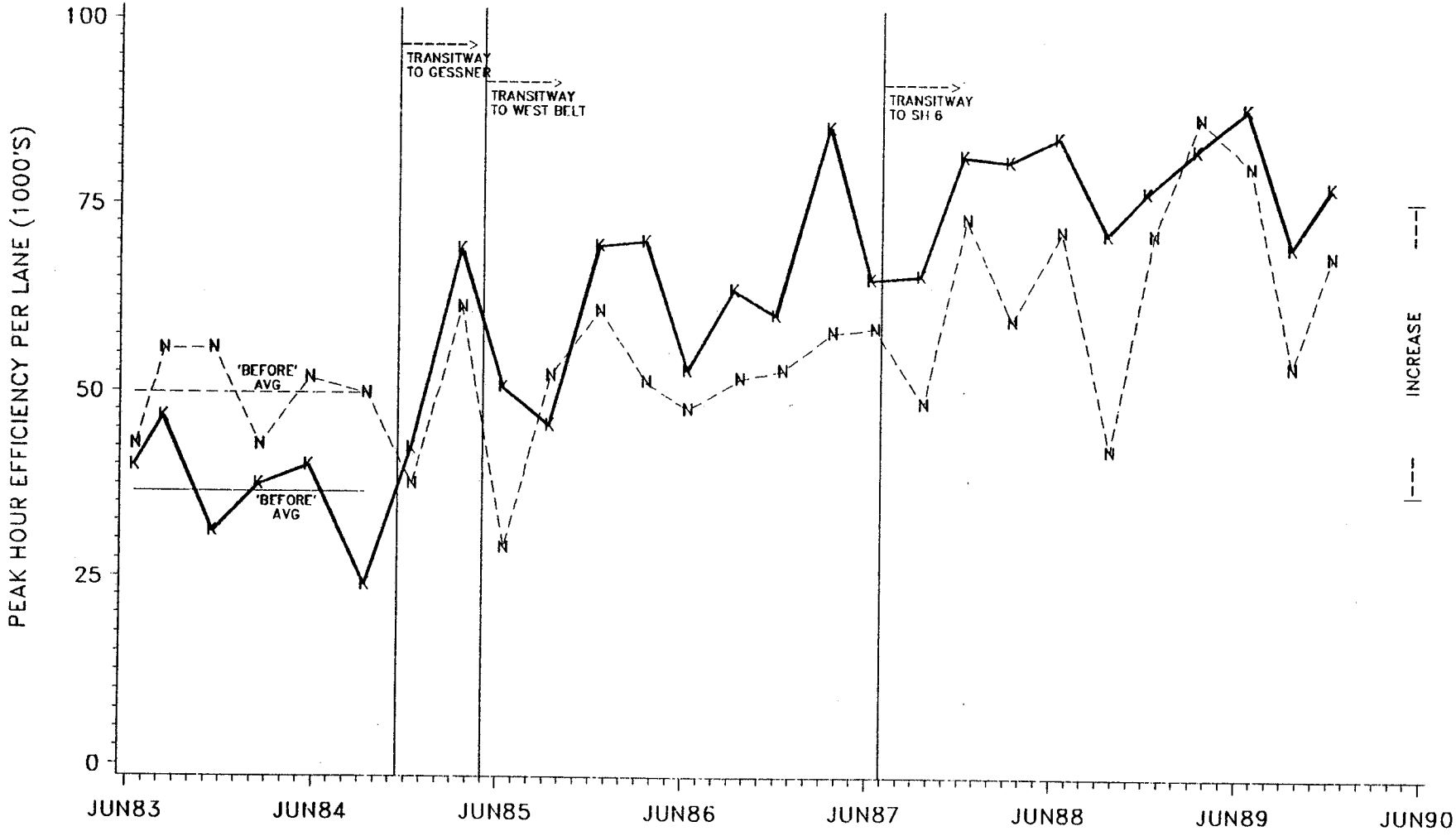


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE TRANSITWAY, IT REPRESENTS TOTAL PERSONS (FREEWAY + TRANSITWAY) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 4 LANES
SOURCE : TEXAS TRANSPORTATION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

LEGEND : K = KATY FREEWAY EFFICIENCY

FIGURE C-17

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

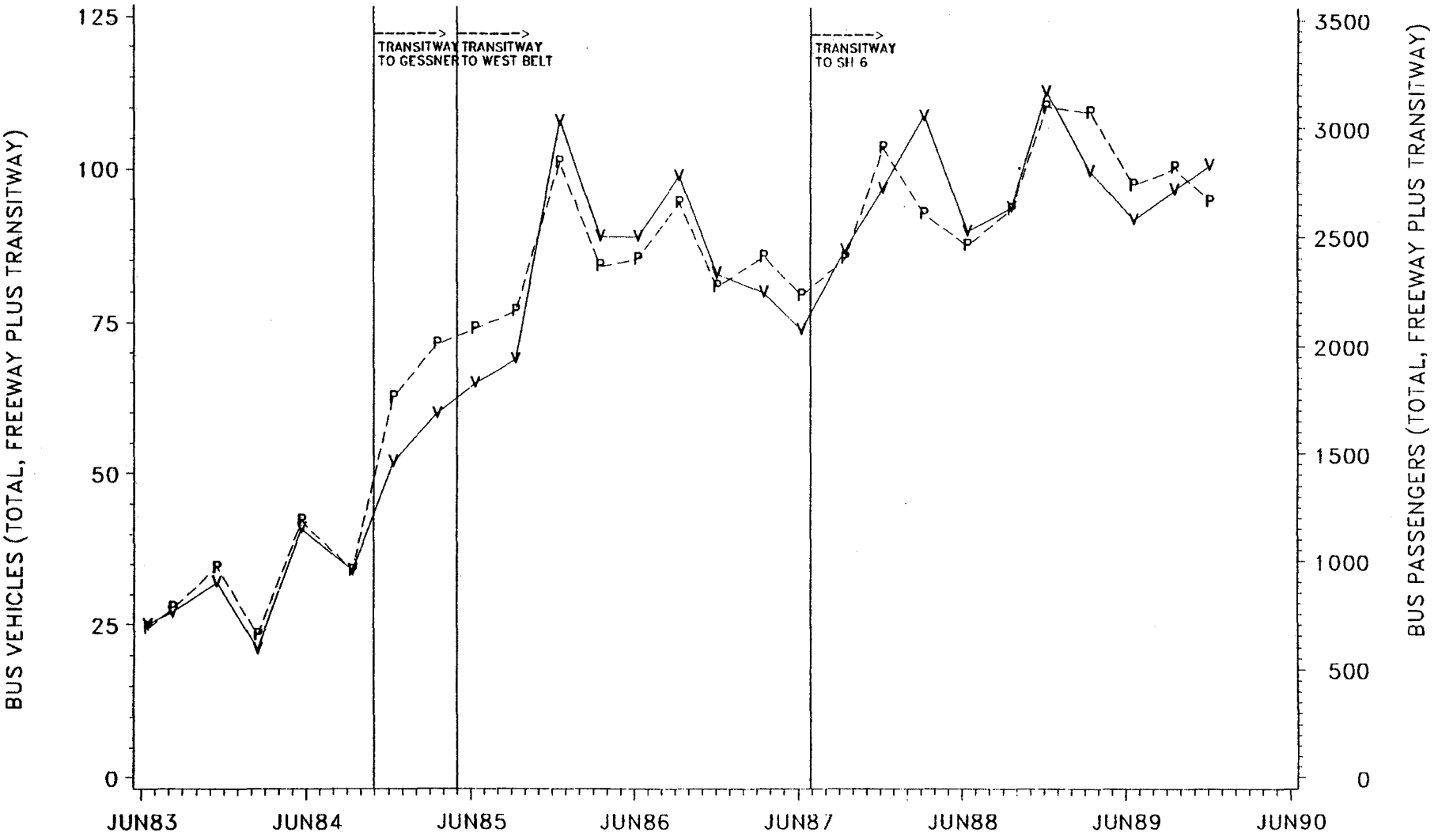


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE TRANSITWAY, IT REPRESENTS TOTAL PERSONS (FREEWAY + TRANSITWAY) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 4 LANES
DATA FOR FREEWAYS WITHOUT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

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

FIGURE C-18

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

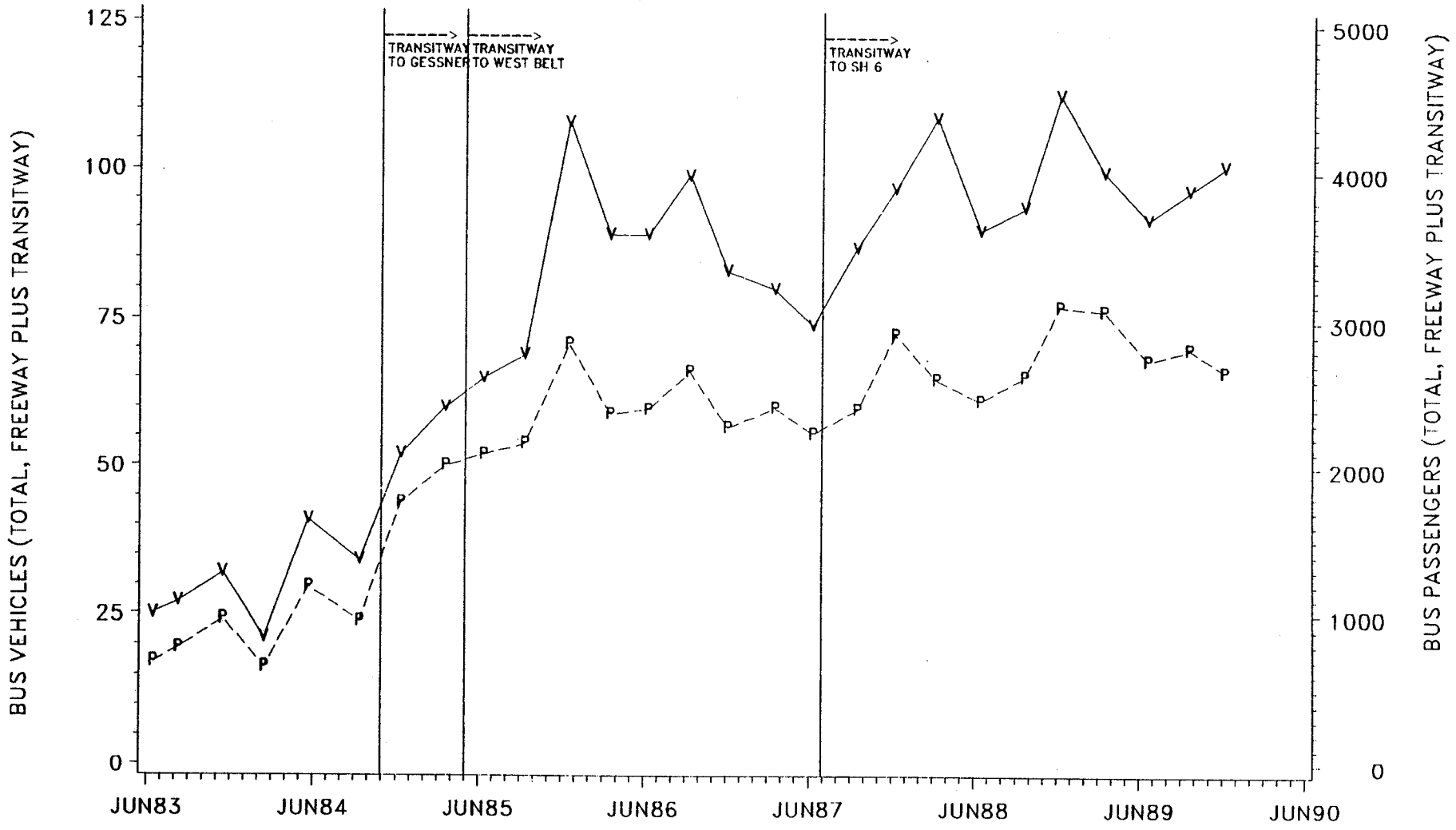


DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE C-19

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

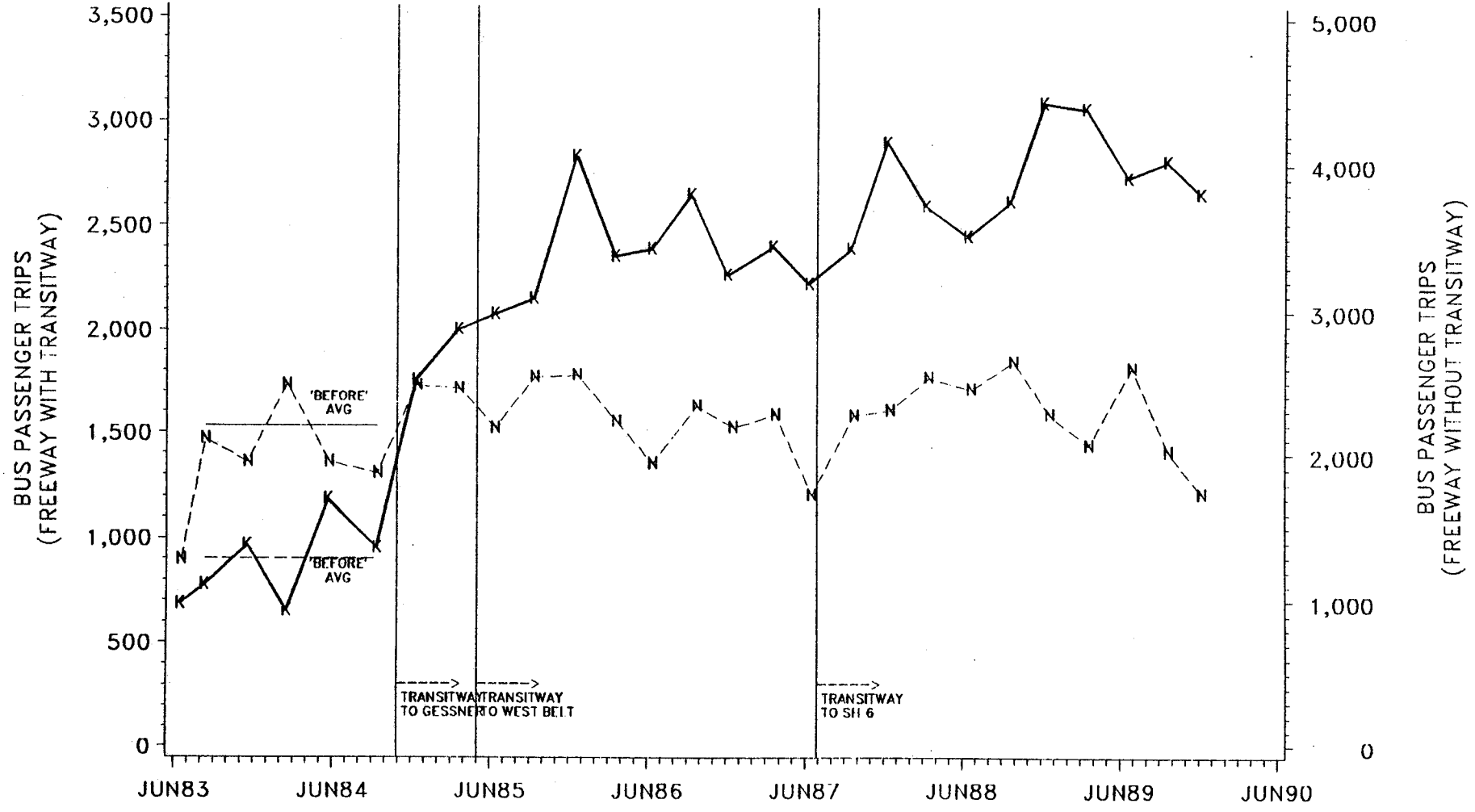


A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA COLLECTED EASTBOUND OVER BUNKER HILL, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE C-20

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

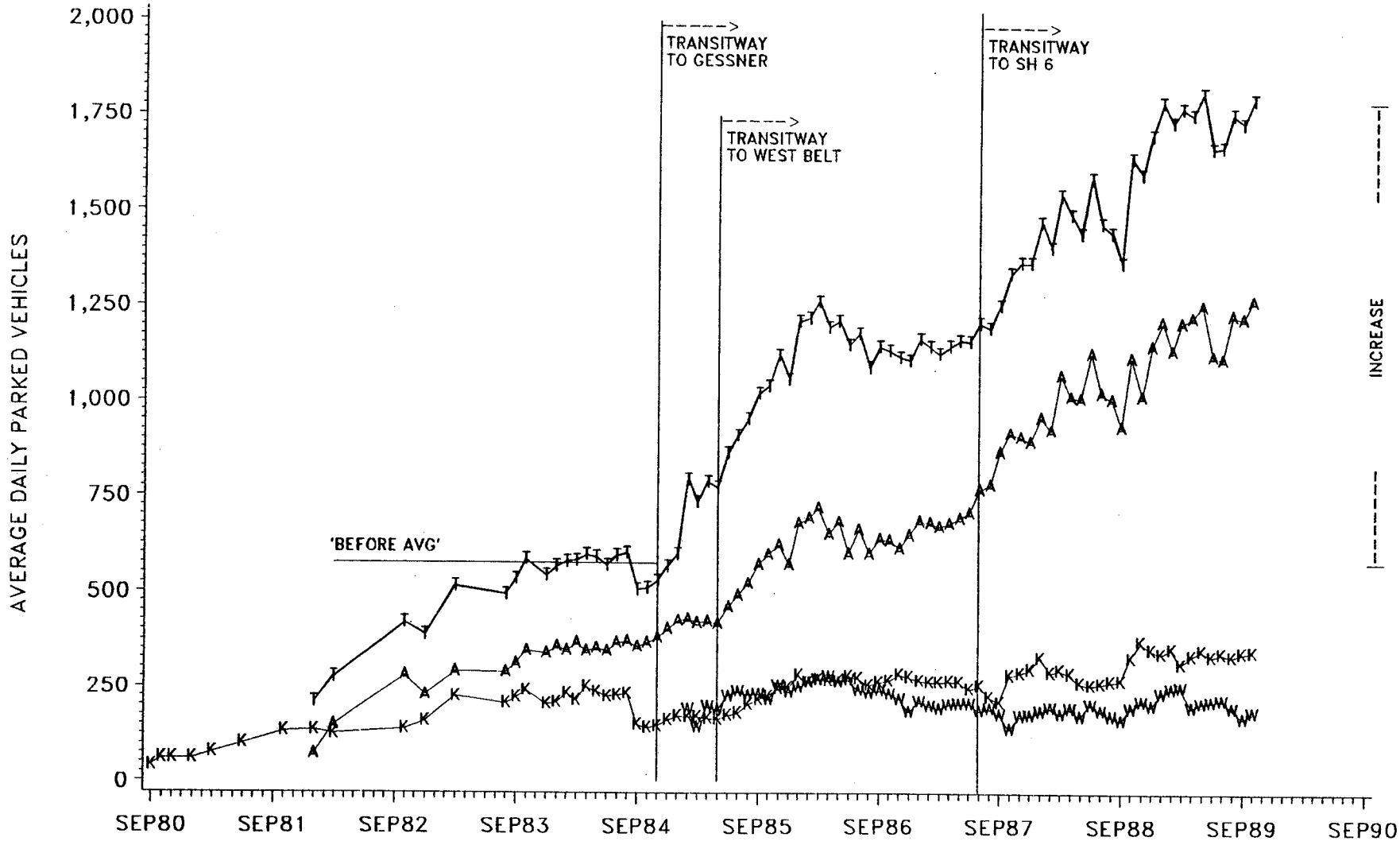


A.M. PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA FOR FREEWAYS WITHOUT TRANSITWAYS ARE A COMPOSITE OF
GULF FWY (6/83 – 4/88) AND SOUTHWEST FWY (9/86 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE C-21

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

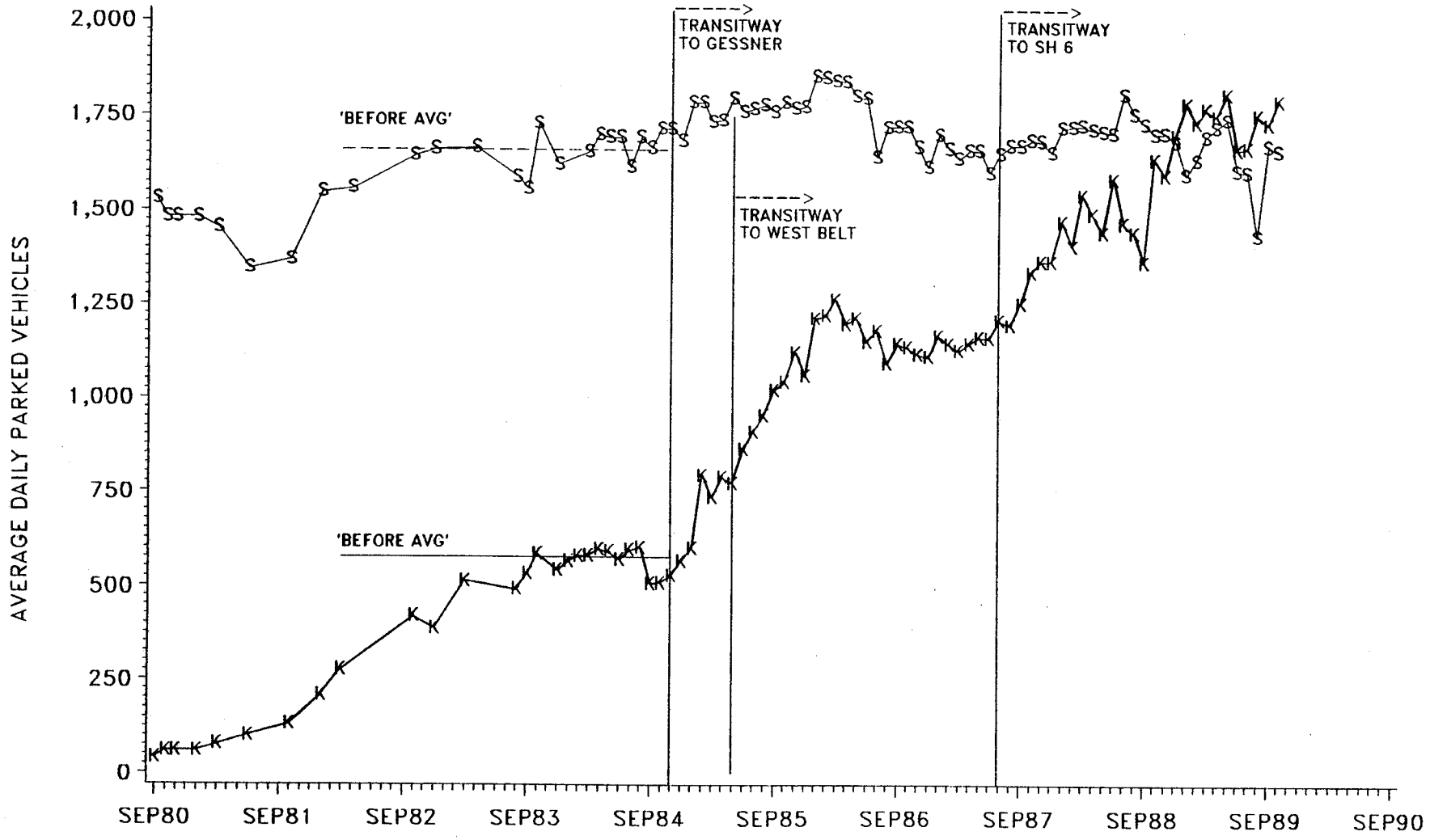


KATY TRANSITWAY PHASE 1, POST OAK TO GESSNER (4.7 MI.), OPENED OCTOBER 29, 1984
TRANSITWAY EXTENSION FROM GESSNER TO WEST BELT (1.7 MI.) OPENED MAY 2,1985
TRANSITWAY EXTENSION FROM WEST BELT TO SH 6 (5.0 MI.) OPENED JUNE 29,1987
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE C-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
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

APPENDIX D

GULF FREEWAY AND TRANSITWAY DATA

GULF FREEWAY (I-45) AND TRANSITWAY, HOUSTON

Summary of A.M. Peak-Period, Peak-Direction Gulf Freeway and Transitway Data, December 1989
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)		$27.3	
Person-Movement			
Peak Hour (7-8 a.m.)	—	2,923	—
Peak Period (6-9:30 a.m.)	—	4,300	—
Total Daily	—	8,139	—
Vehicle Volumes			
Peak Hour	—	878	—
Peak Period	—	1,227	—
Vehicle Occupancy, Peak Hour (persons/veh)	—	3.33	—
Accident Rate (Accidents/MVM)	—	1.59	—
Vehicle Breakdowns (VMT/Breakdown), 9/88 - 12/89	—	33,312	—
Violation Rate		1%	
Peak Hour Lane Efficiency[1](1000's)	—	146	—
Annual Value of User Time Saved (millions)[6]	—	$0.6 to $1.1	—
Freeway Mainlane Data[7] (see note)			
Person Movement			
Peak Hour	7,159	—	—
Peak Period (6:00-9:30 a.m.)	20,132	—	—
Vehicle Volume			
Peak Hour	6,141	—	—
Peak Period	17,682	—	—
Vehicle Occupancy, Peak Hour (persons/veh)	1.17	—	—
Accident Rate (Accidents/MVM)[2]	1.72	1.50	-12.8%
Avg. Operating Speed[3]			
Peak Hour	47	—	—
Peak Period	51	—	—
Peak Hour Lane Efficiency[1] (1000's)	122	—	—
Combined Freeway Mainlane and Transitway Data			
Total Person Movement			
Peak Hour	7,159	—	—
Peak Period	20,132	—	—
Vehicle Volume			
Peak Hour	6,141	—	—
Peak Period	17,682	—	—
Vehicle Occupancy			
Peak Hour	1.17	—	—
Peak Period	1.14	—	—
2+ Carpool Volumes			
Peak Hour	270	—	—
Peak Period	785	—	—
Travel Time (minutes)[3]			
Peak Hour	12[4]	7.5[5]	-37.5%
Peak Period	9.0[4]	7.0[5]	-22.2%
Peak Hour Lane Efficiency[1] (1000's)	—	—	—

Summary of A.M. Peak-Period, Peak-Direction Transitway Data, December 1989 Continued

Type of Data	"Representative" Pre-Transitway Value	"Representative" Current Value	% Change
Transit Data			
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	1,200	+7.6%
Bus Operating Speed (mph)[3]			
Peak Hour	30.7[4]	50.1[5]	+63.2%
Peak Period	41.7[4]	53.7[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 can be considered to be low.

Footnotes on following page.

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

Measure of Effectiveness	"Representative" Pre-Transitway Value	"Representative" Current Value	% Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/transitway	1.29	—	—
Freeway w/o transitway	1.26	1.32	+ 4.8%
A.M. Peak Hour, 2+ Carpool Volume Change			
Freeway w/transitway	475	—	—
Freeway w/o transitway	595	595	- 0.0%
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	1,200	+ 7.6%
Freeway w/o transitway	1,680	1,665	- 0.9%
Facility Per Lane Efficiency[1]			
Freeway w/transitway	—	—	—
Freeway w/o transitway	76	74	- 2.6%

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 9/89.
[3]From Broadway 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 1989 and transitway volumes in 1989, an annual estimate of travel time savings to transitway users is developed. A value of time of $9/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

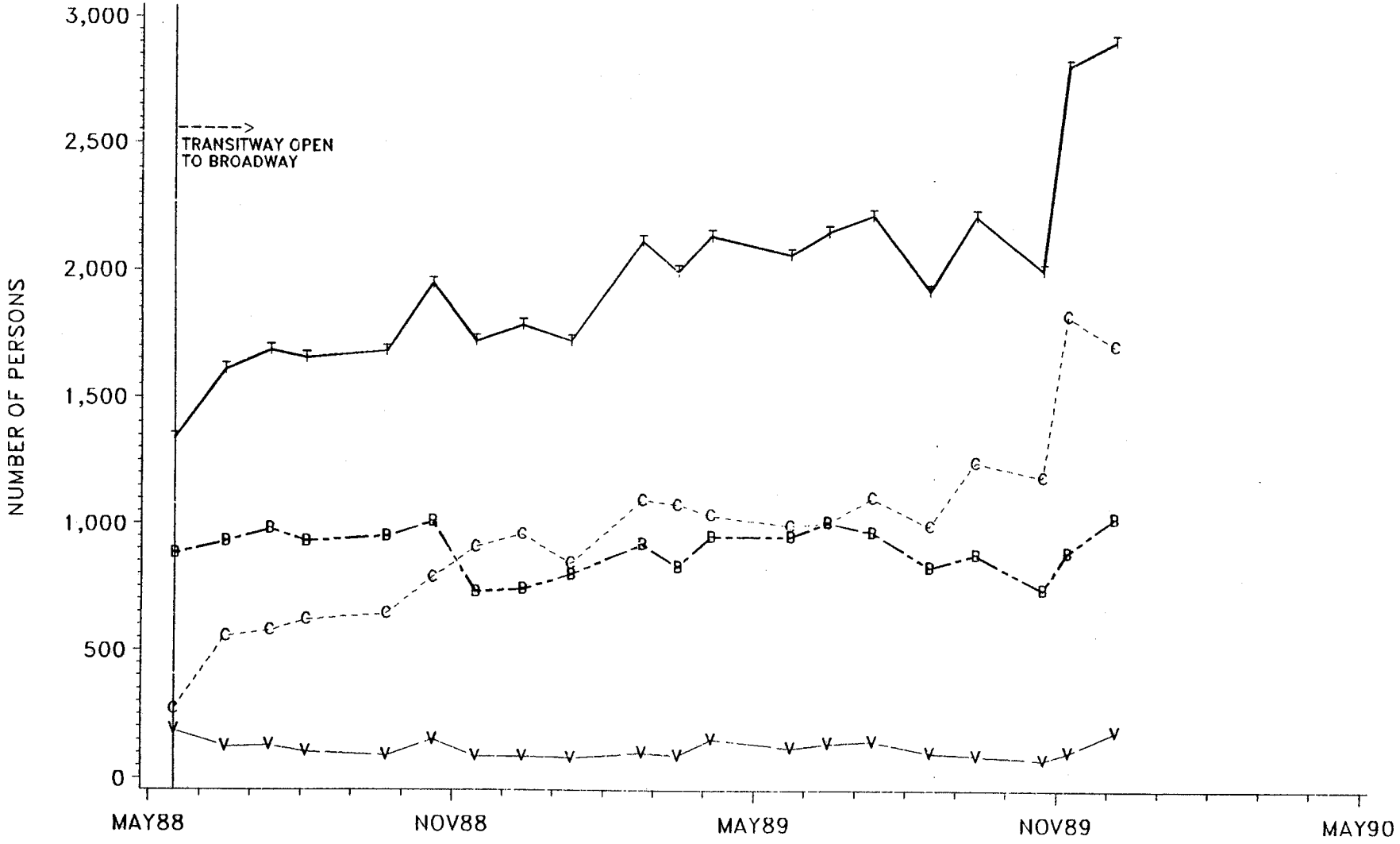
- Phase 1 of the transitway opened May 16, 1988.
- An 6.5 mile transitway operates on the Gulf Freeway (I-45) between Broadway and downtown. The transitway operates inbound from 4:00 a.m. to 1:00 p.m. and outbound from 2:00 p.m. to 10:00 p.m. It operates outbound on Saturdays from 4 a.m. to 10 p.m. and inbound on Sundays during the same hours.
- The transitway (6.5 miles) was constructed for approximately $27.3 million.
- In December 1989, 8,139 person trips per day were served on the transitway. The transitway is used by buses and 2+ carpools.

Person Movement

- A.M. Peak Hour (7-8 a.m.), 2,923 persons/hour.
    - 1,030 (35%) by bus, 182 (6%) by vanpool, 1711 (59%) by carpool (Figure D-1).
    - Average transitway vehicle occupancy = 3.33 persons/vehicle.
- A.M. Peak Period (6-9:30 a.m.), 4,300 persons.

FIGURE D-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

- 1,700 (40%) by bus, 243 (6%) by vanpool, 2,357 (54%) by carpool (Figure D-2).

Vehicle Movement

- A.M. Peak Hour, 878 vph.
  - 30 (3%) bus, 20 (2%) vans, 828 (95%) carpools (Figure D-3).
- A.M. Peak Period (6-9:30 a.m.), 1,227 vehicles.
  - 57 (5%) bus, 28 (2%) vans, 1,142 (93%) carpools (Figure D-4).

Vehicle Breakdown Rates

- As measured from September 1, 1988 through December 1989, the following rates have been observed.
  - Buses; 1 breakdown per 43,547 vehicle-miles of travel (VMT).
  - Vanpools; 0 breakdowns.
  - Carpools; 1 breakdown per 31,568 VMT.
  - Weighted average; 1 breakdown per 33,312 VMT.

Peak Hour Lane Efficiency

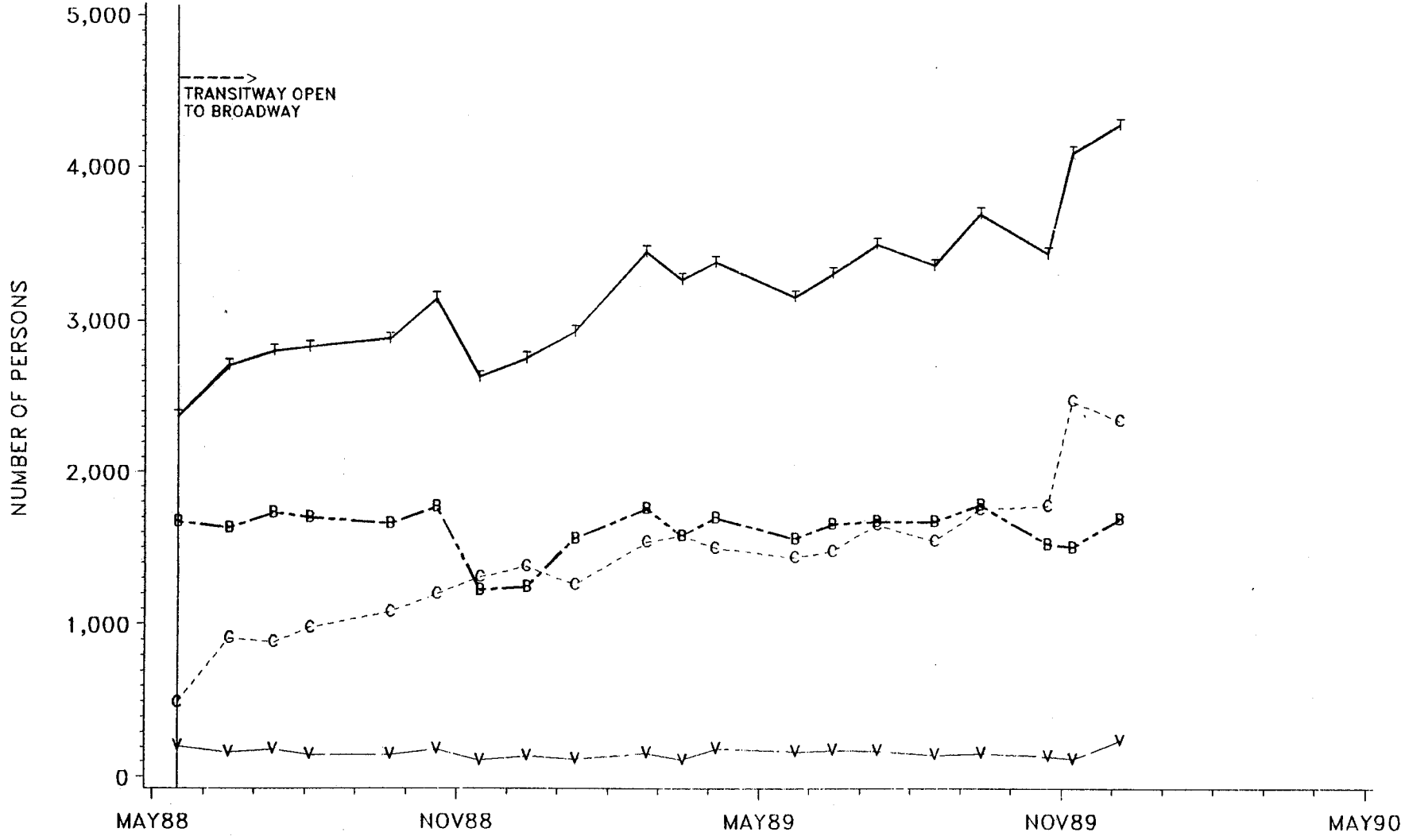
- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. For the transitway lane, this value (expressed in 1000's) is approximately 146 (2,923 persons at 50 mph).

Travel Time Savings

- The users of the transitway experience a travel time savings (Figure D-5).
- The tables below indicate that, on a typical non-incident day, travel time savings of approximately 2,484 hours (14,905 min.) are realized. Assuming 250 days of operation, annual savings would be 62,100 hours. At $9/hour, this equates to about $560,000 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 $0.6 to $1.2 million per year.

FIGURE D-2

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



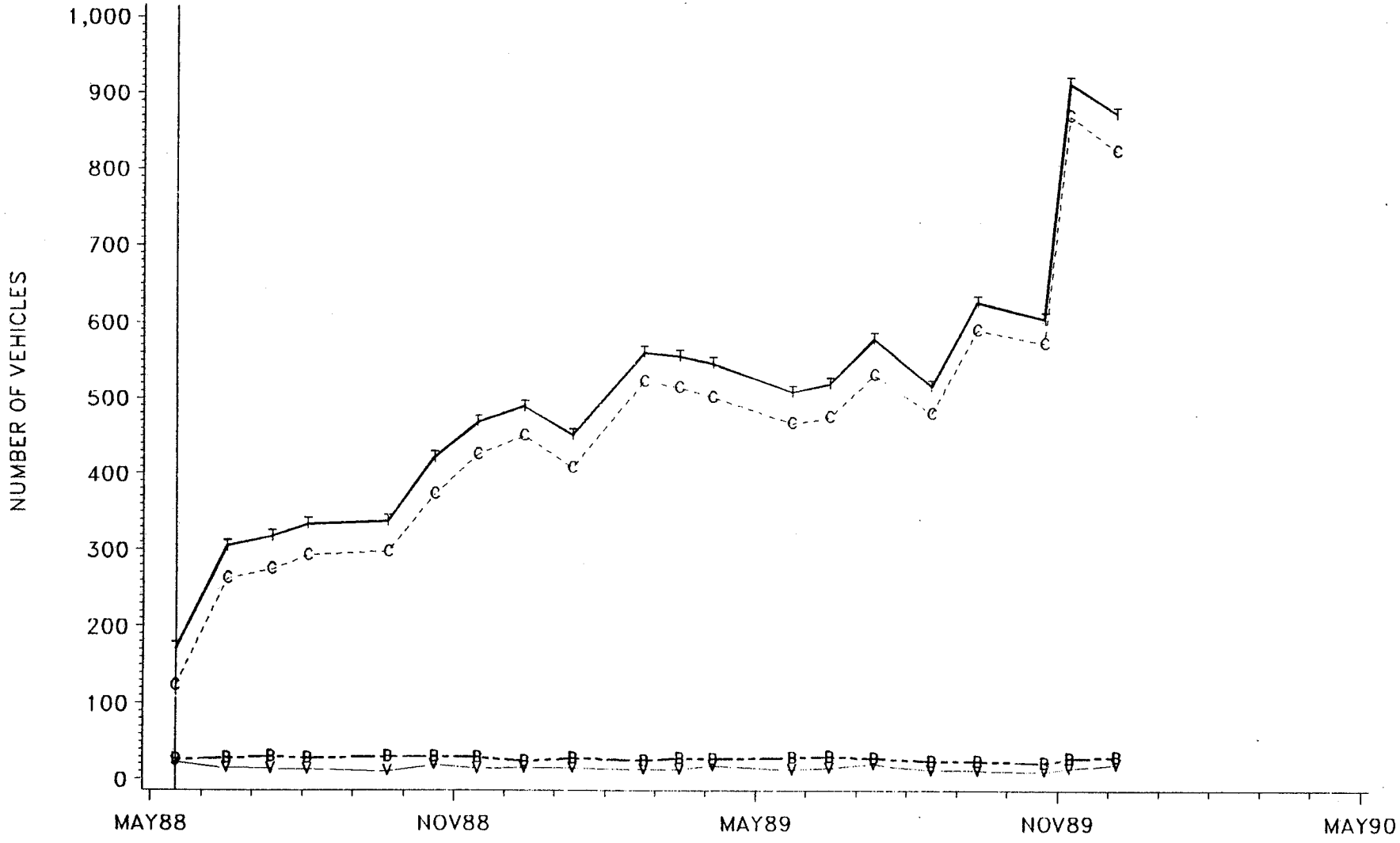
GULF TRANSITWAY, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988
PEAK PERIOD IS FROM 6:00 – 9:30 A.M.

SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-3

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



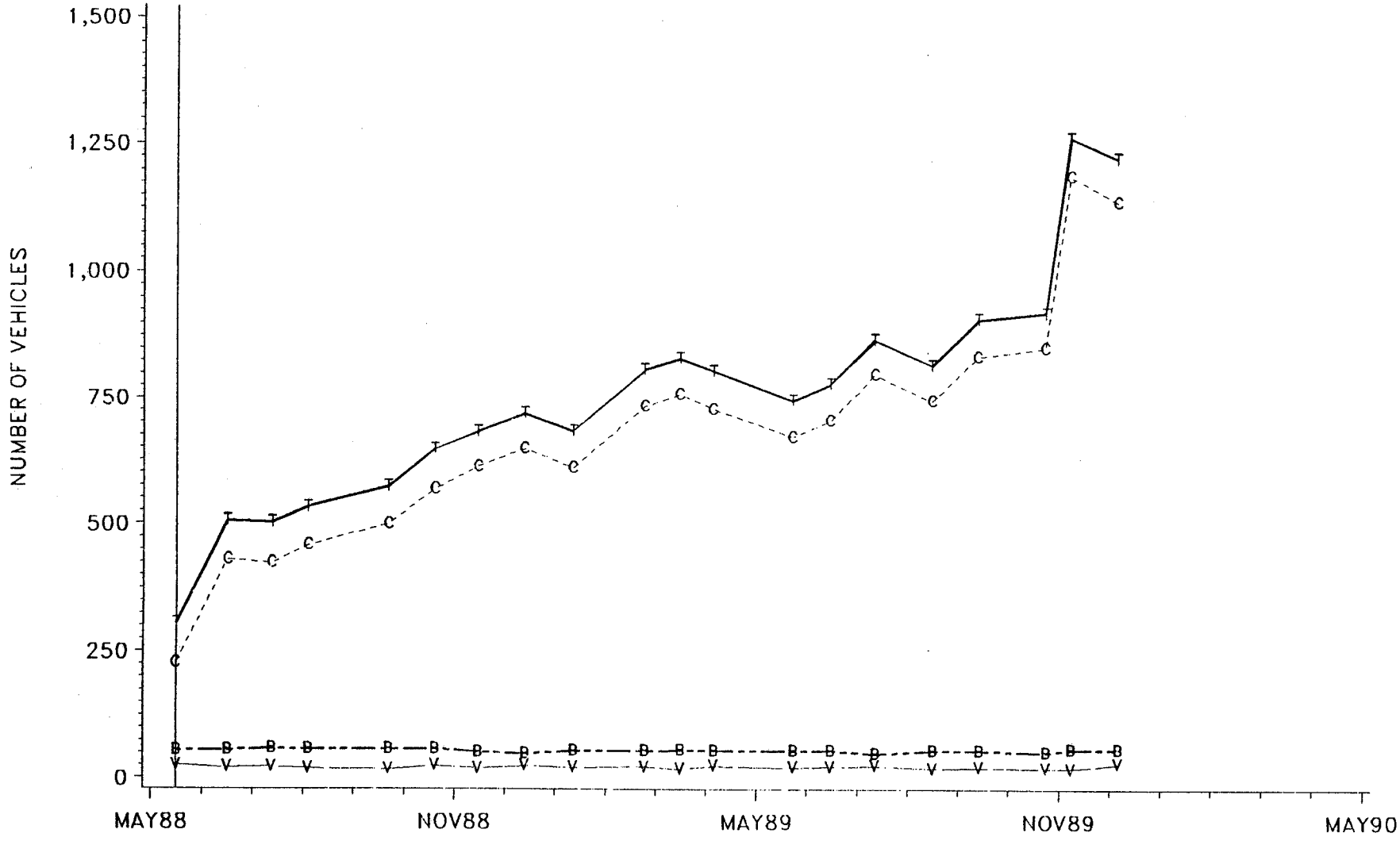
GULF TRANSITWAY, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988

SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-4

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



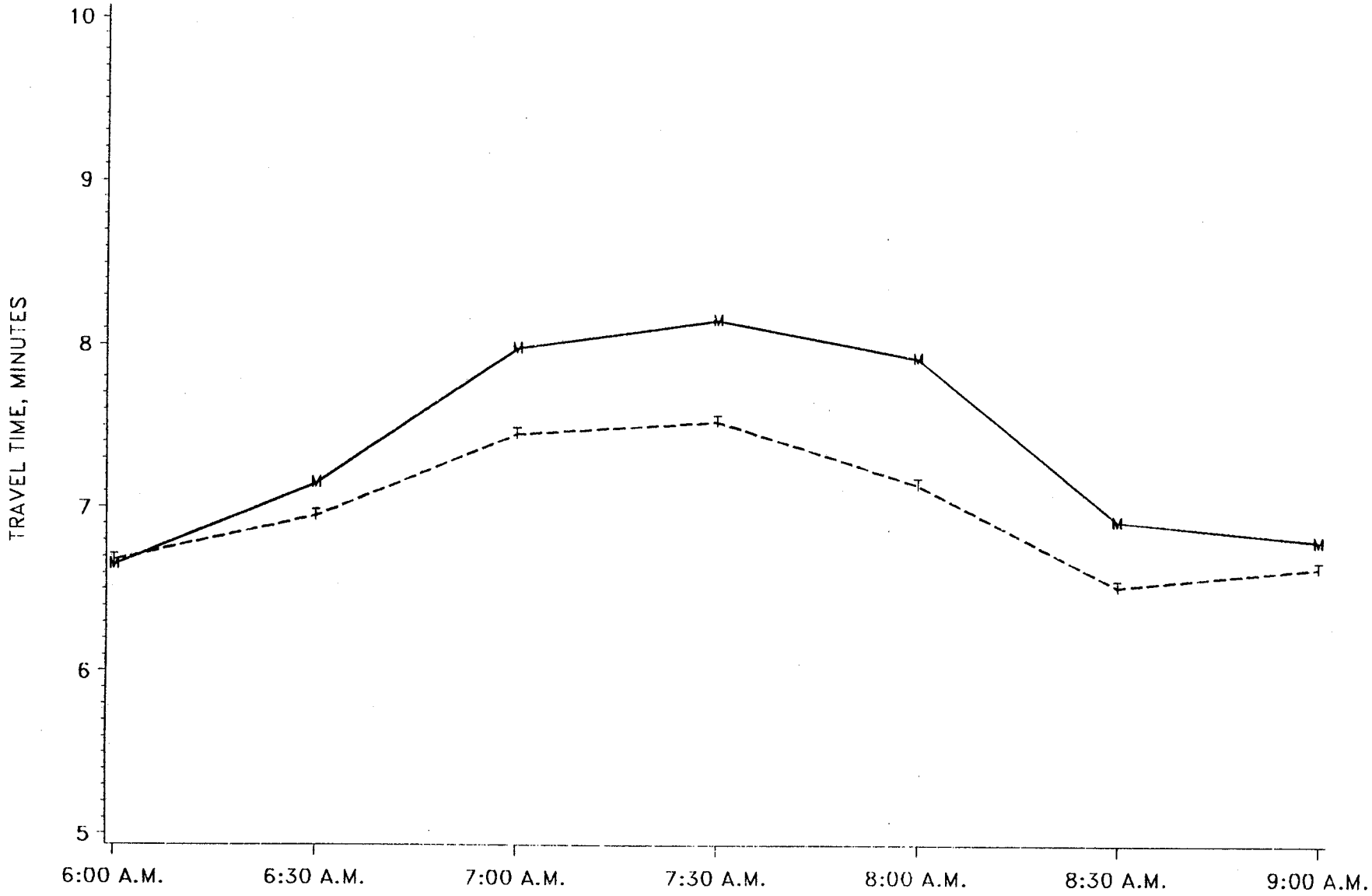
GULF TRANSITWAY, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988
PEAK PERIOD IS FROM 6:00 – 9:30 A.M.

SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-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

Northbound AM Travel Time Savings for Gulf Transitway
Average of 4 Quarterly Travel Time Surveys in 1989

Time of Day	Average Travel Time		Time Saved (minutes)	Transitway Person Volumes			Total Persons	Travel Time Saved (person minutes)
	Freeway (minutes)	Transitway (minutes)		Vans	Buses	Persons		
6:00 a.m.	6.65	6.68	-0.03	4	97	30	131	- 3.64
6:30 a.m.	7.15	6.95	0.20	27	300	139	466	93.15
7:00 a.m.	7.98	7.45	0.53	95	403	441	938	496.36
7:30 a.m.	8.16	7.53	0.63	33	505	795	1333	846.08
8:00 a.m.	7.93	7.15	0.78	9	304	269	582	452.41
8:30 a.m.	6.93	6.53	0.40	3	93	89	185	74.00
9:00 a.m.	6.81	6.65	0.16	0	3	22	25	3.92
Peak Period				171	1704	1784	3659	1962.28

Southbound PM Travel Time Savings for Gulf Transitway
Average of 4 Quarterly Travel Time Surveys in 1989

Time of Day	Average Travel Time		Time Saved (minutes)	Transitway Person Volumes			Total Persons	Travel Time Saved (person minutes)
	Freeway (minutes)	Transitway (minutes)		Vans	Buses	Persons		
3:30 p.m.	7.10	6.76	0.33	11	80	49	141	47.03
4:00 p.m.	11.03	6.92	4.11	37	221	130	387	1591.00
4:30 p.m.	10.28	7.02	3.26	57	380	245	682	2220.42
5:00 p.m.	11.05	7.54	3.51	70	495	489	1054	3694.86
5:30 p.m.	13.12	7.11	6.02	14	386	316	716	4303.93
6:00 p.m.	11.00	7.49	3.51	2	141	125	267	937.47
6:30 p.m.	7.95	6.46	1.49	3	47	49	98	146.41
Peak Period				193	1750	1401	3344	12941.11

Note: The peak-hour volumes in these tables do not exactly agree with those presented in the summary table. The summary table was based on 15-minute volume data. The data for the analyses summarized in the above tables are based on 30-minute volume counts.

FREEWAY MAINLANE DATA

Note

- 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 7,159 (Figure D-6).
- In the a.m. peak period, person movement is approximately 20,132 (Figure D-7).

Vehicle Volume

- In the a.m. peak hour, vehicle volume is 6,141 vph (Figure D-6).
- In the a.m. peak period, vehicle volume is 17,682 (Figure D-7).

Vehicle Occupancy

- In the a.m. peak hour, mainlane occupancy is 1.17 persons per vehicle.
- In the a.m. peak period, mainlane occupancy is 1.14 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 1.72 accidents per million vehicle miles (MVM). "After transitway" accident rate for the mainlanes is 1.50 accidents per MVM and includes the period 6/88 to 9/89. 1989 volumes estimated by TTI to compute rates.

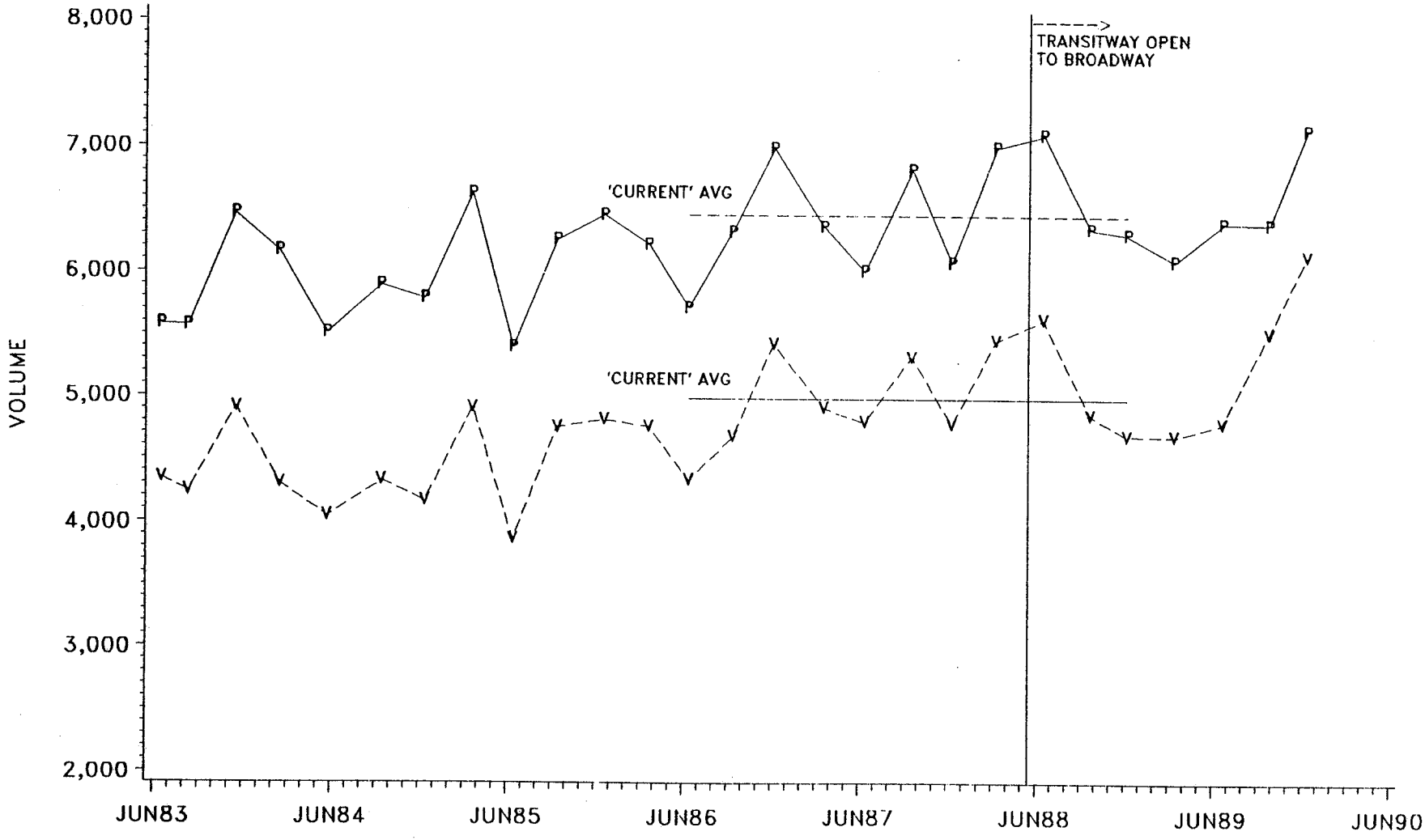
Average Operating Speed

- 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 slightly outside South Loop 610, where the transitway has yet to be implemented (Figure D-8).

Peak Hour Lane Efficiency

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

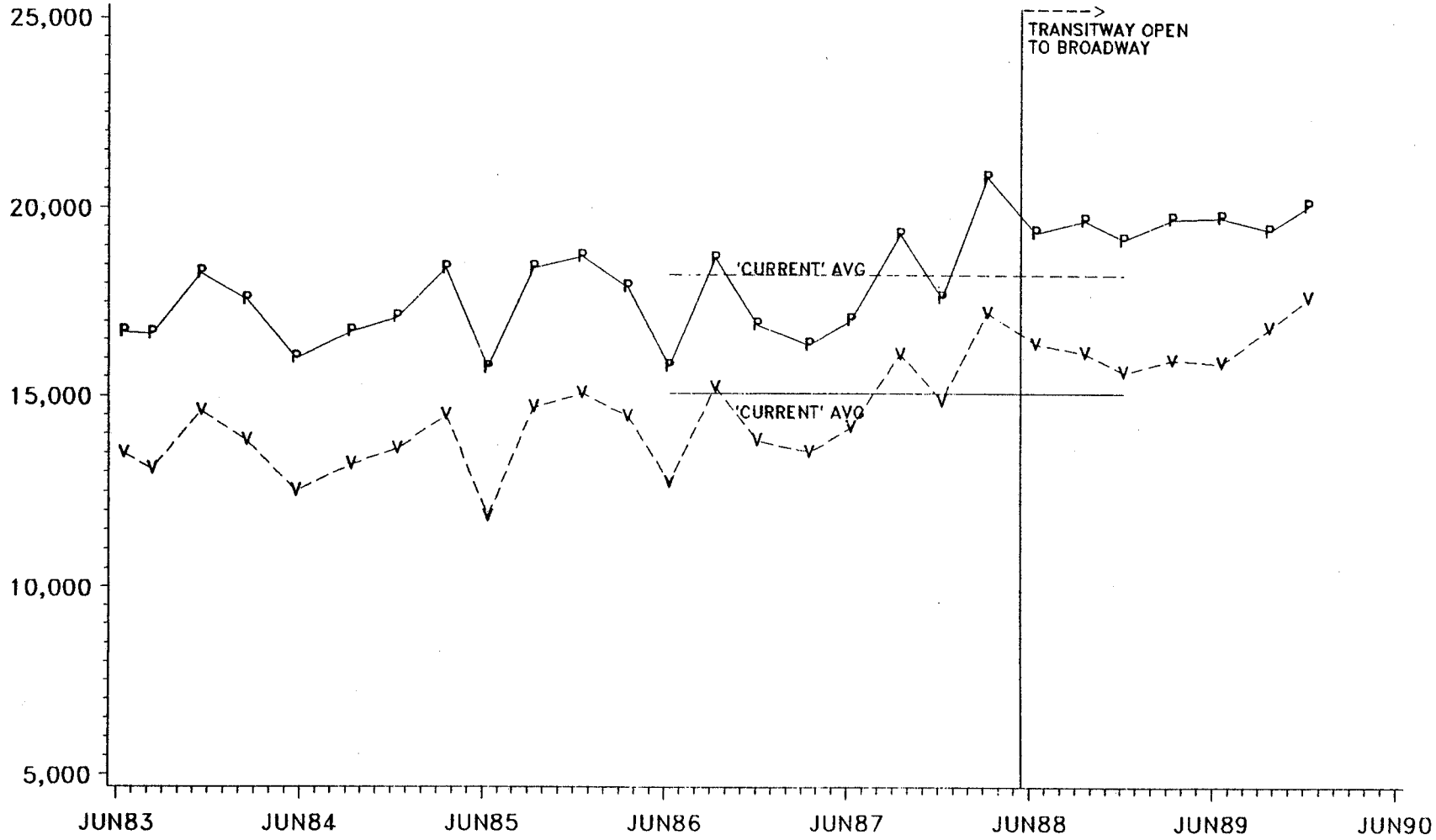
FIGURE D-6
GULF FREEWAY (IH 45S)
A.M. PEAK HOUR MAINLANE TRIPS



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

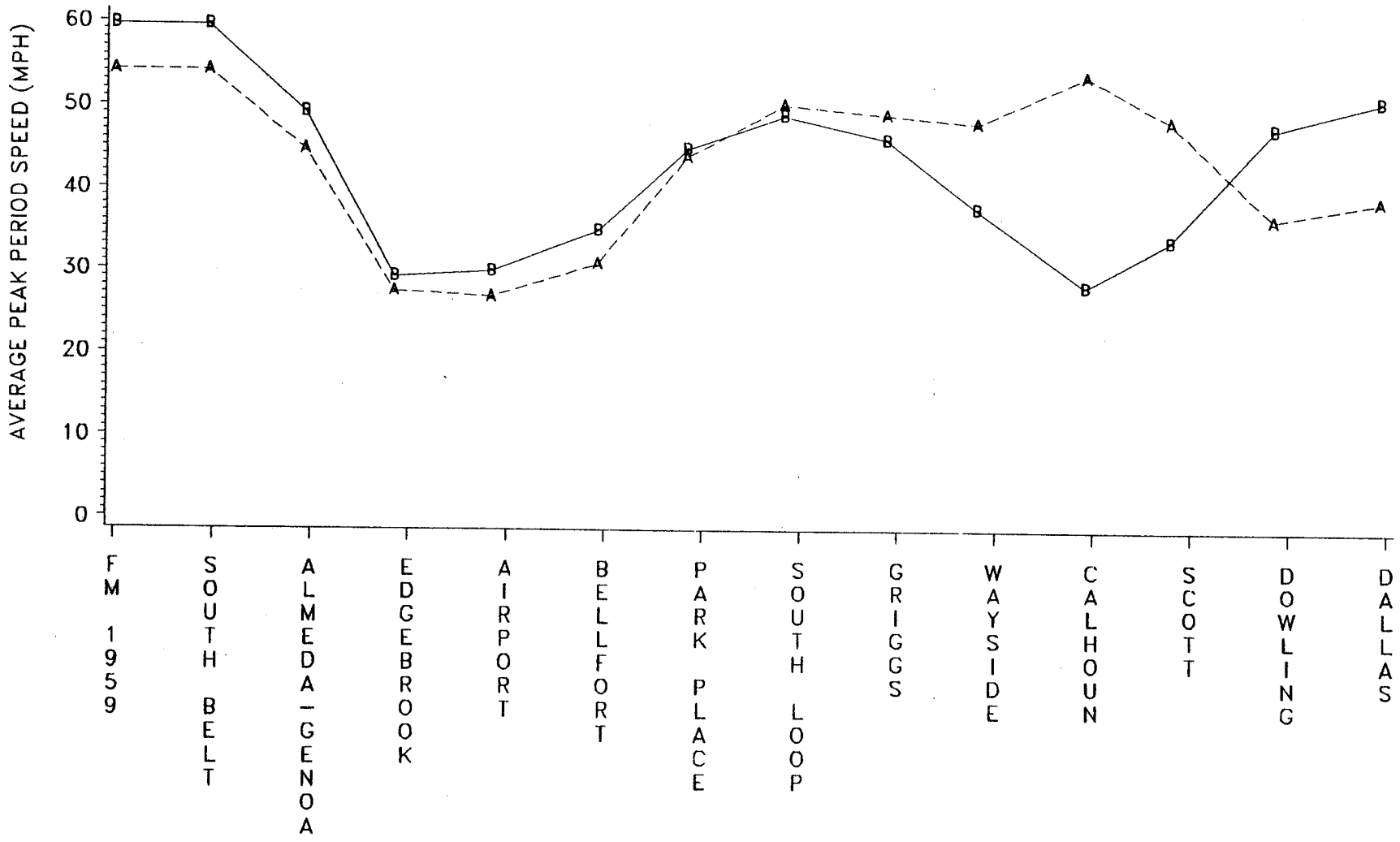
FIGURE D-7
GULF FREEWAY (IH 45S)
A.M. PEAK PERIOD MAINLANE TRIPS



A.M. PEAK PERIOD DEFINED AS FROM 6:00 TO 9:30 A.M.
DATA COLLECTED AT MONROE
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 D-8
GULF FREEWAY (IH 45S) MAINLANE TRAVEL TIME AND SPEED SURVEY
NORTHBOUND, CHOATE RD (FM 1959) TO DALLAS
A.M. PEAK PERIOD



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

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

- The freeway efficiency as measured at Monroe has been varying significantly (Figure D-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 has been varying significantly (Figure D-10). The peak-period volume is shown in Figure D-11.

Peak Hour Lane Efficiency (see note)

BUS TRANSIT

Note

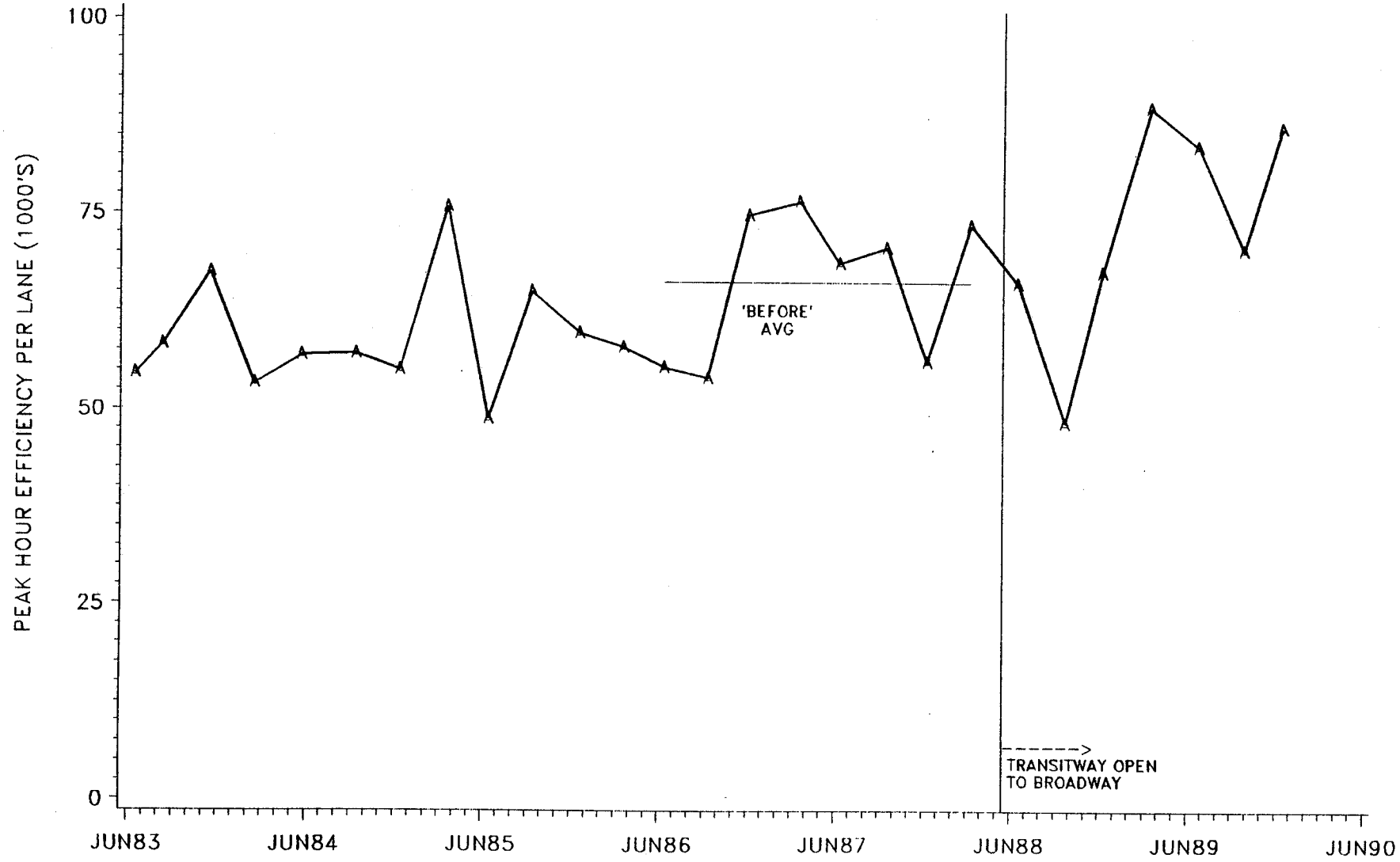
- Transitway data are routinely collected at Telephone Road and freeway data at Monroe. Until the transitway is completed to Monroe, it is not appropriate to combine or compare freeway and transitway data.

Bus Vehicle and Passenger Trips (see note)

- Bus vehicle and passenger trips as counted on the freeway mainlanes at Monroe show: 20 peak-hour bus vehicle trips and 650 peak-hour bus passenger trips; and 52 peak-period bus trips and 1395 peak-period bus passenger trips.

FIGURE D-9

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

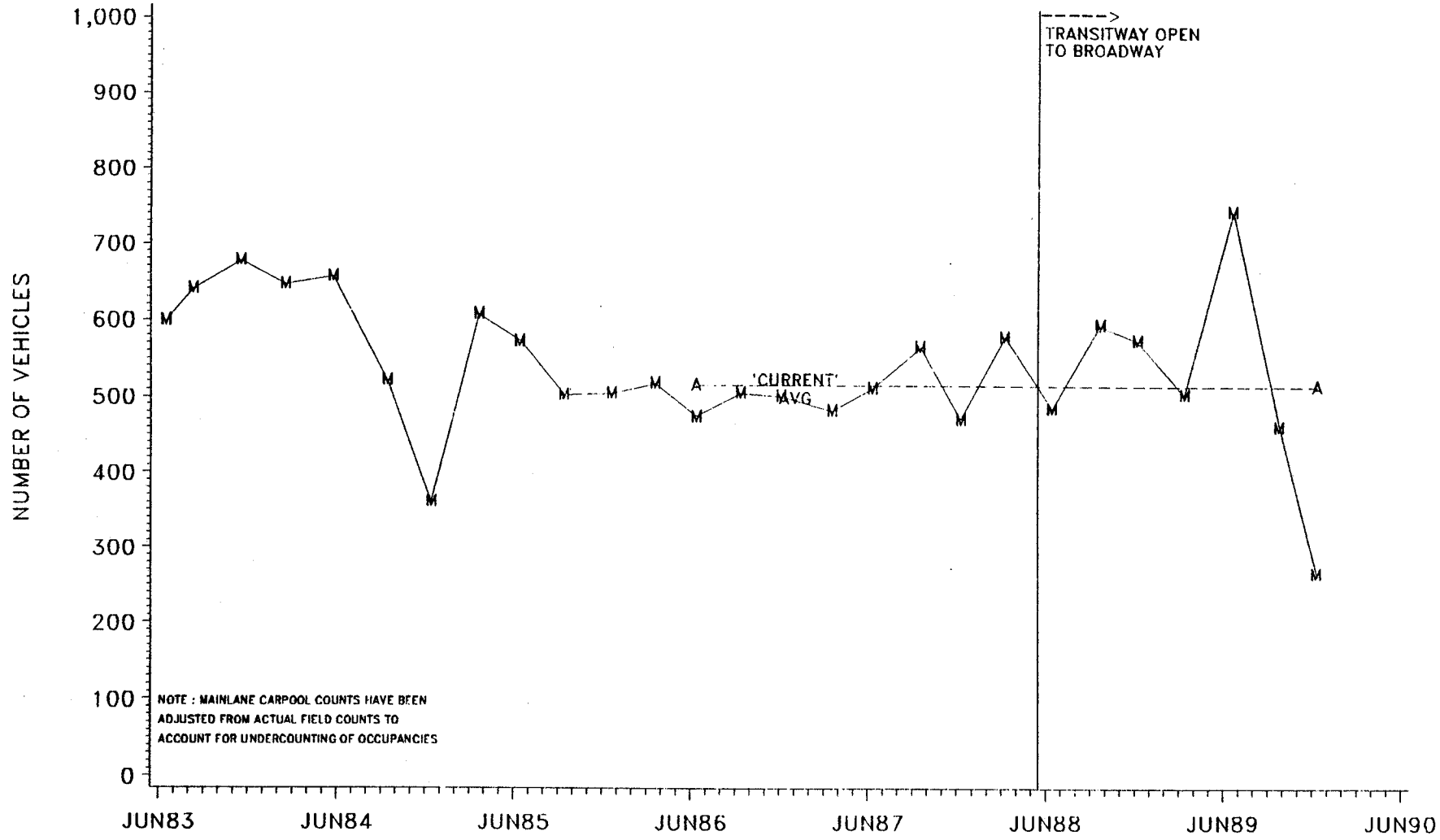


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : A = A.M. PEAK HOUR EFFICIENCY

FIGURE D-10

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

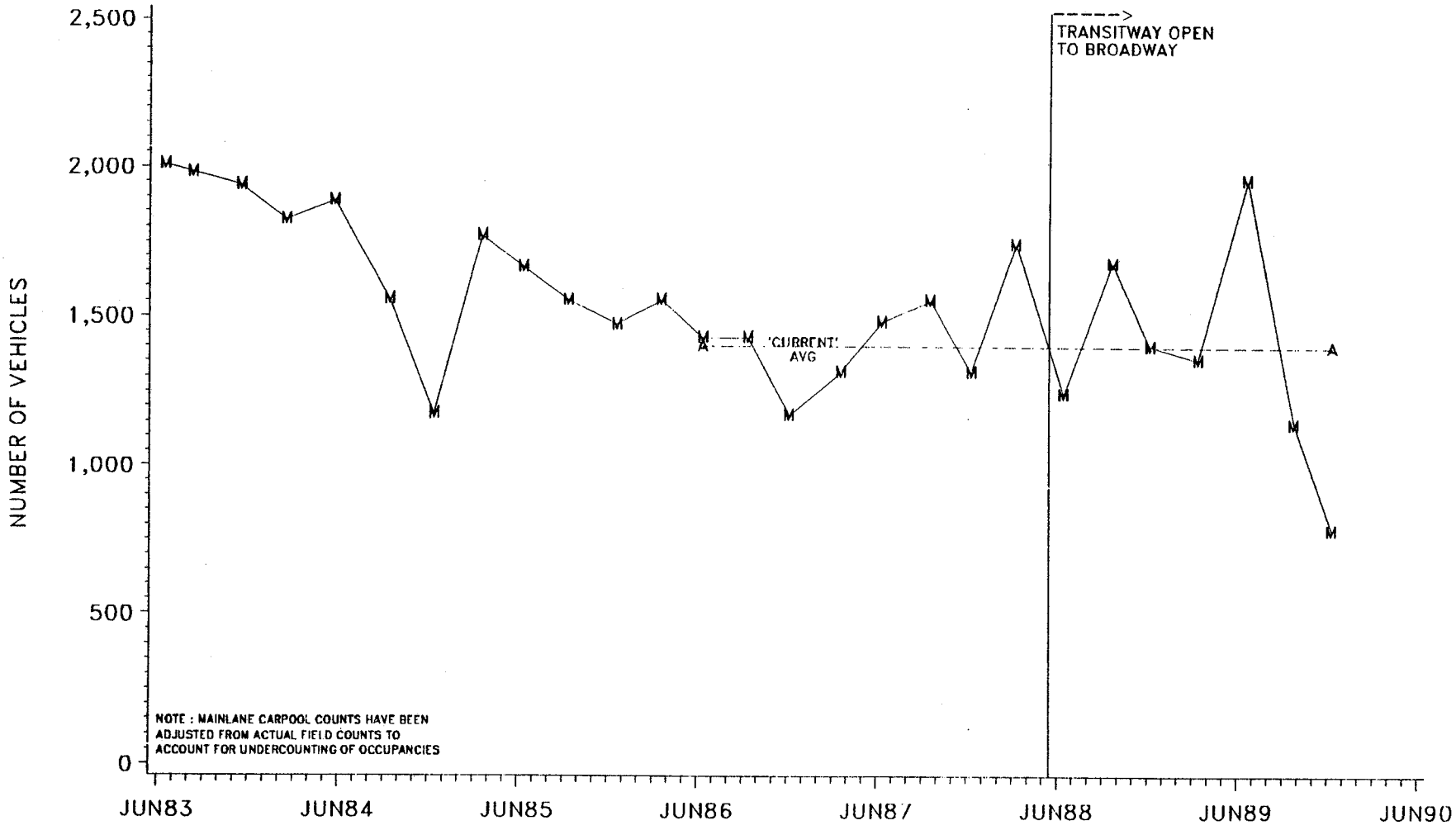


GULF TRANSITWAY, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988
DATA COLLECTED AT MONROE
TRANSITWAY NOT YET COMPLETED TO MONRE, FREEWAY DATA ARE NOT
DIRECTLY COMPARABLE TO TRANSITWAY DATA AT THIS TIME
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE D-11

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

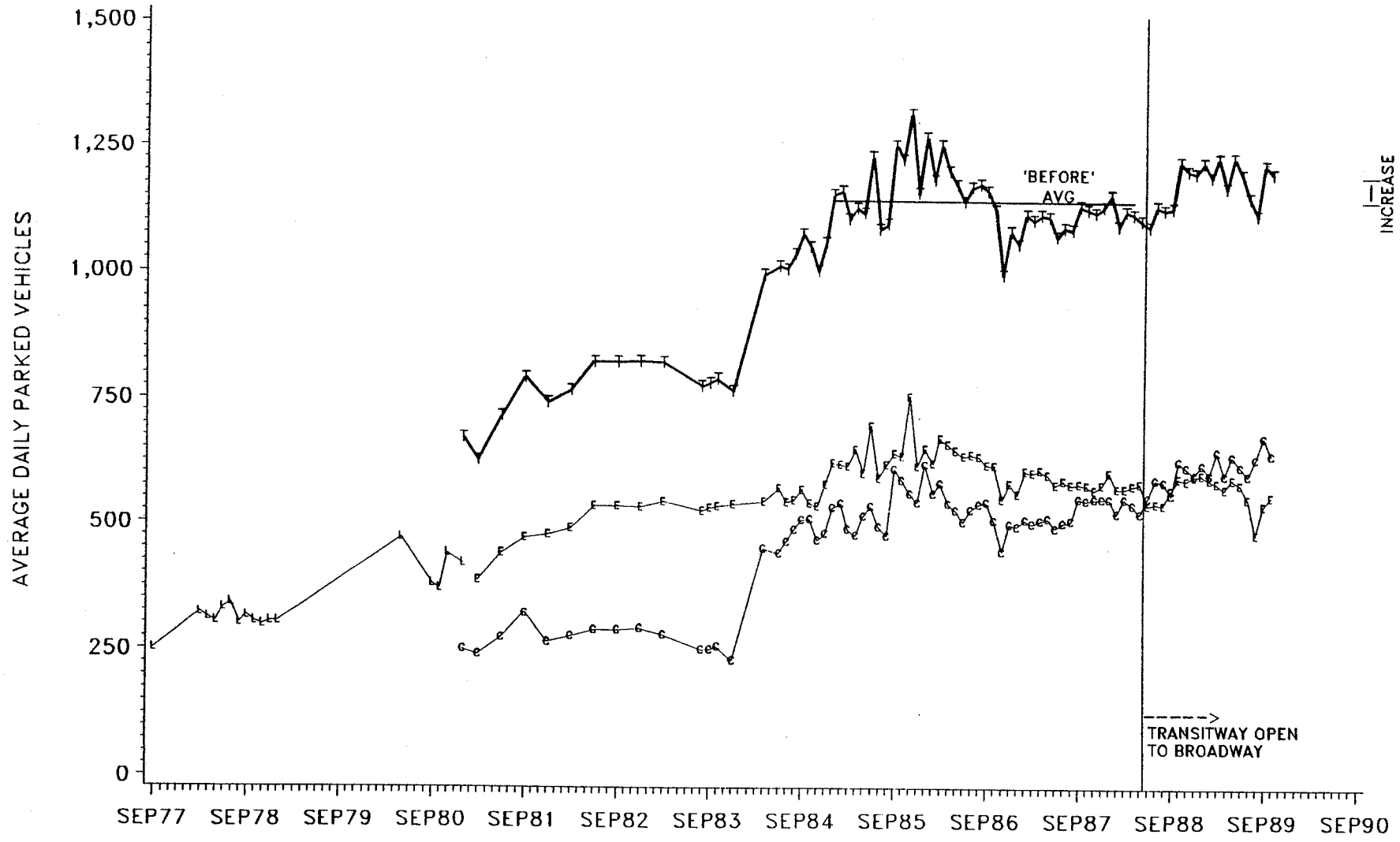
Park-and-Ride

- Prior to opening the transitway, approximately 1115 vehicles were parked in corridor park-and-ride lots. This has increased 7.6% to a current level of 1,200 (Figure D-12).

- Comparison of Southwest Freeway and Gulf Freeway park-and-ride utilization shows that over the years the growth rates to be very similar (Figure D-13).

FIGURE D-12

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



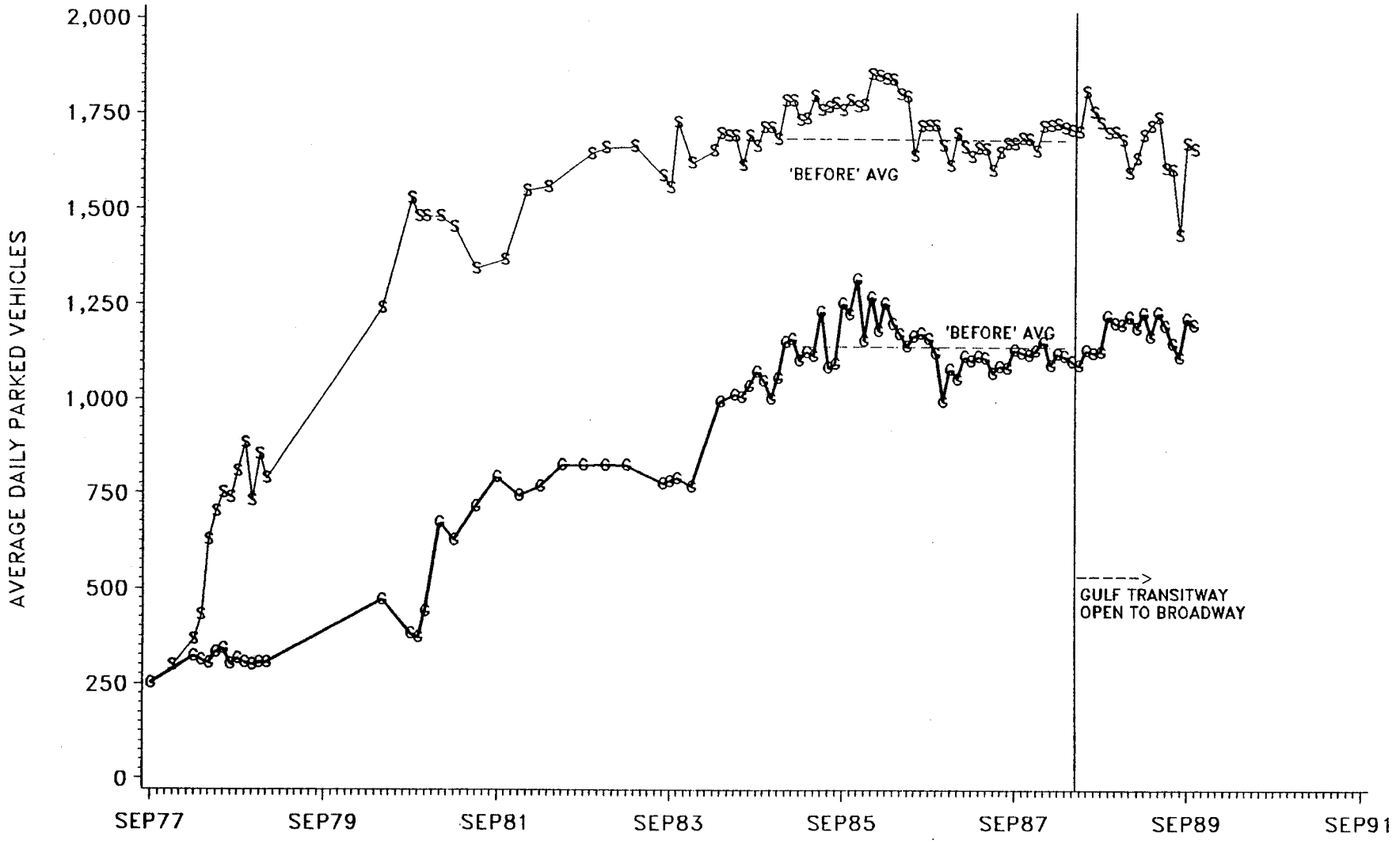
GULF TRANSITWAY, BROADWAY TO DOWNTOWN, OPENED MAY 16, 1988
CURRENT TOTAL CORRIDOR PARKING CAPACITY = 2165 SPACES

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 D-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 E

NORTHWEST FREEWAY AND TRANSITWAY DATA

NORTHWEST FREEWAY (US 290) AND TRANSITWAY, HOUSTON

Summary of A.M. Peak-Period, Peak-Direction Northwest Freeway and Transitway Data, December 1989
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)		9.5	
Transitway Cost (millions)		$44	
Person-Movement			
Peak Hour (7-8 a.m.)	—	2,439	---
Peak Period (6-9:30 a.m.)	—	4,089	---
Total Daily	—	7,275	---
Vehicle Volumes			
Peak Hour	—	841	---
Peak Period	—	1,427	---
Vehicle Occupancy, Peak Hour (persons/veh)	—	2.90	---
Accident Rate (Accidents/MVM)	—	0.53	---
Vehicle Breakdowns (VMT/Breakdown), 9/88 - 12/89	—	47,608	---
Violation Rate		1%	
Peak Hour Lane Efficiency[1](1000's)	—	124	---
Annual Value of User Time Saved (millions)[7]	—	$0.3 to $0.6	---
Freeway Mainlane Data[7] (see note)			
Person Movement			
Peak Hour	6,140	6,095	-0.7%
Peak Period (6:00-9:30 a.m.)	17,450	18,250	+4.6%
Vehicle Volume			
Peak Hour	5,370	5,635	+4.9%
Peak Period	15,295	16,640	+8.8%
Vehicle Occupancy, Peak Hour (persons/veh)	1.14	1.08	-5.3%
Accident Rate (Accidents/MVM)[2]	0.61	0.65	+6.6%
Avg. Operating Speed[3]			
Peak Hour	28	43	+53.6%
Peak Period	40	50	+25.0%
Peak Hour Lane Efficiency[1] (1000's)	62	87	+40.3%
Combined Freeway Mainlane and Transitway Data			
Total Person Movement			
Peak Hour	6,140	8,534	+39.0%
Peak Period	17,450	22,339	+28.0%
Vehicle Volume			
Peak Hour	5,370	6,476	+20.6%
Peak Period	15,295	18,067	+18.1%
Vehicle Occupancy			
Peak Hour	1.14	1.32	+15.8%
Peak Period	1.14	1.24	+ 8.8%
2+ Carpool Volumes[8]			
Peak Hour	490	1,255	+156.1%
Peak Period	1,365	2,440	+ 78.8%
Travel Time (minutes)[3]			
Peak Hour	16.2[4]	8.1[5]	-50.0%
Peak Period	11.4[4]	7.9[5]	-30.7%
Peak Hour Lane Efficiency[1] (1000's)	62	96	+54.8%

Summary of A.M. Peak-Period, Peak-Direction Transitway Data, December 1989 Continued

Type of Data	"Representative" Pre-Transitway Value	"Representative" Current Value	% Change
Transit Data			
Bus Vehicle Trips			
Peak Hour	7	17	+142.9%
Peak-Period	17	32	+ 88.2%
Bus Passenger Trips			
Peak Hour	270	680	+151.9%
Peak Period	605	1,080	+ 78.5%
Bus Occupancy (persons/bus)			
Peak Hour	39	40.0	+ 2.6%
Peak Period	36	33.8	- 6.1%
Vehicles Parked in Corridor Park & Ride Lots	430	913	+112.3%
Bus Operating Speed (mph)[3]			
Peak Hour	29.2[4]	50.8[5]	+ 74.0%
Peak Period	49.2[4]	51.9[5]	+ 5.5%

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

Footnotes on following page.

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

Measure of Effectiveness	"Representative" Pre-Transitway Value	"Representative" Current Value	% Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/transitway	1.14	1.32	+ 15.8%
Freeway w/o transitway	1.26	1.32	+ 4.8%
A.M. Peak Hour, 2+ Carpool Volume Change			
Freeway w/transitway	490	1,255	+156.1%
Freeway w/o transitway	595	595	- 0.0%
Bus Passengers, Peak Period			
Freeway w/transitway	605	1,080	+ 78.5%
Freeway w/o transitway	2,255	2,100	- 6.9%
Cars Parked at Park-and-Ride Lots			
Freeway w/transitway	430	913	+112.3%
Freeway w/o transitway	1,685	1,665	- 1.2%
Facility Per Lane Efficiency[1]			
Freeway w/transitway	62	96	+ 54.8%
Freeway w/o transitway	78	74	- 5.1%

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 generally 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 8/89. 1989 freeway volumes estimated by TTI to compute rates.
[3]From Little York to IH 610, 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 1989 and transitway volumes in 1989, an annual estimate of travel time savings to transitway users is developed. A value of time of $9/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

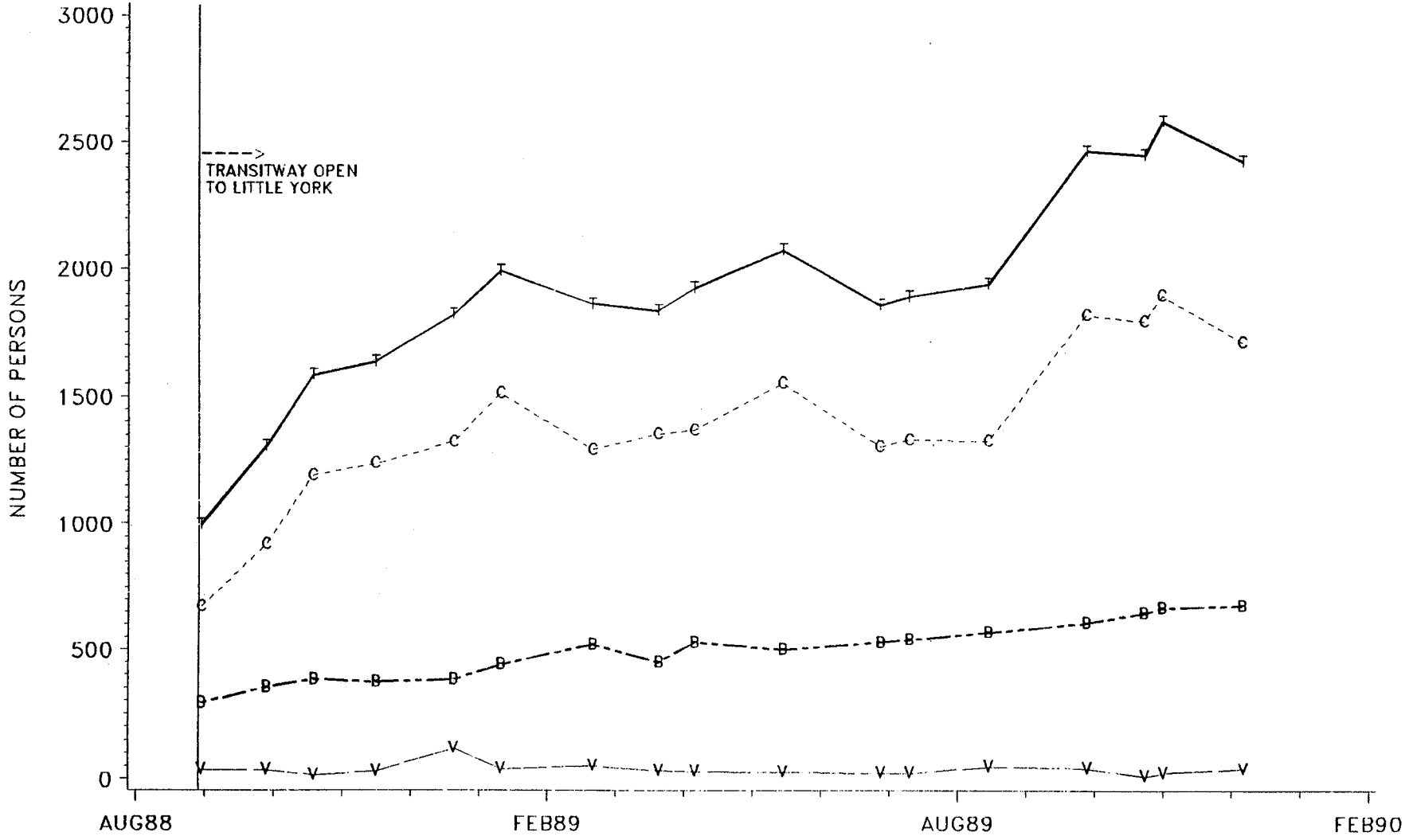
- Phase 1 (9.5 miles) of the transitway opened August 29, 1988.
- A 9.5 mile transitway operates on the Northwest Freeway (US 290) between West Little York Park-and-Ride and Northwest Transit Center. The transitway operates weekdays inbound from 4:00 a.m. to 1:00 p.m. and outbound from 2:00 p.m. to 10:00 p.m.
- The transitway (9.5 miles) was constructed for approximately $44 million.
- In December 1989, 7,275 person trips per day were served on the transitway. The transitway is used by buses and 2+ carpools.

Person Movement

- A.M. Peak Hour (7-8 a.m.), 2,439 persons/hour.
  - 680 (28%) by bus, 39 (2%) by vanpool, 1,720 (70%) by carpool (Figure E-1).
  - Average transitway vehicle occupancy = 2.9 persons/vehicle.
- A.M. Peak Period (6-9:30 a.m.), 4,089 persons.
  - 1,080 (26%) by bus, 110 (3%) by vanpool, 2,899 (71%) by carpool (Figure E-2).

FIGURE E-1

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

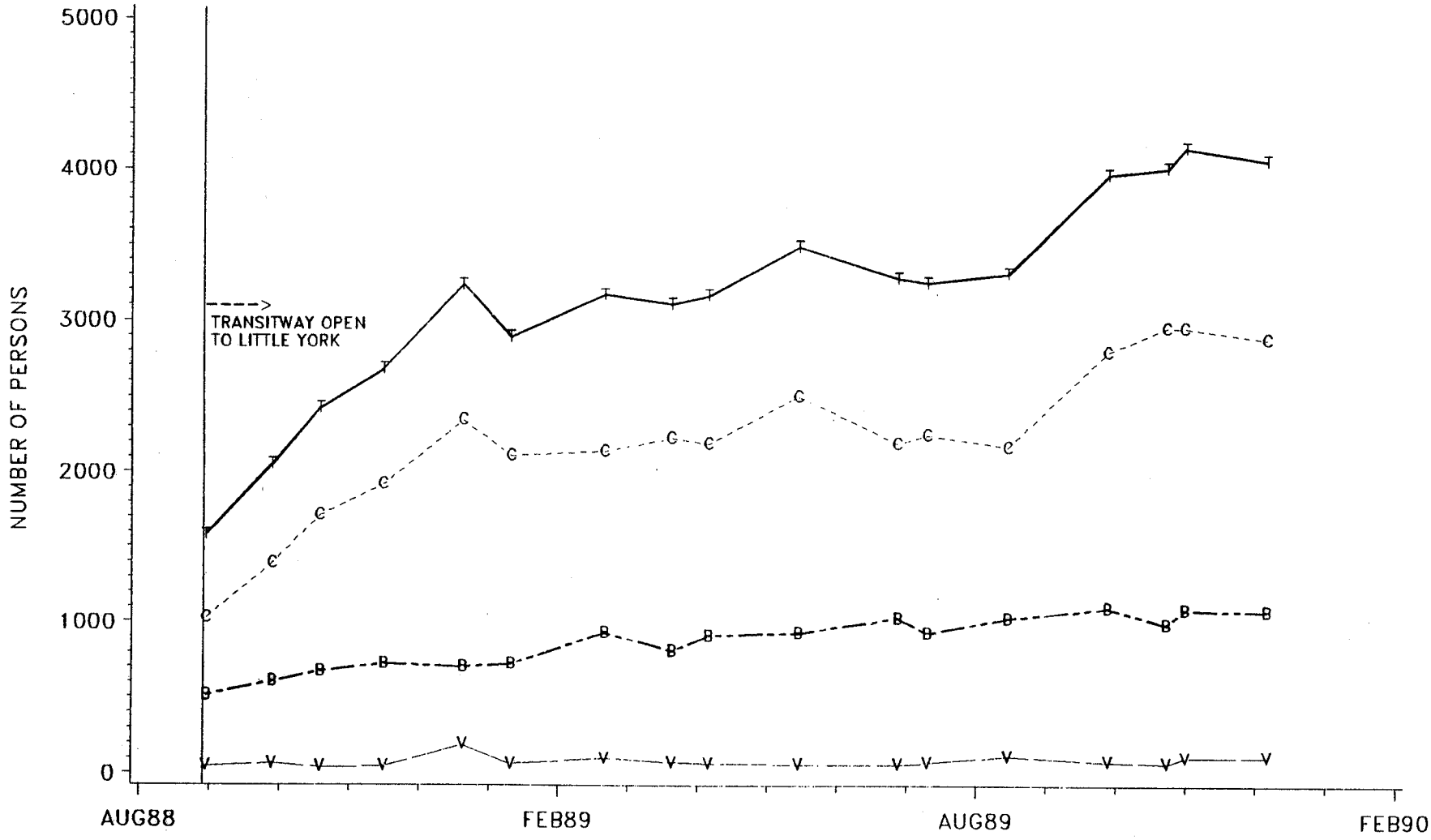


NORTHWEST TRANSITWAY PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (9.5 MI), OPENED AUGUST 29, 1988
DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-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
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

Vehicle Movement

- A.M. Peak Hour, 841 vph
  - 17 (2%) bus, 6 (1%) vans, 818 (97%) carpools (Figure E-3).
- A.M. Peak Period (6-9:30 a.m.), 1,427 vehicles.
  - 32 (2%) bus, 16 (1%) vans, 1,379 (97%) carpools (Figure E-4).

Accident Rate

- For the period from 8/88 through 12/89, the transitway accident rate was 0.53 accidents per million vehicle miles.

Vehicle Breakdown Rates

- As measured from September 1, 1988 through December 1989, the following rates have been observed.
  - Buses; 1 breakdown per 60,749
  - Vanpools; no breakdowns to date.
  - Carpools; 1 breakdown per 46,750 VMT.
  - The weighted average for all vehicle types is 1 breakdown per 47,608 VMT.

Violation Rate

- The observed violation rate (vehicles on the transitway not eligible to use the transitway) is less than 1%.

Peak Hour Lane Efficiency

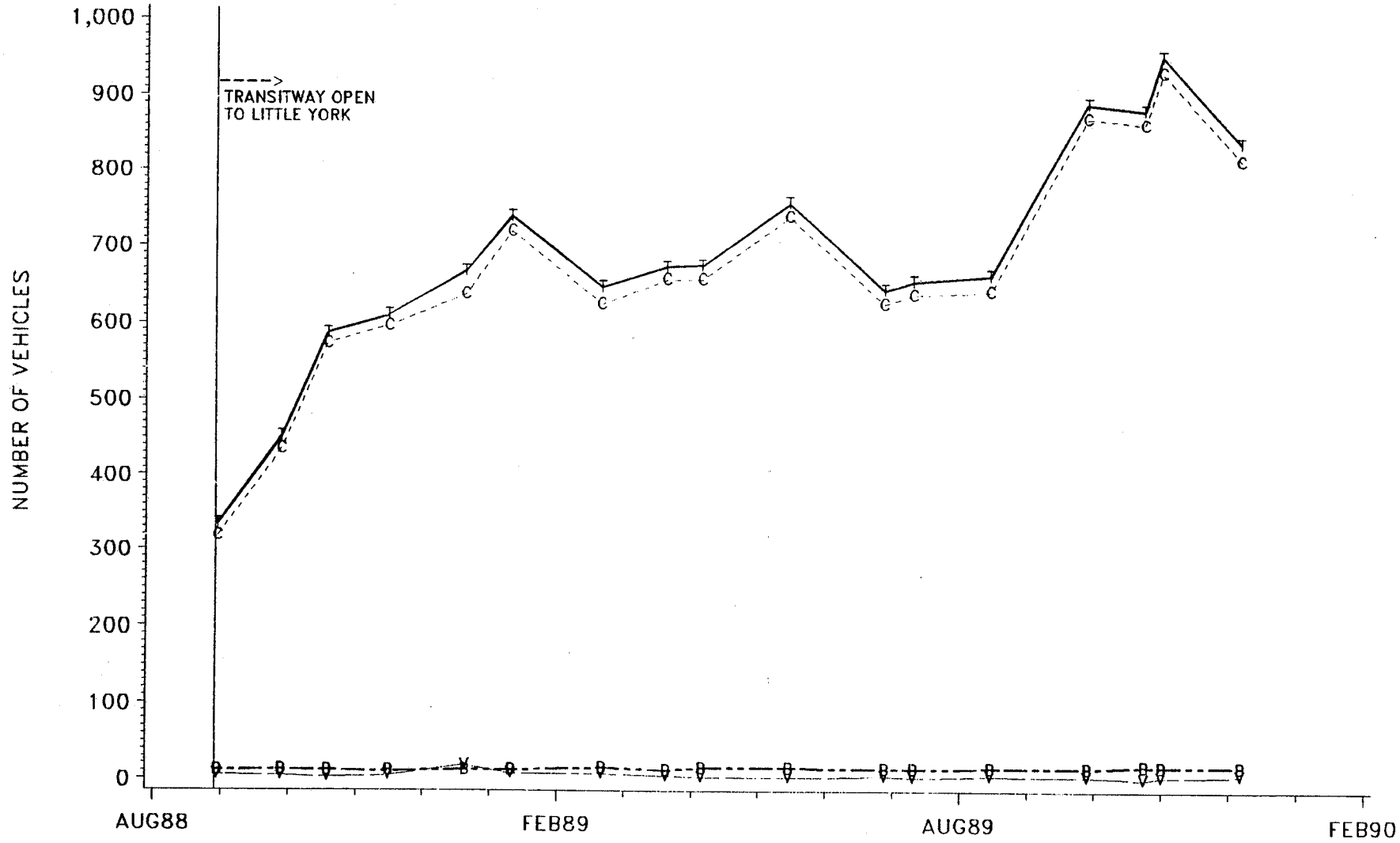
- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. For the transitway lane, this value (expressed in 1000's) is approximately 124 (2,439 persons at 51 mph).

Travel Time Savings

- The users of the transitway experience a travel time savings in the a.m. (Figure E-5). However, the current access/egress arrangement at the

FIGURE E-3

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

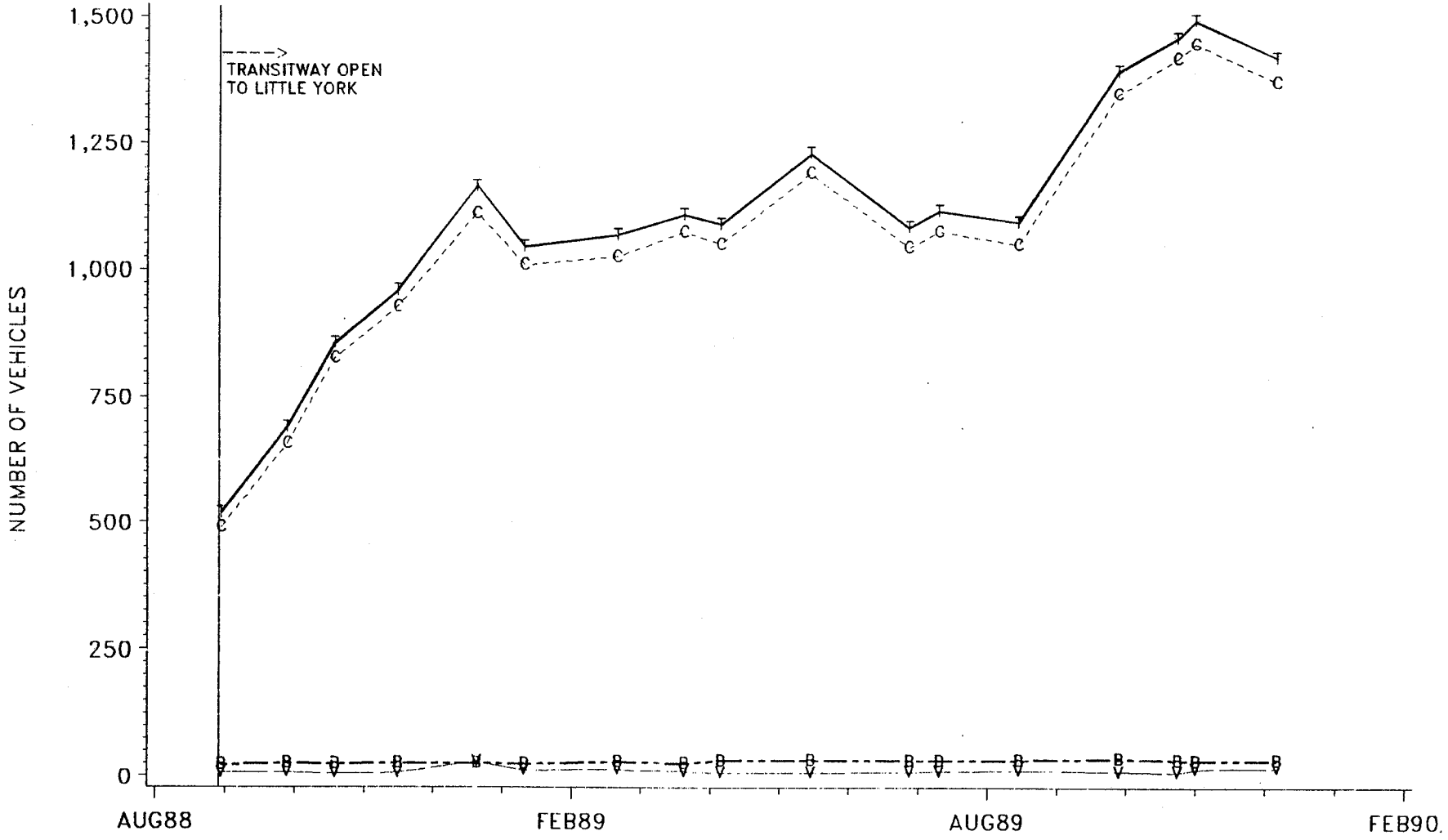


NORTHWEST TRANSITWAY PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (9.5 MI), OPENED AUGUST 29,1988
DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-4

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

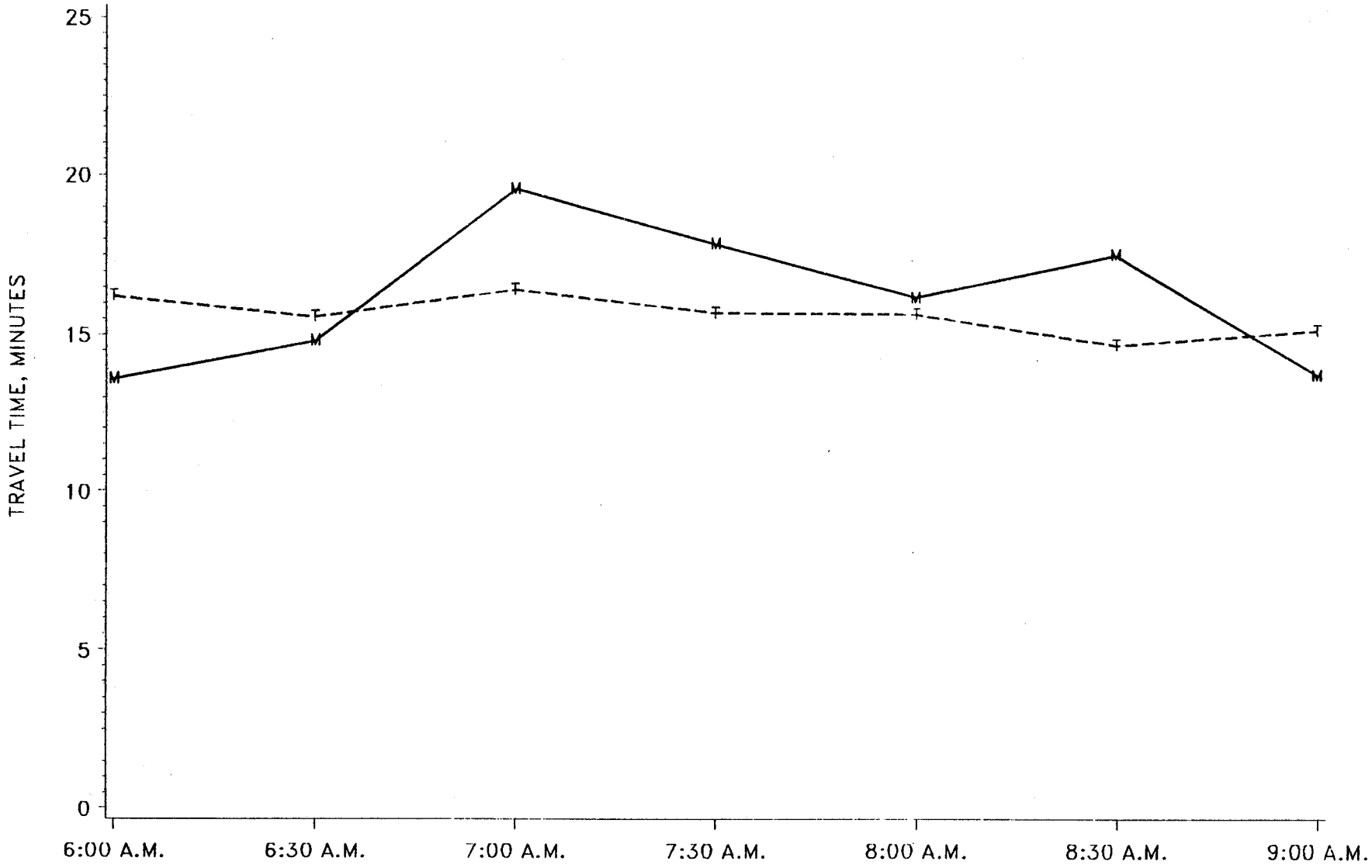


NORTHWEST TRANSITWAY PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (9.5 MI), OPENED AUGUST 29, 1988
PEAK PERIOD IS 6:00 – 9:30 A.M.
· DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-5

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



TRAVEL TIMES ARE FROM SENATE TO THE SP.P RAILROAD
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

temporary transitway terminus at West Little York reduces a.m. travel time savings and actually negates p.m. transitway travel time savings.

- The tables below indicate that, on a typical non-incident day, travel time savings of approximately 7,562 minutes, or 126 hours, are realized; at present, travel time is actually lost using the transitway during most of the afternoon. Assuming 250 days of operation and a value of time of $9.00, 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.

Southbound AM Travel Time Savings for Northwest Transitway
Average of Data Collected in June, September and December 1989

Time of Day	Average Travel Time		Time Saved (minutes)	Transitway Person Volumes				Travel Time Saved (person minutes)
	Freeway (minutes)	Transitway (minutes)		Vans	Buses	Carpools	Persons	
6:00 a.m.	13.56	16.20	-2.64	6	60	69	135	-356.25
6:30 a.m.	14.80	15.56	-0.76	33	200	388	621	-468.95
7:00 a.m.	19.58	16.42	3.16	28	317	796	1140	3604.72
7:30 a.m.	17.87	15.72	2.16	7	290	821	1118	2409.19
8:00 a.m.	16.22	15.69	0.53	9	144	400	552	291.51
8:30 a.m.	17.59	14.73	2.86	0	60	134	194	556.04
9:00 a.m.	13.79	15.21	-1.42	0	0	30	30	-42.97
Peak Period				82	1071	2638	3791	5993.26

Northbound PM Travel Time Savings for Northwest Transitway
Average of Data Collected in June, September and December 1989

Time of Day	Average Travel Time		Time Saved (minutes)	Transitway Person Volumes				Travel Time Saved (person minutes)
	Freeway (minutes)	Transitway (minutes)		Vans	Buses	Carpool	Persons	
3:30 p.m.	16.62	19.32	-2.70	0	51	52	102	-276.30
4:00 p.m.	17.43	20.75	-3.32	24	80	143	247	-818.11
4:30 p.m.	23.52	20.70	2.82	54	153	274	482	1359.69
5:00 p.m.	23.81	23.66	0.16	19	340	475	834	129.68
5:30 p.m.	28.16	24.88	3.28	7	250	407	664	2179.04
6:00 p.m.	20.13	22.31	-2.18	1	143	242	385	-839.17
6:30 p.m.	17.09	18.22	-1.12	3	37	105	145	-162.35
Peak Period				107	1055	1696	2858	1569.49

Note: The peak-hour volumes in these tables do not exactly agree with those presented in the summary table. The summary table was based on 15-minute volume data. The data for the analyses summarized in the above tables are based on 30-minute volume counts. Data collected from Senate to the S.P. Railroad.

FREEWAY DATA

Note

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

Person Movement

- In the a.m. peak hour, person movement has declined by 0.7% (Figure E-6).
- In the a.m. peak period, person movement has increased by 4.6% (Figure E-7).

Vehicle Volume

- In the a.m. peak hour, vehicle volume has increased by 4.9% (Figure E-6).
- In the a.m. peak period, vehicle volume has increased by 8.8% (Figure E-7).

Vehicle Occupancy

- In the a.m. peak hour, mainlane occupancy has declined by 5.3%.
- In the a.m. peak period, mainlane occupancy has declined by 3.5%.

Accident Rate

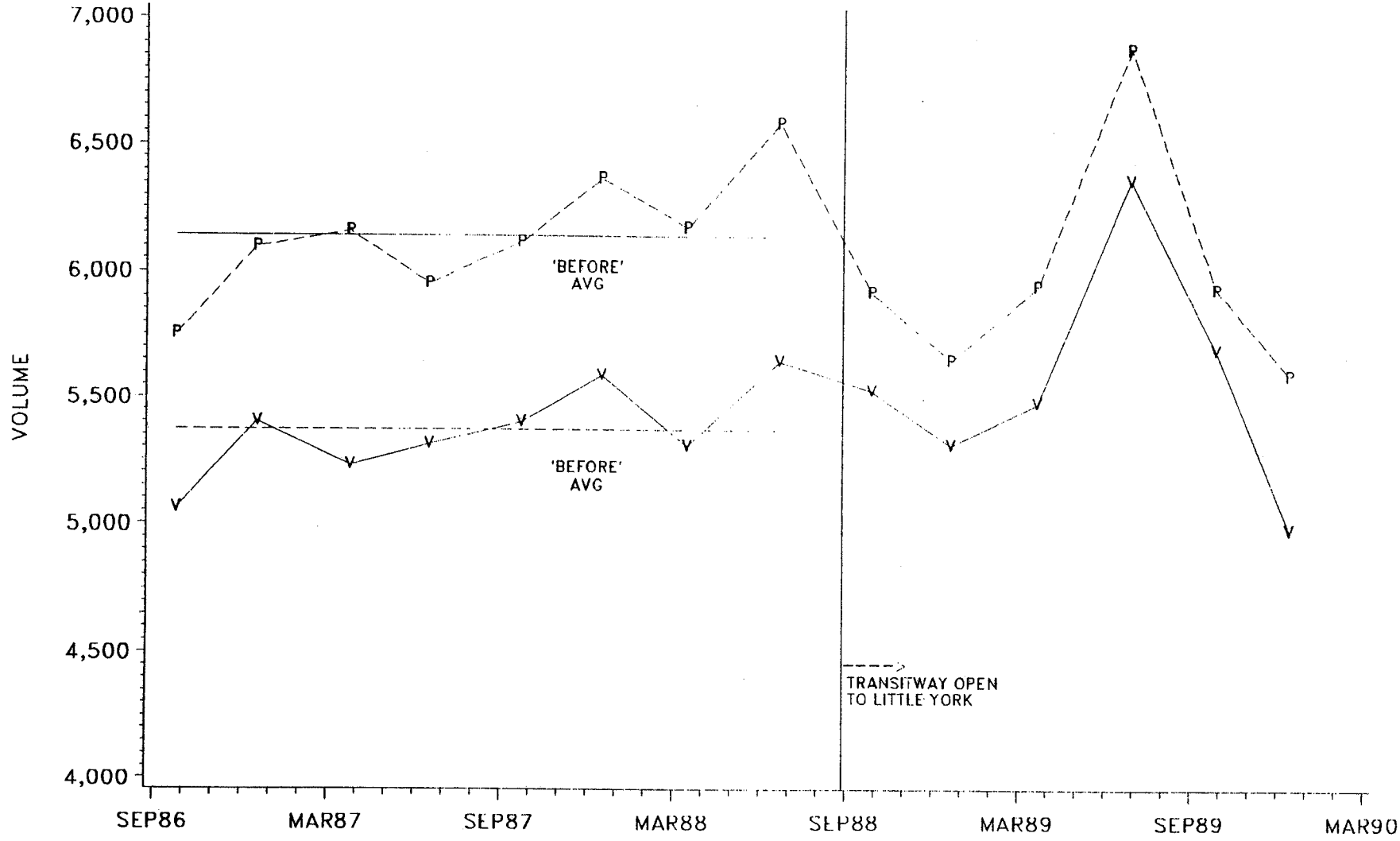
- Implementation of the transitway resulted in narrower freeway lanes and no inside emergency shoulder.
- For the section between Little York and I-610, the accident rate for the period (1/82-8/88) preceding the opening of the transitway was 0.61 accidents per million vehicle miles (MVM). The accident data available for the period (9/88-8/89) after the transitway opened indicates an accident rate of 0.65 accidents/MVM. 1989 freeway volumes estimated by TTI to compute rates.

Average Operating Speed

- In comparison to pre-transitway conditions, mainlane operating speeds have improved in both the peak hour and the peak period. The data in Figure E-8

FIGURE E-6

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

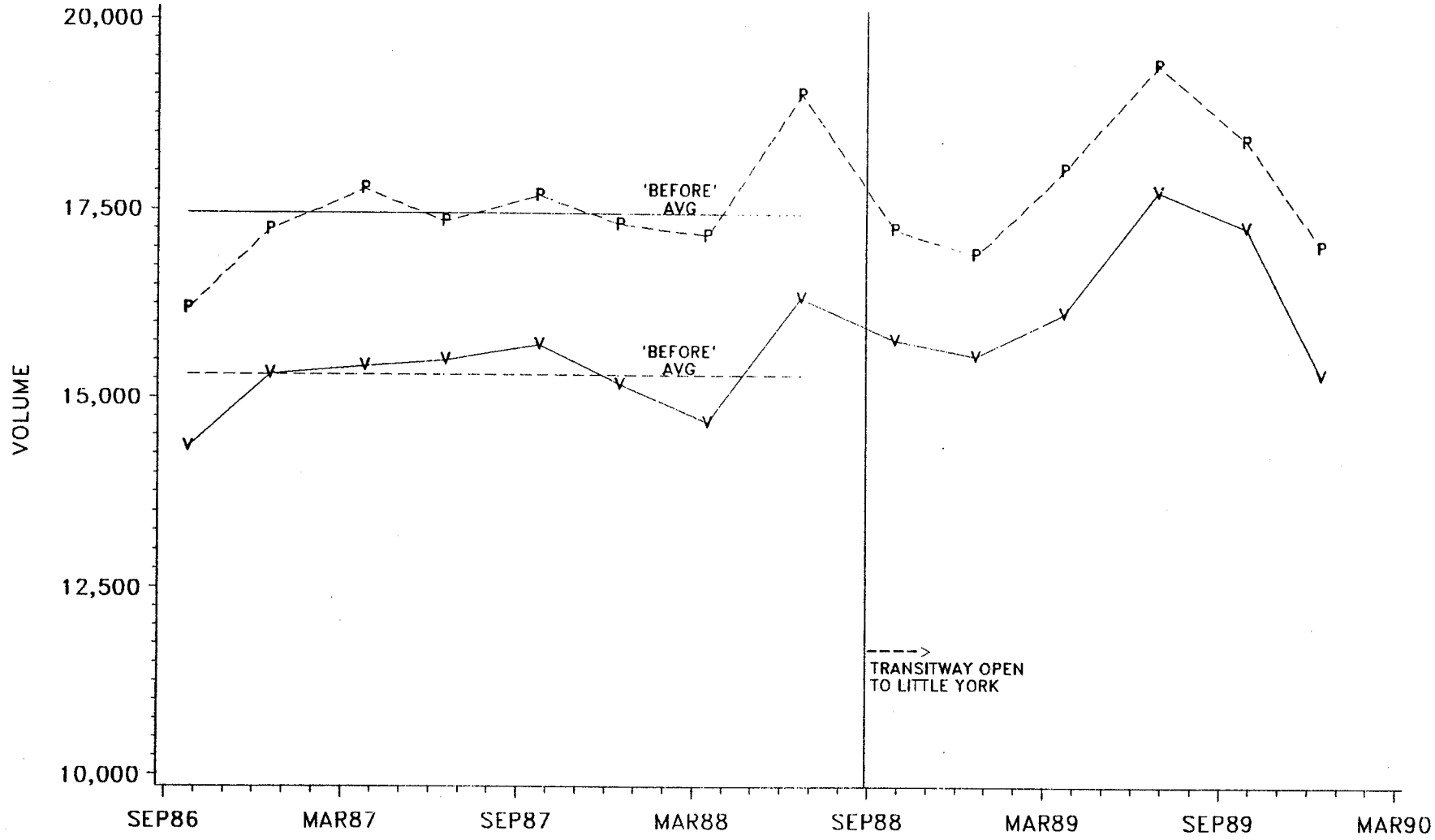


NORTHWEST TRANSITWAY PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (9.5 MI), OPENED AUGUST 29,1988
DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-7

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

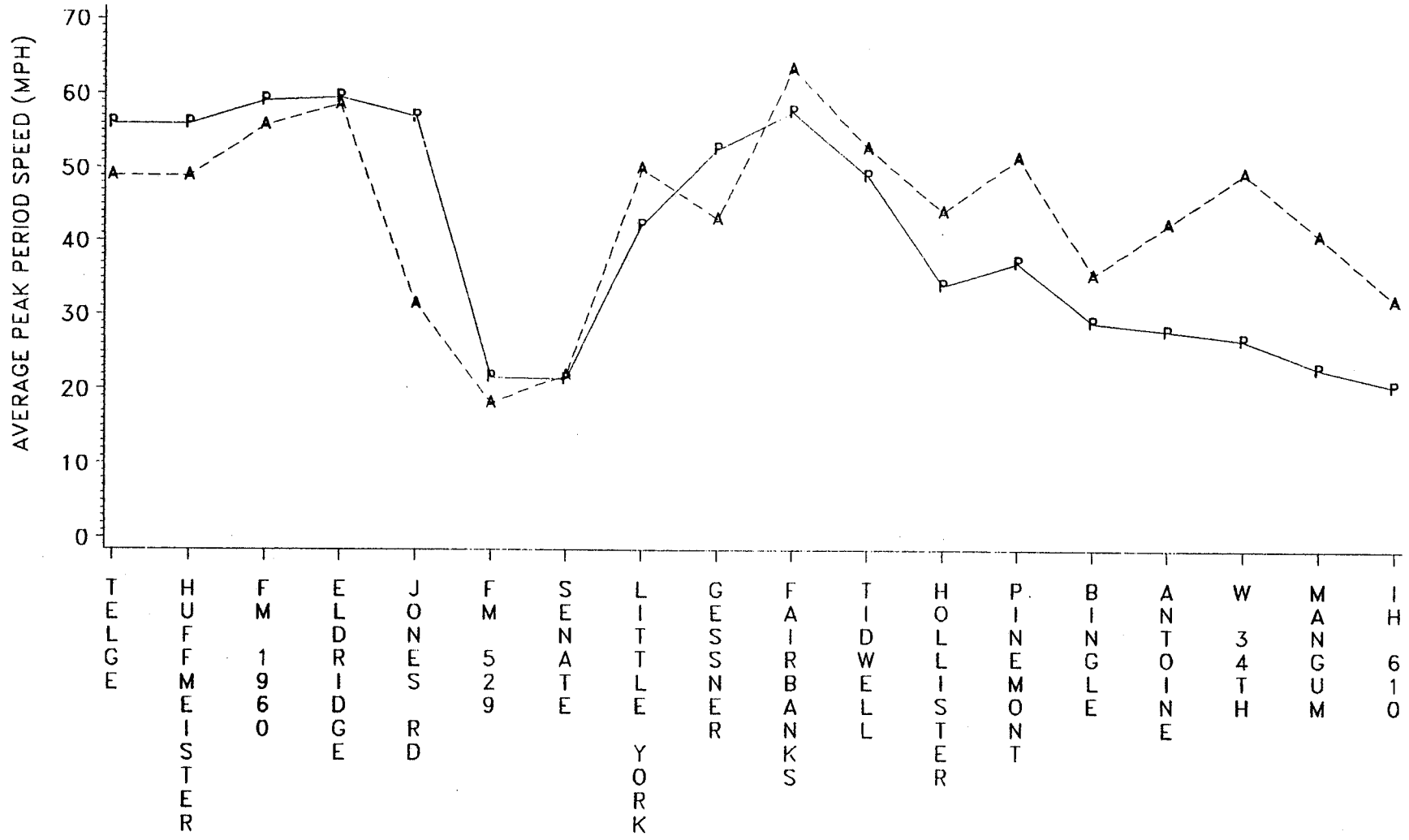


NORTHWEST TRANSITWAY PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (9.5 MI), OPENED AUGUST 29,1988
PEAK PERIOD IS 6:00 TO 9:30 A.M.
DATA COLLECTED UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-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, 1989
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

show the average of all travel time runs made both before and after the transitway opened.

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 increase in average speed has resulted in a increase in per lane efficiency of 40.3%.

COMBINED FREEWAY AND TRANSITWAY DATA

Total Person Movement

- Percent by transitway, a.m. peak.

    - At Pinemont, the transitway is moving 29% of peak-hour person movement (transitway = 2439; freeway = 6095) and 18% of peak-period (transitway = 4089; freeway = 16640) person movement.

- 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 39.0%, from 6,140 to 8534 (Figure E-9). Peak-period person movement has increased by 28.0% from 17,450 to 22,339 (Figure E-10).

Vehicle Occupancy

- The combined occupancy for the freeway and transitway in the peak hour is 1.32, a 15.8% increase over the pre-transitway occupancy (Figure E-11). Occupancy in the peak period is 8.8% greater than pre-transitway levels (Figure E-12).

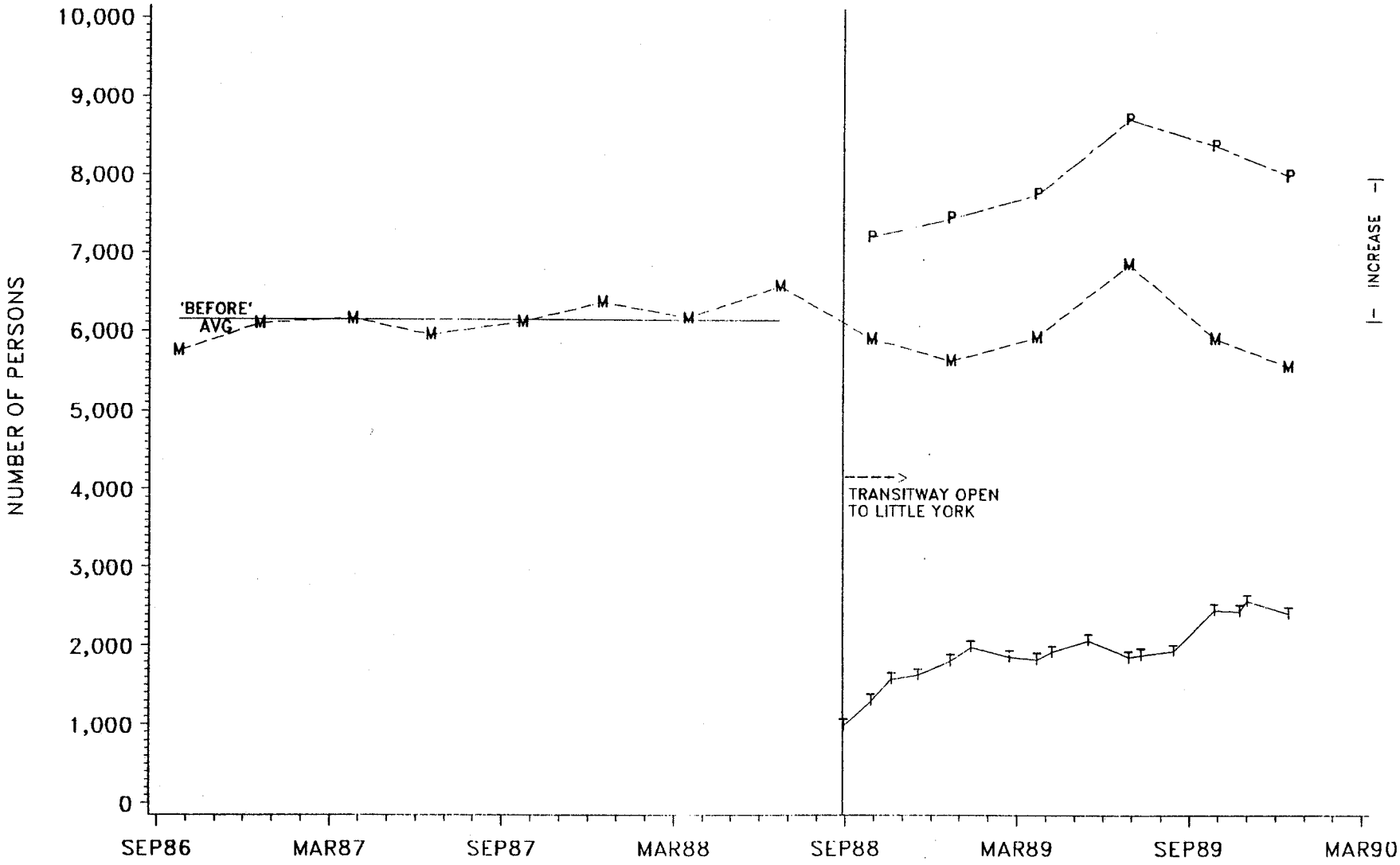
- While the occupancy on the Northwest Freeway has increased, on freeways which do not have transitways occupancy has decreased (Figure E-13).

Carpool Volumes

- In the a.m. peak hour, the total number of 2+ carpools (freeway plus transitway) has increased by 156% compared to pre-transitway levels (Figure

FIGURE E-9

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



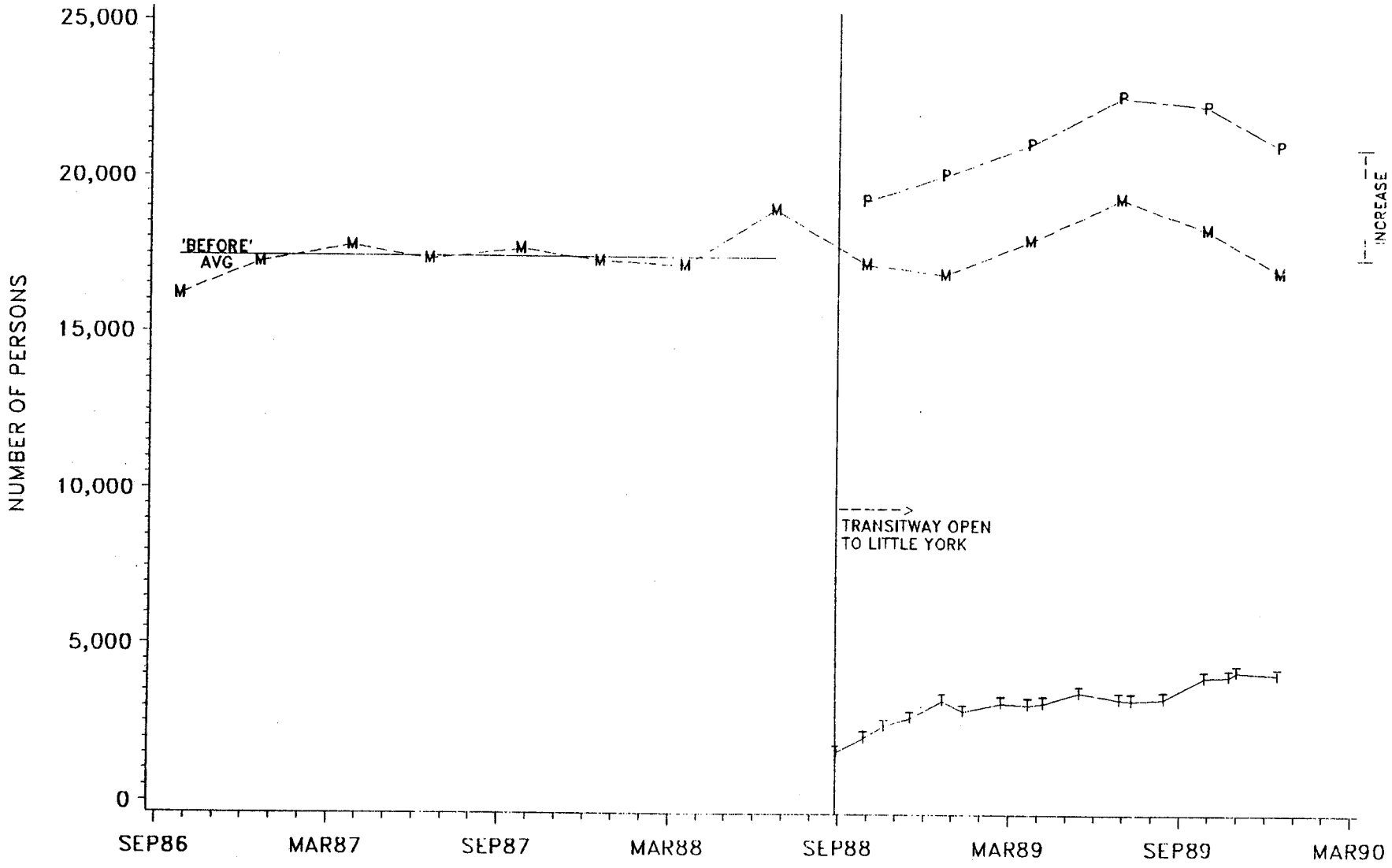
DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION

SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-10

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

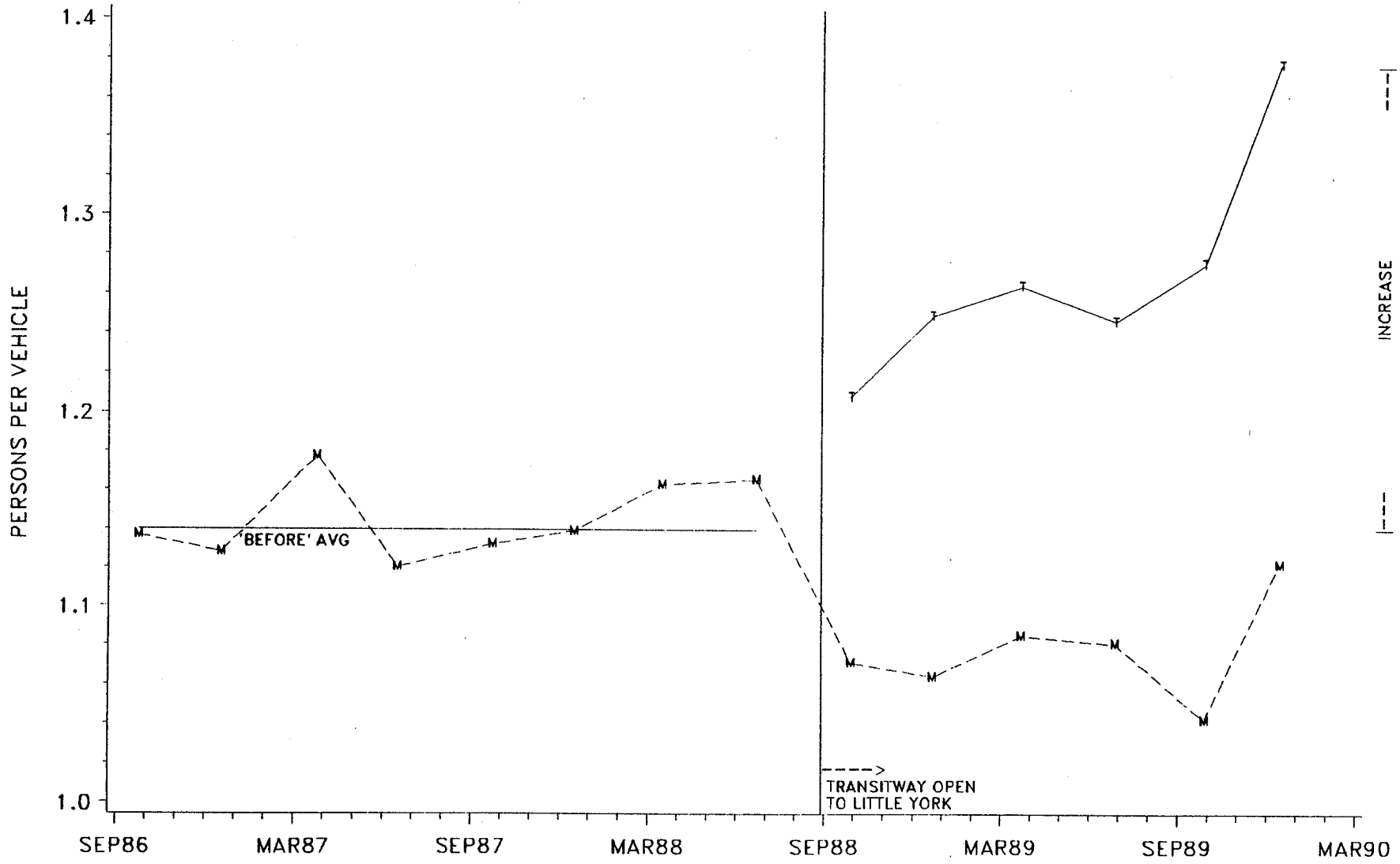


DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION
PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-11

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

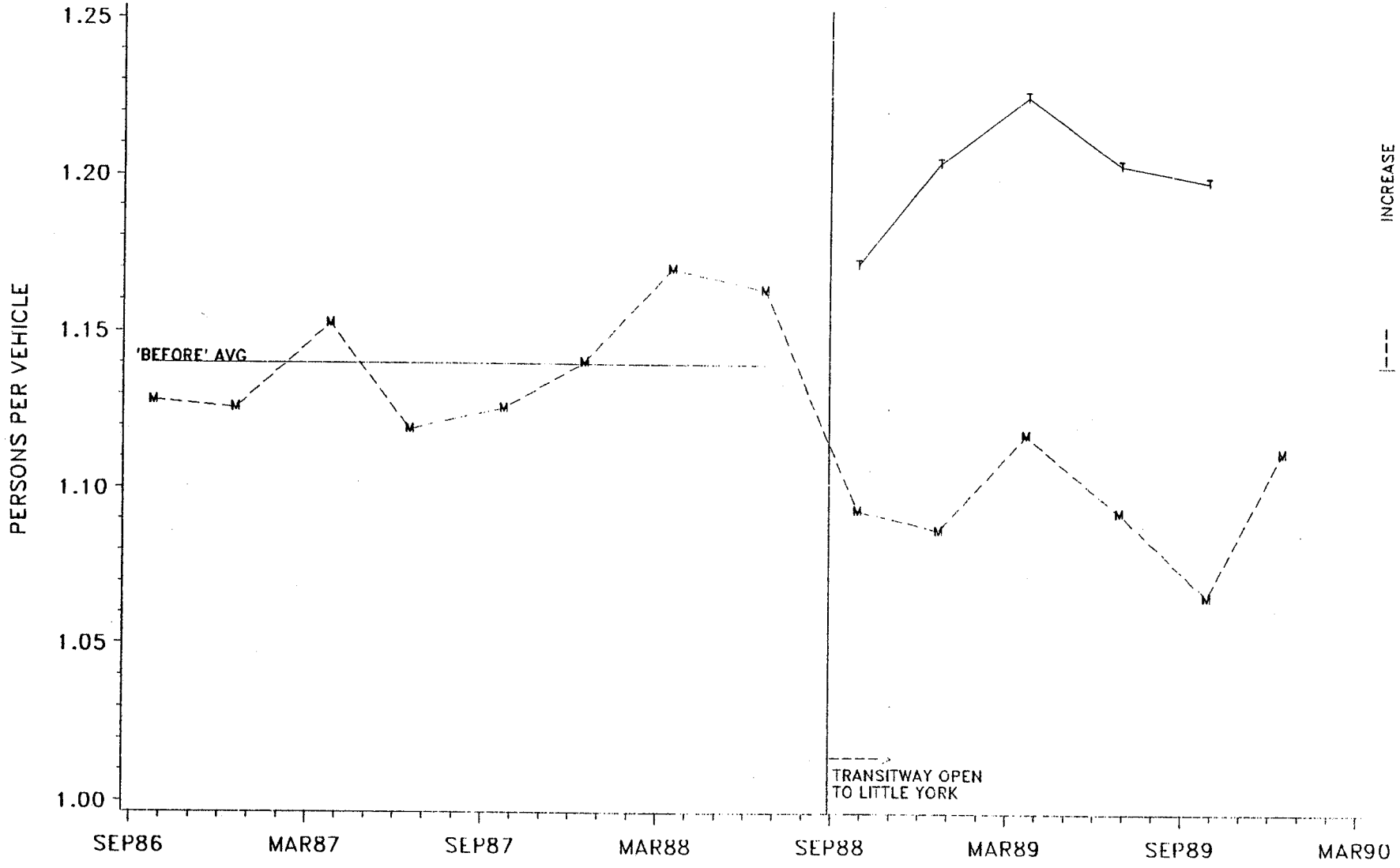


DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-12

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

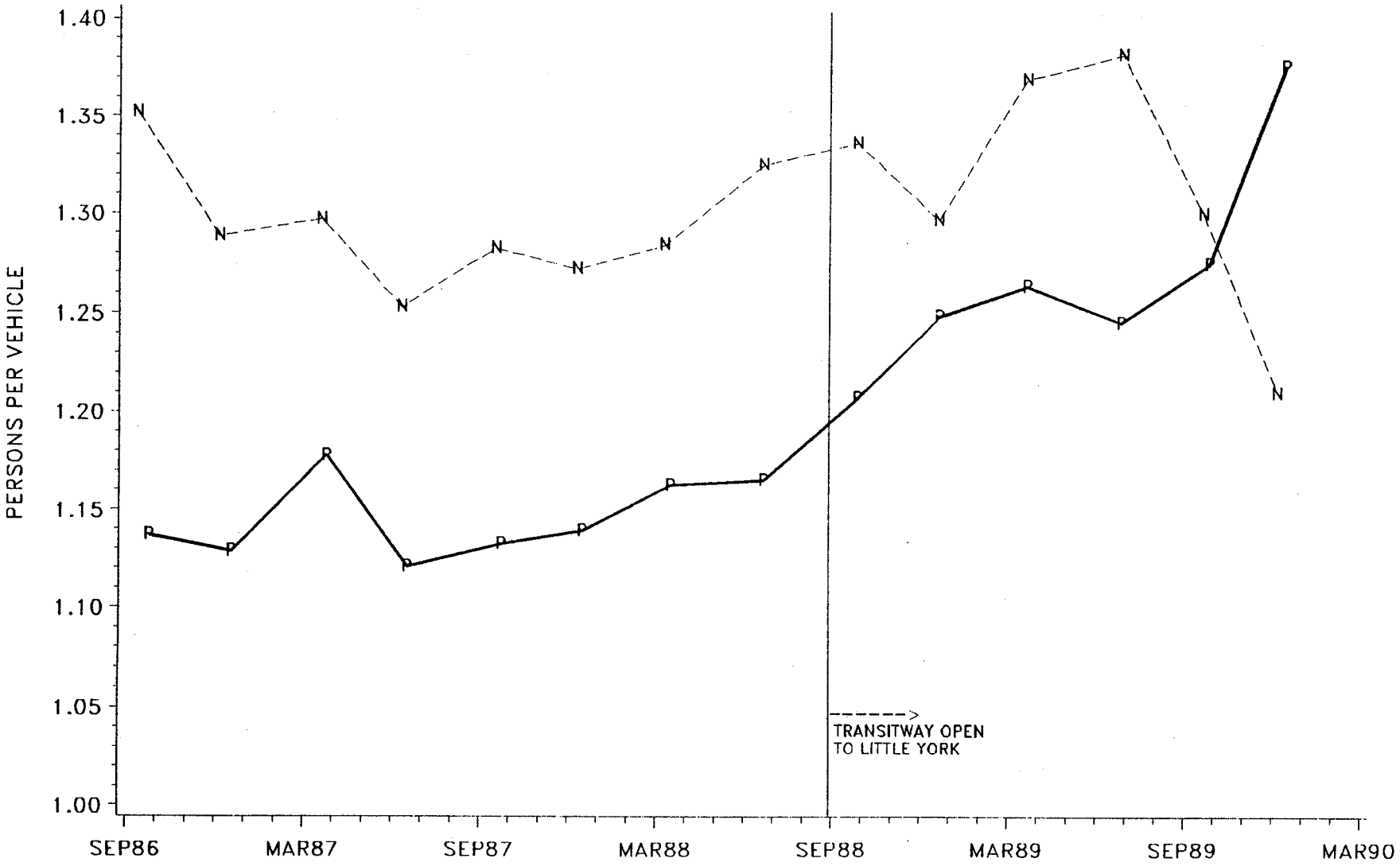


DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION
PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-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

E-14). In the a.m. peak period, the increase has been 79% (Figure E-15). These increases have not been experienced on freeways not having transitways (Figure E-16).

Peak Hour Lane Efficiency

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. The average efficiency of a lane on the freeway (3 freeway lanes plus 1 transitway lane) has increased by 54.8% since the implementation of the transitway (Figure E-17). The increase in per lane efficiency on the Northwest Freeway has been greater than that experienced on a freeway without a transitway (Figure E-18).

BUS TRANSIT DATA

Bus Vehicle and Passenger Trips

- In the a.m. peak hour, bus vehicle trips have been increased by 143% since the transitway opened, and a 152% increase in bus ridership has resulted (Figure E-19). In the peak period, an 88% increase has occurred in bus vehicle trips, and a 79% increase in bus ridership has resulted (Figure E-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 E-21).

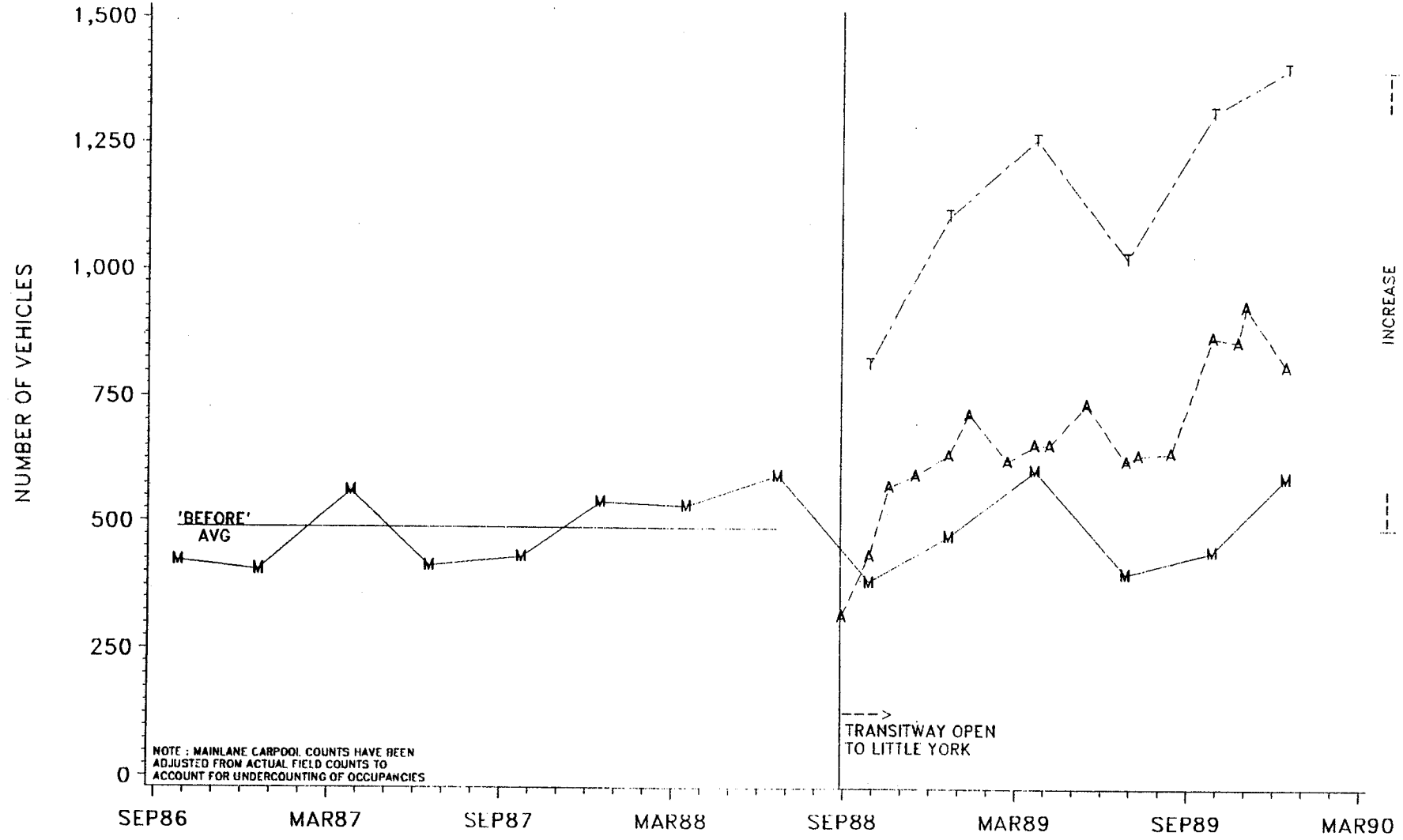
Park-and-Ride

- Prior to opening the transitway, approximately 430 vehicles were parked in corridor park-and-ride lots. This has increased 112% to a current level of 913 (Figure E-22).

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

FIGURE E-14

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

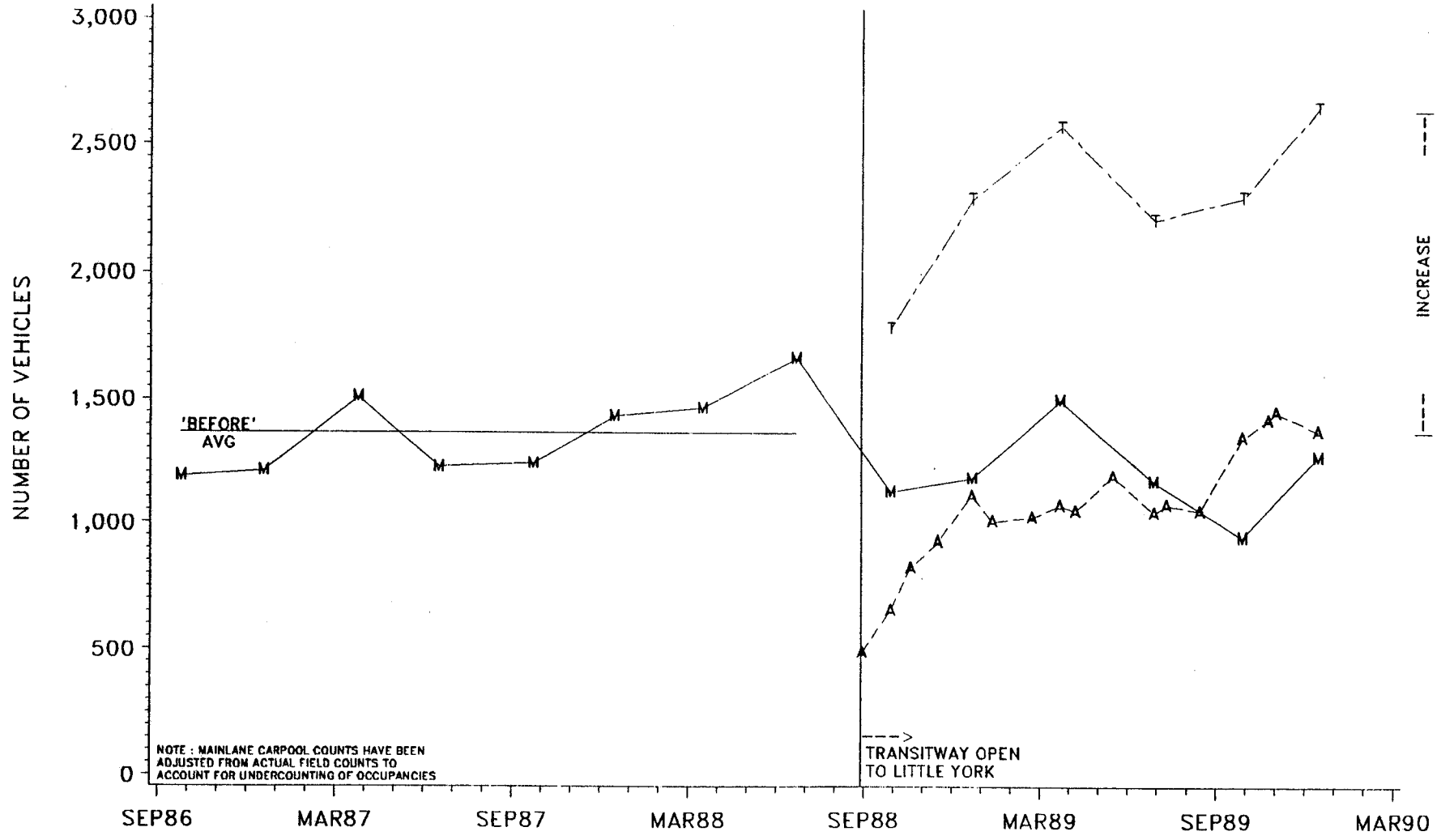


NORTHWEST TRANSITWAY PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (9.5 Mi), OPENED AUGUST 29, 1988
DATA COLLECTED SOUTHBOUND UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-15

NORTHWEST FREEWAY (US 290) MAINLANE AND TRANSITWAY
A.M. PEAK PERIOD 2+ CARPOOL UTILIZATION

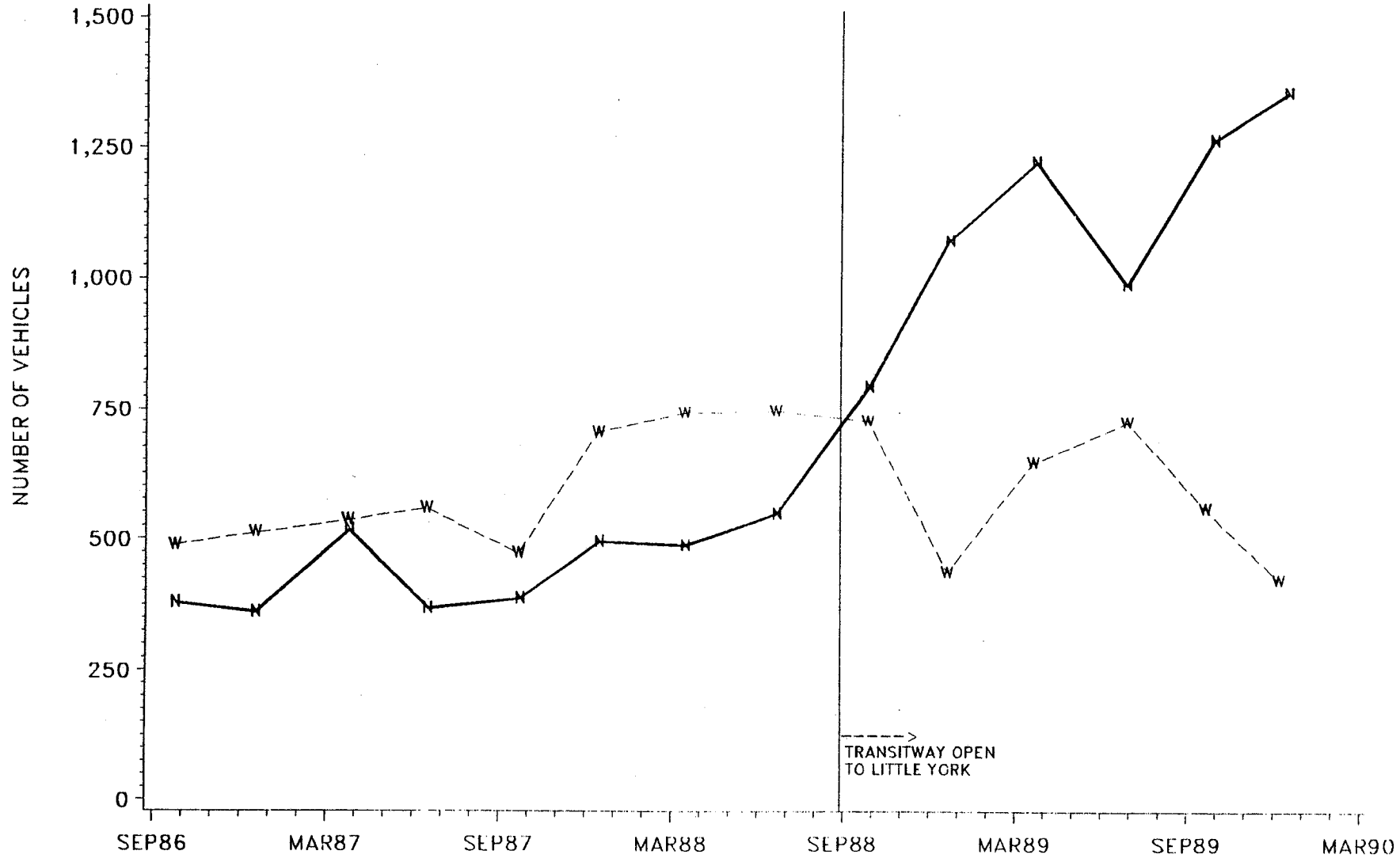


NORTHWEST TRANSITWAY PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (9.5 MI), OPENED AUGUST 29, 1988
PEAK PERIOD IS 6:00 – 9:30 A.M.
DATA COLLECTED SOUTHBOUND UNDER PINEMONT
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-16

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

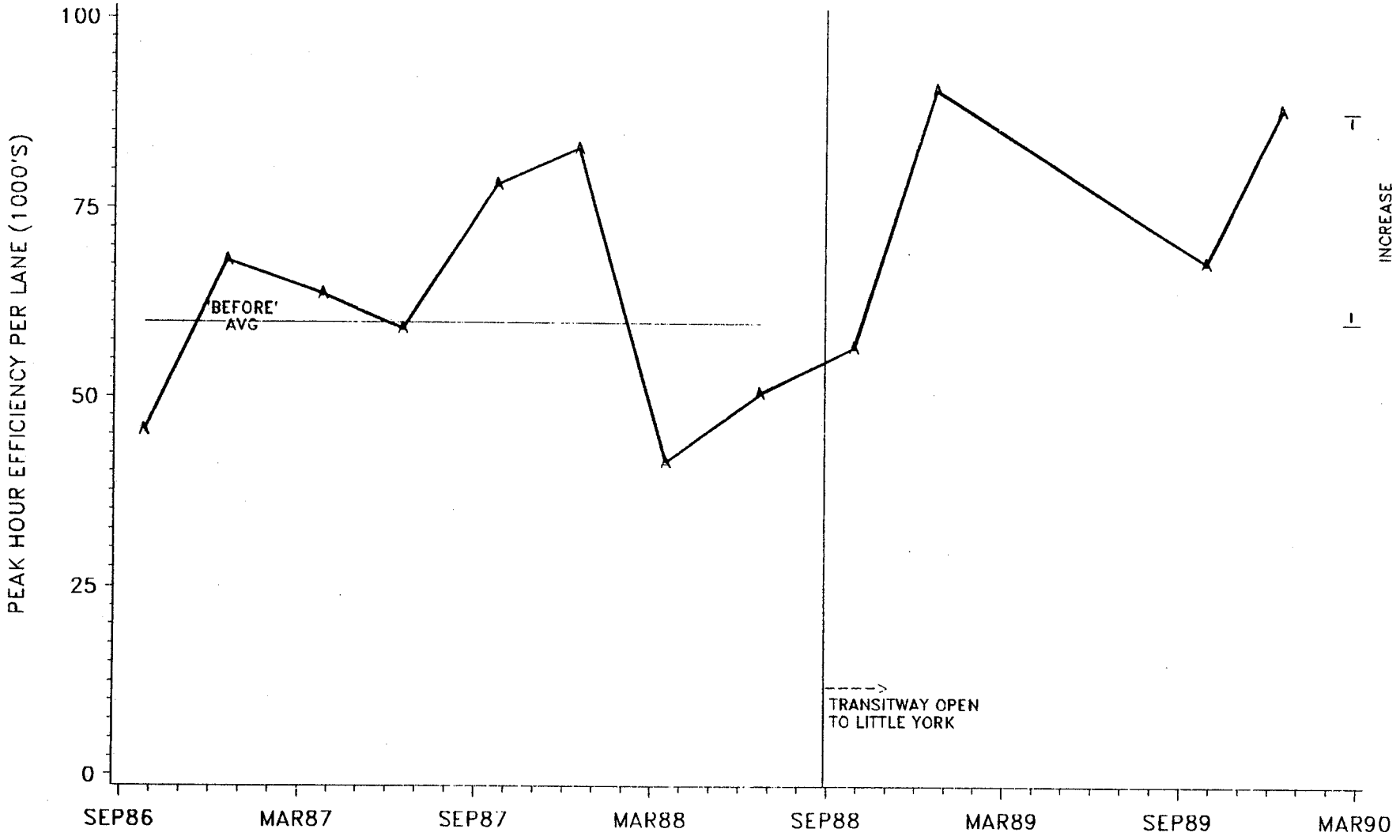


DATA FOR FREEWAYS WITHOUT TRANSITWAYS ARE A COMPOSITE OF
GULF FWY (6/83 – 4/88) AND SOUTHWEST FWY (6/86 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-17

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

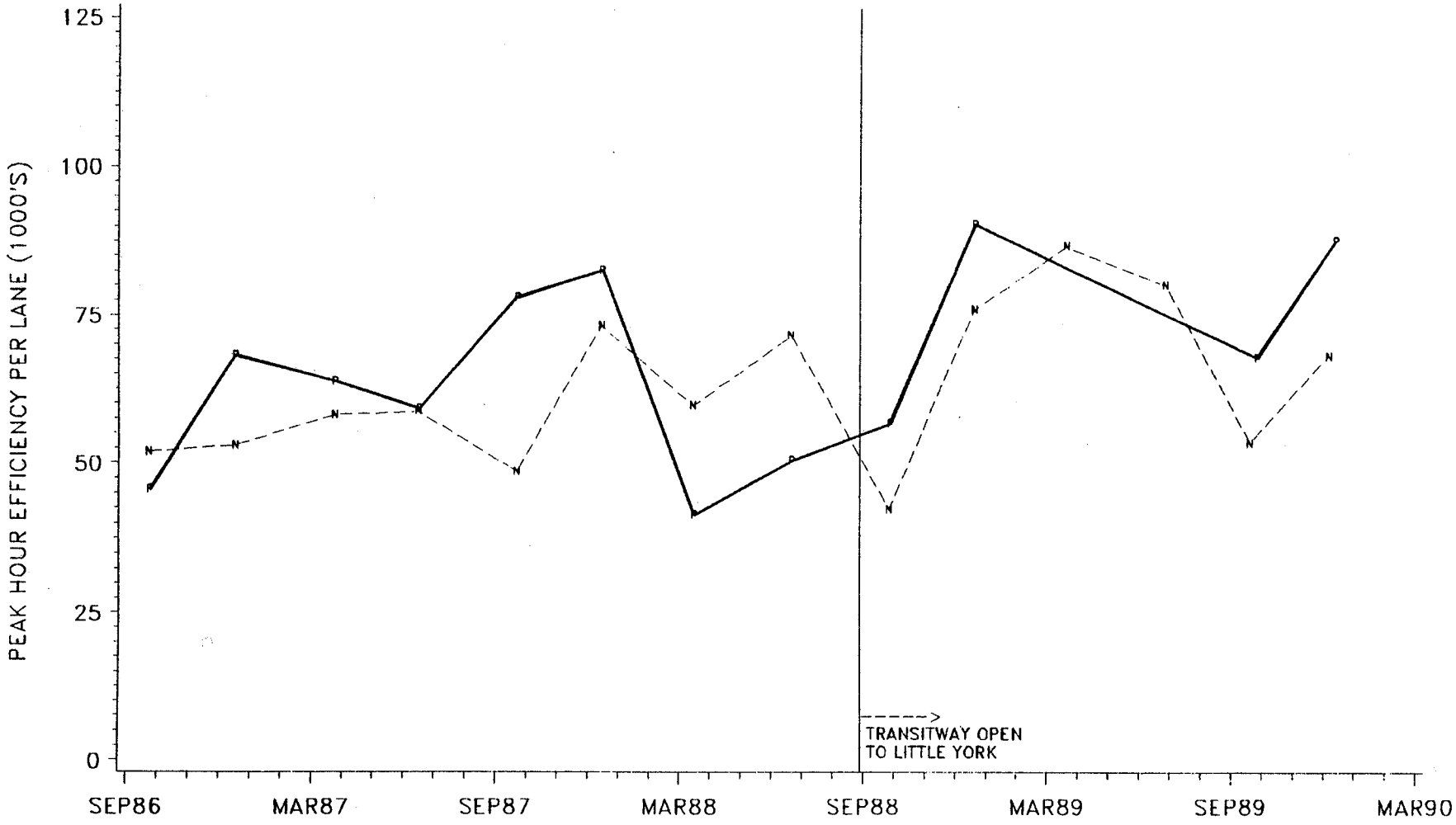


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE TRANSITWAY, IT REPRESENTS TOTAL PERSONS (FREEWAY + TRANSITWAY) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 4 LANES
SOURCE : TEXAS TRANSPORTATION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

LEGEND : A = A.M. PEAK HOUR EFFICIENCY

FIGURE E-18

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

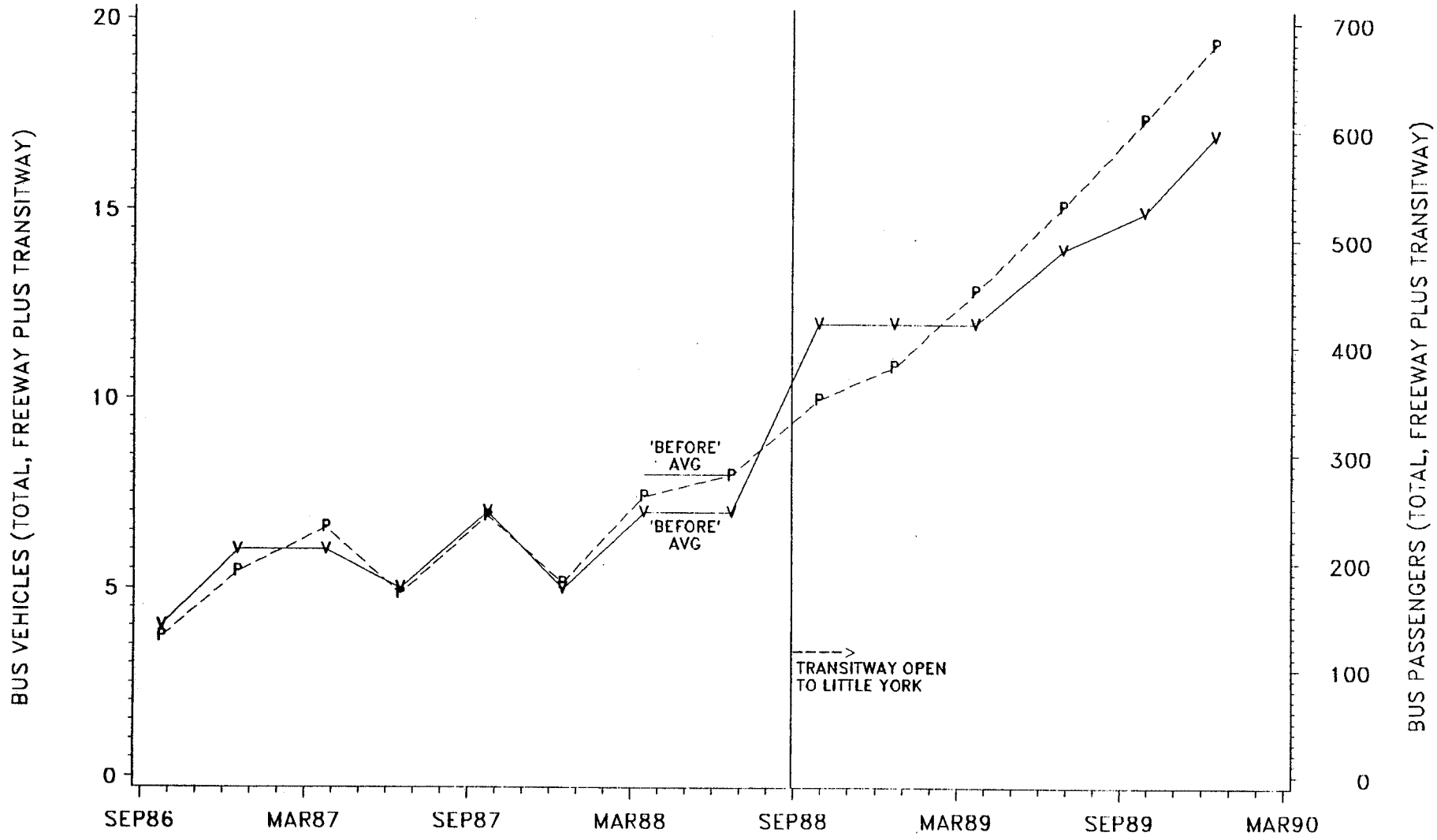


PEAK HOUR EFFICIENCY PER LANE EXPRESSED AS THE MULTIPLE OF PEAK HOUR PASSENGERS TIMES AVERAGE OPERATING SPEED. FOR THE PERIOD AFTER THE OPENING OF THE TRANSITWAY, IT REPRESENTS TOTAL PERSONS (FREEWAY + TRANSITWAY) MULTIPLIED BY THE WEIGHTED AVERAGE SPEED AND DIVIDED BY 4 LANES
DATA FOR FREEWAYS WITHOUT 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 E-19

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

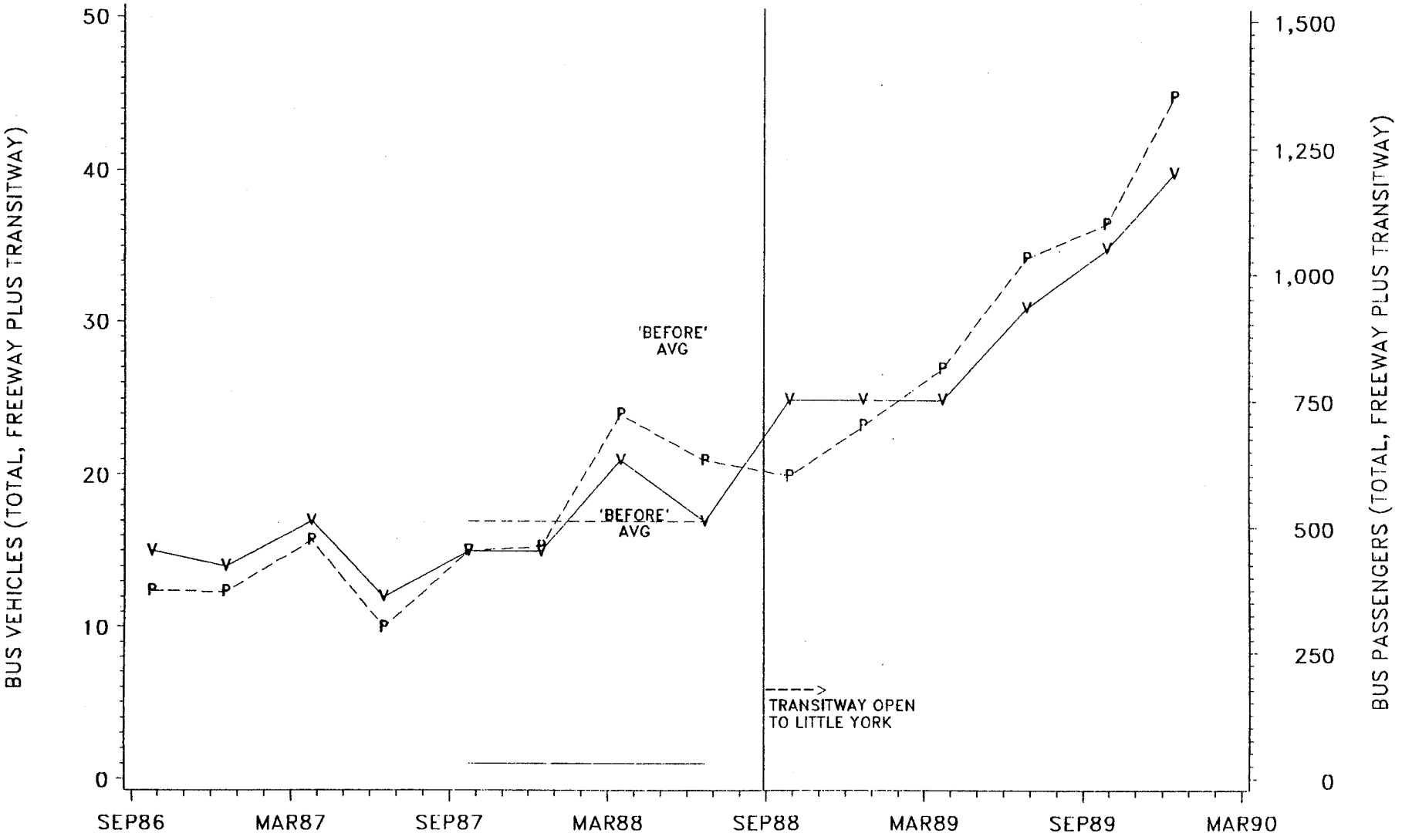


DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-20

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

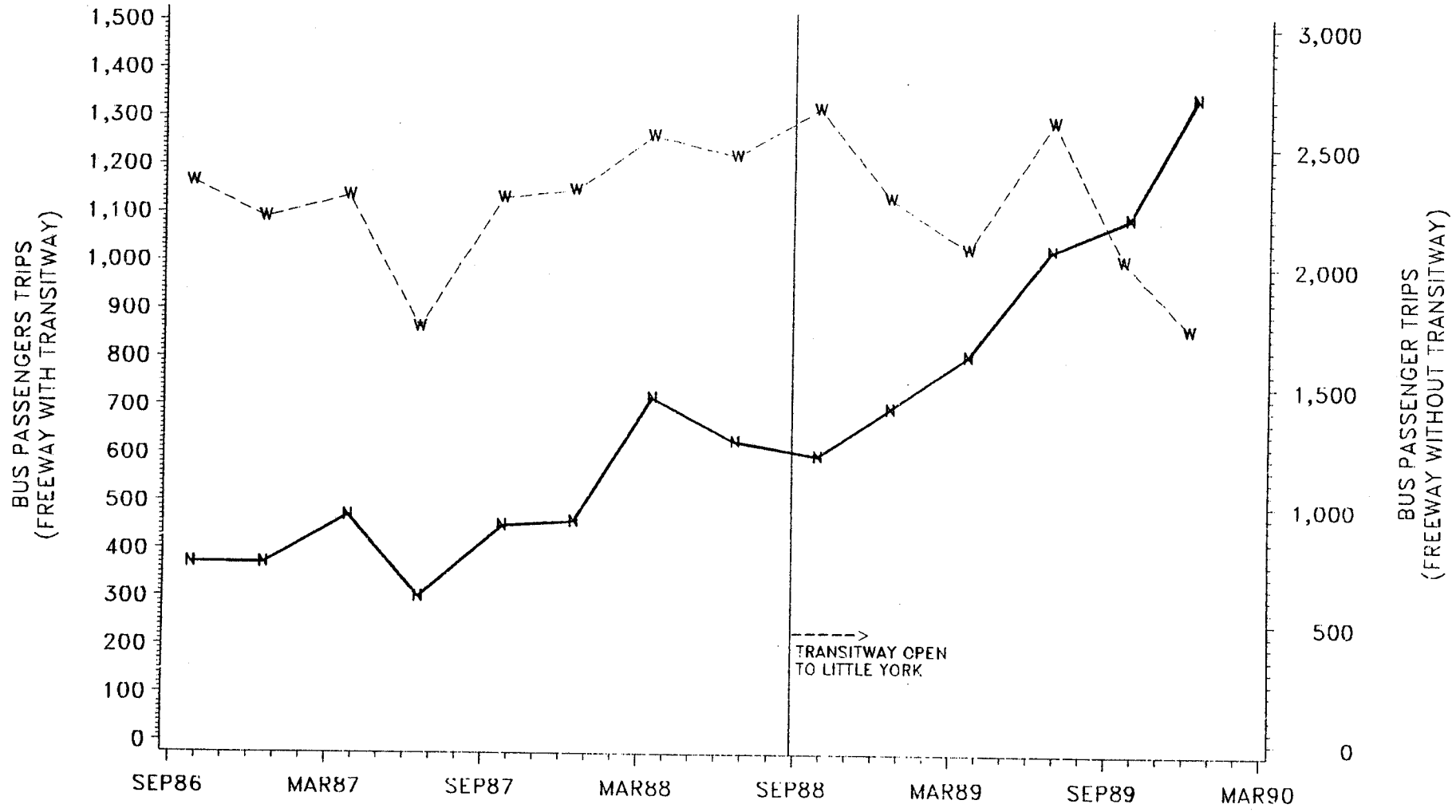


DATA COLLECTED SOUTHBOUND UNDER PINEMONT, 3 LANE SECTION
PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-21

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

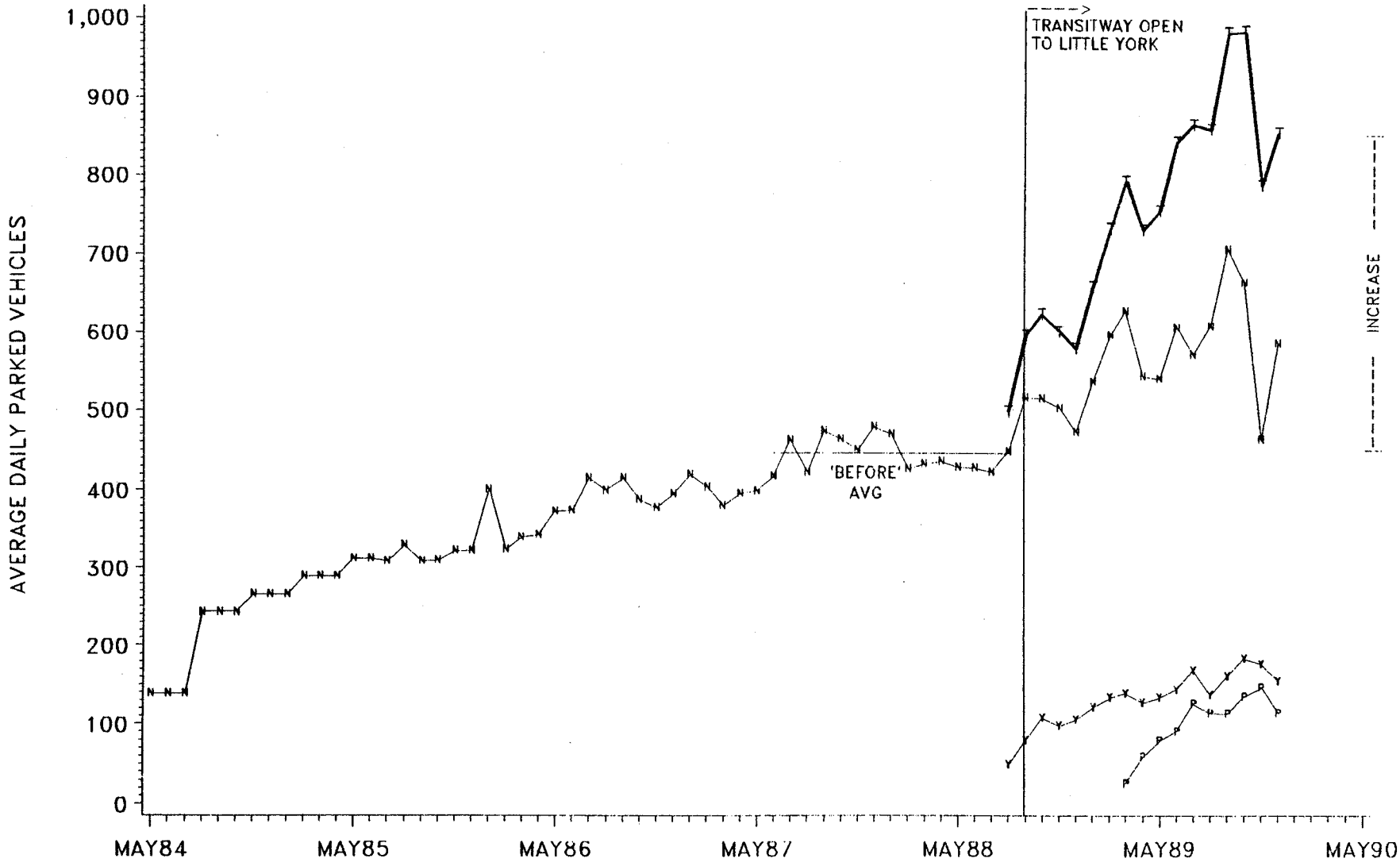


PEAK PERIOD IS FROM 6:00 TO 9:30 A.M.
DATA FOR FREEWAYS WITHOUT TRANSITWAYS ARE A COMPOSITE OF
GULF FWY (6/83 – 4/88) AND SOUTHWEST FWY (9/86 – PRESENT) DATA
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-22

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

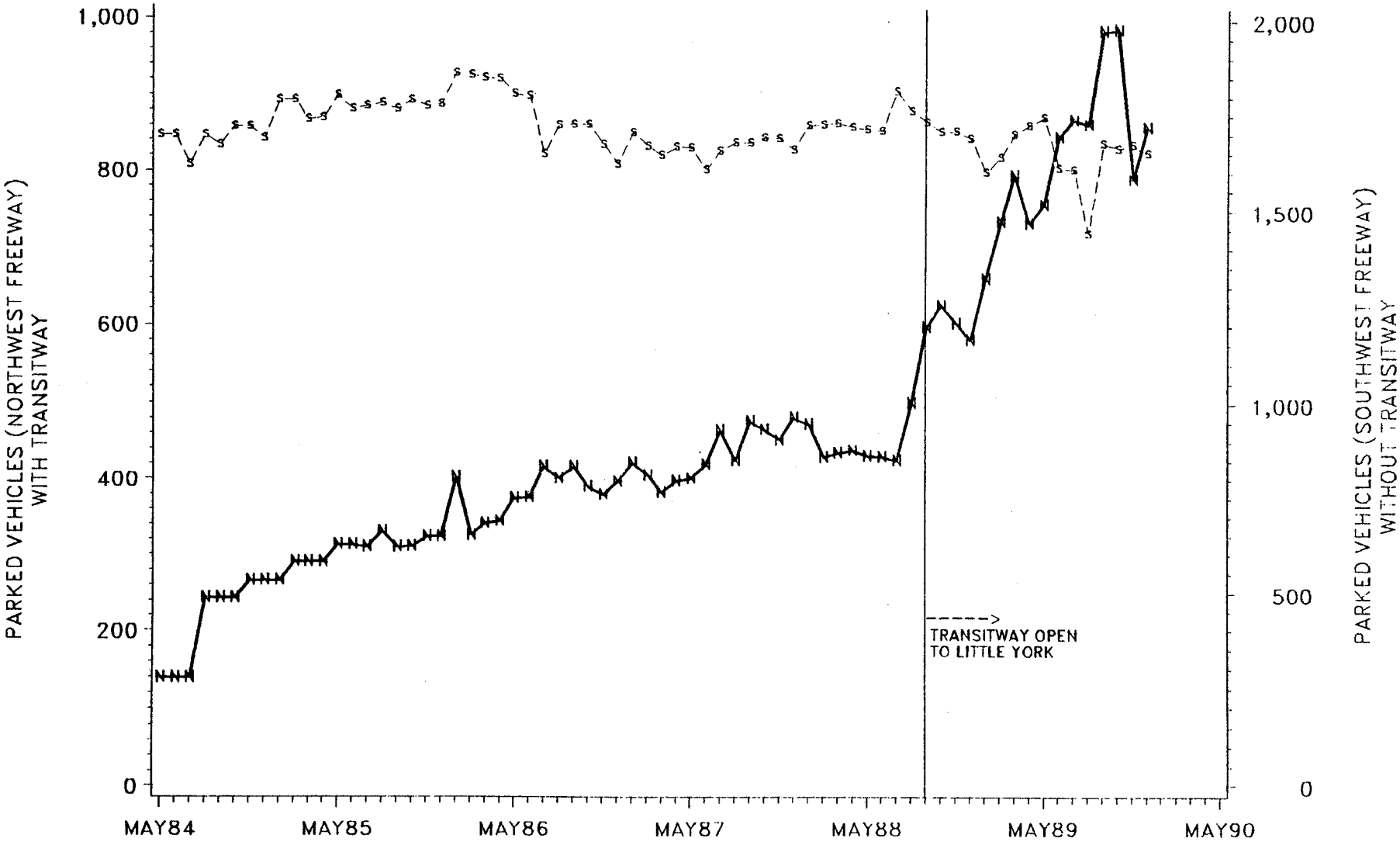


NORTHWEST TRANSITWAY PHASE 1, NORTHWEST TRANSIT CENTER TO LITTLE YORK (9.5 MI), OPENED AUGUST 29, 1988
CURRENT TOTAL CORRIDOR PARKING CAPACITY = 3130 SPACES
SOURCE : TEXAS TRANSPORTATION INSTITUTE

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

FIGURE E-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
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : N = NORTHWEST FREEWAY
S = FREEWAY WITHOUT TRANSITWAY (SOUTHWEST)