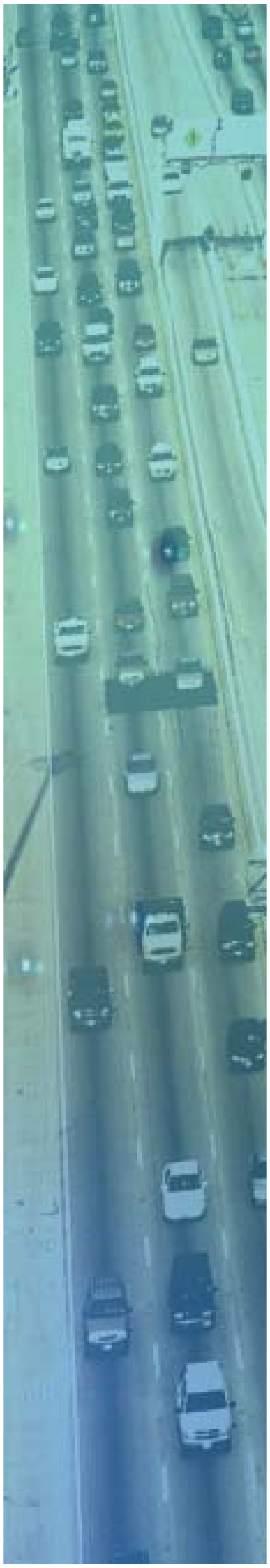

Current State-of-The-Practice for Managed Lanes

1.0 INTRODUCTION

Increasing population in Texas has placed enormous demands on the transportation infrastructure, particularly the freeway systems. There is a growing realization that the construction of sufficient freeway lane capacity to provide free-flow conditions during peak travel periods cannot be accomplished in developed urban corridors due to cost, land consumption, neighborhood impacts, environmental concerns, and other factors. To meet this growing demand, the Texas Department of Transportation (TxDOT) has begun looking at operational strategies offered by managed lane facilities.

A managed lane facility is one that increases freeway efficiency by packaging various operational and design actions. Operating agencies may adjust lane management operations at any time to better match regional goals. Managed lanes are intended to provide peak period free-flow travel to certain user groups.

A review of literature concerning the various operational strategies for managed lanes revealed that numerous studies are being conducted and numerous strategies are being tested in an attempt to improve freeway efficiency. Strategies, terms, and acronyms are often used interchangeably to describe a particular action or variation of a design without strict adherence to definitions. For example, what may be described by one jurisdiction or study as a high-occupancy toll (HOT) lane is described by another jurisdiction as a value express lane. Meanwhile, a third entity uses the term value express lane for a totally different strategy. An effort has been made to distinguish the various strategies. However, in some instances definitions by authors of reports reviewed may seem to conflict traditional definitions of a particular strategy.

Managed lane operational strategies include high occupancy vehicle (HOV) lanes, value-priced lanes or HOT lanes, exclusive-use lanes such as bus or truck lanes, separation and bypass lanes, dual-use lanes, and lane restrictions. HOV lanes are by far the best documented of the managed lane strategies. Managed lanes support increased efficiency of traffic on existing roadways and generally meet the following transportation systems management goals outlined in the Guide for the Design of High Occupancy Vehicle Facilities *(1)*, which were originally developed for HOV lanes:

- improve operating level of service for high-occupancy vehicles, both public and private, thereby maximizing person-moving capacity of roadway facilities;
- provide fuel conservation;
- improve air quality by reducing pollution caused by delay and congestion; and
- increase overall accessibility while reducing vehicular congestion *(1)*.

2.0 MANAGED LANE OPERATIONAL STRATEGIES

2.1 High Occupancy Vehicle (HOV) Lanes

HOV lanes, first implemented in the Washington, D.C., and northern Virginia area in 1969, are designed to increase the person-moving capacity of the existing infrastructure *(2)*. HOV lanes, simply put, are separate lanes that are restricted to vehicles with a specified occupancy and may include carpools, vanpools, and buses *(3)*. Most HOV facilities require that vehicles have two or more (2+) occupants to legally use the facility; however, some facilities require three or more (3+) occupants during peak travel times *(4)*. HOV lanes can be implemented on either arterials or freeways. When implemented on freeways, the following three types of facilities are used—separated roadway, concurrent flow lanes, and contraflow lanes *(1)*. Additionally, the separated roadway facility may be either a two-way facility or a reversible-flow facility.

2.1.1 Separated Two-Way HOV Lanes

The separated HOV facility is physically separated from main lanes or general-purpose lanes of the freeway. Although concrete barriers separate many HOV lanes, a wide painted buffer isolates some separate HOV lanes. As previously noted, the lanes may be either two-way or reversible. Two-way separated HOV lanes usually consist of one lane in each direction, often have limited access, and may have their own direct ingress and egress treatments *(2)*. Examples of separate two-way HOV facilities are found in Los Angeles; Orange County, California; Seattle; and a small section in Houston *(4)*.

The reversible lane is the most common type of separated lane HOV facility. The reversible lane consists of a separated lane or lanes where the direction of travel changes by time of day. A reversible HOV lane typically operates as an inbound lane in the morning and reverses to an outbound lane in the afternoon. This allows maximum use of the lane during peak hours. Examples of barrier-separated reversible HOV lanes are found in Denver, Northern Virginia, Dallas, Houston, San Diego, Minneapolis, Pittsburgh, Norfolk, and Seattle *(4)*.

2.1.2 Concurrent-Flow HOV Lanes

A concurrent-flow HOV lane is a freeway lane that flows in the same direction and is not physically separated from the main lanes of the freeway. Either a buffer or distinctive paint striping may separate the HOV lane from other traffic lanes. The lane, also referred to as a “diamond” lane, is often the inside lane of the roadway *(3)*. This is the most common type of HOV lane. Examples of concurrent-flow HOV lanes can be found in Phoenix; Vancouver, British Columbia; Sacramento; Denver; Hartford; Fort Lauderdale; Miami; Orlando; Atlanta; Honolulu; Montgomery County, Maryland; Boston; Minneapolis; New Jersey Turnpike; New York City; Portland; Ottawa, Ontario; Memphis; Nashville; Dallas; Northern Virginia; Norfolk/Virginia Beach; Seattle; Houston; and numerous California counties *(4)*.

2.1.3 Contraflow HOV Lanes

A contraflow HOV lane is a freeway lane in the off-peak direction of travel that is used for travel by vehicles in the peak direction. For example, an inbound lane is used for outbound travel from the downtown area during the afternoon peak period. The inside lane of the off-peak segment is normally the lane selected, and the lane is separated from off-peak traffic by some type of changeable or moveable barrier or physical treatment *(2)*. Although this type of HOV lane is used primarily by buses, some contraflow lanes allow use by all multiple occupant vehicles. Examples of contraflow HOV lanes can be found in Honolulu, New Jersey, New York City, Dallas, Boston, and Montreal *(4)*.

2.1.4 HOV Lane Expectations and Constraints

The number of operating HOV lanes being proposed and implemented throughout North America is steadily increasing. This indicates that HOV lanes are a widely accepted strategy for addressing traffic mobility in metropolitan areas. However, HOV facilities are not appropriate for all situations, and each facility should be evaluated and monitored to ensure the facility is meeting the goals and expectations of the community *(5)*. Expectations and objectives for a successful HOV lane include moving people, benefiting transit, and improving overall roadway efficiency. Constraints that may affect the successful implementation of strategies involving HOV lanes include adverse impact on general-purpose lanes, cost-effectiveness, public acceptance, and the environmental impact of implementation *(3)*.

2.2 Value-Priced Lanes and High Occupancy Toll (HOT) Lanes

A HOT lane is an HOV lane that allows vehicles with lower occupancy to have access to the lane by paying a toll. Variations of HOT lanes are value-price, value express, and fast and intertwined regular (FAIR) lanes, which may or may not be occupancy driven depending on the region or state. Value express lanes, as proposed by the Colorado DOT, are similar to HOT lanes *(6)*. In most cases, value lanes and FAIR lanes are toll lanes. However, some jurisdictions use these terms to describe strategies similar to a HOT lane.

The idea behind HOT lanes is to improve the HOV lane utilization and sell unused lane capacity *(3)*. In a study for the Colorado DOT, Urban & Transportation Consulting, et al. found that for a HOT lane to be successful, the following assumptions should be present:

- HOT lanes should be incorporated with HOV lanes that are currently in existence or to be constructed.
- There must be recurring congestion where the HOT lanes could help drivers avoid congestion by paying a toll.
- HOT lanes cannot take away an existing main lane in order to be created.
- HOT lanes are not self-supporting *(6)*.

The key to success for HOT lanes is to manage the number of vehicles to maximize the use of the HOV lane without exceeding capacity and creating congestion. One way to manage a HOT lane is through the use of dynamic toll pricing. The toll is a variable toll that changes as often as every 5 minutes, with the price of the toll increasing with the level of congestion. As the toll increases, the number of motorists willing to pay the toll will decrease, thereby managing lane use *(7)*. Concerns regarding HOT lanes include legality, equity, societal issues, and public acceptance *(8, 9)*. HOT lane programs are in operation in Houston; Orange County, California; and San Diego. Feasibility studies and proposal studies for implementing HOT lanes are being conducted in Colorado, Maine, Minnesota, Maryland, Oregon, California, Washington, New York, Texas, and Arizona. Numerous countries have implemented value pricing, including France (Paris), Norway, Singapore, Canada (Toronto), Germany (Stuttgart), South Korea (Seoul), and Hong Kong *(9)*.

2.3 Exclusive Lanes

The operational strategy of exclusive lanes provides certain vehicles, usually designated by vehicle type, an exclusive operational lane. The most common types of vehicles designated for this strategy are buses and large trucks. Buses are often given exclusive lanes to provide an incentive for riders by decreasing delay, whereas trucks are separated in an attempt to decrease the effects of trucks on safety and reduce conflicts by the physical separation of truck traffic from passenger car traffic.

It should be noted that until recently, very few truly exclusive facilities existed, and many of those facilities actually restricted trucks and/or buses to specified lanes and allowed other vehicles to use any lane *(10)*. In recent years, a number of truly exclusive busways have been implemented in various metropolitan areas.

2.3.1 Exclusive Busways

A busway is a bus-only roadway that is separated from the rest of the traffic. The busway, which acts like a "surface subway," allows buses to receive traffic signal preference, thus bypassing stoplights, or to cross over intersections on overpasses *(11)*. Busways may be considered a cost-effective alternative to either subways or light rail and are being implemented by a number of cities. Advantages of busways include flexibility, self-enforcement, incremental development, low construction costs, and implementation speed *(12)*. Busways have been implemented in Ottawa, Canada; Pittsburgh, Pennsylvania; Runcorn, United Kingdom; Brisbane City, Australia; Abidjan, Cote D'Ivoire; Ankara, Turkey; Istanbul, Turkey; Porto, Alegre, Brazil; Sao Paulo, Brazil; Curitiba and Belo Horizonte, Brazil; and South Miami-Dade, Florida *(12, 13)*.

2.3.2 Exclusive Truck Lanes

The issue of increasing truck traffic is of vital concern to both traffic managers and the general public. Highway traffic operations are the "yardstick" by which the user measures the quality of the facility. The characteristics that matter most to the driver are speed of travel, safety, comfort, and convenience. As a result of increasing demand on highways, many transportation agencies have implemented a variety of strategies or countermeasures for trucks in an attempt to mitigate the effects of increasing truck traffic, including exclusive truck lanes. Feasibility studies regarding restrictions and exclusive lanes found that exclusive barrier-separated facilities were most plausible for congested highways where three factors exist: truck volumes exceed 30 percent of the vehicle mix, peak-hour volumes exceed 1800 vehicles per lane-hour, and off-peak volumes exceed 1200 vehicles per lane-hour *(14)*.

In 1986, a research study *(15, 16)* by TTI examined the feasibility of an exclusive truck facility for a 75-mile segment of IH-10 between Houston and Beaumont. The options considered in the study included the construction of an exclusive truck facility within the existing IH-10 right-of-way, construction of an exclusive truck facility immediately adjacent to IH-10 outside of the existing right-of-way, or construction of an exclusive facility on, or immediately adjacent to, an existing roadway that parallels IH-10 (US 90). The studies concluded that existing and future trends in traffic volumes did not warrant an exclusive facility along the IH-10 corridor.

Theoretically, truck facilities could have positive impacts on noise and air pollution, fuel consumption, and other environmental issues. Creating and maintaining an uninterrupted flow condition for diesel-powered trucks will result in a reduction of emissions and fuel consumption when compared to congested, stop-and-go conditions. However, the creation of a truck facility may also shift truck traffic from more congested parallel roadways, thereby shifting the environmental impacts. There may also be increases in non-truck traffic on automobile lanes due to latent demand. Feasibility studies for exclusive truck lanes have also been conducted in Virginia, California, the United Kingdom, and the Netherlands. However, to date, none of the proposed exclusive facilities have been implemented *(11)*.

2.4 Separation and Bypass Lanes

The separation or bypass lane is a treatment for a specific section or segment of roadway. Several areas have successfully used this management strategy that often addresses a roadway segment that has the following characteristics: weaving area, a significant grade, high percentage of truck traffic, and/or congestion. Weaving areas are segments of freeway formed when a diverge area closely follows a merge area. Operationally, weaving areas are of concern because the "crossing" of vehicles creates turbulence in the traffic streams. Trucks limit the visibility and maneuverability of smaller vehicles attempting to enter and exit the freeway system. An indication of the barrier effect is an over-involvement of trucks in weaving area crashes, rear-end collisions, and side collisions. Some studies have shown that this problem may be magnified when a differential speed limit is present *(17, 18)*.

A truck bypass facility exists on a section of northbound IH-5 near Portland, Oregon, at the Tigard Street interchange; it is similar to some of the California facilities. The bypass lane requires trucks to stay in the right lane, exit onto a truck roadway, and reenter traffic downstream of the interchange. Passenger cars are also allowed to use the bypass facilities. One reason this facility is needed is a significant grade on the main lanes of IH-5. Without the truck roadway, larger vehicles would be forced to climb a grade and then weave across faster moving traffic that is entering the main lanes from their right. The resulting speed differentials caused by trucks performing these maneuvers created operational as well as safety problems prior to the implementation of the bypass facility. Truck speeds are now typically 50 mph in the merge area; prior to implementation of the bypass lane, truck speeds were 20 to 25 mph. There were no specific cost data available for construction of the bypass lane *(19)*.

Interstate 5 north of Los Angeles is a corridor with a very heavy volume of truck traffic. In the 1970s, Caltrans built truck bypass lanes on IH-5 near three high-volume interchanges. The lanes were built to physically separate trucks from other traffic and to facilitate weaving maneuvers in the interchange proper. The first truck facility encompasses the section of IH-5 that includes the Route 14 and Route 210 interchanges. The other truck facilities are at Route 99 near Grapevine and at the interchange of Route 110 and IH-405. Although these facilities were built for trucks to bypass the interchanges, automobiles and other vehicles also use the lanes to avoid the weaving sections *(19)*.

2.5 Dual Facilities

Dual facilities are managed lane strategies that have physically separated inner and outer roadways in each direction. The inner roadway is reserved for light vehicles or cars only, while the outer roadway is open to all vehicles. The New Jersey Turnpike has a 35-mile segment that consists of interior (passenger car) lanes and exterior (truck/bus/car) lanes within the same right-of-way. For 23 miles, the interior and exterior roadways have three lanes in each direction. On the 10-mile section that opened in November 1990, the exterior roadway has two lanes, and the interior roadway has three lanes per direction. Each roadway has 12-ft lanes and shoulders, and the inner and outer roadways are barrier separated. The mix of automobile traffic is approximately 60 percent on the inner roadways and 40 percent on the outer roadways *(19)*.

These facilities, referred to as dual-dual segments, were implemented to relieve congestion. Other truck measures that have been implemented on the turnpike are lane restrictions and ramp shoulder improvements. The restriction implemented in the 1960s does not allow trucks in the left lane of roadways that have three or more lanes by direction. On the dual-dual portion of the turnpike from Interchange 9 to Interchange 14, buses are allowed to use the left lane. The resulting effect is that the left lane becomes a bus lane with the right lane(s) occupied by trucks. The New Jersey Turnpike Authority (NJTA) rates compliance for truck lane restrictions as high *(17)*.

2.6 Lane Restrictions

Lane restrictions are a management strategy that limits certain types of vehicles to specified lanes. The most common type of lane restriction addresses truck traffic. A large presence of trucks, both in rural and urban areas, can degrade the speed, comfort, and convenience experienced by passenger car drivers. Some states, to minimize these safety and operational effects, have implemented truck lane restrictions or have designated exclusive truck lane facilities. In 1986, the Federal Highway Administration (FHWA) asked its division offices to conduct a survey and report on experiences encountered by states with lane restrictions. This survey indicated a total of 26 states used lane restrictions. The most common reasons for implementing lane restrictions were:

- improve highway operations (14 states),
- reduce accidents (8 states),
- pavement structural considerations (7 states), and
- restrictions in construction zones (7 states).

It should be noted that some states provided more than one reason for the restriction *(20)*.

3.0 ISSUES REGARDING THE IMPLEMENTATION OF MANAGED LANES

3.1 Operational Issues

Highway traffic operations are the "yardstick" by which the user measures the quality of the facility. The characteristics that matter most to the driver are speed of travel, safety, comfort, and convenience. The major goal of transportation systems management and lane management is to improve vehicular flow and increase the efficiency of the roadway system. Successful implementation of an operational strategy should result in decreased congestion, increased average travel speeds, increased safety, and reduced travel time *(11, 21)*.

3.1.1 HOV Lanes and HOT Lanes

Operational issues regarding HOV lanes should be included in an HOV operation and enforcement plan designed for the facility. Issues to be considered include the type of vehicles allowed to use the facility, the vehicle-occupancy requirement, transit services provided, hours of operation, enforcement techniques, incident management, and ingress and egress points. Operational management strategies should also consider the operational impact of converting a main lane to an HOV lane as well as consider the possibility of using priority-pricing strategies, truck use, intelligent transportation systems (ITS), conversion to a fixed-guideway transit system, and slow vehicles *(2, 5)*. HOV lane operational strategies are commonly associated with the following general objectives:

- improve the capability of a congested freeway corridor to move more people by increasing the number of persons per vehicle,
- increase the operating efficiency of the bus service,
- improve travel time and provide a more reliable trip time,
- favorably impact air quality and energy consumption,
- not unduly impact mainlane operations,
- increase per lane efficiency of the total freeway facility,
- be safe and not unduly impact safety of the freeway mainlanes,
- have public support, and
- be a cost effective transportation improvement *(5)*.

Since the reduction of travel time is a commonly used measure for assessing the efficiency of an HOV facility, any type of incident including vehicle breakdowns on the HOV facility can cause major delays. Incident detection and response are key to minimizing delays. In the *Guide for the Design of High Occupancy Vehicle Facilities,* AASHTO cites operational planning, coordination, and cooperation among agencies as an important part of the operations management for HOV lanes *(1)*.

Another important operational consideration for HOV lanes is the occupancy requirement for vehicles to utilize the lane. HOV facilities should select an initial occupancy requirement that will optimize the number of vehicles utilizing the lane. Peak hour traffic volumes need to be high enough to mitigate public concerns about under-utilization of the HOV facility *(1)*.

Equally important to the proper function of an HOV facility is enforcement. The importance of enforcement cannot be overemphasized *(1)*. A TTI study regarding enforcement found the following:

- The level of enforcement is dependent upon the type of facility, and concurrent flow facilities require more enforcement.
- An officer must have a safe and convenient place to issue citations that is within view of the HOV lane.
- A visible enforcement presence must be maintained.

- On limited access facilities, diversion of potential violators prior to traversing some part of the facility may be safer and more efficient than after the fact.
- Enforcement personnel should be located at terminal points *(22, 1)*.

The concept of the use of priority pricing was first suggested in 1959 as an operational strategy to solve urban congestion problems *(23)*. As previously noted, the idea behind HOT lanes is to improve the HOV lane utilization by selling unused lane capacity. Operational issues agencies must consider for HOT lanes include pricing strategies, toll collection, enforcement, and the type of access provided *(24)*.

Pricing strategy is one of the keys to the operational success of HOT lanes. There are basically two types of pricing, fixed and variable or dynamic pricing. Fixed pricing is a set price for all users and does not change in response to traffic conditions. Although this is the simplest operational pricing strategy, it does not discourage peak period travel and is not always an adequate mechanism for congestion relief. Variable or dynamic pricing, on the other hand, is adjusted to overall demand and traffic conditions, with the price increasing in direct proportion to the traffic congestion *(25)*. The core principle that must be recognized is that the facility is a limited-use HOV lane. If, in the future, the facility reaches capacity from multi-occupant or transit vehicles, then permitted single occupancy vehicle (SOV) or lower occupant vehicle access may be restricted or prohibited *(24)*.

In 1996, Trowbridge et al. *(26)* considered the impacts that would occur from providing trucks reserved capacity lanes that are in some cases separate from general traffic or allowing trucks access to HOV lanes. The authors reference a study by BST Associates *(27)* in 1991 that found that trucks generally make up less than 5 percent of average daily traffic in urban areas and note that an undue amount of effort is used devising strategies to restrict and manage this small portion of total traffic. In lieu of strategies restricting truck traffic, the authors propose providing trucks access to reserve capacity lanes— i.e., high occupancy vehicles lanes— to relieve congestion.

The reserve capacity lanes investigated consisted of two options for roadways in the Seattle area. The first option permitted heavy trucks to use existing HOV lanes, while the second option added a lane for the exclusive use of trucks on all facilities that had an existing or planned HOV lane. The authors attempted to determine the impacts of these options on vehicle travel time and vehicle miles traveled for SOVs, HOVs, and trucks. The authors collected traffic data and performed a traffic simulation and an estimate of the economic impacts of this type of strategy *(26)*.

3.1.2 Busways

Busway transit is a true mass rapid transit operation that offers both flexibility and self-enforcement. Operational issues and considerations for the successful implementation of a busway include:

- the need to integrate the system into existing transit plans in such a way that the busway provides a level of service comparable to private vehicles;
- provide passengers improvements in comfort, economy, travel time, and quality of service;
- provide express service for transit riders;
- busway design should define and control conflicts between the busway and adjacent road traffic; and
- provide riders with busway facilities that are comfortable, convenient, and safe *(12)*.

3.1.3 Exclusive Lanes and Lane Restrictions

As previously stated, exclusive lane facilities and lane restrictions are most often designated for buses and trucks. Agencies must consider a number of operational considerations when implementing this type of managed lane strategy. Highways are designed for a mix of vehicle types; however, an increased presence of large trucks on a roadway may result in serious degradation of flow quality for the following reasons: trucks are significantly heavier than passenger cars, trucks are considerably longer than other vehicles, and trucks have lower rates of deceleration and acceleration *(28)*. In urban areas, the demand on the highway system has grown much more rapidly than the corresponding increases in available capacity. This increase in demand has led to high levels of congestion and an increased awareness for traffic operations. Correspondingly, studies concerning the effect of trucks on highway operations have also increased *(29)*.

In 1990, Zavoina, Urbanik, and Hinshaw examined the effects of truck restrictions on rural interstates in Texas *(30)*. This study analyzed the operational effects of restricting trucks from the left lane in Texas. Study sites were six-lane rural interstate highway sections with speed limits of 65 mph for automobiles and 60 mph for trucks. Vehicle distributions according to classification, vehicle speeds, and time gaps between vehicles were examined. The study found no definitive safety improvements that could be attributed to the truck restriction. Although the lane distribution of trucks changed significantly due to the restriction, no safety effects were found that could be attributed to the truck restriction in terms of the lane distribution of cars, speeds of either cars or trucks, or the time gaps between vehicles. The authors also concluded that even though truck lane restrictions should theoretically improve the capacity and safety of a roadway, the research evidence did not support this assumption *(30)*.

A 1992 study by the Organisation for Economic Co-operation and Development (OECD) regarding truck roads examined operational issues regarding dedicated truck lanes and exclusive truck routes. The authors concluded that truck-only lanes appear to be of limited value because they reduce the operational flexibility of the road. Particular problems may arise when trucks attempt to overtake other trucks or where the road is heavily congested and trucks are traveling faster than vehicles in nonexclusive lanes. Another fear is that designating one lane exclusively for trucks would result in the saturation of that lane by trucks, resulting in little or no operational benefit. Conversely, the lane would receive limited use during holidays and weekends when truck traffic is relatively light *(31)*. A study conducted in the Netherlands found that the designation of a truck lane is feasible only when truck traffic density is in the range of 600-1000 trucks per hour. Densities lower than this would be inefficient lane usage, whereas higher truck traffic densities would result in bottlenecks *(32)*.

In an effort to improve truck safety on Houston freeways, the City of Houston decided to conduct a demonstration project restricting trucks from traveling in the left lane in 1999. The Texas Department of Transportation (TxDOT) and the Texas Transportation Institute (TTI) developed the demonstration project, which consisted of an 8-mile section of IH-10 East Freeway between Waco and Uvalde Streets. The criteria used for site selection included the requirement that the site be a radial freeway section within the city limits of Houston, the minimum length of the section be 6 miles, and the truck volume be at least 4 percent *(33)*. TTI researchers were charged with monitoring and evaluating the restriction for the duration of the demonstration project. In September 2001, the TTI research team published a report outlining and described the monitoring, evaluation, and findings of the study. The research team monitored the following areas: compliance, enforcement, crash records, freeway operations, public perception, and status of the project. The team reported that compliance rates for the restriction were between 70 and 90 percent. The team also found that vehicle crash rates were reduced during the 36-week monitoring period, although several factors including increased enforcement may have contributed to that reduction. Traffic studies conducted during the evaluation revealed that there was no significant impact on freeway operations, travel time, frequency of lane changes, or traffic patterns. Public opinion was extremely positive with 90 percent of automobile users in favor of the restriction *(33)*.

3.2 Safety Issues

The concern for highway safety parallels the historic development of the modern U.S. highway system. As the industrial revolution produced motor vehicles in considerable numbers, the demand for roadways increased, and governments at all levels came to realize that roadway financing, construction, and safety were matters for their concern. Safety was given a new focus with the passage of the National Highway Safety and the National Traffic and Motor Vehicle Safety Acts of 1966. These acts began the development of safety standards and authorities that guide today's transportation manager. As the use of technology increases along with operational concerns such as congestion and increased demand, it is important to remember that safety is paramount. The major safety consideration in implementation of operational strategies can be summed up by the old physician's caution: Primum non nocere, which is loosely translated as "Above all, do no harm."

3.2.1 HOV and HOT Lanes

As in any transportation strategy, safety is paramount for managed lanes. Research has suggested that with the implementation and operation of an HOV or HOT lane, accidents should not increase and that the accident rate should be lower in the HOV lane than on the freeway mainlanes. However, if the creation of the HOV facility results in the narrowing or elimination of mainlanes or shoulder, this may not be a realistic goal. A 1991 TTI study *(5)* found that appropriate safety measures of effectiveness should include a before and after comparison of the number and severity of accidents and the accident rates per million vehicle miles or million passenger miles of travel on both the HOV lanes and freeway mainlanes. In the 1999 study, The A B C's of HOV: the Texas Experience *(3)*, TTI researchers noted that in Texas there were still some locations where the merging of HOV lanes and mixed flow lane traffic occurs. To assure that the interactions in those locations do not become a bottleneck, TTI recommended that the congestion levels, operating speeds, and accident rates on the general purpose lanes adjacent to the HOV lanes be monitored on an ongoing basis.

3.2.2 Busways

Safety problems are an important concern for busways, and like other managed lanes strategies busways can provide a safe mode of transportation. Any type of safety problem may impact the public perception of the busway and, therefore, affect the ridership and efficiency of the strategy. In the Florida International University study, *At-Grade Busway Planning Guide (12)*, researchers identified the following safety concerns regarding at-grade busways:

- pedestrians trespassing on the busway right-of-way where no sidewalk is provided,
- pedestrians jaywalking across at-grade busway right-of-way,
- confusion of motorists and pedestrians about the way the busway vehicle is approaching,
- side-aligned two-way at-grade busways operating on a two-way street may cause motorist confusion,
- motorists making illegal left turns across the busway, unaware of the approaching busway vehicle,
- motorists violating the right-turn arrow, unaware of approaching busway vehicle,
- red time extension for multiple busway preemption makes motorist waiting to cross busways impatient, and
- complex intersection geometry creates confusion.

These and other safety problems should be addressed during the planning and design periods. Monitoring of busways and adjacent roadways by operations personnel will provide indications of potential safety problems *(19)*.

3.2.3 Exclusive Lanes and Lane Restrictions

In 1984, McCasland and Stokes *(34)* examined truck traffic characteristics and problems on urban freeways in Texas. The study evaluated six truck restrictions and regulatory practices through information obtained from a literature review and a survey of state policies. Results indicated that the restriction of truck traffic to one mixed-flow lane would probably not improve freeway safety or operations based on associated constraints and limitations *(34)*.

One area of particular concern when implementing truck restrictions on urban freeways is the creation of a "barrier effect" in weaving areas. Weaving areas are segments of freeway formed when a diverge area closely follows a merge area. Operationally, weaving areas are of concern because the "crossing" of vehicles creates turbulence in the traffic streams. When trucks are restricted to the rightmost lanes of a freeway and are of significant numbers, a barrier composed of trucks can form in the weaving areas. Trucks limit the visibility and maneuverability of smaller vehicles attempting to enter and exit the freeway system. An indication of the barrier effect is an over-involvement of trucks in weaving area crashes, rear-end collisions, and side collisions. Some studies have shown that this problem may be magnified when a differential speed limit is present *(17, 34)*.

3.3 Economic Issues

In recent years, greater scrutiny has been placed on the economic side of transportation. It has become apparent that transportation facilities must provide acceptable service under the strains of increasing demands while meeting the test of financial prudence and limited funding. Aggressive transportation systems management strategies such as managed lanes are estimated to reduce congestion and delay by as much as 25 percent, if properly implemented. This reduction provides a significant impact on demand that translates into sizable savings *(35)*.

3.3.1 HOV and HOT Lanes

Limited resources dictate that HOV and HOT lanes meet the same economic tests to which all transportation improvements are subjected. Benefits of HOV and HOT facilities include a number of different elements including savings from reduced travel time, operating cost savings, fuel consumption savings, and congestion cost savings *(3, 5, 36)*. The benefit-to-cost relationship was analyzed in detail by TTI researchers in the study, An Evaluation of High-Occupancy Vehicle Lanes in Texas *(36)*. The study found that the benefits of the HOV lane include the monetary value of time savings for motorists and bus riders as well as a cost savings from the reduction of fuel consumption. When comparing these benefits to the cost of implementation, HOV lanes had a cost-effectiveness ratio ranging from 6:1 to 48:1 *(3, 36)*.

HOT lane implementation can make the maximum use of available HOV facilities. However, HOV lanes must continue to offer a distinct advantage over adjacent mixed flow mainlanes to be effective and attractive to bus and van pool patrons. Balancing these two objectives form the key to successful HOT lanes. The benefits of HOT lanes, in addition to the previously mentioned benefits for an HOV lane, are the maximum use of an existing facility with little cost of modification and revenue that can be utilized to operate and maintain the facility *(3, 5, 36, 37)*.

3.3.2 Busways

As previously stated, busways act like a surface subway by allowing buses to receive traffic signal preference, thus bypassing stoplights, or by crossing over intersections on overpasses. Exclusive busways improve bus service by increasing travel speeds and improving reliability over conventional bus service. This enhancement of service makes busways an attractive form of commuter transportation. Benefits of busways include savings derived from increased ridership, reduced travel time, reduced congestion, reduced traffic diversion, improved access, lower air pollutant emissions, reduced parking demand, and lower fuel consumption *(38)*.

3.3.3 Exclusive Lanes and Lane Restrictions

As previously stated, when Trowbridge et al. investigated the possibility of using reserved capacity lanes as exclusive truck lanes in the Seattle area, they estimated the benefit and cost of the strategy. Based on current traffic data and simulation, the following economic impacts resulted:

- estimated $10 million in savings in truck travel time,
- estimated 2.5 minutes time savings per average trip (this is less than an 8 percent savings of an average trip), and
- estimated $30 million in savings for SOVs *(26)*.

The economic analysis reflected increased pavement deterioration in the reserved capacity lane and decreased pavement deterioration in other lanes. The net effect would be a modest overall increase in cost due to pavement deterioration and the consequent increased maintenance *(26)*.

When Wishart and Hoel *(39)* investigated exclusive truck facilities in Virginia using Exclusive Vehicle Facilities Simulation (EVFS), they described a list of expected benefits and costs. Broad intended benefits of separating truck traffic from automobiles included improved operations, reduced crashes, less severe crashes, and fewer and shorter delays. Other expected benefits are savings from reduced travel delay, reduced vehicle operation cost, decreased environmental impact from exhaust and fuel consumption, and injury and property damage savings. These benefits are offset by expected costs in engineering, construction, additional right-of-way, signage, enforcement, and maintenance *(39)*. It should be noted that although expected costs may outweigh the benefits, many of the costs are one-time costs, whereas the benefits are recurring.

3.4 Legal and Policy Issues

As previously noted, the tasks of planning, designing, funding, constructing, operating, and enforcing regulations regarding roadways and transportation systems became a governmental responsibility. Policy issues regarding transportation have evolved over the last 50 years as the needs and demands on transportation systems have grown. Legal issues involving managed lanes often cover such varied topics as access, authority, taxation, enforcement, and free trade. It is important to remember that policy and legislative actions are often the result of reaction to a specific issue or public opinion. The following sections include cases describing legislation, court decisions, and policies resulting from management decisions.

3.4.1 HOV Lanes

Policies regarding HOV lane facilities are found at all governmental levels. In most cases the policies regarding these facilities are part of a larger planning and management effort, such as the long- and short-range plans developed by state departments of transportation. HOV lane policies should accurately reflect the goals of both the agency and the community where they are utilized. The policies developed should address land use, economic development, congestion levels, environmental factors, impacts on mixed flow lanes, safety, cost, and support services and facilities *(2)*.

In 1976, the California Department of Transportation began a demonstration project, which reserved a diamond lane in each direction on the eight-lane Santa Monica Freeway for exclusive use of buses and carpools. This was the first attempt to create preferential use lanes from existing freeway mainlanes. The first day of operations was disastrous, featuring traffic operations problems, accidents, an outraged public, and poor press. After 21 weeks, a U.S. district court judge ordered a halt to the project until additional studies could be made *(40)*.

In 1986, the Virginia DOT (VDOT) planned HOV lane facilities for Route 44 and Interstate 64. The Route 44 HOV lanes were concurrent-flow lanes, while the IH-64 lanes were planned as reversible-flow lanes. The Route 44 lanes were completed first, and a decision needed to be made by VDOT as to whether or not to open the Route 44 lanes as the planned HOV concurrent-flow lanes or as mainlanes until the IH-64 lanes could be built. VDOT decided to restrict the lanes as HOV 3+ lanes. Once operational, few motorists elected to take advantage of the short 5 mile HOV facility. During the first month of operation the facility had 50 vehicles per hour usage, and after one year the usage had only grown to 200 vehicles per hour, including violators. Public opinion grew against the HOV lanes, and the Virginia General Assembly passed a law rescinding the HOV concept in the Hampton Roads Area. These legislatively mandated restrictions were in place for four-and-a-half years *(40)*.

In 1998, 20.2 miles of concurrent HOV lanes were completed on IH-287 in New Jersey. The lanes were open to two or more occupants during rush hours and to all vehicles during nonrush periods. The HOV lanes were underutilized due to a variety of factors, and public opinion of the lanes plummeted. The New Jersey DOT (NJDOT) undertook a study to analyze the HOV lanes using the following criteria:

- Do the HOV lanes encourage carpooling?

- Do the HOV lanes carry 700 vehicles per hour for usage, while carrying as many people in the HOV lanes as the average of the mainlanes?
- Do the HOV lanes reduce the current level of congestion and air pollution *(41)*?

NJDOT found that the IH-287 lanes failed two out of the three criteria, and shortly thereafter Governor Whitman announced the elimination of the HOV lanes. The state intended to remove the HOV lanes in November 1998 *(41)*.

A search by a member of the Texas A&M University Office of General Counsel found one lawsuit related to an HOV lane. In 1993, an accident involving a driver driving the wrong direction on a reversible HOV lane on US 290 in Houston, Texas, resulted in two fatalities and two people severely injured. Survivors filed suit against TxDOT, METRO, the City of Houston, and Harris County for negligence and gross negligence. A jury trial found that METRO and the other driver, who was not a defendant, were negligent and that TxDOT and the City of Houston were not negligent. However, the jury found that TxDOT and METRO were engaged in a joint enterprise on the date of the accident and ordered TxDOT to pay restitution as well. TxDOT appealed the ruling to higher courts. Both the First District Court of Appeals and the Texas Supreme Court upheld the initial court ruling *(42)*.

3.4.2 HOT Lanes

Although HOV legal and policy issues often have revolved around operational issues, HOT lanes face legal and policy issues about specific authority to assess tolls, social inequities, and double taxation. The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 specifically authorized congestion pricing programs in Section 1012(b). The Transportation Equity Act for 21st Century (TEA-21) of 1998 reauthorized these programs. To collect tolls on HOV lanes, specific legislative action is often necessary to criminalize nonpayment of tolls or other unauthorized use of the HOV lane. In jurisdictions, legislation may also be required to provide the operating entity specific authority to assess tolls *(37)*.

State of Texas statutes include four chapters in the Transportation Code *(43)* that address toll roads and implementation authority for toll roads. Chapter 257, Road Districts, and Chapter 441, Road Utility Districts, address the establishment of districts that may act to have a toll road become part of the state highway system or road system in a county or municipality. Chapter 365, Road District Toll Roads, pertains to the establishment, construction, financial provisions, and authority for toll roads. Chapter 366 of the Transportation Code, Regional Tollway Authorities, addresses the creation of regional toll authorities and the power to acquire, design, finance, construct, operate, and maintain a turnpike *(43)*.

3.4.3 Busways

Researchers found no specific legal or policy issues regarding busways in the reviewed literature.

3.4.4 Exclusive Lanes and Lane Restrictions

Truck restrictions have been implemented by a number of states in an attempt to increase safety, decrease congestion, and improve operations. The most prevalent form of restriction, by far, is lane restrictions. State transportation officials usually have the authority to implement lane restrictions. In many instances, local jurisdictions have the authority through existing legislation to implement restrictions on state highways.

It should be noted that the Surface Transportation Assistance Act (STAA) in 1982 and Tandem Truck Safety Act (TTSA) in 1984 established a national network of highways as a designated large truck network. The law is insistent that state regulations should not interfere with interstate truck movements, as long as the trucks conform to size and weight limits established by STAA and TTSA *(44)*.

In May 1997, the 75th Texas Legislature passed legislation that permits a local municipality to request lane restrictions on certain highways within the municipality's jurisdiction. The request for a lane restriction must be approved by TxDOT. Specific criteria must be met prior to TxDOT approval of a municipality's request. For example, the highway must be a state-maintained controlled access facility with at least three through-lanes in each direction, and an engineering study must be conducted by TxDOT to determine the feasibility of the proposed lane restrictions. To comply with this legislation, Jasek et al. developed guidelines to aid TxDOT in the implementation of requested truck lane restrictions in urban areas. The guidelines provide TxDOT with the necessary information to evaluate a municipality's request for lane restrictions. Researchers recommended a 12-step process to provide guidance on information related to the proposed lane restrictions that must be contained in the ordinance. The process would include conducting a traffic study, removing/installing the appropriate traffic control devices, and periodically reviewing the lane restrictions to prevent any negative impacts that may result from the lane restrictions. Researchers recommended that TxDOT monitor the extent to which municipalities request truck lane restrictions *(29)*.

3.5 Environmental Issues

Environmental issues are concerns for most urban areas. Congestion requires vehicles to move more slowly, thereby worsening noise and pollution levels. Vehicles moving in a free-flow traffic environment generate a minimum amount of exhaust pollution, and fuel consumption is minimized. Traveling the same mileage under congested conditions results in significantly increased pollution levels and fuel consumption.

3.5.1 HOV and HOT Lanes

One principal premise of HOV and HOT lanes are their potentially favorable impact on air quality and energy savings due to decreased fuel consumption. The actual quantification of these savings should be enhanced to strengthen policy arguments on the basis of environmental criteria *(3)*. These aspects often make HOV and HOT lanes attractive to environmental groups.

It should be noted, however, that environmental groups may also oppose the implementation of HOV or HOT lanes because of increased land usage or expanding the vehicle capacity of the roadway *(40)*. One prime example of environmental opposition to the implementation of an HOV lane was the Cross-Westchester HOV Plan. In the mid-1990s the New York Department of Transportation announced plans to build a high occupancy vehicle lane in the median of IH-287, also known as the Cross-Westchester Expressway. Strong opposition quickly formed by a group known as the Tri-State Transportation Campaign (TSTC). Groups including Scenic Hudson, the Sierra Club, the Environmental Defense Fund, the National Resources Defense Council, Federated Conservationists of Westchester County, and the Regional Plan Association and Transportation Alternatives later joined TSTC in opposing the project. The main arguments against the project were that the highway widening and resulting HOV lane would encourage a greater dependence on the automobile, would exacerbate inefficient land use, were not a sustainable solution to the Lower Hudson Valley transportation problems, and would hinder expansion of public transportation. A massive television campaign was mounted, and in October 1997, Governor Pataki ordered the DOT to end project planning *(45, 46, 47, 48, 49, 50, 51)*.

3.5.2 Busways

Busways lanes are also generally thought to have a favorable impact on mobility, resulting in air quality improvement, energy savings due to decreased fuel consumption, and a reduction in the growth rate of vehicle miles of travel.

3.5.3 Exclusive Lanes and Lane Restrictions

A study by the OECD *(31)* examined the impact of truck facilities and truck lanes on the environment. The environmental issues considered were noise and vibration pollution, fuel consumption, and air pollution.

According to this study, the air pollution produced by trucks is quite different from the pollution produced by cars. Trucks are primarily powered by diesel engines that operate with higher air/fuel ratios than the gasoline engines that power most cars. Diesel engines produce less carbon monoxide and unburned hydrocarbons than gasoline engines. However, diesel engines produce more smoke and solid particles due to the rich fuel/air mix than automobile engines. Vehicle emissions and energy consumption increase with traffic congestion and speed variations. Speed variations can increase both emissions and fuel consumption by 25 to 40 percent, whereas traffic congestion can increase emissions and fuel consumption by 50 to 100 percent *(31)*.

The European Conference of Ministers of Transport held a special conference on the environment in 1989 *(52)*. The reports presented to the conference discussed various concerns regarding environmental damage caused by traffic and traffic congestion. The conference compared the pollution due to trucks versus automobiles. One conclusion reached was that given the current state of traffic a 10 percent reduction in traffic congestion for trucks would result in a significant decrease in environmental pollution, whereas a 10 percent decrease in traffic congestion for automobiles would be inconsequential *(52)*.

3.6 Social and Public Opinion Issues

Societal and public opinion regarding the implementation of a managed lane strategy may be the single most important nonoperational factor. Unfavorable public opinion can result in either the curtailment or cancellation of projects or provide a preconceived notion of the effectiveness of a strategy that may affect future projects. A marketing strategy and public education campaign are therefore paramount for successful implementation of any managed lane strategy.

3.6.1 HOV and HOT Lanes

Public involvement and a successful marketing program are critical to HOV projects and their success. In addition to helping the community and public understand the purpose of the project, a successful public education campaign will increase utilization of the facility *(2)*. Under the sponsorship of the FHWA, a comprehensive HOV Marketing Manual *(40)* was developed in 1994. The authors of this manual provide a comprehensive discussion and case studies of both successful and unsuccessful marketing attempts involving HOV lanes. The major reasons for public involvement and a successful marketing strategy during the planning and implementation of an HOV facility include:

- heighten awareness of issues,
- obtain input on HOV alternatives during the implementation and design process,
- heighten public awareness of the selected HOV alternative,
- build constituencies, partnerships, and support for the selected alternative,
- increase public confidence in the HOV facility,
- develop accurate expectations for use of the HOV facility,
- promote and educate all groups on the use of the HOV facility,
- create awareness of support facilities and services,
- enhance support of future HOV initiatives, and
- meet federal, state, and local requirements *(2)*.

As previously noted in the sections concerning legal and policy issues and environmental issues, poorly thought out strategies combined with insufficient public education can lead to implementation problems. In the case of the Santa Monica Expressway demonstration project, which was the first time that an HOV or preferential lane was created from a preexisting mainlane, it became quickly apparent that the conventional marketing and public education strategy was insufficient. The reduction of an already busy expressway by one lane provoked an emotional and hostile reaction, which resulted in an eventual court order to halt the project. Although the California Department of Transportation (CALTRANS) was aware of the potential problems of reducing one of the busiest freeways in the U.S. by one lane only, a conventional public education and marketing strategy was implemented. A different marketing strategy, in all likelihood, would not have prevented the negative opinions; however, it may have allowed the demonstration project to run its course *(40)*.

The Hampton Roads/Route 44 HOV lane in Virginia fell victim to project delays within a broader system; additionally, little time was allotted to plan and execute a marketing campaign. The 5-mile stretch of newly built HOV facility, which lacked support facilities such as park and rideshare lots, fell prey to underutilization. Public acceptance of an underutilized, highly visible facility created outrage and frustration. During the four-and-a-half year temporary rescission of the HOV strategy, a marketing and public awareness campaign was carefully planned and executed. Measures implemented, which led to the eventual successful implementation of the facility, included:

- the formation of an HOV steering committee, which included local and regional public officials and representatives;
- the development of a long range marketing plan;
- the design of several rideshare support facilities, such as computer ride matching, employer outreach programs, additional park and ride lots, promotion of rideshare lots, express bus service, and a program utilizing subsidized transit fares for participating employees; and
- the redefinition of initial occupancy requirements from HOV-3 to HOV-2+ *(40)*.

In some instances public relations campaigns and marketing strategies do not work. One of the main issues that led to the removal of the HOV facility on IH-287 in New Jersey was poor public opinion due to under utilization. In January 1998, 20.2 miles of concurrent HOV lanes were completed on IH-287 in New Jersey. The lanes were open to two or more occupants during rush hours and to all vehicles during nonrush periods. The HOV lanes were underutilized due to a variety of factors, and public opinion of the lanes plummeted *(41)*. Despite an aggressive public relations campaign and marketing strategy, the task of increasing carpooling on IH-287 HOV lanes failed. In addition to the resistance to carpooling, an aggressive public relations campaign against the HOV lanes was waged *(53)*. On November 30, 1998, less than one year after completion, Governor Christie Todd Whitman opened the HOV lanes to all traffic. The Governor noted that the HOV lanes failed to meet their original goals and added to the congestion, poor air quality, and safety problems *(54)*.

In the case of the IH-287 Cross-Westchester Expressway HOV plan, a good public education and marketing strategy in the planning stages may have been able to counteract a sophisticated campaign mounted by environmental interest groups. As previously noted, in the mid 1990s the New York DOT announced plans to build a high occupancy vehicle lane in the median of IH-287, also known as the Cross-Westchester Expressway. Strong opposition quickly formed by a group known as the Tri-State Transportation Campaign (TSTC). Groups including Scenic Hudson, the Sierra Club, the Environmental Defense Fund, the National Resources Defense Council, Federated Conservationists of Westchester County, and the Regional Plan Association and Transportation Alternatives later joined TSTC in opposing the project.

Although the HOV facility was still in the planning stages, groups opposing the facility released their own "environmental impact" papers, which rejected the proposed facility for the following reasons:

- chaos during construction, in which motorists would be subjected to lane closures, detours, and massive delays;
- no immediate relief to congestion since the project would take five to seven years to complete;
- a return to pre-construction congestion, which would be created by continued growth of vehicular traffic;
- road network congestion, by increasing highway capacity;
- induced traffic and threats to environmentally sensitive open space, by encouraging development on undeveloped lands;
- threats to economic revitalization of existing urban centers, by allowing decentralization of businesses; and

- waste of scarce public resources with a cost of $444 million *(55)*.

In addition to rebuttals to planning documents, groups opposing the Cross -Westchester facility launched a series of television spots urging viewers to call the governor and urge him to call off the project *(56)*.

HOT lanes also pose some potential public relations challenges, even though they improve utilization of existing HOV lanes. The *Maryland DOT Value Pricing Study* found that public acceptance depends on the type of pricing implemented and the quality of the alternatives available. When drivers have an on-the-road choice of travel options and routes and new innovative alternatives expand the public's choice, the public opinion of HOT or value-priced lanes increase *(9)*.

In 1999 and 2000, Urban and Transportation Consulting conducted a series of commuter focus groups to explore public acceptance of the implementation of value express lanes (HOT lanes) in the Denver metropolitan area. The focus groups consisted of commuters who utilize US 36, IH-25, and E-470 *(57, 58, 59)*. These in-depth group sessions produced the following findings:

- Most participants accept the concept of value pricing as a means of better utilizing existing HOV facilities.
- Fewer participants accept the concept of applying value pricing to a new or proposed HOV facility.
- Many participants recognize value pricing as a temporary strategy that "will go away" as congestion increases.
- The most effective marketing strategy or method of selling the concept of value pricing is through real examples.
- The least effective marketing strategy or method of selling the concept of value pricing is through theory on managing demand.
- Most participants could imagine a reason for utilizing a value-priced lane if it were available.
- There were a number of "hot" or sensitive issues regarding value pricing including double taxation, limited capacity, and the short-term value of the lanes.
- The potential use of the funds varied among the participants.
- Although opinions were mixed regarding whether operation of the value-priced lanes should be operated by a public or private organization, just over two-thirds preferred public management *(58, 59)*.

In May 2001, the final reports of the Colorado Value Express Lane Feasibility Study were published *(60, 61)*. The researchers found that value express lanes were technically feasible and publicly acceptable for the IH-25 and US 36 HOV facilities in the Denver metropolitan area. However, the study conclusions urged that a plan for public education on value pricing and its concepts be implemented to forestall any misconceptions about the strategy *(60, 61)*.

Stockton et al. reported in *Feasibility of Priority Lane Pricing on the Katy HOV Lane: Feasibility Assessment (37)* that the critical steps to achieving public acceptance to HOT lanes were:

- understanding historic public feedback nationally,
- understanding local opinion,
- developing a public education/information campaign, and
- developing support among public officials.

3.6.2 Busways

Generally speaking, bus ridership has declined in many cities since the middle of the last century. Public acceptance of the use of buses as a viable transportation alternative is paramount to a quality multi-modal transportation plan *(62)*. Shen et al. found that public acceptance hinged on education about the advantages of busways including flexibility, self-enforcement, incremental development, low construction costs, and implementation speed, as well as the provision of passenger improvements in comfort, economy, travel time, and quality of service *(12)*.

3.6.3 Exclusive Lanes and Lane Restrictions

The most significant obstacle to exclusive truck facilities may be public opinion. In the reserved capacity feasibility study by Trowbridge et al., an attitudinal study of motorists and the general public examined opinions regarding the use of HOV lanes by trucks. The response by the general public indicated considerable resistance to any strategy that was perceived as a special benefit to truck traffic. However, it should be noted that the general public was favorable to truck lane restrictions. Individual comments included responses (19 percent) that trucks were unable to maintain constant speed or traveled at different speeds. Some individuals (13 percent) viewed trucks as dangerous or unsafe *(26)*.

The OECD report on truck roads *(31)* verified that exclusive truck lanes would be unpopular with the general public. Public acceptance of a facility depends on whether individuals find the facility useful. In the case of an exclusive truck road, people living near the facility do not perceive a direct benefit and may oppose the facility. Once again, although public opinion is negative toward exclusive facilities, the public generally favors the restriction of trucks to specific lanes *(31)*. This acceptance of restrictions is consistent with public input on the Capital Beltway truck lane restrictions. In this specific case, public opinion was so favorable that lane restrictions were maintained even though there was no indication of improved traffic operations or a reduction of crashes *(31, 63, 64)*.

3.7 Enforcement Issues

Enforcement, as defined in *Webster's New Collegiate Dictionary (65)*, provides five definitions. The fifth definition, *to carry out effectively <~laws>,* provides the key thought of the role of enforcement in managed lanes. Once operational requirements are decided for a managed lane strategy, enforcement becomes the means by which the strategy is implemented and effectively carried out *(65)*.

3.7.1 HOV and HOT Lanes

The HOV Systems Manual *(2)*, asserts that enforcement is critical to a number of elements in a successful HOV operation. These elements include:

- ensuring that operating requirements including vehicle-occupancy levels are maintained;
- discouraging unauthorized usage;
- maintaining a safe operating environment; and
- providing a visible means of promoting the fairness and integrity of the facility, thereby assisting in gaining public acceptance of the strategy *(2)*.

For an enforcement program to be successful, a number of components must be present. These components include legal authority, fines and citations, enforcement strategies, enforcement techniques, funding, and communication. The first component, simply put, is that for enforcement to be successful, the agency responsible for enforcement of the rules and regulations of the HOV lane must have the legal authority to enforce those regulations. Successful HOV enforcement strategy should also include fines and citations that are appropriate for the various violations that are encountered and that the amount of the fines are high enough to deter violators. There are generally four types of enforcement strategies for HOV lanes: routine enforcement, special enforcement, selective enforcement, and self-enforcement. Self-enforcement is usually accomplished by a program that allows drivers to report violators of the HOV requirements. An example of self-enforcement is the HERO program that has been used in multiple cities including Seattle, Houston, and Washington, D.C.

There are also specific enforcement techniques and methods such as video surveillance and roving patrols Funding is also of primary importance for successful enforcement. State and local police have many responsibilities besides enforcement of HOV lane operational requirements. Therefore, enforcement of these requirements may not be a high priority. If, however, exclusive funding is made available for HOV patrols, police enforcement may become a higher priority. Communication is also an important enforcement tool. The public must become educated about the requirements for using the HOV lanes and the consequences for violations. A good communications program may prove to be a deterrent in its own right *(2)*.

In 1998, Turner *(66)* analyzed technologies for enforcement for HOV lanes. After a qualitative assessment of video, automatic vehicle identification (AVI), and infrared machine vision technologies, the study focused on video technology. The high occupancy vehicle enforcement and review (HOVER) technology was developed and assessed. Turner found that video could potentially be used for the following purposes: mailing HOV information to suspected violators, enforcement screening, and ticket-by-mail enforcement. The latter application could not be used in Texas because it is currently illegal *(66)*.

As is the case with HOV lanes, enforcement is the key for effective implementation and operation of an HOT lane. The concept of the HOT lane strategy is the controlled usage of the facility. Without effective enforcement this control is not possible, because everyone must be assured that there is no free ride *(37)*. In the case of an HOV lane, when a vehicle that does not meet occupancy requirements "uses" the facility, the driver misuses a "free" facility. When a violator misuses a HOT facility, the violator is stealing a service. Although users of the HOV facility may be unhappy with facility misuse, HOT users will not tolerate someone stealing service. Therefore, enforcement is paramount to success *(37)*. One way of enforcing proper HOT usage is stationing an officer to check occupancy or toll tags at the end of a barrier-restricted facility. Video enforcement of violators of HOT lanes has also been suggested *(8)*. Video enforcement is currently being used on the California State Route 91 express lanes for toll enforcement.

3.7.2 Busways

Researchers found little to no enforcement issues associated with busways.

3.7.3 Exclusive Lanes and Lane Restrictions

Mannering, Koehne, and Araucto conducted a study in the Puget Sound region that considered lane restrictions as a means of increasing roadway capacity, improving highway operations, improving the level of roadway safety, and encouraging uniform pavement wear across lanes *(67)*. The study region has a truck volume of approximately 5 percent of the total traffic volume. The portion of the in-depth analysis that addressed enforcement issues focused on violation rates. Researchers found that the violation rate for trucks during the restriction was 2.1 percent, which was the same as the proportion of trucks in that lane prior to the restriction. Increased enforcement did not alter the percentage *(66)*.

The New Jersey Turnpike Authority was one of the first jurisdictions to impose restrictions for trucks. On the dual-dual portion of the turnpike from Interchange 8A to Interchange 14, trucks are restricted to the right outer lanes, and buses are allowed to use the left lane. The resulting effect is that the left lane becomes a bus lane with the right lane(s) occupied by trucks. The NJTA rates compliance for truck lane restrictions as high *(67)*.

The truck bypass facility on a section of northbound I-5 near Portland, Oregon, at the Tigard Street interchange requires trucks to stay in the right lane, exit onto a truck roadway, and reenter traffic downstream of the interchange. Observations of trucks traveling northbound indicated that nearly every truck uses the truck bypass, with little to no need for additional enforcement *(17)*.

4.0 REFERENCES

1. Task Force for Public Transportation Facilities Design of the AASHTO Subcommittee on Design, *Guide for the Design of High Occupancy Vehicle Facilities*, American Association of State Highway and Transportation Officials, Washington, D.C., 1991.
2. Texas Transportation Institute; Parsons Brinckerhoff Quade and Douglas, Inc.; and Pacific Rim Resources, Inc., *HOV Systems Manual*, NCHRP Report 414, Transportation Research Board, National Research Council, Washington, D.C., 1998.
3. W. Stockton, G. Daniels, D. Skowronek, and D. Fenno, The A B C's of HOV: the Texas Experience, Report 1353-I, Texas Transportation Institute, Texas A&M University System, College Station, TX, February 2000.
4. C. Fuhs, *Operational Characteristics of Selected Freeway/Expressway HOV Facilities*, Parsons Brinckerhoff Quade and Douglas, Inc., Houston, TX, January 2001.
5. K. F. Turnbull, R. H. Henk, and D. L. Christiansen, *Suggested Procedures for Evaluating the Effectiveness of Freeway HOV Facilities*, Technical Report 925-2, Texas Transportation Institute, Texas A&M University System, College Station, TX, February 1991.
6. Urban & Transportation Consulting, Parsons Brinckerhoff Quade & Douglas, and Carter Burgess, *Value Express Lanes Regional Assessment Technical Report No. 2,* Colorado Value Express Lane Feasibility Study, Colorado Department of Transportation Region 6 Planning and Environmental Section, Colorado DOT, October 2000, Revision 2.0.
7. Urban & Transportation Consulting, Parsons Brinckerhoff Quade & Douglas, and Carter Burgess, *Briefing Packet,* Colorado Value Express Lane Feasibility Study, Colorado Department of Transportation Region 6 Planning and Environmental Section, Colorado DOT, February 2000.
8. P. Decorla-Souza, "Expanding the Market for Value Pricing," *ITE Journal*, Vol. 70, No. 7, pp. 44-45, Institute of Transportation Engineers, Washington, D.C., July 2000.
9. Maryland Department of Transportation, *Executive Summary, Draft*, Value Pricing Study, Maryland Department of Transportation, June 2000.
10. D. Jasek and D. Middleton*, Literature Review for the S.R. 60 Truck Lane Feasibility Study*. Sponsored by Southern California Association of Governments, June 1999.
11. K. O'Brien and S. O'Brien, Information about Busways, Busways.org website, http://www.busways.com, June 2001.
12. L. D. Shen, H. Elbadrawi, F. Zhao, and D. Ospina, *At-Grade Busway Planning Guide*, Report Number NUTI95FIU1.2, National Urban Transit Institute, Lehman Center for Transportation Research, Florida International University, Miami, FL, December 1998.
13. South Dade Busway, *South Miami-Dade Busway*, Information page, Metro Dade Web Page, http://www.metro-dade.com/mdta/busway.htm, February 23, 2001.
14. B. N. Janson and A. Rathi, *Feasibility of Exclusive Facilities for Cars and Trucks*, Final Report, Contract No. DTFH61-89-Y-00018, Center for Transportation Analysis, Oak Ridge National Laboratory, Oak Ridge, TN, April 1990.
15. R. W. Stokes and S. Albert, *Preliminary Assessment of the Feasibility of an Exclusive Truck Facility for Beaumont-Houston Corridor*, Research Report 393-2, Texas Transportation Institute, Texas A&M University System, College Station, TX, 1986.
16. J. T. Lamkin and W. R. McCasland*, The Feasibility of Exclusive Truck Lanes for the Houston-Beaumont Corridor*, Research Report 393-3F, Texas Transportation Institute, Texas A&M University System, College Station, TX, 1986.
17. S. Sirisoponsilp and P. Schonfeld, *State-of-the-Art Studies/Preliminary Work Scopes: Impacts and Effectiveness of Freeway Truck Lane Restrictions*, Transportation Studies Center, Maryland State Highway Administration, Baltimore, MD, 1988.
18. W. R. McCasland and R. W. Stokes, *Truck Operations and Regulations on Urban Freeways*, Research Report FHWA/TX-85/28+1F, Texas Transportation Institute, Texas A&M University, College Station, TX, 1984.

19. P. Samuel, *How to "Build Our Way Out of Congestion" Innovative Approaches to Expanding Urban Highway Capacity*, RPPI Policy Study 250, Reason Public Policy Institute, Los Angeles, CA, January 1999.
20. Federal Highway Administration, *Effects of Lane Restrictions for Trucks*, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., 1986.
21. B. I. Kenyani and E. S. Putnam, *Transportation System Management: State of the Art*, Office of Policy and Program Development, Urban Mass Transportation Administration, U. S. Department of Transportation, Washington, D.C., 1977.
22. Texas Transportation Institute, *High Occupancy Vehicle Lanes Enforcement Survey*, Prepared for Metropolitan Transit Authority of Harris County, Texas Transportation Institute, Texas A&M University System, College Station, TX, 1988.
23. C. K. Orski, "Congestion Pricing: Promise and Limitations," *Transportation Quarterly*, Vol. 46, No. 2, pp. 39-43, Eno Transportation Foundation, Westport, CT, April 1992.
24. Urban & Transportation Consulting, Parsons Brinckerhoff Quade & Douglas, and Carter Burgess, *Detailed Conceptual Alternatives*, Colorado Value Express Lane Feasibility Study, Technical Report Number 1, Revision 3.0, Colorado Department of Transportation Region 6 Planning and Environmental Section, Colorado DOT, December 1999.
25. K. Zimmerman, "Decision Process for Determining the Usefulness of Road Pricing," *Compendium: Papers on Advanced Surface Transportation Systems*, 2000, Research Report Number SWUTC/00/473700-00003-1, Southwest Region University Transportation Center, Texas Transportation Institute, Texas A&M University System, College Station, TX, August 2000.
26. A. Trowbridge, D. Nam, F. L. Mannering, and J. Carson, *The Potential for Freight Productivity Improvements Along Urban Corridors*, Final Report, Report No. WA-RD 415.1, Washington State Transportation Center, University of Washington, Seattle, WA, December 1996.
27. BST Associates, *1991 Washington Ports and Transportation Systems Study*, Washington Public Ports Association and Washington State Department of Transportation, Seattle, WA, 1991.
28. N. J. Garber and R. Gadiraju, *The Effect of Truck Strategies on Traffic Flow and Safety on Multilane Highways*, Presented at the 69th Annual Meeting, Paper 890117, Transportation Research Board, Washington, D.C., 1990.
29. D. Jasek, M. A. Shafer, D. L. Picha, and T. Urbanik II, *Guidelines for Truck Lane Restrictions in Texas*, Research Report 1726-S, Texas Transportation Institute, Texas A&M University, College Station, TX, 1997.
30. M. C. Zavoina, T. Urbanik II, and W. Hinshaw, *An Operational Evaluation of Truck Restrictions on Six-Lane Rural Interstates in Texas,* Research Report 1152-1F, Texas Transportation Institute, Texas A&M University, College Station, TX, 1990.
31. OECD Scientific Expert Group, *Cargo Routes: Truck Roads and Networks*, Road Transport Research, Organisation for Economic Co-operation and Development, Paris, France, 1992.
32. Rijkswaterstaat, *Segregation of Freight Traffic and Car Traffic: Reasons and Measures*, Transportation and Traffic Research Division, Rijkswaterstaat, Rotterdam, The Netherlands, 1990.
33. TTI Research and Implementation Office-Houston, *Evaluation of the I-10 East Freeway Truck Lane Demonstration Project*, Texas Transportation Institute, Texas A&M University System, September 2001.
34. W. R. McCasland and R. W. Stokes, *Truck Operations and Regulations on Urban Freeways*, Research Report FHWA/TX-85/28-1F, Texas Transportation Institute, Texas A&M University, College Station, TX, 1984.
35. Cambridge Systematics, Inc., JHK & Associates, Roberts Associates, Inc., and Sydec, Inc., *Urban Freeway Gridlock Study: Technical Report*, California Department of Transportation, 1988.
36. W. Stockton, G. F. Daniels, D. Skowronek, and D. Fenno, *An Evaluation of High-Occupancy Vehicle Lanes in Texas*, Report 1353-6, Texas Transportation Institute, Texas A&M University System, College Station, TX, 1997.
37. W. R. Stockton, C. L. Grant, C. J. Hill, F. McFarland, N. R. Edmonson, and M. A. Ogden, *Feasibility of Priority Lane Pricing on the Katy HOV Lane: Feasibility Assessment*, Research Report 2701-F, Texas Transportation Institute, Texas A&M University System, College Station, TX, June 1997.

38. Federal Transit Administration and the Connecticut Department of Transportation, *Executive Summary, Draft Environmental Impact Statement and Section 4(f) Evaluation of New Britain – Hartford Busway, New Britain, Newington, West Hartford and Hartford, CT*, Federal Transit Administration, U.S. Department of Transportation, Washington, D.C., March 2001.
39. H. L. Wishart and L. A. Hoel*, Analysis and Evaluation of Truck Traffic Restrictions and Separation Methods on Interstate Highways*, Final Report, Report No. UVA/529242/CE96/104, Department of Civil Engineering, University of Virginia, Charlottesville, VA, June 1996.
40. J. W. Billheimer, J. B. Moore, and H. Stamm, *High Occupancy Vehicle (HOV) Lane Marketing Manual September 1994*, Final Report Number DOT-T-95-04, Traffic Management Systems Division, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., September 1994.
41. S. Anderson, "Interstate 287," *The Roads of Metro New York Web Page*, http://www.nycroads.com/, 1996-2000.
42. Supreme Court of Texas, Texas Department of Transportation, Petitioner, v. Luke W. Able, Ben Dees and George Hans Knoll, Coexecutioners of the Estate of Margaret Able, deceased, Ramona Lee Dees, and Sylvia Jane Knoll, Respondents, Number 99-0108, Texas Supreme Court, Austin, TX, July 6, 2000.
43. The State of Texas, "The Transportation Code," *Statutes of the State of Texas*, Austin, TX, 2001.
44. D. Jasek, *Truck Restrictions and Legal Issues Concerning the Evaluation of the Feasibility of Dedicated Truck Lanes in Texas*, Unpublished Technical Memorandum prepared for the Texas Transportation Department, Texas Transportation Institute, Texas A&M University, College Station, TX, December 1996.
45. "New York State DOT: Westchester HOV or Bust," *Mobilizing the Region*, Issue 114, Tri-State Transportation Campaign, http://www.tstc.org/, February 14, 1997.
46. "I-287 Widening Contracts Advertised," *Mobilizing the Region*, Issue 118, Tri-State Transportation Campaign, http://www.tstc.org/, March 21, 1997.
47. "Road to Ruin Report Released – NY I 287 HOV, CT Rte. 6 and NJ Rte. 29 Cited," *Mobilizing the Region*, Issue 131, Tri-State Transportation Campaign, http://www.tstc.org/, June 20, 1997.
48. "Gannett Raps I-287 HOV Project – Says Cross-Westchester Plan is Road to Ruin," *Mobilizing the Region*, Issue 132, Tri-State Transportation Campaign, http://www.tstc.org/, June 27, 1997.
49. "NY DOT Advances Westchester HOV Lane," *Mobilizing the Region*, Issue 135, Tri-State Transportation Campaign, http://www.tstc.org/, July 18, 1997.
50. "Pataki Questions I-287 HOV Project," *Mobilizing the Region*, Issue 147, Tri-State Transportation Campaign, http://www.tstc.org/, October 17, 1997.
51. "Governor Pataki Pulls Plug on Cross-Westchester HOV Plan," *Mobilizing the Region*, Special HOV Issue, Tri-State Transportation Campaign, http://www.tstc.org/, February 14, 1997.
52. European Conference of Ministers of Transport, *Freight Transport and the Environment*, Organisation for Economic Co-operation and Development, Paris, France, 1989.
53. New Jersey DOT, "HOV Lanes on I-287 and I-80 are Eliminated," *Clearing the Air*, Vol., 1 No. 1, http://www.state.nj.us/transportation, New Jersey Department of Transportation, Trenton, NJ, December 1998.
54. Office of the Governor, *Whitman Announces November 30th End of HOV Lanes Elimination Would Reduce Congestion and Improve Air Quality*, Archived NJDOT News Release, http://www.state.nj.us/transportation, New Jersey Department of Transportation, Trenton, NJ, October 22, 1998.
55. J. Zupan, *Mobility for the Interstate 287 Corridor, In Response to the New York State Department of Transportation Draft Environmental Impact Statement I-287/Cross Westchester Expressway*, Tri-State Transportation Campaign, Environmental Defense Fund, Regional Plan Association, Scenic Hudson, and Federated Conservationists of Westchester County, December 1995.
56. "Traffic Alert," *Mobilizing the Region*, Issue 143, Tri-State Transportation Campaign, http://www.tstc.org/, September 19, 1997.
57. Urban & Transportation Consulting, *Round One Focus Groups*, Colorado Value Express Lane Feasibility Study, Summary Report Number 1, Revision 1.1, Colorado Department of Transportation Region 6 Planning and Environmental Section, Colorado DOT, January 2000.

58. Urban & Transportation Consulting, *Round Two Focus Groups*, Colorado Value Express Lane Feasibility Study, Summary Report Number 2, Revision 2.0, Colorado Department of Transportation Region 6 Planning and Environmental Section, Colorado DOT, April 2000.
59. Urban & Transportation Consulting, *Commuter Focus Groups*, Colorado Value Express Lane Feasibility Study, Public Outreach Report Number 4, Revision 1.2, Colorado Department of Transportation Region 6 Planning and Environmental Section, Colorado DOT, September 2000.
60. Urban & Transportation Consulting, Parsons Brinckerhoff Quade & Douglas, and Carter Burgess, *Colorado Value Express Lane Feasibility Study*, Executive Summary Colorado Department of Transportation Region 6 Planning and Environmental Section, Colorado DOT, May 2001.
61. Urban & Transportation Consulting, Parsons Brinckerhoff Quade & Douglas, and Carter Burgess, *Colorado Value Express Lane Feasibility Study*, Final Report, Colorado Department of Transportation Region 6 Planning and Environmental Section, Colorado DOT, May 2001.
62. P. Sayeg, "Ticket to Ride…Australia's Busway Boom," *Traffic Technology International*, August/September 2000, UK & International Press, Dorking, Surrey, United Kingdom, 2000.
63. Traffic Engineering Division, *Capital Beltway Truck/Tractor Trailer Restriction Study*, Virginia Department of Transportation, Richmond, VA, 1987.
64. Traffic Engineering Division, *Capital Beltway Safety Study with Truck Accident Update for 1988*, Virginia Department of Transportation, Richmond, VA, June 1989.
65. G. & C. Merriam Company, *Webster's New Collegiate Dictionary*, G.& C. Merriam Company, Springfield, MA, 1977.
66. S. M. Turner, *Video Enforcement for HOV Lanes: Field Test Results for the I-30 HOV Lane in Dallas*, Research Report 2901-S, Texas Transportation Institute, Texas A&M University System, College Station, TX, July 1998.
67. F. L. Mannering, J. L. Koehne, and J. Araucto, *Truck Restriction Evaluation: The Puget Sound Experience*, WA-RD 307.1, Washington State Transportation Center, University of Washington, Seattle, WA, August 1993.
68. D. Middleton, K. Fitzpatrick, D. Jasek, and D. Woods, *Truck Accident Countermeasures on Urban Freeways*, Final Report, Texas Transportation Institute, Texas A&M University, College Station, TX, 1992.
69. Task Force for Public Transportation Facilities Design of the AASHTO Subcommittee on Design, *Guide for the Design of Park-and-Ride Facilities*, American Association of State Highway and Transportation Officials, Washington, D.C., 1992.
70. Highway Programs Development and Implementation, *HOV Performance Program*, Los Angeles County Metropolitan Transportation Authority, Los Angeles, CA, July 2000.
71. Office of Urban Mobility, *Puget Sound Freeway CORE HOV Program: Status, Performance, & Answers*, Washington State Department of Transportation, Seattle, WA, February 3, 2000.
72. C. H. Walters, T. J. Lomax, C. M. Poe, R. H. Henk, D. A. Skowronek, and M. D. Middleton, *The Dallas Freeway/HOV System Planning Study: Year 2015*, Research Report Number TX-95/1994-7, Texas Transportation Institute, Texas A&M University System, College Station, TX, June 1995.
73. LBJ Freeway Project Manager, *Proposed LBJ Freeway (IH 635) HOT Lanes, Preliminary Feasibility Study, Dallas, Texas*, Information Sheet, Texas Department of Transportation, Austin, TX, June 23, 1999.
74. J. Mallinckrodt, *Effectiveness of HOT Lanes on the SR-91 Freeway*, AJM Engineering, January 8, 1998.
75. S. Schijns, "Brisbane, Australia - HOV Metropolis?" *10th International HOV Conference, Dallas, Texas: August 28th 2000*, McCormick Rankin Corporation, Brisbane, Queensland, Australia, August 2000.
76. N. Rumpf, *Enforcement is Key*, http://www.efkon.com/.
77. J. M. Isimaru, M. E. Hallenbeck, and J. Nee, *Potential Use of Puget Sound HOV Lanes by General Purpose Vehicles in Off-Peak Hours: A Summary Paper*, Research Report WA-RD 488.2, Washington State Transportation Center, University of Washington, Seattle, WA, June 2000.
78. J. M. Isimaru, M. E. Hallenbeck, and J. Nee, *Central Puget Sound Freeway Network Usage and Performance, 1999 Update*, Volume 1, Research Report WA-RD-493.1, Washington State Transportation Center, University of Washington, Seattle, WA, May 2001.

79. Transportation Pricing Task Force, *Meeting Notice and Agenda*, Puget Sound Regional Council, Seattle, WA, June 26, 2001.
80. "Caltrans Seeks Congestion Relief with Managed Lanes in San Diego, *Civil Engineering*, Volume 70, Number 9, American Society of Civil Engineers, New York, September 2000.
81. TxDOT, *LBJ Circular*, LBJ Project Office, Texas Department of Transportation, Dallas, TX, Summer 1998.
82. TxDOT, *I.H. 635 (LBJ) Freeway Corridor Study, Project Update*, LBJ Project Office, Texas Department of Transportation, Dallas, TX, Summer 2000.
83. TxDOT, *I.H. 635 & US 75 Interchange Fact Sheet*, LBJ Project Office, Texas Department of Transportation, Dallas, TX, August 25, 1998.
84. TxDOT, *LBJ Circular*, LBJ Project Office, Texas Department of Transportation, Dallas, TX, Spring 1999.
85. TxDOT, *LBJ Circular*, LBJ Project Office, Texas Department of Transportation, Dallas, TX, Fall 1998.
86. TxDOT, *LBJ Circular*, LBJ Project Office, Texas Department of Transportation, Dallas, TX, Spring 2000.
87. TxDOT, *LBJ Freeway (I-635) HOV Lanes Will Quicken Your Commute*, Mobility Programs Development, DART, Dallas, TX, May 1999.
88. R. E. Boenau, "BRT, ITS & HOV Transitways," Presentation *at 10th International HOV Conference*, Federal Transit Administration, Washington, D.C., August 28, 2000.
89. Maryland Department of Transportation, *An Overview of Maryland's Variable Pricing Study*, Maryland Department of Transportation, August 2000.
90. M. D. Hoffman and G. W. Walton*, I-270 HOV Lanes in Maryland: Who is Using Them and Why?* Maryland State Highway Association and Parsons Brinckerhoff Quade & Douglas, 2000.
91. R. N. Taube and C. A. Fuhs, *I-45 Contraflow Interim Report*, Transportation Systems Management Report 80-9, Planning and Programming Department Metropolitan Transit Authority of Harris County, Houston, TX, May 1980.
92. J. M. Isimaru, M. E. Hallenbeck, and J. Nee, *Weekend Freeway Performance and the Use of HOV Lanes on Weekends*, Washington State Transportation Center, University of Washington, Seattle, WA, April 2000.
93. P. Hammond, "High Occupancy Vehicle Lanes in Washington State," Presentation at *10th International HOV Conference*, Federal Transit Administration, Washington, D.C., August 28, 2000.
94. "Reviewing the Status of High-Occupancy Vehicle Lanes: Simple Strategy, Complex Issues, *TR News* Number 214, Transportation Research Board, Washington, D.C., May-June 2001.
95. K. F. Turnbull, Evolution of High-Occupancy Vehicle Facilities: Maximizing Efficiency and Effectiveness," *TR News* Number 214, Transportation Research Board, Washington, D.C., May-June 2001.
96. C. Wellander and K. Leotta, "Gauging the Effectiveness of High-Occupancy Vehicle Lanes: Applying Three Criteria to Available Data Reveals Benefits, Viability," *TR News* Number 214, Transportation Research Board, Washington, D.C., May-June 2001.
97. F. Spielberg and P. Shapiro, "Slugs and Bodysnatchers: Adventures in Dynamic Ridesharing," *TR News* Number 214, Transportation Research Board, Washington, D.C., May-June 2001.
98. C. K. Orksi, "Carpool Lanes – An Idea Whose Time Has Come and Gone," *TR News* Number 214, Transportation Research Board, Washington, D.C., May-June 2001
99. C. C. McGhee, "High-Occupancy Vehicle Lanes – A Valuable Tool in the Traffic Management Toolbox," *TR News* Number 214, Transportation Research Board, Washington, D.C., May-June 2001.

For More Details . . .

Related Reports:
Report 4160-2, *Year 1Annual Report of Progress: Operating Freeways with Managed Lanes*

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