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16. Abstract

Limited capital investment for major transportation improvements and growth in metropolitan areas require the most efficient use of the existing transportation system. Provisions of the Clean Air Act Amendments and TEA21 further intensify these concerns. One means to improve mobility is high-occupancy vehicle (HOV) lanes. Although HOV lanes have been shown to be very successful in Texas, they have been met with skepticism in several areas across the country. Public criticism of HOV lanes in two corridors in New Jersey (IH-287 and IH-80) led to their closure. 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. 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.

While developers plan an extensive system of permanent HOV lanes for the Dallas-Fort Worth urbanized area, the Texas Department of Transportation (TxDOT) 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 research 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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AN EVALUATION OF DALLAS AREA HOV LANES, YEAR 2001

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I. INTRODUCTION

Limited capital investment for major transportation improvements and growth in metropolitan areas require the most efficient use of the existing transportation system. Provisions of the Clean Air Act Amendments and TEA21 further intensify these concerns. One means to improve mobility is high-occupancy vehicle (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 HOV lanes have been designed and implemented, a number of issues must be considered for an efficient and effective HOV facility.

Additionally, HOV lanes are receiving negative publicity in several areas across the country. New Jersey recently closed HOV lanes in two corridors (IH-287 and IH-80) as a result of public criticism. In the wake of New Jersey's actions, 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. 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

Implementing an HOV lane in a corridor can provide a number of benefits. Some of these benefits include:

<u>Travel time savings for eligible vehicles.</u> Multi-occupant vehicles in the HOV lane are able to bypass the congested "stop-and-go" traffic in the general-purpose lanes.

<u>Trip time reliability for eligible vehicles.</u> The travel speed in an HOV lane is generally near free-flow, which does not cause much variation 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 that use the lane. In general, with an increase in vehicle speeds from the stop-and-go congested conditions, a reduction in fuel consumption and vehicle emissions results.

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 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 will exist 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 center-line miles of HOV lanes. Until these permanent treatments can be implemented, the Texas Department of Transportation (TxDOT) and Dallas Area Rapid Transit (DART) have been and continue to pursue short-term or interim HOV lane projects that would enhance public transportation and overall mobility. The Federal Highway Administration (FHWA) considers these projects to be interim projects because they have been retrofitted into the existing freeway facility, resulting in design exceptions from normally required standards.

Figure 1 shows the 35.4 miles of interim HOV lanes that are currently operational in the Dallas area while Table 1 includes the details related to these HOV lanes. A 5.2 mile interim barrier-separated contraflow HOV lane on East R.L. Thornton (ERLT) Freeway (IH-30) opened in September 1991 (Figure 2) while interim buffer-separated concurrent flow HOV lanes opened on Stemmons Freeway (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. Interim buffer-separated concurrent flow HOV lanes also opened on Lyndon B. Johnson (LBJ) Freeway (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 (ERLT)	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 Hour	24 Hour
Length	5.2 miles EB 5.2 miles WB	5.5 miles NB 6.8 miles SB	6.5 miles EB 6.2 miles WB
Construction Cost (M$)	$17.4M[1]	$9.9M[2]	$16.3M
Operating &Maintenance Cost (M$)	$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 use of a movable barrier that "takes away" a freeway lane in the off-peak direction and allows it to be used for peak direction HOV-lane-eligible vehicles creates the IH-30 contraflow lane. The concurrent flow lanes on IH-35E North and IH-635 were created by converting the inside shoulder to an HOV lane. 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 (buffer-separated)

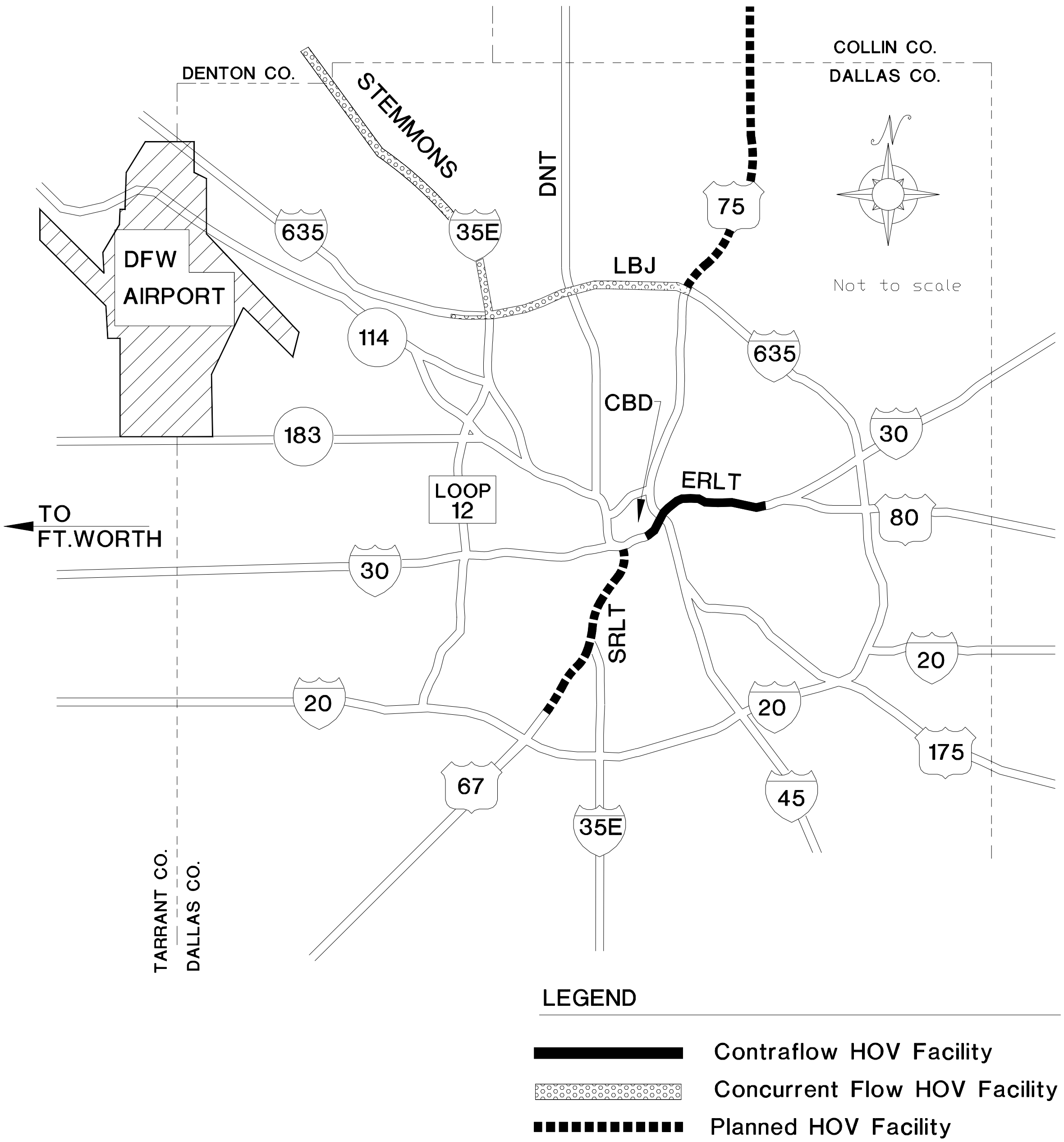


Figure 1. Dallas Area HOV Lanes.

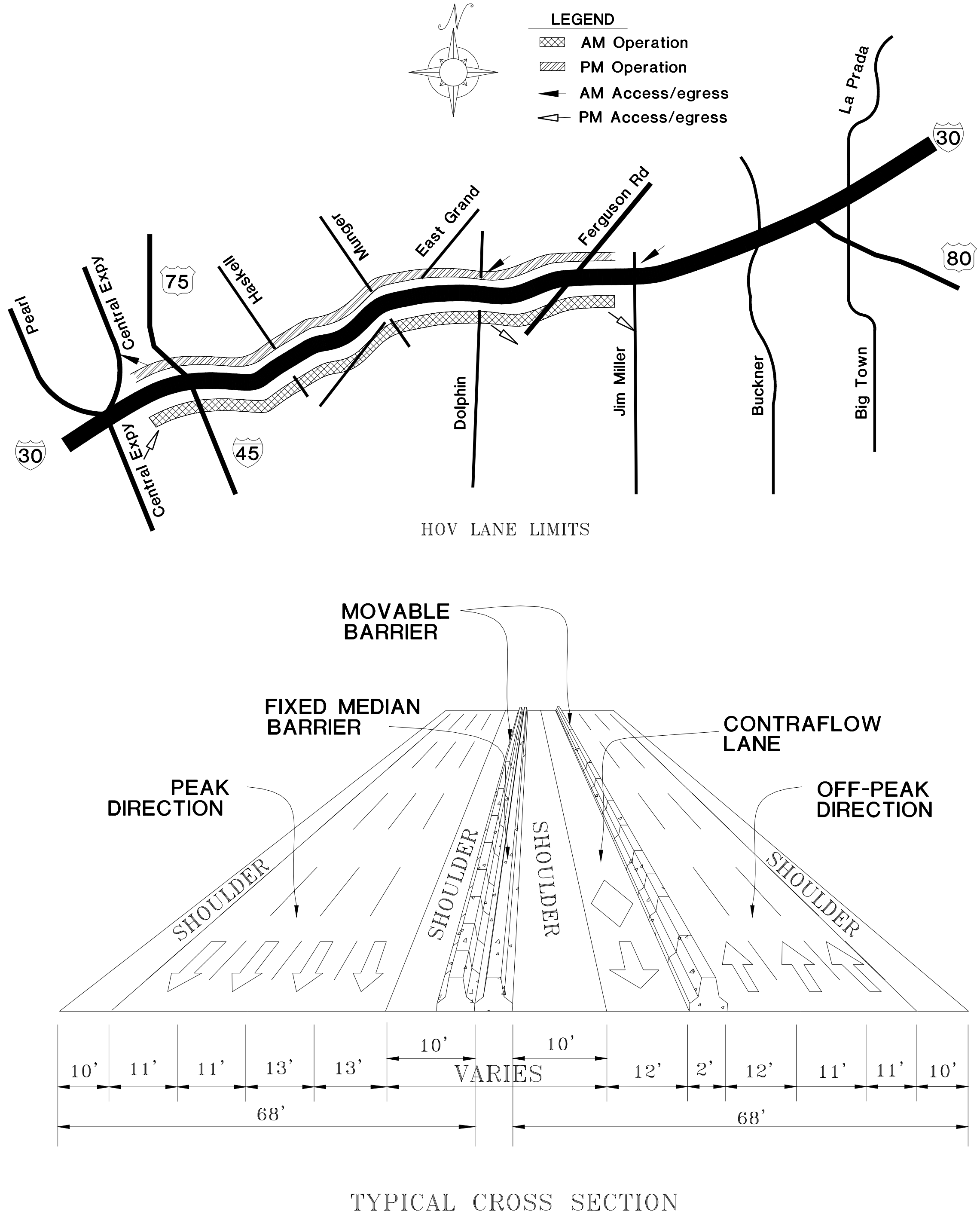


Figure 2. IH-30 (ERLT) Freeway HOV Lane.

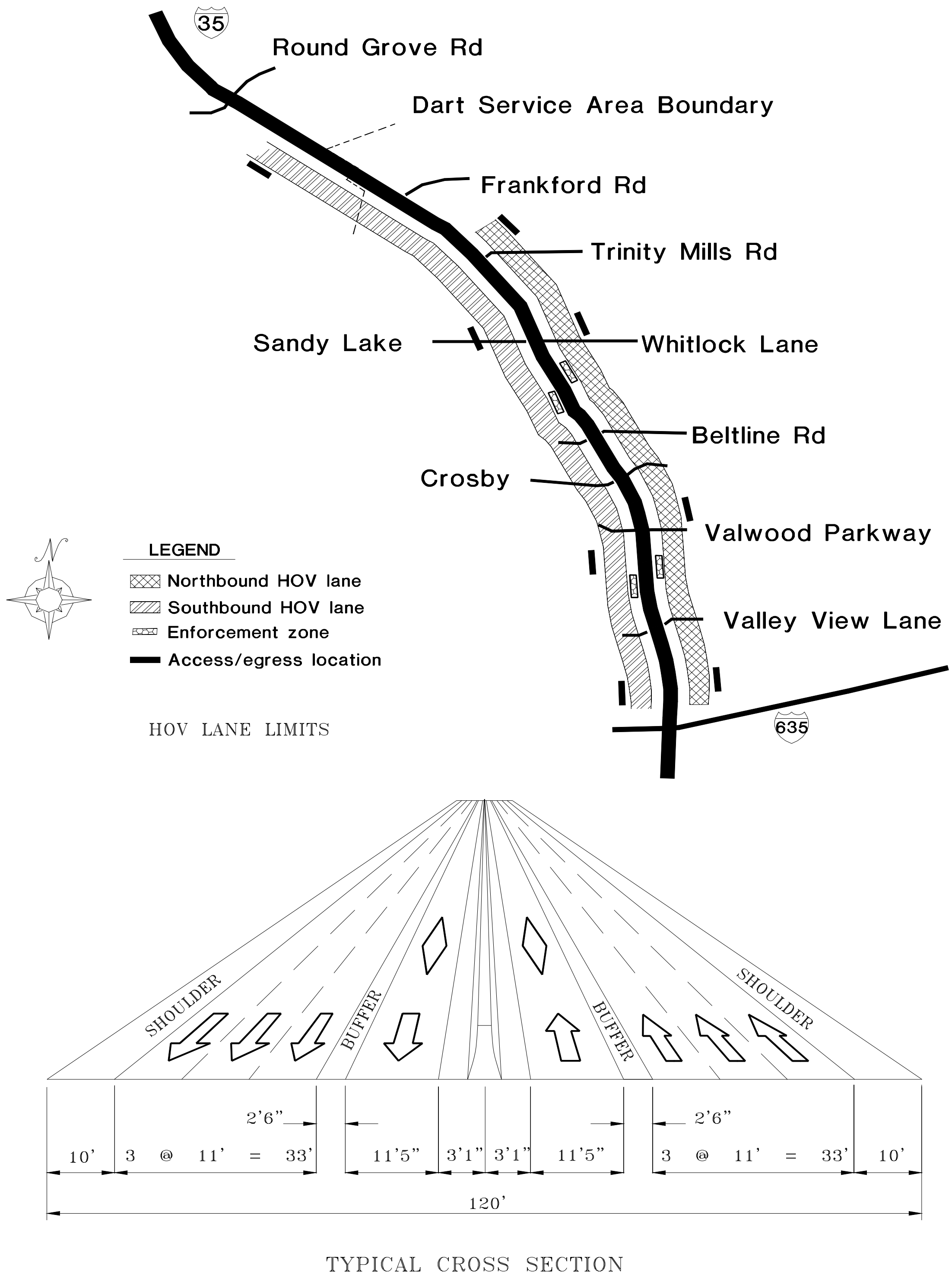


Figure 3. IH-35E North (Stemmons) Freeway HOV Lane.

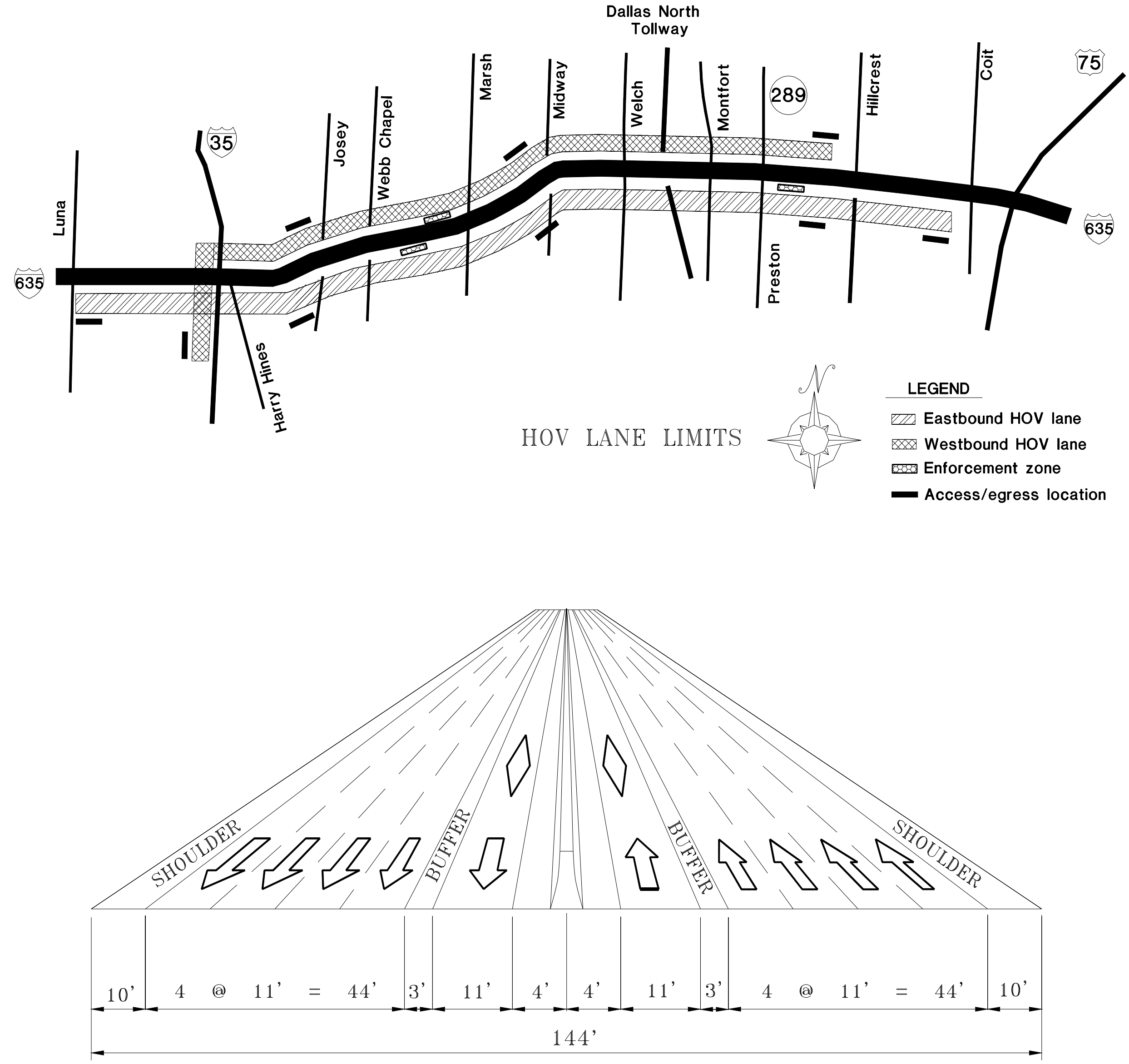


Figure 4. IH-635 (LBJ) Freeway HOV Lane.

versus contraflow (barrier-separated) HOV lanes. Additional research concerns particular to concurrent flow lanes include safety, capacity, enforceability, magnitude of violations, appropriate ingress and egress locations, 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 center-line 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 and San Antonio areas. The first HOV lane in Texas, which opened in August 1979, was the North Freeway (IH-45) contraflow HOV lane in Houston. HOV lanes now operate in Houston on Southwest Freeway (US-59 South), Gulf Freeway (IH-45), Katy Freeway (IH-10), Eastex Freeway (US-59 North), Northwest Freeway (US-290), and North Freeway (IH-45). 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 North and the state's most congested thoroughfare IH-635. HOV lanes will soon be available along South R.L. Thornton (IH-35E South) Freeway and Marvin D. Love (US-67) Freeway, extending 9 center-line miles between downtown Dallas and Camp Wisdom. An additional 9 center-line miles of HOV lanes are planned for North Central Expressway (US-75), between IH-635 and the City of Plano, Texas.

Researchers have addressed the topic of priority treatment in Texas 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 type of evaluation 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 (documented in Research Reports 1146-1 through 1146-6F) have been instrumental in 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 provides 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 TxDOT Dallas District 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. Experience in Houston documents 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. New Jersey converted HOV lanes on IH-80 and IH-287 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 also conducted a study at the request of the U.S. Department of Transportation and determined 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 study 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 investigation is in response to several state legislative bills focusing on alleviating traffic congestion. Previous legislation in the state proposed that high-occupancy vehicle lanes should be completely removed. But 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 high-occupancy toll lanes has been a topic of interest for continued use of underutilized facilities for the purpose of congestion relief and 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 continues for buses and carpools.

HOT lanes promote effective use of available space 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 (IH-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 (SOV) by paying a fee. Carpoolers and those using transit vehicles would continue to use the HOV lanes for free. Recent state legislation requires 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 effect on the safety of the corridor, and the changes in accident characteristics are attributed 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 are 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, engineers should use caution when designing these facilities, especially when design values are at or near the minimum recommended design values. Special care should be used when designing access and egress locations to minimize the potential for accidents. 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 is opened 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 (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 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. DATA COLLECTION METHODOLOGY

To evaluate and monitor HOV lanes, it is necessary to collect a substantial amount of operational data on the HOV lanes and the adjacent freeway general-purpose lanes. This section describes the types 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 semi-annual 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 morning (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 afternoon (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 will describe the monthly and quarterly 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. Texas Transportation Institute 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. Observers stationed on the side of the freeway record HOV lane vehicle occupancy counts, 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 the 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 opened during the peak period.) 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 (March and September) on the general-purpose lanes of the three freeways that have HOV lanes. Researchers use these occupancy counts 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 each quarter or month; 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 are collected on the control section and compared to the facilities with HOV lanes. However, data collection since March 1998 has been suspended on this facility due to the construction of a future interim HOV lane. "Control" corridor data have been held constant on this corridor since March 1998 for comparison purposes.

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 were 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 a several-month delay in the coding of the data into the Accident Data Files. A little more than two years of "after" data were available for the two concurrent flow HOV lanes. The available data have been summarized as part of this project, but they are very preliminary at this point, and additional data will be evaluated as they become available. This project will continue for one more year, and the final report will document a thorough evaluation of the safety aspects.

IV. OPERATIONAL PERFORMANCE OF DALLAS AREA HOV LANES

The operational performance of each HOV lane will be described in this section, which is divided into the following sub-sections: vehicle and person volumes and vehicle occupancy, speeds and travel times, transit operation impacts, cost effectiveness, enforcement and violations, safety, air quality, and public acceptance. Many of the comparisons consist of "before" HOV lane data with "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, as discussed in the "Data Collection Methodology" section of this report. 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 objective 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 carpool (multi-occupant) vehicles utilizing a facility. An increase in the number of multi-occupant vehicles on a facility indicates an increase in the person-throughput of a facility. Figure 5 shows the number of two-or-more person (2+) carpools on each of the facilities before and after the HOV lane opened. After each HOV lane was opened, a significant increase in the number of 2+ carpools on each of the facilities resulted. As shown in Figure 6, the percent increase in carpools ranged from 90 percent on eastbound IH-635 to 256 percent 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.

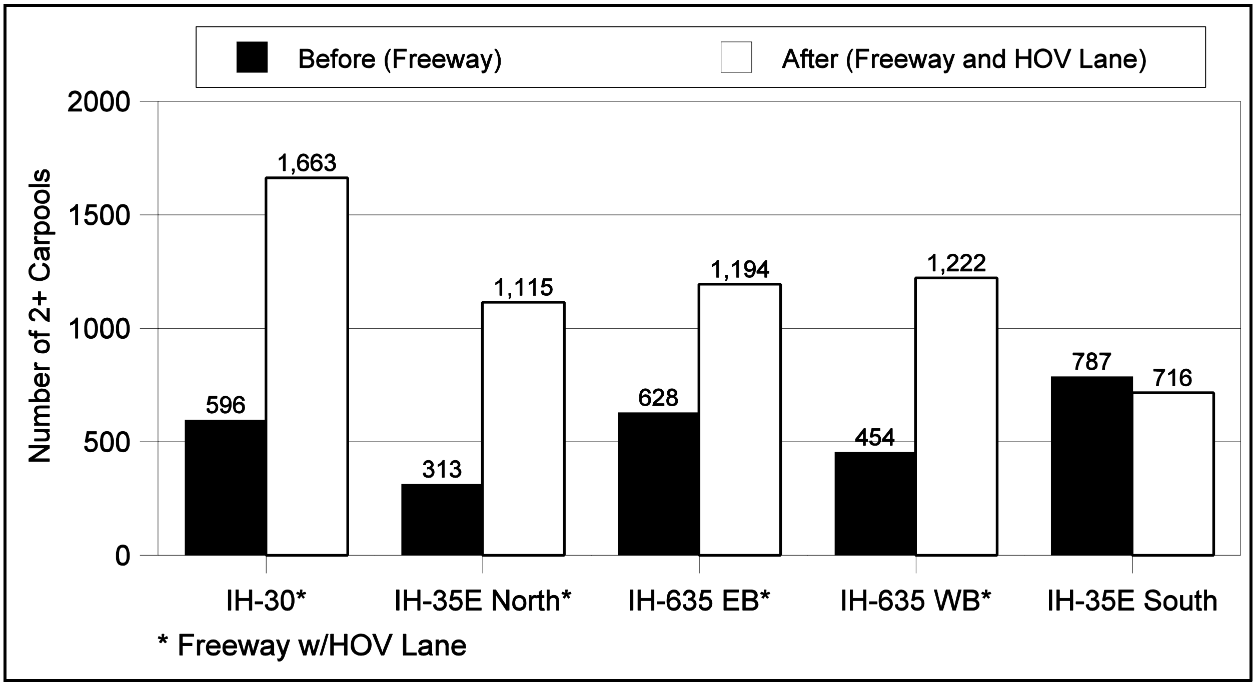


Figure 5. Change in AM Peak Hour Number of Carpools.

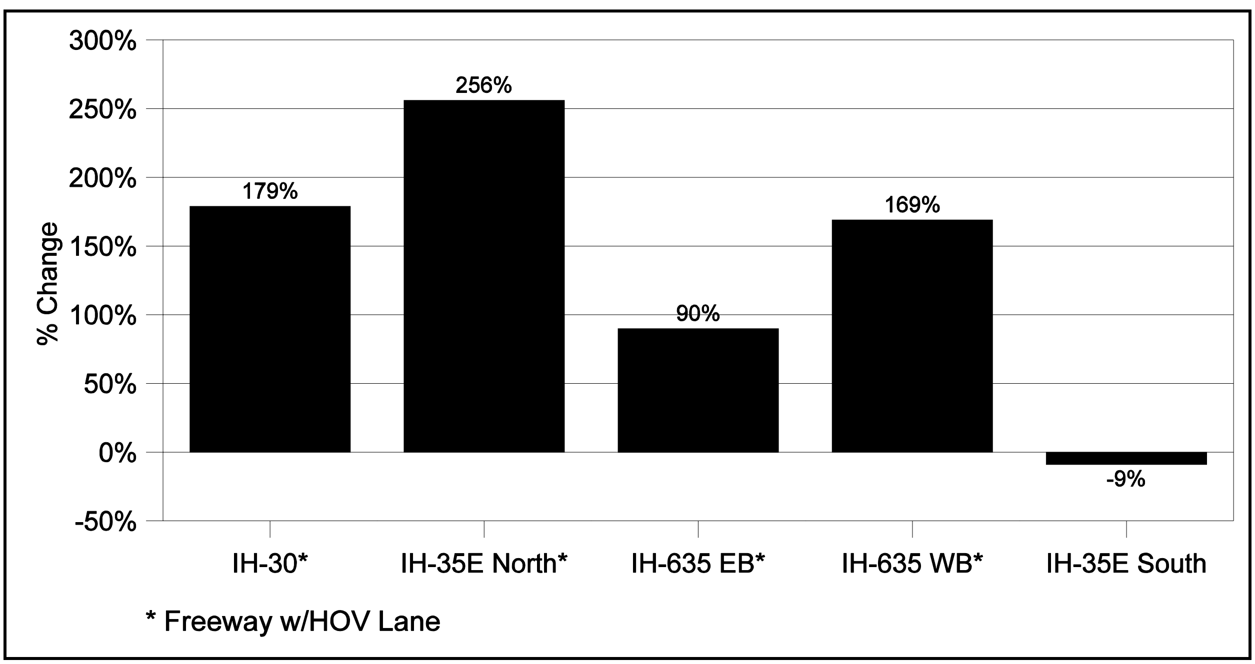


Figure 6. Percent Change in AM Peak Hour Number of Carpools.

Person Volumes

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

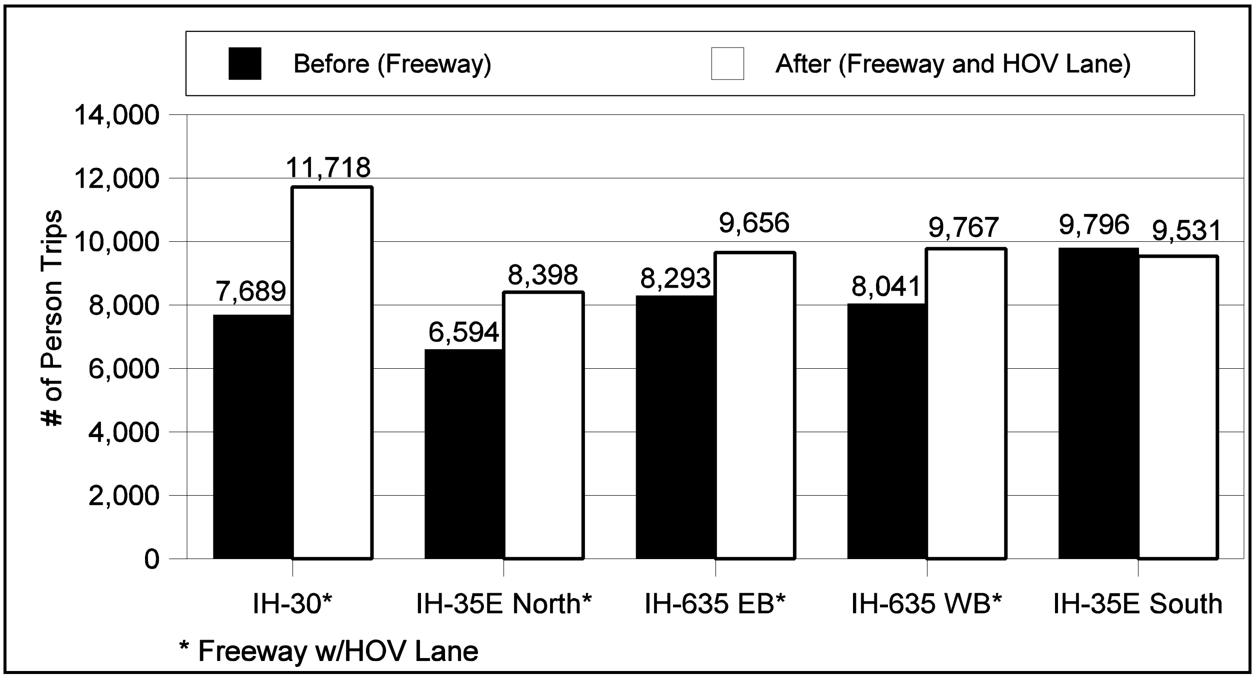


Figure 7. Change in AM Peak Hour Person Trips.

One guideline for HOV lanes is that an HOV lane should carry at least as many people as an adjacent freeway mainlane. 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. Figure 8 shows the peak hour person volume per lane for each of the HOV lanes and adjacent general-purpose lanes. 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 are greater 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.

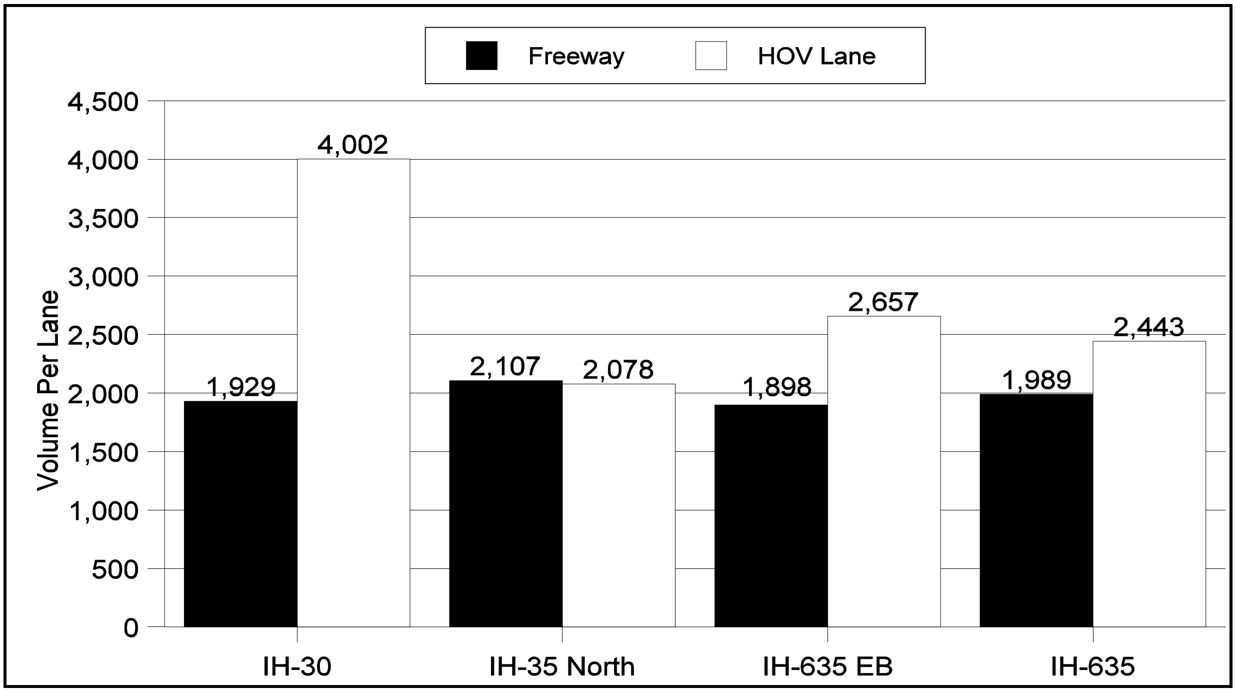


Figure 8. Peak Hour Person Volume Per Lane.

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

Occupancy

Figures 9 and 10, respectively, show the average peak hour automobile and vehicle occupancy for the freeways with an HOV lane and IH-35E South, the control corridor.

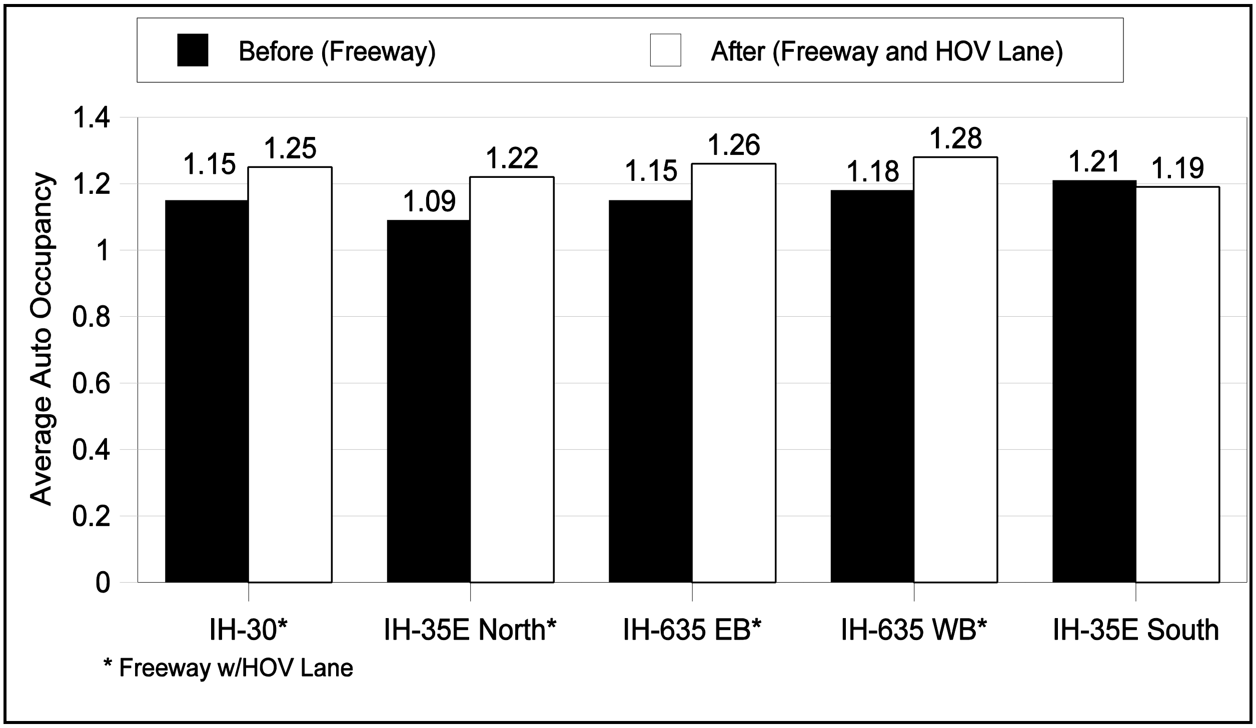


Figure 9. Change in Average Automobile Occupancy.

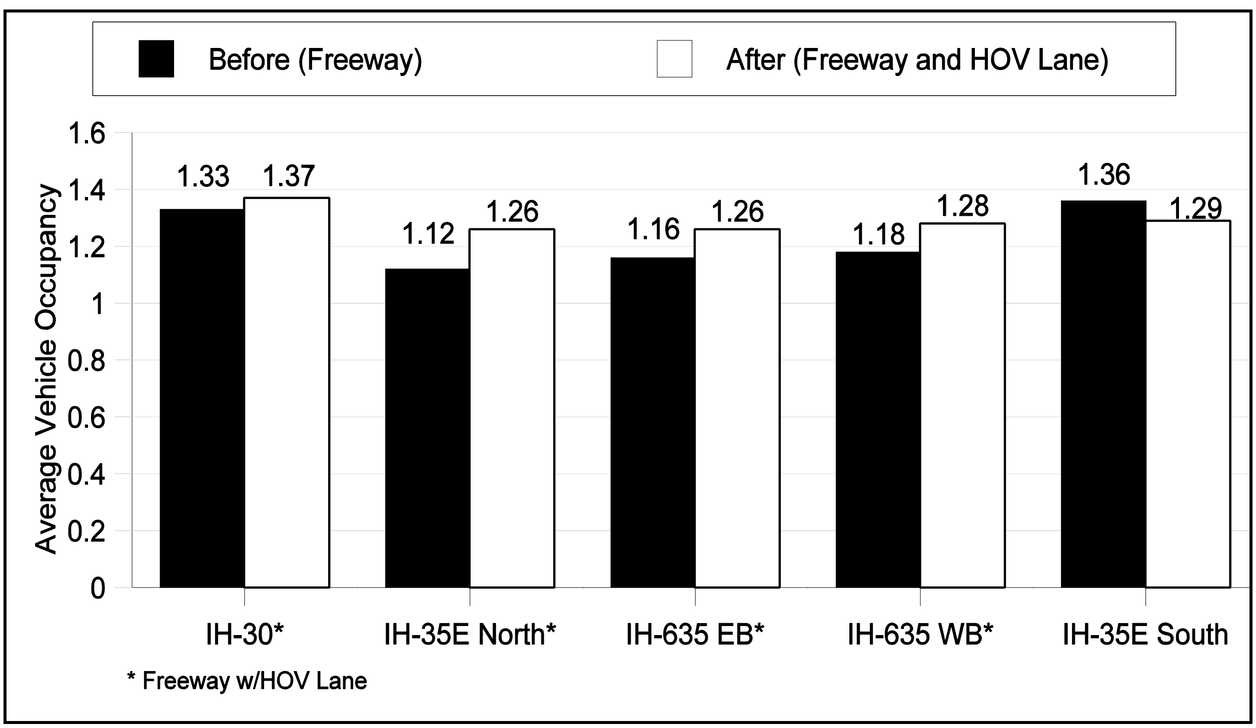


Figure 10. Change in Average Vehicle Occupancy.

Because of the presence of several bus routes on IH-30, both the average vehicle occupancy and the average automobile occupancy were evaluated so 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 the vehicle occupancy varies among 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 HOV lanes were opened on IH-30, IH-35E North, and IH-635 is shown in Figure 11.

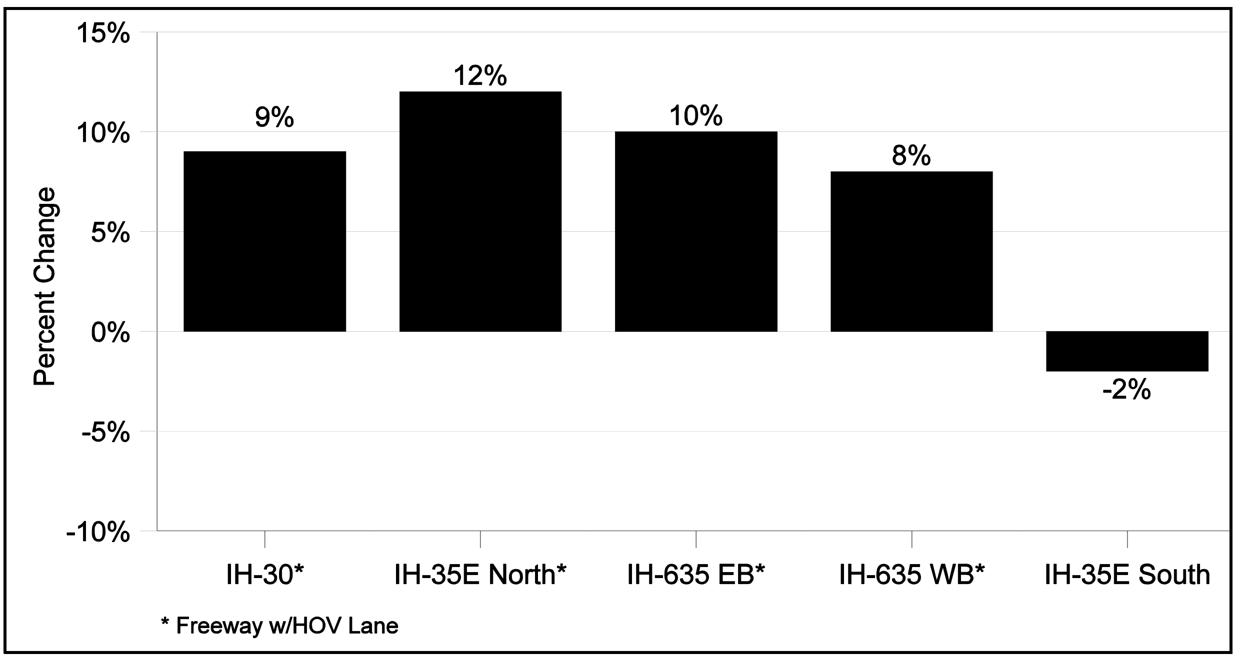


Figure 11. Percent Change in Average Automobile Occupancy.

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. This section summarizes the speed and travel time characteristics of the Dallas area facilities with HOV lanes.

Speeds

A guideline for HOV lanes is that the lane should not negatively impact the mainlanes. If implementing an HOV lane causes travel speeds on the adjacent mainlanes to decrease, the efficiency of the roadway system would be diminished, and there will be public opposition to the project. Figure 12 shows the peak hour travel speeds on the HOV lanes and adjacent mainlanes.

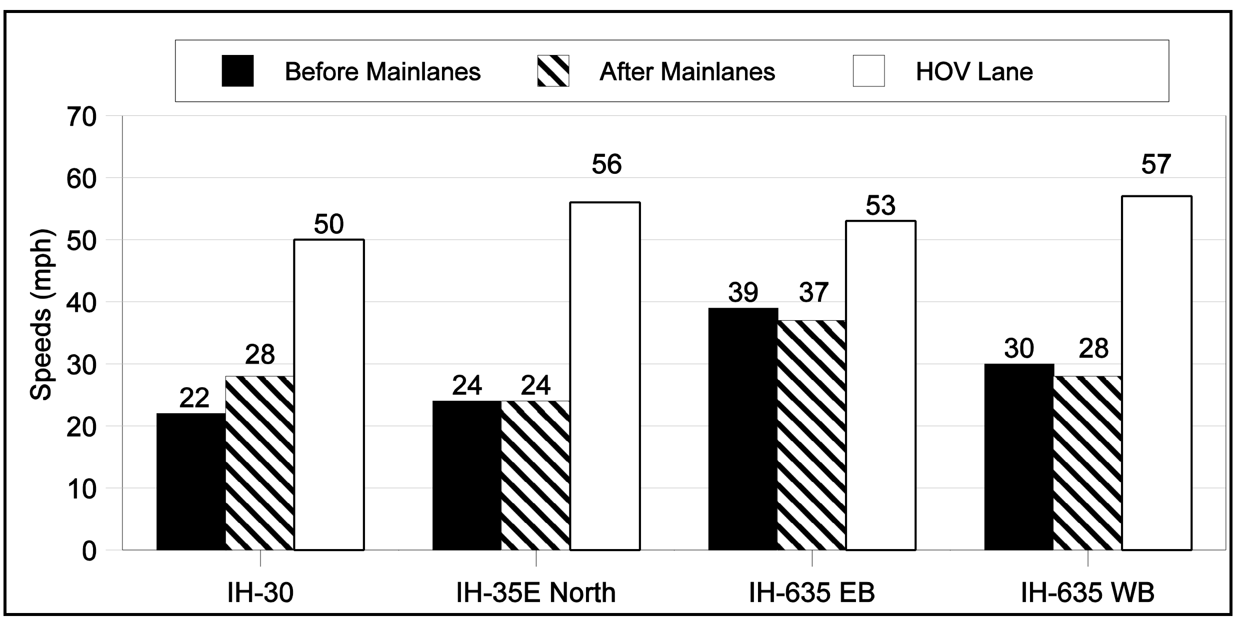


Figure 12. Change in AM Peak Hour Roadway Operating Speeds.

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. Researchers 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 is required. Travel time savings are easiest benefits for passengers to measure directly; therefore, it is imperative that the HOV lane provide users travel time savings over the general-purpose lanes. The peak hour travel time savings on incident-free days for each of the four 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.

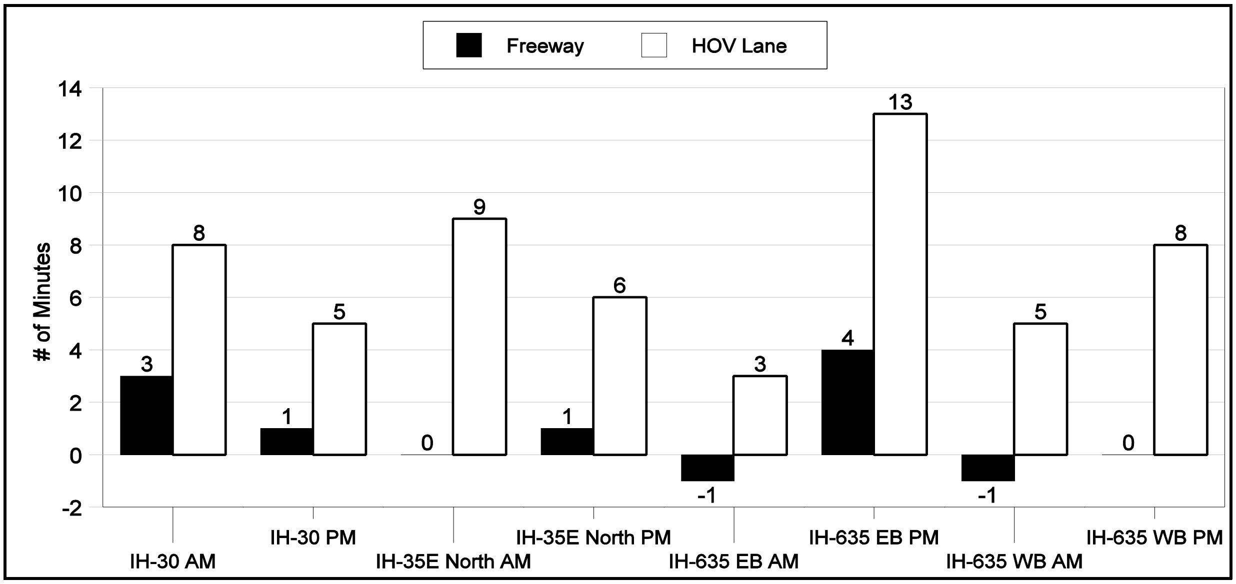


Figure 13. Peak Hour Travel Time Savings After HOV Lane Opening.

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. At this time, there has not been a motorist survey conducted on either the IH-35E North corridor or the IH-635 corridor.

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 hours, as shown in the "Speeds and Travel Times" section of this report. 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

Figure 14 shows the AM and PM peak hour bus ridership. 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, in part, related 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 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 appears to indicate that some commuters utilize whichever mode, bus or carpool, is more convenient on any given day.

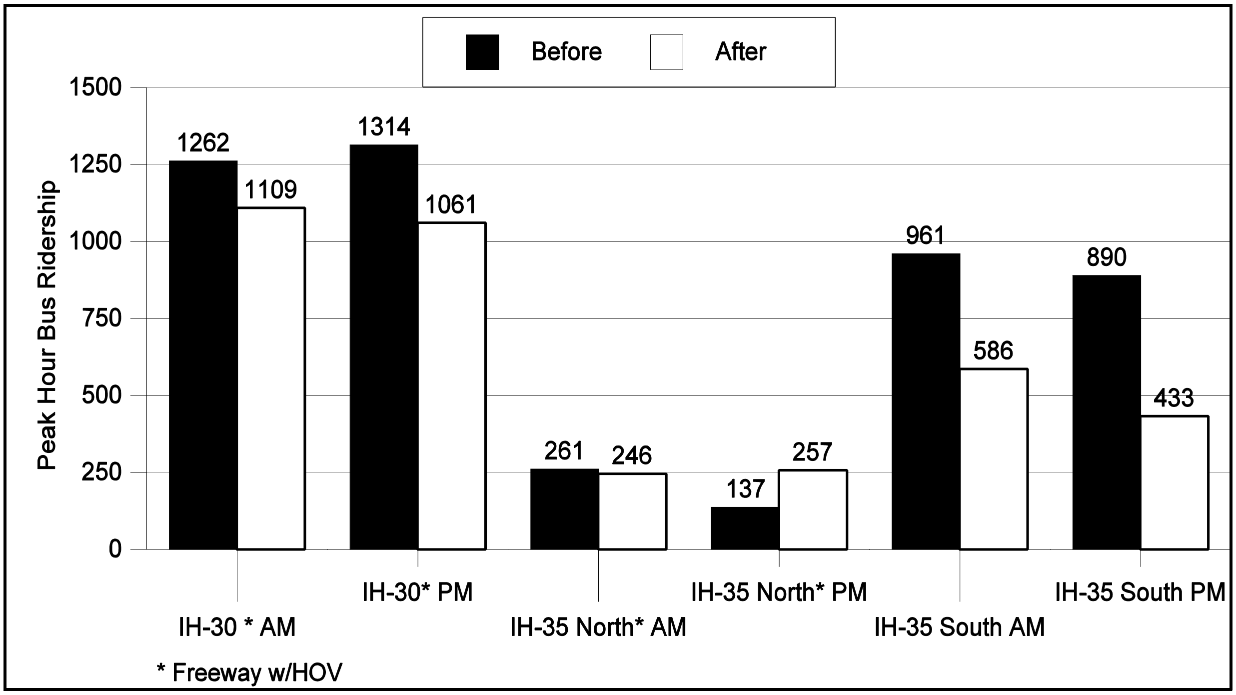


Figure 14. Change in Transit Bus Ridership.

COST EFFECTIVENESS

Tables 2, 3, and 4 show the cost effectiveness of each of the three HOV lanes projected out to 10 years. 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 2. IH-30 (ERLT) Freeway HOV Lane Benefit/Cost Analysis.[1]

Benefits and Costs (Million Dollars)[4]						
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[2]	-	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[3]	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]AM auxiliary lane opened in July 1994.
[3]PM extension opened in February 1996.
[4]Benefits include $402,000 DART bus operating costs per year.

Table 3. 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 DART bus operating costs per year.

Table 4. 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

DART transit police enforce the HOV lanes. 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. Because of the presence of enforcement 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 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.

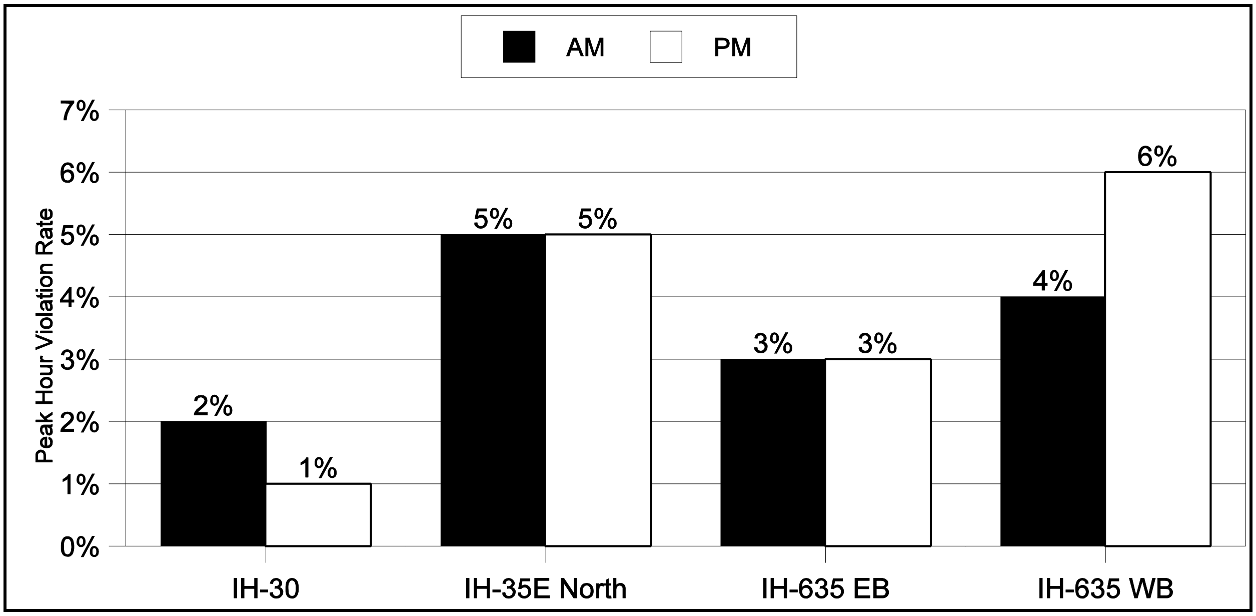


Figure 15. Observed Occupancy Violation Rates.

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

An analysis of before-and-after crash data is necessary to evaluate the safety impacts of barrier- versus buffer-separated facilities. Crash rates are an effective means of measuring highway safety trends based on the concept of vehicle exposure measured in vehicle-miles traveled (VMT). Tables 5, 6, and 7 show combined injury- and fatality-related annual, two-way crash rates (crashes per 100 million VMT) for the three corridors of interest in this research. The data were obtained and summarized from the TxDOT Master Accident/Crash Data Files.

Table 5. IH-30 (ERLT) Freeway Corridor Crash Rates.

IH-30 (ERLT) with Contraflow Barrier-Separated HOV Lane From Central Expressway (US-75) to Jim Miller Rd. (Cont. Sect.: 0009-11 From Milepoint 4.5 to 10.1)			
YEAR	**YEARLY CRASHES** Injury and Fatality Related	**YEARLY VEHICLE MILES TRAVELED (VMT)[4]**	**YEARLY CRASH RATE (Crashes/100 million VMT)** Injury and Fatality Related
1990[1]	149	246,804,539	60.4
1991	178	254,058,929	70.1
1992[2]	182	246,488,427	73.8
1993[3]	201	246,488,427	81.5
1994	234	228,260,915	102.5
1995	270	228,260,915	118.3
1996	276	240,604,032	114.7
1997	232	267,172,415	86.8
1998	192	260,994,944	73.6
1999	222	261,739,274	84.8

Notes:
[1]HOV lane construction began 12/90 and ended 9/91.
[2]Major roadway reconstruction occurred during five of the first six years of HOV lane operation.
[3]Reconstruction of Fair Park bridge began 5/93 and ended 2/96.
[4]Yearly Corridor VMT calculation for 1992-1999 includes HOV lane vehicles.

Table 6. IH-35E (Stemmons) Freeway Corridor Crash Rates.

IH-35E (Stemmons) with Concurrent Flow Buffer-Separated HOV Lanes From IH-635 To Dallas/Denton Co. Line (Cont. Sect.: 0196-03 From Milepoint 28.5 to 34.5)			
YEAR	**YEARLY CRASH NUMBER** Injury and Fatality Related	**YEARLY VEHICLE MILES TRAVELED (VMT)[2]**	**YEARLY CRASH RATE (Crashes/100 million VMT)** Injury and Fatality Related
1990	74	256,520,631	28.8
1991	75	254,933,907	29.4
1992	64	264,277,338	24.2
1993	104	264,277,338	39.4
1994	110	276,508,955	39.8
Construction of HOV Lanes[1]			
1997	157	298,356,833	52.6
1998	162	349,018,190	46.4
1999	162	342,759,346	47.3

Notes:
[1]HOVlane construction began 6/95 and ended 9/96.
[2]Yearly corridor VMT calculation for 1997-1999 include HOV lane vehicles.

Table 7. IH-635 (LBJ) Freeway Corridor Crash Rates.

IH-635 (LBJ) with Concurrent Flow Buffer-Separated HOV Lanes from US-75 to IH-35E (Cont. Sect.: 2374-01 From Milepoint 6.5 to 14.5)			
YEAR	**YEARLY CRASH NUMBER** Injury and Fatality Related	**YEARLY VEHICLE MILES TRAVELED (VMT)**[2]	**YEARLY CRASH RATE (Crashes/100 million VMT)** Injury and Fatality Related
1990	264	547,847,115	48.2
1991	282	594,609,082	47.4
1992	245	605,738,320	40.4
1993	241	605,738,320	39.8
1994	283	660,251,172	42.9
Construction of HOV Lanes[1]			
1997 Jul-Dec	225	344,826,341	65.3
1998	476	752,881,376	63.2
1999	434	741,516,590	58.5

Notes:
[1]HOV lane construction began 6/95 and ended 3/97.
[2]Corridor VMT calculation for 1997-1999 include HOV lane vehicles.

Crash rates for the IH-35E North and IH-635 corridors have increased since implementation of the buffer-separated HOV lanes. However, the rates appear to decrease the longer the HOV lanes are in operation. A review of year 2000 crash data, once available, will be required to support or refute this conclusion.

Several factors have been identified, which may have contributed to an increase in crash rates for both of these corridors. The possible contributing factors, some of which may require additional focused research, are as follows:

- Buffer-separated HOV lanes have been implemented.
- There is no longer an inside shoulder.
- The general-purpose lanes have been reduced from 12 ft to 11 ft wide.
- The speed limit increased during the analysis period.
- There is increased police presence for enforcement of HOV lane requirements.

Crash rates for the control corridors of IH-35E and SH 183 (Airport Freeway) are shown in Tables 8 and 9. Neither corridor provides inside shoulders. The inside shoulders of the IH-35E corridor section were removed in 1992 for the implementation of additional freeway lanes, and Airport Freeway has never had full inside shoulders.

Table 8. IH-35E (Stemmons) Freeway Corridor Crash Rates (Control Corridor).

IH-35E Control Corridor without Inside Shoulders from Royal Lane to Loop 12 (Cont. Sect.: 0196-03 From Milepoint 25.6 to 27.5)			
YEAR	**YEARLY CRASH NUMBER** Injury and Fatality Related	**YEARLY VEHICLE MILES TRAVELED (VMT)**	**YEARLY CRASH RATE (Crashes/100 million VMT)** Injury and Fatality Related
1990	73	118,009,592	61.9
1991	46	127,237,518	36.2
1992[1]	86	127,412,912	67.5
1993	80	127,412,912	62.8
1994	87	140,141,885	62.1
1995	105	140,141,885	74.9
1996	119	134,397,828	88.5
1997	141	139,161,002	101.3
1998	135	152,702,951	88.4
1999	109	155,886,448	69.9

Notes:
[1]Inside shoulders removed in 1996.

Table 9. SH-183 Corridor Crash Rates (Control Corridor).

SH 183 (Airport Freeway) Control Corridor without Inside Shoulders from Story Rd. to Loop 12 (Cont. Sect.: 0094-03 From Milepoint 4.2 to 7.9)			
YEAR	**YEARLY CRASH NUMBER** Injury and Fatality Related	**YEARLY VEHICLE MILES TRAVELED (VMT)**	**YEARLY CRASH RATE (Crashes/100 million VMT)** Injury and Fatality Related
1990	114	166,779,085	68.4
1991	114	169,914,435	67.1
1992	124	173,942,575	71.3
1993	150	173,942,575	86.2
1994	146	135,426,019	107.8
1995	137	135,426,019	101.2
1996	142	135,381,945	104.9
1997	158	137,327,731	115.1
1998	132	141,498,280	93.3
1999	141	147,503,081	95.6

IH-635 between US-75 and Skillman Avenue is another example of where an inside shoulder was removed in only the eastbound direction for the implementation of an additional freeway lane. Crash rates for this corridor are shown in Table 10.

Table 10. IH-635 (LBJ) Corridor Crash Rates (Control Corridor).

IH-635 (LBJ East of US-75) Eastbound Inside Shoulders Removed in 1996 from US-75 to Skillman Ave. (Cont. Sect.: 2374-01 From Milepoint 3.6 to 6.2)			
YEAR	**YEARLY CRASH NUMBER** Injury and Fatality Related	**YEARLY VEHICLE MILES TRAVELED (VMT)**	**YEARLY CRASH RATE (Crashes/100 million VMT)** Injury and Fatality Related
1990	59	66,176,690	89.2
1991	59	74,639,434	79.0
1992	57	77,699,798	73.4
1993	56	77,699,798	72.1
1994	52	82,806,966	62.8
Construction[1]			
1997	100	85,955,894	116.3
1998	79	97,134,588	81.3
1999	80	95,136,987	84.1

Notes:
[1]Shoulder removal began 8/95 and ended 3/96.

Crash rates allow an analyst to make inferences about the safety of highways. Identification of trends may be based on year-to-year comparisons of crash rates for a particular corridor or statistical comparison with an average crash rate calculated for similar corridors. The rate quality control method of crash rate analysis allows comparison of the crash rate for a particular corridor with an average crash rate for similar corridors to determine if differences are statistically significant. The rate quality control method identifies a corridor as prone to crashes if it satisfies the following inequality: corridor crash rate > critical crash rate.

The critical crash rate is determined with the following equation:

$$R_C = \overline{R} + K \times \sqrt{\overline{R}/V} + 1/(2 \times V)$$

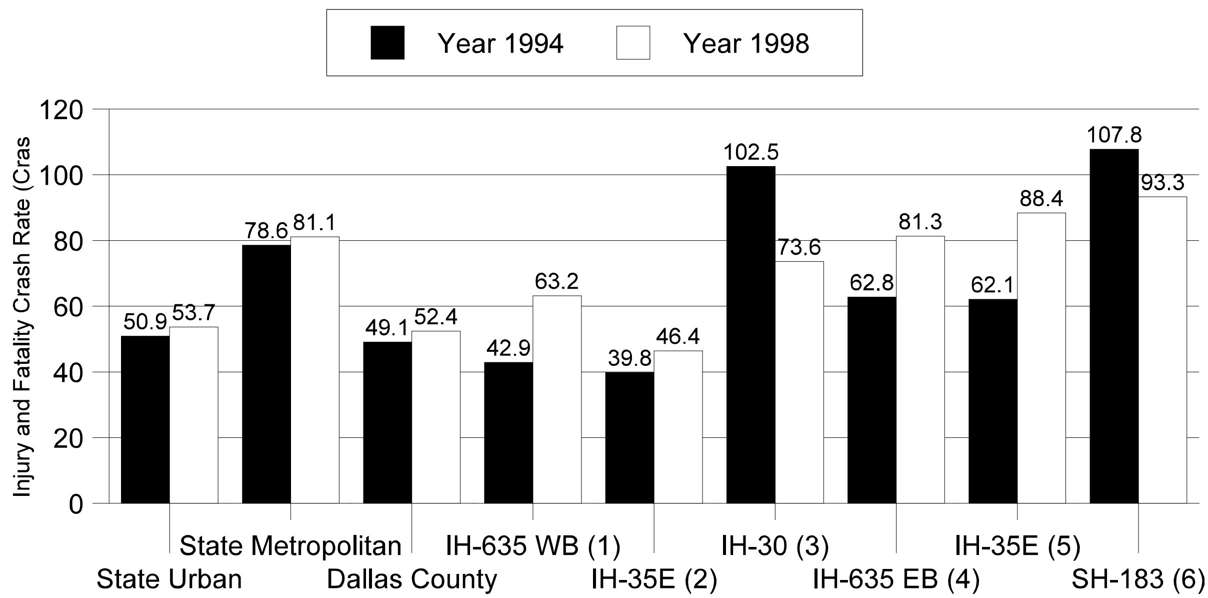
Where, R_C = critical crash rate

$\overline{R}$ = average or mean crash rate for multiple corridors with characteristics similar to those of the corridor under analysis

V = corridor traffic noted in millions of vehicle-miles traveled (Mil VMT), and

K = constant corresponding to level of confidence (LOC) in the analysis findings (for this analysis: LOC = 99% or K = 2.327).

For this analysis, $\overline{R}$ is computed using three definitions from the TxDOT Master Accident/Crash Data Files to group multiple corridors of similar characteristics. The three groupings include state urban interstate highways, state metropolitan areas interstate highways, and Dallas County interstate highways. State urban interstate highways include all interstate highways in an urban setting within Texas. State metropolitan areas interstate highways restricts the prior definition to include only Dallas, Tarrant, Collin, Harris, Bexar, Travis, and Williamson Counties. The final group is restricted even further to include only Dallas County interstate highways. Figure 16 shows a graphical representation of these crash rates and corridor crash rates. The years 1994 and 1998 were chosen as representative of corridor characteristics "before" and "after" the area-wide implementation of interim HOV lanes within Dallas County with the notable exception of IH-30, where the HOV lane has been in operation since 1991.



Notes:
1. US-75 to IH-35E.
2. IH-635 to Dallas/Denton County Line.
3. US-75 to Jim Miller Road.
4. US-75 to Skillman Avenue. Inside shoulder was removed in 1996.
5. Royal Lane to Loop 12. Control corridor without inside shoulders.
6. Story Road to Loop 12. Control corridor without inside shoulders.

Figure 16. Injury- and Fatality-Related Crash Rate Comparisons on Interstate Highways in Texas.

The rate quality control method of crash rate analysis was applied to the corridors with barrier- and buffer-separated HOV lanes and two control corridors for the years 1994 and 1998. Critical crash rates, for use in comparison, were developed for state urban interstate highways, state metropolitan area interstate highways (combination of Dallas, Tarrant, Collin, Harris, Bexar, Travis, and Williamson Counties), and Dallas County only interstate highways. Table 11 shows these critical crash rates along with corridor crash rates. Analysis corridor crash rates that are greater than critical crash rates are indicated with critical crash rates shown below.

Table 11. Corridor Crash Rate Analysis.

Critical Crash Rates Determination Using the Rate Quality Control Method[1]									
	State Urban Interstate Highway Crash Rates			State Metropolitan[2] Interstate Highway Crash Rates			Dallas County Interstate Highway Crash Rates		
Year	Crashes	100 Mil VMT	I & F[3] Related (Crashes/100 Mil VMT)	Crashes	100 Mil VMT	I & F Related (Crashes/100 Mil VMT)	Crashes	100 Mil VMT	I & F Related (Crashes/100 Mil VMT)
1992	12,084	23.6	51.1	9,761	12.4	78.8	2,379	5.3	44.8
1993	12,985	23.6	54.9	10,493	12.4	84.7	2,554	5.3	48.1
1994	13,767	27.1	50.9	11,165	14.2	78.6	2,855	5.8	49.1
AVG	**12,945**	**24.8**	**52.2**	**10,473**	**13.0**	**80.6**	**2,596**	**5.5**	**47.4**
1997	17,248	30.0	57.4	13,795	16.0	86.5	3,688	6.4	57.5
1998	17,112	31.9	53.7	13,687	16.9	81.1	3,620	6.9	52.4
1999	16,482	32.0	51.5	13,209	17.1	77.3	3,516	6.9	51.0
AVG	**16,987**	**31.3**	**54.1**	**13,564**	**16.6**	**81.5**	**3,608**	**6.7**	**53.6**

Year	I & F Related Location Crash Rate			Critical Crash Rates on Interstate Highways			Location Rate Greater Than Any Critical Rate?
	Crashes	100 Mil VMT	Crashes/100 Mil VMT	State Urban (Crashes/100 Mil VMT)	State Metropolitan[2] (Crashes/100 Mil VMT)	Dallas County (Crashes/100 Mil VMT)	
IH-635 with Concurrent-flow Buffer-Separated HOV Lanes from US-75 to IH-35E (Control Section: 2374-01 from Milepoint 6.5 to 14.5)							
1994	283	6.60	42.9	58.9	88.8	53.7	No
1998	476	7.52	63.2	69.4	89.3	59.8	Yes
IH-35E with Concurrent-flow Buffer-Separated HOV Lanes from IH-635 to Dallas/Denton Co. Line (Control Section: 0196-03 from Milepoint 28.5 to 34.5							
1994	110	2.76	39.8	62.5	93.3	57.2	No
1998	162	3.49	46.4	63.4	92.9	62.8	No
IH-30 with Contraflow Barrier-Separated HOV Lanes from US-75 to Jim Miller Road (Control Section: 0009-11 from Milepoint 4.5 to 10.1)							
1994	234	2.28	102.5	63.6	94.6	58.2	Yes
1998	192	2.61	73.6	64.9	94.7	64.3	Yes
IH-35E Control Corridor without Inside Shoulders from Royal Lane to Loop 12 (Control Section: 0196-03 from Milepoint 25.6 to 27.5)							
1994	87	1.40	62.1	66.8	98.6	61.3	Yes
1998	135	1.52	88.4	68.3	98.9	67.7	Yes
SH-183 Control Corridor without Inside Shoulders from Story Road to Loop 12 (Control Section: 0094-03 from Milepoint 4.2 to 7.9)							
1994	146	1.35	107.8	67.1	98.9	61.5	Yes
1998	132	1.41	93.3	68.9	99.5	68.2	Yes

Notes:

[1]ITE Manual of Traffic Engineering Studies, 4th Edition.

[2]State metropolitan areas include only Dallas, Tarrant, Collin, Harris, Bexar, Travis, and Williamson Counties.

[3]I & F = Injury and fatality.

Using the rate quality control method of crash rate analysis, the IH-635 corridor appears not to have been prone to crashes in 1994 but was prone to crashes in 1998. It should be noted that this is only true when making comparisons with the critical crash rates from state urban interstate highways and Dallas County interstate highways. When compared to state metropolitan areas interstate highways, which includes only specific counties, the crash rate analysis does not indicate the corridor was prone to crashes in either 1994 or 1998.

The IH-35E corridor was not prone to crashes in 1994 or 1998. The corridor's crash rates are lower than critical crash rates developed for each of the three groupings of multiple corridors with similar characteristics.

The IH-30 corridor was prone to crashes in 1994 and 1998, with the corridor crash rate noticeably higher in 1994. This tendency is most likely due to construction in the corridor and bridge reconstruction over the Fair Park area (IH-30 from IH-45 to Haskell Avenue), which started in 1993 and was later completed in 1996.

A more detailed evaluation of crash data will be included in the final year research report of this project.

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. Researchers estimate that the volatile organic compound (VOC) emissions are reduced by 51.4 lb/day on IH-30, 109.9 lb/day on IH-35E North, and 236.7 lb/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 (17). 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 public comments about the HOV lanes, and they have been continually improving operations. After the IH-30 HOV lane was opened, DART switched a bus route 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. Because of 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.

V. 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, and flexibility, which are discussed in this section.

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 right-of-way (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 lanes 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 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 roadway 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 operation 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 limits 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, from a traffic operations standpoint, is not a desirable design.

INCIDENT MANAGEMENT

Incident management is an issue that designers must address 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.

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) these 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 usually cannot operate 24 hours a day. Buffer-separated HOV lanes can either operate 24 hours a day or peak periods only and be used as general-purpose lanes or shoulders during certain hours (non-peak) of the day. A "part-time" buffer-separated HOV lane, however, would require special signing needs and could cause confusion for motorists.

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 18 through 20. 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 17 and 18.

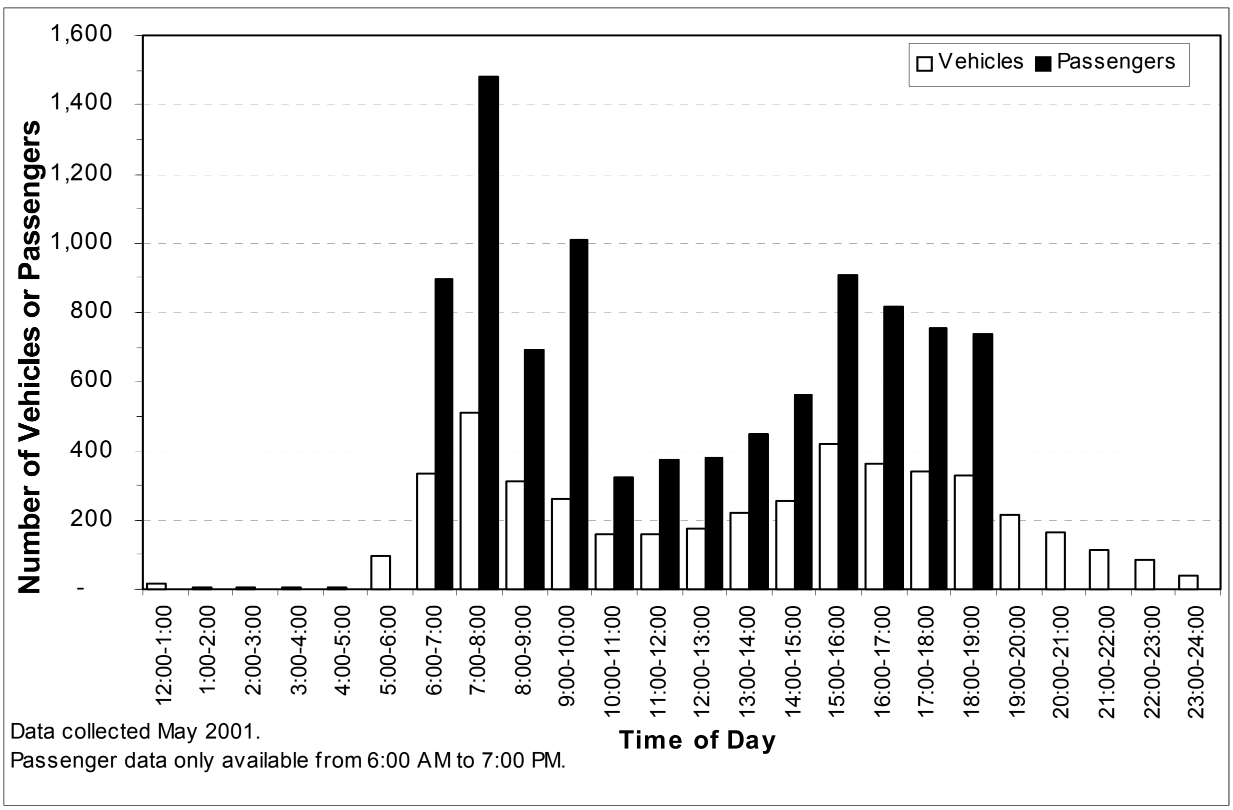


Figure 17. IH-35E North (Stemmons) Freeway Southbound HOV Lane Hourly Volumes.

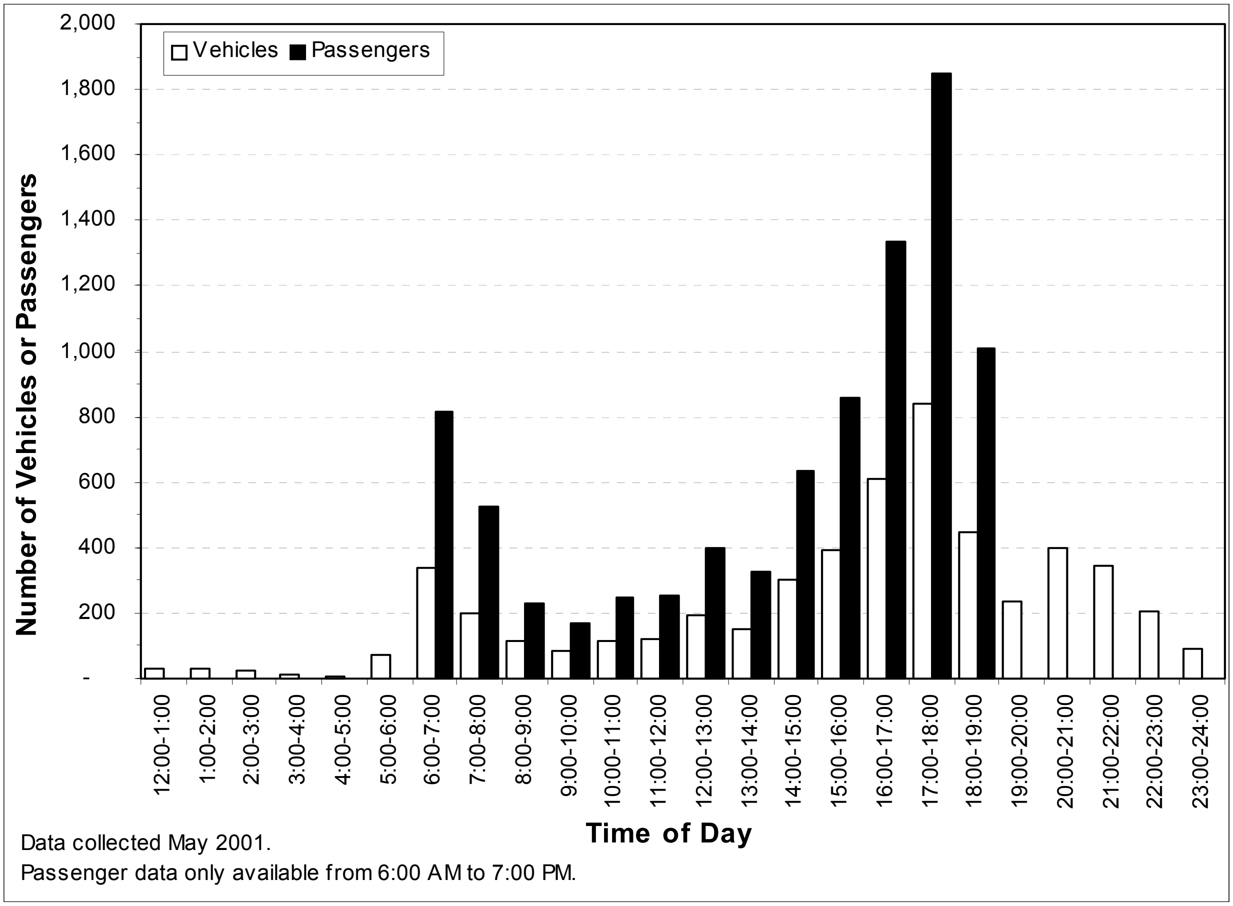


Figure 18. IH-35E North (Stemmons) Freeway Northbound HOV Lane Hourly Volumes.

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 19 and 20. No attempt has been made to quantify any benefits as a result of the off-peak period usage.

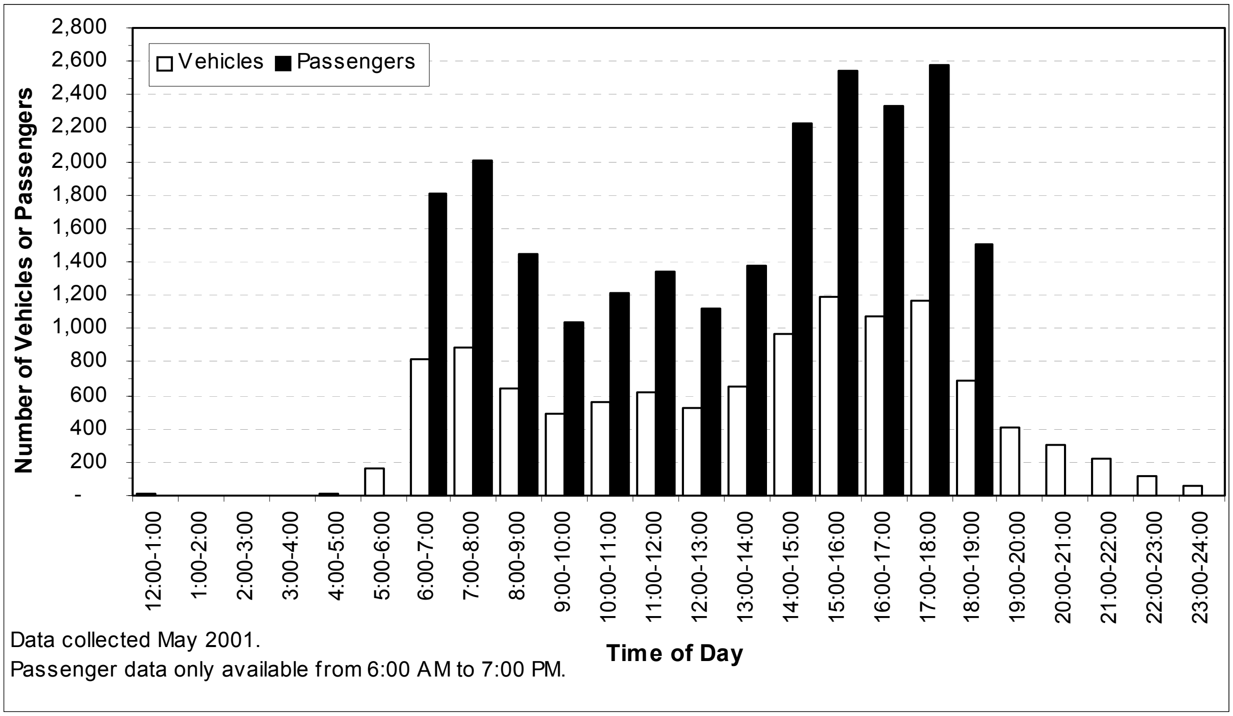


Figure 19. IH-635 (LBJ) Freeway Westbound HOV Lane Hourly Volumes.

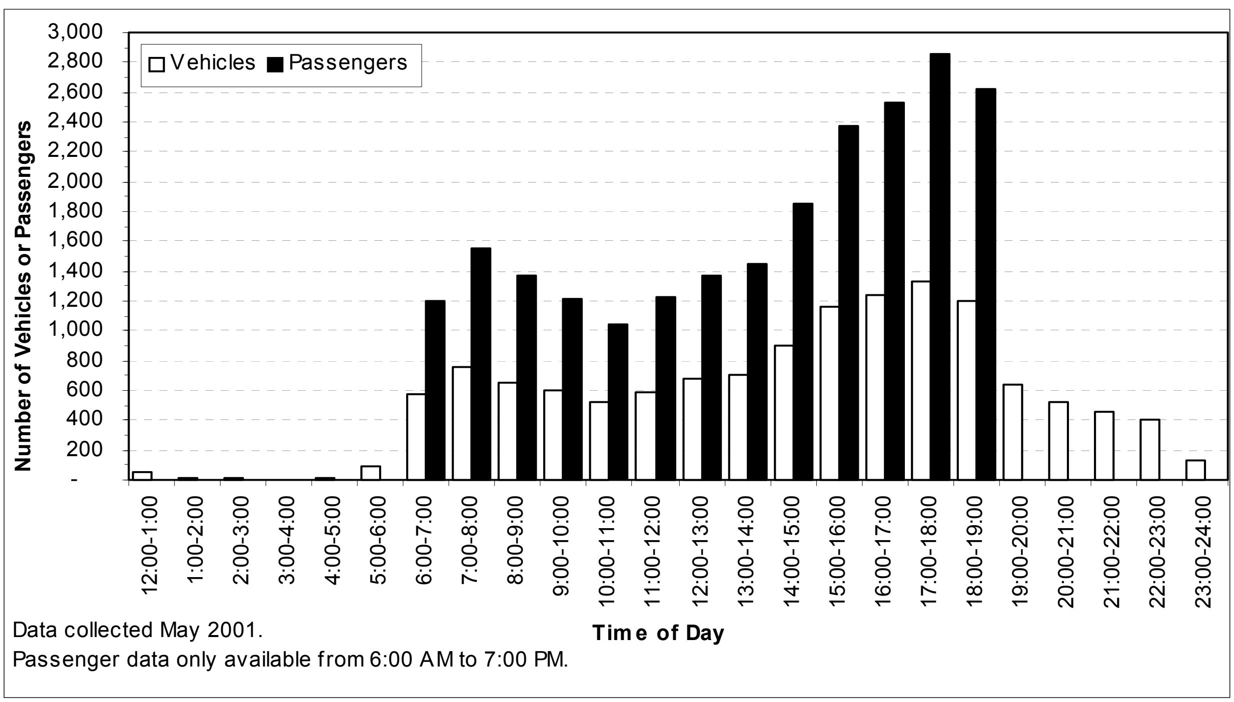


Figure 20. IH-635 (LBJ) Freeway Eastbound HOV Lane Hourly Volumes.

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. Because of this, 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 section, 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 12 shows a summary of the qualitative issues previously discussed.

Table 12. 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	Limited	May be unlimited
Flexibility	Flexibility in eligible users May include congestion pricing	Convert to general-purpose lanes Many different trips served

VI. 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 13 and the data summary in Tables 14 through 18, the concurrent flow lanes have generated a substantial number of carpools, have increased the person movement in the corridor, have increased the occupancy rate in the corridor, and have 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 13. 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?	U [	U [	U [	U [
Does the HOV lane carry as many people as an adjacent general-purpose lane?	U [	U [	U [	U-
Has the person volume increased at least as much as the percent increase in number of lanes?	U [	U	U	U
Has the occupancy rate in the corridor increased?	U [	U [	U [	U [
In terms of speed, has the HOV lane not negatively impacted the general-purpose lanes?	U [	U [	U [	U [
Are the HOV lanes saving HOV lane vehicles at least 5 minutes of travel time?	U [	U [	U	U [
Are the HOV lanes providing motorists at least one minute per mile travel time savings?	U [	U [	U	U

Note:
The table addresses 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.

A before-and-after analysis of crash data was conducted to evaluate the safety impacts of barrier-versus buffer-separated facilities. Crash rates for the IH-35E North and IH-635 corridors have experienced an increase in the analysis years after implementation of buffer-separated HOV lanes. However, the crash rates for these corridors are comparable to the crash rates for similar freeway corridors in each of the state's major metropolitan areas. Several factors have been identified, which may have contributed to the increase in crash rates for the corridors with buffer-separated HOV lanes. Further research will focus on pinpointing the factors that are most critical.

Table 14. IH-35E North (Stemmons) Directional Corridor Operational Data.

Operational Data	"Before"[1] (Mainlanes)	"After"[2] (Mainlanes & HOV)	Percent Change
VEHICLE VOLUMES			
TOTAL			
AM Peak Hour-Southbound	5965	6858	15%
PM Peak Hour-Northbound	5902	6379	8%
2+ OCCUPANT AUTOMOBILES			
AM Peak Hour-Southbound	313	1115	256%
PM Peak Hour-Northbound	465	1161	150%
DART BUS			
AM Peak Hour-Southbound	8	9	13%
PM Peak Hour-Northbound	5	9	80%
PERSON VOLUMES			
TOTAL			
AM Peak Hour-Southbound	6594	8398	27%
PM Peak Hour-Northbound	6607	8020	21%
2+ OCCUPANT AUTOMOBILES			
AM Peak Hour-Southbound	651	2366	263%
PM Peak Hour-Northbound	992	2465	148%
DART BUS			
AM Peak Hour-Southbound	261	258	-1%
PM Peak Hour-Northbound	137	262	91%
OCCUPANCY RATE			
AUTOMOBILE			
AM Peak Hour-Southbound	1.06	1.19	12%
PM Peak Hour-Northbound	1.09	1.22	12%
VEHICLE			
AM Peak Hour-Southbound	1.11	1.22	10%
PM Peak Hour-Northbound	1.12	1.26	12%
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	520	-1%

Notes:
[1]"Before" data are an average of September 1993 to March 1995 data.
[2]"After" data are an average of December 1996 to March 2001 data.
[3]"Before" are data from March 1992 to June 1996, while "After" are data from September 1996 to March 2001.

Table 15. 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	5692	8686	53%
PM Peak Hour-Eastbound	7104	8909	25%
2+ OCCUPANT AUTOMOBILES			
AM Peak Hour-Westbound	596	1663	179%
PM Peak Hour-Eastbound	954	1864	95%
DART BUS			
AM Peak Hour-Westbound	40	42	5%
PM Peak Hour-Eastbound	40	44	10%
PERSON VOLUMES			
TOTAL			
AM Peak Hour-Westbound	7689	11,718	52%
PM Peak Hour-Eastbound	9549	12,216	28%
2+ OCCUPANT AUTOMOBILES			
AM Peak Hour-Westbound	1290	3512	172%
PM Peak Hour-Eastbound	2059	4004	94%
DART BUS			
AM Peak Hour-Westbound	1262	1115	-12%
PM Peak Hour-Eastbound	1314	1084	-18%
OCCUPANCY RATE			
AUTOMOBILE			
AM Peak Hour-Westbound	1.13	1.22	8%
PM Peak Hour-Eastbound	1.15	1.25	9%
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	11.80	-20%
PM Peak Hour-Eastbound	11.2 [3]	10.70	-4%
SPEEDS (MILES PER HOUR)			
AM Peak Hour-Westbound	22	28	27%
PM Peak Hour-Eastbound	29 [3]	31	7%
Operational Data	**"Before" (Mainlanes)**	**"After" (HOV Lane)**	**Percent Change**
TRAVEL TIME (MINUTES)			
AM Peak Hour-Westbound	14.70	6.60	-55%
PM Peak Hour-Eastbound	11.2 [3]	6.20	-45%
SPEEDS (MILES PER HOUR)			
AM Peak Hour-Westbound	22	50	127%
PM Peak Hour-Eastbound	29 [3]	53	83%
PARK-AND-RIDE LOT USAGE	859	883	3%

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 2001.
[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 16. 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	7486	8185	9%
PM Peak Hour	7175	8135	13%
2+ OCCUPANT AUTOMOBILES			
AM Peak Hour	628	1194	90%
PM Peak Hour	868	1616	86%
DART BUS			
AM Peak Hour	1	2	100%
PM Peak Hour	2	2	0%
PERSON VOLUMES			
TOTAL			
AM Peak Hour	8293	9656	16%
PM Peak Hour	8311	10,249	23%
2+ OCCUPANT AUTOMOBILES			
AM Peak Hour	1368	2572	88%
PM Peak Hour	1887	3578	90%
DART BUS			
AM Peak Hour	0	15	??
PM Peak Hour	8	12	50%
OCCUPANCY RATE			
AUTOMOBILE			
AM Peak Hour	1.11	1.18	6%
PM Peak Hour	1.15	1.26	10%
VEHICLE			
AM Peak Hour	1.11	1.18	6%
PM Peak Hour	1.16	1.26	9%
Operational Data	**"Before" (Mainlanes)**	**"After" (Mainlanes)**	**Percent Change**
TRAVEL TIME (MINUTES)			
AM Peak Hour	9.70	10.25	6%
PM Peak Hour	21.20	17.30	-18%
SPEEDS (MILES PER HOUR)			
AM Peak Hour	39	37	-5%
PM Peak Hour	18	22	22%
Operational Data	**"Before" (Mainlanes)**	**"After" (HOV Lane)**	**Percent Change**
TRAVEL TIME (MINUTES)			
AM Peak Hour	9.70	7.20	-26%
PM Peak Hour	21.20	8.20	-61%
SPEEDS (MILES PER HOUR)			
AM Peak Hour	39	53	36%
PM Peak Hour	18	47	161%
PARK-AND-RIDE LOT USAGE	1112	1452	31%

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 2001.

Table 17. 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	7428	8229	11%
PM Peak Hour	7902	8115	3%
2+ OCCUPANT AUTOMOBILES			
AM Peak Hour	454	1222	169%
PM Peak Hour	1166	1808	55%
DART BUS			
AM Peak Hour	2	2	0%
PM Peak Hour	1	2	100%
PERSON VOLUMES			
TOTAL			
AM Peak Hour	8041	9767	21%
PM Peak Hour	9312	10,400	12%
2+ OCCUPANT AUTOMOBILES			
AM Peak Hour	982	2636	168%
PM Peak Hour	2503	3991	59%
DART BUS			
AM Peak Hour	8	15	88%
PM Peak Hour	0	13	??
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	1.19	10%
PM Peak Hour	1.18	1.28	8%
Operational Data	**"Before" (Mainlanes)**	**"After" (Mainlanes)**	**Percent Change**
TRAVEL TIME (MINUTES)			
AM Peak Hour	11.20	11.90	6%
PM Peak Hour	13.60	13.90	2%
SPEEDS (MILES PER HOUR)			
AM Peak Hour	30	28	-7%
PM Peak Hour	25	24	-4%
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	6.10	-55%
SPEEDS (MILES PER HOUR)			
AM Peak Hour	30	57	90%
PM Peak Hour	25	56	124%
PARK-AND-RIDE LOT USAGE	1112	1452	31%

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 2001.

Table 18. HOV Lane Operational Data.

	CONTRAFLOW	CONCURRENT FLOW		
CHARACTERISTIC	**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: 4.6 SB: 4.1	8.4	6.2
VEHICLE VOLUMES				
Total				
AM Peak Hour	1409	887	721	906
AM Peak Period	2934	1889	1852	2282
PM Peak Hour	1233	849	1184	1131
PM Peak Period	2624	1941	3250	2984
24-Hour	5388	9736	13398	12522
Carpool				
AM Peak Hour	1318	818	687	848
AM Peak Period	2723	1722	1757	2141
PM Peak Hour	1149	787	1120	1047
PM Peak Period	2441	1788	3076	2762
DART Bus				
AM Peak Hour	41	8	1	1
AM Peak Period	97	21	2	4
PM Peak Hour	41	9	1	1
PM Peak Period	89	19	2	5
Vanpools, Motorcycles, and Other Buses				
AM Peak Hour	17	15	10	19
AM Peak Period	42	41	30	50
PM Peak Hour	16	14	26	16
PM Peak Period	35	41	70	40
PERSON VOLUMES				
Total				
AM Peak Hour	4002	2078	1529	1984
AM Peak Period	8435	4432	3919	4973
PM Peak Hour	3612	2025	2657	2443
PM Peak Period	7443	4594	7262	6428
24-Hour	15,878	22,515	27,788	27,376
Carpool				
AM Peak Hour	2771	1749	1460	1841
AM Peak Period	5772	3668	3745	4638
PM Peak Hour	2453	1682	2499	2314
PM Peak Period	5229	3817	6841	6082

Table 18. HOV Lane Operational Data (continued).

	CONTRAFLOW	CONCURRENT FLOW		
CHARACTERISTIC	**IH-30**	**IH-35E North**	**IH-635 EB**	**IH-635 WB**
PERSON VOLUMES				
DART Bus				
AM Peak Hour	1109	246	10	14
AM Peak Period	2431	541	20	29
PM Peak Hour	1061	257	6	5
PM Peak Period	2011	539	22	9
Vanpools, Motorcycles, and Other Buses				
AM Peak Hour	89	37	35	92
AM Peak Period	211	118	90	218
PM Peak Hour	72	46	115	59
PM Peak Period	143	145	298	160
OCCUPANCY RATES				
Automobile				
AM Peak Hour	2.09	2.08	2.11	2.14
AM Peak Period	2.08	2.07	2.10	2.14
PM Peak Hour	2.13	2.08	2.24	2.15
PM Peak Period	2.13	2.08	2.23	2.14
Vehicle				
AM Peak Hour	2.84	2.34	2.12	2.19
AM Peak Period	2.88	2.35	2.12	2.18
PM Peak Hour	2.93	2.39	2.24	2.16
PM Peak Period	2.84	2.37	2.23	2.15
ENFORCEMENT				
AM Peak Hour Violation Rate	2%	5%	3%	4%
AM Peak Period Violation Rate	2%	6%	3%	4%
PM Peak Hour Violation Rate	2%	5%	3%	6%
PM Peak Period Violation Rate	2%	5%	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 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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