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16. Abstract

This report is a summary of the first year of a three-year study that will permit a comprehensive assessment of the high-occupancy vehicle (HOV) lanes currently operating the Dallas area. Since various types of HOV lanes are being phased into operation in the Dallas region, several design and operational issues have yet to be resolved and area officials are inquiring about the Texas Department of Transportation's (TxDOT) policy on many of these issues. HOV lanes have shown to be very successful in Texas. However, HOV lanes have been met with skepticism in several areas across the country. HOV lanes in two corridors in New Jersey (IH-287 and IH-80) were recently closed as a result of public criticism. In the wake of the actions of New Jersey, legislation has been introduced in California to limit the implementation of new HOV lanes and to potentially remove existing HOV lanes. Inappropriate data, such as vehicle volumes, are used as a basis for removing the facilities. While some of the claims against HOV lanes may be justified, a need exists to evaluate new HOV lanes implemented in the Dallas area as well as to continue an evaluation of existing HOV lanes and report accurate and detailed operational data.

While an extensive system of permanent HOV lanes is planned for the Dallas-Fort Worth urbanized area, the T xDOT and Dallas Area Rapid Transit (DART) have pursued and continue to pursue short-term or interim HOV lane projects that would enhance public transportation and overall mobility. There are currently 35.4 miles of interim HOV lanes operational in the Dallas area, including a barrier-separated contraflow lane on East R.L. Thornton Freeway (IH-30) and buffer-separated concurrent flow HOV lanes on Stemmons Freeway (IH-35E North) and Lyndon B. Johnson Freeway (IH-635). The objective of this project is to investigate the operational effectiveness of the Dallas area HOV lanes. Issues such as person movement, carpool formation, travel time savings, violation rates, safety, and project cost effectiveness are addressed. By understanding the operational performance and issues of both concurrent flow (buffer-separated) HOV lanes and contraflow (barrier-separated) HOV lanes, recommendations can be made on suggested HOV lane policies, including the type of permanent HOV lanes to be implemented in the Dallas area.

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High-Occupancy Vehicle Lanes, Concurrent Flow Lanes, Contraflow Lanes, Carpools, HOV Facilities

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I. INTRODUCTION

Limited capital investment for major transportation improvements and growth in metropolitan areas requires the most efficient use of the existing transportation system. Provisions of the Clean Air Act Amendments and the Transportation Equity Act for the 21st Century (TEA21) further intensify these concerns. One means to improve mobility is HOV lanes. The concept of an HOV lane is to increase the person-carrying capacity of freeways by providing dedicated lanes for multi-occupant vehicles. By doing so, one HOV lane can serve the travel needs of more people than a freeway lane, thereby increasing the efficiency of the entire system. While a variety of types of HOV lanes have been designed and implemented, there are a number of issues that must be considered for proposed facilities to be efficient and effective.

Additionally, existing HOV lanes have received negative publicity in several areas across the country. Concurrent flow HOV lanes in two corridors in New Jersey (IH-287 and IH-80) closed in November 1998 as a result of public criticism. In the wake of the actions of New Jersey, legislation proposed in California limits the implementation of new HOV lanes and potentially removes existing HOV lanes. Inappropriate data, such as vehicle volumes, are used as the basis for removing the facilities. The states of Colorado, Virginia, and Georgia have also proposed legislation to either eliminate HOV lanes or convert them to high-occupancy toll (HOT) lanes. While some of the claims against HOV lanes may be justified, a need exists to evaluate new HOV lanes implemented in the Dallas area as well as to continue an evaluation of existing HOV lanes.

BENEFITS OF HIGH-OCCUPANCY VEHICLE LANES

The many benefits of implementing an HOV lane include:

- Travel time savings for eligible vehicles. Multi-occupant vehicles in the HOV lane are able to bypass the congested "stop-and-go" traffic in the general purpose lanes during peak commuting periods.
- Trip time reliability for eligible vehicles. The travel speed in an HOV lane is generally near the posted speed limit, resulting in little change in the day-to-day travel times on an HOV lane. The travel time, however, in congested conditions on general purpose lanes can vary greatly from day to day, particularly when incidents occur on the freeway.

- Increased person throughput. HOV lanes are an incentive for motorists to form carpools or ride transit buses to utilize the HOV lane benefits. With more occupants in fewer vehicles, the number of people commuting in a freeway corridor can increase.
- Reduced fuel consumption and decreased vehicle emissions. The addition of an HOV lane in a corridor allows for free-flow travel for buses and other eligible vehicles who use the lane. In general, with an increase in vehicle speeds from the stop-and-go congested conditions, there is a reduction in fuel consumption and vehicle emissions.
- Reduced bus operating costs. Transit service convenience can be measured in terms of adherence to a predetermined schedule and the time between buses (bus headways). If buses must travel in congested corridors, the time between consecutive buses can vary greatly from day to day. HOV lanes reduce the daily variance in time between consecutive buses and may even reduce the number of buses that are needed on a particular route because of a reduction in trip-time.
- Increased efficiency for the entire system. As commuters from the general purpose lanes form carpools or ride buses to obtain the benefits of the HOV lane, excess capacity may become available on the general purpose lanes. Vehicles that had diverted to arterial streets to avoid the congestion on the freeway may divert back to the freeway. The transfer of vehicles from the general purpose lanes to the HOV lane and from the arterial streets to the freeway (general purpose lanes and HOV lane) increases the efficiency of the road system.

IMPLEMENTATION OF HOV LANES IN THE DALLAS AREA

An extensive system of permanent HOV lanes is planned for the Dallas-Fort Worth urbanized area. The North Central Texas Council of Governments (NCTCOG) Mobility 2020 Plan, the long-range transportation plan for the Dallas-Fort Worth area, recommends 225 centerline miles of HOV lanes. Until these permanent treatments can be implemented, TxDOT and DART have been and continue to pursue short-term or interim HOV lane projects that will enhance public transportation and overall mobility. The Federal Highway Administration (FHWA) considers these projects interim because their retrofit into the existing freeway facilities result in design exceptions from normally required standards.

Figure 1 shows the 35.4 miles of interim HOV lanes currently operational in the Dallas area. These consist of HOV lanes on East R.L. Thornton Freeway (IH-30), Stemmons Freeway (IH-35E North), and Lyndon B. Johnson Freeway (IH-635) which are described in Table 1. A 5.2 mile interim barrier-separated contraflow HOV lane on IH-30 opened in September 1991 (Figure 2). Interim buffer-separated concurrent flow HOV lanes opened on IH-35E North in September 1996 (Figure 3). The northbound HOV lane is 5.5 miles in length, and the southbound HOV lane is 6.8 miles in length. The IH-35E North HOV lane also includes a single reversible ramp approximately 0.5 miles in length under the IH-635 interchange. Interim buffer-separated concurrent flow HOV lanes also opened on IH-635 in March 1997 (Figure 4). The eastbound HOV lane is 6.5 miles in length, and the westbound HOV lane is 6.2 miles in length.

Table 1. Interim HOV Lanes Operating in the Dallas Area.

Corridor	IH-30 (East R.L. Thornton)	IH-35E North (Stemmons)	IH-635 (LBJ)
Type of Facility	Contraflow	Concurrent Flow	Concurrent Flow
Opening Date	September 1991	September 1996	March 1997
Hours of Operation	6 - 9 AM, 4 - 7 PM	24 Hours	24 Hours
Length	5.2 mile EB, 5.2 mile WB	5.5 mile NB, 6.8 mile SB	6.5 mile EB, 6.2 mile WB
Construction Cost (M$)	$17.4M[1]	$9.9M[2]	$16.3M
O&M Cost (M$)	$0.6M	$0.2M	$0.2M
Eligibility	Buses, vanpools, 2+ occupant carpools, motorcycles		

Notes:
[1]Includes $12.2M HOV lane construction, $0.2M AM auxiliary lane, and $5.0M PM extension.
[2]Includes a reversible HOV ramp through the IH-635 interchange.

The contraflow lane on IH-30 uses a movable barrier that "borrows" a freeway lane in the off-peak direction and allows its use for peak-direction HOV lane eligible vehicles. The concurrent flow lanes on IH-35E North and IH-635 were created by converting the inside shoulder to an HOV lane. These interim facilities are relatively new in the field of transportation, especially in Texas, and much experimentation is underway to determine optimum operational and design characteristics. Each corridor presents unique challenges in obtaining an operational facility that will attract the formation of carpools and enhance transit ridership. The objective of this research is to investigate the operational effectiveness of the new concurrent flow HOV lanes in the Dallas area, as well as to attempt to assess the effectiveness of concurrent flow and contraflow HOV lanes.

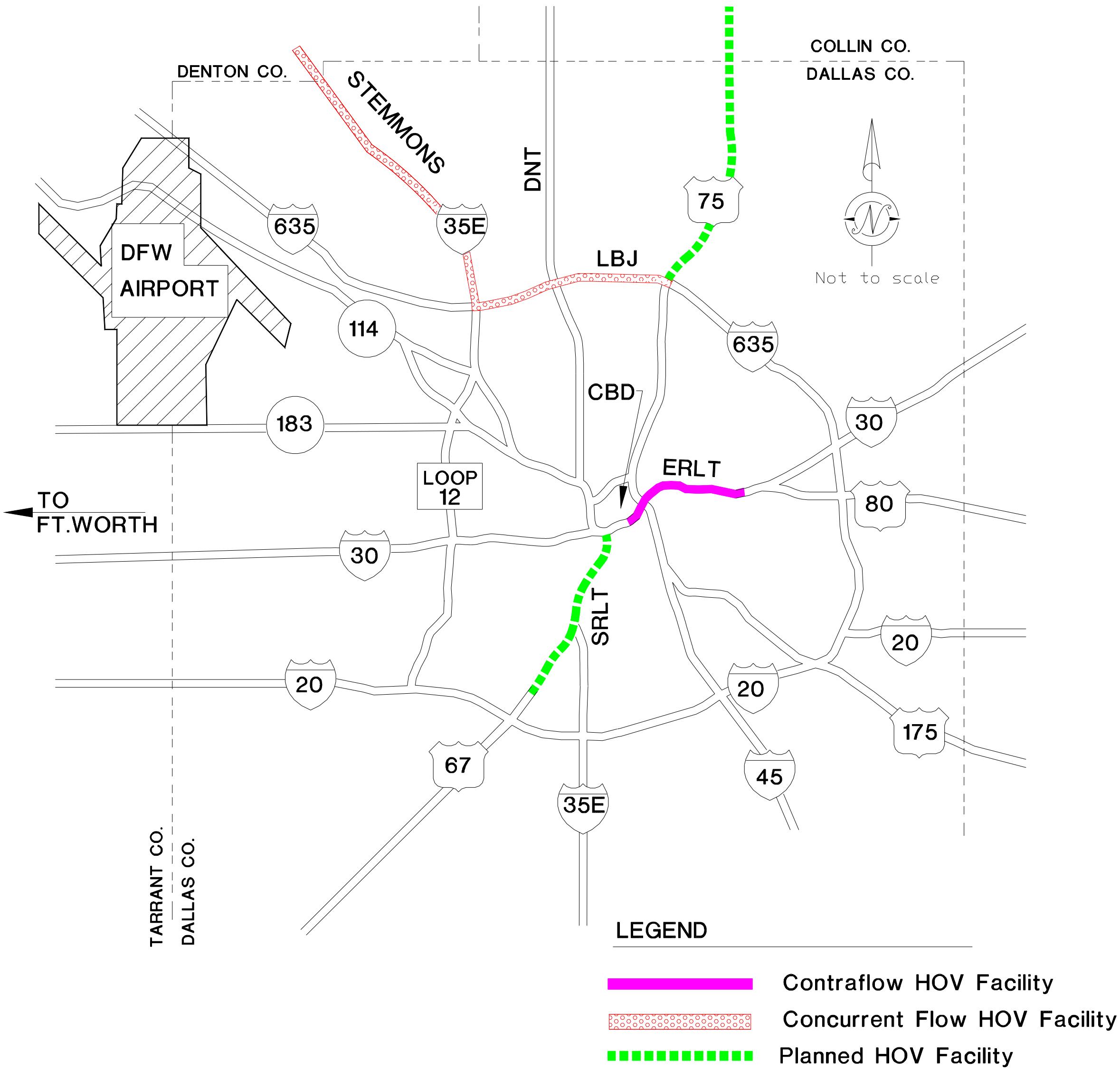


Figure 1. Dallas Area HOV Lanes.

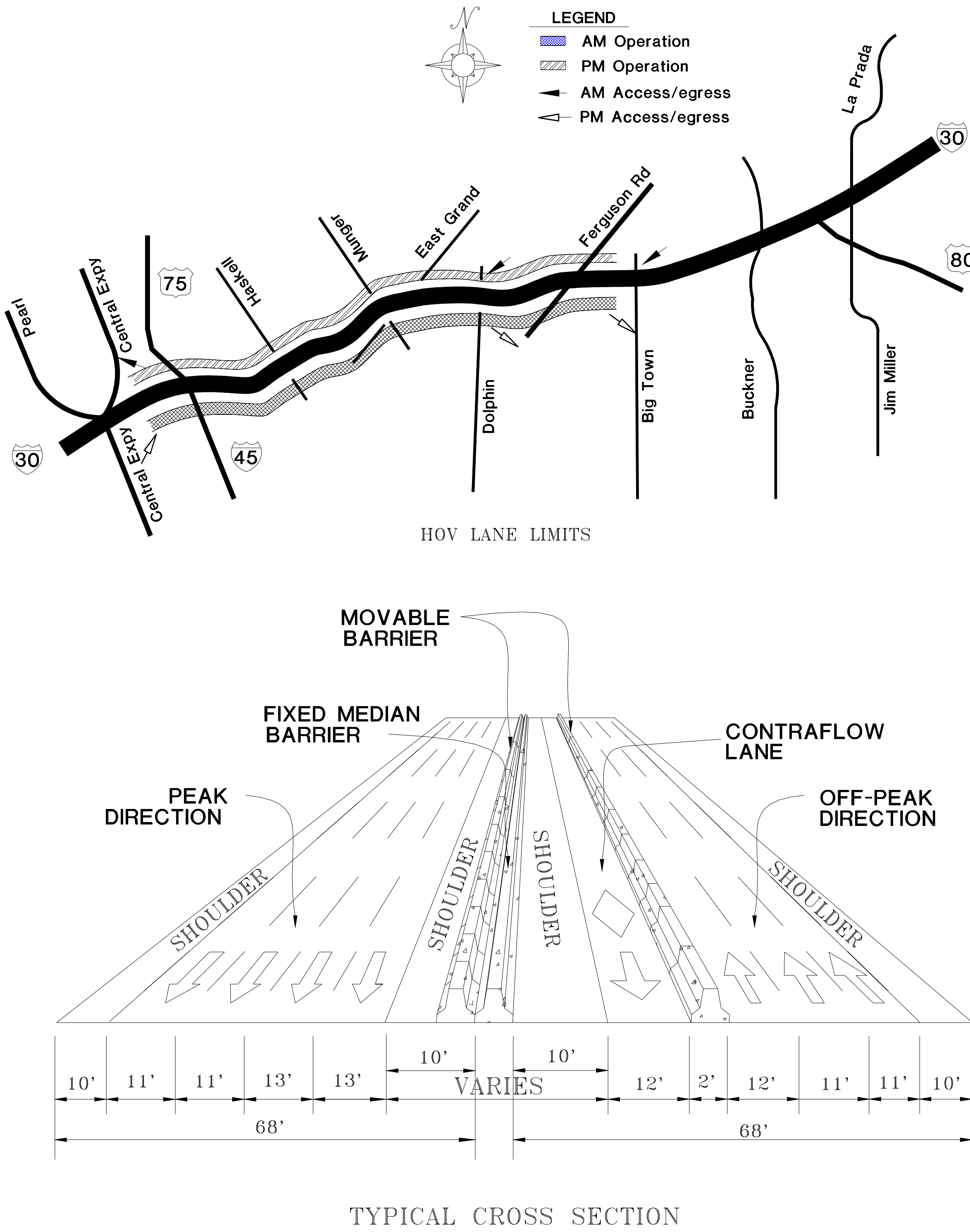


Figure 2. IH-30 (ERLT) Freeway HOV Lane.

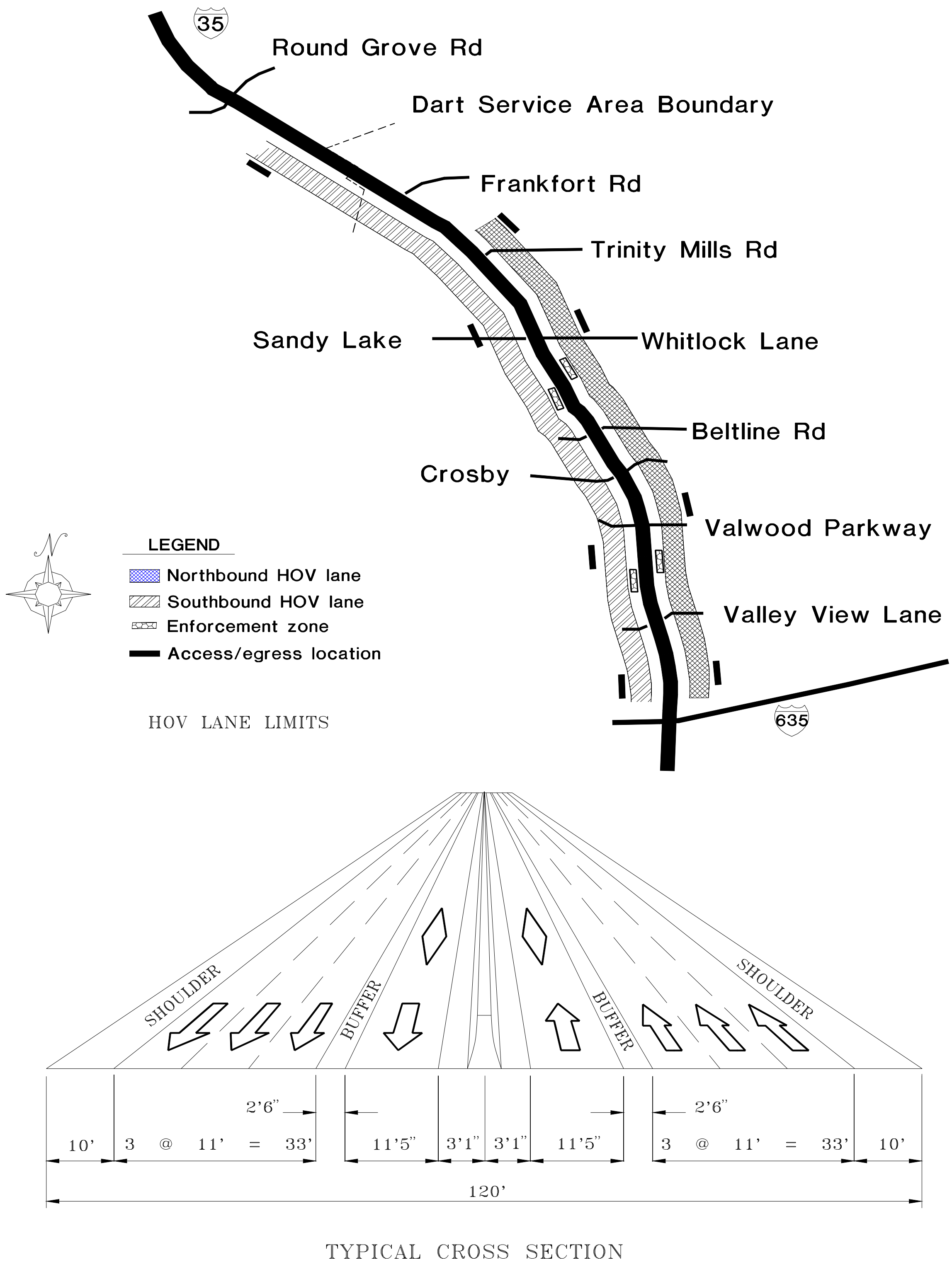
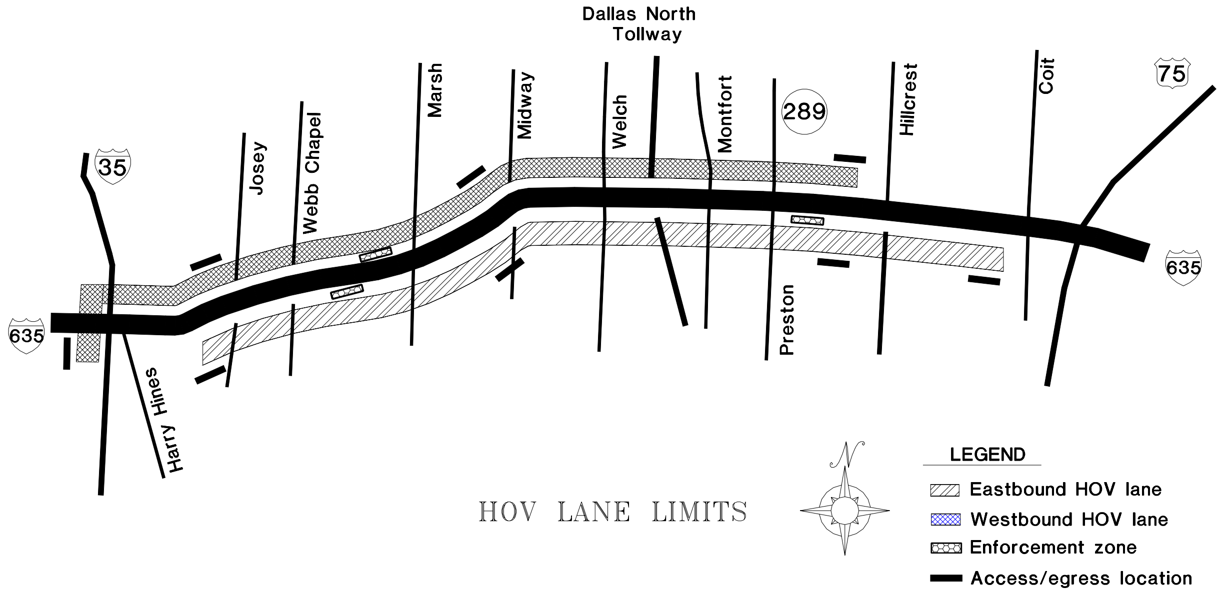


Figure 3. IH-35E North (Stemmons) Freeway HOV Lane.



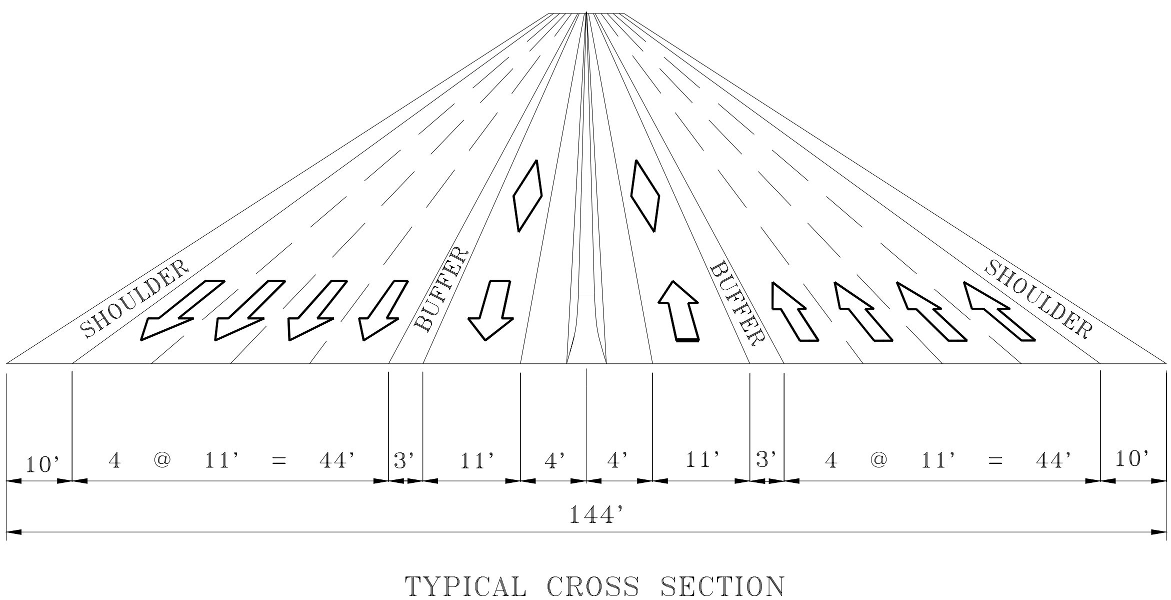


Figure 4. IH-635 (LBJ) Freeway HOV Lane.

Additional research concerns particular to concurrent flow lanes include safety, capacity, enforceability, magnitude of violations, appropriate ingress and egress location, impact on freeway operations, public opinion/acceptance, and effectiveness of 24-hour operation.

Contraflow HOV lanes and concurrent flow HOV lanes have both advantages and disadvantages. The concurrent flow HOV lanes on IH-35E North and IH-635 are the first concurrent flow HOV lanes in Texas; therefore, their operational performance must be monitored and documented. By understanding the operational performance and issues of both concurrent flow (buffer-separated) HOV lanes and contraflow (barrier-separated) HOV lanes, recommendations can be made on suggested HOV lane policies, including the type of permanent HOV lanes to be implemented in the Dallas area.

II. BACKGROUND

There are approximately 980 centerline miles of HOV lanes adjacent to freeway mainlanes in operation in the United States and Canada, and more than three-quarters of these lanes are concurrent flow facilities. Houston and Dallas are the only cities in Texas that currently have HOV lanes in operation with HOV lanes proposed for the Austin, Fort Worth and San Antonio areas. The first HOV lane in Texas, which opened in August 1979, was the IH-45 (North Freeway) contraflow HOV lane in Houston. HOV lanes now operate on the Southwest (U.S. 59), Gulf (IH-45), Katy (IH-10), North (IH-45), Eastex (U.S. 59) and Northwest (U.S. 290) Freeways. These facilities combined equate to 120.3 lane miles of HOV lanes serving the Houston area.

The Dallas area has 35.4 lane miles of HOV lanes currently in operation on three freeways. The first HOV lane in Dallas, which opened in October 1991, was the IH-30 moveable barrier HOV lane. Buffer-separated HOV lanes are provided on IH-35E and the state's most congested thoroughfare IH-635. HOV lanes will soon be available along South R.L. Thornton Freeway (IH-35E) and Martin D. Love Freeway (US-67) extending 9.0 centerline miles between downtown Dallas and Camp Wisdom. An additional nine centerline miles of HOV lanes are planned for North Central Expressway (US-75) between IH-635 and the city of Plano, Texas.

The topic of priority treatment in Texas has been addressed in several previous major TxDOT research projects, including project 0-1353, "An Evaluation of HOV Lanes in Texas," project 7-1994, "Implementation and Evaluation of Concurrent Flow HOV Lanes in Texas," and project 7-3942, "Investigation of HOV Lane Implementation and Operational Issues" (*1*), (*2*), (*3*). The projects addressed the evaluation of HOV lanes in Houston and Dallas using trend line data. This method allows detection of changes that may occur over time. Also, comparisons are made with control freeways without HOV facilities to help isolate HOV lane impacts. The results from these projects and previous projects (2-10-89/3-1146 from 1989 through 1993) have been instrumental for the implementation and continued assessment of HOV lanes in both the Houston and Dallas areas.

An evaluation of the impact on a corridor resulting from implementation of an HOV lane requires a substantial amount of data collection. Dallas area HOV lanes served approximately 30.9 million passenger trips in fiscal year 1999 with an average of 100,000 passenger trips each weekday(*4*). Typical measures of effectiveness include person-throughput, HOV lane utilization, and travel time savings. Continual monitoring and evaluation provide the basis by which incremental changes are made in system management, facility operation, and support services.

Morning and evening peak period data are currently collected on the HOV lanes in the Dallas District of TxDOT on a monthly basis as part of a DART project. The monthly data collected consist of travel times and person volumes on the HOV lanes and travel times on the adjacent freeway general purpose lanes. It is documented from experiences in Houston that substantial changes in the corridor occur during the first two to four years of HOV lane operation (*5*). Increases in HOV lane use tend to level off after four to five years of operation. Usage then increases at a rate comparable to that of the growth rate of adjacent general purpose lanes. It is critical that the corridors with HOV lanes in Dallas be monitored frequently to detect corridor changes, particularly in early years of operation. HOV lane impacts are isolated by also monitoring a control corridor in an area that operates without an HOV lane.

RECENT EXPERIENCES

Recent nationwide debate concerning the success of HOV lanes to reduce congestion has been fueled by negative public sentiment that HOV lanes are not serving their purpose. Carpooling has declined nationally by an average of 30 percent in the past two decades. Yet on Texas freeway corridors with mature HOV lanes, there has been an increase in carpooling of 100 percent or greater during the same period (*6*).

Some people in the northeast section of the country feel that HOV lanes are underutilized and operate inefficiently at the expense of adjacent general purpose lanes. HOV lanes on IH-80 and IH-287 in New Jersey were converted to general purpose lanes in late 1998. The conversion was due to the public's perception that the HOV lanes were unsuccessful in mitigating congestion or solving travel problems within the corridors (*7*).

A study by the New Jersey Department of Transportation (NJDOT) supported changing the HOV lanes to general purpose lanes. The study results indicated that HOV facilities were not performing to their original expectations (*7*). The North New Jersey Transportation Planning Authority conducted another study at the request of the U.S. Department of Transportation. It determined that pollution levels, including contributions from automobile emissions, were still within federal requirements (*8*).

Such research results must be weighed against the many success stories of truly needed HOV lanes with the required characteristics for success. The IH-287 HOV lane was a circumferential route without a central focus or trip attraction. This route did not lend itself to express transit use or carpool formation. A planning level study indicated that 450 to 500 vehicles would use the HOV lane from implementation of an employer-generated trip-reduction program as one of the region's Traffic Demand Management strategies. Unfortunately, the trip-reduction program was short lived and left the IH-287 HOV lane with few of the earlier expected users.

The shortcomings of the IH-287 HOV lane negatively impacted the public's perception of the HOV lane concept in general. As a result, the IH-80 HOV lane was also converted to a general purpose lane even though it drew 800 to 950 vehicles during the peak hour of the first few days of operation. The loss of the IH-80 HOV lane will soon affect the travel time and trip reliability on the facility since it is projected to operate under congested conditions (Level of Service F) during the peak hour by mid year 2001. Another project is currently underway to deal with this loss of mobility.

The Washington State Department of Transportation (WSDOT) is investigating the use of HOV lanes as general purpose lanes on weekends in the Seattle area. This is in response to several state legislative bills focusing on alleviating traffic congestion. Previous legislation in the state proposed that HOV lanes should be completely done away with. However, the possibility of having to repay federal funding used in developing the HOV facilities compelled WSDOT to consider opening HOV lanes to general traffic during off-peak periods only (*9*).

Conversion of HOV lanes into HOT lanes has been a topic of interest for continued use of underutilized facilities for the purpose of congestion relief and for planning purposes. The concept is to offer free access to vehicles with the required number of occupants and allow other vehicles the choice of paying a fee for access. The fee helps manage congestion on the HOT lanes, which ensures the travel time savings on the facility continue for buses and carpools.

HOT lanes promote an effective use of available space (unused capacity) on HOV lanes. Installation of electronic tolling systems on one or more HOV lanes allows communities the flexibility of varying vehicle eligibility by selling unused capacity in the HOV lane. Houston has experienced success during experiments concerning vehicle throughput on the Katy Freeway (I-10) HOV lane when using the facility as a peak-hour HOT lane (*6*).

The Colorado Department of Transportation (CDOT) is conducting a feasibility study on the topic of implementing barrier-separated HOT lanes wherever needed in the Denver area. The focus of the study is to determine their technical feasibility, public desirability, and the area impacts of converting existing HOV lanes to HOT lanes. The purpose of these "Value Express Lanes" is to maximize the use of HOV lanes by allowing access to single-occupant vehicles (SOVs) by paying a fee. Carpoolers and those using transit vehicles would continue to use the HOV lanes for free. Recent state legislation is requiring CDOT to implement HOT lanes in the next few years (*10*).

OTHER ISSUES

Safety Studies (Buffer-Separated HOV Lanes)

The information regarding the safety of HOV projects has been inconclusive. Some studies have concluded that concurrent flow buffer-separated lanes are as safe as other types of projects, while other studies have indicated a safety concern with concurrent flow HOV projects. The largest safety concern with concurrent flow HOV lanes is the potential speed differential between the HOV lane and the general purpose lanes. Research suggests that safety issues may arise when the speed differential is greater than 25 mph. This finding is consistent with the American Association of State Highway and Transportation Officials (AASHTO) report, "A Policy on Geometric Design of Highways and Streets," which suggests that the greater a vehicle deviates from this average speed on a highway, the greater its chances of becoming involved in a traffic accident (*11*).

A study was conducted comparing the frequency and characteristics of accidents before and after an HOV lane was added to Riverside Freeway State Route 91 (SR 91) in the Los Angeles area. The HOV lane was created by taking the inside shoulder of the roadway. The study concluded that the HOV project did not have an adverse affect on the safety of the corridor and attributed the changes in accident characteristics to the change in location and timing of traffic congestion (*12*).

Another study conducted by California Polytechnic State University reported the effects HOV lanes have on the safety of selected California freeways. The study suggested the observed accident pattern resulted from differences in traffic flow and congestion rather than geometric and operational characteristics of the HOV facilities (*13*). The accident "hot spots" during peak periods on freeways with and without HOV lanes were a result of localized congestion (*13*).

As already discussed, the previous studies on the safety of concurrent flow HOV lanes are inconclusive. There have been several highly successful concurrent flow HOV lane projects and several that have not been as successful. Due to the uniqueness of these facilities, planners should exercise caution when designing these facilities, especially when design values are at or near the minimum recommended design values. Designing access and egress locations to minimize the potential for accidents requires special care. Typically, these are the locations with a higher frequency of accidents. The number of traffic accidents that occur in the period of time immediately after a facility opens may be high because drivers are not familiar with HOV operations and facilities. It may take several weeks for the drivers to become familiar with the facility, especially if the design requires taking the inside shoulder. After the first several weeks of operation, the number of traffic accidents should stabilize.

Safety Studies (Barrier-Separated HOV Lanes)

Traffic accidents in the general purpose lanes do not typically disrupt operation of barrier-separated HOV lanes. Separated roadways protect the HOV traffic and the general purpose lanes from the considerable speed differential that may exist between the two traffic streams with concurrent flow HOV lanes (*14*). However, there has been some concern that physically separated roadways are detrimental to traffic flow when an incident occurs in either the HOV lane or mixed-flow facility, as the barrier limits the ability of traffic to maneuver around an incident or park a disabled vehicle if there is no inside shoulder (*14*).

Violation Studies

Concurrent flow HOV lanes generally have a lower compliance rate than other types of HOV lanes regardless of the amount of enforcement (*14*). These facilities have the potential to become as congested as the mainlanes when a high violation rate occurs. If these facilities become congested, there is less incentive to form carpools or to continue to utilize an existing carpool.

Separated roadways generally have a low violation rate because the characteristics of these facilities deter potential violators. Due to the physical separation from the general purpose lanes with controlled access points, violators who are spotted in the HOV lane will not have immediate access to the general purpose lanes. Evidence of violator deterrence has been documented on California barrier-separated HOV facilities where the violation rate is lower than any other mainlane HOV facilities in the state.

III. CONCURRENT FLOW HOV LANE PAVEMENT MARKING AND SIGNING

Concurrent flow HOV lanes operate in many states and have been implemented with little national guidance regarding uniform pavement markings and signing. States independently designed their own facilities using limited national standards. As a result, different designs are in use across the United States with varying degrees of similarities and differences. Current design attributes from 12 states were compiled in an effort to define the current state-of-the-practice regarding concurrent flow HOV lane design.

An information request in the form of electronic mail was sent to states known to operate HOV lane facilities. The request specifically identified the forwarding of standards for the pavement markings and signing of concurrent flow HOV lane facilities. Replies were received from 12 states indicating the current pavement marking and/or signing convention used. Some states only had general provisions from design guides and project plans while other states had detailed specifications and standards. Information for concurrent flow HOV facilities were obtained from Arizona, California, Colorado, Connecticut, Georgia, Maryland, Minnesota, New Jersey, New York, Texas, Virginia, and Washington.

Each of these states currently have or once operated concurrent flow HOV lane facilities categorized as either buffer-separated or non-separated (continuous). Buffer-separated facilities are applicable in Arizona, Connecticut, Colorado, and Texas. Contiguous facilities are applicable in New Jersey, Virginia, and Washington. Buffer-separated and contiguous facilities are both applicable in California, Georgia, Maryland, and New York. The only information obtained from Minnesota was signing standards.

A thorough review of the available design guides and project plans indicates similarities and differences between the states in regard to pavement markings and signing of concurrent flow HOV lanes. The diamond symbol is unanimously used by each state to represent HOV lane facilities on both pavement markings and signing. The various other attributes differ on several levels ranging from being relatively alike between two or more states to the other extreme of being notably dissimilar. Critical attributes of the states' pavement markings and signing convention are presented in Tables 2 and 3.

Table 2. HOV Lane Concurrent Flow Pavement Marking.

STATE	Arizona	California	Connecticut	Colorado	Georgia	Maryland	New Jersey	New York	Texas	Virginia	Washington
HOV Lane Type	**Buffer-Separated**	**Buffer-Separated / Contiguous**	**Buffer-Separated**	**Buffer-Separated**	**Buffer-Separated / Contiguous**	**Buffer-Separated / Contiguous**	**Contiguous**	**Buffer-Separated / Contiguous**	**Buffer-Separated**	**Contiguous**	**Contiguous**
HOV Lane Width	Unavailable	Unavailable	Unavailable	12'	Variable	Unavailable	Unavailable	12'	Unavailable	Unavailable	Unavailable
Inner Shoulder Width	Unavailable	Unavailable	Unavailable	12'	Variable	Unavailable	Unavailable	10'	2' (Min.)	Unavailable	Unavailable
Symbol	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond
Color	White	White	Unavailable	Unavailable	White	White	White	White	White	White	White
Line Thickness	6"	Unavailable	Unavailable	Unavailable	6"	Unavailable	6"	6"	6"	Unavailable	5" - 12"
Spacing	Unavailable	820'	500'	Unavailable	1700'	800' - 1200'	2640'	Unavailable	500'	Unavailable	Unavailable
Dimension	12' X 3'	12' Long	Unavailable	Unavailable	13'-4" x 3'-4"	Unavailable	12' Long	13' Long	13' Long	Unavailable	12' - 16' Long
Implementation Time	Continuous	Continuous	Unavailable	Unavailable	Unavailable	Unavailable	Continuous	Continuous	Continuous	Continuous	Continuous
Text	N/A	CARPOOL ONLY	N/A	N/A	N/A	N/A	CARPOOL & BUS ONLY	N/A	N/A	N/A	N/A
Color	N/A	Unavailable	N/A	N/A	N/A	N/A	White	N/A	N/A	N/A	N/A
Line Thickness	N/A	Unavailable	N/A	N/A	N/A	N/A	Unavailable	N/A	N/A	N/A	N/A
Spacing	N/A	Unavailable	N/A	N/A	N/A	N/A	5280'	N/A	N/A	N/A	N/A
Individual Word Spacing	N/A	98'	N/A	N/A	N/A	N/A	100'	N/A	N/A	N/A	N/A
Dimension	N/A	8' Letters	N/A	N/A	N/A	N/A	8' Letters	N/A	N/A	N/A	N/A
Implementation Time	N/A	Initial Installation	N/A	N/A	N/A	N/A	Initial Installation	N/A	N/A	N/A	N/A
Delineation (Inner)	Unavailable	Line	Line	Unavailable	Line	Line	Line	Line + Diag. Hatch	Line	Line	Line
Color	N/A	Yellow (Solid)	Yellow (Solid)	N/A	Yellow (Solid)	Unavailable	Yellow	Yellow	Yellow	Unavailable	Unavailable
Line Thickness	N/A	4"	4"	N/A	5"	Unavailable	4"	6"	4"	Unavailable	Unavailable
Length	N/A	N/A	N/A	N/A	N/A	Unavailable	N/A	N/A	N/A	N/A	N/A
Spacing	N/A	N/A	N/A	N/A	N/A	Unavailable	N/A	N/A	N/A	N/A	N/A

Table 2. HOV Lane Concurrent Flow Pavement Marking - Continued.

STATE	Arizona	California	Connecticut	Colorado	Georgia	Maryland	New Jersey	New York	Texas	Virginia	Washington
HOV Lane Type	**Buffer-Separated**	**Buffer-Separated / Contiguous**	**Buffer-Separated**	**Buffer-Separated**	**Buffer-Separated / Contiguous**	**Buffer-Separated / Contiguous**	**Contiguous**	**Buffer-Separated / Contiguous**	**Buffer-Separated**	**Contiguous**	**Contiguous**
Delineation (Outer)	Line	Double Line	Line	Unavailable	Double Line	Line (Type III)	Line	Line	Line	Double Line	Line
Color	White (Solid)	Yellow (Solid)	White (Solid)	N/A	White (Broken)	White (Broken)	White (Broken)	White (Solid)	White (Solid)	White (Broken)	Unavailable
Inner Line(s) Thickness	4"	4"	4"	N/A	8" or 5"	Unavailable	4"	12"	5"	Unavailable	Unavailable
Length	N/A	N/A	N/A	N/A	10'	10' and 3'	10'	N/A	N/A	Unavailable	N/A
Spacing	N/A	N/A	N/A	N/A	10'	Unavailable	30'	N/A	N/A	Unavailable	N/A
Buffer Region Width	4' Minimum	1' - 4'	18"	Unavailable	8" or 4"	N/A	N/A	24"	3' - 4'	N/A	N/A
Color	White (Solid)	Yellow (Solid)	Yellow (Solid)	Unavailable	White (Dashed)	N/A	N/A	White (Solid)	White	N/A	N/A
Outer Line(s) Thickness	4"	4"	4"	N/A	8" or 5"	N/A	N/A	12"	6"	N/A	N/A
Length	N/A	N/A	N/A	N/A	10'	N/A	N/A	N/A	N/A	N/A	N/A
Spacing	N/A	N/A	N/A	N/A	10'	N/A	N/A	N/A	N/A	N/A	N/A
Buffer Design	Chevron	None	Chevron	Unavailable	None	N/A	N/A	Diagonal Hatch	N/A	N/A	N/A
Color	White (Solid)	N/A	Unavailable	N/A	N/A	N/A	N/A	White	N/A	N/A	N/A
Thickness	12"	N/A	Unavailable	N/A	N/A	N/A	N/A	24"	N/A	N/A	N/A
Spacing	100'	N/A	200'	N/A	N/A	N/A	N/A	50'	N/A	N/A	N/A
Inner Apex Angle	60E	N/A	90E	N/A	N/A	N/A	N/A	60E/2=30E	N/A	N/A	N/A
Raised Pavement Marker Type	Unavailable	One-Way Yellow Reflective	Unavailable	Unavailable	Clear/Red Type 3 Reflective	Unknown	Unavailable	Unavailable	Type I-C	Unavailable	Unavailable
Location	N/A	Left and Right of Double Line	N/A	N/A	Left, Mid, Right of Double Line	Line Gaps	N/A	N/A	Inside Buffer Region Lines	N/A	N/A
Spacing	N/A	24'	N/A	N/A	40'	40'	N/A	N/A	10'	N/A	N/A

Table 3. HOV Lane Concurrent Flow Signing.

STATE	ARIZONA						CALIFORNIA			
HOV Lane Type	**Buffer-Separated**						**Buffer-Separated / Contiguous**			
Sign Type	Static	Static	Static	Static	Static	Static	Static	Static	Static	Static
Class	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory
Identifier	R3-11	R3-14	R3-14a	R3-14x	R3-12	R3-13	R86-2	R93-2	R87-1	R82-1
Symbol	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond
Location	Upper Left	Upper Left	Upper Left	Upper Left	Mid-Section	Left Section	Upper Section	Upper Section	Left Section	Upper Section
Color	White	White	White	White	White	White	White	White	White	White
Background Color	Black	Black	Black	Black	Black	Black	Black	Black	Black	Black
Text	LEFT LANE	CARPOOLS MOTORCYCLES AND BUSES ONLY	CARPOOLS MOTORCYCLES AND BUSES ONLY	MOTORCYCLES OK	RESTRICTED LANE	RESTRICTED LANE AHEAD	LEFT LANE	CARPOOL IS 2 OR MORE PERSONS PER VEHICLE	CARPOOLS ONLY 2 OR MORE PERSONS PER VEHICLE	CARPOOL LANE AHEAD ½ MILE
Location	Upper Right	Upper Section	Upper Section	Lower Section	Upper Section	Right Section	Mid-Section	Lower Section	Right Section	Lower Section
Color	White	Black	Black	Black	Black	Black	Black	Black	Black	Black
Background Color	Black	White	White	White	White	White	White	White	White	White
Text	CARPOOLS MOTORCYCLES AND BUSES ONLY 6 AM - 9 AM 3 PM - 7 PM MON - FRI	N/A	6 AM - 9 AM 3 PM - 7 PM MON - FRI	N/A	ENDS	N/A	CARPOOLS ONLY	N/A	N/A	N/A
Location	Lower Section	N/A	Lower Section	N/A	Lower Section	N/A	Lower Section	N/A	N/A	N/A
Color	Black	N/A	Black	N/A	Black	N/A	Black	N/A	N/A	N/A
Background Color	White	N/A	White	N/A	White	N/A	White	N/A	N/A	N/A
Directional Arrow	N/A	Down	Down	N/A	N/A	N/A	N/A	N/A	Down	N/A
Location	Median	Overhead	Overhead	Median	Median	Overhead	Median	Median	Overhead	Median
Spacing	5280'	Existing Structures	5280'	5280'	N/A	N/A	4300'	1000' After R86-2	Unavailable	N/A
Dimensions	72" x 48"	60" x 72"	84" x 72"	36" x 36"	Unavailable	Unavailable	30" x 60" 36" x 66" 48" x 84"	30" x 72" 36" x 84"	168" x 70" 192" x 100"	30" x 60" 36" x 66" 48" x 84"

Table 3. HOV Lane Concurrent Flow Signing - Continued.

STATE	CALIFORNIA			CONNECTICUT		COLORADO			GEORGIA	
HOV Lane Type	Buffer-Separated / Contiguous			Buffer-Separated		Buffer-Separated			Buffer-Separated / Contiguous	
Sign Type	Static	Static	Static	Static	Static	Static	Static	Static	Static	Static
Class	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory
Identifier	SR50-2	R84-2	R84-1	Unavailable	Unavailable	Unavailable	Unavailable	Unavailable	Unavailable	Unavailable
Symbol	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond
Location	Upper Section	Upper Section	Upper Section	Upper Left	Upper Left	Upper Left	Upper Left	Upper Left	Upper Left	Upper Left
Color	White	White	White	White	White	Unavailable	White	White	White	White
Background Color	Black	Black	Black	Black	Black	Unavailable	Black	Black	Black	Black
Text	CARPOOL VIOLATION $270 MINIMUM FINE	CARPOOL LANE ENDS ½ MILE	END CARPOOL LANE	RESTRICTED LANE BUSES AND 2 RIDER MINIMUM CAR POOLS	ACCESS TO RESTRICTED LANE PROHIBITED	HOV LANE 2 OR MORE PERSONS PER VEHICLE ONLY	LEFT LANE	EXPRESS LANE	LEFT LANE	BUSES AND 2 PERSON CARPOOLS ONLY
Location	Lower Section	Lower Section	Lower Section	Right Section	Right Section	Right Section	Upper Right	Upper Right	Upper Right	Right Section
Color	Black	Black	Black	Black	Black	Unavailable	White	White	White	Black
Background Color	White	Yellow	Yellow	White	White	Unavailable	Black	Black	Black	White
Text	N/A	N/A	N/A	N/A	N/A	N/A	BUSES AND CARPOOLS ONLY MOTORCYCLES OK	2 OR MORE PERSONS PER VEHICLE ONLY MOTORCYCLES OK	BUSES AND CARPOOLS ONLY	N/A
Location	N/A	N/A	N/A	N/A	N/A	N/A	Lower Section	Lower Section	Lower Section	N/A
Color	N/A	N/A	N/A	N/A	N/A	N/A	Black	Black	Black	N/A
Background Color	N/A	N/A	N/A	N/A	N/A	N/A	White	White	White	N/A
Directional Arrow	N/A	N/A	N/A	N/A	N/A	Down	N/A	N/A	N/A	Down
Location	Median	Median	Median	Overhead	Median	Overhead	Median	Median	Median	Overhead
Spacing	10,500'	N/A	N/A	Existing Structures	Unavailable	Existing Structures	Unavailable	Unavailable	Unavailable	Unavailable
Dimensions	30" x 66" 36" x 78" 48" x 98"	30" x 60" 36" x 66" 48" x 84"	30" x 54" 36" x 60" 48" x 72"	Unavailable	Unavailable	Unavailable	Unavailable	Unavailable	42" x 48"	10' x 7'

Table 3. HOV Lane Concurrent Flow Signing - Continued.

STATE	GEORGIA					MARYLAND				
HOV Lane Type	**Buffer-Separated / Contiguous**					**Contiguous**				
Sign Type	Static	Static	Static	Static	Static	Static	Static	Static	Static	Static
Class	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory
Identifier	Unavailable	Unavailable	Unavailable	Unavailable	Unavailable	Unavailable	R3-11(1)	R3-11(2)	R3-14(1)	R3-11(1)
Symbol	None	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond
Location	N/A	Upper Left	Upper Left	Left Section	Left Section	Upper Left	Upper Left	Upper Section	Middle Left	Mid-Section
Color	N/A	White	White	White	White	White	Black	White	White	White
Background Color	N/A	Black	Black	Black	Black	Black	White	Black	Black	Black
Text	HOV EXPRESS LANE VIOLATORS SUBJECT TO FINES UP TO $150	EXPRESS LANE	EXPRESS LANE	RESTRICTED LANE BEGINS	RESTRICTED LANE ENDS	NOTICE	LEFT LANE	HOV - # OR MORE PERSONS PER VEHICLE	7:00-9:00 AM 3:30-6:30 PM MON - FRI	HOV LANE
Location	N/A	Upper Right	Upper Right	Right Section	Right Section	Upper Right	Upper Right	Lower Section	Upper Section	Upper Section
Color	Black	White	White	Black	Black	White	Black	Black	Black	Black
Background Color	White	Black	Black	White	White	Black	White	White	White	White
Text	N/A	Motorcycle Graphic OK	CERTIFIED AFV OK	N/A	N/A	HOV - # LEFT LANE OTHERS MOVE RIGHT X MILE	HOV - # ONLY 6:00-9:00 AM 4:00-7:00 PM MON - FRI	N/A	HOV - # LANE BUSES & CARPOOLS LEFT LANE	ENDS
Location	N/A	Lower Section	Lower Section	N/A	N/A	Lower Section	Lower Section	N/A	Lower Section	Lower Section
Color	N/A	Black	Black	N/A	N/A	Black	Black	N/A	Black	Black
Background Color	N/A	White	White	N/A	N/A	White	White	N/A	White	White
Directional Arrow	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Down	N/A
Location	Median	Median	Median	Overhead	Overhead	Median	Median	Median	Overhead	Median
Spacing	Unavailable	Unavailable	Unavailable	Unavailable	Unavailable	Unavailable	1300' - 2600'	1300' - 2600'	Unavailable	Unavailable
Dimensions	42" x 48"	42" x 48"	42" x 54"	10' x 5'	10' x 5'	Unavailable	Unavailable	Unavailable	Unavailable	Unavailable

Table 3. HOV Lane Concurrent Flow Signing - Continued.

STATE	MINNESOTA			NEW JERSEY					NEW YORK	
HOV Lane Type	**Unavailable**			**Contiguous**					**Buffer-Separated / Contiguous**	
Sign Type	Static	Static	Static	Static	Static	Static	Static	Static	Static	Static
Class	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory
Identifier	Unavailable	Unavailable	Unavailable	R(NJ)3-14	R3-11	R3-11a	R(NJ)3-13	R(NJ)3-15	R4-26E	R4-25E
Symbol	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond
Location	Upper Left	Upper Section	Left Section	Upper Left	Upper Left	Upper Section	Upper Left	Left Section	Upper Left	Upper Left
Color	White	White	White	White	White	White	White	White	White	White
Background Color	Black	Black	Black	Black	Black	Black	Black	Black	Black	Black
Text	2 PERSON CAR POOLS BUSES & MOTORCYCLES 6AM- 9AM MON-FRI	6AM - 9PM MON - FRI	LANE RESTRICTION ENDS	BUSES AND CARPOOLS WITH 2 OR MORE PERSONS PER VEHICLE	LEFT LANE	LEFT LANE	HOV LANE ½ MILE	HOV LANE ENDS	BUSES OR CARPOOLS ONLY	CAR POOL IS 2 OR MORE PERSONS PER VEHICLE
Location	Right Section	Lower Section	Right Section	Upper Right	Upper Right	Lower Section	Upper Right	Left Section	Upper Right	Upper Left
Color	Black	Black	Black	Black	White	Black	Black	Black	Black	Black
Background Color	White	White	White	White	Black	White	White	White	White	White
Text	N/A	N/A	N/A	2 OR MORE PERSONS ONLY 6AM - 9AM 3PM - 7PM MON - FRI	BUSES AND CARPOOLS ONLY 6 AM - 9 AM 3 PM - 7 PM MON-FRI	N/A	BUSES AND CARPOOLS ONLY	N/A	6-10 AM 3-4 PM MON - FRI	MOTORCYCLES PERMITTED
Location	N/A	N/A	N/A	Lower Section	Lower Section	N/A	Lower Section	N/A	Lower Section	Lower Section
Color	N/A	N/A	N/A	Black	Black	N/A	Black	N/A	Black	Black
Background Color	N/A	N/A	N/A	White	White	N/A	White	N/A	White	White
Directional Arrow	Down	Down	N/A	Down	N/A	N/A	N/A	N/A	Down	N/A
Location	Median	Overhead	Overhead	Overhead	Median	Median	Overhead	Overhead	Overhead	Overhead
Spacing	Unavailable	Unavailable	Unavailable	4500' - 6000'	Unavailable	Between R(NH)3-14	N/A	N/A	Unavailable	Unavailable
Dimensions	Unavailable	Unavailable	Unavailable	14'-6" x 7'-0"(Min.)	5'-0" x 3'-6" 5'-6" x 3'-6"	5' x 2'	9'-0" (Min.) x 10'	7'-0" (Min.) x 8'-6"	9' x 7'	14'-6" x 11'-0"

Table 3. HOV Lane Concurrent Flow Signing - Continued.

STATE	NEW YORK				TEXAS					
HOV Lane Type	Buffer-Separated / Contiguous				Buffer-Separated					
Sign Type	Static	Static	Static	Static	Static	Static	Static	Static	Static	Static
Class	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory
Identifier	R4-21C	R4-10	R4-17	R4-27	Unavailable	Unavailable	Unavailable	Unavailable	Unavailable	Unavailable
Symbol	Diamond	None	None	Diamond	Diamond	Diamond	Diamond	None	Diamond	Diamond
Location	Upper Left	N/A	N/A	Left Section	Upper Left	Upper Left	Upper Left	N/A	Upper Left	Upper Left
Color	White	N/A	N/A	White	White	White	White	N/A	White	White
Background Color	Black	N/A	N/A	Black	Black	Black	Black	N/A	Black	Black
Text	LEFT LANE	CROSSING DIVIDER PROHIBITED	NO TRUCKS TRAILERS IN HOV LANE OR LEFT LANE	HOV LANE ENDS	HOV LANE	HOV LANE	HOV LANE	DO NOT CROSS DOUBLE WHITE LINE	HOV LANE	HOV LANE
Location	Upper Right	N/A	N/A	Right Section	Upper Right	Upper Right	Upper Right	N/A	Upper Right	Upper Right
Color	Black	Black	Black	Black	Black	Black	Black	Black	Black	Black
Background Color	White	White	White	White	White	White	White	White	White	White
Text	BUSES AND 2 OR MORE PERSON CAR POOLS ONLY	N/A	N/A	N/A	BUSES 2+ CARPOOLS VANPOOLS MOTORCYCLES ONLY	TRUCKS OVER 1 TON AND TOWED TRAILERS PROHIBITED	UNAUTHORIZED VEHICLES PROHIBITED $200 FINE	N/A	ENTRANCE ½ MILE LEFT LANE	ENTRANCE
Location	Lower Section	N/A	N/A	N/A	Lower Section	Lower Section	Lower Section	N/A	Lower Section	Lower Section
Color	Black	N/A	N/A	N/A	Black	Black	Black	N/A	White	White
Background Color	White	N/A	N/A	N/A	White	White	White	N/A	Green	Green
Directional Arrow	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Left
Location	Median	Overhead	Median	Median	Median	Median	Median	Median	Overhead	Overhead
Spacing	Unavailable	Unavailable	Unavailable	Unavailable	Unavailable	Unavailable	Unavailable	Unavailable	N/A	N/A
Dimensions	36" x 48"	7' x 5'	5' x 7'	10' x 6'	48" x 60"	48" x 60"	48" x 60"	48" x 48"	12' x 8'	12' x 8'

Table 3. HOV Lane Concurrent Flow Signing - Continued.

STATE	TEXAS	VIRGINIA					WASHINGTON			
HOV Lane Type	Buffer-Separated	Contiguous (Right Shoulder General purpose lane)					Contiguous			
Sign Type	Static	Static	Static	Static	VMS	VMS	Static	Static	Static	Static
Class	Warning	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory	Regulatory
Identifier	Unavailable	Unavailable	Unavailable	Unavailable	Unavailable	Unavailable	R3-1101	R3-11LB	R3-11LD	R3-12
Symbol	Diamond	None	Diamond	None	Diamond	None	Diamond	Diamond	Diamond	Diamond
Location	Upper Left	N/A	Upper Left	N/A	Left Section	N/A	Upper Left	Upper Left	Upper Left	Middle Section
Color	White	N/A	White	N/A	VMS	N/A	White	White	White	Black
Background Color	Black	N/A	Black	N/A	VMS	N/A	Black	Black	Black	White
Text	HOV LANE	HOV - 2 ONLY HIGH OCCUPANCY VEHICLE	LEFT LANE	HOV - 2 & MOTORCYCLES	OPEN TO ALL TRAFFIC ***OR*** HOV - 2 ONLY	SHOULDER	*Bus and 2+ Car Graphic*	LEFT LANE	LEFT LANE	LEFT LANE RESTRICTION
Location	Upper Right	Upper Section	Upper Right	Upper Section	Right Section	Upper Section	Upper Right	Upper Right	Upper Right	Upper Section
Color	Black	Black	White	Black	VMS	Black	Black	Black	Black	Black
Background Color	White	White	Black	White	VMS	Yellow	White	White	White	White
Text	HOV ENDS ½ MILE	2 OR MORE PERSONS PER VEHICLE ½ MILE AHEAD LEFT	HOV - 2 ONLY 5:30 - 9:30 AM MON - FRI	2 OR MORE PERSONS PER VEHICLE 5:30 - 9:30 AM MON - FRI	N/A	SHOULDER CLOSED ***OR*** OPEN TO ALL TRAFFIC	BUSES AND CARPOOLS ONLY	BUSES AND 2 PERSON CARPOOLS ONLY MOTORCYCLES OK	NO TRUCKS OVER 10,000 GVWR	ENDS
Location	Lower Section	Lower Section	Lower Section	Lower Section	N/A	Lower Section	Lower Section	Lower Section	Lower Section	Lower Section
Color	Black	Black	Black	Black	N/A	VMS	Black	Black	Black	Black
Background Color	Yellow	White	White	White	N/A	VMS	White	White	White	Orange
Directional Arrow	N/A	N/A	N/A	N/A	VMS Down	N/A	Down	N/A	N/A	N/A
Location	Overhead	Median	Median	Outer Shoulder	Overhead	Overhead	Overhead	Median	Median	Median
Spacing	N/A	N/A	Unavailable	Unavailable	Unavailable	Unavailable	10,600'	Between R3-1101	Unavailable	N/A
Dimensions	12' x 8'	Unavailable	Unavailable	Unavailable	Unavailable	Unavailable	10' x 9'	48" x 72"	Unavailable	48" x 60"

IV. DATA COLLECTION METHODOLOGY

To evaluate and monitor HOV lanes, researchers must collect a substantial amount of operational data on the HOV lanes and the adjacent freeway general purpose lanes. This section describes the type of data that have been collected to evaluate the effectiveness of the Dallas area HOV lanes.

Most of the HOV facilities in Houston have been operating for several years, resulting in "mature" facilities with little change from year to year; therefore, these facilities are only monitored on a semiannual basis. In Houston, experience has indicated that there is a significant amount of change in the corridor during the first two to four years that an HOV lane is operational (*5*). After this time period, a facility is considered "mature." It is, therefore, essential that the corridors in Dallas with new HOV lanes initially be monitored frequently to detect corridor changes.

FIELD DATA COLLECTION

Monthly and semiannual data collection is conducted to monitor the operational performance of the HOV lanes. The data are collected in the peak direction of the corridor. During the AM peak period, IH-30 and IH-35E North have approximately a 70 percent directional peak inbound (westbound and southbound, respectively). A reverse pattern occurs during the PM peak period. IH-635 in the vicinity of the HOV lane, however, has nearly an equal directional split during the AM and PM peak periods. Data are, therefore, collected in both the eastbound and westbound directions during both peak periods. This section describes the monthly and semiannual field data collection effort.

Monthly Data Collection

Since the Dallas area HOV lanes are relatively new facilities, DART requested that they be monitored on a monthly basis. TTI is under contract with DART to collect AM peak period (6:00 AM to 9:00 AM) and PM peak period (4:00 PM to 7:00 PM) travel time runs and vehicle-occupancy counts in the peak direction on the three HOV lanes in the Dallas area. The HOV lane vehicle-occupancy counts are recorded by observers stationed on the side of the freeway, and the travel time runs are collected using the floating car method. Travel time runs are also conducted on the adjacent freeway mainlanes for each facility that has an HOV lane. By comparing the travel time runs on the

HOV lane with the freeway general purpose lanes, travel time savings (HOV lane benefits) can be calculated. The vehicle-occupancy counts are used to monitor changes in HOV lane occupancy usage and violation rates. In addition, automatic counters are placed on the IH-35E North and IH-635 HOV lanes to obtain daily volume of traffic on the HOV lanes. (Daily counts are not needed on the IH-30 HOV lane because the HOV lane is only operational during the peak periods.) The number of vehicles parked in the park-and-ride lots located near the HOV lanes is also monitored on a monthly basis.

Semiannual Data Collection

In addition to the monthly data collection, AM and PM peak period vehicle-occupancy counts are collected semiannually on the general purpose lanes of the three freeways that have HOV lanes (during the months of September and March). These occupancy counts are used to monitor corridor-wide impacts of HOV lanes during the peak period. These two months of data collection are summarized in separate technical memorandums and are provided to TxDOT *(15, 16)*.

Corridor changes can be evaluated by comparing the data collected; however, without a "control" corridor, corridor changes can be either attributed to the presence of the HOV lane or to changes in freeway traffic characteristics occurring more generally in the Dallas area. Operational data were collected on a quarterly basis on IH-35E South, the "control" section without an HOV lane from March 1990 to March 1998. Each quarter, travel time runs and vehicle-occupancy counts were collected on the control section and compared to the facilities with HOV lanes. Construction of an HOV lane began in the IH-35E South corridor in May 1998, so data collection in that particular corridor was discontinued at that time. Control corridor data are now being collected on SH 183. All control corridor comparisons used in this report, however, reflect the historical data collected on IH-35E South.

ACCIDENT DATA

Annual accident data are available from the Texas Department of Public Safety (DPS) through the Texas Accident Data Files. The accident data can typically be used to calculate accident rates before and after the HOV lanes are operational. In addition, the accident data can be plotted by location (milepoint) to determine the areas where a significant number of accidents are occurring. If there is a significant difference in the pattern of accidents before and after the HOV lane opened, these differences may be attributed to the HOV lane. The geometric and operational characteristics of the HOV lane may provide insight into the high accident location(s). However, there is currently more than a year delay in the coding of the data into the Accident Data Files. Less than two years of "after" data were available for the two concurrent flow HOV lanes. The available data have not been summarized as part of this study because it is not comprehensive enough to draw any conclusions. This study, however, will continue for two more years and will conduct a thorough evaluation of the safety aspects prior to completion.

V. OPERATIONAL PERFORMANCE OF DALLAS AREA HOV LANES

The operational performance of each HOV lane is evaluated by comparing "before" and "after" HOV lane data. The "before" data consist of an average of four to six quarterly data collection periods prior to the construction of the HOV lanes in each corridor. The "after" data are an average of data collected since the HOV lanes became operational.

VEHICLE AND PERSON VOLUMES AND OCCUPANCY

One of the primary objectives of HOV lanes is to increase person-throughput. This goal is accomplished when individuals form carpools or ride transit buses. With more occupants in fewer vehicles, the vehicle occupancy (number of persons in a vehicle) increases, enabling more people to use the facility. This section describes the trends in vehicle and person volumes and occupancy on the HOV lanes and control section (IH-35E South) since the HOV lanes have opened.

Vehicle Volumes

One of the objectives of HOV lanes is to increase *person*-throughput rather than *vehicle*-throughput in the corridor. It is, therefore, not very useful to analyze the number of vehicles using a facility. It is, however, important to investigate the number of persons utilizing a facility (via carpool, vanpool, or bus). An increase in the number of multi-occupant vehicles on a facility indicates an increase in the person-throughput of a facility. The number of two-or-more person (2+) carpools on each of the facilities, before and after the HOV lane opened, is shown in Figure 5. After each HOV lane was opened, there was a significant increase in the number of 2+ carpools on each of the facilities. As shown in Figure 6, the percent increase in carpools ranged from 86 percent on eastbound IH-635 to 279 percent increase on IH-35E North. An analysis of the carpool volumes indicates that the implementation of HOV lanes has resulted in a substantial increase in the number of carpools in each corridor.

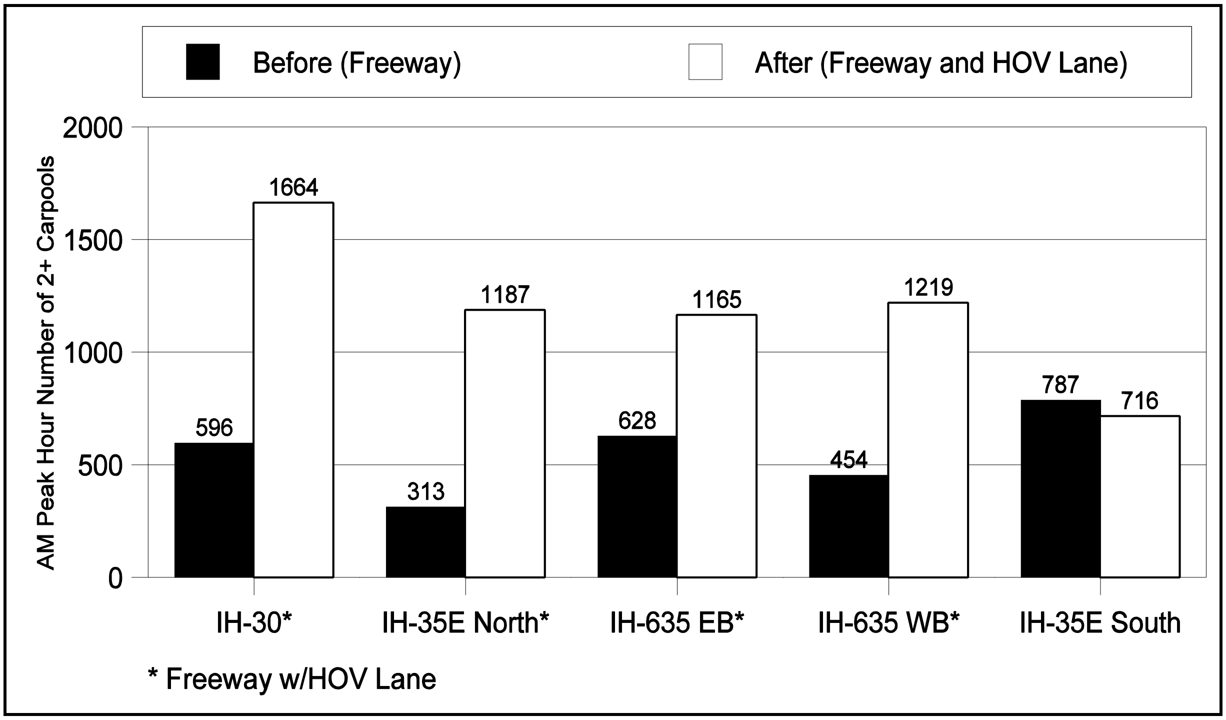


Figure 5. Change in AM Peak Hour Number of Carpools.

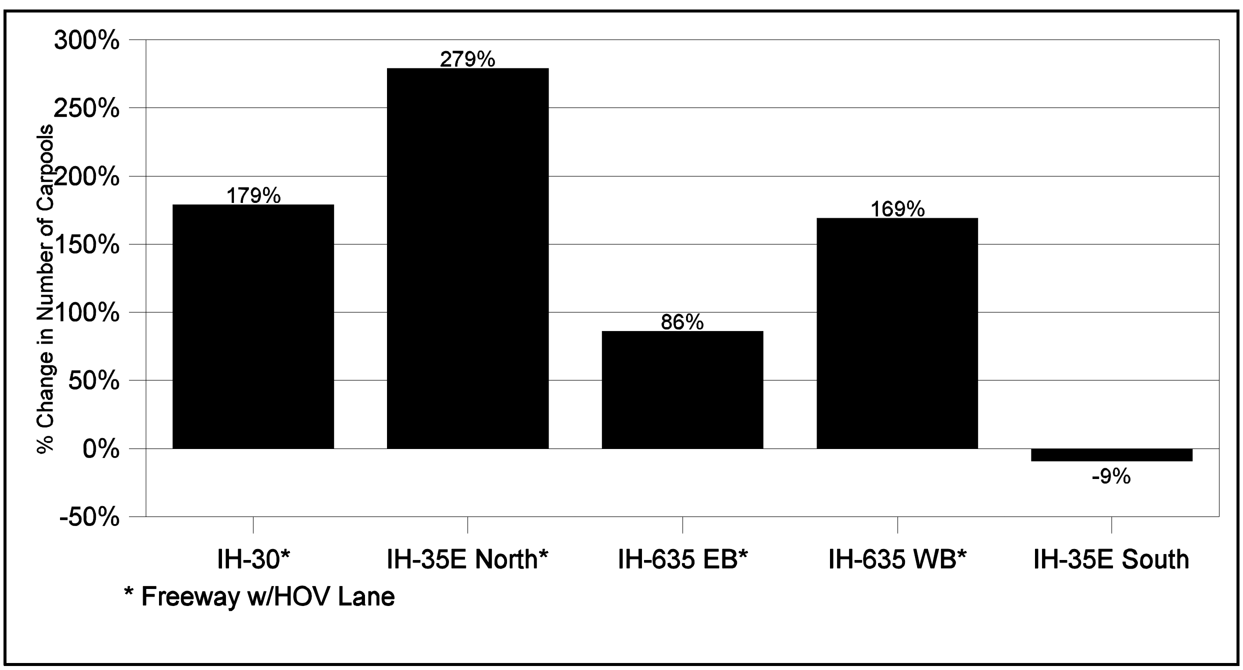


Figure 6. Percent Change in AM Peak Hour Number of Carpools.

Person Volumes

As previously mentioned, HOV lanes should increase person-throughput. Figure 7 shows the AM peak hour "before" and "after" person volumes. An increase in the total person volume has been observed in each corridor since the opening of HOV lanes while a decrease in person movement has been observed in the control corridor.

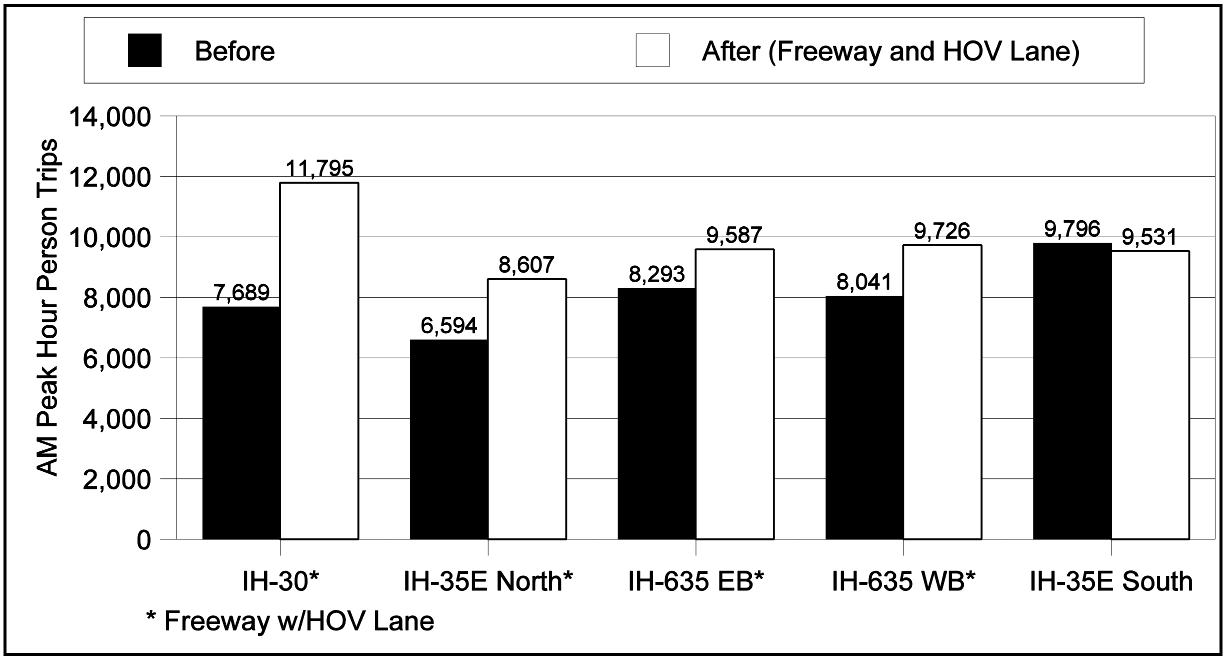


Figure 7. Change in AM Peak Hour Person Trips.

One guideline for an HOV lane is that it should carry at least as many people as the average of the adjacent general purpose lanes. Although there likely will be fewer vehicles in the HOV lane than in a general purpose lane, the *number of people* in an HOV lane should be greater than the average number of people per mainlane. The peak hour person volume per lane for each of the HOV lanes and adjacent general purpose lanes is shown in Figure 8. The IH-30 HOV lane carries more than twice the number of persons as an adjacent freeway lane during the peak hour, while the number of people in the IH-35E North HOV lane is similar to an adjacent freeway lane, and the IH-635 eastbound and westbound HOV lanes have greater person volumes than an adjacent freeway lane. It is important to note that there are approximately 50 DART buses that utilize the IH-30 HOV lane during the peak hour, while only 10 buses utilize the IH-35E North HOV lane. There are

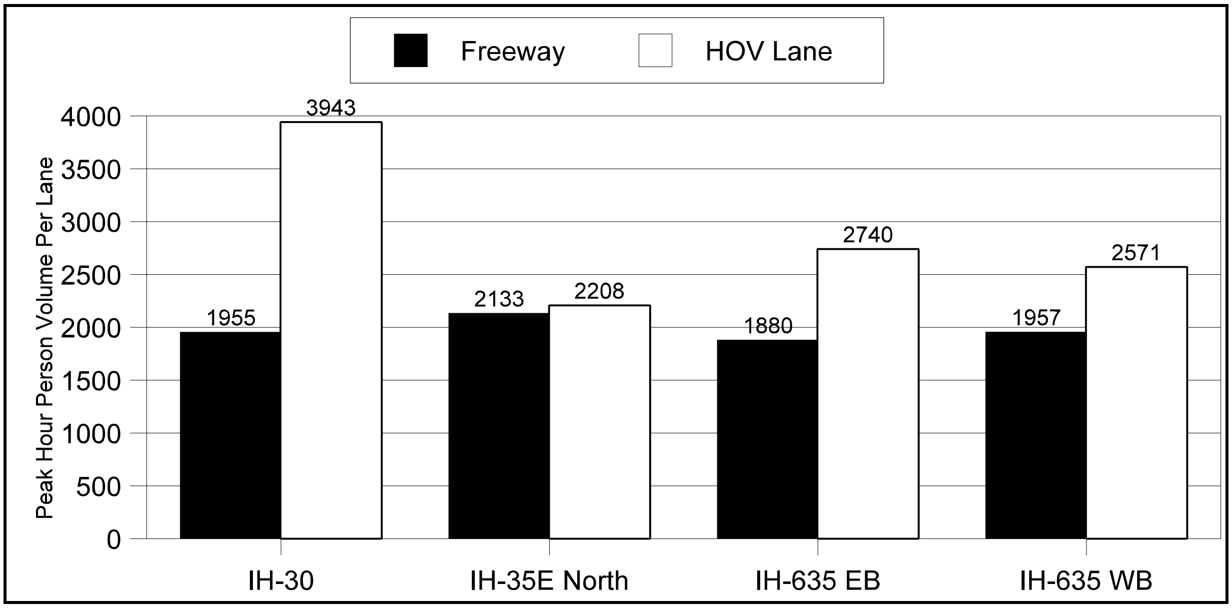


Figure 8. Peak Hour Person Volume Per Lane.

currently no fixed DART bus routes on the IH-635 HOV lanes. The presence of transit routes significantly increases the person-carrying capability of a facility.

Occupancy

The average peak hour automobile and vehicle occupancy for the freeways with an HOV lane and IH-35E South, the control corridor, are shown in Figures 9 and 10, respectively. Due to the presence of several bus routes on IH-30, both the average vehicle occupancy and the average automobile occupancy were evaluated so that an unbiased comparison could be made between the occupancy rates in each corridor. The four facilities with an HOV lane show a similar increase in the average automobile occupancy rate after the HOV lane was implemented, while vehicle occupancy varies amongst the corridors due to the number of transit buses during the peak hour.

Change in automobile occupancy is one method to determine if motorists are forming carpools to utilize the benefits of an HOV lane. The percent change in average automobile occupancy after an HOV lane was opened on IH-30, IH-35E North, and IH-635 is shown in Figure 11.

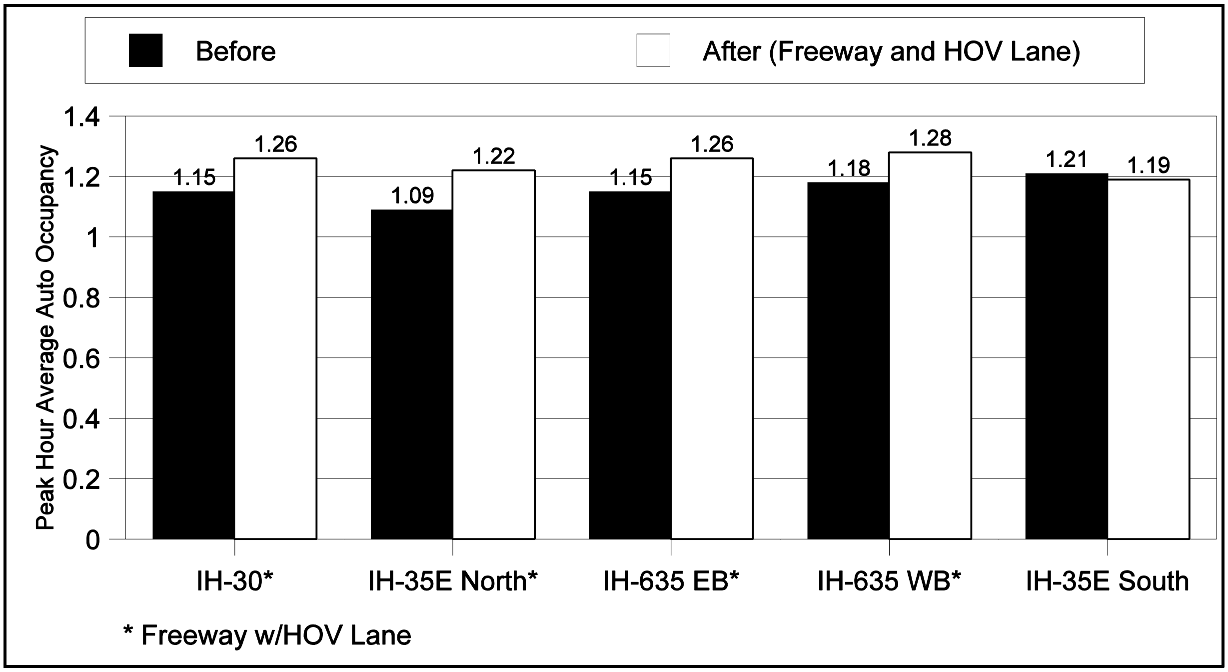


Figure 9. Change in Average Automobile Occupancy.

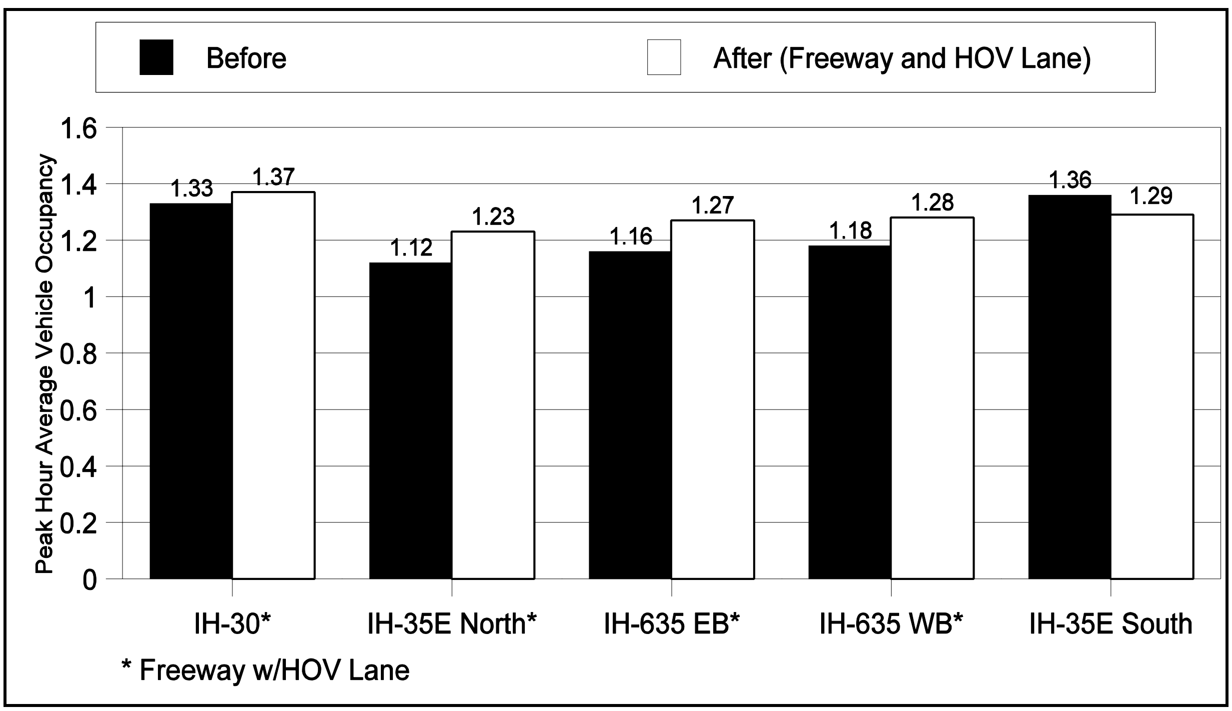


Figure 10. Change in Average Vehicle Occupancy.

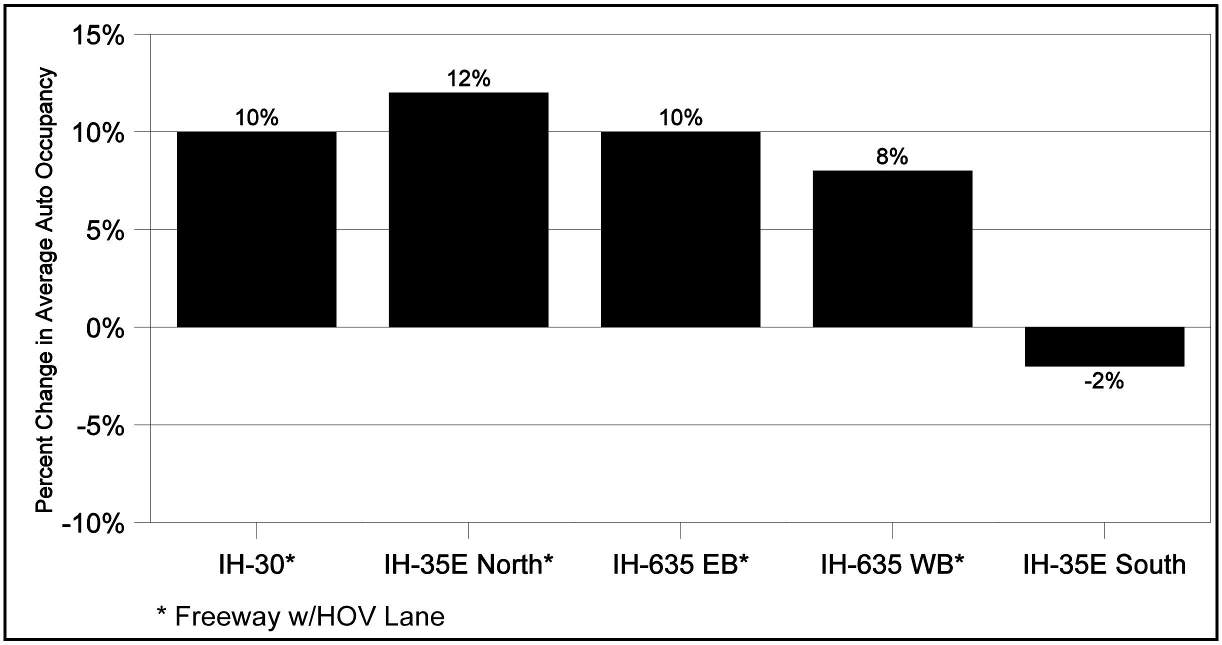


Figure 11. Percent Change in Average Automobile Occupancy.

All four freeways with an HOV lane have an 8 percent to 12 percent increase in the average automobile occupancy, while the average automobile occupancy on IH-35E South (without an HOV lane) has decreased by 2 percent. The increase in average automobile occupancy indicates that motorists are carpooling to gain the benefits of traveling in an HOV lane.

The operational data for the IH-30, IH-35E North, and IH-635 freeways indicate an increase in the person trips and automobile and vehicle occupancy on each facility after an HOV lane opened. In comparison, the control freeway, IH-35E South, did not have a similar increase in person trips and automobile occupancy.

SPEEDS AND TRAVEL TIMES

Operating speeds and travel time savings are two factors that are important to motorists who utilize the HOV lane. HOV lane users expect to travel faster than vehicles in the adjacent general purpose lanes, thus, saving commuting time. The speed and travel time characteristics of the Dallas area facilities with HOV lanes are summarized in this section.

Speeds

A guideline for HOV lanes is that the lane should not negatively impact operations on the mainlanes. If implementing an HOV lane causes travel speeds on the adjacent mainlanes to decrease, the efficiency of the roadway system will be diminished, and there may be public opposition to the project. The peak hour travel speeds on the HOV lanes and adjacent mainlanes before and after implementation of the HOV lane are shown in Figure 12.

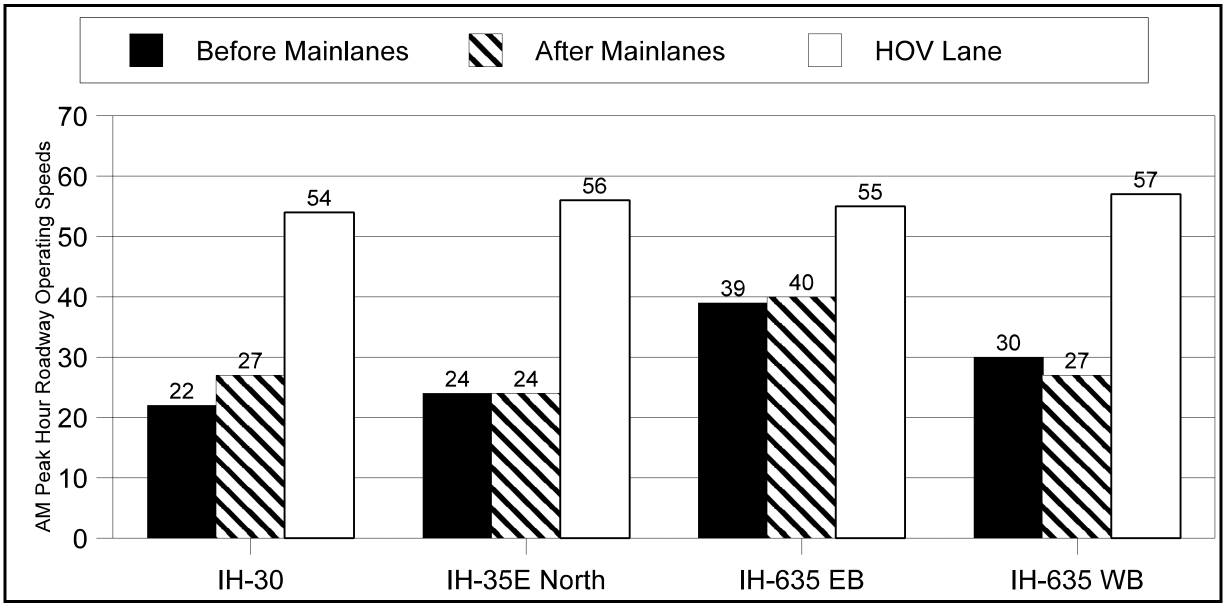


Figure 12. Change in Roadway Operating Speeds.

There was an increase in mainlane speeds after the HOV lane opened on IH-30. Opening an HOV lane on IH-35E North and IH-635 eastbound and westbound appears to have essentially no impact (positive or negative) on the mainlane operating speeds. In addition, on each of the facilities, the HOV lane speeds were significantly higher than the speeds on the adjacent general purpose lanes.

Travel Times

Travel time savings are directly related to operating speed. It has been found that to encourage the formation of carpools or to increase bus utilization, a minimum of five minutes of total travel time savings over the general purpose lanes are required. It is imperative that the HOV lane provide users travel time savings over the general purpose lanes. The peak hour travel time

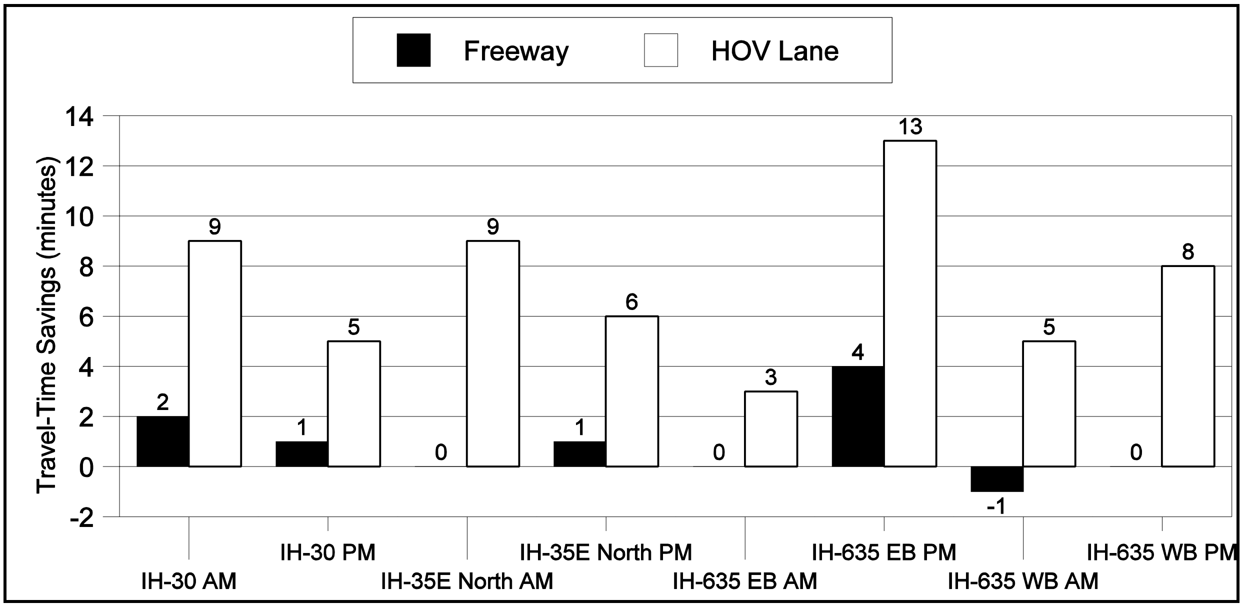


Figure 13. Peak Hour Travel Time Savings after HOV Lane Opening.

savings on incident-free days for each of the HOV lanes are shown in Figure 13. This travel time savings actually underestimates the *average* weekday travel time savings due to incidents on the freeway mainlanes. An incident on the freeway mainlanes would likely increase the travel time on the mainlanes; however, it may or may not have an impact on the HOV lane travel times depending on the type of incident. In general, the HOV lanes save motorists more than five minutes over the general purpose lanes on incident-free days.

Perceived travel time savings may be of greater importance than actual travel time savings. A survey of IH-30 motorists in 1995 determined that the transit users perceived travel time savings as 13 minutes during the AM peak and 12 minutes in the PM peak (*17*). Similarly, the IH-30 carpoolers perceived they saved 16 minutes during the AM peak and 13 minutes in the PM peak over the general purpose lanes. A motorist survey has not been conducted on either IH-35E North or IH-635.

TRANSIT OPERATION IMPACTS

Potential HOV lane impacts on transit operations may affect transit route and transit ridership, which are discussed in the next section. The IH-635 corridor currently does not have any fixed transit bus routes using the HOV lanes on a regular basis.

Transit Routes

Bus operating speeds have more than doubled since the opening of the HOV lanes on IH-30 and IH-35E North during the AM and PM peak hour, as shown in the "Speeds and Travel times" section of this chapter. In the IH-30 corridor, which has approximately 50 DART buses using the HOV lane during the peak hour, the result is that the operating cost of DART buses using the lane has been reduced by approximately $402,000 per year because fewer buses are required to run the "before" HOV lane routes due to the travel time savings and trip-time reliability. Additionally, the bus schedule times have been reduced by six minutes on IH-30 during the AM and PM peak hours as a result of the travel time savings previously discussed. The cost of operating DART buses on IH-35E North has also been reduced by approximately $185,000 per year as a result of implementation of the HOV lane.

Transit Ridership

The AM and PM peak hour bus ridership is shown in Figure 14. An increase in the bus ridership has not been observed since the opening of HOV lanes on IH-30 and IH-35E North and, in fact, a decrease has been observed on IH-30. The reason for this may be related, in part, to the increase in the number of carpools using the HOV lane. A review of the ridership on the HOV lane during the past several data collection periods appears to indicate a correlation between bus and carpool ridership. While the total persons using the HOV lane has remained relatively constant

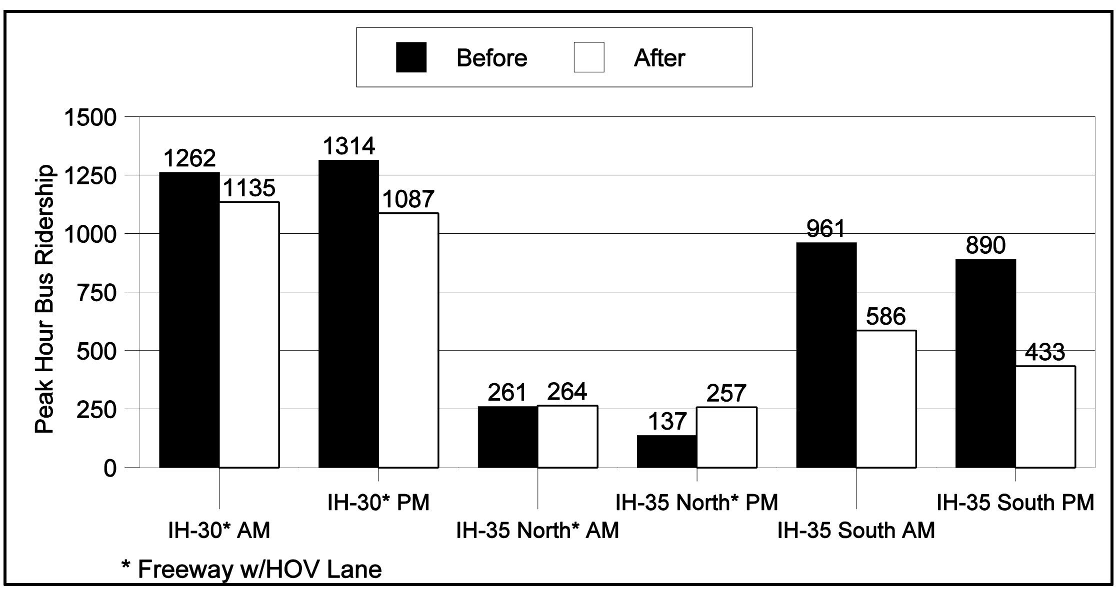


Figure 14. Change in Transit Bus Ridership.

during the past year, the bus and carpool person volumes fluctuate inversely to each other (i.e., the carpool ridership is high while the bus ridership is low during some data collection periods and vice versa during others). This relationship appears to indicate that some commuters utilize whichever mode, bus or carpool, is more convenient on any given day.

COST EFFECTIVENESS

The cost effectiveness of each of the three HOV lanes projected out to 10 years is shown in Tables 4, 5, and 6. The tables show the benefit/cost ratio at the end of each fiscal year (September through August) with the exception of the IH-635 HOV lane. The HOV lane on IH-635 opened half-way into fiscal year 1997, so the benefits are for six months in 1997 and for six months in the final year (2007) for a total of 10 years. The benefits are based on the travel time savings afforded to users of the HOV and, in the case of the IH-30 HOV lane, include benefits to persons on the adjacent freeway general purpose lanes as they realized a travel time savings with the implementation of the lane. The benefits are based on measured travel time savings through fiscal year 1997. Benefits in future years are assumed to be the same as fiscal year 1997 benefits. The value of time used is $11.47 per person. All three HOV lane projects are cost effective and have attained, or are projected to attain, a benefit cost ratio greater than 1.0 within the first five years of operation.

Table 4. IH-30 (ERLT) Freeway HOV Lane Benefit/Cost Analysis.[1]

Benefits and Costs (Million Dollars)[2]						
Comment	Fiscal Year	Capital Cost	Operation/ Enforcement	HOV Lane Benefits	Mainlane Benefits	B/C Ratio
Initial Construction	1992	12.2	0.60	2.85	2.64	0.43
	1993	-	0.60	2.89	3.68	0.88
	1994[3]	-	0.60	2.66	2.45	1.19
AM Auxiliary Lane	1995	0.2	0.60	3.28	3.92	1.57
PM Extension	1996[4]	5.0	0.60	2.99	3.31	1.46
	1997	-	0.60	3.47	2.88	1.68
	1998	-	0.60	4.00	3.00	1.92
	1999	-	0.60	4.12	3.12	2.14
	2000	-	0.60	4.12	3.12	2.34
	2001	-	0.60	4.12	3.12	2.53

Notes:
[1]HOV lane opened in September 1991.
[2]Benefits include $402,000 savings on DART bus operating costs per year.
[3]AM auxiliary lane opened in July 1994.
[4]PM extension opened in February 1996.

Table 5. IH-35E (Stemmons) Freeway HOV Lane Benefit/Cost Analysis.[1]

Benefits and Costs (Million Dollars)[2]						
Comment	**Fiscal Year**	**Capital Cost**	**Operation/ Enforcement**	**HOV Lane Benefits**	**Mainlane Benefits**	**B/C Ratio**
HOV Lane	1997	7.0				
S-Ramp		2.9	0.20	2.59	0.00	0.26
	1998	-	0.20	2.67	0.00	0.50
	1999	-	0.20	2.42	0.00	0.71
	2000	-	0.20	2.42	0.00	0.90
	2001	-	0.20	2.42	0.00	1.07
	2002	-	0.20	2.42	0.00	1.24
	2003	-	0.20	2.42	0.00	1.39
	2004	-	0.20	2.42	0.00	1.54
	2005	-	0.20	2.42	0.00	1.67
	2006	-	0.20	2.42	0.00	1.80

Notes:
[1]HOV lane opened in September 1996.
[2]Benefits include $185,000 savings on DART bus operating costs per year.

Table 6. IH-635 (LBJ) Freeway HOV Lane Benefit/Cost Analysis.[1]

Benefits and Costs (Million Dollars)						
Comment	**Fiscal Year**	**Capital Cost**	**Operation/ Enforcement**	**HOV Lane Benefits**	**Mainlane Benefits**	**B/C Ratio**
Initial Construction	1997[2]	16.3	0.10	4.84	0.00	0.30
	1998	-	0.20	9.23	0.00	0.83
	1999	-	0.20	9.60	0.00	1.35
	2000	-	0.20	9.60	0.00	1.84
	2001	-	0.20	9.60	0.00	2.30
	2002	-	0.20	9.60	0.00	2.73
	2003	-	0.20	9.60	0.00	3.14
	2004	-	0.20	9.60	0.00	3.53
	2005	-	0.20	9.60	0.00	3.89
	2006	-	0.20	9.60	0.00	4.24
	2007[3]	-	0.10	4.80	0.00	4.41

Notes:
[1]HOV lane opened in March 1997.
[2]Includes 3rd and 4th quarters of FY 1997 only (6 months).
[3]Includes 1st and 2nd quarters of FY 2007 only (6 months).

ENFORCEMENT AND VIOLATIONS

The HOV lanes are enforced by DART Transit Police. Although the number of enforcement officers monitoring the lanes varies, the IH-35E North and IH-635 HOV lanes are routinely enforced by a combination of roving and stationary enforcement in squad cars and motorcycles during the peak periods and sporadically during the off-peak periods.

More officers, however, are required to enforce the concurrent flow lanes than the barrier-separated contraflow lane on IH-30. The IH-30 HOV lane is effectively enforced by two transit police officers while the concurrent flow lanes require three to four officers each during the peak periods.

The peak hour violation rate for each of the HOV facilities is shown in Figure 15. Due to the presence of Transit Police officers on the facility, the violation rates on the HOV lanes have been relatively low. The violation rate on the IH-30 HOV lane, which is barrier-separated, is significantly

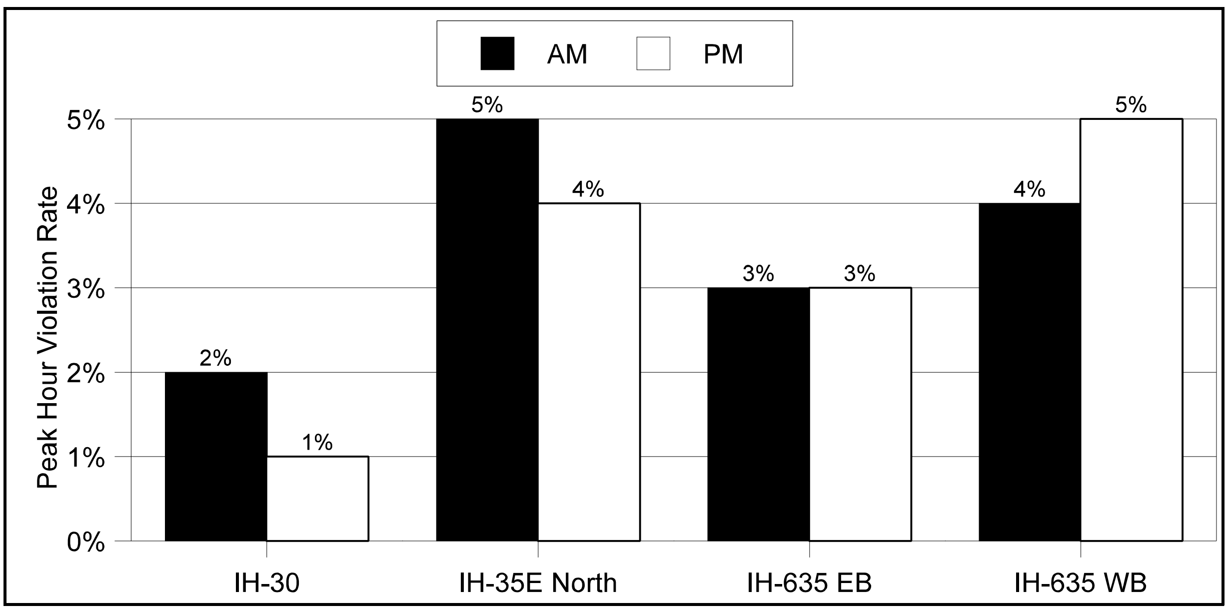


Figure 15. Observed Occupancy Violation Rates.

lower than the rate on the concurrent flow HOV lanes. The violation rates on the concurrent flow lanes, however, are at the lower end of typical nationally reported concurrent flow HOV lane violation rates, ranging between 5 percent and 40 percent.

In addition to traditional HOV lane enforcement methods, a public telephone hotline (HERO) for reporting HOV lane violators, similar to the program in the Seattle area, is currently being studied by DART for implementation. The HERO program consists of a dedicated phone number for motorists to report HOV lane violators and identifies specific individuals who need additional information about the benefits of HOV lanes.

SAFETY

Analysis of accident data, available from the Texas Department of Public Safety, is the preferred way to assess the safety of a corridor. The data can be used to determine if there is a significant difference in the pattern of accidents and crash rates before and after the HOV lane opened. A little more than a year of "after" data was available for the two concurrent flow HOV lanes. The available data have not been summarized as part of this study because it is not comprehensive enough to draw any conclusions. This study, however, will continue for two more years and a thorough evaluation of the safety aspects will be conducted in subsequent years.

AIR QUALITY

As previously mentioned, one of the benefits of HOV lanes is a reduction in fuel consumption and vehicle emissions as vehicle speeds increase from stop-and-go congested conditions. A study conducted by NCTCOG estimated the reduction in vehicle emissions from the implementation of each of the HOV lanes in the Dallas area (*18*). This reduction is based on changes in travel patterns for three groups of commuters: new carpools formed from single-occupant vehicles to use the HOV lane, existing carpools in the mainlanes utilizing the HOV lane, and drivers on the parallel arterials switching to use the mainlanes. It is estimated that the volatile organic compound (VOC) emissions are reduced by 51.4 lbs/day on IH-30, 109.9 lbs/day on IH-35E North, and 236.7 lbs/day on IH-635 due to the HOV lane(s) on each of these facilities. No attempt has been made to refine or verify the estimates since NCTCOG staff used operational data supplied by TTI to estimate the emissions.

PUBLIC ACCEPTANCE

In 1995, a survey of IH-30 carpoolers and bus riders using the HOV lane and motorists in the general purpose lanes was conducted to determine motorists' attitudes regarding commuter travel behavior (*19*). The primary reasons cited for using transit service were that it is cheaper and more convenient than driving, while the primary reasons for carpooling were that it is cheaper than driving alone and saves time.

DART and TxDOT have been very receptive to the public comments about the HOV lanes, and they have been continually improving operations. After the IH-30 HOV lane was opened, a bus route was switched from an arterial to the freeway HOV lane to gain the travel time savings. In July 1994, to improve AM operations, an auxiliary lane was added at the terminus of the westbound HOV lane. In addition, in February 1996, the eastbound HOV lane for PM operations was extended from Dolphin Road to Jim Miller Road to mitigate recurrent congestion at Dolphin Road.

When the IH-635 HOV lane was opened, motorists from the Dallas North Tollway could not access the westbound IH-635 HOV lane. Due to public response, another access location was added to provide access from the Tollway to the westbound HOV lane.

It is anticipated that a survey of HOV lane users and nonusers will be conducted on IH-35E North and IH-635 to assess the public opinion of concurrent flow lanes.

VI. OTHER BARRIER- VERSUS BUFFER-SEPARATED HOV LANE ISSUES

In addition to the quantitative issues associated with barrier-separated and buffer-separated HOV lanes, there are also several qualitative issues that must be considered. These qualitative issues include design requirements, implementation time, capacity, access/egress, incident management, and flexibility, which are discussed in this chapter.

DESIGN REQUIREMENTS

Barrier-separated HOV lanes or separated roadways are generally implemented in corridors with a high HOV demand. The benefits of an HOV project must outweigh the cost of building a separated roadway for HOVs. In addition, separated roadways usually require more right-of-way than other types of HOV facilities because of acceleration and deceleration lanes at access/egress areas and wider areas to allow for direct connect ramps. This, many times, makes it difficult to retrofit these types of facilities into existing cross sections.

Buffer-separated or concurrent flow HOV lanes generally require less ROW than separated roadways. These facilities are typically located on the inside lane of the freeway; however, they can be the outside lane of the freeway, although non-HOV traffic would need to access the HOV lane to enter and exit the freeway, which is undesirable.

IMPLEMENTATION TIME

Separated roadways generally take the longest time to implement. The additional time is required for designing permanent structures, obtaining needed ROW, and obtaining funding for the project, similar to any long-term construction project. The implementation time for concurrent flow HOV lanes is relatively short, particularly when an inside freeway shoulder already exists. Many concurrent flow HOV projects can be accommodated in the existing ROW by converting the inside shoulder to an HOV lane. In addition, reducing the general purpose lane widths or shifting the lanes may be required to provide a buffer or enforcement area along the facility.

CAPACITY

The capacity of any facility is dependent on many factors, including design speed, lane width, and the presence of vehicles other than passenger cars in the traffic stream. Differences in capacity specific to the generic comparison of barrier- versus buffer-separated can be attributed to the number of and the design of access/egress areas and the offset to either a barrier or general purpose lane traffic. The capacity of an HOV facility is in the 1500 vph to 1700 vph range to ensure free-flow operations before considering the buffer- and barrier-separated issues that impact capacity.

Concurrent flow lanes with continuous access and egress will have continuous merging of high- and low-speed traffic, which will reduce the capacity of the facility. Limited access via a painted buffer will focus this merging activity to specific areas and should improve operations. However, without acceleration and deceleration lanes, which typically are provided at barrier-separated access/egress areas, operations and capacity will be negatively impacted.

The reduction in capacity due to an offset of less than 6 ft to a fixed barrier can be quantified using procedures in the Highway Capacity Manual (*19*). The capacity reduction for a buffer-separated lane with an offset of less than 6 ft to a congested general-purpose freeway lane, however, is not known and is beyond the scope of this research to determine.

ACCESS/EGRESS

Access to separated roadways is controlled and more limited than on concurrent flow facilities, which provide safe and efficient operations. Access can be provided with direct connector ramps to/from transit centers, park-and-ride lots, and frontage roads or by slip ramps to/from the freeway mainlanes or frontage road. In addition, the barriers provide effective delineation of entrance and exit points (*14*).

On separate facilities, carpools must travel the entire distance on the HOV lane; however, on concurrent flow facilities, carpools can travel the entire HOV facility or just a portion of the facility, as dictated by their origin and destination. The access to concurrent flow facilities is much less restrictive than separate roadways facilities. On concurrent flow facilities, access may be provided continuously along the facility or restricted to certain locations, as delineated by pavement markings. The amount of access along the facility should be a decision based on safety and traffic operations concerns. Frequent access increases the potential number of carpoolers but also decreases operational effectiveness.

Concurrent flow HOV lanes are typically the inside lane on the freeway. Therefore, vehicles entering the freeway (generally a right-hand entrance ramp) must weave across several congested freeway lanes to access a median HOV lane, and then weave across several congested freeway lanes to exit the freeway (generally a right-hand exit ramp). The weaving to/from the freeway ramps and HOV lane limit the distance that carpools can travel in the HOV lane; therefore, concurrent flow HOV lanes are typically longer distance projects. This weaving maneuver has the potential to negatively affect the mainlane traffic operations. Additionally, if there are left-side entrance or exit ramps, provisions must be made to allow general traffic to use the HOV lane in the proximity of the ramp, which is not a desirable design from a traffic operations standpoint.

INCIDENT MANAGEMENT

Incident management is an issue that must be addressed in all freeway corridors. Incident management in corridors with concurrent flow HOV lanes is especially critical. HOV lane users who do not regularly gain a travel time savings and trip-time reliability may not continue to use the HOV lane. Incidents that occur on the freeway general purpose lanes can, and have, blocked the concurrent flow HOV lane because of the lack of a physical barrier separating the HOV lane and adjacent general purpose lanes. DART has personnel who patrol the HOV lanes and respond to all incidents that occur on the facilities. A project is currently being conducted in the IH-635 corridor to improve incident management response times on the general purpose lanes. It involves staging a tow truck within the corridor to expedite response times to crashes and mechanical breakdowns.

FLEXIBILITY

A separate roadway facility allows for flexibility in the criteria for eligible users because of the limited access. On the other hand, concurrent flow HOV lanes have flexibility in design. Such projects can be interim projects that are retrofitted in the existing cross section or they can be designed as long-term permanent facilities.

Hours of Operation (24-Hour versus Peak Period Operation)

Typically, barrier-separated HOV lanes are reversible, so they can serve the peak direction commuting traffic; therefore, they can not operate 24 hours a day because of the operational requirements to close the lane(s) and reverse its direction. Buffer-separated HOV lanes can either operate 24 hours a day or peak periods only. A buffer-separated HOV lane that does not operate 24 hours a day can be utilized as a shoulder or an additional general purpose lane during the off-peak hours of the day. This, however, will require additional signing, incident management efforts, enforcement, and education of the motoring public to avoid confusion. Several operational issues need to be considered before this type of policy is implemented including:

- Is an additional general purpose lane needed during the off-peak hours?
- Will this type of treatment be accepted and understood by motorists traveling in the corridor?
- Can a disabled vehicle be promptly removed from the inside shoulder prior to its designation of HOV lane operations each day?

The two concurrent flow HOV lanes in the Dallas area currently operate 24 hours a day. The typical vehicle and person volumes for each hour of the day are shown in Figures 16 through 19. The traffic patterns on IH-35E North are such that approximately 70 percent of the total corridor traffic is traveling southbound (inbound) during the morning peak period, and the opposite occurs during the evening peak period in the northbound (outbound) direction. There is no recurrent congestion in the off-peak direction or outside of the peak periods on the freeway general purpose lanes. This pattern is reflected in the HOV lane usage shown in Figures 16 and 17.

IH-635, however, has a nearly equal amount of corridor traffic traveling in each direction during the morning and evening peak periods. There is also some recurrent congestion outside of the peak periods. In addition to the peak periods, the HOV lanes on IH-635 are being utilized during the off-peak periods as shown in Figures 18 and 19. No attempt has been made to quantify any benefits as a result of the off-peak period usage.

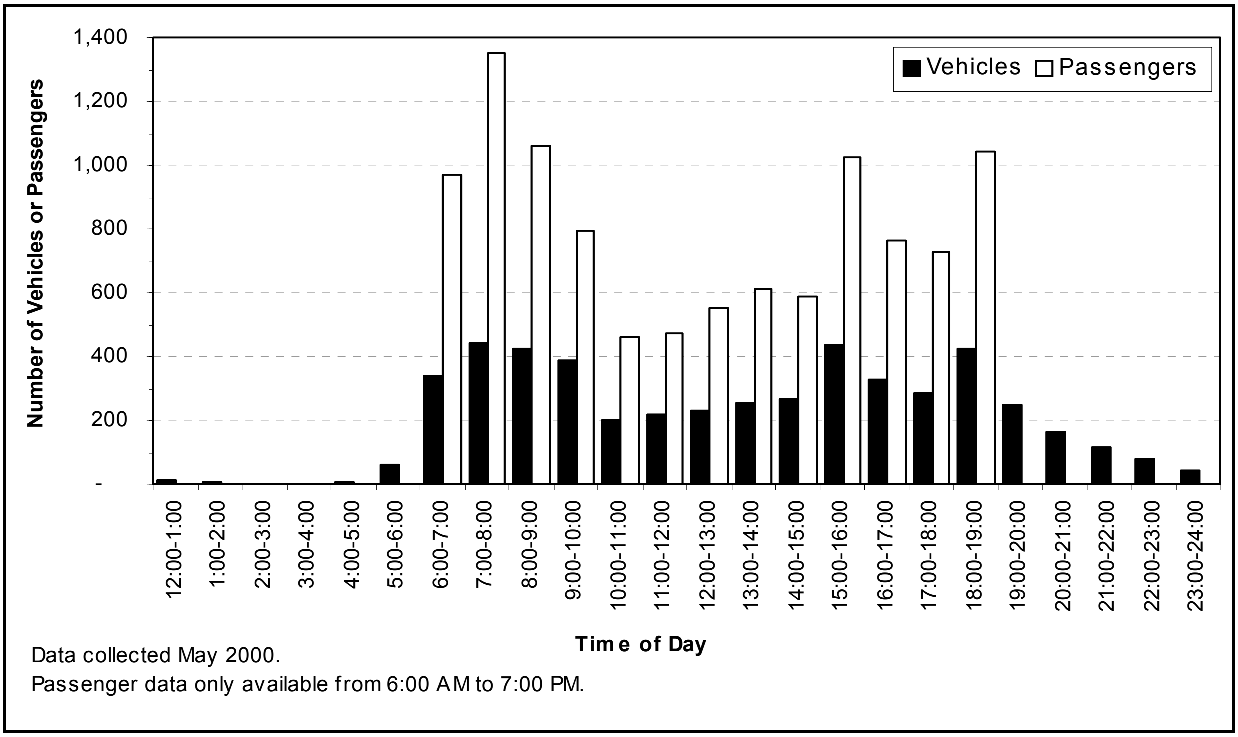


Figure 16. IH-35E North (Stemmons) Freeway Southbound HOV Lane Hourly Volumes.

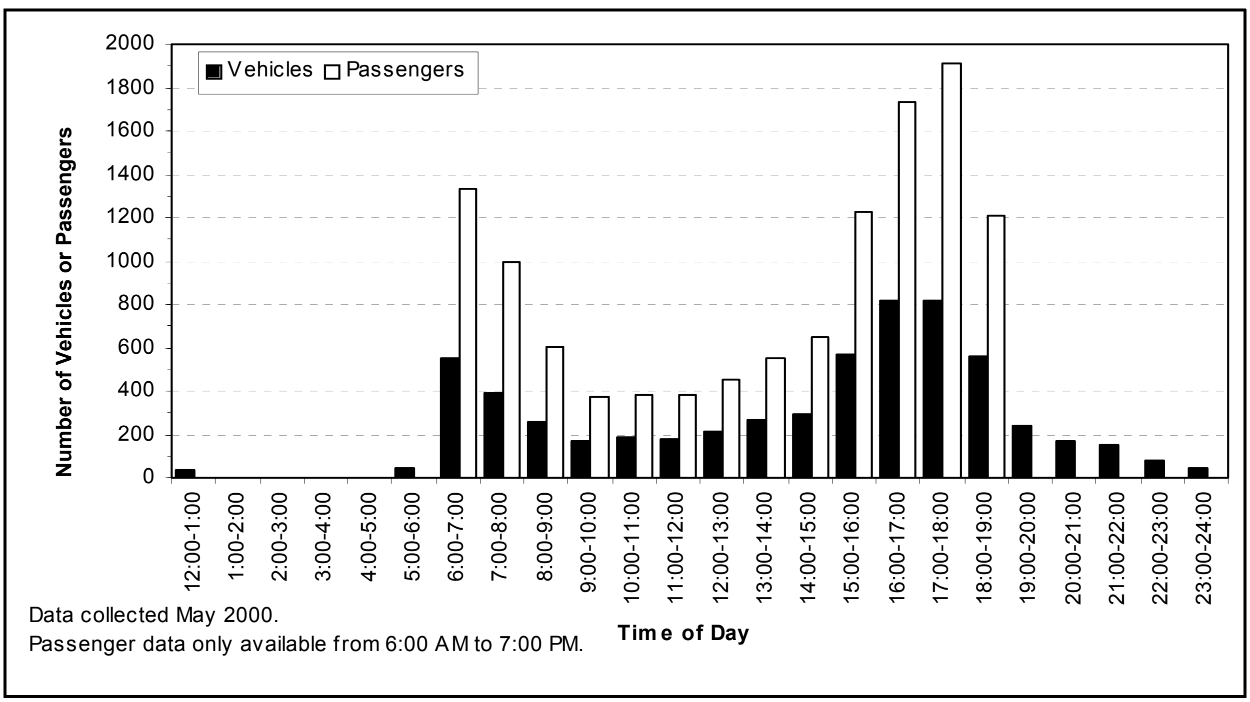


Figure 17. IH-35E North (Stemmons) Freeway Northbound HOV Lane Hourly Volumes.

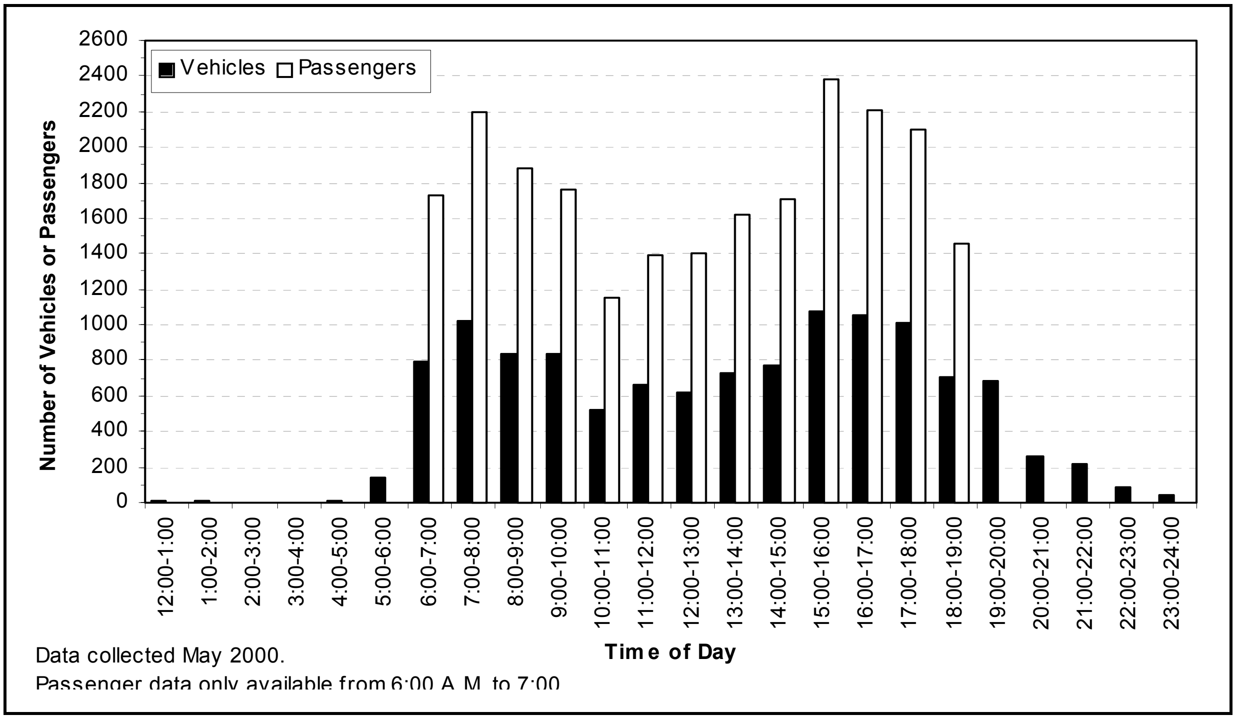


Figure 18. IH-635 (LBJ) Freeway Westbound HOV Lane Hourly Volumes.

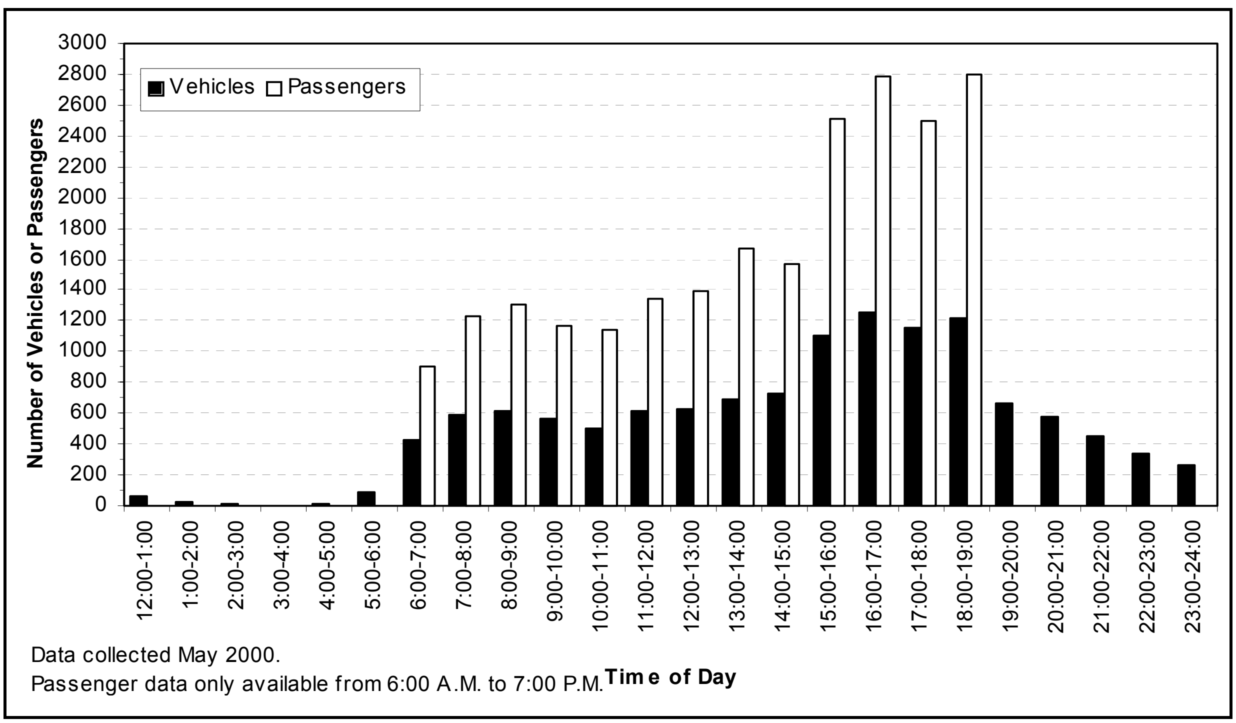


Figure 19. IH-635 (LBJ) Freeway Eastbound HOV Lane Hourly Volumes.

Toll Applications

Congestion pricing can be more easily implemented on barrier-separated HOV lanes, due to their limited access, to allow single-occupant vehicles and/or trucks to pay a toll to use the facility during certain time periods. However, congestion pricing cannot be easily implemented on buffer-separated (concurrent flow) HOV lanes due to the lack of physical separation. If there is no physical separation between the HOV lane and the general purpose lanes, drivers may weave between the HOV lane and the general purpose lane to avoid toll booths or toll tag readers. Thus, it is not recommended that any type of congestion pricing be implemented on the concurrent flow HOV lanes in the Dallas area. Additionally, as discussed in the previous chapter, a need does not currently exist for congestion pricing based on the HOV lane volumes and congestion patterns in the two corridors.

SUMMARY OF QUALITATIVE ISSUES

Table 7 shows a summary of the qualitative issues previously discussed.

Table 7. Qualitative HOV Lane Issues.

Characteristic	Barrier-Separated	Buffer-Separated
Design Requirements	High HOV demand Wide cross section needed	Require less right-of-way
Implementation Time	Longest time to implement	Relatively short
Capacity	1500 vph to 1700 vph	Potentially less than barrier-separated
Access/Egress	Limited	May be unlimited
Incident Management	Easier to ensure trip-time reliability	Freeway incidents likely to have greater detrimental impact to HOV lane
Flexibility	Flexibility in eligible users May include congestion pricing	Many different (short distance) trips can be served
Hours of Operation	Set-up/close-down time required	Operations other than 24 hours per day can cause motorist confusion
Toll Applications	Automated toll collection relatively easy to implement and enforce	Limited options available

VII. CONCLUSIONS

The goal of this research was to investigate the operational effectiveness of the new concurrent flow HOV lanes in the Dallas area, as well as to assess the effectiveness of concurrent flow (buffer-separated) versus contraflow (barrier-separated) HOV lanes in the Dallas area. As shown in Table 8 and the data summary in Tables 9 through 13, the concurrent flow lanes have generated a substantial number of carpools, increased the person movement in the corridor, increased the occupancy rate in the corridor, and not negatively impacted the operation of the adjacent freeway general purpose lanes. The person movement increase, however, to date only, marginally justifies the HOV lanes, as they are moving only slightly more persons than a single adjacent general purpose lane during the peak hour. Experience from Houston, however, indicates that two to four years of operation of a facility is required before a complete and thorough assessment can be made.

Table 8. Summary of HOV Lane Measures of Effectiveness.

Measure	IH-30	IH-35E N	IH-635 EB	IH-635 WB
Has there been an increase in the number of carpools in the corridor?	Yes	Yes	Yes	Yes
Does the HOV lane carry as many people as an adjacent general purpose lane?	Yes	Yes	Yes	Yes
Has the person volume increased at least as much as the percent increase in number of lanes?	Yes	No	No	No
Has the occupancy rate in the corridor increased?	Yes	Yes	Yes	Yes
In terms of speed, has the HOV lane not negatively impacted the general purpose lanes?	Yes	Yes	Yes	Yes
Are the HOV lanes saving HOV lane vehicles at least 5 minutes of travel time?	Yes	Yes	No	Yes
Are the HOV lanes providing motorists at least a minute per mile travel time savings?	Yes	Yes	No	No

Note:
Answers provided are for the AM peak hour.

All three HOV lane projects are cost effective and have attained, or are projected to attain, a benefit cost ratio greater than 1.0 within the first five years of operation. While this appears to indicate that either type of HOV lane is acceptable, other issues must be considered such as the safety of a non-barrier-separated lane. Limited crash data were available when this report was prepared to assess the impact on crash rates as a result of implementing the concurrent flow lanes. It is therefore recommended that the lanes continue to be monitored and a reassessment of their effectiveness be conducted when additional data are available.

Table 9. IH-35E North (Stemmons) Freeway Directional Corridor Operational Data.

Operational Data	"Before"[1] (Mainlanes)	"After"[2] (Mainlanes & HOV)	Percent Change
VEHICLE VOLUMES			
TOTAL			
AM Peak Hour-Southbound	5965	6984	17%
PM Peak Hour-Northbound	5902	6617	12%
2+ OCCUPANT AUTOMOBILES			
AM Peak Hour-Southbound	313	1187	279%
PM Peak Hour-Northbound	465	1182	154%
DART BUS			
AM Peak Hour-Southbound	8	9	13%
PM Peak Hour-Northbound	5	9	80%
PERSON VOLUMES			
TOTAL			
AM Peak Hour-Southbound	6594	8607	31%
PM Peak Hour-Northbound	6607	8193	24%
2+ OCCUPANT AUTOMOBILES			
AM Peak Hour-Southbound	651	2517	287%
PM Peak Hour-Northbound	992	2627	165%
DART BUS			
AM Peak Hour-Southbound	261	264	1%
PM Peak Hour-Northbound	137	257	88%
OCCUPANCY RATE			
AUTOMOBILE			
AM Peak Hour-Southbound	1.06	1.20	13%
PM Peak Hour-Northbound	1.09	1.22	12%
VEHICLE			
AM Peak Hour-Southbound	1.11	1.23	11%
PM Peak Hour-Northbound	1.12	1.23	10%
Operational Data	**"Before" (Mainlanes)**	**"After" (Mainlanes)**	**Percent Change**
Travel time (MINUTES)			
AM Peak Hour-Southbound	16.60	17.00	2%
PM Peak Hour-Northbound	12.10	11.50	-5%
SPEEDS (MILES PER HOUR)			
AM Peak Hour-Southbound	24	24	0%
PM Peak Hour-Northbound	28	29	4%
Operational Data	**"Before" (Mainlanes)**	**"After" (HOV Lane)**	**Percent Change**
Travel time (MINUTES)			
AM Peak Hour-Southbound	16.60	7.30	-56%
PM Peak Hour-Northbound	12.10	6.50	-46%
SPEEDS (MILES PER HOUR)			
AM Peak Hour-Southbound	24	56	133%
PM Peak Hour-Northbound	28	52	86%
PARK-AND-RIDE LOT USAGE[3]	526	652	24%

Notes:
[1]"Before" data are an average of data collected from September 1993 to March 1995.
[2]"After" data are an average of data collected from December 1996 to March 2000.
[3]"Before" are data from March 1992 to June 1996, while "After" are data from September 1996 to March 2000.

Table 10. IH-30 (ERLT) Freeway Directional Corridor Operational Data.

Operational Data	"Before"[1] (Mainlanes)	"After"[2] (Mainlanes & HOV)	Percent Change
VEHICLE VOLUMES			
TOTAL			
AM Peak Hour-Westbound	5,692	8,758	54%
PM Peak Hour-Eastbound	7,104	8,931	26%
2+ OCCUPANT AUTOMOBILES			
AM Peak Hour-Westbound	596	1,664	179%
PM Peak Hour-Eastbound	954	1,884	97%
DART BUS			
AM Peak Hour-Westbound	40	43	8%
PM Peak Hour-Eastbound	40	45	13%
PERSON VOLUMES			
TOTAL			
AM Peak Hour-Westbound	7,689	11,795	53%
PM Peak Hour-Eastbound	9,549	12,262	28%
2+ OCCUPANT AUTOMOBILES			
AM Peak Hour-Westbound	1,290	3,505	172%
PM Peak Hour-Eastbound	2,059	4,044	96%
DART BUS			
AM Peak Hour-Westbound	1,262	1,135	-10%
PM Peak Hour-Eastbound	1,314	1,087	-17%
OCCUPANCY RATE			
AUTOMOBILE			
AM Peak Hour-Westbound	1.13	1.22	8%
PM Peak Hour-Eastbound	1.15	1.26	10%
VEHICLE			
AM Peak Hour-Westbound	1.33	1.35	2%
PM Peak Hour-Eastbound	1.33	1.37	3%
Operational Data	**"Before" (Mainlanes)**	**"After" (Mainlanes)**	**Percent Change**
Travel time (MINUTES)			
AM Peak Hour-Westbound	14.70	12.40	-16%
PM Peak Hour-Eastbound	11.2 [3]	10.00	-11%
SPEEDS (MILES PER HOUR)			
AM Peak Hour-Westbound	22	27	23%
PM Peak Hour-Eastbound	29 [3]	33	14%
Operational Data	**"Before" (Mainlanes)**	**"After" (HOV Lane)**	**Percent Change**
Travel time (MINUTES)			
AM Peak Hour-Westbound	14.70	6.20	-58%
PM Peak Hour-Eastbound	11.2 [3]	6.20	-45%
SPEEDS (MILES PER HOUR)			
AM Peak Hour-Westbound	22	54	145%
PM Peak Hour-Eastbound	29 [3]	53	83%
PARK-AND-RIDE LOT USAGE	859	866	1%

Notes:

[1]"Before" data are an average of data collected from October 1989 to June 1991.

[2]"After" data are an average of data collected from June 1996 to March 2000.

[3]"Before" data are an average of December 1991 to December 1992 data to account for the extension of the PM HOV lane limits.

Table 11. IH-635 (LBJ) Freeway Eastbound Corridor Operational Data.

Operational Data	"Before"[1] (Mainlanes)	"After"[2] (Mainlanes & HOV)	Percent Change
VEHICLE VOLUMES			
TOTAL			
AM Peak Hour	7,486	8,159	9%
PM Peak Hour	7,175	8,099	13%
2+ OCCUPANT AUTOMOBILES			
AM Peak Hour	628	1,165	86%
PM Peak Hour	868	1,645	90%
DART BUS			
AM Peak Hour	1	2	100%
PM Peak Hour	2	2	0%
PERSON VOLUMES			
TOTAL			
AM Peak Hour	8,293	9,587	16%
PM Peak Hour	8,311	10,257	23%
2+ OCCUPANT AUTOMOBILES			
AM Peak Hour	1,368	2,504	83%
PM Peak Hour	1,887	3,653	94%
DART BUS			
AM Peak Hour	0	14	??
PM Peak Hour	8	12	50%
OCCUPANCY RATE			
AUTOMOBILE			
AM Peak Hour	1.11	1.17	5%
PM Peak Hour	1.15	1.26	10%
VEHICLE			
AM Peak Hour	1.11	1.17	5%
PM Peak Hour	1.16	1.27	9%
Operational Data	**"Before" (Mainlanes)**	**"After" (Mainlanes)**	**Percent Change**
Travel time (MINUTES)			
AM Peak Hour	9.70	9.60	-1%
PM Peak Hour	21.20	17.50	-17%
SPEEDS (MILES PER HOUR)			
AM Peak Hour	39	40	3%
PM Peak Hour	18	22	22%
Operational Data	**"Before" (Mainlanes)**	**"After" (HOV Lane)**	**Percent Change**
Travel time (MINUTES)			
AM Peak Hour	9.70	7.00	-28%
PM Peak Hour	21.20	7.90	-63%
SPEEDS (MILES PER HOUR)			
AM Peak Hour	39	55	41%
PM Peak Hour	18	49	172%
PARK-AND-RIDE LOT USAGE	1,112	1,287	16%

Notes:
[1]"Before" data are an average of data collected from June 1994 to June 1995.
[2]"After" data are an average of data collected from June 1997 to March 2000.

Table 12. IH-635 (LBJ) Freeway Westbound Corridor Operational Data.

Operational Data	"Before"[1] (Mainlanes)	"After"[2] (Mainlanes & HOV)	Percent Change
VEHICLE VOLUMES			
TOTAL			
AM Peak Hour	7,428	8,250	11%
PM Peak Hour	7,902	8,105	3%
2+ OCCUPANT AUTOMOBILES			
AM Peak Hour	454	1,219	169%
PM Peak Hour	1,166	1,815	56%
DART BUS			
AM Peak Hour	2	2	0%
PM Peak Hour	1	2	100%
PERSON VOLUMES			
TOTAL			
AM Peak Hour	8,041	9,726	21%
PM Peak Hour	9,312	10,403	12%
2+ OCCUPANT AUTOMOBILES			
AM Peak Hour	982	2,617	166%
PM Peak Hour	2,503	4,011	60%
DART BUS			
AM Peak Hour	8	14	75%
PM Peak Hour	0	10	??
OCCUPANCY RATE			
AUTOMOBILE			
AM Peak Hour	1.07	1.18	10%
PM Peak Hour	1.18	1.28	8%
VEHICLE			
AM Peak Hour	1.08	1.18	9%
PM Peak Hour	1.18	1.28	8%
Operational Data	**"Before" (Mainlanes)**	**"After" (Mainlanes)**	**Percent Change**
Travel time (MINUTES)			
AM Peak Hour	11.20	12.30	10%
PM Peak Hour	13.60	13.40	-1%
SPEEDS (MILES PER HOUR)			
AM Peak Hour	30	27	-10%
PM Peak Hour	25	25	0%
Operational Data	**"Before" (Mainlanes)**	**"After" (HOV Lane)**	**Percent Change**
Travel time (MINUTES)			
AM Peak Hour	11.20	5.90	-47%
PM Peak Hour	13.60	5.90	-57%
SPEEDS (MILES PER HOUR)			
AM Peak Hour	30	57	90%
PM Peak Hour	25	57	128%
PARK-AND-RIDE LOT USAGE	1,112	1,287	16%

Notes:
[1]"Before" data are an average of data collected from June 1994 to June 1995.
[2]"After" data are an average of data collected from June 1997 to March 2000.

Table 13. HOV Lane Operational Data.

CHARACTERISTIC	CONTRAFLOW	CONCURRENT FLOW		
	IH-30	IH-35E North	IH-635 EB	IH-635 WB
GENERAL				
Opening Date	September 1991	September 1996	March 1997	March 1997
Operating Hours	WB: 6-9 AM EB: 4-7 PM	24 hours/day	24 hours/day	24 hours/day
Length (miles)	EB: 5.2 WB: 5.2	NB: 5.5 SB: 6.8	6.5	6.2
VEHICLE VOLUMES				
Total				
AM Peak Hour	1,390	946	723	907
AM Peak Period	2,842	1,988	1,838	2,268
PM Peak Hour	1,209	877	1,217	1,188
PM Peak Period	2,546	2,011	3,341	3,129
24-Hour	5,388	9,154	13,933	12,371
Carpool				
AM Peak Hour	1,308	875	690	847
AM Peak Period	2,649	1,819	1,749	2,142
PM Peak Hour	1,135	820	1,150	1,107
PM Peak Period	2,390	1,862	3,157	2,908
DART Bus				
AM Peak Hour	42	8	1	1
AM Peak Period	98	21	2	4
PM Peak Hour	43	9	1	1
PM Peak Period	90	19	2	5
Vanpools, Motorcycles, and Other Buses				
AM Peak Hour	16	15	11	18
AM Peak Period	39	40	26	36
PM Peak Hour	16	14	27	17
PM Peak Period	35	44	71	44
PERSON VOLUMES				
Total				
AM Peak Hour	3,973	2,208	1,535	1,963
AM Peak Period	8,196	4,661	,3891	4,816
PM Peak Hour	3,575	2,088	2,740	2,571
PM Peak Period	7,224	4,750	7,475	6,738
24-Hour[1]	15,240	20,832	30,652	26,856
Carpool				
AM Peak Hour	2,742	1,868	1,463	1,830
AM Peak Period	5,654	3,875	3,720	4,580
PM Peak Hour	2,420	1,760	2,574	2,444
PM Peak Period	5,100	3,973	7,040	6,396

Table 13. HOV Lane Operational Data - Continued.

CHARACTERISTIC	CONTRAFLOW	CONCURRENT FLOW		
	IH-30	IH-35E North	IH-635 EB	IH-635 WB
PERSON VOLUMES - CONTINUED				
DART Bus				
AM Peak Hour	1,128	258	12	12
AM Peak Period	2,398	563	24	26
PM Peak Hour	1,060	252	8	4
PM Peak Period	1,943	536	23	10
Vanpools, Motorcycles, and Other Buses				
AM Peak Hour	80	35	35	81
AM Peak Period	188	114	85	126
PM Peak Hour	82	52	120	60
PM Peak Period	150	157	301	160
OCCUPANCY RATES				
Automobile				
AM Peak Hour	2.09	2.08	2.10	2.12
AM Peak Period	2.08	2.07	2.10	2.11
PM Peak Hour	2.14	2.09	2.24	2.15
PM Peak Period	2.14	2.09	2.22	2.14
Vehicle				
AM Peak Hour	2.86	2.33	2.12	2.15
AM Peak Period	2.88	2.34	2.12	2.12
PM Peak Hour	2.96	2.38	2.25	2.17
PM Peak Period	2.84	2.36	2.24	2.16
ENFORCEMENT				
AM Peak Hour Violation Rate	2%	5%	3%	4%
AM Peak Period Violation Rate	2%	5%	3%	4%
PM Peak Hour Violation Rate	1%	4%	3%	5%
PM Peak Period Violation Rate	1%	4%	3%	6%
OTHER				
Construction Cost	$17.4 M	$9.9 M	$16.3 M	
Construction Cost Per Mile	$1.67 M	$0.8 M	$1.28 M	
Operation & Enforcement	$0.6 M	$0.2 M	$0.2 M	
COST/YEAR				
FY 2000 Annual HOV Benefits	$6.4 M [2]	$2.4 M	$9.68 M	
Operating Years to be Cost Effective	2.4 years	4.8 years	1.8 years	

Notes:
[1]Daily total (24-hour) counts on the concurrent flow lanes are collected with automatic vehicle counters on the HOV lane with an applied observed occupancy rate to estimate the number of passengers.
[2]Includes mainlane and HOV lane benefits.

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