**FINAL REPORT**

# TRAFFIC CONTROL FOR HIGH OCCUPANCY VEHICLE FACILITIES IN VIRGINIA

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

Virginia Transportation Research Council
(A Cooperative Organization Sponsored Jointly by
the Virginia Department of Transportation and
the University of Virginia)

In Cooperation with the U.S. Department of Transportation,
Federal Highway Administration

Charlottesville, Virginia

January 1998
VTRC 98-R25

## ABSTRACT

High occupancy vehicle (HOV) facilities are an important tool in relieving the congestion that continues to build on many urban roadways. By moving more people in fewer vehicles, the existing infrastructure can be used more efficiently. Operating HOV lanes is not a simple matter however. HOV lanes can be controversial, and the task of making them comprehensible and easy to use is not insignificant. Recognizing the importance of signing and pavement marking strategies on the success of HOV implementation, the Traffic Engineering Division of the Virginia Department of Transportation requested a study of Virginia's HOV facility traffic control strategies. The study includes a literature review of signing and pavement marking for special use lanes, a survey of several states with active HOV programs, and a review of the HOV facilities in Virginia. The literature suggests that the majority of motorist do understand the meaning of the term HOV as well as the use of the diamond symbol that indicates an HOV lane. Motorist confusion occurs when HOV regulations are not consistent across a region, however. Varying the hours of operation or minimum vehicle occupancy increases the signing requirements and places a greater burden on motorists. HOV signs must be clear and state relevant restrictions on use. In addition, other efforts should be undertaken to educate motorists about HOV benefits and requirements for use. Enforcement is critical to the success of HOV programs and should be a coordinated effort between the Department of Transportation and the enforcement agencies.

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## INTRODUCTION

High Occupancy Vehicle (HOV) facilities have become increasingly popular in recent years in answer to the traffic congestion problems that plague a majority of the country's metropolitan areas. These facilities are designed to encourage motorists to carpool by providing exclusive lanes or in some cases, entire roadways, for use by vehicles carrying a specified minimum number of passengers. By increasing the number of passengers in each vehicle, more people can be transported on a given roadway.

To achieve its maximum benefit, a HOV system must be used by an adequate number of people who follow the established HOV guidelines. The regulations regarding HOV system use vary from facility to facility. In Virginia, occupancy requirements, times of operation, and road configurations are tailored to the specific characteristics of the area an HOV system serves. For example, I-66 in Northern Virginia currently has an HOV *lane* on a portion of the interstate outside the Capital Beltway (I-495) with a minimum occupancy requirement of two, in effect in the eastbound direction from 5:30 A.M. to 9:30 A.M. Inside the Beltway, the same roadway becomes an exclusive HOV *facility*, with all eastbound lanes restricted to vehicles carrying at least two people from 6:30 A.M. to 9:00 A.M. These restrictions are applied to the westbound direction during the afternoon peak, from 4:00 P.M. to 6:30 P.M. inside the Beltway and 3:00 P.M. to 7:00 P.M. outside the Beltway. The varying requirements and regulations could cause confusion among motorists using the facility.

At several locations, including I-66 in Northern Virginia and Route 44 in Virginia Beach, the right shoulder is converted to a general use travel lane when the far left travel lane is designated as restricted for HOV travel. This type of lane usage creates several operational problems. When the shoulder is being used as a travel lane, refuge areas for disabled vehicles or enforcement activities are significantly reduced. In addition, motorists not familiar with the HOV operations sometimes mistakenly stop on the shoulder while it is in use as a travel lane, creating a safety hazard. Although the lane reverts to shoulder use during non-HOV hours, motorists continue to use it as a travel lane. This situation can endanger drivers of disabled vehicles legally stopped on the shoulder during these periods.

## PROBLEM STATEMENT

Experience with HOV facilities in Virginia indicates that existing traffic control practices, including signage and pavement markings, may be inadequate in promoting motorist understanding of and compliance with HOV regulations. This study develops a set of recommendations for HOV traffic control. Specific procedures on sign placement and message content for both HOV and shoulder lanes are recommended to improve motorist comprehension. Making HOV facility operations and regulations more clear may reduce violation rates. The result will be a safer, more efficient HOV system in Virginia.

## PURPOSE AND SCOPE

The VDOT Traffic Engineering Division asked the Virginia Transportation Research Council to conduct a study to investigate the traffic control strategies available for all types of HOV facilities, including those that incorporate the use of shoulder lanes as travel lanes. This study focuses on enhancing HOV facilities in Northern Virginia and Tidewater, two areas where VDOT has invested heavily in HOV.

This study attempts to determine the most effective types of traffic control for HOV facilities in Virginia. It investigates the reasons for HOV non-compliance, and recommends sign and pavement marking strategies to aid traffic engineers in Virginia in planning and implementing HOV traffic control.

## METHODOLOGY

The researcher completed the following tasks to achieve the study's objectives:

1. *Literature review of HOV traffic control and enforcement strategies.* A significant body of literature exists on HOV operations. A small subset contains information on signage and pavement marking strategies. Other references are identified that deal with related human factors issues. This literature provides an excellent background with which to evaluate the signage and marking needs for Virginia's HOV facilities.

2. S*urvey of HOV facilities in other states.* The researcher conducted a telephone survey of traffic engineers in several states to determine the types and characteristics of their HOV facilities. Information was requested on shoulder lane use, times of operation, occupancy requirements, geometric configuration, and enforcement.

3. *Inventory of HOV facilities in Virginia.* There are currently several different types of HOV facilities in Virginia, each with a different set of regulations and method for signage and marking. A comprehensive list of facilities as well as the traffic control strategies for each

was assembled.

4. *Investigation of HOV facility enforcement issues.* The researcher conducted interviews with law enforcement personnel responsible for enforcing Virginia's HOV regulations. Those interviewed were asked about their experiences with HOV enforcement and how they believe the facilities could be improved. The researcher sought to determine whether noncompliance is the result of disregard for the regulations or of misunderstanding of the signage and markings. She also asked for opinions on how the number of violations might be reduced (for example, by increasing the penalty for violation, or improving HOV signs).

## RESULTS

### Literature Review

There exists a significant body of literature on the design and operation of HOV lanes. Operational issues, signing, pavement marking, lane control signals and enforcement are discussed below.

#### *Operational Issues*

The push to increase the person throughput of roadways through the use of HOV lanes had its inception during the energy crisis of the early 1970s. Reducing the number of vehicles on the roadway and, by extension, the gallons of fuel consumed, seemed like an ideal way to reduce the country's demand for foreign oil. Although the energy crisis has since subsided, HOV lanes and facilities are increasing in number across the country in order to mitigate increasing traffic congestion. Several criteria have been suggested for determining when HOV mainline priority lanes are effective in increasing person throughput:[1]

- Non-HOV lanes are operating in a congested mode at least during peak hours
- HOV facilities expedite HOV flow without adversely affecting mixed-use traffic flow
- The facility appears adequately utilized (800 to 1000 vehicles per hour (vph))
- HOV time savings exceeds 1 minute per mile with a total time savings of at least 5 to 10 minutes per trip
- Development policy and operations management are closely coordinated from a regional and multi-agency perspective
- HOV lane is separated from mixed-flow lanes by either a physical barrier or buffer area
- Enforcement is integrated into the design of the project
- The HOV lane is implemented in conjunction with other strategies to increase vehicle occupancy.

HOV facilities present unfamiliar situations for motorists. While many drivers are aware of the presence of HOV lanes and understand their associated regulations and restrictions, there

will always be a portion that will encounter them for the first time. Studies have shown these drivers are most likely to drive in an unsafe manner if their information needs are not met. In atypical driving situations, decision-making time increases, making drivers more prone to distraction from control and guidance tasks. In a 1982 report written for the FHWA regarding special use lanes (SULs), a driver decision-making paradigm was developed to illustrate the decisions a motorist must make when encountering an SUL.[2] This paradigm is shown in Figure 1.

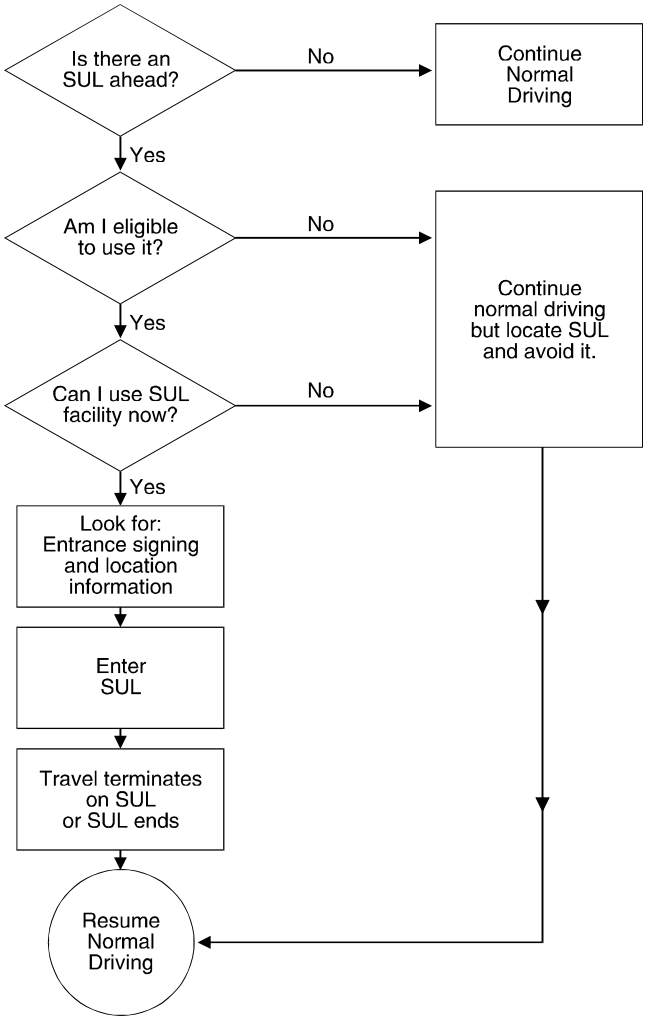


**Figure 1. Driver Decision Making Paradigm**

Several issues complicate HOV operations. First, additional information must be provided in an environment that, in many cases, is already visually cluttered. Second, the use of the diamond symbol on signs, thought to aid in motorist recognition, may cause confusion due to the various meanings associated with it. For example, bicycle lanes also use the diamond symbol. Third,

part-time use of HOV lanes common on many facilities makes signing and marking difficult. Guidelines developed for the Ontario Ministry of Transportation suggest that all HOV lanes should operate 24 hour/day in order to simplify signing and pavement marking requirements.[3] The report adds that if congestion exists 24 hours a day, HOV use should be encouraged. If there is no congestion, use of the HOV lane by mixed use traffic would not be necessary. It is important to note, however, that in many areas the peaking characteristics of the traffic are such that HOV usage during the off peak times would be minimal. Regardless of the level of congestion in the mixed-use lanes, negative public perception of an under-utilized HOV lane could be very detrimental to the success of an HOV project. Fourth, consistency of HOV hours on a regional basis or at least between contiguous HOV facilities is also cited as an important feature.[3]

### *Signing*

Human factors research tells us that driver expectancy is a key factor in driver performance. Consistency is vital to the successful transmission of information to the HOV user.[4] Unfortunately, there is no standard for HOV signing or pavement marking. Due to the fact that HOV lanes are often retrofit to existing facilities, the conditions vary from site to site. These varying conditions often mean that information requirements differ from site to site. Studies have shown, however, that there is a minimum amount of information that must be provided regardless of the type of facility. This information includes: 1) the vehicle types permitted to use the facility (e.g. buses and carpools only, no trucks); 2) the time periods during which the facility operates (e.g., 6:30 A.M. to 9:00 A.M.); 3) the days of operation (e.g., Monday through Friday); 4) the location of the HOV lane (e.g., left lane); and 5) any other rules of use (e.g., minimum occupancy requirements).

An HOV Design and Operations Guide developed by Charles Fuhs of Parsons Brinckerhoff, Quade & Douglas, Inc. includes recommendations for signing and marking for HOV facilities.[5] It lists several pitfalls to current signing:

- Lack of adherence to Manual of Uniform Traffic Control Devices (UTCD) color standards
- Lack of diamond symbol on signs
- Confusing regulatory sign information
- Sign lettering that is too small to be easily read
- HOV signs placed in ways that can be read and misconstrued by mixed flow drivers.

The guide suggests that these problems could be overcome by standardizing all HOV-related signs to include the white diamond on a black background in the upper left corner. It also suggests that regulatory signs should be the MUTCD standard black lettering on a white background and that guide signs should be white lettering on a green background. This will help to meet driver expectation with respect to sign type and content while maintaining the HOV

meaning. When designing signs for HOV roadways, the Guide suggests that states adhere to the same design standards as those used for any other sign. The size of the sign should be consistent with the speed of the traffic that will be reading it. Lettering that is too small to be read at a distance required by the average speed of traffic will negate the existence of the sign.

While the MUTCD does not specifically address HOV signing, it does include a section on Preferential Lane Signing (Section 2B-20).[6] Preferential lanes are defined as those whose usage is limited according to the class of vehicle occupancy. The Manual recognizes the different applications of preferential lanes and states that the signing for all applications should follow standard regulatory signing principles. It specifies that such signs should be rectangular in shape, with a black legend on a white background. The diamond symbol should appear in white on a black background. The format for signs informing motorists of preferential lane restrictions should have the following sequence:

| | |
|---|---|
| Top line: | Lanes to which the preferential treatment applies (e.g. left lane) |
| Middle lines: | Applicable vehicles (e.g., buses only) |
| Bottom lines: | Applicable time and day. (e.g., 7-9 A.M., Monday-Friday). |

The Manual goes on to state that if the sign is mounted overhead, a downward arrow should separate the time and day. The diamond symbol should be located in the top left quadrant.[6] Figures 2 and 3 illustrate MUTCD-compliant side-mounted and overhead signs.


**Figure 2. Side-Mounted HOV Sign**

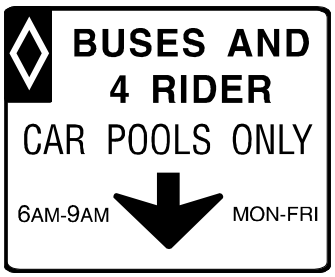


**Figure 3. HOV Overhead-Mounted Sign**

In addition, the Manual recommends advance signing, as well as a sign indicating the end of the preferential lane treatment. These signs are shown in Figures 4 and 5. The frequency at which signs are placed within a preferential treatment is left to engineering judgement on a case-by-case basis. Spacing at .4 km (.25mi) is suggested for freeway applications.

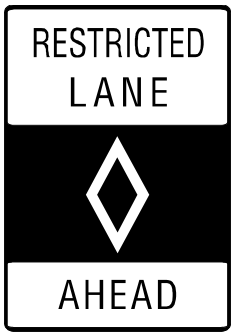


**Figure 4. Advanced HOV Lane Signing (Side-Mounted)**

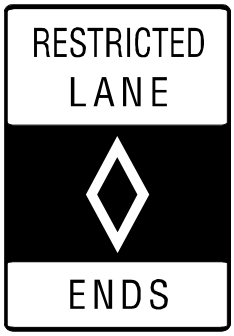


**Figure 5. Sign Indicating the HOV Lane End**

As shown in the sample signs, the MUTCD recommends the use of the term "restricted" for preferential use lanes. In a 1982 study of sign wording and motorist response, motorists chose the words "reserved" or "restricted" equally as often to describe HOV lanes. "Restricted" was chosen to describe lanes that were prohibited to certain vehicle types. The researchers stated that to alleviate confusion, use of the word "reserved" for HOV lanes might be warranted. However, given the fact that there was no appreciable difference in motorists preference between the terms for HOV use and the fact that many locations already use the term "restricted" for HOV signing, the cost and possible confusion of changing to "reserved" might not be worthwhile.[2]

The number and placement of signs has been studied many times for applications of all kinds. In general, the probability of motorists remembering the traffic sign they just passed depends in large part on how relevant they view the information it presents to be to their situation.[2] For HOV applications, this means that any sign presenting HOV information must capture the motorist's attention and then efficiently convey its message. Again, consistency is important, as the repeated use of colors, symbols, and placement can improve motorist recognition.

It is common practice to place HOV signing at all entrance and exit points for separated HOV facilities, or at the beginning and end of HOV lanes. In addition, a survey of motorists found that both advance and repeated signing along the length of an HOV lane would be helpful. When asked to indicate where they would place signs along the roadway on which an HOV lane was located, 92 percent of the respondents placed a sign well in advance of the start of the HOV lane, and 70 percent placed a sign at the start of the lane. In addition, many respondents placed signs repeatedly along the roadway, with 92 percent placing a sign far into the horizon.[2] Backing up this need for repeated signing, a study conducted by the Texas Transportation Institute found that 40 percent of motorists did not see the first sign providing transitway information, and only 70 percent saw the second sign.

Because HOV lanes are often adjacent to mixed-use lanes, the geographic placement of signs can be a critical issue. When signs are placed at the side of the roadway, confusion can result as to whom the sign applies. While there is no way to ensure that only HOV-eligible motorists can see the HOV signs, proper placement can minimize the confusion. Overhead signing has been found to be more effective than side-mounted signing. In fact, in a field study in San Francisco, overhead signs were found to be 25 to 40 percent more effective in reducing violations than shoulder-mounted signs.[2]

The information requirements for HOV signing are extensive. It has been suggested that signs that present too much information overwhelm motorists. The laboratory and field experiments conducted by Pain and Knapp found that motorists could handle more information as long as it was concise.[2] The researchers also examined sign format to determine how best to present the required information. Single signs, repeat signs, and split signs were compared. Repeating the same information on two closely spaced signs was found to have no significant effect on motorist comprehension. The split presentation was found to be better than either repeat or single signing; however it appeared to be negatively correlated to information density. In other words, in situations where a large amount of information must be provided, the improvement of the split presentation over the other two methods decreased. Split presentations are effective in conditions where the presentation time is low due high speeds or significant truck activity. In presenting the information, the research showed that standard word signs like the one shown in Figure 6 result in higher motorist comprehension than signs that use symbols (as shown in Figure 7).

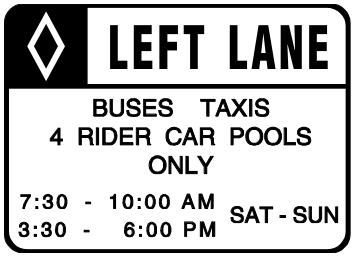


**Figure 6. HOV Eligibility Sign Utilizing Words Only**

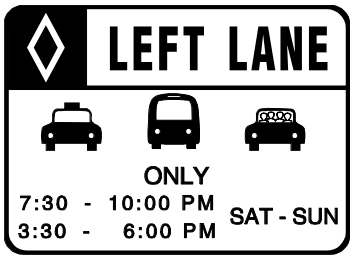


**Figure 7. HOV Eligibility Sign Utilizing Symbols**

*Pavement Marking*

Pavement markings for HOV lanes vary according to the type of HOV lane. It is often recommended that contra-flow lanes use yellow pavement markings to delineate between HOV and mixed-use lanes and concurrent flow lanes be delineated using white pavement markings.[5] If access to a concurrent flow lane is restricted to certain locations, solid lines should be used to

identify those areas where crossing is not allowed. Marking systems for contra flow lanes have been found to work well.[2] Concurrent lanes present more of a problem, especially those that are HOV only part of the time, since they must convey two messages. During peak periods, the restricted nature of the lane must be clear while during non-peak periods the lane should appear open to all traffic.

The MUTCD provides limited guidance on HOV pavement markings. Section 3B-22 discusses pavement markings for preferential lanes but mentions only the use of the diamond symbol in the center of the preferential lane. It does state that the diamond should be formed with white lines at least 15 cm wide (six inches), should be at least 0.75 meters (2 ½ feet) in width and 3.7 meters (12 feet) long. The frequency of the markings is left to engineering judgement based on the site conditions, but a spacing of 305 meters (1000 feet) is suggested for freeway applications.[6]

Section 3B-2 of the MUTCD addresses lane lines, although not specifically for HOV lane delineation. However, several of the recommendations can be applied to HOV use. The manual states that a solid white line should be used to separate through traffic from special lanes and to discourage lane changing. Double solid white lines are recommended for use where lane changing is prohibited. While one would interpret this to mean that a concurrent HOV lane should be separated from the mixed use lanes by a solid white line (based on the special lane recommendation above), Figure 3-5 of the MUTCD shows an HOV lane delineated with the standard white dashed line.[6] A study in Ontario stated that this type of lane, with no separation, typically results in lower HOV lane speeds and less relaxed driving conditions.[3]

Pavement markings for concurrent lanes were considered explicitly in the FHWA report on Special Use lanes (SUL). Through both laboratory and field experiments, motorists were asked to evaluate different pavement marking configurations. The objective was to determine the prohibitive nature of the various marking scenarios as well as to identify the implicit meaning motorists took from the markings. Prohibitiveness was measured in terms of motorists' inclination to cross the markings. They were told that they were in the center of three lanes and forced to change lanes to the right or left, where two different types of markings had been placed. Motorists were not told which direction to go (right or left). Therefore, the direction they chose provided an indication of the relative prohibitiveness of the two marking strategies. By varying the combinations of markings presented to motorists, the relative prohibitiveness of the entire sample set of markings was established. The scenarios tested varied from the standard single dashed line to a dense cross-hatched pattern between two solid lines. The study findings are summarized below.[2]

- Dashed or skip lines are more permissive than solid marking scenarios regardless of color or symbology.
- Solid symbols, such as the HOV diamond symbol, are more prohibitive than symbol outlines.
- Line width had little effect on the prohibitive nature of the marking.

- Color is not a primary factor in motorists' impression of the prohibitive nature of the marking.
- Buffer width also had no significant effect.
- The use of diamonds in the pavement marking helped motorists to recognize the SUL.
- A cross-hatch pattern was viewed as the most prohibitive.
- Patterns that are more dense were viewed as more prohibitive.
- Designs that incorporate a solid look (line or connected pattern) are often misunderstood as delineating a shoulder zone rather than a travel lane.
- Dashed designs are seen as delineating travel zones, not shoulders.
- Thin diamonds connected by a single line are seen as neutral.

The prohibitive nature of a pavement marking is an important factor to consider when designing a delineation scheme for an HOV facility. In many concurrent lane applications, access is not restricted to specific points along the roadway. Vehicles that meet the eligibility requirements may cross over the pavement markings to enter and exit the HOV lane wherever they wish. While this does make the lane more flexible for the motorists, it places additional requirements on the pavement markings. It has been recommended that where continuous access to the HOV lane is provided, the delineation should consist of double dashed lines.[3] This type of marking has the advantage of being similar to standard marking and therefore less obtrusive during the non-peak periods when the lane reverts to mixed flow usage. The drawback of this treatment is that the markings are also less obtrusive during peak periods when the HOV restrictions are in effect. Motorists are less likely to associate the pavement marking with the existence of an HOV lane. A derivation of this pavement-marking scheme is to place the HOV diamond symbol between the dashed lines. The dashed pattern conveys the message that motorists may cross the buffer, while the diamond adds to the awareness of the HOV lane.[2] This pavement marking scheme was field tested on the H1 Freeway in Hawaii. The Department of Transportation in Hawaii reports, however, that these pavement markings are no longer in use. Concurrent HOV lanes are now delineated in the standard lane marking fashion with the single white dashed line. The diamond symbol is placed in the center of the HOV lane to indicate its special use, but no buffer is placed between the HOV and general-purpose lanes. The fact that the lane is a part-time HOV lane and serves general traffic for more hours of the day than it does HOV traffic has led Hawaii to rely on signing as the primary HOV traffic control device. The Hawaii DOT is currently investigating the use of a moveable barrier system.

### *Lane Control Signals*

Section 4E-8 of the MUTCD discusses the use of lane-use control signals (LCS) to indicate that specific lanes of a street or highway are open for travel or closed.[6] Such controls are most commonly used for reversible lane control. However, the manual does list other circumstances where LCS might be used:

- On a freeway, where it is desired to keep traffic out of certain lanes at certain hours to facilitate the merging of traffic from a ramp or other freeway
- On a freeway, near its terminus, to indicate a lane that ends
- On a freeway or long bridge, to indicate a lane which may be temporarily blocked by an accident, breakdown, or other problem

The manual also defines the meaning of LCS indications as follows:

- A steady downward green arrow means that a driver is permitted to drive in the lane over which the arrow signal is located.
- A steady yellow X means that a driver should prepare to vacate, in a safe manner, the lane over which the signal is located because a lane control change is being made, and to avoid occupying that lane when a steady red X is displayed.
- A flashing yellow X means that a driver is permitted to use a lane over which the signal is located for a left turn. The driver is cautioned that he may be sharing that lane with opposite flow left-turning vehicles.
- A steady red X means that a driver shall not drive in the lane over which the signal is located, and that this indication shall modify accordingly the meaning of all other traffic controls present. The driver shall obey all other traffic controls and follow normal safe driving practices.

The manual stipulates that LCS should be placed over the center of the controlled lane and at a frequency such that drivers can see at least one, and preferably two, signals at all times. LCS are to be used continuously.

Some states are experimenting with different uses of LCS. For example, Texas is looking at using a flashing green arrow at toll plazas to indicate exact change booths. Any use of LCS is dependent on motorists correctly interpreting the intended meaning of the signal. A study conducted nearly 40 years ago found that 63 percent of motorists surveyed interpreted the red X indication to mean that they should not drive in that lane. The more traditional red ball (as used in traffic signals) was viewed more often as an indication to stop in the lane. The same study found that 93 percent of motorists interpreted a green upward arrow to mean that a lane was open for travel.

In a more recent laboratory experiment conducted by the Texas Transportation Institute, nearly all subjects tested correctly interpreted the green arrow to mean a lane was open for travel. In addition, over 80 percent of subjects responded that they should vacate a lane with a red X indication.[7] These results seem to indicate that the LCS symbols are well understood.

In many LCS applications, it is desirable to use static signing to indicate both the presence of the signals and their intended meaning. A study conducted in conjunction with the FHWA sponsored report on “Signing and Delineation for Special Usage Lanes”, investigated the types of signs that could be used for this purpose. The study found that a sign that simply states

"Lane Control Signals Ahead" was better understood by motorists than a sign that used symbols to depict the LCS. A symbol sign was interpreted by some motorists to mean something other than a simple warning. For example, if the sign showed a red X and a green arrow side by side, the motorist thought that the sign was indicating that the left lane was closed ahead.[2] If an informational sign is desired to warn of an upcoming LCS, this issue should be considered.

### *Enforcement*

Enforcement is a critical component of any successful HOV implementation. Studies have shown that, regardless of the configuration of the HOV lane, violation rates will be high if there is no consistent enforcement.[1] Given that the public is very sensitive to the issue of HOV lanes and their use, controlling violation rates is a prime concern for any agency implementing or maintaining these lanes. In a survey of both HOV lane users and non-users on the Long Island Expressway, both groups stated that they believed HOV regulations should be enforced.[8] The Suffolk County Police have a detailed enforcement plan that is funded by the New York State Department of Transportation, with a goal of keeping HOV violations below 10 percent. When patrolling, they observe and cite motorists for three types of lane violations: buffer crossings, illegal passing, and occupancy violations.

Another study, an evaluation of the Lincoln Broadway bus lanes, identifies three types of violators: 1) motorists who claim they are unaware of the restrictions, 2) motorists who understand the restrictions but ignore them to bypass a queue in the adjacent lane, and 3) motorists who park in the restricted lane (in arterial applications). The study stated that during the first few years of operation, citations for HOV violations were not upheld. The bus lanes operated only during the peak period and therefore the restrictions were only enforced for certain hours of the day. When violators went to court, they stated that they did not know the time and therefore could not be held responsible since there was nothing in the vehicle code that stated they must have a clock in their vehicle. This problem was overcome by adding flashing lights to overhead signs that stated "Buses and Right Turns Only When Flashing."[9]

In a study that focused on the development of enforcement techniques for arterial HOV lanes, several factors were identified that may affect the level of enforcement that is required.[9] While the study focused on arterial lanes, many of the principles would also apply to freeway HOV applications. These factors include:

- Marketing and public support – if public support is gained and the public truly understands the purpose and benefits of HOV lanes, fewer people violate the rules.

- HOV lane usage – the public is very sensitive to what they perceive to be unused capacity, especially if the general purpose lanes are congested. Adequate usage of the HOV lane alleviates this problem.

- Level of congestion on the adjacent general purpose lane – the more congested the general purpose lane is, the more tempting the free-flowing HOV lane becomes.

- Perceived time savings – time savings is the main benefit of HOV lane use. That same time savings is often why non-eligible drivers become violators.

- Length of the HOV lane – longer HOV lanes offer increased time savings, again increasing the temptation to be a violator.

- Perceived possibility of apprehension – potential violators may be discouraged if they feel their chances of being caught are high.

- Penalties (monetary or points) for violating the occupancy requirement – higher penalties may discourage those who will feel that the benefits are not worth the risk.

It should be noted that other studies have shown that a high penalty alone does not reduce violation rates.[1] Without adequate enforcement and public acceptance of the HOV regulations, violations will continue. No matter how high the fine, if the enforcement is not there to levy it, it is not likely to have a significant impact.

The retrofit nature of many HOV lanes has created enforcement difficulties. In some areas, the creation of an HOV lane has resulted in the loss of the left shoulder. In these cases, enforcement areas must be provided at regular intervals. When needed, these areas should be at least 4m wide (5 m preferable) and should never be located in the buffer between the HOV and general-purpose lanes.[5] One report even suggests that, as an added deterrent to violators, enforcement areas be placed in an area that allows for vehicles to be turned around and released in the opposite direction.[5]

## Survey of Other States

Representatives in Washington, California, and Minnesota were contacted by phone and asked questions regarding the types of signing and marking in use on their state's HOV facilities. They were also asked to summarize how effective they felt the strategy was. Each state's comments are summarized below.

### *Washington*

The state of Washington has an extensive HOV program, encompassing both freeway and arterial applications. The signing and marking used on these facilities vary from site to site based on the application and site characteristics. Some components of the signing and marking applications are consistent, however. The diamond marking is used to identify HOV lanes. For most freeway applications, the diamonds are 4.9 m long by 1.4 m wide (16 ft long by 4 ½ ft

wide) and constructed of 8 inch wide white thermoplastic tape. They are typically spaced at 152 m (500 foot) intervals. The lane delineation is typically a 20.3 cm (8 inch) wide solid white line for inside (left) HOV lanes. For HOV lanes located on the right side of the road, the solid line becomes dashed in the vicinity of ramps to allow for entering and exiting vehicles. Continuous access is allowed for eligible vehicles. All freeway HOV lanes, with the exception of several bus lanes, operate on a 24 hour/day basis. It is the opinion of the Washington DOT official that the traffic characteristics support 24 hour HOV restrictions. Signs are standard MUTCD regulatory black on white and in most cases include the diamond symbol. A few signs include symbols such as a car with a 2 on it to indicate that the lane is restricted to cars with two or more people. The signing strategy includes several signs. The first is a sign placed upstream of the restriction that simply states that such a lane is ahead. The next sign gives the occupancy and other requirements for use of the lane. Since all the HOV lanes are in operation full time, no time of day information is required. When HOV lanes were first introduced, they were referred to as carpool lanes, and some signs still contain this terminology. The HOV abbreviation is more common now however, and appears on all new signs.

An interesting operational insight was also shared by the Washington DOT official. Lane drops often occur at the location where the HOV restrictions end, forcing HOV traffic to merge into mixed-use lane traffic. For the vehicles using the mixed-use lanes, it appeared as though the congestion that resulted from this merge operation was caused by the HOV traffic. To alleviate this perception, the Department has adopted the policy of discontinuing the HOV restrictions in advance of the lane drop. All traffic is therefore allowed to use the previously restricted lane prior to the lane drop.

Enforcement of HOV regulations in Washington is aided by a public participation initiative known as the HERO program. Motorists who witness others using the HOV lanes illegally are encouraged to call a toll free number and report the violator's license plate number. The violator is sent a letter with a brochure explaining the HOV regulations. If the violator is reported a second time, another letter is sent with more forceful language and a warning that the state police will be notified if a third violation is reported. Although no citations are issued through the mail, the program is viewed as being very effective at reducing violations. Very few violators are reported a third time. The violation rate in Washington is reported as low.

### *California*

California's HOV facilities are located in two heavily urbanized areas, the San Francisco Bay area and Orange County in Southern California. The two areas have distinctly different operating procedures and therefore, different signing and marking scenarios. In the Bay area, the HOV facilities are part-time, concurrent flow lanes. Because of their part-time status, the only special pavement marking provided to delineate the HOV usage is the placement of diamond symbols at 153 m ( 500-ft) spacing along the center of the lane. The HOV lane is delineated in the same manner as the other lanes, with the standard white dashed line. In Orange County, the

HOV lanes operate on a 24-hour basis and are separated from the general-purpose lanes by a 0.6 m ( 2 foot) buffer made up of double yellow lines. Access to the HOV lane is provided at specific locations and crossing the buffer between those locations is an HOV violation.

The signing at both California locations is similar, with the exception of the time of day restriction that is posted on the Bay Area signs. The signing is static in nature, mounted on the barrier separating the flow directions. Signs are placed at approximately 305 m (1000-ft) intervals. The term "HOV" is not used on the signs due to a belief that the acronym is not widely understood. Instead, the word "Carpool" is used along with the number of occupants required for HOV designation. For example, a regulatory sign might read "Buses and 2 person carpools only."

Very few of the HOV facilities in California have left shoulders. To facilitate enforcement, 4 m (14-ft) enforcement areas are provided at regular intervals. Enforcement is provided by the California Highway Patrol and violation rates on all facilities are 10 percent or below. There does not appear to be a significant difference in violation rates between the full-time, limited access lanes and the part-time continuous access lanes. The low violation rates are attributed to a consistent CHP presence and a $271 fine for violation.

### *Minnesota*

Minnesota has implemented HOV in the Minneapolis area in the form of concurrent flow lanes and a barrier separated facility. The concurrent flow lanes are delineated with a standard skip stripe. Both types of facilities have the diamond symbol placed in the center of the HOV lane. Overhead signs describe the HOV regulations ("2+ Carpool, Buses, and Motorcycles") and have a downward arrow pointing at the designated lane. Enforcement is viewed as a problem on the concurrent flow lanes because of congestion on the mainline. Any enforcement activity is, in effect, an incident and therefore has a negative impact on operations. Only one of the concurrent flow lanes has a left shoulder that can be used for enforcement. There is no statute for HOV regulations and violations, and therefore enforcement is dependent on good regulatory signing. Judges have been found to be much less sympathetic to violators who claim they did not see or understand the regulations if both signing and pavement markings are used to designate the HOV facilities. Violation rates are a problem on Minnesota's HOV lanes, and tend to be highest just after the HOV restrictions go into effect and just prior to the lifting of the restrictions.

## Virginia's HOV Experience

*Statewide*

Virginia currently operates HOV facilities in two areas of the state, Northern Virginia and Tidewater. In Northern Virginia, the HOV facilities are located on I-66 and I-95/395. In Tidewater, the HOV facilities are located on I-64, Rt. 44, and a short portion of I-564. The configuration and regulations vary from site to site and are summarized in Table 1.

**Table 1. Virginia's HOV Facilities**

| Roadway | HOV Lane Type | Occupancy Requirement | Times of Operation |
|---|---|---|---|
| I-66 (outside Beltway) | Concurrent lane<br>27.4km (17.2 mi) | 2+ | 5:30 – 9:30 A.M. (EB)<br>3:30 – 6:30 P.M. (WB) |
| I-66 (inside Beltway) | Exclusive roadway<br>16.1 km (10 mi) | 2+ | 6:30 – 9:00 A.M. (EB)<br>4:00 – 6:30 P.M. (WB) |
| I-95/395 | Reversible roadway<br>42 km (26.25 mi) | 3+ | 6:30 – 9:00 A.M. (NB)<br>3:30 – 6:00 P.M. (SB) |
| I-64 | Reversible roadway<br>14.5 km (9 mi) | 2+ | 5:00 – 8:30 A.M. (WB)<br>3:00 – 6:00 P.M. (EB) |
| I-64 | Concurrent lane<br>1.6 km (1 mi) | 2+ | 5:00 – 8:30 A.M. (WB)<br>3:00 – 6:00 P.M. (EB) |
| I-44 | Concurrent lane<br>6.4 km (4 mi) | 2+ | 5:00 – 8:30 A.M. (WB)<br>3:00 – 6:00 P.M. (EB) |
| I-564 | Concurrent lane<br>1.6 km (1 mi) | 2+ | 5:00 – 8:30 A.M. (WB)<br>3:00 – 6:00 P.M. (EB) |

Signing and pavement marking strategies vary across these applications. When the portion of I-66 inside the Beltway was opened in December of 1982, VDOT recognized the unique situation that had been created and undertook a study of public reaction to and understanding of the HOV restrictions. [10] The study specifically addressed the issue of HOV signing, specifically, motorist comprehension of the signs provided on I-66. Through the use of surveys of both motorists observed using the interstate and residents of surrounding neighborhoods, it was found that most people do, in fact, understand the HOV abbreviation as it is used on the regulatory signs. Less than 3 percent of those responding to the survey did not know the meaning of HOV. Of interest is the fact that respondents were divided on the issue of whether or not the HOV abbreviation should be used. A significant number of those surveyed stated that they preferred the use of the term "carpool" to "HOV". The study indicates, however, that the opposition to the abbreviation might have been related to a negative reaction to the restrictions rather than to the abbreviation. The use of the HOV abbreviation continues today on all HOV facilities in the state.

*I-66*

The HOV lanes on I-66, inside the Beltway, have existed since the roadway was constructed. The restrictions were, in fact, required as a condition of the approval to build the final portion of the roadway that provides an east/west route from Virginia into Washington, D.C. During peak periods, the entire roadway in the peak direction is restricted to HOV vehicles. A recent demonstration project reduced the occupancy requirement from three to two persons per vehicle. The project was initiated as a result of public criticism that the roadway was underused, carrying as few as 800 vehicles per hour during the morning peak period. HOV lane volumes have increased as a result, with the level of service remaining at an acceptable level. The two-person occupancy requirement remains in effect, and a volume threshold of 1,950 vehicles per lane per hour has been set. Once exceeded, the occupancy requirement will revert to 3+ persons per vehicle. A benefit of the reduced occupancy requirement inside the Beltway is that the requirement is now consistent along the two adjacent I-66 HOV facilities. This consistency alleviates one potential cause of motorist confusion regarding HOV usage along I-66.

Outside the Beltway, from Manassas to the Beltway, a concurrent lane is provided for HOV vehicles during the peak period. When the left lane is designated HOV, the right shoulder is opened to general-purpose traffic. In so doing, the same number of lanes is available for general-purpose traffic throughout the day. The use of the shoulder lane as a travel lane does present a number of operational problems, however. Since shoulders generally exist to provide a refuge for vehicle breakdowns, positive guidance must be provided to motorists to avoid any confusion about when the lane may be used for travel. On I-66, both static and dynamic signing provide this information. Static signs are placed on the right side of the roadway providing information about the use of the shoulder lane, including the times when it may be used for travel (Figure 8).


**Figure 8. Signing for Shoulder Lane Use**

In addition, lane control signals are placed over the shoulder lane to indicate when it is open for travel. A static sign placed over the LCS describes the meaning of the red X and the green downward arrow indications (see Figure 9). By placing static signing with the LCS, motorist confusion over the LCS symbols is avoided. The symbols on the static sign are clearly provided for informational purposes only, and are not intended to indicate anything about the status of the lanes. Additional static signs, also shown in Figure 9, are used to reinforce the shoulder use restrictions. At interchange locations where the exiting traffic must use the right lane as a deceleration lane, signs indicate where that maneuver should begin during times when the shoulder lane is designated for emergency stopping only.


**Figure 9. Lane Control Signal with Static Informational Sign**

In an effort to better delineate the shoulder/part-time travel lane from the full time lanes, VDOT added a thin layer of bituminous pavement to the shoulder. Since the rest of the interstate in this area is concrete pavement, the difference in color helps to highlight the shoulder area. At interchange locations where the shoulder becomes the deceleration lane, the bituminous pavement stops and begins again at the end of the acceleration lane for on-ramp traffic (if any). Figure 10 illustrates the pavement configuration for the shoulder lane. Notice also that a solid white line is used as the delineation between the full-time lanes and the shoulder. Because the shoulder is used as such for part of the time, this type of marking is required.

**Figure 10. Shoulder Lane Pavement Configuration on I-66**

Signing for the HOV lanes on I-66 is a combination of both static and variable message signs. In advance of the HOV lane on eastbound I-66 near Manassas, static signs are placed on the left side of the roadway to alert motorists that the HOV lane begins on the left ahead. The sign is shown in Figure 11. The first sign is placed 0.8 km (.5 mi) in advance of the restricted lane. Notice that the sign uses the HOV abbreviation, and the term is spelled out to define the abbreviation.


**Figure 11. Advance Signing for I-66 Concurrent HOV Lane**

The sign also gives the occupancy requirements for use of the lane. A similar sign is placed 0.4 km (.25 mi) in advance of the restricted lane. The diamond symbol is not used on this sign. At the beginning of the restricted lane, a smaller sign is placed in the median providing the HOV

occupancy requirements and time of day restrictions. The diamond symbol is used on this sign as shown in Figure 12.


**Figure 12. Signing for Start of HOV Lane Restriction, I-66**

The signs shown in Figures 13 and 14 are placed repeatedly along the length of the restricted lane to reiterate the HOV lane restrictions.


**Figure 13. HOV Regulation Sign – I-66 Concurrent Lane**


**Figure 14. HOV Definition Sign**

Figure 15 shows a VMS used to provide HOV lane information. The diamond symbol is provided on the static sign mounted above the VMS.


**Figure 15. Variable Message Sign Used for HOV Information on I-66**

As I-66 nears its intersection with I-495, additional signing is provided to alert motorists that non-HOV traffic must exit. Several miles prior to the last exit before the entire roadway becomes a restricted facility, a static sign is placed overhead that instructs all non-HOV traffic to exit at I-495 during the restricted hours. This sign is shown in Figure 16. Note that there is no diamond symbol on this sign, and the placement of the sign is over the HOV lane.


**Figure 16. HOV Information for I-66 Inside the Beltway**

Another sign is placed over the center of the roadway that is a combination static sign and VMS. The static portion of the sign informs the motorists that all lanes of I-66 are restricted ahead and includes the diamond symbol. The VMS portion of the sign gives the restriction that applies according to the time of day. During HOV periods, the HOV restrictions are provided and during non-HOV periods, the VMS states "No Trucks", since trucks are not allowed to use the portion of I-66 inside the Beltway at any time (see Figure 17).


**Figure 17. Variable Message Sign, I-66 Inside the Beltway**

Another static sign is placed on the right side of the roadway 1.6 km (1 mi) prior to the I-66/I-495 junction that again notifies motorists of the restrictions. This sign does not specifically state that all lanes are restricted; however, another combination static/VMS nearby does include the "all lanes" message.

Pavement marking in the concurrent lane section of I-66 consists of a double dashed white stripe (see Figure 18.)

**Figure 18. Pavement Marking for Concurrent HOV Lane on I-66**

White diamonds are also placed in the center of the lane at regular intervals. No special pavement markings are used on I-66 inside the Beltway.

### *I-95/395*

The HOV lanes on I-95/395 consist of a reversible roadway located in the median. The entrances to the HOV lanes are marked with overhead signs that include the diamond symbol and the occupancy and time of day restrictions. Typical signs are shown in Figures 19 and 20. Note that the signs describe the entrance to the HOV lanes as an exit from the general-purpose lanes. This terminology is considered by some as confusing for HOV-eligible drivers who are looking for the entrance. The guide signing for the HOV roadway does include the black on white panel indicating that it pertains to HOV traffic; however, the panel is placed at the bottom of the guide sign. The panel also includes the occupancy and time of day requirements. When the roadway is not available for HOV traffic in a particular direction, gates are used to close the entrances serving that direction. Variable message signs are used with the gates to inform motorists that the roadway is closed. Deceleration lanes serving the entrances to the HOV roadway are marked with the diamond pavement marking and standard single white dashed stripe.


**Figure 19. Entrance to Reversible HOV Lanes, I-95**

**Figure 20. HOV Signing on I-95**

The violation rates on I-95/395 are reported to be high during the first and last half-hour of the HOV restrictions. A Virginia State Police representative believes that the violation rate for the first half-hour of the restrictions approaches 70 percent. He attributes this to motorists mistakenly believing that if they are in the reversible lane when the HOV restrictions go into effect, they may continue to their destination without being considered in violation of the restrictions. In fact, non-HOV motorists using the reversible lane when the restrictions go into effect must take the next exit.

*I-64*

I-64 in the Tidewater area has two HOV segments. A reversible roadway is located in the median of the interstate that provides two lanes for HOV traffic in the peak direction for a length of approximately nine miles. Concurrent flow lanes are also provided on the left side of the general-use lanes, restricted to HOV traffic during the peak periods. The concurrent lane

currently extends from the south end of the reversible roadway for approximately one mile. It will be extended in the years to come. In fact, in the westbound direction, the signs designating the HOV restrictions in the left lane have already been placed and covered until the construction in this area is complete.

Signing for both segments follows the same principles as that described for I-66. Static signs are placed on the median barrier for the concurrent lane that describe the HOV restrictions including occupancy and time of day (see Figure 21.) The lane is separated from the general-purpose lanes by a buffer created by two white dashed stripes as shown in Figure 22. Diamonds are also placed at regular intervals on the pavement of the restricted lane.


**Figure 21. HOV Regulation Sign, I-64**

**Figure 22. Pavement Marking for Concurrent HOV lane, I-64**

Access to the reversible roadway is controlled by the use of gates on the ramps. On the approach to the entrances to the reversible roadway, VMS are used to provide the HOV requirements or to inform motorists that the entrance is closed, as shown in Figure 23. Notice that the diamond symbol and the words “Restricted Lane” are provided on a static sign mounted

above the VMS. The diamond symbol is also used on the approach to the entrance to reinforce the HOV restriction. Figure 24 illustrates this marking, as well as a sign used to indicate the prohibition of trucks on the reversible roadway.


**Figure 23. Variable Message Signs used for HOV Information, I-64**

**Figure 24. Entrance to Reversible Lanes, I-64**

In many areas, the reversible roadway and the general-purpose lanes are adjacent to one another. In these instances, guide signing for the HOV lanes can been seen by motorists in the general-purpose lanes. These signs may indicate upcoming exits that exist only for the HOV traffic. To alleviate the confusion that this might cause for general-purpose traffic, a panel containing the diamond symbol and words “Restricted Lane” is added to the top of the sign, as shown in Figure 25.


**Figure 25. HOV Guide Sign, I-64**

*Rt. 44*

Concurrent lanes on the left side of Rt. 44 operate as HOV lanes during the peak periods. At the same time, the right shoulder is open to all traffic to maintain the same number of lanes for general-purpose traffic during all hours of the day. Variable message signs mounted over the shoulder are used to indicate the status of the shoulder lane (open to all traffic or closed). During non-peak periods, the VMS contains a message stating "Shoulder Closed," as illustrated in Figure 26.


**Figure 26. Variable Message Sign for Shoulder Lane Use, Rt. 44**

During peak periods the sign states "Open to all traffic." Use of the shoulder lane as a travel lane in the eastbound direction ends at Rosemont Road. Vehicles using the shoulder lane at this

location must either change lanes or exit. The VMS approaching this location must warn motorists of the lane drop. A two phase message is used (see Figures 27 and 28.)


**Figure 27. VMS Message #1 for Shoulder Lane Use, Rt. 44**


**Figure 28. VMS Message #2 for Shoulder Lane Use, Rt. 44**

Pavement marking for the shoulder lane consists of a single, solid white line (standard edge line.) The pavement on Rt. 44 is concrete, like that on I-66 in Northern Virginia. The shoulder lane is also concrete on Rt. 44, as opposed to the bituminous material used on I-66 to help differentiate between the shoulder and regular travel lanes.

Variable message signs are used to indicate the status of the HOV lanes and the ramps that feed the reversible lanes on I-64. Static signing indicating the HOV restrictions are also used. Pavement marking is limited to the use of the diamond symbol at the center of the HOV lane.

*I-564*

A short section of I-564 leading to and from the Norfolk Naval Base includes a concurrent lane that acts as a continuation of the reversible roadway on I-64. Direct access is

provided between the two HOV facilities to benefit carpools on this route. Vehicles traveling in the reversible HOV lane on I-64 have a direct ramp that feeds the concurrent HOV lane on I-564. A ramp is also provided for vehicles traveling on I-564 directly into the reversible lane on I-64. During periods when the reversible roadway is serving the opposite direction of traffic, gates are used to prevent wrong-way access. The signing is similar to the other concurrent flow lanes in the area and like Rt. 44, the only special pavement markings provided are the diamond symbols in the center of the HOV lane.

### *Enforcement*

Violation rates are a primary factor in the performance of HOV facilities. When violation rates are high, the lanes are acting, in effect, as general-purpose lanes. In 1995, violation rates on Northern Virginia HOV lanes were estimated at 74 percent. An enforcement program was established that reduced the rate to approximately 40 percent within three to six months. A state police representative estimated that 50 to 70 percent of the violators are aware of the HOV restrictions and are intentionally choosing to violate them.

State police believe that several improvements to signing and marking could be made that would improve motorist understanding of the restrictions, and thus reduce violation rates. First, where they have experienced wear, the diamond symbol pavement markings should be repainted and maintained. Many of the markings have worn off over the years, and they have not been replaced. Second, signing on I-66 at the Beltway should be clarified. Motorists stopped for violating the restrictions inside the Beltway often tell troopers that they were not travelling in the left lane and therefore they did not think they were violating the restrictions. They have come from outside the Beltway where only the left lane was restricted, and do not realize that those restrictions now apply to all lanes. Third, alternative route information should be provided to drivers forced to exit I-66 during HOV restrictions. The limited HOV information provided on state maps and at rest stops for out-of-town motorists means that even if they are aware of the restrictions, they may not know an alternate route into the D.C. area. While the official Virginia State Transportation Map does indicate the roadways that have HOV restrictions, the restrictions themselves are not provided on the map. This can make pre-trip planning more difficult for drivers unfamiliar with the area.

While overall violation rates are fairly low in Northern Virginia, rates of approximately 60 percent have been observed on I-95/395. These rates are typically seen at the ends of the restricted periods. It would appear that motorists are gambling that enforcement will not happen in the period of time just after the restriction goes into effect and just before it ends. It is the opinion of the state police representative interviewed that the only thing that will help this problem is strict enforcement. In fact, violation rates in general will remain at acceptable levels only if enforcement is both visible and consistent. The fine structure for violating HOV restrictions in Northern Virginia is not insignificant. Special legislation for Planning District Eight has established a schedule of fines that is higher than in other parts of the state. The first violation carries a fine of $50 plus $29 in court costs. The second violation doubles the fine to

$100 plus $29 in court costs and the third violation goes to $250 plus $29. The fourth violation carries a stiff penalty of $500 plus $29 in court costs. Currently, this information is not included on any HOV signing. Tidewater has signs containing fine information, where the fine is $76 (See Figure 23).

HOV violations were originally considered a moving violation and therefore carried a 3 demerit point penalty against the driver's record at DMV. When Virginia undertook a demonstration project of "ticket by mail," the point penalty was eliminated and only fines were assessed. The "ticket by mail" program did not last, but the fine-only penalty has remained. The state police representative stated that he believed a point penalty would be a much stronger deterrent to violators, since with only two violations they would be faced with losing their driver's license.

In 1989, a peer enforcement program modeled after the HERO program in Seattle, Washington was launched in Northern Virginia. For the first six months or so the program was very successful, with violation rates going from approximately 40 percent to around 10 percent. The program, administered by the Virginia Department of Motor Vehicles (DMV), allowed motorists to call a hotline housed at the Tysons Corner DMV office when they witnessed another motorist violating the HOV restrictions. The first offense earned the violator a friendly letter from the DMV with information on HOV restrictions and other educational information. A second violation resulted in a somewhat more forceful letter, and the third violation yielded a letter warning the violator that they could be ticketed if they continued to violate the HOV restrictions. Violators quickly caught on to the fact that there were no teeth behind the warning program and violations quickly returned to their previous level. After two years, the peer enforcement program was disbanded due to budget cuts.

## DISCUSSION AND CONCLUSIONS

HOV facilities have grown in popularity in recent years as a solution to the ever-increasing congestion on urban roadways. By moving more people in fewer vehicles, HOV lanes are an efficient method of increasing capacity without increasing the physical size of the roadway. A popular method of achieving an HOV lane within existing right of way is to convert a regular use lane to a HOV lane during the peak travel periods. This lane then reverts back to a general-purpose lane during non-peak periods. The transient nature of the lanes creates problems when developing signing and marking plans. While officials want to make the HOV restrictions obvious to the motorists during HOV periods, there is also a need to have the lane appear "open" during non-restricted periods. This issue of part-time HOV lanes is being faced by transportation agencies across the country.

In Virginia, signing and marking on HOV facilities is not consistent. Even within facilities, newer signs differ from those placed several years ago. These inconsistencies add to

motorist confusion. Since driver expectancy is an important factor, sign placement and configuration, and pavement marking schemes should be the same in all regions of the state. Based on the review of the relevant literature, and discussions with other states as well as personnel involved in HOV operations in Virginia, the researcher made the following conclusions.

1. HOV regulations that vary from facility to facility, especially within a region, add to motorist confusion.

2. HOV signing that clearly states restrictions on use, including occupancy and time of day requirements, is necessary.

3. Additional efforts to make unfamiliar drivers aware of the HOV lanes and their restrictions are needed.

4. The diamond symbol is recognized by a majority of motorists as an indication of the presence of an HOV lane.

5. The type of delineation between HOV and general-purpose lanes (solid stripe, skip line, crosshatch) has little impact on violation rates.

6. Wide buffers (>1.2m/4 ft) placed between HOV and general-purpose lanes are often mistaken as refuge areas.

7. The meaning of the red X and green downward arrow in lane control signals are understood by the majority of motorists.

8. Enforcement is important to successful HOV operations.

## RECOMMENDATIONS

Based on the results and conclusions of this study, the following recommendations are offered.

### General HOV signing and pavement marking

1. To the extent possible, HOV regulations should be consistent across a region. These include occupancy and time of day requirements. Consistency statewide is not necessary and would likely be difficult to implement due to differences in regional travel patterns.

2. A standard concurrent lane HOV signing plan should include, at a minimum:

   - a sign at least 1.6 km (1 mi) in advance of the start of the HOV lane describing the lane restriction in general terms
   - a second sign approximately 0.8 km (.5 mi) from the start of the HOV lane that explicitly states the HOV restrictions and use requirements
   - a sign at the beginning of the HOV lane indicating that the lane restrictions have started
   - signs at regular intervals of approximately 457 m (1500 ft) describing the HOV lane restrictions
   - signs at regular intervals describing the fine for violating the HOV restrictions
   - a sign at the end of the HOV lane stating that the restrictions no longer apply.

   A diagram of a standard signing layout is provided in Figure 29.

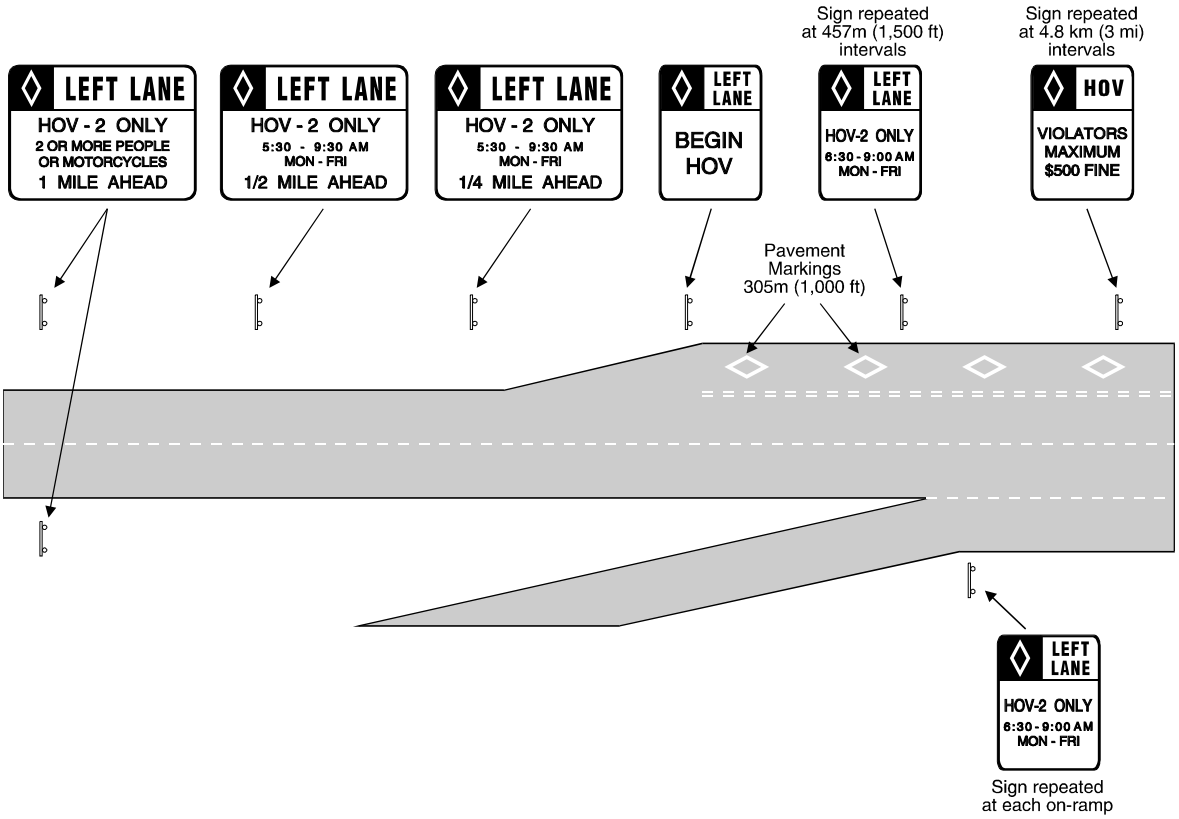


**Figure 29. Standard HOV Signing Layout**

3. Whenever possible, the HOV signing should be mounted overhead directly above the affected lane. Given the cost associated with overhead mounted signs, when an existing structure is not available, side mounted signs may be used.

4. Sign format should follow standard MUTCD guidelines for font size and type. Guide signs should be green signs with white lettering and regulatory signs should be white signs with black lettering. In circumstances where guide signs are visible to general-purpose traffic, a panel should be added with the diamond symbol and the words "Restricted Lane." The guide signs on I-64 in Tidewater are a good example (Figure 25.)

5. The diamond symbol should be used as a pavement marking on all HOV lanes. Spacing of these markings should be 305 m (1000 ft) unless conditions warrant otherwise. Such conditions would include major freeway entry points and changes in freeway geometrics. Where necessary, worn markings should be replaced.

6. Part-time, concurrent HOV lanes should be delineated from general-purpose lanes by a double, dashed, white stripe. This indicates to the driver that there is a special use for the lane while not prohibiting crossing. When sufficient space is available, the two lines should be spaced so as to provide a buffer no more than 1.2 m (4 ft) wide. This type of marking is used on all concurrent HOV lanes in Virginia.

**Shoulder lane use**

7. When shoulder lanes are used for travel lanes during the peak periods, lane control signals should be used to indicate the current status of the lane (emergency stopping only or open to traffic.) A static sign like the ones use on I-66 (Figure 9), describing the meaning of the signal indications should be used with every lane control signal.

8. The standard solid white stripe should be used to delineate the shoulder lane from full-time travel lanes. Where the travel lanes are constructed of concrete, a thin bituminous layer should be added to the shoulder lane to help distinguish between the full time lanes and the shoulder lane. The bituminous layer should be discontinued where the shoulder lane becomes a deceleration lane for vehicles exiting the interstate.

**Public Awareness/Outreach/Education**

9. Opportunities for educating the public on HOV issues and regulations should be identified. Possible methods for outreach include mailers included in registration renewals sent by DMV, public service announcements on radio, and the distribution of pamphlets in rest areas and welcome centers. Information provided might include location of HOV facilities, hours of operation, occupancy requirements, alternative routes (in the case of I-66), rules for use (for example, non-HOV vehicles must exit when HOV restrictions go into effect), and the

penalties for violation. Shoulder lane information should also be provided, along with information on HOV's rationale and benefits.

10. Information regarding HOV facilities and restrictions on the Official State Transportation Map should be enhanced to include the nature of the restriction (left lane, all lanes) and the hours and occupancy restrictions.

## I-66

11. All signs on I-66 approaching the Beltway should include the words "All Lanes" when describing the HOV restrictions. In addition, all signs should include the diamond symbol in the upper left corner of the sign (see Figure 30).


**Figure 30. Advance Warning Sign for I-66**

12. The I-66/I-495 interchange is a major decision point for drivers. Non-HOV traffic must exit at this point and therefore they must be given the information required to make the decision to exit or continue on I-66 as an HOV. Additional panels with the guide signs for the I-495 exits would provide this information. A panel with the words, "Last exit before restricted lanes" should be added to these signs.

13. Additional diamond pavement markings should be placed at the I-66/I-495 junction where all non-HOV traffic must exit.

## Enforcement

14. Signs informing motorists of the penalty for violating HOV restrictions should be placed at regular intervals of 4.8 km (3 mi) along the HOV lane (See Figure 31).


**Figure 31. Violation Penalty Sign**

15. A consistent, dedicated enforcement program should be established and maintained for all HOV facilities in Virginia. Either one statewide or two regional task forces consisting of VDOT HOV operations personnel, VDOT public affairs division personnel and the Virginia State Police is recommended. Decisions regarding the operations and enforcement aspects of the HOV facilities in the state cannot be made without considering both. This task force would provide a forum for this decisionmaking process. If regional task forces are used, formal communication should be established to ensure a statewide approach to HOV is maintained.

16. The Code of Virginia, Section 33.1-46.2, currently states: "Any person driving a motor vehicle in a designated HOV lane in violation of this section shall be guilty of a traffic infraction which shall not be a moving violation and on conviction shall be fined fifty dollars." [11] It is recommended that this section of the code be amended to include the assignment of demerit points as described in Section 46.2-492. Under this section of the code, failure to obey a highway sign carries a penalty of three demerit points in addition to any monetary fine. [12]

## ACKNOWLEDGEMENTS

This research was financed through State Planning and Research Funds administered by the Federal Highway Administration. The author expresses appreciation to Adel Sadek for his assistance in gathering background information for this report. In addition, special thanks go to Chandra Clayton, Karen Rusak, Loren Epton, and Ken Wester of VDOT and Sgt. Rick Keevill of the Virginia State Police for their insight and comments. Appreciation is also extended to the representatives of State DOTs who provided information on HOV policies and experience.

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