HIGHWAY PLANNING AND OPERATIONS FOR THE DALLAS DISTRICT: IMPLEMENTATION AND EVALUATION OF CONCURRENT FLOW HOV LANES IN TEXAS

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Report 1994-14S
Research Study Number 7-1994
Research Study Title: Highway Planning and Operations for the Dallas District: Implementation and Evaluation of Concurrent Flow HOV Lanes

Sponsored by the
Texas Department of Transportation

November 1997

TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

Technical Report Documentation Page

1. Report No.	2.	3. Recipient's Catalog No.
TX-98/1994-14S	PB98-168735	

4\. Title and Subtitle
HIGHWAY PLANNING AND OPERATIONS FOR THE DALLAS DISTRICT: IMPLEMENTATION AND EVALUATION OF CONCURRENT FLOW HOV LANES IN TEXAS

5\. Report Date
November 1997

6\. Performing Organization Code

7. Author(s)
Douglas A. Skowronek, Angela M. Stoddard, Stephen E. Ranft, and Carol H. Walters

8\. Performing Organization Report No.
Report 1994-14S

9. Performing Organization Name and Address
Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843-3135

10\. Work Unit No. (TRAIS)

11\. Contract or Grant No.
Study No. 7-1994

12. Sponsoring Agency Name and Address
Texas Department of Transportation
Research and Technology Transfer Office
P. O. Box 5080
Austin, Texas 78763-5080

13\. Type of Report and Period Covered
Project Summary:
September 1996 - August 1997

14\. Sponsoring Agency Code

15. Supplementary Notes
Research performed in cooperation with the Texas Department of Transportation.
Research Study Title: Highway Planning and Operations for the Dallas District: Implementation and Evaluation of Concurrent Flow HOV Lanes

16. Abstract

Limited capital investment for major transportation improvements and growth in metropolitan areas require the most efficient use of the existing transportation system. One means to achieve this is high-occupancy vehicle (HOV) lanes. While an extensive system of permanent HOV lanes is planned 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 57 km (35.4 mi) of interim HOV lanes operational in the Dallas area, including a barrier-separated contraflow lane on I-30 (East R.L. Thornton Freeway) and buffer-separated concurrent flow HOV lanes on I-35E North (Stemmons Freeway) and I-635 (Lyndon B. Johnson Freeway). 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 assess the effectiveness of concurrent flow (buffer-separated) versus contraflow (barrier-separated) HOV lanes. Issues such as person movement, carpool formation, travel time savings, violation rates, 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.

17. Key Words
High-Occupancy Vehicle Lanes, Concurrent Flow Lanes, Contraflow Lanes, Carpools, HOV Facilities

18\. Distribution Statement
No restrictions. This document is available to the public through NTIS:
National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	48	

Form DOT F 1700.7 (8-72) Reprod

IMPLEMENTATION RECOMMENDATIONS

The Texas Department of Transportation (TxDOT), in cooperation with the Dallas Area Rapid Transit (DART), sponsored this project in an effort 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. One contraflow HOV lane has been operating for six years, and two concurrent flow HOV lanes have began operating within the past twelve months in the Dallas District of TxDOT.

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. Sufficient crash data was not available when this report was prepared to assess the impact on crash rates as a result of implementing the concurrent flow lanes. Also, while the concurrent flow lanes have generated carpools and have increased the person movement in the corridor, the increase currently provides only a marginal justification for the HOV lanes; the HOV lanes are only moving about the same number of persons during the peak hour as a single adjacent general-purpose lane. HOV lanes, however, do not typically "mature" within the first year of operation. It is therefore recommended that the lanes continue to be monitored and a reassessment of their effectiveness be conducted when additional data is available.

DISCLAIMER

ACKNOWLEDGMENT

The authors wish to acknowledge those Texas Department of Transportation personnel who made special contributions to this research. Special thanks are extended to Jim Hunt, Stan Hall, Bob Brown, and Bill Hale in the Dallas District. Thanks are also extended to Koorosh Olyai and Prasad Golkonda of the Dallas Area Rapid Transit.

In addition, Christy Harris, Tammy Pietrucha, and John Brunk of TTI-Arlington provided valuable support and technical assistance throughout the length of the project. Data collection was coordinated by Diana Wallace, Joe Slack, and Robert DeGarmo. Everyone's assistance was greatly appreciated.

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SUMMARY

Limited capital investment for major transportation improvements and growth in metropolitan areas require the most efficient use of the existing transportation system. One means to achieve this is high-occupancy vehicle (HOV) lanes. The concept of an HOV lane is to increase the person-carrying capacity of freeways by providing higher speed dedicated lanes for multi-occupant vehicles without negatively impacting the congestion in the adjacent freeway general-purpose lanes. While an extensive system of permanent HOV lanes is planned 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 57 km (35.4 mi) of interim HOV lanes operational in the Dallas area, including a barrier-separated contraflow lane on I-30 (East R.L. Thornton Freeway), buffer-separated concurrent flow HOV lanes on I-35E North (Stemmons Freeway), and buffer-separated concurrent flow HOV lanes on I-635 (Lyndon B. Johnson Freeway). 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 assess the effectiveness of concurrent flow (buffer-separated) versus contraflow (barrier-separated) HOV lanes. Issues such as person movement, carpool formation, travel time savings, violation rates, 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.

The operational performance of the HOV lanes is measured in terms of vehicle and person volumes, occupancy rates, transit impacts, cost effectiveness, enforcement, safety, and public acceptance. Operational data is collected several times per year so that changes can be identified and documented. The evaluation includes a "before" and "after" HOV lane comparison as well as comparisons with a control corridor that does not have an HOV lane, I-35E South (South R.L. Thornton Freeway).

Vehicle and Person Volumes and Occupancy

Since each of the HOV lanes has opened, there has been a significant increase in the number of 2+ carpools on each of the facilities. The percent increase in carpools ranged from 89 percent on eastbound I-635 to a 243 percent increase on I-35E North. One of the objectives of an HOV lane is to increase the person-throughput on a facility. On I-35E South, the control facility without an HOV lane, there was a 3 percent decrease in the AM peak hour person trips, while the facilities with HOV lanes had at least a 17 percent increase in person trips. Additionally, an HOV lane should carry at least as many people as an adjacent freeway mainlane. Due to several bus routes that utilize the I-30 HOV lane, the HOV lane carries almost twice the number of people as an adjacent general-purpose lane during the peak hour, while the HOV lanes on I-635 and I-35E North carry person volumes similar to the adjacent general-purpose lanes. Increases in automobile occupancy indicate that motorists are forming carpools to utilize the benefits of the HOV lanes. The freeways with an HOV lane had an 8 percent to 10 percent increase in average automobile occupancy, while the average automobile occupancy on I-35E South, without an HOV lane, has decreased by 2 percent.

Travel Times and Speeds

To encourage motorists to rideshare in order to utilize the HOV lane, it is essential that vehicles in the HOV lane be able to travel faster than those in the general-purpose lanes; further, in order to maintain positive public perception, the HOV lane should not negatively impact traffic in the adjacent general-purpose lanes. The HOV lanes typically save motorists at least five minutes over the general-purpose lanes on incident-free days. Opening an HOV lane on I-635 eastbound and westbound had an insignificant impact on the mainlane operating speeds, while there was an increase in mainlane speeds on I-30 and I-35E North after the HOV lane was opened.

Transit

While there are not any fixed DART bus routes on I-635, the bus operating speeds on I-30 and I-35E North have more than doubled since the opening of the HOV lanes on these facilities. Also, the travel time savings has decreased the bus operating costs on I-30 by approximately $350,000 because fewer buses are required to run "before" bus routes.

Cost Effectiveness

Comparing the costs and benefits (peak-period travel time savings) will determine if a project is cost effective. 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.

Enforcement

The HOV lanes are routinely enforced during the peak periods and sporadically enforced during the off-peak periods by the DART transit police. Due to the presence of enforcement officers, the violation rates on I-30 are less than 1 percent, while the violation rate on the concurrent flow facilities ranged from 4 percent to 6 percent. 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.

Safety

The I-35E North and the I-635 HOV lanes have been operational less than one year; therefore, available data is too preliminary to draw conclusions regarding the safety of concurrent flow HOV lanes. These lanes will continue to be monitored so that their safety can be documented.

Public Acceptance

A survey of I-30 HOV users cited that the primary reasons carpoolers use the HOV lane are cost savings over driving alone and time savings, while the bus riders use the HOV lane because it is cheaper and more convenient than driving alone. To date, there has not been a public acceptance study performed on I-35E North or I-635 HOV lanes. DART has been receptive to the public's comments to improve operations including extending the limits of the eastbound I-30 HOV lane and adding an additional access location on the westbound I-635 HOV lane.

I. INTRODUCTION

Limited capital investment for major transportation improvements and growth in metropolitan areas requires the most efficient use of the existing transportation system. One means to achieve this is high-occupancy vehicle (HOV) lanes. The concept of an HOV lane is to increase the person-carrying capacity of freeways by providing dedicated higher speed 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.

BENEFITS OF HIGH-OCCUPANCY VEHICLE LANES

There are many benefits of implementing an HOV lane in a corridor. Some of the HOV lane benefits are described below.

- Travel time savings for eligible vehicles
- Trip time reliability for eligible vehicles
- Increased person throughput
- Reduced fuel consumption and decreased vehicle emissions
- Reduced bus operating costs
- Increased efficiency for the entire 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 362 center line kilometers (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. These projects are considered interim projects by the Federal Highway Administration (FHWA) because they have been retrofitted into the existing freeway facility resulting in design exceptions from normally required standards.

There are currently 57 km (35.4 mi) of interim HOV lanes operational in the Dallas area (Figure 1), consisting of HOV lanes on I-30, I-35E North, and I-635 (Table 1). An 8.4 km (5.2 mi) interim barrier-separated contraflow HOV lane on I-30 (East R.L. Thornton Freeway) opened in September 1991 (Figure 2). Interim buffer-separated concurrent flow HOV lanes were opened on I-35E North (Stemmons Freeway) in September 1996 (Figure 3). The northbound HOV lane is 8.8 km (5.5 mi) in length, and the southbound HOV lane is 10.9 km (6.8 mi) in length. Interim buffer-separated concurrent flow HOV lanes also opened on I-635 (Lyndon B. Johnson Freeway) in March 1997 (Figure 4). The eastbound HOV lane is 10.5 km (6.5 miles) in length, and the westbound HOV lane is 10.0 km (6.2 mi) in length.

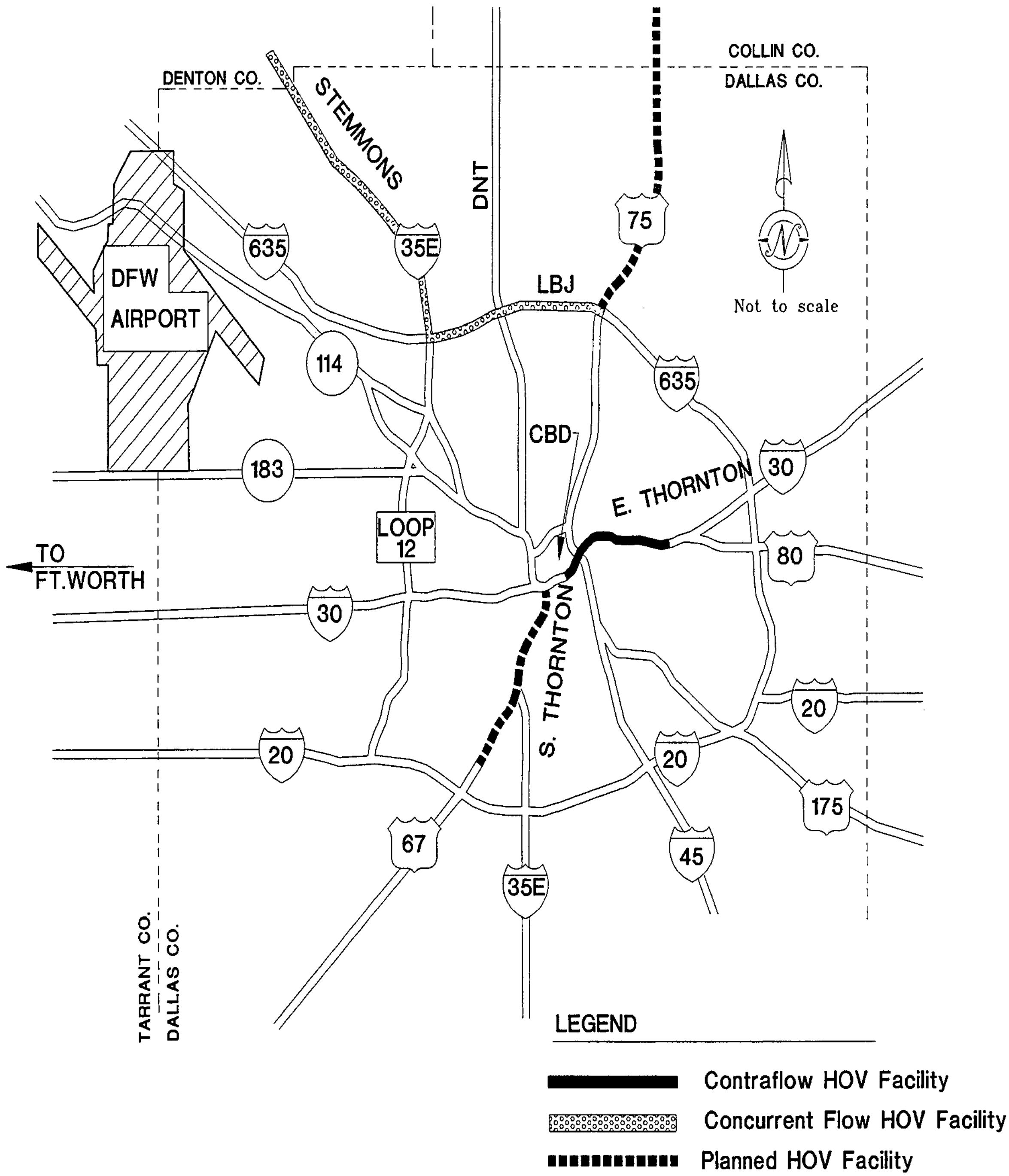
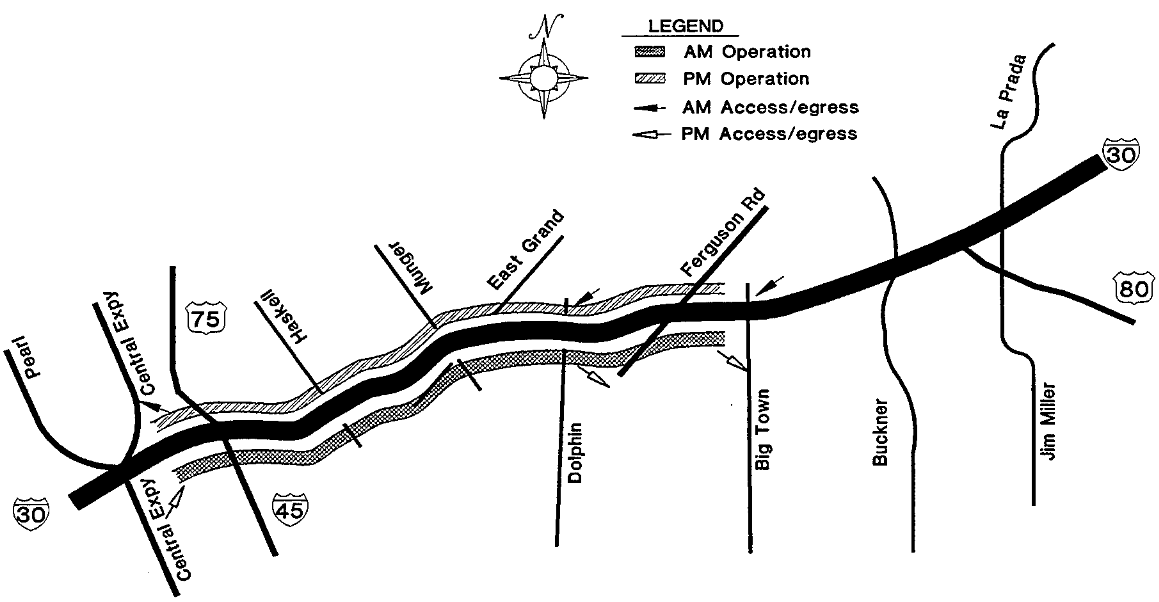
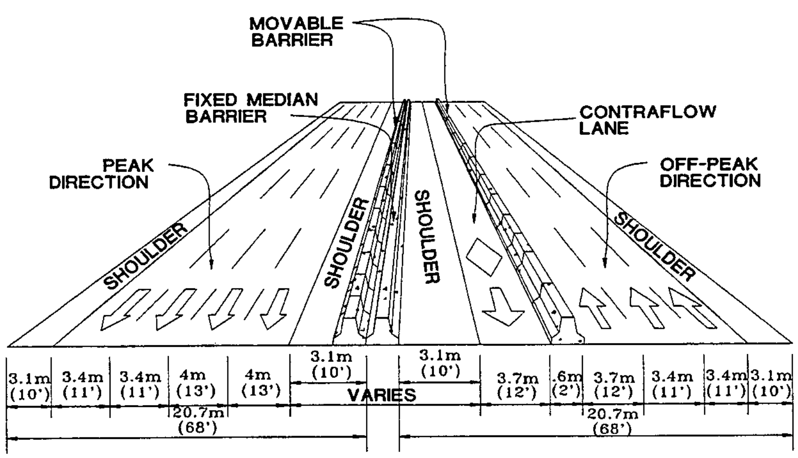


Figure 1. Dallas Area HOV Lanes



HOV LANE LIMITS



TYPICAL CROSS SECTION

Figure 2. I-30 East R.L. Thornton Freeway HOV Lane

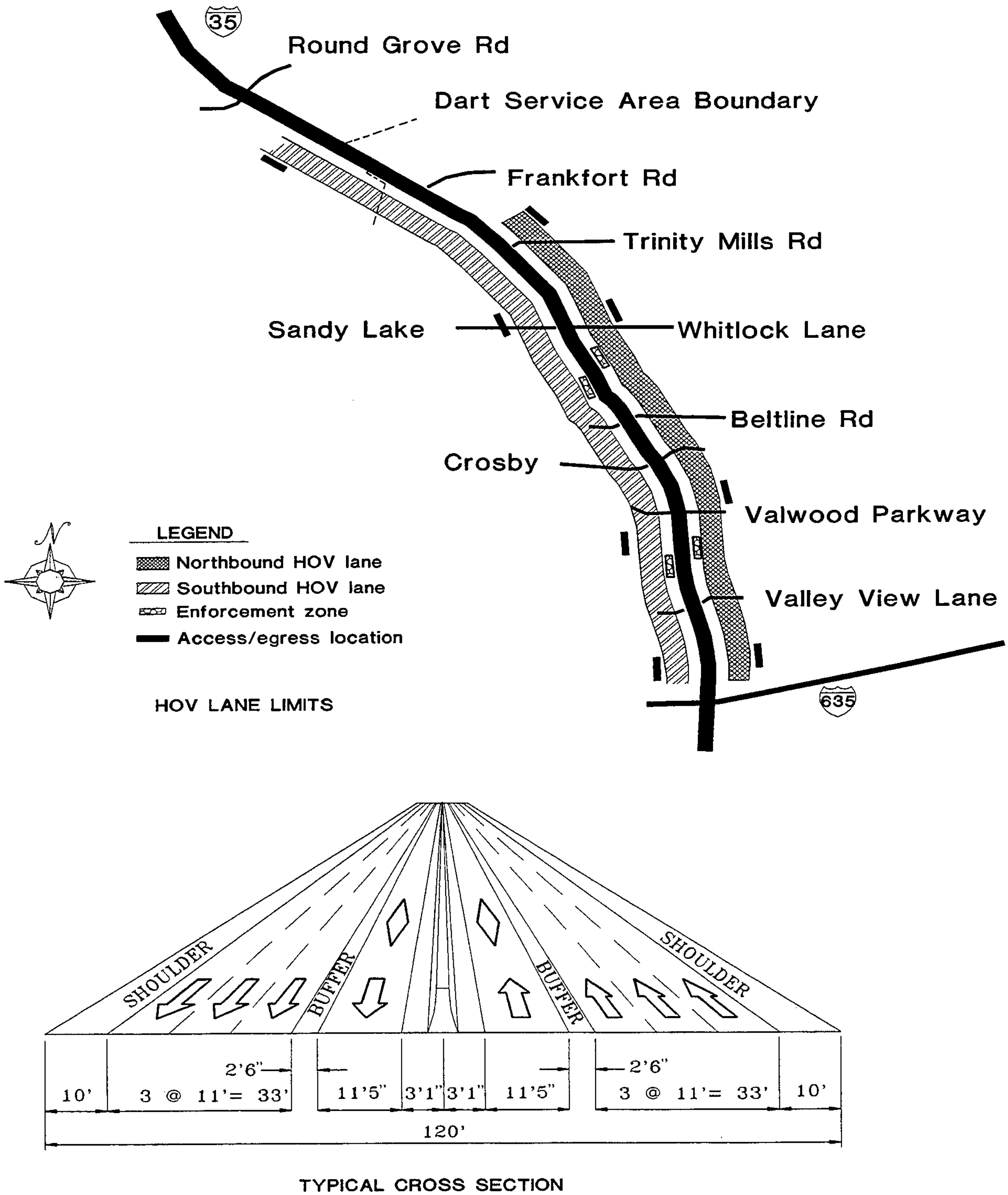


Figure 3. I-35E North Stemmons Freeway HOV Lane

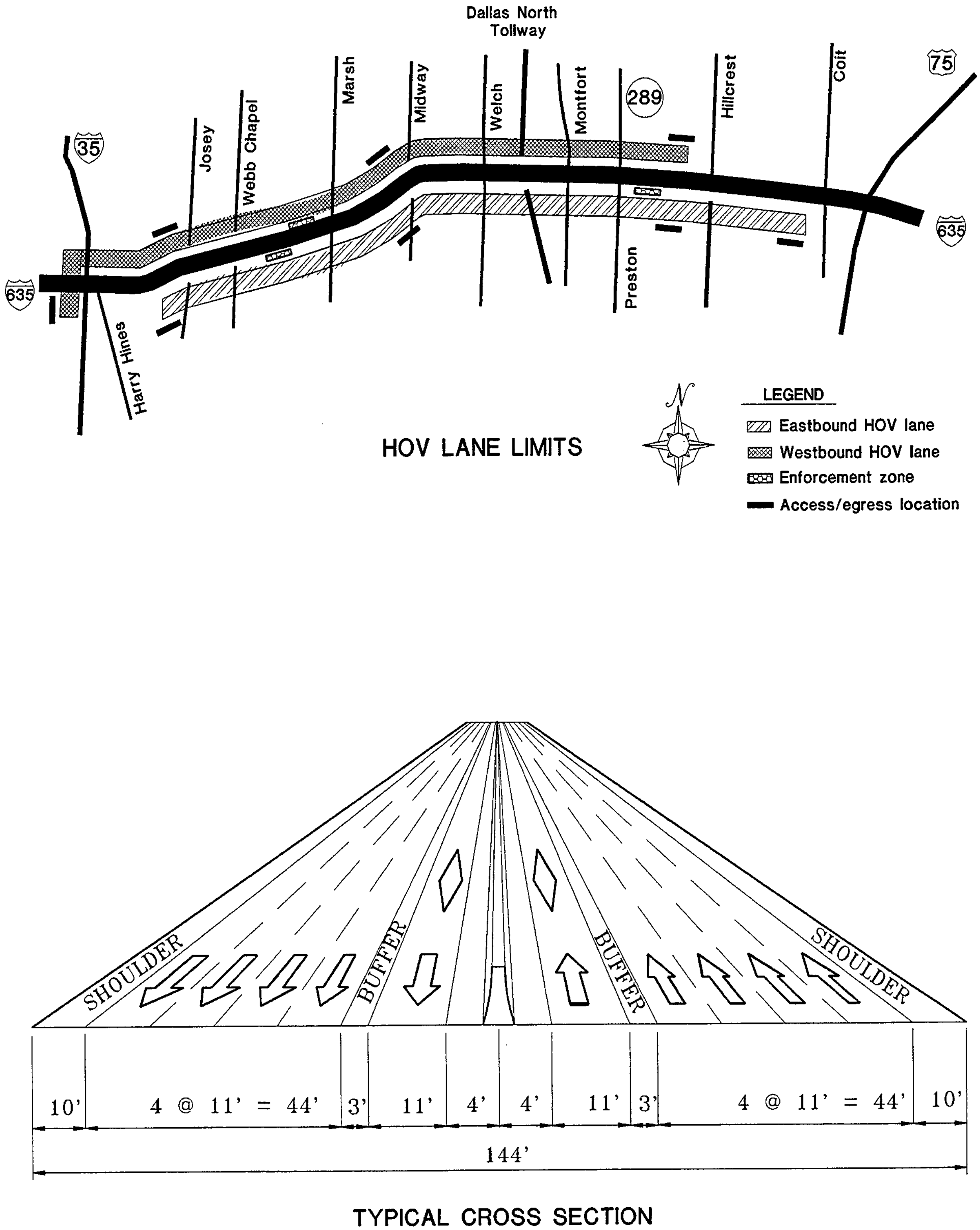


Figure 4. I-635 Lyndon B. Johnson Freeway HOV Lane

Table 1. Interim HOV Lanes Operating in the Dallas Area

Corridor	I-30 (East R.L. Thornton)	I-35E North (Stemmons)	I-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	8.4 km (5.2 mi) EB 8.4 km (5.2 mi) WB	8.8 km (5.5 mi) NB 10.9 km (6.8 mi) SB	10.5 km (6.5 mi) EB 10.0 km (6.2 mi) 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		

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

The contraflow lane on I-30 is created with the use of a movable barrier which "takes away" a freeway lane in the off-peak direction and allows it to be used for peak direction HOV lane eligible vehicles. The concurrent flow lanes on I-35E North and I-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 which 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) 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 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 I-35E North and I-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 1,650 route-kilometers (1,025 route-miles) of freeway HOV lanes operating in the United States and Canada as of August 1997, and they can be broken down as follows: busways: 51.5 route-km (32 route-mi) in nine projects; barrier-separated: 217.4 route-km (135 route-mi) in 18 projects; concurrent-flow: 1,338.1 route-km (831.5 route-mi) in 78 projects; and, contraflow: 44 route-km (27.3 route-mi) in seven projects. The majority of the HOV lane projects and route-kilometers are concurrent flow HOV lane projects in California.

Other than the Dallas area, Houston is the only other city in Texas that currently has HOV lanes in operation. The first HOV lane in Texas, which opened in August 1979, was the I-45 (North Freeway) contraflow HOV lane in Houston. Currently there are five Houston facilities with barrier-separated HOV lanes in operation: I-10W (Katy Freeway), I-45N (North Freeway), I-45S (Gulf Freeway), U.S. 290 (Northwest Freeway), and U.S. 59S (Southwest Freeway). In addition to HOV lanes in the planning stage in the Dallas area and Houston, HOV lanes are also proposed in Austin and San Antonio.

The topic of priority treatment in Texas has been addressed in several previous major TxDOT research studies including, most recently, study 0-1353, "An Evaluation of HOV Lanes in Texas," (1). The study addresses an evaluation of HOV lanes in Houston and Dallas using trend line data to allow changes over time to be detected and a comparison of control freeways without HOV facilities to help isolate the HOV lane impacts. The results from this study as well as previous studies (study 2-10-74-205 from 1974 through 1983, study 2-10-84-339 from 1984 through 1988, and study 2-10-89/3-1146 from 1989 through 1993) have been instrumental in bringing about the implementation of HOV lanes in both Houston and Dallas.

An evaluation of the impact on the corridor as a result of implementation of an HOV lane requires a substantial amount of data collection. Morning and evening peak period data is currently being collected on the HOV lanes in the Dallas District on a monthly basis as part of a DART project. The monthly data collected, however, consists of travel times and person volumes on the HOV lanes and travel times on the adjacent freeway general-purpose lanes. A more thorough evaluation is necessary to determine corridor impacts. Study 0-1353 currently monitors the corridors with HOV lanes in Houston and Dallas on a semi-annual basis only because most of the facilities in Houston have been operating for several years resulting in "mature" facilities. The experience in Houston is that substantial changes in the corridor occur during the first two to four years of HOV lane operation (2). It is therefore essential that the corridors with new HOV lanes in Dallas initially be monitored more often to detect corridor changes. This study supplemented study 0-1353 with semi-annual data collection resulting in data collected four times per year in the Dallas District corridors. The data is collected in the three corridors with HOV lanes in Dallas as well as a fourth corridor without an HOV lane which is used as a control corridor to help isolate HOV lane impacts. The data collected in addition to the DART project consists of person volumes on the freeway general-purpose lanes and person volumes and travel times on the control corridor.

Many of the original objectives of the previous research projects have been accomplished including the development of a comprehensive document for planning, designing, and operating park-and-ride lots (3) and a state manual for planning, designing, and operating HOV facilities (4). The latter manual, however, is specific to transitways which are defined as exclusive, physically separated, access controlled HOV priority treatment facilities. Many aspects of other types of HOV projects, such as concurrent flow lanes, remain less understood. The two interim concurrent flow HOV facilities in the Dallas District are the first concurrent flow lanes implemented in Texas, and they are essentially demonstrations of the buffer-separated HOV lane concept in Texas.

The American Association of State Highway and Transportation Officials (AASHTO) has developed a guide for the design of HOV facilities (5). While the document provides guidance for the planning and design of HOV lanes, it is cautioned that experience is not extensive enough to firmly establish standards for HOV facilities that are incorporated into existing highway rights-of-way where width and lateral clearances are limited. In addition, many of the issues discussed in the AASHTO guide are given only general consideration.

An extensive summary of the experience of HOV lanes across the nation has been prepared by Parsons-Brinckerhoff, Inc. (6). The summary reinforces the fact that a wide variety of HOV lane types and designs have been implemented. It does not, however, evaluate the effectiveness of various types or designs. Additionally, the key to success is a thorough knowledge of the problems in a corridor and the ability to weave compromises into the design to mitigate the problems.

SAFETY STUDIES

Buffer-Separated HOV Lanes

The information regarding the safety of concurrent flow HOV projects has been inconclusive. Some studies have concluded that concurrent flow lanes are as safe as other types of projects, while other studies have indicated a safety concern with concurrent flow HOV projects. Following is a summary of the safety of concurrent flow 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 concerns may result when the speed differential is greater than 40 kph (25 mph) (7). This finding is consistent with the AASHTO report, " 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 an accident (8).

A synthesis of the accident rates on freeway concurrent flow HOV lanes is summarized in Table 2, which compares the accident rates on the freeway with the accident rates on the adjacent general-purpose lanes. Due to the limited amount of data in the report, additional data is needed to draw any conclusions.

A study conducted by the California Polytechnic State University reported the effect that HOV lanes have on the safety of selected California freeways. The results of the study suggest that the accident pattern resulted from differences in traffic flow and congestion rather than geometric and operational characteristics of the HOV facilities (10). The accident "hot spots" during the peak periods on freeways with and without HOV lanes are a result of localized congestion (10).

The attitudes of California drivers towards HOV lanes were obtained through a focus group study. Southern California drivers perceive the OR 55 and LA 91 concurrent flow HOV lanes to be "scary" and "dangerous" due to the high-speed differential, close proximity of the median barrier, and weaving vehicles (11). The OR 55 HOV lane is 3.4 m (11 ft) wide with a 0.6 m (2 ft) inside shoulder and a 0.3 m (1 ft) painted buffer stripe, and the LA 91 HOV is 3.4 m (11 ft) wide with a 0.6 m (2 ft) inside shoulder and a 0.6 m (2 ft) painted buffer (two yellow lines linked by ladder block stripes). Northern California drivers did not have similar concerns with the concurrent flow lanes (Marin 101 and Santa Clara 101). The Marin 101 HOV lane is 3.7 m (12 ft) wide with a 0.6 m to 1.5 m (2 ft to 5 ft) inside shoulder and a painted stripe buffer, while the Santa Clara 101 HOV lane is 3.7 m (12 ft) wide with a 3.1 m (10 ft) inside shoulder and a painted stripe buffer.

In conclusion, 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, caution should be used 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 locations have a higher frequency of accidents. The number of accidents that occur immediately after a facility is opened may be high because drivers are not familiar with the HOV operation and facility. 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, the number of accidents should stabilize as drivers become familiar with the HOV lane and its operation.

Barrier-Separated HOV Lanes

Separate roadways isolate the HOV traffic from the general-purpose lane traffic flow. Accidents in the general-purpose lanes do not significantly disrupt HOV operation, and any impacts that the HOV operation may have on mixed-flow operation are isolated to a few select ingress/egress locations (6).

If the HOV traffic was not on a separate roadway, an incident in the general-purpose lanes may have a significant impact on the HOV traffic, as motorists in the general purpose lanes try to bypass the congestion by using the HOV lane or as motorists in the HOV lane slow down and "rubberneck" to observe the incident. Separate roadways also protect the HOV traffic and the general-purpose traffic from the considerable speed differential that may exist between the two traffic streams with concurrent flow HOV lanes (6).

There has been some concern that separate roadways limit the ability to handle incidents in either the HOV lane or mixed-flow facility, as there is less flexibility in traffic handling around an incident (6). If there were continuous access between the two traffic flows, then traffic could be diverted to either facility during an incident. But incident management may often take place on the HOV lane in this case.

VIOLATION STUDIES

Concurrent flow HOV lanes generally have a lower compliance rate than other types of HOV lanes regardless of the amount of enforcement (6). On California stripe-separated lanes, the violation rates vary considerably, from 5 percent to 10 percent on LA 91 to 15 percent to 20 percent on Santa Clara 101 (9). These facilities have the potential to become as congested as the mainlanes at a high violation rate. If these facilities become as 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 can not enter the general-purpose lanes. For example, the violation rate for California separated HOV facilities is the lowest on any California mainlane HOV lane, with both the El Monte busway and I-15 violation rate below 5 percent (9).

III. DATA COLLECTION METHODOLOGY

In order for the HOV lanes to be evaluated and monitored, 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 type of data that has 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 (2). 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 quarterly data collection is conducted to monitor the operational performance of the HOV lanes. The data is collected in the peak direction of the corridor. During the AM peak period, I-30 and I-35E North have approximately a 70 percent directional peak inbound (westbound and southbound, respectively). A reverse pattern occurs during the PM peak period. I-635 in the vicinity of the HOV lane, however, has nearly an equal directional split during the AM and PM peak periods. Data is, 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. 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 I-35E North and I-635 HOV lanes to obtain daily volume of traffic on the HOV lanes. (Daily counts are not needed on the I-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.

Quarterly Data Collection

In addition to the monthly data collection, AM and PM peak period vehicle occupancy counts are collected quarterly on the general-purpose lanes of the three freeways that have HOV lanes. These occupancy counts are used to monitor corridor-wide impacts of HOV lanes during the peak period.

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. Therefore, operational data is collected on a quarterly basis on I-35E South (South R.L. Thornton Freeway), the "control" section without an HOV lane. Each quarter, travel time runs and vehicle occupancy counts are collected on the control section and compared to the facilities with HOV lanes.

ACCIDENT DATA

Accident data is available from LANSER (Local Area Network Safety Evaluation and Reporting) system database. LANSER is a microcomputer software package that contains Texas accident data for the years 1990 - 1996 from the Texas Department of Public Safety (DPS). 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 LANSER data. Less than four months of after-data was available from LANSER on the I-35E North HOV lane, which opened in mid-September 1996. Additionally, the I-635 concurrent flow HOV lanes were opened in March 1997, and no after-data was available from LANSER. A follow-up study (3942) will add more definition to the accident picture.

IV. OPERATIONAL PERFORMANCE OF DALLAS AREA HOV LANES

This section describes the operational performance of each HOV lane and is divided into the following 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 consists 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 is an average of data collected since the HOV lanes became operational. It should be noted that while multiple quarterly data collection periods have been averaged and represent the after-data for I-30 and I-35E North, there is only one quarterly data collection period representing the after-data for I-635 (June 1997).

VEHICLE AND PERSON VOLUMES AND OCCUPANCY

One of the primary objectives of HOV lanes is to increase person-throughput. This 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 (I-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. 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

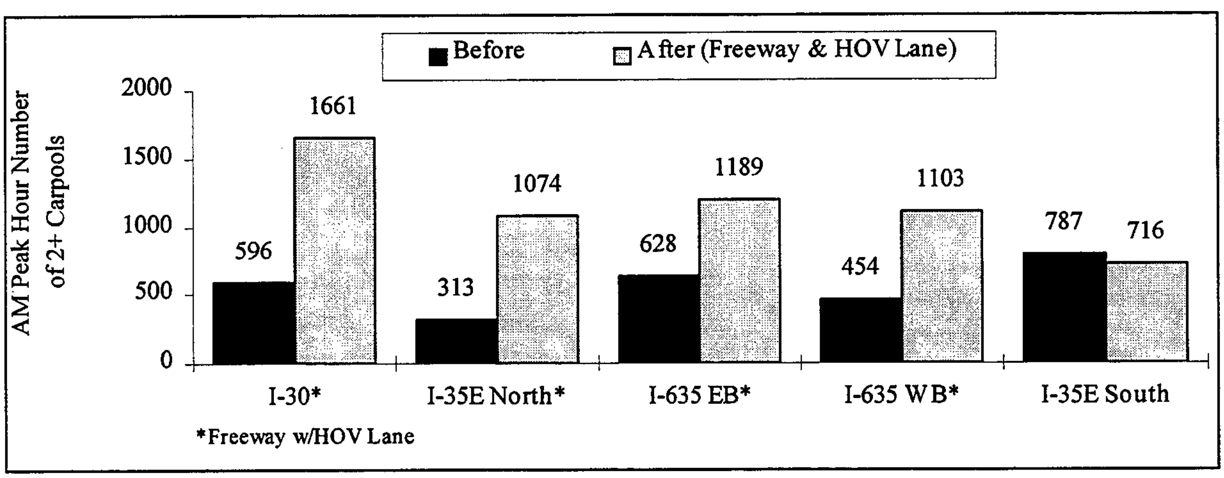


Figure 5. Change in AM Peak Hour Number of Carpools

facilities. As shown in Figure 6, the percent increase in carpools ranged from 89 percent on eastbound I-635 to 243 percent increase on I-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.

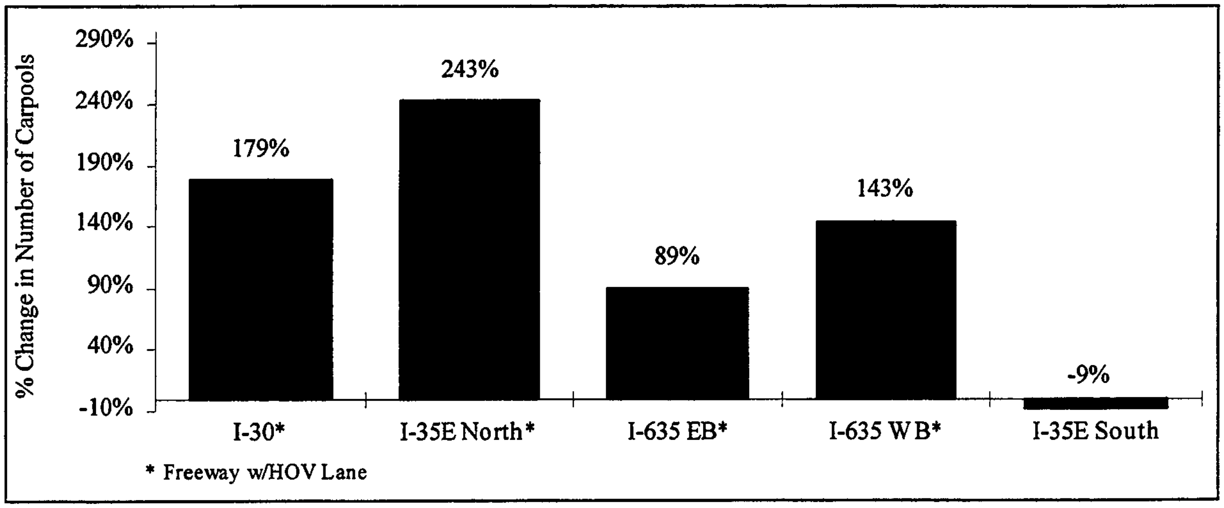


Figure 6. Percent Change in AM Peak Hour Number of Carpools

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. It is interesting, however, to compare the percent increase in the number of directional lanes with the percent increase in peak hour person volumes, as shown in Figure 8. Over time, the percent increase in person volumes should exceed the percent increase in directional lanes. Currently, only the I-30 HOV lane has a greater percent increase in volume as directional lanes. Previous research has indicated that the increase in person movement is related to the length of time that the HOV lane has been operational. The I-30 HOV lane opened in 1991 and had the highest increase in person movement. The smallest increase in person movement occurred in the I-635 corridor; however, these HOV lanes had only been operational for three months when the after-data was last collected in June of 1997. It is anticipated that as this HOV lane "matures," it will have a greater increase in person trips.

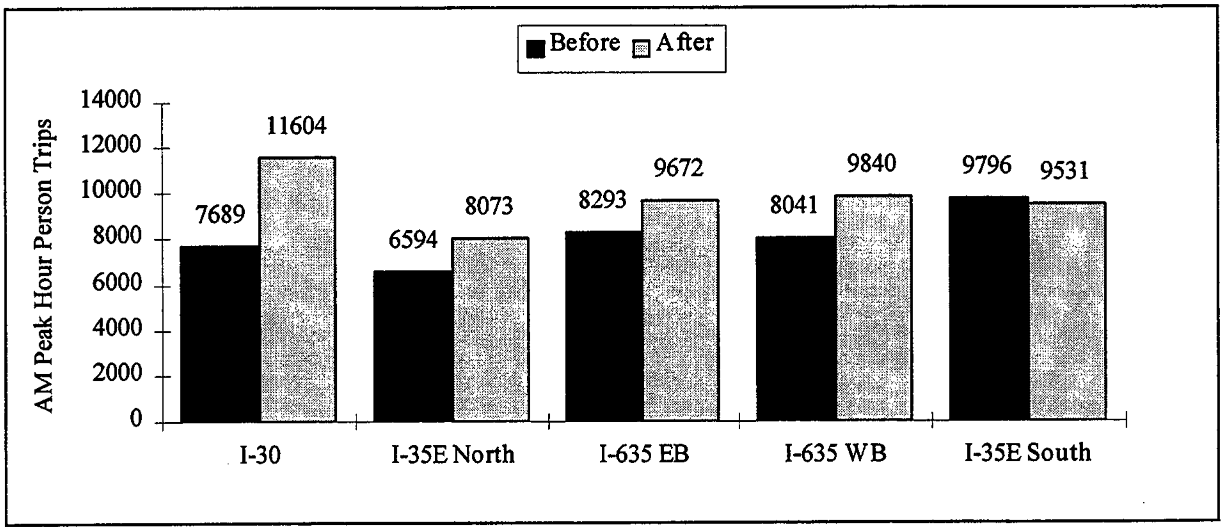


Figure 7. Change in AM Peak Hour Person Trips

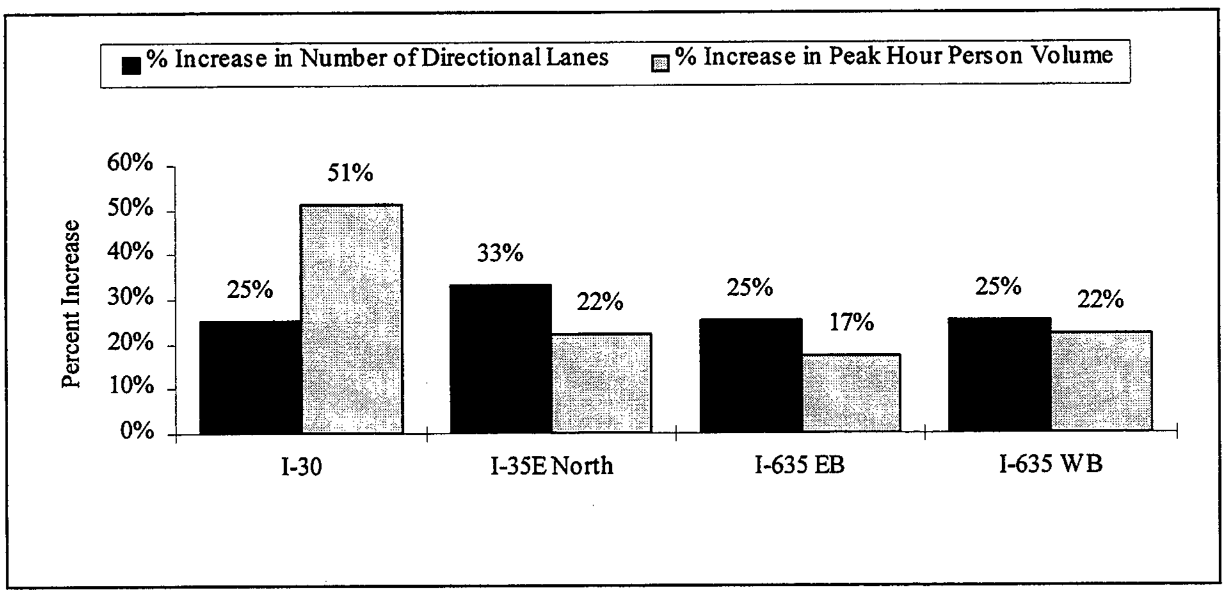


Figure 8. Percent Increase in Number of Lanes versus Peak Hour Person Volumes

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. The peak hour person volume per lane for each of the HOV lanes and adjacent general-purpose lanes is shown in Figure 9. The I-30 HOV lane carries almost twice the number of persons as an adjacent freeway lane during the peak hour, while the number of people in the I-35E North is similar to an adjacent freeway lane, and the I-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 I-30 HOV lane during the peak hour, while only 10 buses utilize the I-35E HOV lane. There are currently no fixed DART bus routes on the I-635 HOV lanes. The presence of transit routes significantly increases the person carrying capacity of a facility.

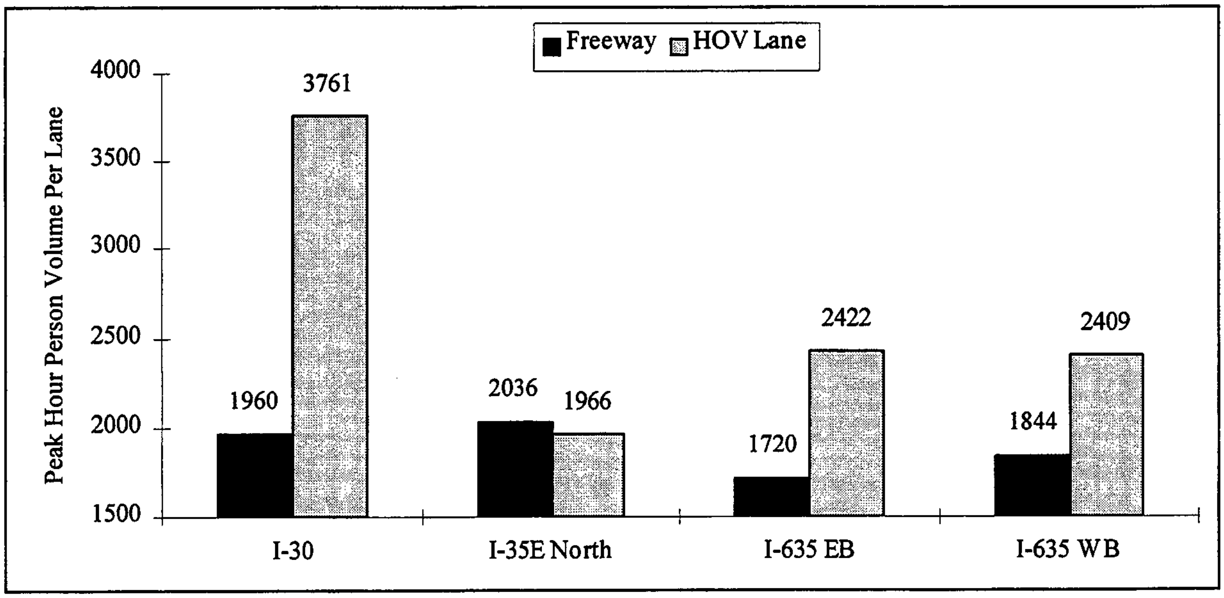


Figure 9. Peak Hour Person Volume per Lane

Occupancy

The average peak hour automobile and vehicle occupancy for the freeways with an HOV lane and I-35E South, the control corridor, are shown in Figures 10 and 11, respectively. Due to the presence of several bus routes on I-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 average automobile occupancy rate after the HOV lane was implemented, while the vehicle occupancy varies amongst the corridors due to the number of transit buses during the peak hour.

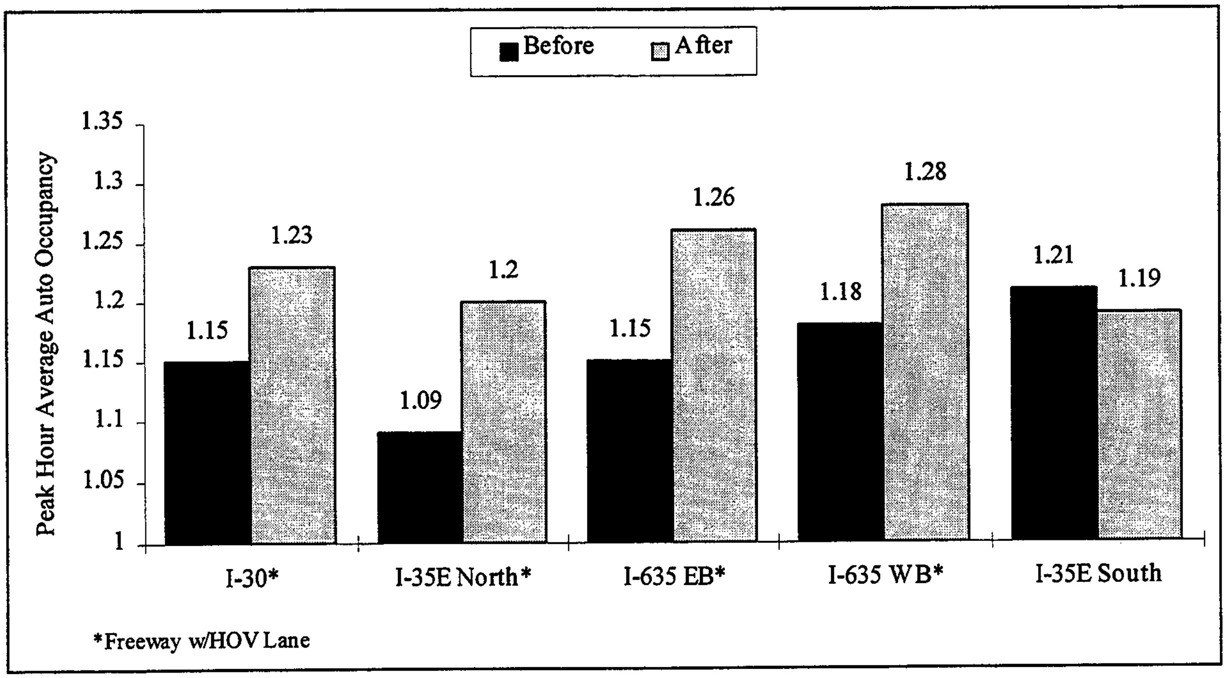


Figure 10. Changes in Average Automobile Occupancy

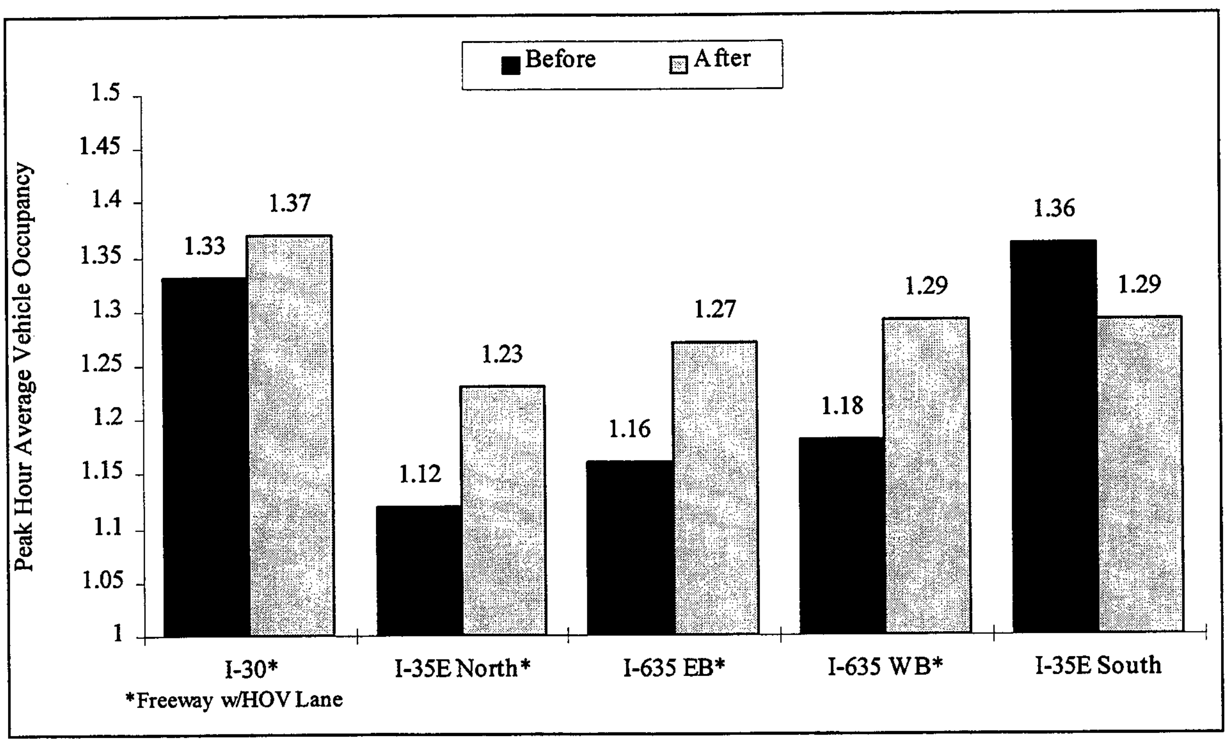


Figure 11. Change in Average Vehicle Occupancy

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 I-30, I-35E North, and I-635 is shown in Figure 12.

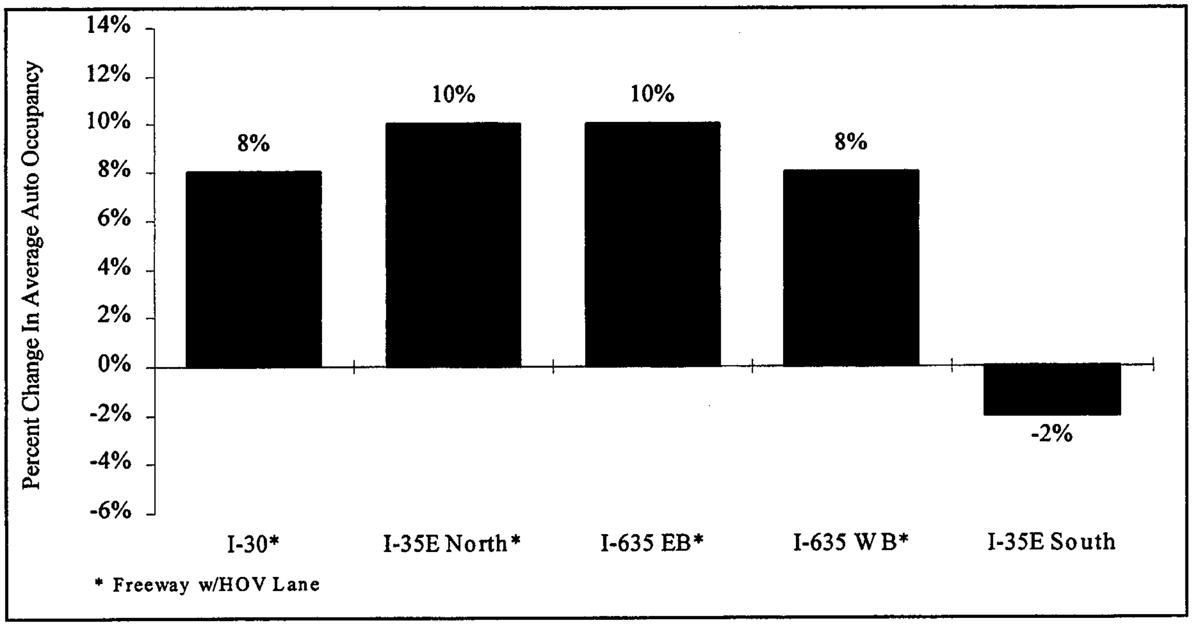


Figure 12. Percent Change in Average Automobile Occupancy

All four freeways with an HOV lane have an 8 percent to 10 percent increase in the average automobile occupancy, while the average automobile occupancy on I-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 I-30, I-35E North, and I-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, I-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 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. The peak hour travel speeds on the HOV lanes and adjacent mainlanes are shown in Figure 13. There was an increase in mainlane speeds after the HOV lane opened on I-30 and I-35E North. Opening an HOV lane on I-635 eastbound and I-635 westbound appears to have a slight impact on the mainlane operating speeds; however, this result is preliminary as it comes from one quarterly data collection effort thus far and is not statistically significant. In addition, on each of the facilities, the HOV lane speeds were significantly higher than the speeds on the adjacent general-purpose lanes.

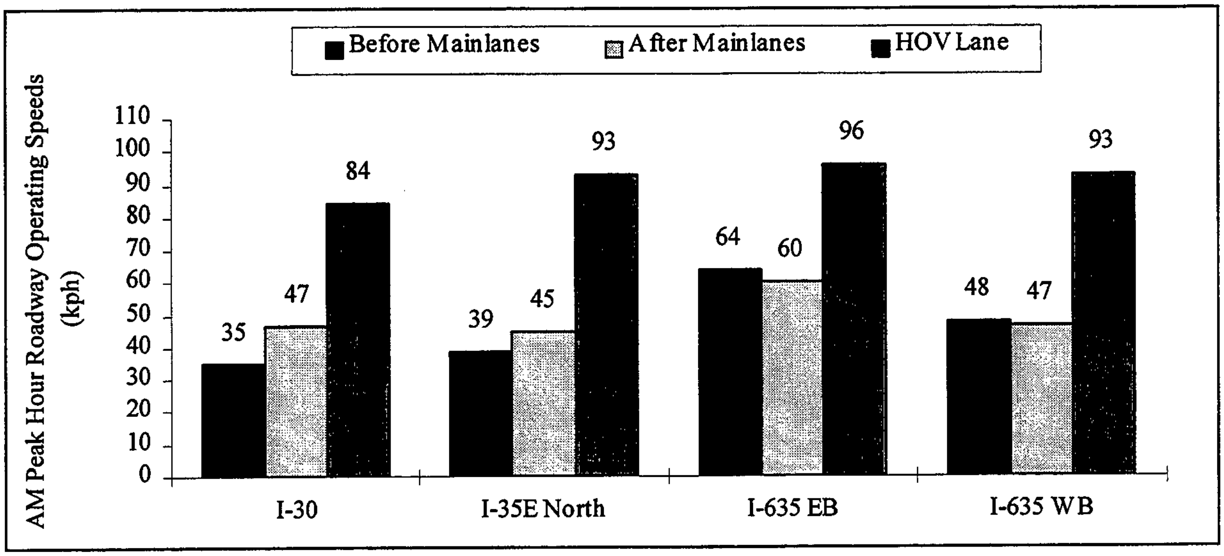


Figure 13. Change in Roadway Operating Speeds

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 is required. Travel time savings are the 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 14. 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.

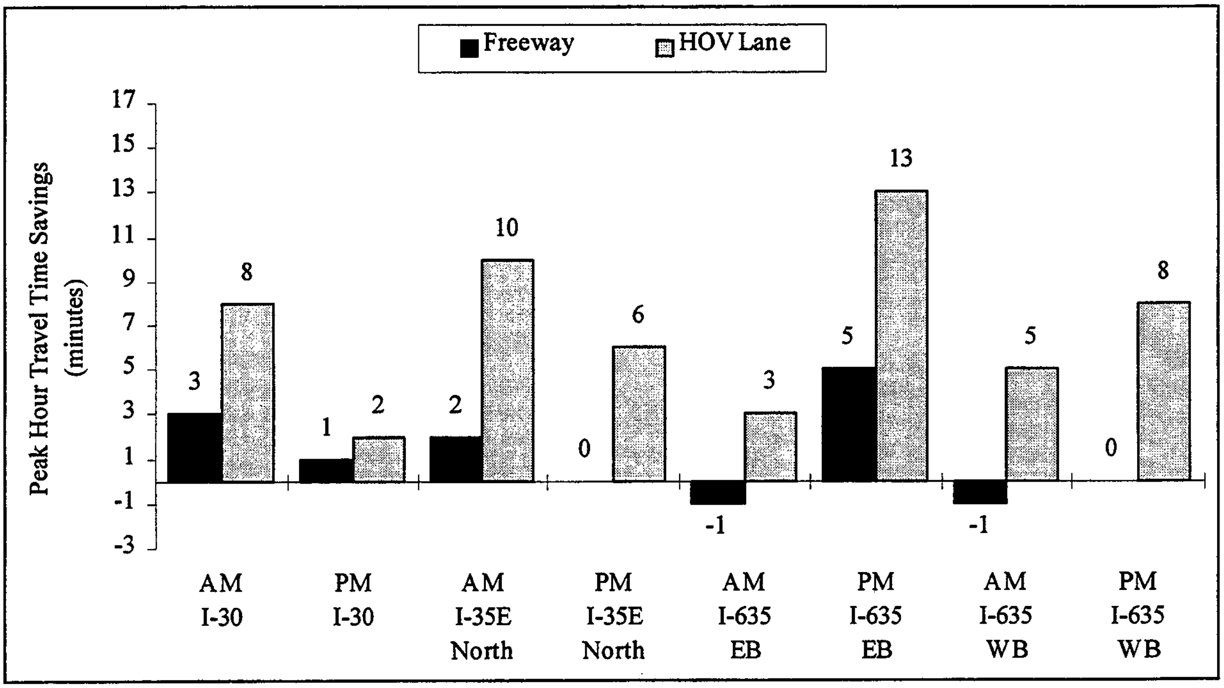


Figure 14. Peak Hour Travel Time Savings After HOV Lane Opened

Perceived travel time savings may be of greater importance than actual travel time savings. A survey of I-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 (13). Similarly, the I-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 I-35E North corridor or the I-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 I-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 I-30 and I-35E North during the AM and PM peak hour, as shown in the "Speeds and Travel Times" section of this report. In the I-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 $350,000 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 I-30 during the AM and PM peak hours as a result of the travel time savings previously discussed.

Transit Ridership

The AM and PM peak hour bus ridership is shown in Figure 15. An increase in the bus ridership has not been observed since the opening of HOV lanes on I-30 and I-35E North and, in fact, a decrease has been observed on I-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.

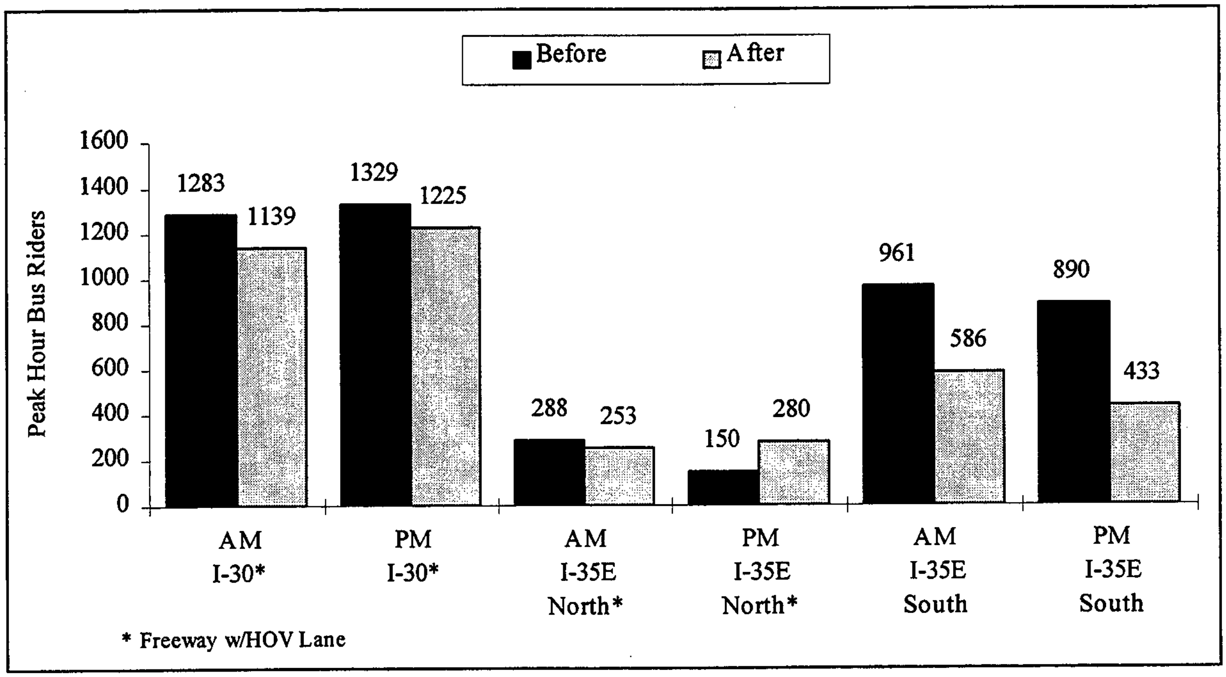


Figure 15. Change in Transit Bus Riders

COST EFFECTIVENESS

The cost effectiveness of each of the three HOV lanes projected out to 10 years is shown in Tables 2, 3, and 4. The tables show the benefit/cost ratio at the end of each fiscal year (September through August) with the exception of the I-635 HOV lane. The HOV lane on I-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 I-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. I-30 East R.L. Thornton HOV Lane Benefit/Cost Analysis

Benefits and Costs (Million Dollars)						
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	-	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	5.0	0.60	2.99	3.31	1.46
	1997	-	0.60	3.47	2.88	1.68
	1998	-	0.60	3.60	3.00	1.90
	1999	-	0.60	3.72	3.12	2.11
	2000	-	0.60	3.86	3.24	2.31
	2001	-	0.60	4.00	3.37	2.50

Notes: HOV lane opened in September 1991; AM auxiliary lane opened in July 1994; PM extension opened in February 1996; Benefits include $350,000 DART bus operating costs per year.

Table 3. I-35E Stemmons HOV Lane Benefit/Cost Analysis

Benefits and Costs (Million Dollars)						
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	2.40	0.00	0.24
	1998	-	0.20	2.40	0.00	0.46
	1999	-	0.20	2.40	0.00	0.66
	2000	-	0.20	2.40	0.00	0.85
	2001	-	0.20	2.40	0.00	1.03
	2002	-	0.20	2.40	0.00	1.19
	2003	-	0.20	2.40	0.00	1.34
	2004	-	0.20	2.40	0.00	1.49
	2005	-	0.20	2.40	0.00	1.62
	2006	-	0.20	2.40	0.00	1.75

Note: HOV lane opened in September 1996.

Table 4 . I-635 LBJ HOV Lane Benefit/Cost Analysis

Benefits and Costs (Million Dollars)						
Comment	Fiscal Year	Capital Cost	Operation/ Enforcement	HOV Lane Benefits	Mainlane Benefits	B/C Ratio
Initial construction	1997*	16.3	0.10	4.84	0.00	0.30
	1998	-	0.20	9.68	0.00	0.85
	1999	-	0.20	9.68	0.00	1.38
	2000	-	0.20	9.68	0.00	1.87
	2001	-	0.20	9.68	0.00	2.33
	2002	-	0.20	9.68	0.00	2.77
	2003	-	0.20	9.68	0.00	3.19
	2004	-	0.20	9.68	0.00	3.58
	2005	-	0.20	9.68	0.00	3.95
	2006	-	0.20	9.68	0.00	4.29
	2007**	-	0.10	4.84	0.00	4.46

Notes: HOV lane opened in March 1997; * Includes 3rd and 4th quarters of FY 1997 only (6 months); ** 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 I-35E North and I-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 I-30. The I-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 16. Due to the presence of enforcement officers on the facility, the violation rates on the HOV lanes have been relatively low. The violation rate on the I-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.

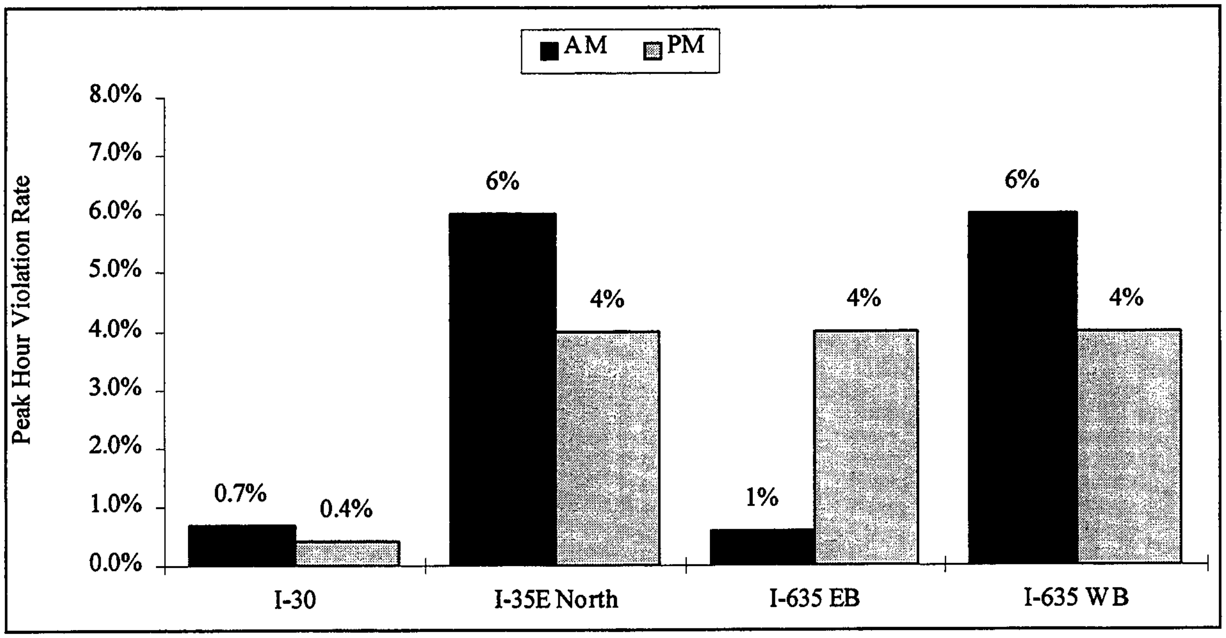


Figure 16. Observed Occupancy Violation Rates

On the buffer-separated HOV lanes, citations are written for vehicles not having the required occupancy and vehicles crossing the buffer between the mainlanes and HOV lane. The current Texas legislation sets the penalty for an HOV lane violation at a fine of not more than $200.00 plus court costs. When the I-35E North HOV lanes opened, a fine of $65.00 was assessed to HOV lane citations. In May 1997, the fine was increased to $200.00 plus a $35.00 court cost because of the large number of citations being issued with the additional lanes open on I-635.

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. Additionally, identifying locations where there may be a high concentration of accidents will assist with identifying possible operational problems. However, as discussed in the "Data Collection Methodology" section of this report, because the I-35E and I-635 concurrent flow HOV lanes have only been operational for a few months prior to this report and because of the several month delay in coding crash data, the safety data is *limited.*

Accident rates are not included in this study because sufficient crash data was not available at the time this report was prepared. While several years of before HOV lane data has been summarized, the authors believe that three months of after-data is insufficient to attempt to draw any comparisons. Further time is needed to assess safety impacts.

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 (12). 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 23.4 kg/day (51.4 lbs/day) on I-30, 50.0 kg/day (109.9 lbs/day) on I-35E North, and 107.6 kg/day (236.7 lbs/day) on I-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 (13) of I-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. 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 I-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 I-635 HOV lane was opened, motorists from the Dallas North Tollway could not access the westbound I-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 I-35E North and I-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 (Section IV), 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 (ROW) 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 1.8 m (6 ft) to a fixed barrier can be quantified using procedures in the Highway Capacity Manual (14). The capacity reduction for a buffer-separated lane with an offset of less than 1.8 m (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 (6).

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 (7). 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, from a traffic operations standpoint, is not a desirable design.

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.

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 can not be easily implemented on buffer-separated (concurrent flow) HOV lanes due to the lack of physical separation. If there was 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.

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 converted to general-purpose lanes or shoulders during certain hours (non-peak) of the day.

SUMMARY OF QUALITATIVE ISSUES

Table 5 shows a summary of the qualitative issues previously discussed.

Table 5. 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	1,500 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 6, 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 only moving about as many persons as a single adjacent general-purpose lane during the peak hour. However, HOV lanes do not typically "mature" within the first year of operation. Experience from Houston indicates that two to four years of operation of a facility is required before a complete and thorough assessment can be made.

Table 6. Summary of HOV Lane Measures of Effectiveness

Measure	I-30	I-35E N	I-635 EB	I-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	No	Yes	Yes
Has the person volume increased at least as much as the percent increase in number of lanes?	Yes	Yes	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	No	No
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. Sufficient crash data was not 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 is available.

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