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16. Abstract

This report evaluates the operation of freeway high-occupancy vehicle (HOV) lanes in Texas through calendar year 1997. As of the end of 1997, HOV lanes were in operation on the five following Houston freeways: 1) Katy Freeway (I-10W); 2) North Freeway (I-45N); 3) Northwest Freeway (US 290); 4) Gulf Freeway (I-45S); and Southwest Freeway (US 59S). There are two facilities operating in Dallas as of the end of 1997: East R.L. Thornton Freeway (I-30E) and Stemmons (I-35E).

This research report provides an analysis of data related to the 1) operation of the HOV lanes; 2) operation of the freeway mainlanes; 3) combined HOV lane and freeway data; and 4) data relating to transit usage and operations. Both "before" and "after" trendline analysis (where applicable) and a comparison to control freeways are used as a means of assessing the impacts of HOV facilities.

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AN EVALUATION OF HIGH-OCCUPANCY VEHICLE LANES IN TEXAS, 1997

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ACKNOWLEDGMENTS

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Dr. Dennis L. Christiansen, P.E., was the initial leader in this research and has maintained a high profile presence and involvement throughout. Other key contributors include: Ms. Tina Collier, who produced the last three editions, Mr. Russell Henk, P.E., who served as research supervisor; Mr. Mike Ogden, P.E., who managed the data collection and analysis in Houston. Mr. Danny Morris and Mr. David Sena, who provided extensive data analysis throughout the project. Mr. Kevin Hall, who assisted with air quality assessment, and Drs. Tim Lomax, P.E.; and Katherine F. Turnbull, who provided guidance and feedback throughout the project.

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SUMMARY

Cooperative efforts between the Texas Department of Transportation (TxDOT) and Texas' largest transit authorities have produced more than 100 miles of HOV lanes in Houston and Dallas. In Houston, TxDOT, and the Metropolitan Transit Authority of Harris County (METRO) are jointly developing these facilities, while TxDOT and Dallas Area Rapid Transit (DART) are developing these projects in Dallas. This report presents and evaluates data relative to HOV lane and freeway performance in Houston and Dallas through calendar year 1997, as well as future expansion plans for the HOV systems in these areas.

There is a long-standing commitment to develop 103 miles of barrier-separated high-occupancy vehicle (HOV) lanes in Houston, at a total cost of over $700 million (1995 dollars), including the entire HOV lane system and all support facilities. These costs include the HOV lanes, HOV lane access and egress ramps, all park-and-ride lots, park-and-pool lots and bus transfer centers; and the HOV surveillance, communication and control system. As of the end of 1997, 67 miles of barrier-separated HOV lanes were in place and operational in five corridors, implemented at a cost of approximately $650 million. The typical Houston HOV lane is located in the freeway median, is approximately 20 ft wide, is reversible, and is separated from the freeway general-purpose mainlanes by concrete median barriers. Grade-separated ramps provide access/egress to most HOV lanes.

As of December 1997, the Houston HOV lane system served 78,800 daily person trips, an increase of 2500 riders over the previous year. Park and ride usage was up 11 percent to 11,092 cars daily. Surveys previously conducted in Houston indicate that the HOV lanes have been successful in attracting young, educated, professional, white-collar patrons. These individuals are choosing to use the high-occupancy vehicle lanes primarily to 1) save time; 2) avoid having to drive in congested traffic; 3) have a reliable trip time; 4) have time to relax; and 5) save money.

The Dallas HOV system is in the early stages of development. As of December 1997, the Dallas HOV system comprised a 5.2-mile barrier-separated contraflow lane on the East R.L. Thornton (East RLT) Freeway, interim concurrent flow lanes along a seven mile stretch of North Stemmons Freeway, and a six-mile section of concurrent flow lanes on the LBJ Freeway. The East RLT and Stemmons HOV lanes are reviewed in this report. The cost to construct the contraflow lane (in 1995 dollars) was $15 million, and the cost to construct the concurrent flow lanes was $12 million. A network of nearly 250 miles of HOV lanes is currently under consideration. The cost of that system is estimated to be $ 1.2 billion..

In December 1997, the East RLT HOV lane served 15,849 daily person trips, an 18 % increase over 1996. By the end of 1997, 881 cars parked in East RLT corridor park-and-ride lots on a typical day, a slight increase from 1996.

MEASURES OF HIGH-OCCUPANCY VEHICLE LANE EFFECTIVENESS

In order to assess the effectiveness of the HOV lanes, it is necessary to identify the impetus behind the development of these facilities. To a large extent, the decision to consider building HOV lanes in Texas came through the realization that it was simply not possible, either physically or economically, to provide enough street and highway lanes to indefinitely serve peak-period travel demands at 1.2 persons per automobile.

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

This report presents data and analyses to determine whether these objectives and implementation strategies are being attained. Researchers used two principal evaluation approaches.

First, researchers collected "before" and "after" trendline data for each freeway where an HOV lane is being developed. Second, researchers collected similar data in control corridors that do not have high-occupancy vehicle lanes. These procedures help to identify and isolate the impacts of the freeway HOV lanes. A summary table (Table S-1) presents each Texas HOV lane analyzed and indicates how well each performed related to the stated objectives.

CHANGES IN ROADWAY PERSON MOVEMENT

A major reason for implementing HOV lane improvements is to increase the effective person-movement capacity of a roadway. Since implementation of the HOV lane increases the number of directional roadway lanes, the high-occupancy vehicle lane should carry a greater percentage of person movement compared to the percentage of lane capacity it provides. The data show that the HOV lanes in Texas are helping to bring about an increase in person movement per lane.

For the HOV lanes to generate increases in person movement, it is necessary to increase the average vehicle occupancy; this has happened in most cases. On the two freeways with the more mature HOV lanes, peak-hour average vehicle occupancies are approximately 1.5 persons per vehicle. Compared to pre-HOV lane conditions, average vehicle occupancy on the North, Katy, Southwest, Northwest, and Stemmons freeways has increased by at least 10 percent. This type of increase has not been experienced on freeways without HOV lanes.

For average occupancy to increase, there needs to be an increase in transit use and carpooling. The HOV lanes have resulted in new carpools and new transit riders, and in most cases, an increase in average occupancy. These increases in ridesharing have not been experienced on freeways without HOV lanes.

HOV LANE IMPACTS ON BUS OPERATIONS

The HOV lanes have generated a large increase in transit use and have attracted a new type of transit rider. Young, educated, white-collar Texans are making extensive use of transit. Also, in comparing pre-HOV conditions to the present, average bus operating speeds during the peak hour have nearly doubled, increasing from 26 mph to 51 mph. The result has been a reduction in schedule times and an increase in schedule reliability, thus adding to the attractiveness of transit.

IMPROVEMENT IN TOTAL ROADWAY EFFICIENCY

The implementation of a high-occupancy vehicle lane should increase the overall efficiency of a freeway. For purposes of this study, the peak-hour per lane efficiency of a freeway is expressed as the multiple of peak-hour person volume and the speed at which that volume is moved (a weighted average for the freeway and the HOV lane). In all cases, this efficiency has increased (Table S-1) since the HOV lanes have been implemented, by a margin of 67% or more. Data indicate that a significant part of that increase is the result of HOV lane implementation.

HOV LANE IMPACTS ON FREEWAY GENERAL-PURPOSE LANE OPERATIONS

Although the HOV facilities move several thousand persons in the peak hour, there has been virtually no adverse impact on the operation of the freeway general-purpose lanes that can be attributed to implementation of these HOV lanes (Table S-1). Per-lane volumes on the general purpose lanes are often higher today than they were prior to HOV implementation. Peak-hour travel speeds on the general-purpose lanes have also increased (in most cases) after HOV lane implementation. In reviewing accident data for the six freeways with HOV lanes, accident rates have typically declined (in some cases substantially) on the mainlanes.

HOV PROJECT COST EFFECTIVENESS

The cost effectiveness analysis conducted in this study examines quantifiable benefits derived primarily from savings in delay and vehicle operating costs. Other benefits of HOV facilities that cannot be readily quantified, such as impacts on air quality, bus schedule reliability, regional economic development, etc., have not been part of the evaluation. Notwithstanding these benefits, an analysis of the actual operation of HOV lanes in Texas has shown that HOV lanes are cost-effective improvements based solely on overall savings in user costs and vehicle operating costs. And in examining these savings over the long term, construction of an HOV lane is shown to be a more cost-effective alternative than the construction of two general purpose lanes.

PUBLIC SUPPORT FOR THE HIGH-OCCUPANCY VEHICLE LANE PROGRAM

Acceptance of HOV lanes in Texas by the public is high and has been increasing over time. Based on 1994 surveys in Houston, over 65 percent of the motorists in the freeway general purpose lanes (not HOV lane users) viewed these projects as being good transportation improvements. On average, fewer than 20 percent stated the projects were not good improvements.

AIR QUALITY AND ENERGY CONSIDERATIONS

Researchers undertook a simulation analysis of the Katy Freeway to compare three different alternatives and their potential air quality and emission benefits. The "add an HOV lane" alternative was compared to both the "do nothing" alternative and the "add a general-purpose lane" alternative. The average vehicle occupancy levels were adjusted between alternatives to reflect the observed impacts of the HOV facility on vehicle occupancy. The demand, as expressed as passenger kilometers using the HOV facility and the general purpose lanes in 1996, was held constant in comparing alternatives.

Based on this analysis, the HOV lane is favorable in terms of reducing both vehicle emissions and energy consumed. The HOV alternative, compared to the add a general purpose lane alternative, had fewer emissions of hydrocarbons and carbon monoxide. The HOV alternative results in a reduction of 59 percent fewer carbon monoxide emissions when directly compared to the "add a lane" alternative. Similar results occur when comparing the two alternatives and the amount of energy consumed. The HOV alternative consumes 12 percent less fuel than the add a general purpose lane alternative. It is noted that the evaluation is a rudimentary analysis of the many systems that interact with each other to obtain emission rates and energy consumption figures. Additional analysis addressing the impacts of HOV lanes on air quality (e.g., vehicle emissions) are summarized in a companion report entitled, "Mobile Source Emission Impacts of High Occupancy Vehicle Facilities", Texas Transportation Institute Research Report 1353-02, William Knowles, November 1994.

FACTORS INFLUENCING HIGH-OCCUPANCY VEHICLE LANE UTILIZATION

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

On a typical non-incident day, the HOV lanes in Houston and Dallas offer a travel time savings to users during the peak hour. In Houston, these savings range up to 18 minutes on the Katy HOV lane. The East RLT and Stemmons HOV lanes in Dallas save users approximately four to six minutes. It is of interest to note that previous research has shown that the time savings perceived by the users (as determined in surveys of HOV lane users) are much greater than the actual time savings.

In addition to the three factors identified above, two additional factors are associated with the level of utilization of HOV lanes in Texas:

- The characteristics of the corridor, both in terms of its orientation to major activity centers and the availability of direct access and support facilities,
- The strength of bus transit service in the corridor and the extent to which transit service takes advantage of the HOV lane.

CONCLUSIONS

This report identified the objectives associated with developing high-occupancy vehicle lanes in Texas. The report reviews and analyzes data collected through calendar year 1997 to assess the performance of the priority lanes in meeting their objectives.

Table S-1 summarizes the success of the various Texas HOV lanes in meeting the objectives of such projects. It shows that while the performance of the HOV lane varies from corridor to corridor, all Texas HOV lanes are effective at their intended purpose.

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

Table S-1. Comparison of HOV Lane Objectives and HOV Lane Performance, 1997

Objectives, Measure of Effectiveness	HOV Facility						
	Katy	North	Gulf	Northwest	Southwest	East RLT	Stemmons
HOV lanes should increase person movement							
• Is daily HOV lane ridership at least 10,000?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
• Does the HOV lane move a greater percentage of persons in the peak-hour than the percentage of total lane capacity it represent?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
• Has the peak-hour vehicle occupancy increased by 10% to15%?	Yes	Yes	No	Yes	No	No	No
• Have new carpools increased by at least 25% due to the HOV lane?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
• Has bus ridership increased at least 25% as a result of the HOV lane?	Yes	N/A	Yes	Yes	Yes	No	No
HOV lanes should enhance bus operations.							
• Have peak-hour bus speeds increased by 50%?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HOV lanes should not result in an adverse impact on freeway general-purpose lane operations.							
• Have general-purpose lane speeds been impacted by the HOV lane?	No	No	No	No	No	No	No
• Has the general-purpose lane accident rate increased significantly due to the HOV lane?	No	No	No	No	No	No	No
Implementation of an HOV lane should increase the overall efficiency of the roadway.							
• Has the roadway per-lane efficiency increased by a value of at least 20 due to the HOV lane?	Yes	Yes	No	Yes	No	Yes	No
HOV lanes should be cost effective.							
• Does the value of the benefit outweigh the costs?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
• Does the HOV lane have an equal or greater benefit-to-cost ratio than a general-purpose lane alternative?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HOV lanes should have public support.							
• Do more than 50% of the persons responding to the surveys indicate support for HOV lane development?	Yes	N/A	N/A	Yes	N/A	Yes	N/A
HOV lanes should have favorable air quality & energy impacts.							
• Has adding an HOV lane been more effective than a general-purpose lane would have been in terms of air quality and energy impacts?	Yes	N/A	N/A	N/A	N/A	N/A	N/A
Overall Assessment: Is the HOV facility effective?	Yes	Yes	Marginally	Yes	Yes	Yes	Marginally

CHAPTER 1. INTRODUCTION

High-occupancy vehicle lanes (HOV lanes) have been in place for almost two decades in Texas. Beginning with a contraflow lane on I-45 in Houston, the system has expanded to 64 mi of HOV lanes in Houston and 20 mi in Dallas. Much experience has been gained in the planning, design and operation of HOV lanes. The Texas Department of Transportation (TxDOT) has funded this long-term research project to document the evolution of the HOV lane system and to provide an assessment of its effectiveness.

This is the sixth and final report in a series under the auspices of the TxDOT research project. The purpose of this report is to provide up-to-date documentation of the evolution of the HOV lane networks and, through analysis of key data, to provide insight for future development and operation.

HOV lanes frequently spark debate among the public and transportation professionals. Because they portend behavior changes, they are often unfairly denigrated by the ignorant and equally often unjustifiably revered by the supposedly informed. Objective, informed understanding of HOV lanes can only be achieved through the examination of the arguments and the study of the facts. This report is structured to address both the arguments and the facts. Chapters 4 through 10 address, individually, each of the seven primary objectives of HOV lanes introduced in Chapter 3. As with its predecessors, this report also provides in-depth analysis of a few key areas. The reader should note that Chapter 8 expands on previous work related to the cost-effectiveness of HOV lanes, providing the most in-depth analysis to date.

CHAPTER 2. OVERVIEW

Two cities in Texas have been operating HOV lanes–Houston and Dallas. Houston's network of HOV lanes began with the North Freeway (I-45) contraflow lane in 1979. Following the success of that facility, Houston built a network of five HOV lanes totaling 64 mi, with plans to eventually expand that to 103 mi. Now all of Houston's HOV lanes are single-lane, reversible facilities, and with one exception, follow a 2+ occupancy standard. (The exception is the Katy (I-10) HOV lane, which has a 3+ occupancy standard during the peak hour, both morning and evening.) Table 1 shows a summary of the status of Houston's HOV lanes, which is also illustrated in Figure 1.

Table 1. Status of the Houston High-Occupancy Vehicle Lane System, December 1997

HOV Facility	Date First Phase Opened	Miles in Operation	Ultimate System Miles	Vehicles Allowed to Use HOV Lane	Hours of Weekday Operation[1]
Katy (I-10W)	October 1984	13.1	15.3	3+ vehicles from 6:45 to 8:00 a.m., 5:00 to 6:00 p.m.; 2+ during other operating hours	5 a.m. to 11 a.m. inbound 2 p.m. to 8 p.m. outbound
North (I-45N)	November 1984[2]	16.9	19.9	2+ vehicles	5 a.m. to 11 a.m.inbound 2 p.m. to 8 p.m. outbound
Gulf (I-45S)	May 1988	12.1	17.7	2+ vehicles	5 a.m. to 11 a.m. inbound 2 p.m. to 8 p.m. outbound
Northwest (U.S. 290)	August 1988	15.5	15.5	2+ vehicles	5 a.m. to 11 a.m. inbound 2 p.m. to 8 p.m. outbound
Southwest (U.S. 59S)	January 1993	13.5	15.0	2+ vehicles	5 a.m. to 11 a.m. inbound 2 p.m. to 8 p.m. outbound
Eastex (U.S. 59N)	Not open in 1997	---	20.2	---	---
Westpark Corridor	Not open in 1997	---	4.5	---	---
Total		64.3	103.2		

[1]Beginning in October 1989, the Katy and Gulf HOV lanes were opened to 2+ carpools on weekends; those facilities operate outbound on Saturday (4 a.m. to 10 p.m.) and inbound on Sundays (4 a.m. to 10 p.m.). In June 1990, the North HOV lane opened on weekends, and in October 1990 the Northwest HOV lane opened on weekends. Weekend use of all HOV lanes except the Katy was discontinued in October 1991 due to low usage.
[2]A contraflow lane was implemented on the North Freeway in August 1979. It was replaced with a barrier-separated, reversible lane in November 1984.

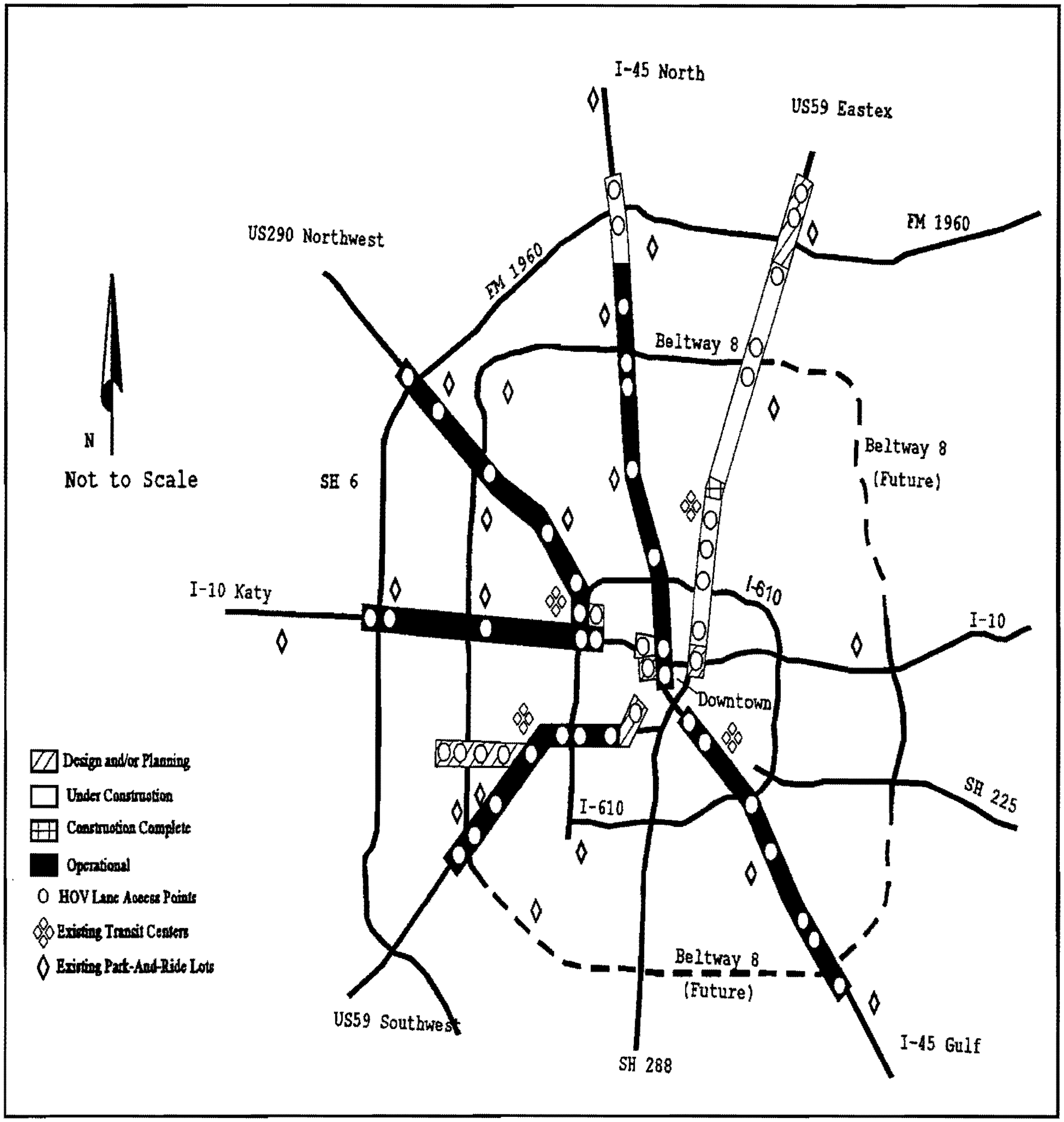


Figure 1. Status of Houston HOV Lane System, December 1997

Dallas' HOV lane system began with the opening of the East R.L. Thornton (I-30) contraflow lane in 1991. Two additional interim HOV lanes, the first concurrent flow lanes in Texas, have opened since then on the Stemmons Freeway (I-35E) and the LBJ Freeway (I-635). The contraflow lane on I-30 (ERLT) operates during the peak periods only, but the Stemmons and LBJ concurrent flow lanes (one each direction), operate 24 hours a day. Dallas is considering an ultimate system of 250 miles of permanent HOV lanes, a portion of which would replace the interim facilities on Stemmons and LBJ. Table 2 shows a summary of the status of Dallas' HOV lanes, which is also illustrated in Figure 2.

Table 2. Status of the Dallas High-Occupancy Vehicle Lane System, December 1997

HOV Facility	Date First Phase Opened	Miles in Operation	Ultimate Miles	Vehicles Allowed to Use HOV Lane	Hours of Weekday Operation
East R.L. Thornton (I-30) Interim Contraflow Lane	September 1991[1]	5.2	5.2	2+ vehicles	6 a.m. to 9 a.m. IB 4 p.m. to 7 p.m. OB
North Stemmons (I-35E) Interim Concurrent Flow Lanes	September 1996	6.8 IB 5.5 OB	7.3 IB 6.0 OB	2+ vehicles	24 hours, including weekends
LBJ (I-635) Interim Concurrent Flow Lanes	March 1997	6.4 EB 5.9 WB	6.5 EB 6.2 WB	2+ vehicles	24 hours, including weekends
South R.L. Thornton (I-35E) Interim Barrier-Separated Reversible Lane[2]	Not open in 1997	---	6.0	---	---
Marvin D. Love (U.S. 67) Interim Concurrent Flow Lanes[2]	Not open in 1997	---	3.9 IB 3.9 OB5[3]	---	---
North Central Expwy. (U.S. 75) Barrier-Separated Reversible Lane[3]	Not open in 1997	---	9.0	---	---
Total		20.3	53.0		

NOTE: IB = inbound, OB = outbound

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

[2]An HOV lane is scheduled for completion in 2000.

[3]HOV lane schematics are currently being prepared for this corridor north of I-635. An exact date and length has not been determined at this time.

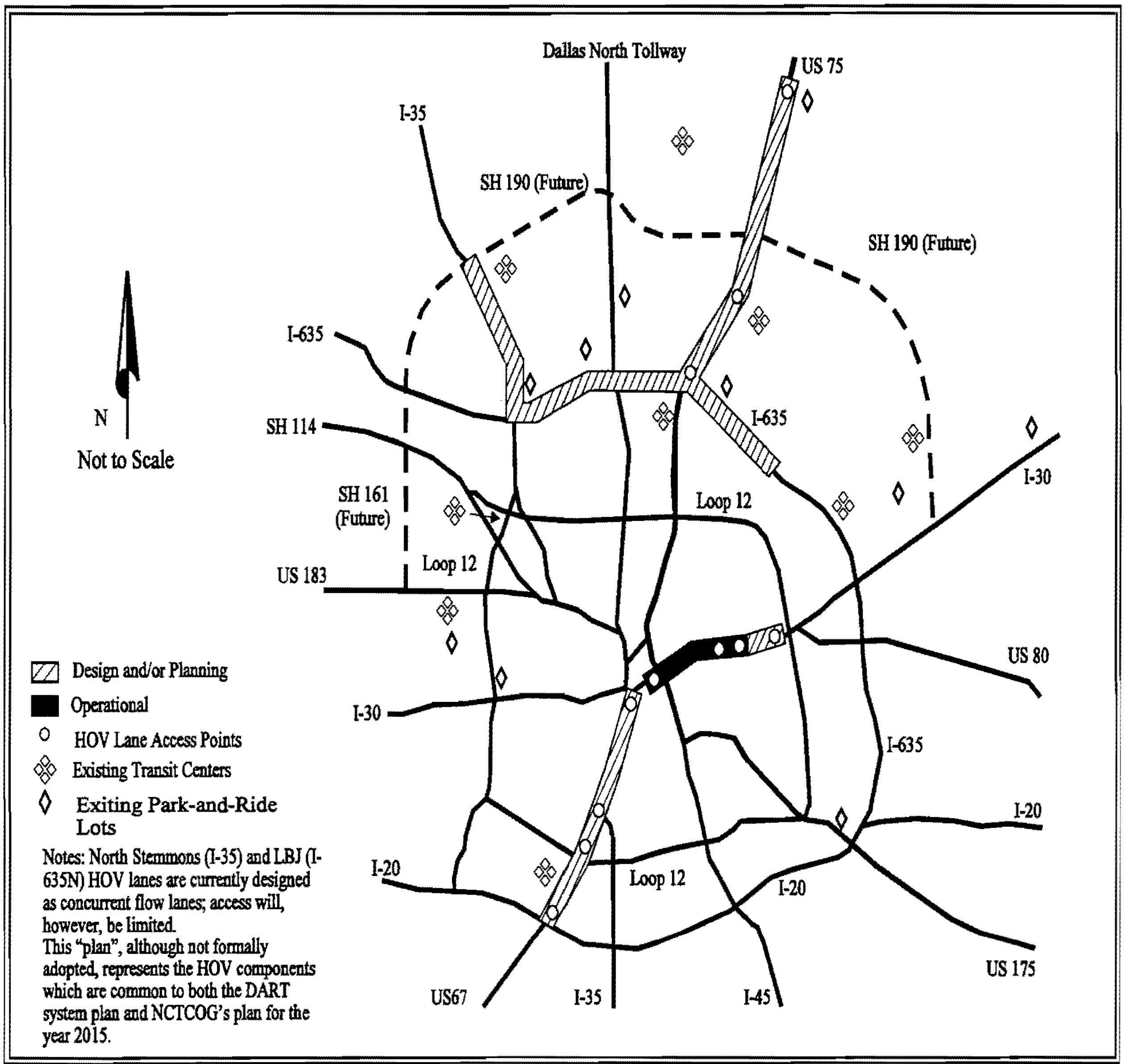


Figure 2. Status of the Dallas HOV Lane System, December 1997

Although none of the other cities in Texas have operational HOV lanes, Austin, Fort Worth, and San Antonio have adopted HOV lanes into their transportation plans and have detailed investigations into implementation underway as of the date of this report.

Additional detail on the history, development, and design of the Houston and Dallas HOV lanes is included in Chapter 12.

TYPES OF HOV LANES

There are three types of HOV lanes used in Texas–reversible, barrier-separated; contraflow; and concurrent flow. These are described below:

Exclusive, reversible HOV lanes, such as all of the current HOV lanes in Houston. These facilities are typically single-lane and separated from the mixed-flow lanes by concrete barriers. (See Figure 3.)

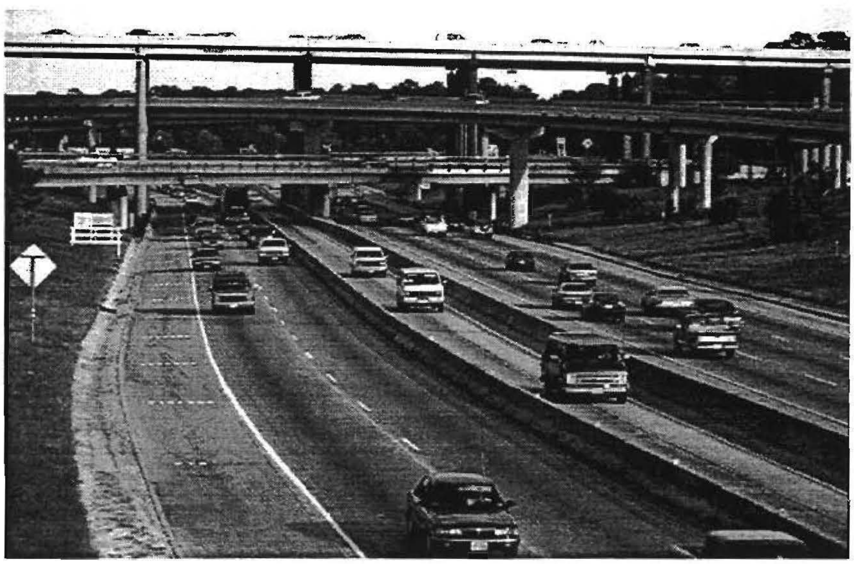


Figure 3. Reversible HOV Lane

Contraflow HOV lanes, like the East R.L. Thornton HOV lane in Dallas. These facilities are found where low traffic demand in the off-peak direction will allow for that lane to be "borrowed" for an HOV lane during the peak; the facilities are separated from oncoming traffic by movable concrete barriers. (See Figure 4.)

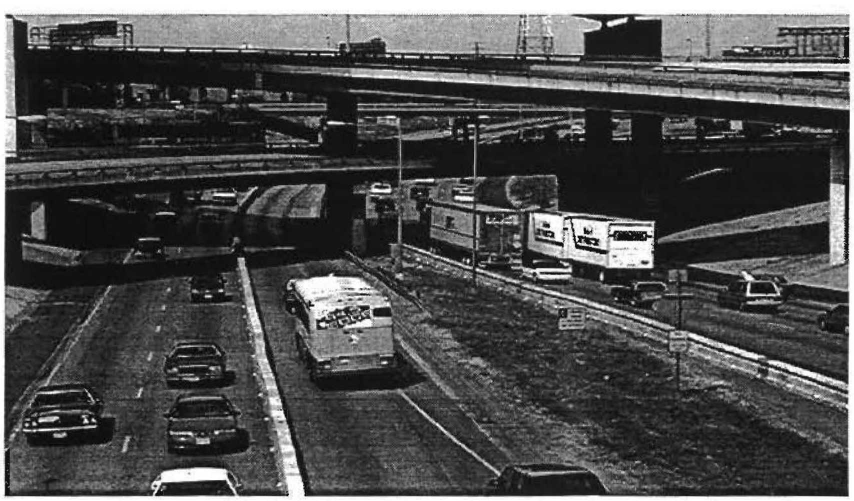


Figure 4. Contraflow HOV Lane

Concurrent flow lanes, such as those on the Stemmons and LBJ Freeways in Dallas. These are freeway lanes in the same direction of travel as the mixed-flow lanes that are not physically separated from mixed flow traffic. They typically have distinctive paint striping to separate the HOV lane from mixed-flow. (See Figure 5.)

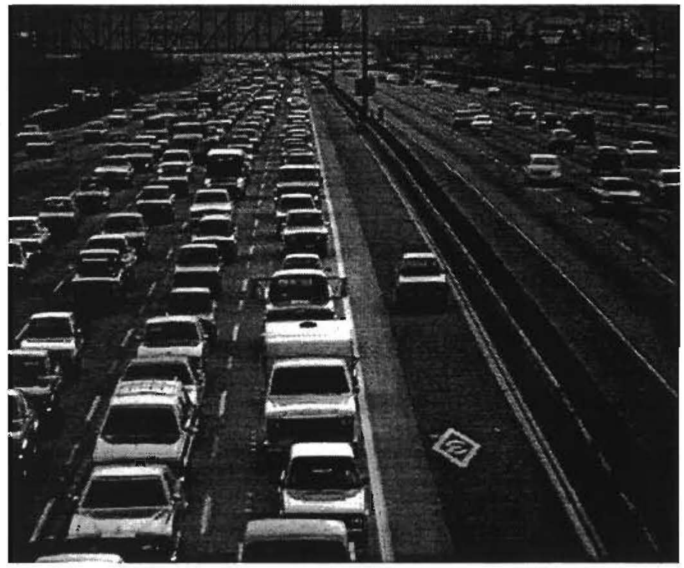


Figure 5. Concurrent Flow HOV Lane

SUMMARY OF HOV LANE USAGE IN TEXAS

Table 3 presents a selection of operating data from the HOV lanes in Texas. Bus operations on the exclusive lanes (all in Houston and the ERLT in Dallas) account for a substantial part of the ridership on those lanes. In all cases the HOV lanes are carrying more persons than adjacent freeway lanes and therefore account for a very high proportion of total person-movement in the corridor. In general, the older facilities in Houston are more productive, but all of them are cost-effective. Violation rates have been modest, except for the Katy HOV lane. Details on all of these statistics are provided in subsequent chapters.

Table 3. Selected HOV Lane Operating Statistics, December 1997

Time Period and Operating Data	HOV Lane						
	Katy	North	Gulf	Northwest	Southwest	E. RLT	Stemmons
Weekday Operations							
HOV Lane Person Volume							
A.M. Peak Hour	3,457	4,337	2,925	3,589	4,074	4,157	2,294
Daily	19,012	19,088	10,892	13,859	15,936	15,849	21,013
HOV Lane Vehicle Volume							
A.M. Peak Hour	868[1]	1,284	1,073	1,303	1,476	1,433	995
Daily	5,936	6,186	3,750	5,141	5,466	5,265	8,921
Percent of Total Person Movement that occurs in the HOV Lane, A.M. Peak-Hour[2]	40%	41%	32%	37%	31%	35%	27%
Vehicles Parked in Corridor Park-and-Ride Lots	2,230	3,641	1,233	1,740	2,158	881	637
Violation Rate, A.M. Peak Period	19%	8%	4%	7%	3%	1%	6%

[1]Carpool vehicle occupancy restricted to 3+ during the peak hour.
[2]Data collected at HOV lane maximum load point. The remaining percentage is in the freeway general-purpose lanes.
Source: Texas Transportation Institute data collection, see appendices.

CHARACTERISTICS OF HOV LANE USERS

Survey data have previously shown that the HOV lanes are attracting younger, educated white-collar professionals to transit and ridesharing. Table 4 presents some selected statistics from the most recent data available, surveys conducted in 1994. Among transit users, 69-95 percent have an automobile available, but find that time savings and the avoidance of congestion are prime reasons to choose to ride HOV lane transit. Surveys of carpoolers and vanpoolers showed that their occupational characteristics and motivation to use the HOV lane are similar to the transit riders, but their trip destinations are much more diverse, which for many is why carpooling is a better option than transit. Control surveys of non-HOV lane users (i.e., freeway users) showed that their trip characteristics were even more dispersed, providing some indication of their limited ability to take advantage of HOV lanes. Additional data on HOV lane users can be found in Chapter 14.

Table 4. Selected Data on HOV Lane Users

Characteristics	Bus Riders on the HOV Lane			Carpoolers on the HOV Lane			Freeway Users		
	Katy	Northwest	East R L. Thornton	Katy	Northwest	East R.L. Thornton	Katy	Northwest	East R.L. Thornton
AM Trip Destination									
Downtown	93%	95%	88%	66%	42%	71%	13%	15%	27%
Galleria, Post Oak/.Las Colinas	2%	1%	1%	3%	32%	3%	13%	17%	9%
Greenway Plaza/Market Center	0%	1%	1%	2	6%	4%	2%	6%	7%
Texas Medical Center/Park Central	2%	1%	1%	5%	6%	1%	3%	6%	3%
Other	0%	2%	9%	24%	14%	21%	69%	56%	54%
Trip Purpose									
% Work	99%	99%	88%	88%	95%	92%	91%	94%	92%
% School				8%	4%	5%	2%	2%	2%
Age, Years (50th Percentile)	38	38	37	38	39	41	42	42	42
Sex (% Male)	43%	49%	29%	48%	53%	45%	60%	57%	54%
Education, Years (50th Percentile)	15	15	14	15	15	14	15	14	14
Occupation									
Professional	61%	56%	42%	53%	57%	54%	48%	45%	46%
Managerial	13%	13%	6%	19%	18%	16%	18%	18%	15%
Clerical	19%	25%	29%	11%	13%	17%	11%	13%	13%
Sales	3%	4%	3%	2%	6%	4%	11%	11%	6%
Service	2%	1%	5%	3%	2%	5%	4%	4%	8%
Auto Available for Trip (% Yes)	95%	96%	69%						
Who Makes Up Carpool									
Family Members				64%	68%	68%			
Neighbors				6%	8%	8%			
Co-Workers				30%	32%	32%			
Does Carpool Stage at Park/Pool Lot (% Yes)				23%	19%	6%			

Source: Texas Transportation Institute data collection, see appendices

CHAPTER 3. HOV LANE PERFORMANCE MEASURES

The role of HOV lanes in the transportation network is important, but often misconstrued. More than anything else, HOV lanes are effective in moving people. While other objectives, such as reducing congestion or improving air quality, may be achieved through the application of an HOV lane, the evidence so far does not support those objectives as much as it does the objective of people movement. Many of the arguments against HOV lanes stem from unsupported expectations, rather than the failure of HOV lanes to perform.

Over the last few years, TTI has developed a set of working objectives for HOV lanes. These reflect realistic reasons why a community would want to consider an HOV lane in a corridor. Those **objectives** are directed at the following:

- moving people,
- benefitting transit, and
- improving overall roadway efficiency.

In addition to those objectives, the authors contend that there are some constraints that should be recognized in the planning and implementation of HOV lanes. If the HOV lane cannot be implemented without violating one of these constraints, then very close examination would be warranted prior to proceeding. Those **constraints** include:

- impacting mixed flow,
- projected cost-effectiveness,
- public acceptability, and
- environmental considerations.

Most of these objectives would or should apply to any HOV lane. The degree to which HOV lanes in Texas individually and collectively meet these objectives is documented in subsequent chapters. The following section introduces the objectives, constraints, and the measures applied.

Objective 1. Increase Roadway Person-Movement (Does the corridor move more people with the HOV lane than without it?)

Of all the objectives, this one should get a resounding "yes"; if not, an HOV lane is not the right improvement. Because it is so critical in determining the success of an HOV lane, several measures have been developed to address this objective. Among the measures analyzed in Chapter 4 are:

- person-movement characteristics of HOV lanes and general-purpose lanes,
- comparison of the percentage of persons moved versus the percentage of vehicles and the percentage of pavement used,
- increases in use of HOV lanes compared to overall increases in travel, and

- impact of HOV lanes on overall occupancy in the corridor.

Objective 2. Improve Bus Transit Operating Efficiency (Does it help transit?)

Although attracting carpools is crucial for public perception of HOV lane utilization, in most corridors the "bang for the buck" in person-movement comes from buses. Two measures of the benefit to transit are:

- impact of HOV lanes on bus operating speeds that results from the free flow, and
- impact on schedule adherence stemming from increased travel time reliability.

Chapter 5 describes in detail the findings of the research related to transit.

Objective 3. Improve Total Roadway Efficiency (Are HOV lanes an effective use of the available pavement/right-of-way?)

Another objective of the HOV lane is to improve the efficiency of the entire roadway (freeway + HOV lane). Such a measure should consider not only the volumes of people moved, but also the speed at which they move. In other words, moving 100 people at 55 mph is of more value than moving 100 people at 20 mph. The detailed analyses of the impact of the HOV lane on efficiency are shown in Chapter 6.

Constraint 1. No Impact on General-Purpose Lanes (Can HOV lanes be installed and operated without causing problems for other traffic?)

In the early years of HOV lane development in Texas, HOV lanes were "shoe-horned" into existing freeway medians. This practice usually led to the narrowing of existing general-purpose lanes and the elimination of shoulders. There was much concern that the safety and operational impacts of these changes would offset the benefits derived from the HOV lanes, so the general-purpose lanes were closely monitored.

More recently HOV lanes have been designed into the reconstruction of congested corridors, alleviating many of the original problems. However, there are still some locations where the merging of HOV lane and general-purpose lane traffic occurs. To assure that such interactions do not become a bottleneck, congestion levels, operating speeds, and accident rates on the general-purpose lanes adjacent to HOV lanes should be monitored on an ongoing basis. Chapter 7 shows the results of that monitoring.

Constraint 2. HOV Lanes Should be Cost-Effective (Are HOV lanes financially prudent? How do they compare with adding freeway lanes?)

Because resources will always be limited, all transportation improvements should be able to meet the test of financial prudence. Thus, HOV lanes should produce a favorable benefit/cost relationship. Further, they should compare favorably to other improvement alternatives, specifically additional general-purpose lanes. Chapter 8 analyzes these relationships for the HOV lanes in Texas. Some general conclusions about the factors that drive the B/C ratios are presented.

Constraint 3. Maintain Public Acceptance (Are HOV lanes understood and accepted by the public?)

The significance of public support is best reflected in the short life of the Santa Monica Diamond Lane in Los Angeles in the mid-1970s. Although this carpool lane was actually performing reasonably well for its newness, the public outcry that stemmed from gross misunderstanding resulted in the cancellation of that project and a decade-long hiatus from carpool lane experiments in California. More recently the I-80 and the I-287 HOV lanes in New Jersey have been "decommissioned" in large part because of public outrage over low usage. HOV lanes in Texas have been carefully and slowly introduced, with little or no public backlash. Detailed research on public acceptance of Texas HOV lanes is presented in Chapter 9. Specific public opinion surveys from users and non-users reinforce the claim of public support in Houston.

Constraint 4. HOV Lanes Should Have a Favorable or Neutral Impact on Air Quality and Fuel Consumption (Are HOV lanes good for the environment?)

HOV lanes should have a beneficial impact on the environment. Intuitively, increasing vehicle occupancy should be a good thing, resulting in fewer emissions and less fuel consumption. Both of those desirable outcomes may occur, but HOV lanes and associated traffic represent such a small portion of the overall travel demand, even during the peaks, that any savings are hard to isolate using currently available tools and computer models. Chapter 10 provides some additional insight into the possibilities.

HOV lane critics contend that carpools meeting at a designated point result in more than one engine start, warm-up, and cool down, thus producing much of the same emissions as if all had traveled as single occupant vehicles (SOVs). At this time there is very little documentation of the emissions implications of HOV lanes. There are numerous competing arguments, all with at least surface validity. In the grand scheme of air quality, HOV lanes may play a very limited role, but their fundamental contribution, increasing vehicular occupancy, should be a counterbalance to limited or even slightly negative air quality impacts.

CHAPTER 4. PERSON-MOVEMENT

The primary reason for implementing HOV lanes is to improve the capability of a congested freeway corridor to move more people by increasing the average number of persons per vehicle. There is growing recognition of the importance of transportation improvements that focus on moving people rather than vehicles, and HOV lanes can be a means of achieving this goal. This section of the report presents data that address the impact of HOV facilities on person-movement.

Mature HOV lanes in Houston have experienced tremendous growth in peak-period person-movement since their inception, with increases in ridership from 150 percent to 400 percent. The newer HOV lanes have experienced growth in ridership as well, ranging from 20 percent to 70 percent. The growth in person-movement on each HOV lane is depicted graphically in the appendices.

To evaluate the effectiveness of HOV lanes in terms of person-movement, three specific measures can be examined (*1*):

- the impact of the HOV lane on person-movement efficiency,
- the impact of the HOV lane on average vehicle occupancy, and
- the impact of the HOV lane on carpooling and bus ridership.

IMPACT ON PERSON-MOVEMENT EFFICIENCY

Evaluation of an HOV lane in terms of person-movement efficiency can be based on how well an HOV lane moves people in comparison with a general-purpose lane. Figure 6 illustrates peak-hour characteristics of Texas HOV lanes in persons moved per lane. The HOV lanes in both Houston and Dallas move a greater volume of persons per lane than the freeway lanes, carrying from 10 percent to 120 percent more persons per lane than the freeway lanes.

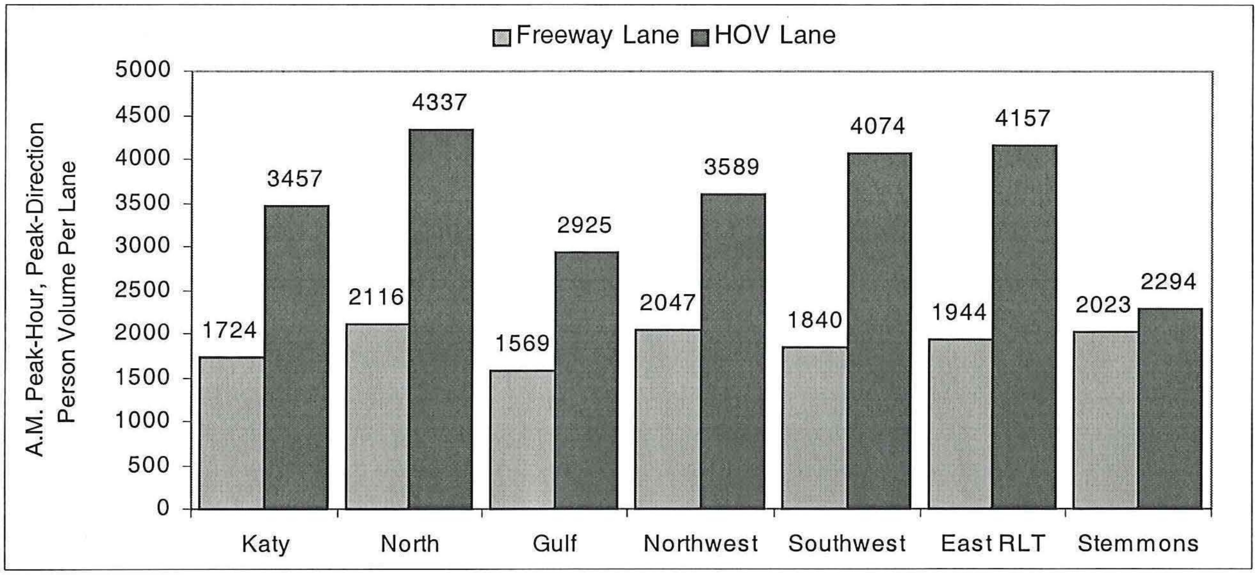


Figure 6. Person-Movement per Lane, on Freeways and HOV Lanes
Source: Texas Transportation Institute data collection, see appendices

Within freeway corridors in Texas that include HOV lanes, the HOV lane represents only one of several total directional lanes. Texas HOV lanes operate in conjunction with three to five general purpose lanes each direction. Yet the HOV lanes carry a higher proportion of peak-hour person-movement per lane, as illustrated in Figure 6. Furthermore, the vehicular volume in the HOV lane is relatively low. Comparing the two together demonstrates that for HOV lanes in Texas, a relatively high amount of person-movement is achieved at a relatively low vehicle volume.

Using the Katy HOV lane as an example, Figure 7 shows that while the HOV lane represents 25 precent of the total directional capacity (three-general purpose lanes plus an HOV lane), it carries 40 percent of the peak-period persons moved. Furthermore, 40 percent of the people are carried in only 15% of the peak-hour vehicles on all lanes combined.

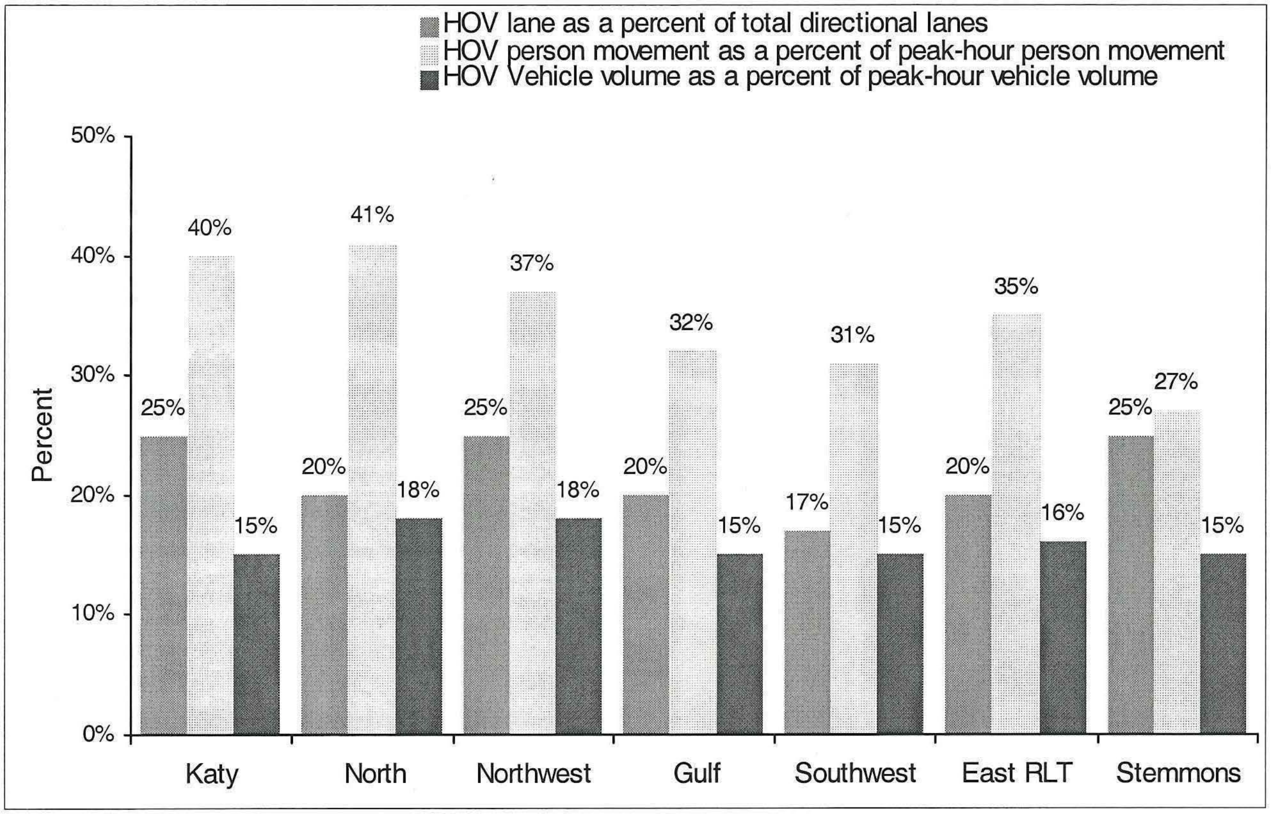


Figure 7. Percent of Peak-Hour Vehicles and Persons Moved on the HOV Lane
Source: Texas Transportation Institute data collection, see appendices

IMPACT ON OVERALL VEHICLE OCCUPANCY

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

On the freeways with the two more mature Houston HOV lanes (Katy and North), peak-hour average vehicle occupancies are unusually high, at an average of 1.49 persons per vehicle (Figure 8). All of the Texas freeway facilities with HOV lanes that are included in this study are experiencing average occupancies higher than the national average of 1.09 for commuting trips (*2*). These occupancies are the combined average of all freeway lanes plus all HOV facility traffic.

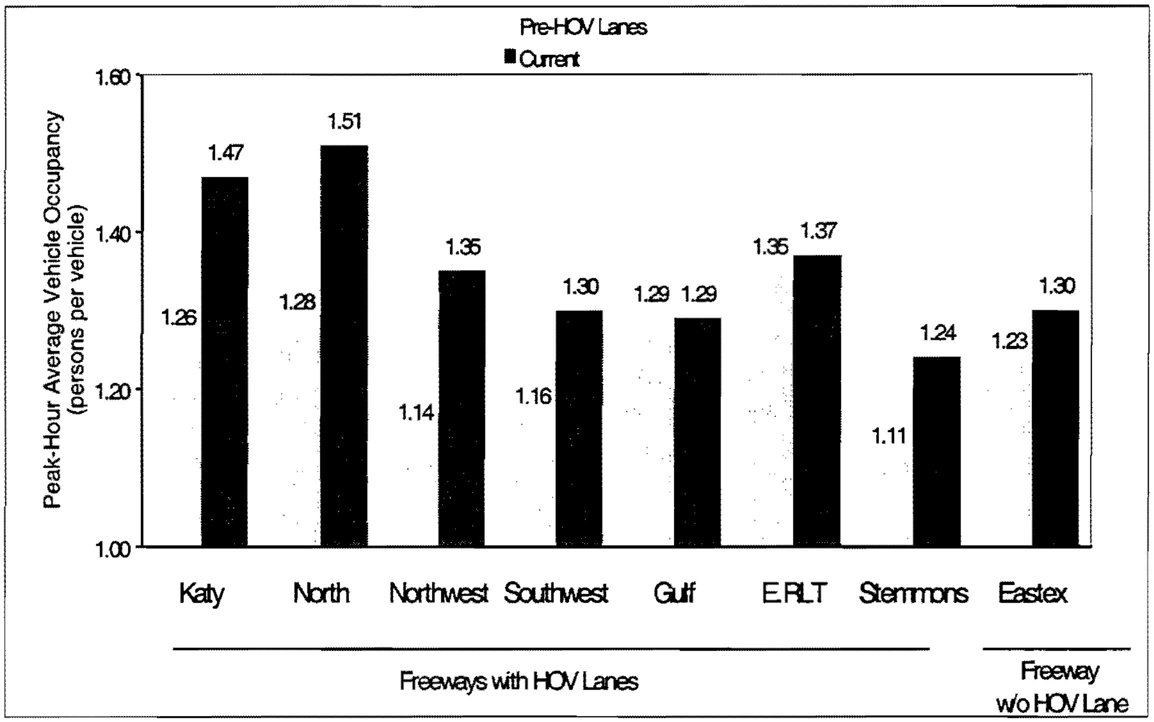


Figure 8. Changes in Peak-Hour Average Vehicle Occupancy (Combined Freeway and HOV Lane Data)

While four HOV facilities have resulted in significant increases in average vehicle occupancy (Figure 9), two, the Gulf HOV lane in Houston and the East RLT in Dallas, have not. This can be attributed to characteristics or conditions unique to these two facilities, particularly with respect to ongoing freeway and HOV lane construction work. The Gulf freeway has experienced continuous construction activity that has repeatedly modified the HOV lane terminus, preventing stable operating conditions. Since operations have stabilized, there has been a gradual growth in vehicle occupancy of 2 percent per year.

Similarly, the E. RLT HOV lane was operationally impacted by a three-year, 0.75 mi project that involved replacement of a bridge structure; the HOV lane itself has only been operational for a total of five years. In addition, the E. RLT previously experienced relatively high levels of bus ridership and carpooling and higher overall vehicle occupancy prior to the implementation of the HOV lane. It is not surprising that occupancy has increased only slightly on this facility. Both HOV lanes, therefore, possess unique characteristics, including the lack of stable operating conditions, which affect the ability of the facilities to meet the increased vehicle occupancy measure.

The data clearly show that the presence of the HOV lane has resulted in a meaningful increase in average vehicle occupancy over time, under stable operating conditions. On the freeways with HOV lanes, in comparison to pre-HOV lane conditions, the average peak-hour, peak-direction vehicle occupancy has increased by an average of 11 percent. Over the same time period, occupancy on a freeway without an HOV lane, the Eastex corridor declined 10 percent to a value of 1.13 in 1994 before rising to its current level of 1.30. This particular corridor has increasing bus ridership levels that account for the rise in overall vehicle occupany.

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

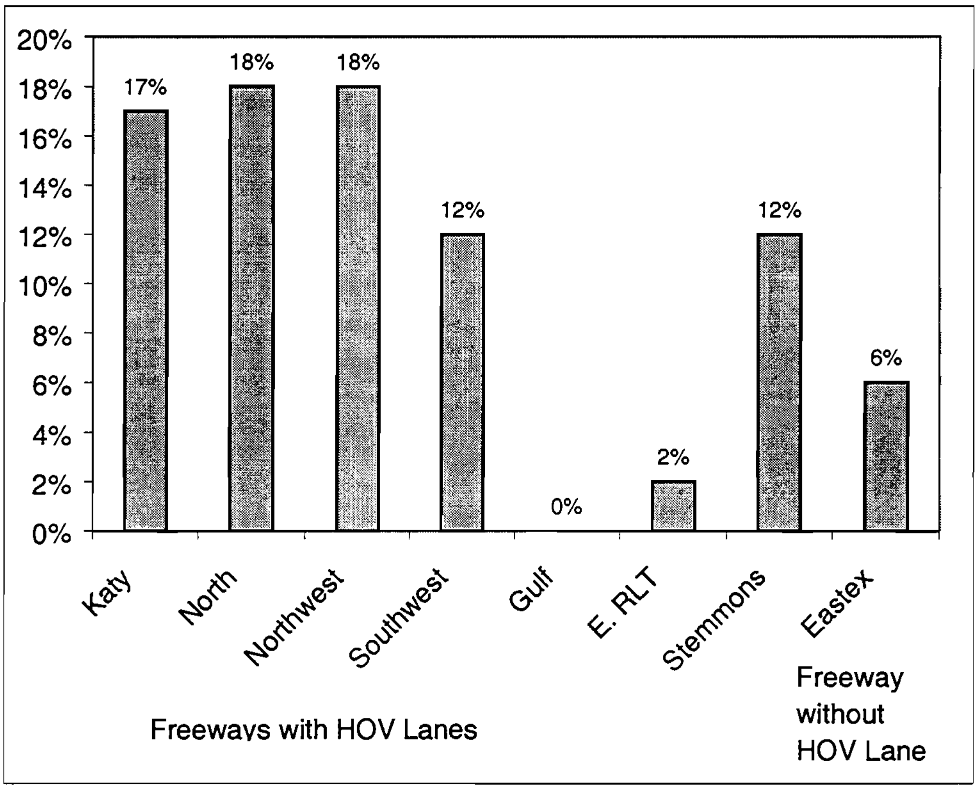


Figure 9. Increase in Peak-Hour Average Vehicle Occupancy

CARPOOLING AND BUS TRANSIT

If HOV lanes are to move significantly more people, then the HOV lane must contribute to an increase in the number and proportion of high-occupancy vehicles. If the additional person-movement measured in the previous section were due simply to a reshuffling of existing carpool and bus passengers, then no real improvement in person-movement has occurred. This section recaps the research into the question of whether the HOV lanes have had a real net impact on person-movement. Carpooling is addressed in the first section, followed by HOV lane impact on bus ridership.

Changes in Carpooling

There have been significant increases in carpool volumes since carpools were allowed to use the HOV facilities (Figure 10). Increases of more than 100 percent are typical. To evaluate the person-movement effectiveness of the HOV lanes, it is necessary to develop estimates of how many of the carpools using the HOV lanes are new carpools formed largely due to the implementation of these priority lanes.

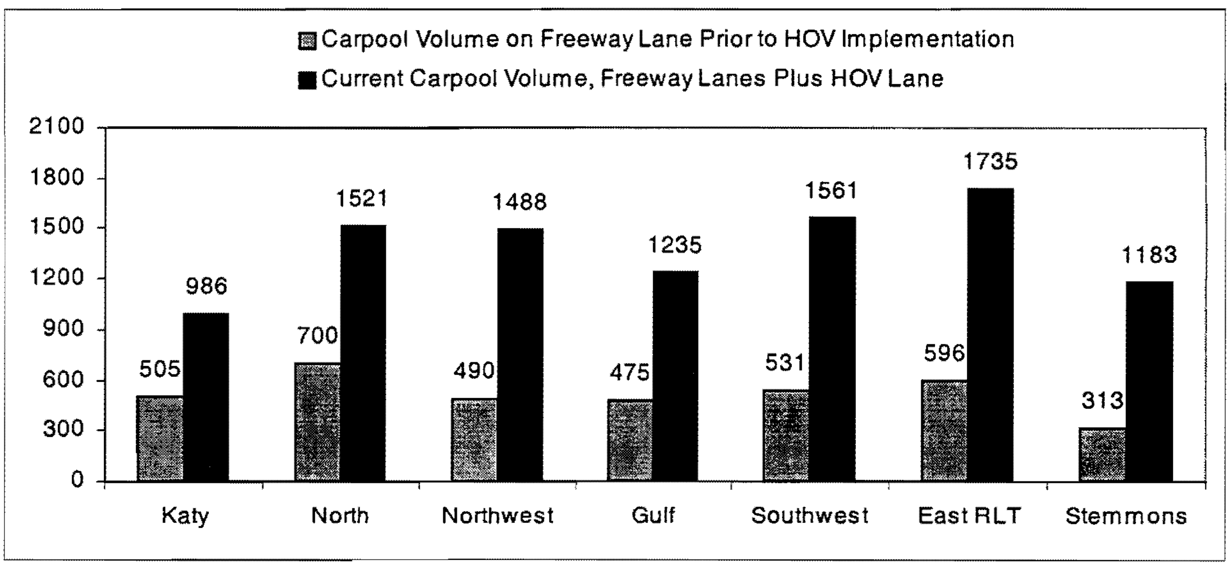


Figure 10. Change in 2+ Carpool Volumes, Absolute Data
Source: Texas Transportation Institute data collection, see appendices.

The impact of HOV lanes on carpooling can be examined in several ways:

- What was the previous mode of current carpoolers?
- Have the carpools on the HOV lane simply diverted from parallel routes?
- Has carpool duration (age) increased for new carpools on the HOV lanes?
- Has carpool formation in the corridors with HOV lanes differed from the control corridors (no HOV lane)?

♦ *If an HOV lane is presumed to have an effect on creating carpools, then the new carpools cannot simply be established carpools diverted from parallel routes.*

According to survey data, only a few of the carpools in the HOV lane were previously in existence on other routes (Table 5)(*3*). This indicates that increases in average vehicle occupancy were primarily from factors other than this diversion.

Table 5. Carpools that Diverted to the HOV Facility from Parallel Routes

HOV Facility, including Years of Operation with Carpools Allowed	Percent of HOV Carpoolers Whose Previous Mode Was Carpooling[1]		Percent of Those Carpoolers Who Previously Used a Parallel Route[2]		Percent of Total Carpools Using HOV Lane that Diverted from Parallel Routes	
	1990	1994	1990	1994	1990	1994
Katy - 11 years	29%	19%	13%	11%	4%	2%
North - 6 years	40%	---	19%	---	8%	--
Northwest - 8 years	33%	22%	15%	9%	5%	2%
East RLT - 5 years	---	51%	---	19%	--	9%
Unweighted Average	34%	31%	16%	13%	6%	4%

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

- *If carpools are created to take advantage of an HOV lane, it is reasonable to assume those carpools would remain in existence longer than would carpools in corridors not having HOV facilities.*

The estimate of new carpools is complicated in that carpools naturally have relatively high turnover rates. Just to keep the carpool volumes constant, many new carpools need to be formed to replace those that discontinue. Available data suggest that carpools in corridors with HOV lanes do remain in existence substantially longer than carpools in corridors without HOV lanes (Figure 11). The median age of a carpool on an HOV facility varies from over two to seven times greater than the median carpool age on a non-HOV facility. It appears that the presence of an HOV lane is causing carpools to remain in existence longer.

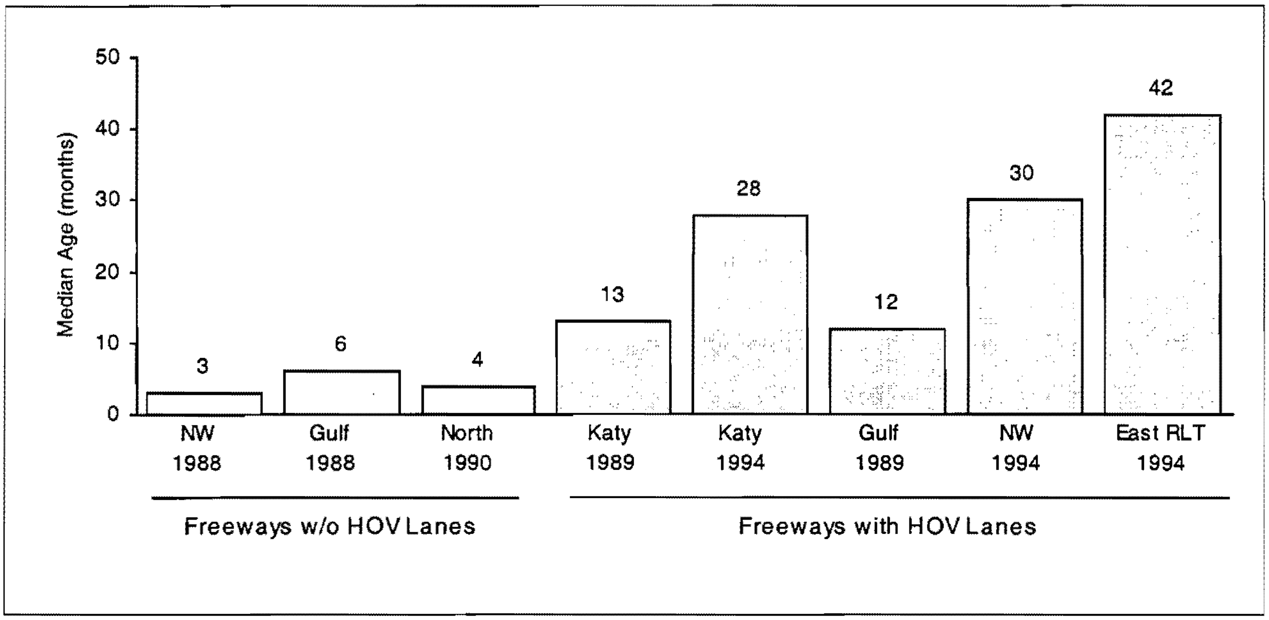


Figure 11. Age of Carpools
Source: Texas Transportation Institute data collection, see appendices.

♦ *The impacts of HOV facilities on creating carpools can be isolated by comparing the change in carpool volumes over time between corridors with and without HOV lanes.*

Comparing what has occurred on freeways with HOV lanes to what has taken place over the same time period on freeways without HOV lanes helps to isolate the impacts of the HOV facilities (Figure 12). The magnitude of increase that has occurred on the freeways with HOV lanes simply has not taken place in the corridor without an HOV lane. Since the major difference in the corridors being compared is the availability of an HOV lane, one reasonable conclusion would be that the priority lane is a significant factor in creating new carpools.

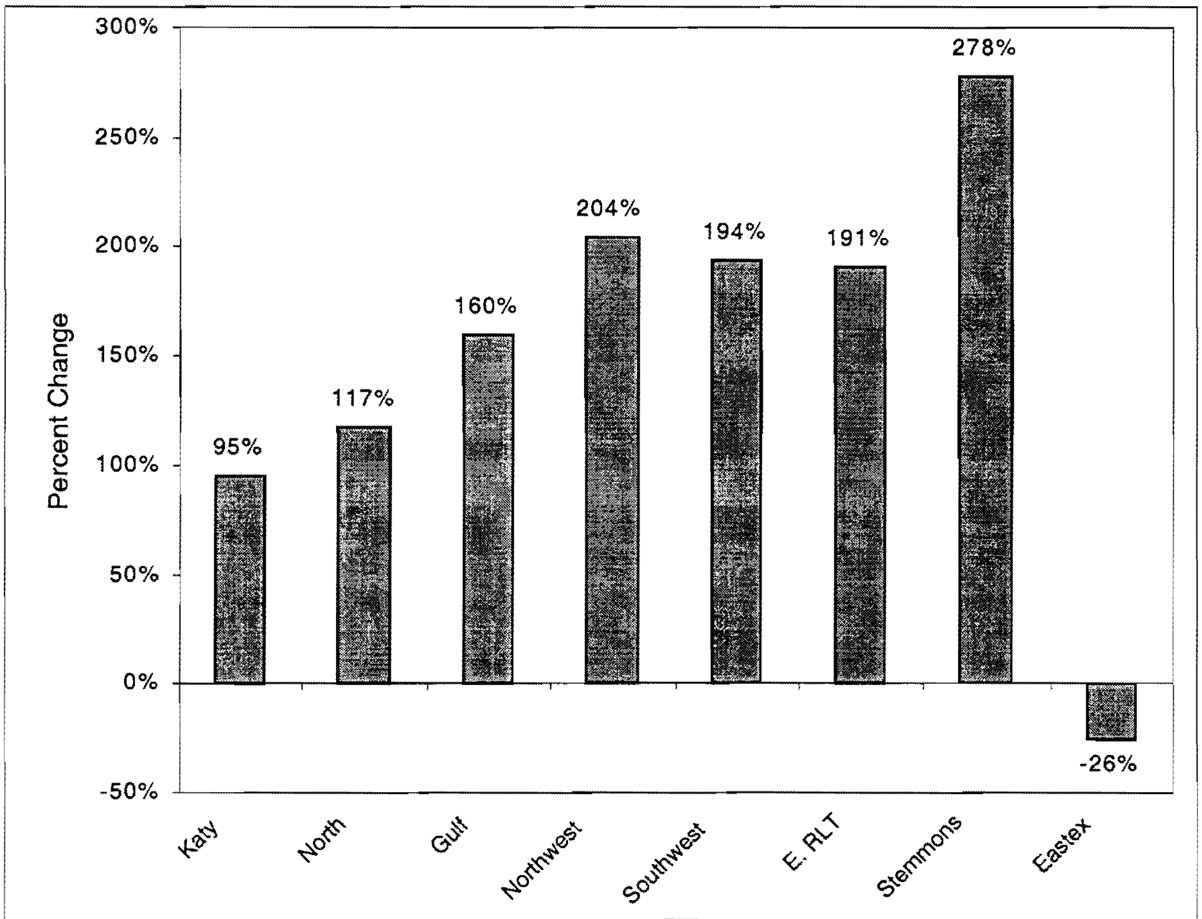


Figure 12. Percent Change (pre-HOV) Lane to Present in 2+ Carpool Volumes, A.M. Peak-Hour, Peak-Direction, Freeway CarpoolVolumes Plus HOV Lane Carpool Volume
Source: Texas Transportation Institute data collection, see appendices.

♦ *The previous mode of carpoolers is an indication of the impact of the HOV lane on creating carpools.*

One indicator of HOV lane impact on carpooling is the "previous mode" of travel for carpoolers; that is, how a trip was made prior to carpooling on the HOV lane (Figure 13). Those data indicate that somewhere between 35 percent and 66 percent of carpoolers on HOV lanes were previously in "drive alone" vehicles. It is important to note that over half of the carpoolers on East RLT were carpoolers before the HOV lane operation began.

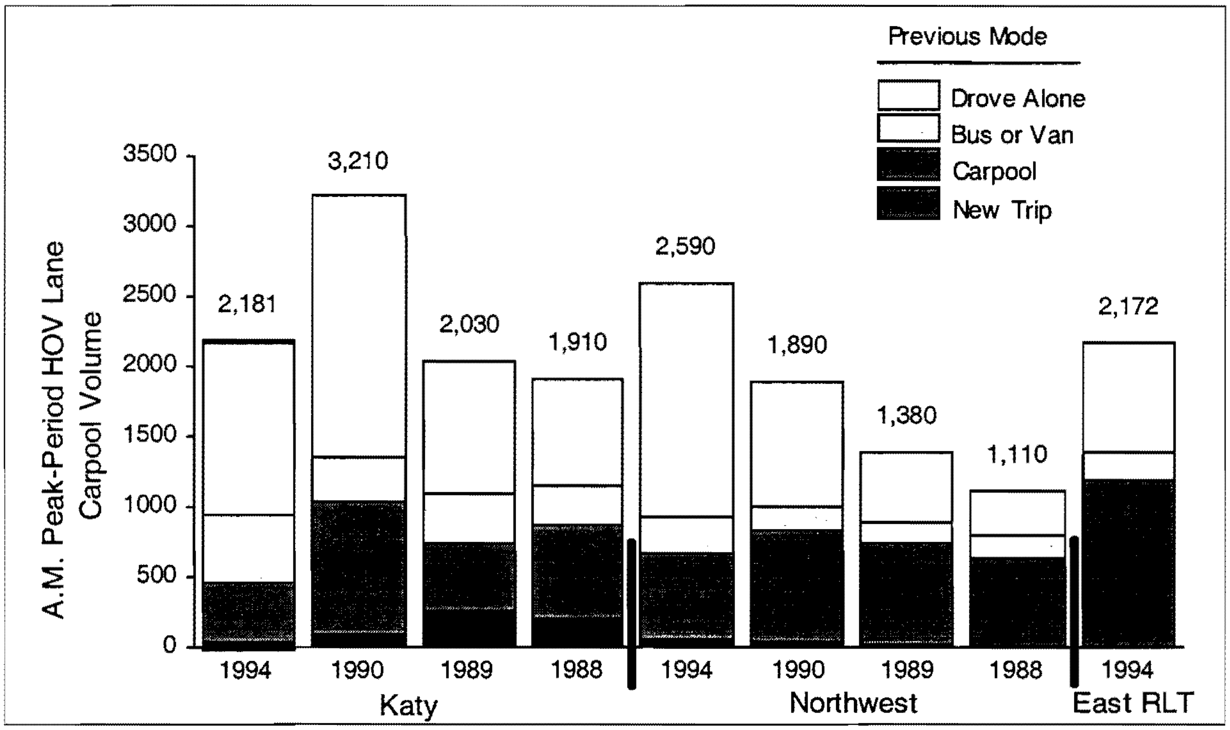


Figure 13. Previous Mode of Travel for HOV Lane Carpoolers
Source: Texas Transportation Institute data collection, see appendices.

The sum of "drive alone" plus "new trips," can be considered an initial indication of the volume of new carpools created as a result of the HOV lane. However, at least some of those with a previous mode of "drive alone" would, in all likelihood, have formed carpools regardless of whether an HOV lane was present. To try to identify this portion of carpool demand, researchers surveyed carpoolers using the HOV lanes to assess the importance of the HOV lane in their decision to carpool.

The question asked was, "How important was the HOV lane in your decision to carpool?" The responses (Figure 14) suggest that the HOV lane was "somewhat important" or "very important" in the decision to carpool to approximately 80 percent of the HOV carpoolers surveyed in 1994.

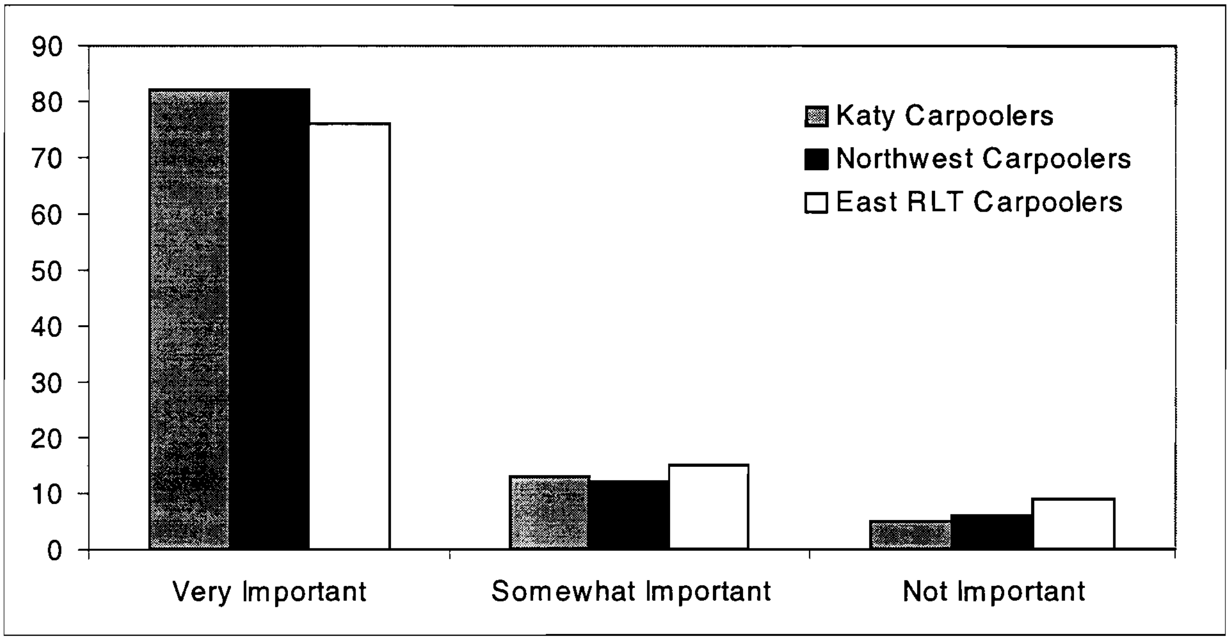


Figure 14. Responses to the Question, "How Important Was the HOV Lane in Your Decision to Carpool?"

Source: Texas Transportation Institute Surveys, 1994

A second question asked carpoolers if they would be carpooling in the absence of the HOV lane (Figure 15). Over half of the respondents to the 1994 surveys in Houston indicated that they would either not carpool or were not sure they would carpool if there were no HOV lanes.

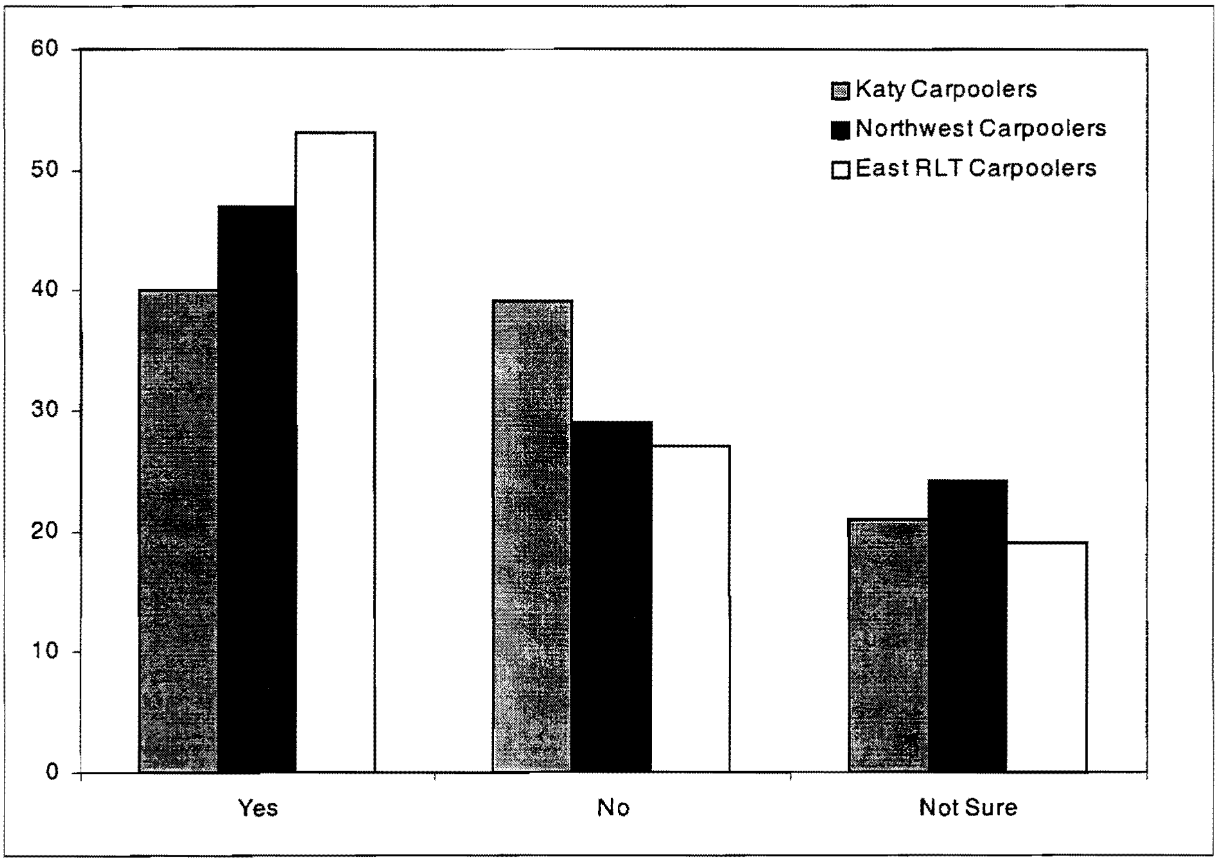


Figure 15. Responses to the Question, "If the HOV Lane Had Not Opened to Carpools, Would You Be Carpooling Now?"
Source: Texas Transportation Institute Surveys, 1994

Conclusions Regarding the Impact of HOV Lanes on Carpooling

Implementation of the HOV lanes appears to have lengthened the median life of a carpool and increased the volume of carpools. The increase in carpooling experienced on freeways with HOV facilities simply has not taken place on freeways that do not have HOV facilities. The surveys indicate that the HOV lane is an important factor in the decision to carpool. It appears that, on the HOV lanes that did not previously experience a significant carpool volume, 40 percent to 50 percent of the current HOV carpoolers formed a carpool as a result of the HOV facility (Table 6).

Table 6. Estimated Impact of HOV Lanes in Forming New Carpools

HOV Facility	Apparent Percent of New Carpools Based on Previous Mode[1]	Would You Carpool If There Were No HOV Lane			Estimated Percent of 1994 HOV Lane Carpools Formed Due to HOV Lane[2]
		Yes	No	Not Sure	
	1994	1994	1994	1994	
Katy	61%	40%	39%	21%	50%
Northwest	67%	47%	29%	23%	42%
E. RLT	35%	73%	14%	13%	21%
Unweighted Average	54%	53%	--	--	38%

[1]The sum of "drove alone" and "new trips."

[2]It is assumed that the sum of "no" responses plus one-half of the "not sure" responses equals the percentage of total HOV lane carpools that were formed due to implementing the HOV lane.

Source: Texas Transportation Institute surveys.

CHANGES IN BUS RIDERSHIP

Young, educated, professional Texans are riding buses on the high-occupancy vehicle lanes. This section of the report presents data describing HOV impacts on bus transit, another component that contributes to the increase in vehicle occupancy and total person-movement. In the previous section, it was determined that the HOV lanes have been responsible for creating a significant volume of new carpools. The available data suggest that these priority lanes have also caused increases in bus ridership.

With the opening of the HOV lanes, increases in bus ridership have been realized (Figure 16). In the North Freeway corridor, there was essentially no bus service prior to the opening of the contraflow lane in 1979. With the exception of the Gulf and E. RLT, which have experienced some limiting factors described in the previous section of this chapter, it appears that the HOV lanes have had an impact on generating transit ridership increases. It should be noted that the E. RLT already had a relatively high transit ridership prior to the HOV lane, particularly in comparison with total ridership now occurring on a number of the other HOV lanes. Also notable is the growth in transit ridership in the Gulf corridor in just one year. Peak-hour transit ridership is up 5 percent, indicating that conditions have stabilized since the completion of construction, and that HOV use is showing signs of growth. A 145 percent increase in bus vehicle trips contributed to the overall HOV lane ridership growth.

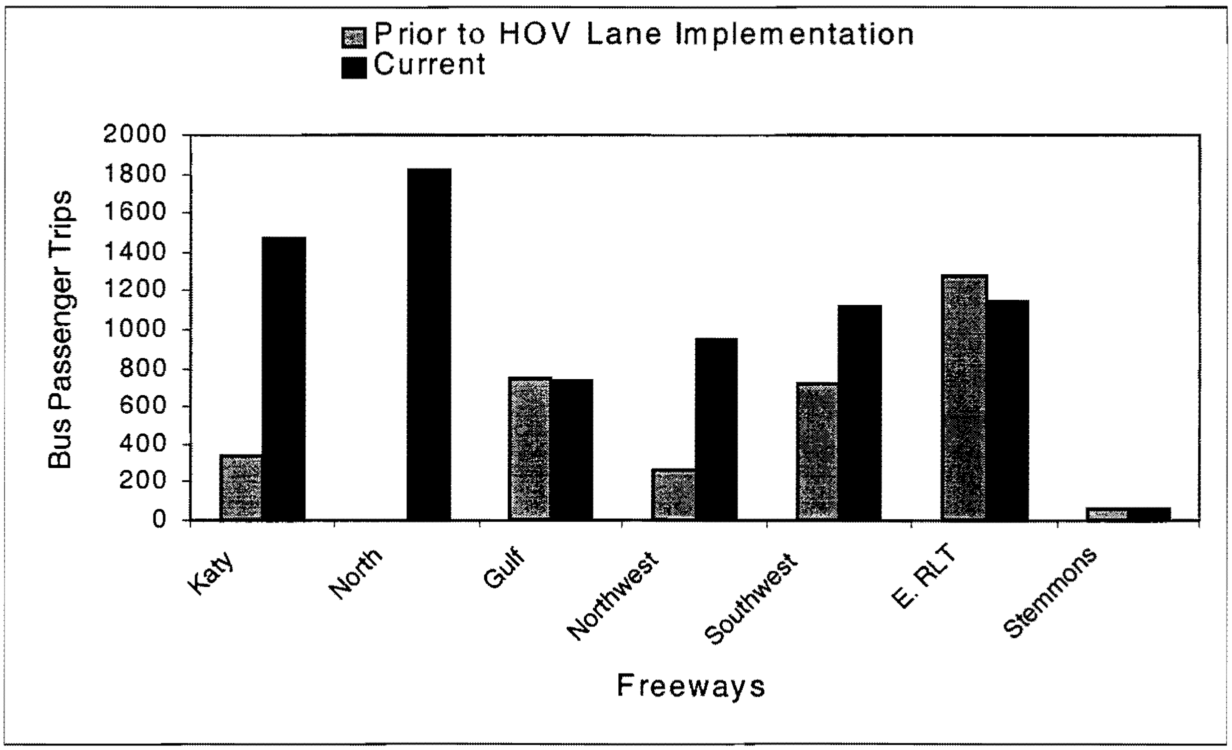


Figure 16. Number of Bus Riders, A.M. Peak-Hour, Peak Direction, Pre-HOV and Current

Source: Texas Transportation Institute data collection, see appendices.

♦ *The impacts of HOV facilities on increasing bus ridership can be isolated by comparing the change in ridership between corridors with and without HOV lanes.*

Bus ridership has increased more rapidly in four of the seven corridors analyzed. As of this writing, there has been no increase in bus service to take advantage of the HOV lane on Stemmons. Although the facility has only been operating a little more than a year, the bus ridership on East RLT was high before the HOV lane was added so there has been no increase over time. The Gulf HOV lane has returned to normal service and has experienced significant growth in bus ridership. Again, these data appear to confirm that the HOV lane has been a factor in increasing bus ridership.

♦ *The previous mode of bus riders is an indication of the impact of the HOV lane on increasing bus ridership.*

An examination of the previous mode of travel for HOV bus riders provides an indication that the HOV lanes have created new bus riders (Figure 17). These data suggest that fewer than 5 percent of existing HOV lane bus riders on the Katy and Northwest rode a bus prior to using the HOV lane, with over one-third of the bus riders previously driving alone. In Dallas, over one-half of the current bus riders rode the bus prior to the HOV lane, with 25 percent previously driving alone.

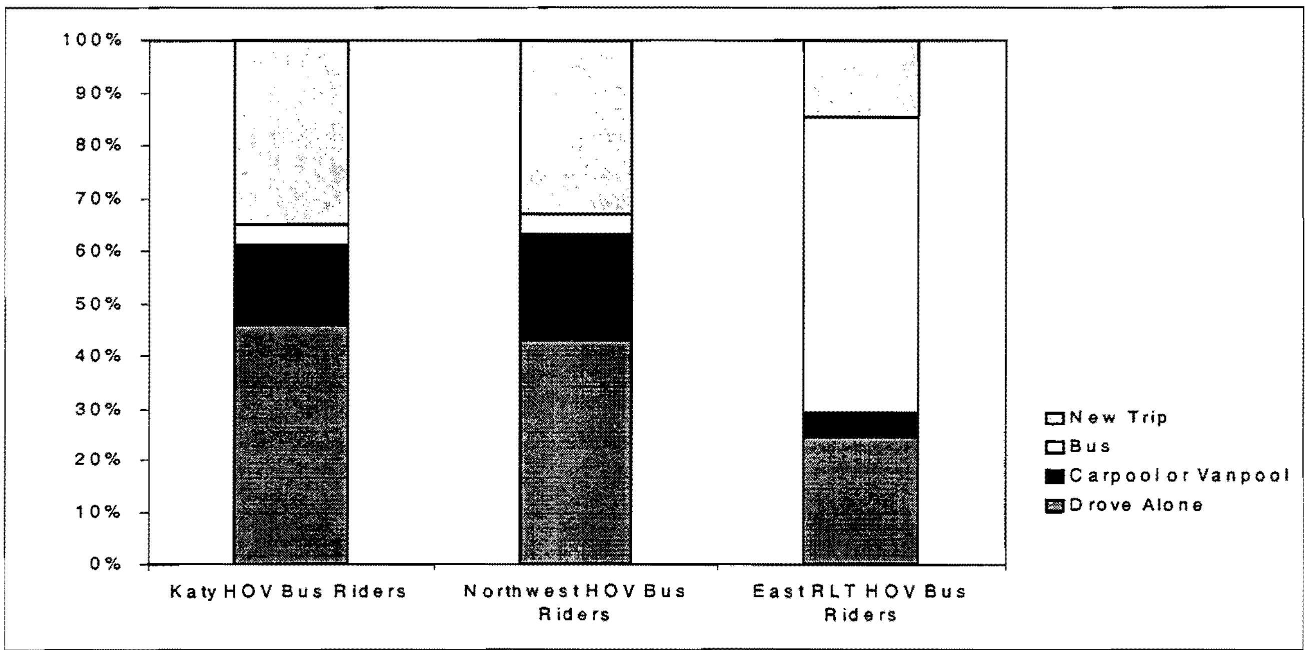


Figure 17. Responses to the Question, "Prior to Riding the Bus, How Did You Normally Make This Trip?"

Source: Texas Transportation Institute Surveys, 1994

Researchers have surveyed the HOV lane bus riders on numerous occasions to help determine the importance of the HOV lane in their decision to ride a bus. The data suggest that the availability of an HOV lane has been a very important consideration in deciding to ride a bus (Figure 18).

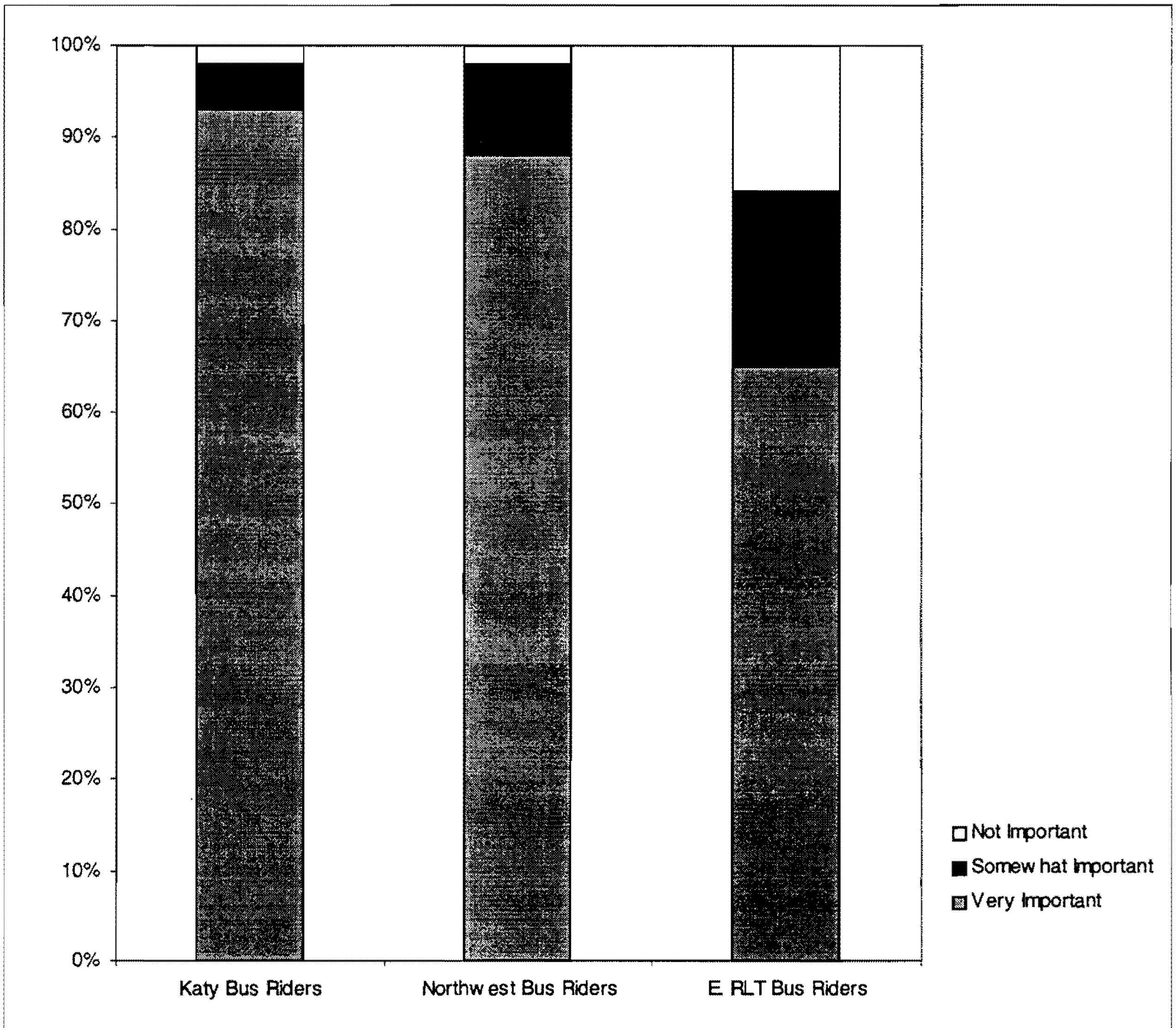


Figure 18. Responses to the Question, "How Important Was the HOV Lane in Your Decision to Ride the Bus?"
Source: Texas Transportation Institute Surveys, 1994

A second question asked of bus riders was whether they would be riding a bus in the absence of the HOV lane. The data for the Houston facilities suggest that 35 percent to 50 percent of total bus ridership would not be riding the bus if there were no HOV facility. Interestingly, 65 percent of the E. RLT bus riders claim the HOV lane is a very important consideration in their decision to ride the bus, yet 74 percent say they would ride the bus even if the HOV lane was not available.

Observations Regarding the Impact of HOV Lanes on Bus Ridership

Implementation of the HOV lanes appears to have increased bus transit ridership. The surveys indicate that the HOV lane is an important factor in the decision to ride the bus. It appears that on the HOV lanes surveyed that did not already experience high transit ridership, approximately 60 percent of the current riders are on buses as a result of the HOV facility (Table 7).

Table 7. Estimated Impact of HOV Lanes on Bus Ridership

HOV Facility	Apparent Percent of New Bus Passenger Trips Based on Previous Mode[1]	If the HOV lane had not opened, would you be riding the bus now?			Estimated Percent of Bus Ridership Due to HOV Lane[2]
		Yes	No	Not Sure	
	1994	1994	1994	1994	
Katy	81%	18%	50%	32%	66%
Northwest	76%	26%	35%	39%	55%
E. RLT	39%	74%	9%	17%	17%
Unweighted Average	65%	39%	31%	29%	46%

[1]The sum of "drove alone" and "new trips."
[2]It is assumed that the sum of "no" responses plus one-half of the "not sure" responses equals the percentage of total HOV lane carpools that were formed due to implementing the HOV lane.
Source: Texas Transportation Institute surveys.

CONCLUSIONS

Based on the data presented, HOV lanes can be considered effective in meeting the objective of increasing person-movement in a corridor. The following observations can also be made:

- HOV lanes have a greater positive impact than a general-purpose lane on person-movement efficiency in a corridor by carrying more persons per directional lane with fewer vehicles.
- All freeways with HOV lanes that were reviewed in this study have higher average vehicle occupancies than the national average, and those HOV lanes that have operated in a stable environment over time have experienced increases in average vehicle occupancy of 10 percent or more.
- An HOV lane has the potential to increase carpooling by up to 50 percent in corridors where carpools are not a predominant mode prior to HOV lane implementation.
- The presence of an HOV lane has the potential to increase bus ridership by as much as 60 percent in corridors where transit is not a predominant mode before HOV lane implementation.

CHAPTER 5. IMPROVE BUS TRANSIT OPERATING EFFICIENCY

A major reason for implementing HOV lanes is to enhance bus operations. The high-occupancy vehicle lanes offer higher travel speeds and more reliable trip times. As shown in the previous chapter, substantial increases in bus ridership have resulted from the implementation of HOV lanes. This chapter describes the impacts that HOV lanes have had on bus operations.

ENHANCEMENT OF BUS SERVICE

Compared to conditions that existed prior to HOV lane implementation, average bus operating speeds have increased dramatically (Table 8). On average, peak-hour bus operating speeds have nearly doubled, increasing from 26 mph to 51 mph. Also, as shown previously in this report and also documented elsewhere, based on a comparison of standard deviations, travel times in the HOV lanes are much more reliable and consistent than are travel times on the freeway mainlanes (*4*).

Table 8. Average A.M. Peak-Hour Bus Operating Speeds, Before HOV Implementation and Current

Freeway	Bus Operating Speed (mph)		
	Before HOV	Current	Percent Increase
Katy	23	60	161%
North	-	49	145%
Gulf	31	52	68%
Northwest	29	53	83%
Southwest	29	36	24%
East RLT	21	56	165%
Stemmons	42	53	126%
Unweighted Average	26	51	196%

Source: See data in appendices.

Figure 19 provides an indication of the impacts that the HOV lanes can have on bus schedules during the peak hour. Due to the increase in bus operating speeds, schedule times have been cut significantly. This improvement in bus operations makes bus travel substantially more attractive. That attraction is reflected in the increased ridership compared to pre-HOV conditions, illustrated in Figure 20.

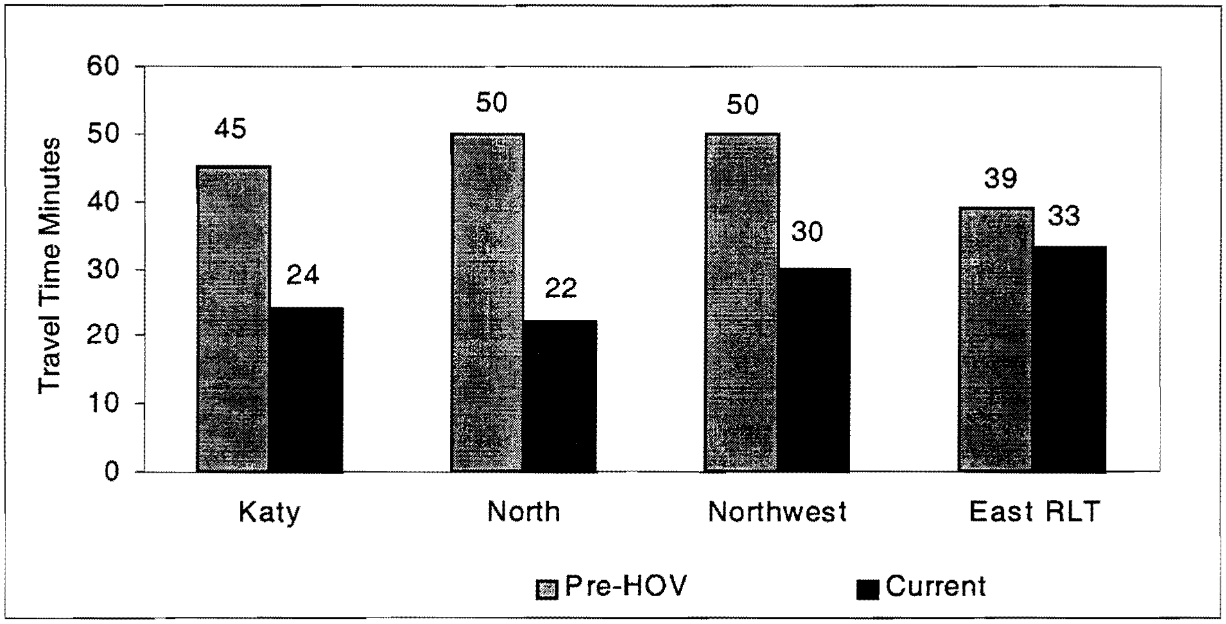


Figure 19. Bus Schedule Time, A.M. Peak
Source: Houston Metropolitan Transit Authority and Dallas Area Rapid Transit

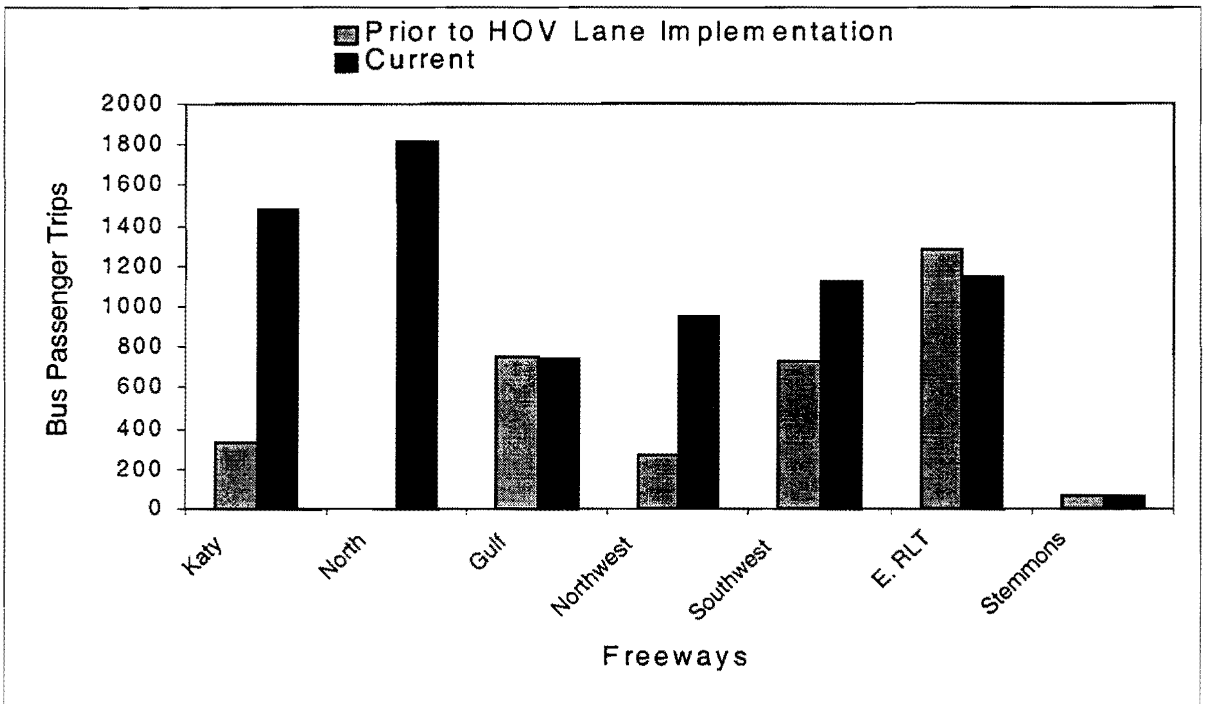


Figure 20. Number of Bus Riders, A.M. Peak-Hour, Peak-Direction, Pre-HOV and Current
Source: Texas Transportation Institute data collection, see appendices.

IMPACT ON COSTS TO TRANSIT

Previous research has shown that even minor improvements related to bus use of HOV lanes can have significant impact on operating expenses (*5*). Analysis of 1990 bus operating costs for Houston METRO showed that the extension of one HOV lane, the re-opening of a section of another, and the improvement of a connector ramp saved the transit authority more than $300,000 annually. That analysis also showed that the presence of the HOV lanes reduced the revenue bus-hours required to provide the service by over $31,000. For commuter bus service in 1990, the average Metro cost was $152 per revenue hour. Thus, the HOV time savings effectively reduced Metro's 1990 bus operating costs by approximately $4.8 million.

CHAPTER 6. IMPROVE TOTAL ROADWAY EFFICIENCY

The HOV facilities are intended to move substantial volumes of commuters at relatively high speeds. As such, successful HOV lane implementation should improve the overall efficiency of a freeway. For purposes of this study, the lane efficiency of the freeway is expressed according to a formula developed by Courage et al. (*6*):

per lane efficiency = (person volume per lane x speed) / 1000.

In all cases for which data are available, the implementation of the HOV lane has increased the number of persons moved on the roadway and thus increased the overall efficiency of the facility (Table 9). It appears that on a facility with a mature HOV lane the priority lane should increase the per lane efficiency by an absolute value of at least 20; an increase of 20 represents 1000 people going 20 mph faster (1000 x 20 / 1000), or 2000 people going 10 mph faster (2000 x 10 / 1000). This level of increase has been observed on the North, Katy, Northwest, and East RLT HOV lanes. By comparison, the control freeways that do not have an HOV lane have varied over the years. (current values in Figure 21).

Table 9. Estimated Change in A.M. Peak-Hour, Peak-Direction per Lane Efficiency[1], "Before" and "After" HOV Lane Implementation

Freeway	Pre-HOV Lane Per Lane Freeway Efficiency (1)	Current Per Lane Efficiency			Absolute Increase in Per Lane Efficiency Due to HOV Lane[2] (5)	Percent Increase in Per Lane Efficiency Due to HOV Lane
		Freeway (2)	HOV Lane (3)	Combined Freeway & HOV Lane (4)		
North	-	51	213	83	42	102%
Katy	-	43	207	84	46	121%
Northwest	-	63	190	95	33	53%
Gulf	66	45	152	67	1	2%
Southwest	56	61	142	75	19	34%
East RLT	41	58	233	93	52	127%
Stemmons	53	47	126	67	14	26%
Control Facilities Eastex[3] (w/o HOV, Houston)	86	81	NA	81	-5	-6%
South RLT[4] (w/o HOV, Dallas)	67	74	NA	74	7	10%

NA - Not applicable.
[1]Peak-hour per lane efficiency is defined as the person volume per lane times the average speed divided by 1000. Thus, it is a measure both of the person volume moved and the speed at which that volume is moved.
[2]Calculated as follows: Column (4) minus Column (1).
[3]For comparison, this is a freeway without an HOV lane. The pre-HOV value is the average of conditions on the Eastex Freeway prior to implementation of the Katy, Northwest, and Gulf HOV lanes.
[4]For comparison to East RLT, this is a freeway without an HOV lane in Dallas.

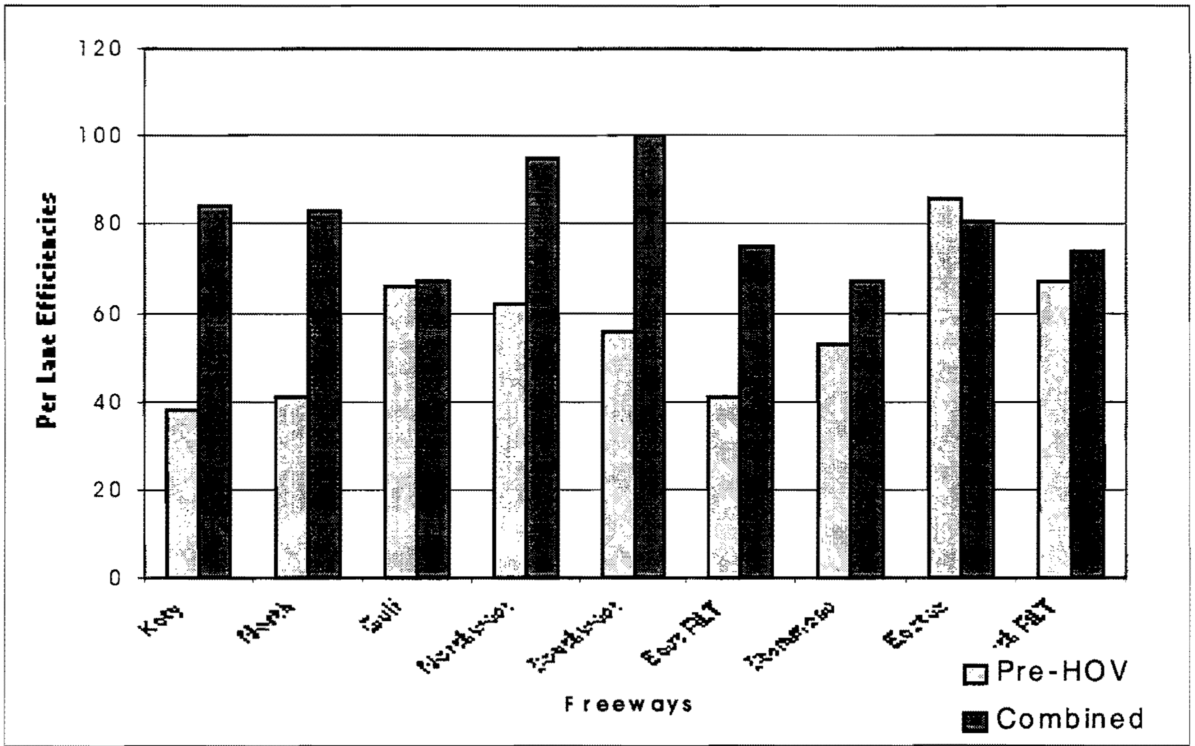


Figure 21. Changes in Per Lane Efficiencies

CHAPTER 7. IMPACT ON FREEWAY GENERAL-PURPOSE LANES

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

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

Available data suggest that the implementation of high-occupancy vehicle lanes of designs similar to those in operation in Houston and Dallas does not greatly affect the operation of the freeway general-purpose lanes. Table 10 shows selected operational characteristics of the seven freeways with operating HOV lanes. Freeway volumes have, on average, increased by more than 6 percent in HOV lane corridors. While speeds on some freeways have actually increased since HOV lane implementation, this is largely attributable to factors other than the HOV lane, such as bottleneck removal.

Implementation of some of the HOV lanes has involved narrowing traffic lanes and inside shoulders. As a result, potential crash impacts have been a concern. Table 10 presents the relevant crash data. Post-implementation crash rates are slightly higher on the East RLT general-purpose lanes, but consistently lower on Houston freeways. The unweighted average crash rate for the five barrier-separated HOV lanes has declined 20 percent (from 22 to 19 per 100 million vehicle-miles [MVM]). It appears that HOV lane implementation has not significantly impacted freeway crash rates. The increase on the East R.L. Thornton adjacent to the contraflow lane does not appear to be related to the presence of the HOV lane.

Table 10. Freeway General-Purpose Lane Operation, Prior to HOV and Current

Freeway General-Purpose Lane Data	HOV Facility or Freeway													
	Katy		North		Gulf		Northwest		Southwest		East RLT		Stemmons	
	Pre-HOV	Current	Pre-HOV	Current	Pre-HOV	Current	Pre-HOV	Current	Pre-HOV	Current	Pre-HOV	Current	Pre-HOV	Current
Vehicle Volume per Hour per Lane[1]														
A.M. Peak Hour	1,350	1,670	1,650	1,450	1,650	1,570	1,790	1,970	1,640	1,740	1,420	1,820	1,990	1,920
A.M. Peak Period	1,220	1,390	---	1,420	1,400	1,380	1,460	1,610	1,430	1,530	1,500	1,670	1,820	1,700
Freeway Peak-Hour Speed[2], mph	31	60	23	49	23	52	29	53	21	36	21	30	24	23
Injury Crashes per 100 MVM[3]	20.0	19.2	30.3	24.6	29.8	19.3	11.7	10.8	26.2	16.6	22.6	26.1	18.6	17.6

[1]Peak-period volumes are for a 3.5-hour period in Houston and a 3.0-hour period in Dallas (East RLT and Stemmons HOV lane).
[2]Many factors other than HOV implementation have had a more significant impact on freeway operating speeds.
[3]Accident rate expressed as injury accidents per 100 million vehicle-miles. Accidents were evaluated for the following roadway sections: Katy, Gessner to Post Oak (4.7 mi); North, N. Shepherd to Hogan (7.8 mi); Northwest, Little York to I-610 (7.7 mi); Gulf, Broadway to Dowling (6.5 mi); Southwest, Bellfort to South Shepard (11.6 mi); East RLT, Central Expressway to Jim Miller (5.2 mi); and Stemmons, Frankford to IH-635 (6.8 mi).

Source: See data in appendices.

CHAPTER 8. HIGH-OCCUPANCY VEHICLE LANE COST-EFFECTIVENESS

CAPITAL AND OPERATING COSTS OF TEXAS HOV LANES

Houston

The Houston HOV lanes have typically been built as part of freeway construction projects, which makes it difficult to determine the precise capital costs. Information provided by METRO and TxDOT was used in developing the costs. Detailed cost breakdowns for each facility are found in the appendices.

The HOV facilities have been funded by a combination of federal and state highway funds and federal and local transit monies. Approximately 80 percent of the total capital cost is from transit funds. Table 11 summarizes the average capital and operating costs for the HOV lanes currently operating in Houston.

Table 11. Capital and Operating Costs for Reversible HOV Lanes in Houston

Average total cost of HOV lane construction	$9.1 million per mile
Average construction cost, including access ramps	$5.8 million per mile
Average construction cost of support facilities (park-and-ride lots, park-and-pool lots, bus transfer centers)	$3.0 million per mile
Average capital cost of surveillance, communication, and control systems for HOV lanes	$0.3 million per mile
Average cost for daily operation and enforcement	$351,500 per year

Note: Costs are shown in 1995 dollars.

Capital costs do not include the value of the existing freeway rights-of-way in which the HOV lanes were built; state-owned right-of-way has been provided for all facilities with the exception of some ramps and support facilities. The costs also do not include the expense of additional buses required to provide HOV service and the bus maintenance facilities to support them.

Dallas

The Dallas HOV lanes have been constructed jointly by TxDOT and DART. Sixty-six percent of the funds have come from federal sources primarily Congestion Mitigation Air Quality (CMAQ) funds, and the remaining 33 percent have been provided equally by TxDOT and DART.

Table 12 summarize the average capital and operating costs for the HOV lanes currently operating in Dallas. Detailed cost figures are provided in the appendix.

Table 12. Capital and Operating Costs of East R.L. Thornton Contraflow HOV Lane in Dallas

	E. RLT	Stemmons
Average total cost of HOV lane construction	$2.8 million per mile	$1.7 million per mile
Average annual cost for daily operation and enforcement	$566,000 per year	$283,000 per year

Note: Costs are shown in 1995 dollars.

For the East R.L. Thornton contraflow lane, the capital costs include the inbound direction auxiliary lane constructed in 1994 and the outbound extension built in 1996. Also included are the costs associated with structural upgrades of the pavement for the HOV lane and the access/egress ramps serving the lane. For both contraflow and concurrent flow facilities, the value of the existing freeway right-of-way in which the HOV lanes were constructed is not included. No new support facilities (e.g., park-and-ride lots and bus transfer centers) have been constructed in conjunction with the HOV lanes in Dallas.

Figures 23 and 24 represent costs by facility for annual operation and enforcement and for construction.

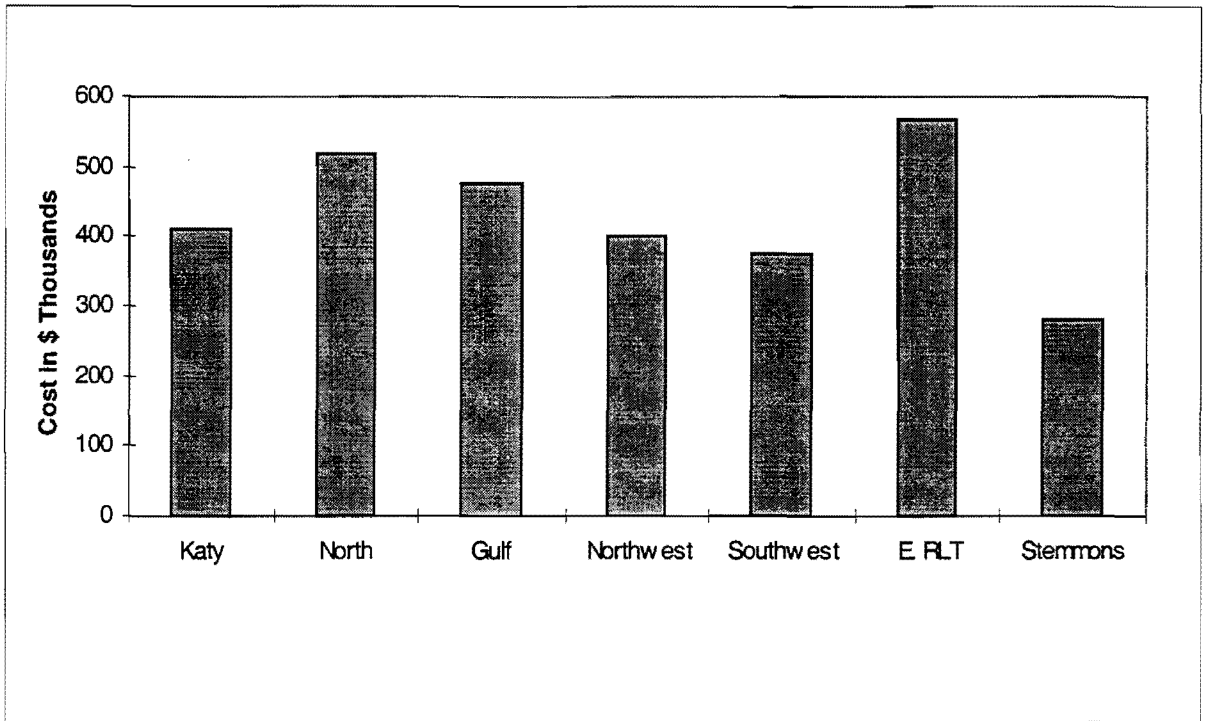


Figure 22. Annual Operation and Enforcement Costs on HOV Facilities
Source: Houston Metropolitan Transit Authority and Dallas Area Rapid Transit

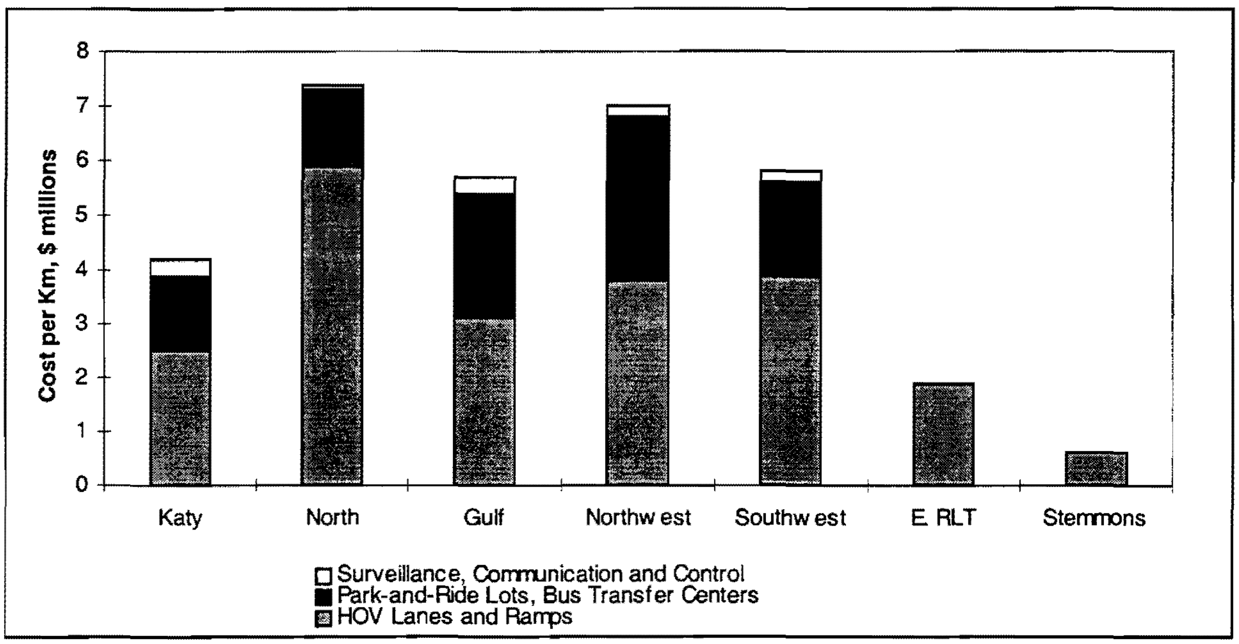


Figure 23. Construction Costs per Mile
Source: Texas Department of Transportation

ANALYSIS OF HOV LANE COST-EFFECTIVENESS

The determination of cost-effectiveness in this report focuses on the HOV facilities that have been operational for at least a full year so that sufficient available data could be used in the analysis. Many of the potential benefits associated with HOV lanes are difficult to quantify. Included in this list of potential benefits are factors such as air quality, impacts on regional economic development, impacts of improved bus schedule reliability, etc. While these are not readily quantifiable, they can, nevertheless, be significant HOV project benefits.

In an effort to assess the cost-effectiveness based on benefits that can be readily quantified, the HOV facilities were analyzed using MicroBENCOST, a planning-level economic analysis tool developed by TTI under NCHRP Project 7-12 (*7*). The MicroBENCOST program uses standard methodologies for traffic allocation and speed and delay calculations. National averages are provided for user costs and vehicle operation costs. The total costs used to compute the gross benefit-to-cost ratio (B/C) include construction costs of improvements, routine facility maintenance and operation costs, vehicle operating costs, and accident costs. Benefits that result from the improvements include savings in delay, reduction in vehicle operating costs including fuel consumption and reduction in accidents. The program calculates costs and benefits for a 24-hour period, 365 days per year over a multi-year time frame by comparing unimproved and improved conditions. Cost effectiveness for this analysis is measured in terms of the B/C ratio generated by MicroBENCOST.

MicroBENCOST is capable of analyzing a wide range of highway improvements, including HOV lanes. The program has the ability to determine the benefits and costs associated with implementation of reversible, concurrent and contraflow HOV lanes. For the purposes of this study, a comparison was made of the existing freeway lane configuration with and without the HOV lane in order to compute the benefit-to-cost ratio. Although some default data are supplied by the program, the majority of data used were actual traffic data and construction costs from HOV lane implementation and operation in Texas in order to obtain the most reliable results for the analysis. Provided below is a summary of actual freeway and HOV lane data used:

- Aggregated construction costs
    - initial construction
    - HOV lane extensions and access ramps
    - improvements such as barrier modifications
    - support facilities, such as park-and-ride lots and bus transfer centers

- Traffic data
    - initial AADT (annual average daily traffic) for a base year of 1995
    - average annual traffic growth rate over a 20-year analysis period
    - composition of automobile fleet on the mainlanes, including occupancies
    - composition of truck fleet on the mainlanes
    - distribution of ADT by hour for a 24-hour period

- Geometric data for mainlanes and HOV lane

- Routine maintenance, operation, and enforcement costs

- Accident rate data

- HOV lane operational data
    - type of HOV lane
    - vehicle classifications and occupancies
    - hours of operation
    - percent of persons using HOV lane, inbound and outbound

Although the implementation of HOV lanes in Texas has resulted in greater bus ridership, incremental costs associated with an increase in commuter bus service directly attributable to HOV lane implementation were not included in the analysis. Transit facilities constructed in support of the HOV lanes are, however, included in the cost data.

A similar analysis of cost-effectiveness was performed in last year's evaluation of Texas HOV lanes. Refinements in the methodology and the underlying assumptions have been made in this year's analysis in order to improve the accuracy of the results. The modifications are described as follows:

- The B/C ratio was derived using Version 2.0 of MicroBENCOST, which has been updated over the original version. Several enhancements have been made to the software that affect HOV lane evaluation:
    - updated vehicle operating costs,
    - update values of time associated with delay,
    - Updated speed calculation methodology consistent with the 1995 Highway Capacity Manual (HCM).

- AADT values for Houston freeways were refined using multiple sources in order to provide more reliable figures for 24-hour traffic volumes.

- MicroBENCOST conducts a full year, 365-day analysis of benefits. Therefore, the final B/C values for the reversible and contraflow HOV lanes were reduced by 30 percent to account the fact that the lanes are not operational on weekends. The B/C result for the Stemmons HOV lane in Dallas was not factored in this manner since it is operational 24 hours a day, seven days a week.

- MicroBENCOST is unable to analyze concurrent flow lanes that are under continuous operation. For the Stemmons facility, the HOV lane alternative was modeled as the addition of one lane in each direction (as with a general-purpose lane alternative) coupled with an increase in overall average vehicle occupancy for passenger vehicles and buses based on actual data.

- The construction cost per mile values used in the analysis of a general-purpose lane alternative for each freeway were updated and based upon an average of 22 construction projects in the Houston area.

RESULTS OF COST-EFFECTIVENESS ANALYSIS

In all cases, the HOV lanes currently operating in Texas produce benefits outweighing the costs over a 20-year life. Table 13 below provides the results of the economic analysis.

Table 13. Benefit-to-Cost Ratios for Texas HOV Lanes

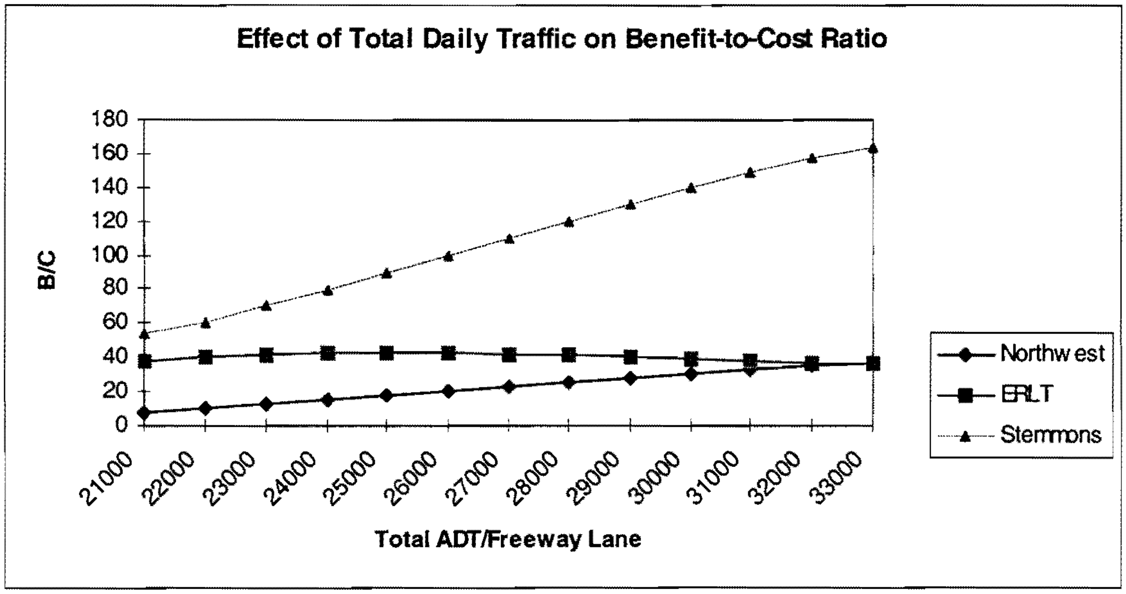
City	HOV Facility	Benefit-to-Cost Ratio
Houston (reversible)	Katy	21
	Gulf	8
	Southwest	8
	Northwest	7
	North	6
Dallas	E. R. L. Thornton (contraflow)	28
	Stemmons (concurrent flow)	48

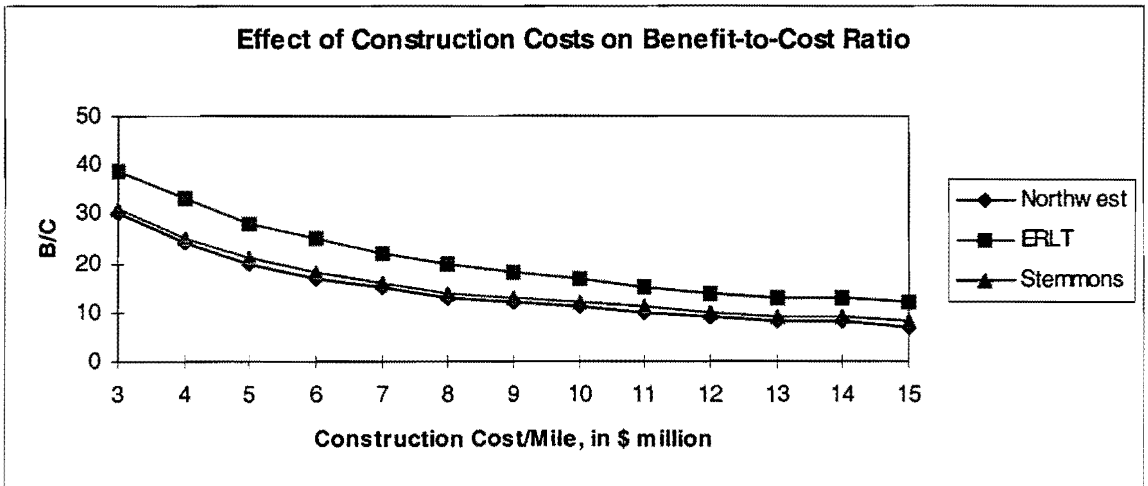
The apparent conclusion from these results is that the HOV lanes that minimize construction costs are more cost effective. However, the cost of park-and-ride lots, transit centers, and other support facilities as well as ITS infrastructure that were included in the analysis for each of the Houston HOV lanes contribute to the high ridership and improved operations. The following sections will explore the factors that affect the evaluation results and will provide a comparative analysis of a general-purpose lane alternative.

A limitation of the analysis is the ability to adjust the HOV demand over time as freeway general-purpose lane congestion increases. It has been documented earlier in this report that as travel time savings increase, use of the HOV lane increases. This particular economic analysis accommodates only one initial input for the percentage of person-movement during the peak periods that takes place in the HOV lane. For this reason, the analysis assumes a constant proportion of HOV person-movement to total person movement, and thus underestimates HOV ridership that may increase over time as the HOV lane becomes a more attractive alternative to congested freeway lanes.

Factors Affecting the Analysis Results

Additional analyses of the Northwest, E. RLT, and Stemmons HOV lanes were conducted to gain an understanding of how the model reacts when one independent variable is changed while all others remain constant. For example, the B/C ratio was calculated for differing levels of ADT while all other parameters remained constant. The results are illustrated in Figure 24.





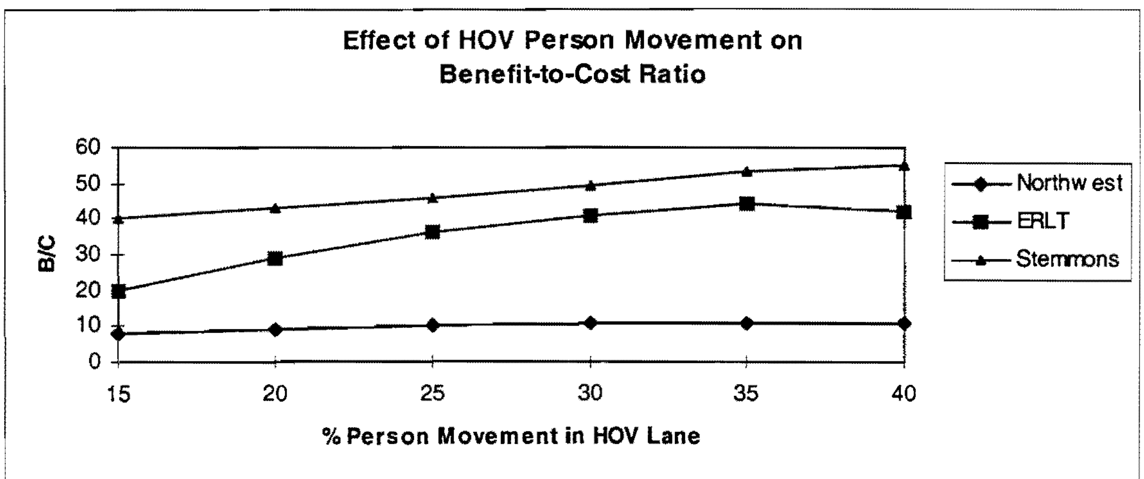


Figure 24. Effects on Benefit-to-Cost Ratios

The Northwest, E. RLT, and Stemmons HOV lanes were selected for this particular review because they cover a full range of HOV facility types. In examining the effects on B/C of the three parameters - ADT, construction cost, and HOV lane person movement - it is noted that average daily traffic provides the greatest range of outcomes, from a B/C of 7 to a B/C of 160. The maximum B/C possible under the scenario of varying construction costs, with all other variables remaining constant, is 40. When the percentage of person-movement in the HOV lane is varied, a maximum B/C of 55 is achieved, all else remaining constant.

The B/C values for the different facility types are most congruent when construction costs among the facility types are equalized. Construction costs are an important factor to be considered in the planning process. While the economic analysis results show that all Texas HOV lanes are very cost-effective improvements, the effectiveness is maximized when capital costs are carefully evaluated. HOV lanes that are built in conjunction with a major freeway reconstruction offer the lowest unit costs. For retrofit situations, it is important to examine the necessity of additional support facilities and the benefits they will provide in terms of increased ridership.

The B/C values for the different facility types are most inconsistent as ADT per lane is varied. Of particular note is the contraflow lane (ERLT) that begins losing efficiency beyond an ADT per lane of 26,000 vehicles per freeway lane per day.

HOV Lanes versus General-Purpose Lanes - Which Alternative is Most Cost Effective?

HOV lanes are considered a capacity-enhancing measure designed to increase person-movement through a corridor. A comparable alternative for increasing freeway capacity is the addition of general-purpose lanes. It has been argued that in many cases the addition of freeway lanes is a more effective alternative than construction of an HOV lane. To assess the validity of this argument from a cost-effectiveness standpoint, the B/C for the addition of two general-purpose lanes to each freeway facility was determined using actual traffic data and general per-lane mile construction costs of $7,000,000 per lane-mile. The comparative results of the HOV lane and general-purpose lane alternatives for each freeway are shown in Table 14.

In all cases the HOV lane produces greater benefits than the general-purpose lane alternative for the dollars invested in the improvements. The variation in the values presented in the last column, which represent the additional benefit offered by HOV lanes, cannot be readily attributed to any one factor, but rather is a combination of influences such as the volume of traffic in the freeway general-purpose lanes, level of person-movement in the HOV lane, and construction cost.

As noted earlier, the MicroBENCOST analysis is an examination of the quantifiable benefits derived primarily from savings in delay and vehicle operating costs. The benefits of HOV facilities that cannot be readily quantified, such as air quality, bus schedule reliability, etc., have not been factored into the evaluation. Notwithstanding these benefits, an analysis of the actual operational experience of HOV lanes in Texas has demonstrated that HOV lanes are cost-effective improvements based solely on overall savings in user costs and vehicle operating costs. And in examining these cases, HOV lanes are shown to be a more cost-effective alternative than the construction of two general-purpose lanes. Because of the unique characteristics of each corridor, comparisons of B/C ratios between corridors is not meaningful.

Table 14. Comparison of Benefit-to-Cost Ratios for Texas HOV Lanes versus a General-Purpose Lane Alternative

City	HOV Facility	Benefit-to-Cost Ratio for HOV Lane	Benefit-to-Cost Ratio for Two General-Purpose Lanes	Additional Benefit Offered by HOV Lane per dollar expended
Houston (reversible)	Katy	15	9	67%
	Gulf	9	4	125%
	Southwest	8	5	60%
	Northwest	7	6	17%
	North	6	4	50%
Dallas	E. R. L. Thornton (contraflow)	28	10	180%
	Stemmons (concurrent flow)	48	43	12%

CHAPTER 9. DEVELOPMENT OF HOV FACILITY SYSTEM SHOULD HAVE PUBLIC SUPPORT

INTRODUCTION

Public attitude toward continued investment in HOV facility development is a major area of interest among public officials in Houston and Dallas. The lanes are seen as a method of serving future growth in travel and have been built using public monies. Approximately $900 million in tax monies have been utilized in Houston alone to plan, design, and construct HOV lanes. Consequently, public perceptions and attitudes pertaining to the HOV lanes are of major consequence regarding the success or failure of this strategy.

TTI researchers have surveyed HOV users (carpoolers and transit riders) as well as general purpose or mainlane users since 1985. However, only the Katy and Northwest HOV lanes have been surveyed with regularity since the surveys were first implemented. The most recent survey was conducted in 1994 and included the East R.L. Thornton facility for the first time. The 1994 surveys were conducted for the Katy, Northwest, and East R.L. Thornton corridors only (*8*). For the purposes of this report, only the 1994 data will be highlighted. Historical information regarding previous surveys can be found in earlier HOV analysis reports (*9*).

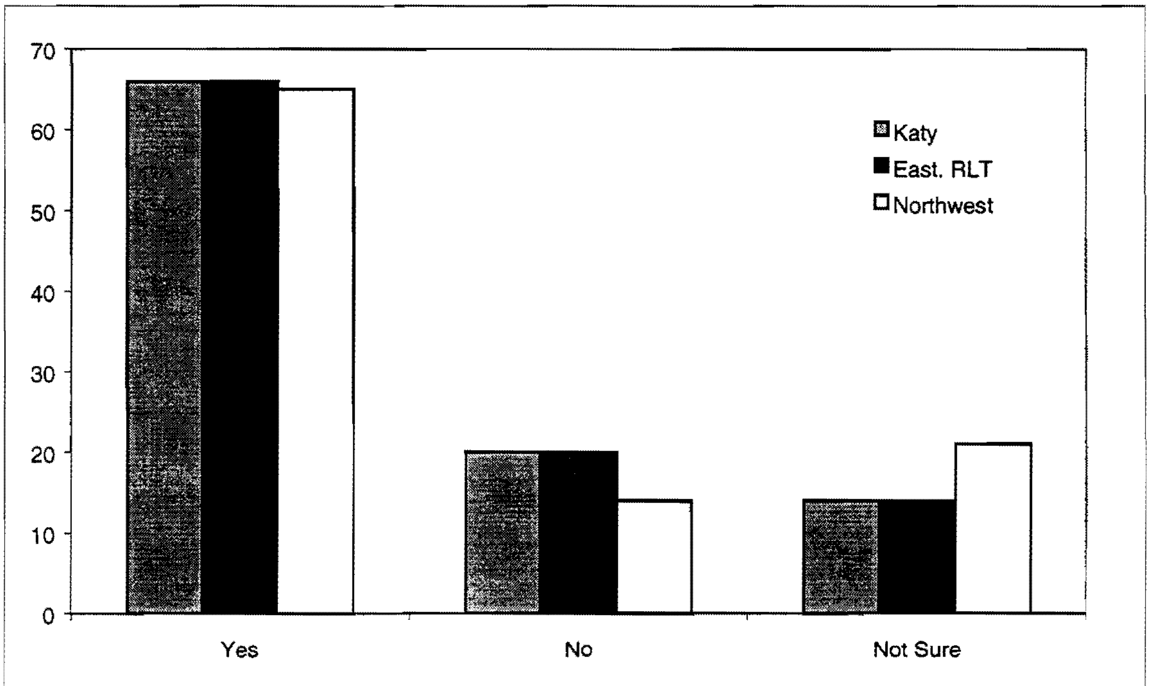
The surveys were developed to identify attitudes and perceptions regarding priority lane utilization. Two primary questions were asked to gauge public acceptance of the HOV lanes in Dallas and Houston: 1) Are the HOV facilities good transportation improvements? and 2) Are the HOV lanes sufficiently utilized? A secondary measure of public acceptance is the impact that the HOV lanes have had on mode choice among carpoolers and transit riders using the HOV lanes. The survey findings regarding public acceptance are discussed next.

ARE THE HOV LANES GOOD TRANSPORTATION IMPROVEMENTS?

In an effort to determine public acceptance of HOV facilities in Houston and Dallas general-purpose lane motorists or non-HOV lane users were surveyed regarding their attitudes towards the priority lanes and their perceptions of HOV lane utilization. The general-purpose lane motorists were surveyed because they may receive relatively few direct benefits from the presence of HOV lanes in their respective corridors. Hence, opinions from non-HOV users in each of the corridors may reveal whether the general public views HOV lanes as good transportation improvements. General-purpose lane motorists were asked specifically if they felt that the HOV lanes being developed in Houston or Dallas are good transportation improvements.

Based on the survey findings from the Katy, Northwest, and East R.L. Thornton corridors, the priority lanes are viewed favorably among non-HOV users in those corridors. Approximately 65 percent of the general-purpose lane motorists in each of the three corridors viewed the priority lane projects positively. Acceptance levels in the Katy corridor have remained above 60 percent since 1987. Prior to 1994, positive acceptance of the priority lanes in the Northwest corridor exceeded 70 percent and remained near that figure in 1994 at 65 percent (*5*). Relatively few motorists surveyed, approximately 20 percent in each corridor, indicated that the priority lanes were not a good transportation improvement in the corridor. Another 14 percent in each of the corridors were unsure of their opinion regarding the HOV lane projects. Figure 25 summarizes the 1994 survey findings from the Katy, Northwest, and East R.L. Thornton mainlane motorist surveys.

In each case, the general motoring public favorably responded to the question, "are the HOV lanes a good transportation improvement?" Hence, relatively strong public support exists for the HOV lane program from non-HOV users in corridors with HOV lane improvements. Furthermore, historical trend data available in previous reports also indicate that this support has held true over time (*5*).



[1] 1994 Summer Survey Data

Figure 25. Responses to the Question, "Are HOV Lanes Good Transportation Improvements?"

ARE THE HOV LANES SUFFICIENTLY UTILIZED?

In contrast to the positive acceptance of HOV lanes from general-purpose lane motorists as good transportation improvements, HOV lanes are generally considered underutilized among non-HOV motorists in the three corridors surveyed. General-purpose lane users were asked two distinct questions regarding their perceptions of HOV lane utilization: 1) "Based on your observation of the number of *vehicles* currently using the HOV lanes, do you feel that they are being sufficiently utilized?" and 2) "Based on your perception of the number of *persons* currently being moved on the HOV lanes, do you feel that they are being sufficiently utilized?" The 1994 surveys were modified to gauge the perception of utilization (by freeway motorists) relative to both vehicles and persons being moved on the HOV lane. Prior to 1994, the freeway motorists on the general-purpose lanes were asked to simply indicate whether they felt that the priority lane was sufficiently utilized without regard to persons and vehicles.

Responses from Freeway Motorists

The motivation for asking general-purpose lane motorists two separate questions concerning vehicle and person utilization is simple. The perception that the HOV lanes do not carry enough traffic when compared to the mainlanes, and are therefore underutilized, is a concern that has existed since the initiation of the HOV programs in Texas. Although general-purpose lane users may feel that vehicle utilization is low (commonly referred to as the "empty lane syndrome"), TTI researchers were also interested in documenting their perceptions concerning the amount of people being moved in the HOV lanes, which is a primary objective of HOV lanes — to move more people than vehicles.

Similar to the survey findings prior to 1994, freeway motorists feel that the HOV lanes are not moving enough traffic or people. Table 15 lists the 1994 survey findings from the Katy, Northwest, and East R.L. Thornton general-purpose lane surveys. Prior to the 1994 survey, generally less than 40 percent of non-HOV users felt that the lanes were utilized sufficiently (*5*). However, these figures declined to 21 percent and 31 percent, respectively, for the Katy and Northwest Freeway motorists in 1994. The East R.L. Thornton general-purpose lane users proved to be the one exception. Non-HOV users on the East R.L. Thornton mainlanes felt that the amount of traffic being moved on the priority lane was sufficient. Approximately 48 percent of the respondents indicated that vehicle utilization was positive.

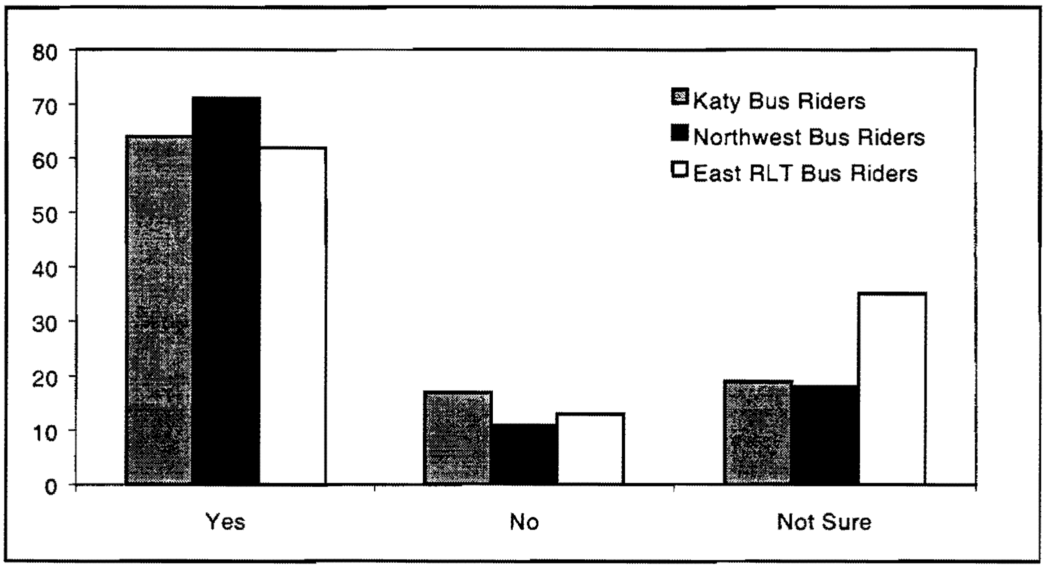
Table 15. Responses from Freeway Mainlane Motorists to the Question, "Is the HOV Lane Sufficiently Utilized?"

Survey Location and Group Responses to Questions	1994 Survey	
	Is Vehicle Utilization Sufficient?	Is Person Utilization Sufficient?
Katy Freeway Mainlane Motorists		
Yes	21%	19%
No	62%	59%
Not Sure	17%	22%
Northwest Freeway Mainlane Motorists		
Yes	31%	25%
No	41%	43%
Not Sure	28%	32%
East R.L. Thornton Freeway Mainlane Motorists		
Yes	48%	38%
No	32%	39%
Not Sure	20%	23%

Perceptions about person-movement on the priority lanes were generally negative, with the East R.L. Thornton being the one exception where it was viewed equally negative and positive among general-purpose lane motorists. Within the Katy corridor, nearly 60 percent of non-HOV users felt that the person-moving characteristics of the priority lane were not sufficient. The Northwest corridor, although lower at 43 percent, also had more people feel that the priority lane was not being utilized by enough people. Since this is the first time that vehicle and person utilization questions were posed, there is no historical data from which to draw extensive conclusions concerning the perceptions of non-HOV users relative to both vehicles and persons being moved in the HOV lanes. The general perception, though, is that the HOV lane is underutilized and has remained that way historically (*5*). Based on these findings, the issue of perceived lane utilization, both vehicle and person, among non-HOV users will continue to be an issue associated with the implementation of a priority lane program.

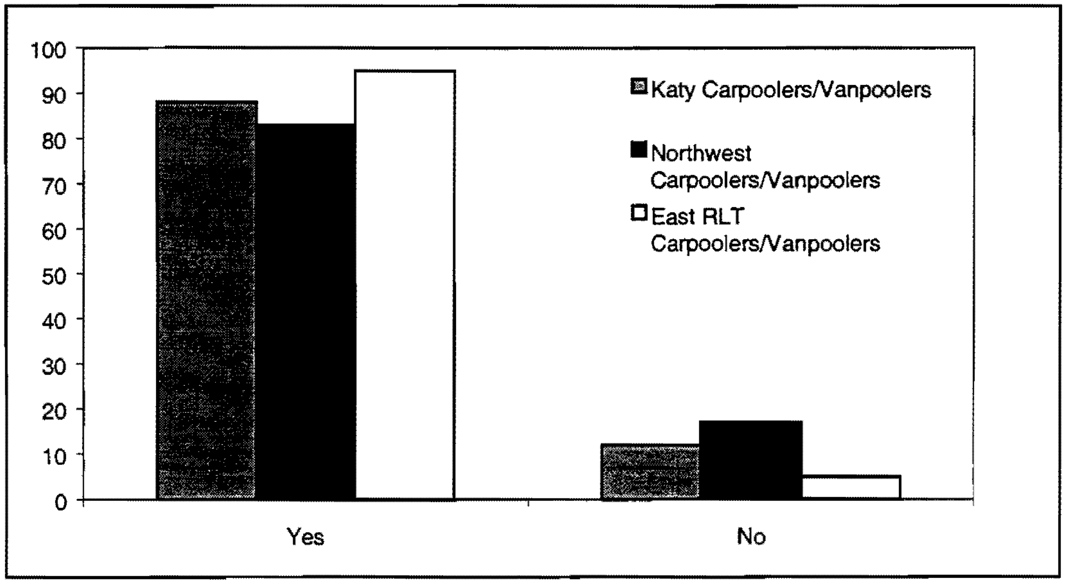
Responses from HOV Lane Users

People that use the HOV lanes (carpoolers, vanpoolers, and bus riders) were also asked to indicate whether they felt that the HOV lane was being sufficiently utilized. This group of people, unlike the general-purpose lane motorists, were not specifically asked questions about person or vehicle utilization. This same general question has been asked on surveys in the Katy corridor since 1985 and in the Northwest corridor since 1989 (5). Figures 26 and 27 summarize the 1994 survey results. The results indicate that there is a significant difference between HOV users and non-HOV users. In all three corridors, carpoolers, vanpoolers, and bus riders resoundingly responded with positive impressions about lane utilization. A minor observation within the data also shows that carpoolers and vanpoolers tend to have a more favorable opinion about how well the lanes are being used when compared to the responses from bus riders. Although general-purpose lane drivers question the efficiency of the priority lanes, utilizers of the lanes (carpoolers and bus riders) strongly indicate a favorable opinion of the priority lanes.



[1]Respondants were asked, "Is the HOV Lane Sufficiently Utilized?"
[2] 1994 Summer Survey Data

Figure 26. Perceived HOV Lane Utilization: Bus Riders[1]



[1]Respondants were asked, "Is the HOV Lane Sufficiently Utilized?"

[2] 1994 Summer Survey Data

Figure 27. Received HOV Lane Utilization: Carpoolers/Vanpoolers[1]

CHAPTER 10. AIR QUALITY AND ENERGY CONSIDERATIONS

INTRODUCTION

Air quality improvements and energy consumption savings have been at the heart of arguments for and against the implementation of priority lanes. Increased emphasis has been given to the air quality and energy conservation impacts of alternative transportation improvements since the enactment of the 1990 Clean Air Act Amendment (CAAA) and the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA). As a result of these two pieces of legislation, public officials have developed programs and strategies that primarily focus on reducing vehicle miles of travel (VMT) and increasing vehicle occupancy levels. HOV lanes attempt to accomplish both of these goals by providing a priority lane that encourages SOVs to take advantage of the travel time differences afforded to higher occupancy vehicles. The 1990 CAAA lists 16 transportation control measures (TCMs) that encourage modal shifts to higher occupancy modes and eliminate or reduce the amount of travel. HOV lanes are listed among the 16 TCMs.

The cost of implementing HOV lanes has also added to the importance of demonstrating air quality conformity to overcome critics of priority lanes. Some critics of the priority lanes point to other TCM strategies, such as improving existing transit services or implementing trip reduction ordinances, as more cost-effective strategies. Furthermore, the actual air quality and energy benefits of HOV lanes have been a focus of arguments against implementing a priority lane program. The generation of some of the air quality criticisms are a result of a lack of accepted methods for quantifying energy and emission benefits. Some of the common criticisms associated with air quality benefits and HOV lane programs include the following:

- With more people removed from the general-purpose lanes, the speeds on the lanes will increase on these lanes, which increases the amount of nitrous oxide emissions.

- Emission benefits are often derived using peak-period information and are not calculated on a 24-hour basis. Questions have arisen as to the benefits of an HOV lane that is only used during defined times (typically during severe congestion) to extra mixed-flow lanes that would be available to all vehicles during a 24-hour period. What are the actual impacts of limited peak-period benefits compared to 24-hour benefits?

- Emission calculations often use an aggregation of vehicles and VMT rather than recognizing that different vehicle types have different emission rates.

- Currently, the technology and/or the amount of data collected does not account for such information as emission rates created when a car is started after it has been sitting for long periods (cold start), after a car has been re-started after only a short period of inactivity (hot start), or emissions created by evaporation while the car is not driving (e.g., a parked vehicle overnight and a parked vehicle in the sun).

- The latent demand for additional capacity on the general-purpose lanes will be accommodated by the shift of people from the general-purpose lanes onto the HOV lane. As shown in previous sections, implementing the high-occupancy vehicle lane does not necessarily reduce the vehicular volumes on the freeway general-purpose lanes. The HOV lane, though, is in effect, allowing more person movement to be served without increasing congestion on the general-purpose lanes. As a result, the travel that takes place in the corridor that serves the HOV facility can be an increase in the total vehicle-kilometers of travel compared to what existed prior to constructing the priority lane. Consequently, in comparison to pre-HOV conditions, implementing an HOV lane may well increase the total vehicle-kilometers of travel, which will also increase energy consumed and pollutants emitted. However, HOV lanes are developed in already congested corridors where demand is projected to continue to increase over time. Hence, the HOV lane can be a strategy for effectively serving the travel demand that is expected to occur over time. A true analysis of this situation would involve a review of several alternatives: "do nothing," "add an HOV lane," and "add another mixed-flow traffic lane."

Unfortunately, evaluating the effectiveness of HOV projects is difficult. There are two approaches being used in Texas to calculate emission and energy benefits of implementing HOV lanes: the use of emission factors and simulation. The North Central Texas Council of Governments (NCTCOG) uses emission factors (grams per mile) based on changes in speed in its study on the effectiveness of various TCMs (*10*). The NCTCOG methodology includes quantifying the benefits of stimulating the formation of new carpools from previously single occupant motorists, the benefits to drivers that previously used parallel facilities but changed routes onto the general-purpose lanes because of the higher speeds on the general-purpose freeway lanes and the benefits to carpoolers now using the HOV lanes that were using the general-purpose lanes.

Simulation packages use models or sketch planning tools to analyze air quality and energy benefits of implementing priority lanes. However, the emission models, to date, have yet to produce endorsed or scientifically approved numbers.

The common assumption in these models and tools has been that the speed differential is smaller on HOV lanes because of the reduced vehicle interaction created by the priority lane. This produces emission benefits over general-purpose lanes because speed differentials and vehicle interaction are greater on these lanes. Any analysis that primarily uses speeds, VMT, and the number of vehicle trips is simply preliminary and does not take into account a number of other factors that effect mobile emission rates. Factors such as vehicle mix, detailed speed profiles, driving cycles, duration of trip and the inclusion of "hot" and "cold" emission data are needed to accurately predict potential benefits of HOV lanes (*11*). Currently, this type of data is not collected as part of this project and would need to be in order to develop an accurate measure for emission and energy rates.

Another "criticism" of the analysis is that emission and energy benefits are associated with vehicles rather than persons, which is contrary to the basic premise of HOV lanes - moving more people than vehicles. The timeline for the development of more accurate tools to analyze TCMs is considered to be near. Until then, accurate conclusions based on current techniques are questionable at best.

ANALYSIS

The air quality and energy consumption analysis presented in this section of the report utilizes a freeway simulation model (FREQ) and applies that model to the Katy Freeway and HOV lane. No other corridor was studied as part of this effort. Differences in volumes to capacity (V/C) ratios between the alternatives is the primary attribute studied to measure emission rates and fuel consumption.

Using the 1996 travel volumes, researchers simulated operation on both the freeway general-purpose lanes and the HOV lane. The demand, expressed as passenger-kilometers, that existed in 1996 was held constant in comparing alternatives. The average vehicle occupancy levels, though, were adjusted between alternatives as necessary to reflect the observed impacts of the HOV facility on vehicle occupancy. Researchers evaluated the following three alternatives:

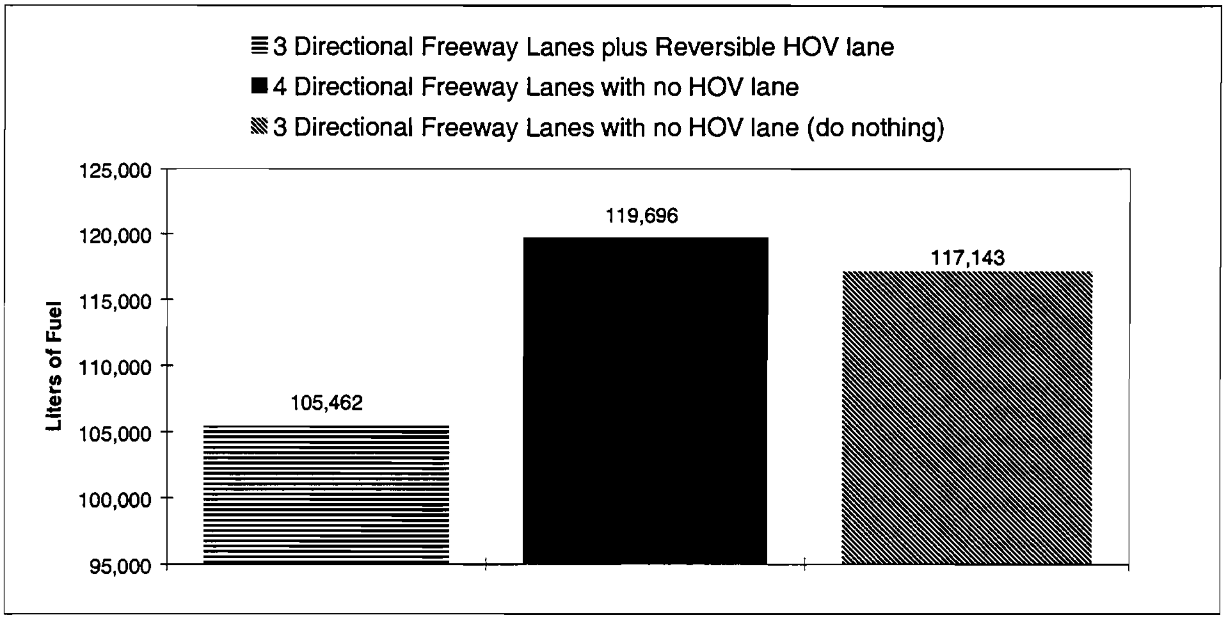
1. **Do Nothing**. The freeway would have three mixed-flow freeway lanes in each direction and no HOV facility. This is the condition that existed prior to adding the HOV facility to the freeway.

2. **Add a General-Purpose Freeway Lane**. This would result in four general-purpose freeway lanes in each direction with no HOV facility. It is the condition that would have resulted had an additional freeway general-purpose lane been added to the freeway instead of an HOV lane. This helps provide data to help answer the question, if one lane is to be added to a freeway, should that lane be designated as a reversible HOV lane, or should it be designated as an additional general-purpose lane? The reversible HOV lane requires approximately the same pavement width as would be required to provide one additional general-purpose lane.

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

Figures 28 and 29 show the results of this analysis. The analysis was from 6:00 a.m. - noon, peak direction for 1996 demand levels. Based on the basic analysis of the Katy corridor, the HOV lane alternative has better results for hydrocarbon and carbon monoxide emissions. The HOV alternative is clearly more favorable than the other two strategies when reviewing the data for carbon monoxide emissions. Because of the improved speeds on the general-purpose lanes, the nitrous oxide emissions are similar between "add an HOV lane" and "add an extra freeway lane with no HOV lane."

When comparing the three alternatives on the Katy corridor, the HOV lane alternative results in a reduced average of more than 10,000 liters of fuel. This is attributable to the increased vehicle occupancy levels created by the HOV lane versus the other scenarios. The "add an additional freeway lane with no HOV lane" alternative clearly stimulates more consumption of fuel, which may be created by encouraging additional single occupant driving on this facility. The scenario is slightly higher than the "do nothing" alternative.

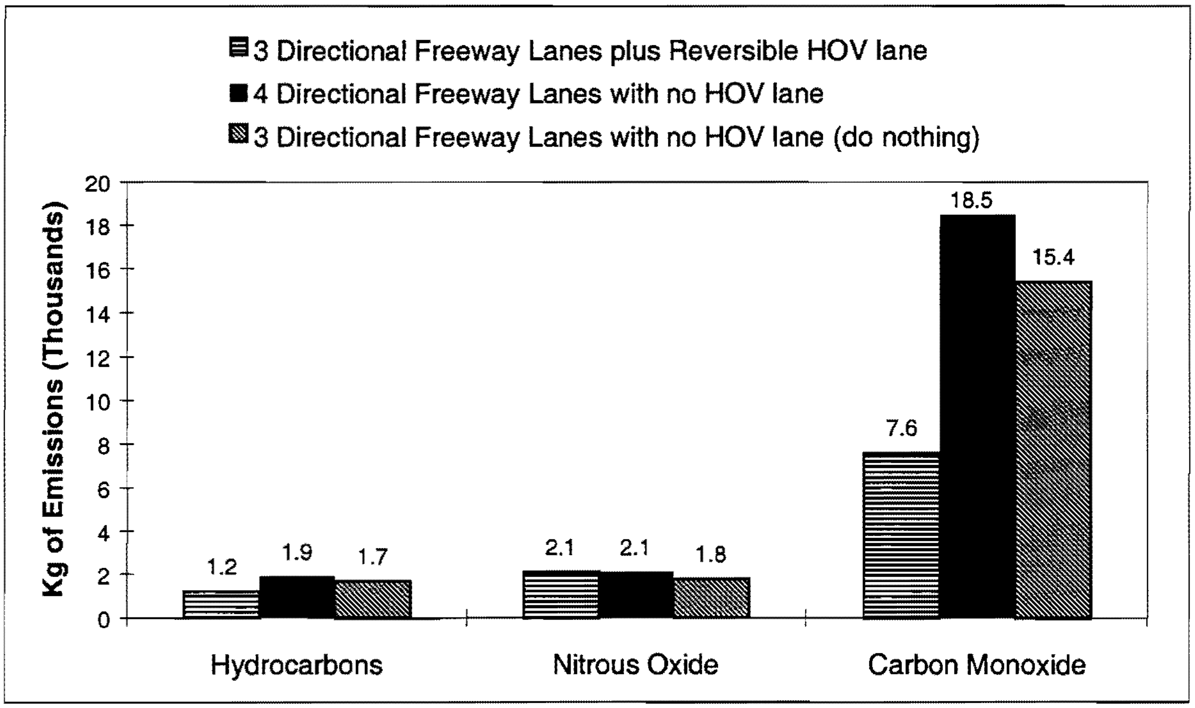


Source: Texas Transportation Institute Simulation Analysis, 6 a.m. - noon, peak direction, 1996 demand levels

Figure 28. Impacts of HOV Improvements of Energy Consumption, Katy Freeway and HOV Lane

Since the demand is projected to increase in the future, the HOV lane should (over time) continue to look even more favorable. The HOV alternative provides capacity to serve additional growth, while the alternatives that provide only freeway mainlanes operate at capacity in 1996 and are unable to serve additional higher volumes. The analysis is limited, as noted earlier; however, it is clear that to serve the passenger-kilometer demand in the peak direction that is occurring today on the Katy freeway, the HOV lane alternative is more favorable in terms of air quality and energy conservation benefits.

Air quality and energy savings analysis of priority lanes clearly needs to be improved in order to strengthen policy arguments based on these two criteria. Analysis of the other corridors with more reliable techniques would improve the overall air quality and energy understanding of these types of facilities being implemented in Houston and Dallas. There is an increased sensitivity towards transportation alternatives and air quality improvements created by the enactment of the 1990 Clean Air Act Amendments, the 1991 Intermodal Surface Transportation Efficiency Act, and the pending attainment measures recently proposed by the EPA. The preliminary analysis of the Katy freeway corridor, though, shows that the HOV lane alternative offers the most favorable impacts on pollutants emitted and energy consumed.



Source: Texas Transportation Institute Simulation Analysis, 6 a.m. - noon, peak direction, 1996 demand levels

Figure 29. Estimated Impacts of HOV Improvements on Air Quality, Katy Freeway and HOV Lane

CHAPTER 11. FACTORS AFFECTING HOV LANE OPERATION

Since 1980, TTI has been conducting evaluations of HOV lanes in Texas on behalf of TxDOT, METRO, and DART. The results of these studies have been important to the development of HOV lanes in Texas and throughout the country. When comparing Texas HOV lanes with facilities developed in other cities, the experiences in Houston and Dallas have both similarities and differences with the development of HOV lanes in other cities. Comparing these two Texas cities, there are similarities and differences as well. The final chapter of this evaluation document will summarize the elements that have been essential to successful HOV lane utilization in Texas based on the current status as well as the history of these facilities, recognizing that differences between the HOV lanes and the individual corridors do exist.

The factors that contribute to HOV lane success in Texas are many. They relate to the characteristics of the corridor, the working relationships among agencies, and the supporting policies and programs *(12)*. In this chapter we will examine three broad categories of technical factors that have contributed to HOV lane success in Texas:

- travel time savings,
- corridor characteristics, and
- transit utilization

The dynamics of these primary factors working together in each corridor has contributed to the demonstrated success of HOV lanes in Texas.

TRAVEL TIME SAVINGS AND HOV LANE USAGE

One of the central arguments for HOV lanes is that as the travel time savings increase, the amount of HOV lane usage also increases. This relationship is described by Henk and Christiansen, et al. *(9)* using a limited supply of data. The conclusion is intuitively obvious: the more time a traveler can save, the more likely they are to sacrifice some flexibility and give up their single-occupant vehicle. The presence of high levels of traffic congestion within a corridor is a foundational element for HOV lane utilization and provides an incentive to motorists to rideshare.

As more data have become available, the relationship between travel time savings and HOV lane usage data has become less obvious. A regression analysis of the data confirms that a positive relationship does exist. When the data are viewed on a scatter diagram (Figure 30), it becomes apparent that the data points are clustered by facility, causing some skepticism about the ability to draw conclusions from the aggregate data. The relationship depicted in Figure 30 is contrary to previous conclusions that ridership grows exponentially as travel time savings increases. Other related factors, such as *travel time reliability* and *perceived travel time savings*, likely contribute significantly to the decision to carpool or use transit.

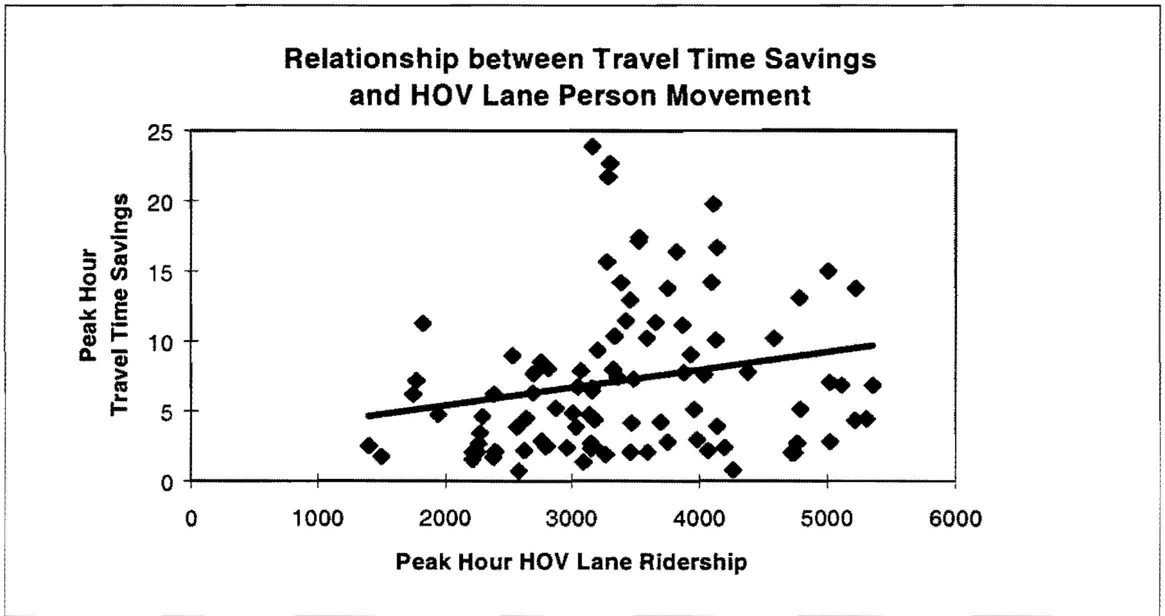


Figure 30. Relationship between Travel Time Savings and HOV Lane Person-Movement

Travel time reliability, or the expectation that travel time will not vary appreciably from day to day, is an advantage of HOV lanes. Although the incentive of travel time savings itself is strong, the traveler would need to anticipate the need to save time prior to making the trip, thus carpooling in the HOV lane to avoid an incident is unlikely. Most HOV lane users will have made their decision prior to departure from home or work. The decision to use the HOV lane means that they have experienced enough consistent delay on the general-purpose lanes (or conversely savings on the HOV lane), to justify the additional effort associated with carpooling.

The reliability advantages of HOV lanes in Houston were documented in a 1995 study conducted by TTI using Houston Transtar's automatic vehicle identification (AVI) traffic monitoring system. Travel time data for eight months were captured from the electronic tag-reading system and analyzed. The results for the Katy freeway are shown in Figures 31 and 32. Similar results were documented for the North and Northwest HOV lanes. The graphs illustrate the variability of mainlane travel times in relation to the HOV lanes and demonstrate the greater travel time reliability afforded by the HOV lane.

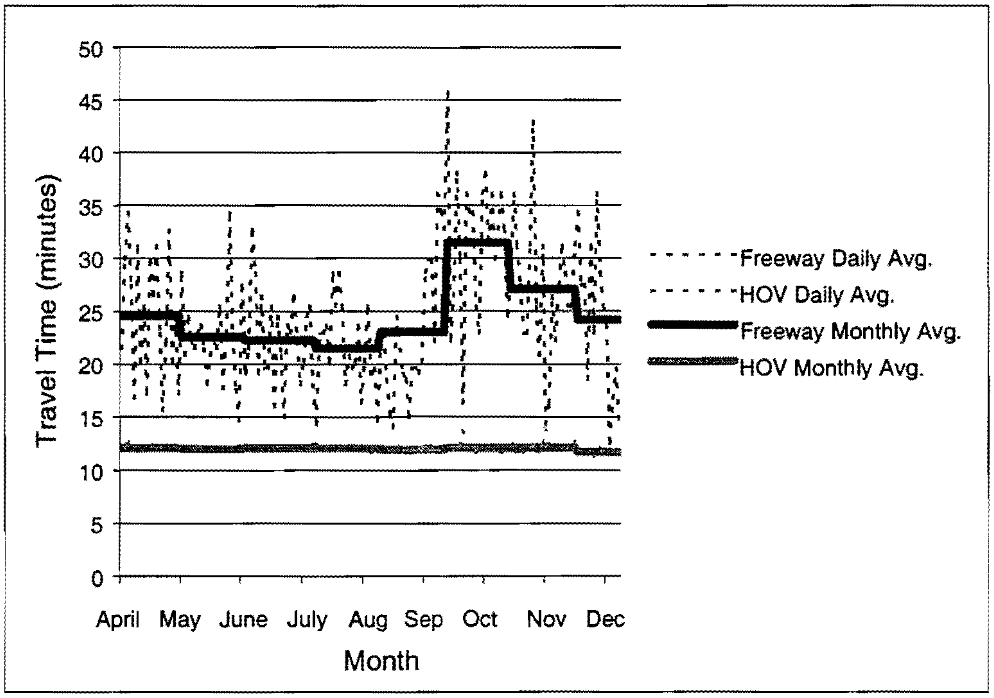


Figure 31. Average Morning Peak-Hour Travel Times for Katy Freeway*(13)*

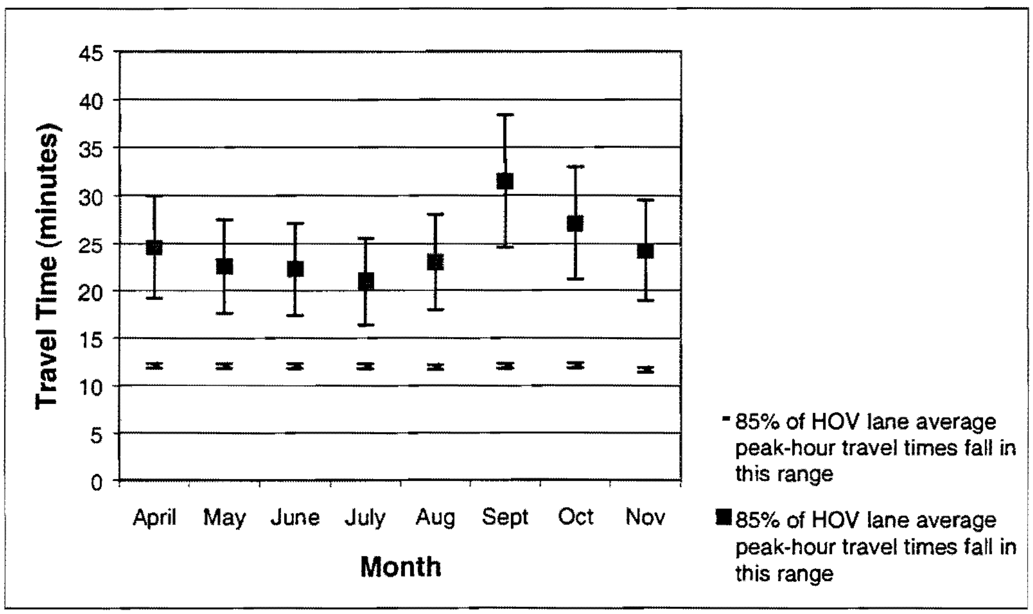


Figure 32. Morning Peak-Hour Travel Time Reliability for Katy Freeway *(13)*

Related to travel time variability is the *perception of travel time savings,* which appears to play a part in the decision to carpool or ride the bus. Surveys conducted periodically during the last 10 years consistently reflect a perception by HOV lane users that travel time savings is greater than that actually measured. Table 16 shows the differences between perceived and actual travel time savings. The sensation of being in motion at high speed on an HOV lane and passing the slow-moving vehicles in the adjacent congested lanes could provide one explanation for higher perceived travel time savings than actual. The same perception of time savings can be found in a driver who passes a line of slower-moving vehicles waiting to enter a ramp and merges at the last possible moment, only to save seconds on the total trip, or in a motorist who navigates a route on local streets through a neighborhood to avoid congestion on an arterial roadway, saving minimal total trip time. It appears that the sensation of continuous movement leads to the perception of time savings, which causes drivers to seek out alternatives that minimize stop-and-go movement.

Table 16. Comparison of Actual and Perceived Travel Time Savings on the HOV Lanes

HOV Facility		Average Perceived HOV Travel Time Savings (minutes)	Measured Peak-Hour Travel Time Savings for Year Survey Conducted (minutes)
Katy	Transit Riders	23	18
	Carpoolers/Vanpoolers	25	
NW	Transit Riders	17	7
	Carpoolers/Vanpoolers	20	
E. RLT	Transit Riders	13	6
	Carpoolers/Vanpoolers	16	
North	Transit Riders	15	7
	Carpoolers/Vanpoolers	15	
Gulf	Transit Riders	10	2
	Carpoolers/Vanpoolers	12	

Source: TTI surveys, 1994; North survey data from 1990, Gulf survey data from 1989.

For the three factors discussed in this section—travel time savings, travel time reliability, and perceived travel time savings—the common attribute linking them is the presence of severely congested conditions on the general purpose freeway lanes, both recurring and nonrecurring congestion. An additional consideration, however, is the presence of congestion on the HOV lane. Figure 33 shows the components that determine travel time savings: (1) the level of congestion on the freeway lanes represented by freeway travel speed and (2) the level of congestion on the HOV lane represented by HOV lane speed. The gray area between represents the magnitude of the speed differential between the HOV lane and freeway lanes.

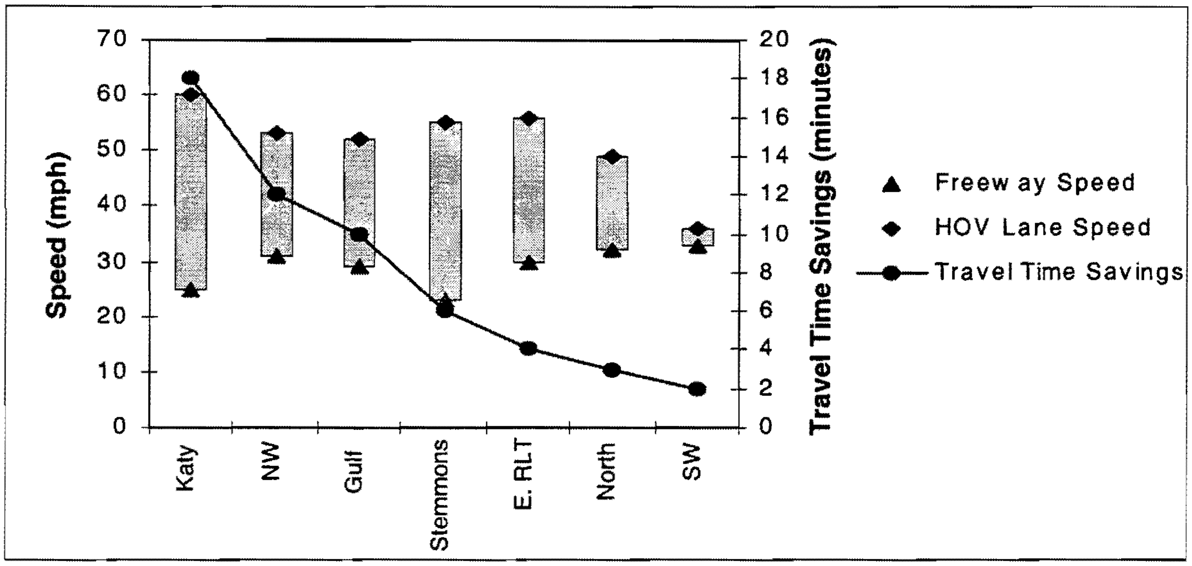


Figure 33. Impact of Congestion on peak-Hour Travel Time Savings, 1997

The level of congestion on the HOV lane is an important factor in the HOV lane's ability to provide a greater level of service through high free-flow speeds. The speed degradation on the Katy HOV lane in 1988 led to an increase in the vehicle occupancy requirement (from 2+ to 3+) for the peak hours so that a high level of service could be maintained, particularly for bus riders. The Southwest HOV lane is nearing capacity and consequently provides a lower travel speed differential and lower travel time savings. It exhibits the highest peak-hour vehicle demand and the lowest HOV lane speed.

CORRIDOR CHARACTERISTICS AND HOV LANE USAGE

In addition to the travel time dynamics, there are characteristics within each individual corridor that contribute to HOV lane usage and, ultimately, its effectiveness. They represent the demographic and socioeconomic characteristics of the travelers within a corridor, their trip purposes, and the extent to which the HOV facilities are designed to meet the needs of those travelers. In reflecting on the more than a decade of HOV lane experience in Houston, the characteristics of each freeway/HOV lane corridor vary so widely that it is difficult to ascertain what is common to all HOV lanes and what is not. The following section examines the apparent corridor characteristics that appear to contribute to HOV lane effectiveness.

HOV Facility Design

All of the corridors included in this study are radial freeways oriented toward the central business districts of two major metropolitan areas. Other major employment and activity centers in the central area are served by the corridors as well. For bus riders using the HOV lanes, over 90 percent are destined for downtown during the morning peak period *(8)*. Carpoolers are slightly more dispersed in their destinations, with anywhere from 43 percent to 71 percent destined for the central business district. This demonstrates that while the HOV lanes can serve dispersed trips well, the orientation toward the central business district and other major activity centers has been a critical element in the ability to serve bus transit and attract bus riders.

The Houston HOV lanes are served by an extensive system of park-and-ride lots and direct access ramps. Approximately $200 million have been invested in the development of park-and-ride lots, park-and-pool lots, and transit centers within the five HOV corridors. An average of 11,000 vehicles per day park in the park-and-ride lots within these corridors.

Characteristics of Travel Demand

Socioeconomic data for each corridor were collected in order to determine if particular demographic factors play a role in ridership on HOV lanes, such as the propensity to ride the bus or carpool. Transit will be examined in more detail in the next section of this chapter. According to previous research documented by FHWA *(14)*, the tendency to carpool increases under the following conditions:

- higher travel times,
- longer trip lengths,
- larger household size,
- income lower than $30,000 per year, and
- higher parking charges at the workplace.

In this section of the chapter, several of the above conditions are explored for Houston and Dallas HOV lanes. The purpose of this review is to determine if these conditions represent the carpooling experience in the HOV corridors.

Corridor Demographics

For the five corridors in Houston and one in Dallas, the following data were collected in an effort to learn more about the characteristics of travelers within the HOV lane corridors:

- number of households,
- household size,
- household income,
- average trip length, and
- population density.

For each of the six freeway facilities, the likely contributing traffic serial zones for the HOV lane were identified, from which the above data were extracted. 1990 and 1995 data were obtained from the Houston-Galveston Area Council (HGAC) for the Houston facilities and from the North Central Texas Council of Governments (NCTCOG) for the Dallas facility. Recent parking costs for major activities were not available, but parking costs were not considered to be a significant factor in the decision to carpool or use transit. For example, 1985 average parking costs for the downtown Houston were $2.84 per day. It is assumed that parking costs have not changed appreciably except for adjustments for inflation. General statistics are provided in Table 17 below.

Table 17 . Planning and Operations Data for HOV Corridors

Corridor	Population Density (persons per square mile)	Average Trip Length (miles)	Peak-Hour HOV Lane Persons Moved in Carpools	Peak-Hour HOV Lane Persons Moved in Buses	Total Peak-Hour HOV Lane Ridership	Estimated Travel Time[1] (min.)
Katy	1,804	13.2	1,982[2]	1,475	3,457	32
North	2,165	14.6	2,522	1,815	4,337	27
Northwest	2,066	13.9	2,636	953	3,589	26
Gulf	2,333	12.9	2,185	740	2,925	27
Southwest	4,104	11.4	2,949	1,125	4,074	21
E. RLT (Dallas)	3,814	7.5	3,009	1,148	4,157	15

[1]Average trip length divided by peak-hour freeway mainlane speed
[2]Minimum vehicle occupancy of 3 persons in the peak-hour

The various household data collected from the planning models are displayed in Figures 34, 35, and 36. The number of households in all corridors rose between 1990 and 1995, and average household size declined during that same time period. In terms of income levels, each corridor exhibits a slightly different distribution of income. Most noticeable is the Katy corridor, which shows a high proportion of upper income households. This is consistent with HOV lane user surveys in this corridor that show a high representation of young, educated white-collar professionals carpooling and riding the bus.

An examination was made of each of the conditions that are conducive to carpooling, as identified in the FHWA report. The review was made in order to identify apparent relationships between characteristics of each of the six corridors and HOV lane usage, particularly with respect to carpooling.

- **Higher travel times** - Higher travel times increase the propensity to carpool. The last column of Table 17 provides travel time computed from the average trip length in the corridor and the average freeway travel speed. These values should not be construed as origin-to-destination trip times, but rather as measures of relative travel time for comparison purposes. A comparison of the travel time values with the associated number of carpools in each corridor does not indicate that a higher travel time for an individual corridor results in a greater number of carpools. However, given that congestion in all six of these corridors is extreme and the HOV lanes offer a time-saving incentive, carpooling levels overall are very high in comparison to typical non-HOV corridors.

- **Longer trip lengths** - Longer trip lengths are associated with a greater likelihood to carpool. All trip lengths shown in Table 17 could be considered high, but there does not appear to be a relationship between trip length and propensity to carpool when examining the six corridors individually.

- **Larger household size** - Larger household size is associated with higher levels of carpooling. In this case, the values for household size indicate an inverse relationship over what would be expected. For instance, the Southwest and East RLT corridors show lower household sizes, yet they experience the higher end of the range in the number of carpoolers.

- **Income lower than $30,000** - Income is an indicator of automobile ownership. The higher the income, the greater the automobile ownership and the less the propensity to carpool. The income data appear to support this presumption in these six corridors and warrant further analysis. The Katy corridor has the lowest percentage of lower income households and the lowest carpooling values. The 3+ occupancy restriction in the peak hours certainly has an impact on the lower incidence of carpooling in comparison with other corridors. The higher carpooling numbers in the East RLT and Southwest corridors are consistent with higher percentages of lower income households.

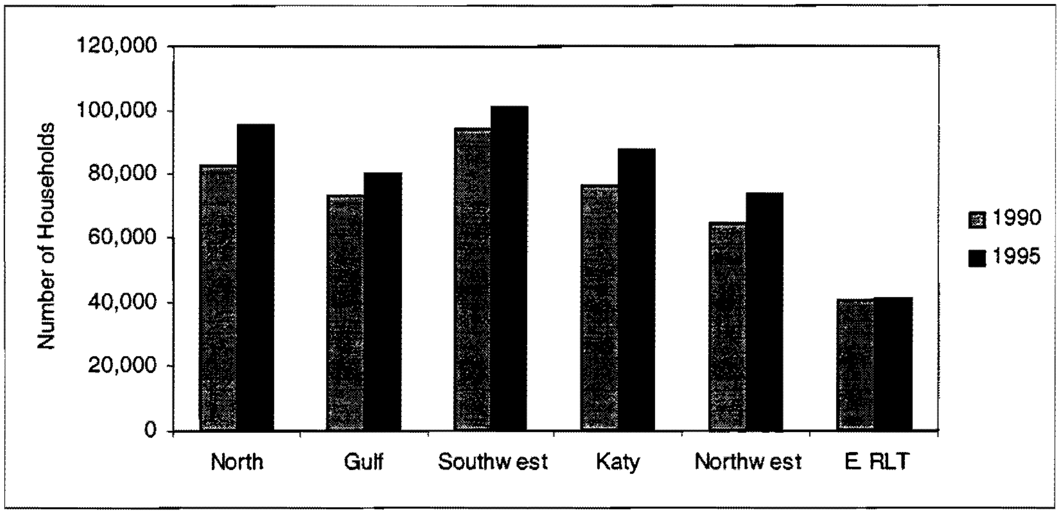


Figure 34. Number of Households in Corridor

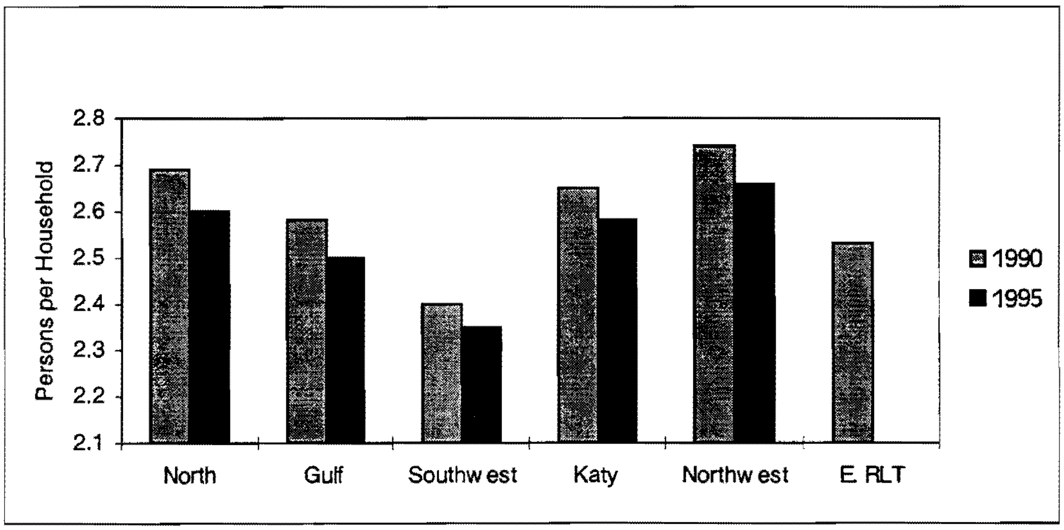


Figure 35. Average Household Size

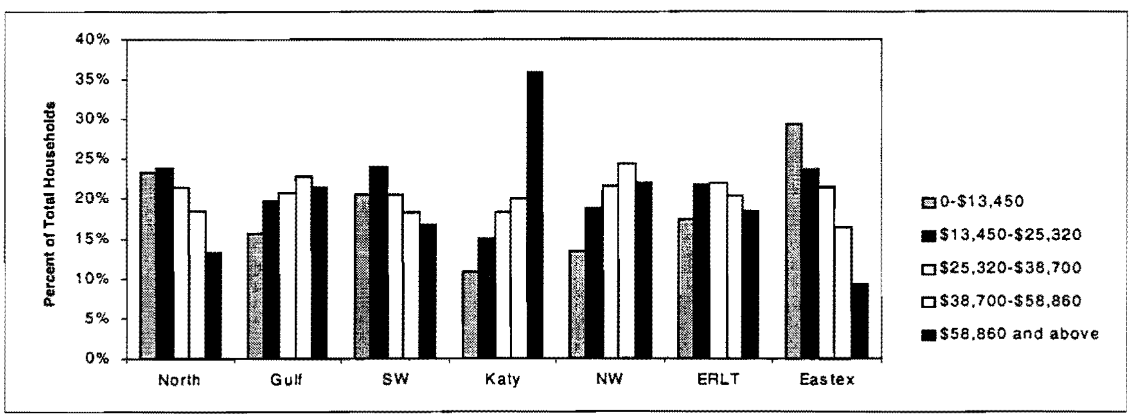


Figure 36. Income Distribution in Corridor

With the exception of household size and parking costs, the factors that are typically considered conducive to carpooling are fairly consistent with the HOV corridors in Texas. By virtue of their design, the HOV lanes provide a time-saving incentive that accommodates longer travel times and greater trip lengths. Income level is the other factor that appears to have a minor influence on the propensity to carpool in these corridors. The high levels of carpooling on the HOV facilities in Texas are particularly notable when considering the overall decline in carpooling throughout the country.

National Trends in Carpooling

On the national level carpooling has declined dramatically since 1970, according to an in-depth study by Ferguson of data from the U.S. Census and National Personal Transportation Study (NPTS) *(15)*. Between 1970 and 1990, all alternatives to driving alone, except telecommuting, lost some market share, with carpooling falling more dramatically than any of the others. Average vehicle occupancy has declined from 1.15 in 1980 to 1.09 in 1990. The 32 percent drop in carpooling is attributed to several demographic and socioeconomic factors. Greater auto availability associated with higher income levels and the effects of auto-oriented urban form are the two most important factors in explaining the carpooling decline.

In another study of the socioeconomics of urban travel by Pucher, et al. based on 1995 NPTS data, car ownership increased 146 percent from 1969 to 1995, six times faster than population growth *(16)*. During the same time period average trip length increased, carpooling declined, and public transit lost market share. Lower income households were found to have fairly high levels of auto ownership, indicating similar auto-dependency as the rest of the population. And surprisingly, the lowest income households traveling by car do not necessarily have a greater propensity to carpool than the wealthiest households. The authors conclude that the flexibility and convenience of solo auto use offset the cost savings of carpooling, even in households with limited incomes.

All of this evidence suggests that HOV lanes have an increasingly difficult time in providing an incentive to solo drivers to retreat from their single-occupant vehicles and form carpools. It may be that there is a maximum level of carpooling that can be attained in a corridor given the socioeconomic characteristics of the travelers in the corridor. Despite the momentum against carpooling, the HOV lanes in Texas have maintained high levels of carpooling, and have provided an incentive for ridesharing and carpool formation even in the face of socioeconomic influences that have contributed to the increase in solo driving at the national level. For example, the non-HOV lane control facility monitored in this study reflects the national trend, showing a 26 percent drop in carpools and a 5 percent decline in overall average vehicle occupancy until recent changes in the corridor that increased bus ridership. Despite the fact the Texas HOV lanes have seen a slight decline in average vehicle occupancies, the freeway corridors with HOV lanes have demonstrated a 100 percent increase or greater in carpooling during the same time period as the national decline, and now exhibit average vehicle occupancies of 1.24 to 1.51 persons per vehicle.

TRANSIT UTILIZATION OF HOV LANES

Bus transit usage has been extremely important to the success of HOV lanes in Texas. Transit agencies in the two cities with operating HOV lanes - Houston METRO and Dallas Area Rapid Transit (DART) - have played integral roles in the planning and operation of successful HOV lanes in their respective communities. Since 1979, Houston has experienced continuous development of HOV lanes, in large part as a result of the emergence of METRO as a well-financed transit agency with a long-range plan dependent upon HOV lanes. DART's involvement in the development of the barrier-separated contraflow lane on East R.L. Thornton has led to enhanced transit service and reduced bus operating costs in the corridor. The HOV lanes in Texas that are considered highly effective have the common characteristic of high bus transit ridership.

The importance of bus transit is illustrated in Figures 37. Figure 37 shows the percentage of total persons in the morning peak hour that are using the HOV lane, broken down by carpool and bus transit. A bar showing the percent of total lane capacity represented by the HOV lane is shown as a comparison. It is provided for this reason: if, for example, the HOV lane was instead a typical general purpose lane, then logically it would carry an equal proportion of people in the peak hour as the remaining lanes. One of the primary objectives of HOV lanes is to increase average vehicle occupancy and consequently increase person-movement, so the expectation is that an HOV lane will carry more people than a general-purpose lane.

As is evident in Figure 37, carpools provide the bulk of the person volume on HOV lanes in the morning peak hour. However, bus transit offers the obvious margin of difference. For instance, the HOV lane on the North Freeway would not be carrying twice the person volume of an adjacent general-purpose lane were it not for the bus transit component. While it is reasonable to speculate that carpool values would increase in the absence of transit, carpooling alone could not provide the significant person-movement percentages without a breakdown in the HOV lane level of service. The experience of the Katy Freeway, which now requires three occupants in carpools during the peak hour due to vehicle overutilization, is a testament to the practical person-movement limitations of HOV lanes exclusively used by carpools.

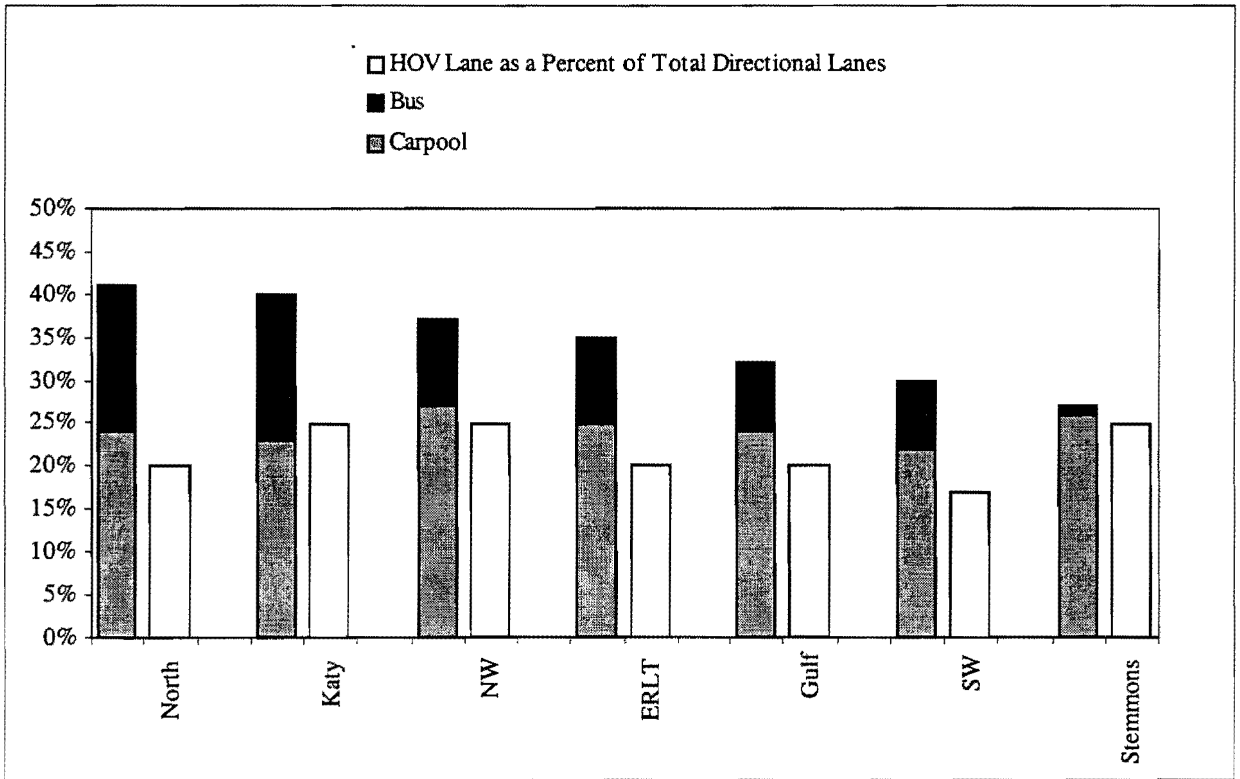


Figure 37. Percent of Peak-Hour Persons Moved on the HOV Lane

Source: Texas Transportation Institute data collection, see appendices

CHAPTER 12. HISTORY OF HIGH-OCCUPANCY VEHICLE LANE DEVELOPMENT IN TEXAS

HOUSTON

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

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

It became evident that, under certain conditions, a significant unserved demand for high-speed, high-quality transit existed in at least some Houston travel corridors. The success of the relatively modest contraflow project and the emergence of METRO as a well-financed transit agency with a long-range plan dependent upon HOV lanes brought about a large-scale commitment in Houston to the HOV concept. As a result, since 1979, the Houston area has seen continuous development of barrier-separated, high-occupancy vehicle projects. The appendices include a listing of milestone dates in the development of the Houston HOV system. Table 18 illustrates the current status of the Houston HOV system.

The Planned System

A commitment is in place in the Houston area to develop approximately 103 mi of high-occupancy vehicle lanes (Figure 38). As of December 1997, five separate HOV facilities totaling 67 mi of barrier-separated, high-occupancy vehicle lanes were operating.

Recent changes in the system include the opening of the first phase of the Southwest HOV lane in January 1993 and the extension of the Gulf HOV lane south to Almeda-Genoa (an extension of 5.1 mi).

Table 18. Status of the Houston High-Occupancy Vehicle Lane System, December 1997

HOV Facility	Date First Phase Opened	Miles in Operation	Ultimate System Miles	Vehicles Allowed to Use HOV Lane	Hours of Weekday Operation[1]
Katy (I-10W)	October 1984	13.1	15.3	3+ vehicles from 6:45 to 8:00 a.m., 5:00 to 6:00 p.m.; 2+ during other operating hours	5 a.m. to 11 a.m. inbound 2 p.m. to 8 p.m. outbound
North (I-45N)	November 1984[2]	12.22	19.9	2+ vehicles	5 a.m. to 11 a.m .inbound 2 p.m. to 8 p.m. outbound
Gulf (I-45S)	May 1988	11.3	17.7	2+ vehicles	5 a.m. to 11 a.m. inbound 2 p.m. to 8 p.m. outbound
Northwest (U.S. 290)	August 1988	14.9	13.5	2+ vehicles	5 a.m. to 11 a.m. inbound 2 p.m. to 8 p.m. outbound
Southwest (U.S. 59S)	January 1993	11.54	15.0	2+ vehicles	5 a.m. to 11 a.m. inbound 2 p.m. to 8 p.m. outbound
Eastex (U.S. 59N)	Not open in 1997	---	20.2	---	---
Westpark Corridor	Not open in 1997	---	4.5	---	---
Total		64.3	166.0 (103.2)		

[1]Beginning in October 1989, the Katy and Gulf HOV lanes were opened to 2+ carpools on weekends; those facilities operate outbound on Saturday (4 a.m. to 10 p.m.) and inbound on Sundays (4 a.m. to 10 p.m.). In June 1990, the North HOV lane opened on weekends, and in October 1990 the Northwest HOV lane opened on weekends. Weekend use of all HOV lanes except the Katy was discontinued in October 1991 due to low usage.
[2]A contraflow lane was implemented on the North Freeway in August 1979. It was replaced with a barrier-separated, reversible lane in November 1984.

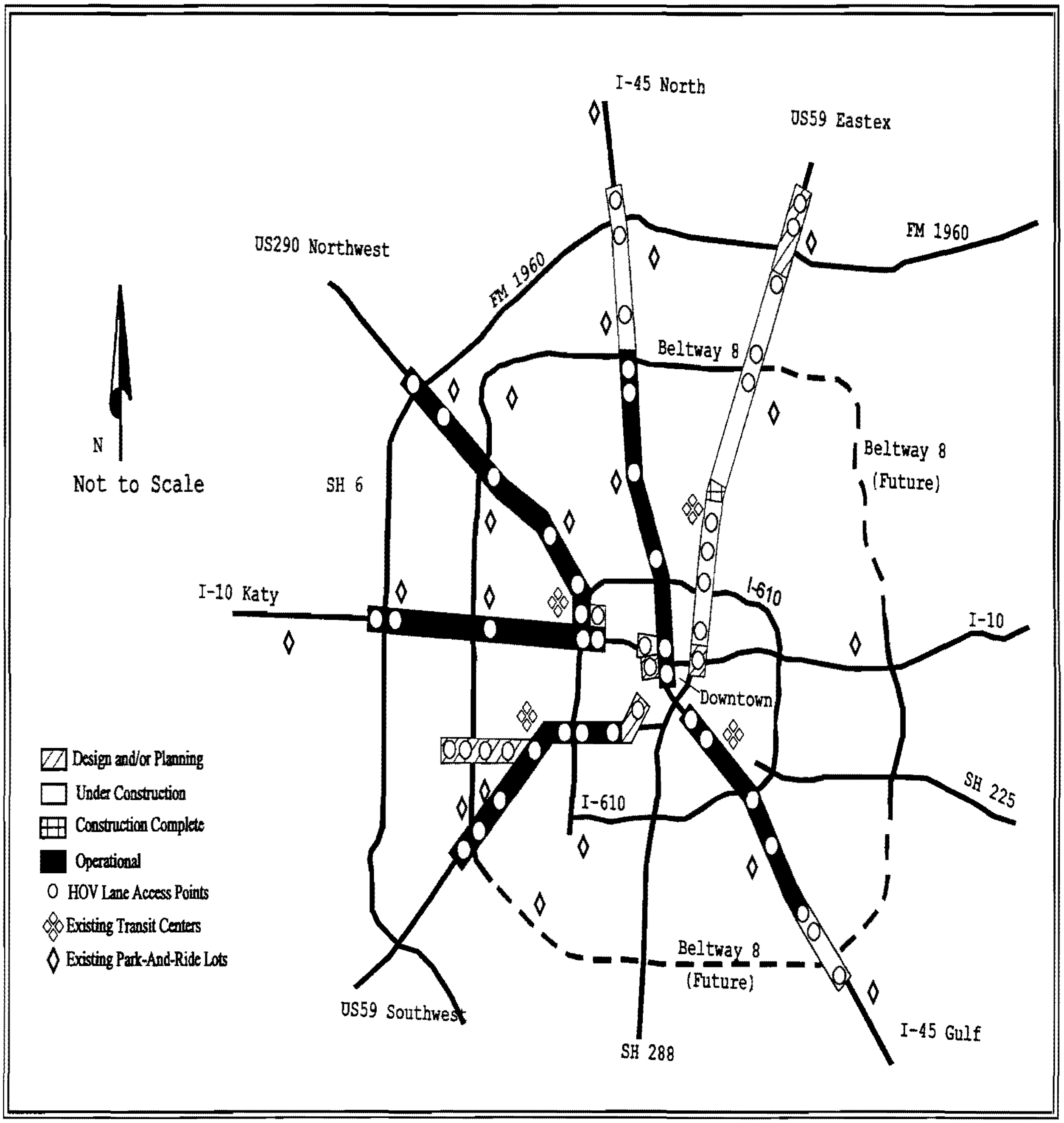


Figure 38. Status of Houston HOV Lane System, December 1997

DALLAS

Dallas began experiencing significant traffic congestion in the late 1980s. Influenced by the success of HOV lanes in Houston and other areas of the nation, TxDOT and DART made a decision to test the high-occupancy vehicle lane concept in Dallas. A 5.2 mi barrier-separated contraflow lane was consequently developed and opened for operation on East R.L. Thornton (East RLT) Freeway (I-30E). This contraflow lane (which opened in September 1991) reserves the inside freeway lane in the off-peak direction for use by carpools, vanpools, and buses.

Similar to the I-45 contraflow lane project in Houston, the East RLT contraflow lane in Dallas has enjoyed some success. Less than one year after opening, the contraflow lane was serving 16,000 daily person trips and saving its users approximately one minute per mile in travel time during the morning peak hour. The early success of the East RLT contraflow lane has helped give rise to a plan for constructing additional HOV lanes in the Dallas urban area.

The second HOV lane in Dallas began operation in September 1996. The Stemmons Freeway (I-35E) interim concurrent flow lanes were constructed on the existing inside shoulders of the general-purpose lanes between I-635 and FM 3040. The facility provides 24-hour operation.

The Planned System

A network of nearly 250 miles of permanent HOV lanes is being considered for the Dallas area. The Dallas District of TxDOT and DART, however, have been implementing low-cost, short-term (interim) transit projects, such as concurrent flow HOV lanes, that will enhance public transportation and overall mobility until permanent treatments can be implemented. The interim HOV lanes, which are detailed in Table 19, are retrofitted into the existing cross section of freeways and typically require design exceptions such as elimination of the inside shoulder and/or narrowing of the freeway general-purpose lanes to accommodate the HOV facility. The interim HOV lanes will likely operate until permanent treatments can be implemented. The current plan for the Dallas HOV system is illustrated in Figure 39.

Table 19. Status of the Dallas High-Occupancy Vehicle Lane System, December 1997

HOV Facility	Date First Phase Opened	Miles in Operation	Ultimate Miles	Vehicles Allowed to Use HOV Lane	Hours of Weekday Operation
East R.L. Thornton (I-30) Interim Contraflow Lane	September 1991[1]	5.2	5.2	2+ vehicles	6 a.m. to 9 a.m. IB 4 p.m. to 7 p.m. OB
North Stemmons (I-35E) Interim Concurrent Flow Lanes	September 1996	6.8 IB 5.5 OB	7.3 IB 6.0 OB	2+ vehicles	24 hours, including weekends
LBJ (I-635) Interim Concurrent Flow Lanes	March 1997	6.5 EB 6.2 WB	6.5 EB 6.2WB	2+ vehicles	24 hours, including weekends
South R.L. Thornton (I-35E) Interim Barrier-Separated Reversible Lane[2]	Not open in 1997	---	6.0	---	---
Marvin D. Love (U.S. 67) Interim Concurrent Flow Lanes[2]	Not open in 1997	---	3.9 IB 3.9 OB[3]	---	---
North Central Expwy. (U.S. 75) Barrier-Separated Reversible Lane[3]	Not open in 1997	---	9	---	---
Total		20.3	53.0		

NOTE: IB = inbound, OB = outbound

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

[2]An HOV lane is scheduled for completion in 2000.

[3]HOV lane schematics are currently being prepared for this corridor north of I-635. An exact date and length has not been determined at this time.

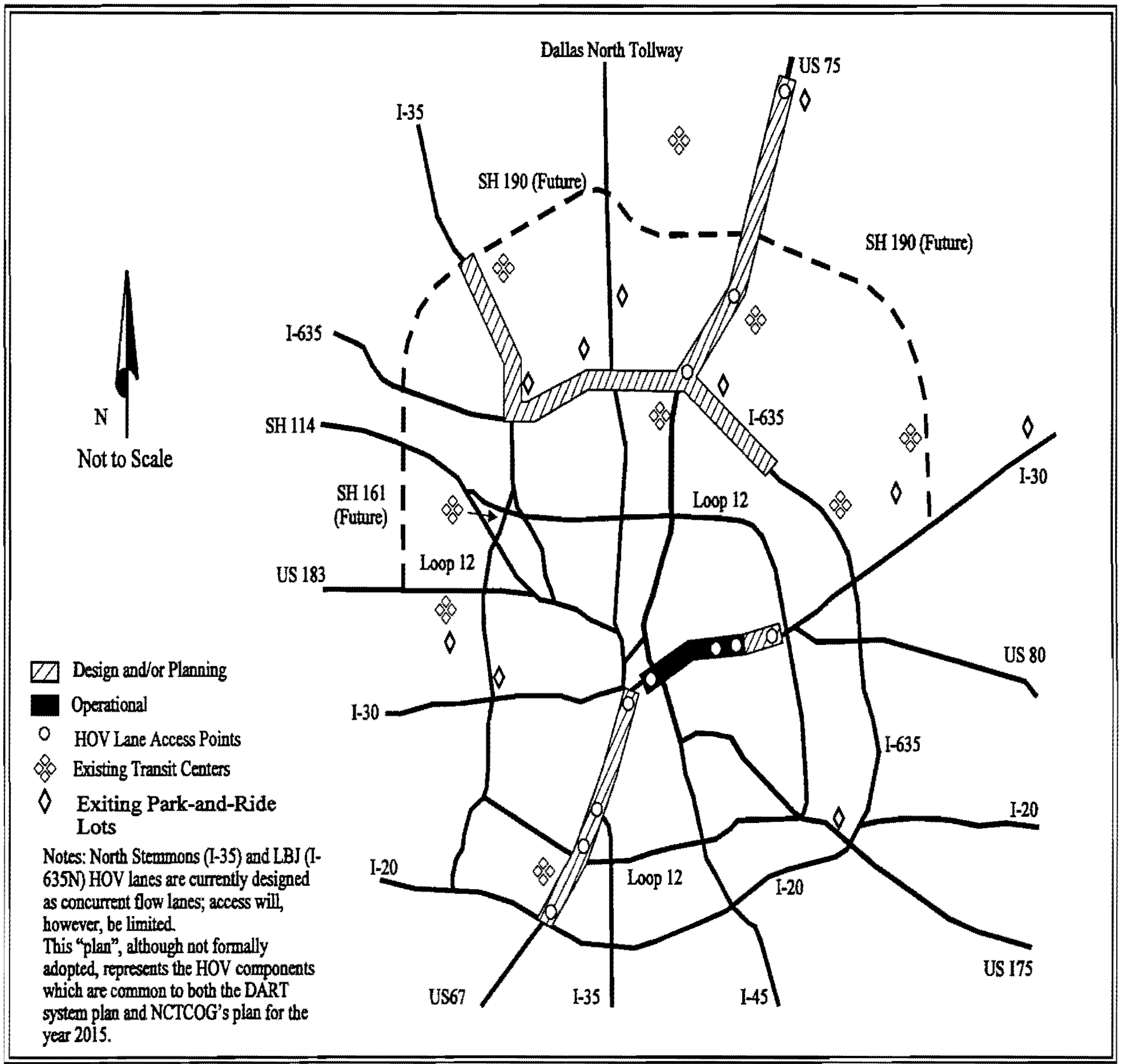


Figure 39. Status of the Dallas HOV Lane System, December 1997

OTHER MAJOR TEXAS URBAN AREAS

While there are no HOV lanes which are currently in operation outside of those in Dallas and Houston, the following urban areas are examining such facilities at varying degrees of planning and/or design.

Austin

A recently completed urban areawide study addresses HOV facility feasibility on Austin's freeway system and major arterials. Advanced planning and design for I-35 currently includes HOV applications from Parmer Lane on the north to Slaughter Lane on the south for most long-range alternatives. Major investment studies (MISs) are either in progress or soon to be initiated in most of the major freeway and arterial street corridors, including U.S. 183 and Loop 1.

Fort Worth

A feasibility study for HOV facility implementation on Fort Worth's freeways has been completed. As a result of this study, plans for a reversible, barrier-separated HOV facility on I.H. 820 (Northeast Loop) and S.H. 183/S.H. 121 (Airport Freeway) have reached the engineering design stage. This proposed facility will stretch from I-35W to the Dallas County line (a distance of approximately 17 mi). Right-of-way or envelopes of space are also being purchased and/or preserved for future HOV lanes on the East Freeway (I-30E), West Freeway (I-30W), South Freeway (I-35W), and possibly the proposed Southwest Freeway/Tollway (S.H. 121 South). A MIS for I-30 is underway.

San Antonio

A long-range plan assessing HOV lane feasibility was completed in December 1994 for San Antonio. This analysis addressed both freeways and major arterials. The results of the study provide a guide for identifying corridors in which HOV alternatives need further study through a Major Investment Study (MIS). A MIS has been developed on IH 410 (Culebra Road to I-35 North) and I-35 (north from Loop 1604 to IH 37/U.S. 281). The MIS on IH 410 concluded HOV lanes were not the preferred alternative. The MIS on IH 35 concluded the addition of two barrier-separated express lanes in each direction with one lane being general purpose and the second lane being an HOV lane was the preferred alternative. The schedule for implementation is undetermined at this time.

CHAPTER 13. PHYSICAL CHARACTERISTICS OF HIGH-OCCUPANCY VEHICLE LANES IN TEXAS

HOUSTON

While some sections of two-direction HOV facilities are being developed, the typical Houston HOV lane is located in the freeway median, is approximately 20 ft wide, is reversible, and is separated from the general-purpose freeway mainlanes by concrete median barriers (Figure 40).

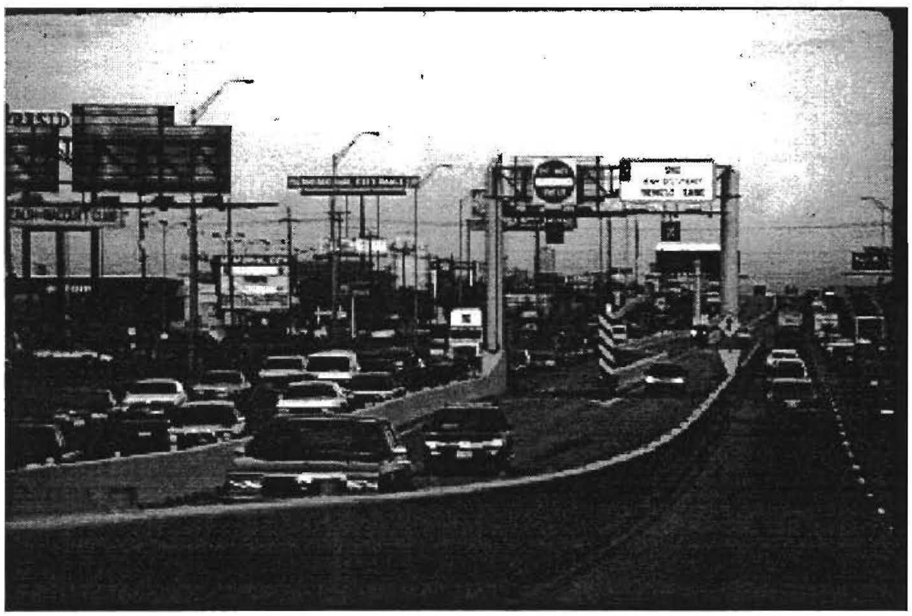


Figure 40. HOV Lane in the Median of the Katy Freeway

Access to the median HOV facilities is provided in a variety of manners. At some locations, "slip ramps" provide access and egress to/from the inside freeway lane (Figure 41). While these are relatively inexpensive, depending on their location, they may create a variety of operational problems. As a consequence, grade-separated interchanges of various designs provide most access to the median HOV lanes (Figure 42.) The HOV lanes become elevated in the median, and ramps go over the freeway lanes to connect with streets, park-and-ride lots, or bus transfer centers. These grade-separated interchanges are typically constructed at a cost in the range of $2 to $7 million each; access to the HOV lanes is typically provided at 3 to 5 mi intervals. In some locations, implementation of the Houston HOV lanes was accomplished by narrowing freeway lanes to 11 ft and reducing inside shoulder widths. A typical section is shown in Figure 43.

Figure 41. Slip Ramp for HOV Lane Access/Egress on Katy Freeway

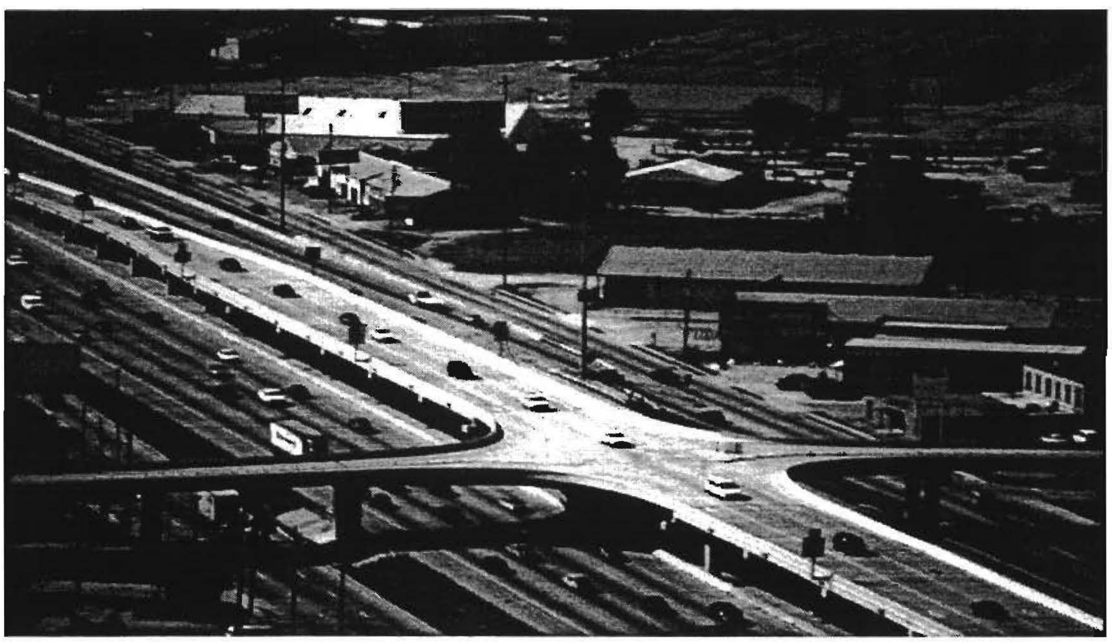


Figure 42. Example of Grade-Separated HOV Lane Interchange

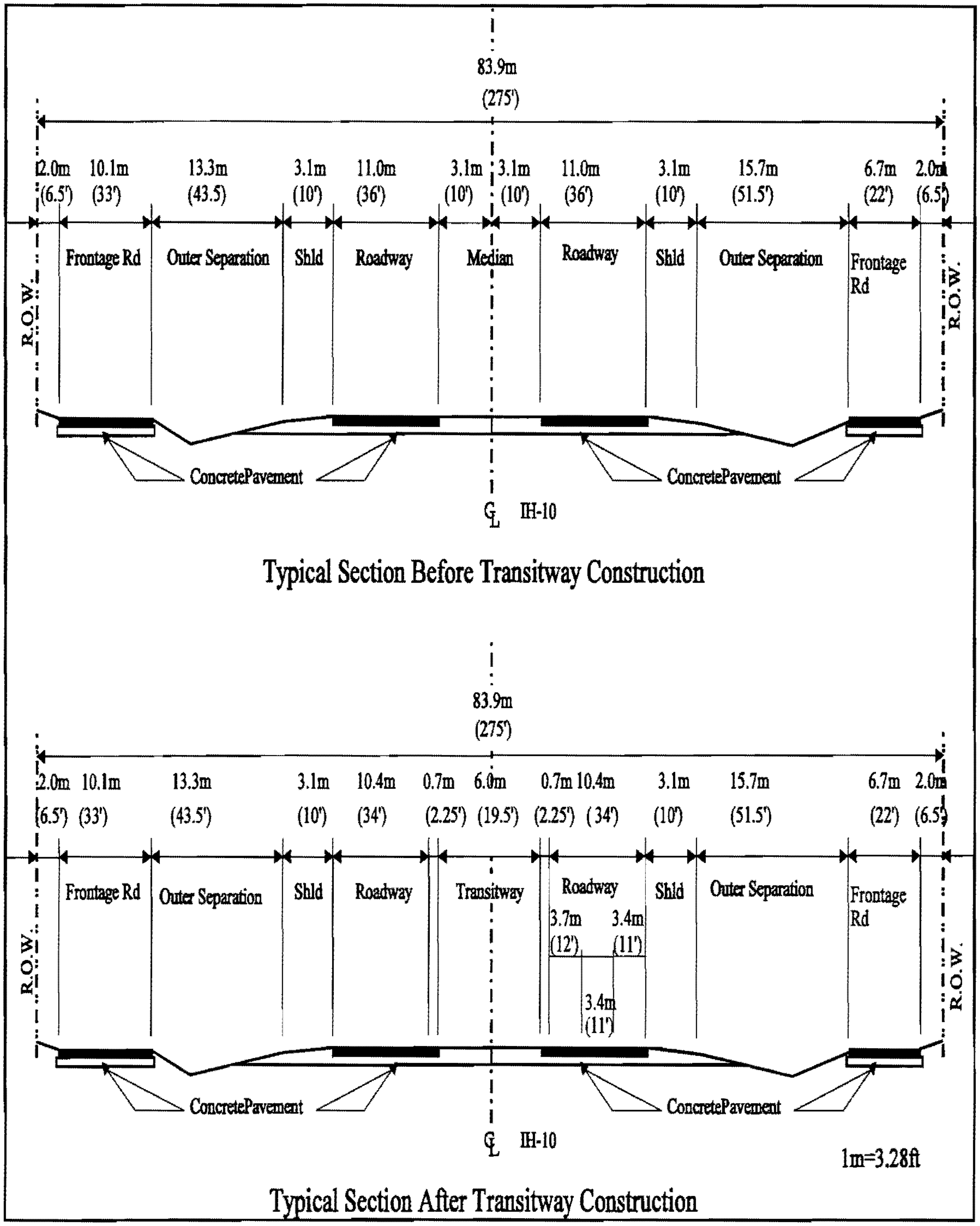


Figure 43. Typical Sections, Before and After Katy HOV Lane Construction

DALLAS

The East RLT HOV lane in Dallas is a movable barrier contraflow lane (Figure 44). The movable barrier, which is used to create the 20 ft wide HOV lane, consists of 3 ft concrete segments joined together by pins. The flexibility created by these pins allows the barrier machine (Figure 44) to shift the barrier approximately 22 ft laterally to create an extra travel lane for the peak direction of flow. The implementation of this HOV lane was accomplished by narrowing freeway lane widths to 11 ft and reducing the inside shoulder of the freeway in some locations (Figure 45). Slip ramps such as the one shown in Figure 46 provide access to, and egress from, the East RLT HOV lane.

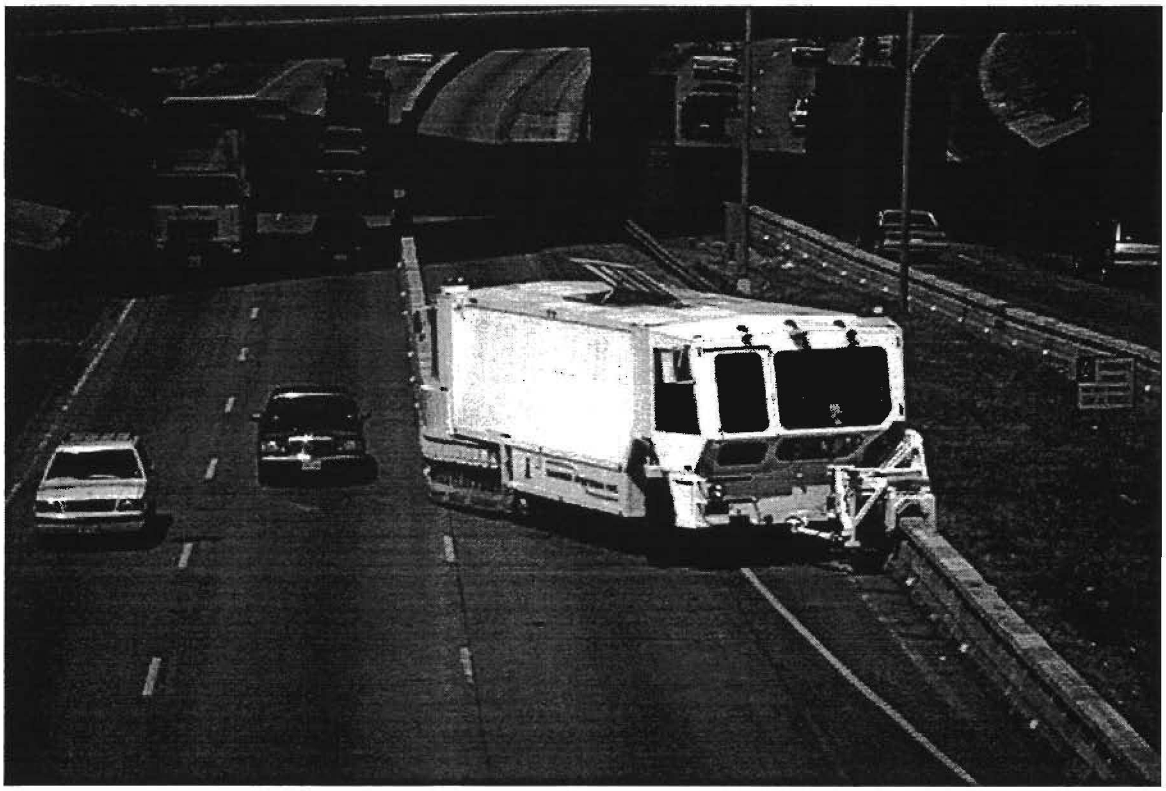


Figure 44. Machine Used to Shift Moveable Concrete Barrier on East R.L. Thornton

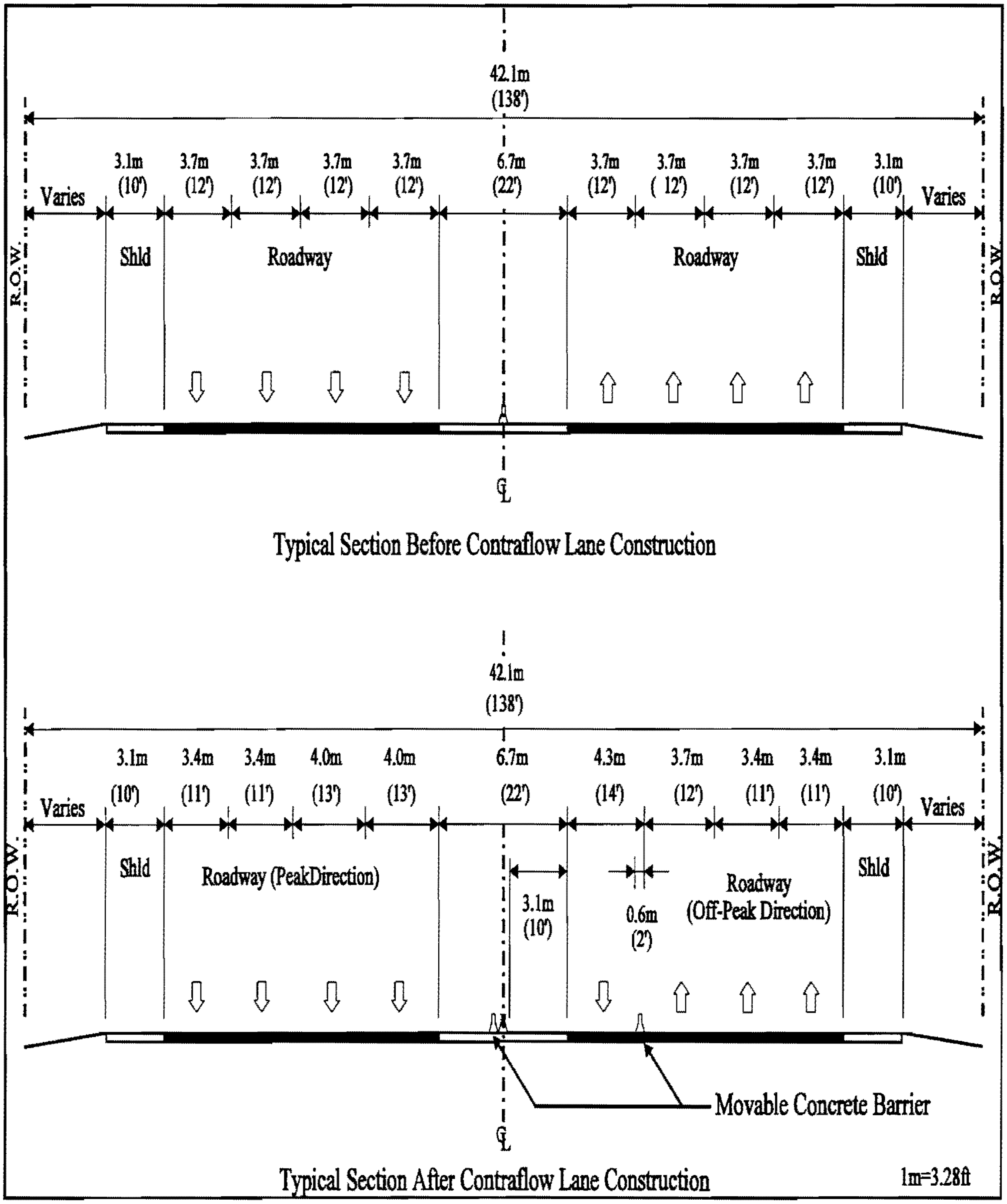


Figure 45. Typical Sections, Before and After East R.L. Thornton Contraflow Lane Construction

Contraflow Lane - The HOV facility consists of a freeway lane in the off-peak direction of travel, the innermost lane, and is designated for exclusive use by the direction general-purpose travel lanes by a moveable barrier. The HOV lane is operated during the peak periods only.

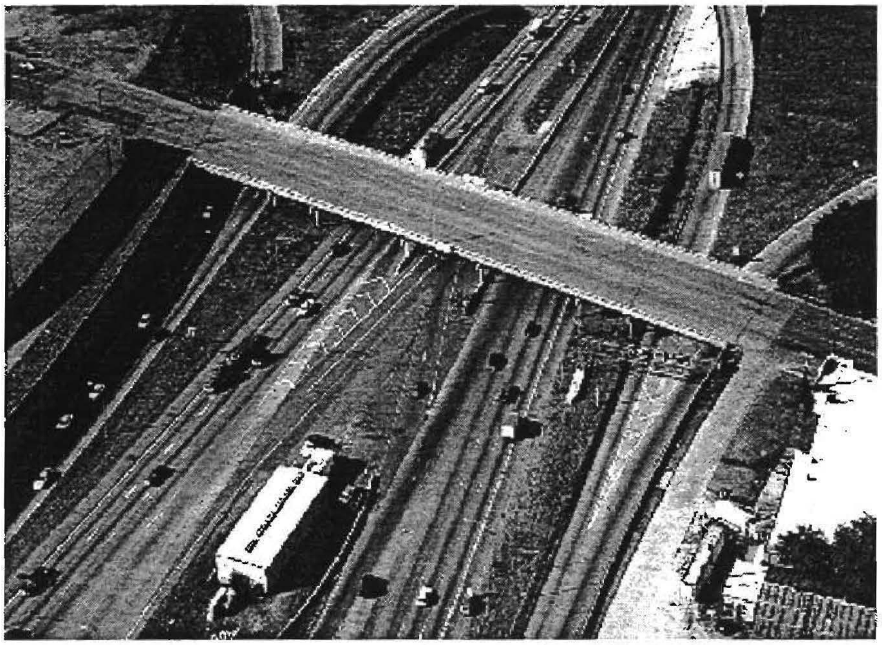


Figure 46. Example of Access Point on East R. L. Thornton HOV Lane

The Stemmons Interim HOV lanes in Dallas consist of a concurrent flow lane in each direction. The implementation of these HOV lanes was accomplished by narrowing freeway lane widths to 11 ft and reducing the inside shoulder of the freeway (Figure 47). The HOV lanes are 11.5 ft wide and are separated from the general-purpose lanes by a 2.5 ft striped buffer. Access and egress points are limited to two locations each direction.

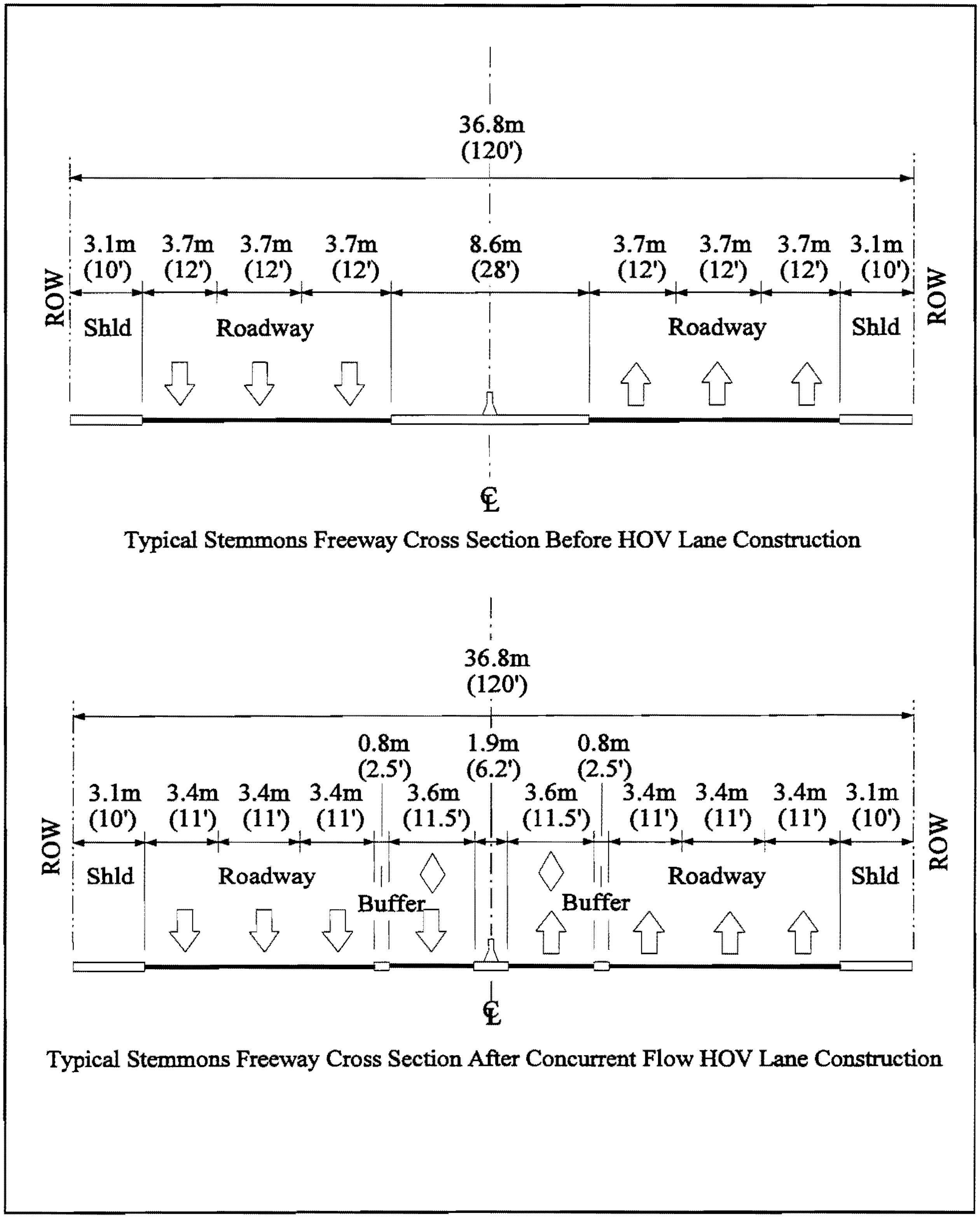


Figure 47. Stemmons Freeway HOV Implementation Cross Section

CHAPTER 14. CHARACTERISTICS OF HIGH-OCCUPANCY VEHICLE LANE USERS

On several occasions, TTI has surveyed both bus patrons and carpoolers using the HOV facilities. Those surveys, which are thoroughly documented elsewhere, are highlighted herein (*5*). The most recent surveys were completed in 1994 and include the East R.L. Thornton HOV facility in Dallas, along with all the HOV corridors in Houston.

TRANSIT SURVEYS

Table 20 summarizes selected data from the surveys. The HOV facilities have attracted young, educated, white-collar professionals to ride transit. The bus is being used to serve long-distance commute trips, primarily to downtown. These individuals are using the HOV lanes primarily to save time, avoid driving in congested traffic, have time to relax, and have a reliable trip time. The bus patrons are transit users by choice, with over 85 percent having an auto available for the trip in Houston and approximately 70 percent having an auto available in the East R.L. Thornton corridor in Dallas. Over 60 percent of the bus passengers have all or part of their bus fare paid by their employer. Interestingly, on the two Houston HOV facilities surveyed in 1994 that have been open to carpool use for at least five years (Katy and Northwest), about half of the bus riders have at some time carpooled or vanpooled on the HOV lane. By comparison, approximately 25 percent of East R.L. Thornton HOV lane bus riders have carpooled on the HOV lane. This Dallas HOV lane has now been in operation for seven years.

Carpool and Vanpool Surveys

Carpoolers also tend to be young, educated, white-collar professionals (Table 21). They are using the HOV lane for a long-distance commute trip. The carpools are more effective at serving dispersed trip patterns; compared to bus patrons, fewer destinations are in the downtown area. Over 60 percent of the carpools are made up of family members. Approximately 20 percent of the carpools on Houston HOV lanes form at either a park-and-ride or a park-and-pool lot, which compares to only 6 percent for East R.L. Thornton in Dallas.

Freeway Motorist Surveys

As indicated in Table 22, motorists using the general-purpose lanes in HOV lane corridors tend to be slightly older and a greater percentage are men (compared to HOV lane transit users and carpoolers). Trip destinations for freeway motorists are extremely dispersed with a comparatively small percentage commuting to downtown. Compared to transit users and carpoolers, a smaller percentage of freeway motorists commuting during the peak periods of travel indicate their occupations as professionals.

Table 20. Selected Characteristics of HOV Lane Bus Patrons, 1994

Characteristic	HOV Lane				
	Katy	North[1]	Northwest	Gulf[2]	East R.L. Thornton
A.M. Trip Destination (Houston/Dallas)					
Downtown	93%	91%	95%	86%	88%
Galleria, Post Oak/Las Colinas	2%	0%	1%	1%	1%
Greenway Plaza/Market Center	0%	1%	1%	0%	1%
Texas Medical Center/Park Central	2%	6%	1%	5%	1%
Other	3%	--	2%	--	9%
Trip Purpose (% Work)	99%	98%	99%	96%	88%
Age, Years (50th Percentile)	38	38	38	34	37
Sex (% Male)	43%	40%	49%	30%	29%
Education, Years (50th Percentile)	15	15	15	14	14
Occupation					
Professional	61%	43%	56%	41%	42%
Managerial	13%	17%	13%	16%	6%
Clerical	19%	30%	25%	32%	29%
Sales	3%	3%	4%	2%	3%
Service	2%	---	1%	---	5%
Auto Available for Trip (% Yes)	95%	95%	96%	87%	69%
Does Employer Pay for Transit[1]					
Yes, All	17%	16%	17%	14%	---
Yes, Part	44%	48%	54%	48%	---
No	39%	36%	29%	38%	---
Why Use HOV Lane[1]					
Freeway Too Congested	20%	23%	---	---	---
Saves Time	16%	20%	---	---	---
Time to Relax	18%	15%	---	---	---
Reliable Trip Time	14%	15%	---	---	---
Costs Less	14%	12%	---	---	---
Dislike Driving	11%	10%	---	---	---
Have You Carpooled on HOV Lane (% Yes)	56%	32%	58%	---	25%

[1]Data from 1990 transit user survey.
[2]Data from 1989 transit user survey.
Source: Texas Transportation Institute surveys.

Table 21. Selected Characteristics of Carpoolers Using the HOV Facilities, 1994

Characteristic	HOV Lane				
	Katy	North[1]	Northwest	Gulf[2]	East R.L. Thornton
A.M. Trip Destination (Houston/Dallas)					
Downtown	66%	76%	42%	78%	71%
Galleria, Post Oak/Las Colinas	3%	3%	32%	6%	3%
Greenway Plaza/Market Center	2%	2%	6%	2%	4%
Texas Medical Center/DFW Airport	5%	7%	6%	4%	1%
Other	24%	12%	14%	10%	21%
Trip Purpose					
% Work	88%	95%	95%	98%	92%
% School	8%	5%	4%	2%	5%
Age, Years (50th Percentile)	38	37	39	38	41
Sex (% Male)	48%	53%	53%	41%	45%
Education, Years (50th Percentile)	15	15	15	14	14
Occupation					
Professional	53%	38%	57%	46%	54%
Managerial	19%	21%	18%	15%	16%
Clerical	11%	21%	13%	26%	17%
Sales	2%	11%	6%	4%	4%
Service	3%	---	2%	---	5%
Why Use HOV Lanes[2]					
Freeway Too Congested	19%	20%	---	---	---
Saves Time	20%	20%	---	---	---
Time to Relax	14%	13%	---	---	---
Reliable Trip Time	12%	13%	---	---	---
Costs Less	14%	15%	---	---	---
Who Makes Up Carpool					
Family Members	64%	61%	68%	---	60%
Neighbors	6%	13%	8%	---	8%
Co-workers	30%	25%	32%	---	32%
Does Carpool Stage at Park/Pool Lot (% Yes)	23%	11%	19%	---	6%

[1]Data from 1990 survey.
[2]Data from 1986 survey.
Source: Texas Transportation Institute surveys.

Table 22. Selected Characteristics of Freeway Motorists, 1994

Characteristic	Freeway		
	Katy	Northwest	East R.L. Thornton
A.M. Trip Destination (Houston/Dallas)			
Downtown	13%	15%	27%
Galleria, Post Oak/Las Colinas	13%	17%	9%
Greenway Plaza/Market Center	2%	6%	7%
Texas Medical Center/DFW Airport	3%	6%	3%
Other	69%	56%	54%
Trip Purpose			
% Work	91%	94%	92%
% School	2%	2%	2%
Age, Years (50th Percentile)	42	42	42
Sex (% Male)	60%	57%	54%
Education, Years (50th Percentile)	15	14	14
Occupation			
Professional	48%	45%	46%
Managerial	18%	18%	15%
Clerical	11%	13%	13%
Sales	11%	11%	6%
Service	4%	4%	8%

Source: Texas Transportation Institute Surveys.

CHAPTER 15. CONCLUSIONS

Based on our collective HOV lane evaluation experience of more than a decade, the researchers who have participated in the HOV lane evaluations have drawn the following general conclusions. While these conclusions are based more on the preponderance of evidence than on an experimental design, they are well supported by the research, which has produced consistent results throughout the study period.

PERSON-MOVEMENT

- Texas HOV lanes move a greater volume of people per lane than a general-purpose lane - from 10 percent up to 120 percent. HOV lanes have a greater positive impact than a general-purpose lane on person-movement efficiency in a corridor by carrying more persons per directional lane with fewer vehicles.

- The data clearly show that the presence of an HOV lane has resulted in a meaningful increase in average vehicle occupancy. All Texas freeways with HOV lanes that were reviewed in this study have higher average vehicle occupancies than the national average, and those HOV lanes that have operated in a stable environment over time have experienced increases in average vehicle occupancy of 10 percent or more.

Carpooling

- Implementation of the HOV lanes appears to have lengthened the median life of a carpool and increased the volume of carpools. Freeways without HOV lanes have experienced a decline in carpooling. Surveys indicate that the HOV lane is an important factor in the decision to carpool. On freeway corridors that did not experience high carpooling prior to implementation of an HOV lane, the data suggest that 40 percent to 50 percent of the current HOV carpoolers formed a carpool as a result of the HOV facility.

- The HOV lanes in Texas have shown that it is possible to increase the average number of people in each vehicle. The average in Texas HOV corridors ranges from 1.24 to 1.5, versus a national average of 1.09 in 1990. Carpooling has increased by more than 100 percent on Texas HOV lanes. This Contrasts with national declines of 32 percent from 1970 to 1990.

Bus Transit

- Bus transit usage is extremely important to the success of HOV lanes. The highly effective HOV lanes in Texas would only be marginally effective if bus transit were removed.

- The presence of an HOV lane has the potential to increase bus ridership by as much as 60 percent in corridors where transit is not a predominant mode before HOV lane implementation.

- Compared to conditions that existed prior to HOV lane implementation, average bus operating speeds have increased dramatically. On average, peak-hour bus operating speeds have more than doubled, increasing on average from 25 mph to 52 mph. As a result, schedule times have been cut significantly, making bus travel a substantially more attractive alternative.

TOTAL ROADWAY EFFICIENCY

- The implementation of HOV lanes in Texas has resulted in corridor efficiency increases ranging from 30 percent to 140 percent during the peak-hour. Total roadway efficiency is a measure that combines the number of people using the entire facility in the peak hour with the speed at which they travel.

IMPACT ON GENERAL-PURPOSE LANES

- Construction of HOV lanes has frequently involved narrowing traffic lanes and inside shoulders, yet these changes have not created operational problems for adjacent freeway lanes, either in terms of freeway speeds or crash rates.

COST-EFFECTIVENESS

- The benefits offered by individual Texas HOV lanes outweigh the costs for implementation, including annual operations and enforcement costs, by margins ranging from 8:1 to 48:1. In all cases, the benefit-to-cost ratio for the HOV lane exceeded that of a general-purpose lane alternative.

- The volume of traffic on the general-purpose lanes is the most important variable in determining the potential cost-effectiveness of an HOV lane, because high-traffic volumes slow freeway speeds, thus making the HOV lane attractive.

- Construction cost is also an important determining factor in cost-effectiveness evaluations. Support facilities such as park-and-ride lots and transit centers play an important but delicate role: they are crucial to making HOV lanes accessible and attractive, but they can be expensive and if overdone, can reduce the B/C ratio of a project.

PUBLIC SUPPORT

- Survey data suggest relatively strong public support for the HOV lane programs from both users and non-users in corridors with HOV lane improvements, although non-users generally consider the lanes to be underutilized both in terms of vehicle usage and person-movement. The issue of perceived HOV lane utilization among non-HOV users will continue to be an issue associated with the implementation of HOV lane programs.

AIR QUALITY AND FUEL CONSUMPTION

- The techniques and methods available to conduct air quality and energy savings evaluations of HOV lanes clearly need to be enhanced in order to strengthen policy arguments based on these two criteria. A simulation analysis of the Katy Freeway corridor shows that the HOV lane alternative offers favorable impacts on pollutants emitted and energy consumed.

FACTORS AFFECTING HOV LANE UTILIZATION

- HOV lanes are effective alternatives for congested freeway corridors that meet certain "qualifying criteria," including:
    - a differential between freeway and HOV lane speeds that will generate sufficient travel time savings for the user to consider carpooling or bus transit as an attractive alternative,
    - corridor characteristics and facility design factors that include orientation to major activity centers and physical opportunities to completely "bypass" congested section, and,
    - effective integration of transit service into HOV lane operation.

- Travel time reliability, or the expectation that travel time will not vary appreciably from day to day, is a demonstrated advantage of HOV lanes. Travel time recorded over an eight-month period on the Katy Freeway general-purpose lanes had a statistical variation of six minutes, while Katy HOV lane travel times varied by less than one minute.

- The socioeconomic and demographic factors that are typically considered conducive to carpooling are fairly consistent with the HOV corridors in Texas. By virtue of their design, the HOV lanes provide a time-saving incentive that accommodates longer travel times and greater trip lengths, which are factors considered important to the propensity to carpool. A higher percentage of lower income households in the corridor is the one factor that appears to have a greater influence on the propensity to rideshare in these corridors than other socioeconomic factors. Household size and parking costs appear to have little or no influence on carpooling in these corridors.

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APPENDIX A

KATY FREEWAY AND HOV LANE DATA

KATY FREEWAY (I- 10) AND HOV LANE, HOUSTON

Table A-1. Summary of A.M. Peak-Direction Katy Freeway and HOV Lane Data, 1997

Type of Data Phase 1 of HOV Lane Became Operational 10/29/84	"Representative" Pre-HOV Lane	"Representative" Current Value	Percent Change
HOV Lane Data			
HOV Lane Length		13.1	
HOV Lane Cost (millions)		$108.4	
Person-Movement			
Peak-Hour (7-8 a.m.)	---	3,457	---
Peak-Period (6-9:30 a.m.)	---	8,507	---
Total Daily	---	19,012	---
Vehicle Volume			
Peak-Hour (7-8 a.m.)	---	868	---
Peak-Period	---	2,536	---
Vehicle Occupancy, Peak-Hour (persons/veh)	---	3.98	---
Accident Rate (i.e., Injury accidents/100 MVM)[1]	---	21.2	---
Vehicle Breakdowns (VMT/Breakdown)	---	45,193	---
Violation Rate (6-9:30 a.m.)	---	19%	---
Peak-Hour Lane Efficiency (1000's)[2]	---	207	---
Annual Discounted Benefits (millions)[3]	---	$41	---
Annual Delay Savings (millions)[4]	---	$17	---
Travel Time (minutes)[5]			
Peak-Hour	33.9	13.3	-60%
Peak-Period	23.1	13.3	-42%
Freeway Mainlane Data			
Person-Movement			
Peak-Hour	5,100	5,172	+1%
Peak-Period (6-9:30 a.m.)	15,655	15,276	-2%
Vehicle Volume			
Peak-Hour	4,045	4,998	+24%
Peak-Period	12,750	14,629	+15%
Vehicle Occupancy, Peak-Hour (persons/veh)	1.26	1.03	-18%
Accident Rate (i.e., Injury accidents/100 MVM])[1]	20.0	19.2	-4%
Avg. Operating Speed[5] (mph)			
Peak-Hour	23	25	+9%
Peak-Period	33	33	0%
Peak-Hour Lane Efficiency (1000's)[2]	38	43	+13%

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

[1]Due to inconsistencies in reporting accidents in Harris County, this analysis includes only injury accidents. Accidents were analyzed between Gessner and Post Oak, a distance of approximately 4.7 mi. This corresponds to Phase 1 of the HOV lane. "Before" data are for the period 1/82 through 10/84. "After" data are for the period from 11/84 to 12/97. Only officer-reported accidents are included in current files. TTI estimated 1997 freeway volumes.

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

[3]Based on average annual delay savings, reduced vehicle operating costs and reduced accident costs generated by MicroBENCOST, over a 20-year life.

[4]per MicroBENCOST, over a 20-year life.

[5]Pre-HOV travel times were collected by manual travel time studies from SH 6 to Washington, a distance of 12.2 mi. Current travel times are calculated using data from automatic vehicle identification (AVI) readers located along the HOV Lane, representing travel over 13.1 miles.

Table A-1. Summary of A.M. Peak-Direction Katy Freeway and HOV Lane Data, 1997 (Continued)

Type of Data Phase 1 of HOV Lane Became Operational 10/29/84	"Representative" Pre-HOV Lane	"Representative" Current Value	Percent Change
Combined Freeway Mainlane and HOV Lane Data			
Total Person-Movement			
Peak-Hour	5,100	8,629	+69%
Peak-Period	15,655	23,783	+52%
Vehicle Volume			
Peak-Hour	4,045	5,866	+45%
Peak-Period	12,750	17,165	+35%
Vehicle Occupancy			
Peak-Hour	1.26	1.47	+17%
Peak-Period	1.23	1.39	+13%
Carpool Volume[1]			
2+, 6 a.m. to 7 a.m.	505	986	+95%
3+, 7 a.m. to 8 a.m.	76	328	+332%
3+, 5 p.m. to 6 p.m.	104	280	+169%
Peak-Hour Lane Efficiency (1000's)[2]	38	84	+121%
Transit Data			
Bus Vehicle Trips			
Peak-Hour	11	44	+300%
Peak-Period	32	99	+209%
Bus Passenger Trips			
Peak-Hour	335	1,475	+340%
Peak-Period	900	3,058	+240%
Bus Occupancy (persons/bus)			
Peak-Hour	30.5	33.5	+10%
Peak-Period	28.1	30.9	+10%
Vehicles Parked in Corridor Park-and-Ride Lots	575	2,320	+303%
Bus Operating Speed (mph)			
Peak-Hour	23[3]	60[4]	+161%
Peak-Period	33[3]	60[4]	+82%

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

[1]Carpool counts are adjusted in an effort to compensate for undercounting of occupancies in the field.
[2]This represents the multiple of peak-hour passengers and average speed (HOV lane efficiency +[mainlane freeway efficiency x number of freeway directional lanes]/number of total directional lanes). It is used as a measure of per lane efficiency.
[3]Speeds are calculated from manual travel time studies.
[4]Speeds are calculated from Automatic Vehicle Identification (AVI) data.

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

Measure of Effectiveness	"Representative" Pre-HOV Lane Value[1]	"Representative" Current Value	Percent Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/HOV lane	1.26	1.47	+17%
Freeway w/o HOV lane	1.23	1.30	+6%
Peak-Hour 3+ Carpool Volume			
Freeway w/HOV lane	76	328	+332%
Freeway w/o HOV lane	123	78	-37%
Bus Passengers, Peak Period			
Freeway w/HOV lane	900	3,004	+234%
Freeway w/o HOV lane	1,188	1,123	-5%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	575	2,320	+303%
Freeway w/o HOV lane	1,236	1,099	-11%
Facility Per Lane Efficiency[2]			
Freeway w/HOV lane	38	91	+139%
Freeway w/o HOV lane	86	81	-6%

[1]Representative Pre-Hov data for freeways without HOV lanes are comprised of data collected on the Eastex Freeway (1/93 to present).
[2]This represents the multiple of peak-hour passengers and average speed (passengers x mph/number of lanes). It is used as a measure of per lane efficiency.

HOV LANE DATA

DESCRIPTION

- Phase 1 (4.7 mi) of the HOV lane opened October 29, 1984.
- The HOV lane is now complete with 13.1 mi in operation.
- The capital cost (including all support facilities) for the completed facility in 1997 dollars was $108.4 million. Table A-3 provides a more detailed cost breakdown (including dates) on the following page.
- Selected milestone dates are listed below. Other dates are shown in the capital cost table.
  - 10/29/84 Post Oak to Gessner (4.7 mi) opens, used by buses and vans.
  - 4/1/85 4+ authorized carpools allowed onto HOV.
  - 5/2/85 HOV extended to West Belt (6.4 mi).
  - 11/4/85 3+ authorized carpools allowed onto HOV.

- 8/11/86 2+ carpools, no authorization, hours extended.
- 8/25/86 Hours of operation extended.
- 6/29/87 HOV extended to SH 6 (11.5 mi).
- 10/17/88 3+ from 6:45 a.m. to 8:15 a.m.
- 10/1/89 Weekend operation begins (4:00 a.m. - 10:00 p.m.).
- 1/9/90 Eastern extension opens (13.0 mi).
- 4/1/90 Northwest Transit Center opens.
- 5/23/90 3+ carpool hours changed to 6:45 a.m. to 8:00 a.m.
- 9/16/91 3+ carpool restriction, 5:00 p.m. to 6:00 p.m.
- 9/8/92 Motorcycles allowed on HOV facility (no occupancy restrictions).
- 3/14/94 Weekend operation ends.
- 4/4/94 Weekend operation resumes (5:00 a.m. - 9:00 p.m.).
- 9/30/96 Hours of operation modified (5:00 a.m. - 11:00 a.m.; 2:00 p.m. - 8:00 p.m.).

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

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1995 dollars
HOV Lane and Ramps			
Eastern Extension (1990)	$7.1	1.16	$8.2
Phase 1, Silber to West Belt (1984) Design and	10.5	1.38	14.5
Construction	11.7	1.27	14.9
Phase 2, West Belt to SH 6 (1987) Design and Construction	2.8	1.27	3.6
Addicks North Ramp (1987)	0.3	1.32	0.4
Addicks South Ramp	9.7	0.94	9.1
Northwest Transit Center to Inner Katy Connection (1997)	4.3	1.16	5.0
Misc. (1990)			
SUB-TOTAL	$46.4		$55.7
	$3.6		$4.3
Per Mile			
	$4.6	1.27	$5.8
Surveillance, Communication & Control (1987)			
	$4.6		$5.8
SUB-TOTAL			
	$0.4		$0.5
Per Mile			
Support Facilities			
	$4.8	1.38	$6.6
West Belt P/R (1984)	3.9	1.19	4.6
Addicks P/R (1981)	6.3	1.23	7.8
Addicks P/R Expansion (1988)	3.8	1.34	5.1
Kingsland P/R (1985)	0.2	1.27	0.3
Fry Road Park-and-Pool (1987)	0.2	1.30	0.3
Mason Road Park-and-Pool (1986)	0.2	1.30	0.3
Barker-Cypress Park-and-Pool (1986)	6.3	0.94	5.9
Addicks P/R 2nd Expansion (1997)			
	$25.7		$30.9
SUB-TOTAL			
	$2.0		$2.4
Per Mile			
	$76.7		$92.4
TOTAL COST			
	$5.9		$7.1
COST PER MILE (13.0 mi)			

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

Table A-4. Estimated Capital Cost (millions), Katy HOV Lane, Future Segments

Cost Component	Estimated Year of Construction	Estimated Cost ($Millions)
HOV Lane Ramps/Connectors		
Katy-CBD Ramp, 2.3 Mi	2000	39.8
Temporary Eastern Extension Slip Ramps	1999	0.6
		40.4

PERSON-MOVEMENT

- In 1997, the HOV lane served approximately 19,000 person trips per day.

- A.M. Peak Hour, 3,457 persons/hour.

    - 1,475 (43%) by bus, 73 (2%) by vanpool, 1,898 (55%) by carpool, and 11 by motorcycle (Figure A-1).
    - Average HOV lane vehicle occupancy = 3.98 persons/vehicle.

- A.M. Peak Period, 8,507 persons.

    - 3,058 (36%) by bus, 143 (2%) by vanpool, by carpool 5,275 (62%), and 32 by motorcycle (Figure A-2).

VEHICLE MOVEMENT

- A.M. Peak Hour, 868 vph.

    - 44 (5%) buses, 13 (2%) vans, 801 (92%) carpools, and 11 by motorcycle (Figure A-3).

- A.M. Peak Period, 2,536 vehicles.

    - 99 (4%) buses, 26 (1%) vans, 2,380 (94%) carpools, and 32 by motorcycle (Figure A-4).

ACCIDENT RATE

- For the period from November 1984 through December 1997, the HOV lane accident rate was 21.2 injury accidents per 100 million vehicle miles.

VEHICLE BREAKDOWN RATES

- As measured for 11/84 to 12/97, the following rate has been observed.

    - The weighted average for all vehicle types is one breakdown per 45,193 VMT.

FIGURE A–1. KATY FREEWAY (IH 10W) HOV LANE
A.M. PEAK HOUR HOV LANE PERSON MOVEMENT

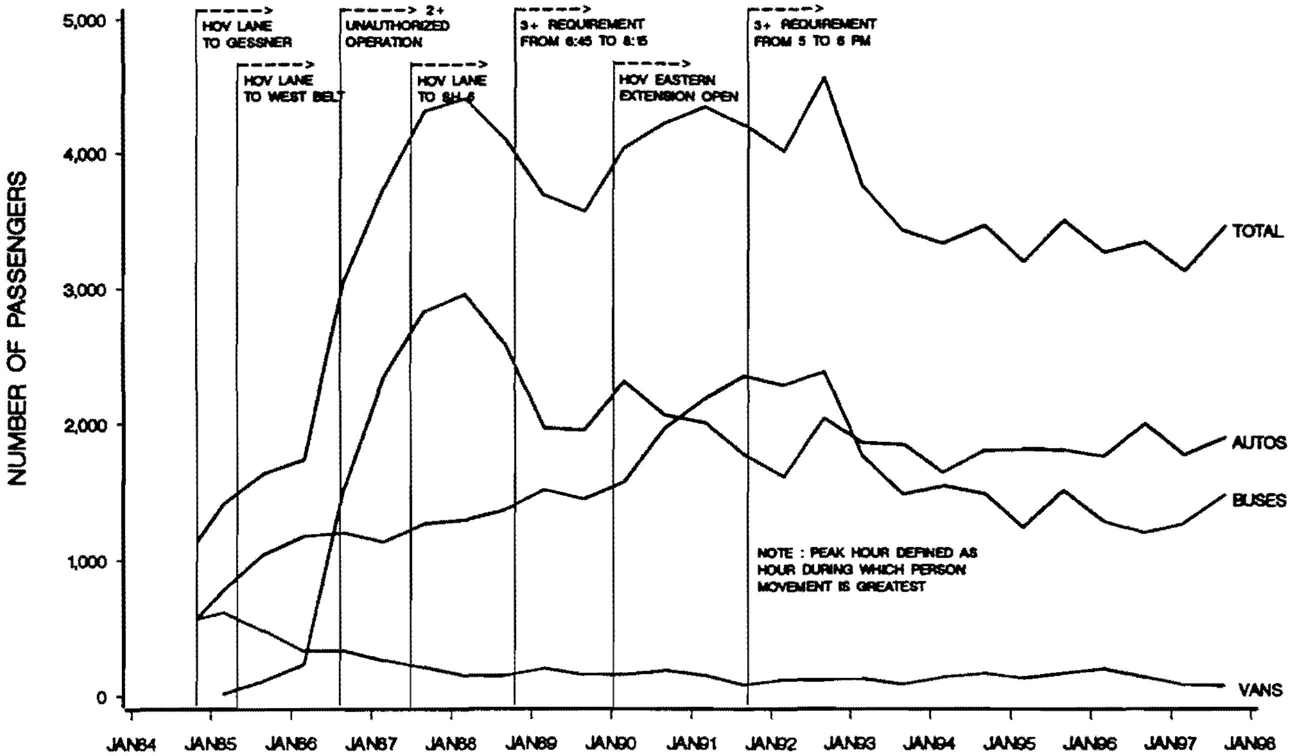


FIGURE A–2. KATY FREEWAY (IH 10W) HOV LANE
A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT

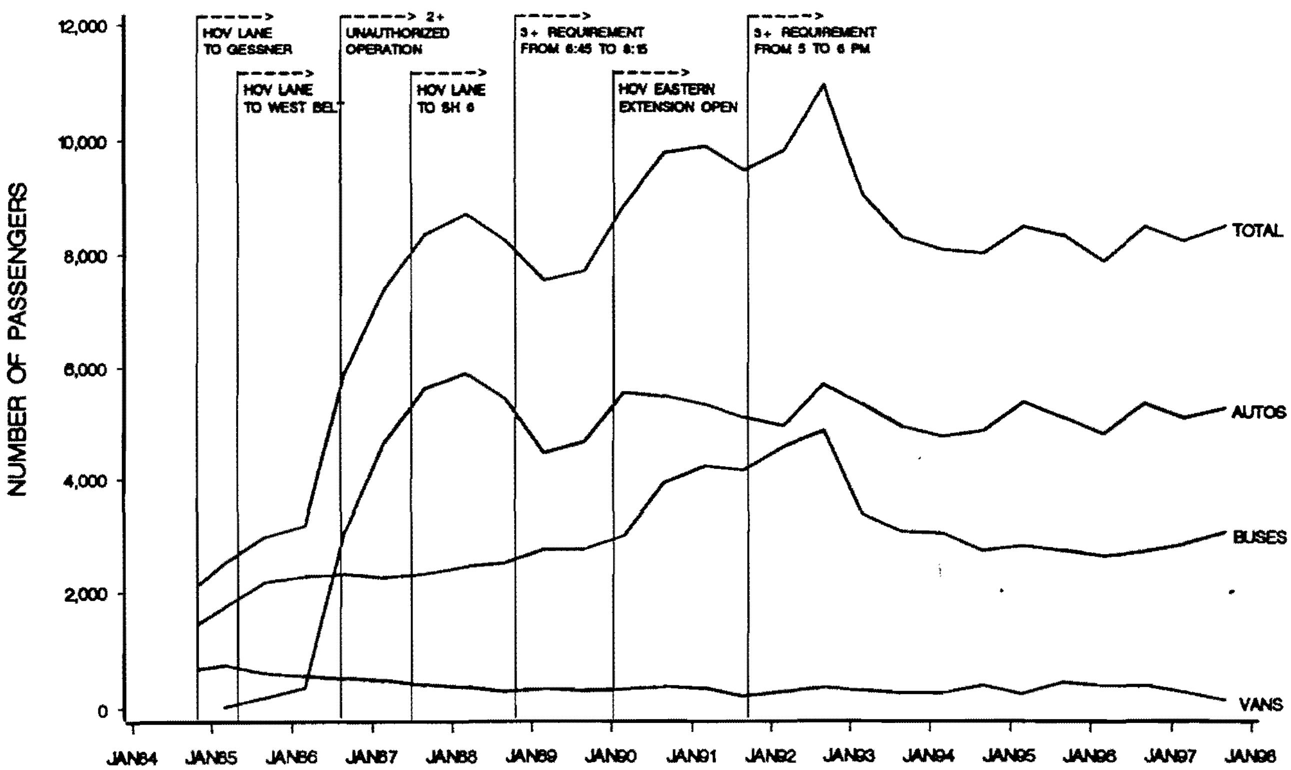


FIGURE A-3. KATY FREEWAY (IH 10W) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION

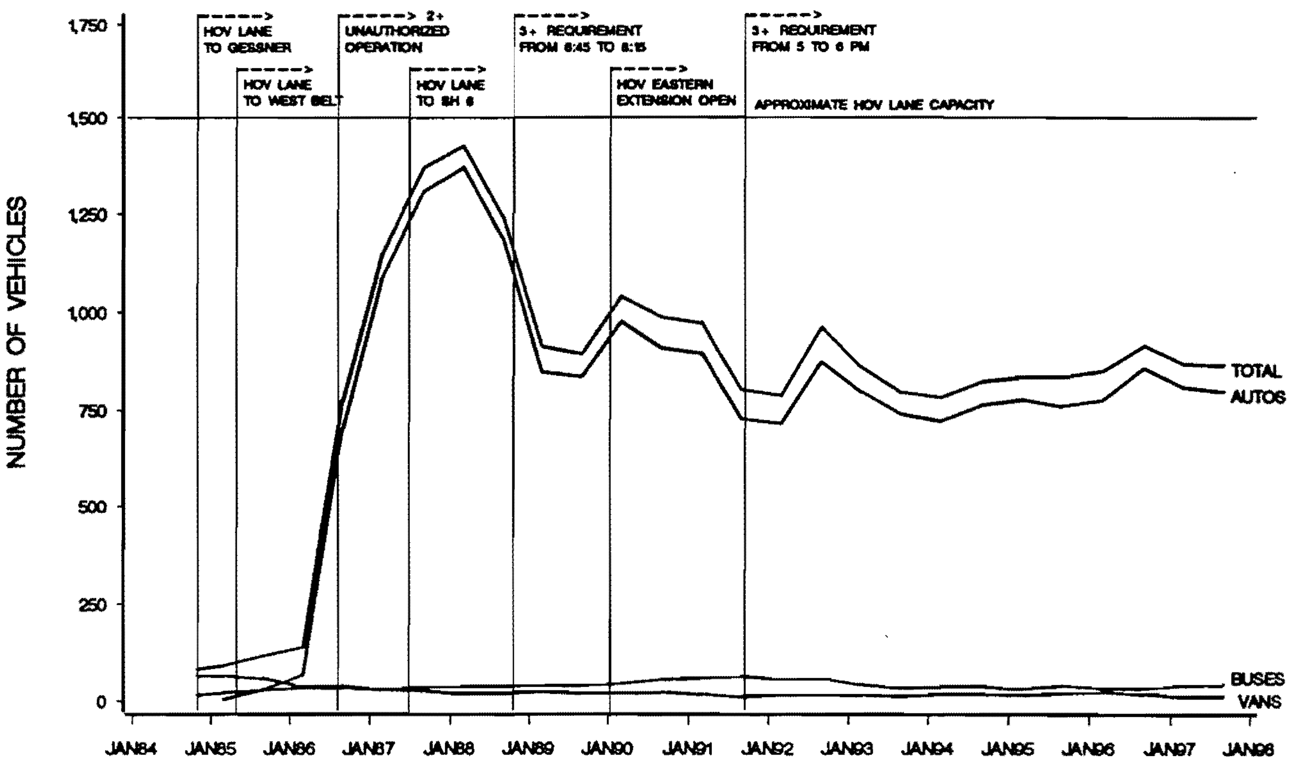
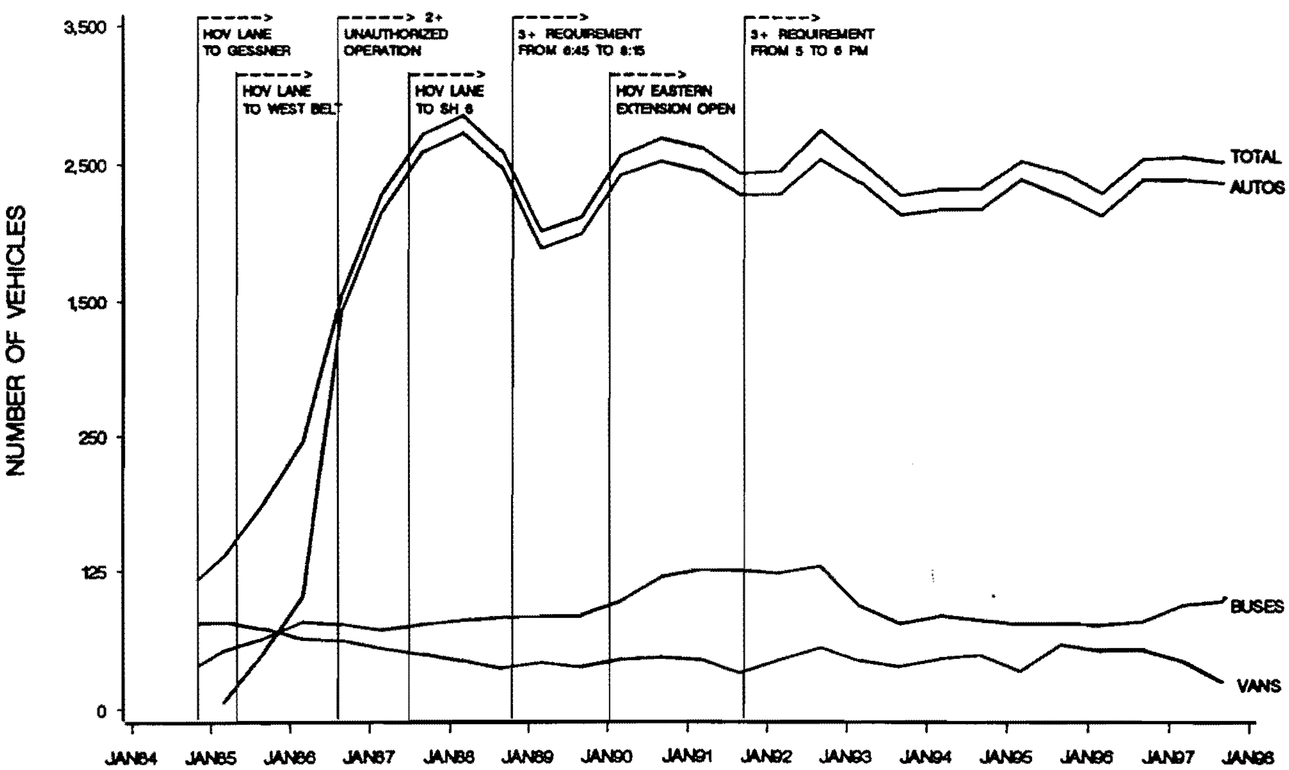


FIGURE A-4. KATY FREEWAY (IH 10W) HOV LANE
A.M. PEAK PERIOD HOV LANE VEHICLE UTILIZATION



VIOLATION RATE

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

  - For the overall a.m. peak period, it is 19 percent.
  - For the period from 7:00 a.m. to 8:15 a.m. (the 3+ operating time), it averaged 44 percent for 1997 and was 46 percent in September.
  - For the p.m. peak hour (the 3+ operating time), the violation rate was 46 percent in 1997.

PEAK-HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is used as a measure of the efficiency of a lane. For the HOV lane, this value (expressed in 1000's) is approximately 207 (3,457 passengers at 60 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane experienced an average travel time savings of 18 minutes during the morning peak hour in 1997 (Table A-5, Figure A-5).

Table A-5. Travel Time Savings for Katy HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1997)

Time of Day	Measured Travel Time: Freeway (min)	HOV (min)	Savings (min)	HOV Lane Person Trips: Carpool	Vanpool	Bus	Total	Travel Time Saved (Person-Minutes)
Eastbound A.M. Travel Time Savings for Katy HOV Lane								
Section from SH 6 to Gessner Interchange								
6:00	8.25	6.11	2.14	258	19	128	404	1,010
6:30	12.37	6.38	6.00	780	19	506	1305	8,000
7:00	16.02	5.97	10.06	362	7	520	889	8,930
7:30	15.18	6.01	9.17	448	17	381	845	7,830
8:00	11.51	5.96	5.56	893	18	233	1144	6,360
8:30	9.26	5.98	3.28	593	34	56	684	2,290
9:00	7.44	5.81	1.63	421	9	12	442	720
Peak Period Total				3755	123	1836	5713	35,130
Section from Gessner Interchange to Washington								
6:00	7.74	6.96	0.78	337	36	267	639	580
6:30	10.56	7.85	2.72	1,077	48	529	1,655	4,570
7:00	14.73	7.41	7.32	712	51	731	1,492	10,750
7:30	17.02	7.37	9.65	872	27	684	1,583	15,250
8:00	14.58	7.46	7.13	962	22	513	1,496	10,720
8:30	11.34	7.15	4.19	742	35	213	989	4,270
9:00	9.21	6.86	2.35	485	10	30	526	1,240
Peak Period Total				5,187	229	2,967	8,380	47,380
Westbound P.M. Travel Time Savings for Katy HOV Lane								
Section from Washington to Gessner Interchange								
3:30	11.61	7.07	4.53	547	13	157	717	3,260
4:00	12.72	7.23	5.49	660	24	296	979	5,420
4:30	15.43	7.82	7.62	1,239	55	526	1,819	13,940
5:00	20.23	7.29	12.95	613	49	657	1,317	17,150
5:30	19.84	7.39	12.45	568	37	723	1,327	16,480
6:00	15.58	7.71	7.87	1,058	23	423	1,504	12,000
6:30	11.23	7.22	4.02	579	21	288	887	3,670
Peak Period Total				5,264	222	3,070	8,550	71,910

Table A-5. Travel Time Savings for Katy HOV Lane (Average of 4 Quarterly Travel Surveys Conducted in 1997) (continued)

Westbound P.M. Travel Time Savings for Katy HOV Lane								
Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section from Gessner Interchange to SH 6								
3:30	6.68	5.84	0.84	340	1	113	454	380
4:00	7.40	5.94	1.46	359	5	255	620	900
4:30	8.54	6.10	2.45	718	52	178	948	2,380
5:00	10.95	6.15	4.80	481	7	408	896	4,200
5:30	10.74	6.10	4.64	380	45	575	999	4,580
6:00	9.63	6.17	3.46	655	12	280	946	3,290
6:30	8.01	6.06	1.96	330	10	119	459	920
Peak Period Total				3,263	132	1,928	5,322	16,650

Table A-6. Katy Freeway Travel Time Summaries

Travel Time Data	Travel Times					
	97[1]	96[2]	95[2]	94[2]	93[2]	Pre-HOV
HOVL Travel Time AM Peak-Hour PM Peak-Hour	 13 min 13 min	 14 min 14 min	 14 min 14 min	 16 min 15 min	 14 min 14 min	 - -
Freeway Mainlanes Travel Time AM Peak-Hour PM Peak-Hour	 31 min 31 min	 38 min 30 min	 38 min 31 min	 39 min 24 min	 29 min 22 min	 32 min 27 min
Net Travel Time Savings AM Peak-Hour (Person-Minutes) PM Peak-Hour (Person-Minutes)	 18 min (42,760) 18 min (42,410)	 24 min (27,188) 16 min (18,843)	 24 min (26,080) 17 min (11,810)	 23 min (24,399) 9 min (12,538)	 15 min (17,166) 8 min (10,000)	 - -

Travel Times are calculated over a distance of 19.6 km (12.2 mi).
[1]Data collected using Automatic Vehicle Identification (AVI).
[2]Data collected using manual travel time data.

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 may be low in comparison to typical freeway operations.

PERSON-MOVEMENT

- In the a.m. peak hour, person- movement has not changed significantly relative to pre-HOV conditions (Figure A-6).

- In the a.m. peak period, person- movement has not changed significantly relative to pre-HOV conditions (Figure A-7).

VEHICLE VOLUME

- In the a.m. peak hour, vehicle volume has increased by 24 percent, relative to pre-HOV conditions (Figure A-8).

- In the a.m. peak period, vehicle volume has increased by 15 percent, relative to pre-HOV conditions (Figure A-9).

VEHICLE OCCUPANCY

- In the a.m. peak hour, mainlane occupancy has decreased by 18 percent, relative to pre-HOV conditions (Figure A-10).

- In the a.m. peak period, mainlane occupancy has decreased by 15 percent, relative to pre-HOV conditions (Figure A-11).

ACCIDENT RATE

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

- The accident data shown are for the section between Gessner and Post Oak (toll road construction impacted the freeway section west of Gessner). The accident rate for the period (1/82-10/84) preceding Phase 1 of the HOV lane was 20.0 accidents per 100 million vehicle miles. For the period from 11/84 to 12/97, the freeway accident rate was 19.2

accidents/100 MVM. These statistics do not include driver reported accidents; current accident files include only officer reported accidents.

AVERAGE OPERATING SPEED

- In comparison to pre-HOV lane conditions, mainlane operating speeds have increased by 9 percent in the peak hour and remained steady in the peak-period (Figure A-12).

PEAK-HOUR LANE EFFICIENCY

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

- For the freeway mainlanes, there has been an increase in per lane efficiency.

FIGURE A–5. KATY FREEWAY (IH 10W) MAINLANES AND HOV LANE A.M. TRAVEL TIME

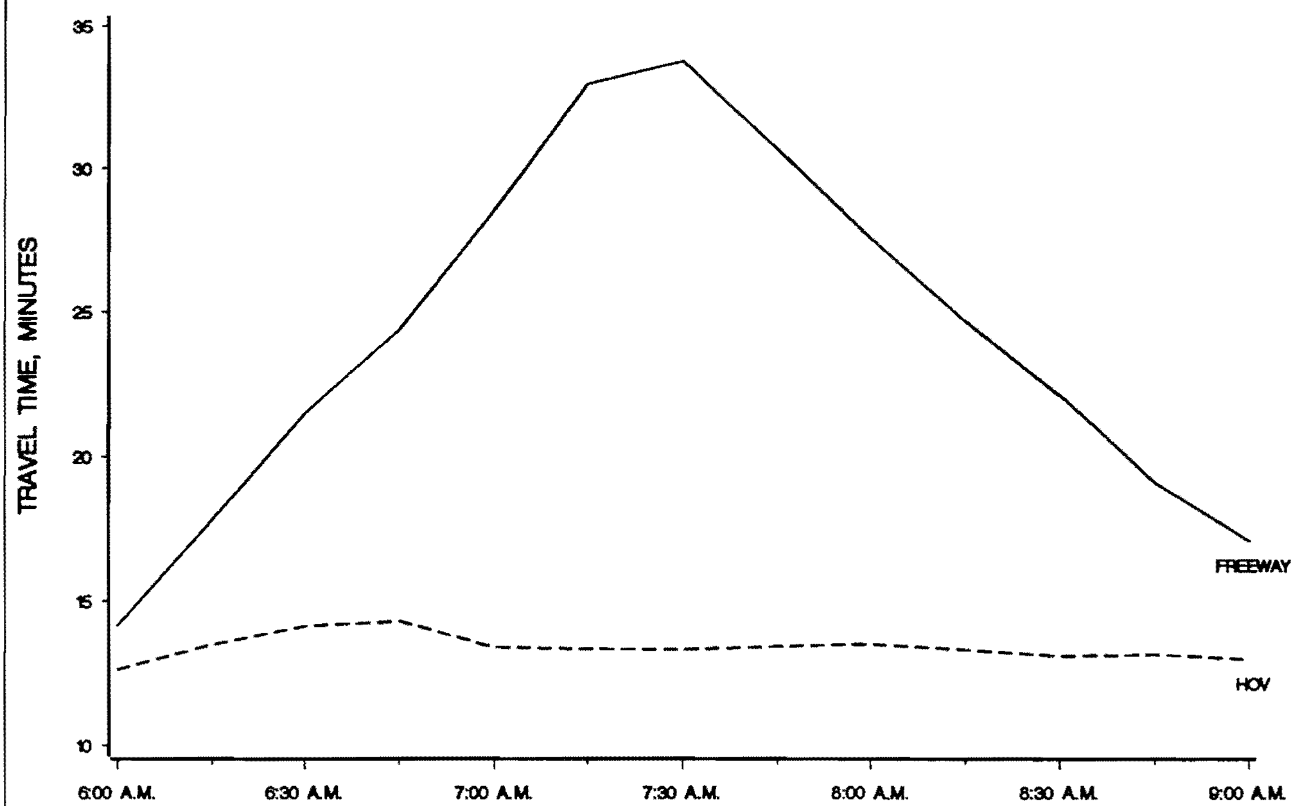


FIGURE A–6. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK HOUR PERSON TRIPS

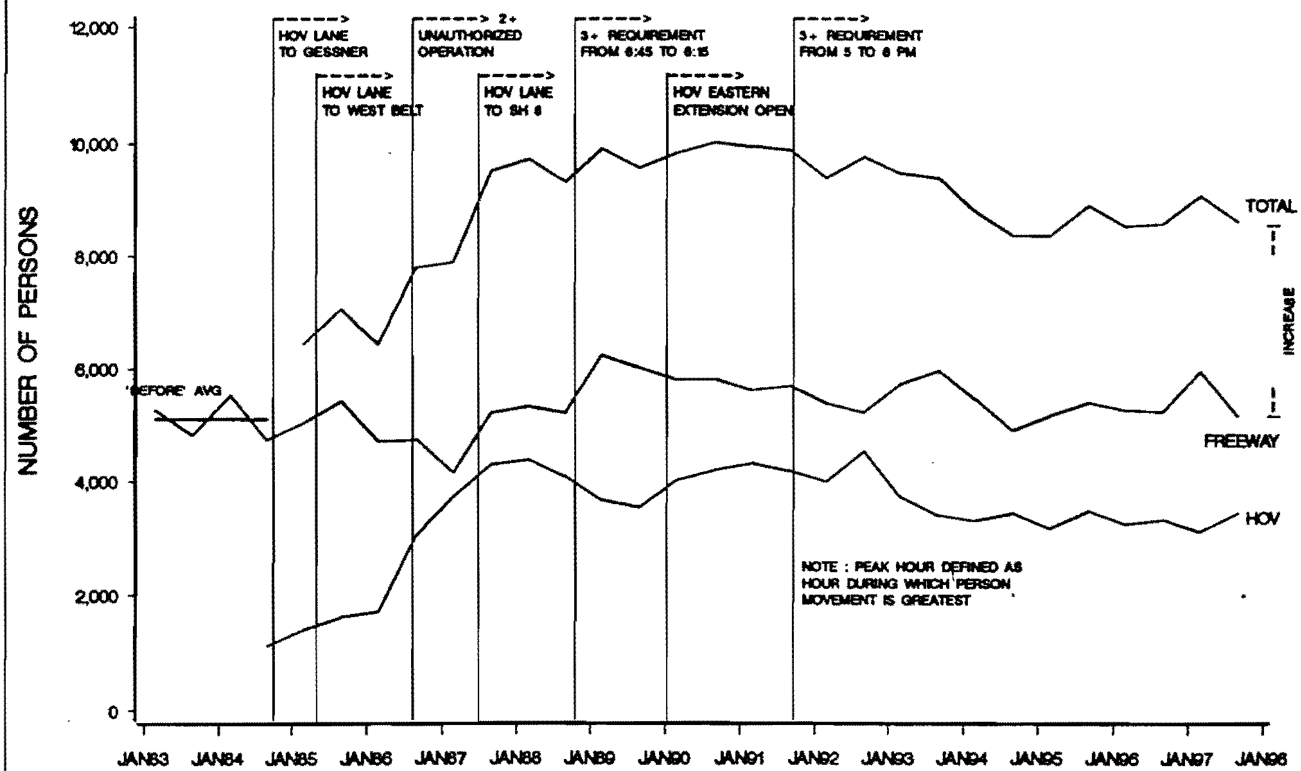


FIGURE A-7. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK PERIOD PERSON TRIPS

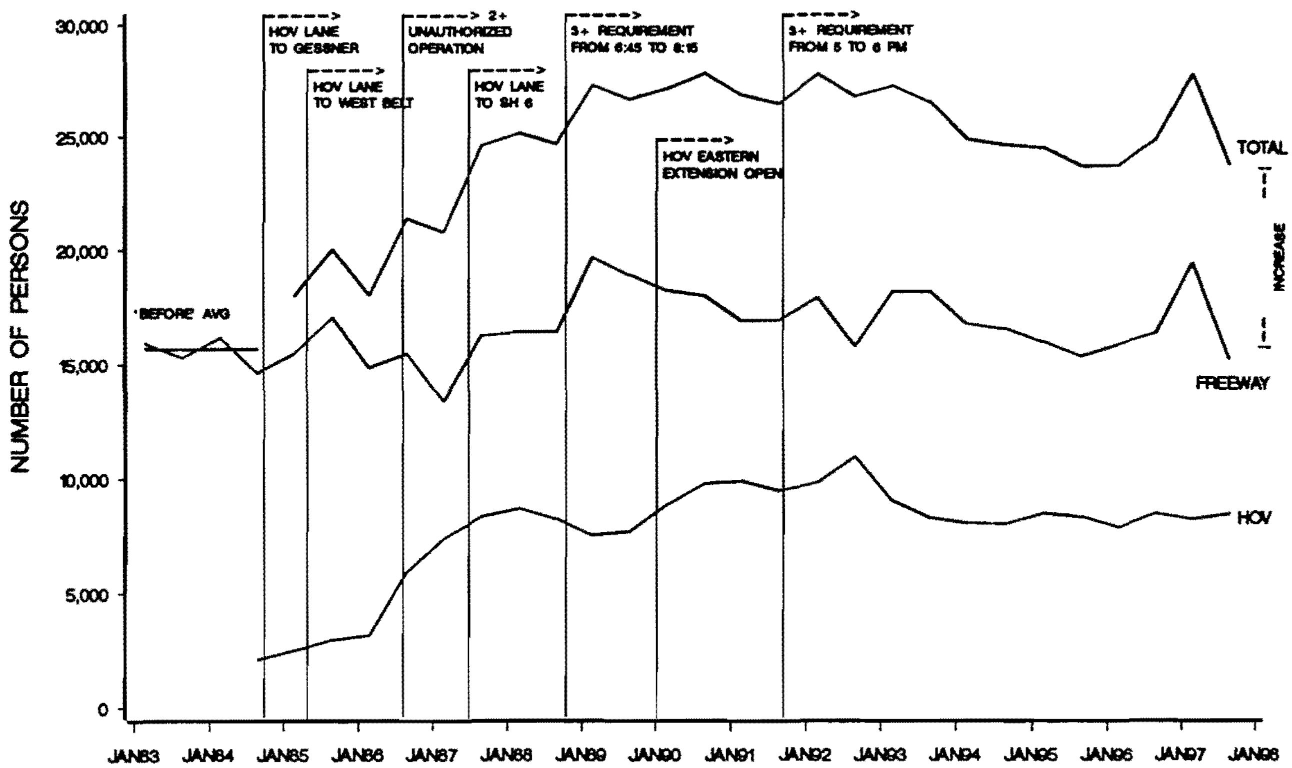


FIGURE A-8. KATY FREEWAY (IH 10W)
A.M. PEAK HOUR MAINLANE TRIPS

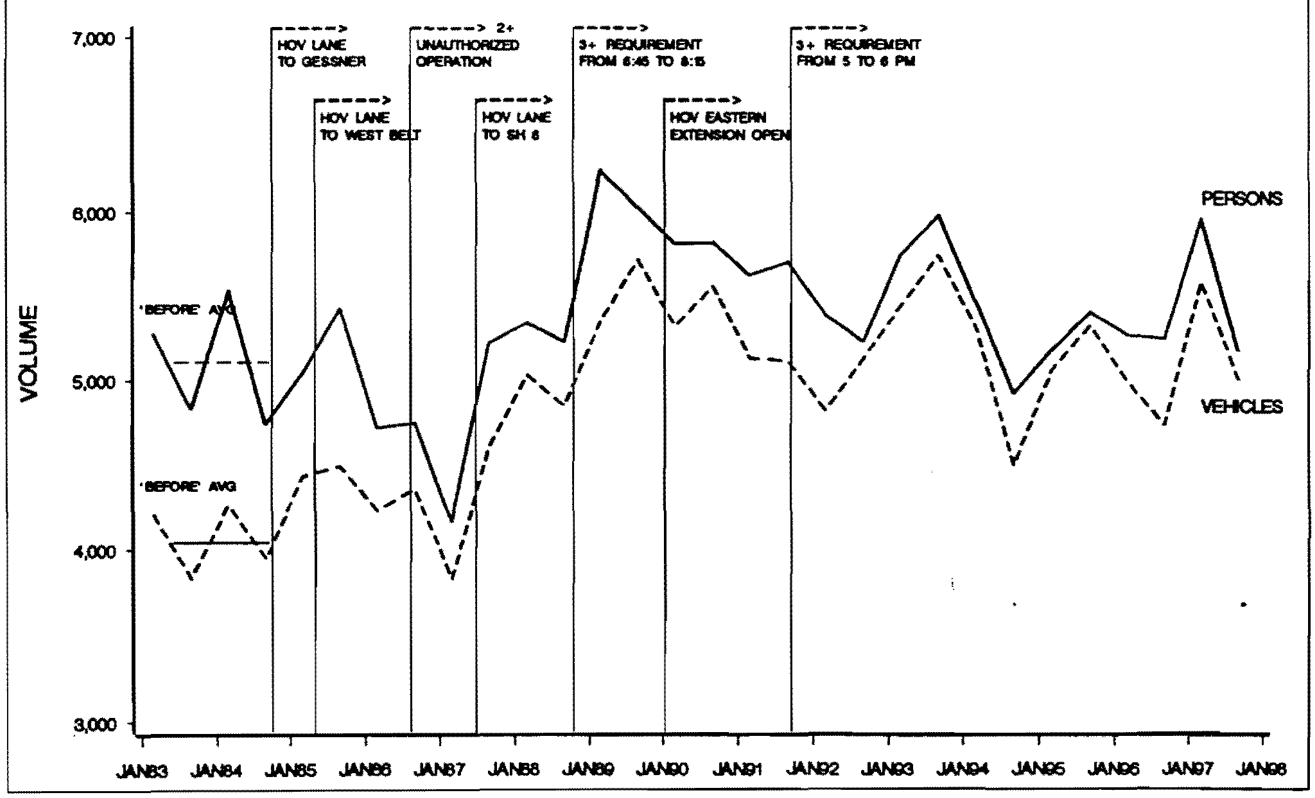


FIGURE A-9. KATY FREEWAY (IH 10W)
A.M. PEAK PERIOD MAINLANE TRIPS

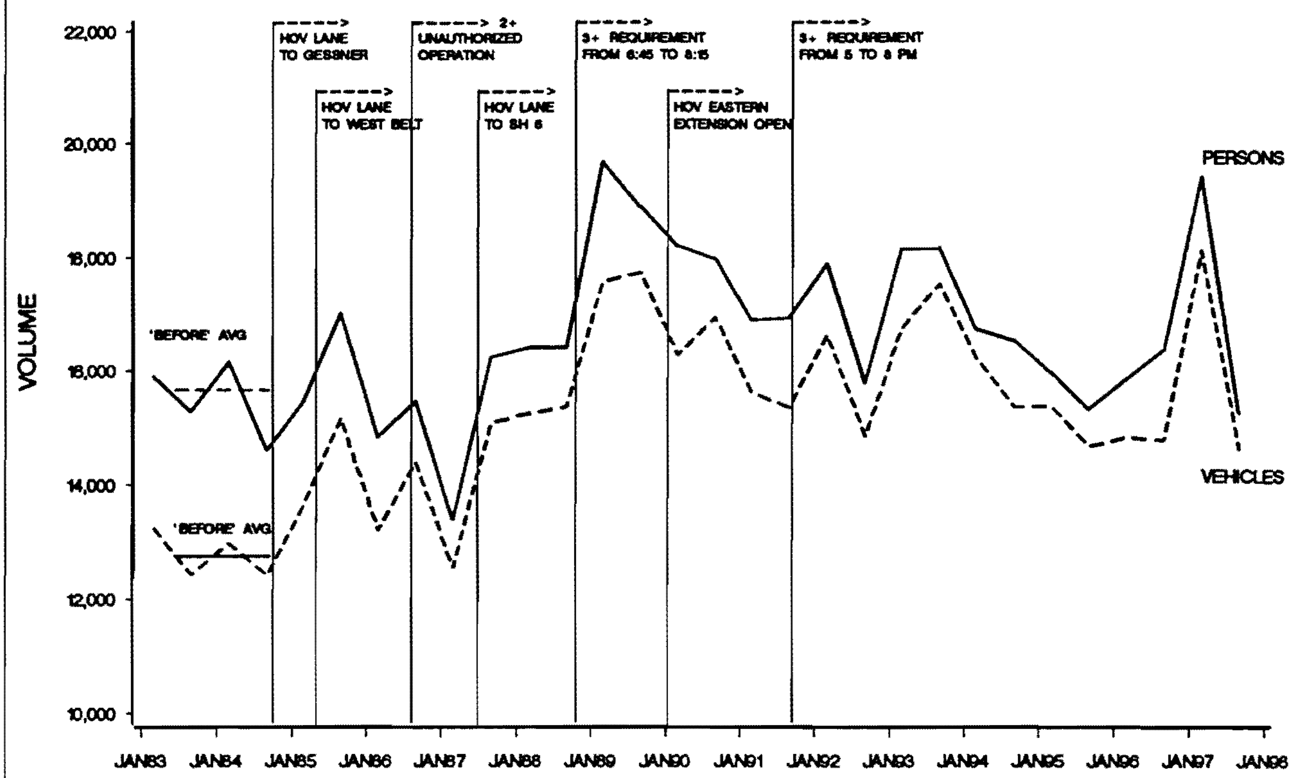
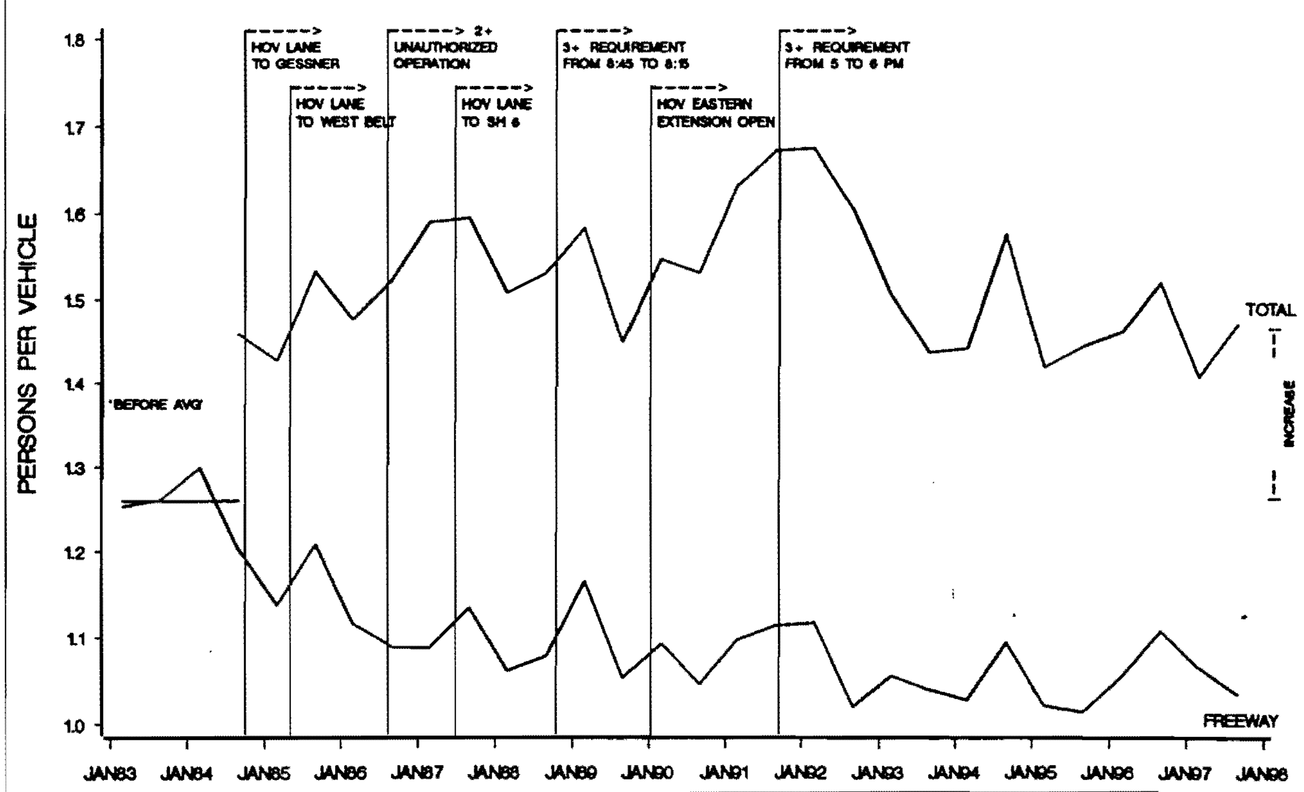


FIGURE A-10. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK HOUR AVERAGE OCCUPANCY



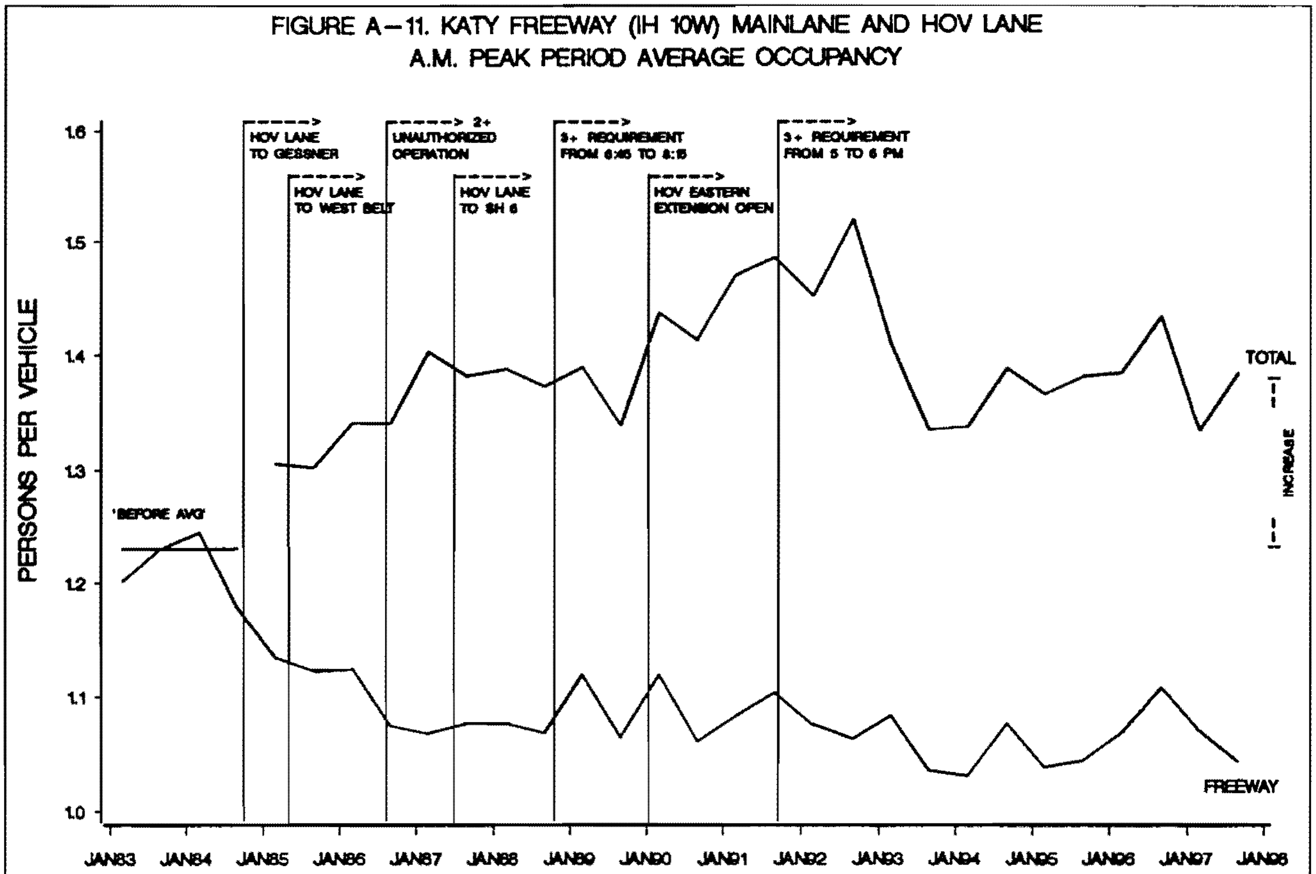


FIGURE A-11. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK PERIOD AVERAGE OCCUPANCY
PERSONS PER VEHICLE
HOV LANE TO GESSNER
HOV LANE TO WEST BELT
2+ UNAUTHORIZED OPERATION
HOV LANE TO SH 6
3+ REQUIREMENT FROM 6:45 TO 8:15
HOV EASTERN EXTENSION OPEN
3+ REQUIREMENT FROM 5 TO 6 PM
'BEFORE AVG'
TOTAL
INCREASE
FREEWAY
JAN83 JAN84 JAN85 JAN86 JAN87 JAN88 JAN89 JAN90 JAN91 JAN92 JAN93 JAN94 JAN95 JAN96 JAN97 JAN98

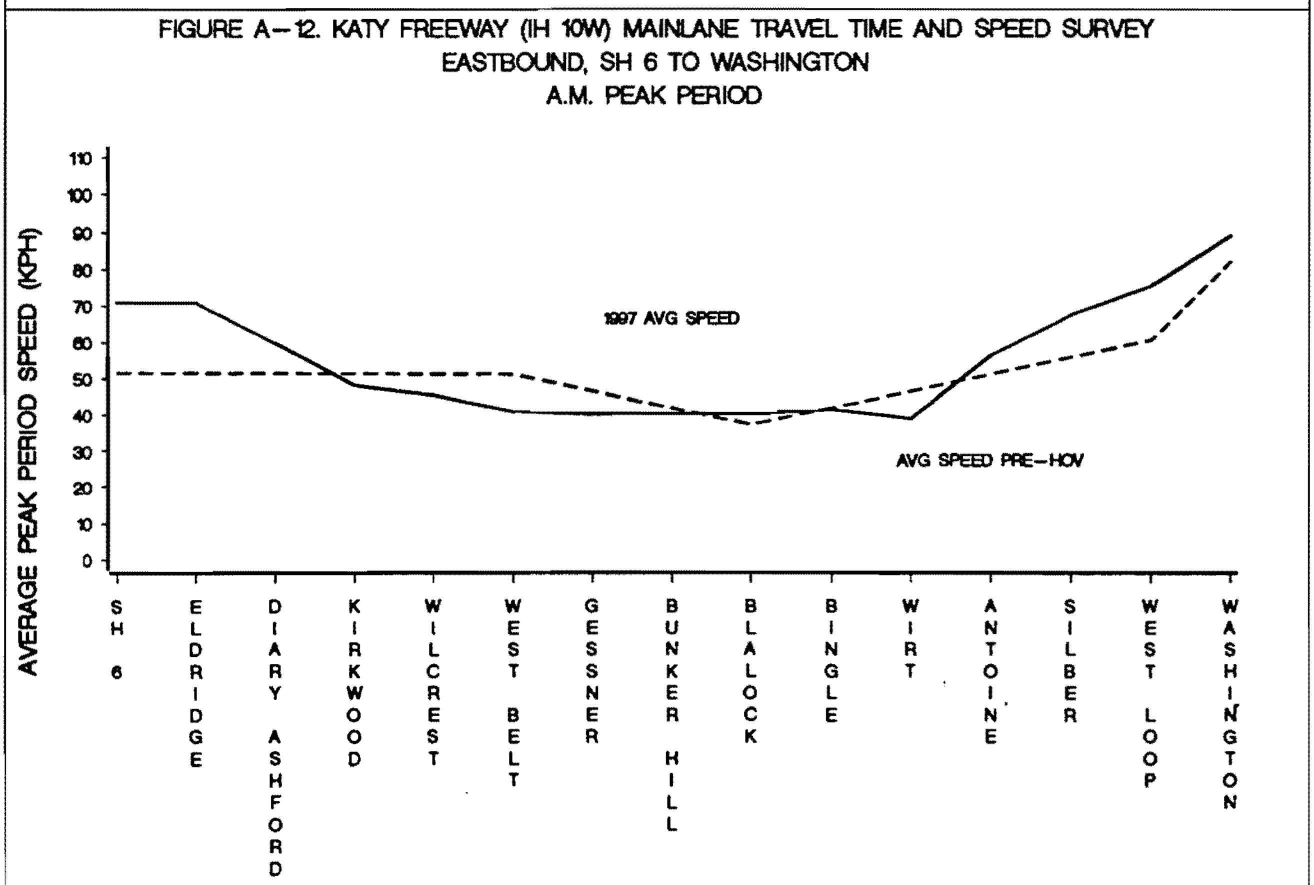


FIGURE A-12. KATY FREEWAY (IH 10W) MAINLANE TRAVEL TIME AND SPEED SURVEY
EASTBOUND, SH 6 TO WASHINGTON
A.M. PEAK PERIOD
AVERAGE PEAK PERIOD SPEED (KPH)
1997 AVG SPEED
AVG SPEED PRE-HOV
SH 6
ELDRIDGE
DIARY ASHFORD
KIRKWOOD
WILCREST
WEST BELT
GESSNER
BUNKER HILL
BLALOCK
BINGLE
WIRT
ANTOINE
SILBER
WEST LOOP
WASHINGTON

COMBINED FREEWAY MAINLANE AND HOV LANE DATA

TOTAL PERSON-MOVEMENT

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

  - At Bunker Hill, the HOV lane is responsible for 40 percent of peak-hour person-movement (HOV lane = 3,457; freeway = 5,172) and 36 percent of peak-period (HOV lane = 8,507; freeway = 15,276) person-movement.

- Increase in a.m. person-movement at Bunker Hill relative to pre-HOV lane operations.

  - Provision of the HOV lane increased total directional lanes by 33 percent.
  - Total peak-hour person-movement has increased by 69 percent from 5,100 to 8,629 (Figure A-6). Peak-period person-movement has increased by 52 percent from 15,655 to 23,783 (Figure A-7).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.47, a 17 percent increase over the pre-HOV lane occupancy (Figure A-10). Occupancy in the peak period is greater than pre-HOV lane levels (Figure A-11), increasing from 1.23 to 1.39 (13 percent).

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

CARPOOL VOLUMES

- Prior to the HOV lane, 2+ carpool volume from 6 a.m. to 7 a.m. was 505 vehicles - now it is 986 vehicles (Figure A-14).

- In the a.m. peak hour, the total number of 3+ carpools (freeway plus HOV lane) has increased by 332 percent compared to pre-HOV lane levels (Figure A-15).

PEAK-HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is used as a measure of the efficiency of a lane. The average efficiency of a lane on the freeway (3 freeway lanes plus 1 HOV lane) has increased by84 percent since the implementation of the HOV lane (Figure A-16).

BUS TRANSIT DATA

BUS VEHICLE AND PASSENGER TRIPS

- In the a.m. peak hour, bus vehicle trips have been increased by 300 percent since the HOV lane opened, and a 340 percent increase in bus ridership has also resulted (Figure A-17). In the peak period, a 209 percent increase has occurred in bus trips and a 240 percent increase in bus ridership has resulted (Figure A-18).

- While bus passenger trips have increased significantly in the Katy Freeway corridor, this has not occurred in the corridors which do not have HOV lanes (Figure A-19).

PARK-AND-RIDE

- Prior to opening the HOV lane, approximately 575 vehicles were parked in corridor park-and-ride lots. This has increased 303 percent to a current level of 2,320 (Figure A-20).

- The same magnitude of increase in cars parked at park-and-ride lots in the Katy corridor has not been realized in the freeway corridors that do not have HOV lanes (Figure A-21).

FIGURE A-13. A.M. PEAK HOUR AVERAGE OCCUPANCY
KATY FREEWAY AND FREEWAY WITHOUT HOV LANE

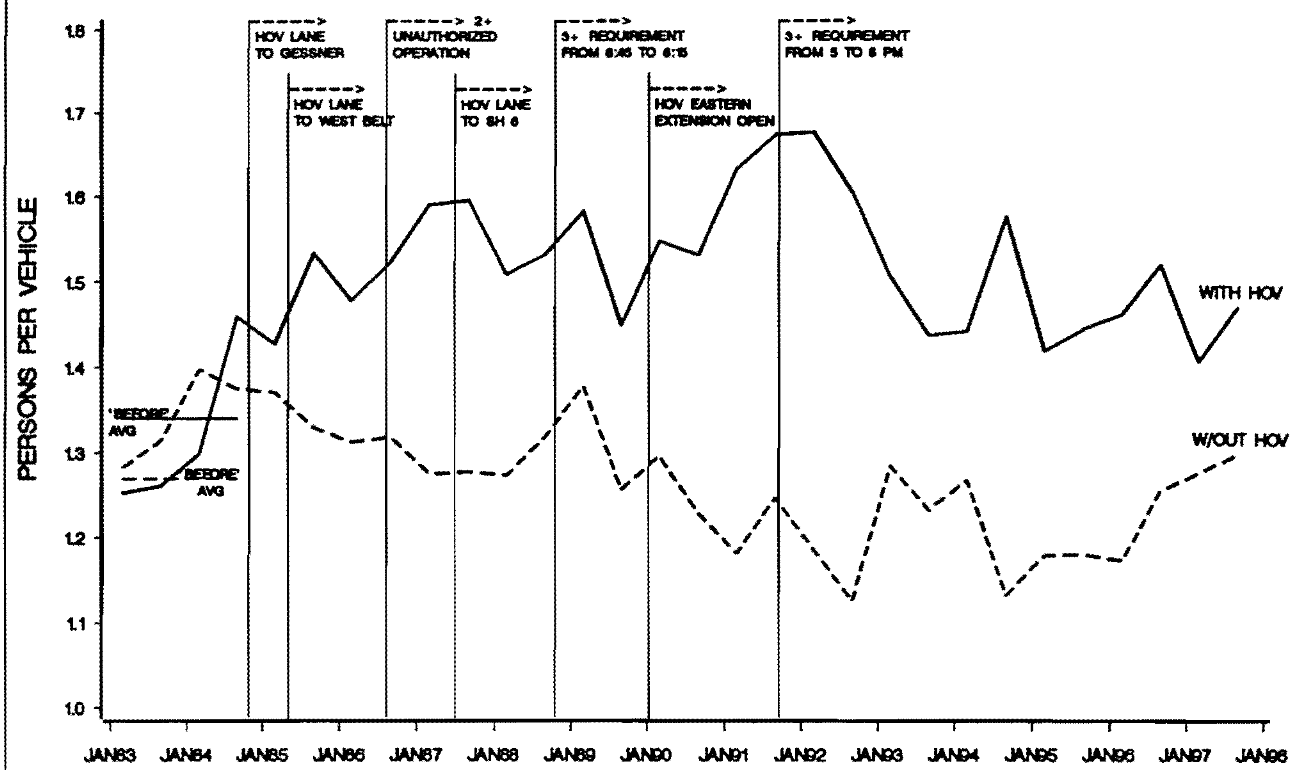


FIGURE A-14. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK HOUR 2+ CARPOOL UTILIZATION

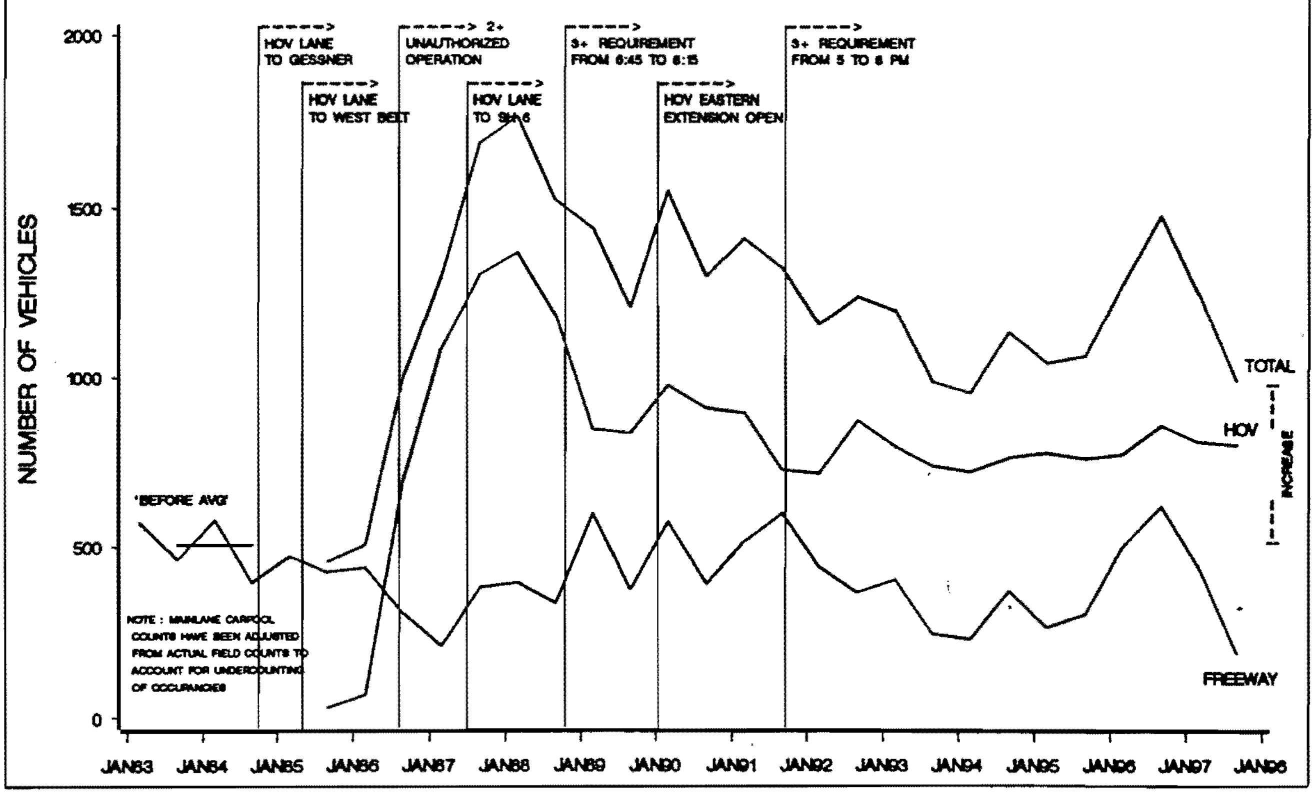


FIGURE A-15. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
7:00 A.M. TO 8:00 A.M. 3+ CARPOOL UTILIZATION

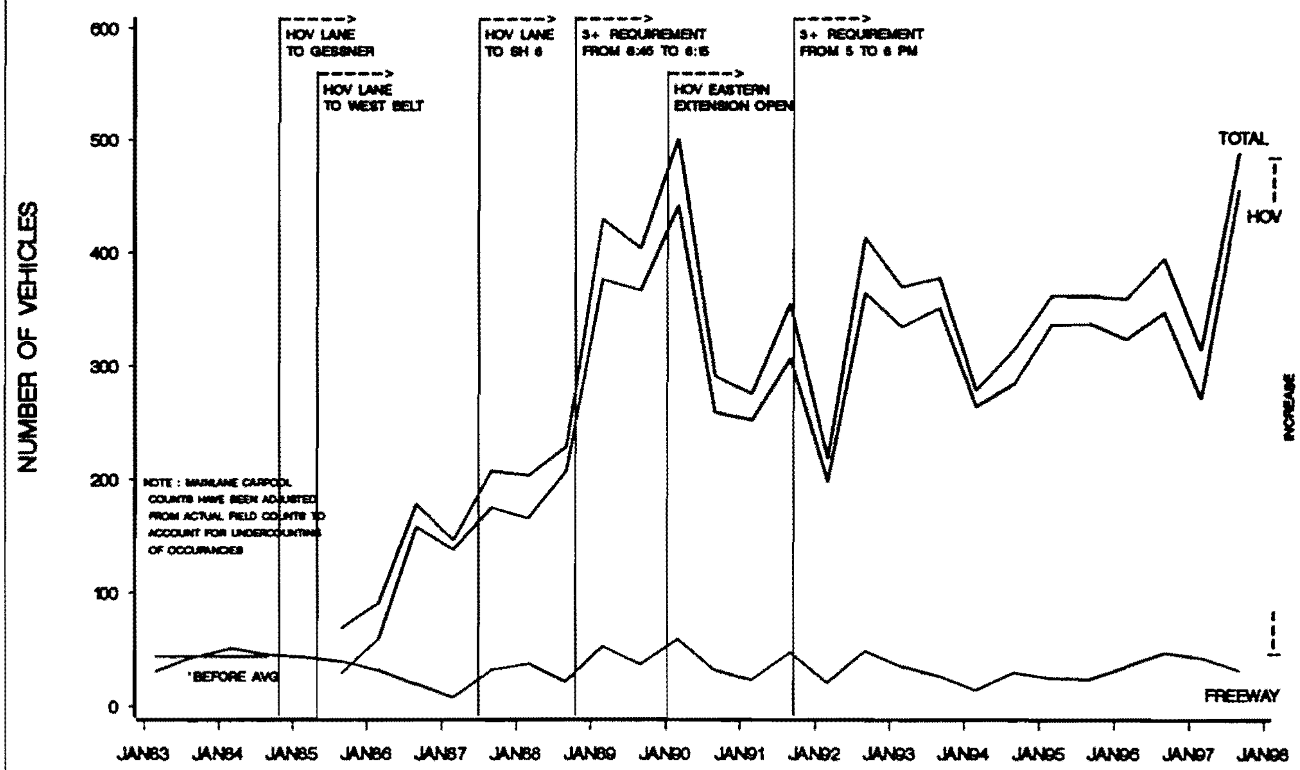


FIGURE A-16. A.M. PEAK HOUR FREEWAY PER LANE EFFICIENCY
KATY FREEWAY AND FREEWAY WITHOUT HOV LANE

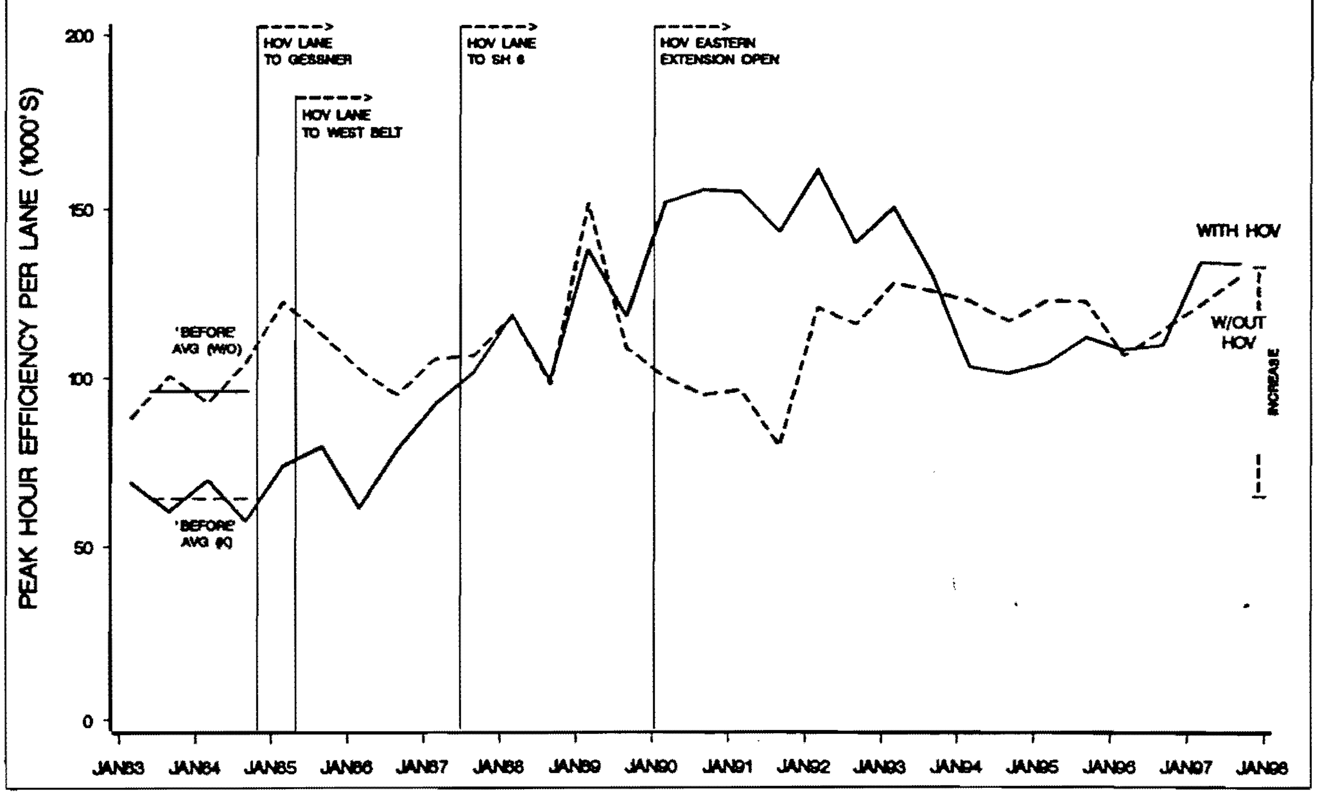


FIGURE A-17. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS

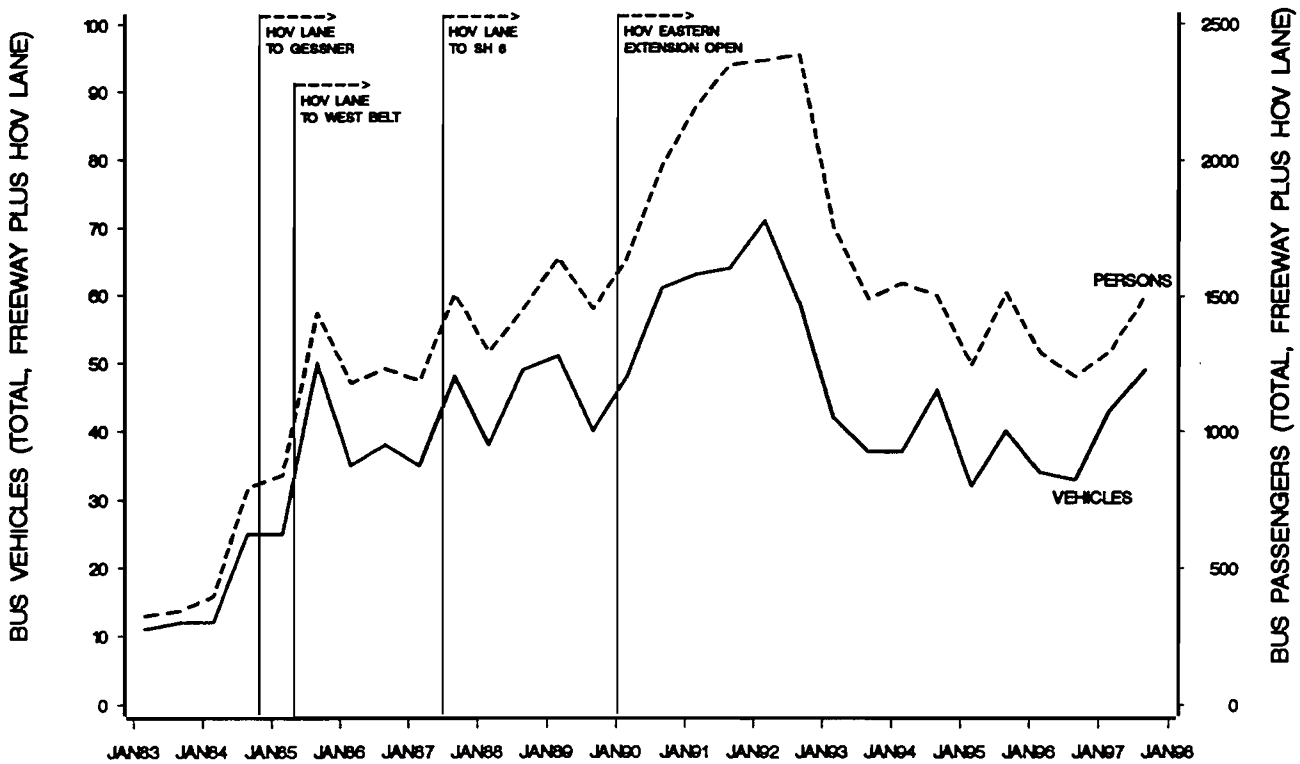


FIGURE A-18. KATY FREEWAY (IH 10W) MAINLANE AND HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS

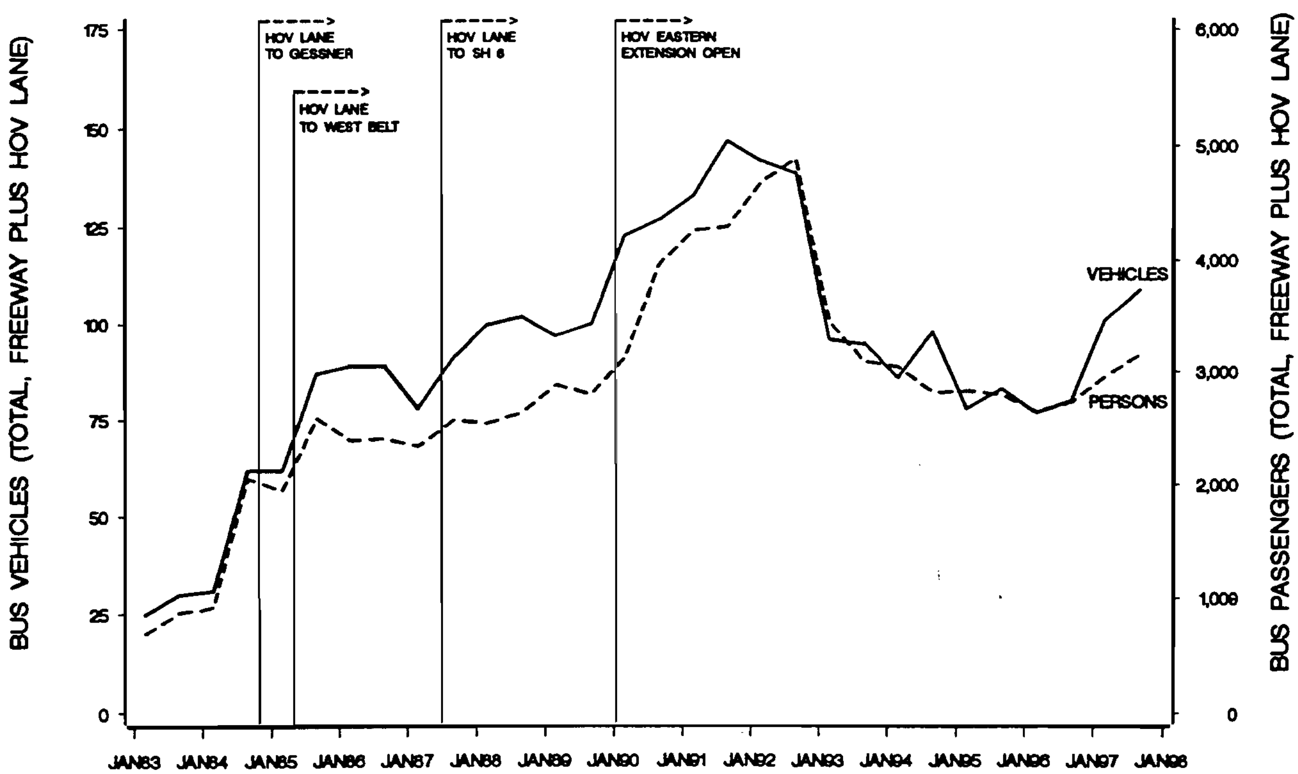


FIGURE A-19. A.M. PEAK PERIOD BUS PASSENGER TRIPS
TOTAL, FREEWAY PLUS HOV LANE VOLUMES
KATY FREEWAY AND FREEWAY WITHOUT HOV LANE

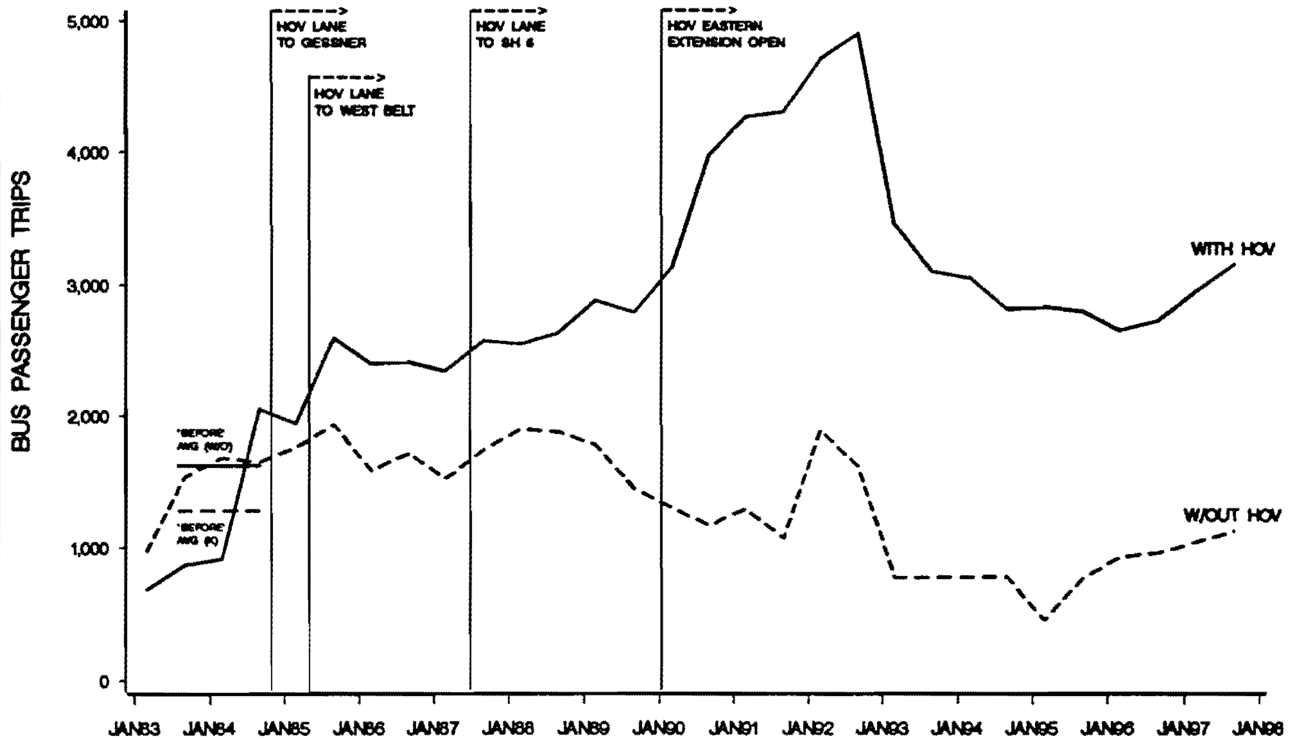
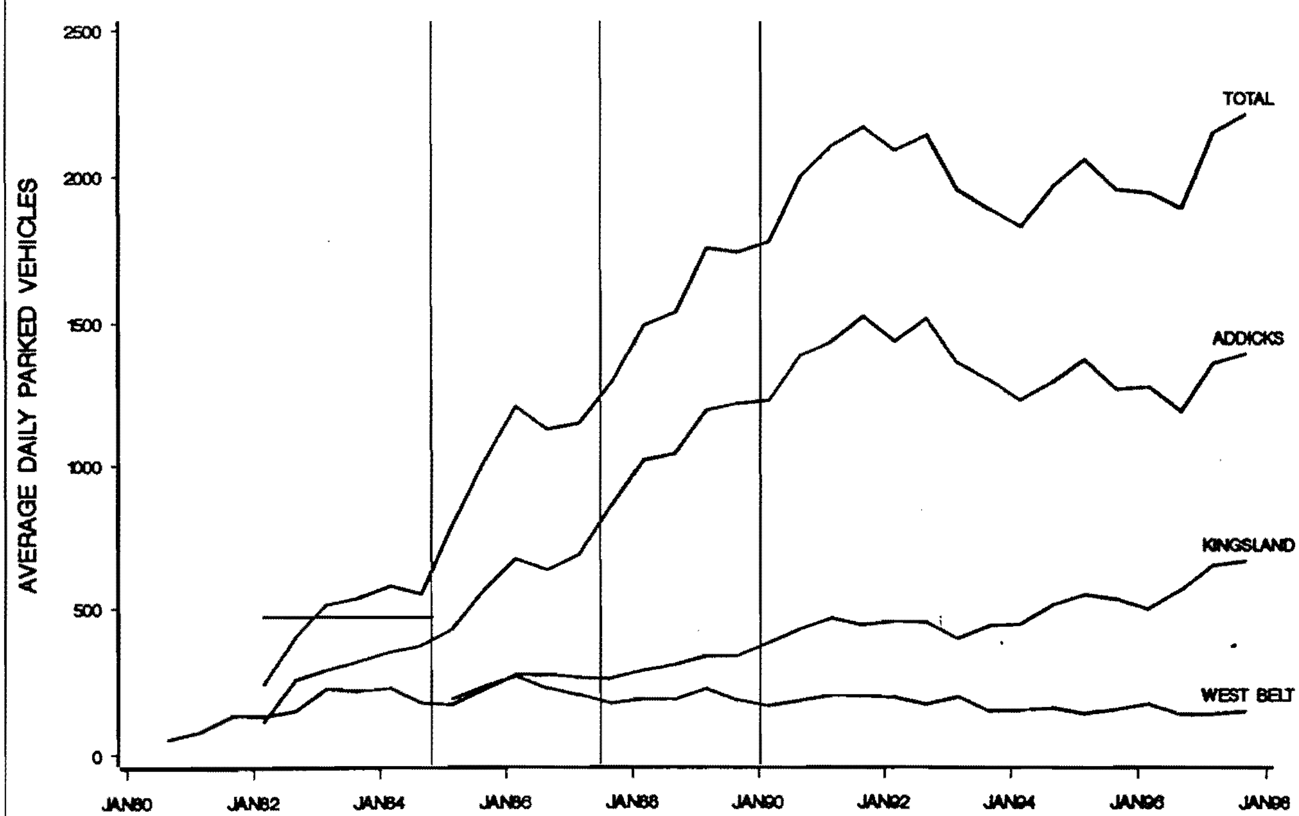


FIGURE A-20. KATY FREEWAY (IH 10W) CORRIDOR PARK-AND-RIDE DEMAND



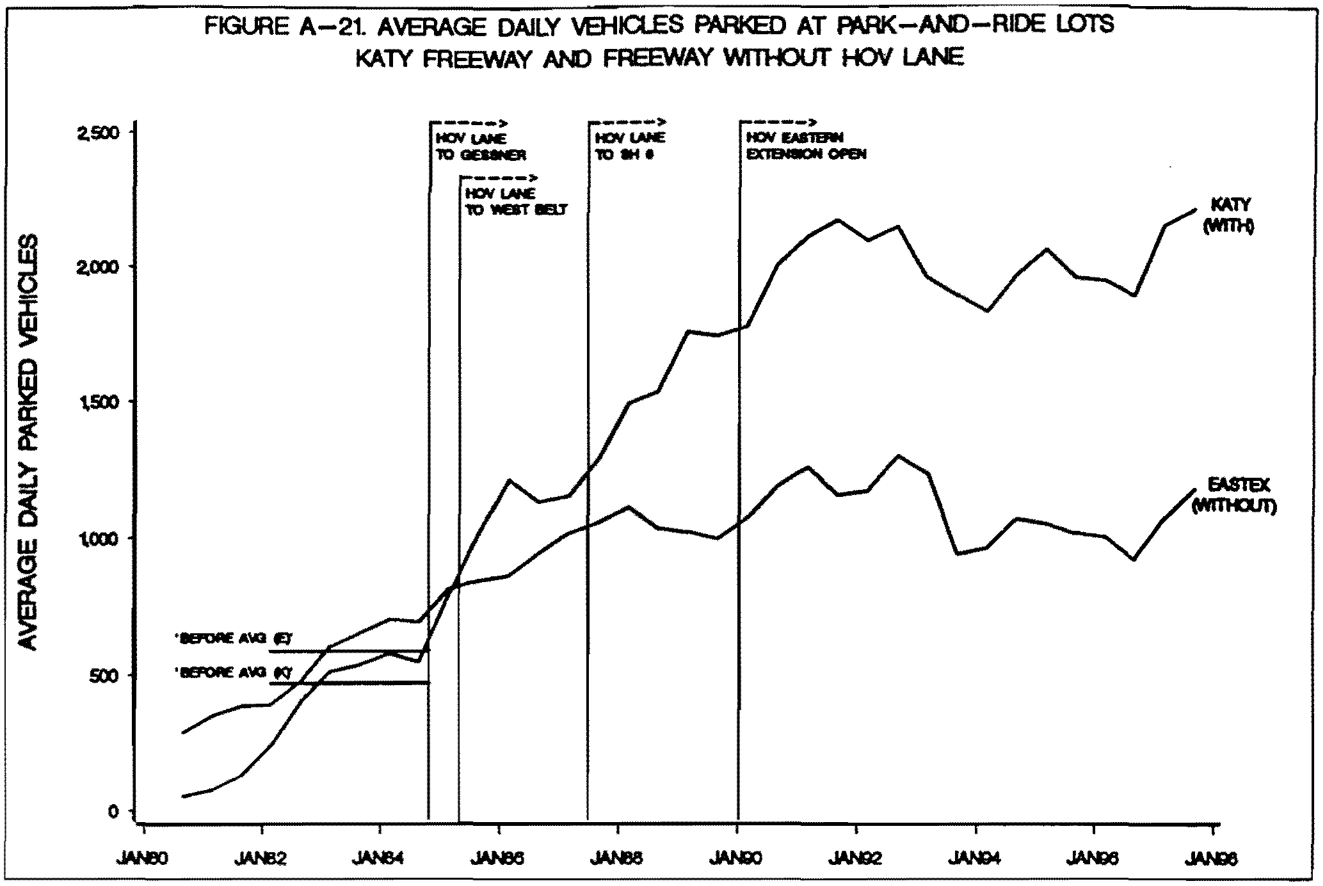


FIGURE A-21. AVERAGE DAILY VEHICLES PARKED AT PARK-AND-RIDE LOTS
KATY FREEWAY AND FREEWAY WITHOUT HOV LANE
AVERAGE DAILY PARKED VEHICLES
2,500
2,000
1,500
1,000
500
0
HOV LANE TO GESSNER
HOV LANE TO WEST BELT
HOV LANE TO SH 6
HOV EASTERN EXTENSION OPEN
KATY (WITH)
EASTEX (WITHOUT)
'BEFORE AVG (E)'
'BEFORE AVG (K)'
JAN80
JAN82
JAN84
JAN86
JAN88
JAN90
JAN92
JAN94
JAN96
JAN98

APPENDIX B

NORTH FREEWAY AND HOV LANE DATA

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

Table B-1. Summary of A.M. Peak-Direction North Freeway and HOV Lane Data, 1997

Type of Data Phase 1 of HOV Lane Became Operational 11/23/84 Contraflow Lane Became Operational 8/79	"Representative" Pre-Contraflow Value[1]	"Representative" Current Value	Percent Change
HOV Lane Data			
HOV Lane Length (miles)		12.2	
HOV Lane Cost (millions)		$192.4	
Person-Movement			
Peak-Hour (7-8 a.m.)	---	4,337	---
Peak-Period (6-9:30 a.m.)	---	9,275	---
Total Daily	---	19,088	---
Vehicle Volumes			
Peak-Hour	---	1,284	---
Peak-Period	---	2,824	---
Vehicle Occupancy, Peak-Hour (persons/veh)	---	3.4	---
Accident Rate (i.e., Injury accidents/100 MVM)[2]	---	39.4	---
Vehicle Breakdowns (VMT/Breakdown)	---	62,857	---
Violation Rate (6-9:30 a.m.)		8%	
Peak-Hour Lane Efficiency (1000's)[3]	---	213	---
Annual Discounted Benefits (millions)[4]	---	$36	---
Annual Delay Savings (millions)[5]		$4	
Travel Time (minutes)[6]			
Peak-Hour		15.15	
Peak-Period		14.16	
Freeway Mainlane Data (see note)			
Person-Movement			
Peak-Hour	6,335	6,347	+23%
Peak-Period (6-9:30 a.m.)	---	21,008	---
Vehicle Volume			
Peak-Hour	4,950	5,804	+55%
Peak-Period	---	19,851	---
Vehicle Occupancy, Peak-Hour (persons/veh)	1.28	1.09	-20%
Accident Rate (i.e., Injury accidents/100 MVM)[2]	30.3	24.6	-19%
Avg. Operating Speed (mph)[6]			
Peak-Hour	20	32	+60%
Peak-Period	30	41	+37%
Peak-Hour Lane Efficiency (1000's)[3]	41	51	+24%

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

[1]Pre-HOV lane values are generally not shown since these data were not collected prior to the opening of the contraflow lane in August 1979. A barrier-separated reversible HOV lane replaced the contraflow lane in November 1984. Pre-contraflow data are for 1978.

[2]Due to inconsistencies in reporting accidents in Harris County, this analysis includes only injury accidents. Accidents analyzed are between North Shepherd and Hogan, a distance of approximately 7.8 mi. This corresponds to Phase 1 of the HOV lane. "Before" data are for the period 1/82 through 11/84. "After" accident rate shown is for the time period from 12/84 to 12/97. Only officer-reported accidents are included in files. 1997 freeway volumes were estimated by TTI to compute rates.

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

[4]Based on average annual delay savings, reduced vehicle operating costs, and reduced accident costs generated by MicroBENCOST over a 20-year life.

[5]Per MicroBENCOST, over a 20-year life.

[6]Current operating speeds are calculated using data from Automatic Vehicle Identification (AVI) readers over a distance of 12.2 mi.

Table B-1. Summary of A.M. Peak-Direction North Freeway and HOV Lane Data, 1997 (Continued)

Type of Data Phase 1 of HOV Lane Became Operational 11/23/84 Contraflow Lane Became Operational 8/79	"Representative" Pre-Contraflow Value[1]	"Representative" Current Value	Percent Change
Combined Freeway Mainlane and HOV Lane Data			
Total Person-Movement			
Peak-Hour	6,335	10,684	+69%
Peak-Period	---	30,283	---
Vehicle Volume			
Peak-Hour	4,950	7,088	+43%
Peak-Period	---	22,675	---
Vehicle Occupancy			
Peak-Hour	1.28	1.51	+18%
Peak-Period	1.28	1.34	+5%
2+ Carpool Volumes			
Peak-Hour	700	1,521	+117%
Peak-Hour Lane Efficiency (1000's)[3]	41	83	+102%
Transit Data[7]			
Bus Vehicle Trips			
Peak-Hour	---	56	---
Peak-Period	---	117	---
Bus Passenger Trips			
Peak-Hour	---	1,815	---
Peak-Period	---	3,665	---
Bus Occupancy (persons/bus)			
Peak-Hour	---	32.4	---
Peak-Period	---	31.3	---
Vehicles Parked in Corridor Park-and-Ride Lots	---	3,641	---
Bus Operating Speed[6] (mph)			
Peak-Hour	---	49	---
Peak-Period	---	52	---

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

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

[1]Pre-HOV lane values are generally not shown since these data were not collected prior to the opening of the contraflow lane in August 1979. A barrier-separated reversible HOV lane replaced the contraflow lane in November 1984. Pre-contraflow data are for 1978.

[2]Due to inconsistencies in reporting accidents in Harris County, this analysis includes only injury accidents. Accidents analyzed are between North Shepherd and Hogan, a distance of approximately 7.8 mi. This corresponds to Phase 1 of the HOV lane. "Before" data are for the period 1/82 through 11/84. "After" accident rate shown is for the time period from 12/84 to 12/97. Only officer-reported accidents are included in files. 1997 freeway volumes were estimated by TTI to compute rates.

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

[4]Based on average annual delay savings, reduced vehicle operating costs, and reduced accident costs generated by MicroBENCOST over a 20-year life.

[5]Per MicroBENCOST, over a 20-year life.

[6]Current operating speeds are calculated using data from Automatic Vehicle Identification (AVI) readers over a distance of 12.2 mi.

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

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

Measure of Effectiveness	North Freeway	Eastex Freeway
Average A.M. Peak-Hour Vehicle Occupancy	1.51[1]	1.30
Bus Passengers, Peak Period	3,665	1,123
Cars Parked at Park-and-Ride Lots	3,641	1,099
Facility Per Lane Efficiency[2]	83	81

[1]1978 pre-contraflow occupancy estimated at 1.28 persons per vehicle.
[2]This represents the multiple of peak-hour passengers and average speed for the HOV lane and freeway mainlanes combined (passengers x mph/number of lanes).

HOV LANE DATA

DESCRIPTION

- The contraflow lane operation began 8/28/79.

- Phases 1 and 2 of HOV lane operation began 11/23/84.

- The capital cost for the operating segment (including all existing support facilities) in 1990 dollars was $75.9 million. The estimated total cost for the completed HOV lane (1990 dollars) is $142.1 million. Tables B-3 and B-4 provide a more detailed cost breakdown.

- Selected milestone dates are listed below. The capital costs tables show other dates.
  - 8/29/79 Contraflow lane operations begin (9.1 mi).
  - 3/31/81 A.M. concurrent flow lane to West Road opens (12.9 mi).
  - 11/23/84 HOV lane replaces contraflow (Shepard to Hogan 7.8 mi.).
  - 4/2/90 HOV lane extended to Beltway 8 (13.5 mi).
  - 6/26/90 Carpools allowed on HOV.
  - 6/30/90 Weekend operations begin (4:00 a.m. - 10:00 p. m.).
  - 10/5/91 Weekend operations end.
  - 9/8/92 Motorcycles allowed on HOV facility (no occupancy restrictions).
  - 3/14/94 Hours of operation revised (5:00 a.m. - 10:00 a.m.; 3:00 p.m. - 8:00 p.m.).
  - 4/4/94 Hours of operation revised (5:00 a.m. - 12:00 p.m.; 2:00 p.m. - 9:00 p.m).
  - 9/30/96 Hours of operation revised (5:00 a.m. - 11:00 a.m.; 2:00 p.m. - 8:00 p.m.).
  - 9/22/97 HOV lane extended to Airtex (16.9 mi).

PERSON-MOVEMENT

- In 1997, 19,088 person trips per day were served on the HOV lane.

- A.M. peak hour, 4,337 persons/hour.

  - 1,815 (42 percent) by bus, 56 (1 percent) by vanpool, 2,464 (57 percent) by carpool, and 3 by motorcycle (Figure B-1).
  - Average HOV lane vehicle occupancy = 3.38 persons/vehicle.

- A.M. peak period, 9,275 persons.

  - 3,665 (40 percent) by bus, 290 (3 percent) by vanpool, 5,308 (57 percent) by carpool, and 12 by motorcycle (Figure B-2).

VEHICLE MOVEMENT

- A.M. peak hour, 1,284 vph

  - 56 (4 percent) buses, 9 (1 percent) vans, 1,217 (95 percent) carpools, and three by motorcycle (Figure B-3).

- A.M. peak period, 2,824 vehicles.

  - 117 (4 percent) buses, 40 (1 percent) vans, 2,655 (94 percent) carpools, and 12 by motorcycle (Figure B-4).

ACCIDENT RATE

- For the period from December 1984 through December 1997, the HOV lane accident rate was 39.4 injury accidents per 100 million vehicle miles.

VEHICLE BREAKDOWN RATES

- The following vehicle breakdown rates were observed between December 1984 and December 1997.
  - Overall weighted average: one breakdown per 62,857 VMT.

VIOLATION RATE

- The observed violation rate (vehicles on the HOV lane not eligible to use the HOV lane) for 1997 was approximately 8 percent.

PEAK-HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. For the HOV lane, this value (expressed in 1000's) is approximately 213 (4,337 passengers at 49 mph).

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

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1995 Dollars
HOV Lane and Ramps			
Phase 1 Construction (1984)	$17.3	1.38	$23.9
Phase 2 Construction (1987)	50.6	1.27	64.3
Phase 3 Construction (1990)			
Incl. Aldine-Bender Interchange	5.4	1.16	6.3
Phase 4 Construction (1990)	7.6	1.16	8.8
Phase 4A Beltway 8 to Airtex (1997)	5.8	0.94	5.5
Phase 4A Kuykendahl Interchange (1997)	7.6	0.94	7.1
Connection L (1992)	1.9	1.09	2.1
Miscellaneous (all phases) (1988)	6.2	1.23	7.6
HOV Lane Barrier Mod (1996)	0.3	0.97	0.3
SUB-TOTAL	$102.7		$118.3
Per Mile	$6.1		$7.4
Surveillance, Communication, and Control (1990)	$2.4	1.16	$2.8
SUB-TOTAL	$2.4		$2.8
Per Mile	$0.2		$0.2
Support Facilities			
North Shepherd P/R (1980)	$2.2	1.56	$3.4
North Shepherd P/R Expansion (1982)	2.1	1.47	3.1
Kuykendahl P/R (1980)	1.7	1.56	2.7
Kuykendahl P/R Expansion (1983)	1.8	1.43	2.6
Spring P/R (1982)	3.7	1.47	5.4
Seton Lake P/R (1983)	3.3	1.43	4.7
Woodlands P/R (1985)	2.6	1.34	3.5
Woodlands P/R Expansion (1991)	0.8	1.13	0.9
Kuykendal P/R Expansion (1996)	11.4	0.97	11.1
SUB-TOTAL	$29.6		$37.4
Per Mile	$1.8		$2.3
TOTAL COST	$134.7		$158.5
COST PER MILE (16.0 miles)	$8.0		$9.9

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

Table B-4. Estimated Capital Cost (millions), North HOV Lane, Future Segments

Cost Component	Estimated Year of Completion	Estimated Cost ($Millions)
HOV Lane and Ramps		
Airtex to FM 1960 (3.0 mi.)	1999	$3.7
FM 1960 Interchange	1999	4.7
Crosstimbers Access Ramp	1998	13.0
SUB-TOTAL		$21.4
Per Mile		$7.1
Support Facilities		
Northline Transit Center	1999	2.0
TOTAL COST		$23.4
COST PER MILE (3.0 miles)		$7.8

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

TRAVEL TIME SAVINGS

- The users of the HOV lane experienced an average travel time savings of 8 minutes during the morning peak hour in 1997 (Table B-5, Figure B-5).

Table B-5. Travel Time Savings for North HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1997)

Southbound A.M. Travel Time Savings for North HOV Lane								
Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section from Sam Houston Parkway to N. Shepherd								
6:00	5.53	4.80	0.73	213	249	819	1,282	930
6:30	7.11	4.60	2.51	609	50	407	1,067	2,670
7:00	7.25	5.53	1.73	989	19	525	1,534	2,630
7:30	6.02	5.57	0.45	835	8	259	1,103	460
8:00	4.64	5.37	(0.73)	393	25	489	906	-400
8:30	4.25	6.23	-1.98	239	0	87	326	-660
9:00	4.15	4.53	-0.39	137	59	0	196	-60
Peak-Period Total				3,415	410	2,586	6,414	5,580
Section from N. Shepherd to the Hogan Overpass								
6:00	9.01	8.68	0.33	271	93	361	725	360
6:30	11.83	8.93	2.91	799	105	716	1,620	4,810
7:00	14.78	9.77	5.02	1,175	39	953	2,167	10,890
7:30	17.19	9.94	7.25	1,333	24	1,024	2,380	17,260
8:00	13.46	8.83	4.63	937	27	513	1,477	6,970
8:30	10.79	8.23	2.56	534	8	221	764	2,030
9:00	10.03	8.11	1.92	274	5	75	354	674
Peak-Period Total				5,323	301	3,863	9,487	42,980
Northbound P.M. Travel Time Savings for North HOV Lane								
Section from Sam Houston Parkway to N. Shepherd								
3:30	4.55	4.44	0.11	100	15	59	173	10
4:00	4.67	4.53	0.15	282	31	124	437	70
4:30	4.87	4.56	0.31	423	86	196	704	220
5:00	5.08	4.64	0.45	609	62	329	1,000	440
5:30	5.34	4.69	0.66	807	107	497	1,412	920
6:00	5.03	4.75	0.29	584	26	190	800	220
6:30	4.47	4.44	0.04	261	17	46	324	20
Peak-Period Total				3,066	344	1,441	4,850	1,900

Table B-5. Travel Time Savings for North HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1997)

Northbound P.M. Travel Time Savings for North HOV Lane								
Section from N. Shepherd to Hogan Overpass								
Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
3:30	9.65	8.17	1.47	242	12	140	393	630
4:00	10.31	8.47	1.84	520	16	274	809	1,490
4:30	11.09	8.79	2.31	773	151	632	1,555	3,590
5:00	12.34	9.05	3.30	1,062	130	902	2,094	6,930
5:30	12.23	9.31	2.92	1,216	70	900	2,185	6,470
6:00	10.26	8.90	1.37	935	17	639	1,591	2,240
6:30	8.62	8.29	0.33	483	10	236	728	290
Peak-Period Total				5,231	406	3,723	9,355	21,640

Table B-6. North Freeway Travel Time Summaries

Travel Time Data	Travel Times[1]					
	97[1]	96[2]	95[2]	94[2]	93[2]	Pre-HOV
HOVL Travel Time AM Peak-Hour PM Peak-Hour	 8 min 7 min	 9 min 7 min	 9 min 11 min	 10 min 9 min	 9 min 9 min	 - -
Freeway Mainlanes Travel Time AM Peak-Hour PM Peak-Hour	 11 min 9 min	 20 min 10 min	 19 min 10 min	 18 min 10 min	 13 min 12 min	 23 min 22 min
Net Travel Time Savings AM Peak-Hour (Person-Minutes) PM Peak-Hour (Person-Minutes)	 3 min (31,240) 2 min (14,760)	 11 min (34,911) 3 min (4,320)	 10 min (20,050) -1 min (2,060)	 8 min (30,559) 1 min (5,452)	 4 min (10,206) 3 min (10.953)	 - -

[1]Travel Times are calculated over a distance of 12.2 mi.
[1]Data collected using Automatic Vehicle Identification (AVI).
[2]Data collected using manual travel time data.

FIGURE B-1. NORTH FREEWAY (IH 45N) HOV LANE
A.M. PEAK HOUR HOV LANE PERSON MOVEMENT

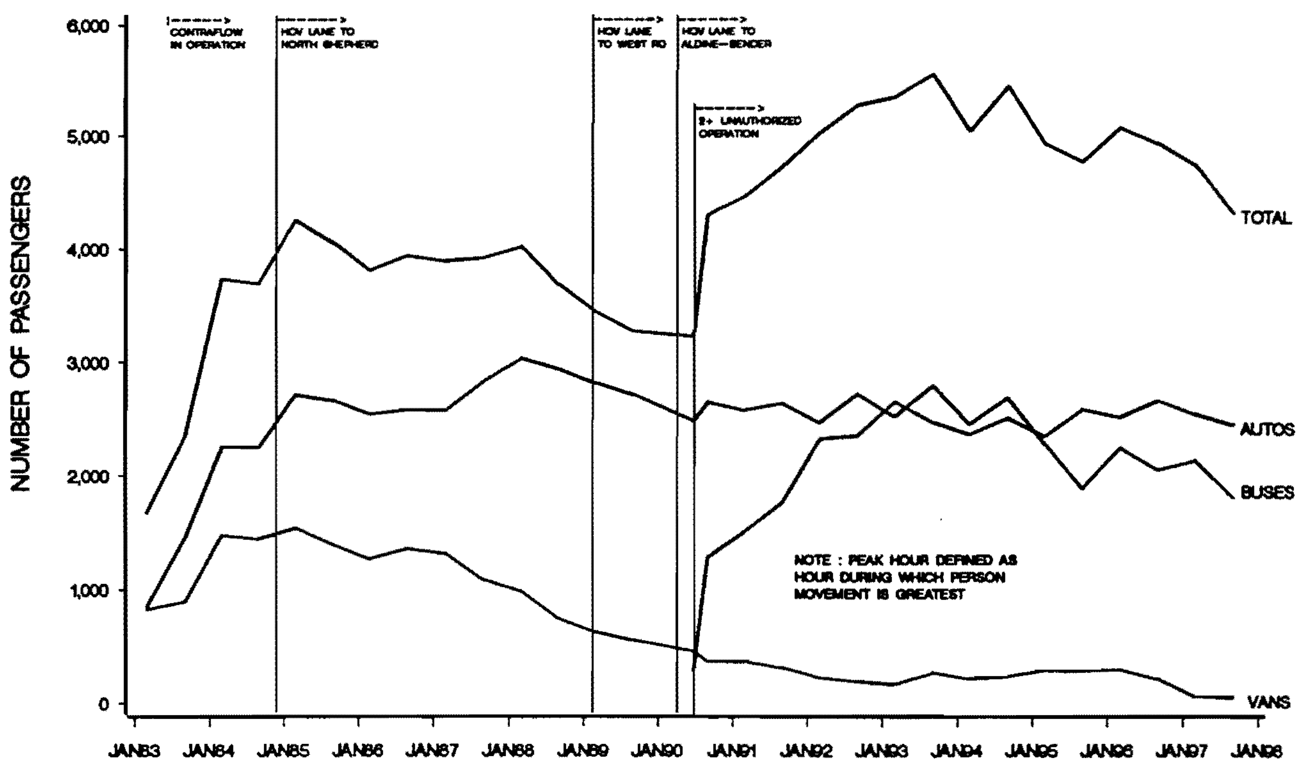


FIGURE B-2. NORTH FREEWAY (IH 45N) HOV LANE
A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT

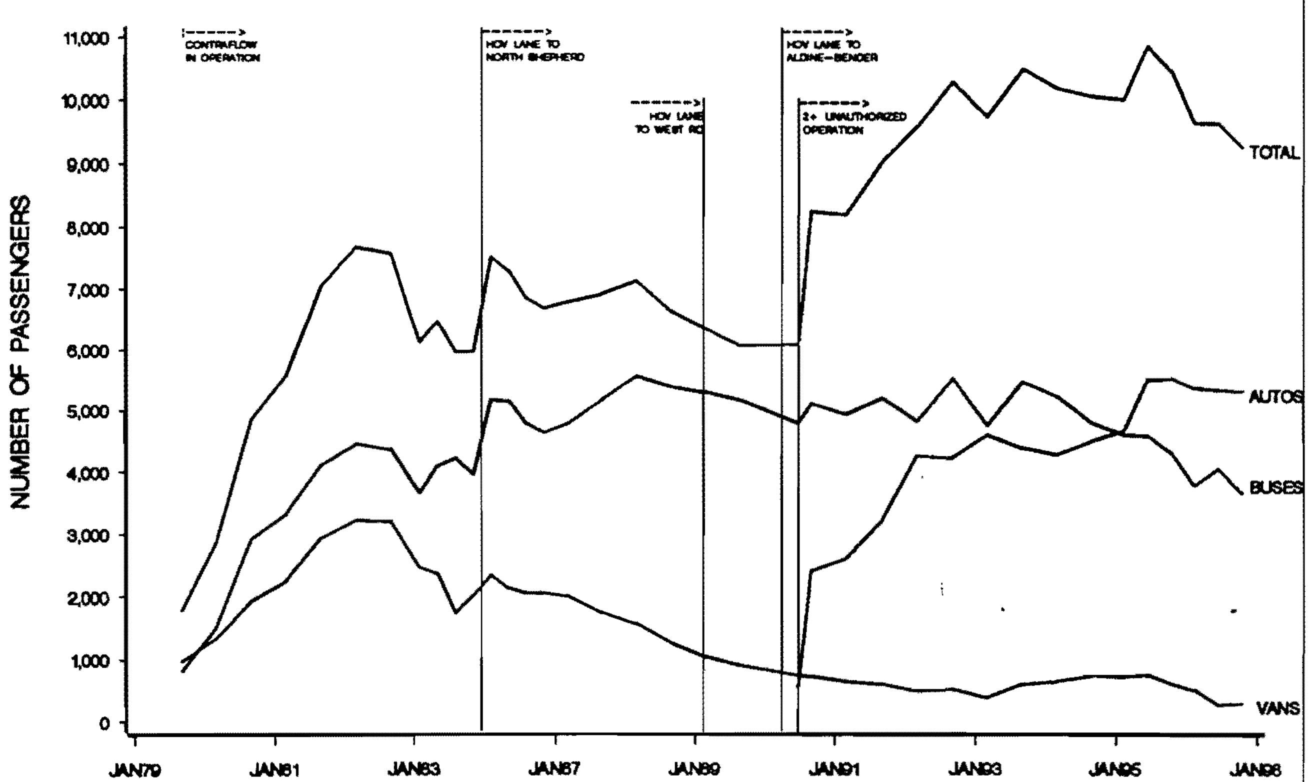


FIGURE B-3. NORTH FREEWAY (IH 45N) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION

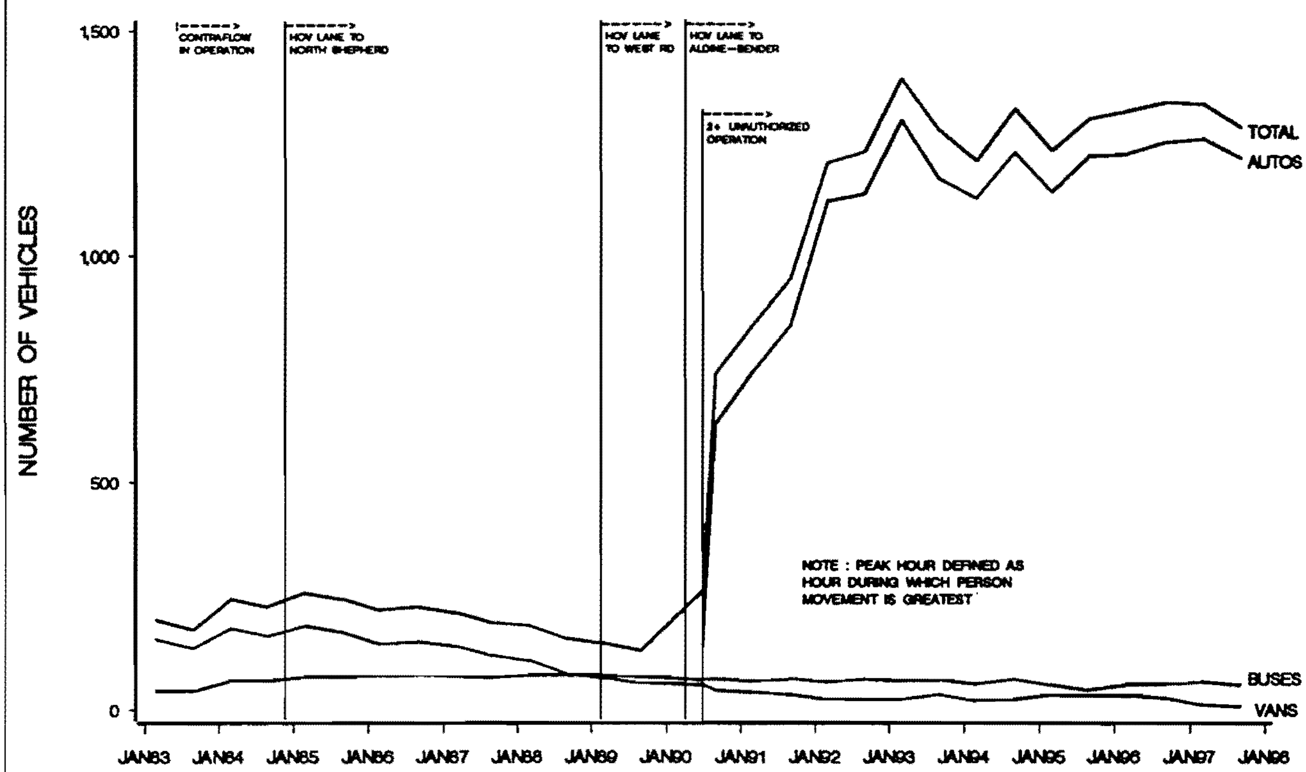
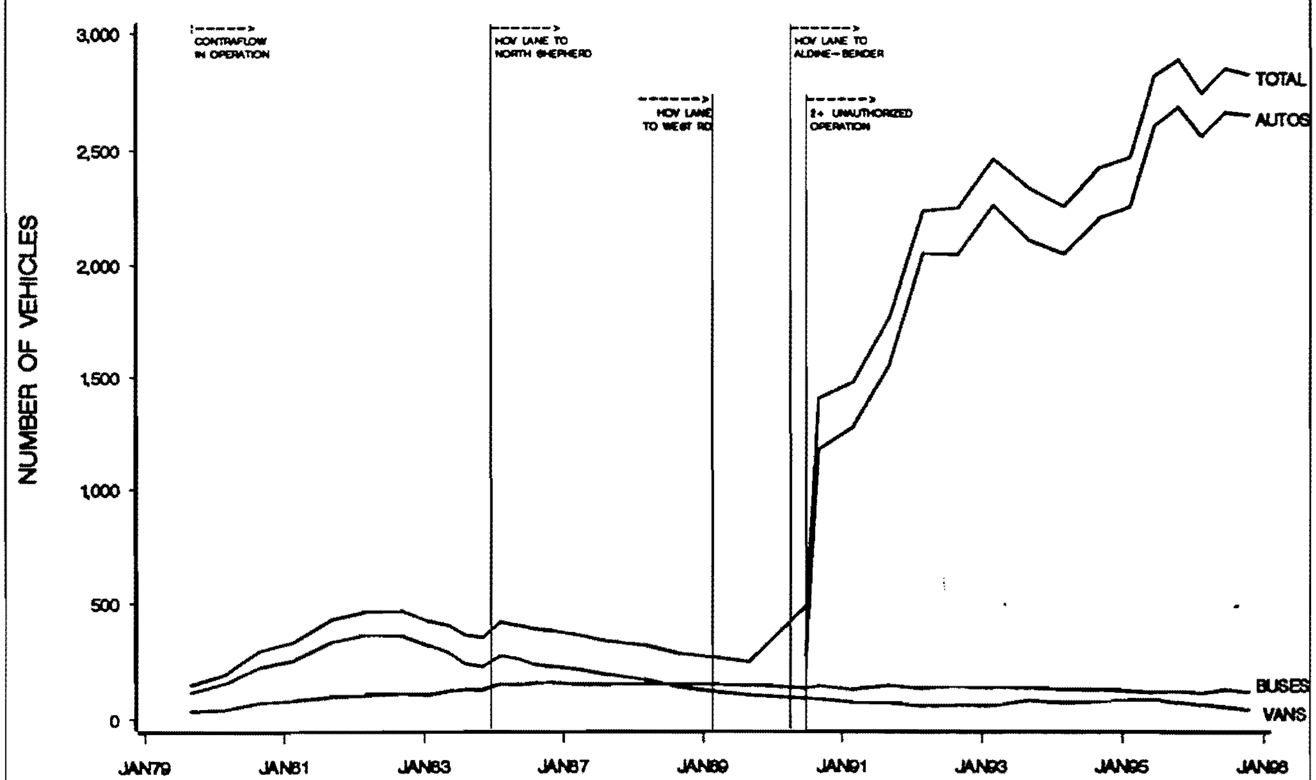


FIGURE B-4. NORTH FREEWAY (IH 45N) HOV LANE
A.M. PEAK PERIOD HOV LANE VEHICLE UTILIZATION



FREEWAY DATA

NOTE

- For purposes of safety and visibility, freeway volumes are counted at Little York between an exit ramp and an entrance ramp. Thus, freeway volumes may be low in comparison to typical freeway operations. The cross-section at the count location has been expanded from three to four 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 6,347 persons in the peak-hour (Figure B-6). Prior to contraflow implementation, limited data suggest this value was 6,335.

- Figure B-7 shows a.m. peak period mainlane person trips.

VEHICLE VOLUME

- In the a.m. peak hour, an average of 5,804 vehicles used the mainlanes during 1997 (Figure B-6). Prior to contraflow implementation, limited data suggest this value was 4,950.

VEHICLE OCCUPANCY

- In the a.m. peak period, an average of 19,851vehicles used the mainlanes (Figure B-7).

- In the a.m. peak hour, mainlane occupancy is approximately 1.09 (Figure B-8).

- In the a.m. peak period, mainlane occupancy is approximately 1.06 (Figure B-9).

ACCIDENT RATE

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

- Prior to opening the barrier-separated HOV lane, a contraflow lane was in operation. For this period (1/82 to 11/84), the freeway accident rate was 30.3 injury accidents per 100 million vehicle miles (100 MVM). From 12/84 through 12/97, (since the barrier-separated HOV lane opened) the accident rate has been 24.6 injury accidents/100 MVM. Only officer-reported accidents are included.

AVERAGE OPERATING SPEED

- Average operating speed on the mainlanes has increased since the HOV lane opened (Figure B-10).

PEAK-HOUR LANE EFFICIENCY

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

- For the freeway mainlanes, the current peak-hour per lane efficiency is 51 (1,587 passengers per lane at 32 mph).

COMBINED FREEWAY AND HOV LANE DATA

TOTAL PERSON-MOVEMENT

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

  - At Little York, the HOV lane is carrying 41 percent of the total peak-hour person-movement (Figure B-11). In the peak period, the HOV lane carries 31 percent of the a.m. peak-period person trips (Figure B-12). Compared to pre-contraflow conditions, peak-hour person-movement has increased by 69 percent.

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.51 versus 1.09 occupants per vehicle for the mainlanes (Figure B-8). Occupancy in the peak period has also increased with the opening of the HOV lane (Figure B-9). Prior to implementing the contraflow lane in 1978, average occupancy on the North Freeway was 1.28 persons per vehicle.

- The occupancy on the North Freeway, which has had a priority HOV lane since 1979, has consistently been higher than the occupancy of freeways without HOV lanes (Figure B-13).

PEAK-HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a freeway corridor. The efficiency of the North corridor is 83 (persons x mph/number of lanes) (Figure B-14). Prior to contraflow lane implementation in 1978, the per lane efficiency was estimated to be 51 (persons x mph). Freeway corridors without HOV lanes experience lower efficiencies (Figure B-15).

BUS TRANSIT DATA

BUS VEHICLE AND PASSENGER TRIPS

- Within the a.m. peak period, bus passenger trips have decreased slightly over the past year. Currently there are about 1,815 passengers per peak-hour (Figure B-16) and 3,665 passengers per peak-period (Figure B-17). Likewise, the bus vehicle trips for the peak period have decreased slightly to 117 bus trips per peak period (Figure B-17).

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

PARK-AND-RIDE

- Currently, 3,641 vehicles are parked in the corridor park-and-ride lots. Approximately 49 percent of the 7,386 parking spaces are utilized (Figure B-19).

- The Eastex Freeway corridor (which does not have an HOV lane) has 74 percent less park-and-ride patrons than the North Freeway corridor. Eastex Freeway park-and-ride lots are operating at only 28 percent capacity as opposed to 49 percent on North Freeway (Figure B-20).

FIGURE B-5. NORTH FREEWAY (IH 45N) MAINLANES AND HOV LANE A.M. TRAVEL TIME

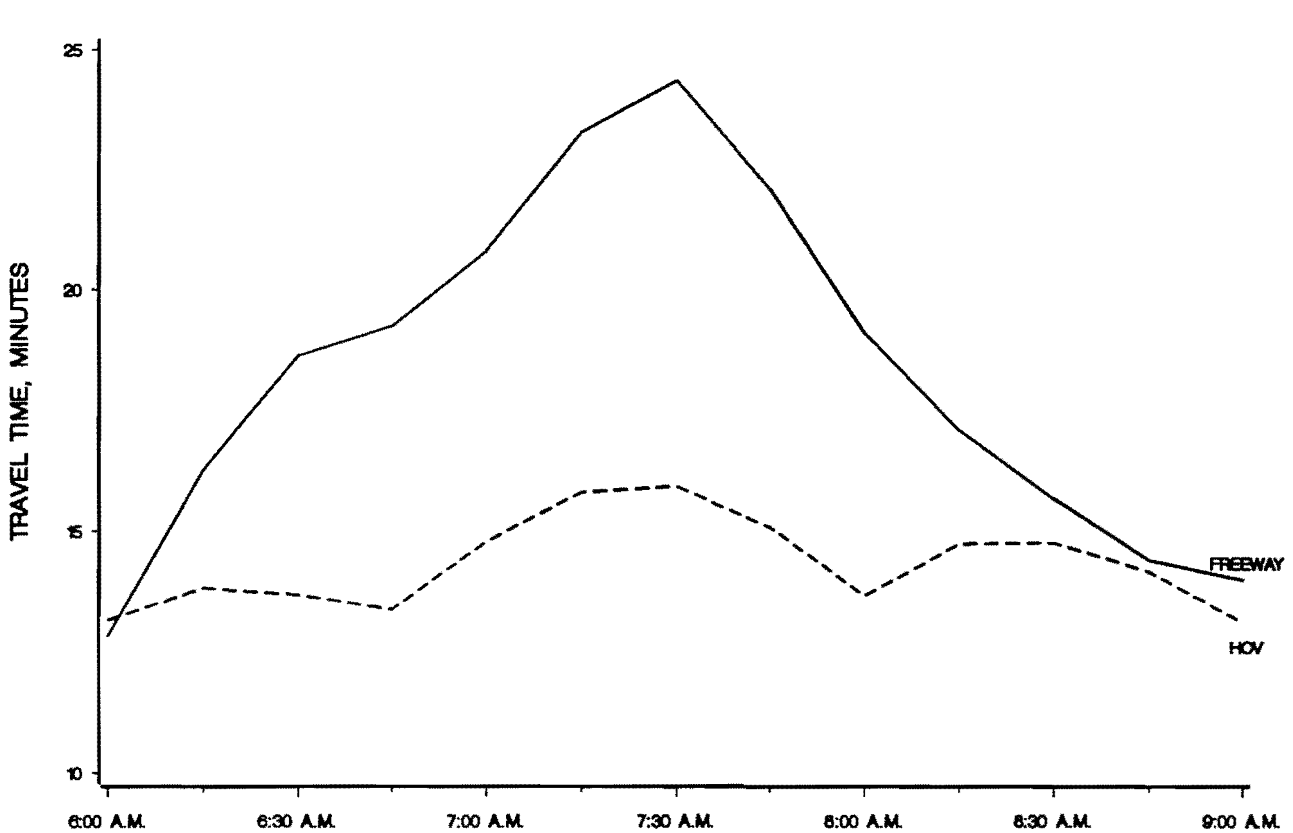


FIGURE B-6. NORTH FREEWAY (IH 45N)
A.M. PEAK HOUR MAINLANE TRIPS

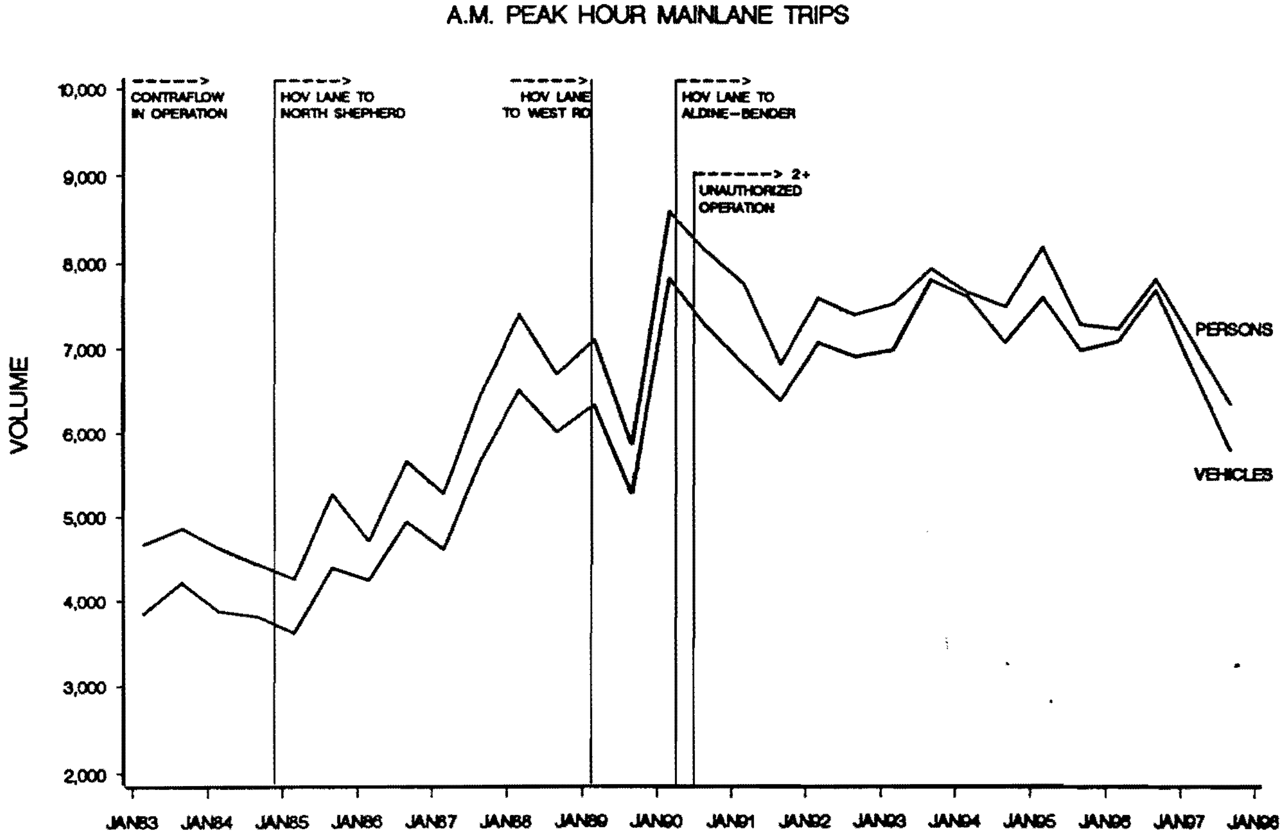


FIGURE B-7. NORTH FREEWAY (IH 45N)
A.M. PEAK PERIOD MAINLANE TRIPS

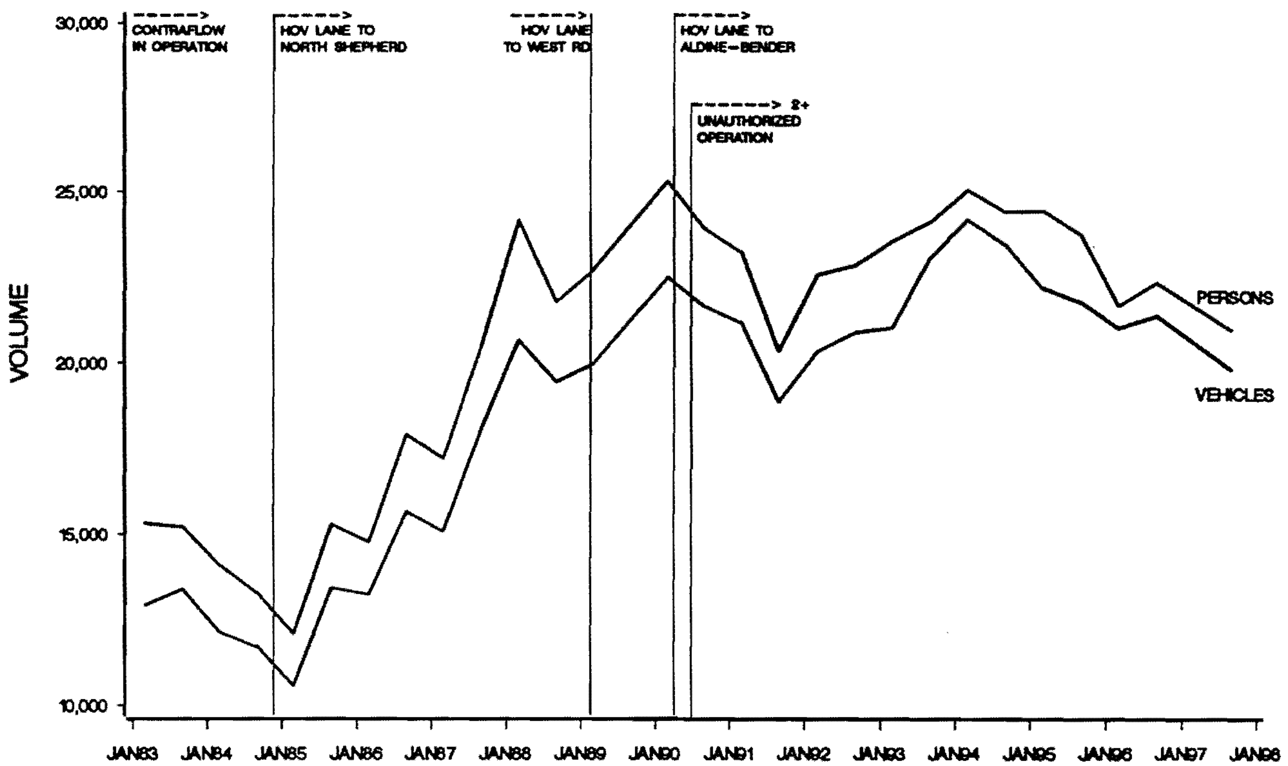
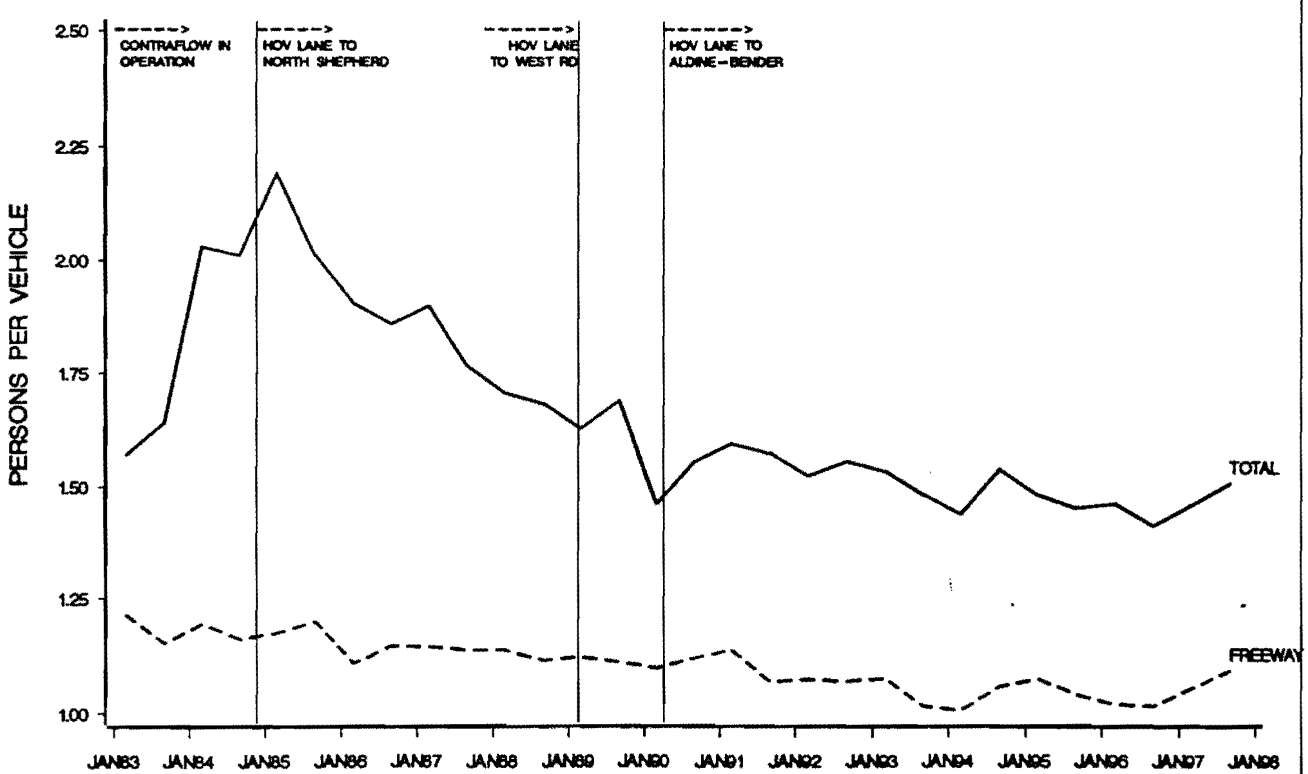


FIGURE B-8. NORTH FREEWAY (IH 45N) MAINLANE AND HOV LANE
A.M. PEAK HOUR AVERAGE OCCUPANCY



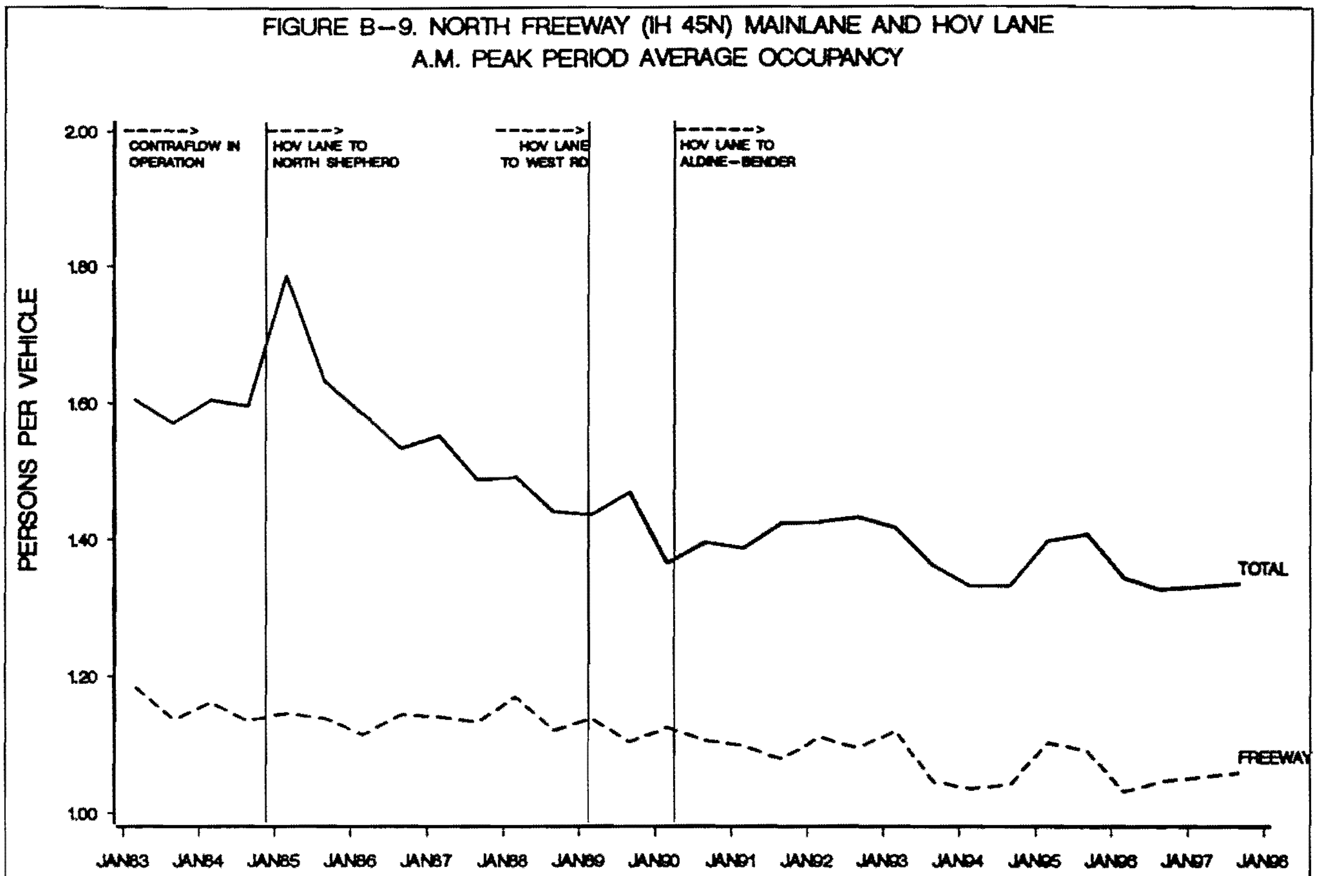


FIGURE B-9. NORTH FREEWAY (IH 45N) MAINLANE AND HOV LANE
A.M. PEAK PERIOD AVERAGE OCCUPANCY
PERSONS PER VEHICLE
CONTRAFLOW IN OPERATION
HOV LANE TO NORTH SHEPHERD
HOV LANE TO WEST RD
HOV LANE TO ALDINE-BENDER
TOTAL
FREEWAY
2.00
1.80
1.60
1.40
1.20
1.00
JAN83 JAN84 JAN85 JAN86 JAN87 JAN88 JAN89 JAN90 JAN91 JAN92 JAN93 JAN94 JAN95 JAN96 JAN97 JAN98

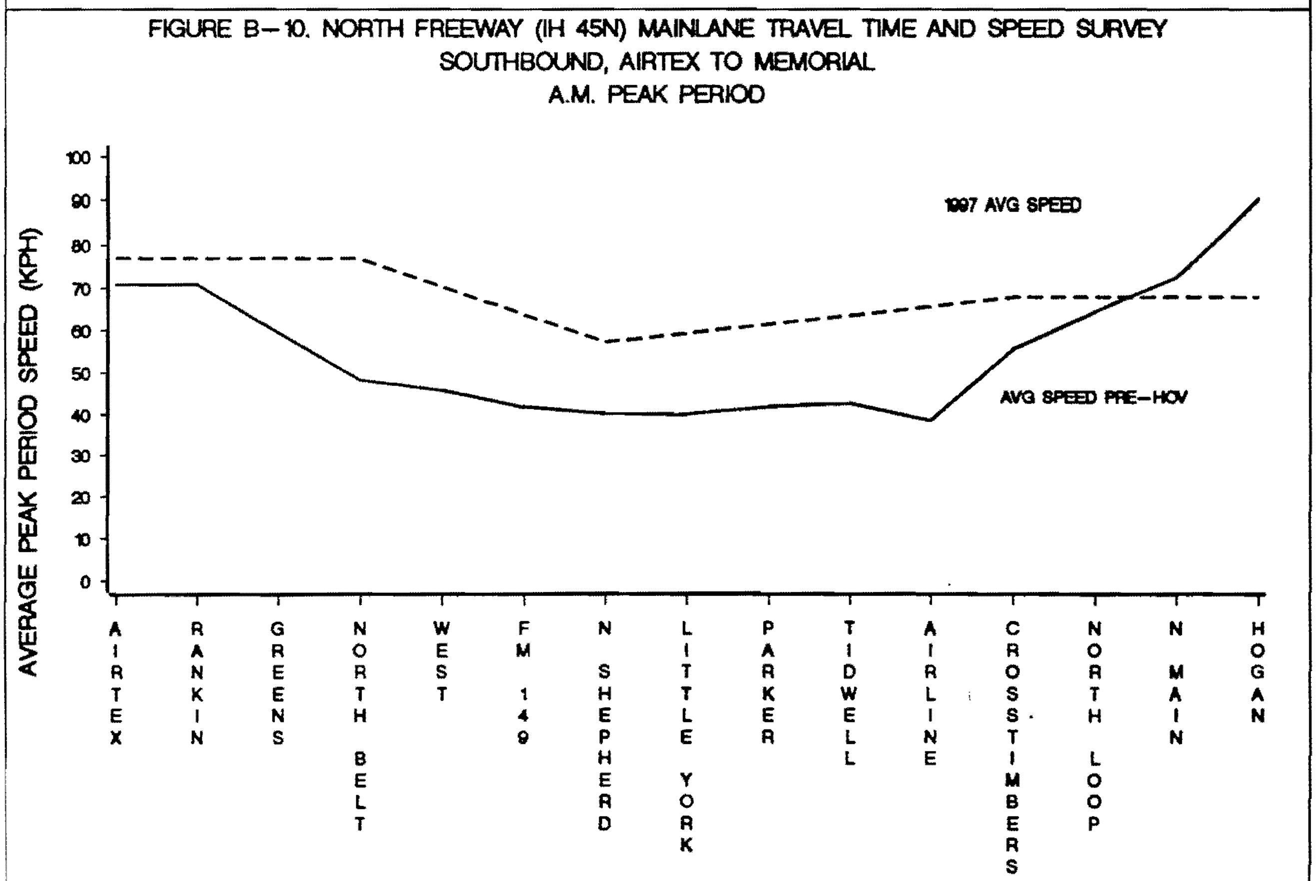


FIGURE B-10. NORTH FREEWAY (IH 45N) MAINLANE TRAVEL TIME AND SPEED SURVEY
SOUTHBOUND, AIRTEX TO MEMORIAL
A.M. PEAK PERIOD
AVERAGE PEAK PERIOD SPEED (KPH)
1997 AVG SPEED
AVG SPEED PRE-HOV
100
90
80
70
60
50
40
30
20
10
0
AIRTEX
RANKIN
GREENS
NORTH BELT
WEST
FM 149
N SHEPHERD
LITTLE YORK
PARKER
TIDWELL
AIRLINE
CROSSTIMBERS
NORTH LOOP
N MAIN
HOGAN

FIGURE B-11. NORTH FREEWAY (IH 45N) MAINLANE AND HOV LANE
A.M. PEAK HOUR PERSON TRIPS

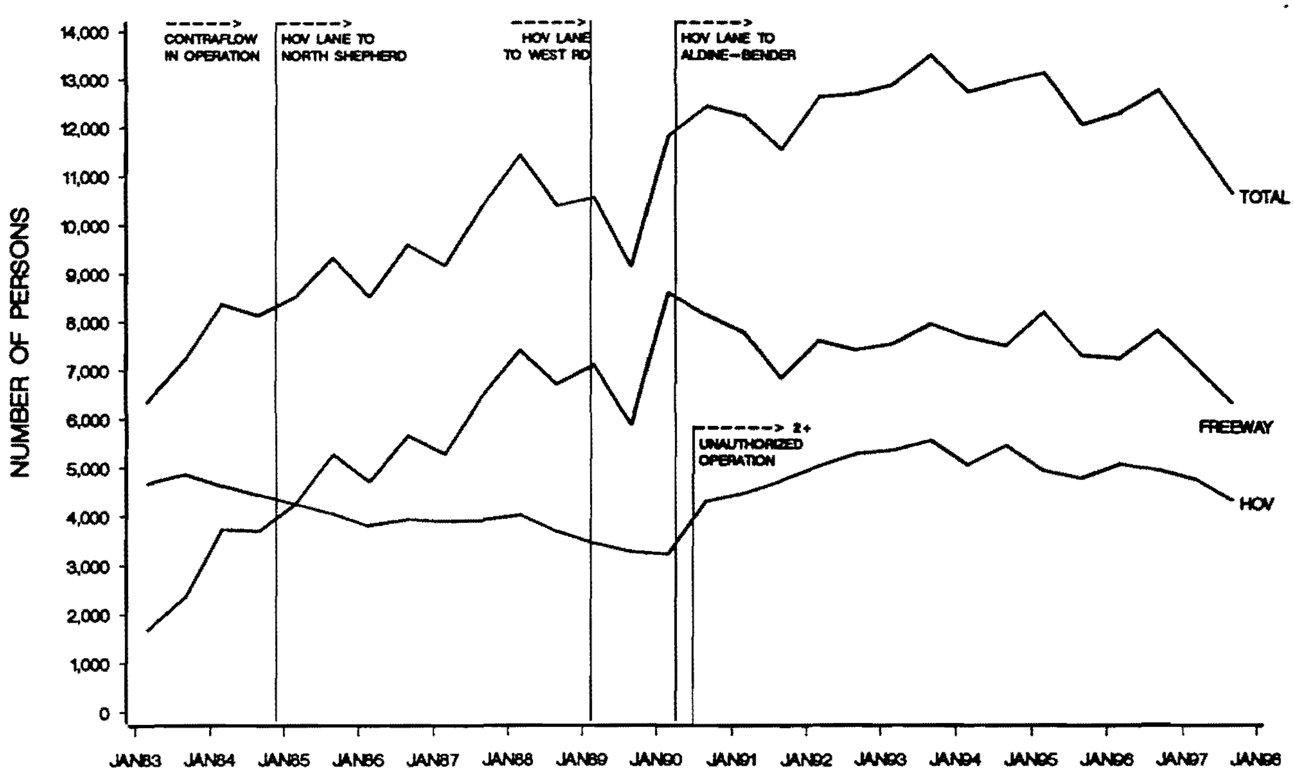


FIGURE B-12. NORTH FREEWAY (IH 45N) MAINLANE AND HOV LANE
A.M. PEAK PERIOD PERSON TRIPS

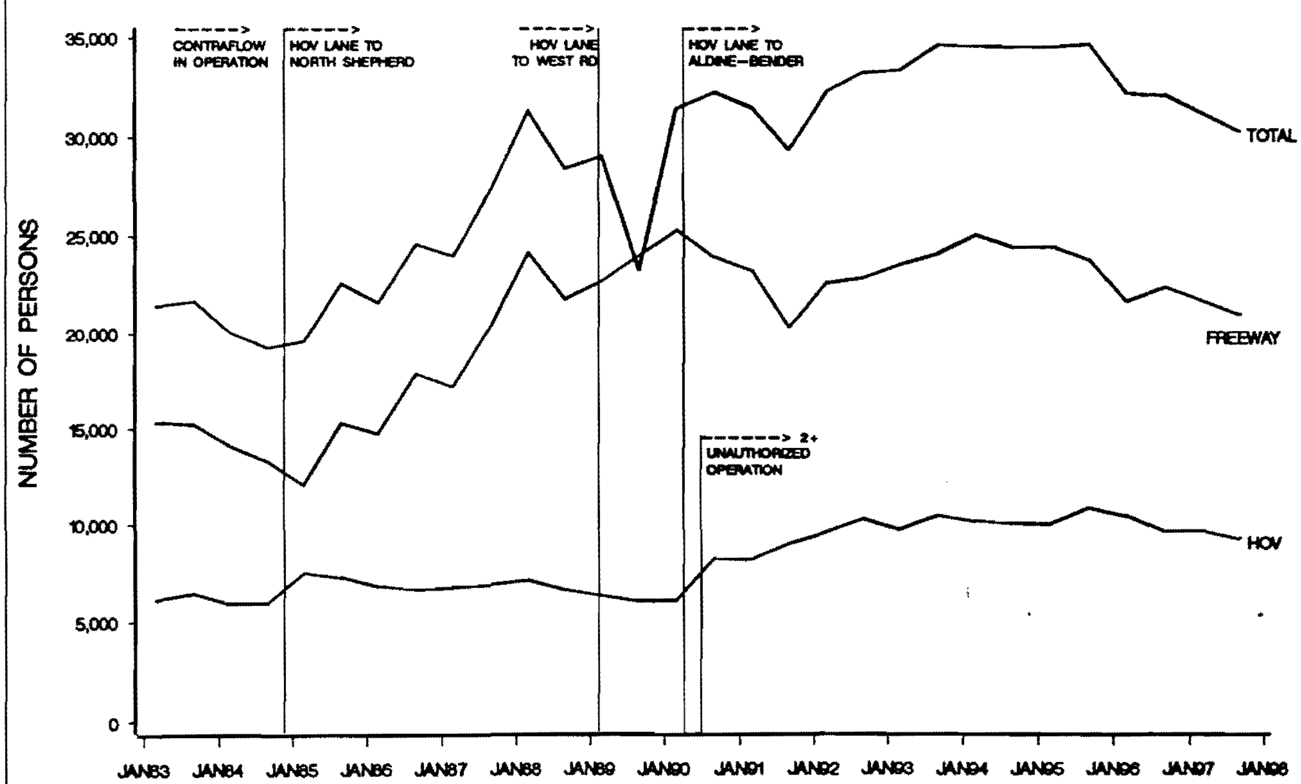


FIGURE B-13. A.M. PEAK HOUR AVERAGE OCCUPANCY
NORTH FREEWAY AND FREEWAY WITHOUT HOV LANE

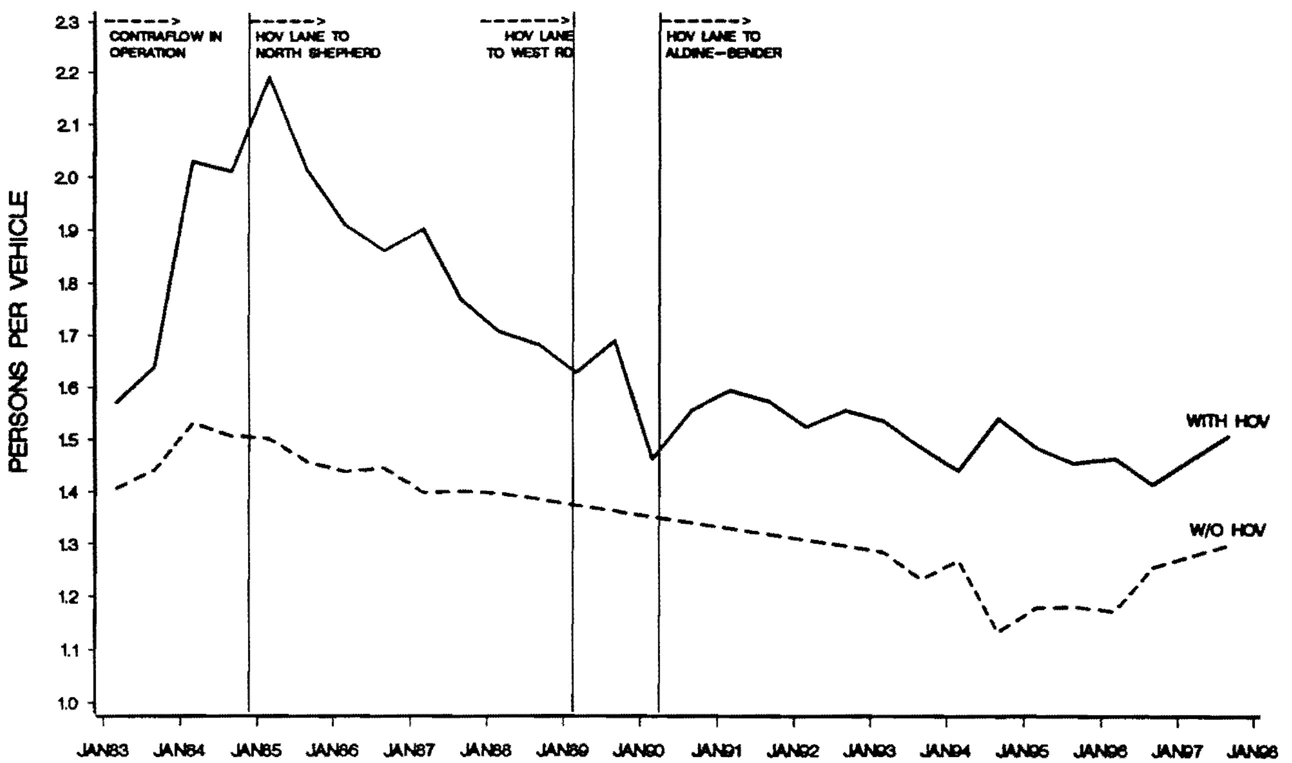


FIGURE B-14. NORTH FREEWAY (IH 45N) MAINLANE AND HOV LANE
A.M. PEAK HOUR 2+ CARPOOL UTILIZATION

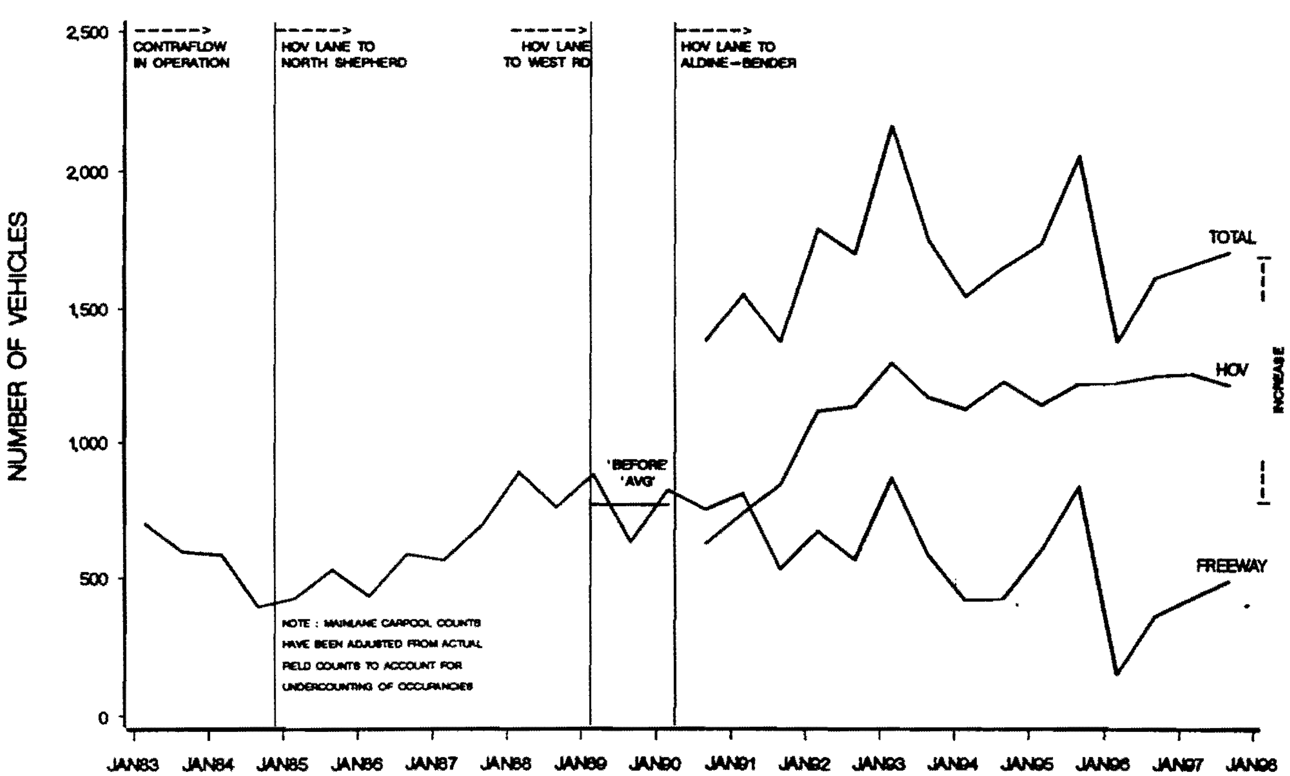


FIGURE B-15. A.M. PEAK HOUR FREEWAY PER LANE EFFICIENCY
NORTH FREEWAY AND FREEWAY WITHOUT HOV LANE

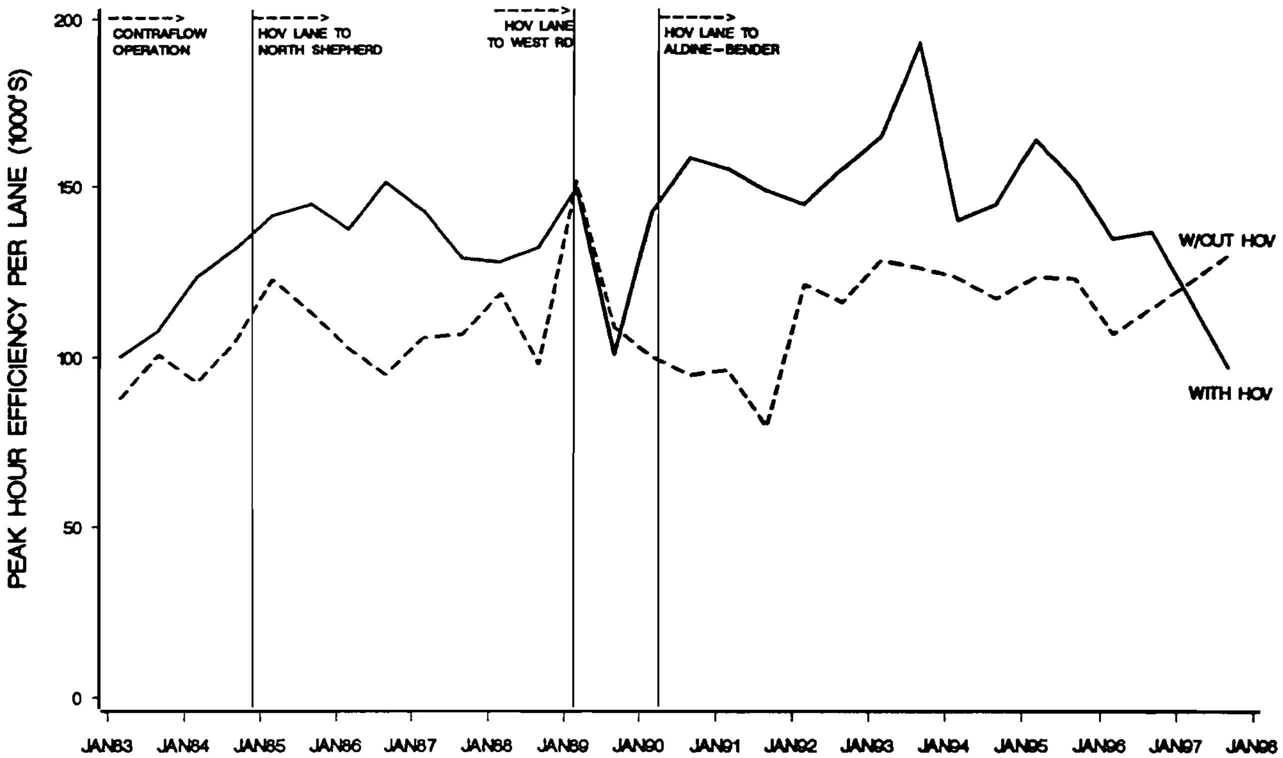


FIGURE B-16. NORTH FREEWAY (IH 45N) HOV LANE
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS

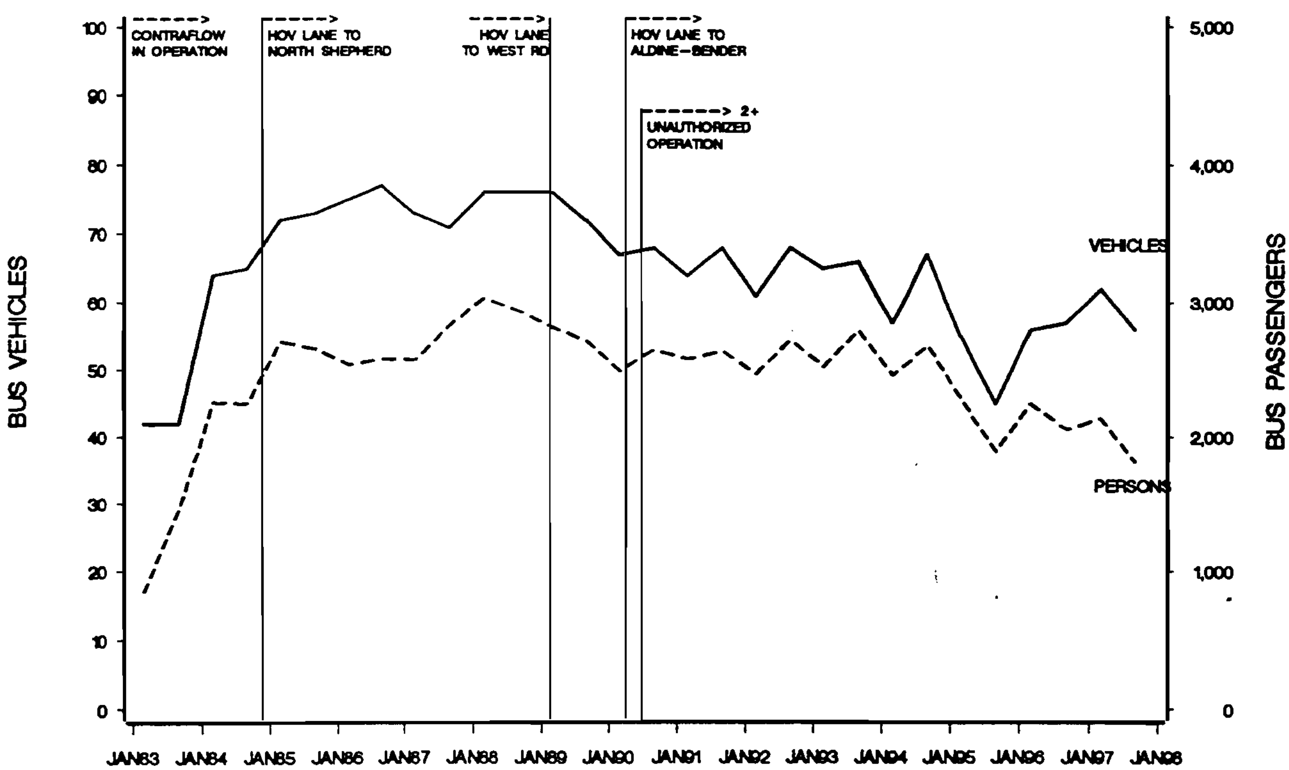


FIGURE B-17. NORTH FREEWAY (IH 45N) HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS

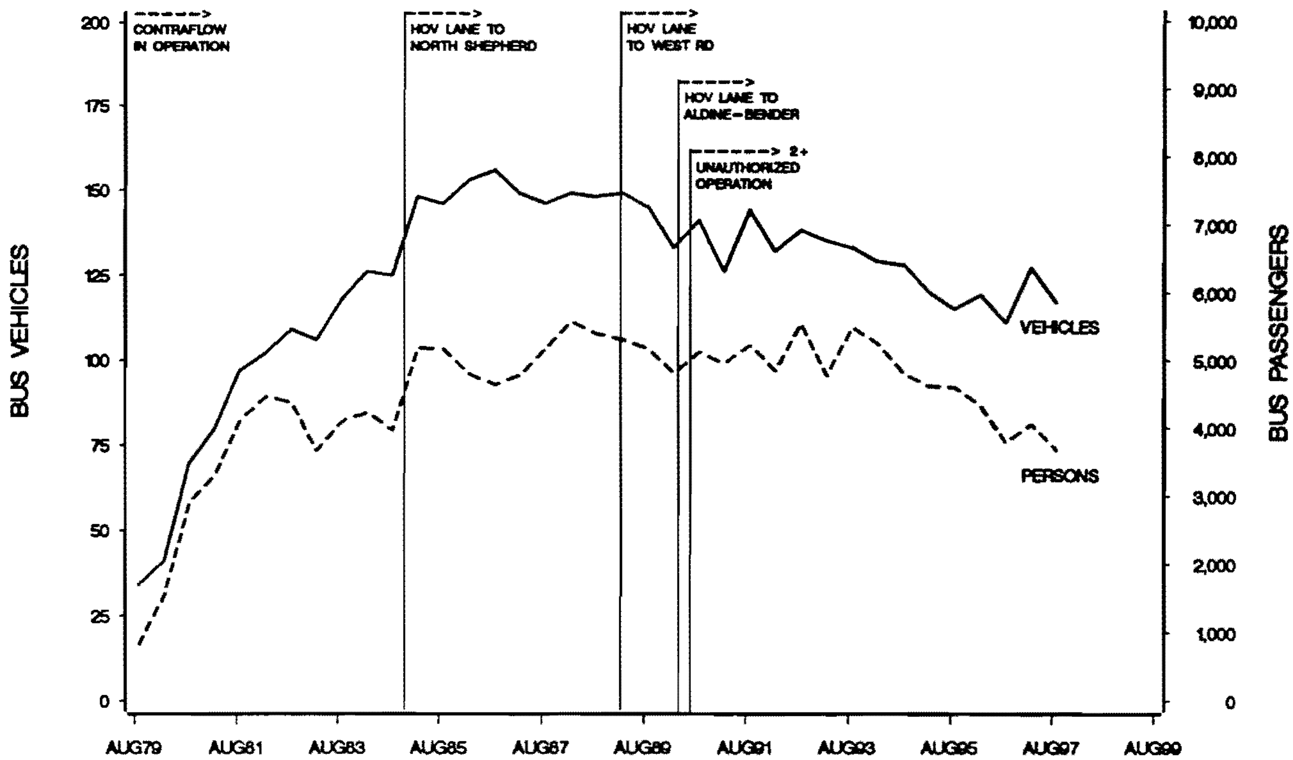


FIGURE B-18. A.M. PEAK PERIOD BUS PASSENGER TRIPS
TOTAL, FREEWAY PLUS HOV LANE VOLUMES
NORTH FREEWAY AND FREEWAY WITHOUT HOV LANE

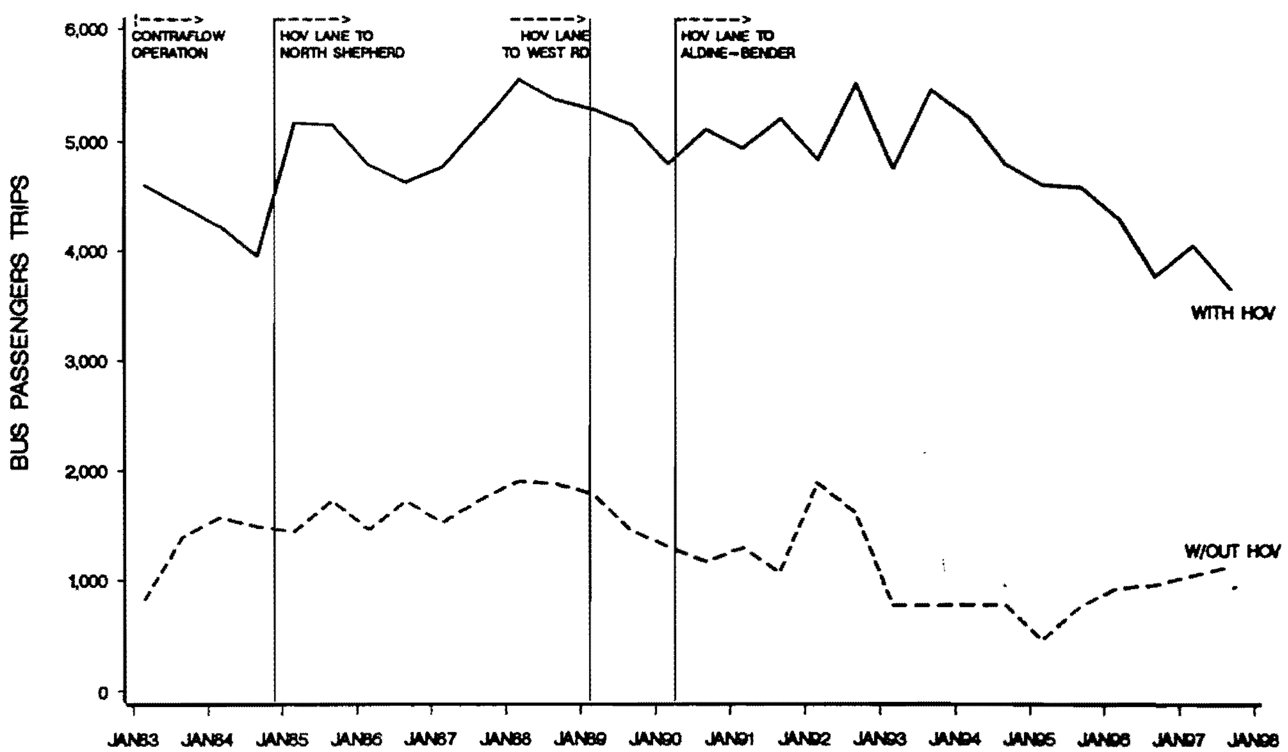


FIGURE B-19. NORTH FREEWAY (IH 45N) CORRIDOR PARK-AND-RIDE DEMAND

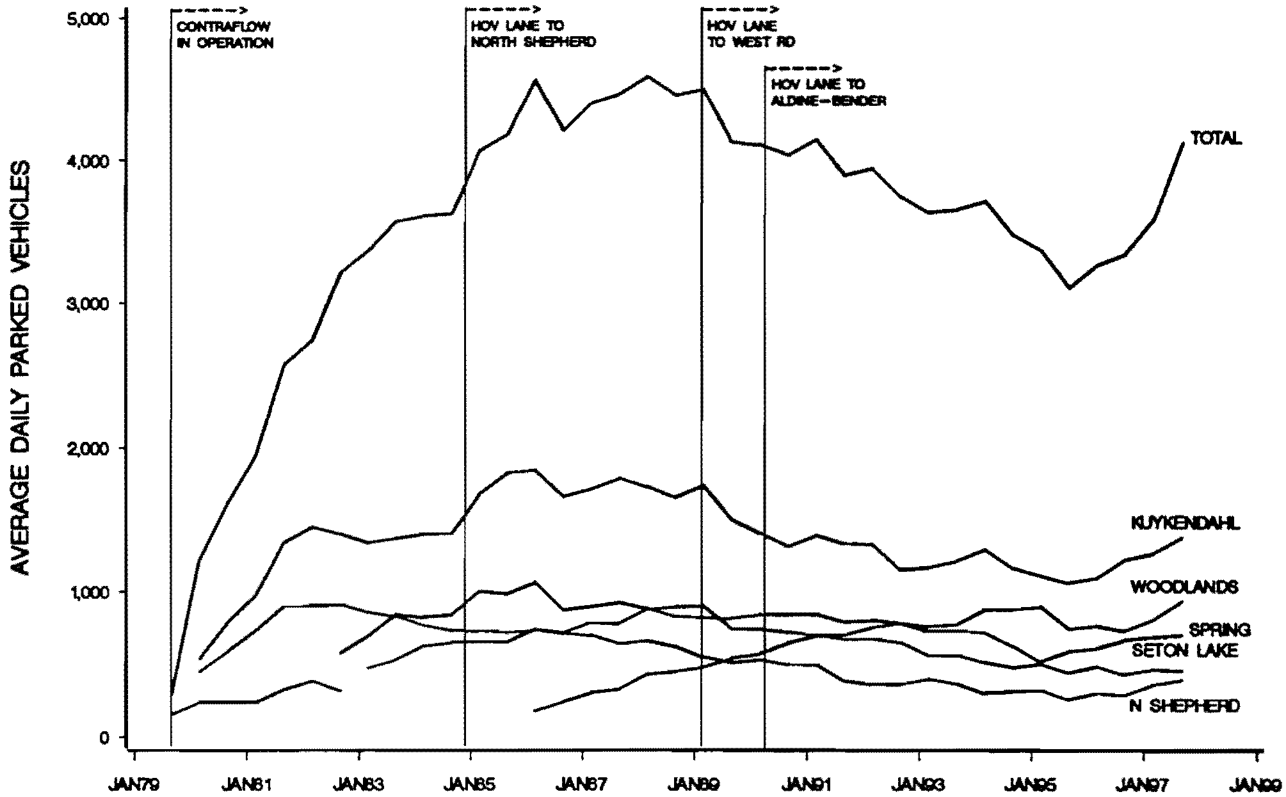
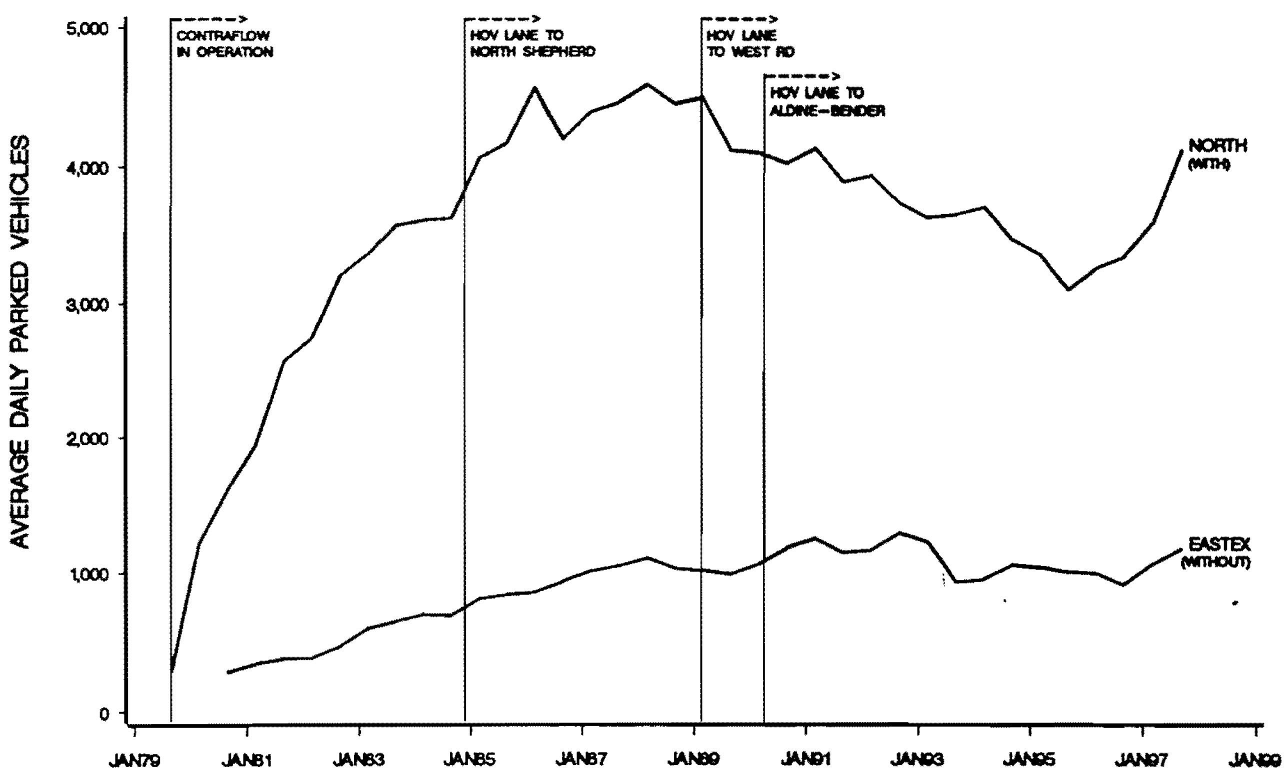


FIGURE B-20. AVERAGE DAILY VEHICLES PARKED AT PARK-AND-RIDE LOTS NORTH FREEWAY AND FREEWAY WITHOUT HOV LANE



APPENDIX C

GULF FREEWAY AND HOV LANE DATA

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

Table C-1. Summary of A.M. Peak-Direction Gulf Freeway and HOV Lane Data, 1997

Type of Data[1] Phase 1 of HOV Lane Became Operational 5/16/88	"Representative" Pre-HOV Lane Value	"Representative" Current Value	Percent Change
HOV Lane Data			
HOV Lane Length (miles)		11.3	
HOV Lane Cost (millions)		121.0	
Person-Movement			
Peak-Hour (7-8 a.m.)	---	2,925	---
Peak-Period (6-9:30 a.m.)	---	5,362	---
Total Daily	---	10,892	---
Vehicle Volumes			
Peak-Hour	---	1,073	---
Peak-Period	---	1,930	---
Vehicle Occupancy, Peak-Hour (persons/veh)	---	2.7	---
Accident Rate (Injury accidents/100 MVM)[2]	---	11.0	---
Vehicle Breakdowns (VMT/Breakdown)	---	84,308	---
Violation Rate (6-9:30 a.m.)	---	4%	---
Travel Time (minutes)[3]			---
Peak-Hour	9.7	13.1	---
Peak-Period	8.1	12.7	
Peak-Hour Lane Efficiency (1000's)[4]	---	152	
Annual Discounted Benefits (millions)[5]	---	$ 22	
Annual Delay Savings (millions)[6]	---	$ 3.9	
Freeway Mainlane Data (see note)			
Person-Movement			
Peak-Hour	6,415	6,275	-2 %
Peak-Period (6-9:30 a.m.)	17,845	20,648	+16%
Vehicle Volume			
Peak-Hour	4,962	6,046	+22%
Peak-Period	14,740	19,337	+31%
Vehicle Occupancy, Peak-Hour (persons/veh)	1.29	1.04	-19%
Accident Rate (i.e., Injury accidents/100 MVM])[2]	29.8	19.3	-35%
Avg. Operating Speed (mph)			
Peak-Hour	31	29	-6%
Peak-Period	36	40	+11%
Peak-Hour Lane Efficiency (1000's)[4]	66	45	-32%

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

[1]Freeway data are collected at Monroe. HOV lane data are collected at Eastwood.

[2]Due to inconsistencies in reporting accidents in Harris County, this analysis includes only injury accidents. Accidents were analyzed between Broadway and Dowling, a distance of approximately 6.5 mi, which corresponds to Phase 1 of the HOV lane. The pre-HOV lane includes four years of mainlane accident data from 5/16/84 to 5/15/88. The current value is from 5/16/88 to 12/97.

[3]Pre-HOV travel times were collected by manual travel time studies from Broadway to Dowling, a distance of 6.5 mi. Current travel times are calculated using data from automatic vehicle identification (AVI) readers located along the HOV lane, representing travel over a distance of 11.3 mi.

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

[5]Based on average annual delay savings, reduced vehicle operating costs and reduced accident costs generated by MicroBENCOST over a 20-year life.

[6]Per MicroBENCOST, over a 20-year life.

Table C-1. Summary of A.M. Peak-Direction Gulf Freeway and HOV Lane Data, 1997 (Continued)

Type of Data	"Representative" Pre-HOV Lane Value	"Representative" Current Value	Percent Change
Combined Freeway Mainlane and HOV Lane Data			
Total Person-Movement			
Peak-Hour	6,415	9,200	+43%
Peak-Period	17,845	26,010	+46%
Vehicle Volume			
Peak-Hour	4,962	7,119	+43%
Peak-Period	14,740	21,267	+44%
Vehicle Occupancy			
Peak-Hour	1.29	1.29	0
Peak-Period	1.21	1.22	+1%
2+ Carpool Volumes			
Peak-Hour	475	1,235	+160%
Peak-Period	1,304	2,810	+115%
Peak-Hour Lane Efficiency (1000's)[1]	66	67	+34%
Transit Data[2]			
Bus Vehicle Trips			
Peak-Hour	23	27	+17%
Peak-Period	40	59	+48%
Bus Passenger Trips			
Peak-Hour	746	740	-1%
Peak-Period	1,230	1,455	+18%
Bus Occupancy (persons/bus)			
Peak-Hour	32.6	27.4	-16%
Peak-Period	30.8	24.7	-20%
Vehicles Parked in Corridor Park-and-Ride Lots	1,115	1,233	+11%
Bus Operating Speed (mph)[3]			
Peak-Hour	31	52	+60%
Peak-Period	36	52	+47%

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

[1] This represents the multiple of peak-hour passengers and average speed (HOV lane efficiency +[mainlane freeway efficiency x number of freeway directional lanes]/number of total directional lanes). It is used as a measure of per lane efficiency.
[2] Pre-HOV data collected at Monroe; current data collected at Eastwood.
[3] Pre-HOV speeds were calculated using data from manual travel time studies from Broadway to Dowling, a distance of 6.5 mi. Current speeds were calculated using travel time data from automatic vehicle identification (AVI) readers, representing travel over the same distance.

Table C-2. Comparison of Measures of Effectiveness, Freeway with (Gulf I-45S) and Freeway without (Eastex U.S. 59) HOV Lane, Houston

Measure of Effectiveness	"Representative" Pre-HOV Lane Value[1]	"Representative" Current Value	Percent Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/HOV lane	1.29	1.29	0%
Freeway w/o HOV lane	1.23	1.30	+6%
A.M. Peak Hour, 2+ Carpool Volume			
Freeway w/HOV lane	475	1,235	+160%
Freeway w/o HOV lane	600	1,165	+94%
Bus Passengers, Peak Period			
Freeway w/HOV lane	1,230	740	-40%
Freeway w/o HOV lane	1,188	1,123	-5%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	1,115	1,233	+11%
Freeway w/o HOV lane	1,236	1,099	-11%
Facility Per Lane Efficiency[2]			
Freeway w/HOV lane	66	88	+34%
Freeway w/o HOV lane	86	81	-6%

[1]Representative pre-HOV data for freeways without HOV lanes are comprised of data collected on the Eastex Freeway 1/93.
[2]This represents the product of peak-hour passengers and average speed (passengers x mph/number of lanes). It is used as a measure of per lane efficiency.

HOV LANE DATA

DESCRIPTION

- Phase 1 (6.5 mi) of the HOV lane opened 5/16/88. Weekend operation began 10/1/89. The capital cost for the operating segment (including all support facilities) in 1990 dollars was $44.2 million. The cost to complete the entire facility (1997 dollars) will be $136.2 million. Table C-3 provides a more detailed cost breakdown (including dates).

- Selected milestone dates are listed below.

  - 5/16/88 CBD to Broadway opens (6.5 mi).
  - 10/1/89 Weekend HOV operation begins (4:00 a.m. - 10:00 p.m.).
  - 10/5/91 Weekend HOV operation ends.
  - 9/8/92 Motorcycles allowed on HOV facility (no occupancy restrictions).
  - 3/14/94 HOV lane extended to Almeda-Genoa; an additional distance of 5.1 mi- bringing the total operational HOV length to 11.6 mi.
  - 3/13/94 Hours of operation revised (5:00 a.m. - 10:00 a.m.; 3:00 p.m. - 8:00 p.m.)
  - 4/4/94 Hours of operation revised (5:00 a.m. - 12:00 p.m.; 2:00 p.m. - 9:00 p.m.).
  - 1/17/95 Monroe Park-and-Ride opened.

- 6/14/96 Edgebrook Park-and-Ride closed.
- 6/17/96 Fuqua Park-and-Ride opened.
- 9/30/96 Hours of operation revised (5:00 a.m. - 11:00 a.m.; 2:00 p.m. - 8:00 p.m.).
- 4/14/97 HOV Lane extended to Choate Road, an additional distance of 3.9 mi., bringing the total operational length to15.5 mi.

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

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1995 Dollars
HOV Lane and Ramps			
Phase 1 Metro (1988)	$1.6	1.23	$2.0
Phase 2 Metro (1988)	0.4	1.23	0.5
Phase 1 SDHPT (1988)	14.0	1.23	17.2
Phase 2 SDHPT (1988)	6.4	1.23	7.9
Phase 3 (1997)	37.9	0.94	35.6
Miscellaneous (1995)	3.6	1.00	3.6
Hobby West Access Ramps (1995)	0.5	1.00	0.5
Almeda-Genoa Slip Ramp (1996)	0.4	0.97	0.4
SUB-TOTAL	$50.4		$67.7
Per Mile	$4.0		$5.6
Surveillance, Communication, and Control (1988)	$3.8	1.23	$4.7
SUB-TOTAL	$3.8		$4.7
Per Mile	$0.3		$0.4
Support Facilities			
Bay Area P/R (1984)	$3.7	1.38	$5.1
Edgebrook P/R (1981)	3.3	1.51	5.0
Eastwood Transit Center (1988)	5.0	1.23	6.2
Monroe P/R (1994)	9.1	1.03	9.4
Fuqua P/R (1995)	10.4	1.00	10.4
Fuqua Park/Pool (1995)	5.9	1.00	5.9
SUB-TOTAL	$37.4		$42.0
Per Mile	$2.9		$3.5
TOTAL COST	$91.6		$114.4
COST PER MILE (12.1 miles)	$7.3		$9.5

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

PERSON-MOVEMENT

- In 1997, the HOV lane served 10,892 person trips per day.
- A.M. peak hour, 2,925 persons/hour.
  - 740 (25 percent) by bus, 63 (2 percent) by vanpool, 2,121 (73 percent) by carpool, and 2 by motorcycle (Figure C-1).
  - Average HOV lane vehicle occupancy = 2.7 persons/vehicle.
- A.M. peak period, 5,362 persons.
  - 1,455 (27 percent) by bus, 109 (2 percent) by vanpool, 3,794 (71 percent) by carpool, and 5 by motorcycle (Figure C-2).

VEHICLE MOVEMENT

- A.M. Peak Hour, 1,073 vph
  - 27 (3 percent) buses, 9 (1 percent) vans, 1,036 (97 percent) carpools, and 2 by motorcycle (Figure C-3).
- A.M. Peak Period, 1,930 vehicles.
  - 59 (3 percent) buses, 16 (1 percent) vans, 1,851 (96 percent) carpools, and 5 by motorcycle (Figure C-4).

ACCIDENT RATE

- Implementation of the HOV lane resulted in narrower freeway lanes and no inside emergency shoulder.
- For the section of Gulf Freeway between Broadway and downtown, the accident rate for the mainlanes for four years of operation (5/16/84 to 5/15/88) was 29.8 accidents per 100 million vehicle miles [100 MVM]). The "after HOV lane" accident rate for the mainlanes is11.0 accidents per 100 MVM and includes the period 5/88 to 12/97. Current accident files include only officer-reported accidents.

FIGURE C-1. GULF FREEWAY (IH 45S) HOV LANE
A.M. PEAK HOUR HOV LANE PERSON MOVEMENT

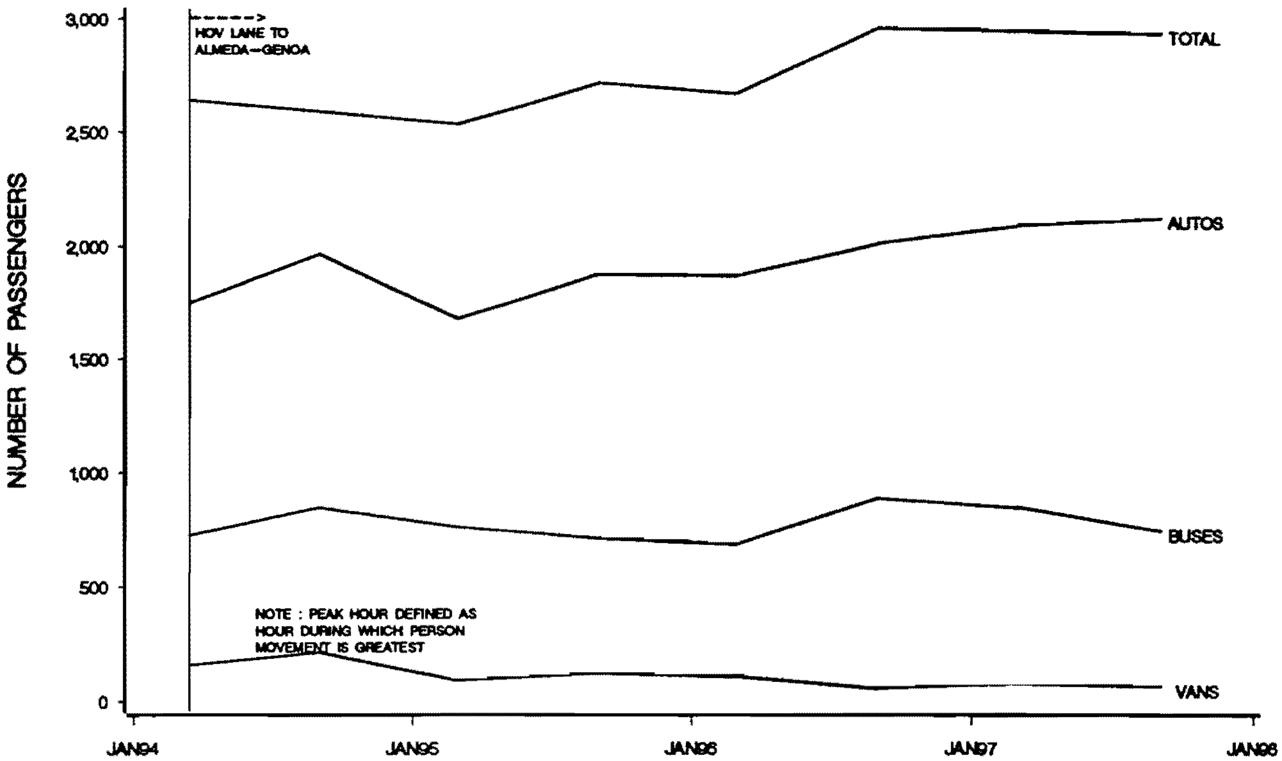


FIGURE C-2. GULF FREEWAY (IH 45S) HOV LANE
A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT

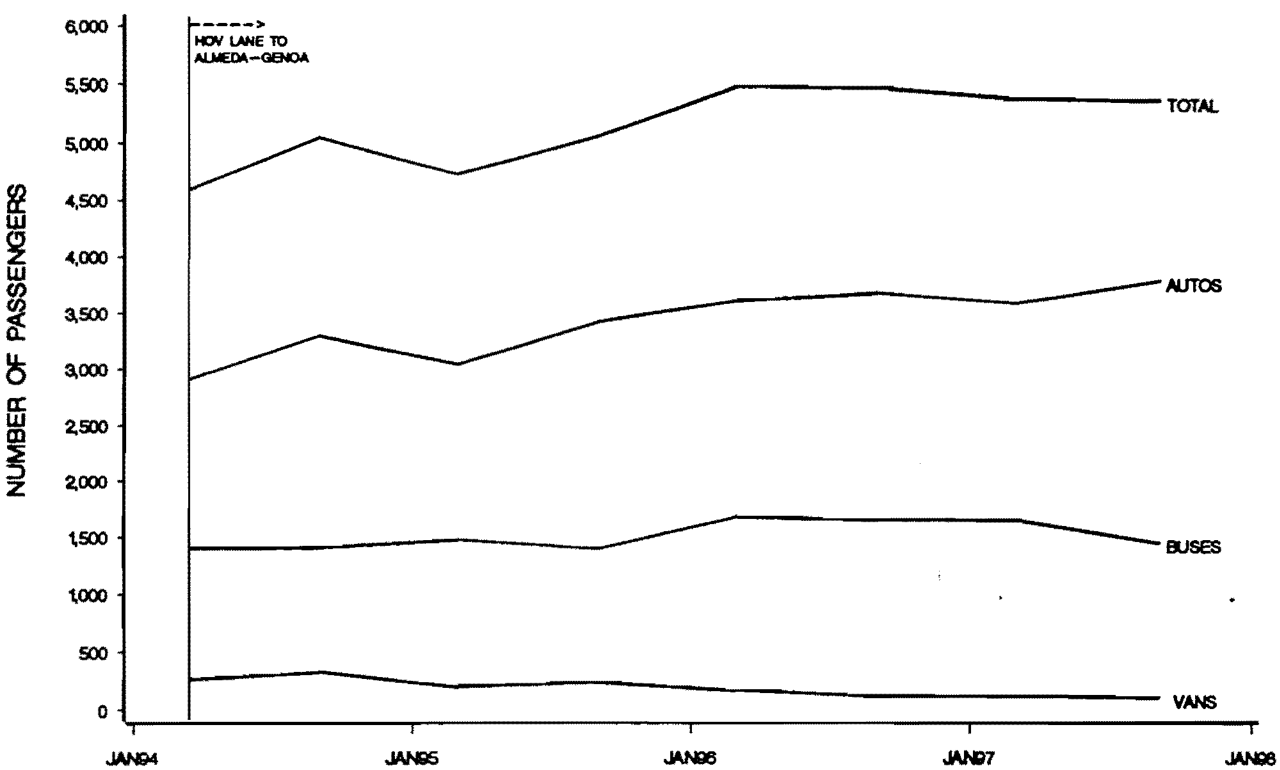


FIGURE C-3. GULF FREEWAY (IH 45S) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION

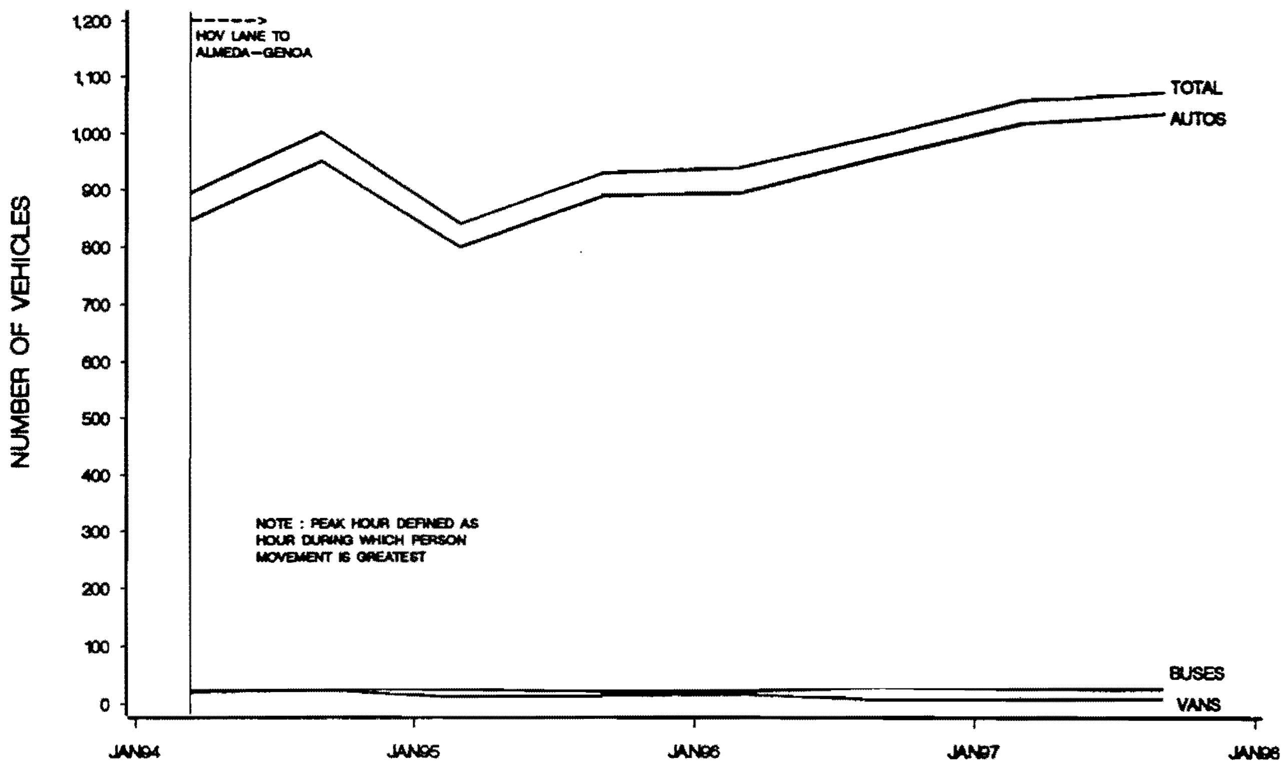
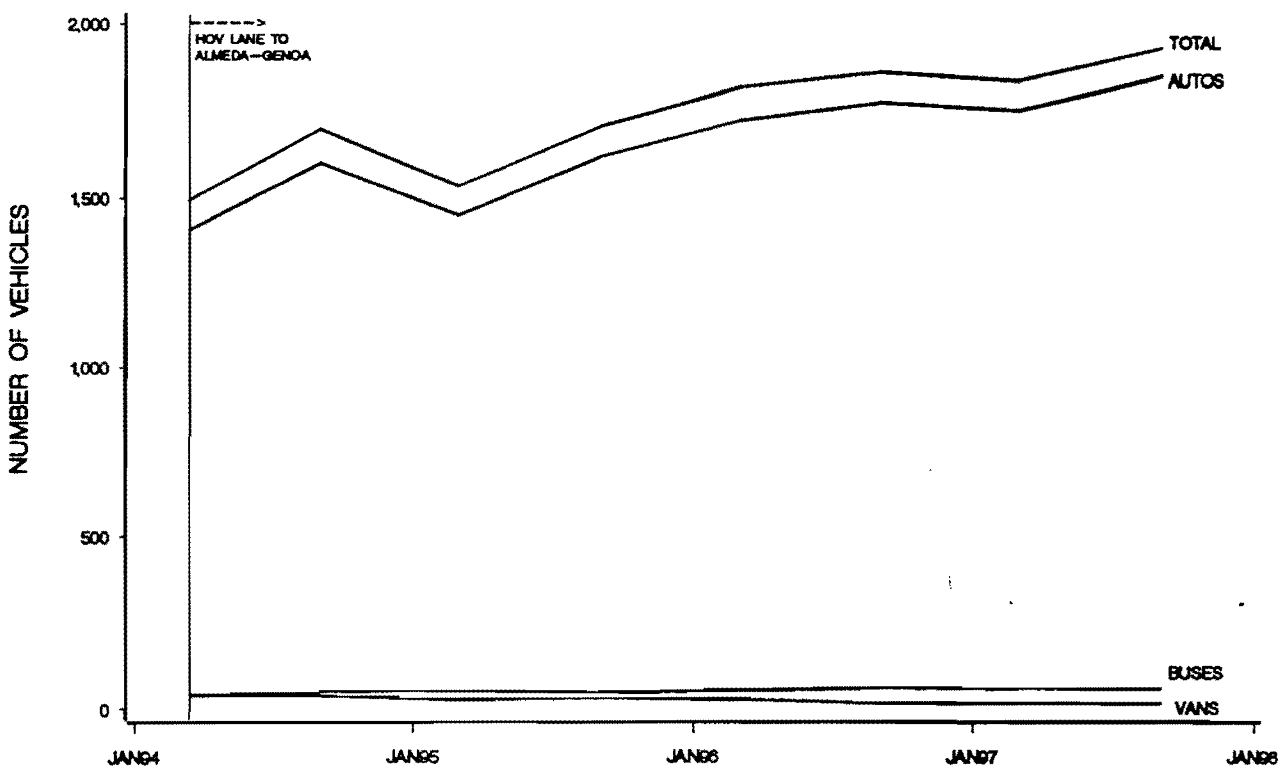


FIGURE C-4. GULF FREEWAY (IH 45S) HOV LANE
A.M. PEAK PERIOD HOV LANE VEHICLE UTILIZATION



VEHICLE BREAKDOWN RATES

- As measured from September 1988 through December 1997, the following rate has been observed.

  - Weighted average: one breakdown per 84,308 VMT.

PEAK-HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. For the HOV lane, this value (expressed in 1000's) is approximately 152 (2,925 passengers x 52 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane are experiencing a travel time savings of approximately 10 minutes during the peak hour (Table C-5, Figure C-5).

Table C-5. Travel Time Savings for Gulf Freeway HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1997)

Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Northbound AM Travel Time Savings for Gulf HOV Lane[1]								
Section from Almeda-Genoa to Broadway								
6:00	6.23	5.66	0.57	169	2	25	196	230
6:30	10.08	5.57	4.51	381	43	154	578	2600
7:00	13.43	5.92	7.51	744	29	236	1,010	7760
7:30	14.33	5.81	8.53	933	3	292	1,228	10630
8:00	8.93	5.68	3.25	506	0	114	620	2130
8:30	6.45	5.45	1.00	213	0	31	244	330
9:00	5.01	5.45	-0.45	91	11	0	102	-40
Peak-Period Total				3,037	88	852	3,978	23640
Northbound AM Travel Time Savings for Gulf HOV Lane								
Section from Broadway to Dowling								
6:00	6.14	7.01	-0.87	88	16	148	251	-200
6:30	6.92	6.94	-0.02	324	21	223	567	-10
7:00	8.05	7.10	0.95	786	53	371	1,208	1220
7:30	9.53	7.33	2.20	1,204	34	470	1,709	3750
8:00	7.75	7.03	0.73	758	17	230	1,005	730
8:30	6.72	7.41	-0.69	396	4	88	488	-290
9:00	6.10	6.61	-0.51	141	19	33	193	-130
Peak-Period Total				3,697	164	1563	5,421	5060
Southbound PM Travel Time Savings for Gulf HOV Lane								
Section from Broadway to Dowling								
3:30	6.22	7.87	-1.65	182	6	66	253	-420
4:00	6.94	7.28	-0.35	306	8	137	451	-150
4:30	7.88	7.03	0.85	497	22	258	777	670
5:00	9.70	7.10	2.61	829	58	381	1,267	3,430
5:30	9.56	7.16	2.40	770	39	520	1,329	3,290
6:00	7.41	7.81	-0.40	522	2	223	746	-200
6:30	6.14	7.91	-1.77	247	5	135	387	-670
Peak-Period Total				3,353	140	1,720	5,210	5,960.00

[1] In 1997 AVI data collection efforts focused on the section from Dowling to Broadway only; therefore, the Measured Travel Time data in this section represent historical data.

Table C-5. Travel Time Savings for Gulf HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1997) (Continued)

Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Southbound PM Travel Time Savings for Gulf HOV Lane[1]								
Section from Almeda-Genoa to Broadway								
3:30	4.87	5.35	-0.48	137	0	35	172	-80
4:00	4.98	5.69	-0.72	127	2	56	186	-130
4:30	5.08	5.49	-0.41	275	14	96	384	-160
5:00	5.43	5.59	-0.16	463	43	238	745	-120
5:30	5.40	5.56	-0.16	659	39	454	1,152	-180
6:00	5.07	5.36	-0.30	520	0	122	642	-180
6:30	4.79	5.65	-0.87	206	0	29	236	-200
Peak-Period Total				2,387	98	1,030	3,517	-1,050

[1] In 1997 AVI data collection efforts focused on the section from Dowling to Broadway only; therefore, the Measured Travel Time data in this section represent historical data.

Table C-6. Gulf Freeway Travel Time Summaries

Travel Time Data	Travel Times[1]					
	97[1]	96[2]	95[2]	94[2]	93[2]	Pre-HOV
HOVL Travel Time						
AM Peak-Hour	13 min	8 min	8 min	7 min	7 min	-
PM Peak-Hour	13 min	7 min	8 min	8 min	8 min	-
Freeway Mainlanes Travel Time						
AM Peak-Hour	23 min	8 min	13 min	8 min	9 min	13 min
PM Peak-Hour	15 min	8 min	9 min	7 min	16 min	14 min
Net Travel Time Savings						
AM Peak-Hour	10 min	0 min	5 min	1 min	2 min	-
(Person-Minutes)	(23,360)	(912)	(6,750)	(1,201)	(1,618)	-
PM Peak-Hour	2 min	1 min	1 min	-1 min	8 min	-
(Person-Minutes)	(6,420)	(2,900)	(2,196)	(-985)	(10,365)	

[1]Travel Times are calculated over a distance of 11.3 mi.
[1]Data collected using Automatic Vehicle Identification (AVI).
[2]Data collected using manual travel time studies.

FREEWAY DATA

NOTE

- Freeway data collected in the Gulf corridor since 1983 have been, for a variety of reasons (primarily safety), collected at Monroe.

PERSON-MOVEMENT

- Prior to HOV lane implementation, the average a.m. peak-hour person volume was 6,415 (Figure C-6). This volume is now 6,275.

- The a.m. peak period, person volume was approximately 17,845 (Figure C-7). This volume has risen to 20,648.

VEHICLE VOLUME

- In the a.m. peak hour, the vehicle volume was 4,962 vph prior to HOV lane implementation and is now 6,046 (Figure C-6).

- In the a.m. peak period, the vehicle volume was 14,740 and is now 19,337 (Figure C-7).

VEHICLE OCCUPANCY

- In the a.m. peak hour, mainlane occupancy was 1.29 persons per vehicle prior to HOV lane implementation and has decreased to 1.04 persons per vehicle.

AVERAGE OPERATING SPEED

- In comparison to pre-HOV lane conditions, mainlane operating speeds in the peak-period increased between South Loop 610 and Dowling - the portion of the Gulf corridor which corresponds to Phase I of the HOV lane. Speeds have also increased outside South Loop 610, where Phase II of the HOV lane has now been implemented (Figure C-8).

PEAK-HOUR LANE EFFICIENCY

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

- The pre-HOV freeway efficiency, as measured at Monroe, was 66 (2,138 passengers per lane at 31 mph). It is now 45 (2,092 at 40 mph).

FIGURE C-5. GULF FREEWAY (IH 45S) MAINLANES AND HOV LANE A.M. TRAVEL TIME

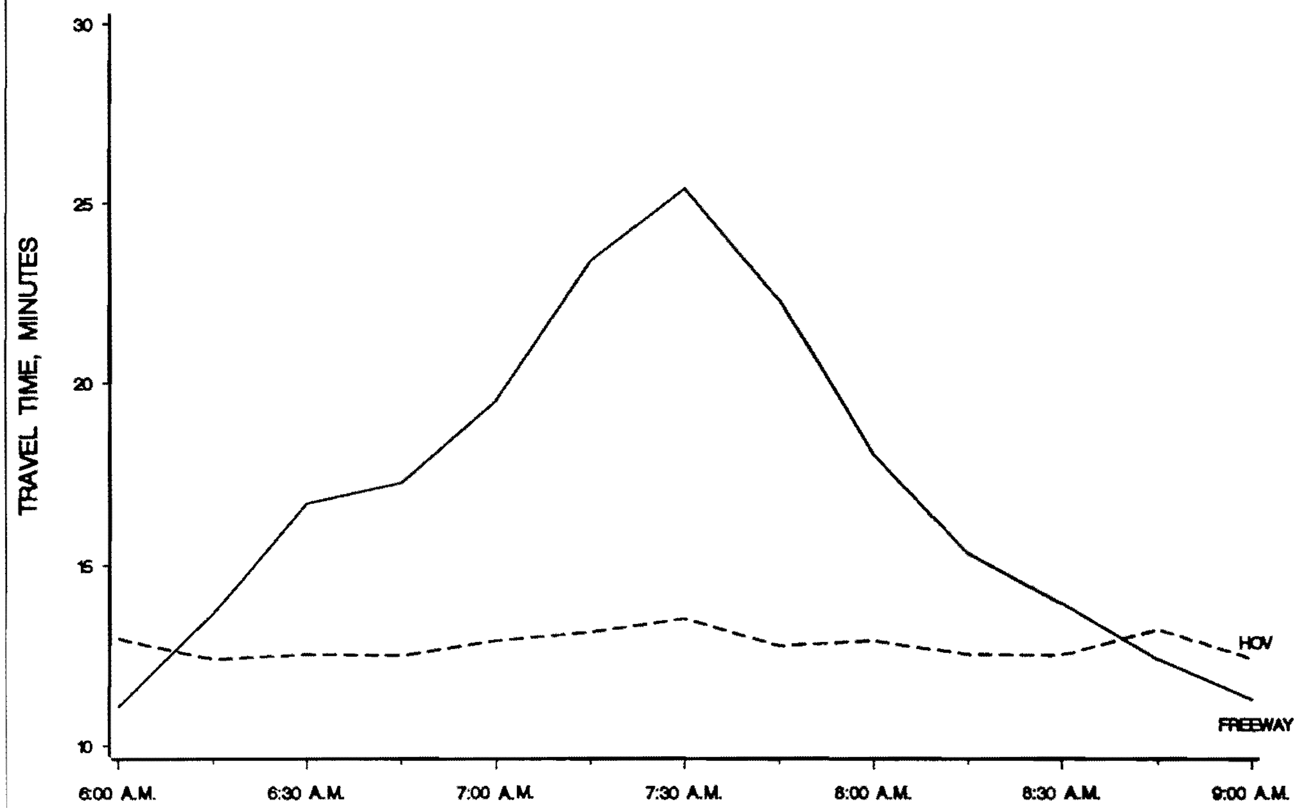


FIGURE C-6. GULF FREEWAY (IH 45S)
A.M. PEAK HOUR MAINLANE TRIPS

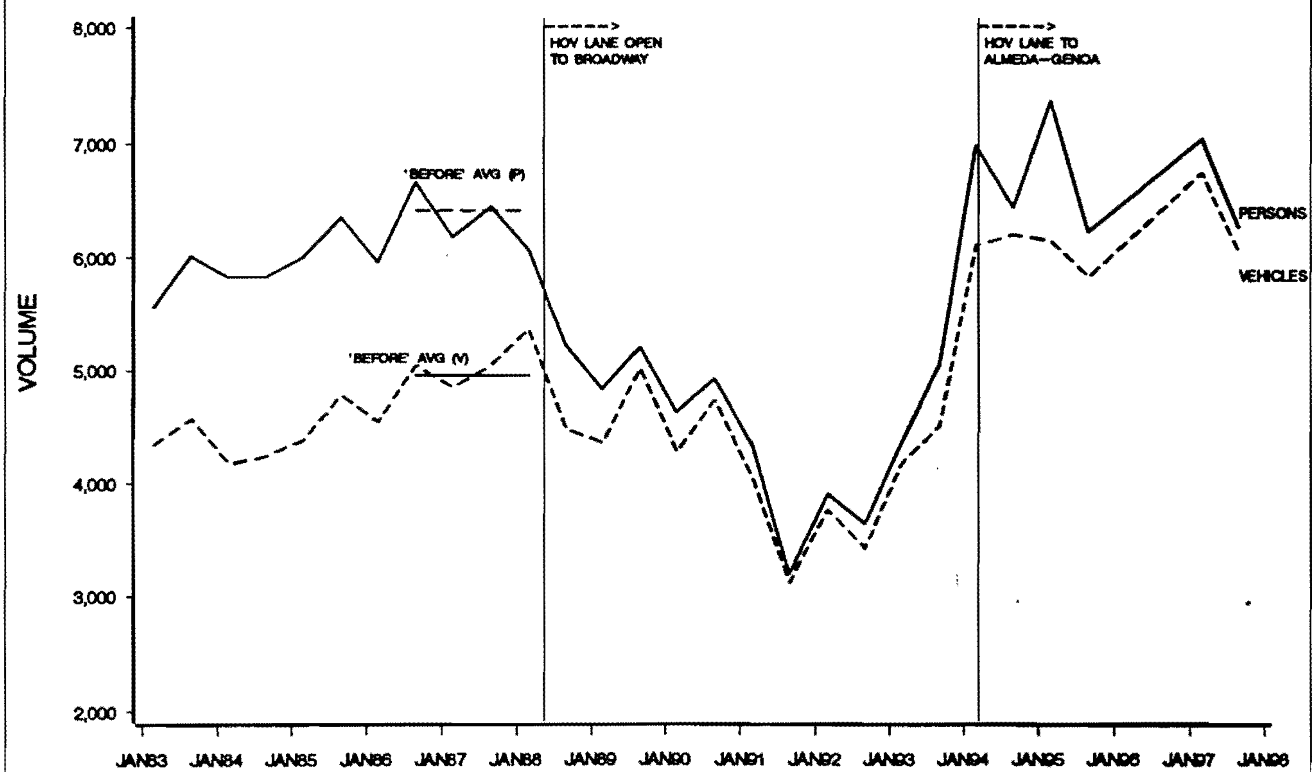


FIGURE C-7. GULF FREEWAY (IH 45S)
A.M. PEAK PERIOD MAINLANE TRIPS

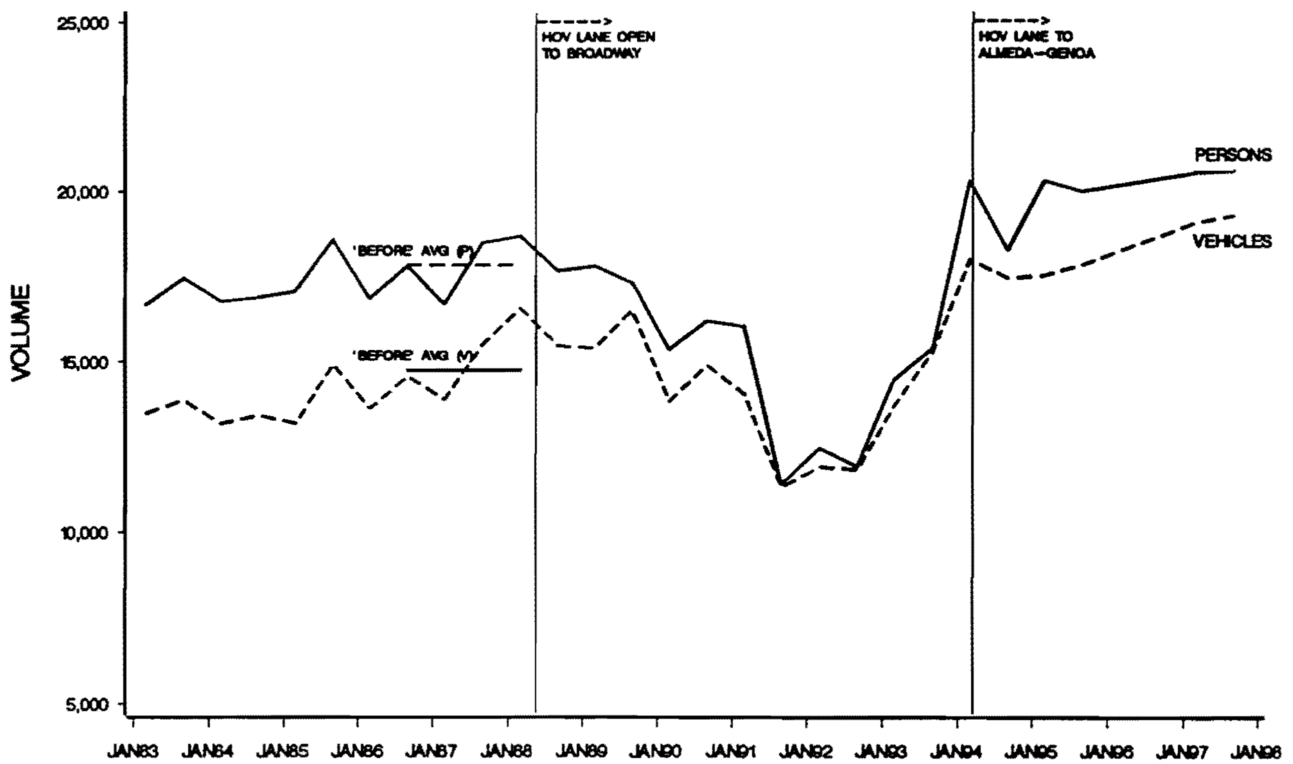
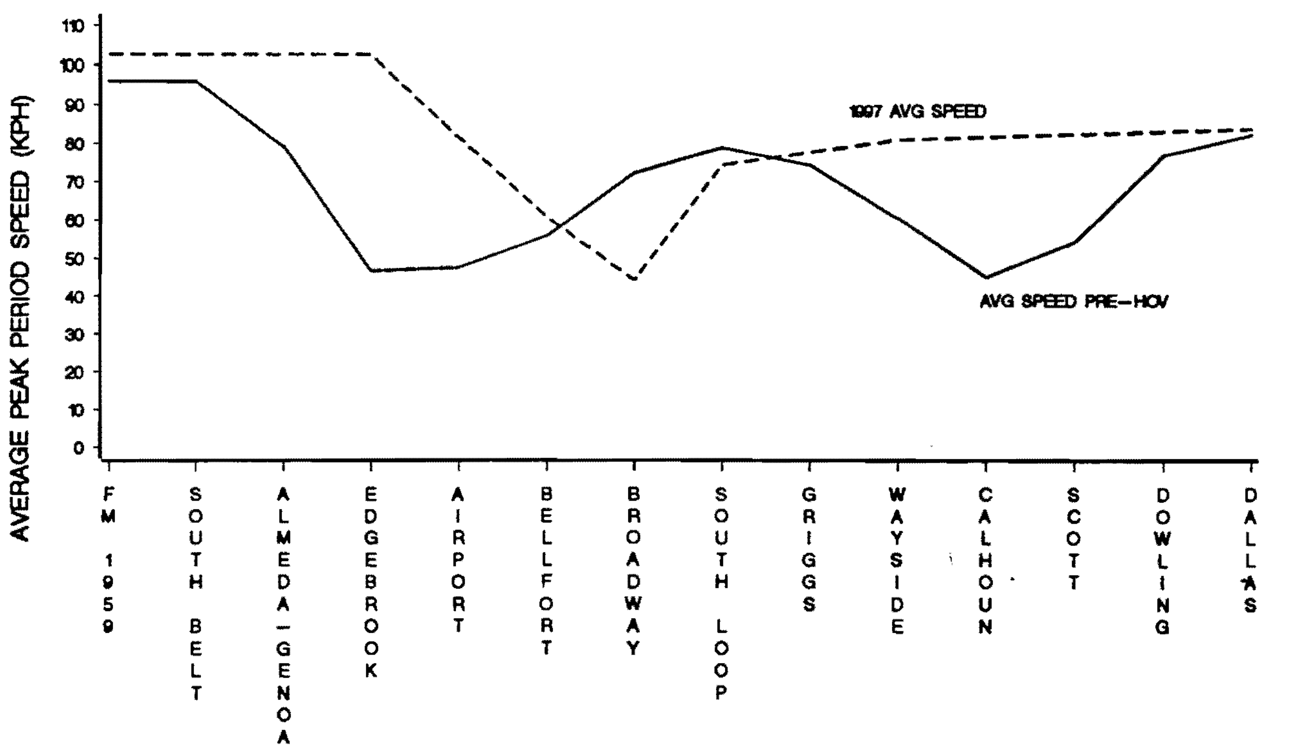


FIGURE C-8. GULF FREEWAY (IH 45S) MAINLANE TRAVEL TIME AND SPEED SURVEY
NORTHBOUND, FM 1959 TO DALLAS
A.M. PEAK PERIOD



COMBINED FREEWAY AND HOV LANE DATA

TOTAL PERSON-MOVEMENT

- Percent by HOV lane, a.m. peak.
  - At Monroe, the HOV lane is carrying 32% of the total peak-hour person movement (Figure C-9). In the peak period, the HOV lane carries 21% of the a.m. peak-period person trips (Figure C-10).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.29 compared to 1.04 for the mainlanes (Figure C-11). Occupancy in the peak period has increased with the opening of the HOV lane (Figure C-12).

CARPOOL VOLUMES

- In the a.m. peak hour, the total number of 2+ carpools (freeway plus HOV lane) has increased by 160 percent compared to pre-HOV lane levels (Figure C-14).

- Prior to the HOV lane, the peak-hour 2+ carpool volume was 475. Now it is 1,235 vehicles (Figure C-14).

PEAK-HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by an average speed is sometimes used as a measure of the efficiency of the lane. The average efficiency of a lane on the freeway (4 freeway lanes plus 1 HOV lane) has increased by 67% since the implementation of the HOV lane (Figure C-15).

BUS TRANSIT DATA

NOTE

- HOV lane data are routinely collected at Eastwood Road and freeway data at Monroe. Data from these two locations are not directly comparable. Therefore, the summary table reports only pre-HOV data.

BUS VEHICLE AND PASSENGER TRIPS

- Pre-HOV bus vehicle and passenger trips, as counted at Monroe, show 23 peak-hour bus vehicle trips and 746 bus passenger trips (Figure C-16); and 40 peak-period bus vehicle trips and 1,230 bus passenger trips (Figure C-17).

- These figures increased to 27 peak-hour bus trips and 740 passenger trips; and 59 peak-period bus trips and 1,455 passenger trips.

PARK-AND-RIDE

- Prior to opening the HOV lane, approximately 1,115 vehicles were parked in corridor park-and-ride lots. This has increased 11 percent to a current level of 1,233 (Figure C-19).

- Figure C-20 shows a comparison of Eastex Freeway (freeway without an HOV lane) and Gulf Freeway park-and-ride utilization.

FIGURE C-9. GULF FREEWAY (IH 45S) MAINLANE AND HOV LANE
A.M. PEAK HOUR PERSON TRIPS

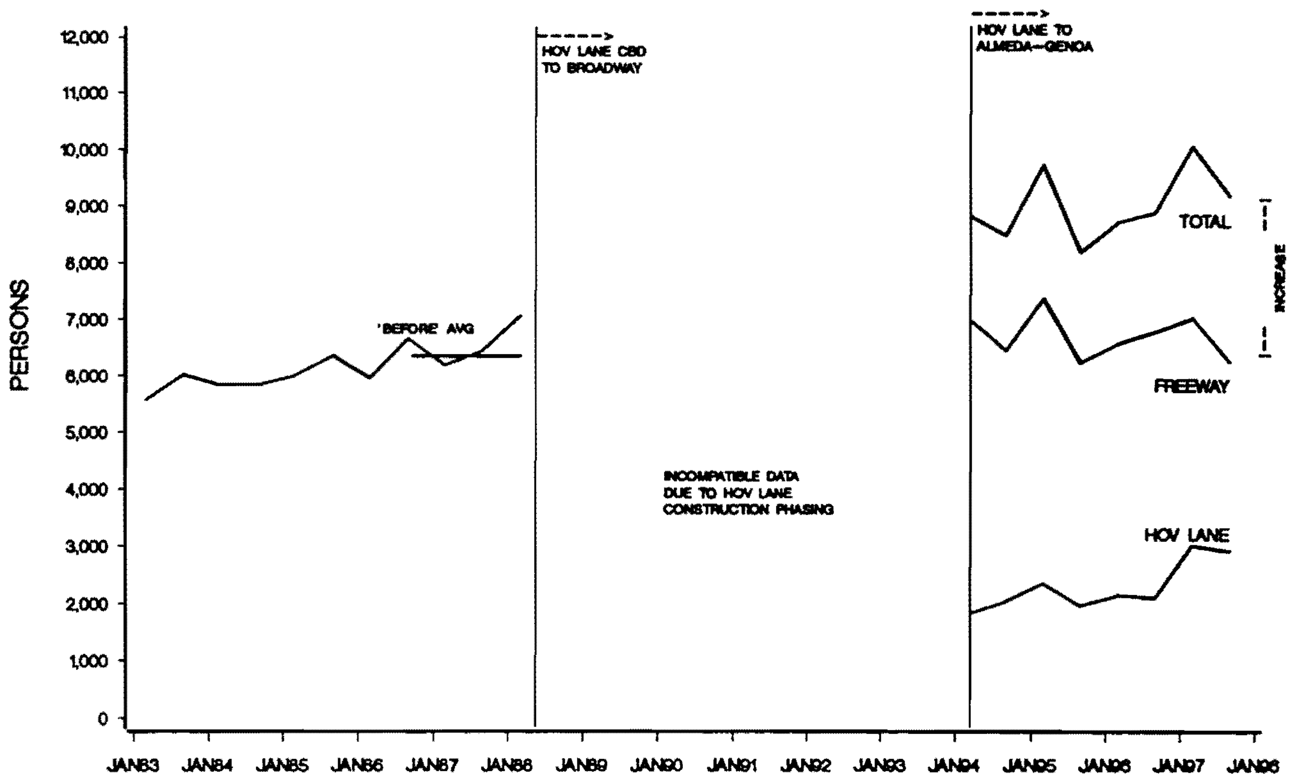


FIGURE C-10. GULF FREEWAY (IH 45S) MAINLANE AND HOV LANE
A.M. PEAK PERIOD PERSON TRIPS

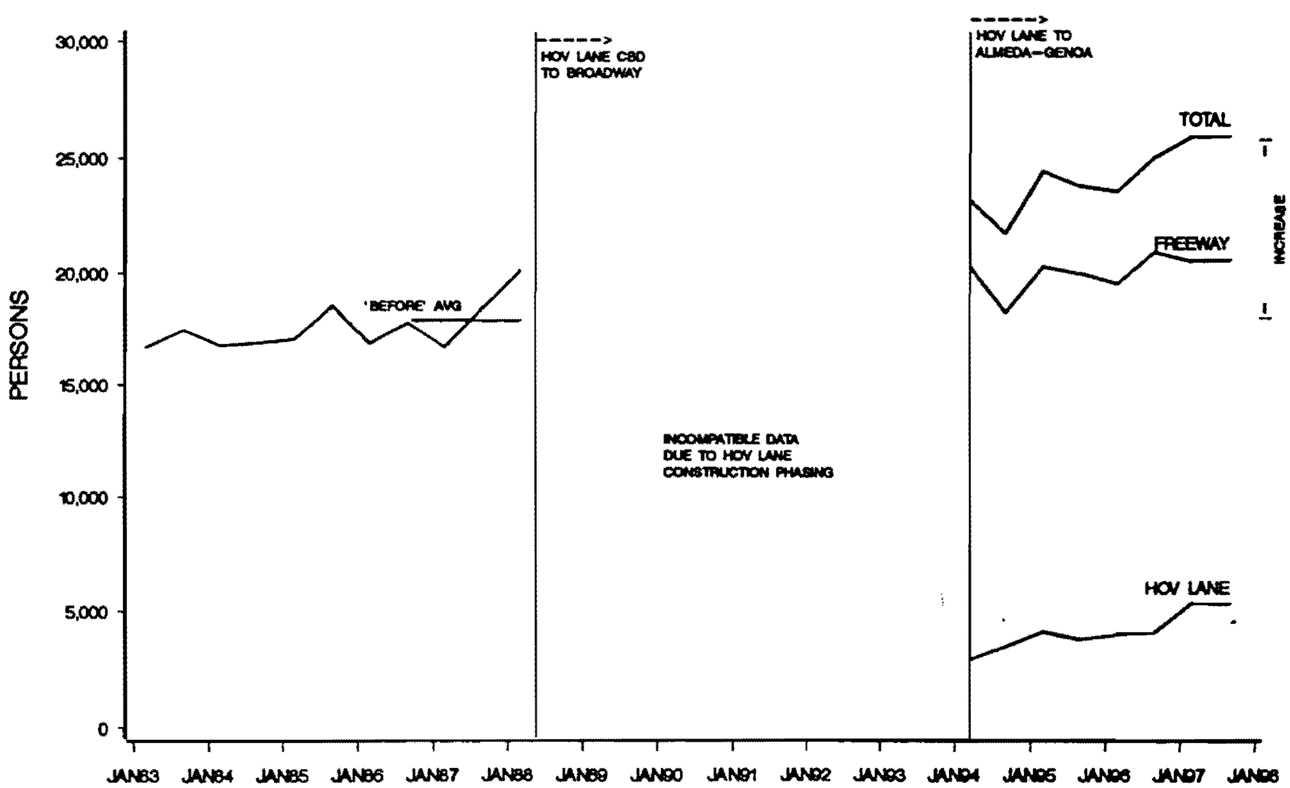


FIGURE C-11. GULF FREEWAY (IH 45S) MAINLANE AND HOV LANE
A.M. PEAK HOUR AVERAGE OCCUPANCY

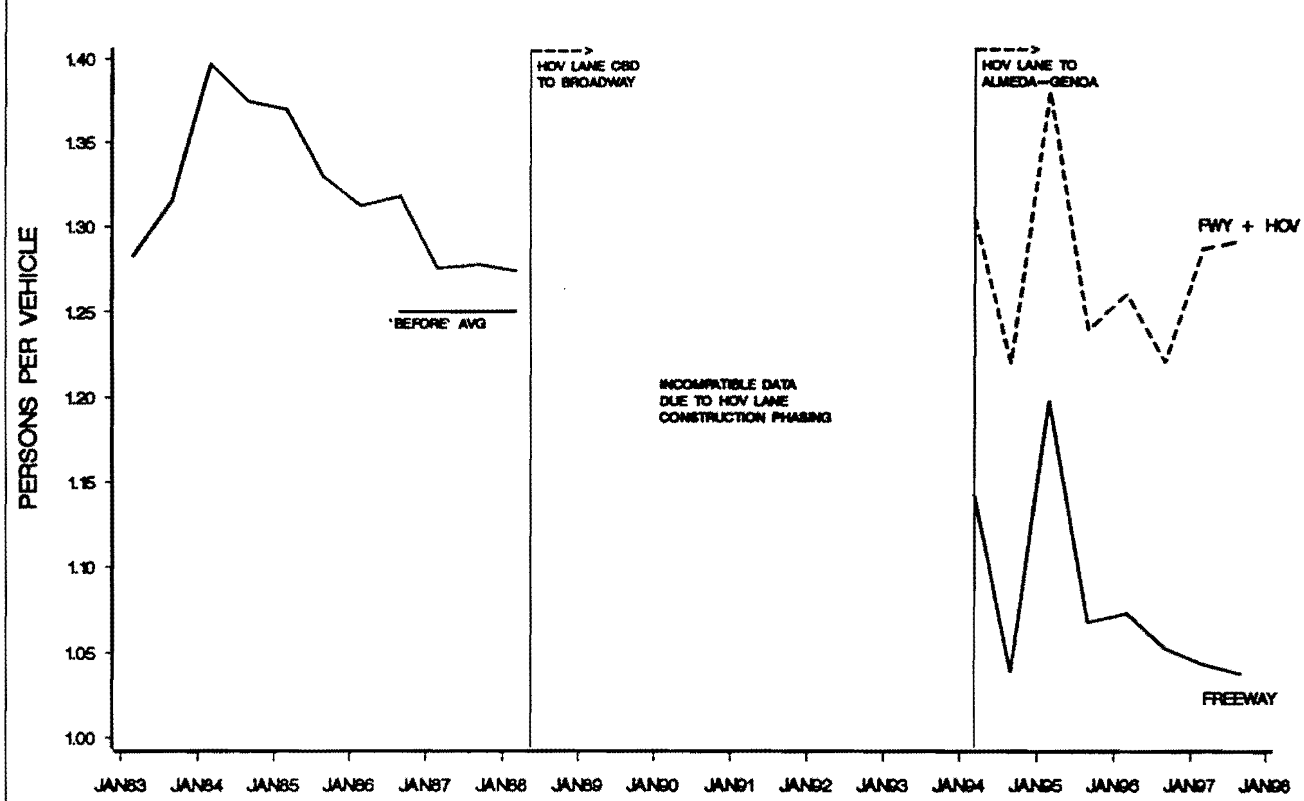
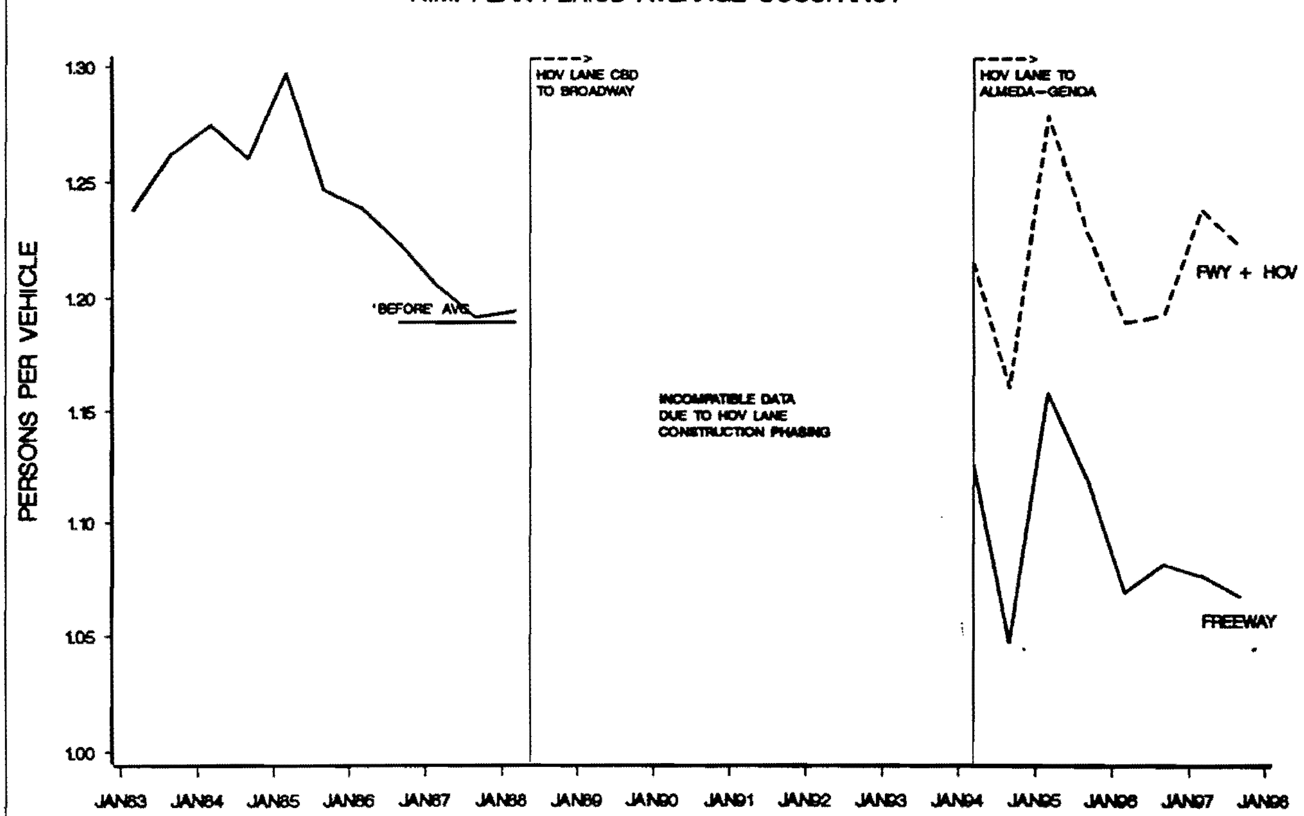


FIGURE C-12. GULF FREEWAY (IH 45S) MAINLANE AND HOV LANE
A.M. PEAK PERIOD AVERAGE OCCUPANCY



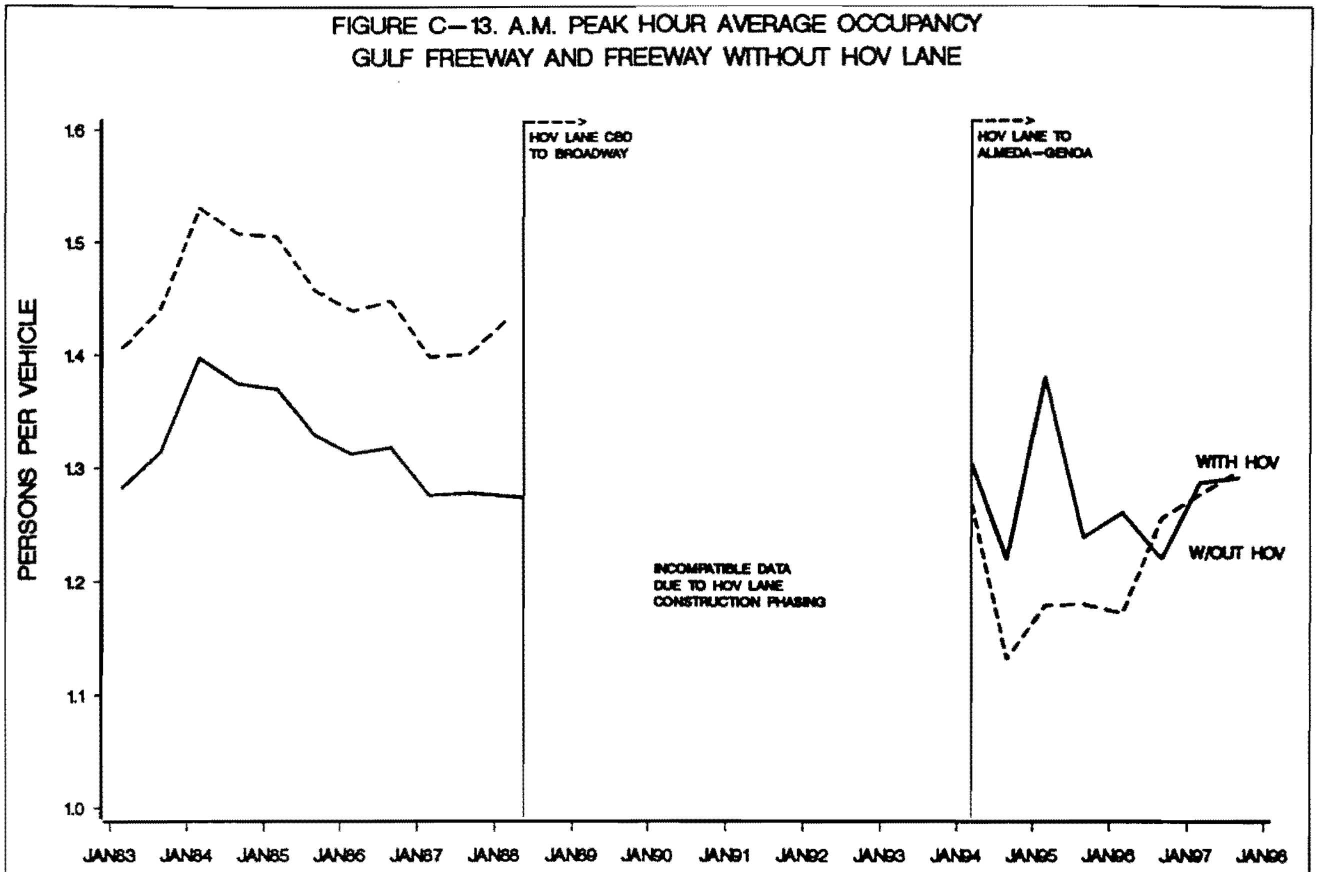


FIGURE C-13. A.M. PEAK HOUR AVERAGE OCCUPANCY
GULF FREEWAY AND FREEWAY WITHOUT HOV LANE
PERSONS PER VEHICLE
1.6
1.5
1.4
1.3
1.2
1.1
1.0
HOV LANE CBD TO BROADWAY
HOV LANE TO ALMEDA-GENOA
INCOMPATIBLE DATA DUE TO HOV LANE CONSTRUCTION PHASING
WITH HOV
W/OUT HOV
JAN83 JAN84 JAN85 JAN86 JAN87 JAN88 JAN89 JAN90 JAN91 JAN92 JAN93 JAN94 JAN95 JAN96 JAN97 JAN98

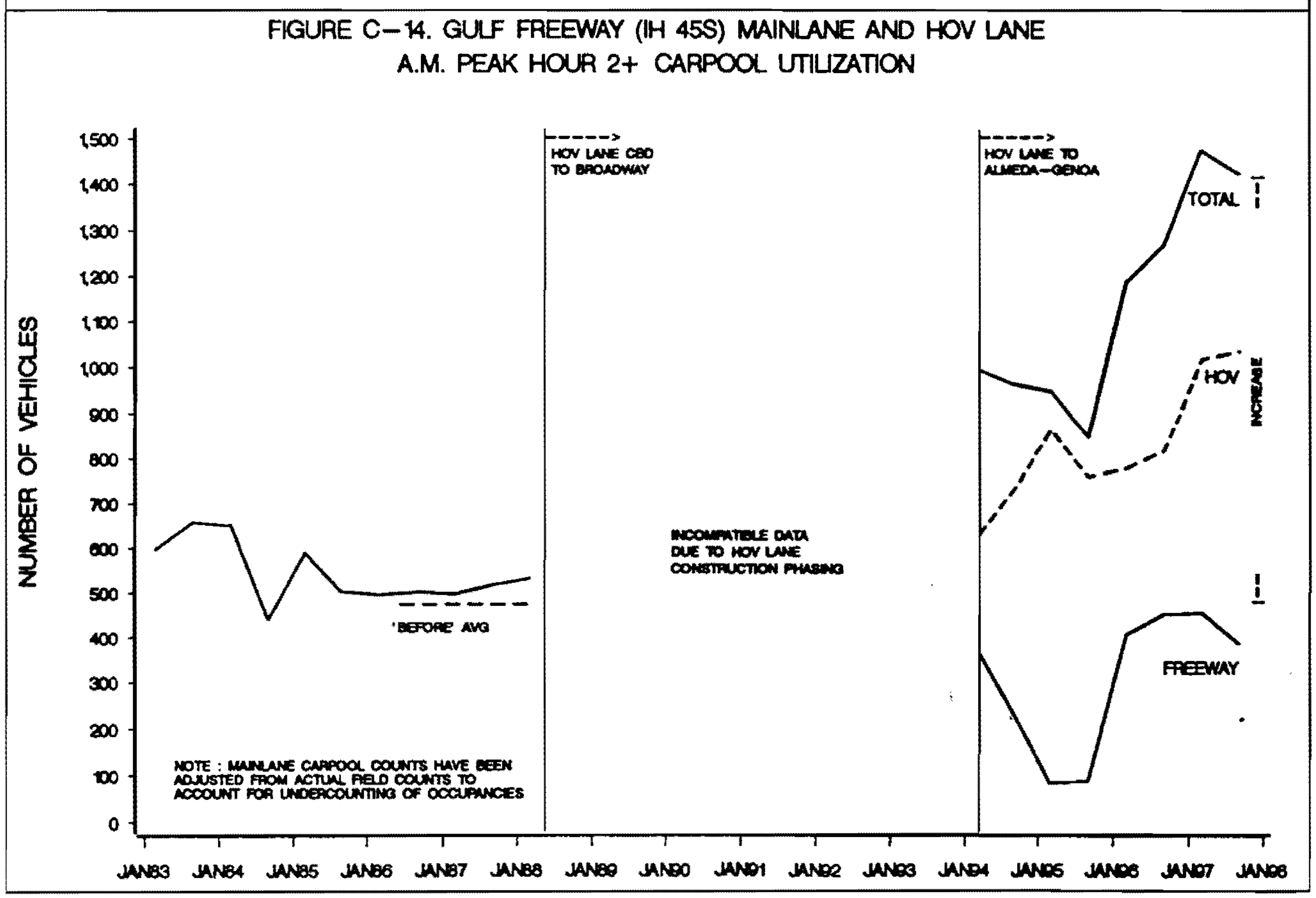


FIGURE C-14. GULF FREEWAY (IH 45S) MAINLANE AND HOV LANE
A.M. PEAK HOUR 2+ CARPOOL UTILIZATION
NUMBER OF VEHICLES
1,500
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
HOV LANE CBD TO BROADWAY
HOV LANE TO ALMEDA-GENOA
INCOMPATIBLE DATA DUE TO HOV LANE CONSTRUCTION PHASING
'BEFORE' AVG
TOTAL
HOV
INCREASE
FREEWAY
NOTE : MAINLANE CARPOOL COUNTS HAVE BEEN ADJUSTED FROM ACTUAL FIELD COUNTS TO ACCOUNT FOR UNDERCOUNTING OF OCCUPANCIES
JAN83 JAN84 JAN85 JAN86 JAN87 JAN88 JAN89 JAN90 JAN91 JAN92 JAN93 JAN94 JAN95 JAN96 JAN97 JAN98

FIGURE C-15. A.M. PEAK HOUR FREEWAY PER LANE EFFICIENCY
GULF FREEWAY AND FREEWAY WITHOUT HOV LANE

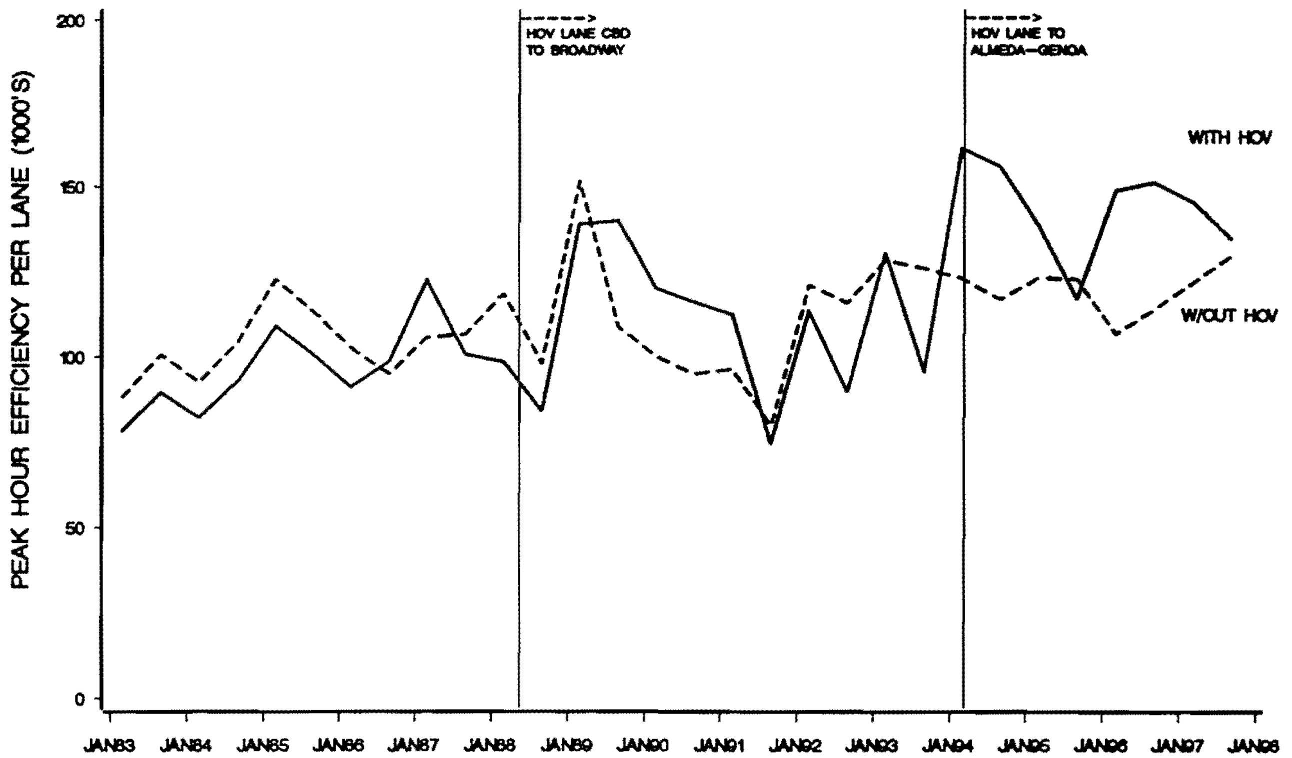


FIGURE C-16. GULF FREEWAY (IH 45S) MAINLANE AND HOV LANE
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS

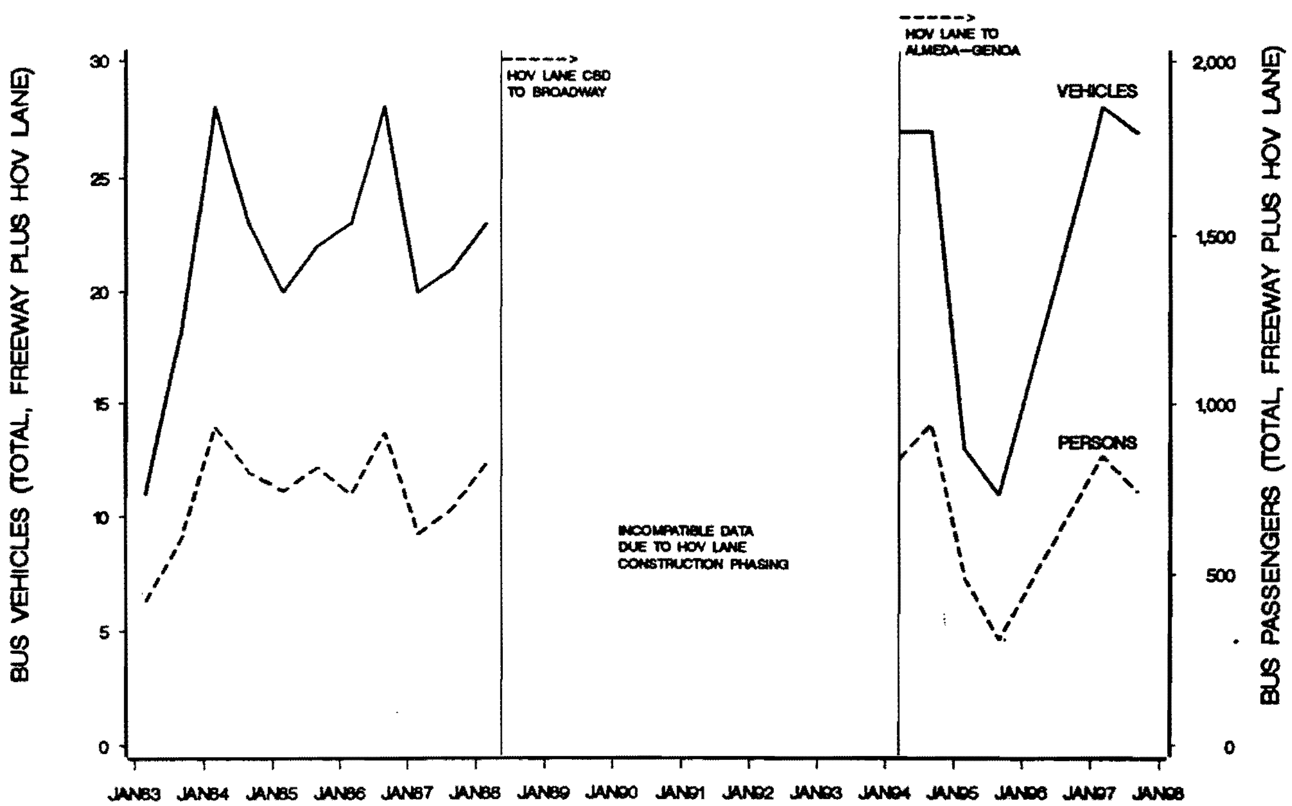


FIGURE C-17. GULF FREEWAY (IH 45S) MAINLANE AND HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS

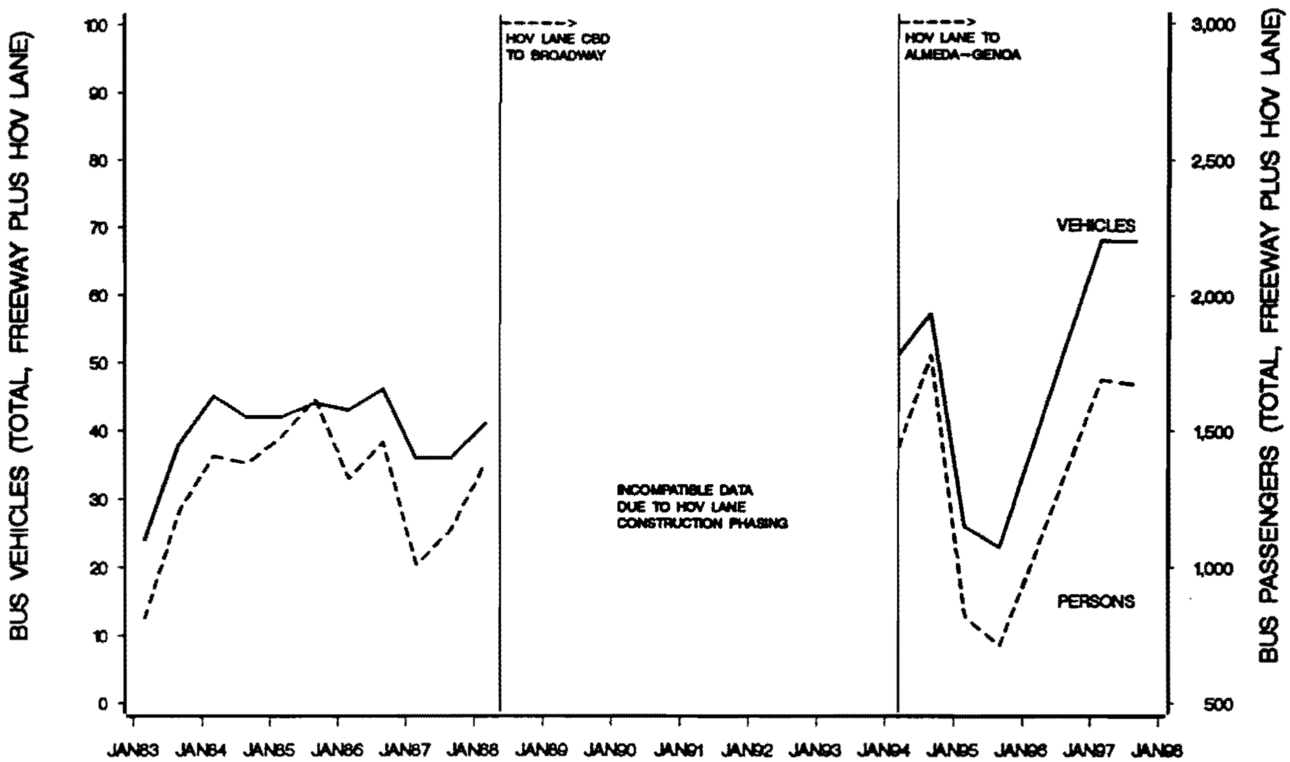


FIGURE C-18. A.M. PEAK PERIOD BUS PASSENGER TRIPS
TOTAL, FREEWAY PLUS HOV LANE VOLUMES
GULF FREEWAY AND FREEWAY WITHOUT HOV LANE

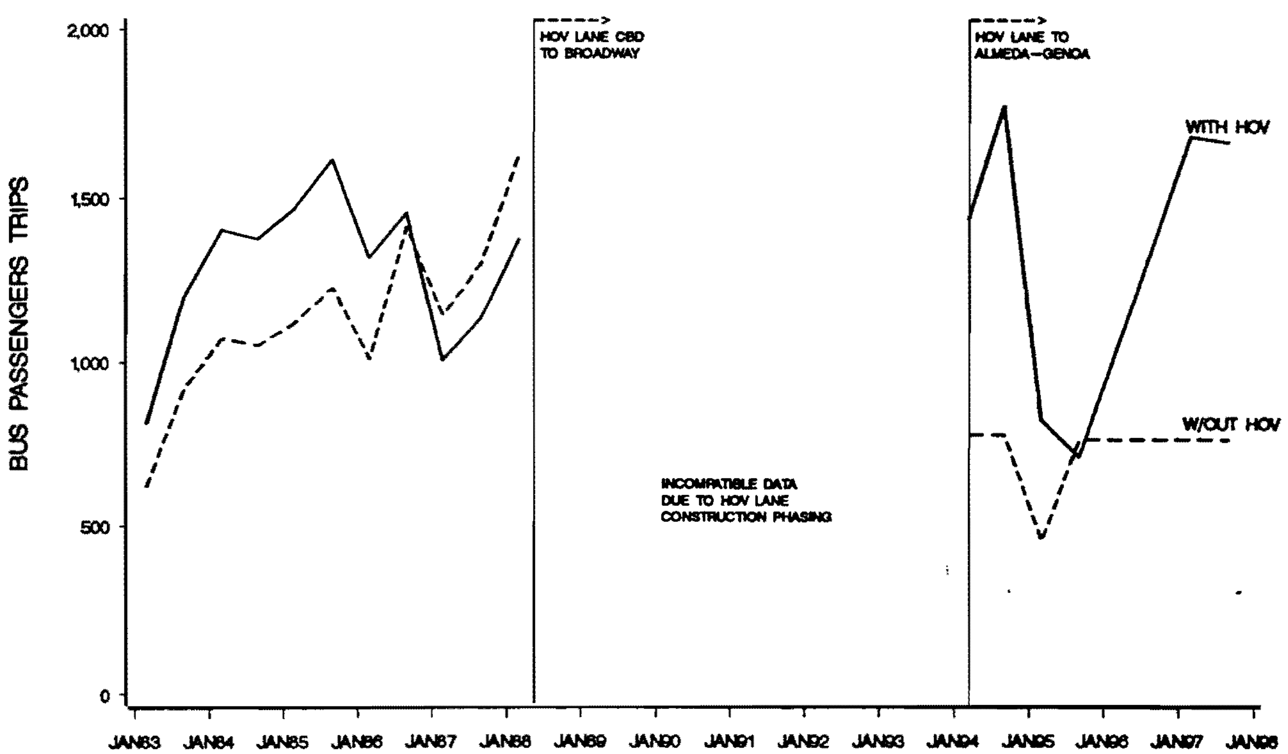


FIGURE C-19. GULF FREEWAY (IH 45S) CORRIDOR PARK-AND-RIDE DEMAND

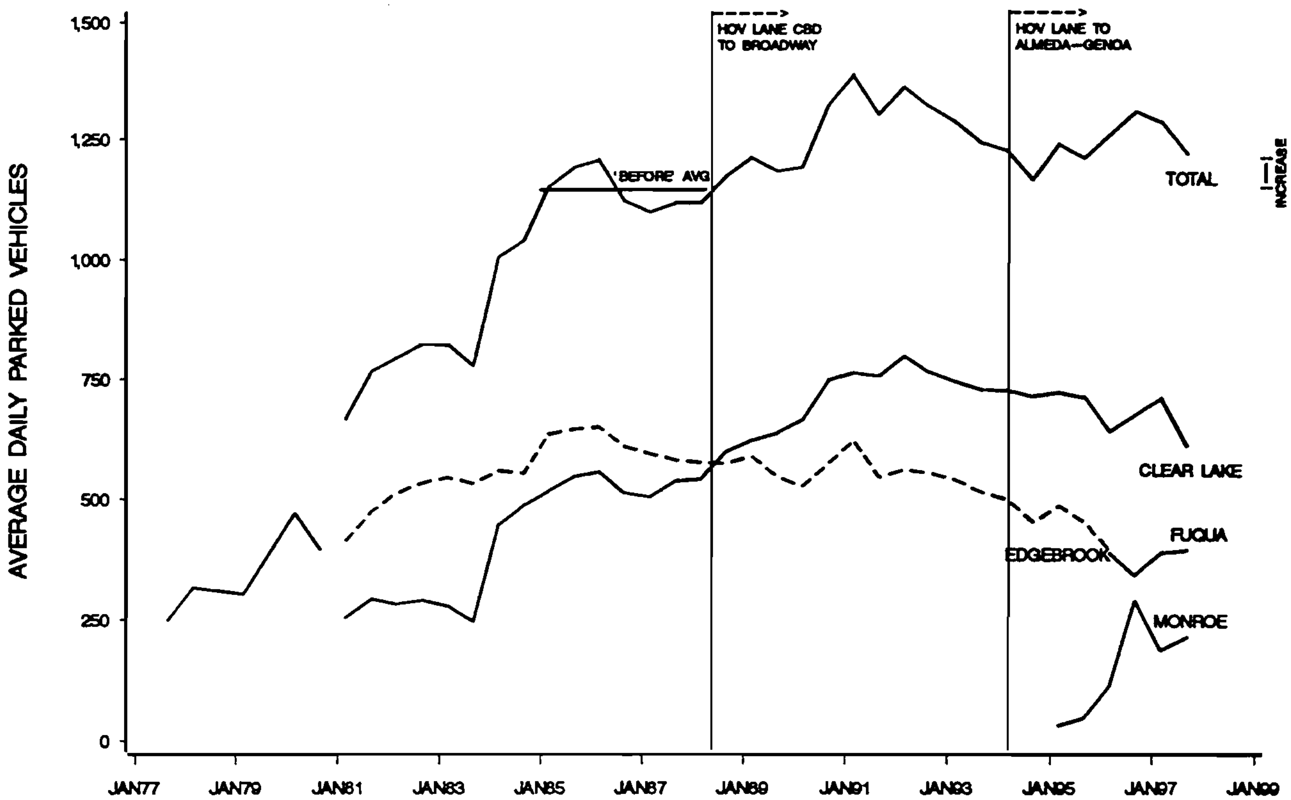
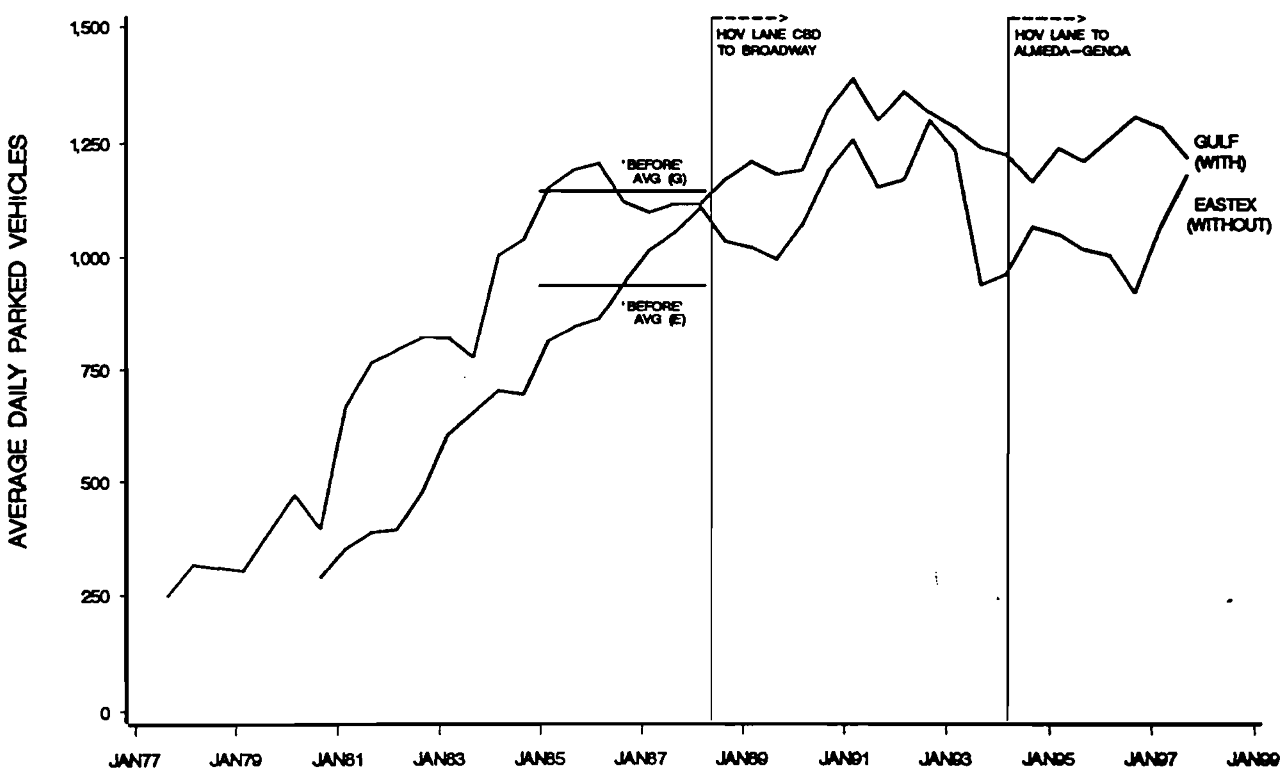


FIGURE C-20. AVERAGE DAILY VEHICLES PARKED AT PARK-AND-RIDE LOTS
GULF FREEWAY AND FREEWAY WITHOUT HOV LANE



APPENDIX D

NORTHWEST FREEWAY AND HOV LANE DATA

NORTHWEST FREEWAY (U.S. 290) AND HOV LANE, HOUSTON

Table D-1. Summary of A.M. Peak-Direction Northwest Freeway and HOV Lane Data, 1997

Type of Data Phase 1 of HOV Lane Became Operational 8/29/88	"Representative" Pre-HOV Lane Value	"Representative" Current Value	Percent Change
HOV Lane Data			
HOV Lane Length (miles)		14.9	
HOV Lane Cost (millions)		$150.0	
Person-Movement			
Peak-Hour (7-8 a.m.)	---	3,589	---
Peak-Period (6-9:30 a.m.)	---	6,633	---
Total Daily	---	13,859	---
Vehicle Volumes			
Peak-Hour	---	1,303	---
Peak-Period	---	2,515	---
Travel Time (minutes)[1]	---		---
Peak-Hour	---	16.62	---
Peak-Period	---	14.70	---
Vehicle Occupancy, Peak-Hour (persons/veh)	---	2.8	---
Accident Rate (i.e., Injury accidents/100 MVM)[2]	---	11.7	---
Vehicle Breakdowns (VMT/Breakdown)	---	86,794	---
Violation Rate (6-9:30 a.m.)		7%	
Peak-Hour Lane Efficiency (1000's)[3]		190	
Annual Discounted Benefits (millions)[4]		$23	
Annual Delay Savings (millions)[5]		$7	
Freeway Mainlane Data (see note)			
Person-Movement			
Peak-Hour	6,140	6,141	0%
Peak-Period (6-9:30 a.m.)	17,450	18,109	+4%
Vehicle Volume			
Peak-Hour	5,370	5,909	10%
Peak-Period	15,295	16,935	+11%
Vehicle Occupancy, Peak-Hour (persons/veh)	1.14	1.04	-9%
Accident Rate (i.e., Injury accidents/100 MVM)[1]	11.7	10.8	-8%
Avg. Operating Speed[6] (mph)			
Peak-Hour	28	31	+11%
Peak-Period	40	43	+1%
Peak-Hour Lane Efficiency (1000's)[3]	62	64	+2%

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

[1]Current travel times are calculated using data from Automatic Vehicle Identification (AVI) readers along the HOV lane, representing travel over a distance of 14.9 mi.

[2]Due to inconsistencies in reporting accidents in Harris County, this analysis includes only injury accidents. Accidents were analyzed between Little York and IH 610, a distance of approximately 7.7 mi. This corresponds to Phase 1 of the HOV lane. "Before" data are for the period from 1/82 to 8/88. "Current" accident data are for the period 9/88 to 12/97. TTI estimated 1995 freeway volumes to compute rates.

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

[4]Based on average annual delay savings, reduced vehicle operating costs, and reduced accident costs generated by MicroBENCOST over a 20-year life.

[5]Per MicroBENCOST over a 20-year life.

[6]Pre-HOV speeds are calculated using manual travel time data. Current speeds are calculated using data from Automatic Vehicle Identification (AVI) readers located along the HOV lane.

Table D-1. Summary of A.M. Peak-Direction Northwest Freeway and HOV Lane Data, 1997 (Continued)

Type of Data	"Representative" Pre-HOV Lane Value	"Representative" Current Value	Percent Change
Combined Freeway Mainlane and HOV Lane Data			
Total Person-Movement			
Peak-Hour	6,140	9,730	+58%
Peak-Period	17,450	24,742	+42%
Vehicle Volume			
Peak-Hour	5,370	7,212	+34%
Peak-Period	15,295	19,450	+27%
Vehicle Occupancy			
Peak-Hour	1.14	1.35	+18%
Peak-Period	1.14	1.27	+11%
2+ Carpool Volumes			
Peak-Hour	490	1,488	+204%
Peak-Period	1,365	3,361	+146%
Peak-Hour Lane Efficiency (1000's)[1]	62	95	+53%
Transit Data			
Bus Vehicle Trips			
Peak-Hour	7	19	+171%
Peak-Period	17	35	+106%
Bus Passenger Trips			
Peak-Hour	270	953	+253%
Peak-Period	605	1,570	+160%
Bus Occupancy (persons/bus)			
Peak-Hour	39	50.2	+29%
Peak-Period	36	44.9	+25%
Vehicles Parked in Corridor Park-and-Ride Lots	430	1,740	+305%
Bus Operating Speed (mph)[2]			
Peak-Hour	29	53	+83%
Peak-Period	49	60	+22%

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

[1] This represents the multiple of peak-hour passengers and average speed (HOV lane efficiency +[mainlane freeway efficiency x number of freeway directional lanes]/number of total directional lanes). It is used as a measure of per lane efficiency.

[2] Pre-HOV speeds are calculated using manual travel time data. Current speeds are calculated using data from Automatic Vehicle Identification (AVI) readers located along the HOV lane.

Table D-2. Comparison of Measures of Effectiveness, Freeway with (Northwest U.S. 290) and Freeway without (Eastex U.S. 59) HOV Lane, Houston

Measure of Effectiveness	"Representative" Pre-HOV Lane Value[1]	"Representative" Current Value	Percent Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/HOV lane	1.14	1.35	+18%
Freeway w/o HOV lane	1.23	1.30	+6%
A.M. Peak Hour, 2+ Carpool Volume Change			
Freeway w/HOV lane	490	1,488	+204%
Freeway w/o HOV lane	600	1,165	+94%
Bus Passengers, Peak Period			
Freeway w/HOV lane	605	1,570	+160%
Freeway w/o HOV lane	1,188	1,123	-5%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	430	1,740	+305%
Freeway w/o HOV lane	1,236	1,099	-11%
Facility Per Lane Efficiency[2]			
Freeway w/HOV lane	62	104	+67%
Freeway w/o HOV lane	86	81	-6%

[1]Representative Pre-HOV data for freeways without HOV lanes are comprised of data collected from the Eastex Freeway 1/93.
[2]This represents the product of peak-hour passengers and average speed (passengers x kph/number of lanes [passengers x mph/number of lanes]). It is used as a measure of per lane efficiency.

HOV LANE DATA

DESCRIPTION

- Phase 1 (9.5 mi) of the HOV lane opened August 29, 1988.
- The HOV lane is now complete with 14.9 mi in operation.
- The capital cost (including all support facilities) for the completed facility in 1996 dollars was $151.4 million.
- Selected milestone dates are listed below. The capital cost table (Table D-3) shows other dates.
  - 8/29/88 Northwest Transit Center to Little York opens (9.5 mi).
  - 2/6/90 HOV extended to FM 1960 (13.5 mi).
  - 4/1/90 Northwest Transit Center opens.
  - 10/6/90 Weekend HOV operation begins (4:00 a.m. - 10:00 p.m.).
  - 10/5/91 Weekend HOV operation ends.
  - 9/8/92 Motorcycles allowed on HOV facility (no occupancy restrictions).
  - 3/14/94 Hours of operation revised (5:00 a.m. - 10:00 a.m.; 3:00 p.m. - 8:00 p.m.).
  - 4/4/94 Hours of operation revised (5:00 a.m. - 12:00 p.m.; 2:00 p.m. - 9:00 p.m.).

- 9/30/96 Hours of operation revised (5:00 a.m. - 11:00 a.m.; 2:00 p.m. - 8:00 p.m.).
- 7/28/97 Inner Katy connector opened.

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

Cost Component	Year of Construction Cost		Factor	Estimated Cost 1995 Dollars	
HOV Lane and Ramps					
Phase I (1990)		$54.7	1.16		$63.5
FM 1960 to FM 529 (1990)		3.2	1.16		3.7
FM 529 to Little York (1990)		2.4	1.16		2.8
Phase 2A, N.W. Station Ramp (1990)		3.4	1.16		3.9
Phase 2B, W. Little York Ramp (1988)		1.2	1.23		1.5
Miscellaneous		0.4	1.16		0.5
Widen Bridge # 135 (1997)		0.3	0.94		0.3
SUB-TOTAL	$65.6			$76.2	
Per Mile		$4.9			$5.6
Surveillance, Communication, and Control (1990)		$2.9	1.16		$2.5
SUB-TOTAL	$2.9			$2.5	
Per Mile		$0.2			$0.2
Support Facilities					
W. Little York P/R (1988)		$6.9	1.23		$8.5
Pinemont P/R (1989)		9.4	1.19		11.2
Northwest Transit Center (1990)		21.3	1.16		24.7
N.W. Station P/R (1984)		4.0	1.38		5.5
N.W. Station P/R Modification (1990)		1.6	1.16		1.4
N.W. Station P/R 2nd Expansion (1993)		5.9	1.06		6.3
SUB-TOTAL	$43.2			$57.6	
Per Kilometer (Mile)		$3.2			$4.3
TOTAL COST	$111.7			$136.3	
COST PER MILE (13.5 miles)	$8.3			$10.1	

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

Table D-4. Estimated Capital Costs, Northwest HOV Lane, Future Segments

Cost Component	Estimated Year of Construction	Estimated Cost ($ millions)
Support Facilities		
Northwest Station 2nd Expansion	1998	$1.6
Northwest Station 3rd Expansion	2001	$8.6

PERSON-MOVEMENT

- In 1997, 13,859 person trips per day were served on the HOV lane.
- A.M. peak hour, 3,589 persons/hour.
  - 953 (27 percent) by bus, 33 (1 percent) by vanpool, 2,599 (72 percent) by carpool, and 5 by motorcycle (Figure D-1).
  - Average HOV lane peak-hour vehicle occupancy = 2.8 persons/vehicle.
- A.M. peak period, 6,633 persons.
  - 1,570 (24 percent) by bus, 136 (2 percent) by vanpool, 4,912 (74 percent) by carpool, and 15 by motorcycle (Figure D-2).

VEHICLE MOVEMENT

- A.M. peak hour, 1,303 vph.
  - 19 (1 percent) buses, 6 (1 percent) vans, 1,274 (98 percent) carpools, and 5 by motorcycle (Figure D-3).
- A.M. peak period, 2,515 vehicles.
  - 35 (1 percent) buses, 21 (1 percent) vans, 2,445 (97 percent) carpools, and 15 by motorcycle (Figure D-4).

ACCIDENT RATE

- For the period 9/88 through 12/97, the HOV lane accident rate was 11.7 accidents per 100 million vehicle miles.

FIGURE D-1. NORTHWEST FREEWAY (US 290) HOV LANE
A.M. PEAK HOUR HOV LANE PERSON MOVEMENT

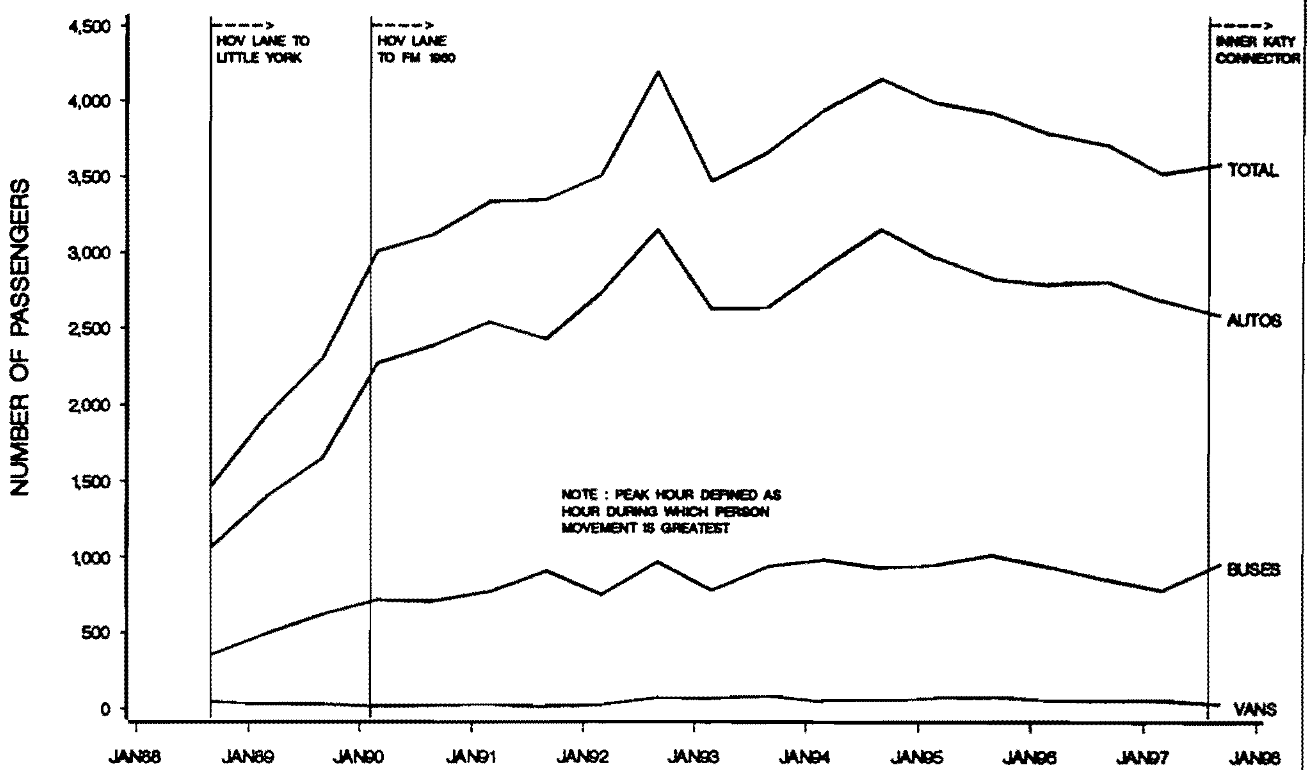
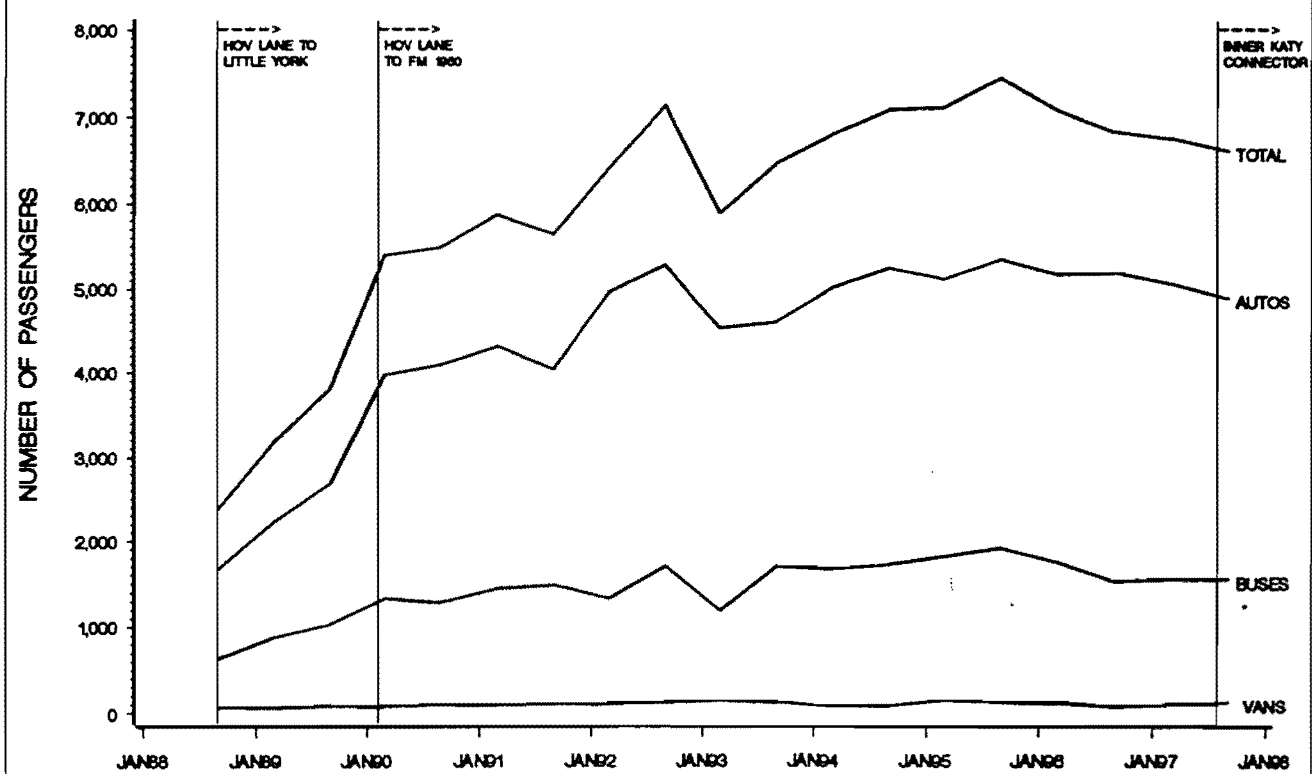


FIGURE D-2. NORTHWEST FREEWAY (US 290) HOV LANE
A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT



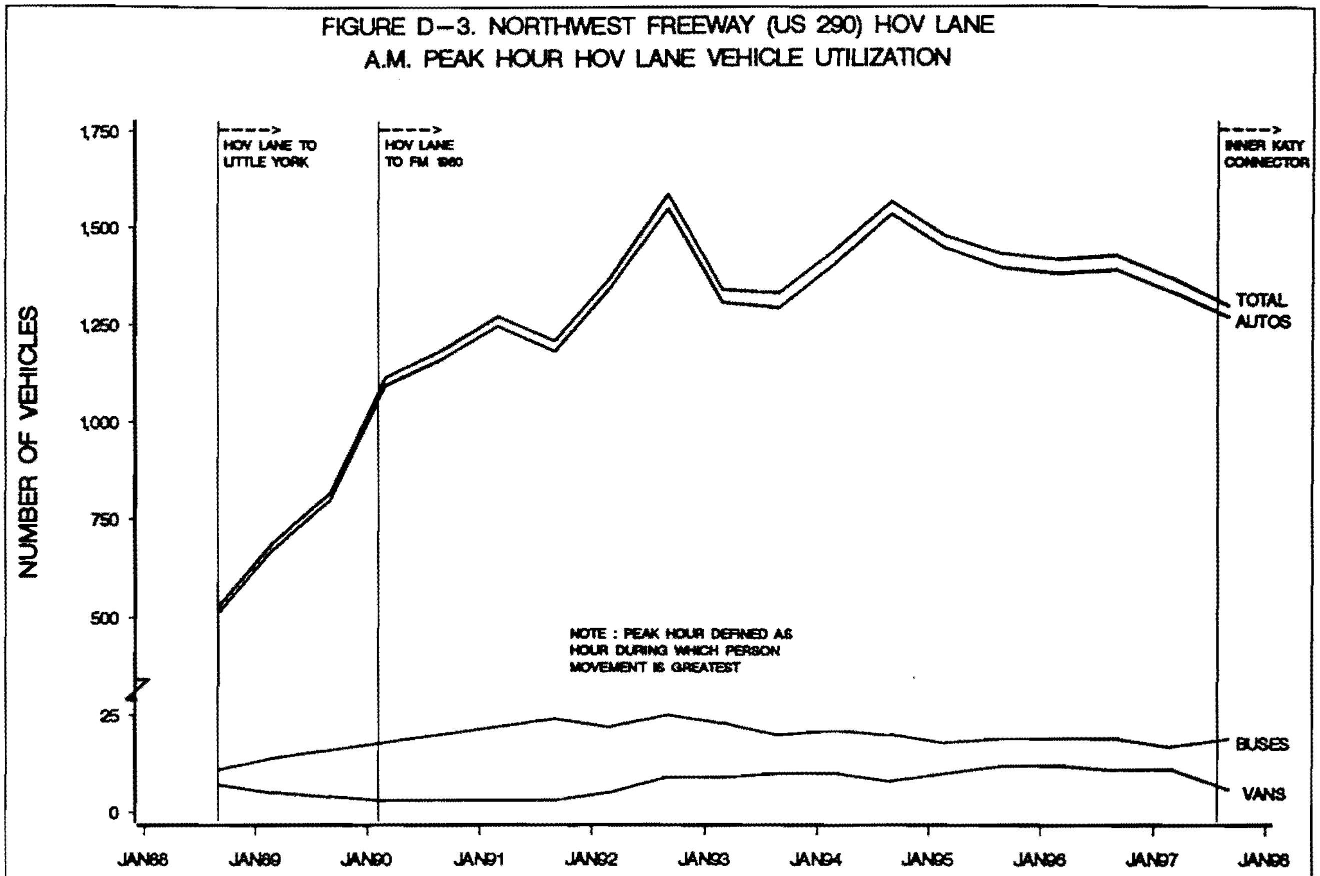


FIGURE D-3. NORTHWEST FREEWAY (US 290) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION
NUMBER OF VEHICLES
1,750
1,500
1,250
1,000
750
500
25
0
HOV LANE TO LITTLE YORK
HOV LANE TO FM 1960
INNER KATY CONNECTOR
TOTAL
AUTOS
BUSES
VANS
NOTE : PEAK HOUR DEFINED AS HOUR DURING WHICH PERSON MOVEMENT IS GREATEST
JAN88
JAN89
JAN90
JAN91
JAN92
JAN93
JAN94
JAN95
JAN96
JAN97
JAN98

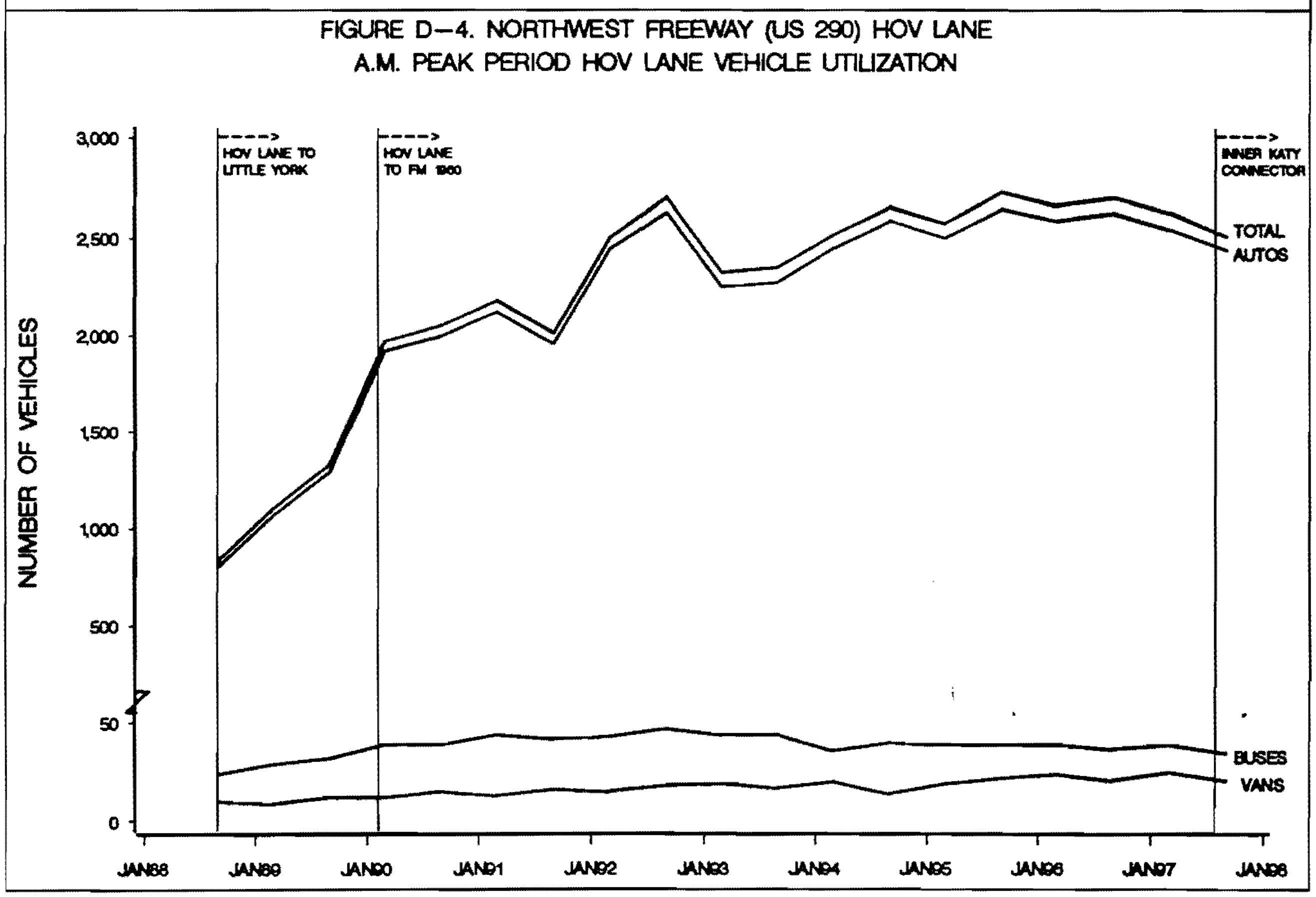


FIGURE D-4. NORTHWEST FREEWAY (US 290) HOV LANE
A.M. PEAK PERIOD HOV LANE VEHICLE UTILIZATION
NUMBER OF VEHICLES
3,000
2,500
2,000
1,500
1,000
500
50
0
HOV LANE TO LITTLE YORK
HOV LANE TO FM 1960
INNER KATY CONNECTOR
TOTAL
AUTOS
BUSES
VANS
JAN88
JAN89
JAN90
JAN91
JAN92
JAN93
JAN94
JAN95
JAN96
JAN97
JAN98

VEHICLE BREAKDOWN RATES

- As measured from September 1, 1988, through December 1997, the following rate has been observed:
  - The weighted average for all vehicle types is one breakdown per 86,794 VMT.

VIOLATION RATE

- The observed violation rate (vehicles on the HOV lane not eligible to use the HOV lane) is approximately 7 percent.

PEAK-HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is used as a measure of the efficiency of a lane. For the HOV lane, this value (expressed in 1000's) is approximately 190 (3,589 passengers x 53 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane experience an average travel time savings of 12 minutes in the a.m. peak hour (Table D-5, Figure D-5).

Table D-5. Travel Time Savings for Northwest HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1997)

Time of Day	Measured Travel Time: Freeway (min)	Measured Travel Time: HOV (min)	Measured Travel Time: Savings (min)	HOV Lane Person Trips: Carpool	HOV Lane Person Trips: Vanpool	HOV Lane Person Trips: Bus	HOV Lane Person Trips: Total	Travel Time Saved (Person-Minutes)
Southbound A.M. Travel Time Savings for Northwest HOV Lane								
Section from Eldridge to Senate								
6:00	3.12	3.04	0.09	351	20	104	476	80
6:30	3.61	3.15	0.47	872	31	254	1,157	540
7:00	3.93	3.66	0.27	913	6	84	1,002	320
7:30	3.85	3.48	0.38	950	0	209	1,160	440
8:00	2.99	2.97	0.02	707	0	416	1,124	40
8:30	2.70	2.82	-0.13	167	0	96	263	-30
9:00	2.65	2.80	-0.15	34	0	7	42	-10
Peak-Period Total				3,994	57	1,170	5,224	1,380
Section from Senate to S.P. Railroad								
6:00	10.87	11.16	-0.29	206	32	161	399	200
6:30	17.05	11.49	5.56	789	44	196	1,029	5,860
7:00	24.10	13.13	10.97	1,207	37	376	1,620	17,910
7:30	26.15	12.96	13.19	1,317	9	454	1,779	23,510
8:00	21.31	11.15	10.17	841	11	287	1,138	11,700
8:30	15.17	10.64	4.53	476	6	101	582	2,840
9:00	10.41	10.43	-0.02	159	2	26	186	10
Peak-Period Total				4,995	141	1,601	6,733	62,040
Northbound P.M. Travel Time Savings for Northwest HOV Lane								
Section from Senate to Eldridge								
3:30	2.73	2.92	-0.19	114	0	7	121	-20
4:00	2.95	3.00	-0.05	274	3	33	309	-20
4:30	3.08	3.06	0.02	577	25	179	781	20
5:00	3.64	3.15	0.49	765	143	90	998	460
5:30	4.37	3.25	1.13	1,020	8	526	1,555	1,760
6:00	3.64	3.14	0.50	581	0	142	723	390
6:30	2.81	3.02	-0.21	343	0	110	453	-90
Peak-Period Total				3,674	179	1,087	4,940	2,490

Table D-5. Travel Time Savings for Northwest HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1997) (Continued)

Northbound P.M. Travel Time Savings for Northwest HOV Lane								
Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section from the S.P. Railroad to Senate								
3:30	9.93	10.66	-0.74	160	0	53	213	-140
4:00	11.88	10.88	1.00	338	16	109	461	520
4:30	15.16	11.22	3.94	624	61	218	902	3,610
5:00	20.25	11.73	8.52	1,107	103	422	1,631	13,870
5:30	19.99	11.83	8.16	1,250	19	528	1,795	14,900
6:00	15.11	11.23	3.87	839	0	286	1,125	4,550
6:30	10.93	10.85	0.08	438	11	139	588	150
Peak-Period Total				4,756	210	1,755	6,715	37,460

Table D-6. Northwest Freeway Travel Time Summaries

Travel Time Data	Travel Times					
	97[3]	96[4]	95[4]	94[4]	93[4]	Pre-HOV
HOVL Travel Time[1]						
AM Peak-Hour	17 min	16 min	16 min	16 min	15 min	-
PM Peak-Hour	15 min	16 min	15 min	15 min	15 min	-
Freeway Mainlanes Travel Time[2]						
AM Peak-Hour	29 min	30 min	22 min	24 min	22 min	25 min
PM Peak-Hour	24 min	22 min	22 min	19 min	18 min	20 min
Net Travel Time Savings						
AM Peak-Hour	12 min	14 min	6 min	8 min	7 min	-
(Person-Minutes)	(42,180)	(25,527)	(12,597)	(15,877)	(7,184)	-
PM Peak-Hour	9 min	6 min	7 min	4 min	3 min	-
(Person-Minutes)	(30,970)	(9,950)	(5,542)	(5,165)	(3,814)	

[1]Travel times are calculated over a distance of 14.9 mi for the HOV lane.
[2]Travel times are calculated over a distance of 11.82 mi for the freeway mainlane.
[3]Travel times calculated using Automatic Vehicle Identification (AVI).
[4]Travel times calculated using manual travel time data.

FREEWAY DATA

NOTE

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

PERSON-MOVEMENT

- In the a.m. peak hour, compared to pre-HOV conditions, person movement has remain essentially unchanged (Figure D-6).

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

VEHICLE VOLUME

- In the a.m. peak hour, vehicle volume has increased by 10 percent (Figure D-6).

- In the a.m. peak period, vehicle volume has increased by 11 percent (Figure D-7).

VEHICLE OCCUPANCY

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

- In the a.m. peak period, compared to pre-HOV conditions, mainlane occupancy has declined by 6 percent (Figure D-12).

ACCIDENT RATE

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

- For the section between Little York and I-610, the accident rate for the period (1/82- 8/88) preceding the opening of the HOV lane was 11.7 accidents per 100 million vehicle miles. The accident data available for the period (9/88-12/96) after the HOV lane opened indicate an accident rate of 10.8 accidents/100 MVM.

FIGURE D-5. NORTHWEST FREEWAY (US 290) MAINLANES AND HOV LANE A.M. TRAVEL TIME

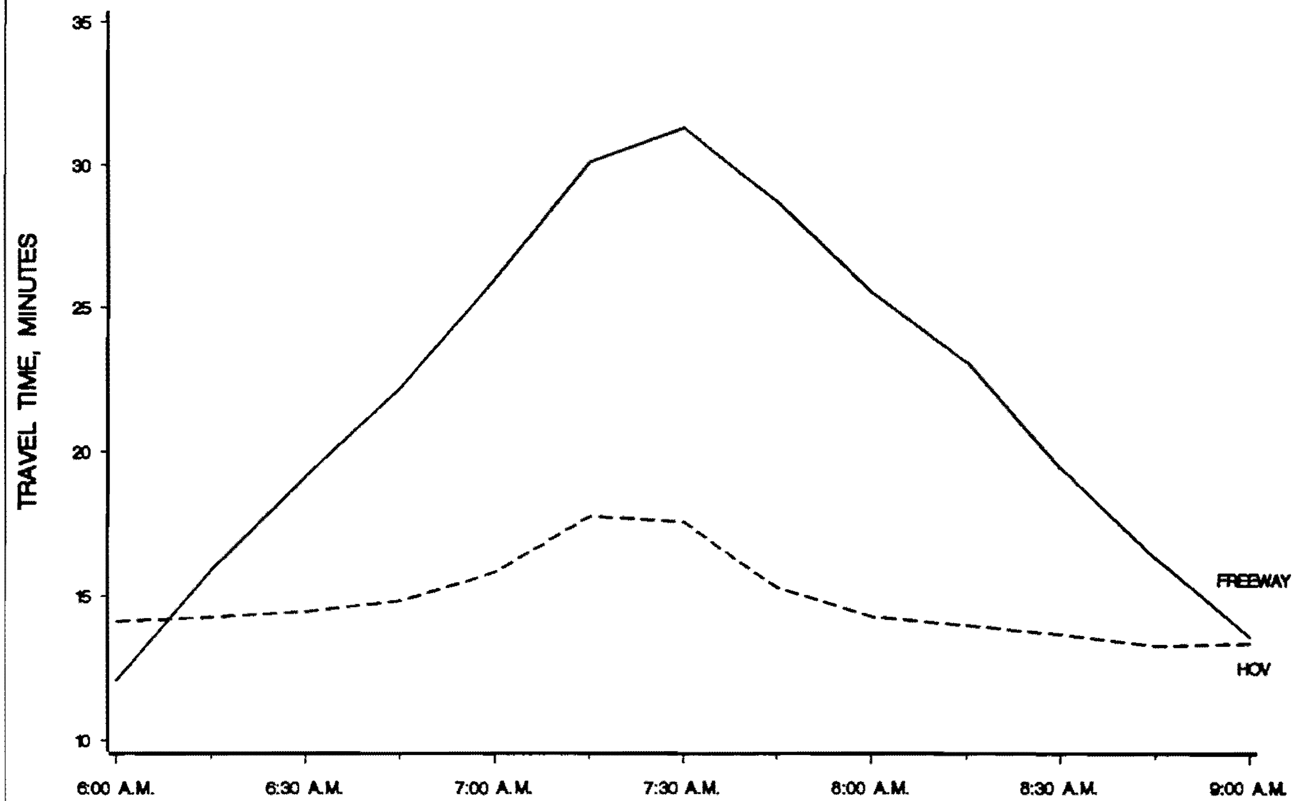


FIGURE D-6. NORTHWEST FREEWAY (U.S. 290)
A.M. PEAK HOUR MAINLANE TRIPS

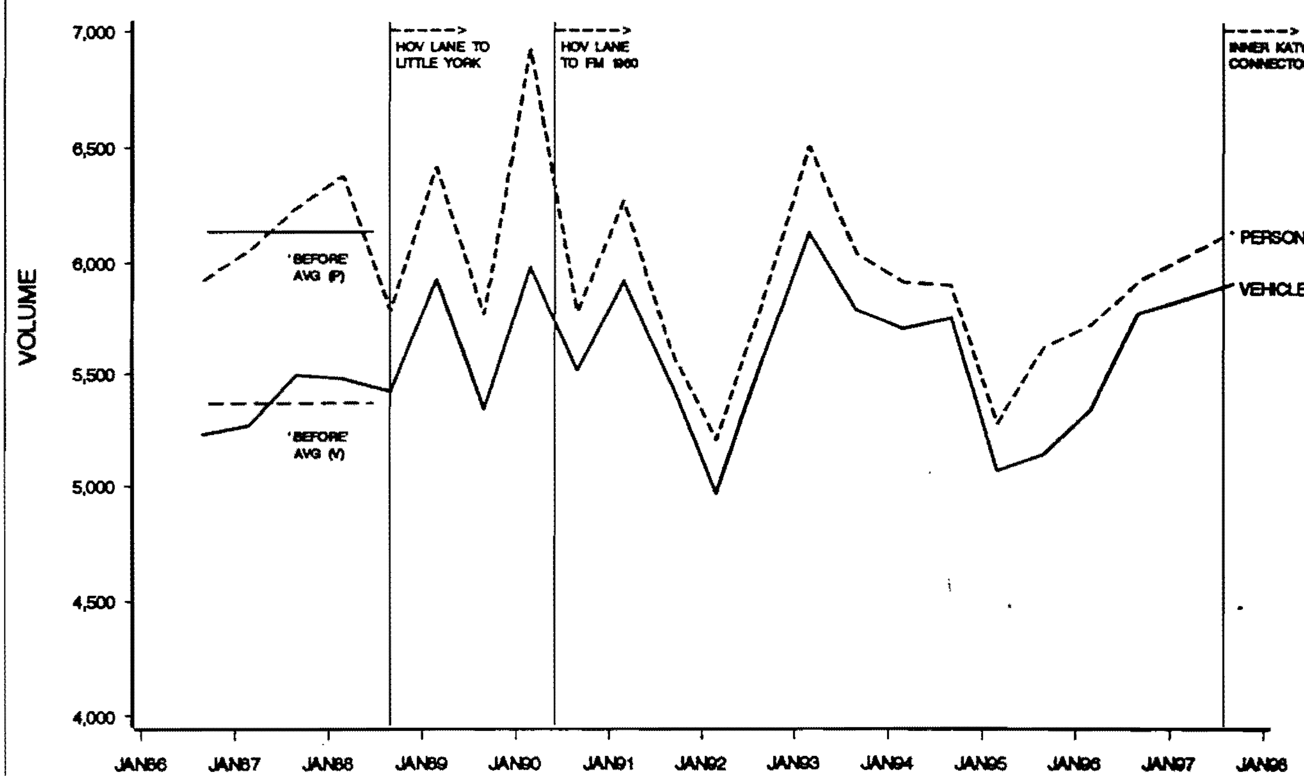


FIGURE D-7. NORTHWEST FREEWAY (U.S. 290)
A.M. PEAK PERIOD MAINLANE TRIPS

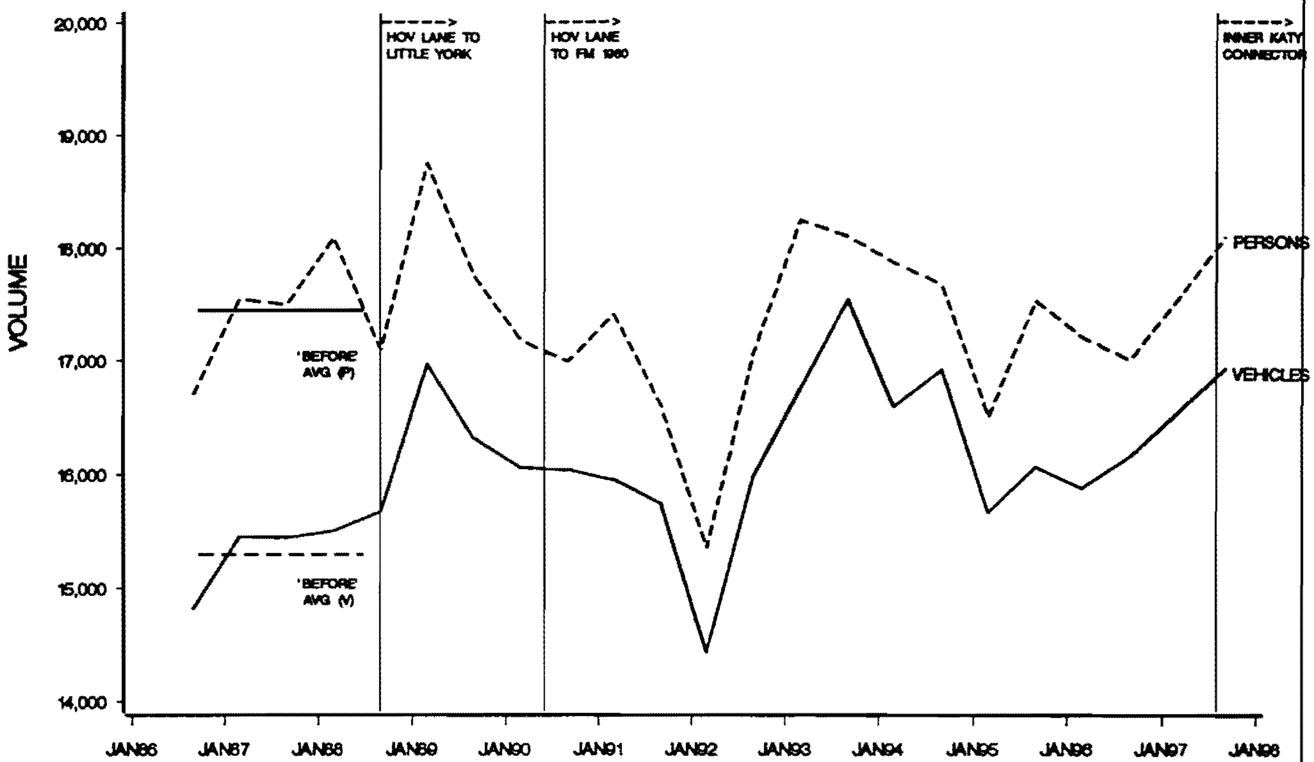


FIGURE D-8. NORTHWEST FREEWAY (U.S. 290) MAINLANE TRAVEL TIME AND SPEED SURVEY
SOUTHBOUND, TELGE TO IH 610
A.M. PEAK PERIOD

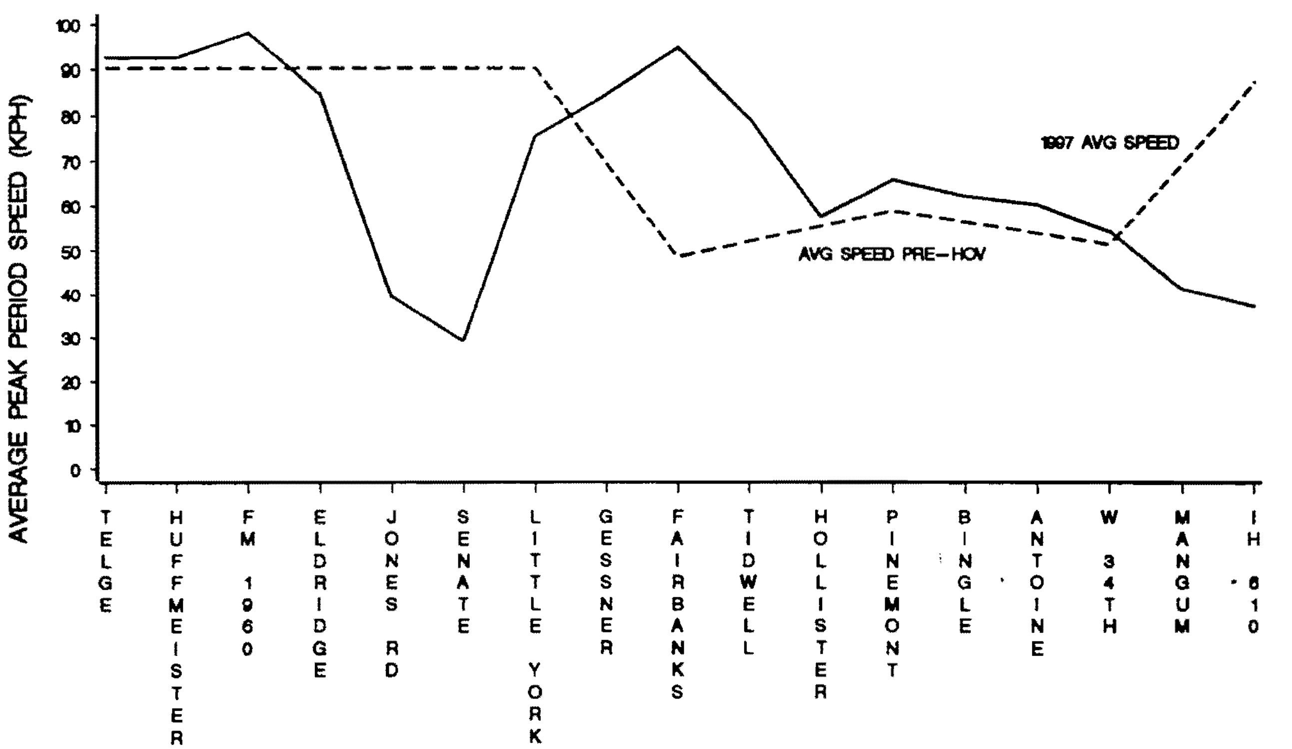


FIGURE D-9. NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE
A.M. PEAK HOUR PERSON TRIPS

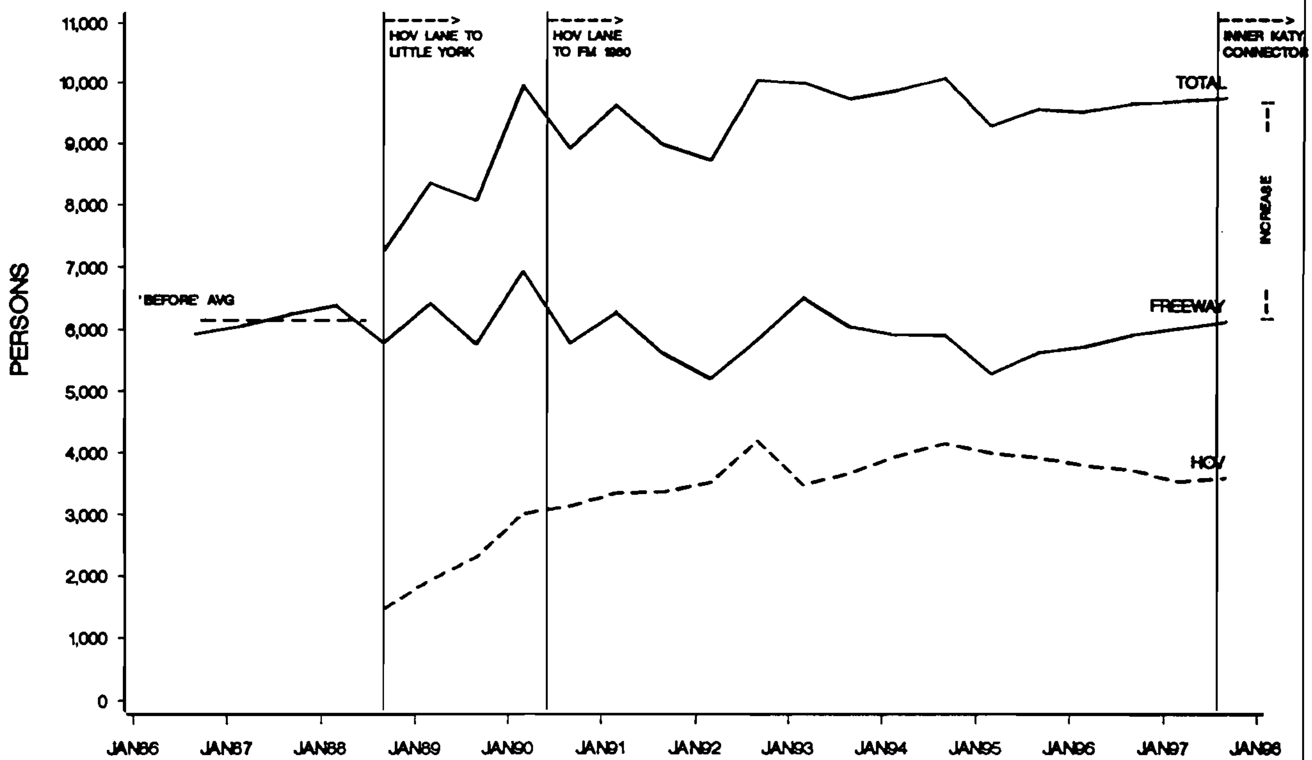


FIGURE D-10. NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE
A.M. PEAK PERIOD PERSON TRIPS

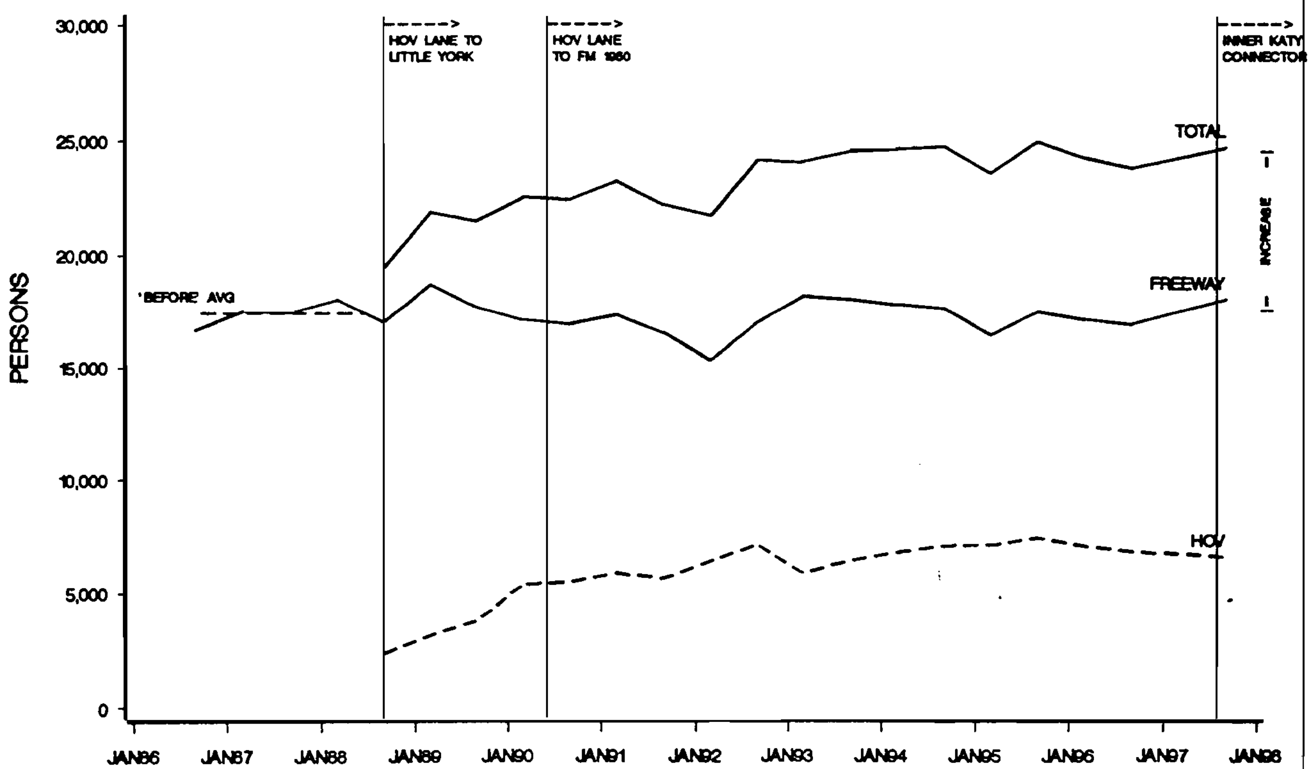


FIGURE D−11. NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE
A.M. PEAK HOUR AVERAGE OCCUPANCY

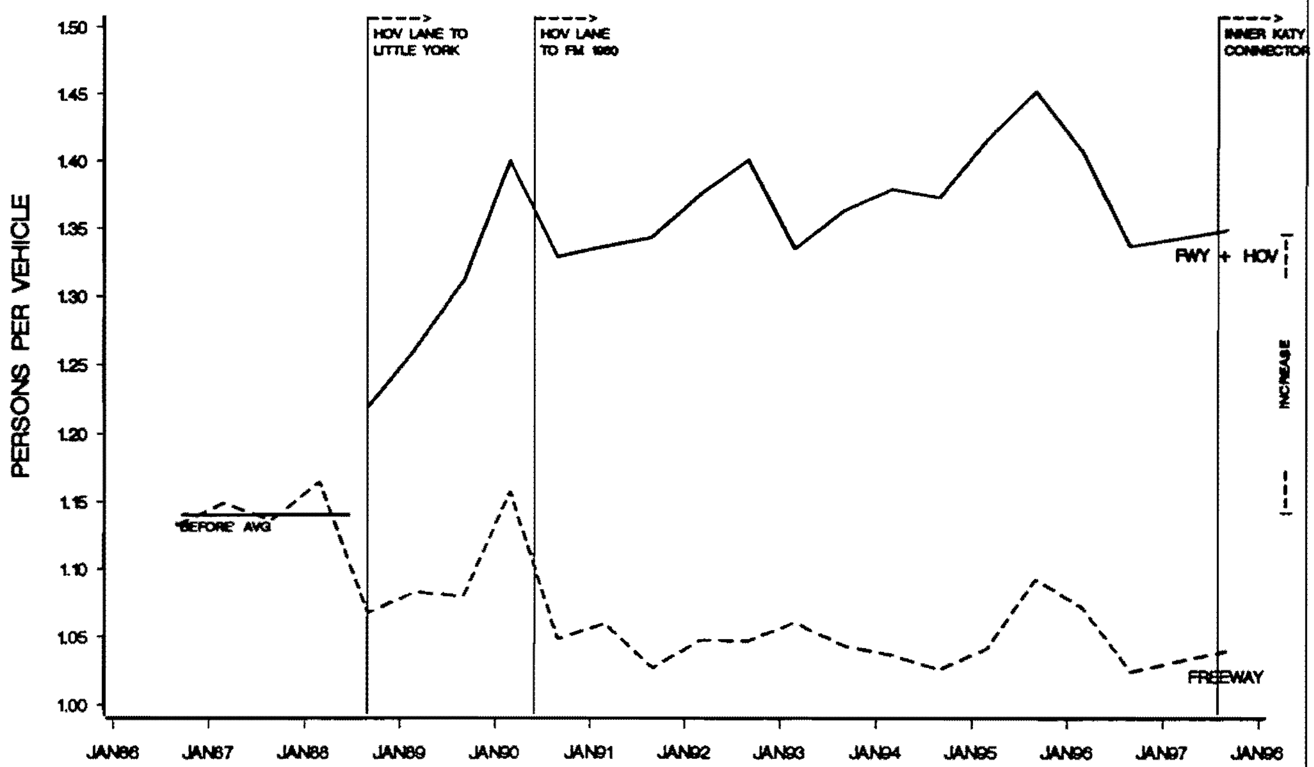
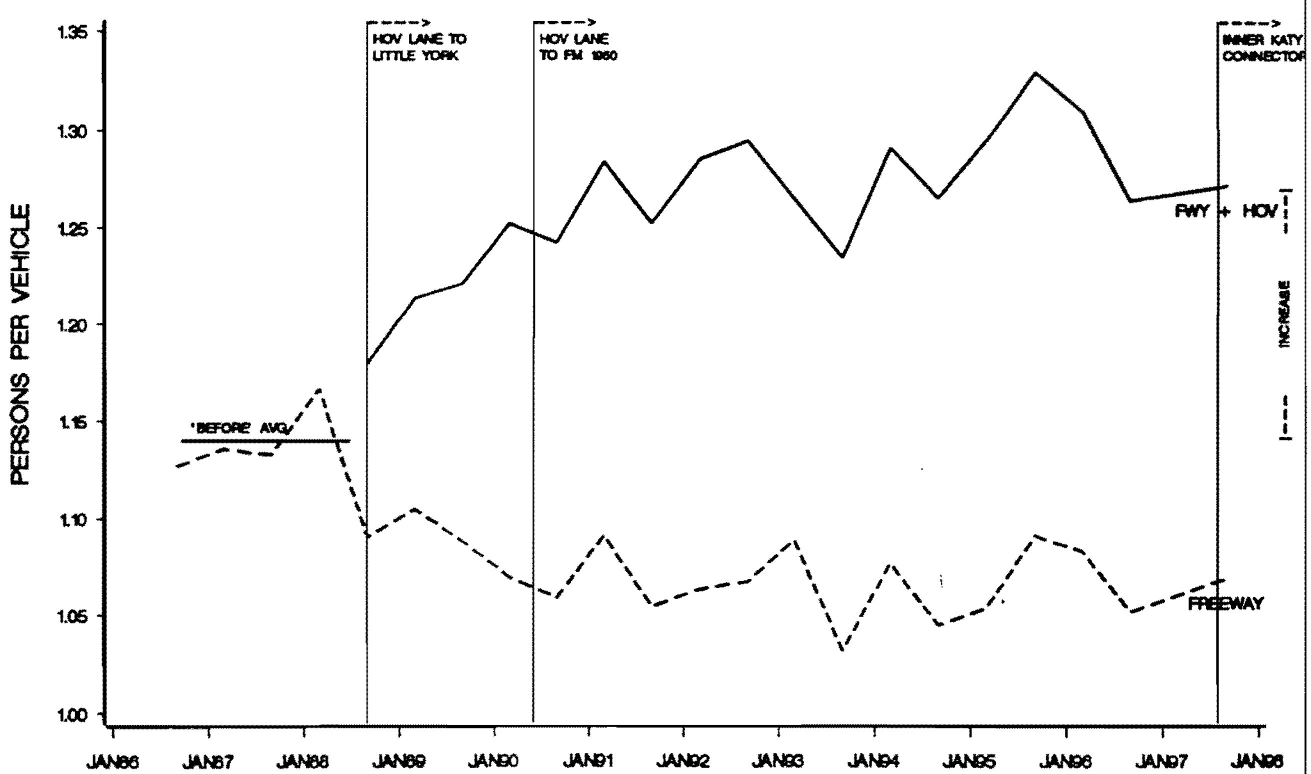


FIGURE D−12. NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE
A.M. PEAK PERIOD AVERAGE OCCUPANCY



AVERAGE OPERATING SPEED

- In comparison to pre-HOV lane conditions, mainlane operating speeds have increased in the peak hour and the peak period. The data in Figure D-8 show the average of all travel time runs made both before and after the HOV lane opened for the a.m. peak period.

PEAK-HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is used as a measure of per lane efficiency.
- For the freeway mainlanes, increased travel speeds have resulted in an increase in per lane efficiency of 63 percent.

COMBINED FREEWAY AND HOV LANE DATA

TOTAL PERSON-MOVEMENT

- Percent by HOV lane, a.m. peak.
  - At Pinemont, the HOV lane is responsible for 37 percent of peak-hour person-movement (HOV lane = 3,589; freeway = 6,141) and 27 percent of peak-period (HOV lane = 6,633; freeway = 18,109) person-movement (Figure D-10).
- Increase in a.m. person-movement at Pinemont
  - Provision of the HOV lane increased total directional lanes by 33 percent.
  - Total peak-hour person-movement has increased by 58 percent, from 6,140 to 9,730 (Figure D-9). Peak-period person movement has increased by 42 percent, from 17,450 to 24,742 (Figure D-10).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.35, a 18 percent increase over the pre-HOV lane occupancy (Figure D-11). Occupancy in the peak period is 11 percent greater than pre-HOV lane levels (Figure D-12).
- While the occupancy on the Northwest Freeway has increased, on freeways which do not have HOV lanes, occupancy has decreased (Figure D-13).

CARPOOL VOLUMES

- In the a.m. peak hour, the total number of 2+ carpools (freeway plus HOV lane) has increased by 204 percent compared to pre-HOV lane levels (Figure D-14). In the a.m. peak period, the increase has been 146 percent. These increases have not been experienced on freeways not having HOV lanes.

PEAK-HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. The average efficiency of a lane on the freeway (3 freeway lanes plus 1 HOV lane) has increased by 95 percent since the implementation of the HOV lane (Figure D-15). Per-lane efficiency has at the same time, decreased by 6 percent on freeways without HOV lanes.

BUS TRANSIT DATA

BUS VEHICLE AND PASSENGERS TRIPS

- In the a.m. peak hour, bus vehicle trips have been increased by 171 percent since the HOV lane opened, and a 253 percent increase in bus ridership has resulted (Figure D-16). In the peak period, a 106 percent increase has occurred in bus vehicle trips, and a 160 percent increase in bus ridership has resulted (Figure D-17).

- While bus passenger trips have increased in the Northwest Freeway corridor, in the corridors which do not have HOV lanes, bus passenger trips have decreased slightly (Figure D-18).

PARK-AND-RIDE

- Prior to opening the HOV lane, approximately 430 vehicles were parked in corridor park-and-ride lots. This has increased 305 percent to a current level of 1,740 (Figure D-19).

- The increase in cars parked in the Northwest corridor has not occurred in the freeway corridor that does not have an HOV lane (Figure D-20).

FIGURE D-13. A.M. PEAK HOUR AVERAGE OCCUPANCY
NORTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

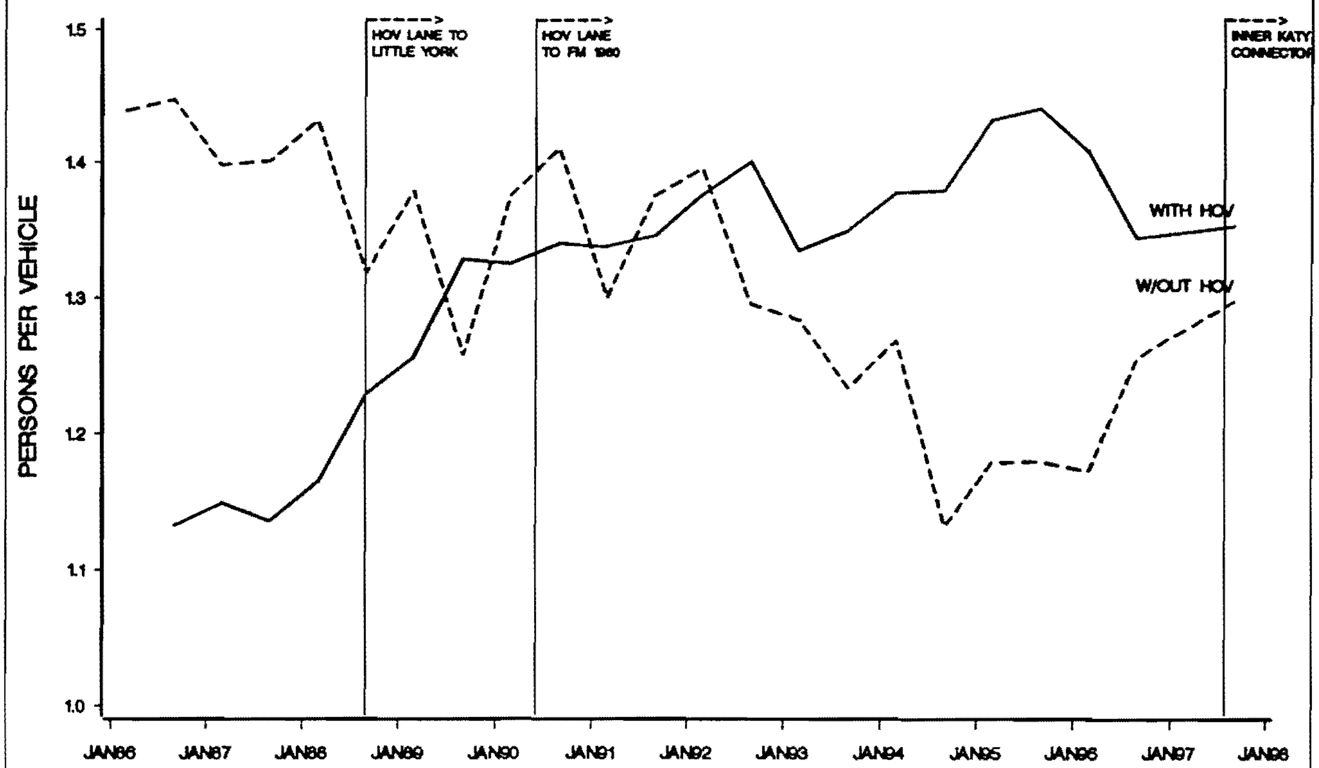


FIGURE D-14. NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE
A.M. PEAK HOUR 2+ CARPOOL UTILIZATION

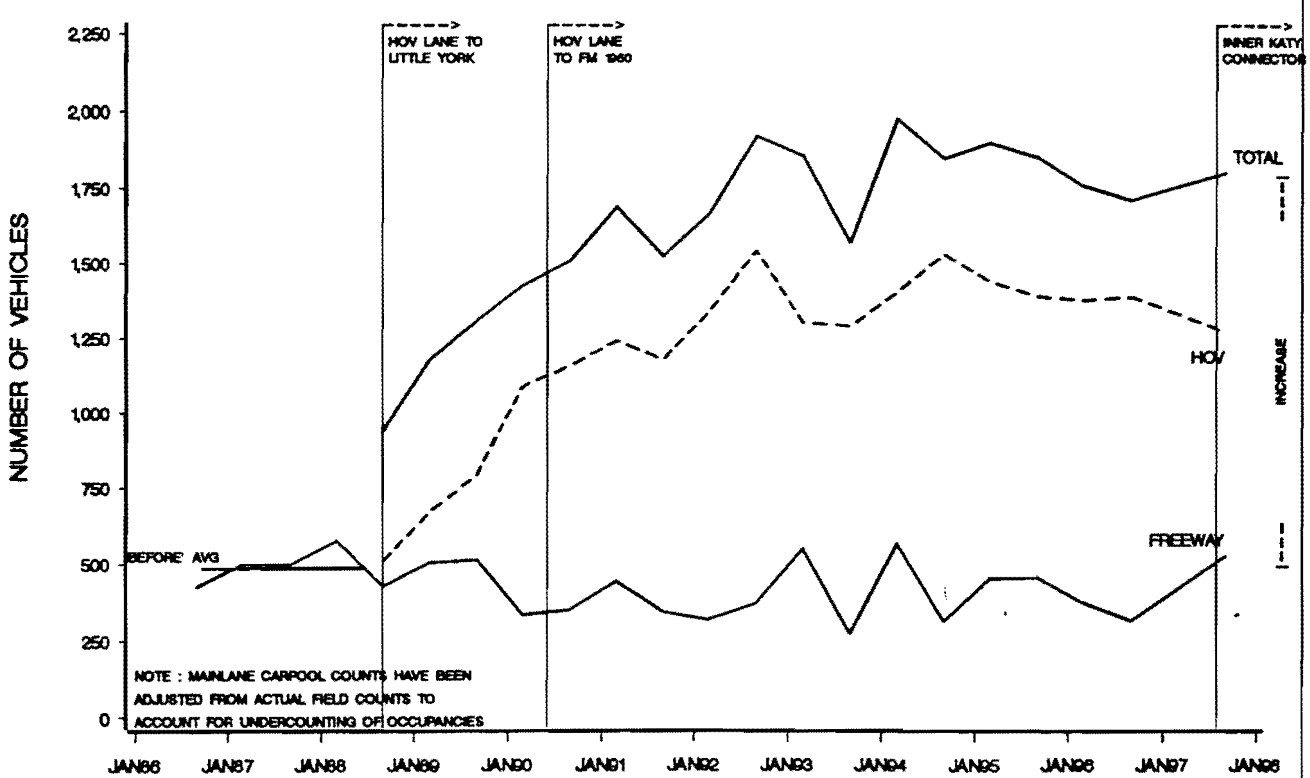


FIGURE D-15. A.M. PEAK HOUR FREEWAY PER LANE EFFICIENCY
NORTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

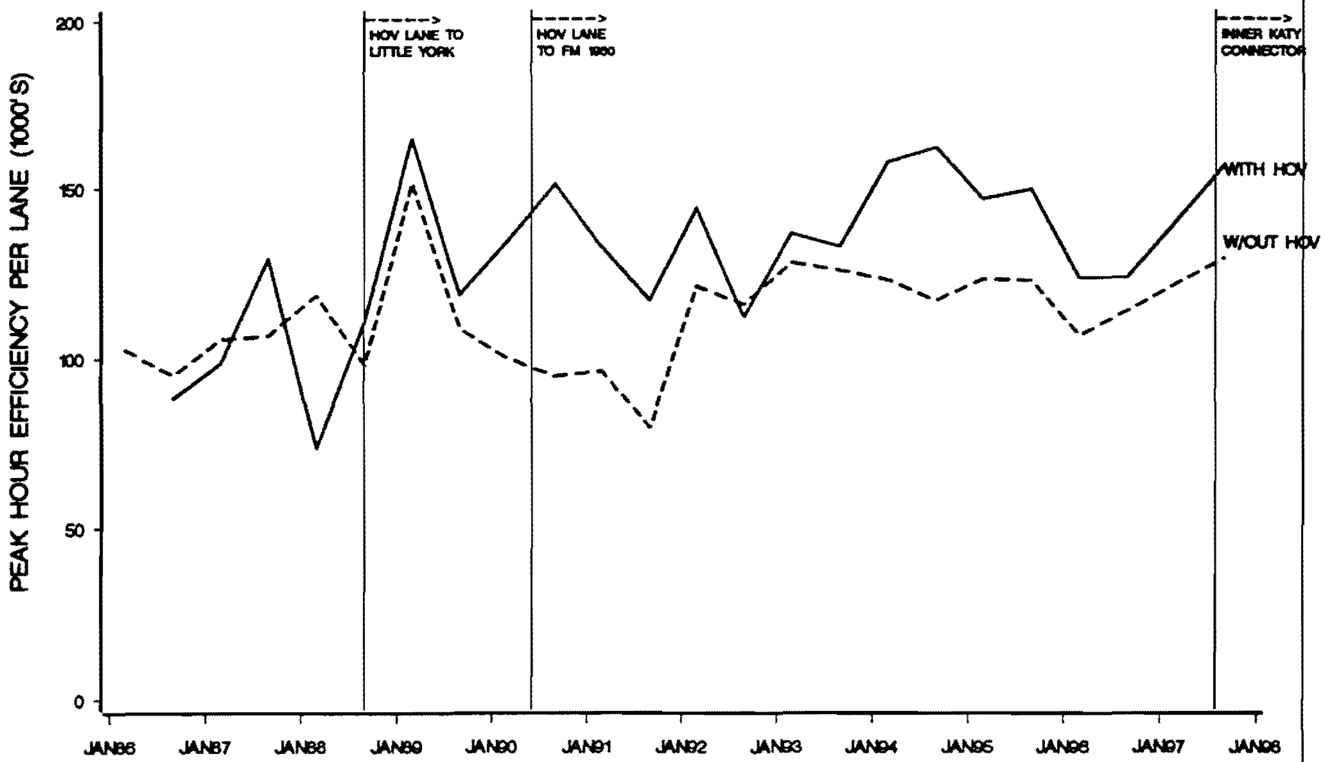
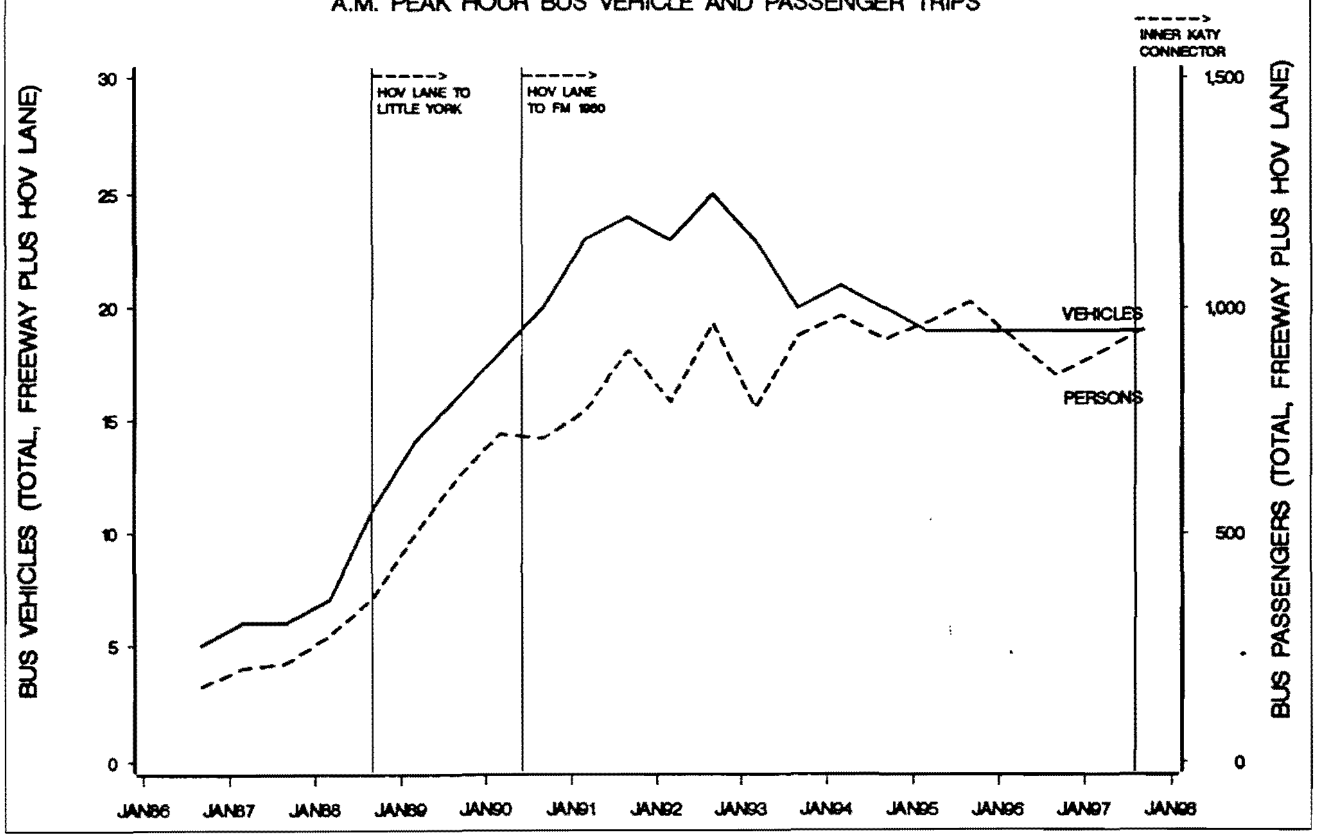


FIGURE D-16. NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS



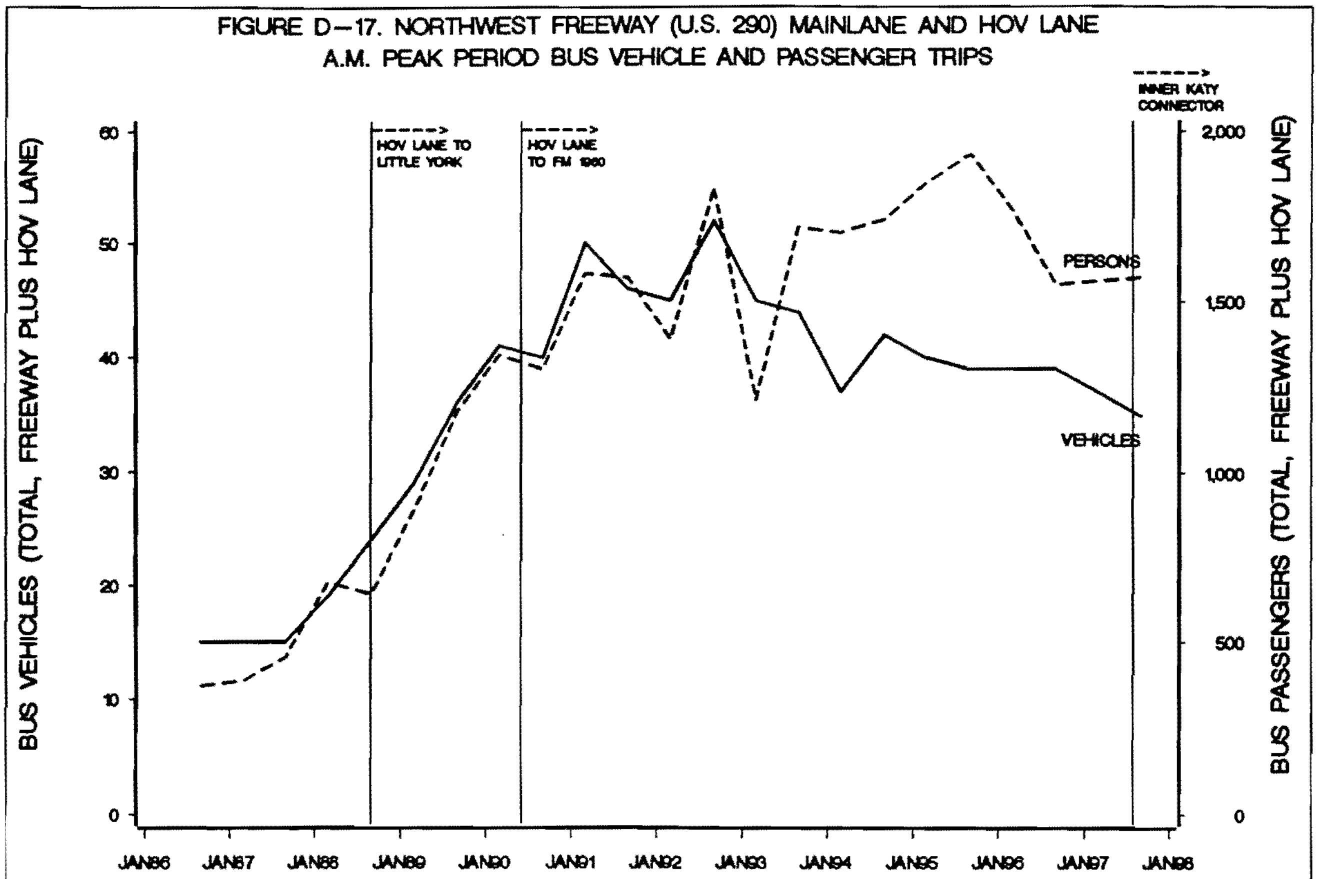


FIGURE D-17. NORTHWEST FREEWAY (U.S. 290) MAINLANE AND HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS
BUS VEHICLES (TOTAL, FREEWAY PLUS HOV LANE)
BUS PASSENGERS (TOTAL, FREEWAY PLUS HOV LANE)
HOV LANE TO LITTLE YORK
HOV LANE TO FM 1960
INNER KATY CONNECTOR
PERSONS
VEHICLES
0
10
20
30
40
50
60
0
500
1,000
1,500
2,000
JAN86
JAN87
JAN88
JAN89
JAN90
JAN91
JAN92
JAN93
JAN94
JAN95
JAN96
JAN97
JAN98

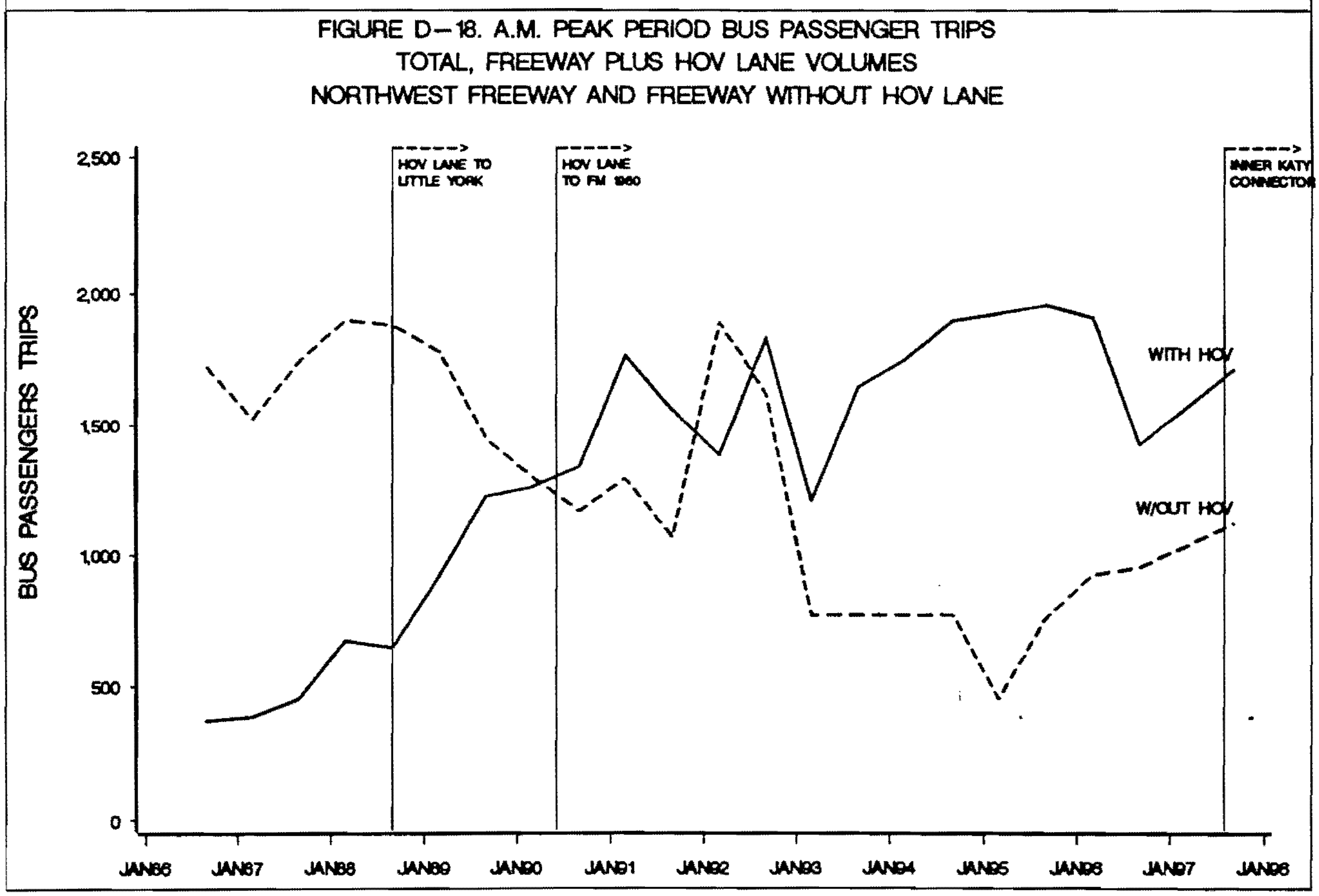


FIGURE D-18. A.M. PEAK PERIOD BUS PASSENGER TRIPS
TOTAL, FREEWAY PLUS HOV LANE VOLUMES
NORTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE
BUS PASSENGERS TRIPS
HOV LANE TO LITTLE YORK
HOV LANE TO FM 1960
INNER KATY CONNECTOR
WITH HOV
W/OUT HOV
0
500
1,000
1,500
2,000
2,500
JAN86
JAN87
JAN88
JAN89
JAN90
JAN91
JAN92
JAN93
JAN94
JAN95
JAN96
JAN97
JAN98

FIGURE D-19. NORTHWEST FREEWAY (U.S. 290) CORRIDOR PARK-AND-RIDE DEMAND

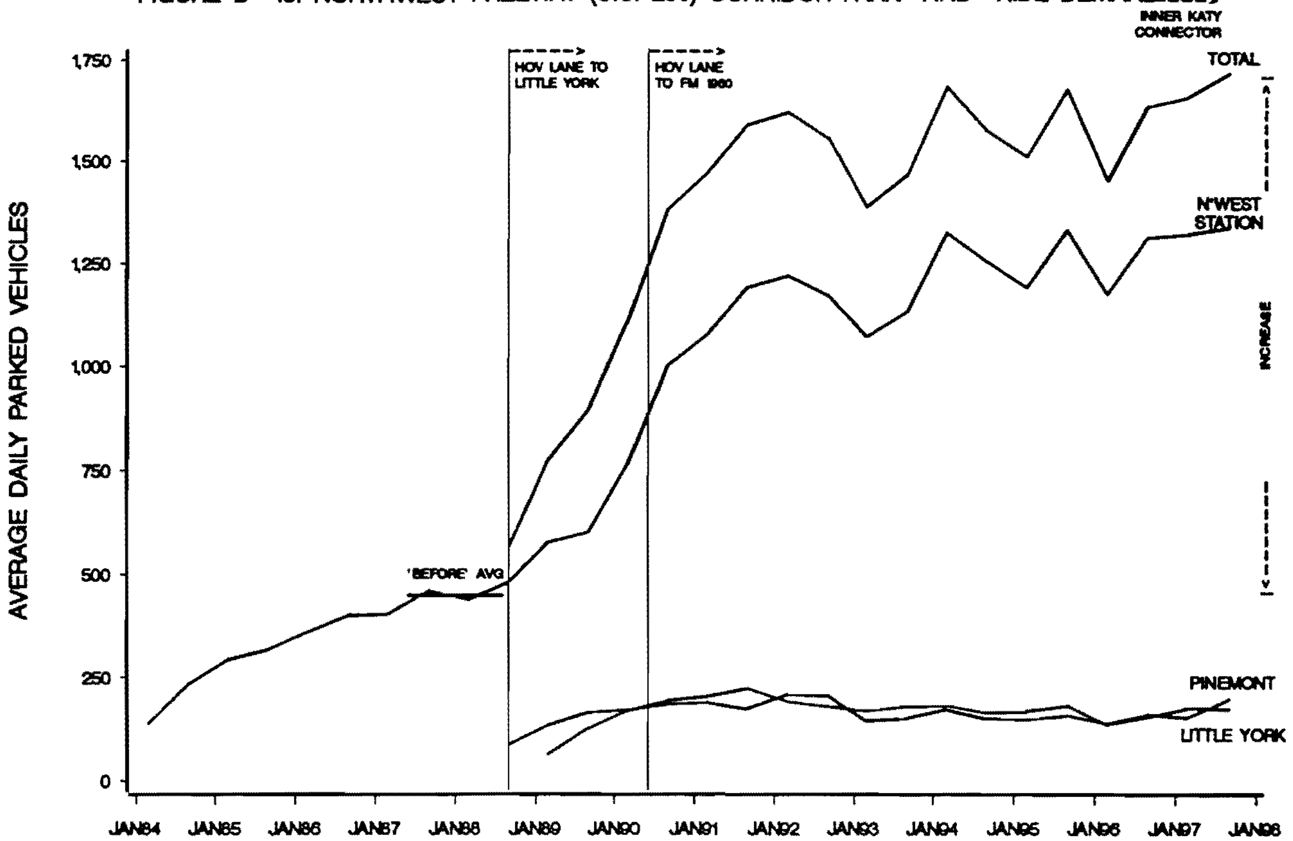
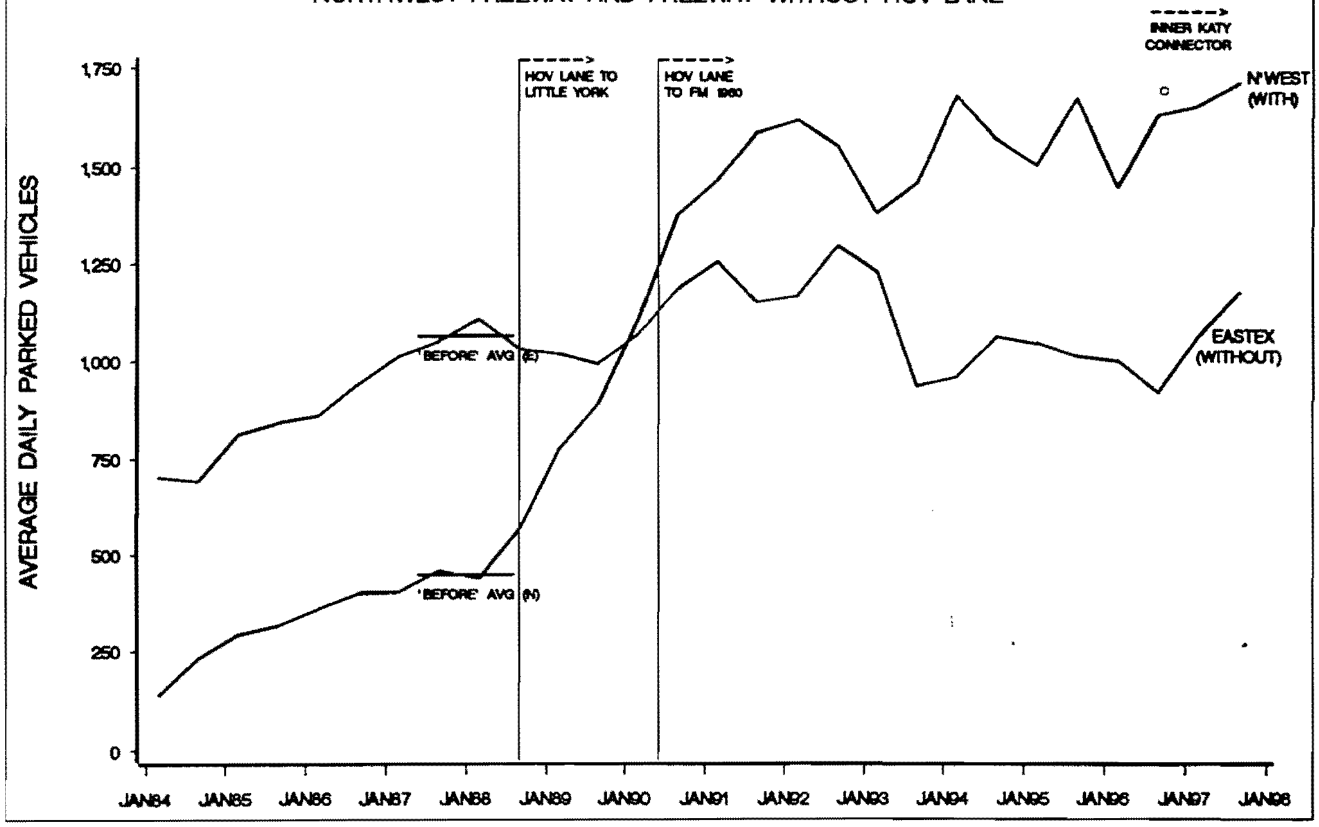


FIGURE D-20. AVERAGE DAILY VEHICLES PARKED AT PARK-AND-RIDE LOTS
NORTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE



APPENDIX E

SOUTHWEST FREEWAY AND HOV LANE DATA

SOUTHWEST FREEWAY (U.S. 59S) AND HOV LANE, HOUSTON

Table E-1. Summary of A.M. Peak-Direction Southwest Freeway and HOV Lane Data, 1997

Type of Data Phase 1 of HOV Lane Became Operational 1/11/93	"Representative" Pre-HOV Lane Value	"Representative" Current Value	Percent Change
HOV Lane Data			
HOV Lane Length (miles)		11.5	
HOV Lane Cost (millions)		$122.6	
Person-Movement			
Peak-Hour (7-8 a.m.)	---	4,074	---
Peak-Period (6-9:30 a.m.)	---	7,772	---
Total Daily	---	15,936	---
Vehicle Volumes			
Peak-Hour	---	1,476	---
Peak-Period	---	2,728	---
Vehicle Occupancy, Peak-Hour (persons/veh)	---	2.76	---
Accident Rate (i.e., Injury accidents/100 MVM])[1]	---	12.6	---
Vehicle Breakdown Rate (VMT/Breakdown)		73,026	---
Violation Rate (6-9:30 a.m.)	---	3%	---
Peak-Hour Lane Efficiency (1000's)[2]	---	147	---
Annual Discounted Benefits (millions)[3]	---	$37	---
Annual Delay Savings (millions)[4]		$3	
Travel Time (minutes)[5]			
Peak-Hour	16.2	18.7	
Peak-Period	11.4	15.3	
Freeway Mainlane Data (see note)			
Person-Movement			
Peak-Hour	5,685	9,198	+62%
Peak-Period (6-9:30 a.m.)	17,357	28,288	+63%
Vehicle Volume			
Peak-Hour	4,922	8,697	+77%
Peak-Period	15,032	26,736	+78%
Vehicle Occupancy, Peak-Hour (persons/veh)	1.16	1.06	-9%
Accident Rate (i.e., Injury accidents/100 MVM])[1]	26.2	16.6	-37%
Avg. Operating Speed (mph)[5]			
Peak-Hour	29	33	+14%
Peak-Period	41	43	+5%
Peak-Hour Lane Efficiency (1000's)[2]	56	61	+0%

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

[1]Due to inconsistencies in reporting accidents in Harris County, this analysis includes only injury accidents. Accidents analyzed between Bellfort and S. Shepherd, a distance of approximately 11.5 mi. This corresponds to Phase 1 of the HOV lane. "Before" data are for the period from 1/91 to 12/92. "Current" accident data are for the period from 1/93 to 12/97. TTI estimated 1997 freeway volumes to compute rates.

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

[3]Based on average annual delay savings, reduced vehicle operating costs, and reduced accident costs generated by MicroBENCOST over a 20-year life.

[4]Per MicroBENCOST over a 20-year life.

[5]Pre-HOV travel times and speeds were calculated using manual travel time studies from Bellfort to Sheperd, a distance of 12.6 mi. Current travel times are calculated using data from Automatic Vehicle Identification (AVI) readers along the HOV lane representing travel over the same distance.

Table E-1. Summary of A.M. Peak-Direction Southwest Freeway and HOV Lane Data, 1997 (Continued)

Type of Data	"Representative" Pre-HOV Lane Value	"Representative" Current Value	Percent Change
Combined Freeway Mainlane and HOV Lane Data			
Total Person-Movement			
Peak-Hour	5,685	13,272	+133%
Peak-Period	17,357	36,060	+108%
Vehicle Volume			
Peak-Hour	4,922	10,173	+107%
Peak-Period	15,032	29,464	+96%
Vehicle Occupancy			
Peak-Hour	1.16	1.30	+12%
Peak-Period	1.16	1.22	+5%
2+ Carpool Volumes			
Peak-Hour	531	1,561	+194%
Peak-Period	1,235	3,316	+169%
Peak-Hour Lane Efficiency (1000's)[1]	56	75	+34%
Transit Data			
Bus Vehicle Trips			
Peak-Hour	25	41	+64%
Peak-Period	75	100	+33%
Bus Passenger Trips			
Peak-Hour	724	1,125	+55%
Peak-Period	1,670	2,378	+42%
Bus Occupancy (persons/bus)			
Peak-Hour	20	27.4	+37%
Peak-Period	18	23.8	+32%
Vehicles Parked in Corridor Park-and-Ride Lots	1,441	2,158	+50%
Bus Operating Speed[2] (kph [mph])			
Peak-Hour	29	36	+24%
Peak-Period	49	46	-8%

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

[1]This represents the multiple of peak-hour passengers and average speed (HOV lane efficiency +[mainlane freeway efficiency x number of freeway directional lanes]/number of total directional lanes). It is used as a measure of per lane efficiency.

[2]Pre-HOV travel times and speeds were calculated using manual travel time studies from Bellfort to Shepherd, a distance of 12.6 mi. Current travel times are calculated using data from Automatic Vehicle Identification (AVI) readers along the HOV lane representing travel over the same distance.

Table E-2. Comparison of Measures of Effectiveness, Freeway with (Southwest U.S. 59S) and Freeway without (Eastex U.S. 59) HOV Lane, Houston

Measure of Effectiveness	"Representative" Pre-HOV Lane Value[1]	"Representative" Current Value	Percent Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/HOV lane	1.16	1.30	+112%
Freeway w/o HOV lane	1.23	1.30	+5%
A.M. Peak Hour, 2+ Carpool Volume Change			
Freeway w/HOV lane	531	1,561	+194%
Freeway w/o HOV lane	600	1,165	+94%
Bus Passengers, Peak-Period			
Freeway w/HOV lane	1,670	1,125	-33%
Freeway w/o HOV lane	1,188	1,123	-5%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	1,441	2,158	+50%
Freeway w/o HOV lane	1,236	1,099	-11%
Facility Per Lane Efficiency[2]			
Freeway w/HOV lane	56	100	+79%
Freeway w/o HOV lane	86	81	-6%

[1]Representative pre-HOV data for freeways without HOV lanes are comprised of data collected on the Eastex Freeway 1/93.
[2]This represents the product of peak-hour passengers and average speed (passengers x mph/number of lanes). It is used as a measure of per lane efficiency.

HOV LANE DATA

DESCRIPTION

- Phase 1 (12.2 mi) of the HOV lane opened January 11, 1993.
- The capital cost (including all support facilities) for the completed facility in 1995 dollars was $122.6 million. The following pages (Table E-3, Table E-4) provide a more detailed cost breakdown including dates.
- Selected milestone dates are listed below.
    - 1/11/93 Shepherd to Bellfort opens (12.2 mi).
    - 3/14/94 Hours of operation revised (5:00 a.m. - 10:00 a.m.; 3:00 p.m. - 8:00 p.m.).
    - 4/4/94 Hours of operation revised (5:00 a.m. - 12:00 p.m.; 2:00 p.m. - 9:00 p.m.).
    - 9/30/96 Hours of operation revised (5:00 a.m. - 11:00 a.m.; 2:00 p.m. - 8:00 p.m.).
    - 11/4/96 HOV lane extended to county line (additional distance of 0.4 mi).

Table E-3. Estimated Capital Cost (millions), Southwest HOV Lane, Operating Segments

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1995 Dollars
HOV Lane and Ramps			
Segment I (1991)	$25.1	1.13	$28.4
Segment II (1992)	9.9	1.09	10.8
Segment III (1992)	13.0	1.09	14.2
Segment IV (1992)	6.3	1.09	6.9
W. Belfort T-Ramp (1992)	3.6	1.09	3.9
Segment IA (1996)	4.2	0.97	4.1
Miscellaneous (1996)	6.4	0.97	6.2
SUB-TOTAL	$64.3		$74.5
Per Mile	$5.1		$5.9
Surveillance, Communication, and Control (1990)	$3.5	1.16	$4.1
SUB-TOTAL	$3.5		$4.1
Per Mile	$0.3		$0.3
Support Facilities			
W. Bellfort P/R (1991)	$8.6	1.13	$9.7
Westwood P/R (1991)	3.3	1.13	3.7
Hillcroft Transit Center (1992)	16.2	1.09	17.7
SUB-TOTAL	$28.1		$31.1
Per Mile	$2.2		$2.5
TOTAL COST	$95.9		$109.7
COST PER KILOMETER (12.6 miles)	$7.6		$8.7

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

Table E-4. Estimated Capital Cost (millions), Southwest HOV Lane, Future Segments

Cost Component	Year of Completion	Year of Construction Cost
HOV Lane and Ramps		
Greenway Plaza Ramp	1999	$10.3
Segment VA 0(.6 m.)	2000	6.3
Segment VB (1.5 m.)	2004	14.7
TOTAL COST		$31.3
COST PER MILE (2.1 miles)		$14.9

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

PERSON-MOVEMENT

- In 1997, 15,936 person trips per day were served on the HOV lane.
- A.M. peak hour, 4,074 persons/hour.
  - 1,125 (28 percent) by bus, 33 (1 percent) by vanpool, 2,909 (71 percent) by carpool, and 8 by motorcycle (Figure E-1).
  - Average HOV lane vehicle occupancy = 2.76 persons/vehicle.
- A.M. peak period, 7,772 persons.
  - 2,378 (31 percent) by bus, 107 (1 percent) by vanpool, 5,273 (68 percent) by carpool, and 15 by motorcycle (Figure E-2).

VEHICLE MOVEMENT

- A.M. peak hour, 1,476 vehicles.
  - 41 (3 percent) buses, 5 (1 percent) vans, 1,422 (96 percent) carpools, and 8 by motorcycle (Figure E-3).

- A.M. peak period, 2,728 vph
    - 100 (4 percent) buses, 17 (1 percent) vans, 2,597 (95 percent) carpools, 15 by motorcycle (Figure E-4).

ACCIDENT RATE

- For the period 1/93 through 12/97, the HOV lane accident rate was 12.6 per 100 million vehicle miles.

VEHICLE BREAKDOWN RATES

- As measured from January 11, 1993, through December 1997, the following rate has been observed.
    - The weighted average for all vehicle types is one breakdown per 73,026 VMT.

VIOLATION RATE

- The observed violation rate (vehicles on the HOV lane not eligible to use the HOV lane) is approximately 3 percent.

PEAK-HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. For the HOV lane, this value (expressed in 1000's) is approximately 147 (4,074 passengers x 36 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane experience an average travel time savings of two minutes in the a.m. peak hour (Table E-5, Figure E-5).

Table E-5. Travel Time Savings for Southwest HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1997)

Time of Day	Measured Travel Time: Freeway (min)	Measured Travel Time: HOV (min)	Measured Travel Time: Savings (min)	HOV Lane Person Trips: Carpool	HOV Lane Person Trips: Vanpool	HOV Lane Person Trips: Bus	HOV Lane Person Trips: Total	Travel Time Saved (Person-Minutes)
Northbound A.M. Travel Time Savings for Southwest HOV Lane								
Section from Bellfort to Hillcroft Flyover								
6:00	6.01	7.91	-1.90	108	11	41	161	-300
6:30	8.05	8.22	-0.18	526	20	162	707	-130
7:00	11.31	10.48	0.83	1,094	9	336	1,439	1,130
7:30	11.25	11.34	-0.09	1,508	8	123	1,639	-260
8:00	8.33	7.90	0.43	754	7	223	983	510
8:30	6.74	7.55	-0.81	379	0	81	460	-340
9:00	5.99	7.35	-1.36	170	0	0	170	-230
Peak-Period Total				4,539	55	966	5,559	389
Section from Hillcroft Flyover to S. Shepherd								
6:00	5.22	6.19	-0.97	101	38	192	332	-310
6:30	6.52	6.27	0.26	651	23	360	1,033	310
7:00	8.59	7.18	1.41	1,235	24	443	1,701	2,440
7:30	11.23	8.36	2.86	1,506	17	426	1,949	5,440
8:00	10.11	6.50	3.61	1,050	17	339	1,405	5,130
8:30	7.52	5.96	1.56	524	27	223	774	1,300
9:00	5.88	5.70	0.18	173	8	69	249	50
Peak-Period Total				5,240	154	2,052	7,443	14,370
Southbound P.M. Travel Time Savings for Southwest HOV Lane								
Section from S. Shepherd to Hillcroft Flyover								
3:30	5.71	5.88	-0.18	160	5	129	293	-50
4:00	6.57	6.04	0.54	385	17	245	647	370
4:30	7.64	6.12	1.52	685	59	307	1,049	1,590
5:00	9.79	6.33	3.46	982	25	381	1,389	4,850
5:30	9.03	6.42	2.62	1,276	27	635	1,936	5,090
6:00	7.16	6.17	1.00	887	12	335	1,233	1,310
6:30	5.85	5.90	-0.06	525	13	190	727	0
Peak-Period Total				4,900	158	2,222	7,274	13,150

Southbound P.M. Travel Time Savings for Southwest HOV Lane								
Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section from the Hillcroft Flyover to Bellfort								
3:30	6.23	7.55	-1.32	50	5	11	67	-90
4:00	6.93	7.86	-0.93	392	16	126	534	-440
4:30	8.67	8.06	0.61	513	65	79	658	360
5:00	12.00	8.34	3.67	574	13	163	749	2840
5:30	13.15	8.58	4.58	769	43	138	949	4340
6:00	11.38	8.16	3.22	722	13	212	947	3130
6:30	8.08	8.03	0.06	413	12	48	472	50
Peak-Period Total				3,433	167	777	4,376	10200

Table E-6. Southwest Freeway Travel Time Summaries

Travel Time Data	Travel Times[1]					
	97[1]	96[2]	95[2]	94[2]	93[2]	Pre-HOV
HOVL Travel Time AM Peak-Hour PM Peak-Hour	 19 min 15 min	 14 min 15 min	 14 min 14 min	 14 min 14 min	 13 min 14 min	 - -
Freeway Mainlanes Travel Time AM Peak-Hour PM Peak-Hour	 21 min 22 min	 16 min 19 min	 26 min 15 min	 22 min 17 min	 16 min 19 min	 24 min 25 min
Net Travel Time Savings AM Peak-Hour (Person-Minutes) PM Peak-Hour (Person-Minutes)	 2 min (8,750) 7 min (17,120)	 2 min (6,200) 4 min (10,756)	 12 min (17,925) 1 min (2,809)	 8 min (13,244) 3 min (3,669)	 3 min (3,675) 5 min (9,585)	 - - -

[1]Travel Times are calculated over a distance of 11.6 mi.
[1]Data collected using Automatic Vehicle Identification (AVI).
[2]Data collected using manual travel time studies.

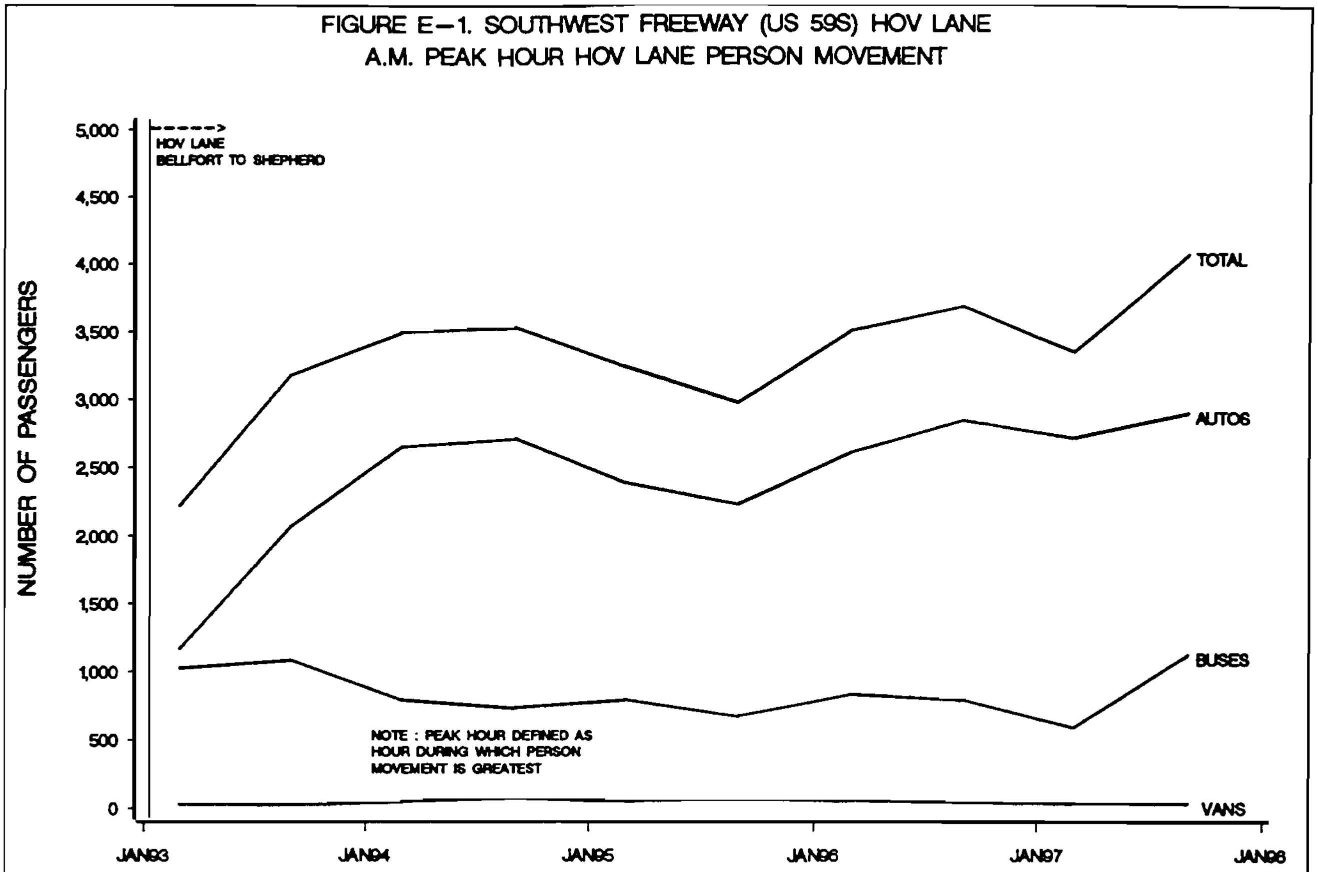


FIGURE E-1. SOUTHWEST FREEWAY (US 59S) HOV LANE
A.M. PEAK HOUR HOV LANE PERSON MOVEMENT
NUMBER OF PASSENGERS
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
HOV LANE
BELLFORT TO SHEPHERD
TOTAL
AUTOS
BUSES
VANS
NOTE : PEAK HOUR DEFINED AS
HOUR DURING WHICH PERSON
MOVEMENT IS GREATEST
JAN93
JAN94
JAN95
JAN96
JAN97
JAN98

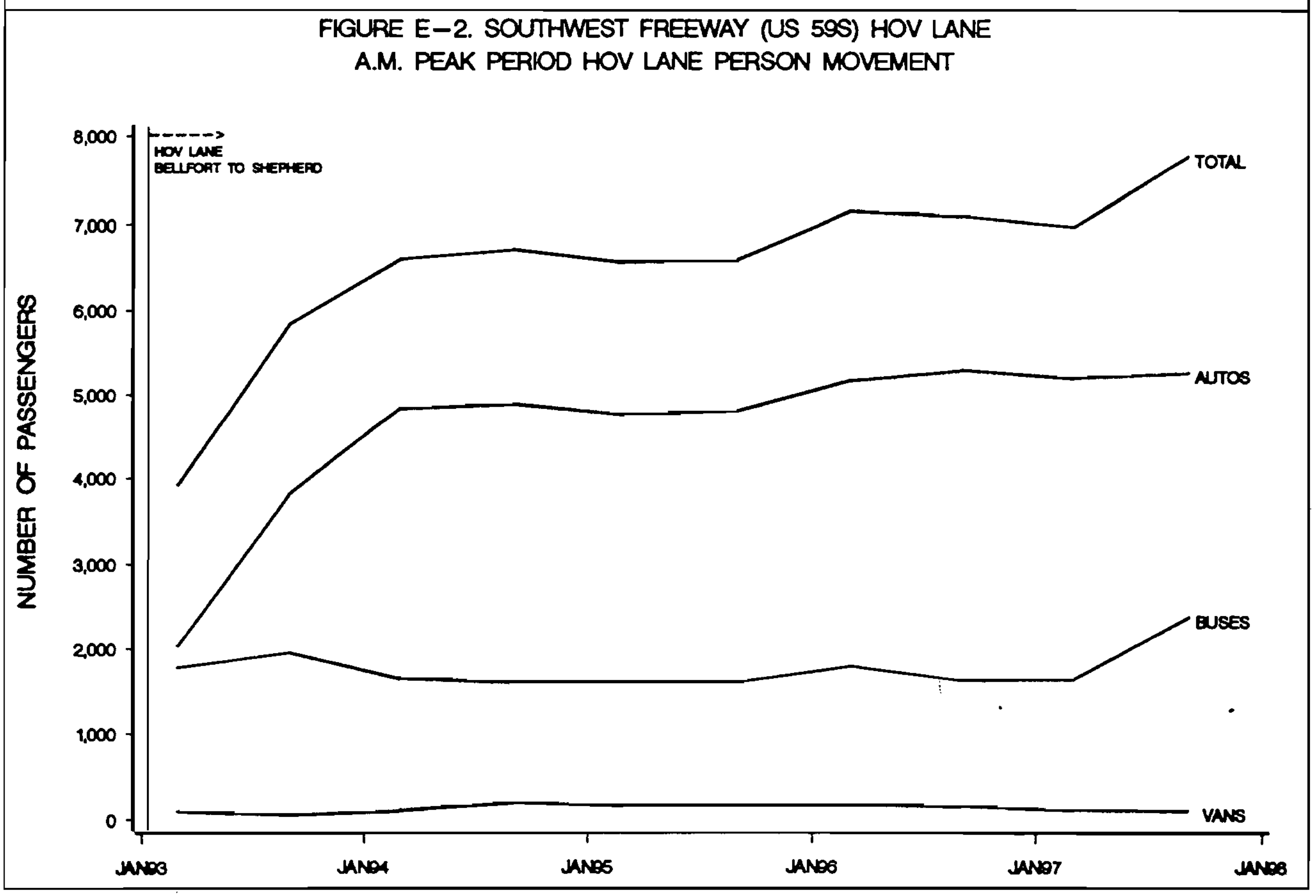


FIGURE E-2. SOUTHWEST FREEWAY (US 59S) HOV LANE
A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT
NUMBER OF PASSENGERS
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
HOV LANE
BELLFORT TO SHEPHERD
TOTAL
AUTOS
BUSES
VANS
JAN93
JAN94
JAN95
JAN96
JAN97
JAN98

FIGURE E–3. SOUTHWEST FREEWAY (US 59S) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION

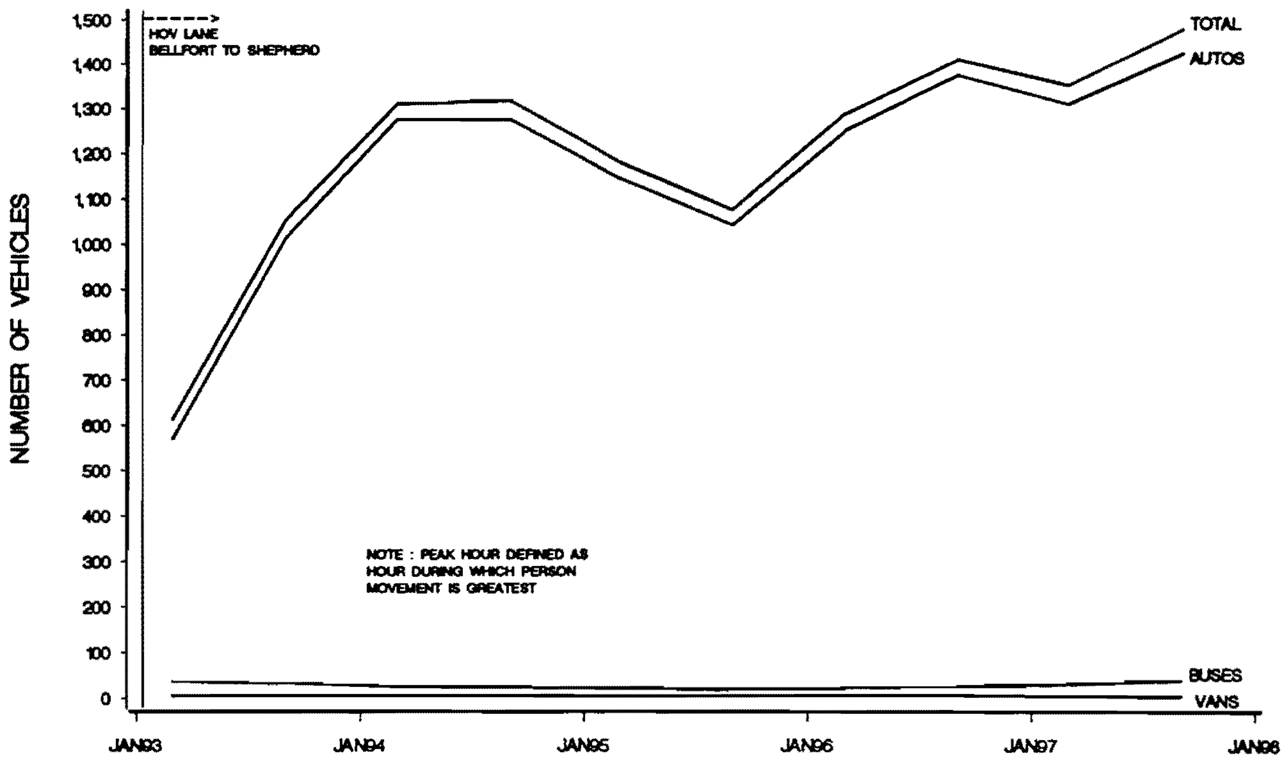
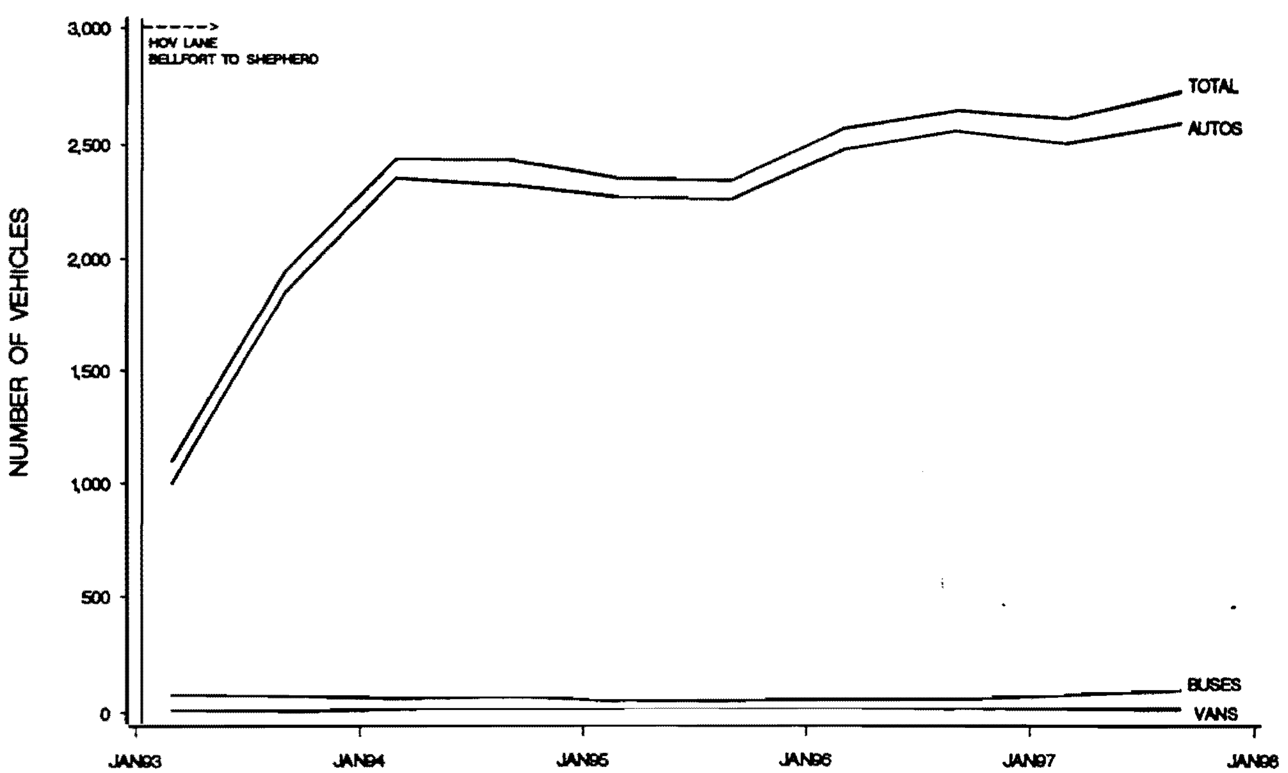


FIGURE E–4. SOUTHWEST FREEWAY (US 59S) HOV LANE
A.M. PEAK PERIOD HOV LANE VEHICLE UTILIZATION



FREEWAY DATA

NOTE

- For purposes of safety and visibility, freeway volumes are counted at Westpark overpass between an exit ramp and an entrance ramp. Thus, freeway volumes may be low in comparison to actual freeway operations. Data are collected in a section with 5 lanes in each direction.

PERSON-MOVEMENT

- In the a.m. peak hour, compared to pre-HOV conditions, person-movement has increased by 62 percent (Figure E-6).

- In the a.m. peak period, compared to pre-HOV conditions, person-movement has increased by 63 percent (Figure E-7).

VEHICLE VOLUME

- In the a.m. peak hour, vehicle volume has increased by 77 percent (Figure E-6).

- In the a.m. peak period, vehicle volume has increased by 78 percent (Figure E-7).

VEHICLE OCCUPANCY

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

- In the a.m. peak period, compared to pre-HOV conditions, mainlane occupancy has declined by 8 percent (Figure E-12).

ACCIDENT RATE

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

FIGURE E-5. SOUTHWEST FREEWAY (US 59S) MAINLANES AND HOV LANE A.M. TRAVEL TIME

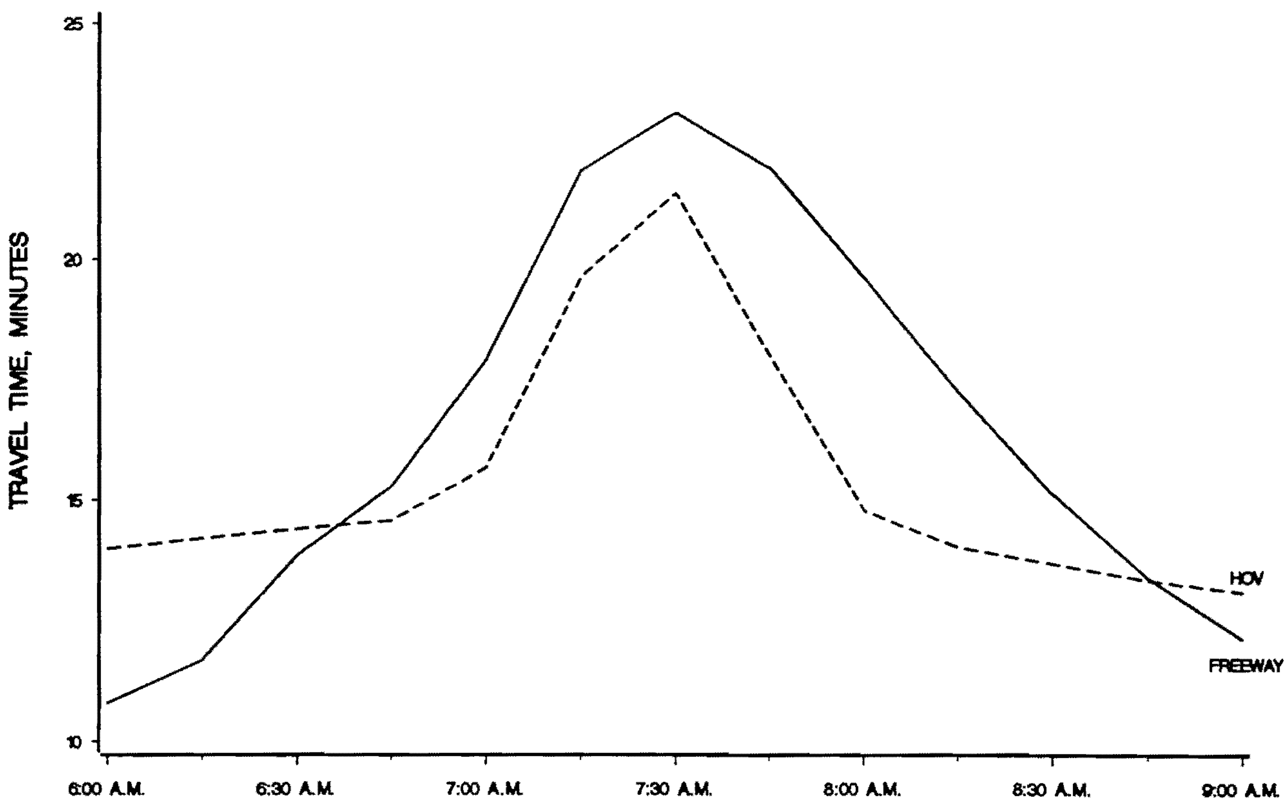


FIGURE E-6. SOUTHWEST FREEWAY (U.S. 59S)
A.M. PEAK HOUR MAINLANE TRIPS

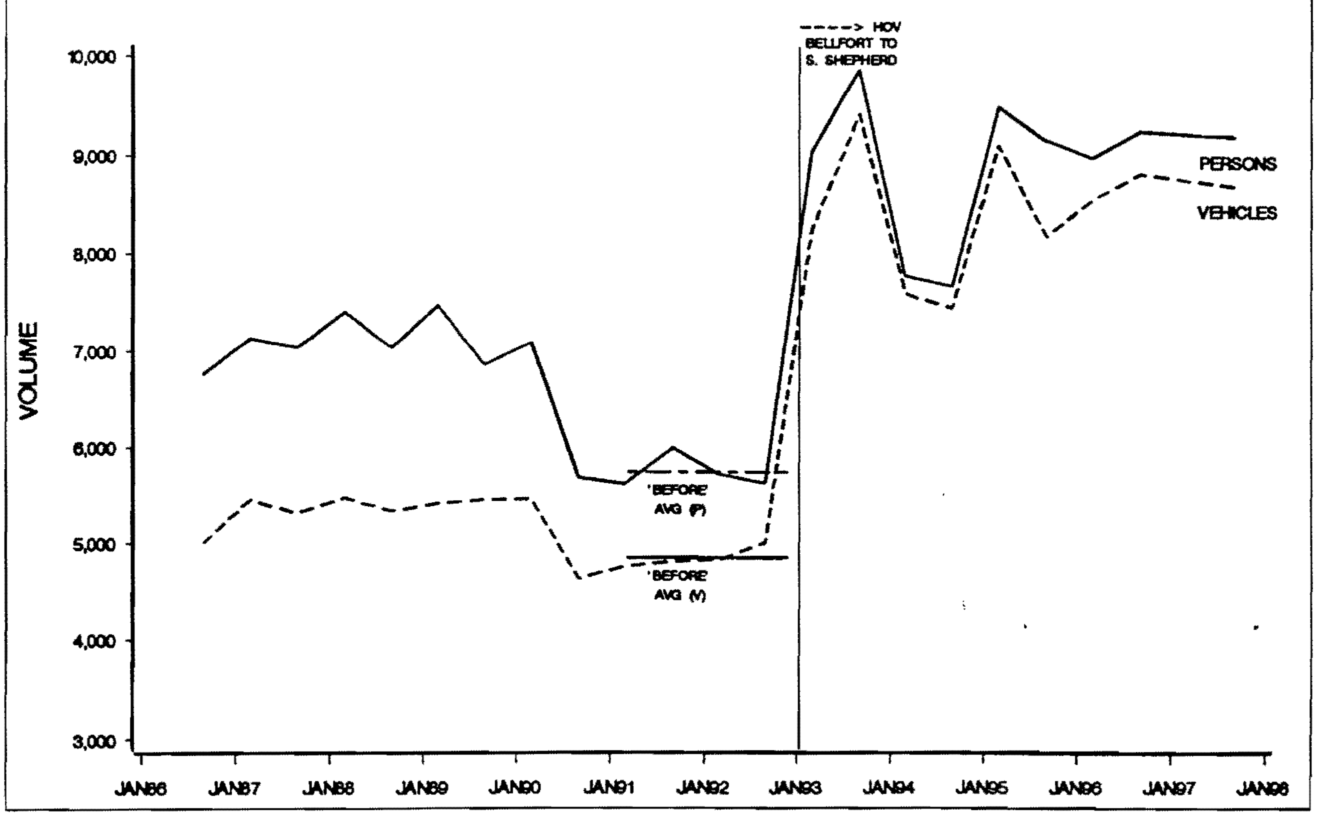


FIGURE E-7. SOUTHWEST FREEWAY (U.S. 59S)
A.M. PEAK PERIOD MAINLANE TRIPS

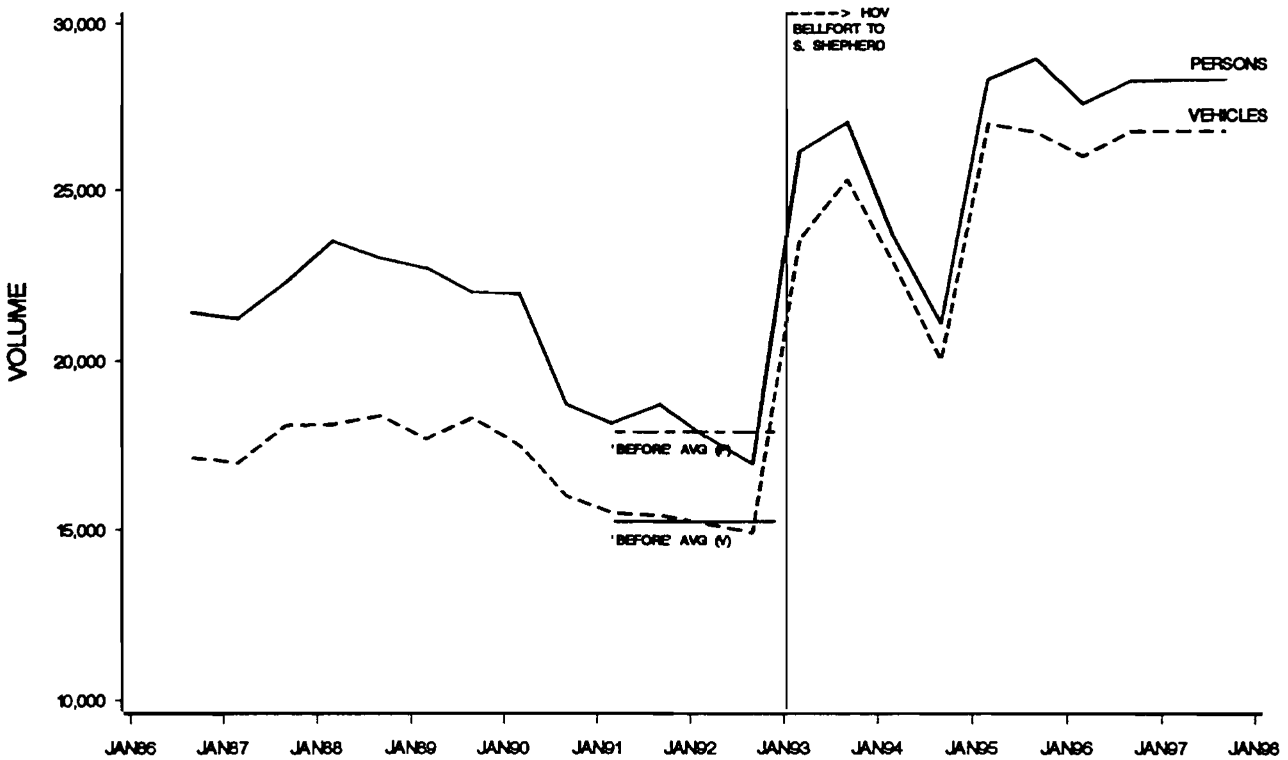


FIGURE E-8. SOUTHWEST FREEWAY (U.S. 59S) MAINLANE TRAVEL TIME AND SPEED SURVEY
NORTHBOUND, BELLFORT TO MANDELL
A.M. PEAK PERIOD

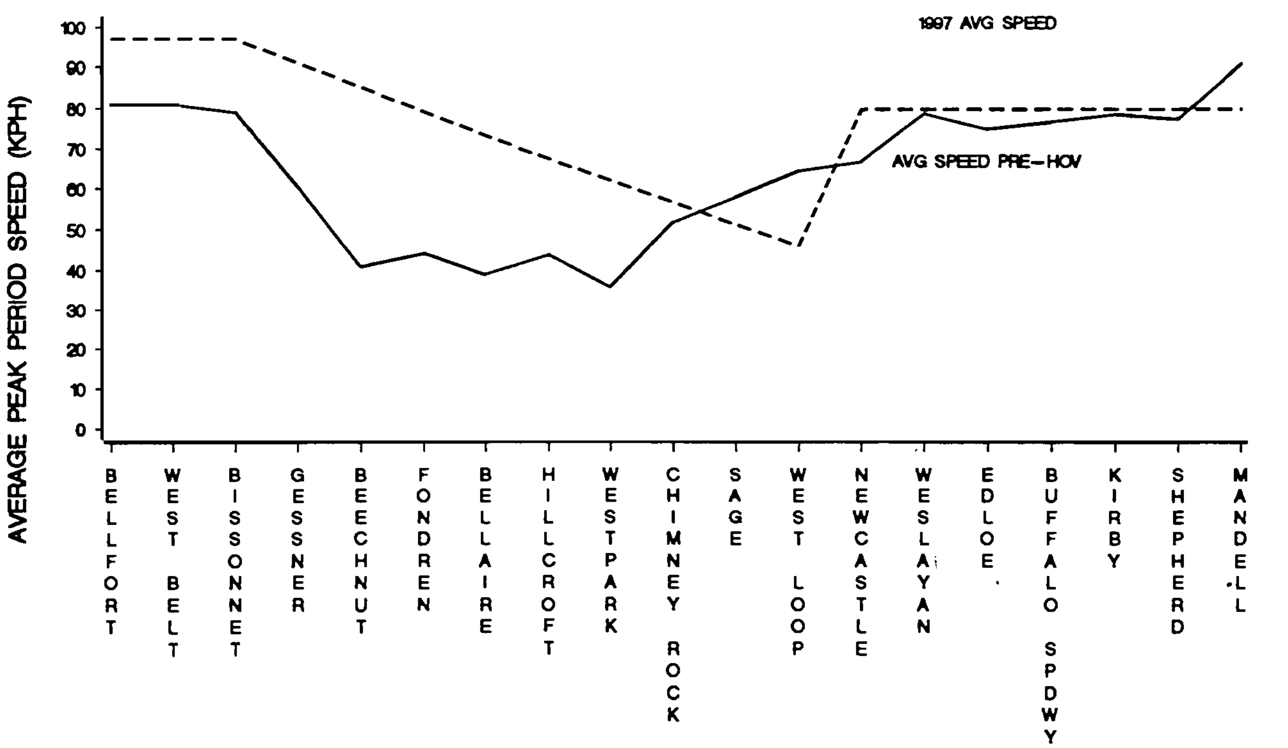


FIGURE E-9. SOUTHWEST FREEWAY (U.S. 59S) MAINLANE AND HOV LANE
A.M. PEAK HOUR PERSON TRIPS

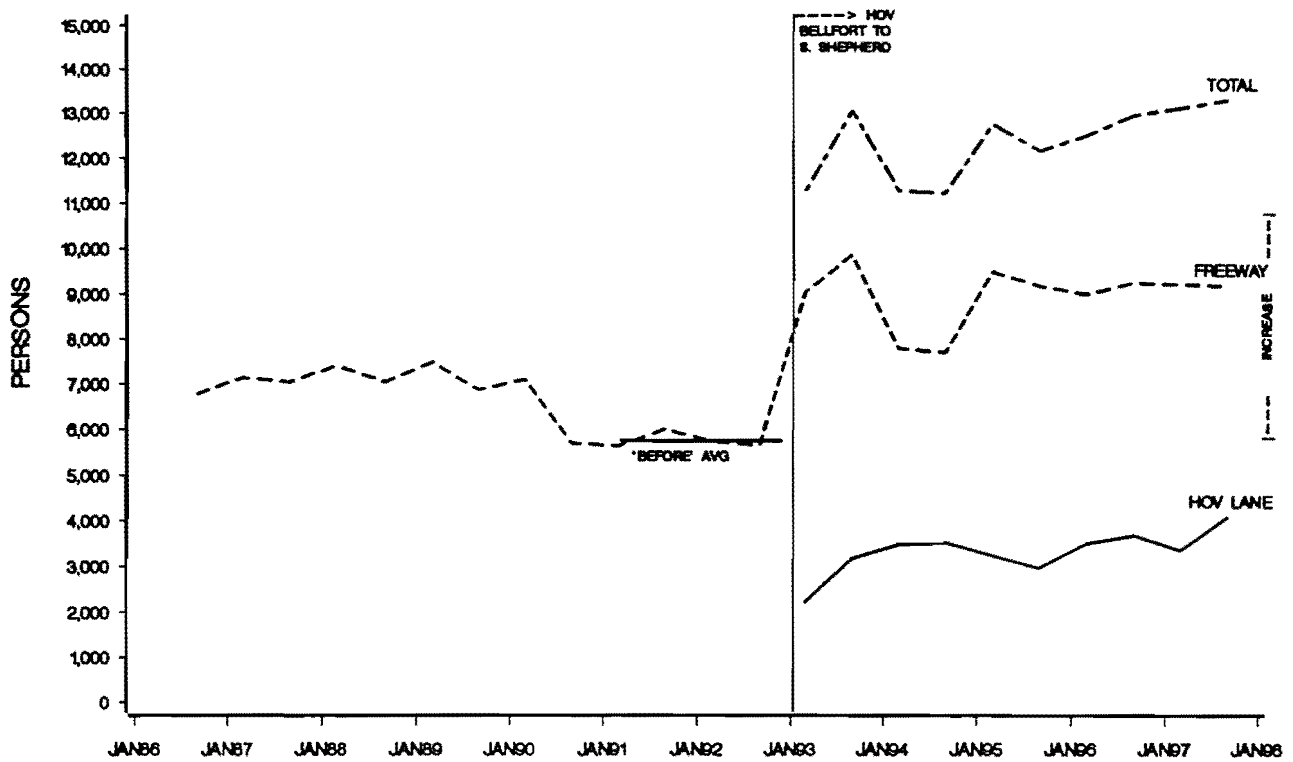


FIGURE E-10. SOUTHWEST FREEWAY (U.S. 59S) MAINLANE AND HOV LANE
A.M. PEAK PERIOD PERSON TRIPS

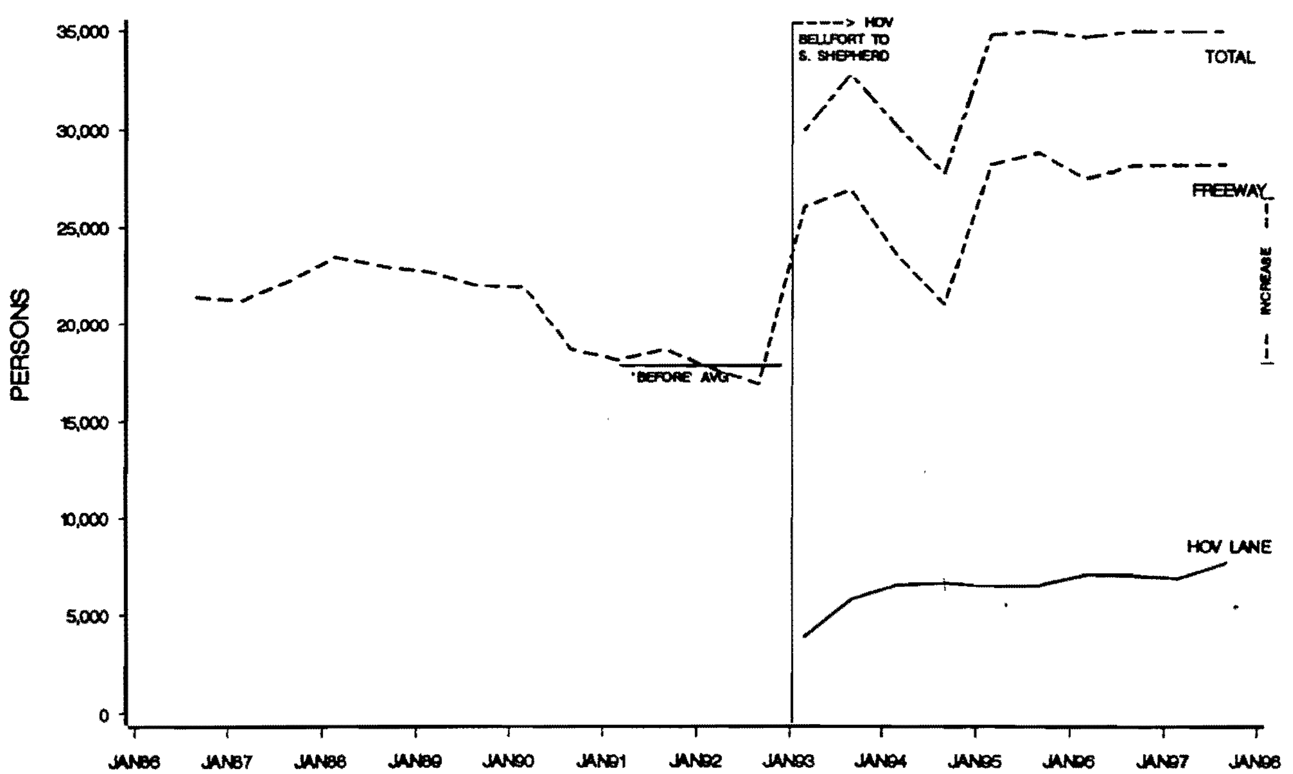


FIGURE E-11. SOUTHWEST FREEWAY (U.S. 59S) MAINLANE AND HOV LANE
A.M. PEAK HOUR AVERAGE OCCUPANCY

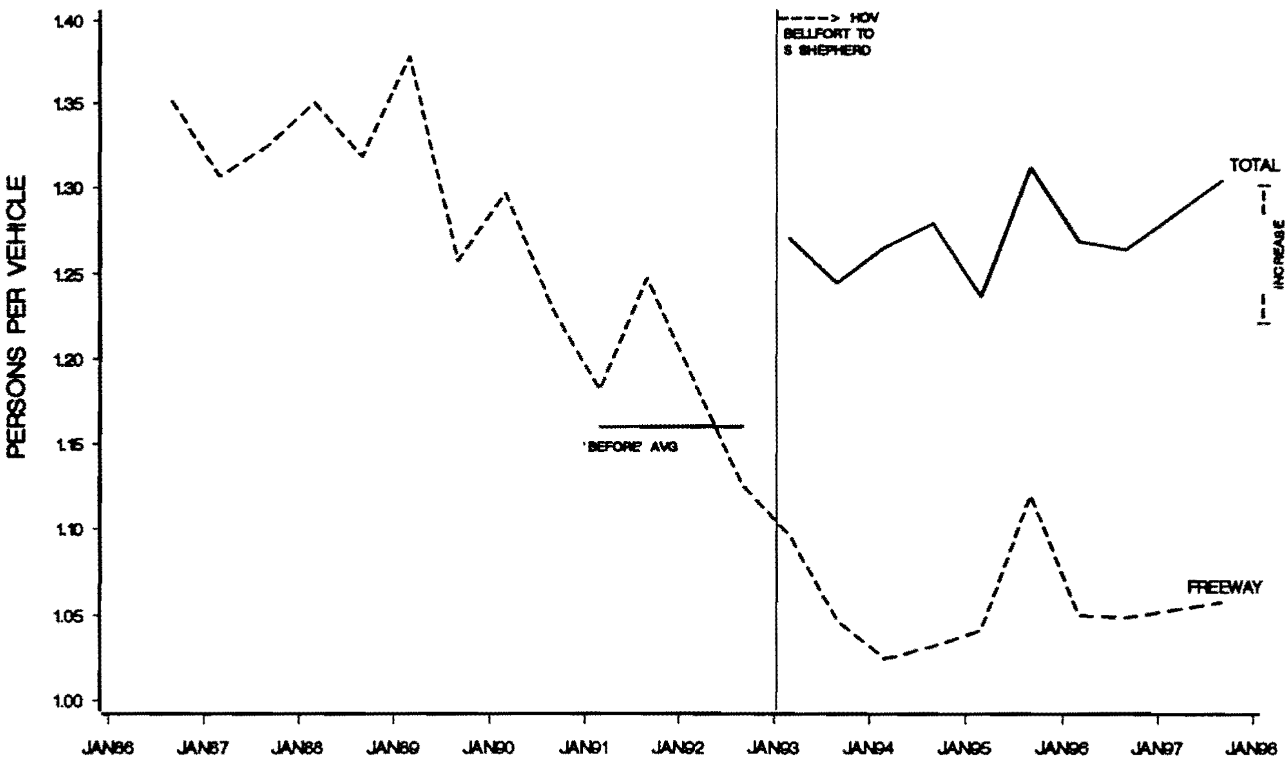
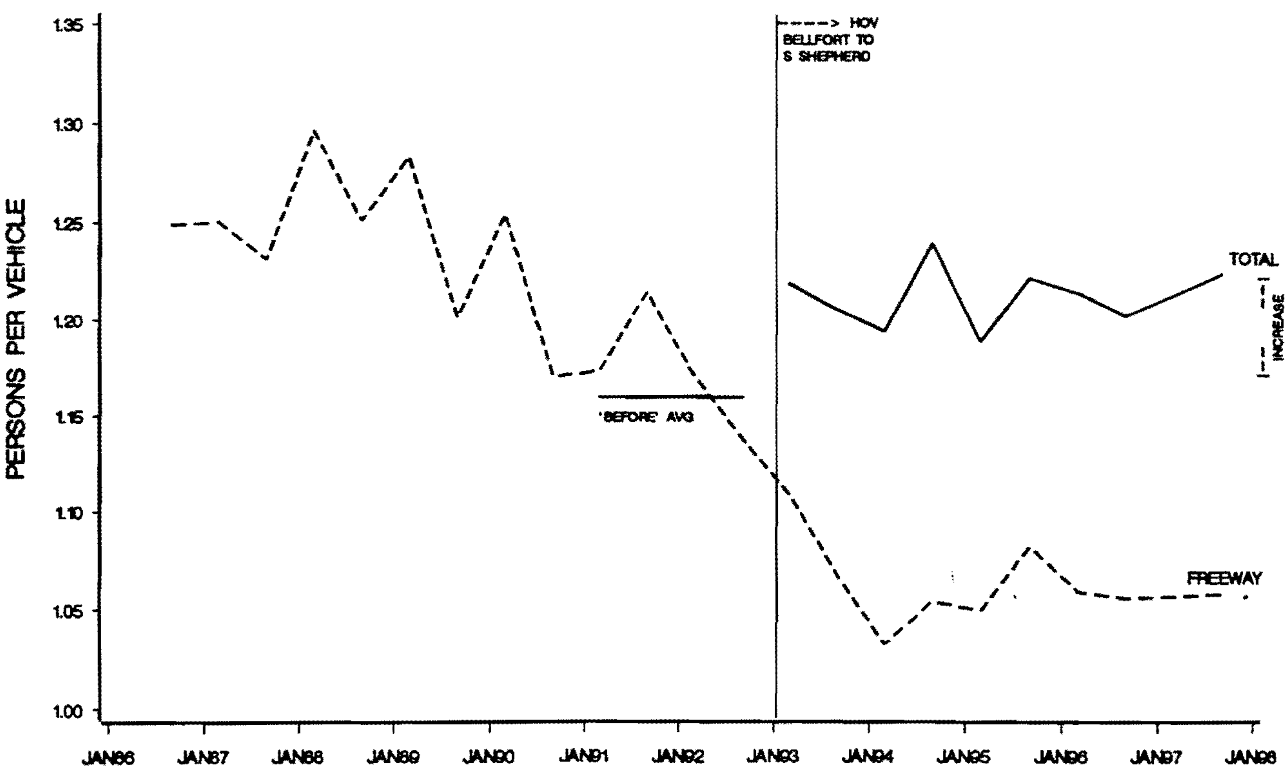


FIGURE E-12. SOUTHWEST FREEWAY (U.S. 59S) MAINLANE AND HOV LANE
A.M. PEAK PERIOD AVERAGE OCCUPANCY



- For the section between Shepherd and Bellfort, the accident rate for the period preceding the opening of the HOV lane was 26.2 accidents per 100 million vehicle miles. The accident data available for the period (1/93-12/97) after the HOV lane opened indicate an accident rate of 16.6 accidents/100 MVM.

AVERAGE OPERATING SPEED

- In comparison to pre-HOV lane conditions, mainlane operating speeds have increased in the peak hour and increased in the peak-period. The data in Figure E-8 show the average of all travel time runs made both before and after the HOV lane opened for the a.m. peak period.

PEAK-HOUR LANE EFFICIENCY

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

- For the freeway mainlanes, increased travel speeds have resulted in an increase in per lane efficiency of 61 percent.

COMBINED FREEWAY AND HOV LANE DATA

TOTAL PERSON-MOVEMENT

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

  - At Pinemont, the HOV lane is responsible for 31 percent of peak-hour person-movement (HOV lane = 4,074; freeway = 9,198) and 22 percent of peak-period (HOV lane = 7,772; freeway = 28,288) person-movement (Figure E-10).

- Increase in a.m. person-movement at Pinemont.

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

  - Total peak-hour person-movement has increased by 133 percent, from 5,685 to 13,272 (Figure E-9). Peak-period person-movement has increased by 108 percent, from 17,357 to 36,060 Figure E-10).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.30, a 12 percent increase over the pre-HOV lane occupancy (Figure E-11). Occupancy in the peak period is 5 percent greater than pre-HOV lane levels (Figure E-12).

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

CARPOOL

- In the a.m. peak hour, the total number of 2+ carpools (freeway plus HOV lane) has increased by 194 percent compared to pre-HOV lane levels (Figure E-14). In the a.m. peak period, the increase has been 169 percent. Freeways without HOV lanes have not experienced these increases.

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 (5 freeway lanes plus 1 HOV lane) has increased by 75 percent since the implementation of the HOV lane (Figure E-15). Currently, no discernable trend in efficiency is evident when the Southwest Freeway is compared with freeways that have no HOV lane (Figure E-15).

BUS TRANSIT DATA

BUS VEHICLE AND PASSENGER TRIPS

- In the a.m. peak hour, bus vehicle trips have increased by 64 percent since the HOV lane opened, and an increase of 55 percent in bus ridership has resulted (Figure E-16). In the peak period, a 33 percent increase has occurred in bus vehicle trips, and a 42 percent increase in bus ridership has resulted (Figure E-17).

- While bus passenger trips have increased in the Southwest Freeway corridor, in the corridors which do not have HOV lanes, bus passenger trips have remained fairly constant (Figure E-18).

PARK-AND-RIDE

- Prior to opening the HOV lane, approximately 1,441 vehicles were parked in corridor park-and-ride lots. This has increased 50 percent to a current level of 2,158 (Figure E-19).

- The increase in cars parked in the Southwest corridor has not occurred in the freeway corridor that does not have an HOV lane (Figure E-20).

FIGURE E-13. A.M. PEAK HOUR AVERAGE OCCUPANCY
SOUTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

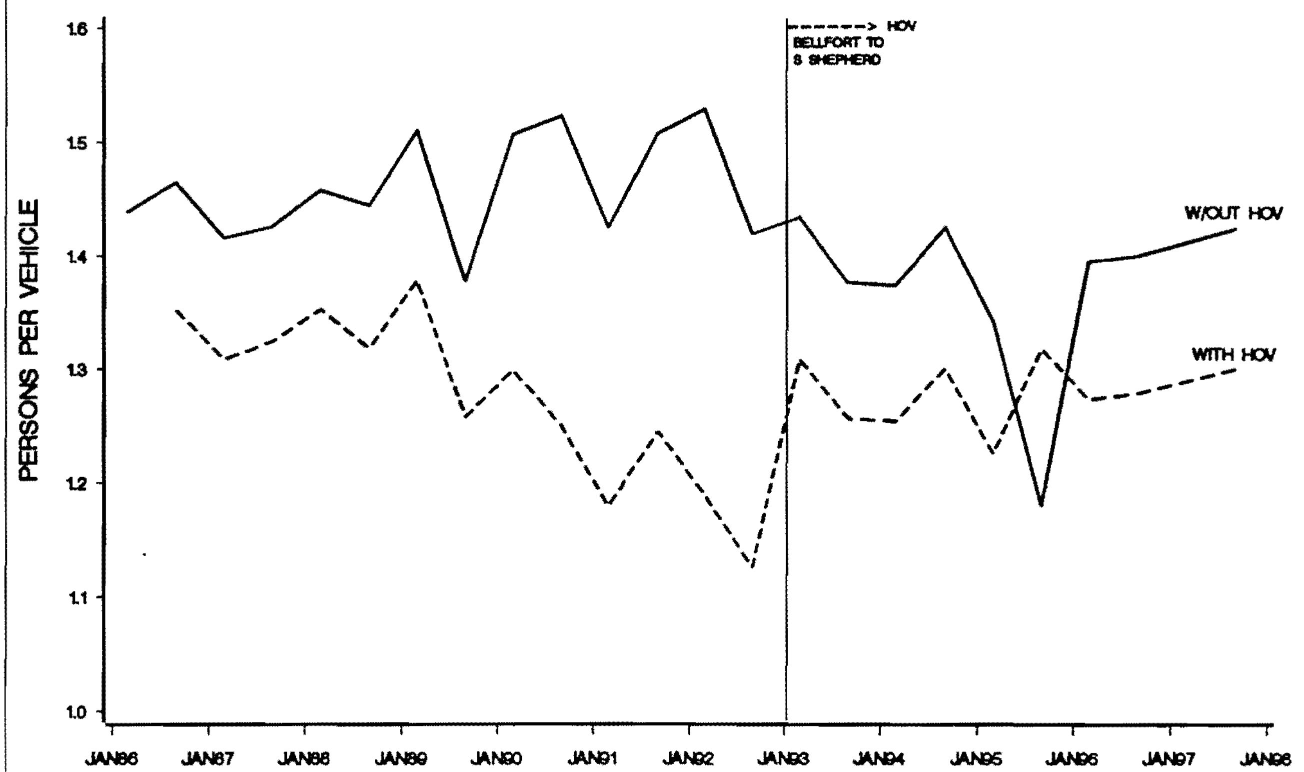


FIGURE E-14. SOUTHWEST FREEWAY (U.S. 59) MAINLANE AND HOV LANE
A.M. PEAK HOUR 2+ CARPOOL UTILIZATION

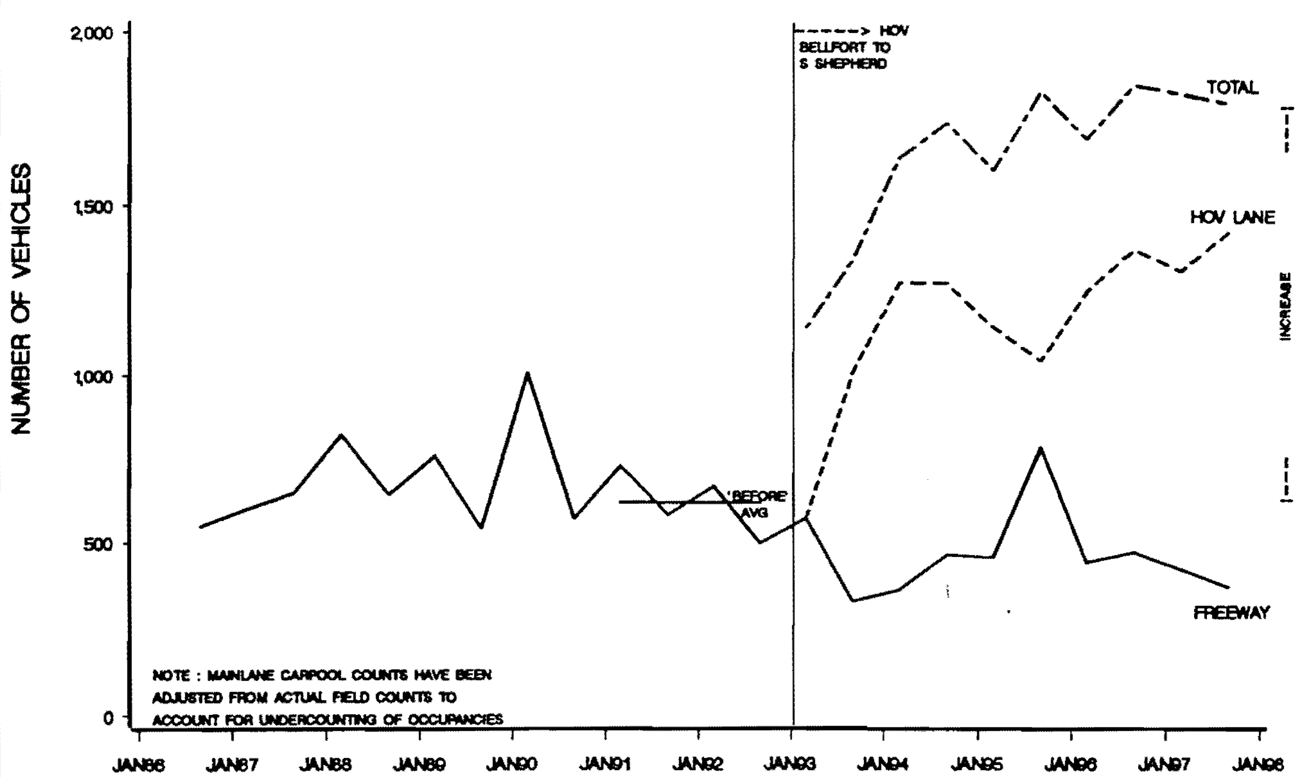


FIGURE E-15. A.M. PEAK HOUR FREEWAY PER LANE EFFICIENCY
SOUTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

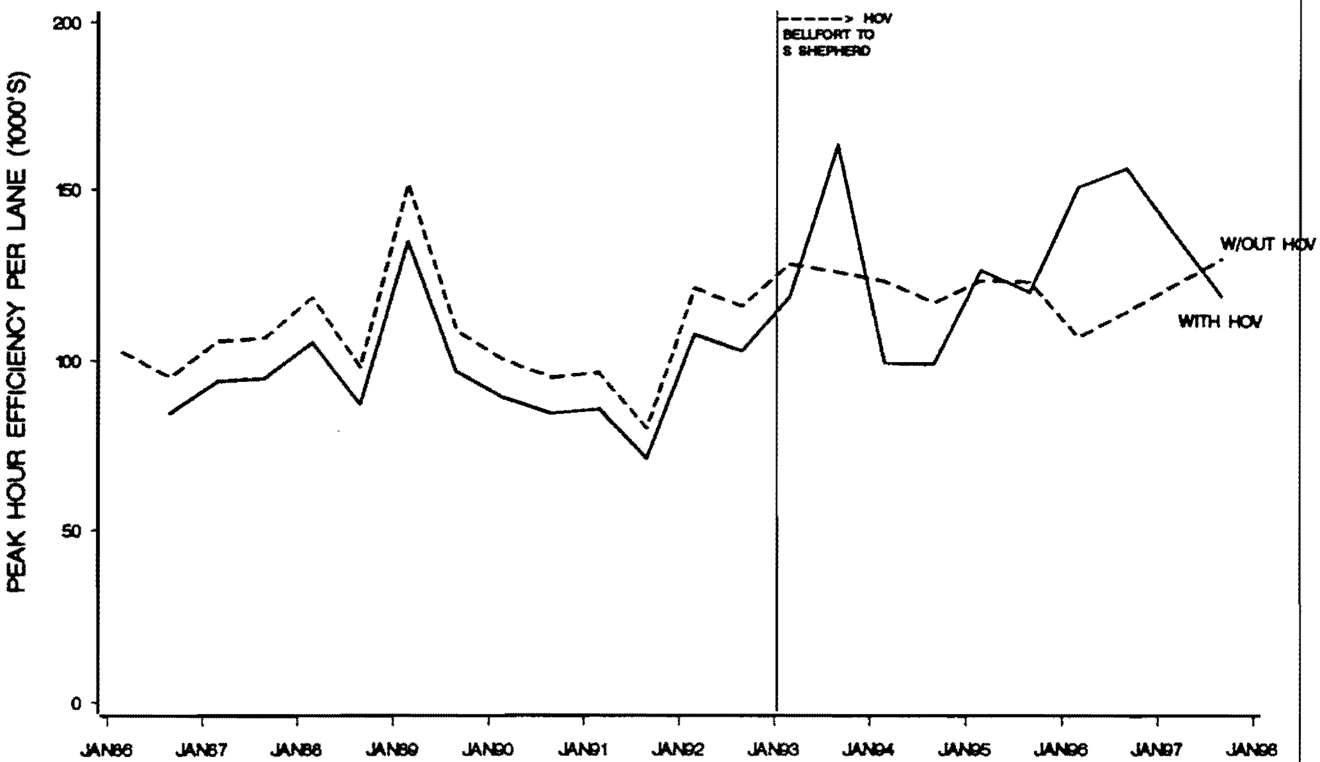


FIGURE E-16. SOUTHWEST FREEWAY (U.S. 59S) MAINLANE AND HOV LANE
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS

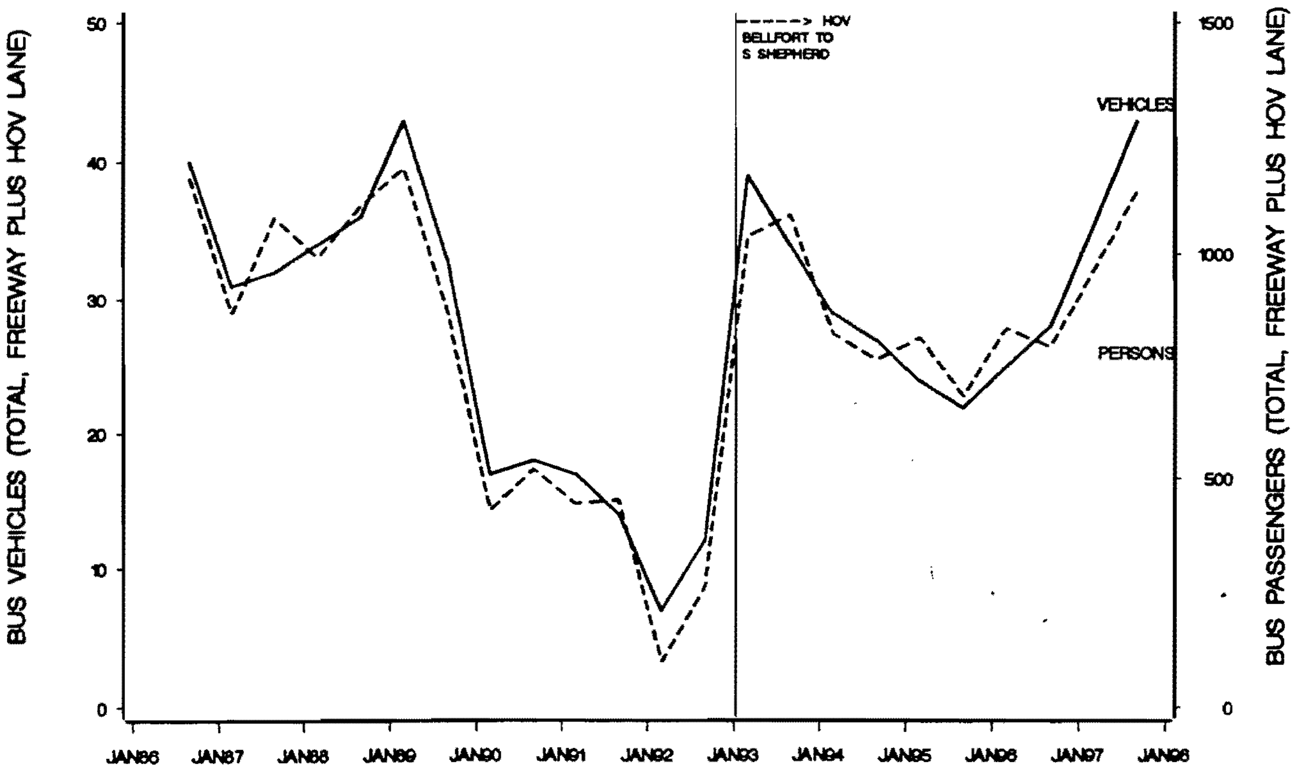


FIGURE E-17. SOUTHWEST FREEWAY (U.S. 59S) MAINLANE AND HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS

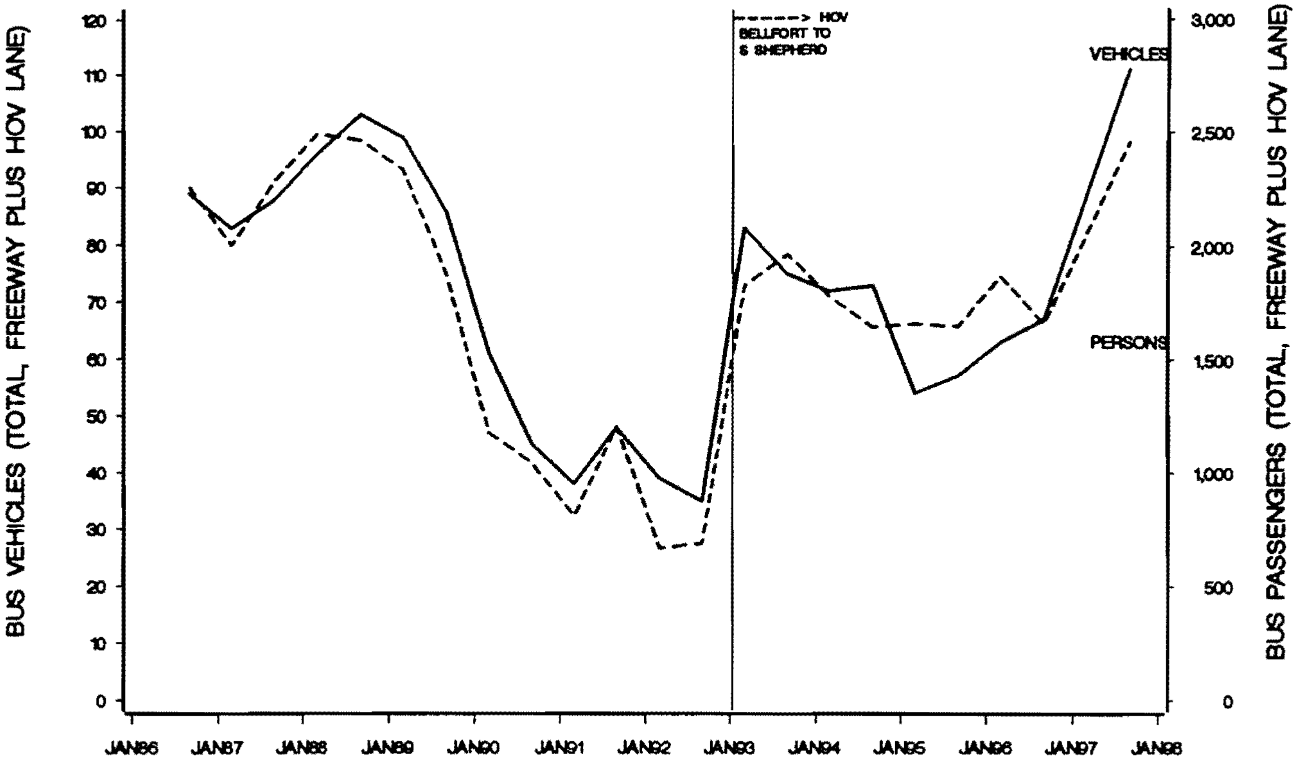


FIGURE E-18. A.M. PEAK PERIOD BUS PASSENGER TRIPS
TOTAL, FREEWAY PLUS HOV LANE VOLUMES
SOUTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE

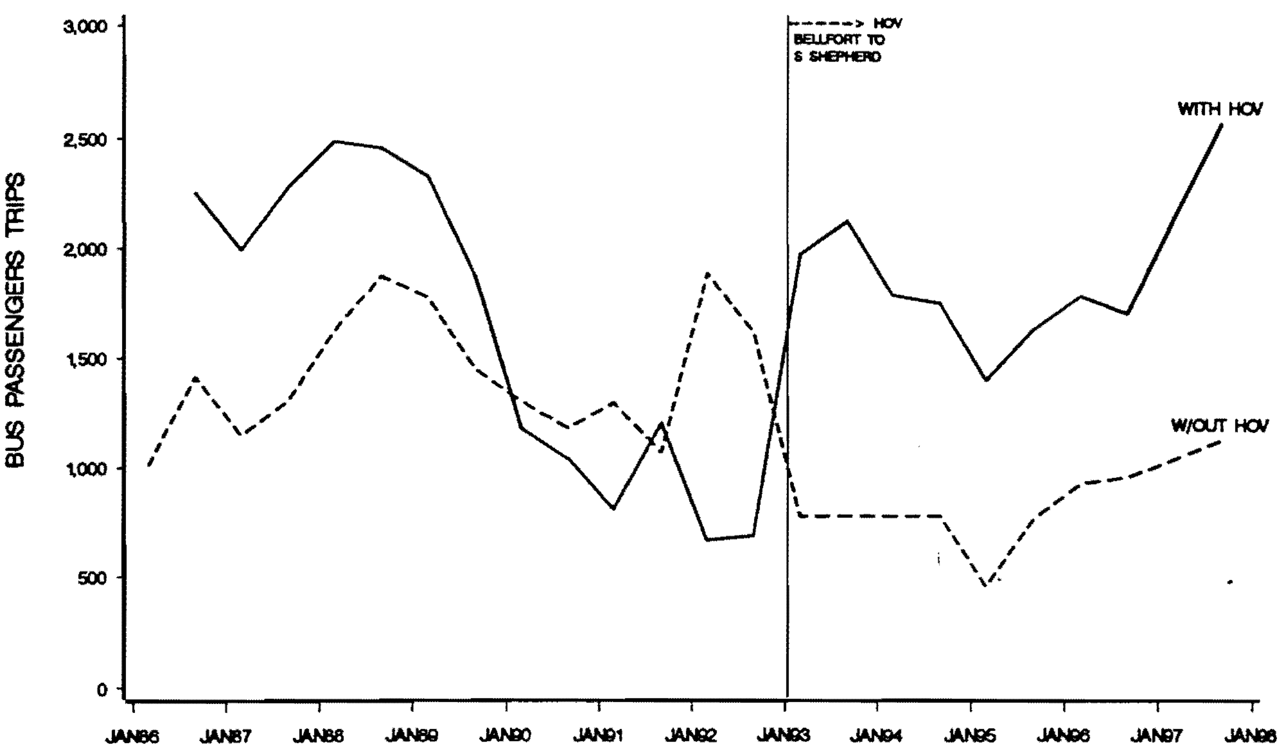


FIGURE E-19. SOUTHWEST FREEWAY (U.S. 59S) CORRIDOR PARK-AND-RIDE DEMAND

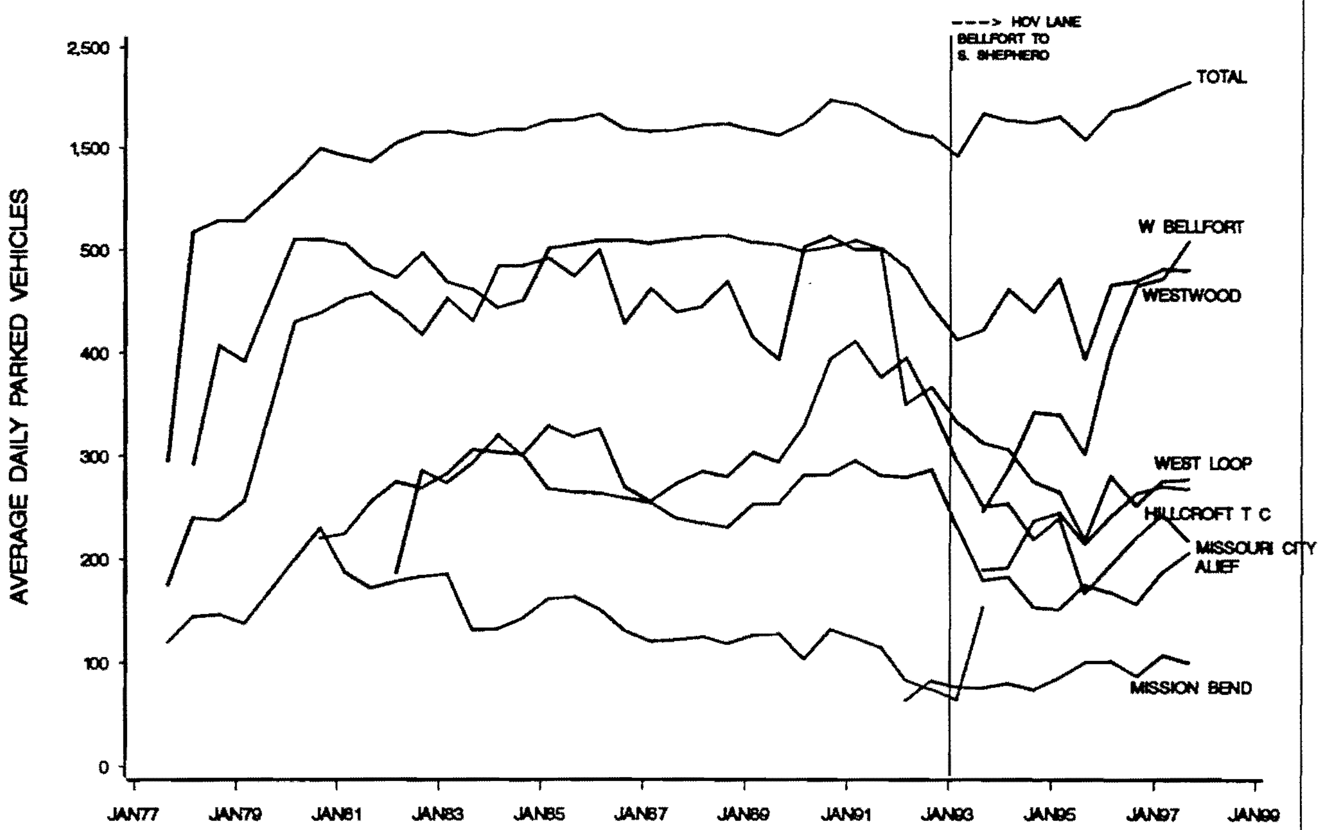
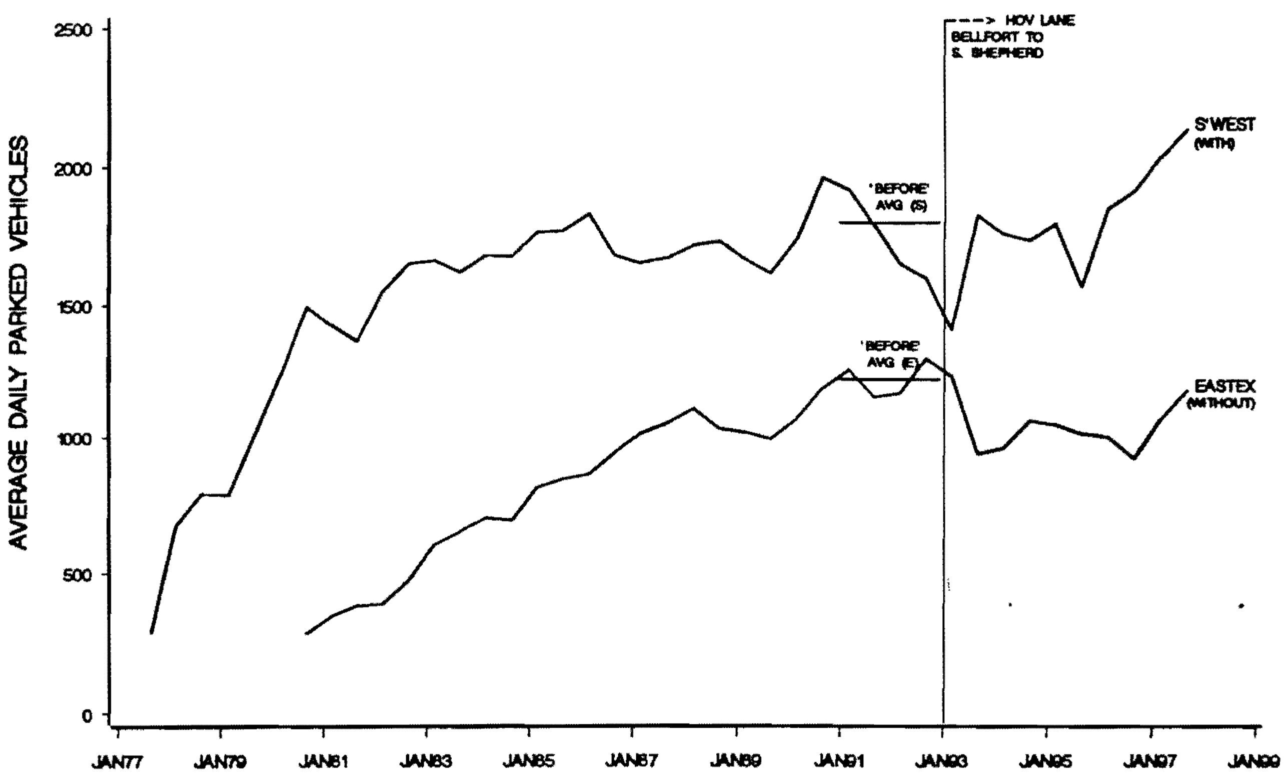


FIGURE E-20. AVERAGE DAILY VEHICLES PARKED AT PARK-AND-RIDE LOTS
SOUTHWEST FREEWAY AND FREEWAY WITHOUT HOV LANE



APPENDIX F

EAST R. L. THORNTON FREEWAY

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

Table F-1. Summary of A.M. Peak-Direction East R.L. Thornton Freeway and HOV Lane Data, 1997

Type of Data HOV Lane Became Operational 9/23/91	Representative Pre-HOV Lane	Representative Current Value	Percent Change
HOV Lane Data			
HOV Lane Length (miles)		5.2	---
HOV Lane Cost (millions of 1990 dollars)		$12.7	---
Person-Movement			
Peak-Hour (7:00-8:00 a.m.)		4,157	---
Peak-Period (6:00-9:00 a.m.)		8,515	---
Total Daily		15,849	---
Vehicle Volumes			
Peak-Hour		1,433	---
Peak-Period		2,916	---
Vehicle Occupancy, Peak-Hour (persons/veh)		2.9	---
Accident Rate (i.e. Injury accidents/100 MVM)[2]		14.5	---
Vehicle Breakdowns (VMT/Breakdown)		51,418	---
Violation Rate (6:00-9:00 a.m.)		1.0%	---
Peak-Hour Lane Efficiency (1000's)[3]		233	---
Annual Discounted Benefits (millions)[4]		$36	---
Annual Delay Savings (millions)[5]		$27	---
Freeway Mainlane Data (see note)			
Person-Movement			
Peak-Hour	7,689	7,776	+1%
Peak-Period (6:00-9:00 a.m.)	23,030	21,312	-8%
Vehicle Volume			
Peak-Hour	5,692	7,299	+28%
Peak-Period	17,946	20,058	+12%
Vehicle Occupancy, Peak-Hour (persons/veh)	1.35	1.07	-21%
Accident Rate (i.e. Injury accidents/100 MVM)[2]	22.6	26.1	+15%
Avg. Operating Speed (mph)[6]			
Peak-Hour	21	30	+41%
Peak-Period	30	39	+31%
Peak-Hour Lane Efficiency (1000's)[3]	41	58	+41%

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

Current values are an average of calendar year 1997 quarterly data (March, June, September, and December).

[1] Does not include westbound auxiliary (July 1994) or PM extension (February 1996).

[2] In order to directly compare accidents to Houston, the analysis includes injury accidents only. "Before" data are for the period from October 1990 through September 1991. "Current" values are for the period from October 1991 through December 1997.

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

[4] Based on average annual delay, reduced vehicle operating costs, and reduced accident costs generated by MicroBENCOST over a 20-year life.

[5] Per MicroBencost, over 20-year life.

[6] From Jim Miller to Central Expressway, the distance is 5.2 mi.

Table F-1. Summary of A.M. Peak-Direction East R.L. Thornton Freeway and HOV Lane Data (CONTINUED)

Type of Data HOV Lane Became Operational 9/23/91	"Representative" Pre-HOV Lane	"Representative" Current Value	Percent Change
Combined Freeway Mainlane and HOV Lane Data			
Total Person-Movement			
Peak-Hour	7,689	11,932	+55%
Peak-Period	23,030	29,827	+30%
Vehicle Volume			
Peak-Hour	5,692	8,731	+53%
Peak-Period	17,946	22,973	+28%
Vehicle Occupancy			
Peak-Hour	1.35	1.37	+1.5%
Peak-Period	1.26	1.30	+3%
2+ Carpool Volumes			
Peak-Hour	596	1,735	+191%
Peak-Period	1,903	3,742	+975%
Peak-Hour Lane Efficiency (1000's)[3]	41	93	+127%
Transit Data			
Bus Vehicle Trips			
Peak-Hour	41	41	0
Peak-Period	103	97	-6%
Bus Passenger Trips			
Peak-Hour	1,283	1,148	-11%
Peak-Period	2,819	2,415	-14%
Bus Occupancy (persons/bus)			
Peak-Hour	31.3	28.0	-11%
Peak-Period	27.4	24.9	-9%
Vehicles Parked in Corridor Park-and-Ride Lots	847	881	+4%
Bus Operating Speed (mph)			
Peak-Hour	21[1]	56[2]	+165%
Peak-Period	30[1]	58[2]	+94%

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

Current values are an average of calendar year 1997 (March, June, September, and December).

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

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

[3] This represents the multiple of peak-hour passengers and average speed (passengers x mph/number of lanes).

Table F-2. A.M. Peak Direction Data - Comparison of Measures of Effectiveness, Freeway with (ERLT) and Freeway without (SRLT) HOV Lane, Dallas

Measure of Effectiveness	Representative Pre-HOV Lane Value	Representative Current Value	Percent Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/HOV lane	1.35	1.37	+1.5%
Freeway w/o HOV lane	1.25	1.20	-4%
Peak-Hour 2+ Carpool Volume			
Freeway w/HOV lane	596	1,735	+191%
Freeway w/o HOV lane	802	695	-13%
DART Bus Passengers, Peak-Period			
Freeway w/HOV lane	2,819	2,415	-14%
Freeway w/o HOV lane	2,540	1,393	-45%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	847	881	+4%
Freeway w/o HOV lane	425	452	+6%
Facility Per Lane Efficiency[1]			
Freeway w/HOV lane	41	93	+127%
Freeway w/o HOV lane	67	74	+10%

Current values are an average of calendar year 1997 quarterly data (March, June, September, and December)
[1] This represents the multiple of peak-hour passengers and average speed (passengers x mph/number of lanes).

HOV LANE DATA

DESCRIPTION

- The evening operation (3.3 mi) opened September 23, 1991.
- The morning operation (3.3 mi) opened September 30, 1991.
- The morning operation (5.2 mi) extended November 4, 1991. The evening operation (5.2 mi) extended February 1996.
- The capital cost for the completed facility in 1990 dollars was $12.7 million. The following page provides a more detailed cost breakdown (including dates).
- Selected milestone dates are listed below. The capital cost table (Table F-3) shows other dates.
    - 9/23/91 Evening lane opens Central Expressway to Dolphin Road (3.3 mi), used by buses and vans.
    - 9/30/91 Morning lane opens Dolphin Road to Central Expressway (3.3 mi), used by buses and vans.

- 10/7/91 3+ carpools allowed onto HOV lane.
- 10/21/91 2+ carpools allowed onto HOV lane.
- 11/04/91 Morning operation extended to begin at Jim Miller (5.2 mi,total).
- 11/25/91 DART adds bus service to existing routes.
- 5/93 Reconstruction of Fair Park Bridge begins, A.M. operating hours shortened.
- 7/93 A.M. operating hours extended.
- 12/93 E. Garland Park-and-Ride closes.
- 3/94 Audoban Park-and-Ride closes. Lake Ray Hubbard Park-and-Ride opens.
- 7/94 Westbound Auxiliary Lane added at contraflow lane egress.
- 4/95 Construction of P.M. extension begins.
- 10/95 A.M. operating limits shortened due to construction of PM extension.
- 2/96 Construction of P.M. extension ends. Reconstruction of Fair Park Bridge ends.

Table F-3. Estimated Capital Cost (millions), East R.L. Thornton HOV Lane

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1995 dollars
HOV Lane and Ramps (1990)			
Barrier	$6.0	1.16	$7.0
Barrier Machine(s)	0.9	1.16	1.0
Contraflow Lane	5.6	1.16	6.5
Support Vehicles	0.2	1.16	0.2
TOTAL COST	$12.7		$14.7
COST PER MILE (5.2 mi)	$2.4		$2.8

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

PERSON-MOVEMENT

- In 1997, the HOV lane served an average of 15,849 person trips per day.
- A.M. peak-hour, 4,157 persons/hour.
  - 1,148 (28 percent) by DART bus, 53 (1 percent) by vanpool, 2,872 (69 percent) by carpool, and 6 by motorcycle (Figure F-1).
  - Average HOV lane vehicle occupancy = 2.9 persons/vehicle.

- A.M. peak-period, 8,515 persons.

  - 2,395 (28 percent) by DART bus, 9 (1 percent) by vanpool, by carpool 5,779 (68 percent), and 13 by motorcycle (Figure F-2).

VEHICLE MOVEMENT

- A.M. peak-hour, 1,433 vph

  - 40 (3 percent) DART buses, 17 (1 percent) vans, 1,358 (95 percent) carpools, and 6 (1 percent) by motorcycle (Figure F-3).

- A.M. peak-period, 2,916 vehicles

  - 94 (3 percent) DART buses, 17 (1 percent) vans, 2,749 (94 percent) carpools, and 13 (1 percent) by motorcycle (Figure F-4).

ACCIDENT RATE

- For the period from October 1991 through December 1997, the HOV lane accident rate was 14.5 injury accidents per 100 million vehicle miles of travel.

VEHICLE BREAKDOWN RATES

- As measured for 1/97 to 12/97, the following rate has been observed.

  - The average vehicle breakdown rate for all vehicle types is one per 82,713 miles traveled.

VIOLATION RATE

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

  - For the overall a.m. peak period, it is 1.0 percent.

PEAK-HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is used as a measure of the efficiency of a lane. For the HOV lane, this value (expressed in 1000's) is approximately 233 (4,157 passengers at 56 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane experienced an average travel time savings of four minutes during the morning peak hour in 1997 (Table F-4, Figure F-5).

Table F-4. Travel Time Savings for R. L. Thornton HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1997)

Westbound A.M. Travel Time Savings for Thornton HOV Lane								
Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section from Jim Miller to Central Expressway								
6:00	5.44	5.36	0.08	112	0	70	182	15
6:15	5.44	5.36	0.08	260	2	308	570	46
6:30	6.87	5.73	1.14	396	9	240	645	735
6:45	6.97	5.89	1.08	507	15	280	802	866
7:00	8.33	5.60	2.73	594	25	285	904	2,468
7:15	8.33	5.60	2.73	726	12	360	1.098	3,000
7:30	11.14	5.93	5.21	798	13	308	1,119	5,830
7:45	12.31	5.96	6.35	755	4	260	1,019	6,471
8:00	9.02	5.78	3.24	618	7	145	770	2,495
8:15	9.02	5.78	3.24	478	0	128	06	1,963
8:30	9.33	5.65	3.68	337	7	123	467	1,719
8:45	8.59	5.72	2.87	274	2	95	371	1,065
Peak-Period Total				5,855	96	2,602	8,553	26,671

Table F-4. Travel Time Savings for R. L. Thornton HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1997))(Continued)

Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Eastbound P.M. Travel Time Savings for Thornton HOV Lane								
Section from Central Expressway to Jim Miller								
4:00	5.96	5.65	0.31	253	8	173	434	135
4:15	5.96	5.65	0.31	349	7	136	492	153
4:30	6.05	5.70	0.35	476	10	146	632	221
4:45	6.88	5.95	0.93	541	7	368	916	852
5:00	8.77	5.89	2.88	580	19	258	857	2,468
5:15	8.77	5.89	2.88	689	19	390	1,098	3,162
5:30	10.37	6.72	3.65	573	5	263	841	3,070
5:45	9.48	6.09	3.39	467	1	143	611	2,071
6:00	8.22	5.82	2.40	346	2	174	522	1,253
6:15	8.22	5.82	2.40	342	2	68	412	989
6:30	6.64	5.57	1.07	238	12	113	363	388
6:45	5.63	5.54	0.09	103	1	48	152	14
Peak-Period Total				4,957	93	2,280	7,330	14,775

FIGURE F-1. EAST R.L. THORNTON FREEWAY (IH 30E) HOV LANE
A.M. PEAK HOUR HOV LANE PERSON MOVEMENT

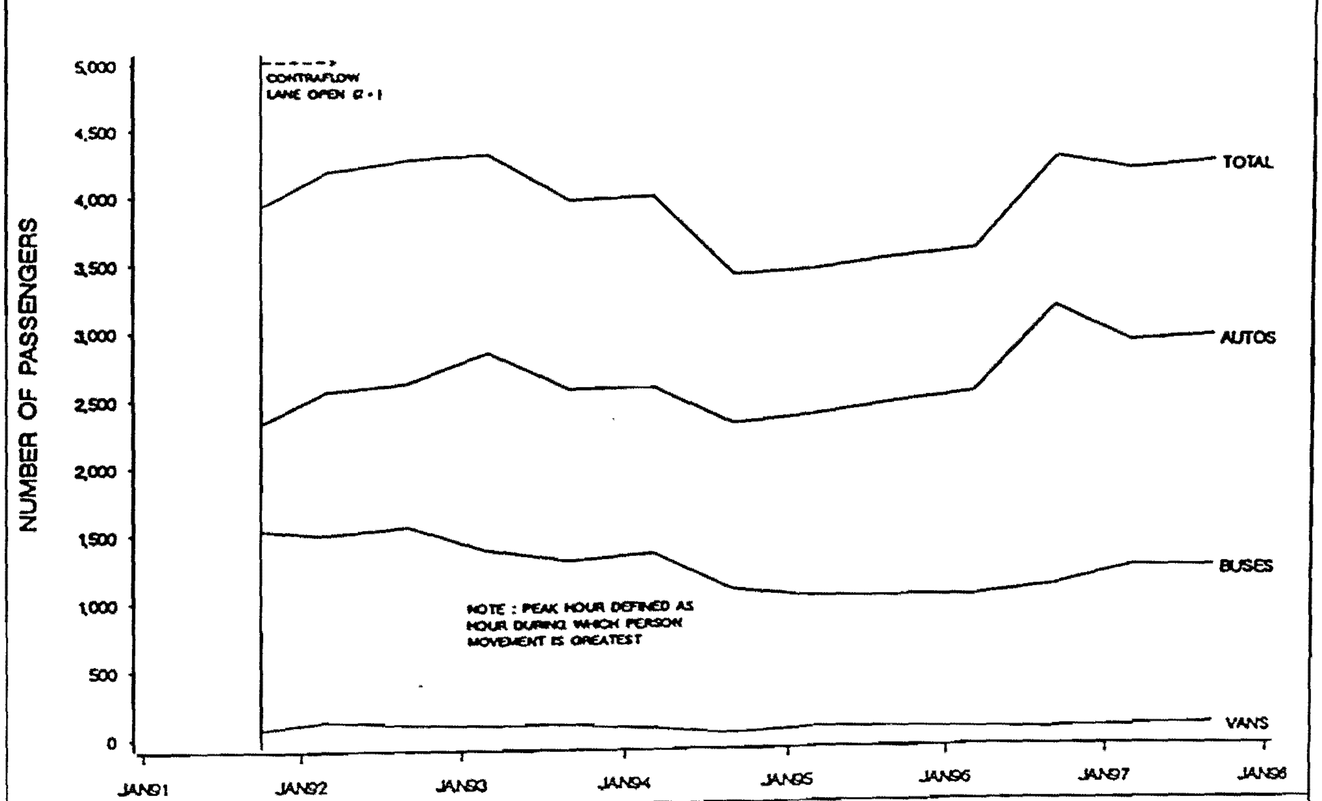
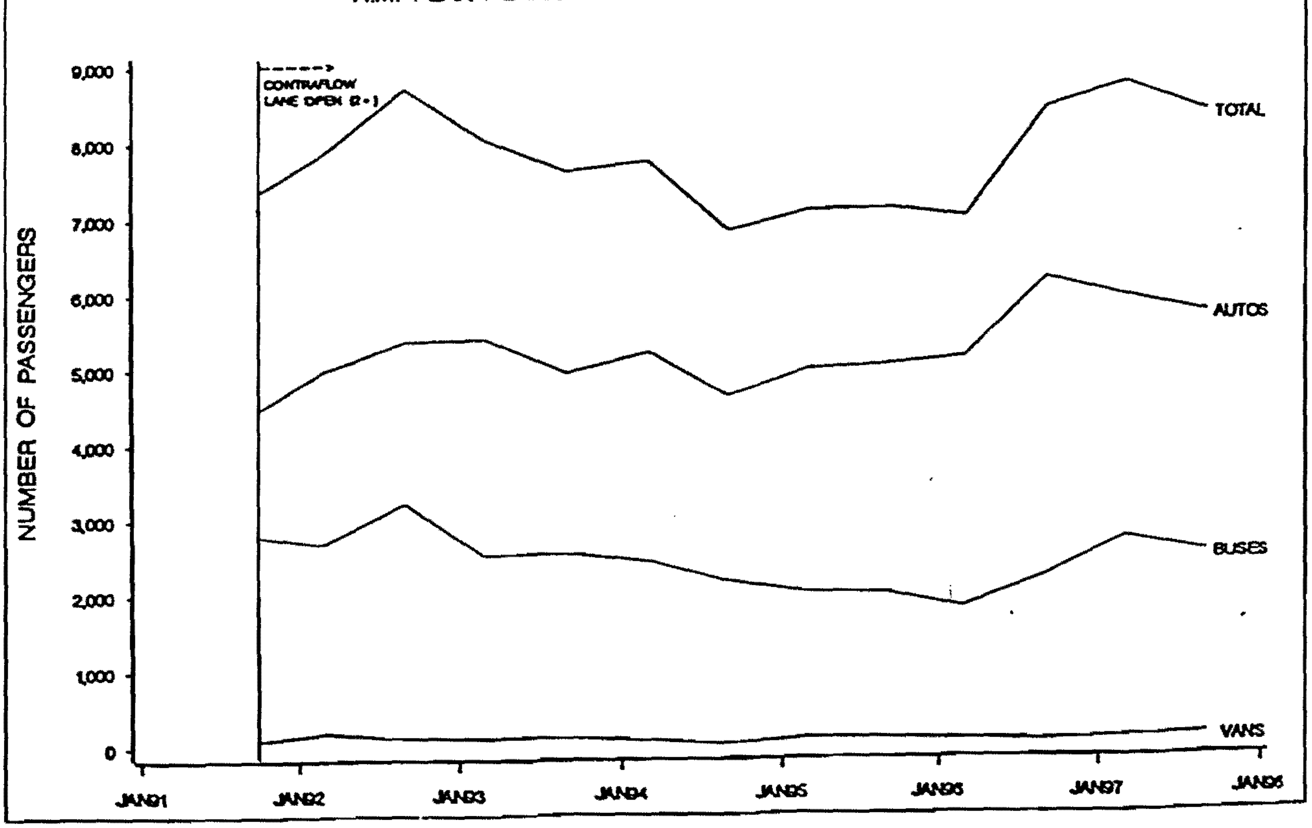


FIGURE F-2. EAST R.L. THORNTON FREEWAY (IH 30E) HOV LANE
A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT



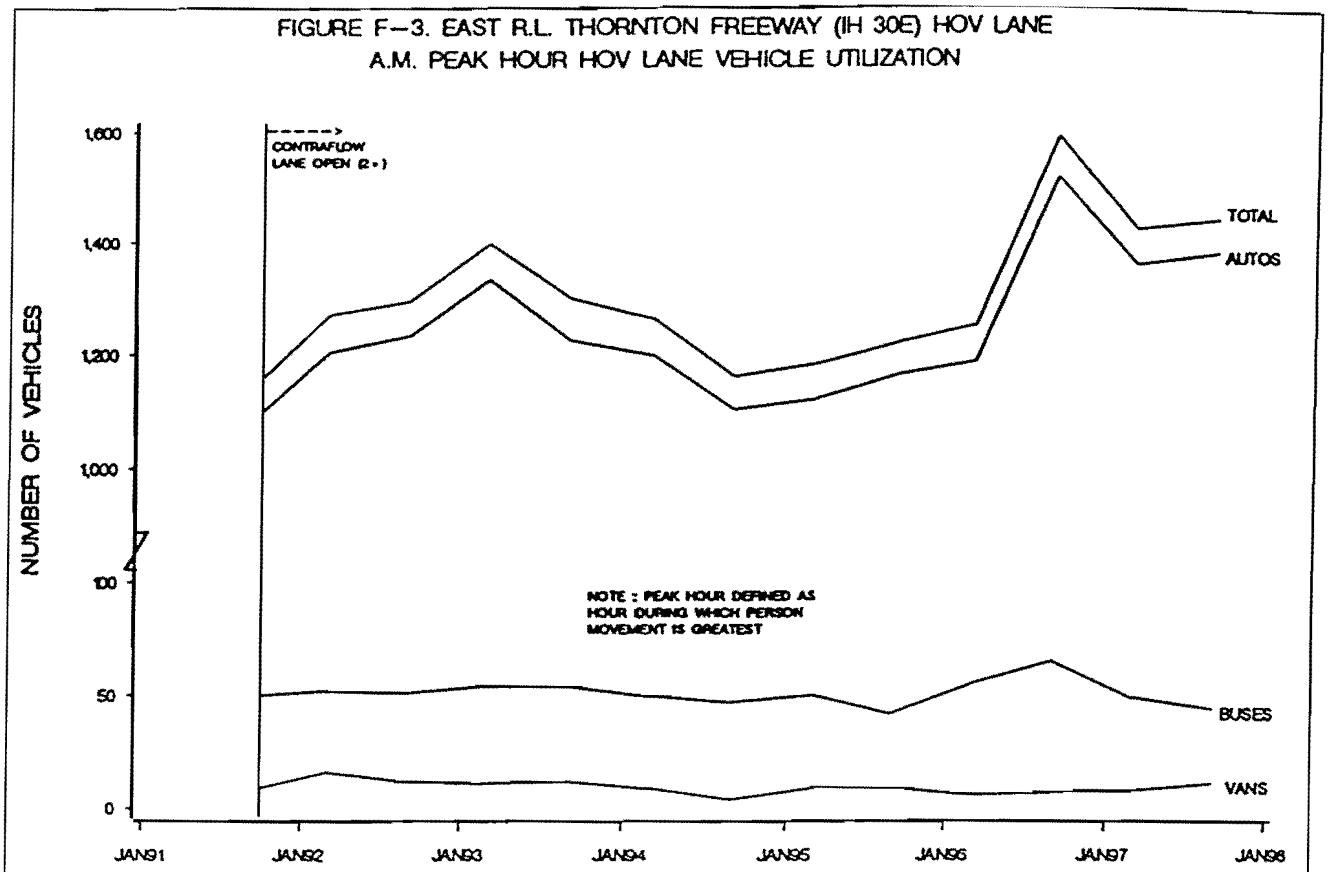


FIGURE F-3. EAST R.L. THORNTON FREEWAY (IH 30E) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION
NUMBER OF VEHICLES
1,600
1,400
1,200
1,000
100
50
0
CONTRAFLOW LANE OPEN (2+)
NOTE : PEAK HOUR DEFINED AS HOUR DURING WHICH PERSON MOVEMENT IS GREATEST
TOTAL
AUTOS
BUSES
VANS
JAN91
JAN92
JAN93
JAN94
JAN95
JAN96
JAN97
JAN98

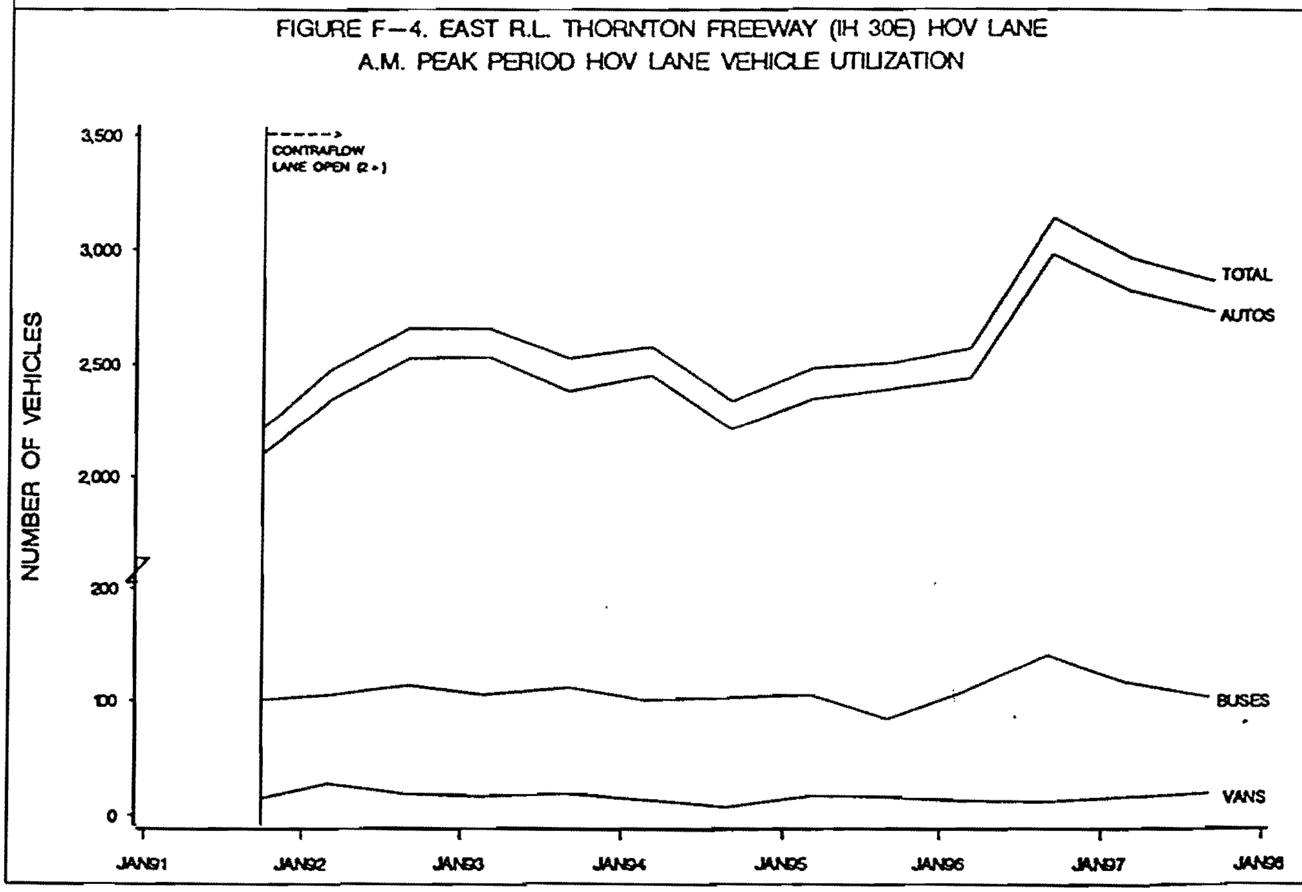


FIGURE F-4. EAST R.L. THORNTON FREEWAY (IH 30E) HOV LANE
A.M. PEAK PERIOD HOV LANE VEHICLE UTILIZATION
NUMBER OF VEHICLES
3,500
3,000
2,500
2,000
200
100
0
CONTRAFLOW LANE OPEN (2+)
TOTAL
AUTOS
BUSES
VANS
JAN91
JAN92
JAN93
JAN94
JAN95
JAN96
JAN97
JAN98

Table F-5. East R.L. Thornton Freeway Travel Time Summaries

Travel Time Data	Travel Times[1]					
	97	96	95	94	93	Pre-HOV
HOVL Travel Time						
AM Peak-Hour	6 min	6 min	7 min	7 min	7 min	-
PM Peak-Hour	6 min	6 min	5 min	5 min	5 min	-
Freeway Mainlanes Travel Time						
AM Peak-Hour	10 min	12 min	12 min	10 min	11 min	15 min
PM Peak-Hour	17 min	8 min	7 min	9 min	8 min	15 min
Net Travel Time Savings						
AM Peak-Hour	4 min	6 min	5 min	3 min	5 min	-
(Person-Minutes)	(4,442)	(5,742)	(4,373)	(3,626)	(4,079)	
PM Peak-Hour	11 min	2 min	2 min	4 min	3 min	-
(Person-Minutes)	(5.386)	(1,565)	(1,786)	(2,662)	(2,167)	

[1]Travel Times are calculated over a distance of 8.4 km (5.2 mi).

FREEWAY DATA (MAINLANE ONLY)

NOTE

- For purposes of safety and visibility, freeway volumes are counted near Dolphin Road between an entrance ramp and an exit ramp. This location is not necessarily the highest traffic volume section; however, the location gives reasonable estimates of traffic volumes which can be used for monitoring trends.

PERSON-MOVEMENT

- In the a.m. peak hour, person-movement has increased by 1 percent relative to pre-HOV conditions (Figure F-6).

- In the a.m. peak period, person-movement has decreased by 8 percent relative to pre-HOV conditions (Figure F-7).

VEHICLE VOLUME

- In the a.m. peak hour, vehicle volume has increased by 28 percent relative to pre-HOV conditions (Figure F-6).

- In the a.m. peak period, vehicle volume has increased by 12 percent relative to pre-HOV conditions (Figure F-7).

VEHICLE OCCUPANCY

- In the a.m. peak hour, mainlane occupancy has decreased by 21 percent relative to pre-HOV conditions (from 1.35 to 1.07).

- In the a.m. peak period, mainlane occupancy has decreased by 16 percent, relative to pre-HOV

ACCIDENT RATE

- Implementation of the HOV lane resulted in narrower freeway lanes and no inside emergency shoulder in the off-peak direction during HOV lane operation.

- The accident data shown are for the section between Pearl/Central Expressway and Jim Miller Road. The accident rate for the period (10/90-9/91) preceding Phase 1 of the HOV lane was 22.6 accidents per 100 million vehicle miles. For the period from 10/91 to 12/97, the freeway accident rate was 26.1 accidents/100 MVM. These statistics do not include driver-reported accidents; current accident files include only officer-reported accidents.

AVERAGE OPERATING SPEED

- In comparison to pre-HOV lane conditions, mainlane operating speeds have increased by 41 percent in the peak hour and 31 percent in the peak period (Figure F-8).

PEAK-HOUR LANE EFFICIENCY

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

    - For the freeway mainlanes, an increase in per lane efficiency of 41 percent has occurred.

FIGURE F-5. EAST R.L. THORNTON (IH 30E) MAINLANES AND HOV LANE A.M. TRAVEL TIME

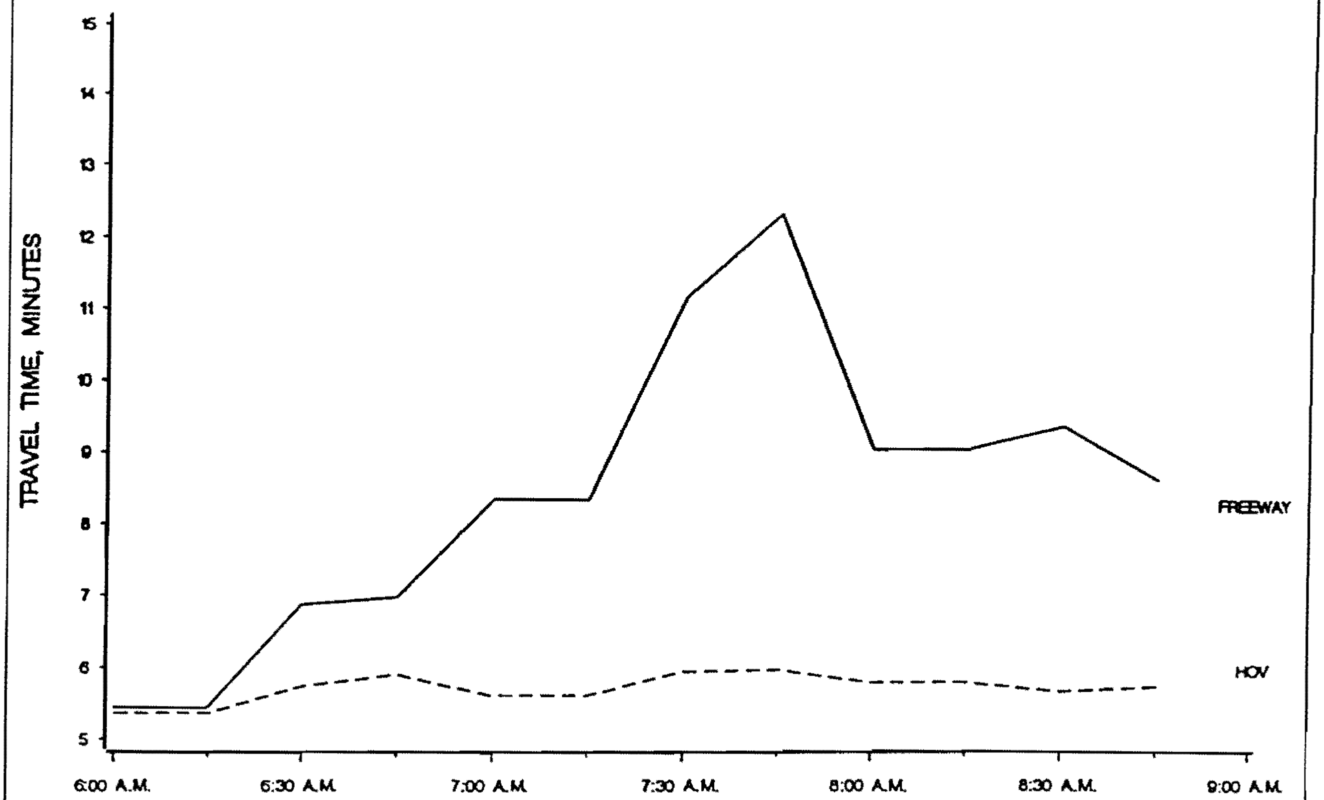


FIGURE F-6. EAST R.L. THORNTON FREEWAY (IH 30E)
A.M. PEAK HOUR MAINLANE TRIPS

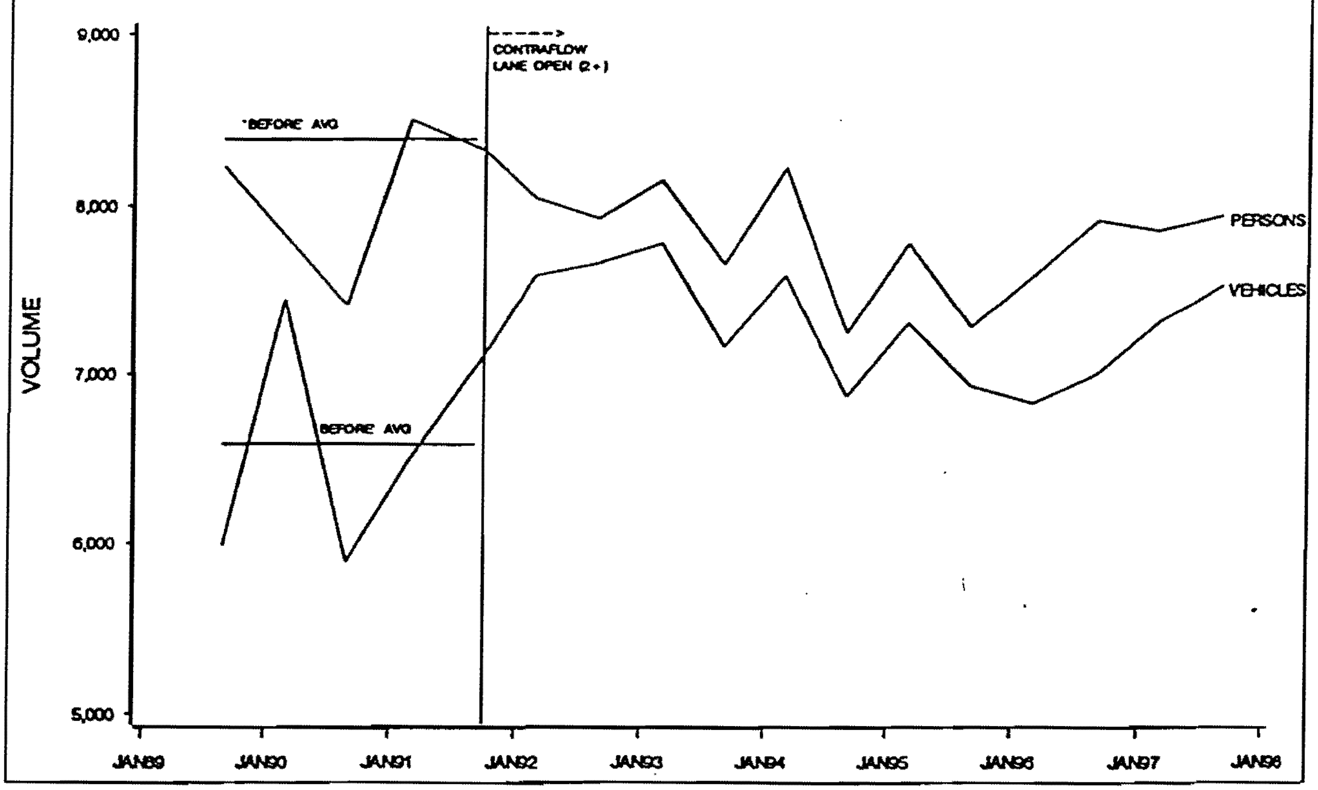


FIGURE F-7. EAST R.L. THORNTON FREEWAY (IH 30E)
A.M. PEAK PERIOD MAINLANE TRIPS

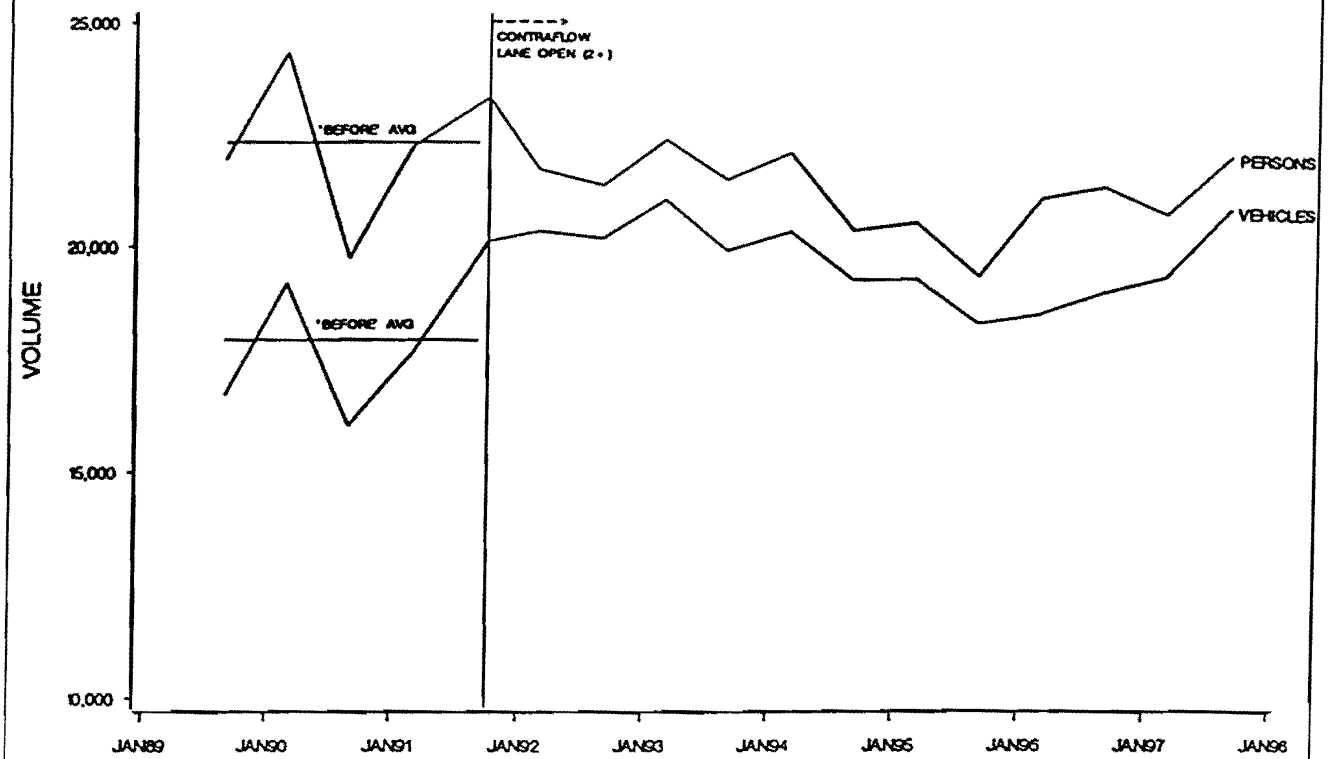
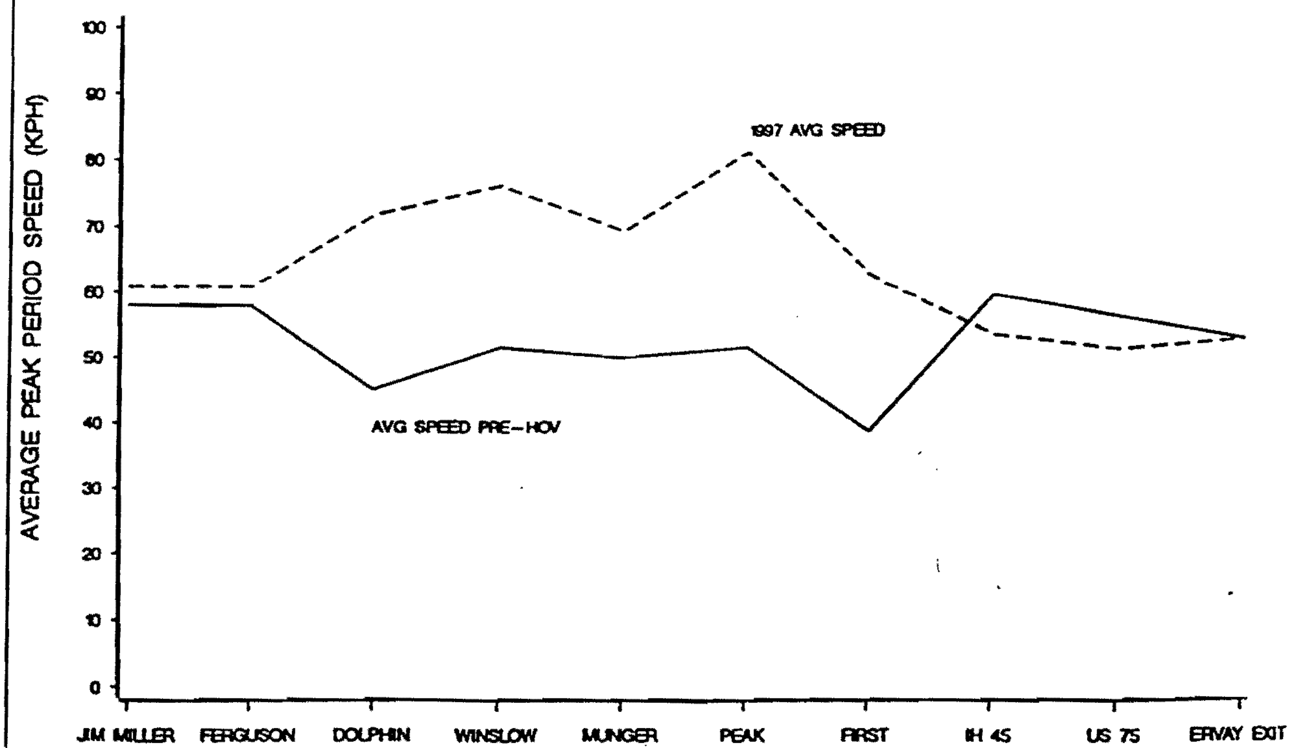


FIGURE F-8. EAST R.L. THORNTON (IH 30E) MAINLANE TRAVEL TIME AND SPEED SURVEY
WESTBOUND, JIM MILLER TO ERVAY EXIT
A.M. PEAK PERIOD



COMBINED FREEWAY MAINLANE AND HOV LANE DATA

TOTAL PERSON-MOVEMENT

- Percent by HOV lane, a.m. peak hour.
    - The HOV lane is responsible for 35 percent of peak-hour person-movement (HOV lane = 4,157; freeway = 7,776) and 29 percent of peak-period (HOV lane = 8,515; freeway = 21,312) person-movement.
- Increase in a.m. person-movement at Dolphin Road relative to pre-HOV lane operations.
    - Provision of the HOV lane increased total directional lanes by 25 percent in the peak period.
    - Total peak-hour person-movement has increased by 55 percent from 7,689 to 11,932 (Figure F-9). Peak-period person-movement has increased by 30 percent from 23,030 to 29,827 (Figure F-10).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.37 - a 1.5 percent increase over the pre-HOV lane occupancy (Figure F-11). Occupancy in the peak period has increased by 3 percent (Figure F-12).
- While the occupancy on the East Thornton Freeway has increased, freeways which do not have HOV lanes have experienced a decrease in occupancy (Figure F-13).

CARPOOL VOLUMES

- In the a.m. peak hour, the total number of 2+ carpools (freeway plus HOV lane) has increased by 191 percent compared to pre-HOV lane levels (Figure F-14).

PEAK-HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. The average efficiency of a lane on the freeway (4 freeway lanes plus 1 HOV lane) has increased by 127 percent since the implementation of the HOV lane (Figure F-15). The per lane efficiency has increased slightly during this same time period on freeways not having HOV lanes.

BUS TRANSIT DATA

BUS VEHICLE AND PASSENGER TRIPS

- In the a.m. peak hour, DART bus vehicle trips have remained the same since the HOV lane opened, and an 11 percent decrease in bus ridership has also resulted (Figure F-16). In the peak period, a 6 percent decrease has occurred in bus trips, and a 14 percent decrease in bus ridership has resulted (Figure F-17).

PARK-AND-RIDE

- Prior to opening the HOV lane, approximately 847 vehicles were parked in corridor park-and-ride lots; this has increased 4 percent to a current level of 881 (Figure F-19).

- The number of parked vehicles in the representative freeway corridor without an HOV lane (South R.L. Thornton Freeway) has decreased (8 percent) (Figure F-20).

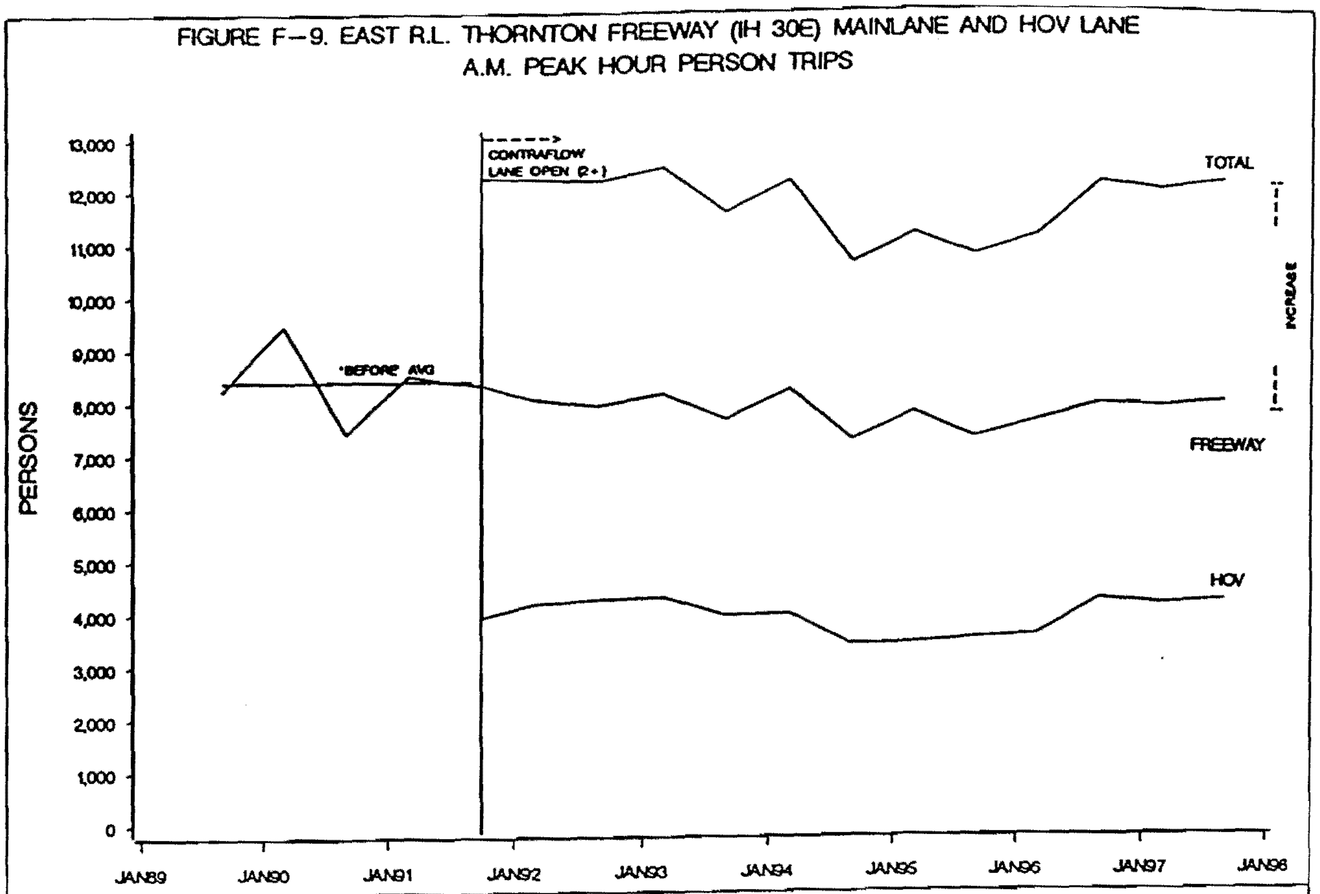


FIGURE F-9. EAST R.L. THORNTON FREEWAY (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK HOUR PERSON TRIPS
PERSONS
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
CONTRAFLOW
LANE OPEN (2+)
TOTAL
INCREASE
BEFORE AVG
FREEWAY
HOV
JAN89
JAN90
JAN91
JAN92
JAN93
JAN94
JAN95
JAN96
JAN97
JAN98

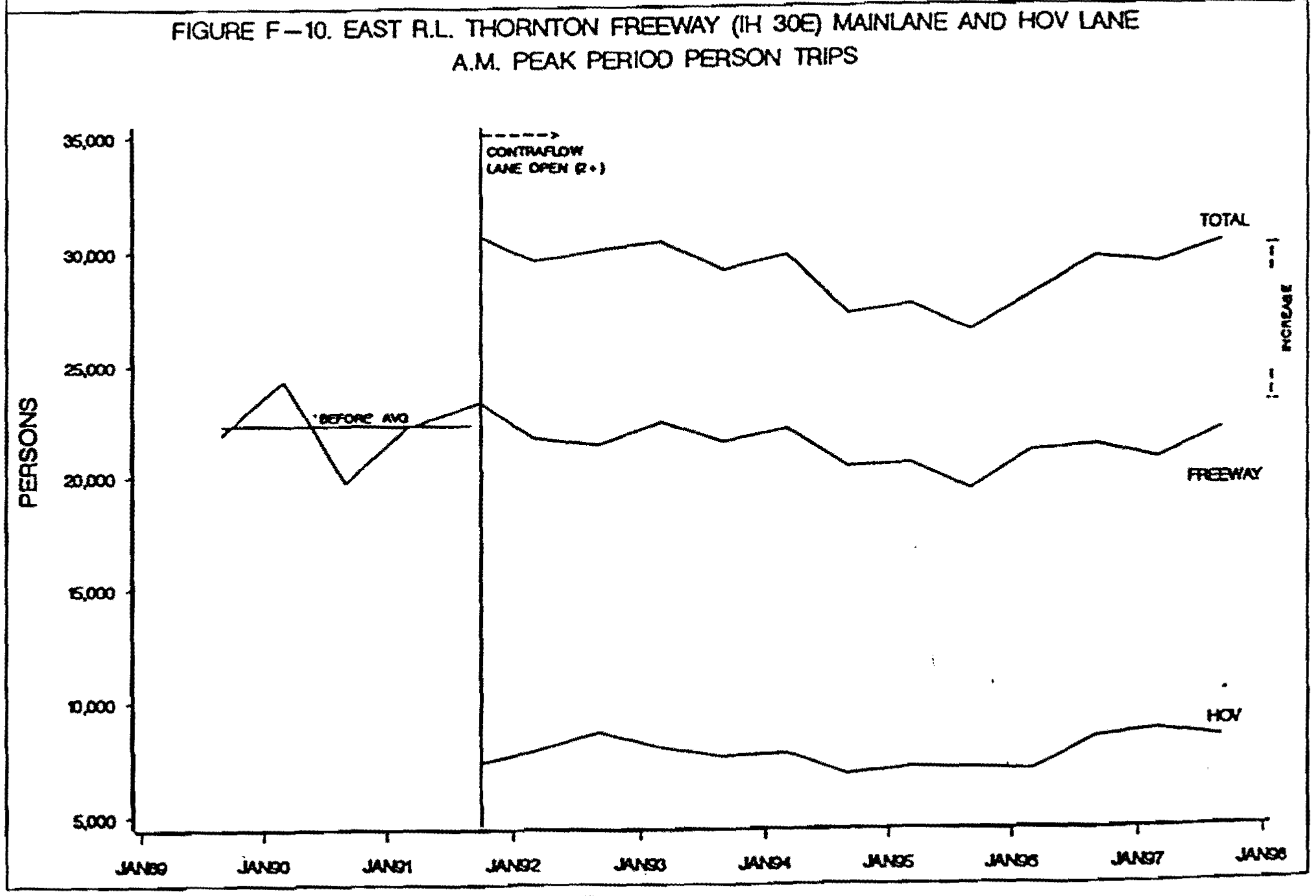


FIGURE F-10. EAST R.L. THORNTON FREEWAY (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK PERIOD PERSON TRIPS
PERSONS
35,000
30,000
25,000
20,000
15,000
10,000
5,000
CONTRAFLOW
LANE OPEN (2+)
TOTAL
INCREASE
BEFORE AVG
FREEWAY
HOV
JAN89
JAN90
JAN91
JAN92
JAN93
JAN94
JAN95
JAN96
JAN97
JAN98

FIGURE F-11. EAST R.L. THORNTON FREEWAY (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK HOUR AVERAGE OCCUPANCY

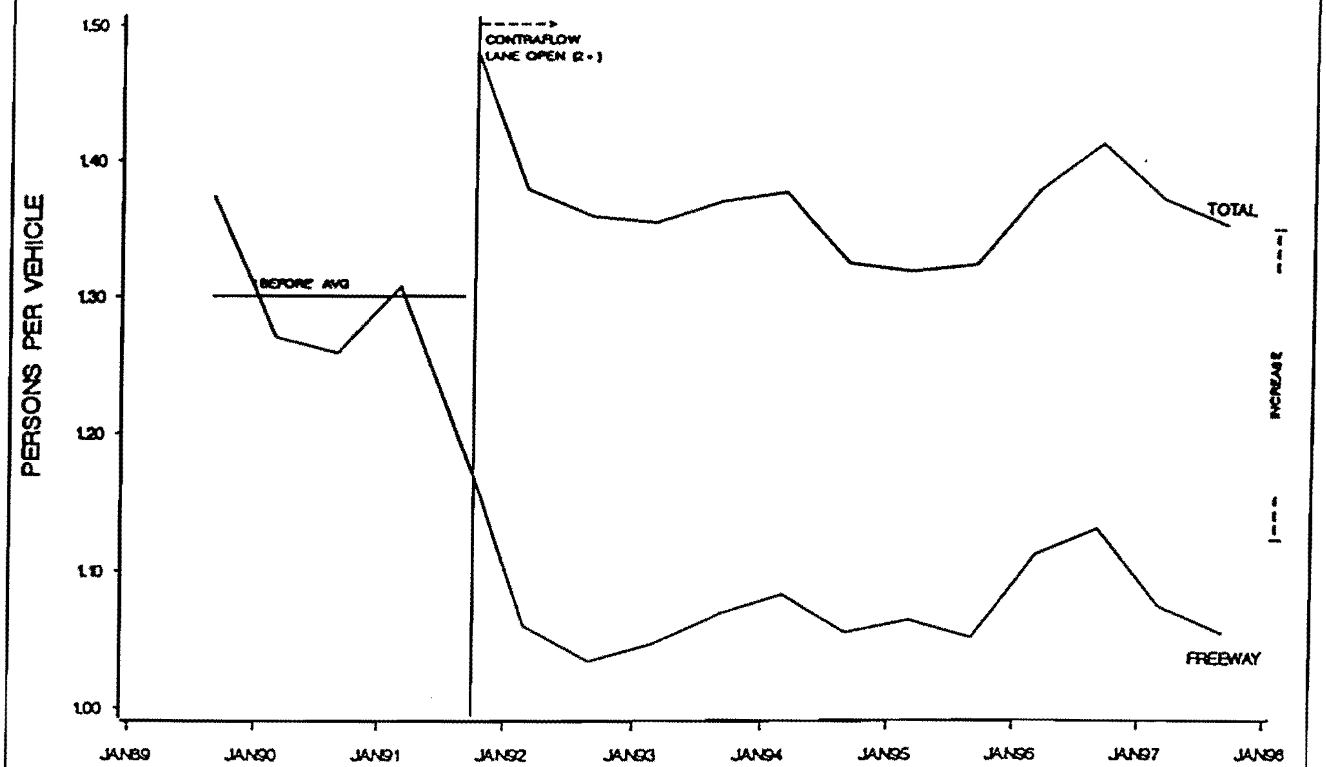


FIGURE F-12. EAST R.L. THORNTON FREEWAY (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK PERIOD AVERAGE OCCUPANCY

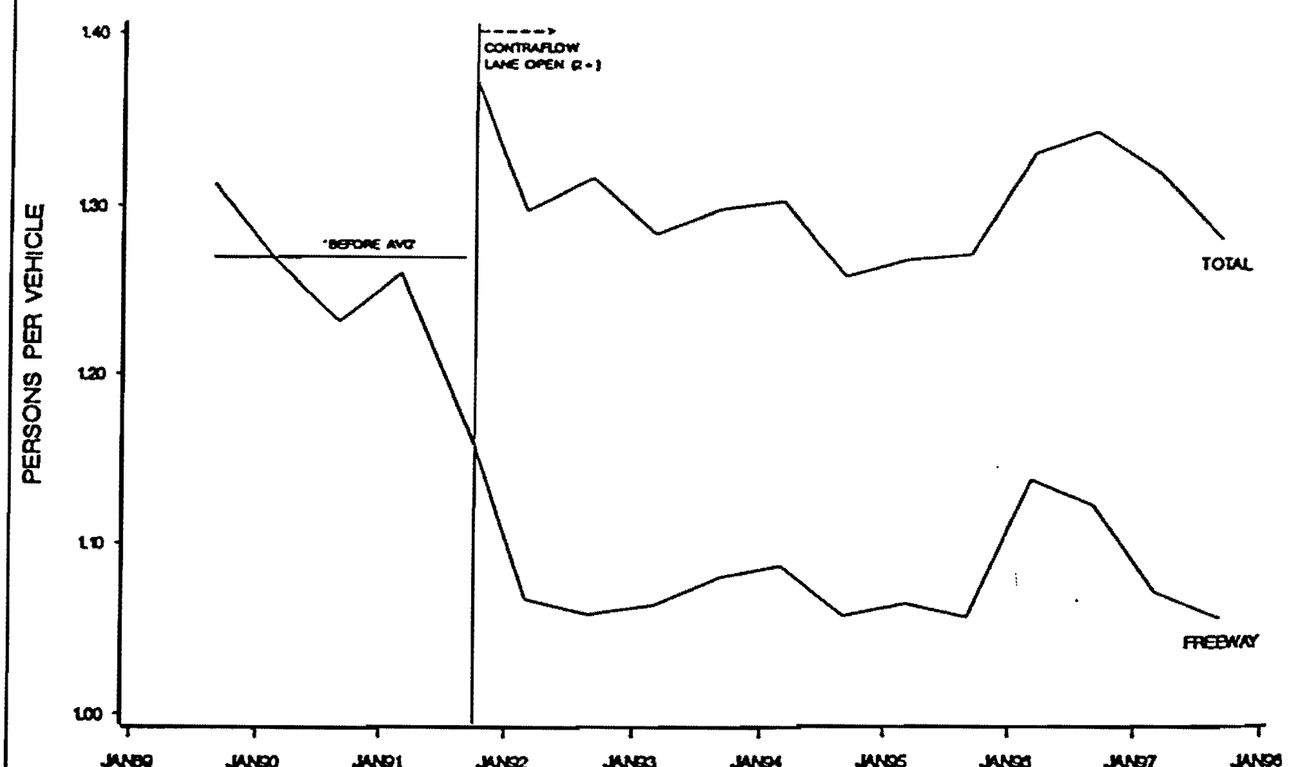


FIGURE F-13. A.M. PEAK HOUR AVERAGE OCCUPANCY
EAST R.L. THORNTON (IH 30E) AND FREEWAY WITHOUT HOV LANE

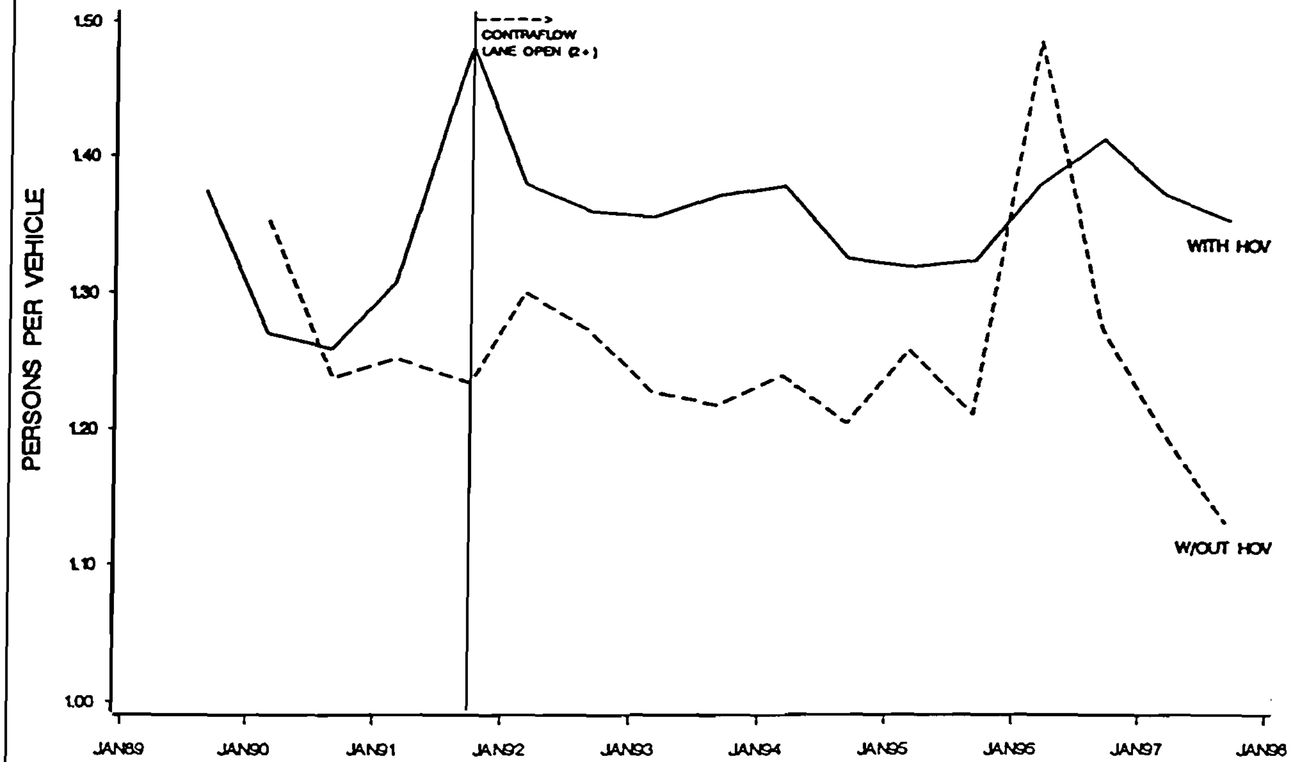


FIGURE F-14. EAST R.L. THORNTON (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK HOUR 2+ CARPOOL UTILIZATION

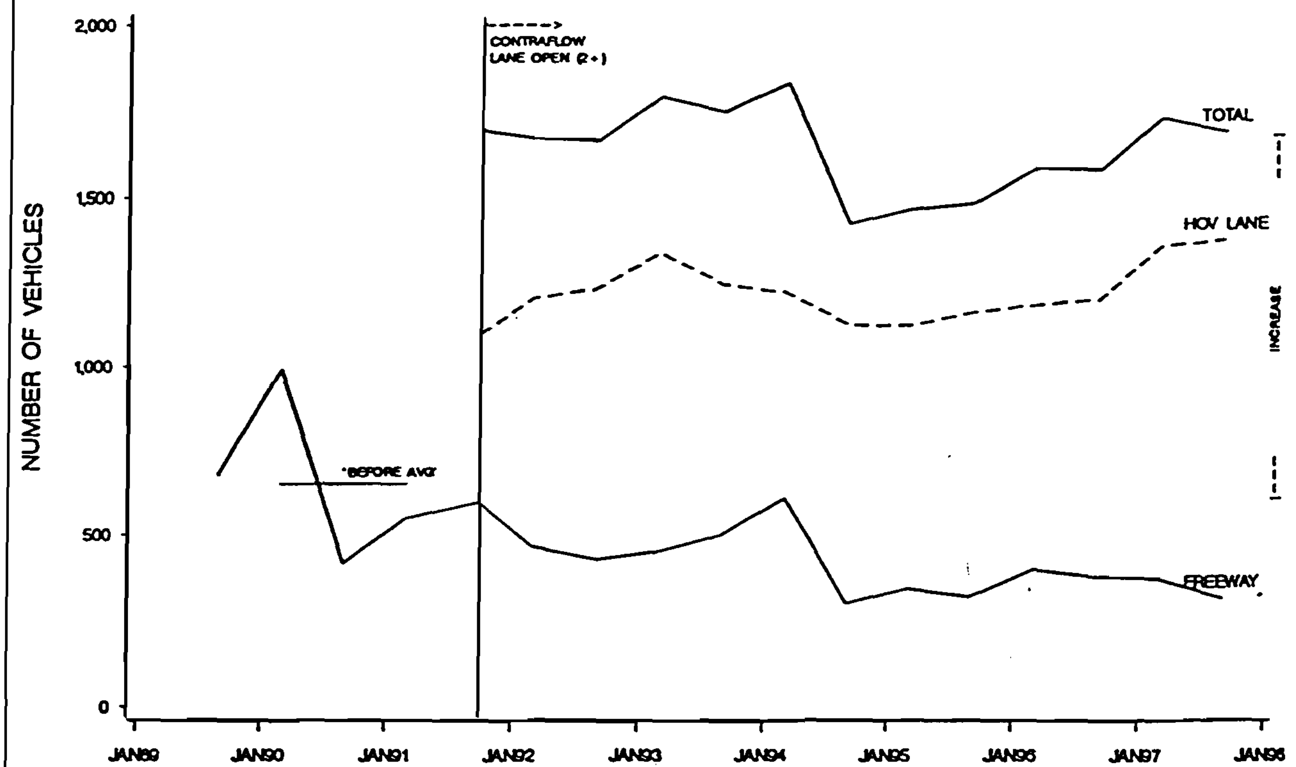


FIGURE F-15. A.M. PEAK HOUR FREEWAY PER LANE EFFICIENCY
EAST R.L. THORNTON FREEWAY AND FREEWAY WITHOUT HOV LANE

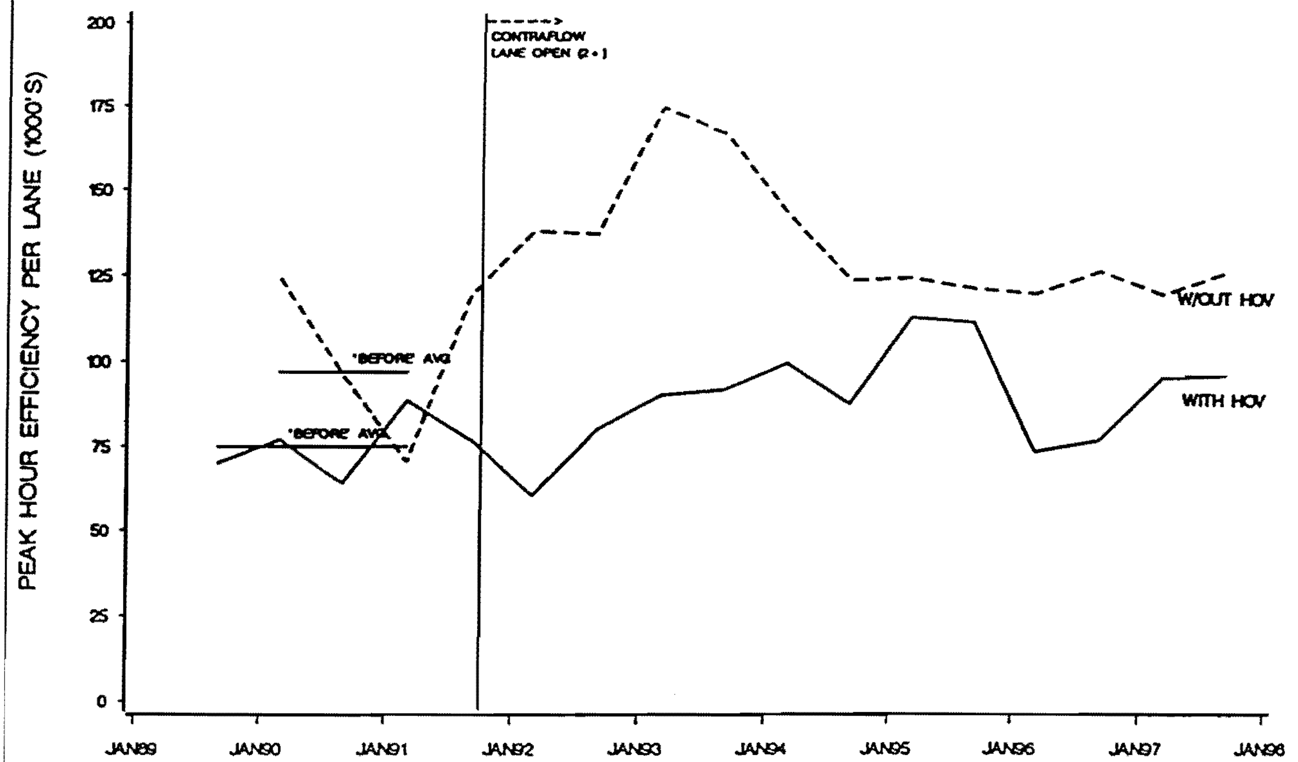


FIGURE F-16. EAST R.L. THORNTON (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS

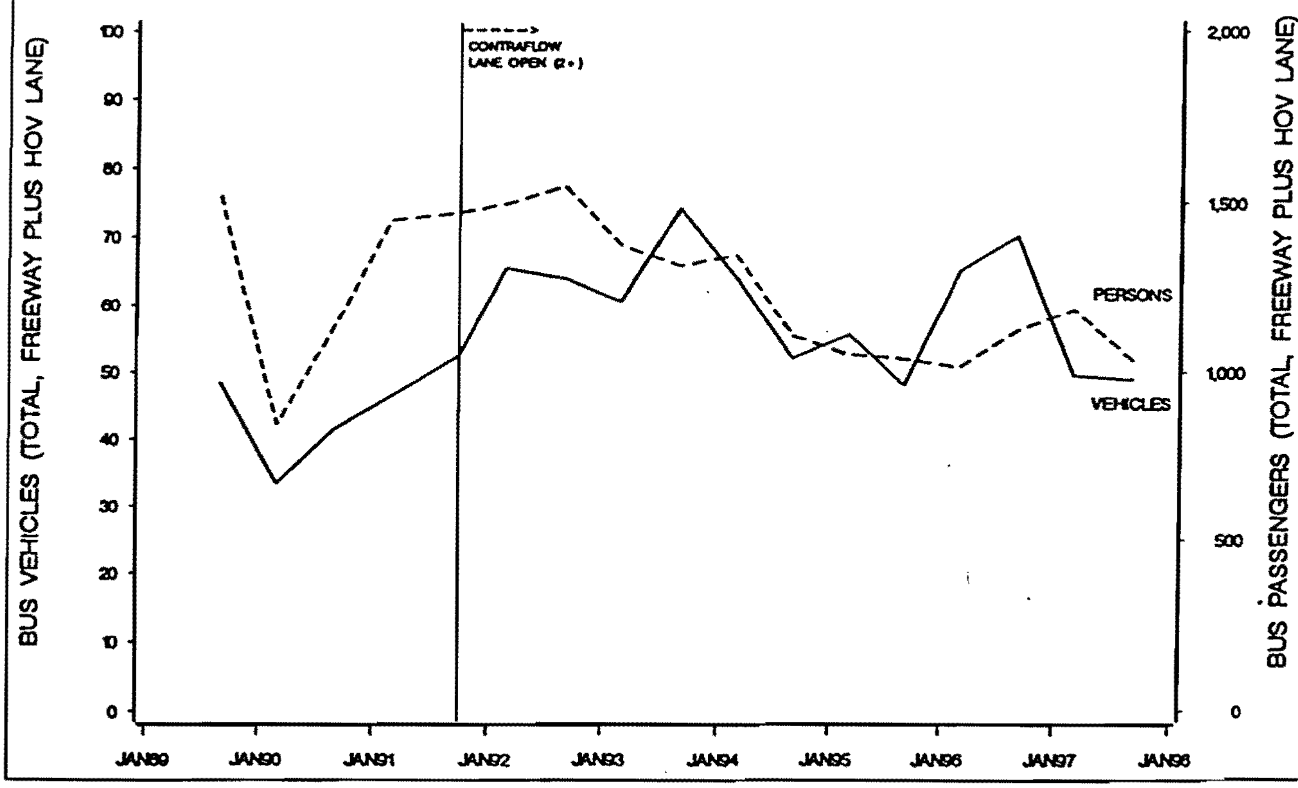


FIGURE F-17. EAST R.L. THORNTON (IH 30E) MAINLANE AND HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS

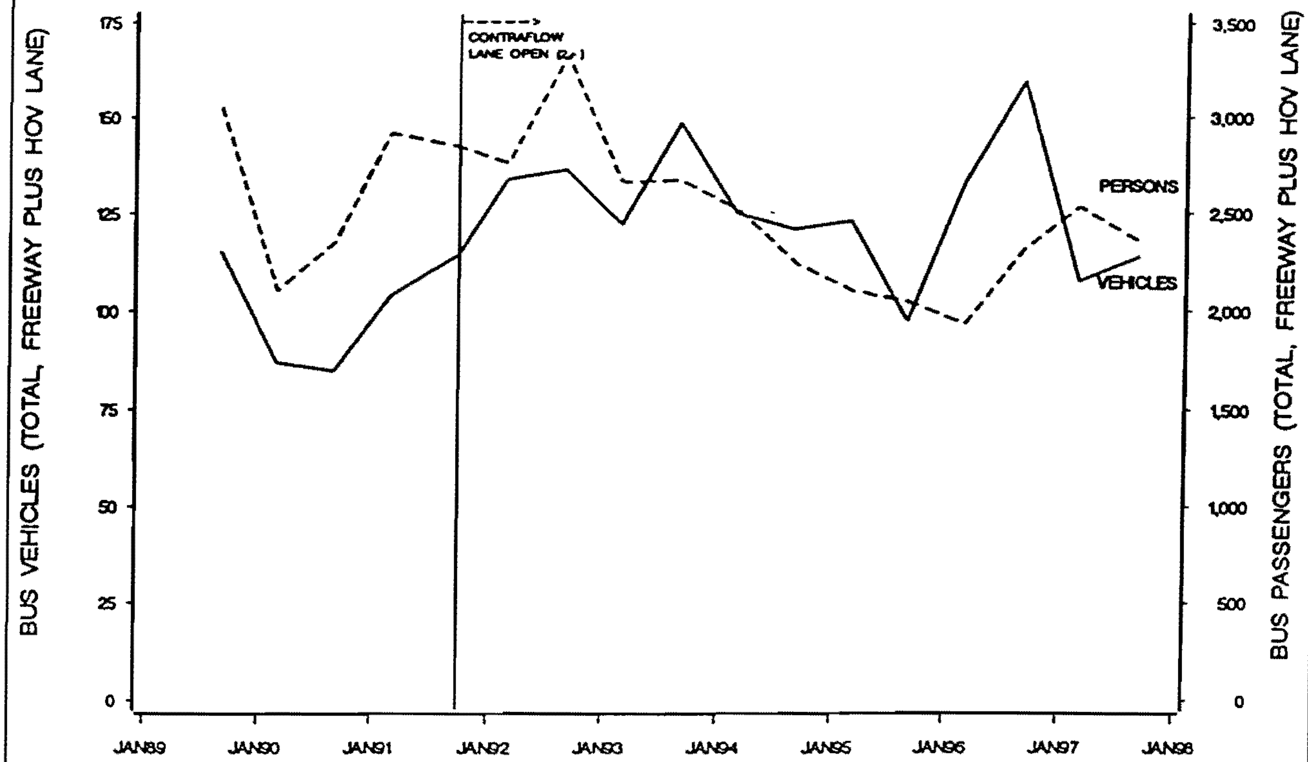
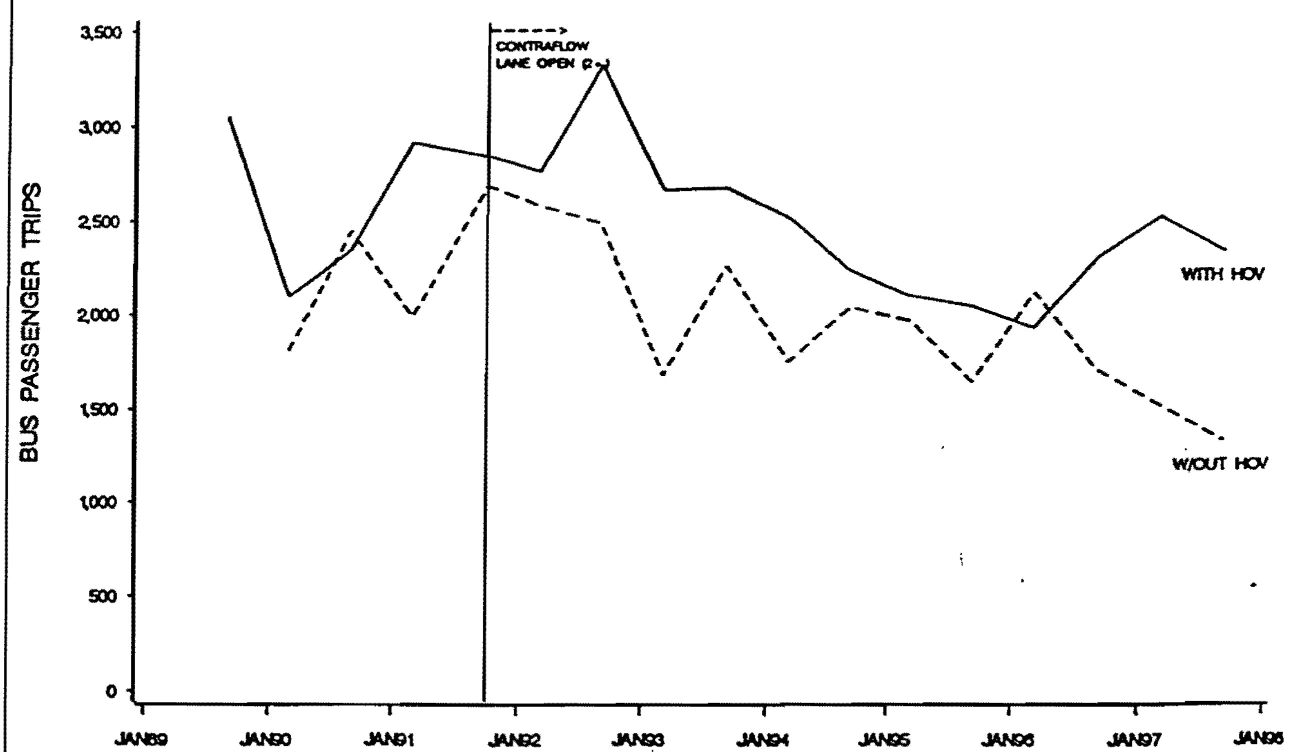


FIGURE F-18. A.M. PEAK PERIOD BUS PASSENGER TRIPS
TOTAL, FREEWAY PLUS HOV LANE
EAST R.L. THORNTON FREEWAY AND FREEWAY WITHOUT HOV LANE



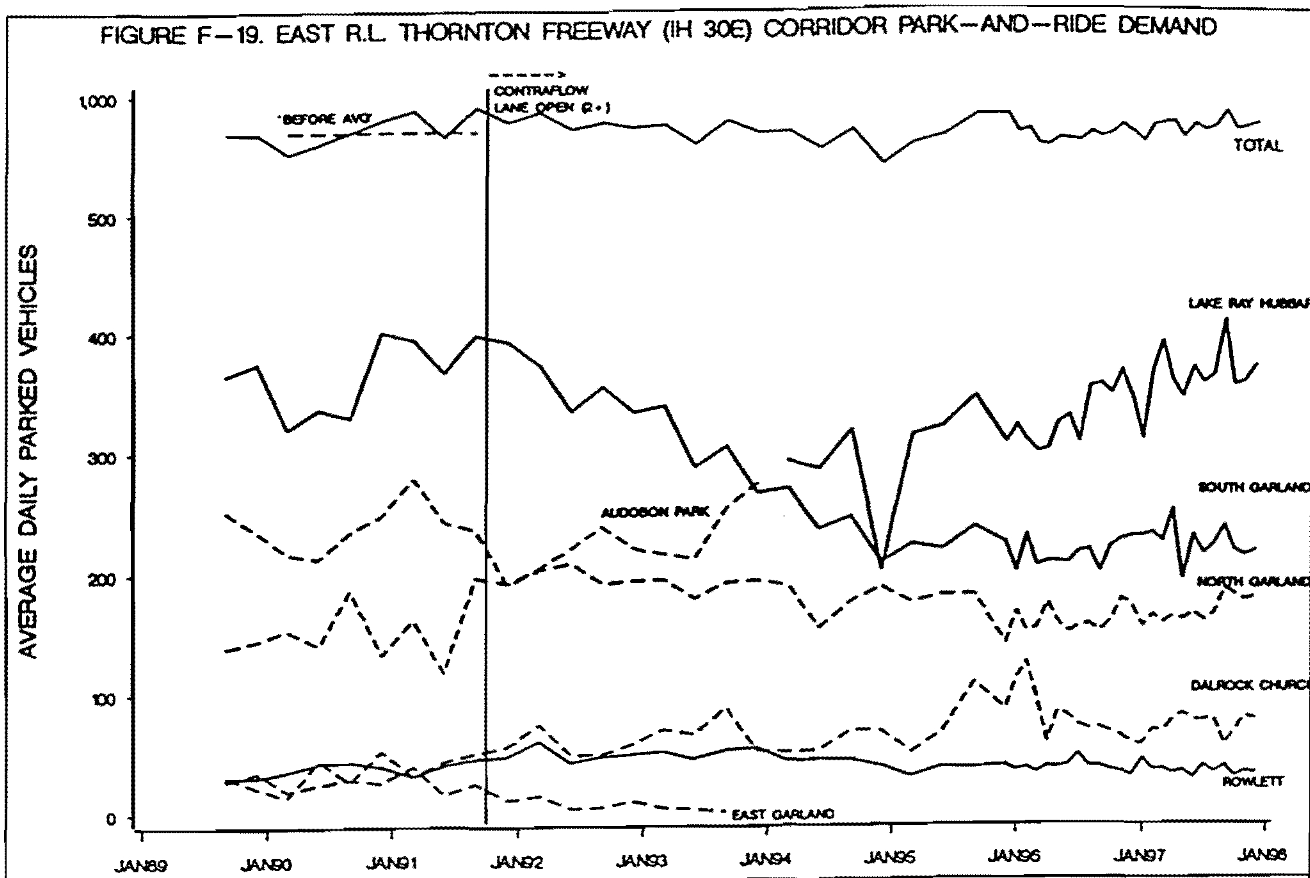


FIGURE F-19. EAST R.L. THORNTON FREEWAY (IH 30E) CORRIDOR PARK-AND-RIDE DEMAND
CONTRAFLOW LANE OPEN (2+)
"BEFORE AVG"
TOTAL
LAKE RAY HUBBARD
AUDOBON PARK
SOUTH GARLAND
NORTH GARLAND
DALROCK CHURCH
ROWLETT
EAST GARLAND
AVERAGE DAILY PARKED VEHICLES
1,000
500
400
300
200
100
0
JAN89
JAN90
JAN91
JAN92
JAN93
JAN94
JAN95
JAN96
JAN97
JAN98

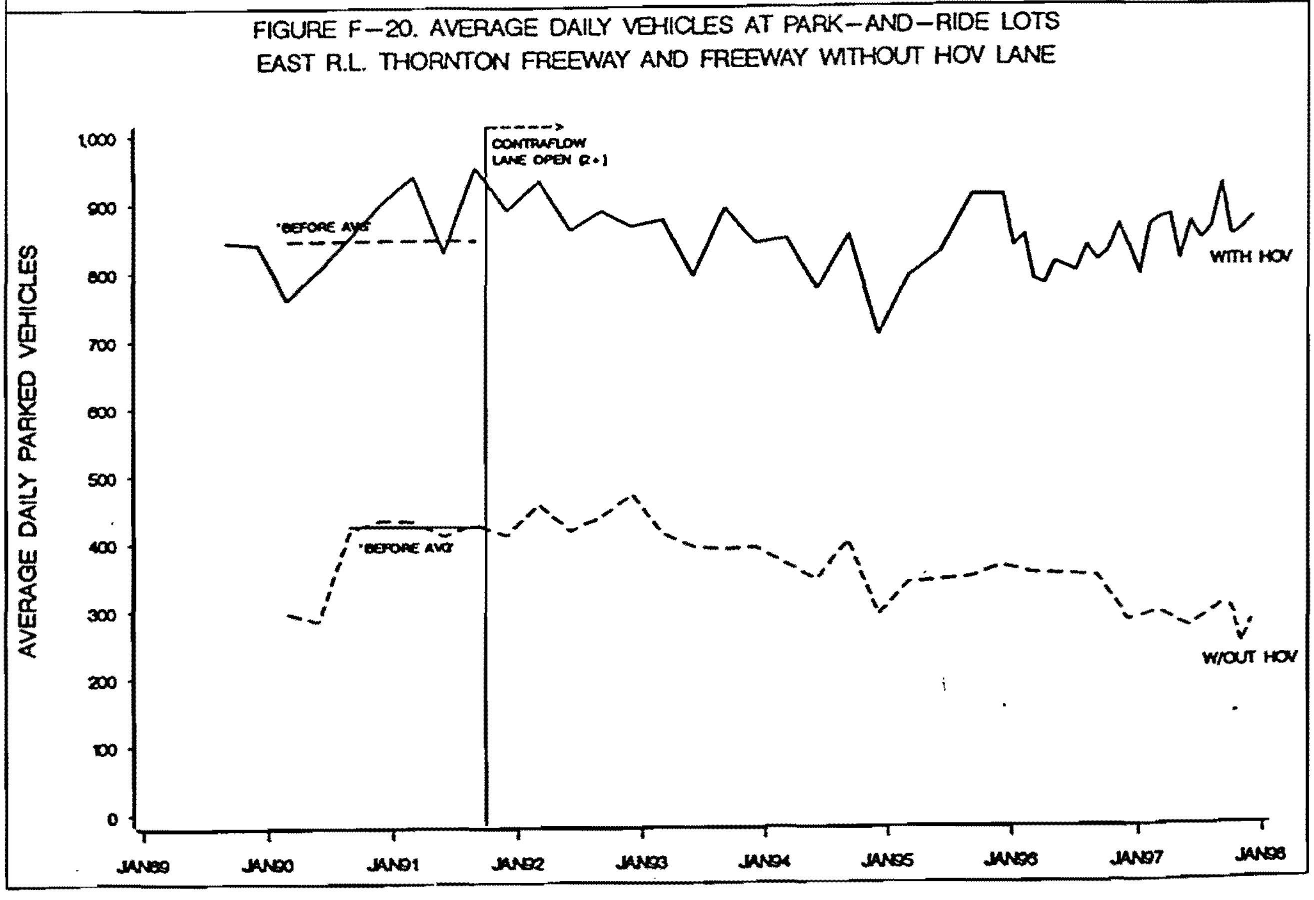


FIGURE F-20. AVERAGE DAILY VEHICLES AT PARK-AND-RIDE LOTS
EAST R.L. THORNTON FREEWAY AND FREEWAY WITHOUT HOV LANE
CONTRAFLOW LANE OPEN (2+)
"BEFORE AVG"
WITH HOV
W/OUT HOV
AVERAGE DAILY PARKED VEHICLES
1,000
900
800
700
600
500
400
300
200
100
0
JAN89
JAN90
JAN91
JAN92
JAN93
JAN94
JAN95
JAN96
JAN97
JAN98

APPENDIX G

STEMMONS FREEWAY AND HOV LANE DATA

STEMMONS FREEWAY (I-35) AND HOV LANE, DALLAS

Table G-1. Summary of A.M. Peak-Direction Stemmons Freeway and HOV Lane Data, 1997

Type of Data HOV Lane Became Operational 9/16/96	"Representative" Pre-HOV Lane	"Representative" Current Value	Percent Change
HOV Lane Data			
HOV Lane Length kilometers (miles)			
Northbound		5.5	
Southbound		6.8	---
HOV Lane Cost (millions of 1990 dollars)		$9.9	
Person-Movement			---
Peak-Hour (7:00-8:00 a.m.)		2,294	---
Peak-Period (6:00-9:00 a.m.)		4,685	
Total Daily		21,013	---
Vehicle Volumes			---
Peak-Hour		995	---
Peak-Period		2,012	---
Vehicle Occupancy, Peak-Hour (persons/veh)		2.3	---
Accident Rate (i.e., Injury accidents/100 MVM)[1]		16.4	---
Vehicle Breakdowns (VMT/Breakdown)		100,361	---
Violation Rate (6:00-9:00 a.m.)		5.5%	---
Peak-Hour Lane Efficiency (1000's)[2]		126	---
Annual Discounted Benefits (millions)[3]		$14	
Annual Delay Savings (millions)[4]		$6	
Freeway Mainlane Data (see note)			
Person-Movement			
Peak-Hour	6,594	6,070	-8%
Peak-Period (6:00-9:00 a.m.)	17,884	16,241	-9%
Vehicle Volume			
Peak-Hour	5,965	5,755	-4%
Peak-Period	16,338	15,276	-7%
Vehicle Occupancy, Peak-Hour (persons/veh)	1.11	1.05	-5%
Accident Rate (i.e., Injury accidents/100 MVM])[1]	18.6	17.6	-12%
Avg. Operating Speed[5] (mph)			
Peak-Hour	24	23	-5%
Peak-Period	35	36	+4%
Peak-Hour Lane Efficiency (1000's)[2]	53	47	-13%

Source: Texas Transportation Institute. The Texas A&M University System.
Current values are an average of calendar year 1997 quarterly data (March, June, September, and December).
Pre-HOV is an average of September 1993-March 1995 quarterly data.

[1] In order to compare accidents to Houston, this analysis includes only injury accidents. "Before" data are for the period from 1/94 through 12/94. "After" data is for the period from 1/97 through 12/97.

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

[3] Based on average annual delay, reduced vehicle operating costs, and reduced accident costs generated by MicroBENCOST over a 20-year life.

[4] per MicroBENCOST, over 20-year life.

[5] From Frankford to IH-635, the distance is 6.8 mi.

Table G-1. Summary of A.M. Peak-Direction Stemmons Freeway and HOV Lane Data

Type of Data HOV Lane Became Operational 9/16/96	Representative Pre-HOV Lane	Representative Current Value	Percent Change
Combined Freeway Mainlane and HOV Lane Data			
Total Person-Movement			
Peak-Hour	6,594	8,363	+27%
Peak-Period	17,884	20,926	+17%
Vehicle Volume			
Peak-Hour	5,965	6,750	+13%
Peak-Period	16,338	17,287	+6%
Vehicle Occupancy			
Peak-Hour	1.11	1.24	+12%
Peak-Period	1.09	1.21	+11%
2+ Carpool Volumes			
Peak-Hour	313	1,183	+278%
Peak-Period	870	2,620	+201%
Travel Time (minutes)			
Peak-Hour	16.6[1]	7.3[2]	-56%
Peak-Period	11.7[1]	6.9[2]	-41%
Peak-Hour Lane Efficiency (1000's)[1]	53	67	+24%
Transit Data			
Bus Vehicle Trips			
Peak-Hour	8	9	+13%
Peak-Period	20	23	+15%
Bus Passenger Trips			
Peak-Hour	61	63	+1%
Peak-Period	549	593	+8%
Bus Occupancy (persons/bus)			
Peak-Hour	31.6	29.2	-8%
Peak-Period	27.8	25.5	-8%
Vehicles Parked in Corridor Park-and-Ride Lots	526	637	+21%
Bus Operating Speed (mph)			
Peak-Hour	24[2]	55[3]	+126%
Peak-Period	35[2]	59[3]	+70%

Source: Texas Transportation Institute. The Texas A&M University System.
Current values are an average of calendar year 1997 (March, June, September, and December).
[1]This represents the multiple of peak-hour passengers and average speed (passengers x mph/number of lanes).
[2]Data pertain to operation in the freeway mainlanes.
[3]Data pertain to operation in the HOV lane.

Table G-2. A.M. Peak Direction Data - Comparison of Measures of Effectiveness, Freeway with (Stemmons) and Freeway without (South R.L. Thornton) HOV Lane, Dallas

Measure of Effectiveness	Representative Pre-HOV Lane Value	Representative Current Value	Percent Change
Average A.M. Peak-Hour Vehicle Occupancy			
Freeway w/HOV lane	1.11	1.24	+12%
Freeway w/o HOV lane	1.25	1.20	-4%
Peak-Hour 2+ Carpool Volume			
Freeway w/HOV lane	313	1,183	+278%
Freeway w/o HOV lane	802	695	-13%
Bus Passengers, Peak-Period			
Freeway w/HOV lane	549	593	+8%
Freeway w/o HOV lane	2,540	1,393	-45%
Cars Parked at Park-and-Ride Lots			
Freeway w/HOV lane	526	637	+21%
Freeway w/o HOV lane	425	452	+6%
Facility Per Lane Efficiency			
Freeway w/HOV lane	53	67	+24%
Freeway w/o HOV lane	67	74	+10%

Current values are an average of calendar year 1997 quarterly data (March, June, September, and December).

HOV LANE DATA DESCRIPTION

- The Northbound operation (5.5 mi) and Southbound operation (6.8 mi) opened September 16, 1996.
- The capital cost for the completed facility in 1996 dollars was $9.9 million. The following table (Table G-3) provides a more detailed cost breakdown (including dates).

Table G-3. Estimated Capital Cost (millions), Stemmons HOV Lane

Cost Component	Year of Construction Cost	Factor	Estimated Cost 1995 dollars
HOV Lane and Ramps (1996)			
Concurrent Flow Lane	7.0	0.97	$7.8
S-ramp (Reversible ramp through the IH-635 Interchange)	2.9	0.97	2.8
TOTAL COST	$9.9		$10.6
COST PER KILOMETER (6.2 mi)	$1.6		$1.7

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

PERSON-MOVEMENT

- In 1997, the HOV lane served an average of 21,013 person trips per day.
- A.M. peak hour, 2,294 persons/hour.
    - 245 (11 percent) by DART bus, 22 (1 percent) by vanpool, 1,965 (86 percent) by carpool, and 7 by motorcycle (Figure G-1).
    - Average HOV lane vehicle occupancy = 2.3 persons/vehicle.
- A.M. peak period, 4,685 persons.
    - 540 (12 percent) by DART bus, 71 (2 percent) by vanpool, 3,948 by carpool (84 percent), and 16 by motorcycle (Figure G-2).

VEHICLE MOVEMENT

- A.M. peak hour, 995 vph
    - 8 (1 percent) DART buses, 4 (1 percent) vans, 922 (93 percent) carpools, and (1 percent) by motorcycle (Figure G-3).
- A.M. peak period, 2,012 vehicles
    - 20 (1 percent) buses, 11 (1 percent) vans, 1,854 (92 percent) carpools, and 16 (1 percent) by motorcycle (Figure G-4).

ACCIDENT RATE

- For the period from January 1997 through December 1997, the HOV lane accident rate was 16.4 injury accidents per 100 million vehicle miles.

VEHICLE BREAKDOWN RATES

- As measured for 1/97 to 12/97, the following rate has been observed.
    - The average for all vehicle types is 100,361 miles traveled per breakdown.

FIGURE G-1. STEMMONS FREEWAY (IH 35N) HOV LANE
A.M. PEAK HOUR HOV LANE PERSON MOVEMENT

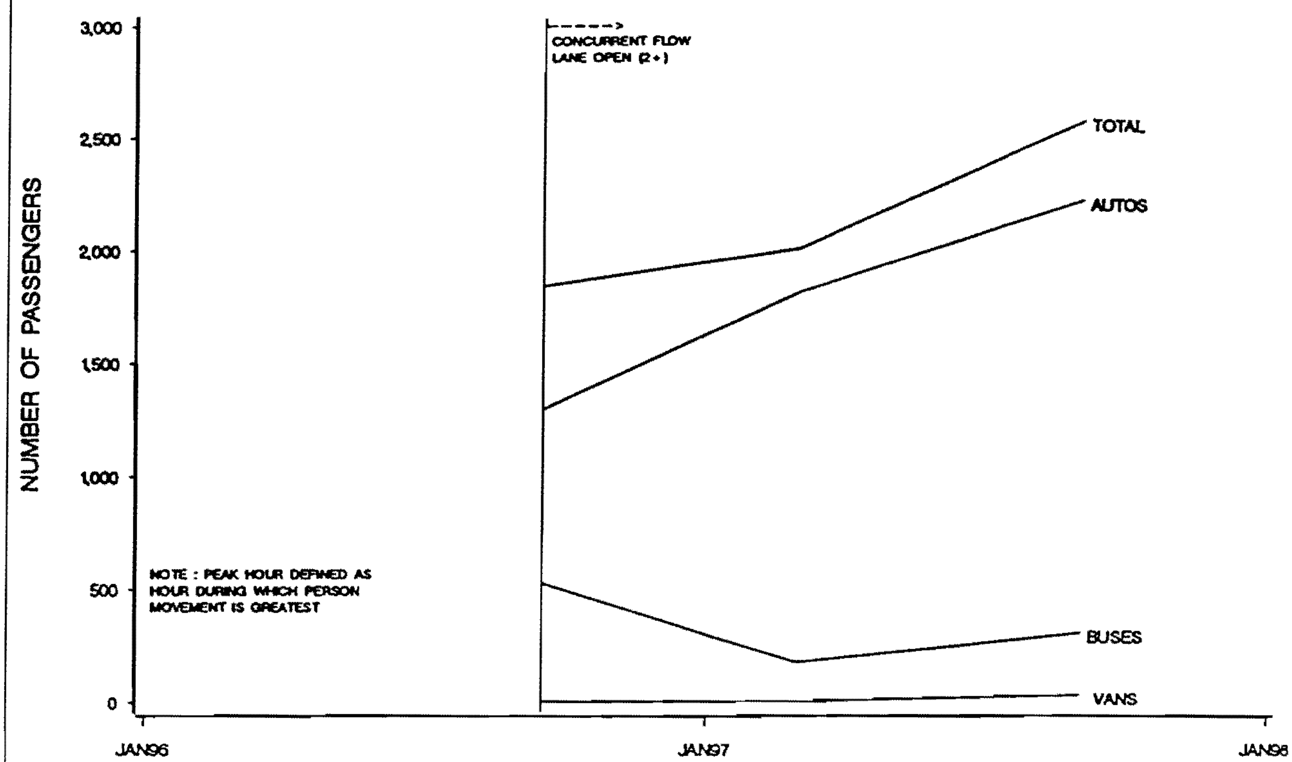


FIGURE G-2. STEMMONS FREEWAY (IH 35N) HOV LANE
A.M. PEAK PERIOD HOV LANE PERSON MOVEMENT

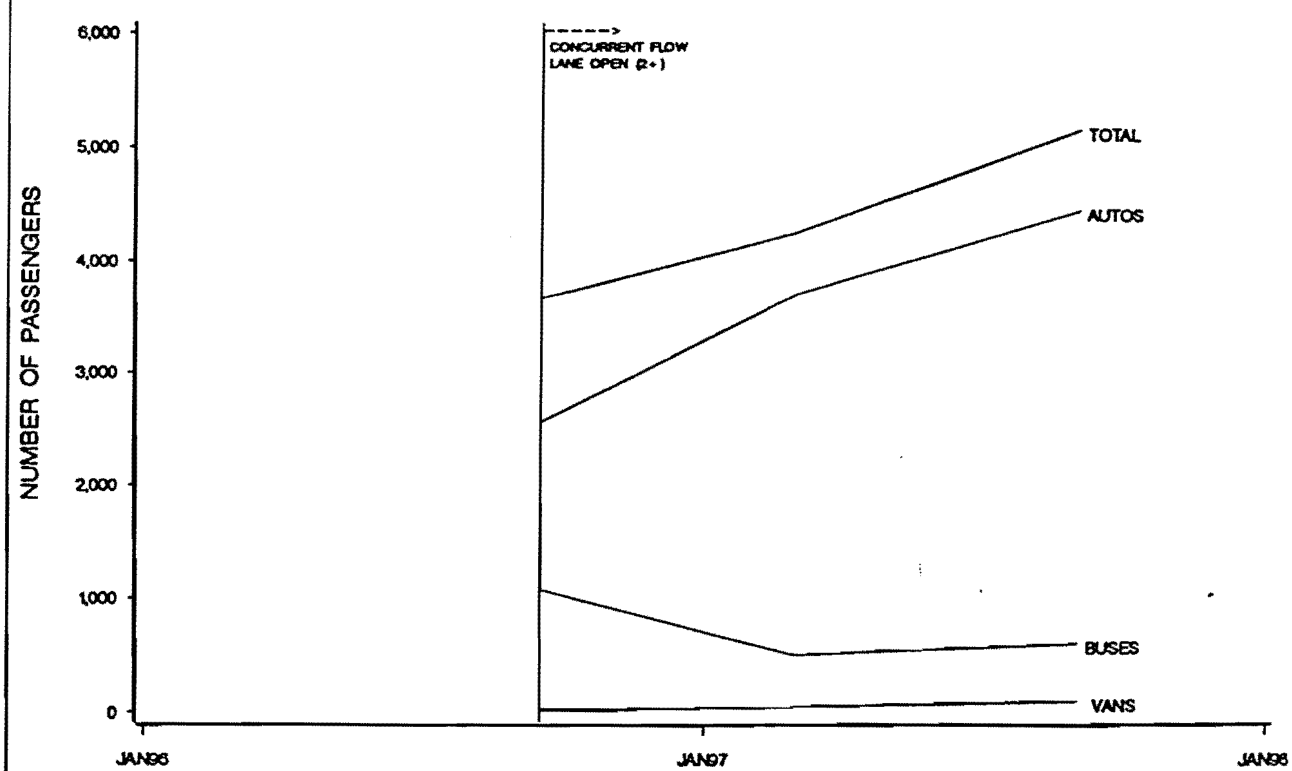


FIGURE G-3. STEMMONS FREEWAY (IH 35N) HOV LANE
A.M. PEAK HOUR HOV LANE VEHICLE UTILIZATION

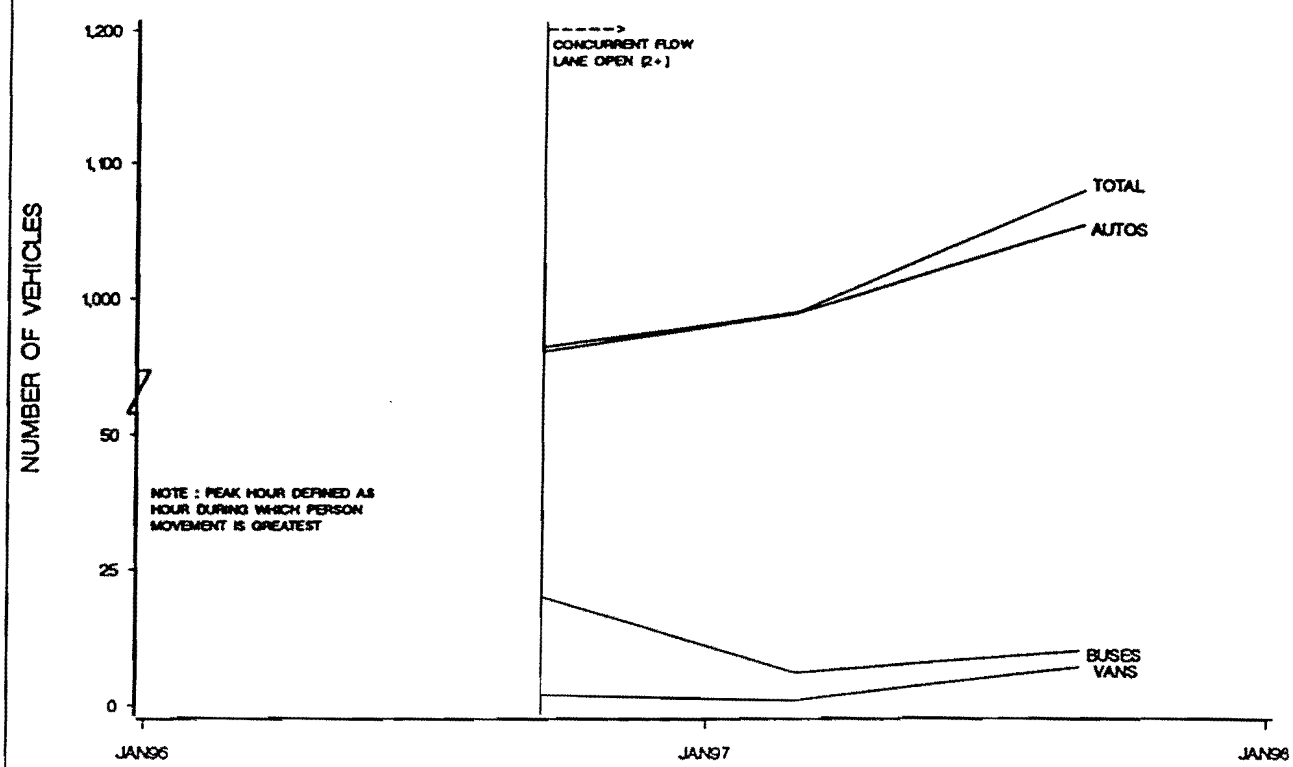
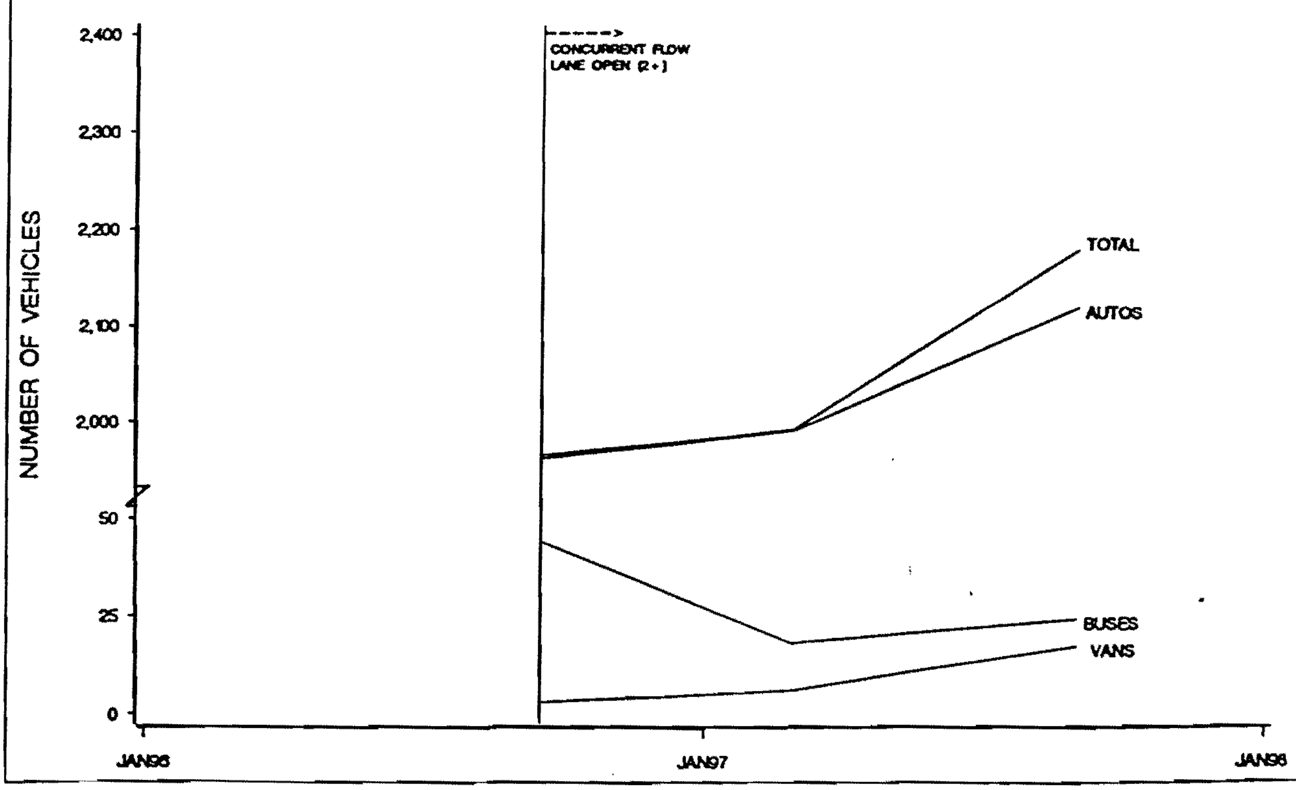


FIGURE G-4. STEMMONS FREEWAY (IH 35N) HOV LANE
A.M. PEAK PERIOD HOV LANE VEHICLE UTILIZATION



VIOLATION RATE

- The observed violation rate (vehicles on the HOV lane not eligible to use the HOV lane), varies by time period.
  - For the overall a.m. peak period, it is 5.5 percent.

PEAK-HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is used as a measure of the efficiency of a lane. For the HOV lane, this value (expressed in 1000's) is approximately 126 (2,294 passengers at 55 mph).

TRAVEL TIME SAVINGS

- The users of the HOV lane experienced an average travel time savings of six minutes during the morning peak hour in 1997 (Table G-4, Figure G-5).

Table G-4. Travel Time Savings for Stemmons HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1997)

Southbound A.M. Travel Time Savings for Stemmons HOV Lane								
Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Section from Northern Limits of HOV lane to S-Ramp								
6:00	6.79	6.51	0.28	126	5	10	141	39
6:15	6.79	6.51	0.28	194	7	35	236	66
6:30	8.38	6.82	1.56	277	8	53	338	527
6:45	11.58	7.38	4.20	324	14	90	428	1,798
7:00	13.79	7.60	6.19	359	6	83	448	2,773
7:15	13.79	7.60	6.19	522	10	60	592	3,664
7:30	19.64	7.59	12.05	590	6	58	654	7,881
7:45	20.34	7.33	13.01	476	1	70	547	7,116
8:00	13.97	7.30	6.67	366	3	30	399	2,661
8:15	13.97	7.30	6.67	286	1	50	337	2,248
8:30	10.82	7.30	3.52	252	9	0	261	919
8:45	6.89	7.29	-0.40	169	3	3	175	-70
Peak-Period Total				3,941	73	542	4,556	29,623

Table G-4. Travel Time Savings for Stemmons HOV Lane (Average of 4 Quarterly Travel Time Surveys Conducted in 1997) (Continued)

Time of Day	Measured Travel Time			HOV Lane Person Trips				Travel Time Saved (Person-Minutes)
	Freeway (min)	HOV (min)	Savings (min)	Carpool	Vanpool	Bus	Total	
Northbound P.M. Travel Time Savings for Stemmons HOV Lane								
Section from S-Ramp to Northern Limits of HOV Lane								
4:00	6.05	5.66	0.39	199	3	13	215	84
4:15	6.05	5.66	0.39	222	1	28	251	98
4:30	6.94	5.78	1.16	248	6	38	292	339
4:45	8.36	5.79	2.57	322	5	25	352	905
5:00	12.22	6.33	5.89	354	4	58	416	2,450
5:15	12.22	6.33	5.89	439	6	78	523	3,080
5:30	12.34	6.68	5.66	479	4	63	546	3,090
5:45	12.19	6.74	5.45	420	1	100	521	2,839
6:00	10.98	6.37	4.61	368	2	35	405	1,867
6:15	10.98	6.37	4.61	301	1	30	332	1,531
6:30	9.55	6.17	3.38	230	0	43	273	923
6:45	6.07	6.03	0.04	103	5	3	111	4
Peak-Period Total				3,685	38	514	4,237	17,210

FREEWAY DATA

NOTE

- For purposes of safety and visibility, freeway volumes are counted near Sandy Lake Road between an entrance ramp and an exit ramp. This location is not necessarily the highest traffic volume section; however, the location gives reasonable estimates of traffic volumes which can be used for monitoring trends.

PERSON-MOVEMENT

- In the a.m. peak hour, person-movement has decreased by 8 percent relative to pre-HOV conditions (Figure G-6).

- In the a.m. peak period, person movement has decreased by 9 percent relative to pre-HOV conditions (Figure G-7).

VEHICLE VOLUME

- In the a.m. peak hour, vehicle volume has decreased by 4 percent relative to pre-HOV conditions (Figure G-6).

- In the a.m. peak period, vehicle volume has decreased by 7 percent relative to pre-HOV conditions (Figure G-7).

VEHICLE OCCUPANCY

- In the a.m. peak hour, mainlane occupancy has decreased by 5 percent relative to pre-HOV conditions (from 1.11 to 1.05).

- In the a.m. peak period, mainlane occupancy has decreased by 3 percent, relative to pre-HOV conditions (from 1.09 to 1.06).

ACCIDENT RATE

- The accident data shown are for the section between LBJ Freeway and Frankford Road. The accident rate for the period (1/94-12/94) preceding the HOV lane was 18.6 accidents per 100 million vehicle miles. For the period from 1/97 to 12/97, the freeway accident rate was 17.6 accidents/100 MVM. These statistics do not include driver-reported accidents; current accident files include only officer-reported accidents.

AVERAGE OPERATING SPEED

- In comparison to pre-HOV lane conditions, mainlane operating speeds have decreased by 5 percent in the peak hour and increased by 4 percent in the peak period (Figure G-8).

PEAK-HOUR LANE EFFICIENCY

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

    - For the freeway mainlanes, a decrease in per lane efficiency of 13 percent has occurred.

FIGURE G-5. STEMMONS (IH 35N) MAINLANES AND HOV LANE A.M. TRAVEL TIME

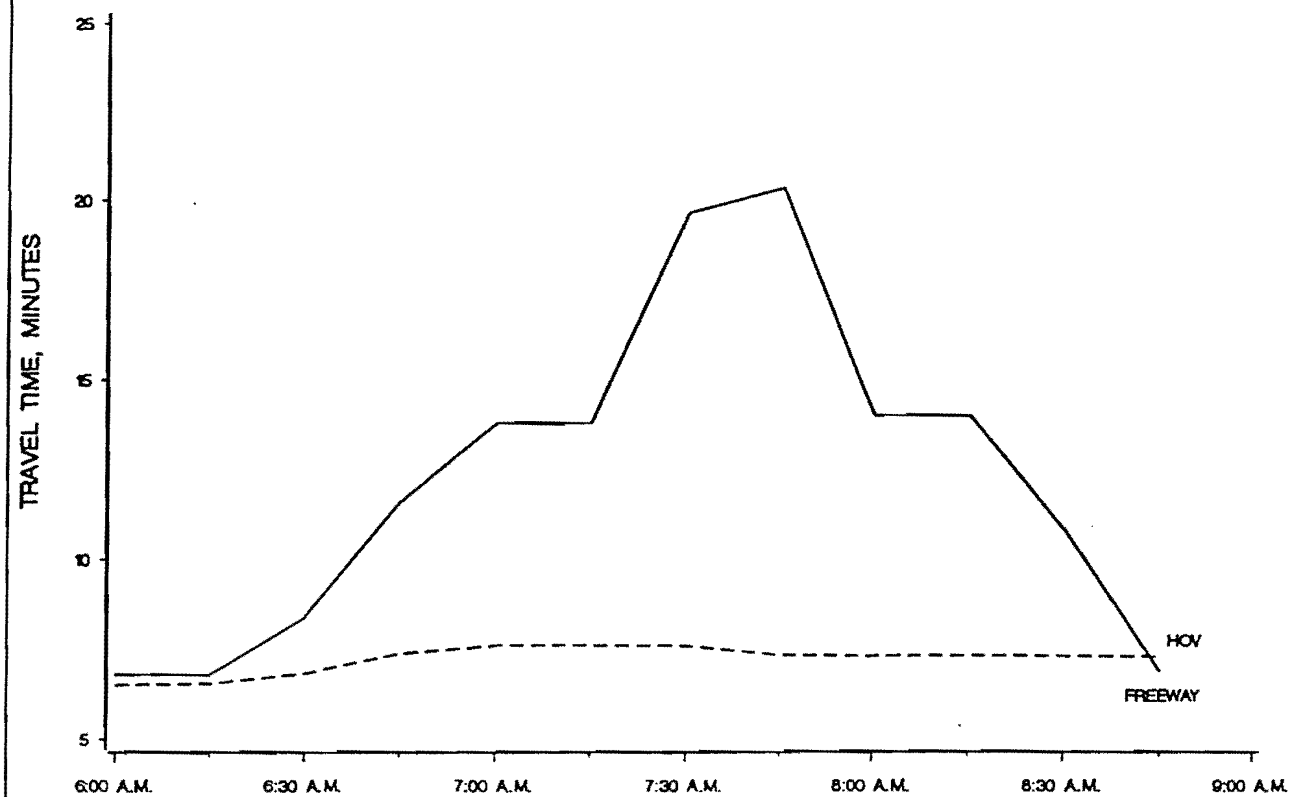


FIGURE G-6. STEMMONS FREEWAY (IH 35N)
A.M. PEAK HOUR MAINLANE TRIPS

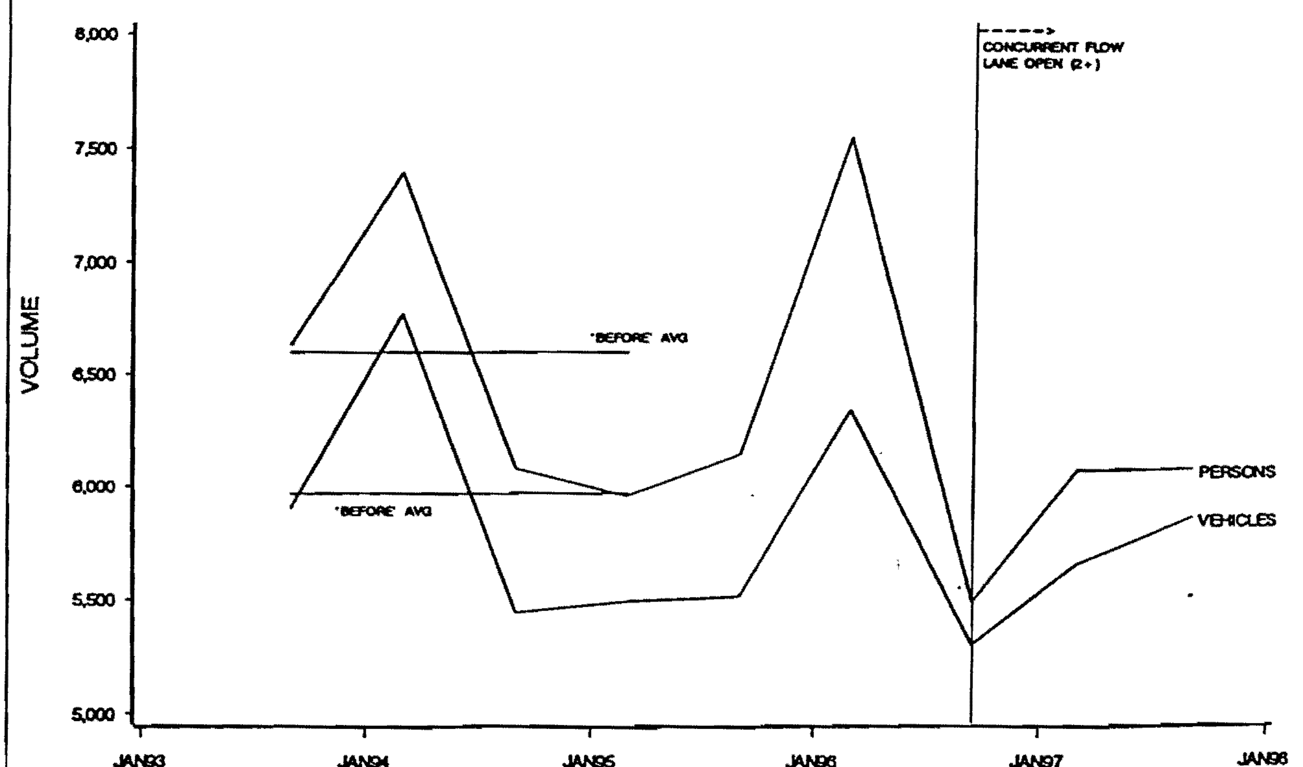


FIGURE G-7. STEMMONS FREEWAY (IH 35N)
A.M. PEAK PERIOD MAINLANE TRIPS

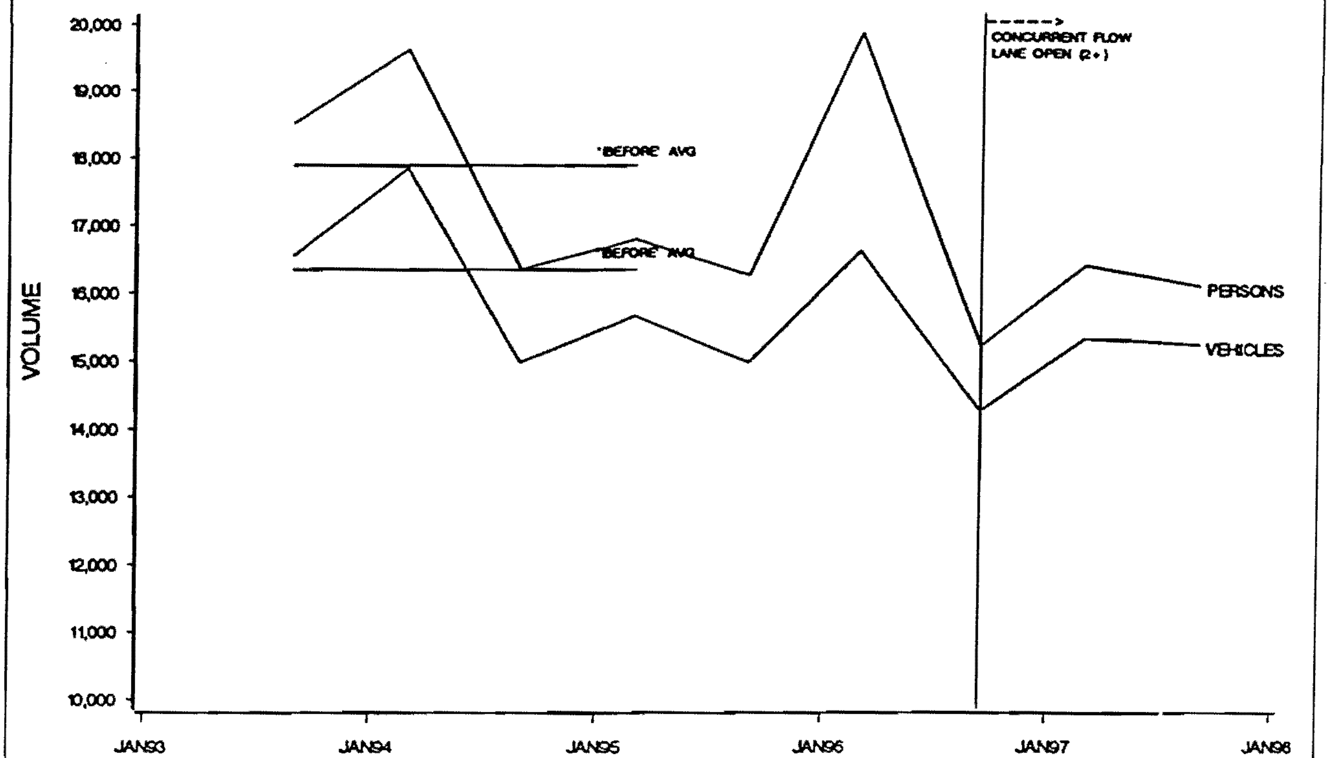
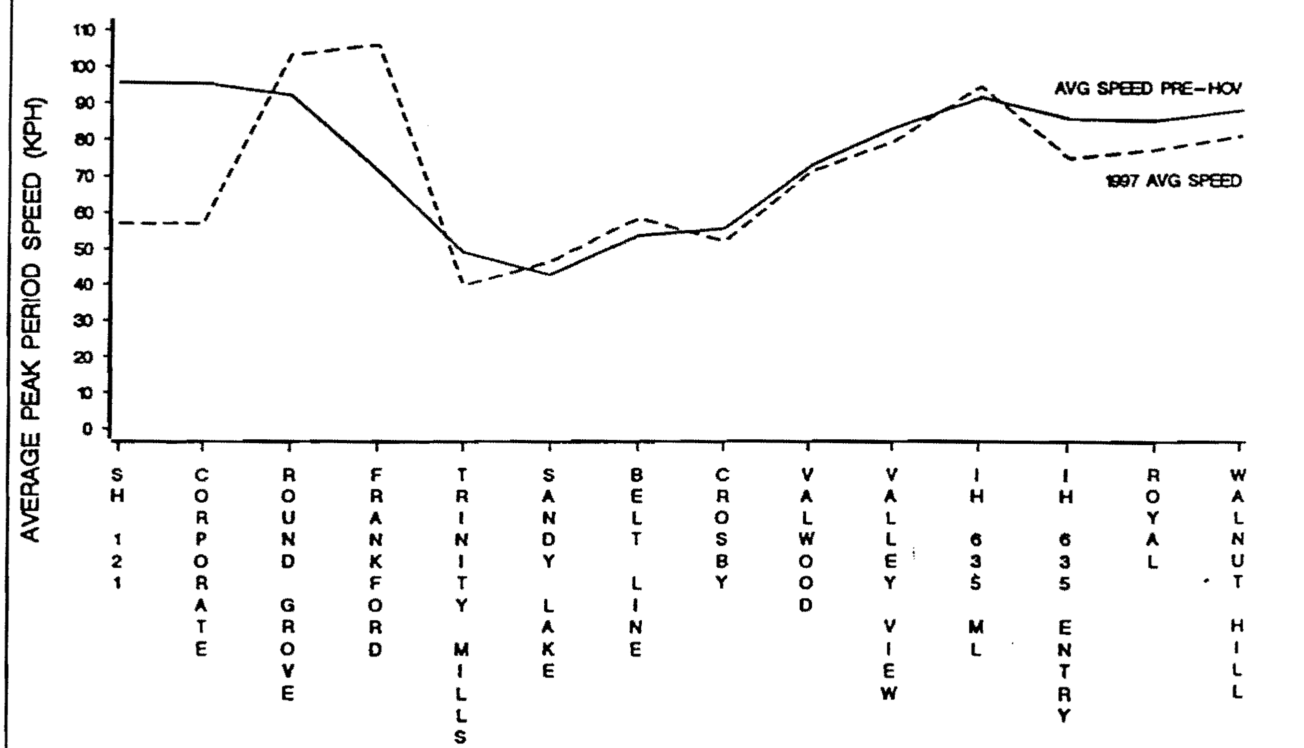


FIGURE G-8. STEMMONS (IH 35N) MAINLANE TRAVEL TIME AND SPEED SURVEY
SOUTHBOUND, SH 121 TO WALNUT HILL
A.M. PEAK PERIOD



COMBINED FREEWAY MAINLANE AND HOV LANE DATA

TOTAL PERSON-MOVEMENT

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

  - The HOV lane is responsible for 27 percent of peak-hour person-movement (HOV lane = 2,294; freeway = 6,070) and 22 percent of peak-period (HOV lane = 4,685; freeway = 16,241) person-movement.

- Increase in A.M. person-movement at Sandy Lake relative to pre-HOV lane operations.

  - Provision of the HOV lane increased total directional lanes by 33 percent in the peak period.
  - Total peak-hour person-movement has increased by 27 percent from 6,594 to 8,363 (Figure G-9). Peak-period person movement has increased by 17 percent from 17,884 to 20,926 (Figure G-10).

VEHICLE OCCUPANCY

- The combined occupancy for the freeway and HOV lane in the peak hour is 1.24 - a 12 percent increase over the pre-HOV lane occupancy (Figure G-11). Occupancy in the peak period has increased by 11 percent (Figure G-12).

- While the occupancy on the Stemmons Freeway has increased, freeways which do not have HOV lanes have experienced a decrease in occupancy (Figure G-13).

CARPOOL VOLUMES

- In the a.m. peak hour, the total number of 2+ carpools (freeway plus HOV lane) has increased by 278 percent compared to pre-HOV lane levels (Figure G-14).

PEAK-HOUR LANE EFFICIENCY

- Peak-hour passengers multiplied by average speed is sometimes used as a measure of the efficiency of a lane. The average efficiency of a lane on the freeway (3 freeway lanes plus 1 HOV lane) has increased by 24 percent since the implementation of the HOV lane (Figure G-15). The per-lane efficiency increased only 10 percent during this same time period on freeways not having HOV lanes.

BUS TRANSIT DATA

BUS VEHICLE AND PASSENGER TRIPS

- In the a.m. peak hour, bus vehicle trips have increased by 13 percent since the HOV lane opened, and a 1 percent increase in bus ridership has also resulted (Figure G-16). In the peak period, a 15 percent increase has occurred in bus trips and an 8 percent increase in bus ridership has resulted (Figure G-17).

PARK-AND-RIDE

- Prior to opening the HOV lane, approximately 526 vehicles were parked in corridor park-and-ride lots; this has increased 21 percent to a current level of 637 (Figure G-19).

- The number of parked vehicles in the representative freeway corridor without an HOV lane (South R.L. Thornton Freeway) has decreased (8 percent) (Figure G-20).

FIGURE G-9. STEMMONS FREEWAY (IH 35N) MAINLANE AND HOV LANE
A.M. PEAK HOUR PERSON TRIPS

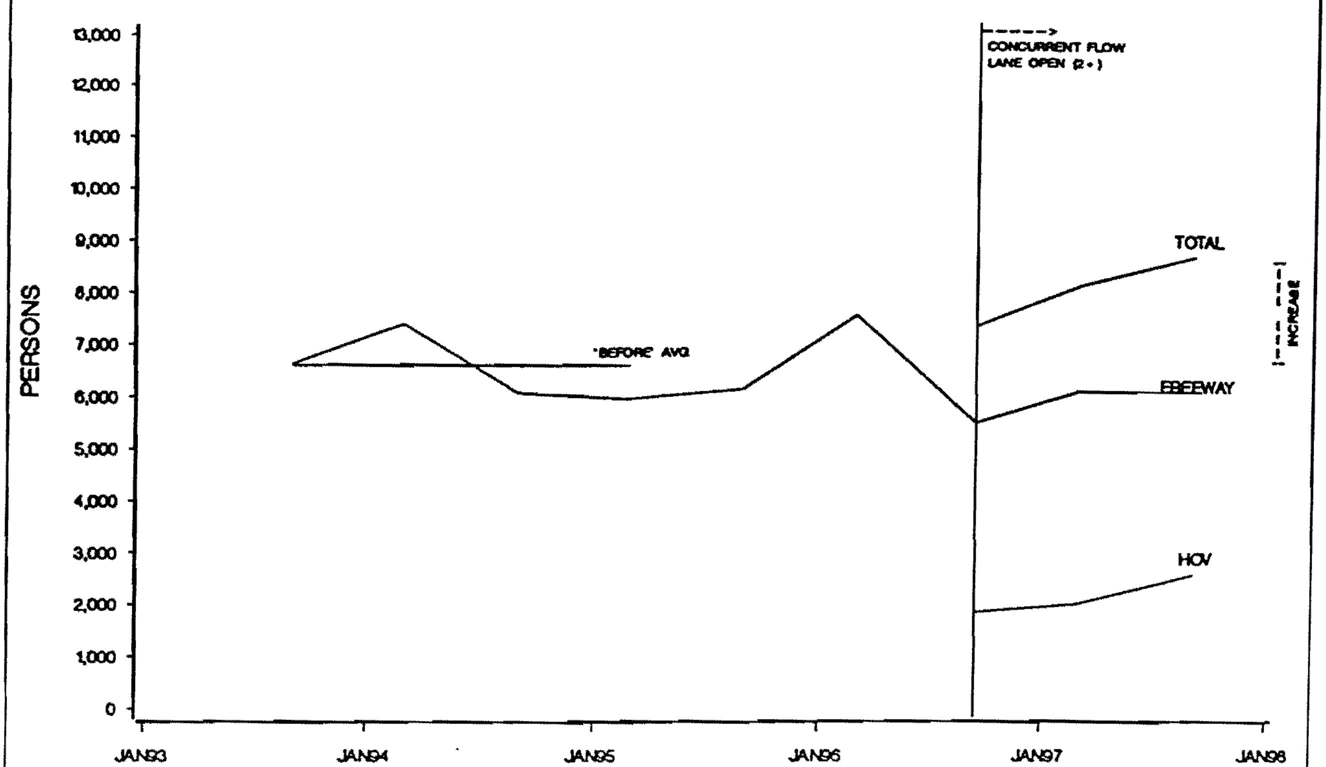


FIGURE G-10. STEMMONS FREEWAY (IH 35N) MAINLANE AND HOV LANE
A.M. PEAK PERIOD PERSON TRIPS

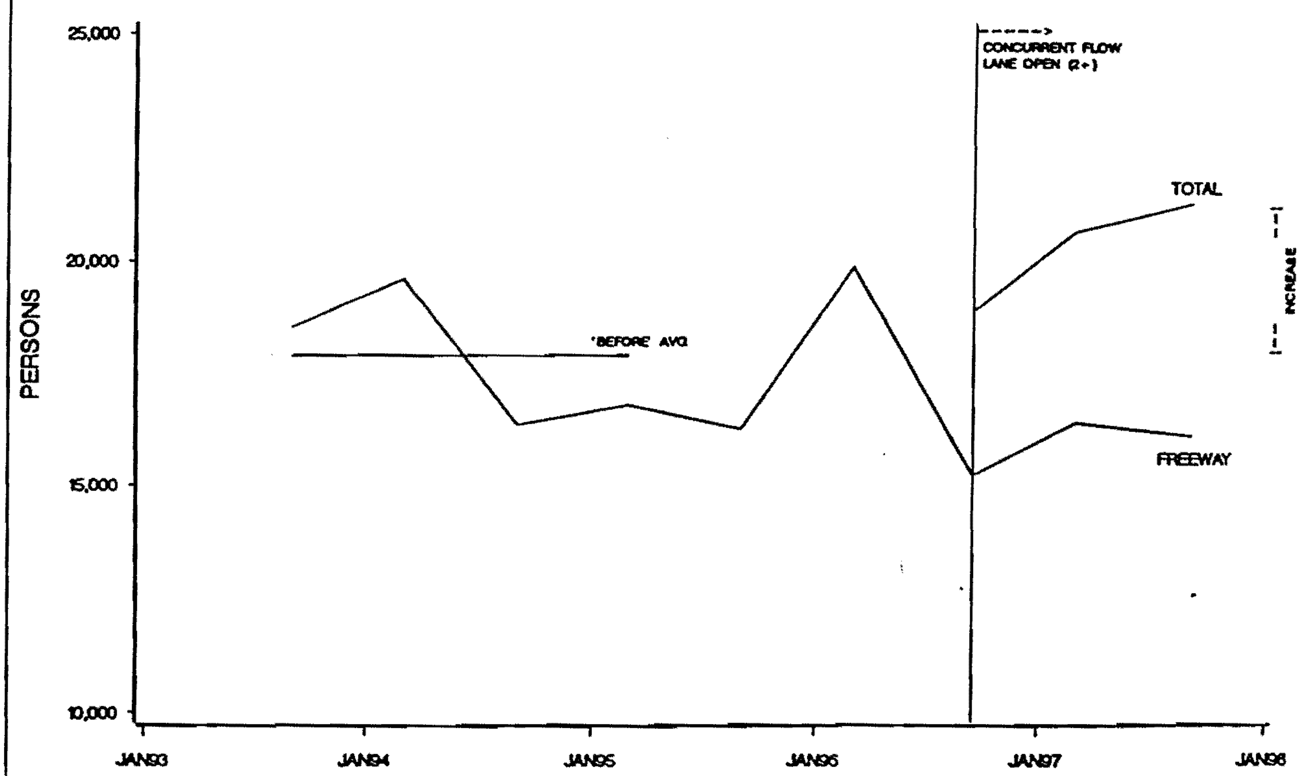


FIGURE G-11. STEMMONS FREEWAY (IH 35N) MAINLANE AND HOV LANE
A.M. PEAK HOUR AVERAGE OCCUPANCY

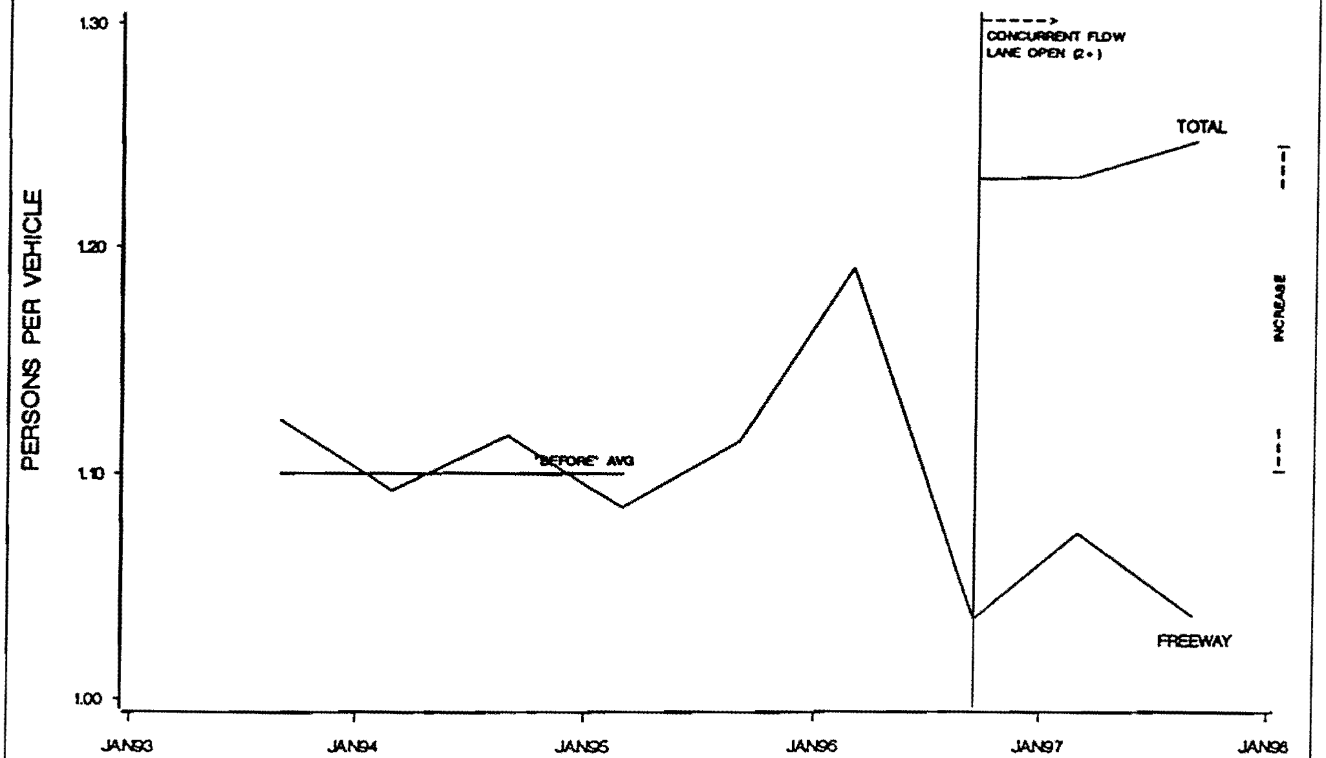


FIGURE G-12. STEMMONS FREEWAY (IH 35N) MAINLANE AND HOV LANE
A.M. PEAK PERIOD AVERAGE OCCUPANCY

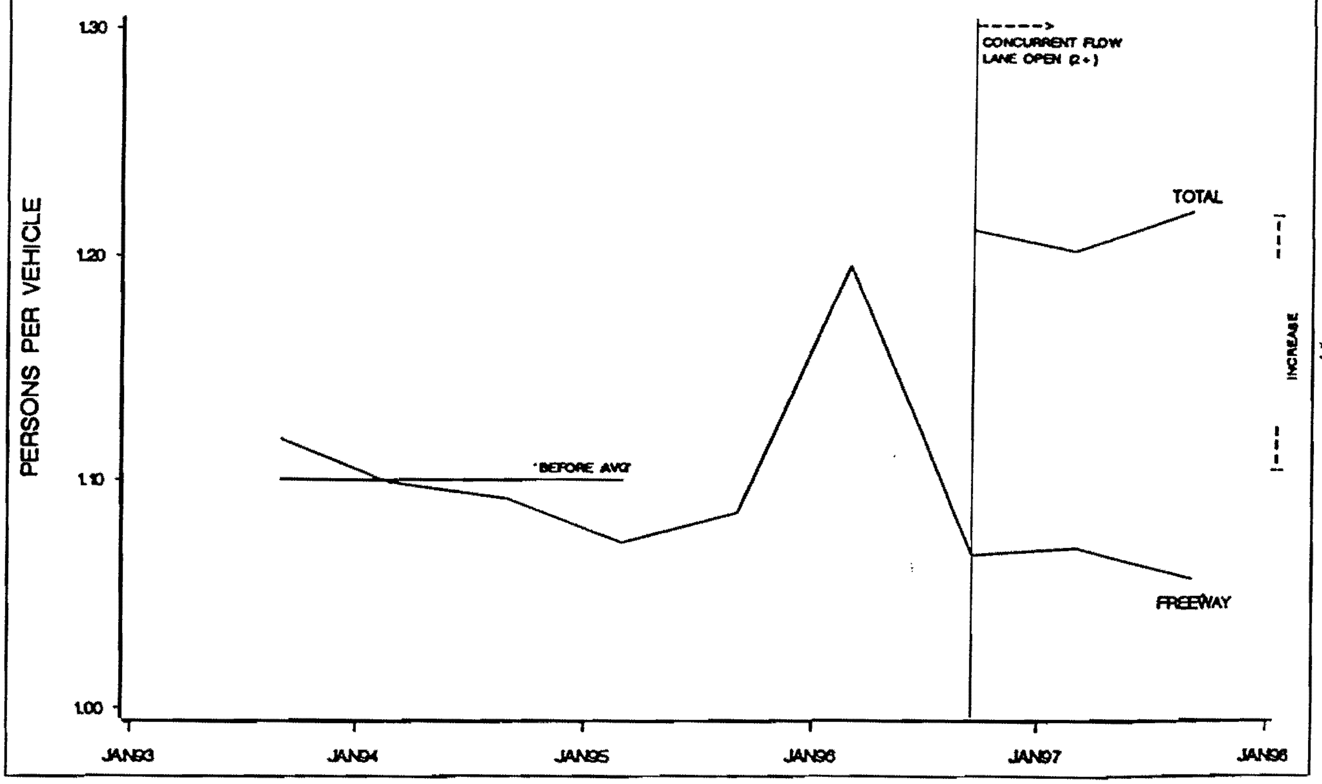


FIGURE G-13. A.M. PEAK HOUR AVERAGE OCCUPANCY STEMMONS (IH 35N) AND FREEWAY WITHOUT HOV LANE

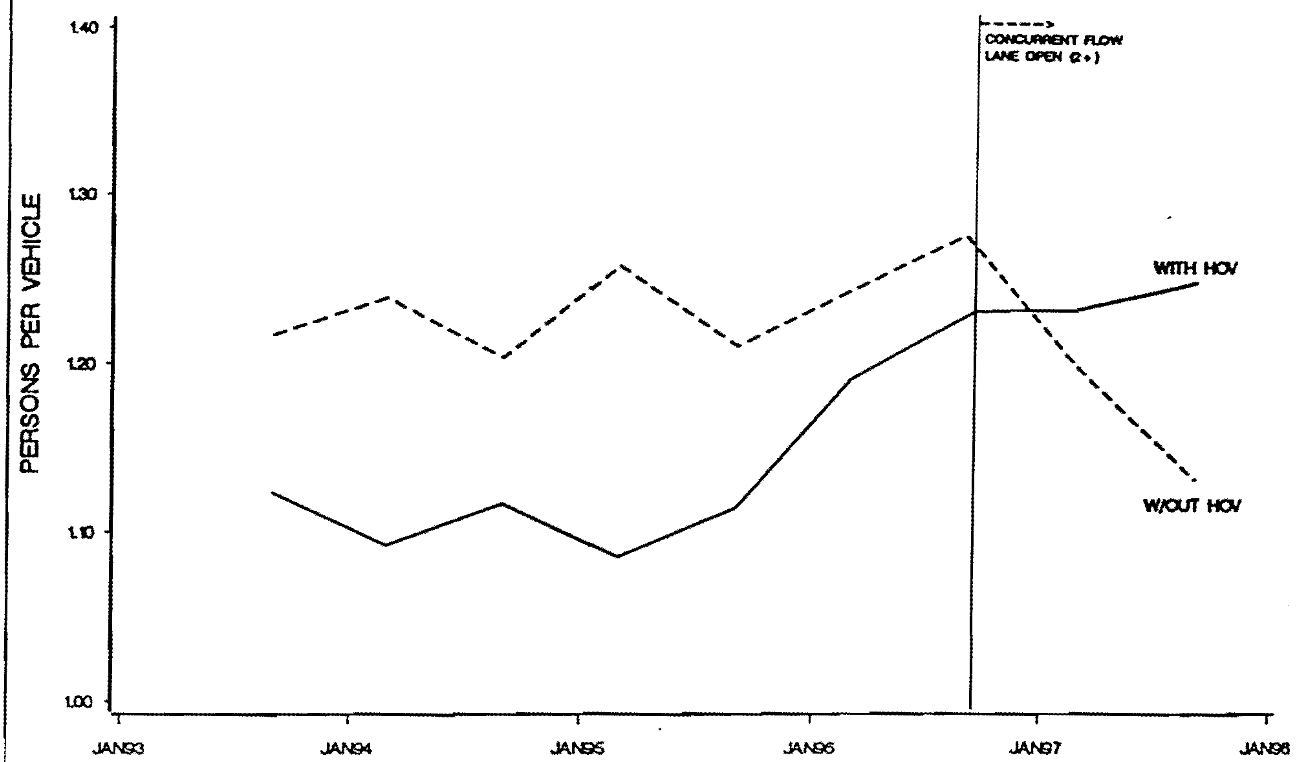


FIGURE G-14. STEMMONS (IH 35N) MAINLANE AND HOV LANE A.M. PEAK HOUR 2+ CARPOOL UTILIZATION

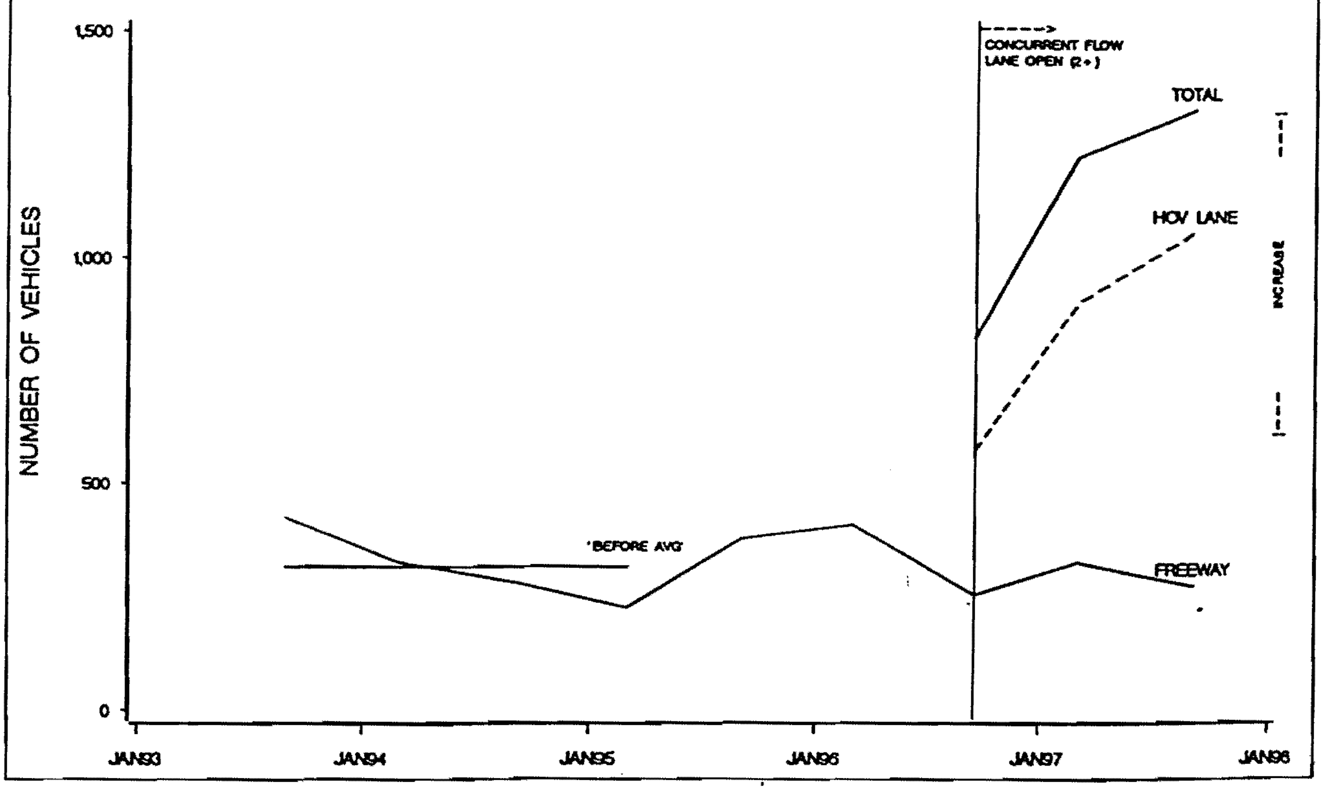


FIGURE G-15. A.M. PEAK HOUR FREEWAY PER LANE EFFICIENCY
STEMMONS FREEWAY AND FREEWAY WITHOUT HOV LANE

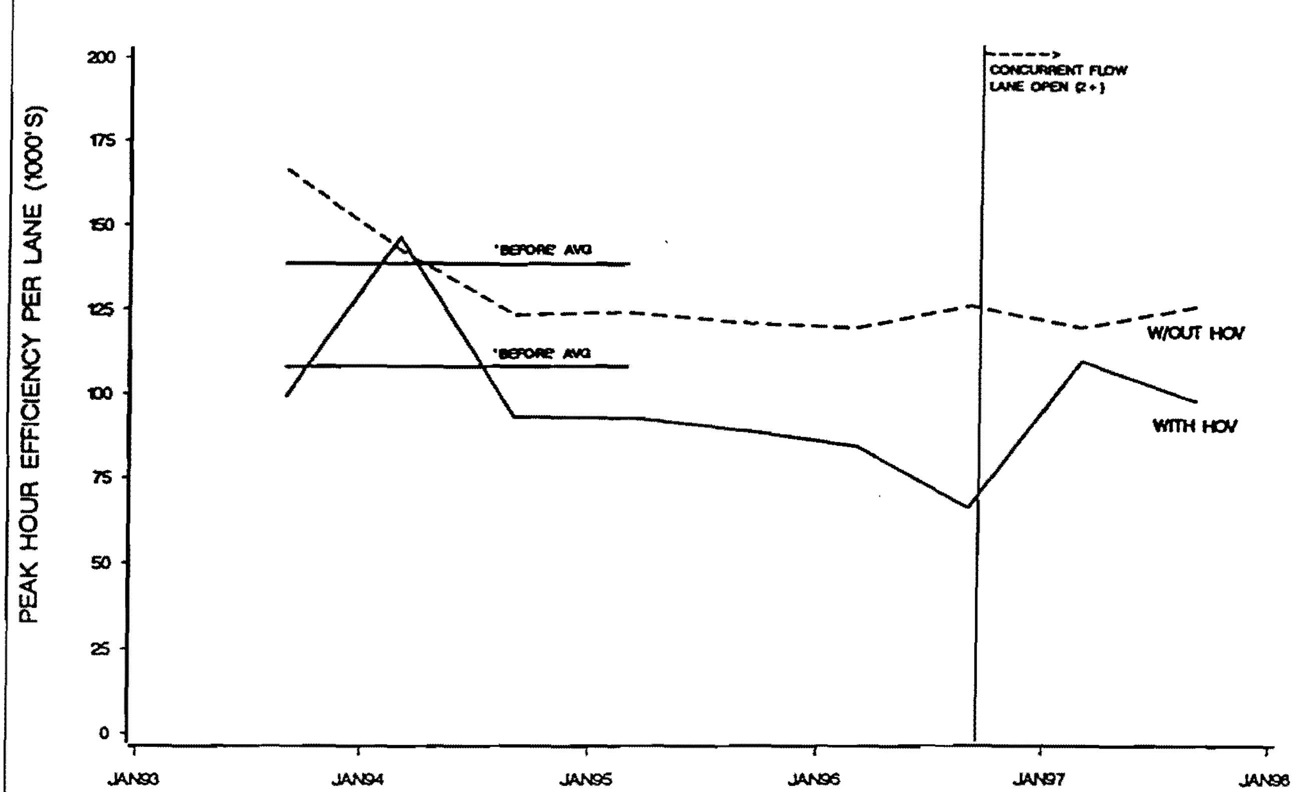


FIGURE G-16. STEMMONS (IH 35N) MAINLANE AND HOV LANE
A.M. PEAK HOUR BUS VEHICLE AND PASSENGER TRIPS

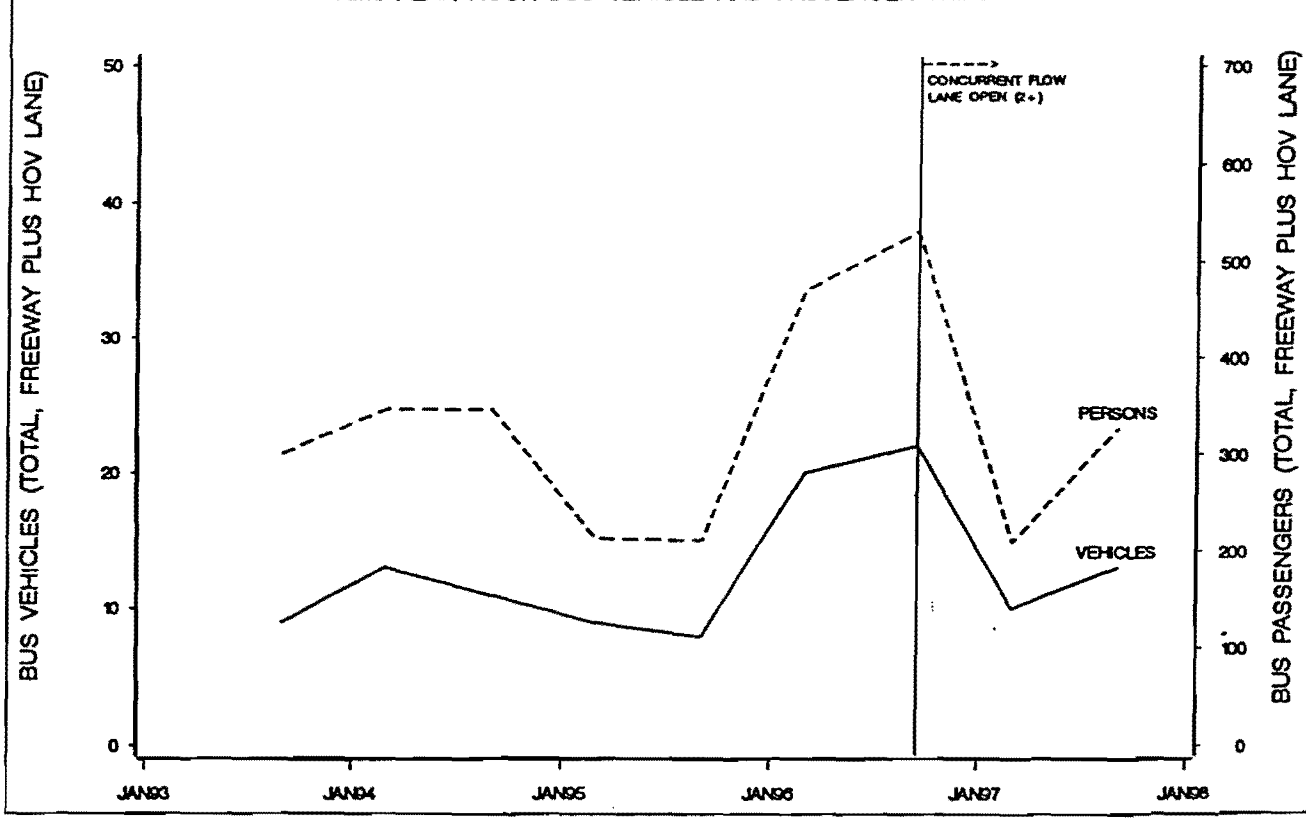


FIGURE G-17. STEMMONS (IH 35N) MAINLANE AND HOV LANE
A.M. PEAK PERIOD BUS VEHICLE AND PASSENGER TRIPS

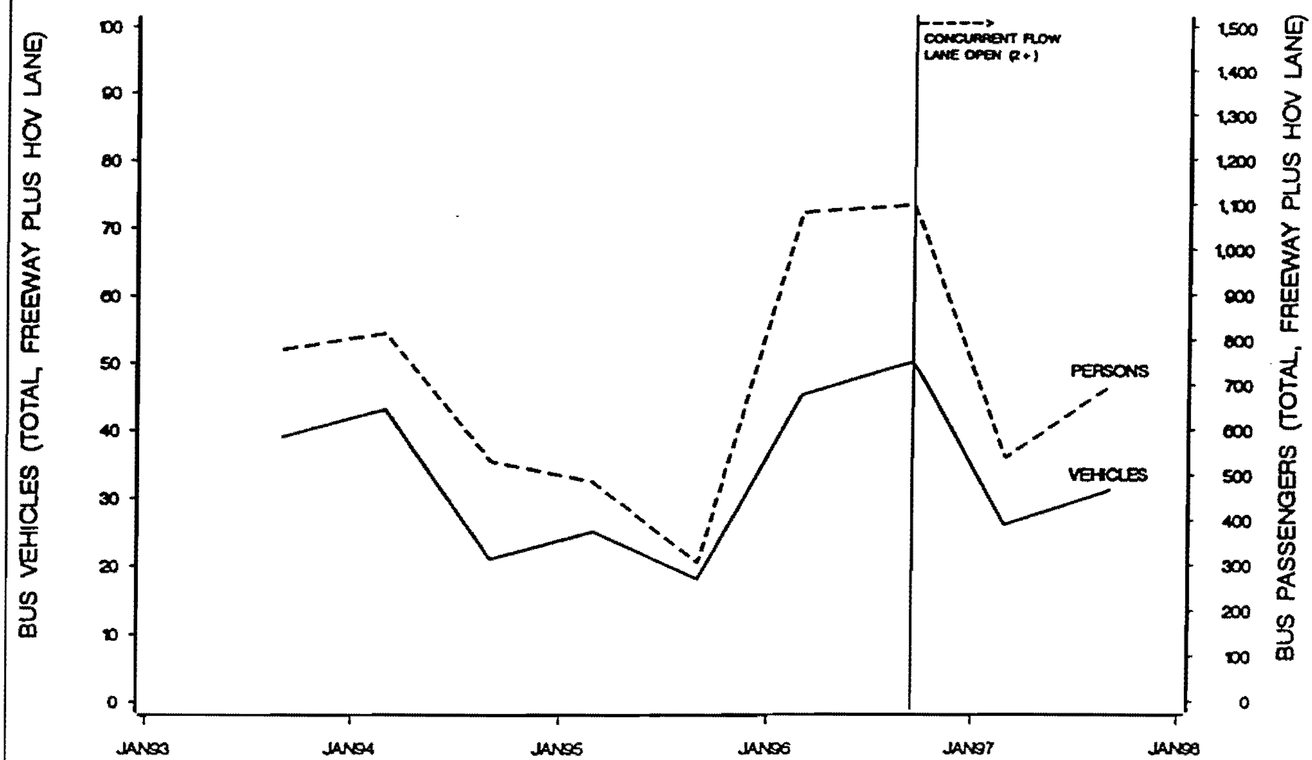


FIGURE G-18. A.M. PEAK PERIOD BUS PASSENGER TRIPS
TOTAL, FREEWAY PLUS HOV LANE
STEMMONS FREEWAY AND FREEWAY WITHOUT HOV LANE

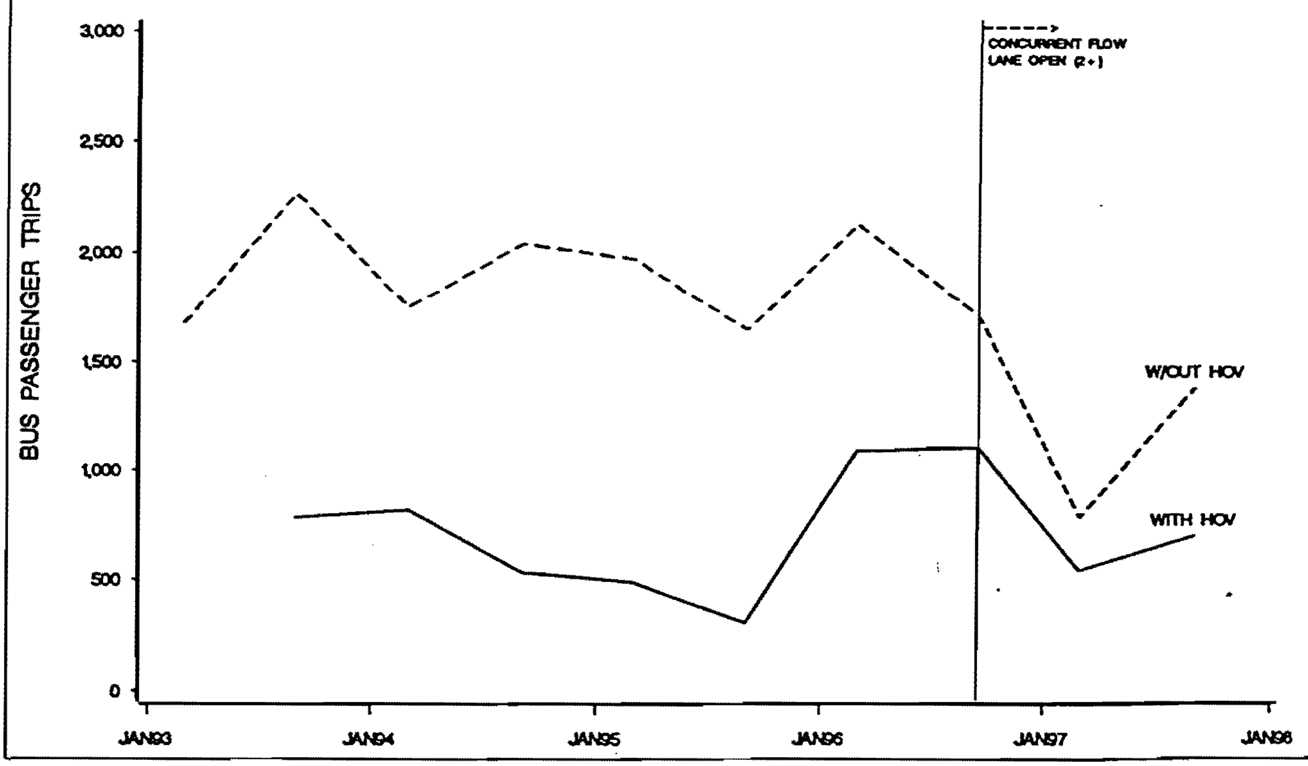


FIGURE G-19. STEMMONS FREEWAY (IH 35N) CORRIDOR PARK-AND-RIDE DEMAND

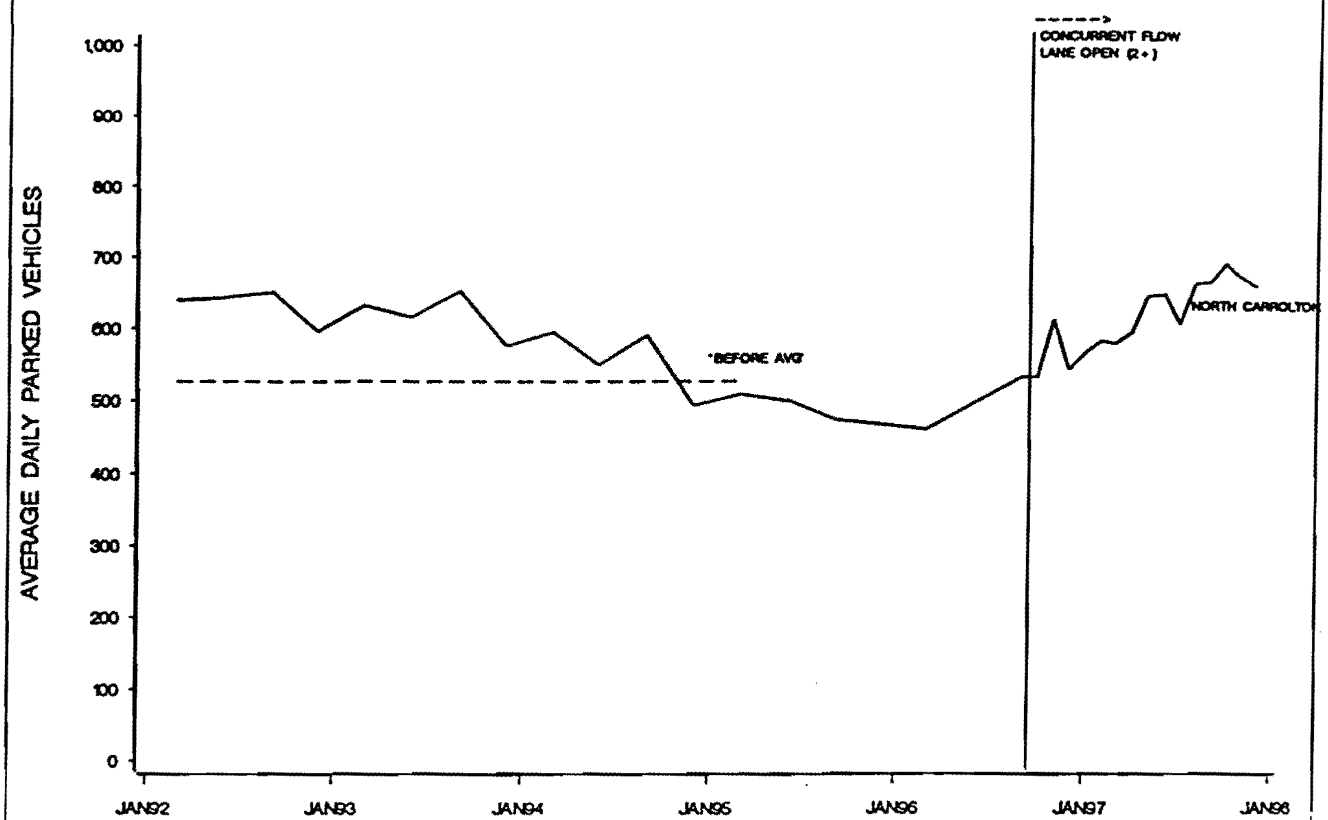


FIGURE G-20. AVERAGE DAILY VEHICLES AT PARK-AND-RIDE LOTS
STEMMONS FREEWAY AND FREEWAY WITHOUT HOV LANE