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16. Abstract

This report documents the second year's operation of the I-45 North Freeway Transitway in Houston, Texas. The second year covers the period from December 1985 to November 1986. A detailed discussion of the construction sequencing and traffic control strategies implemented is also presented. Impacts to the freeway mainlane traffic are assessed through an analysis of travel times and speeds, vehicle and passenger flow rates, and freeway accident rates. Transitway operation is assessed through an analysis of high-occupancy vehicle demand volumes and peaking characteristics, park-and-ride volumes, travel time savings, occupancy rates, violation rates, disabled vehicle incident rates, and a variety of other performance measures. Comparisons are made for the second year of transitway operation with that of the previous year.

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METRIC CONVERSION FACTORS

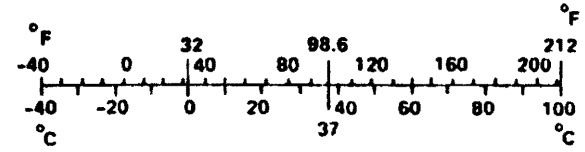
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



THE NORTH FREEWAY TRANSITWAY: EVALUATION OF THE SECOND YEAR OF BARRIER-SEPARATED OPERATION

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Research Report 339-12

Improving Urban Mobility Through Application
of High Occupancy Vehicle Priority Treatments

Research Study Number 2-10-84-339

Sponsored by
Texas State Department of Highways and Public Transportation
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Federal Highway Administration

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

March 1988

ABSTRACT

This report documents the second year's operation of the I-45 North Freeway Transitway in Houston, Texas. The second year covers the period from December 1985 to November 1986. A detailed discussion of the construction sequencing and traffic control strategies implemented is also presented. Impacts to the freeway mainlane traffic are assessed through an analysis of travel times and speeds, vehicle and passenger flow rates, and freeway accident rates. Transitway operation is assessed through an analysis of high-occupancy vehicle demand volumes and peaking characteristics, park-and-ride volumes, travel time savings, occupancy rates, violation rates, disabled vehicle incident rates, and a variety of other performance measures. Comparisons are made for the second year of transitway operation with that of the previous year.

SUMMARY

Since 1979, peak-period, peak-direction vehicle and passenger throughput on the I-45 North Freeway has increased through implementation of a high-occupancy vehicle priority lane on the freeway between North Shepherd Drive and downtown Houston. Until November 1984, the priority treatment consisted of a 9.6 mile contraflow lane. Transitway operation, characterized by the separation of the exclusive facility from the freeway mainlanes by concrete median barriers, officially commenced on November 21, 1984, and the contraflow lane was discontinued. The North Freeway priority lane is used by authorized buses and vanpools.

Throughout the two year life of the transitway facility, priority transitway operation has continued in spite of the ongoing freeway reconstruction and widening activities. Phase I construction extended from downtown Houston to North Shepherd Drive, essentially replacing the contraflow lane with a narrow (approximately 16 feet), barrier-separated median reversible priority lane. The Phase II construction, which began in March of 1985, will result in the widening of the transitway to its final width (approximately 20 feet) and the provision of additional freeway capacity between North Shepherd Drive and the I-610 North Loop. This phase of construction, which included provisions to continue the priority treatment during the morning and afternoon peak hours, was completed in May of 1987. Impacts of the construction on the freeway mainlane traffic flow have been minimal. Although the freeway accident rates are higher than those experienced during contraflow operation, the rates are no higher during the Phase II construction when compared to those of Phase I.

In the second year of barrier-separated transitway operation (December 1985 to November 1986), the transitway volumes averaged 779 vehicles carrying approximately 13,573 people each operating day. This represents a 5.3% decline in vehicle demand, and a 6.7% decline in passenger demand when compared to the previous year of transitway operation. On the other hand, utilization of five park-and-ride lots (measured by the number of parked vehicles) increased by 7.6%, with over 60% of the available spaces occupied on a daily basis. Travel time savings to transitway users averaged about 4.2

minutes per trip during the morning peak period and 8.0 minutes in the afternoon peak period.

Although vehicle trips on the transitway accounted for approximately 3% of the total freeway and transitway vehicle trips, the transitway passenger trips represented at least 30% of the total passenger trips during a typical 3-hour peak period. The reliability of transitway operations has continued to improve as the occurrences of disabled and towed vehicles within the transitway have declined. The accident rate along the transitway has declined by 29% when compared to its previous year of operation; the accident rate is approximately 1.07 accidents per million vehicle miles. Significant further reduction in these rates is expected once the entire length of the transitway is separated from the freeway lanes by concrete median barrier.

IMPLEMENTATION STATEMENT

This study was sponsored by the Texas State Department of Highways and Public Transportation as part of an overall effort entitled "Improving Urban Mobility Through Application of High Occupancy Vehicle Priority Treatments" (Research Study Number 2-10-84-339). An objective of this research is to evaluate for the Department the implementation of high-occupancy vehicle priority treatment projects. An intent of these evaluations is to develop guidelines for planning, designing, and operating transitways on Texas freeways. This is the second evaluation report on the I-45 North Freeway Transitway in Houston.

DISCLAIMER

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INTRODUCTION

The I-45 North Freeway in Houston, Texas, is a major interstate highway serving travel demands from northern Harris County and central Montgomery County to various parts of Houston (Figure 1). Extensive residential and commercial development has occurred along this corridor. The population within the corridor has been estimated to grow by 38% between 1980 and 1995, resulting in a population of 88,000 people in the area by 1995 (1). This development and population growth has led to progressively worse levels of traffic congestion throughout the corridor. Average daily traffic volumes on I-45N in 1984 exceeded 194,000 vehicles in an 8-lane section. Peak direction freeway speeds averaged less than 30 mph during both the morning and afternoon peak hours. The North Freeway has been one of Houston's more congested freeways for many years.

As early as 1979, the Texas State Department of Highways and Public Transportation (SDHPT) and the Metropolitan Transit Authority of Harris County (METRO) jointly developed a 9.6 mile contraflow lane (CFL) on the I-45 North Freeway between downtown Houston and North Shepherd Drive (Figure 2). This project was an interim measure designed to relieve some of the corridor congestion by providing additional peak direction capacity. This peak-direction capacity was obtained without extensive roadway construction. A lane was "borrowed" from the off-peak direction roadway and dedicated to authorized high-occupancy vehicles (buses and vanpools) traveling in the peak direction. Since the project began in 1979, utilization increased from 2900 daily passengers in September 1979 to more than 16,500 daily passengers (its highest utilization rate) in September 1983 (1). Because of the high occupancy rates of the vehicles utilizing the contraflow lane as well as the high peaking characteristics of the vanpools, the contraflow lane was serving more person trips during a typical peak hour of operation than two adjacent freeway lanes, and at a much higher level of service. In March 1981, the SDHPT and METRO implemented a 3.3 mile concurrent flow lane (CCFL) in the inbound median shoulder of the freeway, thus extending the priority operation in the morning to West Road (Figure 2).

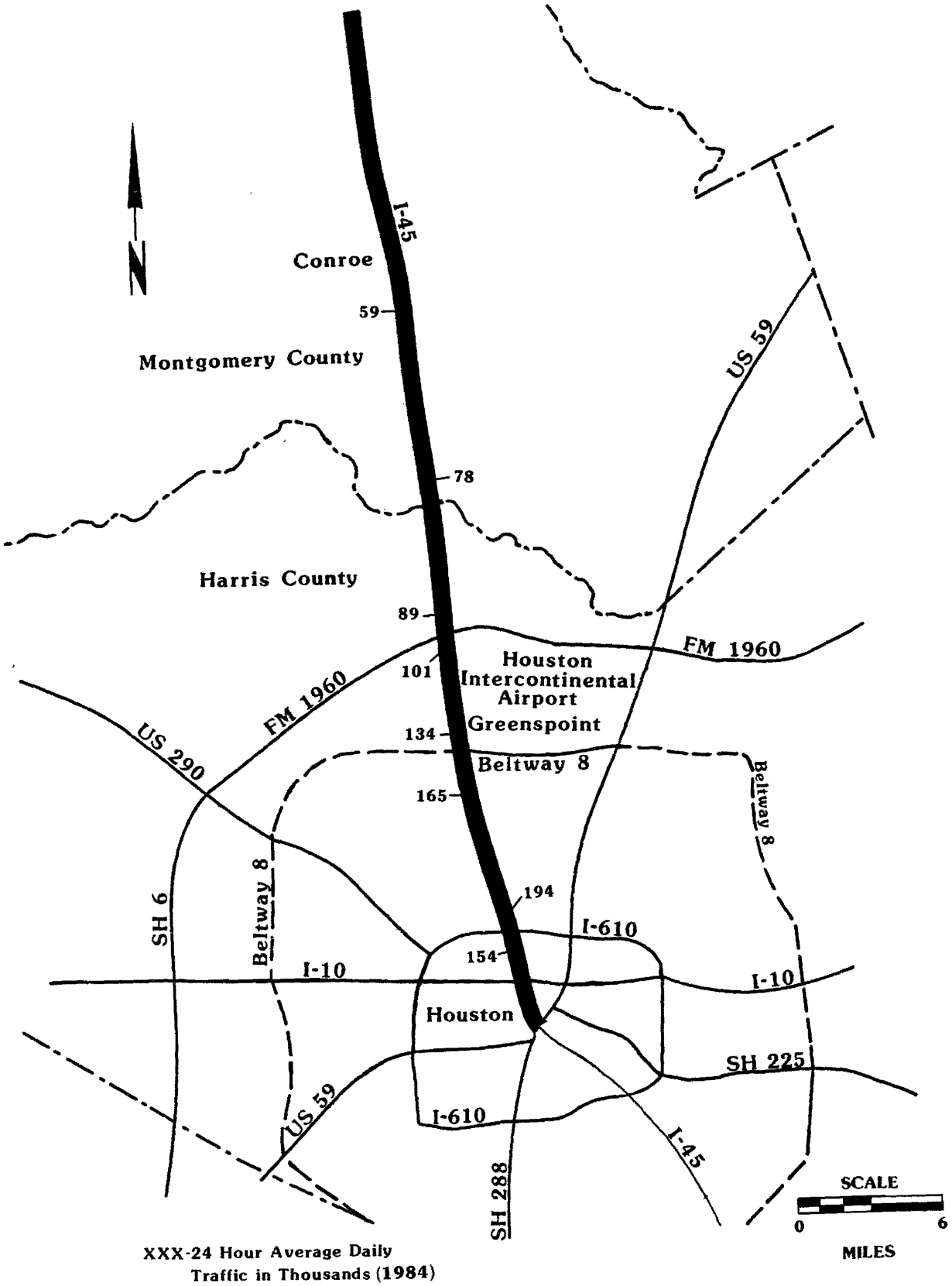


Figure 1. I-45 North Freeway Service Corridor

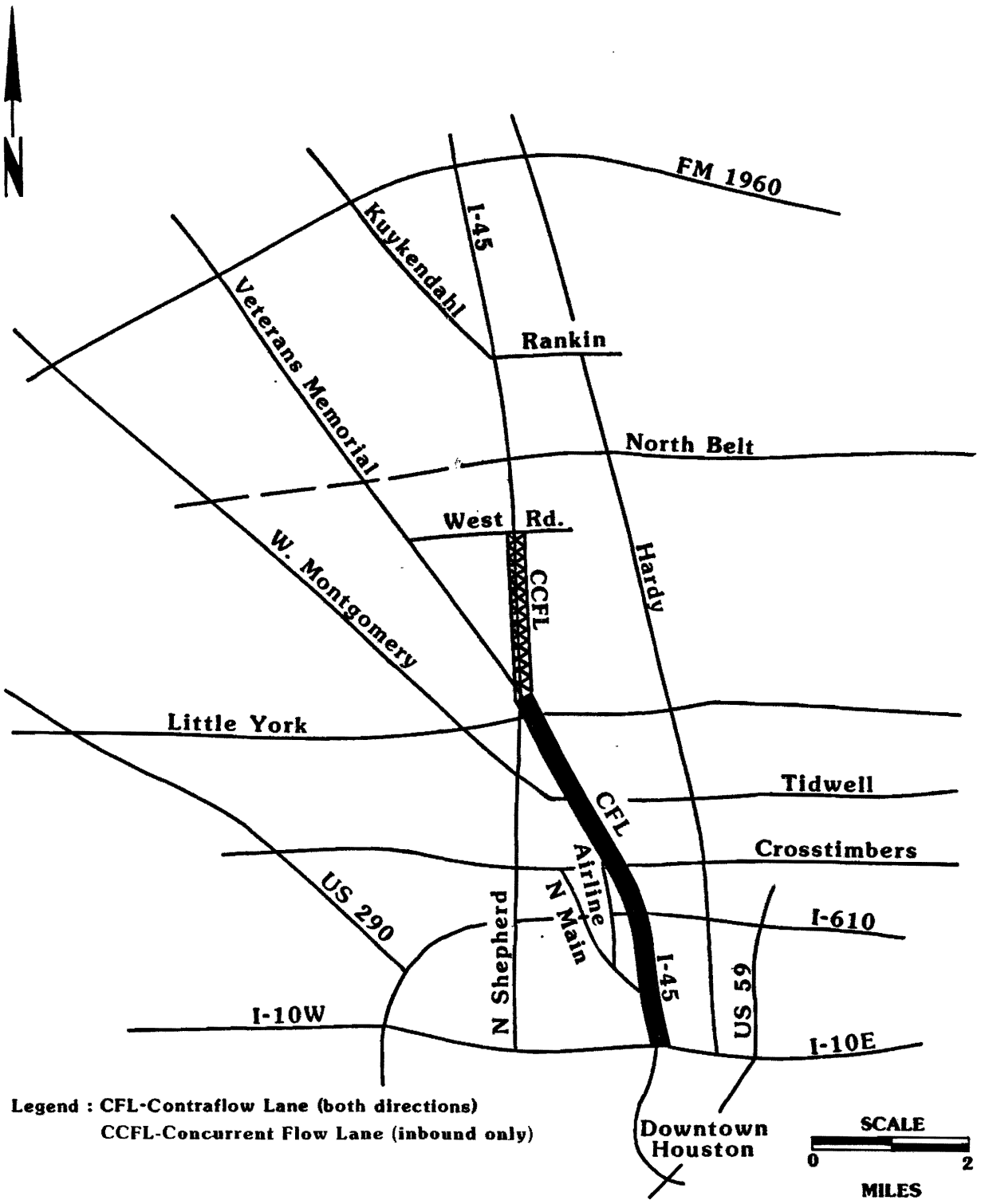


Figure 2. Limits of HOV Priority Treatment

The priority treatment lane on the I-45 North Freeway may be used only by authorized high-occupancy vehicles. This limits the facility to use by buses and vanpools. In order to be authorized, the van must be designed to carry 8 or more persons and have at least 8 persons registered as riders. The drivers of the vanpools must be certified to drive an authorized vehicle on the lane. In addition to meeting requirements for licensing, insurance, and vehicle inspection, each vanpool driver must complete the METRO Transitway Driver Training Session. Each authorized vanpool is issued a decal which must be placed on the vehicle prior to using the facility. Several rules of operation must be obeyed by users, including the use of seat belts, headlights, operating speed (maximum speed of 55 mph unless otherwise posted), headways, and guidelines for disabled vehicles and for passing any disabled vehicles. In 1979, City of Houston Ordinance #19-1214 was adopted to provide for the enforcement of restricted access lanes for mass transportation services as designated by the SDHPT. It also includes provisions for the removal of vehicles causing a hazard to the operation of a designated lane (2).

The contraflow project was only considered an interim solution to the need in the corridor for additional capacity. Increases in the traffic demands in the off-peak direction precluded the reduction in capacity beyond the mid 1980's without increasing off-peak direction congestion to unacceptable levels (3). Although the continuation of the contraflow project was no longer desirable, neither was it economically nor physically feasible to provide enough additional freeway lanes to satisfy even existing peak-period travel demand, much less serve projected future demand levels. The need for a transitway was clear; moreover, the construction of a transitway within a relatively short time frame was critical in order to preserve the express transit benefits and the resulting transit ridership levels that were derived from the contraflow lane operation.

In 1982, the SDHPT and METRO agreed to develop a transitway in the median of the I-45 North Freeway as part of a corridor improvement project. This project included widening bridges, resurfacing the freeway, providing more efficient and safer lighting and drainage, as well as increasing the freeway capacity along a 9 mile segment of the freeway from the North Loop

(I-610) to the North Belt (Beltway 8). A previously published TTI report documented the development, construction, and subsequent first year of operation of this transitway within the I-45 North Freeway corridor (4). This report describes the operation of the transitway during its second year of barrier-separated operation. It specifically addresses the time period from December 1985 to November 1986.

TRANSITWAY CONSTRUCTION

Project Description

The I-45 North Freeway Transitway and Freeway Improvement Project is being implemented in four phases (Figure 3). Phase I construction extended from downtown Houston to North Shepherd Drive, essentially replacing the contraflow lane with a 16 foot wide barrier-separated reversible median HOV lane; this narrow transitway width will exist only until the freeway construction is completed in this freeway section. Phase IA involved the relocation of signing and lighting in order to clear out the freeway median for the reversible lane. Phase IB provided for the reconstruction of the median to place the contraflow lane within the freeway median so that it could be protected from the freeway mainlanes by concrete median barriers. Phase I construction was completed, and contraflow operation ceased in November 1984; and barrier-separated transitway operations began. Phase II construction, which began in March 1985, includes freeway widening, shoulder replacement, construction of u-turn lanes, and widening of the transitway to its final width. The limits of this project are from North Shepherd to near downtown (Quitman Street). The project is scheduled for completion by May 1987. The Phase III construction, which extends the transitway from North Shepherd to Beltway 8, began in April 1986. The project, which also includes freeway rehabilitation and widening, replacement of bridge structures, intersection improvements, and transitway construction (including an elevated transitway interchange), is scheduled for completion in October 1988. The transitway is expected to become operational in this section in a temporary configuration in April 1988. The Phase IV segment is undergoing conceptual design and is scheduled to be operational by 1993.

This report focuses on the second year (December 1985 to November 1986) of barrier-separated transitway operation. The transitway width has been 14-16 feet wide in most sections, with no freeway lanes "borrowed" from the off-peak direction as was the case during contraflow operation. However, transitway sections south of I-610 North Loop were as narrow as 12 feet in width at some underpasses.

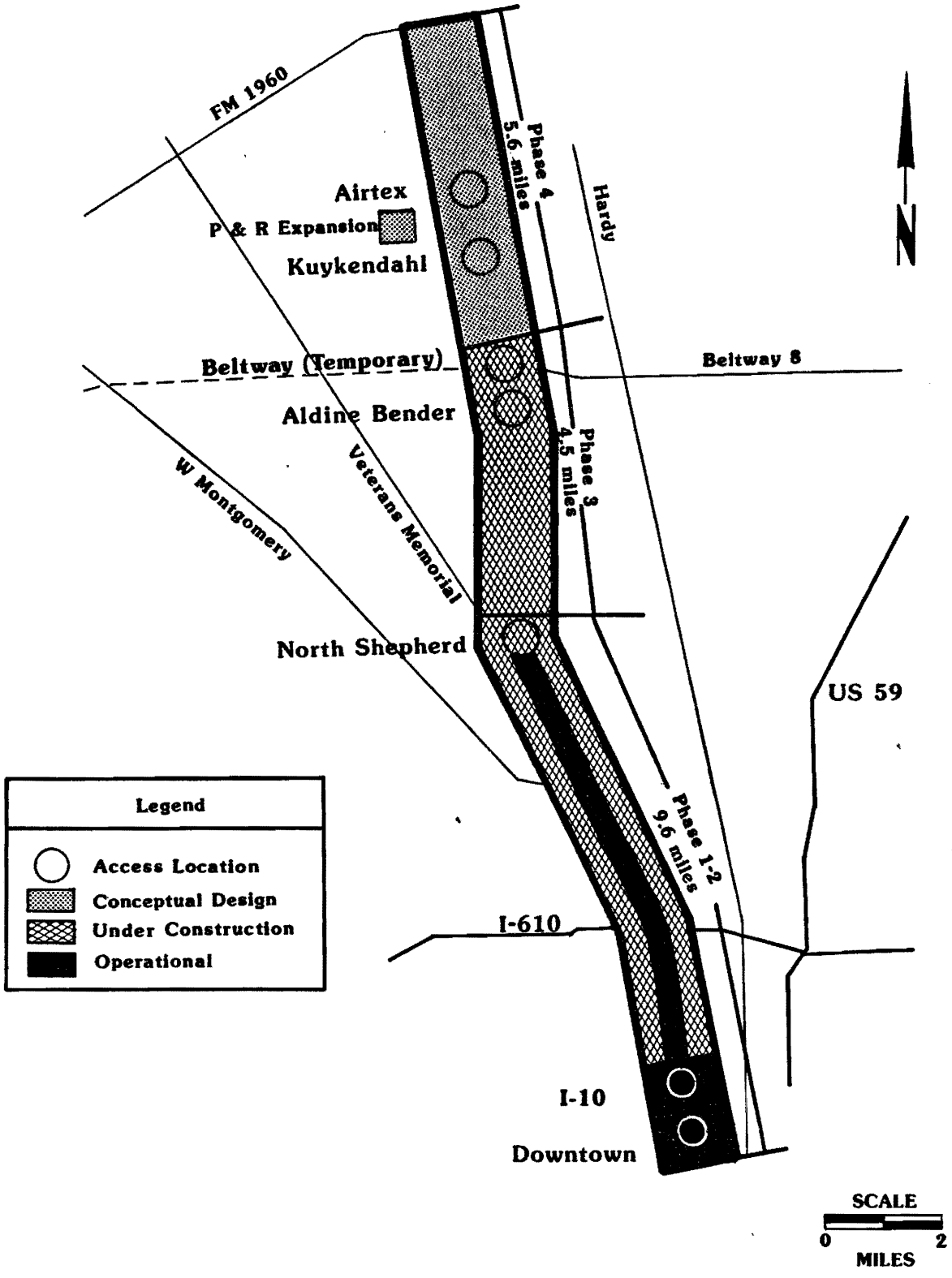


Figure 3. I-45 North Freeway Construction Phases

In order to expedite the construction of the project's first two phases, METRO agreed to fund both the transitway- and freeway-related costs for Phases I and II, and SDHPT agreed to fund and construct Phase III. Phase IV is to be jointly funded, with SDHPT supervising the construction. The total expected costs for each phase of the transitway and freeway construction are included in Table 1.

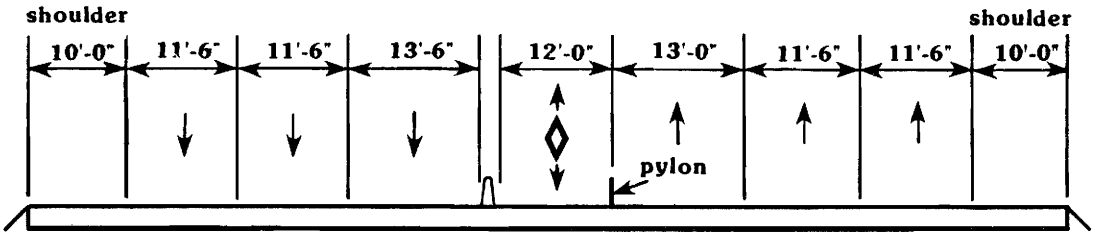
Table 1. I-45 North Freeway Construction Costs

Project Phase	Total Costs	Cost/Mile
Phase I:		
Interim Transitway - North Shepherd to Downtown		
Actual Costs	$13.0 M	$ 1.35M
Phase II:		
Transitway and Freeway Widening - North Shepherd to Downtown		
Actual Costs	$50.1 M	$ 5.22M
Phase III:		
Transitway and Freeway Widening - Beltway 8 to North Shepherd		
Engineer's Estimate	$67.9 M	$15.09M
Phase IV:		
Beltway 8 to FM 1960		
Engineer's Estimate	$49.9 M	$ 8.91M

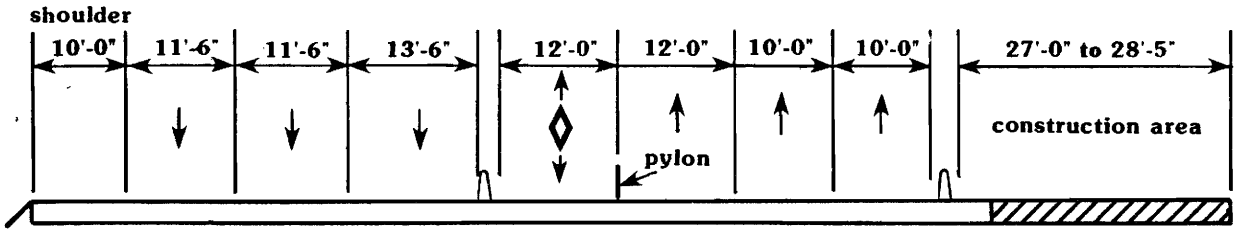
Source: Reference (1).

Construction Sequencing

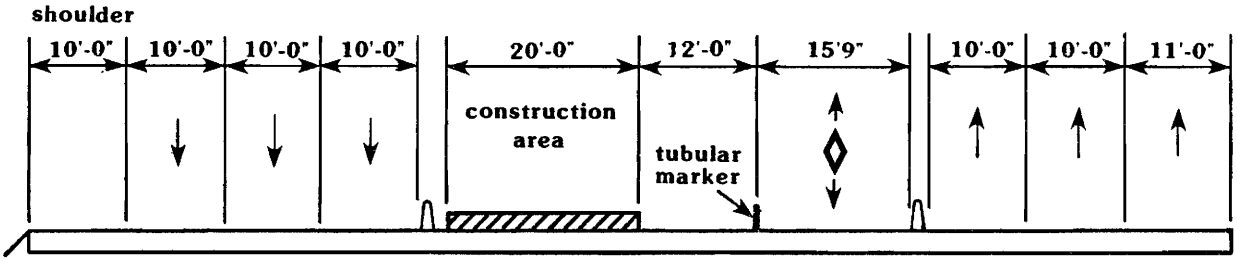
The Phase II construction activities were sequenced to provide minimum disruption to both freeway and transitway users. Specifically, this required that no freeway mainlanes would be closed during peak periods (in the peak direction of flow), and the transitway would remain operational during both peak periods. Freeway capacity would be reduced as a result of the narrowing of lanes; sections of freeway would exist without emergency shoulders for extended periods of time. To efficiently perform the construction tasks, a seven step sequence was implemented for the construction to the north of I-610 North Loop (Figure 4). This sequenced construction allowed separation of the freeway traffic from the construction workers by concrete median barriers (CMB). The workers were also separated from the transitway traffic



EXISTING (PHASE I-FINAL)

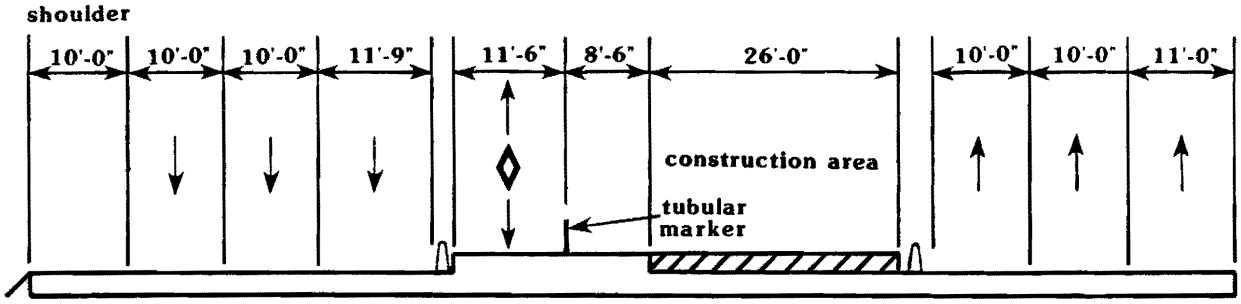


STEP I

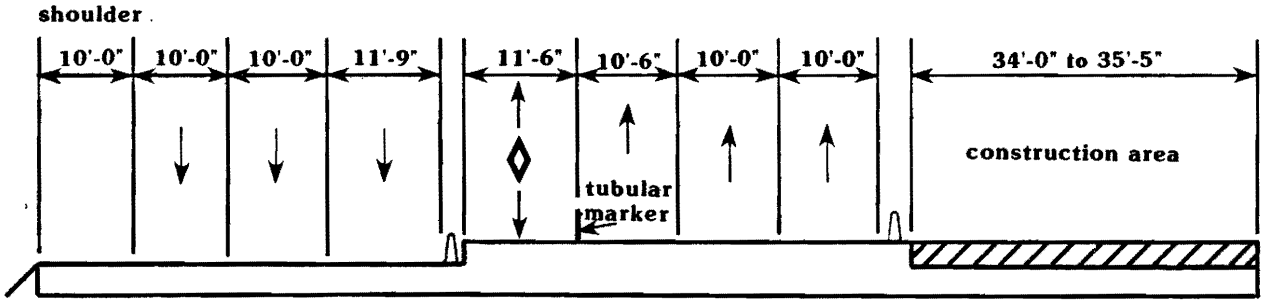


STEP II

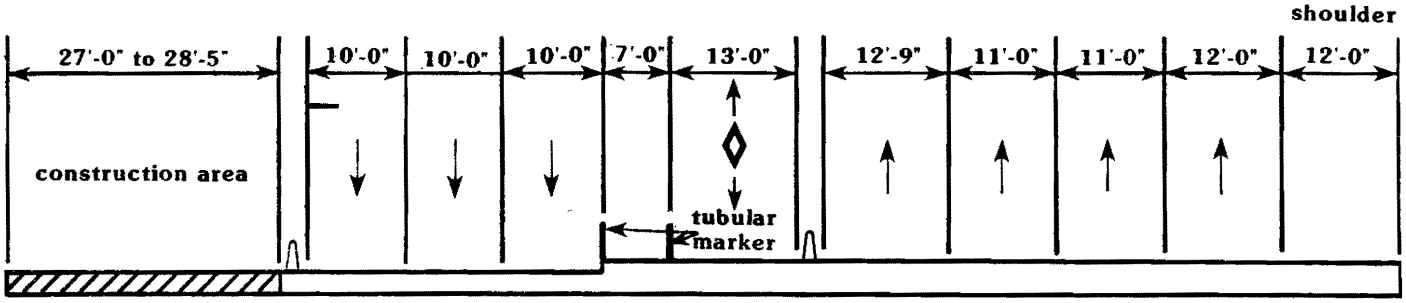
Figure 4. Typical Freeway Construction, Sequence, Phase II



STEP III

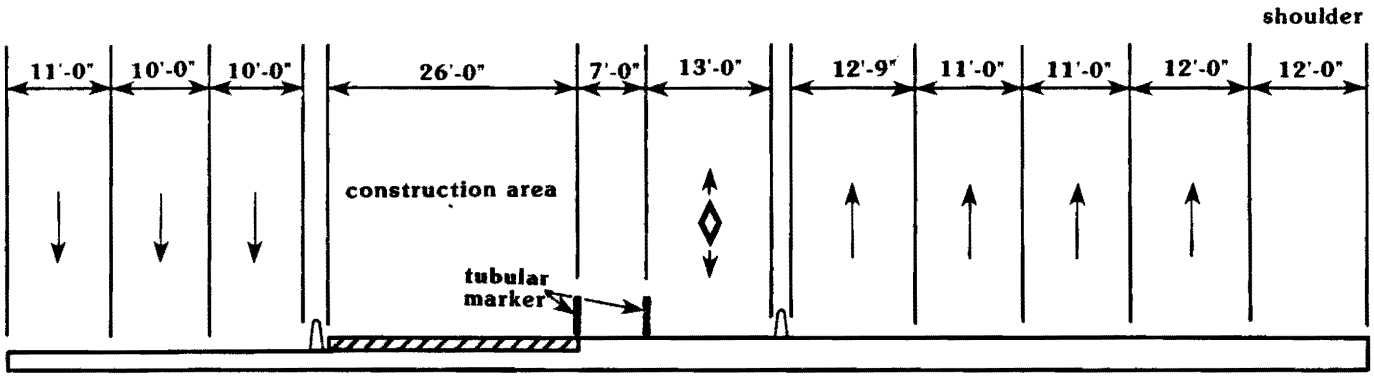


STEP IV

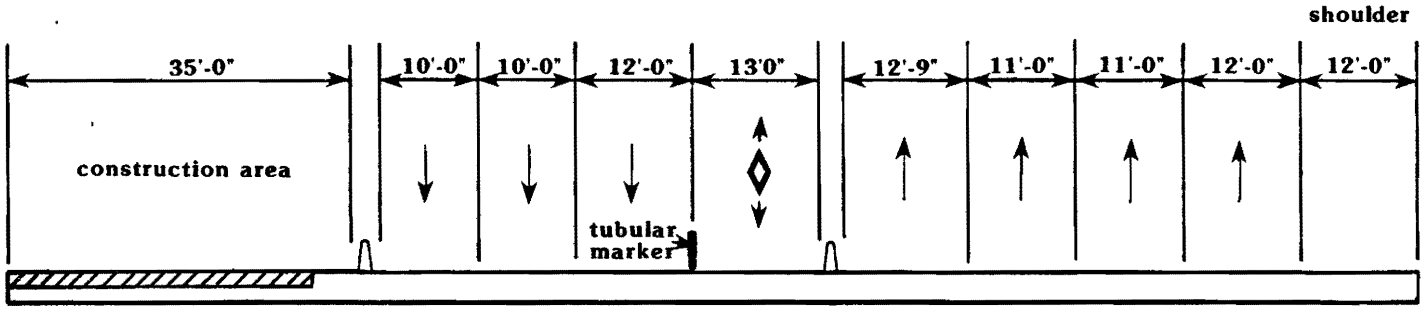


STEP V

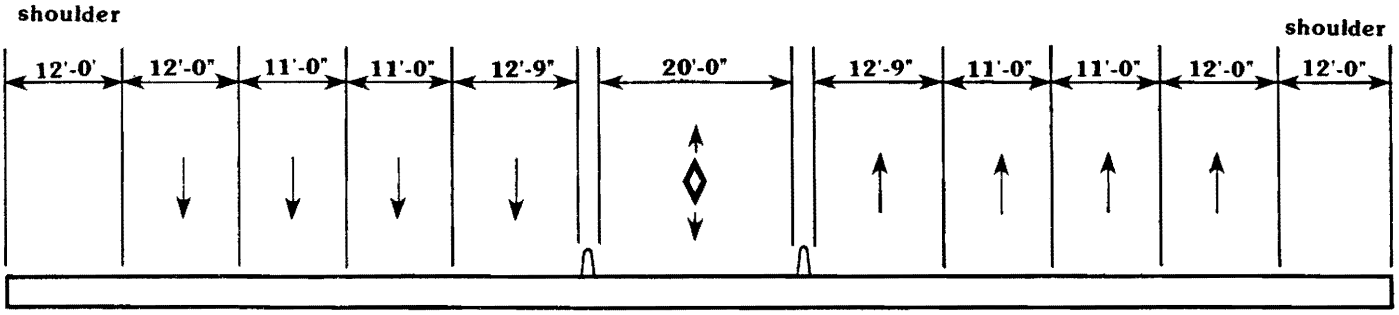
Figure 4. Typical Freeway Construction Sequence, Phase II (Con't)



STEP VI



STEP VII



FINAL

Figure 4. Typical Freeway Construction Sequence, Phase II (Con't)

by the CMB, except during steps II, III, and VI when tubular markers and an additional buffer separation distance were used. This plan presented no safety problems for either the construction workers or the transitway users due to the limited hours of transitway operation and the attentive driving of the buses and vanpools. Informative signing and pylons (or tubular markers) were used to separate the transitway from the freeway traffic (Figures 5 and 6). At all times, the transitway was separated from the freeway traffic on at least one side by a concrete median barrier.

Due to the extent of their deterioration, the freeway reconstruction project also required the rehabilitation of bridge structures. This construction activity required special traffic control plans to facilitate the traffic handling and ensure the safety of both motorists and the construction workers. The bridge rehabilitation included a wide range of construction activities, such as bridge deck replacement, pavement overlays, and expansion joint repairs. The traffic control plan varied by location, depending on the number of segments which were reconstructed and the number of freeway mainlanes. Figure 7 illustrates the implementation of the four step traffic control plan which was used in the 8-lane freeway section south of I-610 North Loop. This traffic control plan guided motorists through the work zones by splitting the freeway traffic flow. This resulted in unique situations of construction activities which were located between the adjacent travel lanes. However, the implementation of this traffic control strategy allowed for the rehabilitation of the bridge structures to be completed in an efficient manner. The construction activities progressed from the outside lane of the existing structures to the median, as illustrated by Figure 7. Innovative signing and pavement markings were used to guide motorists through these work zones (Figures 8 and 9).

Impacts of Construction on Traffic Flow

Prior to the onset of the Phase II construction, METRO and SDHPT developed a plan to address the potential impacts of the transitway and freeway construction on the motoring public. As part of their concerns to minimize such impacts, TTI was contracted to monitor traffic flows and delays throughout the I-45 North Freeway corridor for the duration of the Phase II

Figure 5. Transitway and Freeway Separation - Phase I (Final)

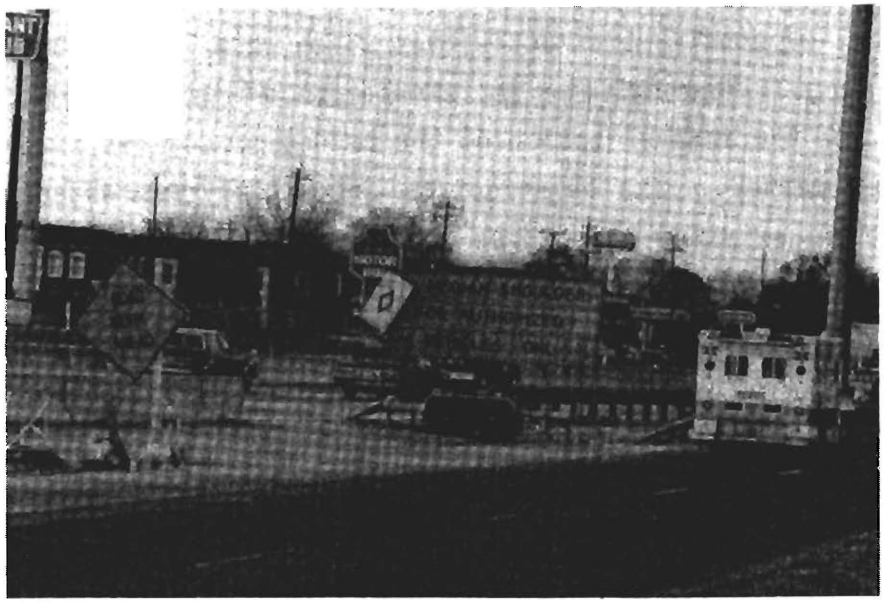


Figure 6. Signing Designating Transitway

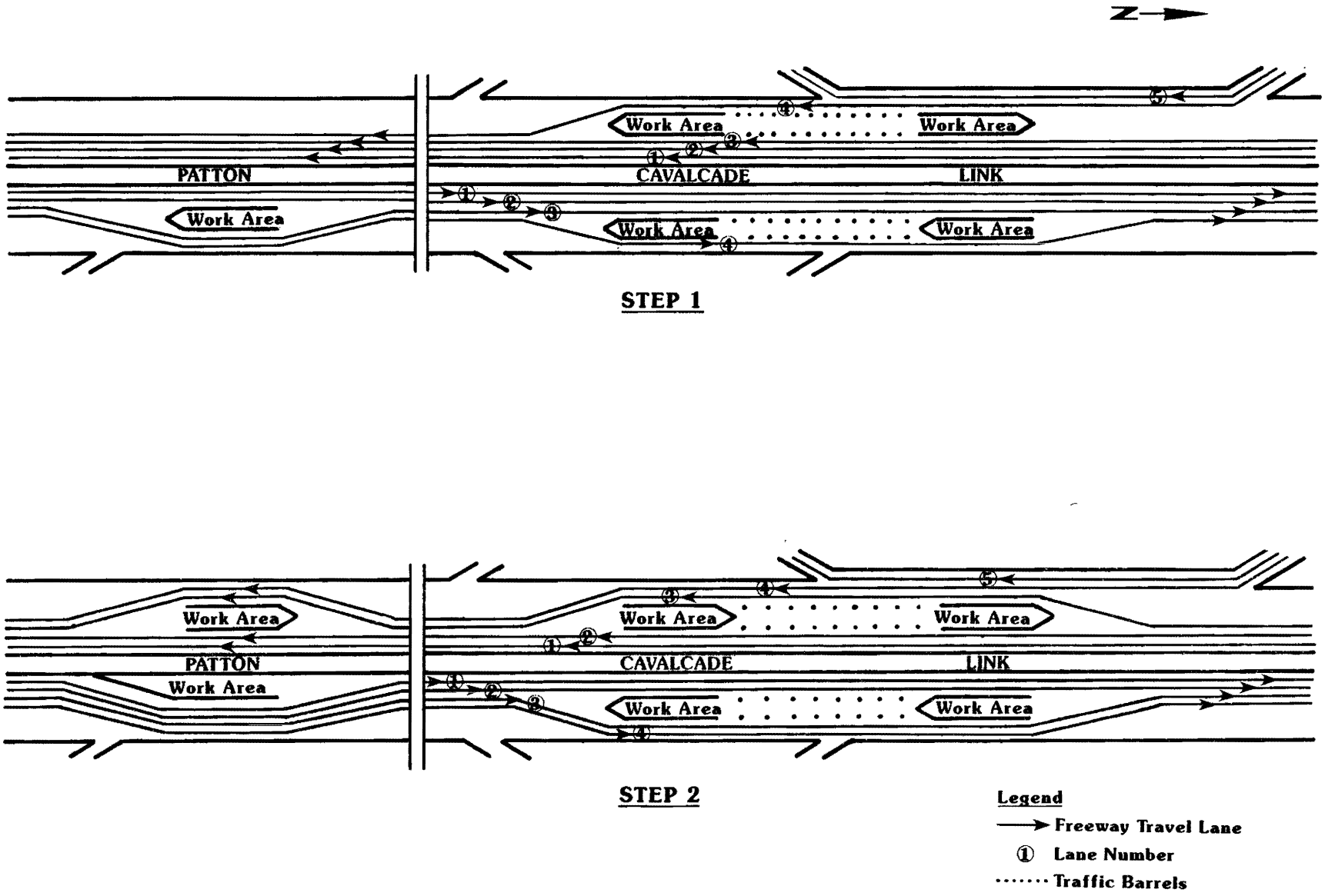


Figure 7. Traffic Control Plan for Bridge Deck Overlays

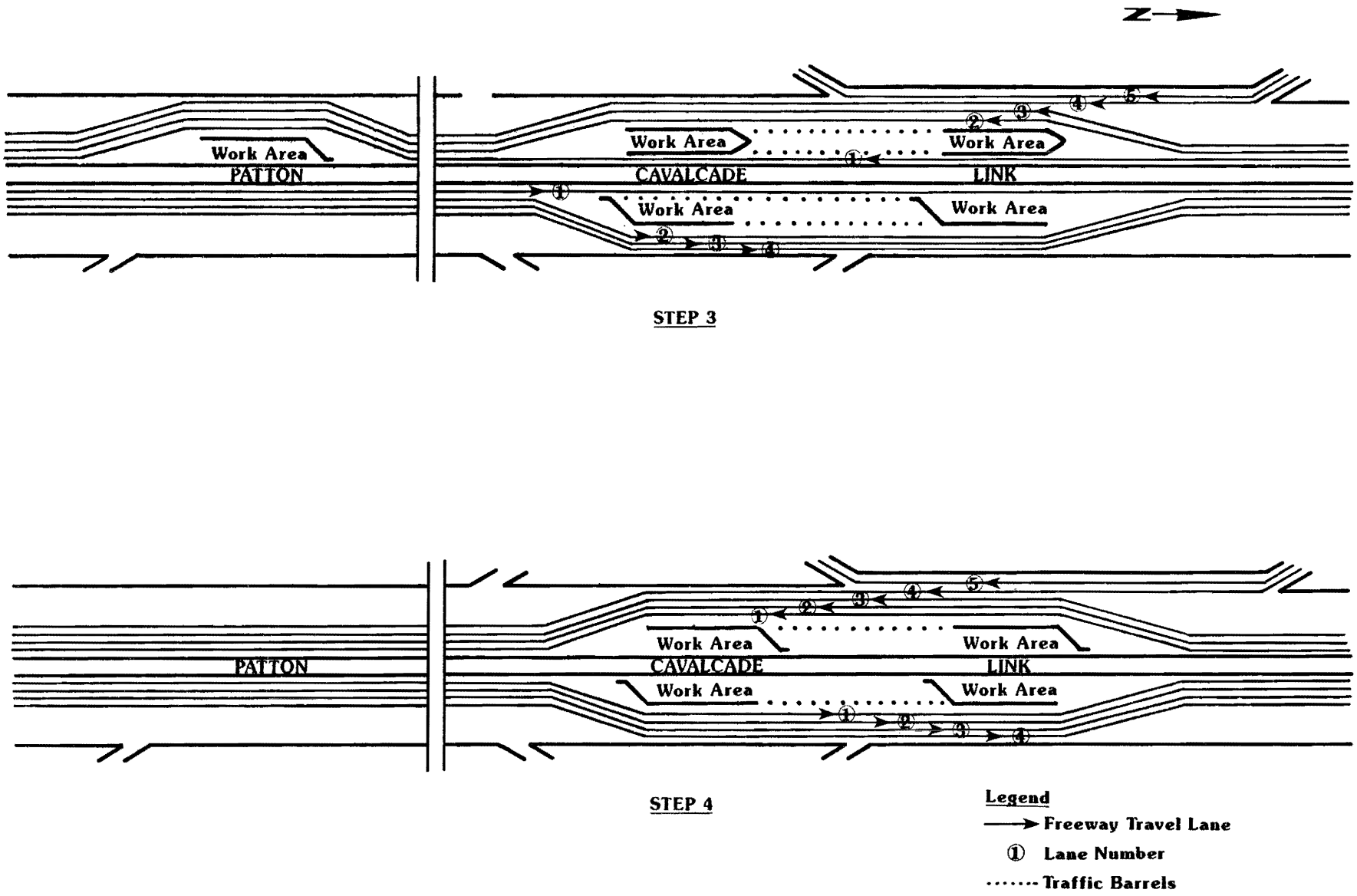


Figure 7. Traffic Control Plan for Bridge Deck Overlays (Con't)

Figure 8. Advanced Signing for Bridge Deck Overlay Traffic Control

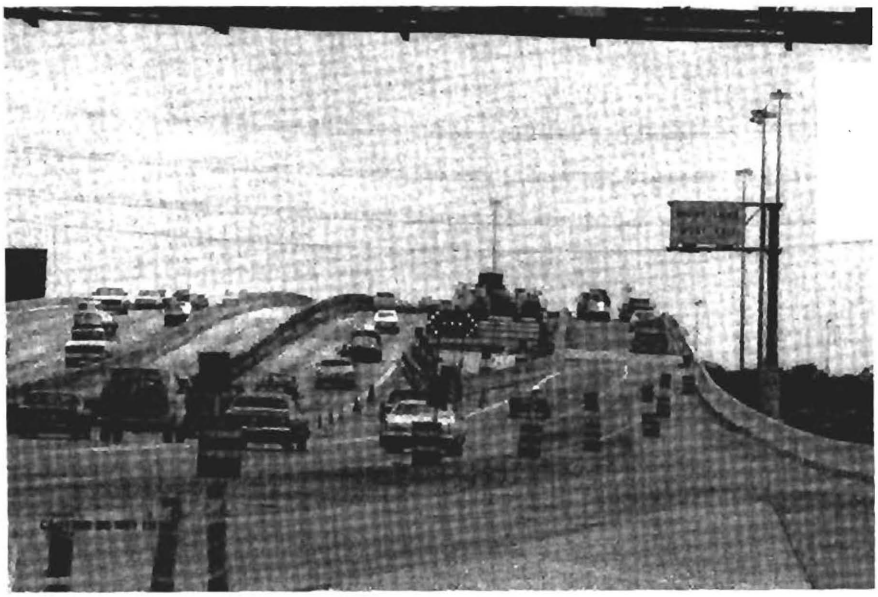


Figure 9. Use of Arrow Boards at Traffic Splits

construction. Traffic flow conditions of both major and minor arterials throughout the corridor were evaluated, with emphasis placed on the freeway mainlanes and adjacent frontage roads. Study results for the period ending January 1986 indicated that the initial stages of the Phase II construction did not significantly change the traffic congestion during the peak periods (5). Volume levels along the freeway mainlanes changed by less than 3% for the a.m. peak inbound flow and increased by 4% to 10% for the p.m. peak outbound flow. Changes in the freeway travel times and speeds were not significant enough to be noticed by the motoring public. Park-and-ride bus service and vanpool usage were encouraged by METRO through the use of portable trailer mounted signs at selected locations (Figure 10).

Figure 10. Trailer Mounted Sign Encouraging HOV Usage

TTI conducted a detailed analysis of the bridge deck overlay construction sequences implemented on I-45 northbound between Cavalcade and I-610 North Loop (Figure 7). Steps 1, 2, and 3 of the traffic split configurations were studied to determine any impacts to traffic flow which could be attributed to the splitting of the freeway traffic. The study results indicated that none of the three configurations caused major problems

to traffic flow through that section of freeway. No queueing resulted due to the separation of the freeway travel lanes. Motorists may have been apprehensive on their first encounter with each configuration, but they quickly adapted to the situation as they became more familiar with the geometrics. Some movements, such as the exit to I-610 North Loop, had very narrow lanes, and the closeness of the concrete traffic barriers to the travel lanes made the cross sections seem "tight", but not intolerable, based on the freeway travel speeds. No significant differences in travel speeds within the construction zone were noticeable from the monthly travel time and delay studies. Traffic volumes during both the peak and off-peak periods were also not significantly affected by the various geometric configurations.

Commuter Perceptions of the Impact of the Construction

User surveys of bus riders (local, park-and-ride, other express), vanpool drivers, and auto commuters within the I-45 North Freeway corridor were conducted to measure their perceptions of the effects of the construction on their travel (6, 7). The results of a second survey conducted in December 1985 indicated that the majority of local bus riders, park-and-ride bus users, other express bus riders, and vanpool drivers (76%, 56%, 55%, and 67% respectively) perceived that there had been no change in their travel times during the freeway reconstruction. An additional 8% of the local bus riders, 21% of the park-and-ride users, 30% of the express bus users, and 14% of the vanpool drivers indicated that their travel times had decreased. However, 16% of the local bus riders, 23% of the park-and-ride users, 15% of the express bus riders, and 19% of the vanpool drivers reported longer travel times.

The auto commuter group was more likely to be impacted by the freeway construction. Of the 125 auto commuters responding to the survey, only 48% perceived no change, and 10% perceived shorter travel times during the construction. However, the remaining 42% stated that their travel times were 5 to 45 minutes longer. Results of travel time studies for the freeway mainlanes did not indicate that the travel time increases were of the same magnitude as indicated by the survey respondents (5).

TRANSITWAY OPERATIONS

The I-45 North Freeway contraflow lane began operating between North Shepherd Drive and downtown Houston on August 28, 1979. The contraflow facility was officially converted to a barrier-separated transitway on November 29, 1984. The approximate hours of operation are from 5:45 to 8:45 am (southbound) and from 3:45 to 6:45 pm (northbound). The hours varied slightly as the transitway support crew had to assure that all construction activities were removed from the available transitway width and the tubular markers or pylons were properly erected prior to opening the priority lane. However, the opening and closing times varied by less than 10 minutes. This section of the report summarizes the transitway operations for the second year of barrier-separated operation, from December 1985 to November 1986. Comparisons are also made with the previous year of transitway operation (4).

Demand Volumes

Tables 2 and 3 present the monthly I-45 North Freeway Transitway vehicle and passenger demand volumes for the year ending November 1986. The cumulative changes from month to month are also presented. Average peak-period vehicle and passenger demands are depicted graphically in Figures 11 and 12. Comparing the previous year's vehicle demands with those for the second year of transitway operation, average daily bus demand volumes have increased by 6.8%, while the vanpool demand volumes have decreased by 12.1%. The increase in bus volumes is due to a combination of the opening of The Woodlands Park-and-Ride lot in May 1986 and increased usage of the transitway by non-commuter buses. Based on TTI observations, an average of 6 non-commuter buses use the transitway each day. This normally includes 2 buses from the Texas Department of Corrections and 4 intercity buses operated by Greyhound and Continental Trailways. The decline in vanpool usage is due to decreased support of the vanpool program in general by major corporations, this being at least partially a reflection of the depressed local economy. In particular, the recent economic decline in the petroleum industry has resulted in job layoffs reducing the work force in the downtown area. Overall, transitway vehicle demand has declined by 5.3% within the past year

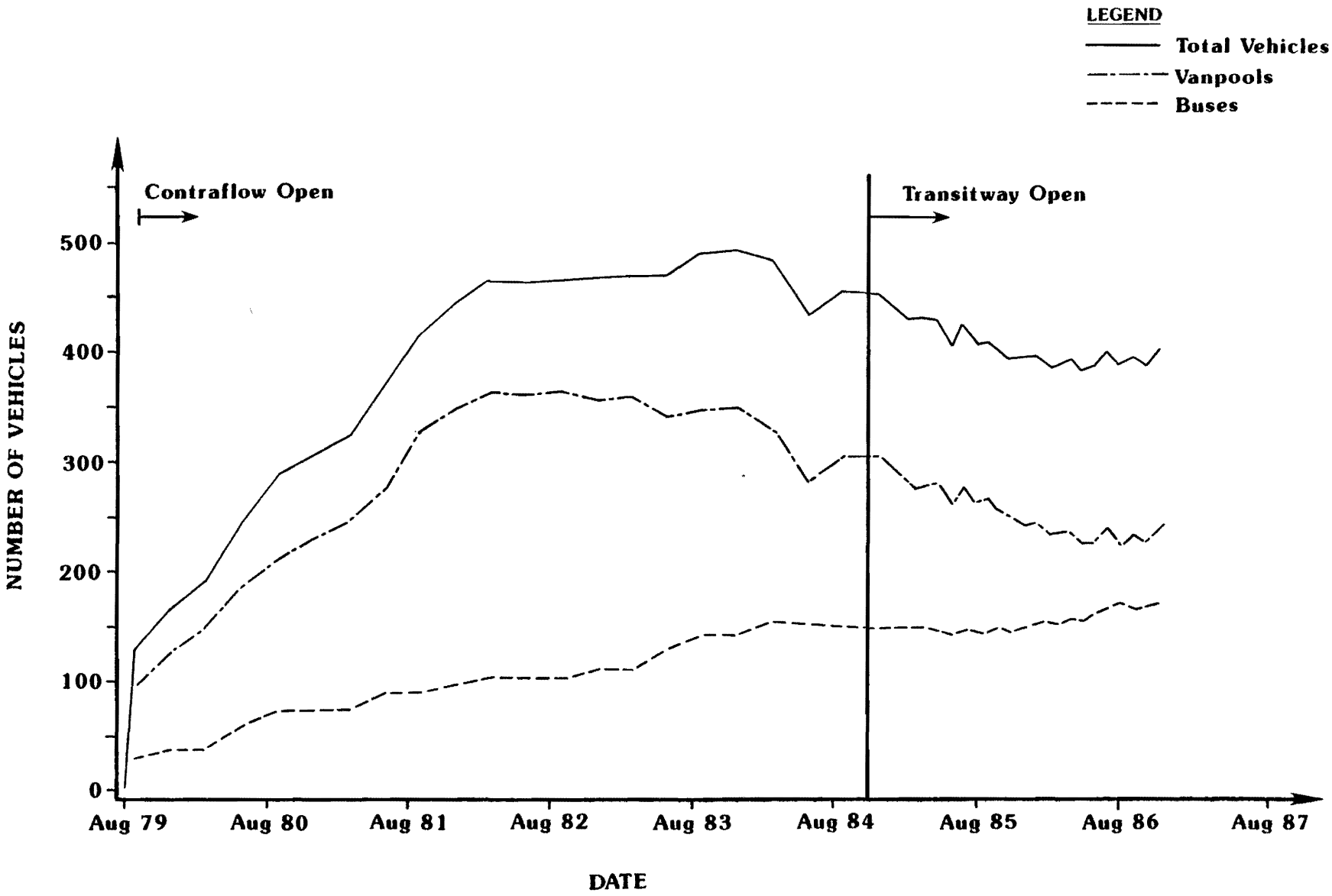


Figure 11. Average of AM and PM Peak Period Transitway Vehicle Volumes

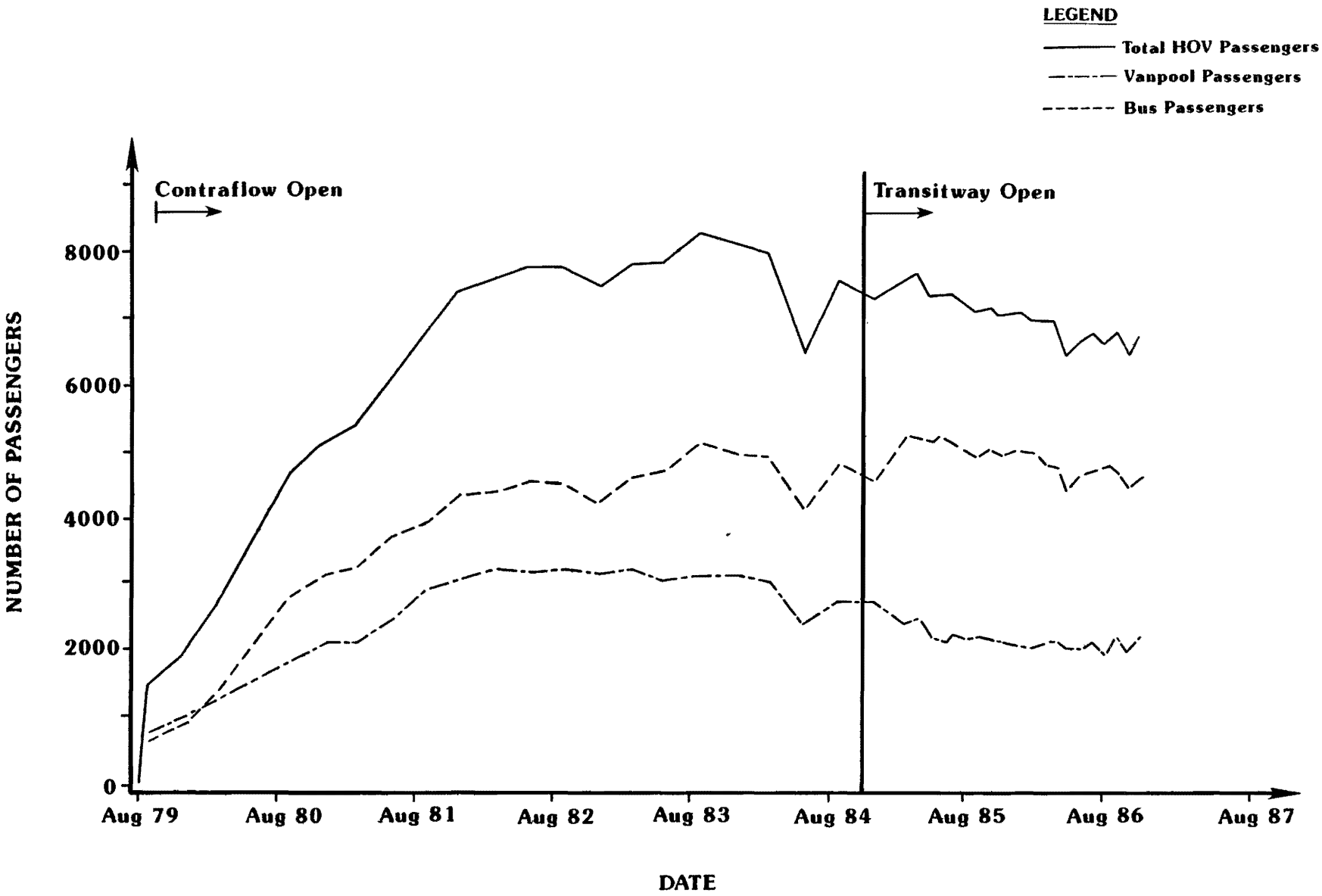


Figure 12. Average of AM and PM Peak Period Transitway Passenger Volumes

Table 2. Daily Transitway Vehicle Demand

Date	Daily Vehicles			Percent Change	
	Buses	Vanpools	Total	Per Month	Cumulative
December '85	301	490	791	---	---
January '86	305	492	797	1%	1%
February '86	308	473	781	-2%	-1%
March '86	306	474	780	0%	-1%
April '86	315	475	790	1%	0%
May '86	313	460	773	-2%	-2%
June '86	327	452	779	1%	-1%
July '86	316	465	781	0%	-1%
August '86	321	441	762	-3%	-4%
September '86	311	460	771	1%	-3%
October '86	313	446	759	-2%	-4%
November '86	319	466	785	3%	-1%
12 Month Average (December '85 - November '86)	313	466	779	---	---
12 Month Average (December '84 - November '85	293	530	823	---	---
Percent Change	6.8%	-12.1%	-5.3%	---	---

Table 3. Daily Transitway Passenger Demand

Date	Daily Passengers			Percent Change	
	Buses	Vanpools	Total	Per Month	Cumulative
December '85	10,070	4,128	14,198	---	---
January '86	10,060	4,102	14,162	-0%	-0%
February '86	9,940	4,049	13,989	-1%	-2%
March '86	9,650	4,259	13,909	-1%	-2%
April '86	9,530	4,261	13,791	-1%	-3%
May '86	8,940	4,060	13,004	-6%	-9%
June '86	9,290	4,025	13,315	2%	-6%
July '86	9,340	4,229	13,569	2%	-5%
August '86	9,370	3,858	13,228	-3%	-7%
September '86	9,280	4,319	13,599	3%	-4%
October '86	8,790	3,923	12,713	-8%	-11%
November '86	9,080	4,328	13,408	5%	-6%
12 Month Average (December '85 - November '86)	9,445	4,128	13,573	---	---
12 Month Average (December '84 - November '85)	10,016	4,526	14,542	---	---
Percent Change	-5.7%	-8.8%	-6.7%	---	---

Transitway passenger demand volumes have also experienced decreases since 1985. Bus passenger demands have declined by an average of 570 passengers per day, and vanpool patronage has declined by almost 400 passengers per day. The reduction in passenger demand by 970 transitway users each day results in a 6.7% decrease when compared to the previous year.

Mode Split

Previous reports (8) have shown that provision of priority treatment on a freeway can essentially double the bus transit mode split. These mode splits are in the range of 15% to 20% at park-and-ride lots in corridors without priority treatment; bus mode splits at park-and-ride lots with priority treatment tend to be in excess of 30%.

Mode split data for the I-45 North Transitway are shown in Table 4. This mode split is measured at West Little York Road, which is essentially the last opportunity to enter the transitway. Table 4 shows AM work trips to the major activity centers; the percentage of those trips that are on the freeway and on the transitway are also shown.

Table 4. Mode Split for AM Peak Period Person Trips, I-45 North Freeway at West Little York

	Peak-Period Person Trips				
	Freeway	Transitway			Total, Freeway
Trip Destination	Mainlanes	Total	Bus	Van	Plus Transitway
Downtown	5580 (50%)	5590 (50%)	4270	1320	11,170
City Post Oak	1620 (89%)	200 (11%)	50	150	1,820
Greenway Plaza	720 (80%)	180 (20%)	90	90	900
Texas Medical Center	540 (71%)	220 (29%)	50	170	760
Other	9540 (95%)	520 (5%)	90	430	10,060
Total	18,000 (72%)	6710 (28%)	4550	2160	24,710

Source: Texas Transportation Institute surveys.

Transitway Occupancy Rates

In response to the decline in passenger and vehicle demand volumes, bus and vanpool occupancy rates of the I-45 North Freeway Transitway have also declined. During the first year of transitway operation, bus occupancy averaged 34.2 passengers during the peak period, and 36.4 passengers during the peak hour. Beginning in November 1985, bus occupancy declined for a seven month period (Figure 13). In June 1986, the peak-hour occupancy rate had fallen to an average of 31.2 passengers per bus. Between July and November of 1986, bus occupancy began a slight increase; however, the levels of the previous year were not achieved. Averaged throughout the second year of transitway operations, the bus occupancies were 30.2 and 33.1, respectively for the peak period and peak hour. Figure 14 presents the occupancy rates for authorized vanpools using the transitway since its conversion from contraflow operations. Vanpool occupancies have increased since May 1985. Comparing the first and second years of operation, average vanpool occupancies have increased from 8.7 to 9.0 persons per vehicle. However, as previously indicated, total vanpool passenger demand has decreased (Table 3). Combining both buses and vanpools, the occupancy rate for the North Freeway Transitway was 17.6 persons per vehicle. That for the adjacent freeway mainlanes was 1.18 persons per vehicle for the same time period. For the second year of barrier-separated operation, the total (freeway plus transitway) occupancy rate was 1.70 persons per vehicle. This represents a decline from 1.81 as noted during the previous year of operation (Figure 15).

Park-and-Ride Demand

The locations of the five park-and-ride lots currently providing service within the I-45 North Freeway corridor are illustrated in Figure 16. Total park-and-ride capacity was increased by 600 spaces with the opening of The Woodlands Park-and-Ride lot on May 28, 1986. That park-and-ride facility and its operations have been funded with a mixture of public and private money (9). The joint public/private funding gave The Woodlands Corporation the opportunity to provide the same benefit to residents of The Woodlands that has been available in other suburban developments around Houston through

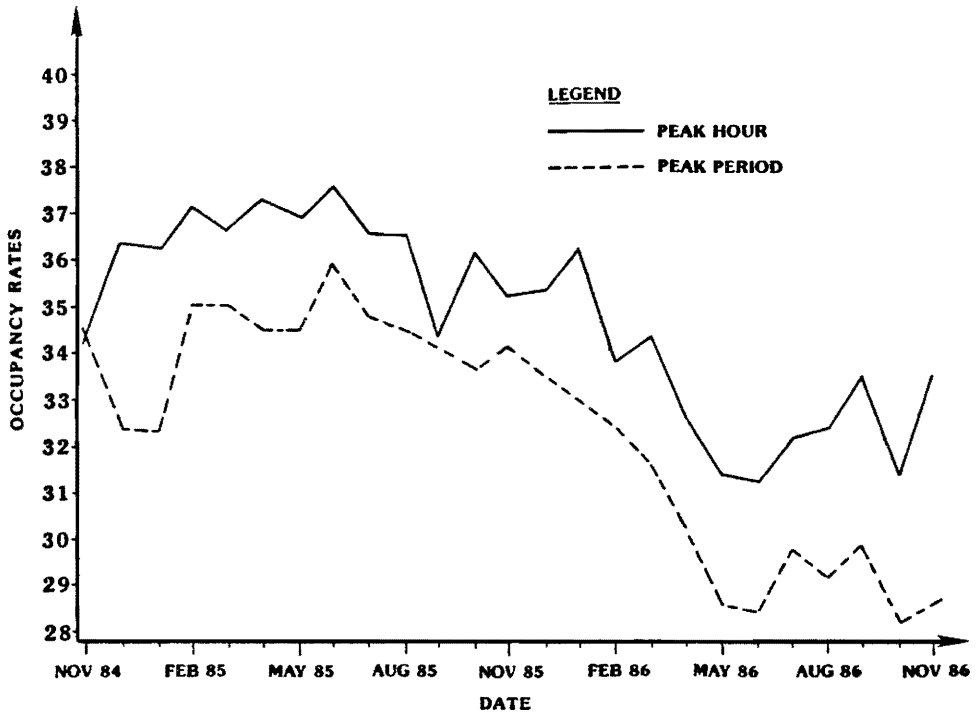


Figure 13. Transitway Bus Occupancy Rates

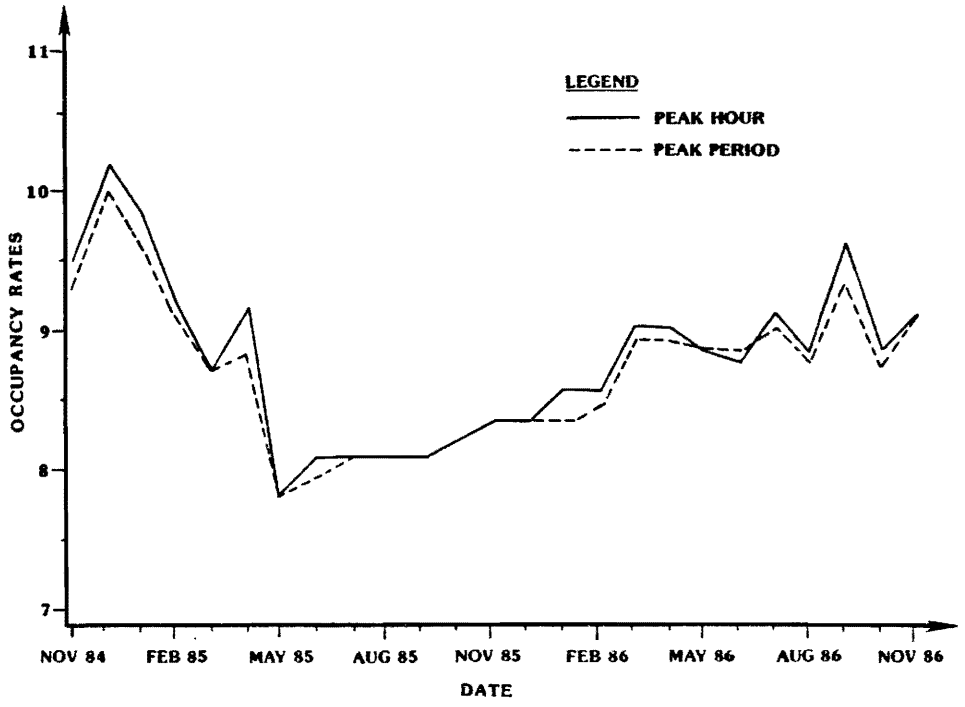


Figure 14. Transitway Vanpool Occupancy Rates

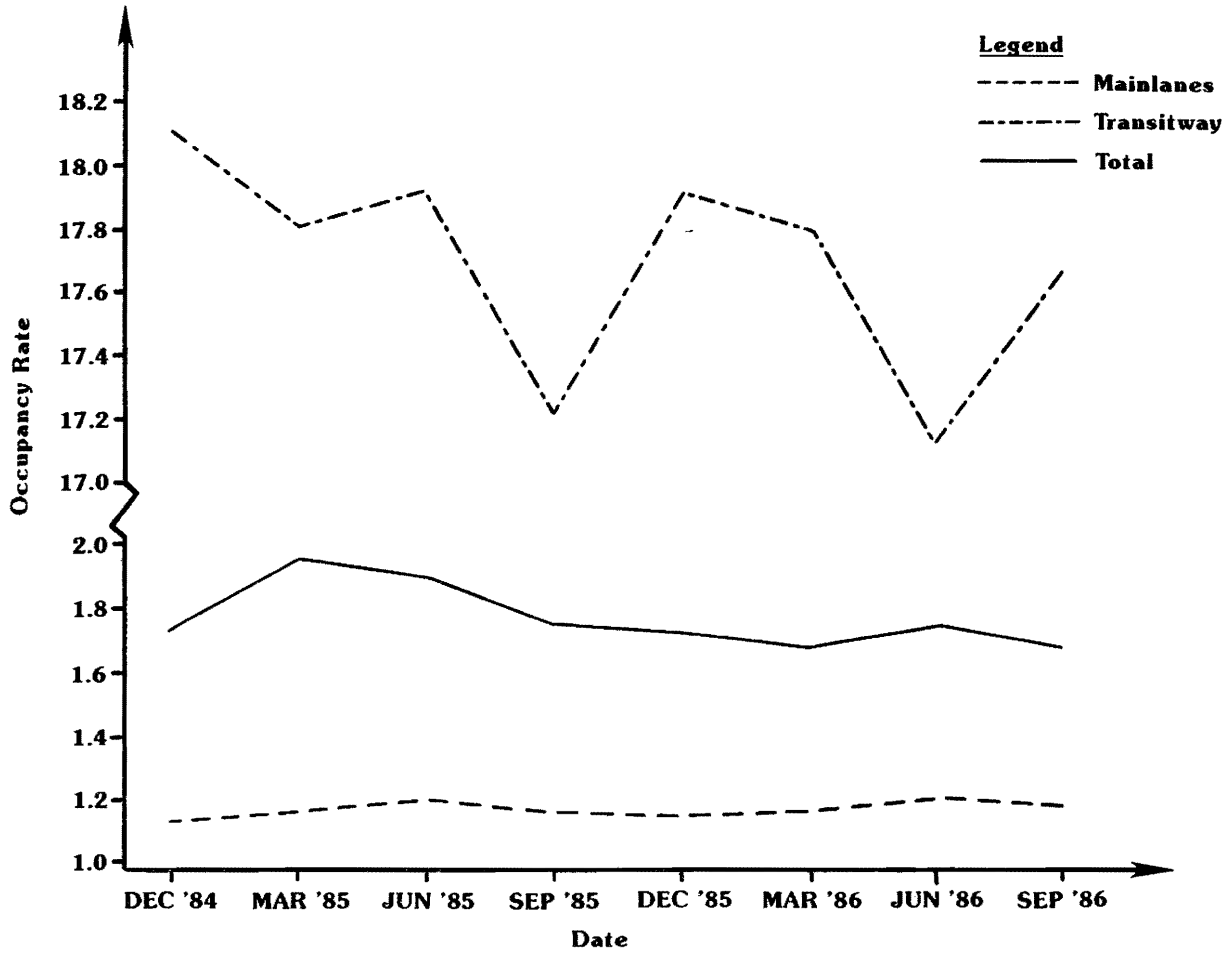


Figure 15. I-45 North Freeway and Transitway Peak-Period Occupancy Rates

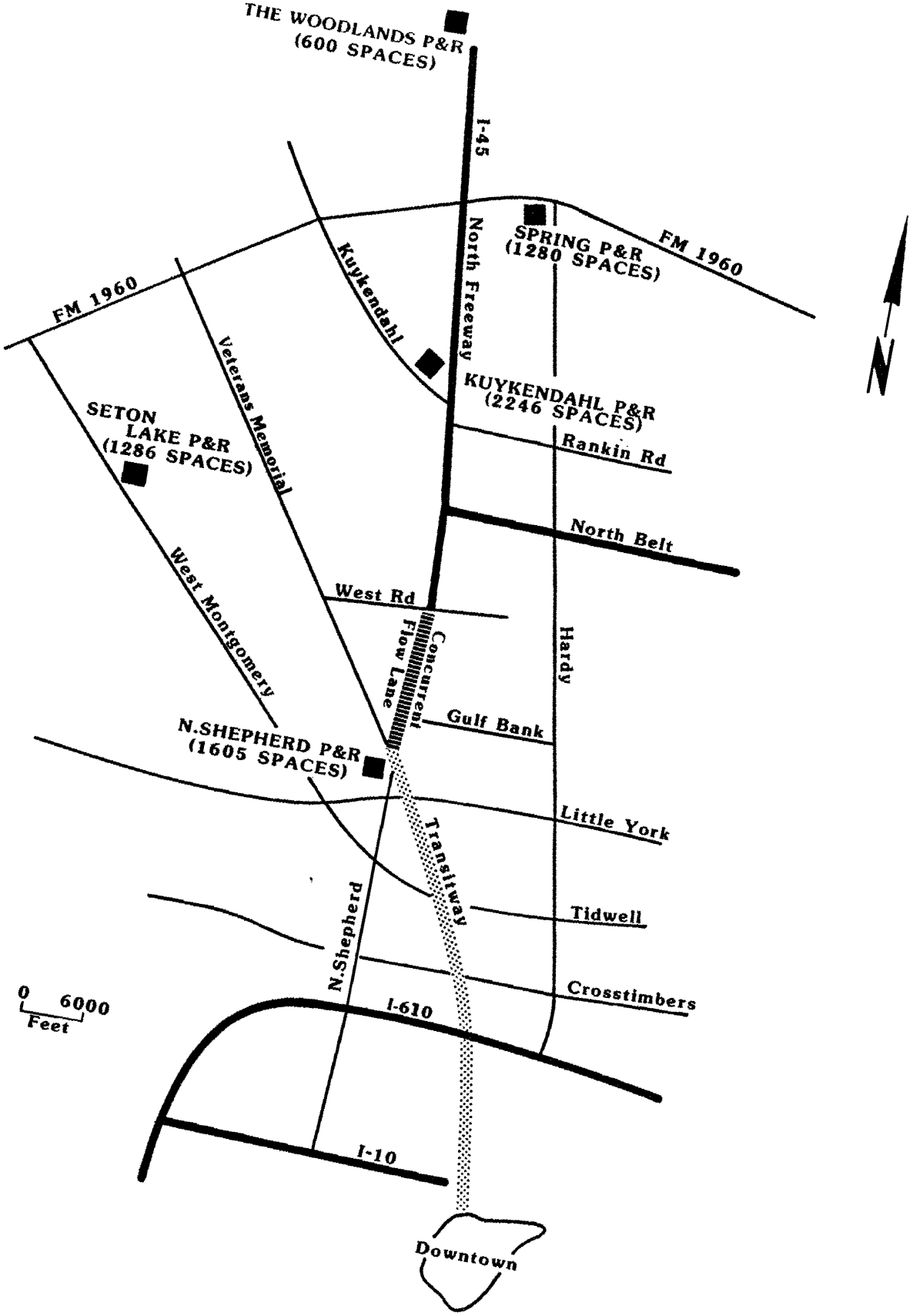


Figure 16. I-45 North Freeway Corridor Park-and-Ride Lots

METRO. Section 18 Federal funds paid for 80% of the cost of the new $2.9 million park-and-ride facility, Montgomery County contributed around 6%, and a land-grant from The Woodlands Corporation provided the remaining 14%. Trailways Commuter Transit Company was awarded a contract to provide weekday service between the park-and-ride lot and downtown Houston. The subsidy cost of the Trailways contract is funded with Section 18 Federal funds matched with an equal contribution by The Woodlands Corporation. Contract administration expenses for the service will be funded 80% by Section 18 and 20% by The Woodlands. The expected annual cost of the Trailways contract, which includes performance criteria and liquidated damages for failure to meet the standards, is around $300,000 at presently envisioned levels of service. The Woodlands keeps all farebox revenue (Passes are $90 per month, comparable with METRO's Park-and-Ride rates), which is expected to be around $250,000 for the first year. Although the service only operates express to downtown Houston, The Woodlands Corporation has options for an intermediate stop at METRO's Spring Park-and-Ride lot and an extension of the service to the Texas Medical Center.

With the addition of The Woodlands Park-and-Ride Lot, there are 7017 spaces available in the I-45 North Freeway Corridor to serve park-and-ride demand. METRO plans to expand the Kuykendahl Park-and-Ride lot by early 1990. Park-and-Ride demand within the corridor has continued to increase, as indicated by Figure 17. Within the past year of transitway operation, total corridor park-and-ride demand has increased by an average of 300 parked vehicles per day. As indicated by Table 5, this represents a 7.6% increase above the previous year. This noted increase in park-and-ride patronage contradicts the previous section indicating a decline in transitway passenger demands. There are at least two possible reasons to explain this contradiction. First, the decline in bus passengers may be due to a decline in passenger volumes for express buses using the transitway. Secondly, although the total bus passengers using the park-and-ride facility has decreased, the number of vehicles parked at each lot has increased as kiss-and-ride activities have declined. These two possible explanations have not been confirmed by any data collection activities. The addition of The Woodlands Park-and-Ride Lot did not account for all this increase, as the number of parked vehicles at the Spring and Kuykendahl lots decreased with

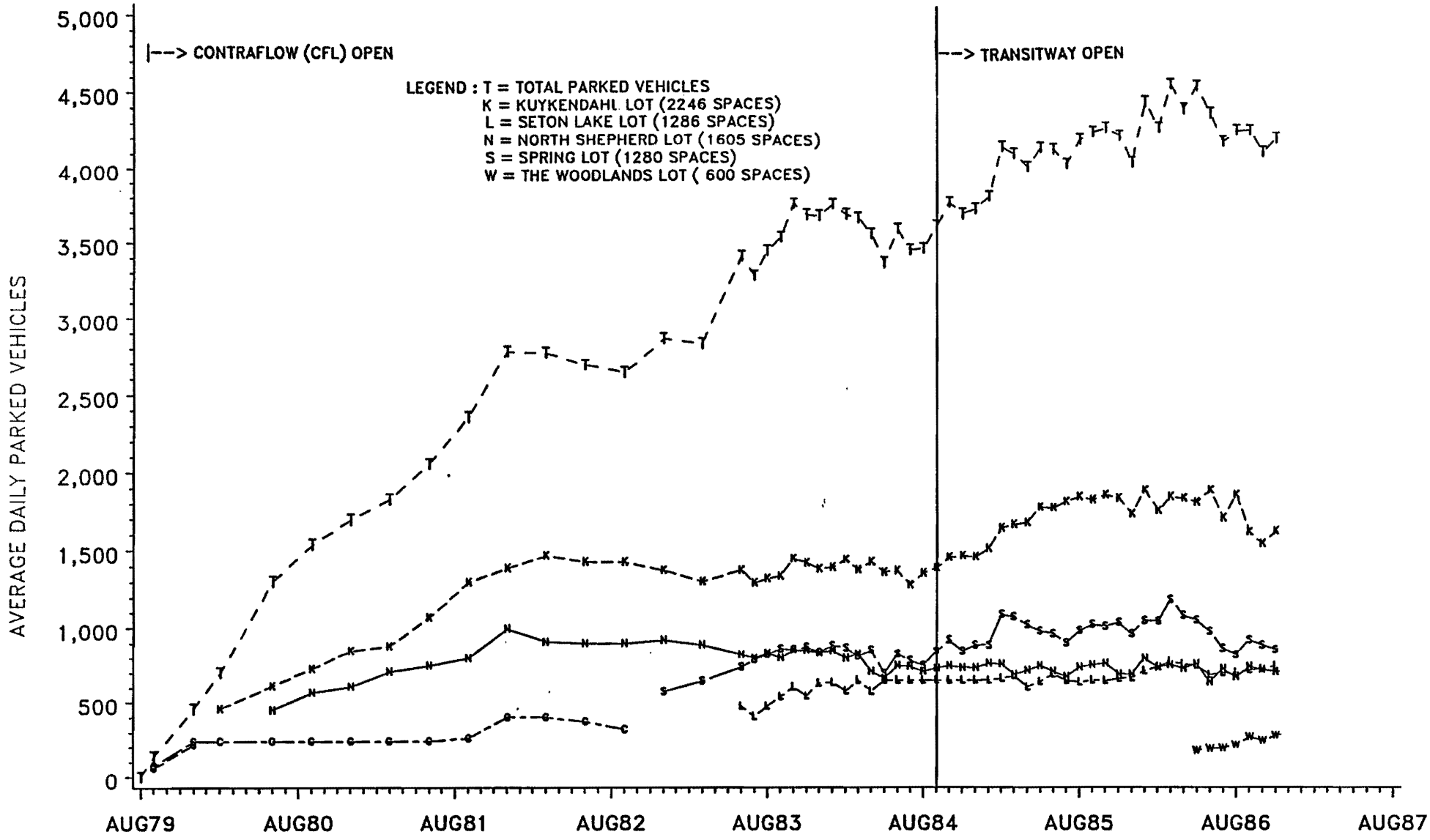


Figure 17. I-45 North Freeway Corridor Park-and-Ride Lot Utilization

Table 5. I-45 North Freeway Corridor Park-and-Ride Demand, Average Daily Parked Vehicles

Date	Park-and-Ride Lot						
	Seton Lake	Spring	The Woodlands	Kuykendahl	N. Shepherd	Total	% Change from Dec. 85
December '85	668	961	---	1,737	690	4,056	---
January '86	713	1,050	---	1,894	798	4,455	9%
February '86	743	1,046	---	1,760	737	4,286	6%
March '86	775	1,189	---	1,850	755	4,569	12%
April '86	760	1,082	---	1,840	730	4,412	8%
May '86	751	1,053	*174	1,817	761	4,556	12%
June '86	689	976	184	1,894	639	4,382	8%
July '86	700	867	189	1,712	728	4,196	3%
August '86	703	823	209	1,864	672	4,271	5%
September '86	719	921	265	1,625	743	4,273	5%
October '86	728	888	242	1,549	722	4,129	2%
November '86	747	857	275	1,631	708	4,218	4%
12 Month Average (December '85 - November '86)	725	976	220	1,764	724	4,409	---
12 Month Average (December '84 - November '85)	652	988	---	1,729	729	4,098	---
Percent Change	11.2%	-1.2%	---	2.0%	-0.7%	7.6%	---

*The Woodlands Park-and-Ride Lot Opened May 28, 1986

its opening (Figure 17, Table 5). The Seton Lake Park-and-Ride Lot provided the largest increase (11.2%) when compared to the previous year, an average increase of 74 parked vehicles per day. Table 6 presents the utilization rates by users of the five park-and-ride lots serving the I-45 North Transitway. Of the total of 7,017 available spaces, approximately 63% are used on a daily basis.

Table 6. Park-and-Ride Lot Available Vehicle Parking Capacity

Park-and-Ride Lot	Lot Capacity (vehicles)	Average Demand (vehicles)	Average % Utilized	Available Capacity (vehicles)
Seton Lake	1,286	725	56.4	561
Spring	1,280	976	76.2	304
The Woodlands	600	220	36.7	380
Kuykendahl	2,246	1,764	78.5	482
N. Shepherd	1,605	724	45.1	881
Total	7,017	4,409	62.8	2,608

Transitway User Characteristics

In another study sponsored jointly by SDHPT and METRO, TTI conducted surveys of transitway and non-transitway users for the I-45 North Freeway corridor (10). These data are summarized in Table 7.

Transitway Peaking Characteristics

Although the total number of authorized vehicles using the I-45 North Transitway has declined throughout its second year of operation, peaking characteristics have remained relatively constant. As illustrated in Figures 18 and 19, approximately 50% of total peak-period bus volume is observed on the facility during a typical peak hour of operation, and 14% is observed in the peak 15-minutes of operation. Vanpools exhibit a somewhat different pattern, with 65% using the facility in the peak hour. Approximately 25% of the vanpools use the transitway during a typical peak 15-minutes. Overall,

Table 7. Personal and Trip Characteristics of Survey Respondents

Characteristics	Transitway Users		Non-Transitway Users
	Transit	Vanpool	
Median Age (years)	34	39	36
Sex (% male)	44	55	61
Median Education (years)	14.9	15.0	14.8
Trip Purpose			
Work	99%	100%	91%
School	1%	0%	2%
Other	0%	0%	7%
Occupation			
Professional	38%	45%	38%
Managerial	23%	24%	21%
Clerical	30%	23%	15%
Sales	3%	7%	13%
Other	6%	1%	13%
Trip Destination			
Downtown	94%	61%	31%
Galleria/City Post Oak	1%	7%	7%
Texas Medical Center	1%	8%	4%
Greenway Plaza	2%	4%	4%
Other	2%	20%	54%
Previous Travel Mode*			
Drove Alone	35%	30%	87%
Carpooled	10%	21%	8%
Vanpooled	7%	12%	1%
Park-and-Ride Bus	18%	12%	--
Regular/Express Bus	4%	2%	--
Did Not Make Trip	25%	21%	--
Other	1%	2%	4%

Source: Reference (10)

* Non-transitway users were questioned as to how the trip was usually made

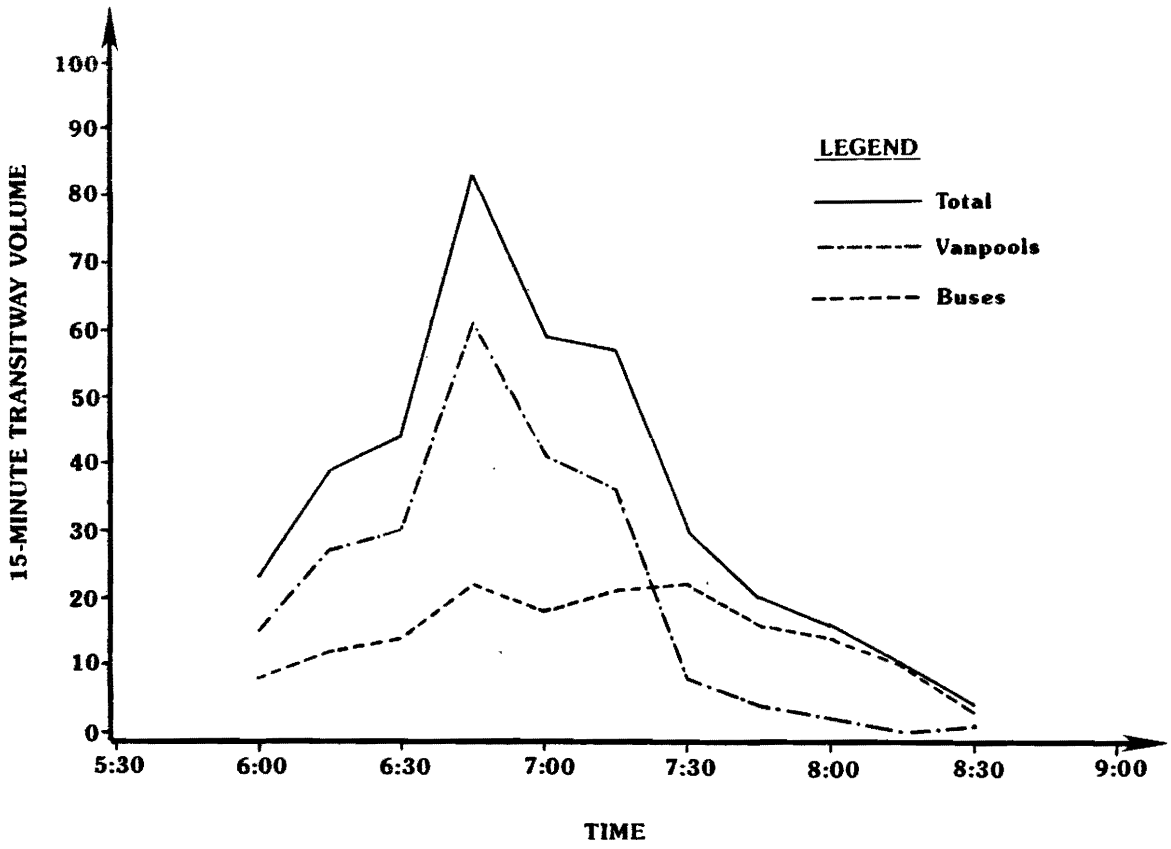


Figure 18. North Transitway Morning Volume Distribution

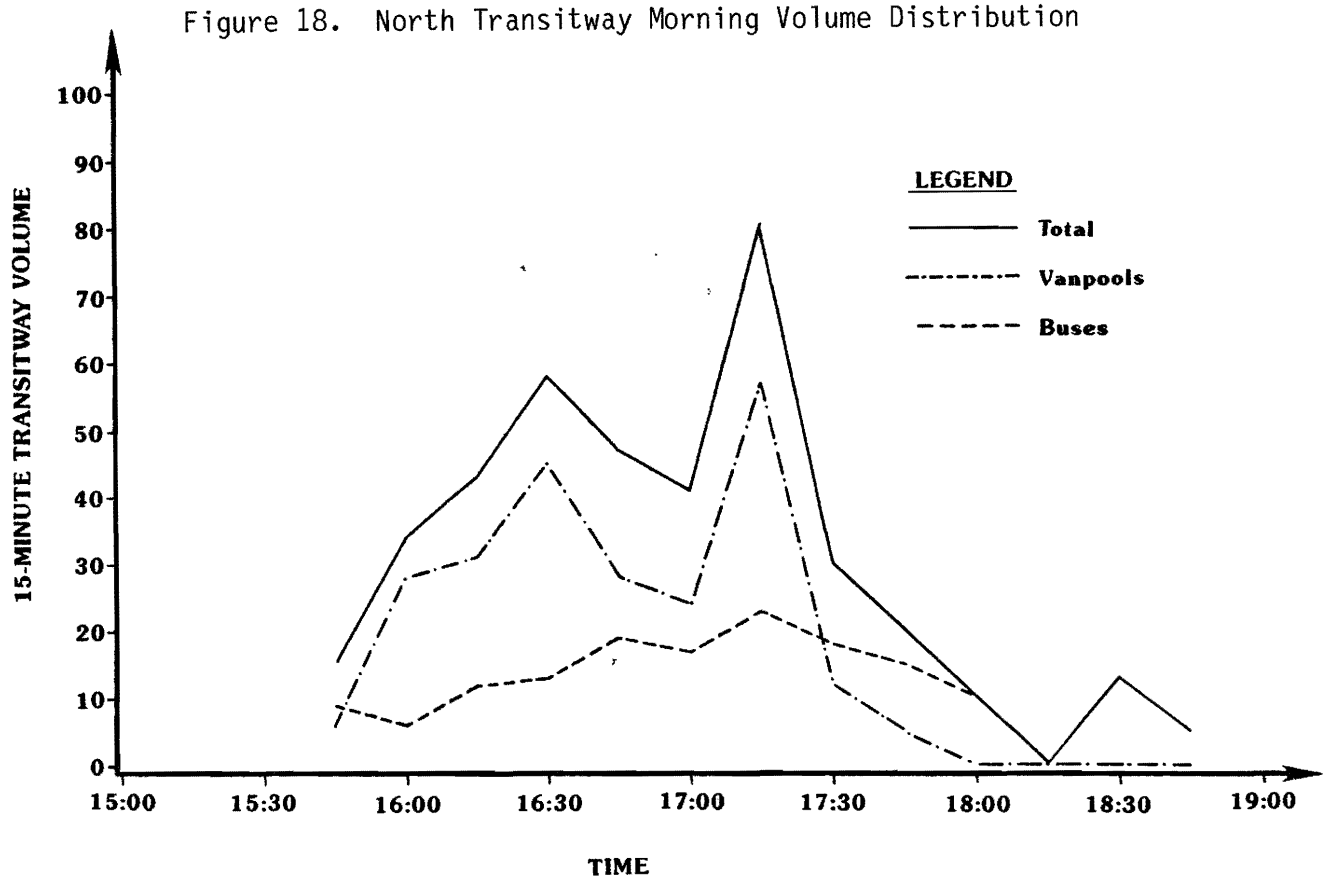


Figure 19. North Transitway Afternoon Volume Distribution

almost 60% of all peak-period authorized transitway vehicles utilize the facility during the peak hour of operation.

The peak hours for the transitway begin at 6:45 am and 4:30 pm for the morning and afternoon periods. The peaking characteristics for the buses are generally consistent between the two operating periods due to the bus scheduling and adherence to the schedules. Vanpool volumes exhibit markedly different patterns of peaking in the morning as opposed to the afternoon. The peak 15-minutes for transitway vanpool volumes in the morning started at approximately 6:45 am, and declined throughout the remainder of the peak period. In the afternoon, vanpool volumes consistently peaked at two different 15-minute time periods, starting at 4:30 pm and 5:15 pm. This pattern was consistent throughout the year and similar to that noted during the previous year of transitway operation.

Transitway Travel Time Savings

Travel time and speed studies were conducted along the I-45 North Freeway mainlanes from Airtex to downtown Houston. The studies were completed on a quarterly basis and were conducted at 30-minute intervals throughout the peak 3-hours of operation during the morning as well as the afternoon peak period. Of particular concern for this analysis is the segment of the freeway which contains the barrier-separated transitway (North Shepherd to downtown Houston). As indicated by Table 8 and illustrated in Figures 20 and 21, transitway users receive a distinct advantage over the freeway mainlane motorists. Transitway users save an average of approximately 4.2 minutes per trip in the morning and 8.0 minutes per trip in the afternoon over freeway mainlane trips made during a typical 3-hour peak period. These time savings are lower compared to the first year of barrier-separated transitway operations, when an estimated 4.7 and 8.7 minutes were saved during the morning and afternoon peak periods. During the peak hour of traffic demand, the savings increase to 7.1 minutes and 12.4 minutes, respectively; as compared to 8.2 minutes and 14.8 minutes during the previous year. For both the first and second years of transitway operation, the freeway cross-section remained basically unchanged. However, several entrance and exit ramps were temporarily closed or relocated as required for

the Phase II construction. The actual travel time savings is somewhat different from that perceived by the transitway users. A recent survey of users of the I-45 North Freeway Transitway indicated a perceived savings of 20 and 25 minutes (50th percentile) for the am and pm peak hours (10). This is almost double that determined from the travel time and speed studies.

Table 8. North Freeway Travel Times and Average Speeds - Mainlanes vs. Transitway (N. Shepherd to Downtown)

	Average Travel Time*		Average Speeds	
Starting Time	Mainlanes	Transitway	Mainlanes	Transitway
6:00 am	10.4 min.	9.4 min.	50 mph	55 mph
6:30	14.4		36	
7:00	16.5		31	
7:30	16.0		32	
8:00	12.9		40	
8:30	11.3		46	
Morning Average	13.6 min.	9.4 min.	39 mph	55 mph
16:00 pm	17.0 min.	9.4 min.	30 mph	55 mph
16:30	18.9		27	
17:00	21.8		24	
17:30	21.8		24	
18:00	17.6		29	
18:30	15.4		34	
19:00	9.5		54	
Afternoon Average	17.4 min.	9.4 min.	30 mph	55 mph

*Average of quarterly studies (December 1985 to November 1986)

Disabled and Unauthorized Vehicles

For the second year of barrier-separated operation, an average of 7.2 vehicles became disabled within the facility each month (Table 9 and Figure 22). This is somewhat reduced when compared to the previous year's average of 9.0 vehicles each month. Of these vehicles, less than 50% required the services of the METRO wrecker to tow them from the facility (Figure 23). The

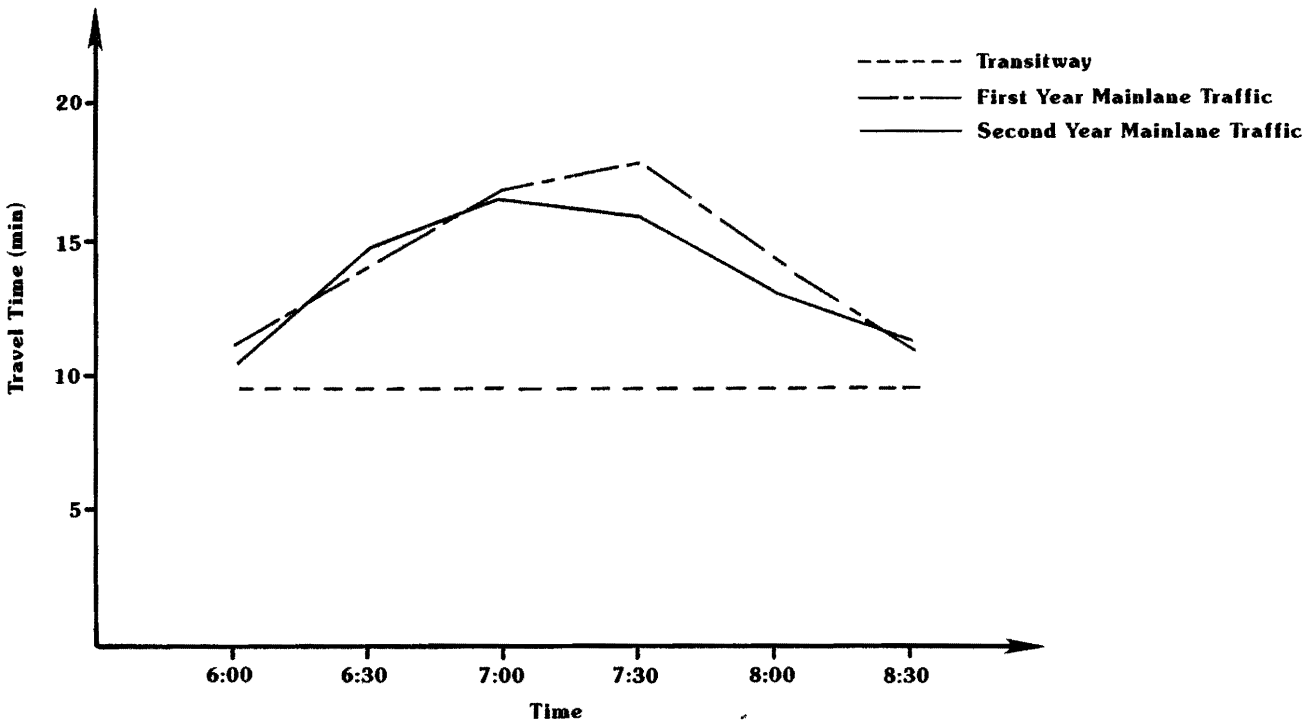


Figure 20. North Freeway Transitway and Mainlane Travel Times, North Shepherd to Downtown, Morning

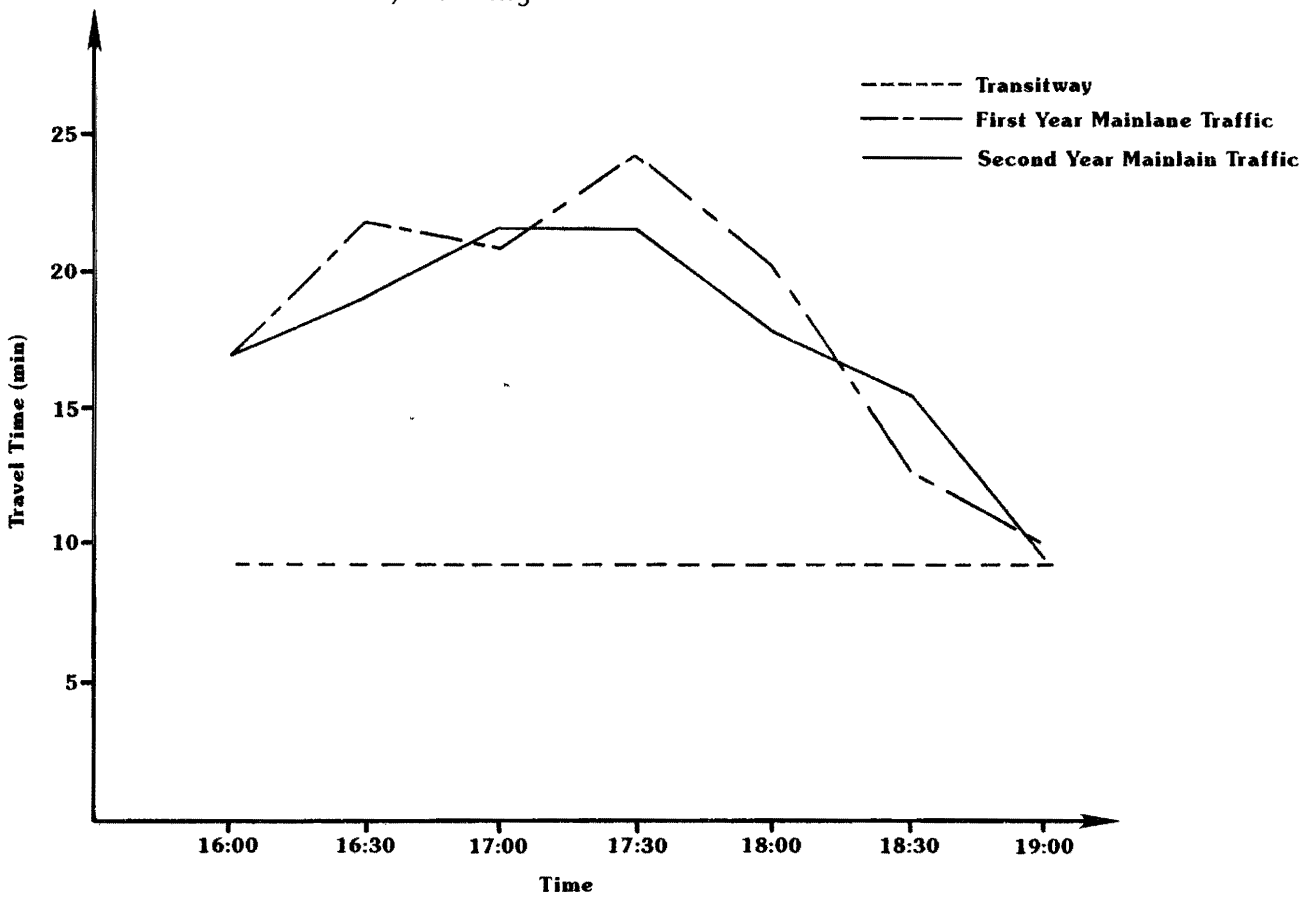


Figure 21. North Freeway Transitway and Mainlane Travel Times, Downtown to North Shepherd, Afternoon

remaining disabled vehicles were able to exit the transitway after being given short term remedies such as having tires re-inflated. Overall, there has been an approximate 20% decline in the total number of disabled vehicles within the transitway. Buses accounted for approximately 40% of the disabled vehicles, although the total number of disabled buses has declined by almost 30%. The largest reduction in disabled vehicles was 50% as experienced by

Table 9. North Transitway Disabled and Towed Vehicles

	Buses		Vanpools		Others*		Total	
Month/Year	Disabled	Towed	Disabled	Towed	Disabled	Towed	Disabled	Towed
December '85	5	2	1	0	6	6	12	8
January '86	1	0	1	0	4	3	6	3
February '86	2	2	0	0	1	0	3	2
March '86	2	1	1	0	0	0	3	1
April '86	3	1	2	0	1	0	6	1
May '86	4	1	1	0	4	3	9	4
June '86	3	1	1	1	6	3	10	5
July '86	2	0	2	0	6	5	10	5
August '86	5	3	0	0	6	1	11	4
September '86	3	1	2	0	1	1	6	2
October '86	2	0	0	0	2	0	4	0
November '86	2	0	1	0	3	3	6	3
(December '85 - November '86)								
12-Month Total	34	12	12	1	40	25	86	38
Monthly Average	2.8	1.0	1.0	0.1	3.3	2.1	7.2	3.2
(December '84 - November '85)								
12-Month Total	48	16	24	4	36	28	108	48
Monthly Average	4.0	1.3	2.0	0.3	3.0	2.3	9.0	4.0

*Usually unauthorized vehicles.

Source: (1)

the authorized vanpools. However, the number of non-authorized vehicles disabled increased from 3.0 to 3.3 each month, an approximate 10% increase.

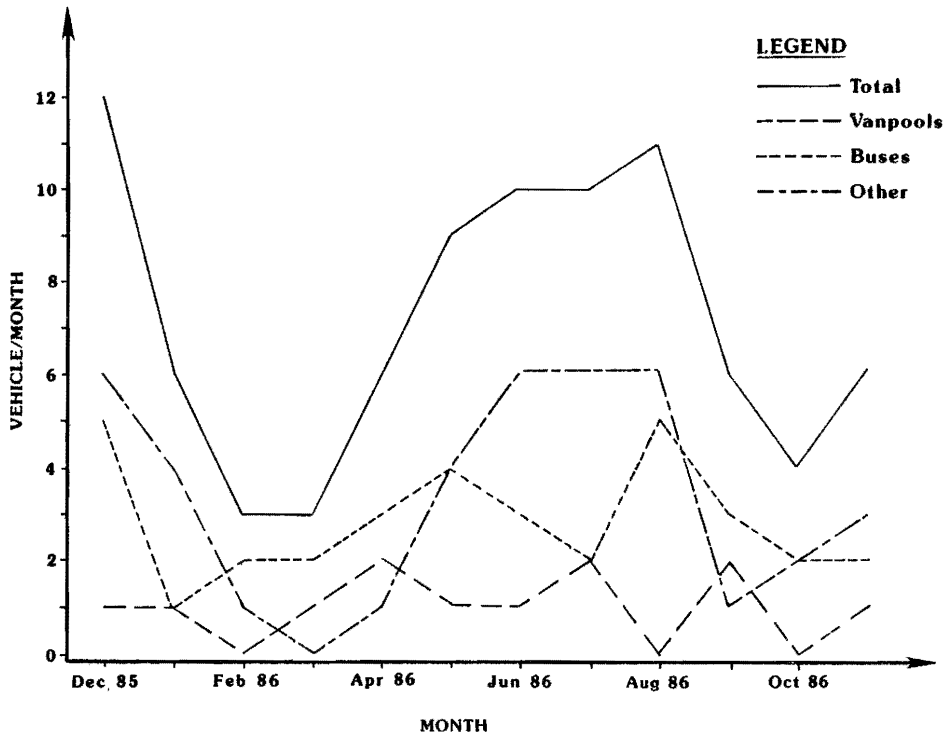


Figure 22. Total Transitway Disabled Vehicles

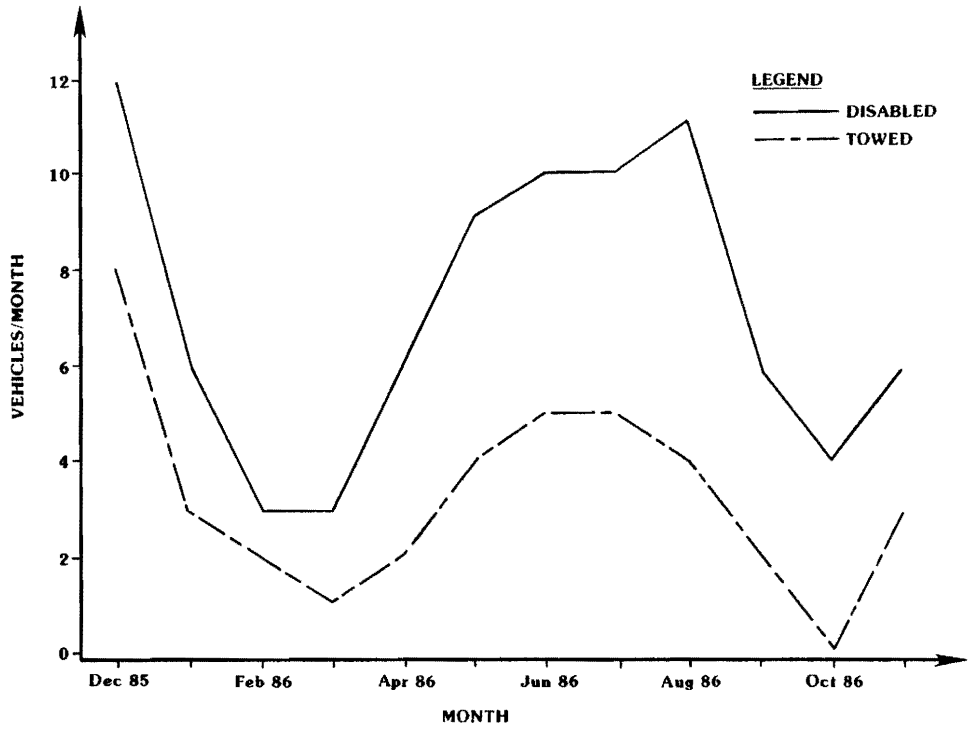


Figure 23. Transitway Disabled and Towed Vehicles

The overall reduction in disabled and towed vehicles is a combined result of lower transitway demand volumes and improved vehicle operations. This is especially noted for the METRO buses, which have experienced a systemwide decrease in disabled vehicles. During the interim operation of the transitway (prior to completion of Phase II), the reduction in the number of disabled vehicles is significant. In several of the sequenced steps of the Phase II construction, the transitway is not wide enough to allow other transitway vehicles to drive around a disabled vehicle (Figure 4). In many cases, the transitway operation is halted until the disabled vehicle is moved (under its own power) or towed by the METRO wrecker. During the second year of barrier-separated operation, there were six instances which required the facility to be totally closed (1). Two of these instances involved accidents. The other four total closures were caused by buses which became disabled in narrow sections of the transitway. These closures lasted from 10 to 30 minutes, depending upon the time required to move the disabled vehicle. The occurrences of complete transitway closure reduce the overall benefits to users as they incur delays which may exceed those experienced by freeway motorists. Upon completion of the Phase II construction, the final width transitway (20 feet) will reduce the instances of transitway closure due to disabled vehicles.

In addition to the occurrence of disabled vehicles within the facility, the I-45 North Freeway Transitway has experienced several unauthorized vehicles entering the facility each month (Figure 24). For the second year of transitway operation, an average of 166 vehicles per month entered the facility without prior authorization. This represents a 38% increase above the 120 vehicles per month during the first year of barrier-separated operation (December 1984 to November 1985). As indicated by Figure 24, there was a dramatic increase in the total number of unauthorized vehicles entering the transitway after August 1986. There were two major reasons for the dramatic increases in the number of unauthorized vehicles. First, during steps of the Phase II construction which separated the freeway lanes from the transitway by tubular markers or pylons, freeway motorists would use the facility to go around disabled vehicles located in the inside freeway mainlane. This particular problem occurred most often during the afternoon operation, especially near North Shepherd Drive. Secondly, on August 11,

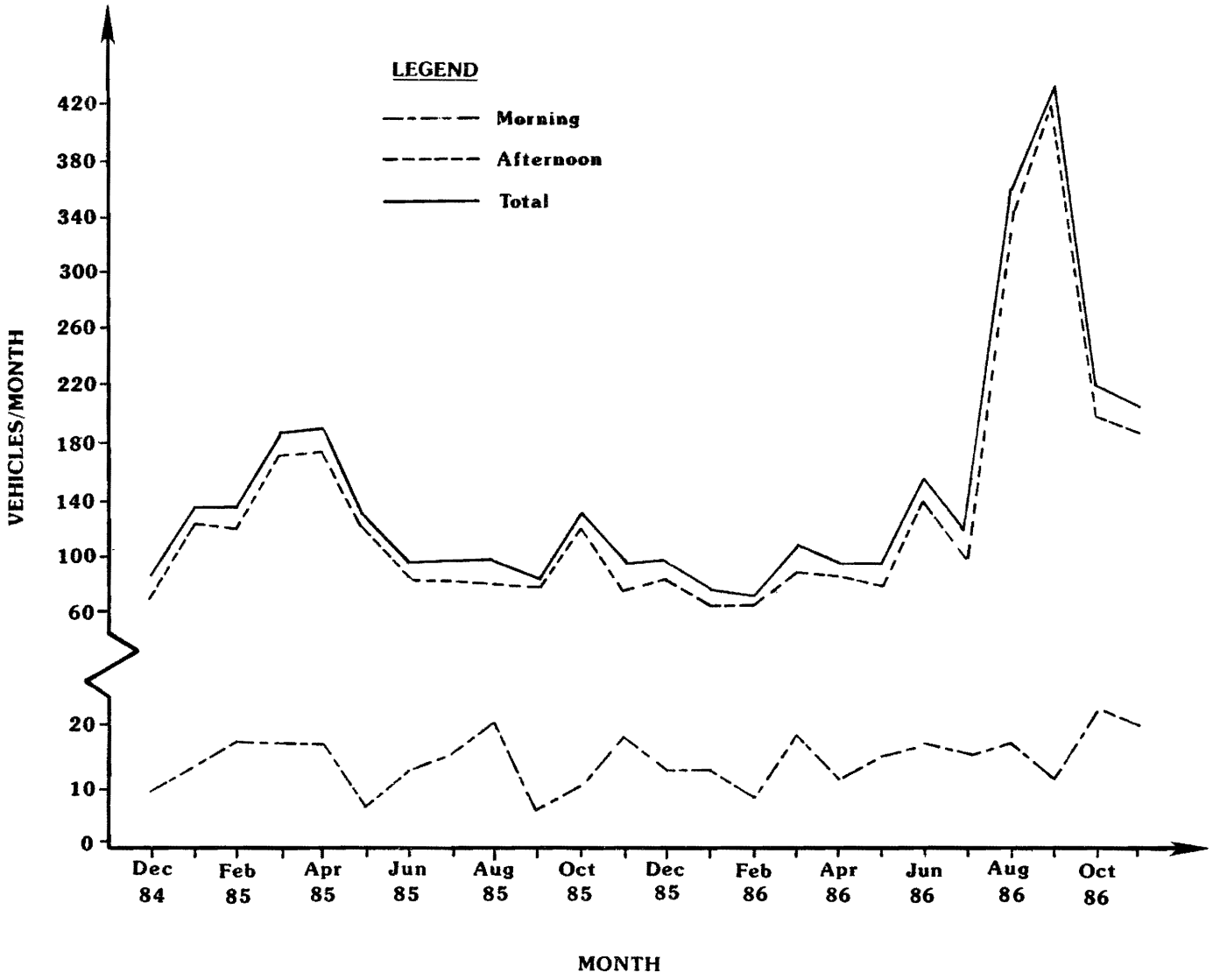


Figure 24. Total Morning and Afternoon Unauthorized Vehicles

1986, the requirement for carpool usage of the I-10 Katy Freeway Transitway was changed to allow vehicles with as few as two occupants to use the facility. During the afternoon peak period, carpools destined to the I-10 Katy Freeway Transitway entered the I-45 North Freeway Transitway at its downtown terminus at Louisiana and Franklin, assuming that this would provide access to the Katy Transitway. These unauthorized vehicles were stopped and directed to the I-10 Katy Freeway westbound mainlanes by either the METRO Transit Police or the transitway support crew. To reduce these occurrences of "confused carpoolers", METRO and SDHPT installed permanent signing along northbound Louisiana Street to provide better guidance to both the I-10 Katy Freeway mainlanes and the North Transitway (Figure 25 and 26). Of the total 1992 unauthorized vehicles entering the facility, over 90% were noted to have occurred during the afternoon operation. Approximately 18% of the unauthorized vehicles were issued traffic citations carrying a maximum fine of $200 per violation. The remainder were given either verbal warnings, directed out of the facility, or were simply not apprehended (Figure 27).

Upon completion of the Phase II construction, the transitway will be fully enclosed by CMB from North Shepherd to downtown Houston. This should significantly reduce the number of unauthorized vehicles which enter the transitway. The CMB will also reduce the potential for accidents, as freeway motorists will not be able to use the facility to go around disabled vehicles located in the inside freeway mainlane. The only entrance points for unauthorized vehicles will be at the transitway termini. Adequate enforcement at these locations can effectively control the entrance of unauthorized vehicles into the facility. As a result, the violation rate of approximately 1% (for the second year of operation) will be reduced further.

Transitway Accidents and Unusual Incidents

The I-45 North Freeway Transitway has experienced several transitway accidents and unusual incidents during the second year of operation. According to METRO, there were 15 serious accidents which occurred in the transitway within the past year (1). Nine of these serious accidents occurred in the concurrent flow lane (CCFL) between West Road and North

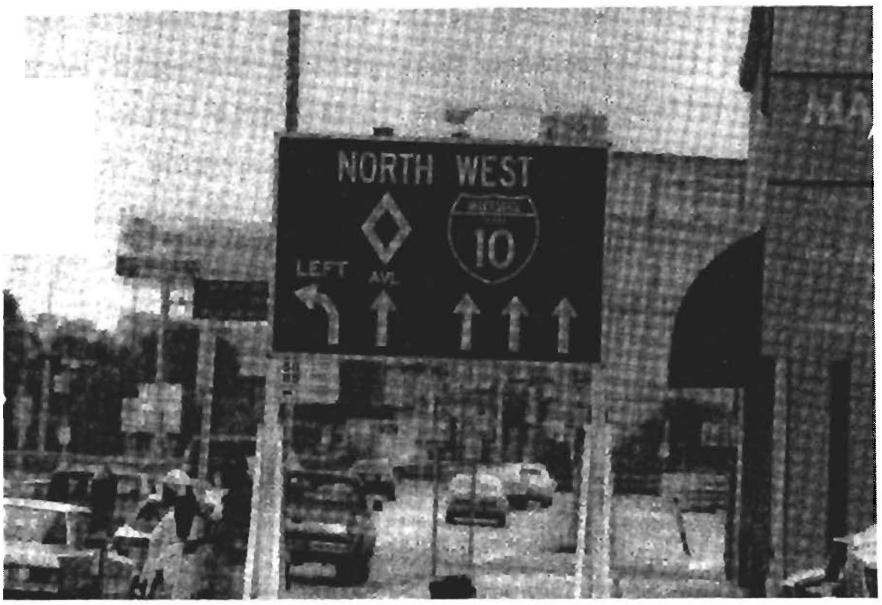


Figure 25. Advanced Signing Along Louisiana Street

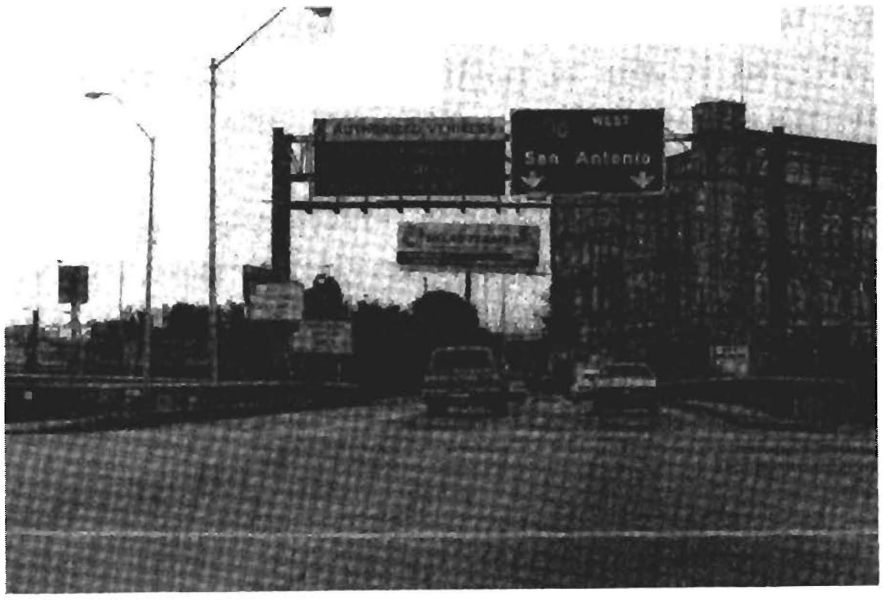


Figure 26. Transitway Signing at Downtown Terminus of North Transitway

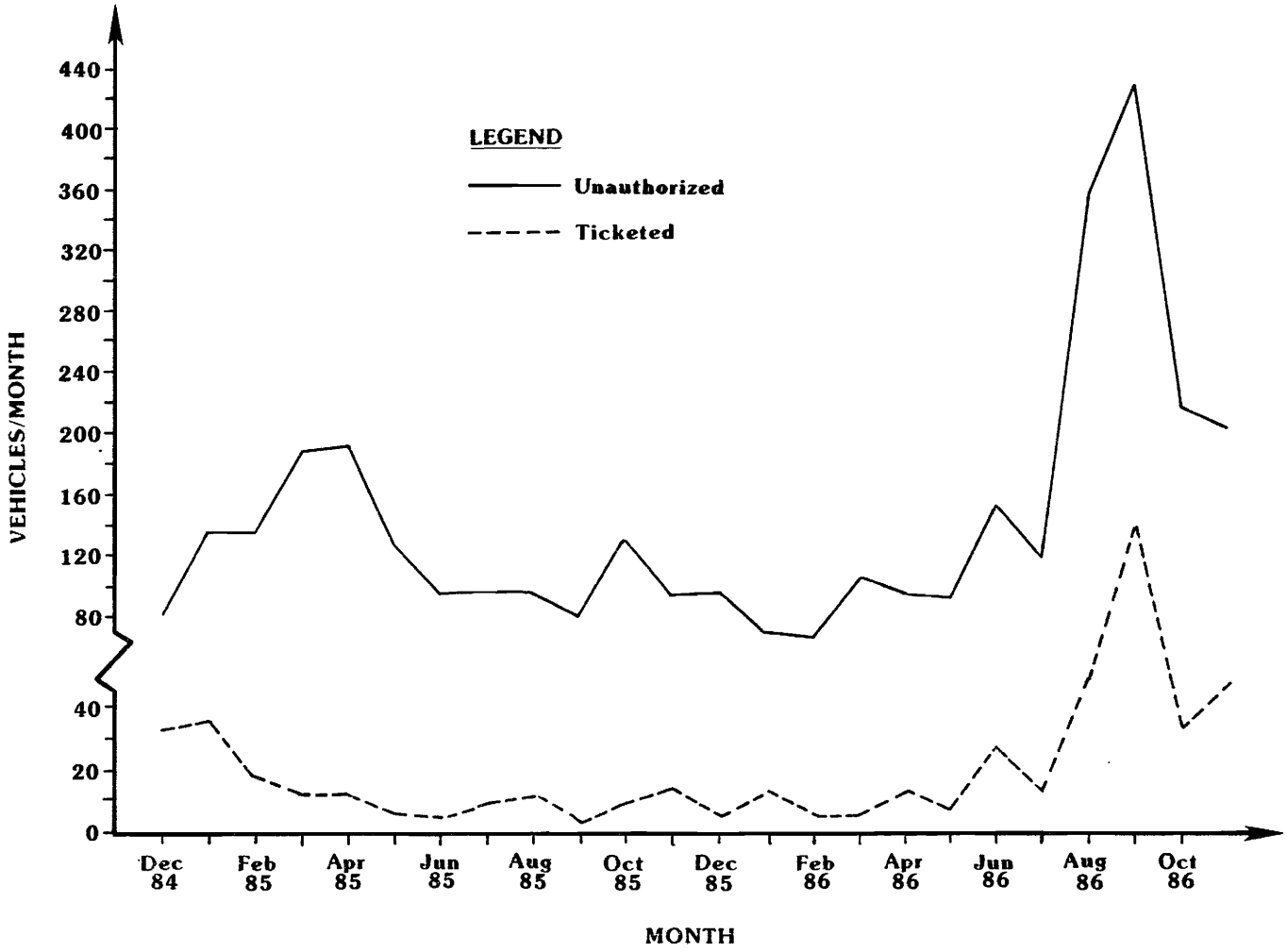


Figure 27. Unauthorized Versus Ticketed Vehicles

Shepherd. Reasons for the accidents varied for each accident and are summarized below:

- Pedestrians on facility
- Unauthorized vehicles electing to enter the facility
- Unauthorized vehicles entering (uncontrolled or skidding) the facility to avoid an accident on freeway mainlanes
- Merging in CCFL

As the majority of these accidents occurred in the CCFL section or in areas where the transitway and freeway mainlanes were separated by plastic pylons, this type of accident should be eliminated as the facility is fully enclosed (Phase II) and the CCFL eliminated (Phase III). The number of accidents involving transitway vehicles and pedestrians on the facility will continue to be a major concern. Within the past year, two accidents involved pedestrians on the facility. The most serious of these involved the death of the pedestrian, as the bus was unable to stop in time to avoid the pedestrian who jumped from the concrete median barrier into the path of the vehicle. In both cases of accidents involving a pedestrian, the pedestrian was noted to be walking across the freeway.

In addition to the two accidents involving pedestrians, there were nine other instances in which the transitway support crew removed pedestrians from the facility. The support crew provides for improved transitway operations by performing "facility maintenance" before, during, and after its normal hours of operation. This includes removing unwanted items (pedestrians, road debris) from the facility and denoting damaged concrete median barriers or vehicle impact attenuators. During the Phase II construction (Figure 4), the transitway support crew was also required to assure that the tubular markers separating the transitway from the freeway traffic provided the needed delineation during the hours of transitway operation.

There were also a variety of unusual incidents which occurred during the second year of barrier-separated operation of the I-45 North Freeway Transitway. These incidents, as reported by METRO transitway support crew, include as follows:

- Vehicle operations (speeding, tailgating)
- Police units using facility
- Vehicle escorts for medical emergencies
- Information handouts to vanpools regarding traffic control during specific construction sequences
- Two vanpools reported windows shot out near Cottage Street
- Facility opened (during non-operating hours) for an escort of the Democratic National Committee
- Facility opened at 2:45 pm (one hour early) to accommodate holiday traffic demands

Operational Modifications

There were two operational modifications implemented on the I-45 North Transitway during its second year of operation. On May 14, 1986, the ramp which provided a direct connection between the transitway and westbound I-10 Katy Freeway during morning became operational (Figure 28). "Ramp B" provided travel time savings to vanpools which previously used the exit to the surface street system (at Quitman) to access I-10 Katy Freeway. Shortly after the opening of "Ramp B" to vanpools, an operational and safety test for bus operation on the ramp was conducted. The test results for the GMC RTS-04 bus revealed that the buses could not use the ramp without an extreme concern for safety. To provide a safe merge of the bus with the traffic on the freeway connection ramp, the driver was required to stand to locate gaps in the traffic stream. An Eagle Model 5 bus, primarily used to serve outlying park-and-ride lots, was also tested on the ramp. The test bus driver required the assistance of passengers to safely complete the merge. These two tests were conducted during the morning peak period. As a result of these tests, the use of "Ramp B" is presently limited to authorized vanpools (Figure 29). There are presently less than 40 vanpools that use this connection during the morning peak period of transitway operation.

A second operational modification occurred in July 1986 which allowed authorized taxi cabs with at least three passengers (including driver) to use the I-45 North Transitway. METRO was asked by several taxi cab companies if they could use the transitway during peak hours. This would facilitate cab

Figure 28. North Transitway Connection to I-10 Katy Freeway

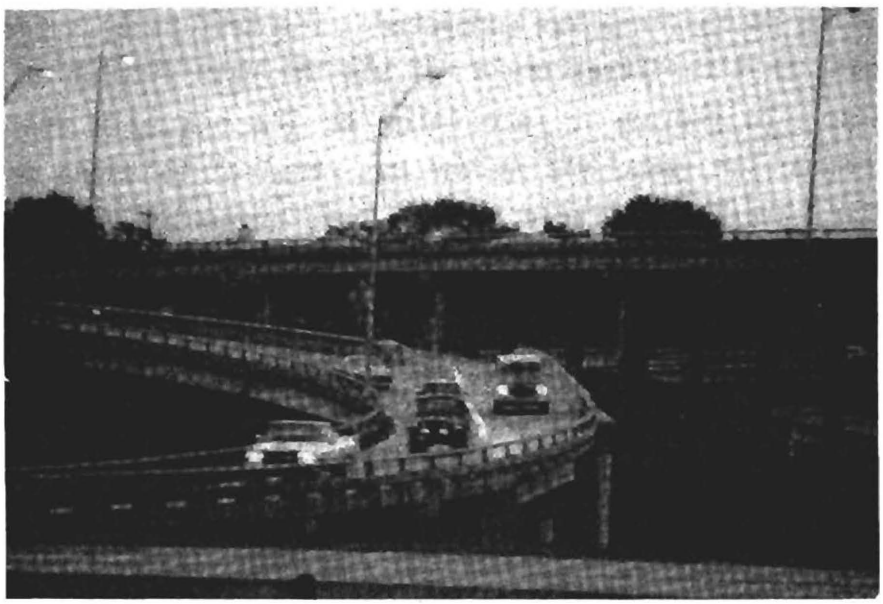


Figure 29. Vanpool Using I-45 North Transitway "Ramp B"

trips to and from the Houston Intercontinental Airport. Of particular concern to METRO and SDHPT was the impact of the taxi cab demand (estimated at 75 to 100 per hour) during the afternoon peak period at the North Shepherd terminus. Vehicle classification studies revealed that approximately 70 taxi cabs used the I-45 North Freeway during a typical 3-hour afternoon peak period, substantially below the demand estimates provided to METRO. An analysis by TTI indicated that the addition of 50 to 100 vehicles per hour to the transitway total would have no significant impact on freeway traffic operations, since the roadway capacity is already exceeded by the traffic demand at that location. The taxi cabs were granted access to the facility, provided that each vehicle and driver was authorized and that the vehicle carried at least three passengers (including driver). METRO provided the required driver training and vehicle authorization process for the taxi cab companies. To date, there has been limited use of the authorized taxi cabs (less than one per day) on the I-45 North Freeway Transitway.

Summary of Transitway Performance Measures

The previous sections documented several aspects of the performance of the I-45 North Freeway Transitway during its second year of barrier-separated operation. Direct comparisons of the specific measures were made with the previous year's operation. However, a comparison which combines demand volumes, time savings, disabled and towed vehicles, and transitway accidents with the length of the transitway, provides a more accurate measure of transitway performance as vehicle and passenger demand volumes have declined. Table 10 provides this comparison for the transitway segment from North Shepherd to downtown Houston. The results of this analysis indicate that the total passenger demands have decreased by an average of 7%, and the average daily transitway delay savings have been decreased by 15%. On the positive side, miles between disabled and towed vehicles had dramatically increased for all vehicles using the transitway, effectively reducing the delay to transitway users due to such incidents. The accident rate on the transitway between North Shepherd and downtown Houston has decreased by 61% for all accidents within the transitway, and by 29% for those involving only transitway vehicles. As the facility is fully enclosed by the concrete median barriers, the interference from the adjacent freeway mainlanes will be

minimized, further reducing the accident rate. The summary provided in Table 10 does not include the 3.3 mile concurrent flow lane which operates during the morning hours between West Road and North Shepherd.

The measures used for comparison are affected by transitway demand volumes, transitway travel time savings, and the length of the transitway which is considered. These values will drastically change after completion of both the Phase II and III construction. The additional freeway mainlane capacity will reduce the travel time savings to transitway users, as well as increase the potential of modal shift away from transit. The transitway accident rate will likely decline further as the entire facility is separated by concrete median barriers on both sides, and the concurrent flow lane is eliminated.

Table 10. Summary of North Transitway Performance Measures

Transitway Performance Measure	12/84 to 11/85[1]	12/85 to 11/86[2]	Change
Total Vehicle Demand			
Buses	73,900	78,600	6%
Vanpools	133,800	116,900	-13%
Total	207,700	195,500	-6%
Total Vehicle Miles of Travel			
Buses	708,120	753,000	6%
Vanpools	1,285,200	1,121,970	-13%
Total	1,993,320	1,874,970	-6%
Total Passenger Demand			
Buses	2,526,000	2,369,000	-6%
Vanpools	1,140,000	1,036,000	-9%
Total	3,666,000	3,405,000	-7%
Daily Transitway Delay Savings (passenger-hours)	1,624	1,380	-15%
Miles Between Disabled Vehicles			
Buses	14,780	22,180	50%
Vanpools	53,510	93,560	75%
Total (all vehicles)[3]	18,460	21,820	18%
Miles Between Towed Vehicles			
Buses	44,330	62,840	42%
Vanpools	321,090	1,122,690	250%
Total (all vehicles)[3]	41,530	49,390	19%
Transitway Accident Rate (accidents/million vehicle-miles)			
Transitway and Unauthorized Vehicles[4]	5.52	2.13	-61%
Transitway Vehicles Only[5]	1.51	1.07	-29%

[1]252 days of operation

[2]251 days of operation

[3]Includes unauthorized vehicles

[4]Includes accidents involving both transitway and non-transitway vehicles

[5]Accident rate for transitway vehicles only

MAINLANE EFFECTS FROM TRANSITWAY IMPLEMENTATION

The completion of the Phase I construction, which placed the transitway behind concrete median barriers, has effected freeway traffic operations in two ways. First, both the average speeds and volume throughput have increased for the freeway during both peak periods. Comparing the first and second year of transitway operations, average speeds throughout the entire peak period have increased from 35 mph to 39 mph in the morning and from 28 mph to 30 mph in the afternoon. These travel speeds are averages of the quarterly data collected by TTI and vary on a day to day basis. These slight increases in average freeway mainlane travel speeds are not significant enough to be noticed by motorists. Figures 30 and 31 present comparisons of the operating speeds on the freeway mainlanes. Although the increased operating speeds have reduced the delay to freeway users, they have also reduced the travel time savings benefits to users of the I-45 North Freeway Transitway.

Comparing the first and second years of transitway operation, throughput volumes on the freeway mainlanes have also increased. As indicated by Figure 32, flow rates in the morning near Little York Road remain fairly constant until after 8:00 a.m., when the congestion begins to dissipate. Average flow rates across the 3-hour peak period have increased from 1340 to 1390 vehicles per hour per lane. Comparing the peak hour in the morning, the average flow rate has increased from 1350 to 1400 vehicles per hour per lane for the second year of operation. Flow rates during the afternoon peak period have also increased as compared to those of the first year of transitway operation (Figure 33). The average afternoon peak-period flow rate has increased from 1280 to 1350 vehicles per hour per lane, and from 1330 to 1450 vehicles per hour per lane during the peak hour. These flow rates were determined from traffic volume counts taken upstream of a bottleneck location. Therefore, these volumes appear to be low for peak-hour traffic for Level-of-Service F conditions. The flow rates through this section begin to increase during the am peak-period as the downstream traffic demands decrease (Figure 32). As the peak-hour traffic demands throughout the corridor decrease, the flow rates observed also decrease, indicating the end of the am peak hour. For the pm peak period (Figure 33), the outbound traffic volumes decrease after

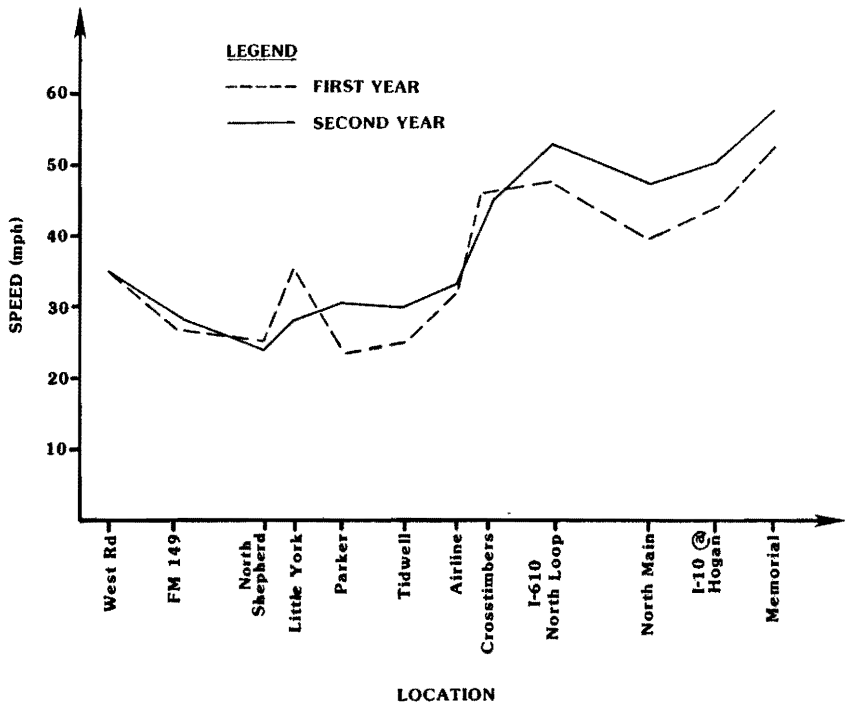


Figure 30. Average Morning Inbound Mainlane Speeds, Peak Period

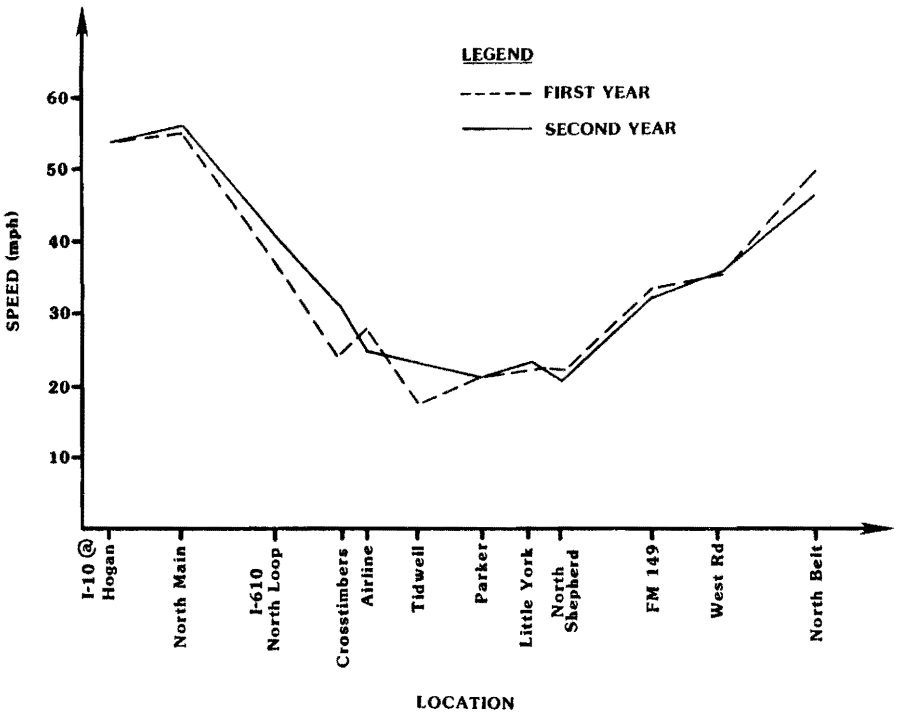


Figure 31. Average Afternoon Outbound Mainlane Speeds, Peak Period

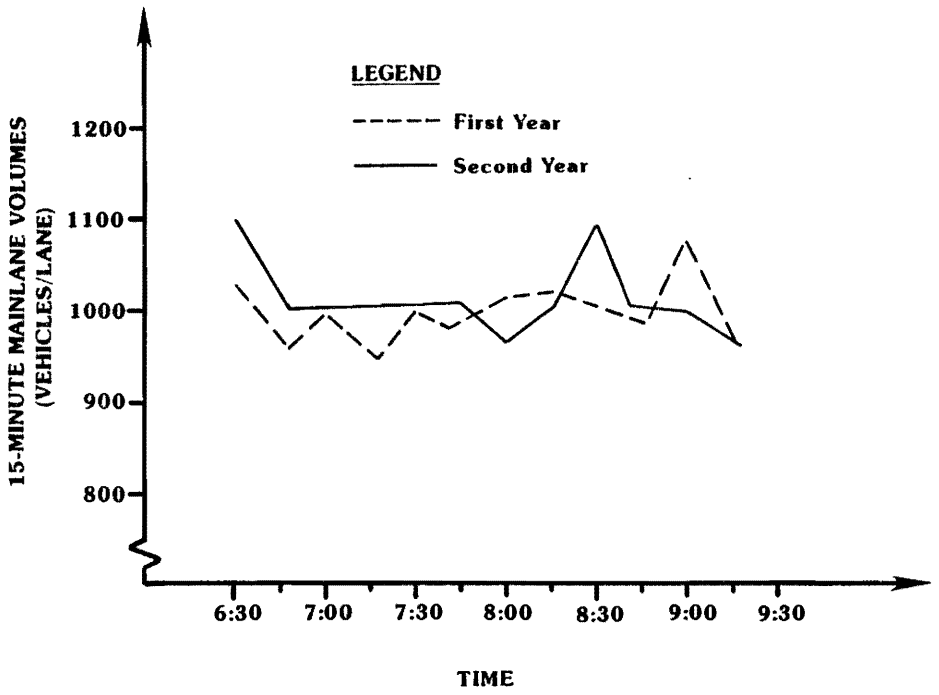


Figure 32. Average Morning Inbound Mainlane Volumes, Peak Period

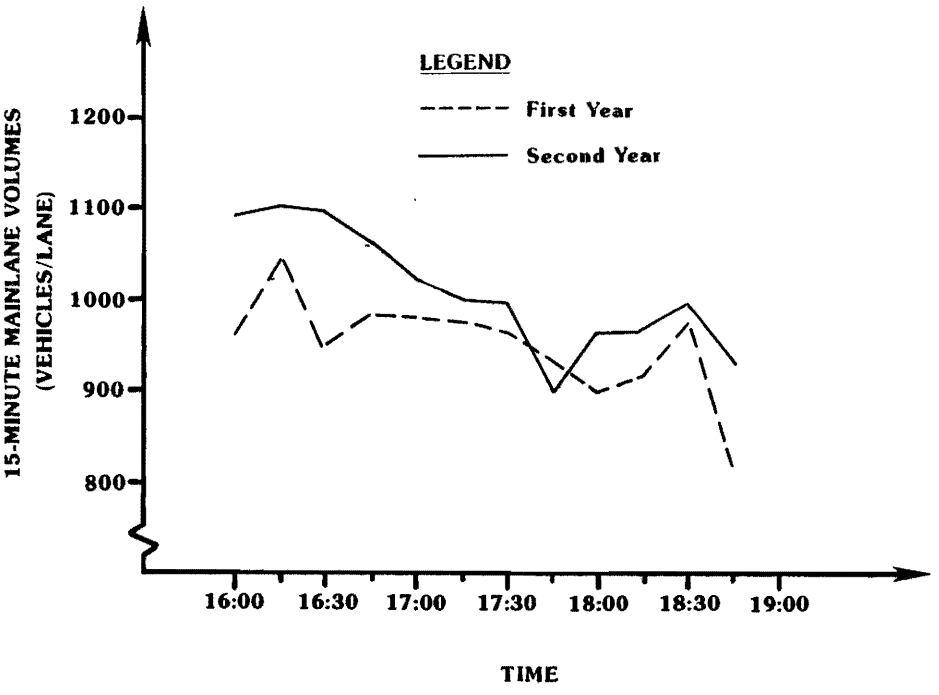


Figure 33. Average Afternoon Outbound Mainlane Volumes, Peak Period

4:30 p.m. due to a downstream bottleneck. The flow rates through the freeway segment studied begin to increase as the traffic demands decrease after 6:00 p.m.

Besides the effect of the transitway implementation upon the freeway mainlane flow, it may also have an impact upon freeway accident rates. As indicated by Table 11, the accident rate has increased in the past year when compared to the first year of transitway operation. It should be noted that the rate for the second year is similar to that realized during the Phase I construction. Although the Phase II construction began in March 1985, the construction activities were confined to the frontage road system, and the area between the frontage road and the freeway, for approximately six months. These first stages had limited impact on the freeway traffic. During the second year of transitway operation, the work progressed to the freeway mainlanes, resulting in narrow travel lanes and roadway sections without emergency shoulders. This may account for the 25% increase in accident rate for I-45 North Freeway mainlanes during the second year. It is expected that the accident rate for this freeway section will decline upon completion of the Phase II construction in May 1987.

Table 11. North Freeway Mainlane Accident Rates

(North Shepherd to Hogan)

Time Period	Total # Accidents	# Days	Average ADT	Accidents/MVM
CFL Operation (1/16/83-1/15/84)	929	365	151,138	2.105
During Construction (Phase I) (1/16/84-11/20/84)	958	310	158,807	2.432
Transitway Operation* (11/21/84-11/20/85)	964	365	171,425	1.926
(11/21/85-11/30/86)	1303	375	180,711	2.403

Source: SDHPT accident and roadway inventory records.

*Phase II construction commenced March 1985

COMBINED FREEWAY AND TRANSITWAY IMPACTS

Although the transitway usage has slightly declined, combined freeway and transitway throughput has increased. As indicated by Table 12, an average of more than 12,100 vehicle trips are served by the freeway and transitway during a typical am peak period. This represents an increase of approximately 2060 vehicle trips as compared to the first year of barrier-separated operation. As trips on the transitway have decreased, those using the freeway mainlanes have increased by 20%. Although vehicle trips on the transitway accounted for 3% of the total, the transitway served 34% of the total passenger trips during the am peak period. The transitway served as many passengers as 1.5 adjacent freeway mainlanes for the entire peak period. Table 13 presents similar comparisons for the pm peak period. The freeway and transitway served over 12,400 vehicle trips during the peak period, an increase of 16% for the previous year. The transitway served 31% of the peak-period passenger demand with 3% of the total vehicle trips, equivalent to 1.3 adjacent freeway mainlanes.

Similar to that experienced for the peak period, total vehicle and passenger (freeway and transitway) throughput during the peak hour has also increased (Table 14). Total vehicle trips increased by 16%, and passenger trips increased by 4% during the am peak hour. For the pm peak hour, the increases were 9% and 3%, respectively. The transitway served 46% of the passengers during the am peak hour with only 5% of the total vehicle trips. This represents the passenger movement equivalent to 2.5 adjacent freeway mainlanes. During the pm peak hour, the transitway served 42% of the passenger demand for the combined freeway and transitway with less than 5% of the vehicle trips. This represents the passenger movement of 2.3 adjacent freeway mainlanes during the pm peak hour.

Table 12. Total Freeway and Transitway Throughput - AM Peak Period

Month	Freeway Mainlanes		Transitway		Total	
	Vehicles	Passengers	Vehicles	Passengers	Vehicles	Passengers
12/84	10,235	11,463	370	6,669	10,605	18,132
3/85	7,944	8,886	431	7,668	8,375	16,554
6/85	9,818	11,181	422	7,582	10,240	18,763
9/85	10,687	12,178	413	7,315	11,100	19,493
Average	9,671	10,927	409	7,309	10,080	18,236
12/85	11,830	13,004	400	7,205	12,230	20,209
3/86	13,327	14,933	388	6,953	13,715	21,886
6/86	9,314	10,199	385	6,502	9,699	16,701
9/86	12,513	14,277	385	6,872	12,898	21,149
Average	11,751	13,103	390	6,883	12,141	19,986

Note: Volumes reflect hours of transitway operation -- 6:00-8:45 AM

Table 13. Total Freeway and Transitway Throughput - PM Peak Period

Month	Freeway Mainlanes		Transitway		Total	
	Vehicles	Passengers	Vehicles	Passengers	Vehicles	Passengers
12/84	11,158	12,777	395	7,191	11,553	19,968
3/85	9,519	11,498	424	7,592	9,943	19,090
6/85	9,177	11,517	398	7,084	9,575	18,601
9/85	11,382	13,447	414	6,899	11,796	20,346
Average	10,309	12,310	408	7,192	10,717	19,502
12/85	10,753	13,001	391	6,993	11,144	19,994
3/86	11,788	14,448	392	6,956	12,180	21,404
6/86	13,245	17,121	394	6,813	13,639	23,934
9/86	12,412	15,195	386	6,727	12,798	21,922
Average	12,050	14,941	391	6,872	12,441	21,813

Note: Volumes reflect hours of transitway operation -- 3:45-6:45 PM

Table 14. Peak Hour Freeway and Transitway Throughput

Time Period	Freeway Mainlanes		Transitway		Total	
	Vehicles	Passengers	Vehicles	Passengers	Vehicles	Passengers
AM Peak Hour						
12/84-11/85	3,522	3,952	248	4,216	3,770	8,186
12/85-11/86	4,163	4,610	228	3,926	4,391	8,536
PM Peak Hour						
12/84-11/85	3,689	4,365	234	3,964	3,923	8,329
12/85-11/86	4,088	4,986	201	3,606	4,289	8,592

Note: AM Peak Hour 6:45-7:45 AM
PM Peak Hour 4:30-5:30 PM

Table 15 presents occupancy rates for both the freeway mainlanes and transitway for an average peak period. Also included are data for four other Houston freeways with and without transitways for the same time periods. Comparing the facilities with transitways in operation, the average occupancies for both the freeway and transitway were similar during the first year. However, that for the I-10 Katy Freeway Transitway declined substantially after carpools with as few as 2 occupants were allowed to use the facility. The freeway mainlane occupancy for I-45 Gulf Freeway and US 59 Southwest Freeway, which do not have operational transitways, is higher than that for the two facilities with transitways. However, the total occupancy (mainlanes and transitway) rate is higher on the freeways with transitways than for the others. The occupancy data for US 290 Northwest Freeway indicate a mainlane occupancy rate comparable to those freeways with operating transitways. This is most likely due to the proximity of the I-10 Katy and US 290 Northwest corridors; and considering that the US 290 facility experiences high degrees of congestion in segments where only frontage roads exist and the freeway cross sections have yet to be built. The total occupancy for the I-45 North Freeway is substantially higher than that on I-10 Katy Freeway (1.70 versus 1.38) due to a greater number of buses and vanpools using the facility.

Table 15. Average Peak Period Occupancy Rates

Facility	Freeway Mainlanes	Transitway	Total
12/84-11/85			
I-45 North	1.16	17.7	1.81
I-10 Katy	1.17	17.4	1.34
I-45 Gulf	1.28	---	1.28
12/85-11/86			
I-45 North	1.18	17.6	1.70
I-10 Katy	1.16	11.0*	1.38
I-45 Gulf	1.26	---	1.26
US 290 Northwest+	1.16	---	1.16
US 59 Southwest+	1.27	---	1.27

*2+ carpools allowed 8/11/86

+Data for month of 9/86

MOTORIST ATTITUDES REGARDING TRANSITWAY

In a recent survey (10) of transit users, vanpoolers, and motorists within the I-45 North Freeway corridor, respondents were asked their opinions regarding the transitway construction. Table 16 summarizes the results of selected questions from the survey. At least 80% of all the users of the I-45 North Freeway Transitway indicated that the transitway was sufficiently utilized to justify the project. Conversely, only 26% of the nonusers felt that it was, at present, sufficiently utilized. However, 62% of the nonusers stated that the transitway is a good transportation improvement. While sizeable percentages of transitway users indicated that they would be using their current mode even if there were no transitway, 27% of the vanpoolers and 41% of the transit users indicated that they would not. Thus, it would appear that the implementation of the I-45 North Freeway Transitway has encouraged some individuals to switch travel modes. In addition, 68% of the vanpoolers and 76% of the transit users stated that the transitway was "very important" in their decision to use their current mode.

Table 16. Motorist Attitudes Regarding I-45 North Freeway Transitway

Survey Response	Transitway Users		Non-Transitway Users
	Transit	Vanpool	
Is the Transitway Sufficiently Utilized			
Yes	81%	84%	26%
No	6%	7%	56%
Not Sure	13%	9%	18%
Is the Transitway a Good Transportation Improvement			
Yes	---	---	62%
No	---	---	20%
Not Sure	---	---	18%
Would You Ride in Bus or Vanpool if Transitway Not Available			
Yes	23%	43%	---
No	41%	27%	---
Not Sure	36%	30%	---
How Important is the Transitway in Your Decision to Use Bus or Vanpool			
Very Important	76%	68%	---
Somewhat Important	17%	18%	---
Not Important	7%	14%	---

Source: Reference (10).

BENEFIT/COST ANALYSIS

For the first and second years of transitway operations, persons traveling by authorized bus or vanpools realized a travel time savings over the freeway mainlanes of 1624 and 1380 passenger hours, respectively. These delay savings are based on the average travel time savings throughout the entire peak period. They are somewhat conservative, as the majority (60%) of transitway users use the facility during the peak hour, when travel time savings are much greater. Placing a value of $8.03 for each person-hour of delay, and assuming that the transitway patronage and travel time savings remain constant, this translates into an undiscounted benefit in excess of $3.27 million for the first year, and $2.79 million for the second year of transitway operation (11).

An examination of the benefits and costs associated with Phase I of the I-45 North Freeway Transitway confirm the facility's long-term cost-effectiveness. The extremely conservative analysis is based upon the assumptions below.

1) All construction costs are stated at their nominal value (i.e., are assumed to have been expensed at the time the transitway became operational). The costs included for this analysis are those attributable to the transitway construction only. Costs associated with the freeway improvements are not considered.

2) METRO's current level of operating expenses will remain constant over the 20 year analysis period at approximately $21,700 per month (1).

3) Transitway volumes will remain constant at their present levels for the length of the 20 year analysis period at approximately 13,570 person-trips per day. This is extremely conservative as the transitway passenger demands are expected to increase as the priority lane is extended to the north.

4) Bus operating costs (valued at $60/bus-hour) can be reduced by the transitway assuming that the same headway between buses would need to be provided regardless of the availability of the transitway, and that without the transitway more buses would be needed to maintain that same headway (1).

5) Travel time savings for transitway users will remain constant for the 20 year analysis period. This is somewhat conservative as the freeway congestion will increase due to the projected increases in traffic demands; resulting in increased travel time savings to transitway users.

6) A discount rate of 10% is assumed for the 20 year analysis period.

As summarized in Table 17, the first phase of the I-45 North Freeway Transitway justifies itself with a benefit to cost ratio of 2.3. Combining that of the Phase I and II transitway construction, the benefit to cost ratio is reduced to 1.1. This estimate is extremely conservative in that it does not consider any increases in transitway and freeway traffic demand throughout the 20 year analysis period and uses a relatively high discount rate. As both the transitway demand volumes and freeway traffic congestion are expected to increase, the actual benefits realized by users of the transitway will be greater, resulting in a higher benefit to cost ratio. Although not included in this analysis, freeway motorists will benefit from the additional freeway capacity as provided by the Phase I and II construction.

Table 17. Estimated Benefits and Costs for Phases I-III

Benefit or Cost Component	Present Value (Millions of 1985 Dollars)	
Benefits:		
Travel Time Savings	$29.3	
Reduced Bus Operating Costs	5.9	
Total Benefits		$35.2
Costs:		
Transitway Design and Construction		
Phase I	$13.0	
Phase II	18.0	
Transitway Operation	2.2	
Total Costs		$33.2
Benefit Cost Ratio		
Phase I	2.3	
Phase I and II	1.1	

CONCLUSIONS

Since 1979, peak-period, peak-direction vehicle and passenger throughput on the I-45 North Freeway has been increased through implementation of a high-occupancy vehicle priority lane on the freeway between North Shepherd Drive and downtown Houston. In November 1984, the contraflow lane concept was discontinued, and the transitway operated separated from the freeway traffic by concrete median barriers within the freeway median.

In the second year of barrier-separated operation (December 1985 to November 1986), the transitway volumes averaged 779 vehicles carrying 13,573 people each operating day. This represents a 5.3% decline in vehicle demand and a 6.7% decline in passenger demand when compared to the previous year of transitway operation. On the other hand, utilization of five park-and-ride lots (measured by the number of parked vehicles) increased by 7.6%, with over 60% of the spaces occupied on a daily basis. Travel time savings to transitway users averaged 4.2 minutes per trip in the morning peak period and 8.0 minutes in the afternoon peak period.

Although vehicle trips on the transitway accounted for approximately 3% of the total freeway and transitway vehicle trips, the passenger trips represented at least 30% of the total passenger trips during a typical 3-hour peak period. In the peak hour alone, the transitway passenger movement was equivalent to that of at least 2.3 adjacent freeway mainlanes. The reliability of transitway operations have continued to improve as the occurrences of disabled and towed vehicles within the transitway have declined. The accident rate along the transitway has declined to 1.07 accidents per million vehicle miles, a 29% reduction from the previous year. A benefit to cost ratio of 2.3 was determined for the Phase I construction, confirming the cost effectiveness of the transitway. Combining Phases I and II, the benefit to cost ratio is 1.1.

The Phase II transitway construction will provide for a full width (20 feet) transitway and additional capacity for the freeway mainlanes. Phase III will provide similar improvements further north to Beltway 8. The northern extension of the transitway, combined with increasing freeway

congestion (due to projected traffic growth), will provide increased travel time savings to users of the transitway. Thus, it might be expected that additional mode shifts towards high-occupancy vehicles using the transitway will occur. Although already deemed as a success, the transitway will continue to serve a higher proportion of the weekday commuter passenger demand of the I-45 North Freeway corridor. It offers a means of accommodating projected growth in corridor travel demands.

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