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**Arterial Street High-Occupancy Vehicle (HOV)
Lanes in Texas**

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An Examination of Arterial Street High-Occupancy Vehicle (HOV)
Lanes in Texas

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ABSTRACT

This report examines the current use of high-occupancy vehicle (HOV) lanes on arterial streets in cities in Texas and throughout North America. It documents the application of downtown bus malls and bus-only lanes, as well as arterial street bus and HOV lanes in major travel corridors and suburban areas. Examples of providing priority for buses at signalized intersections are also highlighted. Information is presented on the design and the use of different treatments. General guidelines for planning and designing arterial street HOV lanes are presented. Potential benefits from arterial street HOV facilities include increasing vehicle occupancy levels, improving fuel efficiency, reducing energy use, and enhancing air quality levels.

EXECUTIVE SUMMARY

Introduction

High-occupancy vehicle (HOV) facilities are one approach being used in many areas to deal with concerns related to traffic congestion, mobility, and air quality. HOV projects, which offer priority treatments to buses, vanpools, and carpools, increase the person-movement efficiency of a roadway and enhance the mobility of area residents. HOV applications may be located in separate rights-of-way, on freeways, and on arterial streets.

HOV facilities have been in operation in Texas cities for over 20 years. The 1979 contraflow HOV lane demonstration project on I-45 North in Houston represents the first major HOV lane in the state. The success of this project led to the development of an extensive system of barrier separated, reversible HOV lanes in Houston. Freeway HOV lanes are also in operation in the Dallas area and are being considered in other cities.

Arterial street HOV facilities are found in many cities throughout the country. Examples of arterial street HOV projects in North America include bus malls, bus lanes, HOV lanes, and priority treatments at signalized intersections. Many different design and operational strategies may be used with arterial street HOV facilities. Further, these projects may provide links to freeway HOV lanes and busways or they may be stand-alone facilities.

Arterial street HOV projects may provide benefits to transit operators, bus riders, and carpools, and vanpoolers. Arterial street HOV projects facilitate the movement of buses, carpools, and vanpools through congested areas, providing travel time savings and improved trip time reliability. Arterial street HOV facilities may also provide operating savings to transit operators, improve fuel efficiency, reduce energy use, and enhance air quality.

This report examines the use of arterial street HOV facilities in Texas cities and in metropolitan areas throughout North America. The potential issues associated with various types of treatments are discussed. Guidelines for planning and designing HOV projects in Texas are presented.

Arterial Street HOV Facilities

A number of different approaches can be used to provide priority to buses, vanpools, and carpools on arterial streets. Most of these techniques use existing travel or curb lanes rather than adding new lanes. These approaches include bus malls, right-side lanes, center lanes, contraflow lanes on one-way streets, and providing priority to buses at signalized intersections.

Bus Malls. Bus malls are streets reserved exclusively for public transit vehicles. Most also include improved sidewalks and other pedestrian amenities. Access to emergency vehicles is usually provided and some projects allow taxis. Bus or transit malls are primarily found

in downtown areas. Existing transit malls range in length from a few blocks to facilities covering 10 to 15 blocks. Transit and pedestrian malls were developed in a number of cities in the 1970s. Some of these facilities have been removed or modified, but a number are still in operation.

Right Side Bus-Only and HOV Lanes. This type of HOV facility uses the right side lane, usually the curb lane or the second lane, on an arterial street for an HOV lane. This approach represents the most common application of HOV lanes on arterial streets. Right side HOV lanes may be open only to buses or buses, vanpools, and carpools may be allowed. Bus-only lanes are found in many downtown areas. These facilities may operate only during the morning and afternoon peak-hours or throughout most of the day and help move buses through congested downtown areas. Right side arterial street bus lanes are currently in operation in Dallas, Houston, and San Antonio.

Left-Side Bus-Only and HOV Lanes. Few examples exist of left-side HOV lanes. Operating an HOV facility in the left lane of an arterial street eliminates potential traffic conflicts related to curb lanes, such as on-street parking, delivery vehicles, and right turn movements at driveways and intersections. This approach may be appropriate for longer-distance HOV facilities. Potential issues with this technique include accommodating left-turns for general traffic, as well as HOVs weaving across the general traffic lanes to make right turns. This treatment may also present significant problems to transit operations if buses must pull over to the curb to pick up and drop off passengers. An alternative is to provide passenger waiting platforms adjacent to the left lane, which requires additional right-of-way and capital expenditures.

Center Bus-Only and HOV Lanes. Bus-only and HOV lanes located in the center of an arterial street represent another type of possible treatment. As highlighted in this section, a few examples of these types of approaches exist. This type of facility provides bus-only or HOV lanes in the center of an arterial street. A number of different treatments can be used with this approach, including a single reversible lane or lanes in both directions. Further, the lanes may be physically separated from the general-purpose lanes or paint striping can be used.

Contraflow Bus-Only and HOV Lanes on One-Way Streets. This approach uses a lane on a one-way arterial street for buses-only or HOVs operating in the opposition direction of travel. The only facilities of this type currently in operation in North America are restricted to buses-only and operate in downtown areas. These lanes are usually separated from the general-purpose traffic lanes by special curbs, striping, and signs.

Spot HOV Treatments. Special treatments may be used on arterial streets to give buses or HOVs priority around a specific bottleneck or with special access to a facility. These techniques provide HOVs with travel time savings, enhanced travel time reliability, and improved access to specific developments or activity centers. Examples of HOV spot

treatments include special turning lanes, allowing buses only to make left turns at signalized intersections, and special access lanes at ferries.

Signal Queue Priority. Another set of techniques focus on providing priority for HOVs at signalized intersections through queue jump lanes or other approaches. Since traffic signals represent a major source of delay on arterial streets, time savings provided by these techniques can have a positive influence on bus operations. The current use of these approaches are directed primarily at public transit vehicles.

Priority at Signalized Treatments. Priority treatment for buses and HOVs may also be provided at signalized intersections. These approaches may be used in combination with other techniques or as stand-alone elements. A number of different techniques and technologies can be used to provide HOVs with priority at signalized intersections, including the timing of the signal and changing the signal phasing. Most approaches use some type of technology to communicate with the signal controller. The timing of the signal cycle is then altered by either extending the green phase or truncating the red phase. These approaches involve modifying the signal algorithms.

Planning and Designing Arterial Street HOV Facilities

The operating environment on arterial streets is much different from freeways. These differences relate primarily to the functions of freeways and arterial streets. Freeways are intended to serve long distance trips, are designed to accommodate travel speeds of 55 to 70 miles per hour (mph), and have limited access points to help maintain a high volume of traffic.

Arterial streets provide access to local streets and businesses. Arterial streets are designed to operate at travel speeds of 35 to 50 mph, include signalized intersections, and often have driveway access for businesses and other land use activities. The curb lane on many arterial streets is reserved for some combination of parking, delivery vehicles, and bus stops. Bicycles may also be allowed to use the curb lane in some areas.

Arterial streets are found within a wide range of settings and environments in an urban area. These include the downtown or central business district, suburban activity centers, neighborhood commercial areas, strip development corridors, and major commuter travel corridors. All of these settings have different characteristics, which need to be considered in planning, designing, and operating arterial street HOV facilities.

The intent of HOV projects on arterial streets is similar to those on freeways and in separate rights-of-way—that is to provide travel time savings and travel time reliability to buses, vanpools, and carpools. To accomplish these objectives, arterial street HOV facilities need to be coordinated with the other functions and elements of the roadway system, including driveway access to businesses, schools, hospitals, and other land uses; signalized intersections; left and right turns for non-HOV traffic; on-street parking; delivery vehicles; pedestrians and bicyclists; and buses stopping to drop off and pick up passengers.

Since arterial street HOV facilities may require changes in on-street parking, loading zones, and turn restrictions, a larger group of constituents often needs to be involved in planning and designing a project, and in the ongoing operation.

Numerous agencies and groups should be involved in planning and designing arterial street HOV facilities. The participation of the appropriate agencies and individuals is key to ensuring that all groups are involved in discussing the elements of a proposed project, that potential issues are identified and resolved, and that all groups have a common understanding of the project.

In many cases multi-agency teams or multi-department teams within an agency are formed to help plan and design a facility. The various agencies and groups that should be considered for inclusion in the development of an arterial street HOV facility are highlighted in this section. Usually the transit agency is the lead organization on arterial street HOV facilities, working closely with the city, county, or state department of transportation. The organizations included in the planning and design process, and the roles and responsibilities of these groups, will depend on the ownership of the roadway, the nature of the project, local institutional arrangements, and other issues.

This report contains examples of cross sections for the various types of arterial street HOV facilities described previously. It also highlights examples of regulatory signs and pavement markings. The information on planning and designing arterial street HOV facilities, including the example cross sections, should be of use to transportation professionals considering the applications of these techniques.

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CHAPTER ONE—INTRODUCTION

Background

High-occupancy vehicle (HOV) facilities represent one approach being used in many areas to deal with concerns related to traffic congestion, mobility, and air quality. HOV projects, which offer priority treatments to buses, vanpools, and carpools, increase the person-movement efficiency of a roadway and enhance the mobility of area residents. HOV applications may be located in separate rights-of-way, on freeways, and on arterial streets.

HOV facilities have been in operation in Texas cities for over 20 years. The 1979 contraflow HOV lane demonstration project on I-45 North in Houston represents the first major HOV lane in the state. The success of this project led to the development of an extensive system of barrier separated, reversible HOV lanes in Houston. Freeway HOV lanes are also in operation in the Dallas area and are being considered in other cities. The operation and the benefits of these facilities have been examined in ongoing research studies.

Arterial street HOV facilities are found in many cities throughout the country, including Texas. Examples of arterial street HOV projects in North America include bus malls, bus lanes, HOV lanes, and priority treatments at signalized intersections. Many different design and operational strategies may be used with arterial street HOV facilities. Further, these projects may provide links to freeway HOV lanes and busways or they may be stand-alone facilities.

Arterial street HOV projects may provide benefits to transit operators, bus riders, and carpoolers, and vanpoolers. Arterial street HOV projects facilitate the movement of buses, carpools, and vanpools through congested areas, providing travel time savings and improved trip time reliability. Arterial street HOV facilities may also provide operating savings to transit operators, improve fuel efficiency, reduce energy use, and enhance air quality.

A number of elements should be considered with arterial street HOV facilities. Elements that frequently need to be addressed include reducing the potential for conflicts among buses, HOVs, general traffic, pedestrians, bicyclists, on-street parking, delivery vehicles, and other users of the arterial street system. The complexity of the local roadway environment often makes arterial street HOV facilities more difficult to operate than those on freeways.

This report examines the use of arterial street HOV facilities in Texas cities and in metropolitan areas throughout North America. The potential issues associated with various types of treatments area discussed. Guidelines for planning and designing HOV projects in Texas are presented.

Organization of Report

The remainder of this report is organized into three chapters following this Introduction. Chapter Two provides an overview of arterial street HOV applications in North America and highlights examples of different approaches. Chapter Three presents information on arterial street HOV projects in Dallas, Fort Worth, Houston, and San Antonio. Chapter Four presents guidelines for planning and designing arterial street HOV lanes in Texas. The references used in this report are provided, along with sources of further information.

CHAPTER TWO—ARTERIAL STREET HOV APPLICATIONS IN NORTH AMERICA

Overview

A number of different approaches can be used to provide priority to buses, vanpools, and carpools on arterial streets. Most of these techniques use existing travel or curb lanes rather than adding new lanes. The various types of arterial HOV lanes and traffic signal strategies are described in this Chapter. As illustrated in Figure 1, these approaches include bus malls, right-side lanes, center lanes, and contraflow lanes on one-way streets. Possible signal treatments and other supporting elements are also highlighted. The advantages and limitations with various approaches are described and examples of different techniques are summarized.

Bus Malls

Bus malls are streets reserved exclusively for public transit vehicles. Most also include improved sidewalks and other pedestrian amenities. Access to emergency vehicles is usually provided and some projects allow taxis. Bus or transit malls are primarily found in downtown areas. Existing transit malls range in length from a few blocks to facilities covering 10 to 15 blocks. Transit and pedestrian malls were developed in a number of cities in the 1970s. Some of these facilities have been removed or modified, but a number are still in operation. Two of the best examples of successful bus malls are found in downtown Denver and downtown Minneapolis.

Bus malls provide a number of benefits to transit operators and transit riders. These facilities provide a high level of service for bus operations by enhancing the flow of transit vehicles through a congested area and providing a focal point for transit within an area. Additional benefits may be realized through coordinated traffic signal phasing or providing priority for buses at signalized intersections.

Transit malls are usually considered only in major activity centers with high bus volumes and congested streets. It is important that capacity exists on the remaining street system so that general-purpose traffic is not negatively effected. Some existing bus malls were one part of larger downtown re-development programs. The capital costs associated with bus malls frequently limit the application of this technique. Variables that may influence capital costs include the length of the facility, modifications in street or sidewalk design, passenger waiting areas or bus stations, links to buildings or skywalk connections, passenger amenities, trees, and other street furniture or enhancements.

Bus Malls ↓ : : ↑

Right Side

Curb Lane : ↑ ↑ ↑

Second Lane : ↑ ↑ ↑

Curb and Second Lane : ↑ ↑ ↑

Left Lane : ↑ ↑ ↑

Center Lanes

Two-Direction ↓ ↓ ↓ ↑ ↑ ↑

Reversible ↓ ↓ ⇄ ↑ ↑

Contraflow Lanes on One-Way Street

Right Lane ↓ ↓ ↑

Left Lane ↑ ↓ ↓

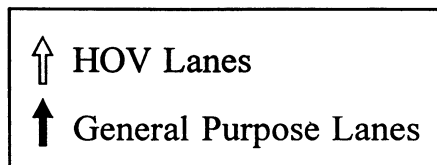


Figure 1. Arterial Street HOV Lane Approaches.

16th Street Mall - Denver, Colorado. The 16th Street Mall in Denver, Colorado opened in 1982. The mall is approximately 1-mile in length and includes major transit stations at each end. The mall cross section includes two 12-foot travel lanes for buses and 24-foot sidewalks on both sides. A shuttle bus operating strategy is employed on the mall, using low floor electric and diesel buses. Figure 2 shows a section the 16th Street Mall.

Regional and express buses entering downtown Denver terminate at the two transit centers located at each end of the mall. The stations are underground facilities which include multiple bus bays, passenger waiting areas, and other amenities. Passengers transfer from the regional and express buses to the free mall shuttle to reach other destinations along the mall. The mall shuttle operates at 70 second headway for most of the day. This system has removed between 300 to 400 daily bus trips from the downtown streets.



Figure 2. 16th Street Mall in Denver.

Nicollet Mall - Minneapolis, Minnesota. Opened in 1967, the Nicollet Mall represents one of the first transit and pedestrian malls in the country. The original 8 block long mall was characterized by its “serpentine” design and included numerous transit and pedestrian amenities. The mall was extended to 11 blocks in the 1970s and the late 1980s. A major redesigned and rebuilding effort was completed in 1992. This effort included straightening the serpentine curve, new pavement, circular glass towers linking the mall and the skyway system, pocket parks, and other amenities. Figure 3 highlights a portion of the Nicollet Mall.

The Nicollet Mall is open to buses and emergency vehicles. Taxis are allowed to use the mall at the south end, primarily to access a hotel located along the mall. The mall includes

two 12-foot bus travel lanes and pull-in areas at stops. It also includes wider sidewalks in many areas. The mall enhances the movement of buses through the downtown area. Approximately 820 daily bus trips were made on the Nicollet Mall in the late 1990s. The Mall provides not only a focal point for bus service in the downtown area, but also serves as a major attraction for Minneapolis. The Nicollet Mall has been credited with enhancing the vitality of the downtown area and continues to represent an important element to the city.



Figure 3. Nicollet Mall in Minneapolis.

Right Side Bus-Only and HOV Lanes

This type of HOV facility uses the right side lane, usually the curb lane or the second lane, on an arterial street for an HOV lane. This approach represents the most common application of HOV lanes on arterial streets. Right side HOV lanes may be open only to buses or buses, vanpools, and carpools may be allowed. Bus-only lanes are found in many downtown areas. These facilities may operate only during the morning and afternoon peak-hours or throughout most of the day and help move buses through congested downtown areas.

As highlighted in Figure 4, New York City has an extensive system of bus-only lanes in the downtown area, including some sections that reserve two lanes for buses. Longer distance bus-only lanes are also found in some areas, including Tucson, Pittsburgh, and Toronto. Right side lanes open to buses, vanpools, and carpools are found in a few areas. These include the San Tomas and Montague Expressways in San Jose, California shown in Figure 5, arterial streets in Toronto; North Washington Street in Alexandria, Virginia; and SR 99 and Airport Road/128th Street in the Seattle area.



Figure 4. Bus Only Lanes in New York City.



Figure 5. San Tomas Expressway HOV Lane in San Jose.

Advantages of right side HOV lanes include compatibility with transit boarding patterns, easy connections with freeway access ramps, and less potential for disruptions to intersection turning movements. Possible issues associated with right-side HOV lanes may include the need to address on-street parking, stopping areas for delivery vehicles, enforcement, and turning movements at driveways and intersections. The major characteristics, advantages, and disadvantages of different types of right-side arterial street HOV lanes are highlighted next.

Curb Lane Bus-Only Facilities. This approach utilizes the curb lane for buses-only during a portion or all of a day. This technique is commonly found in many downtowns as a way to help move buses through congested areas. During other times of the day, parking, delivery vehicles or general traffic may be allowed to use the lane. A few longer distance bus-only curb lanes are currently in use. Examples of this approach include SR 522 in Seattle, Broadway Boulevard and 22nd Street in Tucson, Fifth Avenue in Pittsburgh, and a number of streets in the Toronto area.

This type of arterial street HOV facility is usually considered in corridors with relatively high volumes of buses and high levels of traffic congestion in the general-purpose lanes. Bus-only lanes can help speed the movement of transit vehicles through congested areas, providing increased operating efficiencies for transit agencies and travel time savings and improved travel time reliability for bus riders. Potential issues with this technique may

include addressing the need for other vehicles to use the lane to make right turns at intersections or at other access points, illegally parked or stopped vehicles in the lane, and concerns by businesses about the loss of on-street parking and space for delivery vehicles.

Bus-Only Facilities Using the Second Travel Lane. A variation on the use of the curb lane is found in Ottawa, Ontario, where the second lane from the curb is used as a bus-only lane on two parallel one-way streets. The use of the second lane, called the *Fast Acting Lanes*, leaves the curb lane open for buses to stop to pick-up and drop-off passengers, as well as for other functions. The *Fast Acting Lanes* connect to the Ottawa Transitway at both ends of the downtown.

This approach may be considered in corridors with high volumes of buses and as a way to link with other HOV facilities, such as the Ottawa Transitway. By maintaining the curb lane for other functions, such as stopping buses, delivery trucks, turning vehicles, and parking, this approach may eliminate some of the potential conflicts associated with other arterial street HOV techniques. Capacity must be available on the roadway, however, so that the general-purpose lanes are not adversely effected.

Curb Lane HOV Facilities. This type of HOV treatment provides priority lanes on arterial streets for buses, vanpools, and carpools. The few examples of this technique currently include the San Tomas and Montague Expressways in San Jose, Dundas Street in the Toronto area, North Washington Street in Alexandria, SR 99 and Airport Road in the Seattle area, and Hastings Street in Vancouver. This approach may be considered in corridors with high volumes of carpools and vanpools and as a way to link freeway HOV facilities to a downtown area or to other major activity centers. Possible drawbacks include addressing the needs of other curb lane users and turning vehicles, and not degrading the general-purpose lanes. Conflicts may also emerge between buses and carpools and vanpools unless bus-bays or pull-ins are provided for buses.

Second Lane HOV Facilities. This type of treatment uses the second lane from the curb as an HOV lane. As noted previously, the *Fast Acting Lanes* in downtown Ottawa represent an example of this approach for buses-only. This technique requires converting a general-purpose traffic lane to an HOV lane. The HOV lane on Airport Road in the Seattle area uses the second lane for a short section when the right lane becomes a right-turn only lane and drops at a downstream intersection.

A major advantage of this approach is that the curb lane can be maintained for on-street parking, delivery vehicles, bus stops, right turns, and other functions. The major issues with using the second lane for HOVs include ensuring that available capacity exists on the roadway to not degrade the remaining general traffic lanes and addressing right-turn movements.

Left-Side Bus-Only and HOV Lanes

Few examples exist of left-side HOV lanes. Operating an HOV facility in the left lane of an arterial street eliminates potential traffic conflicts related to curb lanes, such as on-street parking, delivery vehicles, and right turn movements at driveways and intersections. This approach may be appropriate for longer-distance HOV facilities. Potential issues with this technique include accommodating left-turns for general traffic, as well as HOVs weaving across the general traffic lanes to make right turns. This treatment may also present significant problems to transit operations if buses must pull over to the curb to pick up and drop off passengers. An alternative is to provide passenger waiting platforms adjacent to the left lane, which requires additional right-of-way and capital expenditures.

Center Bus-Only and HOV Lanes

Bus-only and HOV lanes located in the center of an arterial street represent another type of possible treatment. As highlighted in this section, a few examples of these types of approaches exist. This type of facility provides bus-only or HOV lanes in the center of an arterial street. A number of different treatments can be used with this approach, including a single reversible lane or lanes in both directions. Further, the lanes may be physically separated from the general-purpose lanes or paint striping can be used.

Two-Directional Center Bus-Only and HOV Lanes. This approach includes a bus-only or an HOV lane in each direction of travel in the center of a roadway. Treatments that may be used to separate the HOV lanes from the general-purpose lanes include barriers or paint striping. The two-way bus-only lanes in the median of Canal Street in downtown New Orleans, illustrated in Figure 6, provide one example of this approach. Center HOV lanes eliminate many of the problems noted previously with curb HOV facilities. Potential problems with this approach include accommodation of left-turns by general-purpose traffic at intersections and providing bus stops in the center of a roadway.

Reversible Center Bus-Only and HOV Lanes. This approach provides a reversible HOV lane in the center of a roadway. The lane may be open only to buses or buses, carpools, and vanpools and may be separated from the general-purpose lanes by barriers, buffers, or paint stripes. A reversible HOV lane may also be appropriate to consider in some areas or situations. An interim reversible center HOV lane was used on the Highway 12/I-394 project in Minneapolis to help manage traffic during the multi-year construction period and to introduce the HOV concept to commuters in the corridor. A related approach is used on the Kalanianaʻole Highway in Honolulu, Hawaii, where a contraflow HOV lane is in operation.



Figure 6. Center Bus-only Lanes on Canal Street in Downtown New Orleans.

A reversible center HOV lane may be appropriate for consideration on an arterial street with a high directional split. This approach may have less negative impacts on general traffic lanes than other techniques. Possible limitations with reversible lanes include accommodating left turns from the general-purpose lanes at intersections, the operating costs and personnel needed to open and close the facility, access treatments for HOVs to enter and exit the lane, the potential for vehicles to enter the lanes in the wrong direction of travel at intersections, and passenger access.

Contraflow Bus-Only and HOV Lanes on One-Way Streets

This approach uses a lane on a one-way arterial street for buses-only or HOVs operating in the opposition direction of travel. The only facilities of this type currently in operation in North America are restricted to buses-only and operate in downtown areas. Examples of contraflow arterial street bus lanes are found on Spring Street in downtown Los Angeles and on Marquette, Second, and Hennepin Avenues in downtown Minneapolis. As highlighted below and illustrated in Figures 7 and 8, these lanes are separated from the general-purpose traffic lanes by special curbs, striping, and signs.



Figure 7. Contraflow Bus-only Lane on Spring Street in Downtown Los Angeles.



Figure 8. Contraflow Bus-only Lane in Downtown Minneapolis.

Arterial street contraflow lanes represent an effective approach for moving high volumes of buses and HOVs through a congested area. This technique, which is fairly common with LRT systems, can provide benefits to transit operations by increasing the speeds of buses and enhancing travel time reliability. Routes can also be consolidated onto the contraflow lane, simplifying operations and providing a focal point for passengers

Spring Street - Los Angeles, California. A contraflow bus-lane had been in operation in downtown Los Angeles on Spring Street since 1974. The lane was initially developed to support the 1973 opening of the San Bernardino Busway. The lane was developed to help alleviate congestion in the downtown area, to improve the flow of buses through the downtown, and to enhance travel time savings to transit users. The facility has been modified over the years to enhance bus operations and to reduce conflicts with general-purpose traffic.

The Spring Street contraflow lane is 1.5 miles long. Before implementation of the project, Spring Street was a four-lane one-way street, operating in the southbound direction. The eastern most lane was converted into a 12-foot lane operating in the northbound direction to form the contraflow bus facility. The changes necessary to accomplish this were relatively minor. The traffic lanes were re-striped and new signage was added. The lane was separated from the general southbound purpose traffic lanes by a painted stripe. Bus stops for both express and local buses were added. Bus routes in the downtown area were rerouted from parallel streets to take advantage of the new contraflow lane.

In 1979, a number of improvements were made to the facility to address operational problems. The changes included widening portions of the lane to allow passing room for buses, separating stops for local and express bus services, and converting New High Street from a one-way southbound street to two-way operation. Design changes included widening

the original 12-foot contraflow lane to 21-26 feet. This was accomplished by slightly reducing the width of the southbound general-purpose lanes and converting the number one lane to a left turn pocket at intersections. Revisions were made in the signal timing to help ensure that this modification did not adversely impact the number one lane. Local and express bus stops at the City Hall and the U. S. Courthouse were separated and the widened lane allowed buses to pass loading, disabled, or turning buses.

The implementation of the Spring Street contraflow lane increased the speed and reduced the travel time of both express and local buses traveling through the downtown area. Given the orientation of service from the San Bernardino Busway, the facility is more heavily used in the afternoon peak-period than in the morning peak-period. Approximately 270 buses operate on the contraflow lane in the afternoon peak hour, while some 140 utilize the facility in the morning peak hour.

Marquette, Second, and Hennepin Avenues - Minneapolis, Minnesota. Three reverse flow bus lanes are currently in operation in downtown Minneapolis. The reverse flow bus lanes on Marquette and Second avenues, which are north/south one-way pairs, were implemented in the mid-1970s in response to growing traffic congestion in the downtown area. The lanes were developed to improve the flow of buses through the downtown and to reduce conflicts between buses and general-purpose traffic.

The reverse flow bus lanes on Marquette and Second Avenues were implemented initially as temporary facilities in 1974. When this test proved successful, development of permanent lanes was undertaken. The bus lane is 11 feet wide, while the three general purpose lanes range from 10 feet to 12 feet in width. A turning lane for general-purpose traffic is also provided.

Spot HOV Treatments

Special treatments may be used on arterial streets to give buses or HOVs priority around a specific bottleneck or with special access to a facility. These techniques provide HOVs with travel time savings, enhanced travel time reliability, and improved access to specific developments or activity centers. The following highlight two examples of HOV spot treatments that may be appropriate for consideration on arterial streets.

Bus-Only or HOV-Only Access. Special access for buses-only or HOVs-only may be provided at specific locations. For example, a short arterial street HOV street lane or other treatment could be used to provide HOVs with direct or preferential access to a freeway entrance ramp, a park-and-ride facility, or a major activity center. These facilities may be part of a larger HOV network or a stand-alone treatment. One example of an existing HOV spot treatment is the HOV lanes approaching the ferry loading areas in the Puget Sound region. This priority provides significant time savings and can ensure HOVs access to crowded ferries.

Buses or HOV Turn-Only Lane or Part of Dual Turn Lane. Allowing buses or HOVs only to turn left or right at designated intersections represents another spot treatment. This technique is used in some Texas cities. A related approach would reserve one lane of a dual left or right turn lane for HOVs only. These techniques can provide buses and HOVs with significant travel time savings at congested intersections or direct access to a major activity generator, adding further incentives to individuals to use an HOV mode.

Signal Queue Priority

Another set of techniques focus on providing priority for HOVs at signalized intersections through queue jump lanes or other approaches. Since traffic signals represent a major source of delay on arterial streets, time savings provided by these techniques can have a positive influence on bus operations. The current use of these approaches are directed primarily at public transit vehicles.

Signal Queue Jump Lanes. This approach provides short lanes at the approach to an intersection reserved for buses or HOVs. These lanes may be used in combination with a bus stop or a bus pull-in or as stand-alone projects. These lanes allow buses and HOVs to move around the line of general traffic at a signal and travel through the intersection. A way to merge back into the general traffic lane after the intersection must be provided with this approach. One technique is to provide a separate traffic signal head for the HOV queue jump lane and to give the lane an advance green light, while holding the general traffic lanes on red. This approach allows HOVs to move through the intersection and re-enter the general traffic lanes in advance of other traffic.

Bus Advance Areas or Gating. A slightly different approach, called bus advance areas, or gating, is being used in a few cities in Great Britain and Switzerland. The bus advance area is a segment of road before a signalized intersection. A set of pre-signals are used to hold general-purpose traffic at this location, while allowing buses to advance around the general traffic queue. This allows buses to move to the front of the traffic stream at the intersection. This concept is currently being tested in a few applications in London and is in use in Berne, Switzerland.

Priority at Signalized Treatments

Priority treatment for buses and HOVs may also be provided at signalized intersections. These approaches may be used in combination with other techniques or as stand-alone elements. A number of different techniques and technologies can be used to provide HOVs with priority at signalized intersections, including the timing of the signal and changing the signal phasing. Most approaches use some type of technology to communicate with the signal controller. The timing of the signal cycle is then altered by either extending the green phase or truncating the red phase. These approaches involve modifying the signal algorithms.

To date, most applications of signal priority treatments have focused on buses only. During the 1970s, a few demonstrations were conducted using bus pre-emption techniques. These approaches always gave priority to buses, regardless of the situation. A number of concerns were raised with these demonstrations, primarily relating to the impact on cross-street traffic. Advancements in technologies and traffic signal algorithms have renewed interest in examining approaches to provide buses and HOVs with priority at signalized intersections. For example, it is possible to selectively give priority to buses that are behind schedule or that are full, rather than arbitrarily giving all buses priority.

A number of issues will need to be examined if signal priority is being considered. Ensuring that cross street traffic is not adversely affected still represents the primary concern with this approach. Other issues that may need to be addressed include maintaining even traffic flow on the roadway, motorist and transit operator understanding of the system, coordination with emergency vehicle priority systems, integrating traffic signal systems in multiple jurisdictions, and the ability to operate and maintain the system. The following types of priority treatments may be appropriate for consideration with arterial streets HOV facilities.

Timing of Traffic Signals. One relatively simple approach that can be used with arterial street HOV lanes is to time the traffic signals to allow vehicles to progress along the roadway at the speed limit. This approach is used on arterial streets in many areas with and without HOV facilities. The one potential problem with this technique is that buses stopping to drop off and pick up passengers may get out of synch with the signal timing. This approach can work well with arterial street HOV lanes used by carpools and vanpools, and in areas where buses do not stop at every block. Examples of coordinating signal timing with HOV facilities include the 16th Street Mall in Denver, the Nicollet Mall and contraflow bus lanes in downtown Minneapolis, and the bus and HOV facilities in the Toronto area.

Signal Priority. A number of approaches can be used to provide priority to buses at signalized intersections. Possible techniques, identified in the *Traffic Control Systems Handbook* include extending the green phase of the single cycle, truncating the red phase early, interrupting the red phase, suppressing or skipping a phase, compensation, and window stretching. These techniques allow buses to continue through an intersection without stopping, or to start through an intersection in advance of other traffic. Elements to consider with these techniques include the number of buses on a roadway, the number of buses delayed by a signal, the location of bus stops, general traffic and pedestrian conditions, the type of signal and detection capabilities, and other priority measures. Only a few bus signal priority projects are currently in operation. Recent demonstrations have been conducted on the Ritchie Highway in Anne Arundel County, Maryland; selected roadways in Bremerton and Tacoma, Washington; and Albemarle Road in Charlotte, North Carolina. An Advanced Detection demonstration project, which provides buses with priority, is underway on Roesser Road in Phoenix. In Charlotte, priority for express buses is provided at 11 signalized intersections. The results from this project indicate that bus delays at the signals have been reduced by 67 percent and ridership has increased.

Bus Stop Treatments

Many arterial street HOV applications are oriented toward enhancing the movement of buses through congested areas. The travel times of buses are influenced not only by the general traffic conditions and signals along a roadway, but also by the need to pull into bus stops, drop off and pick up passengers, and re-enter the traffic stream. These movements can add significant travel time to the overall operation of public transit vehicles.

The location and design of bus stops, bus bays or bus pull-in areas, bus bulbs, and other treatments can enhance transit operations and traffic flow along arterial streets. Many of these techniques can be used with or without HOV lanes. The general types of bus stop treatments that may be appropriate for consideration with arterial street HOV facilities include near-side stops, far-side stops, and mid-block stops. The advantages, disadvantages, and issues associated with the various techniques are discussed in a recent TCRP Report, *Guidelines for the Location and Design of Bus Stops*. This report also provides a detailed discussion of elements to consider in the use of these approaches.

CHAPTER THREE—ARTERIAL STREET HOV APPLICATIONS IN TEXAS

This chapter presents examples of arterial street HOV facilities in Texas. Projects in Dallas, Fort Worth, Houston, and San Antonio are highlighted. Most of these facilities are lanes on downtown streets reserved for buses at all times or only during the morning and afternoon peak-periods. Priority treatments for buses at signalized intersections are also in operation in a few areas. The most commonly found signal technique allows buses to make left turns while restricting turns by other vehicles. Currently, there are no arterial street HOV lanes open to carpools and vanpools in Texas.

Dallas

Bus-only lanes and bus-only turns at signalized intersections are currently in use in Dallas. Most of these facilities are located in the downtown area. There are also bus-only lanes on Harry Hines Boulevard connecting the Dallas Medical Center and the downtown area. The lanes and traffic signals provide priority to Dallas Area Rapid Transit (DART) buses.

Downtown Bus-Only Lanes. Curb bus-only lanes are in operation weekdays between 6:00 a.m. and 6:00 p.m. on Commerce Street and Elm Street, a couplet of one-way streets. The bus lane on Commerce Street is five blocks in length and the bus lane on Elm Street is eight blocks long. Figure 9 provides an example of the bus-only lanes in downtown Dallas. Approximately 81 buses use the Commerce Street lane and 77 buses use the lane on Elm Street in the afternoon peak hour.

The cross-section for both streets consist of the bus lane adjacent to the right side curb, three general-purpose traffic lanes, and a parking lane adjacent to the left side curb. A double paint strip separates the bus lane from the adjacent general-purpose lane and diamonds are painted on the pavement at periodic intervals. Signs with a diamond symbol and *Right Lane Buses Only 6 AM – 6 PM Mon-Fri* are located at every block along both streets. Also, a *Restricted Lane Ahead* sign is located one block before the lanes start.

There is a one block bus-only lane on Houston Street from Jackson Street to Reunion West Boulevard. The bus lane continues on Reunion West Boulevard and provides priority treatment to buses serving Reunion Arena. The cross section of the one-way street is the bus lane and three general-purpose lanes. A *Right Lane Buses Only* sign is located in the block.

Downtown Signals Bus-Only Turns. Only buses are allowed to make left hand turns at signalized intersections at Main Street and Harwood Street and at Main Street and Central. The restriction at Harwood is at all times of the day and the restriction at Central is from 7:00 a.m. to 9:00 a.m. Signs with the time restrictions are located on the signal heads.



Figure 9. Downtown Bus-Only Lane.

Other Bus Lanes. There are peak-period bus-only lanes on Harry Hines Boulevard between Exchange Park and Oaklawn/Throckmorton. These lanes connect the Dallas Medical Center and downtown Dallas. The bus-only restriction is in effect weekdays from 7:00 a.m. to 9:00 a.m. and from 4:00 p.m. to 6:00 p.m. The lanes are open to general-purpose traffic at all other times. Approximately 150 buses an hour use the lanes in each direction.

The Harry Hines Boulevard cross section includes a bus lane, two general-purpose lanes, a grass median, two general-purpose lanes, and a bus lane. A double white paint strip separates the bus lanes from the adjacent general-purpose lanes. Overhead *Warning Entering Controlled Bus Lane Zone* signs are located at the beginning of the restricted zones and right hand *End Controlled Bus Lane Zone* signs are located at the termination. *Bus Lanes and Right Turn Only* signs are located at intersections along the lanes, indicating that motorists may enter the lanes to make right turns.

Fort Worth

Two bus-only lanes represent an important element of the transit system in downtown Fort Worth. The lanes provide travel time savings to buses operated by the Fort Worth Transportation Authority (the T). In addition, the timing of one traffic signal has been adjusted by the City of Fort Worth to benefit buses turning into a major transfer center.

Downtown Bus-Only Lanes. Curb bus-only lanes are in operation on Throckmorton Street and Houston Street, a couplet of one-way streets. Figure 10 shows one of the bus lanes in operation. The lanes are approximately 12 blocks in length, traversing the downtown area. The lanes are restricted to buses 24-hours a day, seven days a week. Approximately 40 buses an hour use the lanes during the morning and afternoon peak hours, with some 483 buses using the lanes on a daily basis. Motorists making right turns are able to enter the lanes at mid-block.



Figure 10. Fort Worth Bus Lane.

The cross section for both streets is three general-purpose lanes and the concurrent flow bus lane adjacent to the right curb. On blocks that right turning vehicles are not allowed the bus lanes are separated from the general-purpose lane by a double set of closely spaced white buttons. On blocks that vehicles may turn right, the bus lanes are separated from the general-purpose lanes by a single set of closely spaced white buttons. Overhead *Bus Lane* signs with the diamond symbol and curb signs with *Curb Lane Buses Only* and the diamond symbol are located in every block. There are also pavement markings with the diamond symbol and *Bus Lanes* at periodic intervals.

There is also a one-block long contraflow bus lane on West Balknap Street between Throckmorton and Houston Streets. The contraflow bus lane connects the concurrent flow HOV lanes on Throckmorton and Houston Streets, allowing buses to make a u-turn. The contraflow bus lane is separated from the general-purpose lane by a raised median with vegetation. Two diamond symbols are painted in the pavement.

Traffic Signal Timing. The City of Fort Worth has adjusted the timing of the traffic signal at East Lancaster and Sargent Streets. The T's East Side Transfer Center is located at this corner. The modified timing benefits buses turning into the Transfer Center, without negatively influencing general-purpose traffic.

Houston

Houston has an extensive system of freeway HOV lanes, direct access ramps, park-and-ride facilities, and express bus service. HOV lanes are in operation in six freeway corridors. The HOV lanes are primarily barrier separated, reversible facilities. Arterial street bus applications include reserving the curb lane on some downtown streets for buses-only from 7:00 a.m. to 6:00 p.m. and the development of a regional synchronized signal system that may provide benefits to buses. The lanes provide travel time savings and improved trip time reliability to Metropolitan Transit Authority of Harris County (METRO) buses.

Downtown Bus-Only Lanes. The right lane is reserved for buses on four north-south streets in the downtown area. Three of these streets – Louisiana, Milam, and Travis – are one-way streets. Figure 11 shows the bus-only lane on Milam Street. Main Street, which had the heaviest volume of buses, is a two-way street and had bus lanes on both sides before construction of the light rail transit (LRT) line started. The curb lanes on the four streets are restricted for buses weekdays from 7:00 a.m. to 6:00 p.m. Motorists are allowed to use the curb lanes to make right turns. The bus lanes on Main Street are 18-blocks long, while the lanes on the other three streets are eight or nine blocks in length.

The cross section on the three one-way streets generally includes the bus lane and three general-purpose lanes. The cross section on Main Street was a bus lane, two general-purpose lanes, and a bus lane. Signs and pavement markings are used along the streets to inform motorists of the restrictions.

It is anticipated that the bus routings will be altered once the LRT line is opened as many buses will link with the Transit Centers or LRT stations. The bus-only lanes on Louisiana, Milam, and Travis may continue to be used, however, while the lanes on Main will not.



Figure 11. Downtown Houston Bus-Only Lane.

Regional Computerized Traffic Signal System (RCTSS). The RCTSS is a joint effort by METRO and local governments to modernize and coordinate control of some 2,800 traffic signals in the Houston metropolitan area. The system will provide for greatly enhanced management of the signalized intersections and will allow for priority to be provided to buses and emergency vehicles. The exact nature of the priority treatments are still being determined.

San Antonio

Bus-only lanes are in operation on six streets in downtown San Antonio. Both concurrent flow and contraflow bus-only lanes are in use. The lanes provide priority to VIA Metropolitan Transit Authority buses. Currently, there are no freeway HOV lanes in the San Antonio area.

Downtown Bus-Only Lanes. The right lane on four streets in the downtown area are reserved for buses and contraflow bus lanes are in operation on two streets. Concurrent flow lanes, using the right side lane, are in operation on Delorosa/West Market Streets, Commerce Street, Navarro Street, and St. Mary's Street. Delorosa/West Market and Commerce Street are one-way east/west couplets and St. Mary's and Navarro are north/south one-way couplets. Contraflow bus lanes are in operation on Alamo Plaza and a short section of Navarro Street to the northwest of the concurrent flow lane.

The lanes are reserved for buses all day, but other vehicles are allowed to use the lanes for right turns. The lanes are separated from the general-purpose lanes by a solid line. Diamond markings are located in the pavement and *Bus-Only Lane* signs are located in each block. At the highest use point, some 877 daily buses, or 62 buses during the peak hour, travel east bound on Market Street.

CHAPTER FOUR—GUIDELINES FOR PLANNING AND DESIGNING ARTERIAL STREET HOV LANES IN TEXAS

This chapter presents general guidelines for planning and designing HOV facilities on arterial streets. It includes an overview of the arterial street environment, the groups commonly involved in the planning and design process, key elements of the planning process, and design features of various types of arterial street HOV facilities. Examples of cross-sections and other design elements are presented.

Overview of Arterial Street Environments

The operating environment on arterial streets is much different from freeways. These differences relate primarily to the functions of freeways and arterial streets. Freeways are intended to serve long distance trips and are designed to accommodate travel speeds of 55 to 70 miles per hour (mph). Freeways also have limited access points to help maintain a high volume of traffic.

Arterial streets provide access to local streets and businesses. Arterial streets are designed to operate at travel speeds of 35 to 50 mph, include signalized intersections, and often have driveway access for businesses and other land use activities. The curb lane on many arterial streets is reserved for some combination of parking, delivery vehicles, and bus stops. Bicycles may also be allowed to use the curb lane in some areas.

Arterial streets are found within a wide range of settings and environments in an urban area. These include the downtown or central business district, suburban activity centers, neighborhood commercial areas, strip development corridors, and major commuter travel corridors. All of these settings have different characteristics, which need to be considered in planning, designing, and operating arterial street HOV facilities.

The intent of HOV projects on arterial streets is similar to those on freeways and in separate rights-of-way—that is to provide travel time savings and travel time reliability to buses, vanpools, and carpools. To accomplish these objectives, arterial street HOV facilities need to be coordinated with the other functions and elements of the roadway system, including driveway access to businesses, schools, hospitals, and other land uses; signalized intersections; left and right turns for non-HOV traffic; on-street parking; delivery vehicles; pedestrians and bicyclists; and buses stopping to drop off and pick up passengers.

Since arterial street HOV facilities may require changes in on-street parking, loading zones, and turn restrictions, a larger group of constituents often needs to be involved in planning and designing a project, and in the ongoing operation. The groups frequently involved in planning and designing arterial street HOV projects are discussed next.

Groups Involved in Planning and Designing Arterial Street HOV Facilities

Numerous agencies and groups should be involved in planning and designing arterial street HOV facilities. The participation of the appropriate agencies and individuals is key to ensuring that all groups are involved in discussing the elements of a proposed project, that potential issues are identified and resolved, and that all groups have a common understanding of the project.

In many cases multi-agency teams or multi-department teams within an agency are formed to help plan and design a facility. The various agencies and groups that should be considered for inclusion in the development of an arterial street HOV facility are highlighted in this section. Usually the transit agency is the lead organization on arterial street HOV facilities, working closely with the city, county, or state department of transportation. The organizations included in the planning and design process, and the roles and responsibilities of these groups, will depend on the ownership of the roadway, the nature of the project, local institutional arrangements, and other issues.

Local Municipalities. City or county departments may have the lead responsibility on arterial street HOV facilities. As the lead agency, the city or county may be responsible for all aspects of a project including planning, designing, implementing, operating, and maintaining an arterial street HOV facility. In these cases, the local municipalities would also head any multi-agency team. In other cases, a transit agency may have overall responsibility for an arterial street project. City or county personnel still usually play a major role even in these cases, however, as they have authority over the local street and traffic signal systems. The engineering and planning departments most frequently are responsible for these activities, although staff from other departments may also be involved.

Transit Agency. A transit agency may have the lead responsibility with HOV facilities on arterial streets or may be a co-sponsor of a project. In either case, the transit agency usually works closely with the local municipality or state department of transportation that has jurisdiction over the street and traffic signal systems. If the transit agency is in a support role, key responsibilities may focus on planning and designing for bus operations, enforcement, and overall project coordination.

State Department of Transportation. The state usually will have the lead role with HOV projects on state-owned arterial streets. The state department of transportation or the state highway department may be a supporting agency with arterial HOV facilities on city or county roadways, especially if the project provides a link from a freeway HOV lane. Representatives from the state may be involved in the multi-agency team or may provide assistance throughout the development, implementation, and operation of arterial street HOV projects.

Local and State Police. Representatives from the state, city, and county police departments should be involved in the development of arterial street HOV projects. Depending on the

roadway classification, one of these agencies is usually responsible for enforcing arterial street HOV projects. The early and ongoing involvement of enforcement personnel has been identified as an important element of successful HOV projects.

Rideshare Agency. The rideshare agency in an area may be involved in planning arterial street HOV projects if the facility will be open to carpools and vanpools. In these cases, the rideshare agency is usually included as a member of the multi-agency team.

Metropolitan Planning Organization (MPO). Representatives from the MPO may participate on the multi-agency team and may provide assistance with planning and designing arterial street HOV facilities. Involvement of MPO staff may depend on the nature and scope of a project and the link to metropolitan-wide facilities.

Federal Agencies. Representatives from the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) may wish to be involved or at least to monitor the development of arterial street HOV facilities. Personnel from these agencies may provide technical assistance on specific issues or suggestions on how certain elements have been addressed in other areas. Representatives from FHWA and FTA often participate on the multi-agency team.

Other Groups. Consideration should be given to including representatives from other groups or obtaining their input during the planning and design phases of an arterial street HOV facility, as well as the ongoing operation. These may include representatives from the local judicial system who will be responsible for enforcing fines and citations; EMS, fire, and other emergency personnel who have to respond to incidents and accidents on the facility; tow truck operators who may be responsible for removing disabled vehicles; businesses; delivery companies and vendors; and neighborhood groups. Involving representatives from businesses and neighborhood groups may be especially important if the project will impact on-street parking or other elements.

Operating Thresholds

As discussed previously, the goal of an HOV facility is to provide travel time savings and travel time reliability to buses, vanpools, and carpools. The vehicle eligibility criteria and vehicle-occupancy requirement should be established at a level that will encourage use of the facility, but that will not create too much demand to make the lane congested. The goals and objectives of a project may influence the minimum operating thresholds. For example, a project intended to give buses priority through a congested downtown area or other activity center segment could be expected to have a lower threshold than longer distance lanes open to vanpools and carpools. Local policies on bus-only and carpool definitions will influence the operating thresholds and should be considered in the development of local guidelines.

The type of HOV facility will probably have the most influence on the development of local minimum operating guidelines. The following general levels provide an indication of the national experience and can be used in developing local guidelines.

- Bus Malls—80-100 vphpl
- Right-Side Bus Only—50-80 vphpl
- Right-Side HOV—200-400 vphpl
- Left-Side Bus Only—50-80 vphpl
- Left-Side HOV—200-400 vphpl
- Center Two-Way—200-400 vphpl
- Center Reversible—80-160 vphpl
- Contraflow Bus Only on One-Way Street—50-80

Typical Cross Sections and Layouts

This section presents examples of cross sections and layouts for the various types of arterial street HOV treatments. These examples are provided to help in designing projects in Texas. The characteristics of a specific street and area will influence the ultimate design of a facility.

The physical and operating characteristics of the vehicles that will use the facility will influence the design of an arterial street HOV project. Buses are the primary vehicles allowed to use most arterial street HOV facilities. Standard buses, articulated buses, and mini-buses may all be part of the transit fleet operating on arterial street HOV facilities. The dimensions and turning radii for a 40 foot bus, a 45 foot bus, and an articulated bus are available in the American Association of State Highway and Transportation Officials (AASHTO) Design Manual. These dimensions, which will also accommodate vanpools and carpools, can be used by practitioners to assist with the design of arterial street HOV projects.

Bus Malls. The design characteristics of a transit mall are usually very site specific. In general, bus malls will have 12 foot travel lanes in each direction. A variety of design treatments, including bus pull-ins, bus bulbs, center medians, special sidewalk space, connections to tunnels or skywalk systems, and bus passenger and pedestrian amenities may also be provided. The design features of a transit mall will reflect the goals and objectives of the project and the characteristics of the area. A bus mall may be part of a larger project focusing on enhancing a downtown area or a major activity center.

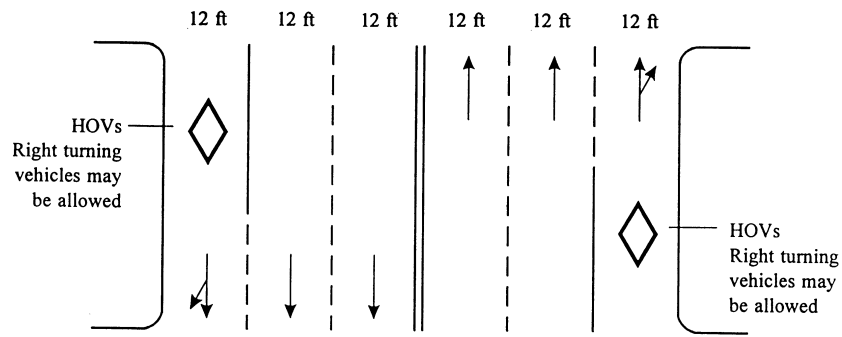
Right Side Bus-Only and HOV Lanes. Similar design characteristics are found with the four treatments commonly associated with HOV lanes located on the right side of a roadway. These are curb lane bus-only facilities, curb lane HOV facilities, bus-only facilities using the second travel lane, and HOV facilities using the second travel lane. These approaches usually use the existing curb or travel lanes, with little or no modifications in design. In some cases, the existing cross section may be modified to narrow the general-purpose lanes and restripe the roadway or other changes may be made to accommodate the HOV facility.

As shown in Figures 12 through 14, the cross section for these types of facilities usually include standard 12-foot curb and traffic lanes. In some cases, the travel lanes may be reduced to 11 feet or 10 feet. Figure 12 illustrates a typical layout for a curb-lane HOV facility. As illustrated, general traffic may or may not be allowed to make right turns at intersections using the HOV lane. Figure 13 provides an example of a project using the second lane. With this approach, consideration will need to be given if general-purpose traffic should be allowed to merge through the HOV lane to make right or left turns. Figure 14 highlights a curb HOV lane on a one-way street.

Left Side Bus-Only and HOV Lanes. Although there are only a few examples of left-side bus-only and HOV lanes currently in operation, a number of design treatments may be used with these facilities. A relatively simple approach, illustrated in Figure 14, reserves the 12-foot left lane for buses or HOVs. This technique may be used in cases where there are high volumes of HOVs in one direction of travel or to provide access to an HOV-only left turn lane. Another design, shown in Figure 15, includes a barrier separation and a transit stop. Still another approach, shown in Figure 16, uses the left curb lane on a one-way street for an HOV facility.

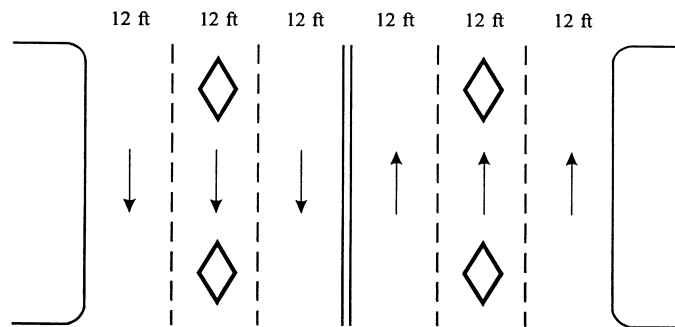
Center Bus-Only and HOV Lanes. HOV facilities located in the center of a roadway may include a single reversible lane or HOV lanes in both directions of travel. These facilities may be physically separated from the general-purpose travel lanes or paint striping can be used to delineate the lanes. Figure 18 provides an example of a barrier separated reversible center HOV lane. For safety reasons, consideration should be given to using some type of barrier or buffer separation with a reversible facility. Figure 19 illustrates an example of a non-separated two-directional facility and Figure 20 shows barrier-separated lanes. In all cases, the HOV travel lanes are 12 feet wide. The barrier separation may add 2 feet to 4 feet to the cross section depending on the type of treatment used.

Center located bus stops may also be used with these type of facilities. In most cases, stops will be positioned on either the near-side or the far-side of an intersection to allow easy passenger access. If the facility is shared by buses and carpools, consideration should be given to providing passing lanes or bus pull-ins at stops. Although these treatments allow carpools to bypass buses picking-up or dropping-off passengers, they also require additional right-of-way and will increase the capital cost of a project.



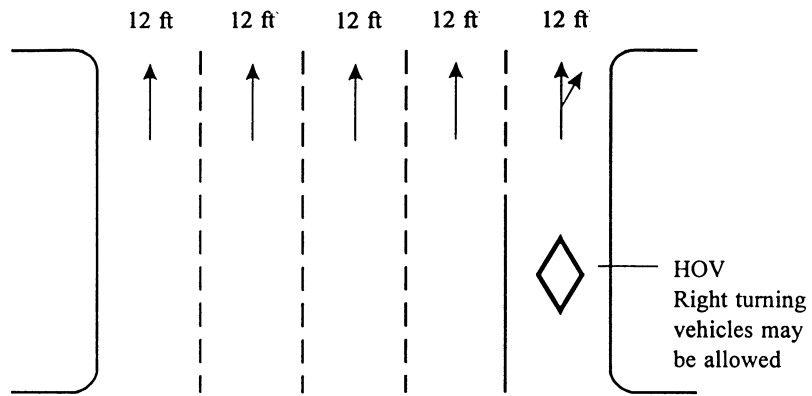
Note: In some cases consideration may be given to narrowing the travel lanes to 11 feet to 10 feet.

Figure 12. Layout for Curb-Lane HOV Facility on Two-Way Street.



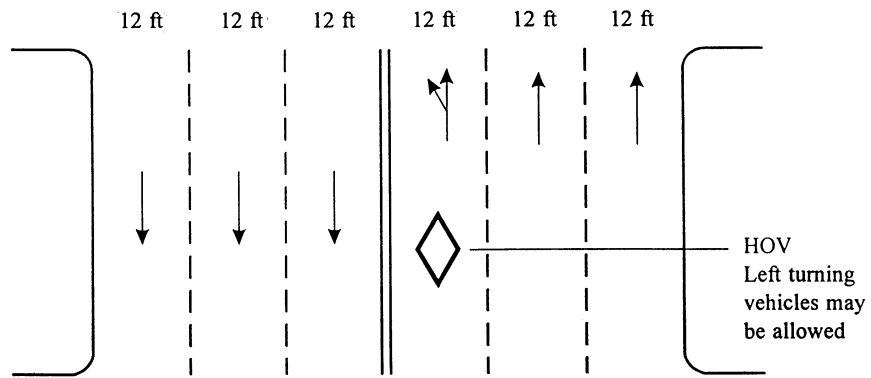
Note: In some cases consideration may be given to narrowing the travel lanes to 11 feet to 10 feet.

Figure 13. Layout for Second-Lane HOV Facility on Two-Way Street.



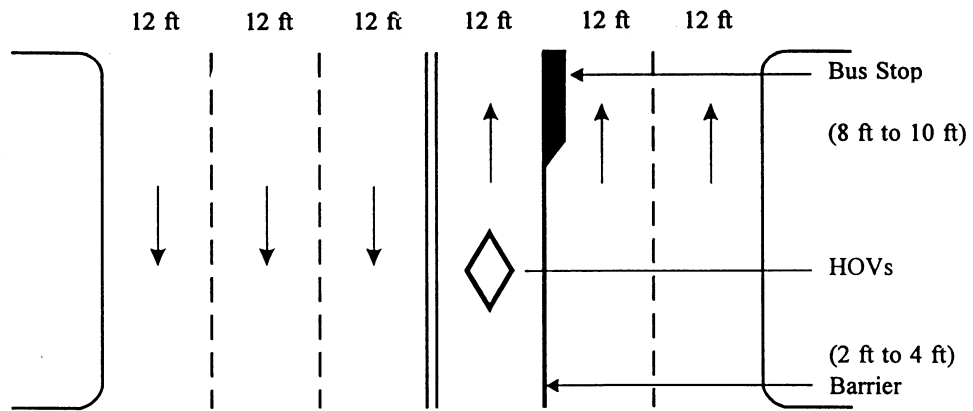
Note: In some cases consideration may be given to narrowing the travel lanes to 11 feet to 10 feet.

Figure 14. Layout for Curb-Lane HOV Facility on One-Way Street.



Note: In some cases consideration may be given to narrowing the travel lanes to 11 feet to 10 feet.

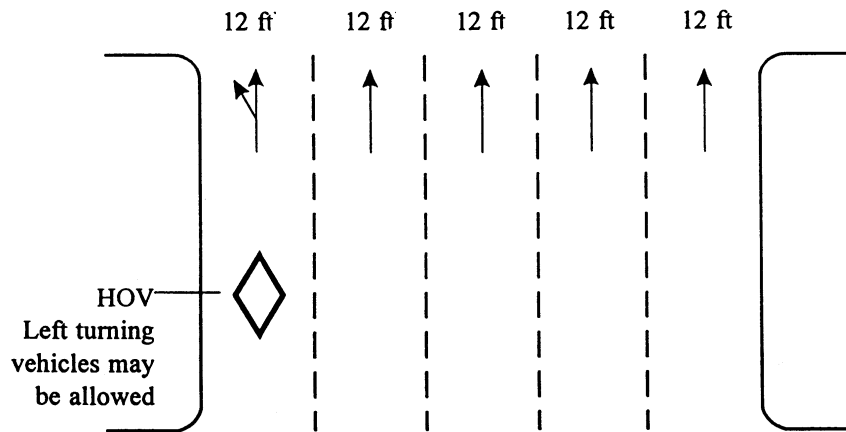
Figure 15. Layout for Left-Side HOV Facility on Two-Way Street.



Note: In some cases consideration may be given to narrowing the travel lanes to 11 feet to 10 feet.

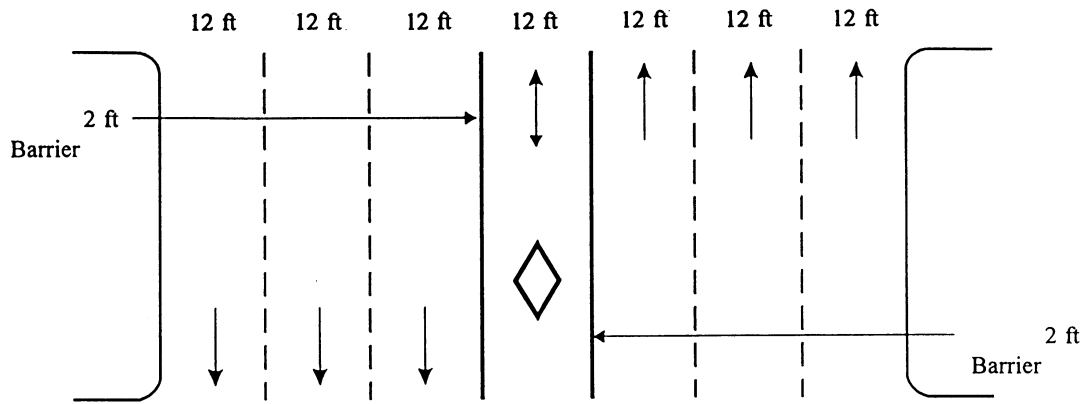
Figure
Layout for Left-Side Barrier Separated HOV Lane on Two-Way Street.

1 6 .



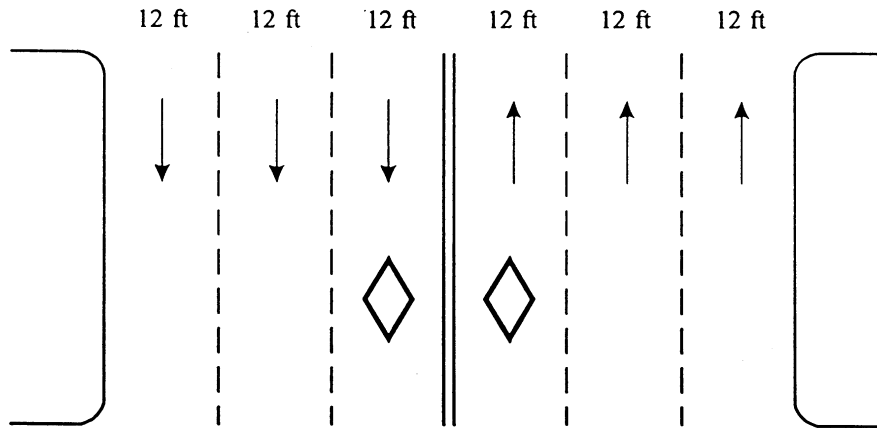
Note: In some cases consideration may be given to narrowing the travel lanes to 11 feet to 10 feet.

Figure 17. Layout for Left-Side HOV Lane on One-Way Street.



Note: In some cases consideration may be given to narrowing the travel lanes to 11 feet to 10 feet.

Figure 18. Layout for Barrier Separated Reversible Center HOV Lane.



Note: In some cases consideration may be given to narrowing the travel lanes to 11 feet to 10 feet.

Figure 19. Layout for Non-Barrier Separated Two-Direction Center HOV Lanes.

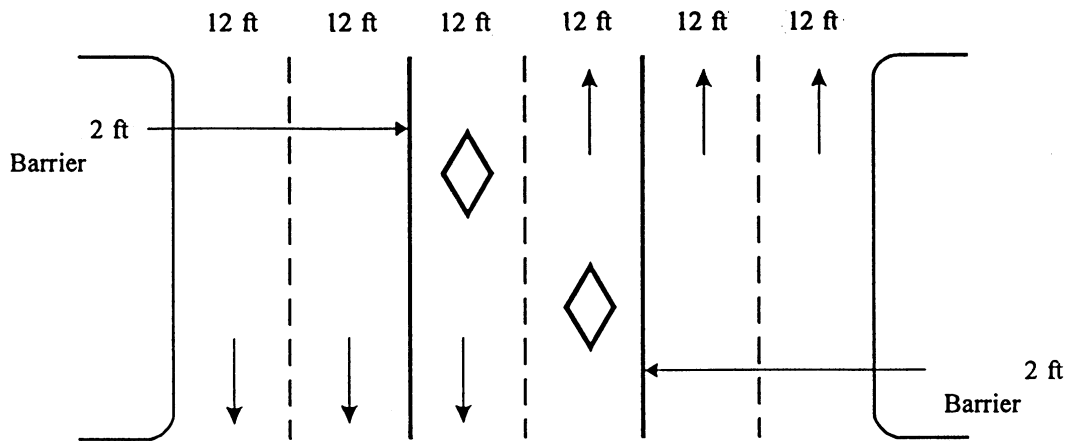


Figure 20. Layout for Barrier Separated Two-Direction Center HOV Lane.

Contraflow Bus-Only and HOV Lanes on One-Way Arterial Streets. Examples of layouts for the contraflow lanes in downtown Minneapolis and Los Angeles are illustrated in Figures 21 and 22. The cross-sections on the three streets in downtown Minneapolis include 11-foot bus lanes and three general-purpose lanes ranging from 10 feet to 12 feet in width. A general purpose turn lane is also provided. A small curb separates the bus lane from the general-purpose lanes.

The Spring Street facility initially included a 13-foot bus lane. The general-purpose lanes were narrowed to 11 foot or 12-foot lanes. Paint striping is used to separate the contraflow bus lane. Changes were made in the design of the facility in response to operational issues. The 13-foot bus lane was widened to widths ranging from 21 feet to 26 feet to allow buses to pass those stopped to pick-up and drop-off passengers. This modification was accomplished by reducing the width of the general-purpose lanes slightly and converting the number one lane to a left turn pocket at intersections.

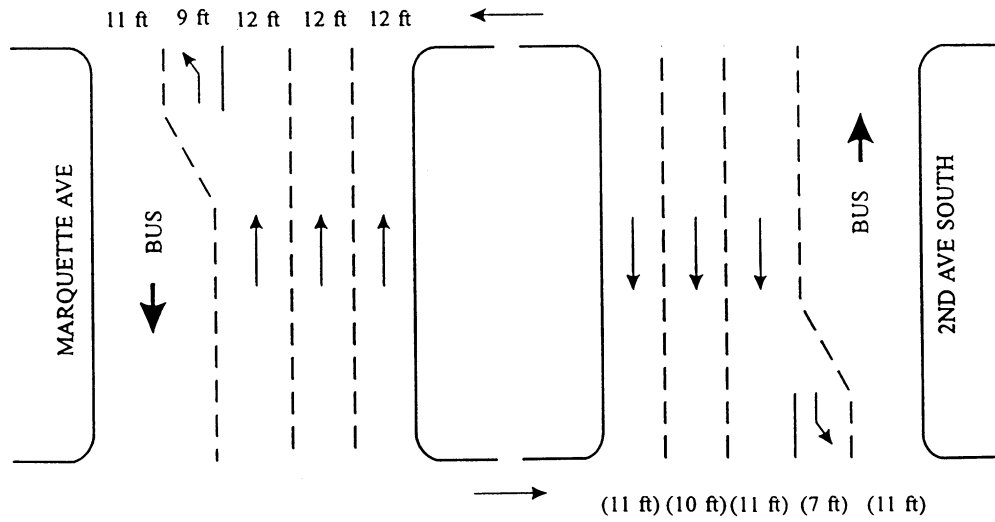


Figure 21. Layout for Contraflow HOV lanes on Marquette and Second Avenues in Downtown Minneapolis.

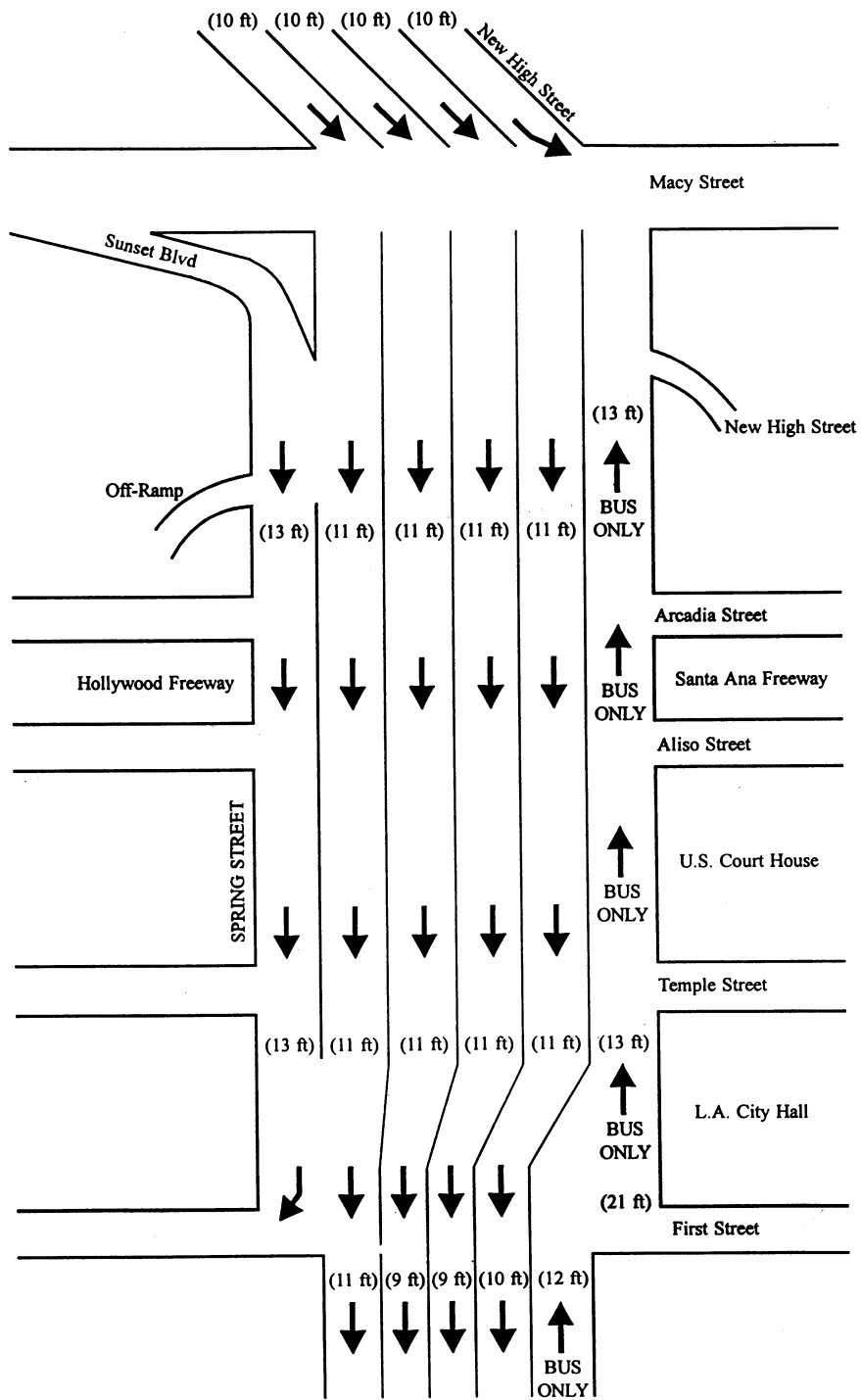


Figure 22. Layout for Contraflow HOV Lane on Spring Street in Downtown Los Angeles.

Safety Design Considerations. Additional consideration may need to be given in the design phase to ensuring the safe operation of an arterial street HOV facility. Projects should be designed to minimize the potential for conflicts among buses, HOVs, general traffic, pedestrians, on-street parking, delivery vehicles, bicyclists, and other users of the arterial street system. Elements that should be considered to address possible safety concerns include turning movements at intersections and driveways, treatments to separate the HOV and general-purpose lanes, considering the needs of pedestrian and bicyclist, and other issues. The potential safety concerns and specific techniques used to address them will depend on the characteristics of the roadway, the vehicle volumes, the type of HOV treatment, and other site-specific elements.

Due to the arterial street environment, there are usually fewer opportunities to design and develop special enforcement areas. In most cases, enforcement personnel will simply use available roadway, curb, or driveway space. The type, level, and design needs of enforcement activities should be matched to the specific HOV facility, eligible users, and opportunities within the corridor. For example, providing enforcement pockets may be appropriate to consider with a longer distance HOV lane, while the use of an alley, side street, or bus stop may be logical with a short downtown bus-only lane.

Regulatory Signing and Marking. Providing a standard set of symbols, signs, and pavement markings for HOV facilities is important to building public awareness, understanding, and acceptance. Adequate signage is critical for both users and non-users of the HOV facility and plays a key role in public education and enforcement strategies. Ideally, a uniform approach should be used with all HOV facilities in a metropolitan area, including freeway and arterial projects.

The *Manual of Urban Traffic Control Devices* (MUTCD) should be used in the design of signs and pavement marking for arterial street HOV facilities. Bus-only and HOV lanes should be clearly demarcated and signed. The primary approaches used to denote arterial street HOV facilities in most metropolitan areas are pavement markings, overhead signs, and side-mounted signs. The diamond symbol is commonly applied to the pavement on arterial HOV lanes in many areas. Additional wording, such as *buses-only*, *HOVs-only*, *restricted lane*, or other messages are often included. Signs should use terms that will be easily understood in the local area.

Pavement markings should be painted to ensure ongoing visibility. Repainting may be needed periodically, especially in areas where snow plowing, high vehicle volumes, and other conditions may limit the durability of the markings. Other approaches that have been used in some areas to give greater visibility to the HOV lane or to provide a unique identity to the lanes include larger and bolder markings and using a distinctive pavement color or payment type on the facility.

Overhead or roadside signs may also be used with arterial street HOV projects. Signs may contain information on eligible users, hours of operation, penalties for misuse such as fines or loss of points on a driver's license, and other regulations. Symbols, such as a bus, a carpool, a bicycle, or a diamond, may also be used. In addition, active signage, such as the use of flashing lights, changeable lane assignment arrows, or changeable message signs may be appropriate for consideration in some circumstances.

REFERENCES AND ADDITIONAL INFORMATION SOURCES

The following references were used in this report. Additional information may be obtained from these sources.

1. American Association of State Highway and Transportation Officials. *A Policy on Geometric Design of Highways and Streets*. Washington, D.C.: American Association of State Highway and Transportation Officials, 1994.

This report provides guidance for designing highways, roadways, streets, and other related elements of the surface transportation system.

2. Federal Highway Administration. *Manual on Uniform Traffic Control Devices*. Washington, D.C.: Federal Highway Administration, 1988.

This Manual provides guidance on all types of traffic control devices.

3. Metropolitan Transit Authority of Harris County. *Final Draft—Design Criteria for METRO Park-and-Ride and Transit Center Facilities*. Houston, Texas: Metropolitan Transit Authority of Harris County, April 1995.

This report provides design criteria used by METRO for various types of transit facilities.

4. Texas Transportation Institute, Parsons Brinckerhoff Quade and Douglas, Inc., and Pacific Rim Resources, Inc. *HOV Systems Manual*. National Cooperative Highway Research Program Report 414, Transportation Research Board, 1998.

This report provides a comprehensive guide to developing policies, planning, designing, implementing, marketing, operating, enforcing, and evaluating all types of HOV facilities. The Manual provides extensive photographs, layouts, cross-sections, and check lists to assist practitioners in all elements associated with HOV facilities.

5. Transit Cooperative Research Program. *Guidelines for the Location and Design of Bus Stops*. Washington, D.C.: Transportation Research Board, 1996.

This report presents guidelines for locating and designing bus stops in different environments. Information is provided on the advantages and limitations of various bus stop treatments and the trade-offs among different approaches. Cross-sections, checklists, and layouts are provided to help practitioners locate and design bus stops and supporting elements.