Charlotte Region HOV/HOT/Managed Lanes Analysis

Technical Memorandum Task 1.1

EXPERIENCES WITH MANAGED LANES IN THE USA

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Executive Summary

This technical memorandum reviews the history of how managed lanes, primarily in the form of high-occupancy vehicle (HOV) and high-occupancy toll (HOT) lanes, have been implemented primarily on freeways within the U.S. Arterial experience is primarily related to bus lanes in major urban centers. Experiences have been collected from project practitioners and a wide variety of references and resources published by AASHTO, NCHRP, TCRP and ITE, as well as various state departments of transportation. A compilation of these experiences is condensed into a series of lessons learned. While much experience is available for HOV lanes, more limited and recent experience exists for HOT lanes. Truck and commercial goods movement has been studied in a wide number of areas, but truck lanes only exist currently as bypasses at a few major interchanges primarily in California and as climbing lanes on numerous interstate highways. All types of dedicated lanes that are restricted by either eligibility, access or pricing strategies in order to maintain free-flow operation are termed managed lanes.

The following highlights experiences from each of these types of managed lane treatments. More detailed findings are provided in the following chapters.

HOV Lanes

- High Occupancy Vehicle lanes were first implemented as bus-only lanes on several congested expressways in the late 1960s in northern New Jersey, Washington D.C. and Los Angeles. They served as the first examples of bus rapid transit and were very popular in providing an incentive to ride transit. The Route 495 bus lane in northern New Jersey carried over 34,000 bus passengers per hour, saving each person an average of 20 minutes per trip.
- The El Monte Busway along I-10 in Los Angeles was the first to test carpool use when a bus strike occurred in 1976. The temporary use of allowing carpools showed potential to move more people in fewer vehicles. Subsequent federal policies encouraged the development of first 3+, then 2+ HOV lanes on freeways and major routes where the potential existed to promote better use through the encouragement of transit and ridesharing. Accordingly, the number of cities and routes employing HOV lanes grew from 125 route-miles in 1985 to over 1500-route miles (3000 lane-miles) by 2005.
- HOV lane benefits are primarily travel time savings and improved commute trip reliability.
- HOV lanes seem to be most successful where there is adequate use, where transit services can take advantage of the dedicated lanes and where enforcement is performed to a level that promotes respect for the rules and regulations related to lane operations.
- Most HOV lanes have been implemented by state DOTs, but a majority of HOV and bus lane treatments on arterials have been implemented by respective local city, county and transit agencies.
- HOV lanes have typically shown that about 40% of their use comes from spatial shifts (carpools coming from adjacent lanes on the freeway or other routes), about 40% are newly formed carpools coming from former drive-alone commuters, and the balance as new trips or coming from other modes and taking bus transit or carpooling. Trends in average vehicle occupancies tracked for the past 20 years show that corridors with HOV lanes have higher bus and carpool use than those which do not.

- Growth in the implementation of HOV lanes doubled about every five to eight years through the 1990s, but has slowed since 2000. Still, about 50 lane-miles of HOV lanes are added annually, mostly to complete current systems in major cities in excess of one million.
- The initial demand threshold for successful HOV lane use is about 400 to 600 vehicles (800-1200 persons per hour, with long-range person carrying parity being required when compared to adding a general purpose lane (typically 2000-2200 persons/hour).
- The desirable travel time savings for successful operations is around 0.5 minutes per mile when compared to adjacent traffic speeds, or a total trip savings of about 5 to 8 minutes to induce mode shifts to transit and ridesharing.
- For HOV lanes to work, they need a minimum of about 600 to 800 vehicles per hour or about 1800 persons per hour to be considered justifiable.

HOT Lanes

- High-occupancy/Toll lanes offer the potential to better manage an HOV lane by more finely regulating demand, giving some HOVs free use and tolling others.
- HOT lanes were first introduced in the mid-1990s based on emerging electronic toll collection technology that allowed pricing to be added to HOV lanes without the need for a conventional toll booth. The first projects included I-15 in San Diego and a public-private initiated project to fill in a missing HOV gap between Orange and Riverside County in California. Federal policies since the mid-1990s encouraged the demonstration of congestion pricing in a variety of forms, and HOV lanes were one of these applications.
- The first pricing demonstrations were on projects that served as commute “pipelines” with a single entrance and exit and separated by a barrier from adjacent traffic. These designs made pricing easier and more economical to implement. Since 1995 five other pricing demonstrations have been implemented on HOV lanes in Houston (I-10 and US 290), Denver (I-25), Minneapolis (I-394) and Salt Lake City (I-15). While most HOV lanes allowed solo drivers to use the lanes for a toll, the two Houston examples responded to excessive HOV demand by raising minimum free use to 3+ HOVs and tolled the 2-occupant HOVs.
- Three of the seven HOT lanes use flat-based tolls either on a single trip or by registering for a monthly toll permit for unlimited use. The other four examples apply variable tolls that price according to the level of use in the HOT lane. Some variable tolls are fixed according to a schedule, so motorists will always know the prevailing toll, while others vary the price in accordance with prevailing demand conditions and post the toll in advance of the entrance.
- A number of HOT lanes are currently in development, so the number of projects will grow in the coming decade.
- Pricing for most single HOV lanes generates only enough revenue to cover the cost of pricing implementation, operation/administration and enforcement. Multiple lane projects like those in San Diego and Orange County have produced excess revenue which has largely been reinvested into the corridor in either paying down the construction cost of the HOT lanes or funding additional bus services.
- For a HOT lane to work, it needs about 1200 to 1500 vehicles per hour which are either HOVs or toll-paying users. The maximum vehicle carrying capacity for a directional lane is about 1650 hourly vehicles.

TOT Lanes

- Truck-only Toll lanes offer the potential to apply the same benefits for commercial goods movement as are provided to commuters.
- While there have been various studies of truck-only lanes and roadways and more recent studies to toll trucks on these lanes, several operational and institutional issues have prevented such lanes from being implemented. These obstacles relate to the need to provide two directional lanes so that trucks can pass one another, otherwise service capacity and operational benefits can be lost. There is also differences in the practitioner community about whether large volumes of trucks, transit and commuter flows can be mixed on such lanes and still preserve the intended level-of-service benefits to all. Perhaps most difficult to resolve is the high cost of building dedicated truck lanes and strong stance trucking interests have taken against mandatory tolling if they were precluded from current highway lanes. This institutional barrier has prevented some potential projects from moving forward.
- For TOT lanes to work, they need about 800 trucks per hour (400 per lane for two lanes directionally) with common origin-destinations over a corridor or region.

Other Types of Managed Lanes

While express lanes that assure a higher level of service through restrictions on access have been operated on various urban interstates in Chicago, St Louis, Seattle and other cities for many years, a broader application of dynamically managing express lanes through tolling is planned for a number of areas. These plans do not necessarily involve offering any free or discounted use to HOVs, but rather, serve all traffic. Some treatments are targeted at offering special lanes to serve commercial goods movement, as exemplified in Atlanta on I-75 and I-285. Southern California is also examining truck-only toll roadways. While no experiences are available yet from these plans, the nature of how managed lanes will be implemented and who they are tailored to are changing from past experience.

Listed below are a few trends to watch.

- Local, state and private toll road agencies may be implementing more managed lanes than traditional DOT-sponsored projects.
- Toll road sponsored managed lane projects are likely to be targeting a pricing structure that pays more of the capital cost, requiring wider lane configurations involving four or more lanes to make them economically viable.
- More managed lane systems will be implemented involving connections between one facility and another.
- Trucks, which value time greater than commuters, may be a more sought-after market for managed lanes.
- The need to create flexibility to serve different types of managed lane users is already apparent, where such lanes may serve a BRT or HOV function in the peak period and a commercial goods movement function in the off-peak, necessitating a more flexible design.
- Planning and design guidance to address wider applications of managed lanes is just now being identified as a national need, and research into best practices is ongoing. It is likely that current plans will be influenced by this guidance before many of these projects are implemented.

1.0 INTRODUCTION

This section provides a background the managed lane concept and an introduction to the different types of lane treatments most commonly implemented in the U.S. Following sections provide experiences and lessons learned in planning, implementing and high-occupancy vehicle (HOV) and high-occupancy toll (HOT) lanes. No examples exist yet of truck-only toll (TOT) lanes or managed toll lanes from which to develop such experience. Collective experiences on these topics are addressed in the Introduction section.

1.1 Background of the Concept

In highly congested corridors where traditional strategies for improving mobility and roadway capacity cannot address unmet demand, dedicated lanes are often implemented more aggressively manage use to improve roadway efficiency. This strategy provides a choice to motorists who would otherwise be stuck in traffic congestion. In the late 1960s managed lanes began as restricted, often curbside lanes for buses on streets and a few expressways. By mid 1970s carpools and vanpools usually with 3 or more persons were allowed use to some dedicated lanes, which were termed *HOV lanes* (Figure 1). In the late 1980s changes in federal policies allowed each locale to consider HOV lane eligibility to carpools with two or more persons. By the mid-1990s pricing was tested on several HOV lanes, and the term high-occupancy/toll or *HOT lane* was coined. Today there are more than 2900 lane-miles of managed lanes on freeways in North America plus a wide number of lanes primarily reserved for buses on arterials. Practically all managed lanes are located in highly congested metropolitan areas where they provide a travel time advantage over adjacent lanes.

Definition of a Managed Lane

While the transportation profession applies *managed lanes* to a broad range of strategies targeted at ensuring “free flow” conditions to a portion of the roadway, the term has many locally accepted acronyms and evokes different meanings and connotations depending on location or individual project. At present there is no nationally recognized definition of managed lanes. The Federal Highway Administration offers the following definition:

> *“(Managed lanes) offer an enhanced operational condition within separated lanes, which result in outcomes such as greater efficiency, free-flow speeds or reduced congestion.”*

Two states—Texas and Washington—have developed definitions to guide implementation of projects beyond their current system of HOV lanes.
The Texas Department of Transportation (TxDOT) has developed the following definition for managed lanes as part of its managed lanes research program:

> *“A managed lane facility is one that increases freeway efficiency by packaging various operational and design actions. Lane management operations may be adjusted at any time to better match regional goals.”*

As specific managed lanes projects in Texas undergo development, the definition is tailored to address specific project needs. For example, the following variation on the definition was developed for managed lanes project in Dallas:

"Managed lanes increase freeway efficiency by offering a predictable trip with little congestion for those who carpool, ride bus transit, vanpool, ride a motorcycle or if driving alone, are willing to pay a toll. Lane management operations and pricing structure may be adjusted at anytime to better serve modal needs."

This project definition specifically addresses priority user groups and the use of pricing as a means to achieve objectives for the project.

The Washington State Department of Transportation also developed the following definition of managed lanes:

"Managed Lane facilities include any roadway lane that can be managed to prevent congestion from occurring. In managed lanes, one or more of these techniques is used to control the number of vehicles using the lane or roadway:

- *Limiting access -- providing infrequent on-ramps, as on the I-5 and I-90 express lanes*
- *User eligibility requirements -- such as HOV-only, truck-only, permit-only, etc.*
- *Pricing -- tolls can be varied by time of day to control traffic volumes.*

By considering these as different forms of traffic management, it is possible to plan the best combination of tools to keep a roadway from becoming congested over time, and to optimize traffic to achieve the best person and vehicle throughput."

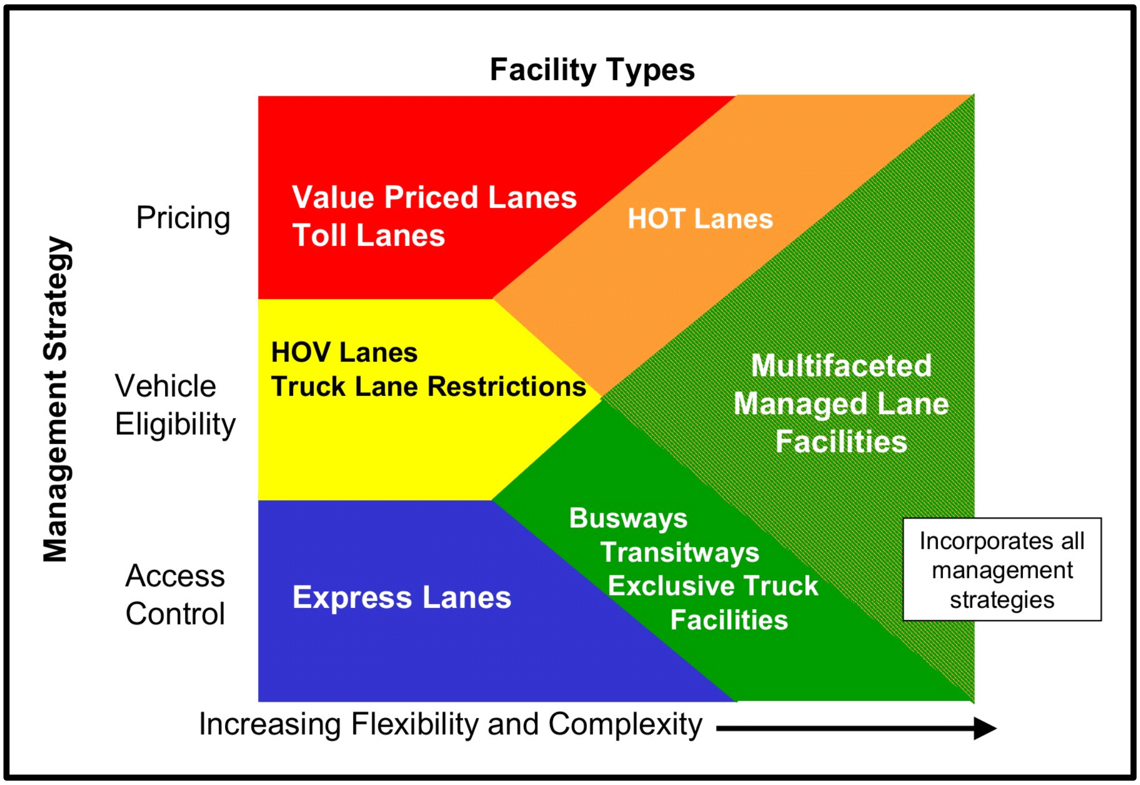
A common element in the definitions is the inclusion of a broad range of potential strategies applied dynamically to better manage traffic flow to the greatest number of users. There is also an emphasis on achieving an enhanced operational condition within the managed lanes, as either explicitly stated in the definitions (i.e., freeway efficiency, reduction of congestion, optimized throughput), or through implicit qualities such as travel time savings, trip reliability, improved speeds and improved operational efficiency.

HOV lanes fit within the managed lane definitions described above, although HOV applications are only one of many managed lane approaches that currently exist or are being proposed. The following treatments could be considered managed lanes if they are designed and operated to enhance promote an assured travel condition over adjacent lanes:

- HOV and High Occupancy/Toll (HOT) lanes
- Truck-only Toll lanes (TOT)
- Value priced lanes
- Express or special use lanes and roadways
- Bypass lanes, primarily for commercial vehicles

Figure 1 shows the entire menu of management options that exist under the umbrella of managed lanes.

Figure 1: Types of Managed Lanes



Goals and Objectives

Goals for implementing managed lanes include, but are not limited to the following:

- Maintaining mobility
- Improving roadway operation efficiency, safety and reliability
- Improving air quality
- Promoting transit and ridesharing
- Improving safety
- Providing travel options to meet user needs, such as "time-sensitive" travel, and
- Generating revenue to offset capital and operating expenses

Traditionally, the first five goals were associated with HOV lane planning and implementation. As technology has evolved to allow electronic pricing to become more accepted, the latter two goals have been evidenced on projects that address multiple user groups.

Objectives can be region and/or corridor specific, and often include the following:

- Increasing person-moving capacity of the roadway

- Promoting transit and ridesharing mode split
- Optimizing vehicle-carrying capacity
- Promoting travel time savings, reliability, or efficiency for selected travel modes
- Promoting air quality by increasing ridesharing and transit as part of a conformity plan
- Increasing funding opportunities for new mobility improvements
- Enhancing existing transit investments and services in the region/corridor
- Providing a greater choice in serving multi-modal needs (people, goods, services)
- Improving the movement of commerce (goods and services movements)
- Supporting community land use and development goals, particularly to major areas of employment

Fundamental to these goals and objectives is an implicit set of conditions that should exist for managed lanes to be considered a viable project. These conditions include the following:

- A recurring congestion problem to level of service D or worse within a corridor or region for a significant period of time each weekday
- A significant backlog of unmet travel demand, and/or lack of available resources (right-of-way, funding, regional consensus or environmental issues) to address capacity deficiencies in a more conventional means through adding roadway or transit capacity
- An interest and ability to minimally increase roadway capacity by managing its use to specific dedicated purposes to ensure that a high level of service can be provided as an alternative to recurring congestion

Ultimately, the goals and objectives that are set for a corridor improvement or managed lanes project should dictate the operational strategies employed.

Management Strategies

Common lane management strategies used to regulate demand fall into three broad categories:

- Eligibility
- Access
- Pricing

While these strategies are applied in other traffic management applications and may offer benefits, they have specific relevance to actively managing lane demand in this context. A wide variety of emerging projects is likely to expand the manner and in how each strategy is applied. Each strategy described more fully below can be applied and implemented individually or in combination, depending on the unique travel demand conditions associated with each project setting.

Eligibility

Restricting a dedicated lane to specific users will limit demand. HOV lanes are primary examples of limiting use to specific vehicle classes based on the number of persons they are carrying. Most commonly, user restrictions on HOV lanes have taken the form of eligibility requirements based on the requisite minimum number of people traveling in a vehicle (Figure 1). Over the years restrictions on

HOV lanes have evolved to include several other occupancy-exempt vehicle classes (e.g., motorcycles, inherently low emission vehicles (ILEVs) or hybrid vehicles, emergency vehicles, deadheading buses, paratransit vehicles, etc.). Other examples include designated bus-only or truck/freight-only roadway facilities. Eligibility restrictions can be in effect 24 hours or vary by time of day or day of the week. A managed lane using a variable eligibility strategy may restrict use to HOVs with a minimum of three or more occupants during the peak commute hours, and relax restrictions to include lower occupancy vehicles and occupancy-exempt vehicles or other users during off-periods or weekends. Signing requirements can become confusing and cumbersome if the eligibility rules are made unusually complicated.

Access

Limiting access has traditionally been applied to HOV and express lanes as a means of regulating entry and exit movements (Figure 2). Restricting access by this means helps ensure that the lanes do not become overloaded regardless of the level of demand they generate. Access restrictions may also help alleviate specific traffic bottlenecks where short distance trips cause a lane to exceed its capacity.

Figure 2: Example Eligibility Restriction

As an example, HOV access restrictions are applied on most lane treatments in the Los Angeles area where demand on all HOV lanes is high. Access is also restricted in various multi-lane facilities and on reversible freeway facilities where positive separation between opposing flow is required. On some roadways like the New Jersey Turnpike, access is managed or metered between separate, parallel roadways, thereby giving preferential service to one of the two roadways during incidents. Access can be restricted under normal conditions 1) by metering demand at entrance ramps via the use of traffic signals or gates, 2) by limiting access at specific ramps to selected users like HOVs (e.g., I-5 Seattle downtown ramps) or 3) by limiting the number of entrance and exit ramps so that free-flow is ensured (e.g., I-5N Seattle, I-94 Chicago and I-15 San Diego). In several areas, such as Chicago and Seattle, this latter application is sometimes referred to as *express lanes*, and the lanes are open to all traffic at an enhanced level of service. Once traffic enters the express lanes, vehicles can typically travel at unimpeded speeds to downstream exits. Some express lanes like those in Seattle and New Jersey also include HOV priority ramps or connect to HOV lanes on either end or on other routes.

Figure 3: Example Access Treatments

Express lanes, reversible lanes and dual express/local roadway systems are examples of facilities where access can be managed either dynamically and/or by design.

Pricing

The introduction of electronic toll collection (ETC) technology has allowed this tool to become an increasingly practical and inexpensive in regulating demand (Figure 3). Pricing can help maximize the use of available pavement while continuing to prioritize operation for selected users such as HOVs. The introduction of pricing offers an opportunity to manage a dedicated lane by allowing others to use the lane as capacity allows.

Figure 4: Electronic Toll Technology Applied to Managed Lanes

Pricing can be a crude or fine-tuned tool. If fixed pricing is applied it simplifies the message to users but limits the ability to regulate demand in peak periods. Dynamically varying pricing in accordance to demand is a better solution, but makes communicating the price to users potentially harder. This application is often called congestion, demand-based, or value pricing. Value pricing involves charging a fee or toll to travel on a lane or roadway which varies according to time of day (peak/off-peak) and day of week or by the level of congestion on the managed lane or adjacent lanes. While value pricing has potential in many different contexts, the primary purpose in this application is to varying the pricing so that the lane does not become congested. Higher tolls are usually charged when congestion is heaviest and delay is at its worst, while lower tolls or free access may be provided to some or all users during periods of low demand. Pricing is applied to better balance demand to lane capacity and can encourage some peak period users to shift their trip to lower demand periods. Pricing can give preference to selected user groups, as has been demonstrated on several HOV lanes, so that lower occupancy vehicles pay a higher price than higher occupancy vehicles. Pricing is implemented using electronic toll tag readers, and typically all vehicles that are priced are required to have a toll tag to use the facility.

Pricing has been implemented in a limited number of areas on existing HOV lanes. Value pricing may permit all vehicles to access the managed lanes or only a select user group. Revenue generated from value pricing typically covers the operation, enforcement and administrative costs associated with toll collection and may also cover other expenditures such as capital costs associated with construction. Enforcement of toll evasion may be automated if electronic toll tags are employed and all users are treated equally, or enforcement may be more complicated if pricing preferences are applied to selected users (i.e., single occupants are tolled and HOVs are free), thereby requiring increased on-site law enforcement presence as is the case for monitoring HOV occupancy requirements.

1.2 HOV Lanes

Managed lanes over the past 30 years have typically been termed high-occupancy vehicle (HOV) lanes. Various guidelines use the following definition for HOV facilities:

> *HOV Facility: A lane or roadway dedicated to the exclusive use of specific high-occupancy vehicles, including buses, carpools, vanpools or a combination thereof, for at least a portion of the day.*

By offering a reserved lane for multi-person vehicles, HOV lanes emphasize *person movement* rather than traditional *vehicle movement,* thus improving the roadway's ability to move more people in fewer vehicles (Figure 5). This approach only works when an assured level of service in the HOV lane is preserved and time savings that encourage mode shifts to transit, vanpooling and carpooling are realized. To provide this benefit, the dedicated lanes are managed at a vehicle flow rate that is below traditionally defined lane capacity so that the lane does not become congested. HOV facilities enable transportation agencies to better manage and offer an alternative to congestion. When operated and managed at a high level of service, HOV lanes save peak-period travel time over adjacent mixed-flow lanes and have a theoretical capacity to move substantially more commuters than general use lanes during peak demand periods when priority must be assigned to the highest and best use. During these periods, HOV lanes provide significant benefits to those choosing to ride a bus or participate in a vanpool or carpool.

Figure 5: Example HOV Lane from California

- In New York the Route 495 bus lane moves more than 34,000 commuters per hour.
- In Los Angeles County the average HOV lane moves more than 3200 commuters per hour.

The primary tools used to manage HOV lane use are eligibility and access. Eligibility restricts lane use to vehicles with a minimum number of persons traveling in each vehicle. Access has sometimes been restricted at entries to manage demand and promote better traffic flow.

Since 1969 a growing number of congested corridors in North America have had HOV lanes implemented to both improve person moving efficiency in these corridors and provide commuters an additional travel choice to sitting in congestion. Although HOV lanes can be found on both freeways and arterials, this paper focuses on freeways involving the only experiences in HOV lane conversions. Growth in HOV lanes really took off and were implemented in a number of freeway corridors in the 1980s for a number of reasons (Figure 6). Air quality mandates created funding that was earmarked for transportation strategies that aided a region's air quality, and HOV lanes fit this role will in reducing dependence on single-occupancy travel. Federal policies, notably from the Federal Highway Administration (FHWA), also encouraged consideration of HOV lanes as an effective traffic management tool. Lane mileage almost doubled every five years during the 1980s into the mid-1990s. These projects were largely implemented in major cities with over one million in population, often in corridors where few other travel options existed. There are currently more than 2900 lane-miles of HOV lanes represented in over 120 projects in the U.S. (Figure 7). The largest growth in HOV lanes occurred in the 1990s. Most projects being implemented now are extensions and gap closures to existing systems.

HOV lanes make the most sense when:

- Adjacent general-purpose lanes are heavily congested during peak periods;
- Sufficient demand exists among transit and rideshare users to justify a dedicated lane.
- Travel benefits are enough to cause solo commuters to shift to transit or ridesharing; and
- Resources are limited for expanding roadway capacity to meet future demand conventionally.

HOV lane experience has shown that they can have a positive impact on corridor transit and rideshare use. Various before/after studies have shown that about 40 percent of HOV users come from previous carpoolers who have shifted from adjacent lanes or other routes into the HOV lane (called "spatial shifts"); another 40 percent are newly formed carpools and vanpools and transit riders who previously drove alone (called "mode shifts"); and the balance were new trips in the corridor often created because the dedicated lane provided a superior way of commuting. These trips often changed the nature of lane use and commuting in the corridor.

Growth in transit and ridesharing as a result of an implemented HOV lane usually occurs in the first six months of project operation. It typically takes a trip savings on the affected route of 5 to 7 minutes to promote spatial and mode shifts into an HOV lane. The actual and perceived savings by users is significantly different. Most users surveyed indicated they saved about twice the actual time.

Figure 6: Growth in HOV Lanes from 1969 to 2000

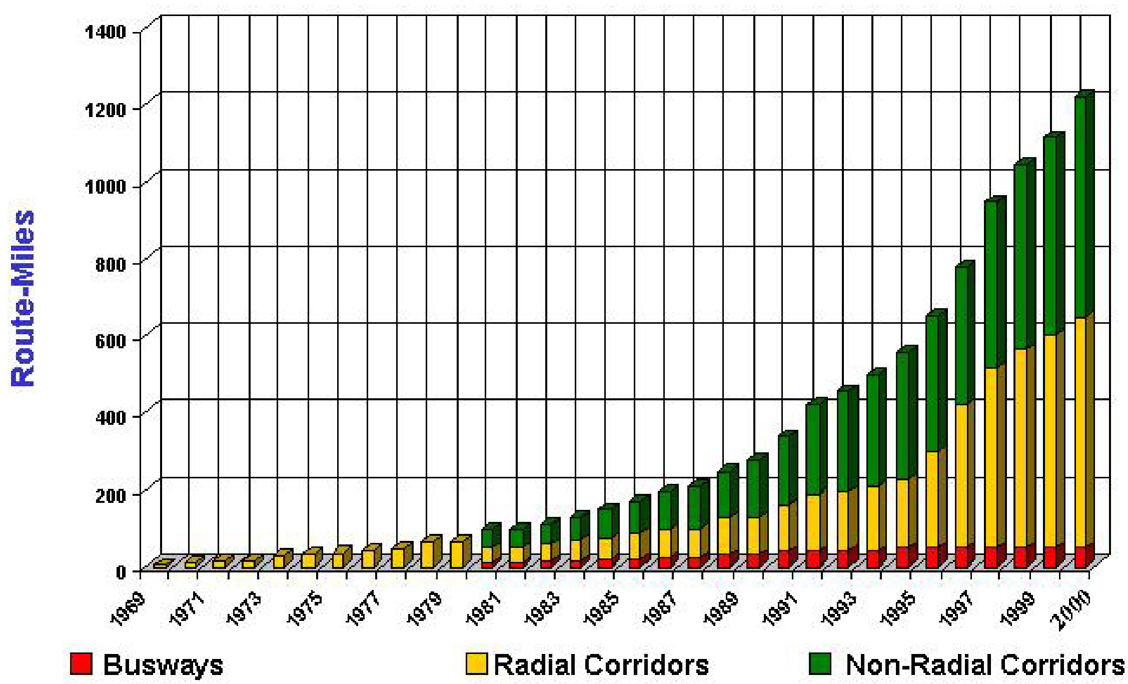
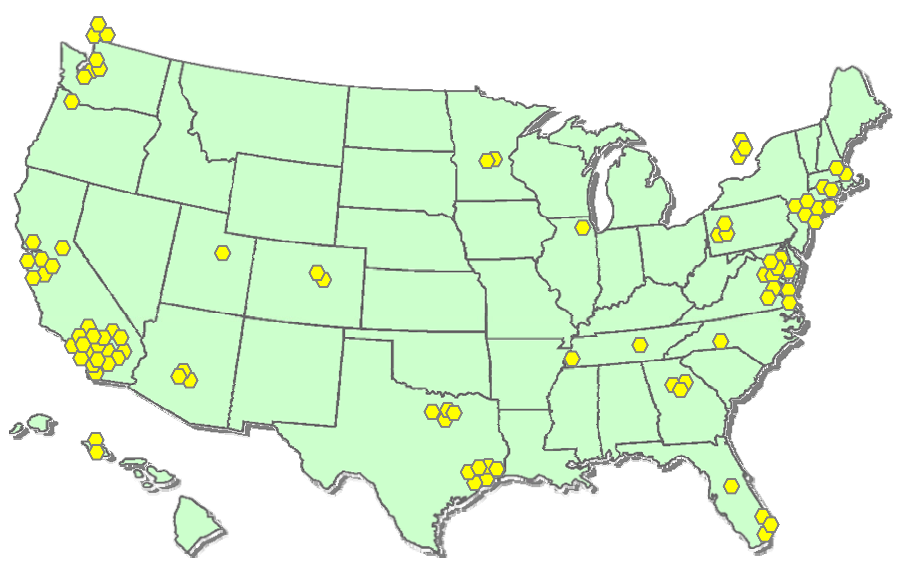


Figure 7: Locations of HOV Lanes in North America



1.3 HOT Lanes

While many HOV projects are adequately used, some are not, leaving space for others to use the lanes. In some instances HOV demand outpaces lane capacity, potentially requiring raising of minimum occupancies to 3+. In both cases, adding pricing to an HOV lane, creating a HOT lane, can help regulate demand better by either permitting others to use the lane or pricing some out. HOT lanes are derived from the concept of congestion pricing, which recognizes that the value of travel-time savings will vary for trips at different times and places and that these trips have different values for different individuals. These different values of time carry a real and perceived value of time-savings at the particular moment for commuters. Depending upon that self-identified value of time, the commuter may elect to purchase their way into an uncongested roadway (saving time) or choose to remain in the general-purpose lanes (saving money), thus providing a commute choice.

HOT Facility: An HOV lane or roadway in which electronic pricing is applied in conjunction with eligibility preference given to buses, vanpools and perhaps carpools to give others a travel option to use the lane. Others may include solo motorists or lower occupancy carpools.

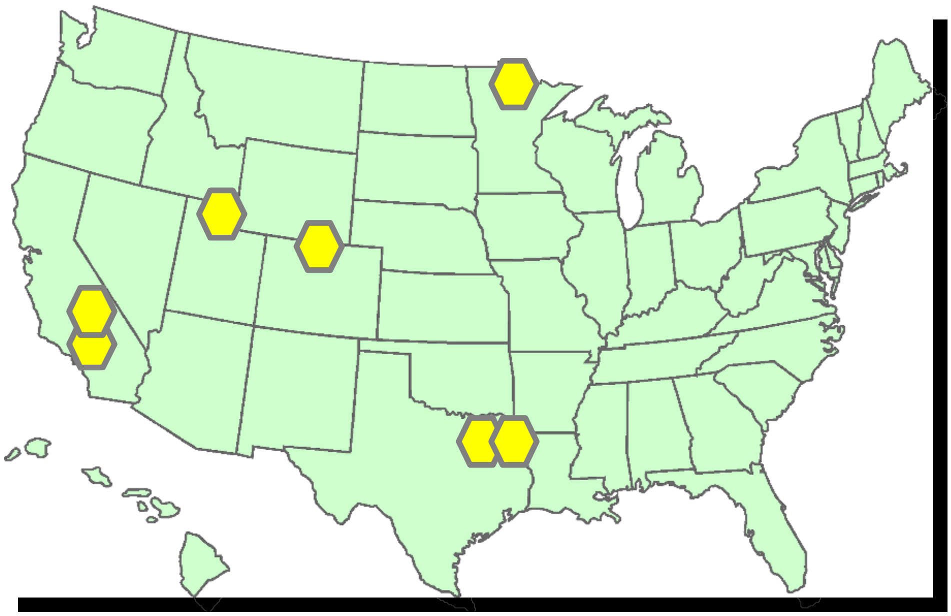
The advent of electronic pricing started in the 1990s. In parallel with this growth in HOV lanes, improved technology was quickly transforming the means by which tolls could be collected on toll roads worldwide. Electronic toll collection through the use of transponders located in the windshields of vehicles was gaining popularity, thereby eliminating the need to stop and pay tolls through a conventional toll plaza (previous Figure 4).

The timeframe this technology took to be adopted closely mirrored, both institutionally and operationally, the ways pricing began to be considered in a wider range of potential applications, both for dual purposes of more efficiently collecting revenue and as a potential traffic management tool. FHWA embraced this potential tool through a series of value pricing initiatives aimed at local and state agencies. Value pricing pilot projects were approved in a number of locales in the mid-1990s. Some of these were awarded to HOV lane projects including those in Minneapolis, San Diego and Houston.

Although the general perception was that pricing could address lack of HOV lane use, pricing was also implemented in these first demonstration projects to address both under-utilization and over-utilization. The first seven HOT lane projects which were implemented from 1995 through 2007 (Figure 8) have involved both conversion (six of seven projects) and addition of pricing to new managed lanes constructed. Two of these seven projects represented full or partial involvement of private equity investors as public-private partnerships (PPPs).

HOT lanes offer one possible means of addressing mobility needs and helping ensure the long-term availability of HOT lanes for improved person movement. Transit and carpools are typically allowed to continue to use the HOT lanes for free. The toll value is set so that their prior “free-flow” level of service is not degraded and in at least one instance, maintained high enough to reflect parity with the prevailing transit fare in the corridor.

Figure 8: Locations of HOT Lanes



HOT lanes make the most sense when:

- The HOV facility's adjacent general-purpose lanes are heavily congested during peak periods;
- Significant excess capacity exists on the HOV facility, even at its peak utilization, or significant excess capacity will be created by raising restrictions on HOV lanes that are overloaded.
- Resources are limited for either expanding roadway or transit capacity; and
- The public is concerned by low utilization of the HOV lanes.

1.4 TOT Lanes

Truck-only Toll lanes offer the potential to apply the same benefits for commercial goods movement as are provided to commuters. While there have been various studies of truck-only lanes and roadways and more recent studies to toll trucks on these lanes, several operational and institutional issues have prevented such lanes from being implemented. These obstacles relate to the need to provide two directional lanes so that trucks can pass one another, otherwise service capacity and operational benefits can be lost. There is also differences in the practitioner community about whether large volumes of trucks, transit and commuter flows can be mixed on such lanes and still preserve the intended level-of-service benefits to all. Perhaps most difficult to resolve is the high cost of building dedicated truck lanes and strong stance trucking interests have taken against mandatory tolling if they were precluded from current highway lanes. This institutional barrier has prevented some potential projects from moving forward.

Studies and plans for TOT lanes have been undertaken in Los Angeles (I-710 and SR 60 corridors), Atlanta (I-75 and I-285 corridors) and Virginia (I-64 and I-81 corridors). Consideration of adding medium-sized trucks on an HOV facility was also studied on the I-880 corridor in the Bay Area. <u>None</u> of these has moved forward into construction.

For TOT lanes to work, they need about 800 trucks per hour (400 per lane for two lanes directionally) with common origin-destinations over a corridor or region. This volume may be considered with other users if all users can be accommodated within a common design with suitable access.

TOT lanes make sense when:

- High volumes of trucks have common origins and destinations which will benefit from a limited access roadway.
- Potential to provide meaningful time and reliability benefits indicates truck toll lanes are cost effectiveness and will generate revenue.
- There is political and institutional support to toll trucks, perhaps by mandating that all through trucks without local destinations use the TOT lanes.

1.5 Other Forms of Managed Lanes

While express lanes that assure a higher level of service through restrictions on access have been operated on various urban interstates in Chicago, St Louis, Seattle and other cities for many years, a broader application of dynamically managing express lanes through tolling is planned for a number of areas. While none of these projects are currently in operation, a variety are planned or being implemented in the U.S. One such project on I-10 (Katy Freeway) in Houston will open in 2008. The Katy managed lanes, two in each direction, will replace a single reversible HOT lane in the median for a 12-mile distance. It will give preference to 3+ HOVs and transit buses as free users. In this context, the Katy project is intended to cover the added construction, operation and maintenance costs, and it is owned by the local toll road authority. Most such toll-express lanes may not involve offering any free or discounted use to HOVs, but rather, serve all traffic. Some planned projects are targeted at offering special lanes to serve commercial goods movement, as exemplified in Atlanta on I-75 and I-285.

While no experiences are available yet from these plans, the nature of how managed lanes will be implemented and who they are tailored to are changing from past experience. Listed below are a few trends to watch.

- Local, state and private toll road agencies may be implementing more managed lanes than traditional DOT-sponsored projects.
- Toll road sponsored managed lane projects are likely to be targeting a pricing structure that pays more of the capital cost, requiring wider lane configurations involving four or more lanes to make them economically viable.
- More managed lane systems will be implemented involving connections between one facility and another.
- Trucks, which value time greater than commuters, may be a more sought-after market for managed lanes.
- The need to create flexibility to serve different types of managed lane users is already apparent, where such lanes may serve a BRT or HOV function in the peak period and a commercial goods movement function in the off-peak, necessitating a more flexible design.
- Planning and design guidance to address wider applications of managed lanes is just now being identified as a national need, and research into best practices is ongoing. It is likely that current plans will be influenced by this guidance before many of these projects are implemented.

Other active traffic management strategies that are applied in Europe and could be employed on managed lanes to improve travel speeds or reliability include dynamic speed controls and temporary travel on emergency breakdown shoulders at traffic bottlenecks. This wide array of emerging management tools is just now being studied in a select number of cities.

Other forms of managed lanes may make sense when:
- General-purpose lanes are heavily congested during peak periods;
- There is not enough HOV demand to justify preferential treatment, but enough commute demand and travel benefits to justify a managed lane.
- Resources are limited for expanding the roadway.

2.0 HOV PLANNING, IMPLEMENTATION & OPERATION EXPERIENCE

Much like the adoption and development of HOV lanes, HOT lane demonstrations often take much Since many more HOV lanes have been in operation for many years, the wealth of these experiences clearly helps guide not only the development of HOV lanes, but other managed lane treatments as well. The following discussion focuses on these experiences and in for subsequent discussions, only refers to the differences in experience with other managed lane treatments.

2.1 Sponsorship and Funding

Successful HOV lane planning and development requires a commitment to build, maintain and most importantly, operate the lanes in perpetuity. Operation requirements can be more intense than for overall freeway operations, because demand must be dynamically managed and use enforced. Most often the state department of transportation (DOT) is the lead agency since the vast majority of HOV lanes are located on roadway facilities owned by the state. There is also a need for involvement from the city, local transit, police and other agencies who share an obligation in making the project a success. Experience indicates each of these functions vary widely, depending on available and interested agency partners.

Funding for HOV lanes typically involves a match from the Federal Highway Administration (FHWA), state and local highway funding sources. Some projects or transit support facilities to HOV lanes have been implemented with matching funding from the Federal Transit Administration (FTA). Funding needs to be considered in project planning include capital project functions (planning, design, construction administration, etc.), costs associated with operations such as enforcement staffing, training, operations management and monitoring performance of operations; and maintenance needs (typically roadway and structures but sometimes inclusive of specialized traffic control devices or tolling equipment). Estimates of these costs should be included in the budget development and capital programming activities. Some costs may be related to one-time events such as project openings, where extraordinary needs associated with enforcement are most concentrated. Project marketing costs need to be considered, primarily for project opening and for ongoing activities of the project. Operations and maintenance costs can be funded from local, state and federal (e.g. STP) funds. Local funding may come from transit providers, particularly where transit service is planned.

HOV project costs vary depending on the type of facility. All involve roadway widening or restriping in some cases to maximize available pavement use. Restripe treatments can cost \$3 to \$5 million per route-mile, assuming one new lane in each direction. Full widening within available right-of-way can cost \$8-15 million or more per route-mile. Barrier separated treatments are much more expensive than buffer-separated treatments due to the extra shoulder requirements, but empirical data show various operational benefits including safer performance, improved reliability and higher overall speeds. Soft barriers (traffic channelizers and pylons) are applied on some projects to reduce this cost, but maintenance costs to maintain and replace these can run \$30,000 per mile annually.

Enforcement represents the most common and significant ongoing operation and maintenance cost over and above the investment already made for regional traffic management. HOV enforcement costs vary widely. An order-of-magnitude cost for concurrent flow lane enforcement on a non-dedicated basis is about $20,000 per mile annually for a modest level of police presence. This level will need to be greatest during the first six months of a new project opening.

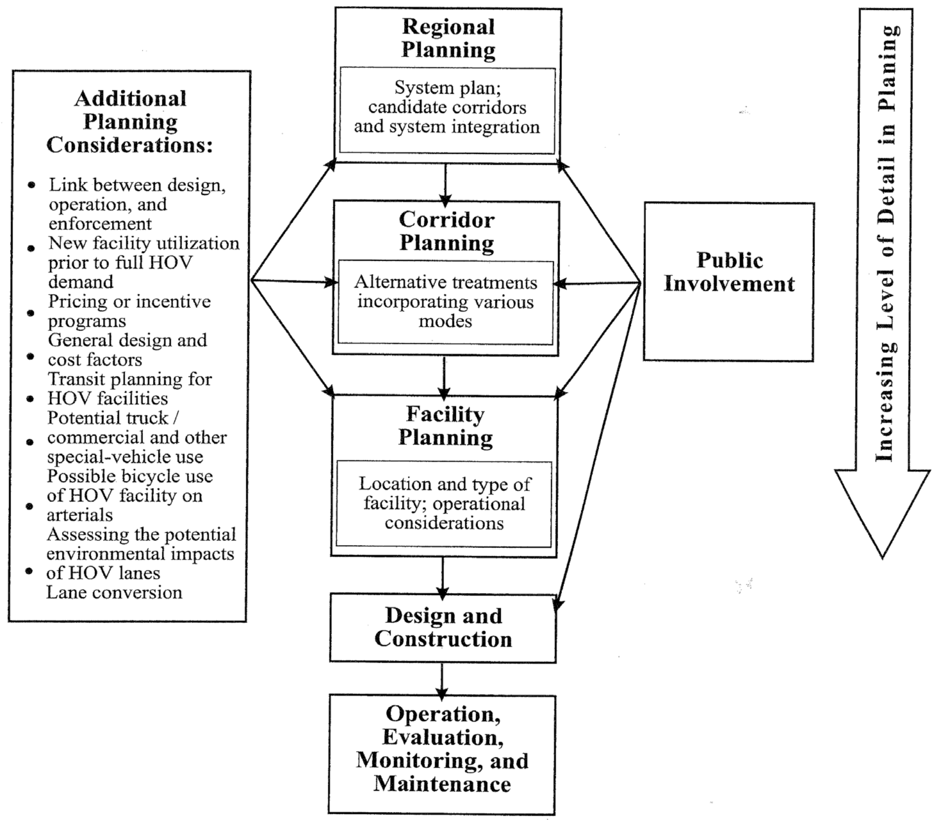
2.2 Planning Experience

For HOV lanes to work, they need a minimum of about 600 to 800 vehicles per hour or about 1800 persons per hour to be considered justifiable. HOV lanes are often implemented as part of a larger transportation investment program for a corridor, becoming part of an overall plan which may include a variety of other capacity, safety and operational improvements. These opportunities often set the stage for development of an implementation plan. Most regions have based a phasing plan on implementing projects of opportunity first, focusing on adding dedicated lanes along a corridor, and then gradually coming back and adding access and safety enhancements as demand warrants. Then enhancements have been added as HOV lane use grows and lane capacity is reached. Phasing for a "first" project in any region sets the stage for overall public perceptions and can affect the success of a managed lane strategy for many years. If the first project is a success, there is less scrutiny on subsequent expansion. If it fails, there is a lowered likelihood that the public will support another similar project. Few projects have actually "failed" or been terminated over the past 30 years, but some projects have been marginalized to the point that they are no longer viable in meeting their original goals. Goals may need to change over time to meet changing commute and demand requirements. Most common pitfalls for failure relate to a lack of congestion (resulting in few benefits), inadequate demand and lax enforcement.

Ideally, a first project addresses the region's most significant congestion bottleneck, serves transit and rideshare needs well, can generate an early level of acceptable demand and is supported by a variety of local partnering agencies at all levels. Not all of these factors need to exist, but they can compliment one another and make the role of marketing more effective with different stakeholders so that all perceive benefits.
Figure 9 highlights general steps in the implementation process. HOV projects progress through regional, corridor and facility or project levels to final design, construction, operation and performance monitoring. Figure 9 shows how the public involvement process needs to be present through all phases of project development. Project management teams should address the major activities listed when planning any HOV facility. Some elements continue through the entire project, such as involvement of appropriate agency stakeholders like transit operators and police.

Planning for HOV (and other types of managed lanes) has usually occurred at different levels. A broad regional planning effort is often taken first before corridor planning occurs. This level focuses on the general needs, issues and opportunities throughout a metropolitan area. The outcome is a long-range plan that identifies the general types of transportation facilities anticipated in the major travel corridors. However, regional plans do not usually define the exact type of treatment or design. More detailed analyses are then conducted at the corridor and facility level. This level is much more detailed and focuses on preliminary alternative design treatments, access options, vehicle eligibility, pricing and other issues. Not all regions in the US have undertaken a top-down approach to HOV planning. Some regions with particularly severe congestion have moved directly into testing HOV on a demonstration corridor basis first. Where this happens, the success of a demonstration has often led to a regional assessment after the fact.

Figure 9: HOV Planning and Implementation Process



Source: Reference 1.

Criteria most often considered when determining whether any HOV lane is appropriate include the following:

- *Congestion:* The presence of severe and recurring congestion indicates that congestion management strategies, including HOV, managed lanes may be appropriate.   A common measure is average travel speeds of 30 mph or less for at least two hours each peak commute period.
- *Bottlenecks:* Specific traffic bottlenecks or congestion points may cause significant delays. The existence of bottlenecks may point to the need for only isolated HOV treatments such as direct access ramps to provide a bypass.
- *Transit Service:* The level of transit service on a candidate roadway can provide an indication of the need for an HOV lane. Bus volumes may justify consideration of some type of HOV lane treatment, particularly at bottlenecks. Factors can include the number of buses, anticipated ridership levels or bus operating time savings.
- *Travel Patterns:* Examining the travel patterns, including origins and destinations served along each corridor, is critical to determining the viability of HOV lanes since the prevalence of common trip patterns is needed to create modal shifts to transit or ridesharing, and access to lanes precludes short-distance trips from taking advantage of a dedicated lane. Trips need to be long enough on a given route to generate time savings that cause spatial and modal shifts into the HOV lane. At the

sketch planning level, this analysis usually focuses on travel producers, such as residential areas and attractions, which include major employment and activity centers.

- *HOV Demand:* Existing and likely levels of HOV demand in a corridor can be used to provide information on potential use for an HOV lane. Vehicle occupancy counts and other available information on potential eligible vehicles in a corridor can be used to ascertain whether enough demand exists to justify a dedicated lane. Minimum demand is critical to determine whether an HOV lane can be a success in its opening year. Person throughput, generated from an assessment of demand, can determine if an HOV lane will move more people than a general purpose lane will. However, the public's perception of success in the HOV lane is also dependent upon the number of vehicles using the lane. This number varies by the type of lane treatment.
- *Available Space to Add a Lane:* No successful HOV lane has been able to be implemented in a congested corridor by taking a general purpose lane and designating it for HOV use during peak periods. This approach often creates more congestion than it addresses due to displaced traffic onto remaining lanes and thoroughfares. So an important lesson learned is that peak direction HOV lanes should be added in some way to the existing roadway. Adding lanes can be accommodated either by widening the roadway or through modifying the existing roadway lanes and shoulders to provide for added capacity. Borrowing a lane from the off-peak direction side of the roadway during peak commute periods may be an option for adding a lane.
- *Connectivity:* The success of a managed lane system may be enhanced if it is part of a larger system of lanes. A specific link in a regional system may affect, or be affected by, other links. Consideration should be given to those HOV lane segments that are critical to an overall network plan. Key links may be needed for specific movements through interchanges or to major activity centers such as CBDs. For example, eligible vehicles may experience significant delays getting from one dedicated lane to another, or weaving into and out of the lane to reach ultimate destinations.

2.3 Types of HOV Lanes

In meeting the unique challenges associated with each corridor's design and operation, various physical types of HOV lanes have been applied. This section addresses the following HOV facility types and orientations.

- Concurrent Flow
- Reversible Flow
- Contraflow
- Queue Bypass
- Direct Access Ramps

Each is briefly described in the following section with comparative attributes when considering different HOV lane design approaches.

Concurrent Flow Lanes

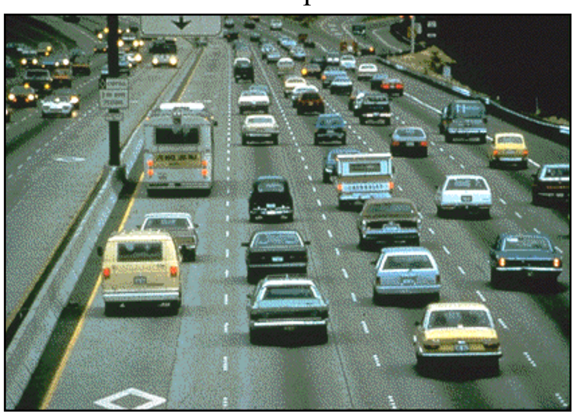
Concurrent flow HOV lanes typically involve the dedication of at least one lane in each direction of travel located next to the median barrier. The lane is either functional during the respective peak period and peak direction or operational at all times (Figure 10). This operation is appropriate where demand and congestion is evident in both directions of travel, either within the respective peak directions or for both directions. The geographic dispersion of trip patterns in many emerging cities exhibits this characteristic. The use of two-way operation eliminates the need for directional traffic control features, allows for continuous use, and is the most flexible to fit within an existing freeway where bridges columns and other freeway and roadway impediments are located such that symmetrical widening is the only approach that is practicable. For these reasons concurrent flow lanes far surpass all other forms of HOV lane treatments and orientations, representing about 70 percent of all route-miles implemented in the U.S.

By locating the HOV lane next to the median, high-volume, high-speed traffic may be maintained. Several outside concurrent flow "shoulder" bus lanes exist in various cities (e.g. Minneapolis, Toronto, Ottawa, Vancouver) and are primarily applied where both entering/exiting ramp volumes and bus volumes are low, thus alleviating any cross-over friction. Most concurrent-flow median lanes carry a traffic volume that would preclude consideration of right side lanes for safety reasons.

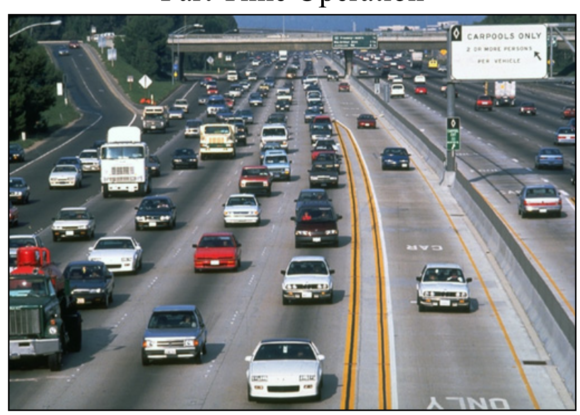
Concurrent flow lanes have many different forms of access and separation treatments. While most are separated by a dashed or solid pavement marking or narrow buffer from adjacent lanes, examples exist which are separated by concrete barriers and plastic traffic channelizers or pylons. Some lanes operate only part-time, reverting to general traffic use during off-peak periods, and thus, allow continuous access.

Figure 10: Concurrent Flow HOV Lanes

Full-time Operation



Part Time Operation



Concurrent-flow lanes are applied when:
- Corridors have balanced directional splits (less than 60% in the peak direction)
- Substantial congestion exists in both directions
- Design makes this approach the most cost effective from a capital and operation and maintenance perspective.

Potential advantages:
- Cost effectiveness is often favorable, since fewer modifications are typically required and demand can be served in one or both directions for the same relative construction investment.
- Less right-of-way is usually required than with other treatments.

- Faster implementation is possible, particularly if widening can occur within an existing median.

Potential disadvantages:

- Lower performance (slower speeds and vehicle throughput than other treatments) due to side friction caused by stopped or slowly moving traffic.
- Greater likelihood that crashes or incidents on either roadway will affect both traffic streams.
- Enforcement is more complicated by traffic able to enter and exit lane indiscriminately.
- Unless barrier separated, potential safety issues may arise. Some recent studies show a higher than average accident rate associated with speed differentials between parallel traffic streams.
- HOVs may have difficulty merging across the general-purpose lanes to enter and exit the concurrent flow lanes, although most projects report that ingress/egress movements, whether allowed continually or at designated locations, can operate well without adversely affecting performance.

Reversible Flow Lanes

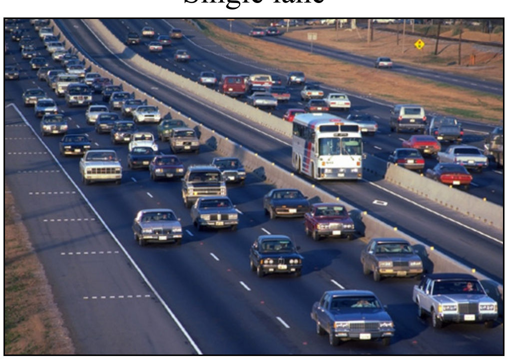
Reversible-flow operation can be appropriate when there is a substantially higher demand traveling in one direction than the other, and when the heavy travel demand reverses between the morning and afternoon peak periods (Figure 11). Unequal directional traffic distribution exists in urban areas where most of the residents who live in outlying suburbs commute to their places of employment in the morning peak period and return home in the evening peak period. The observed directional split, or lack thereof in some corridors, can depend on the number of available mixed-flow lanes, nature of commute trips and dispersion characteristics of commuters. Because of the need to safely separate oncoming freeway traffic and avoid confusion, reversible-flow operations on freeways are always barrier-separated, gated and controlled through a combination of remote and on-site monitoring. For arterial settings reversible lanes may be activated through overhead lane controls, signals and signing. Some limited on-site deployment personnel is needed for freeway applications and may be needed for arterial treatments.

Consider reversible lanes when:

- Corridors are forecast to have high directional splits (60/40) of the target market of travelers
- Substantial congestion will exist in one direction, and a low or tolerable level of congestion will exist in the other (off-peak) direction during the peak periods

Figure 11: Reversible Flow HOV Lanes

Single lane



Dual lane

Potential advantages:

- Positive separation from adjacent traffic operations, thereby improving performance
- Better service in the only direction where congestion warrants a dedicated lane treatment
- Ease of enforcement

Potential disadvantages:

- Higher cost than other treatments as widening may require replacement of median oriented bridge columns, signs and drainage structures
- Greater need to monitor and quickly respond to incidents, and potential for wrong way movements
- Harder to respond to incidents due to infrequent access openings
- Harder to sign and mark
- On-site personnel required to confirm proper deployment and closure, even if the traffic controls are automated

Contraflow Lanes

Much like reversible flow lanes, contraflow operation requires a select set of conditions in which demand is strong in a peak direction and unused roadway capacity exists in the off-peak direction. One or more off-peak lanes are borrowed for peak direction HOV use by the daily deployment (placement and removal) of moveable barriers or pylons to separate the opposing flows (Figure 12). Contraflow lanes are created only for the specified operating period and returned to general traffic lanes at other times. For example, a contraflow lane borrows an outbound lane in the AM peak and converts it to inbound HOV operation, or vice versa in the PM peak. This strategy requires unique conditions to exist, such as safe places for HOVs to cross-over the median at each end of the project to enter the lane, space to place and store moveable barriers and special moving equipment next to the median, and a commitment to daily operations by a team of trained personnel to move and place barriers or pylons, and activate other traffic control devices. Contraflow lanes are rarely applied because of their relatively high operating costs and needs for specialized barrier moving equipment.

Figure 12: Contraflow Lane using Moveable Barrier

Contraflow lane in operation

Barrier moving machine

Consider contraflow lanes only when:

- There is a high directional split (preferably 70/30) of the target market of travelers and where the remaining lanes for off-peak direction traffic will not be adversely affected by the loss of borrowing one or more lanes
- There is little need for intermediate access (i.e., long distance demand with common trip ends)

Potential advantages:

- Provides a relatively low-cost way of adding capacity and addressing traffic congestion in some corridors where excess off-peak roadway capacity exists
- Easy to enforce and regulate at a single entrance point
- Relatively safe, with a proven track record in a limited number of locales

Potential disadvantages:

- High operating and maintenance costs compared to other HOV lane treatments
- Limited access, best when operating as a "pipeline" between an entrance and exit
- Safety concerns may also be higher with contraflow facilities that are not barrier separated, requiring consideration of exclusive use by professional drivers

Queue Bypass Lanes

The nature of congestion may warrant a short-distance dedicated lane around an isolated bottleneck. This treatment is termed a queue bypasses. Queue bypasses allow buses, HOVs or trucks to save time by avoiding congestion associated with an isolated bottleneck. The bottleneck may be operationally induced by factors such as congestion bottleneck or may be artificially induced by factors such as a ramp meter, ferry dock, or toll plaza. Queue bypasses offer a dedicated lane for HOVs to bypass bottleneck. If located at ramp meter, the HOV lane may be metered at a more frequent rate or not metered at all.

Queue bypasses can be considered in conjunction with (or separate from) longer distance median HOV lanes on the same roadway. There are literally hundreds of HOV queue bypasses operating along freeway entrance ramps in a number of states including California, Washington, Minnesota and Nevada. The largest number is in California (Figure 13).

Figure 13: Freeway Ramp Meter Bypasses

Consider queue bypasses when:

- Congestion is limited to a site-specific location
- Modest HOV time savings benefits can be provided for relatively low cost.
- Demand for the bypass is justified, usually by a transit service or a minimum of about 100 HOVs per hour

Potential advantages:

- Cost effectiveness, since only a limited amount of widening is required for a short distance
- Fast implementation, due to the modest nature of the improvement
- Can be a "stand-alone" improvement not requiring full consideration of HOV lanes and supporting facilities in a corridor

Potential disadvantages:

- Modest benefits, not typically sufficient to generate mode shifts into transit or rideshare modes
- Enforcement made more complicated by traffic able to enter and exit lane at will
- Users may have difficulty merging into and out of the bypass lane

Direct Access Ramps

Access may be continuous or at designated locations along concurrent-flow HOV lanes. If access is designated, openings can be delineated through striping with the adjacent lanes, or through direct access ramps as shown on the next page. Direct access ramps reduce weaving across the general use lanes and provide time savings for high HOV volumes. Such access ramps typically serve both directions, since the lanes are patterned similarly. Low speed access ramps can service local streets and transit facilities. High speed ramps service major interchanges where one HOV lane accesses another.

Reversible and contraflow lanes require access only at designated locations that can be gated. The associated access connector can be reversible flow that serves only the peak direction. Typical examples of both types of direct access ramps are provided in Figure 14.

Figure 14: Examples of HOV/Managed Lane Direct Access Ramps

Examples of Two-Way Connector Ramps to Concurrent-flow Lanes

Examples of Reversible-flow Connector Ramps

2.4 HOV Operation Experience

Over 35 years of operation experience has been accrued on HOV lanes in the U.S., largely on freeways. Arterial experience is perhaps longer dating from the 1950s, but this experience has largely been related to reserved bus lanes in highly congested urban cores. Experiences for freeway HOV lanes are briefly summarized below.

- HOV operations typically include a restriction on either limiting use to 2+ or 3+ HOVs. Deadheading transit buses clearly defined as buses are considered exempt along with emergency response vehicles in transit to an incident. Motorcycles are exempt from occupancy requirements by federal law. Hybrid and inherently low emission vehicles may be allowed as registered users of an HOV lane if they meet specific federal criteria and studies are undertaken to ascertain if their inclusion will adversely affect operation. Such inclusion is subject to other federal program requirements that are still in the process of being prepared by the USDOT based on SAFTEA-LU provisions.
- Operational benefits are typically time savings, and the average time savings for successful projects is around 0.5 minutes per mile traveled. It takes about five minutes of accrued savings on a given trip to sustain HOV mode shifts into transit or carpools.
- Operational benefits are most compromised at the project termini where the HOV lane rejoins other lanes and users are forced to merge back into regular flow. Some studies have found fully half or more of the time savings benefits offered are lost at these locations unless the HOV lane is carried downstream without the designated restriction and a general purpose lane is dropped on the right side.
- The greatest challenge to HOV benefits is violators who frequently can enter and exit a concurrent-flow lane and not be apprehended. Other forms of HOV lanes make such violations more difficult and enforcement easier.
- HOV lanes can be operated in the peak periods only, reverting to general purpose lanes at other times if they are implemented as concurrent flow lanes, or they can be operated all day or 24 hours a day. Some types of treatments, namely reversible flow and contraflow lanes, are operated only in

the peak commute direction and must be closed during parts of the day so they can be redeployed in the opposing direction.

- The greatest operational expense for an HOV lane is enforcement. If a reversible or contraflow lane is implemented, then the normal transition costs for deploying the project will represent the greatest expense, requiring a complement of staffing on site for freeway treatments.
- Typical maintenance for HOV lanes involves sweeping the lane of debris, particularly if it is located close to the median barrier without proper shoulder space to catch debris. Other requirements involve ITS, pavement, signing and marking maintenance. These roles are no different from other routine roadway maintenance needs.
- Operational safety issues are different for each type of HOV lane treatment. Concurrent-flow lanes are exposed to side friction from the speed differentials associated with the two parallel traffic streams, and designating narrow buffers can help alleviate some of this friction. However, even the best designed concurrent-flow lane operations seldom provide greater than a 20 mph speed differential (i.e., HOV travel speeds of 40 mph next to general traffic operating at 20 mph). So the travel and reliability benefits of a concurrent flow (no-barrier) operation are limited, and trade-offs to the lower capital costs often associated with barrier separated HOV treatments. Reversible and contraflow lanes can create potential for wrong-way movements. These projects require greater design attention to transitions and ramps, employing gates and other traffic control devices to help ensure safe operation. Queue bypasses need good visibility and enough use to avoid becoming another ramp lane that general traffic uses. All HOV treatments can be operated safely, but their different characteristics suggest that design and operational policy practice should be developed based on similar projects in other regions where experiences have been gained.
- Performance monitoring is undertaken for many, but not all HOV projects nationally. FHWA encourages performance monitoring to help address any safety and operational issues, provide a basis from which to measure performance to established goals, and base decisions related to needed changes in design or operation policy.

For arterial concurrent-flow HOV treatments which are largely located next to the curb, many more operational issues can arise. Curbside and intersection conflicts make preservation of space, even during peak hours, more difficult. Competition for through bus and turning movements complicates signal phasing, enforcement and reliability. For these reasons, few arterial HOV lanes in congested areas serve a wider base of users than buses. The higher the bus frequency, the greater the potential that the arterial lane becomes somewhat self-enforcing.

3.0 HOT PLANNING, IMPLEMENTATION AND OPERATION EXPERIENCE

3.1 Background

Much like the adoption and development of HOV lanes, HOT lane demonstrations often take much longer to plan and implement than first envisioned. Early expectations in the mid-1990s among various articles and papers written and new media released were that most if not all HOV lanes would have pricing installed by the end of the decade. In reality some 12 years later, fewer than five percent of the HOV lane-miles currently in operation are HOT lanes, and half of these projects have been operational for a decade or longer. Pricing policy also tended to be more polarizing as a public and political issue than originally believed with many perceptions – positive and negative – driving the decision-making process to proceed forward. As a result, some HOT projects have not moved forward and other moved forward only after several attempts. Common reasons relate to lack of a political champion, weak public outreach efforts, inadequate revenue forecasts to cover costs, lack of future capacity to sell (if eligible HOVs were continued to be given free use), and misunderstandings about the level of investment ultimately required to adapt the existing HOV project for pricing.

A prevailing sentiment in the 1990s was that meaningful revenue could be gained by pricing an HOV lane, thereby creating significant financial windfalls to not only cover the added operation and maintenance (O&M) associated with pricing installations, but also generate excess revenue to help offset capital construction costs. While these experiences were true with some demonstrations located in highly congested areas where more than a single directional HOV lane was priced, they were not true for a majority of candidate corridors. In fact, at least five of the seven current HOT lanes in operation do not generate enough revenue to cover their operation and maintenance (O&M) costs, nor are they expected to. Pricing was implemented in these locations to make better use of the HOV lane and better manage traffic.

All HOV lane candidates ended up not being the same in terms of ease of conversion. The first pricing demonstrations were accomplished on rather "low-hanging fruit," on barrier-separated projects serving as conduits in their region and providing only point of access and egress. These physical attributes made the augmentation of pricing installations rather simple and easy to enforce. A single electronic tolling installation could capture all potential users, and communicating the toll at the entrance involved straight forward signage. Accordingly, these demonstrations were able to be rather easily implemented and declared successes. Some of the first candidates to open in the mid-1990s, notably I-15 FasTrak in San Diego and the SR 91 Express Lanes in Orange County, were financial successes insofar as exhibiting enough demand to help offset other unrelated expenses to operation and maintenance. I-15 generated excess revenue above O&M costs in its first decade of operation with this excess applied to subsidizing transit service in the corridor, a policy which has generated positive public support among users and non-users. However, recent adjoining roadway improvements have siphoned enough demand off the corridor that HOT lane demand is down and significant excess revenue generation is doubtful.

Experiences with project delivery have largely reflected public agency sponsorship. SR 91 was the only HOT lane constructed as a public-private franchise awarded by the public sector. However, the Orange Country Transportation Agency – a local public authority sponsoring road and transit projects –

recently purchased the Express Lanes in order to circumvent a non-compete clause in the franchise agreement which precluded other needed road projects from being implemented.

Success was defined in other ways on the remaining five projects. In Houston a vast network of reversible lanes was implemented on most of the region's radial freeways to feed express buses directly from remote park-and-ride lots to distant employment destinations including the CBD. This system was subsequently opened to carpools of two or more. When some corridors reached capacity, and something had to be done to curb demand and occupancy requirements were raised to a minimum of three or more persons per vehicle. This approach caused excess capacity to be created. Pricing was augmented sell back this capacity to two-occupant carpools on the US 290 and I-10 corridors. Thus, pricing was demonstrated as an effective means of balancing HOV demand.

In Minneapolis, early technical feasibility was found on the region's I-394 HOV facility since it contained two reversible lanes which were designed to handle a higher level of demand than was being experienced. Beyond an early indication of technical feasibility, getting political support proved elusive for several years. Eventually the project was implemented in concert with a limited PPP to add pricing for both the reversible and adjoining concurrent-flow HOV lanes, thereby testing the potential for testing multiple tolling zones and enforcement tools to better handle management on an open-road environment without barriers to adjacent lanes.

Denver also found it would be feasible to convert the I-25 HOV lanes to HOT operation but had to consider the impacts to federal transit funding which was largely employed to implement these lanes. Resolving federal policy on this issue, together with the need to address ingress and egress improvements to address the added HOT demand, took several years. The project opened in 2006 with a well prepared education and outreach effort.

Salt Lake City initiated pricing on I-15 HOV lanes in a very straight-forward fashion at low cost, demonstrating that HOT lanes need not be sophisticated or involve intensive investment. A monthly fixed fee of $50 is charged for unlimited use with registration handled over the internet. The total number of registrations is capped to avoid over-taxing the HOT lanes. Eventually the project will evolve to electronic pricing to better manage demand as the lanes are extended south toward Provo. A similar sticker or "vignette" scheme was used on the I-15 in San Diego to test the HOT concept on a trail basis prior to the decision to make the HOT operations permanent and install electronic toll collection equipment.

3.2 Planning Experience

The planning implementation process associated with HOT lanes is deceptively similar to that of other highway improvements. However, there are a number of issues that are likely to arise that may require special attention and have the potential to introduce the unexpected. This section discusses some of the issues and challenges that are likely to arise in the planning process for HOT lanes.

In order to appreciate the types of issues that distinguish the planning process for HOT lane project it is helpful to note how HOT lanes different from traditional highway and HOV projects.

- For a HOT lane to work, it needs about 1200 to 1500 vehicles per hour which are either HOVs or toll-paying users

- HOT lanes use market price and other management tools to provide dependable and superior travel conditions, particularly during highly congested peak travel periods.
- HOT lanes provide a new and desirable transportation option for motorists and transit users in congested travel corridors.
- HOT lanes generate revenues that can be used to pay for their implementation or to help underwrite other transportation improvements.
- HOT lanes can be implemented among any of the types of facilities described for HOV lanes.
- HOT lanes require considerable attention to roadway management, including monitoring traffic operation and responding to incidents.
- HOT lanes offer new ways to apply traffic management and toll collection technologies.
- HOT lanes require ongoing marketing and pubic awareness outreach efforts.
- HOT lanes are likely to require interagency cooperation.

HOT lanes utilize traffic management techniques – pricing and occupancy requirements – in new ways, and in many jurisdictions HOT lanes may involve the introduction of tolls for the first time. These facts may require DOTs to establish new legal and institutional structures and operational capabilities before HOT lane projects can actually be implemented. They may also introduce unfamiliar project financing and operational approaches. Most importantly, they introduce public relations challenges that have the potential to bring HOT lane initiatives to an abrupt halt at nearly any stage of their development. While many planning studies have been conducted since the mid-1990s indicating technical feasibility toward adding pricing to HOV lanes, relative few projects have moved forward or moved forward as quickly as originally envisioned. The following issues seem to have steered the development of HOT lanes for many of the planned and current projects, including candidate locations that were not pursued.

- Public and Political Attitudes

  Pricing on managed lanes often gets wrapped into overall perceptions regarding tolling, particularly in areas without any toll roads or recent tolling experience. Both the context for pricing as a traffic management strategy and the need to regulate demand on a finite piece of roadway make it difficult to move forward without this understanding in place. HOT lanes are often misconstrued as toll roads for the primary purpose of making revenue. It takes many champions to push pricing in a region and only one significant, respected voice to stop the project. More potential HOT projects have been stopped for this reason than perhaps any other. As attitudes have changed over time, as in Minneapolis, the HOT project has been able to happen.

- Governance and Control of Revenue

  If there is meaningful excess revenue that is likely to be generated from a HOT lane, who manages the project and collects the revenue becomes more important to other partnering agencies. Addressing this issue early in the planning and development process helps foster a sound basis for partnering support. Multiple agencies may play a role in planning, implementing, operating and maintaining the HOT lane, based on resources they can provide. Many existing HOT lanes involve the DOT, local transportation agencies (both transit and toll operators) and enforcement agencies.

- Funding

  Funding will seldom cover the total cost for constructing lanes as a new HOT lane project, but funding may come close to covering the added capital improvements, operations, maintenance, and enforcement costs of pricing on an existing HOV lane. Perceptions by policy makers, often exacerbated by toll advocacy groups, have raised expectations in many studies that the revenue generated for a new HOT project can cover all associated costs, particularly for added lanes. This likelihood is rare for most areas and has affected the pace and interest in conversions. Reasons relate to the nature of demand and finite road space being considered for pricing. In most urban areas, congestion is limited to several hours each peak period, not all day. HOV demand even on marginal projects often consumes 40 to 60 percent of a single lane's capacity, leaving little to sell, particularly in future years. These conditions are common because most urban areas such as Charlotte do not exhibit congestion all day, and most existing HOV lanes only provide one dedicated lane in each direction. Funding will need to be sought from other sources to augment HOT lane development in most instances.

- Design

  Many HOV lanes were implemented as design exceptions to prevailing roadway standards with the requisite understanding that only a limited number of vehicles, often involving trained or professional drivers if designed for buses, were to use the lanes. Opening up some projects to all traffic involves revisiting both the adopted design and how the HOV lane is separated from adjacent traffic. For example, most HOV lanes cannot accommodate trucks due to vertical and horizontal restrictions from bridges, drainage inlets and median barriers. Design issues have caused the cost for conversions to grow substantially above original estimates.

- Enforcement

  More effort is often placed on the enforcement community in trying to determine who has paid and who is allowed to travel a HOT lane for free. While technology and legislation exists in most states with toll facilities to process toll evaders by mail, on-site enforcement presence is still required for occupancy compliance among HOVs. This added burden is an ongoing issue affecting the efficacy of enforcement practice.

- Tolling Policy

  Equity is a major issue often raised in public forums in the conversion discussion. Although the option to pay or not pay a toll is typically discretionary among prospective users and current experience shows rather universal appeal at all income levels, the concerns raised still need attention in the planning and development process. While dynamic pricing which responds to changing traffic conditions offers the most precise ability to manage the roadway, communicating an understanding of this policy can be complicated. Tolling policy must weigh management needs against simplicity of public and user understanding.

- Institutional and Legislative Hurdles

  States may not have legislation or the institutional framework in place to sponsor pricing, since tolling requires back-office of support for administering toll tags, account management and enforcement. Federal funding for the original HOV project may require resolution to pay-back options under a toll initiative, transit may be adversely affected and the environmental documentation may have to be revisited with affected resource agencies. Federal program guidance is available to address some of these issues. Addressing these needs has slowed HOT adoption on current projects and demonstrations.

- Communicating with Users

  With the likelihood of multiple ingress and egress locations and variable pricing to best match limited roadway supply with demand, communicating the toll rate becomes complicated. Various strategies are being employed, and more will be learned from projects currently set to open. Users also want to know what travel benefits they are gaining when electing to enter a HOT lane, either in terms of travel time to their destination or speed on the lanes. Signing must be simplified and yet meet these needs. The upcoming edition of the MUTCD will attempt to address this issue.

3.3 Public Outreach for HOT Lane Projects

While they will utilize many of the same techniques to exchange information, public outreach activities designed for HOT lane initiatives need to be *different* from those designed for more conventional transportation improvements.

Education

HOT lanes are a new concept in most places, and public outreach for HOT proposals should involve a larger educational component than traditional transportation projects. HOT lanes are unlike conventional resurfacing or interchange reconfiguration projects where the public may readily understand the future benefits. HOT lanes' market-oriented approach to allocating roadway space is often a new concept to the public, and outreach efforts need to teach the public what distinguish HOT facility user fees from ordinary tolls. Where the public knows that HOT facility tolls purchase premium traffic service, reliable trip times and time savings, support for HOT facilities may be greater. Therefore, effective public outreach efforts for HOT projects will communicate the critical function of user fees, how and by whom tolls will be collected, and how toll revenues will be spent.

Equity

Given that HOT lanes provide paying drivers the opportunity to bypass congestion, some critics have asserted that HOT facilities favor higher income individuals. In spite of this concern, HOT lane usage data show that drivers in all income brackets use and support the facilities.
Experience from the nation's operating HOT lane facilities indicate that lower income motorists support HOT lanes and use them when circumstances dictate that the reliability of their trip time is more important than under ordinary circumstances. The same applies to self-employed contractors and other small business people, who must make appointments on time or risk lost business.
Outreach efforts that to listen to the public's concerns, address equity questions directly, and communicate experiences from operating HOT facilities can allay local concerns that HOT project benefits may be enjoyed unevenly.

Disposition of Toll Revenues

Because HOT lanes produce revenues, a number of policy questions and administrative issues come to the fore. Depending on the locale, community stakeholders and elected officials may have a keen interest in how the toll revenues will be spent. Some communities may be more accepting of the facility if the generated revenues are used only for a dedicated purpose or a specific initiative, while other communities may support using the fees to support the general fund.

Project Champions

A prominent project champion can be one of the most instrumental factors in garnering support for a HOT facility proposal or its implementation. A public champion may be an elected official, a community leader, or private sector leader who effectively communicates an individual or organizational rationale for supporting the project. Although local departments of transportation, transportation authorities, MPOs will likely serve as HOT lane sponsors, respected public figures who are not transportation professionals can play a critical role by supporting the project.

Public champions may guide the development of HOT lane projects during critical public outreach processes. In some cases, a project champion may also be influential in political processes if the HOT project requires legislative action or if it is debated in public elections. Project champions also act as effective coalition builders for a project, building consensus among different interest groups.

Building Consensus

Public outreach efforts establish meaningful processes for public participation in the planning and implementation of transportation projects and ensure that the different stakeholders have a voice in the planning process. This enables diverse interests involved to arrive at a transportation solution that is broadly accepted and beneficial.

As discussed above, the backing of political champions is often an essential element in building political consensus. Greater involvement by local and regional officials and stakeholders, in early planning stages and onward, may increase the effectiveness of public outreach efforts for HOT lane facilities. Including a broad spectrum of stakeholders in the public outreach can be critical. In many cases, a single decision maker, such as a governor or mayor, may be in a position to derail or bolster the proposed HOT project. Greater involvement by local business leaders, community groups, and other public officials in project planning helps to ensure that key decision makers will consider the broad range of interests when they take a position on a proposed HOT project. Table 1 identifies a wide spectrum of stakeholders who may be willing to support HOT lane project, together with their likely motivations for doing so.

3.4 HOT Operational Experience

While an increasing number of state DOTs are studying the HOT lane concept, there are only six HOT lane facilities currently operating in the United States. This section provides basic information about these facilities, together with analysis of the lessons learned from their operational experience.

Table 1: Stakeholders Commonly Involved in HOT Lane Projects

Group	Why they may support
Newspaper Editorial Boards and Local Media	Media support may come where the project rationale is well understood and where editorial boards believe the project benefits and deserves support of their readers.
Elected officials	Elected officials may support if they favor the HOT lanes' market-oriented approach HOT facility benefits, if they want an innovative project in their district, or if their constituents support the proposal.
Environmental Advocates	If a HOT project converts an existing general-

Group	Why they may support
	purpose lane, it could make single-occupant auto travel less attractive.
Taxi Associations	Taxis that use a HOT lane may be able to generate more fares in less time during peak periods.
Transit Agencies; Transit Advocates	In corridors without preferential lane treatment for HOVs or transit, transit operators may support HOT lanes due to transit time savings.
Emergency Medical Service / Police and Fire Departments	A HOT facility may enable emergency services to respond more quickly to incidents.
Rideshare Agencies, Transportation Management Associations	For an over utilized HOV lane changing from 2+ to 3+ HOT operation, HOT lane tolling may enable the facility to recapture operational benefits.
Employers; Business Groups	Employers and business may support HOT lanes for the potential to make transportation operations more efficient and to reduce delay time.
Developers	Developers may support HOT facilities that enhance access to office buildings, shopping centers, residences or other locations they own.
Neighborhood Associations	Area residents may support the HOT facility if it enhances their mobility and travel options.

State Route 91 (SR 91) Express Lanes – Orange County, California

SR 91 Express Lanes are a 10-mile, four lanes, HOT facility located in the median of an existing highway. Opened in December 1995, current toll rates on the Express Lanes vary from $1.2 to $9.25 by time of day, day of the week and direction of travel. Orange County Transportation Authority (OCTA) monitors traffic conditions and adjusts toll rates on a regular basis in order to maintain smooth free-flow traffic conditions. In 2006, for example it made adjusts to toll rates in 10 out of 336 commuting hours per week.

Motorists using the Express Lanes must have a prepaid account and transponder to use the Express Lanes. More than 170,000 FasTrack™ transponders are currently in use on the SR 91 Express Lanes. In order to encourage carpooling in the SR-91 corridor, vehicles with three occupants are allowed to use the Express Lanes at no cost. In addition, OCTA offers 50 percent discounts to motorists driving zero-emission vehicles or motorcycles, as well as those diving vehicles with disable veteran or disabled person license plates.

As shown in Table 2, traffic volumes and revenues have demonstrated dramatic growth over the past several years, with average daily trips increasing from 23,850 in 2000 to 40,110 in 2007. Due to the SR-91's pricing policy increased traffic volumes have not resulted in congestion, as higher toll rates during peak periods encourage users to travel at other times of the day.

In fiscal year 2007 annual revenues in fiscal were $40.6 million. Revenues are used primarily to service OCTA's underlying debt from its purchase of the SR-91 Express Lanes and to cover operating and maintenance costs. Toll receipts will also be used to leverage additional debt to cover the cost of the planned expansion of the Express Lanes further into Riverside County.

Table 2: SR 91 Express Lanes Historic Traffic and Revenue Data

Fiscal Year	Average Daily Transactions	Annual Toll Revenue
2002	23,850	$23,320,000
2003	28,400	$26,560,000
2004	30,600	$26,972,000
2005	34,900	$32,518,000
2006	38,860	$37,510,000
2007	40,110	$40,574,000

Source: OCTA, 2007

I-15 FasTrak – San Diego, California

The I-15 FasTrak involved the conversion of an underutilized preexisting eight-mile 2-lane HOV facility built in 1988 to a peak-period reversible HOT. Opening for operations in December 1996, the I-15 FasTrak program allows single occupancy vehicles to pay a toll ranging from $0.50 to $4.00 to use the HOT lanes normally reserved for vehicles with two or more occupants. While toll rates do not normally exceed $4.00, they can spike as high as $8.00 during periods of peak congestion.

Customers must have a FasTrak account and transponder to use the HOT lanes. HOV2+ vehicles may use the facility at no cost. The I-15 FasTrak generates approximately $2.0 million in annual toll revenue. This covers its $750,000 annual operating costs and $60,000 for enforcement provided by the California Highway Patrol. Project revenues are also used to fund the Inland Breeze (Route 980/990) express bus service which operates in the I-15 corridor.

The project is sponsored by the San Diego Association of Governments (SANDAG), the local metropolitan planning organization (MPO). Daily traffic volumes on the I-15 FasTrak lanes increased from 5,000 vehicles a day in 1988 to 13,600 vehicles a day in 2002. In addition, more than 900 people a day ride the 53 county buses that use the lanes. Motorists using the Express Lanes can generally travel times by 10-15 minutes.

The I-15 FasTrak is the first variably priced toll facility in the United States to use real-time dynamic pricing. The automated system sets toll rates every six minutes and used real time information on travel conditions in the parallel general purpose lane to adjust toll prices up or down in order to maintain free-flow travel conditions on the lane while maximizing through put.

Initially the dynamic pricing system calculated toll rates based on a singe traffic service measurement made at the tolling point two miles from the southern end of the FasTrak lanes. As a result, when localized congestion occurred elsewhere along the corridor, the system did not always detect the effects of tie ups in time to trigger toll increases to keep the lanes in free-flow condition. As a result of frequent delays at the northern end of the facility where the lanes merge back into the general purpose lanes, SANDAG completed a study of the situation in 2005 that recommended implementing a supplemental toll-setting algorithm that would override the earlier system whenever congested conditions are detected at any of several traffic monitoring points.

The I-15 Managed Lanes will be constructed in three segments. The first segment, also known as the middle segment, is scheduled to open between State Route 56 and Rancho Bernardo in late 2007, and between Rancho Bernardo and Centre City Parkway in the City of Escondido in late 2008.

A movable center barrier inside the I-15 Managed Lanes will allow for up to three added lanes in the peak direction. Carpools and FasTrak users will be able to enter and exit the managed lanes from the main freeway lanes at approximately seven access points along I-15. The tolls on the managed lanes will be charged on a per-mile basis that is based on traffic conditions.

A BRT system will operate in the I-15 Managed Lanes by 2012. Transit stations and park-and-ride lots will be located along I-15 and connected to the managed lanes via direct access ramps. BRT buses, carpoolers, motorcycles, permitted 'clean air access' vehicles, and FasTrak customers will be able to access the managed lanes through these direct access ramps in addition to the regular freeway on-ramps and the in access points.

SANDAG has embarked upon a major expansion of the I-15 FasTrak that will extend the facility to a total of 20 miles and widen it from two to four lanes. The first segment of the expanded facility is slated for completion in late 2008. Work will then begin on the northern most segment of the corridor and the project will conclude with the widening of the existing 8-mile section. SANDAG plans to operate bus rapid transit (BRT) service on the expanded corridor, which will include large park-and-ride lots and BRT stations with dedicated slip ramps providing easy access to the FasTrak lanes. Interestingly, Caltrans and SANDAG are using traditional financing sources rather than toll-backed debt to pay for these expensive improvements. SANDAG's primary motive for embarking upon the project is to improve mobility in the corridor.

Katy Freeway QuickRide – Houston, Texas

The Katy Freeway is an existing highway with a 13-mile, 6-lane freeway with a single-lane reversible BRT lane in the median. In 1998 the lane was opened to HOV 2+ traffic, bus soon became over-utilized. The facility was the converted to HOV 3+ operation in order to reduce congestion. However, this change resulted in excess capacity on the facility during the peak periods. As a result, the QuickRide program was introduced, allowing HOV 2 vehicles to pay $2.00 per trip to use the facility during peak periods, while HOV 3+ vehicles continued to use the facility at no cost. Customers must have a QuickRide account, transponder, and windshield tag to use the facility. There are a number of park-and-ride facilities along the corridor where SOV motorists my stop and pick up ride shares and then use the QuickRide lane.

Northwest Freeway (U.S. 290) QuickRide – Houston, Texas

The US 290 Northwest Freeway connects the northwest suburbs of Houston with downtown, and has had a one-lane, barrier-separated, 15.5-mile, reversible HOV facility in its median since 1988. In November 2000 the Northwest Freeway HOV lane was converted to HOT use, and is operated in a manner similar to the Katy Freeway. The Northwest QuickRide allows paying two-plus carpools to use the lane only in the morning peak when three-plus occupancy requirements are in effect. From 6:45AM to 8:00AM, when the facility serves inbound traffic, three-plus occupant vehicle may use the lane for free, but two-plus vehicles must pay $2.00 to use the lane. HOV3+ vehicles may use the facility at no cost, while single-occupant vehicles are never allowed on the QuickRide lane.

The I-394 MnPASS Express Lanes – Minneapolis, Minnesota

The I-394 is a radial highway corridor extending west out of downtown Minneapolis. In 1992 a new HOV facility was opened in the I-394 corridor. The 11-mile HOV facility included a three-mile barrier separated reversible section providing access into Downtown Minneapolis and eight miles of concurrent HOV lanes with one lane operating in both directions.

After many years of study and vacillating levels of support, the State Legislature approved the conversion of the I-394 HOV lanes to HOT operation. The new MnPASS HOT facility opened to traffic in May 2005. This $10 million project featured real time dynamic pricing with two different toll levels and was the first partly non-barrier separated HOT lane to open in the United States. Toll rates vary based on real-time traffic levels to make sure that traffic flows at about 50 to 55 miles per hour. Tolls rates are distances based and depend on where motorists enter and exit the lanes.

Tolls levels average from $1 - $4 during rush hours, but can rise to a maximum of $8 during highly congested periods. The fee is posted on overhead signs just before the entrances to the MnPASS lanes. If more than one passenger is in the car the transponder can be turned off. There is a monthly fee of $1.50 for leasing the MnPASS transponder.

Minnesota DOT found that after the first six months of operations there was an increase in traffic volumes on the MnPASS lanes and no decrease in traffic service. In the reversible section, an average of 1,908 vehicles is using the MnPASS lane during the morning peak hour (7:15 a.m. to 8:15 a.m.), up from 1,551 before the lane opened. An average of 1,819 vehicles per hour is using the MnPASS lane during the evening peak hour (5 p.m. to 6 p.m.) up from 1,503 before the lane opened. While traffic has increased during certain times in the MnPASS lanes, the travel speeds have not decreased. Survey results indicate that 85 percent of MnPASS Lane users are satisfied with the speed of the traffic flow in the MnPASS lane.

The I-394 MnPASS Express Lanes project was developed and completed through a public/private partnership involving the State of Minnesota and service vendor Wilbur Smith Associates. The private firm funded 20 percent of the project's estimated $10 million price tag. Income from tolls is used to pay for operation of the MnPASS Express Lanes. Excess revenues are used to improve transit and other transportation needs on I-394.

I-25 Express Lanes – Denver, Colorado

The 7-mile, 2 lane reversible flow I-25 Express Lanes is the most recent HOT facility in the United States, opening to service in June of 2006. Prior to the conversion, the facility carried approximately 2,000 passengers/hour, and this figure was anticipated to increase to 3,300 passengers/hour after the HOT conversion.

Revenue generated from the tolls is used for the operations, maintenance, and enforcement of the HOV/Express Lanes facility. This includes snow removal, law enforcement, day-to-day operations, and eventual reconstruction.

During its tenth month of operation, April 2007, 80,665 vehicles paid a toll to travel in the I-25 Express Lanes using their EXpressToll® transponder. Approximately $160,000 in toll revenue was collected, exceeding the month’s projection of $80,000.

The Colorado Tolling Enterprise (CTE) projected 500 toll-paying vehicles would use the Express Lanes each morning and afternoon peak period by the end of the first year. Currently more than 1400 toll-paying vehicles are using the lanes in each peak period. In fact, just 10 months after opening, toll revenue is nearly double what was projected as more than $1.6 million has been collected—far exceeding the $800,000 original projection.

The number of Express Lanes users is growing every month. In March, 80,665 vehicles used the tolled Express Lane as compared to just 21,551 in June 2006, the first month of operation—an increase of 73%. Carpools, buses and motorcycles continue to use the lanes at no cost as long as they are in the lane marked “HOV” when they pass through the toll collection point near 58th Avenue. That is the only time there is a designated lane for HOVs and for toll-paying vehicles.

Toll rates for the I-25 Express Lanes vary by time of day to ensure the lanes remain free-flowing. Toll collection is electronic only, with an EXpressToll® transponder. No cash is accepted. The purpose of the I-25 Express Lanes is not to generate revenue but rather to cover expenses such as maintenance and snow removal that was previously paid for by taxpayers. The underutilized HOV lanes are now being maximized giving motorists another option to escape traffic congestion.

Projects in the Pipeline

There are a number of new HOT lane project nearing completion. Unlike their predecessors, these are larger facilities providing multiple points of access and egress.

By 2008 in Houston a 2x2 HOT lane facility will open in the median of I-10. Pricing on the lanes will involve multiple access zones, and the lanes will separated from the adjacent general purpose lanes by plastic pylons. The new facility will replace the current single barrier-separated reversible HOT lane on the same freeway.

In Washington State, a new HOT lane facility will also open in 2008 on SR 167 in the Puget Sound region outside Seattle. This project involves the conversion of an existing HOV lane, will be the first HOT lane to operate without any physical separation from the parallel general purpose lanes. San Diego is rapidly moving toward completion of a major expansion and extension of the I-15 managed lanes involving more than 20 separate ingress and egress locations, and to the north in California plans are in place to extend the SR 91 Express Lanes into Riverside County.

RESEARCH INTO SPECIFIC TOPICS

4.1 Marketing and Public Acceptance

A majority of HOV lane projects since 1969 have been considered local successes. Of approximately 120 projects, only 6 projects have been terminated. Public acceptance played a major role in projects considered marginal and were terminated. Many of the lessons learned regarding public outreach, marketing and acceptance are embodied in the following list which was generated as part of HOV training courses for the Transportation Research Board and the Federal Highway Administration.

Public Acceptance "Do's"

- Support from elected officials
- Policies and programs supporting transit use
- Commute trip reduction legislation
- Existing communication network with employers along the corridor
- Collaborative working relationships with neighborhood/community groups along the corridor
- Collaborative working relationships with neighborhood/community groups along the corridor
- Collaborative working relationships with local jurisdictions/transit agencies/DOT's along the corridor
- Commitment to evaluation to accurately show benefits/disadvantages

Public Acceptance "Don'ts

- Converting existing general purpose lane to HOV or toll lane which results in negative impacts (increased accidents, increased travel time, etc.) in general purpose lanes or protests by the public. Taking any pavement away that taxpayers feel they have paid for creates public relations problems, unless the pavement is not missed.
- Little support from enforcement authorities (state and local police and municipal judges/magistrates)
- For HOV lanes, no or little transit service in the corridor
- Poor working relationships with local media
- Poor working relationships with neighborhood/community groups along the corridor
- Lack of relationships with elected officials (especially critical during election years)
- Changing lane designation from general purpose to HOV or HOT during lane construction (example: begin construction as general purpose, change designation during construction phase to HOV)
- Lack of adequate ride matching services

A more comprehensive list of lessons learned can be found in the FHWA HOV Marketing Manual in reference 10.

4.2 Determining Specific Operation Policies

Operation policies in this context refer to the rules and regulations affecting how a managed lane is to be operated, including who is eligible to use the lane, when it is open and how access to the lane is provided. Operation policies can also involve respective roles different agencies can play in lane management. In this planning stage, pertinent research collected from national experience focuses on what drives specific operation policy decisions.

The greatest influence on a specific HOV or HOT design is the intended operation policy that will be applied. For example if an HOV lane is intended to operate only part-time during peak commute hours, then it will likely become a general purpose travel lane in the other hours, and its design should make it look like a general use lane to avoid driver confusion. The operation policies applied to HOV and HOT lanes in a region have traditionally been developed for the first few projects and institutionalized to other projects over time. This means that local consistency has mostly occurred, but not necessarily based on a regional plan vision. Setting different operation policies for each corridor in a region can occur, but preferably there are no different rules along different parts of a corridor.

HOV Lanes

- Most HOV lanes restrict use to a minimum occupancy of 2+. Only about 10% of the lane-miles in operation have a 3+ or bus only restriction. The reason a 2+ occupancy policy is so popular is because the average mix of traffic contains about 3 percent 3+ occupant vehicles, about 12% 2-occupant vehicles and the balance solo drivers. Most projects can easily accommodate all 2+ HOVs with reserve capacity for future growth and appear adequately utilized.
- While some types of HOV lane treatments such as reversible flow and contraflow serve only a peak direction during the requisite commute period each day, concurrent flow treatments can operate either during the peak periods only or all day, and can function in one or both directions. About half of all concurrent flow lanes operate 24 hours a day, and the other half operate only on a part-time basis, reverting to a general purpose lane in the off-peak periods. A region can operate some projects full-time and some part-time, but consistency in operation policies typically found for most HOV systems. There are advantages and disadvantages to both approaches as noted in Table 3.
- Most projects have changed operation policies over time as demand and conditions warrant. The most common changes that occurred in early projects was reducing the mandatory eligibility requirement on federal-aid HOV projects from 3+ to 2+ (based on a 1987 change in program guidance).

Table 3: Advantages and Disadvantages of Different HOV Operation Policies

	Advantages	Disadvantages
Part-time Operation	• Alleviates appearance of an empty lane in off-peak periods • Reduced enforcement requirements	• Not available if congestion occurs at other times • Can be confusing to motorists unless it looks like another regular use lane • Hard to take back from general traffic as a HOV or HOT lane

		when congestion increases
Full-time Operation	• Easier to sign and communicate operation policy • Harder to segregate speed differential since only a skip stripe is typically applied • Preserves benefits at all times	• Not typically needed outside the regular commute periods. • Harder to enforce • Harder to preserve credibility with the public and politicians unless congestion exists all day.

Since 1987 few HOV projects have raised occupancies to a higher 3+ restriction even though some have experienced capacity conditions. More recently hours of operation have been changed on a number of projects to address changes in congestion, demand and needs for corridor and regional consistency.

HOT Lanes

Perhaps the most important issue confronting HOT lanes is whether the lane is being developed new or converted from a prior HOV lane. Since the vast majority of HOT lanes to date (6 of 7 projects) have involved converting prior HOV lanes, there's been a tendency to leave many prior operation policies intact and create as little change as possible while introducing pricing.

For new HOT lanes such as would occur in Charlotte, there is greater flexibility to establish the appropriate operation policy with pricing in mind. Experience has shown it is better to establish a pricing basis for all hours of the day, perhaps on a 24-hour basis, and allow free or reduced priced travel during non-congested periods than to price only during congested periods and be forced to take away a "free" travel lane when congestion increases over time. This lesson learned from Minneapolis on their HOT lane caused them to pull back from their intended desire to operate HOT lanes in both directions (peak and off-peak) over all daylight hours. Currently pricing on I-394 HOT lanes is only applied in the peak direction during the peak period, commensurate with the prior HOV restriction.

Other lessons learned on HOT lanes implemented on prior HOV lanes:

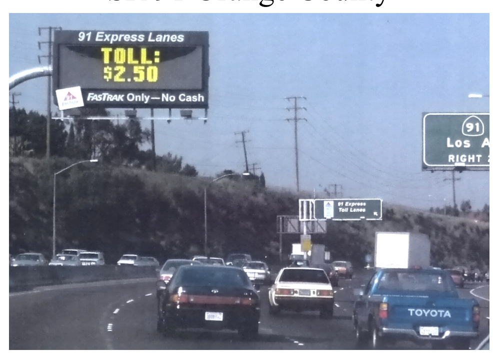
- Operation policies have not typically changed occupancy requirements, even though leaving such requirements in place has limited revenue generation potential. Of the six converted projects, four allow single-occupant vehicles to use the HOV lanes and two allow buy-in by lower 2-occupant carpools into otherwise 3+ restricted lanes.
- HOT lanes typically do not encourage other non-HOVs free use in their operation policies. Even with the latest SAFETEA-LU legislation encouraging consideration of HOV lanes by inherent low emission and certified hybrid vehicles, most projects are not allowing expanded free use of HOV lanes. Utah's I-15 HOT lanes are the only exception to allow a limited number of hybrids free use at present through a sticker program.
- While operation policies are established jointly by the state DOT and local agencies, operation administration is handled by various agencies—either the state DOT (Minneapolis, Denver and Salt Lake City), local transportation authority (I-15 in California) and transit authority (Houston).
- Operation policies were clearly communicated through a variety of media prior to and during the pricing implementation.

- All projects used either locally applicable transponders with local or statewide interoperability with other toll roads or adopted a simplified sticker program for unlimited use.
- All projects applied rather easy means to obtain transponders or monthly stickers on-line or at local outlets.
- The changes in operation policy had to meet conditions regarding federal program guidance from FHWA or FTA, depending on whether the prior HOV lane was "federalized, " or involving the prior expenditure of federal funds for HOV lane construction.
- Since most prior HOV lanes allowed motorcycles free use, they continue to use the HOT lanes for free.
- Two distinct pricing practices exist as part of the operation policies for current HOT lane conversions: fixed price for use or dynamic pricing based on demand. Three projects apply dynamic pricing (I-15 in California, I-25 in Denver and I-394 in Minneapolis); while three apply fixed pricing (I-15 Salt Lake fixed monthly fee and I-10 and US 290 in Houston fixed toll per trip). The price per mile traveled varies widely from as low as $0.08 per mile (Salt Lake) to more than $1.00 per mile (Orange County, CA).
- Augmentation of pricing has not unduly complicated operation policy communication to users, although most projects to date have involved single toll zones with limited ingress and egress. Signing has been augmented and access restrictions have been added to one project in Minneapolis. On dynamic priced HOT lanes, the toll is posted in advance of each entry (Figure 15).

Figure 15: Communication of Toll Rate

I-394 Minneapolis

SR 91 Orange County



Following are a few lessons learned regarding the HOT lane operation policy from projects being opened as HOT lanes that may have specific relevance to Charlotte. Special note should be made that most of these projects have not yet opened, but are in the process of being implemented.

- Pricing policy, particularly in an area without tolling, often raises fundamental questions about governance and handling of any excess revenues. While national experience does not suggest a right or wrong approach to which agency performs the role lane management, there is a need to engage all affected local, state and federal agencies at the time that a project operation plan is being developed. A policy regarding excess revenues is best addressed up front and not after the project is operational.
- Equity among those willing to pay is frequently raised, particularly in the project planning stage. Experience to date from the longest running HOT lanes on I-15 in San Diego and SR 91 in Orange County, California, suggests that a broad spectrum of commuters are taking advantage of projects

allowing solo drivers to use a HOT lane. The value of time perspective associated with any HOT lane can influence who pays and how much they are willing to pay. No project to date has worked out a credible and fair way of discounting or rebating tolls to low income commuters, although this has been a frequent issue of discussion when developing operating policies.

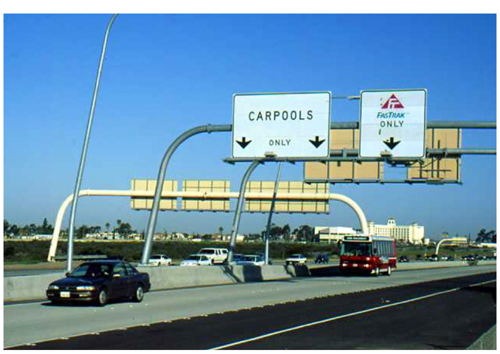
- Surveys of prospective HOT lane users suggests they want the operation policy to provide a benefit (improved travel time and/or more reliable trip) and they want to know this benefit in real time when they are making the decision to take the HOT lane. One project came up with the following conceptual sign at each entrance to try to better provide the user with this information (Figure 16):
- Operation management on initial projects often called for separate "inspection lanes" to better help police determine who can travel the lane for free and who pays. These lanes were implemented on the first HOT lanes in San Diego and Orange County and have been subsequently implemented in I-25 Denver and planned for I-10 in Houston (Figure 17). These separate lanes consume much roadway space and in the case of San Diego, are no longer used. Future operation policies should probably discourage this particular practice as the electronic tools police can use for determining toll payment are improved.

No projects involving truck-only toll lanes have been implemented to assess operation policies. Some toll lanes are being implemented as managed lanes, but operation policies have not yet been adopted for these projects.

Figure 16: Conceptual Sign to Communicate User Benefits

Figure 17: Separation of Free and Paid Users at a Tolling Location

I-15 San Diego



I-25 Denver

4.3 Implementation Outcomes from HOV to HOT Lanes

As noted in prior discussions regarding experiences in converting HOV to HOT lanes, implementation outcomes have generally been successful once implementation was allowed to move forward. Getting to implementation has often proved to be difficult, at least for early demonstrations.

Specific outcomes have been as follows for the six initial HOT lane conversions implemented since 1995.

- Each HOT lane project improved public attitudes toward previous HOV lanes, specifically with regard to flexibility in using the lanes and perceptions of use. Attitudes through surveying taken in San Diego and Orange County found rather high support for HOT lanes.
- Commuters were typically more likely to use the HOT lanes to ensure a reliable trip. Accordingly, the average use for the SR 91 HOT lanes was one in every eight commute trips. This experience suggests that HOT lanes attract a very discretionary user who only takes the lane when getting somewhere by a specific time is important. In most cases user surveys found that perceptions of time saved were greater than actual savings, mirroring earlier similar perceptions from HOVs users when similar questions were asked. On average time saved was less than 0.5 minutes per mile, but users perceived more than double this amount of savings.
- Adding a measured amount of additional priced demand to previous HOV lanes did not adversely impact transit patronage or benefits provided. In the early years of San Diego's I-15 HOT lanes, patronage actually increased in part to the flexibility afforded by providing for a wider selection of modes using the lanes.
- Overall use by tolled users varied widely, from less than 200 users per hour (12 percent of total on Houston's lanes) to more than 1800 users per hour (55% of total on SR 91 in Orange County, California). The level of use was influenced by who was allowed to travel for free and how many lanes were made available.
- The priced charged to preserve a free-flow level of service in the managed lanes is still being tested on some projects. Typically, a price of around $0.25 to $0.50 encompasses the maximum toll charged in maximum demand conditions, but some projects are currently charging in excess of $1.00 per mile (SR 91, Orange County), and are still finding it difficult to regulate demand during isolated periods. This suggests that the elasticity for pricing is quite high, particularly in periods of greatest demand.
- There is no definite correlation between higher income groups favoring HOT lanes over lower income groups. Isolated projects experiences vary.
- The primary purpose of pricing on the current projects is to better manage the lane. Enough excess capacity was identified that justified the implementation of pricing as an additional management tool alongside eligibility and access. For single-lane projects which carried less than 50 percent of their demand in tolled vehicles, no excess revenue was generated. Excess revenue was created in two of six projects where more than one directional lane was priced and where only 3+ HOVs were given free use of the lane. Most but not all of the six projects were covering their added administration, operation and enforcement costs from the revenues collected.
- Costs for HOT operation varied widely, with sticker programs representing the lowest cost with no invested site infrastructure, to dynamic pricing installations and dynamic signs that involved a cost of up to $600,000 per lane-mile.
- All projects are considered locally successful, and all are in the process of expanding their operations in a variety of ways. Some projects are being transformed from single lane to multiple

lane facilities (Houston), extending project lengths (Salt Lake-Provo, San Diego and Orange/Riverside Counties), and enhancing current operations (Minneapolis and Denver).

- Successes generated from these early projects will create new examples within the next year on SR 167 in Washington and I-680 in California. New projects will be both conversions (SR 167) and new projects (I-680) where no HOV lane previously existed.
- Project findings suggest continued interest in PPP opportunities on some corridors, notably in the most congested metropolitan areas including the mid-Atlantic, Texas and California.

4.4 Preserving Operational Flexibility

As noted in section 4.1, most projects and regions have changed their operational policies over time. These changes reflect the changing nature of commute and transit usage patterns, agency sponsorship of the HOV or HOT lanes, improvements in the design of the project based on accrued safety and crash data, desire for either regional consistency or need to depart from a regional policy to improve efficiency on a specific project, and changing technology such as electronic road pricing that offers another tool for lane management. Looking into the future, it is certainly possible that new technologies both within the road infrastructure and within the vehicle will allow for automated highways, or at least automated lanes. Managed lanes may be the first to be adopted for this new roadway operation. While predicting and trying to account for future technology considerations is worthwhile in any managed lane project, looking back at the changes that have occurred and accounting for these lessons learned is probably more appropriate.

Following is a listing of the most common issues and lessons learned in preserving operational flexibility for any managed lane:

- Many early HOV projects were developed with specific market and stakeholder needs in mind, and the more focused the vision, the harder it was to make needed changes when that vision changed. One system in particular was constructed as an exclusive bus transit way system, with most access ramps running through transit centers and park-and-ride lots. When the public and elected leaders realized that the lanes connecting these facilities could also easily accommodate vanpools and carpools, simply opening up the lanes to a greater number of users could create safety and operational problems at the ramps. Converting these lanes to HOT would further funnel unneeded commuters through transit loading areas and clog access to park-and-ride facilities. On another HOV project which changed their operation policy to allow for solo drivers, the downtown oriented access ramps had to be lengthened and modified to account for the added volume of traffic. In so many cases, had the managed lane facility been designed in accordance with prevailing design standards to assume general traffic use and full lane capacity regardless of the user mix, these shortcomings would have been easier to address when changes were proposed. In many cases, these design shortcomings keep a specific project from being able to accept HOT lane conversion.
- The design of a managed lane has a strong influence on its ability to accept a different functionality. Over half of the nation's 2900 lane-miles of HOV lanes were implemented in very restrictive design settings, often converted from previous median emergency breakdown shoulders with a low horizontal sight distance around median barriers and bridge columns. Resulting drainage inlets were sometimes left next to or within the new edge of travel way. Adjacent lanes have been narrowed below nominal 12-foot widths. Had such steps not been taken, these projects would not have been able to be implemented. Conditions placed on their implementation related to limiting both the vehicle mix and type of vehicles allowed to travel in the lanes. For example, no large commercial goods movement trucks are permitted in any HOV or HOT lane. Buses and their

respective side mirrors pose potential operational hazards on some projects where lane widths are below 11 feet. Converting such lane designs to serve general traffic represents both a safety and liability concern to the roadway owner/operator. While some projects have been able to be modified over time to bring their designs up to current standards acceptable for all traffic, most have not. The impact to address such design adjustments is typically cost-prohibitive.

- As a system of dedicated lanes is contemplated, every effort should be taken to account for present and future design needs, such as allowing for auxiliary lanes beyond major managed lane ramp junctions, providing full adjacent breakdown and enforcement shoulders, preserving options to restrict access by protecting the potential to create transition lanes between both roadways and leaving space for direct access ramps. These design considerations can help protect future options to retain an acceptable roadway design that meets all potential user needs, including trucks.
- Proactive design treatments that best fit the need for protecting operational flexibility include some of the following best practices on projects currently being implemented:
  - Prepare a contiguous pavement section both for general use lanes, managed lanes, shoulders and buffer areas without breaks in the cross fall or textured surface treatments at lane edges. Protecting this flexibility outweighs concerns in most settings related to sheet flow drainage requirements, snow removal and storage and related localized standards of practice. Such an approach also preserves options for handling traffic around major maintenance needs in the future (Figure 18).
  - Lane separation options between the general use and managed lanes should be preserved. Options that may be applied in the future include either barriers (cast or placed on the pavement, not integral to the pavement); use of permanent traffic channelizers and pylons or painted buffers.
  - ITS treatments, if implemented alongside the roadway, should account for future conduit requirements that may be needed for pricing and other in-roadway communication to managed lane users.
  - To the extent possible, freeway furniture including signs, illumination and drainage structures should not be placed in the median or on the median barrier.
  - No wide refuge areas should be applied between parallel roadways unless those areas are occupied by barriers or channelizers, as exposing vehicle breakdowns to high-speed traffic on both sides is probably the most hazardous of options (Figure 19). A common inside shoulder can be used by both traffic streams if there is no physical separation applied, or inside breakdown shoulders can be applied for each roadway if physical separation is applied.

Figure 18: Contiguous Pavement Half Section being Applied to I-10 in Houston

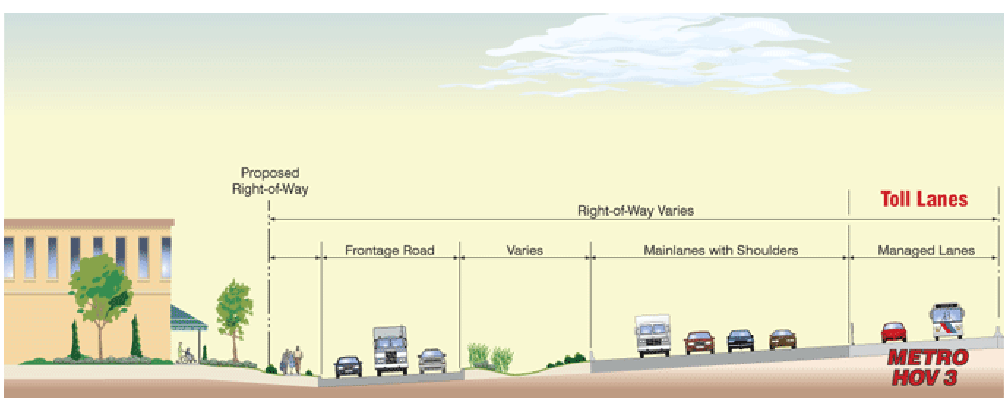


Figure 19: Shoulder Considerations

Use of common shoulder for both roadways

Placing breakdown shoulder between roadways

- Signing needs will invariably change on most managed lane projects as hours of operation, user requirements and user mixes are adjusted. It is important to consider signing not only the current operation policy but future changes in mind. Lessons learned are that sign panels should be properly sized for the vehicle design speed, but if options exist to oversize some panels this is a helpful approach to handle future changes. The correct sign background should be applied for regulatory and guide signing, although options exist to combine both messages on the same panel. Frequently changes are made over existing signs. Signing confusion can result when managed lane needs compete with messages targeted at general traffic (Figure 20).

Figure 20: Typical Signing Issues Confronted

- It is always appropriate to keep a system perspective in mind, even for a region's first demonstration project. Oftentimes, a region's first project involved a limited investment with caveats placed on how the project could be converted back to a general purpose lane if demand failed to materialize. Planning for failure is less likely to become a shortcoming than planning for success. The vast majority of HOV lanes, and all HOT lanes to date, have seen a resurgence in wanting to extend them and make them fit a longer term need that often involves other types of users and involves other types of management tools than originally intended.

- Planning and environmental steps in a project need not unnecessarily bind a alternative design to a specific operation strategy, which in fact should be allowed to change over time as demand changes. Various managed lane alternatives have been cleared without specifically defining access locations, user mix preferences or even pricing as a predetermined condition to an operation policy. However, all potential tools that may be applied should be presented in public dialogs and project meetings. At worse, supplemental environmental documentation may be needed if the project becomes a PPP endeavor or tolling is proposed prior to project construction and opening.

4.5 System Level Needs

While each HOV and HOT lane project is unique, the following discussion outlines common system level needs and experiences associated in meeting those needs.

HOV Lanes

HOV lanes as a minimum need consideration for enforcement needs, access, ITS needs and transit and rideshare needs. The most common system level needs that are most important in early regional planning are transit and access needs. Transit needs are critical if modal shifts to transit are a regional goal and are supported by the infrastructure and services needed at both the collection and distribution ends of each commute trip. For cities such as Charlotte without a high density of employment outside the downtown area and rather low residential densities outside the central city, collection means consideration of park-and-ride facilities to augment modal shifts into express transit services, that in turn, serve one or more major employment centers with enough demand to justify frequent service headways. The typical system needs to support park-and-ride services are lots averaging 5 to 7 acres (500-1200 spaces) strategically located to reduce bus access time to and from the lot and the HOV lane. Some areas locate lots close enough that direct bus-only access ramps are provided (Figure 21). These locations tend to be within 1000 feet of the freeway right-of-way. Off-freeway bus loading areas have generally been found to be preferable to median bus stations that typically are more costly than off-site designs and subject patrons to less than desirable surroundings amidst high-speed traffic.

Figure 21: Typical Park-and-Ride and Direct Access Ramp

At the destination end transit system needs include bus loading areas along streets within walking distance of major employment centers, access to other transit guide-way stations, or bus transfer stations which serve multiple destinations. Some systems include dedicated curbside bus loading lanes in CBDs to better distribute passengers from a host of park-and-ride routes. The best service examples promote patron access to the most number of destinations nonstop without the need for intermediate transferring to other routes or transit modes. In the off-peak periods transit services between park-and-ride lots in a corridor may be linked with one route servicing all lots. Mature radial corridors with residential development extending 15 to 30 miles from a CBD may justify an investment of up to four to six park-and-ride lots, each offering service frequencies of five to ten minutes to distance employment destinations. While the opportunity is available in some corridors to lease lots, most projects have dedicated lots and are increasingly examining ways of making lots more accommodating for compatible services (i.e. dry cleaning, banking, day care) and land uses that encourage walk-in or bicycle access.

Access needs relate to preserving travel time savings between high-volume, intersecting major routes in a regional system and better accessing major activity centers. Direct access ramps serve this function in a variety of designs. Most commonly, direct access ramps are added to existing interchanges using high-speed (45-50 mph) at major interchanges and lower speed designs to access the local street network. Such ramps are best oriented away from existing freeway intersections where HOV movements can complete for signal time with local access freeway ramps. Examples of both designs are shown in previous Figure 14. Direct access ramps are only justified for high volume movements at major interchanges, typically serving 30 to 50 percent of an HOV lane's vehicle carrying capacity, and for transit destinations were at least 12 to 15 fully loaded buses per hour are anticipated. Because direct access features commonly reflect the highest cost component to an HOV system, their justification and implementation needs careful consideration.

Rideshare modes also need consideration on both the collection and distribution ends of trips to encourage ridesharing to the greatest extent possible. Providing common areas for drivers to meet and carpool is an imprecise science, often utilizing an understanding of where commute sheds feed onto freeways. Frequently ad-hoc sites are tested using intersections where excess right-of-way exists and paving a small area for parking. These sites are seldom larger than 60 spaces in size (Figure 22). On the downstream end of the commute, offering preferential parking is a system need to encourage ridesharing. Providing a dedicated rideshare and vanpool matching program is also an invaluable component of an HOV system.

Figure 22: Examples of Rideshare Promotion

Preferential parking

Park-and-pool lots

HOT Lanes

While no system level implementation of HOT lanes has occurred, several systems have been studied for Atlanta, San Diego and the Bay Area.

- The most prominent system level need is universal adoption of a tolling technology that is interoperable with other toll facilities in the state, if not a multi-state region. The I-95 corridor coalition adopted a standardized electronic toll transponder technology that allows for interoperability throughout the mid-Atlantic and Northeast. The adoption of any HOT lane or HOT lane system needs to consider a compatible technology and administrative process that makes use of HOT lanes as easy as possible for potential users.
- Signing to post prevailing user requirements, toll rate and related benefit information should be consistent, both within a region and to the extent possible with the latest version of the Manual on Uniform Traffic Control Devices that will address these applications.
- The supporting systems that promote transit and ridesharing on HOT lanes, including access through park-and-ride lots, transit access ramps and related improvements should not be operationally compromised with added HOT lane traffic. This should not be an issue on new projects.
- Gaps in a system will be more pronounced in a HOT lane system because of the higher level of traffic it is intended to serve, so lane drop at project termini, even if temporary, may compromise travel time benefits and reliability.

4.6 Enforcement

Enforcement has been both the key and curse to HOV and HOT lane success and effectiveness. A host of lessons have been learned that are worthy of mention, and most of these apply to both HOV and HOT lane treatments.

- All HOV and HOT operation policies require some on-site enforcement presence. This is because the nature of typical traffic infractions involves the same police visibility to apprehend and cite violators, a practice not uncommon for another other traffic offense.
- Police often share HOV lane enforcement with other regular duties. Few projects and agencies have dedicated police responsible for HOV or HOT lane enforcement. HOT lanes offer the potential to cover dedication of police activities as part of the project's operation and administration budget which is covered by tolls. Some project sponsors contract with police agencies where officers can be made available..
- The most common infraction on an HOV lane is violating the occupancy restriction. For HOT lanes the most common infractions are toll evasion and failure to meet the minimum occupancy requirements.
- The only infraction that can be automated to avoid on-site enforcement presence and handled off site in issuing a bill or citation by mail is for toll evasion. All other infractions involve the need for some on-site police presence.
- The fine for typical occupancy and toll evasion infractions varies up to about $100, but court costs in some states can cause the total value of fine to vary from between $100 and $400.

- Involving police agencies early in the development of a project can help address their needs. Various design provisions can be made for managed lane treatments to ease the role of providing for safe enforcement.
- Measuring compliance is worthwhile for any HOV or HOT lane, and an accepted rule of thumb is to maintain a compliance rate of 90 percent of the traffic during peak operating periods. Toll infractions may achieve a compliance rate of 99 percent with proper handling of violations.
- There are various alternative means to achieve acceptable compliance without a daily enforcement regiment. These strategies include different enforcement strategies, including the use of saturation enforcement at periodic intervals, use of "HERO" type programs in which violators are reported and targeted by police, and posting of fines. Police experience suggests that visibility can be as effective a deterrent as issuing citations, so their presence in handling other traffic infractions can often support acceptable compliance on the adjacent managed lanes.

Looking to the future, a means of automating the HOV occupancy enforcement process has always been sought. Research into more automated means to handle occupancy infractions (to see inside a vehicle and accurately account for the requisite number of occupants) has been performed for over a decade, and there is ongoing research currently. Findings suggest that a wide variety of infrared and in-vehicle electronic sensors offer technology to accomplish a more automated enforcement option, but institutional issues are preventing interest in application and adoption. Such issues include differences between agencies operating the road infrastructure and vehicle manufacturers, legal and legislative obstacles, and acceptance of data by respective courts and judges as being accurate enough when contested.

LIST OF NATIONAL GUIDELINES AND RESOURCES

5.1 Guidelines

1.	Guide for High-Occupancy Vehicle Facilities, American Association of State Highway and Transportation Officials, Washington D.C., November 2004.
2.	Freeway and Geometric Design Handbook - HOV/Managed Lanes Chapter 12, Institute of Transportation Engineers, Washington, D.C., 2004
3.	Guide for Park & Ride Facilities, American Association of State Highway and Transportation Officials, Washington D.C., November 2004.
4.	Managed Lanes: A Cross Cutting Study, Federal Highway Administration, DTFH61-01-C-00182, Washington D.C., November 2004, (http://ops.fhwa.dot.gov/freewaymgmt/managed_lanes/doc/crosscuttingstudy/index.htm)
5.	Manual on Uniform Traffic Control Devices for Streets and Highways-2003 Edition (or subsequent updates), (restricted lane guide and regulatory signing sections), Federal Highway Administration, U.S. Department of Transportation, 2003.
6.	High Occupancy Vehicle (HOV) Guidelines, California Department of Transportation, Division of Traffic Operations, August 2003.
7.	A Guide for HOT Lane Development, Parsons Brinckerhoff and Federal Highway Administration, FHWA-OP-03-009 or EDL #13668, 2003. www.ops.fhwa.dot.gov
8.	HOV Facility Development: A Review of National Trends, Transportation Research Record No. 1781, “HOV and Demand Management,” Transportation Research Board, Washington, D.C., 2002
9.	HOV Systems Manual, #414, National Cooperative Highway Research Program, Transportation Research Board, Washington, D.C., 1998.
10.	High Occupancy Vehicle (HOV) Lane Marketing Manual, DOT-T-95-04, Federal Highway Administration, U.S. Department of Transportation, September 1994.
11.	Preferential Lane Treatments for High Occupancy Vehicles," `National Cooperative Highway Research Program Synthesis 185, Transportation Research Board, 1993.
12.	HOV Project Case Studies: History and Institutional Arrangements, Technical Study 2-11-89/1-925. Technology sharing document sponsored by the Texas DOT and the Urban Mass Transportation Administration, December 1990.
13.	High Occupancy Vehicle Facilities: A Planning, Design and Operation Manual, Parsons Brinckerhoff, December 1990.

5.2 Weblinks

Federal Guidelines

http://www.ops.fhwa.dot.gov/travel/traffic/hov/index.htm
http://hovpfs.ops.fhwa.dot.gov
http://www.its.dot.gov/itsweb (documents 13663 and 13648)

HOV Lane Enforcement Handbook
http://hovpfs.ops.fhwa.dot.gov/cfprojects/new_detail.cfm?id=49&new=0

HOT Lane Development Guide
http://www.its.dot.gov/itsweb/EDL_webpages/webpages/SearchPages/Abstract.cfm?docnumber=13668

Managed Lane Cross Cutting Study
A new FHWA publication, "Managed Lanes: A Cross Cutting Study". This report is now available electronically at
http://ops.fhwa.dot.gov/freewaymgmt/managed_lanes/index.htm
http://ops.fhwa.dot.gov/Travel/traffic/hov/index.htm

Washington State:

http://www.wsdot.wa.gov/hov/
or http://www.wsdot.wa.gov/regions/northwest/hovpage/hovmain/htm
http://trac29.trac.washington.edu/projects/project/show_form/84

SR 167
http://www.wsdot.wa.gov/projects/sr167/hotlanes

Massachusetts HOV website:

http://www.magnet.state.ma.us/mhd/hov/hovmain.htm
http://www.magnet.state.ma.us/mhd/hov/hovmain/htm
http://www.state.ma.us/mhd/hov/hovmain/htm

California:

CT HOV Guidelines:
http://www.dot.ca.gov/hq/traffops/systemops/hov/hov_sys/guidelines/index.html
http://www.dot.cagov.paffairs/about/faq.htmachor#29
http://www.vcn.bc.ca/t2000bc/newsletters/issues/hov.html
http://www.dot.ca.gov.dist07/facts/118facts.htm
http://www.dot.ca.gov/dist07/facts/hovfs.htm

SR 91
http://www.91expresslanes.com/virtdrive.html

SR 91 express lanes, Orange County, California
http://www.91expresslanes.com/

Florida:

http://www.95express.com/

Minnesota:

http://www.hhh.umn.edu/centers/slp/projects/conpric/index.htm

Texas:

http://tti.tamu.edu/publications/summaries/texas_lanes.stm
http://www.azfms.com/DocReviews/Nov96/art11.htm
http://www.hou-metro.harris.tx.us/hov.htm

Utah:

http://expresslanes.utah.gov/expresslanes/