

1. Report No. FHWA/TX-04/0-4160-16		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle TRAFFIC CONTROL DEVICES FOR MANAGED LANES				5. Report Date April 2004	
				6. Performing Organization Code	
7. Author(s) Susan T. Chrysler, Alicia Williams, Steven D. Schrock, and Gerald Ullman				8. Performing Organization Report No. Report 0-4160-16	
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135				10. Work Unit No. (TRAIS)	
				11. Contract or Grant No. Project No. 0-4160	
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office P. O. Box 5080 Austin, Texas 78763-5080				13. Type of Report and Period Covered Research Report: March 2003 – February 2004	
				14. Sponsoring Agency Code	
15. Supplementary Notes Research performed in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration. Research Project Title: Managed Lanes in Texas, Task 15 Traffic Control Devices					
16. Abstract U.S. standards for traffic control devices for managed lanes, high occupancy vehicle lanes, preferential lanes, special use lanes, and toll facilities are reviewed. A summary of current practices in the United States and other countries is included. U.S. standards have improved, especially in the area of preferential lane signing and pavement markings, with the release of the 2003 <i>Manual on Uniform Traffic Control Devices</i> (MUTCD). Differences between current practice and the new standards are highlighted. Standards for allowed vehicle symbols, access point terminology, and route labeling are still not in place. Planners of managed lanes facilities are encouraged to consider traveler information needs in the early stages of planning to allow sufficient distance for conveying complex operating rules. Careful sign placement and color coding are discussed as alternative ways to avoid driver information overload.					
17. Key Words Managed Lanes, HOV Lane, Toll Lane, Special Use Lane, HOT Lane, Traffic Control Device, Signing, Pavement Marking, Traveler Information, Preferential Lane			18. Distribution Statement No restrictions. This document is available to the public through NTIS: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161		
19. Security Classif.(of this report) Unclassified		20. Security Classif.(of this page) Unclassified		21. No. of Pages 50	22. Price

TRAFFIC CONTROL DEVICES FOR MANAGED LANES

by

Susan T. Chrysler, Ph.D.
Research Scientist
Texas Transportation Institute

Alicia Williams
Research Associate
Texas Transportation Institute

Steven D. Schrock, P.E.
Assistant Research Engineer
Texas Transportation Institute

and

Gerald Ullman, Ph.D., P.E.
Research Engineer
Texas Transportation Institute

Report 0-4160-16
Project Number 0-4160
Research Project Title: Managed Lanes in Texas, Task 15 Traffic Control Devices

Sponsored by the
Texas Department of Transportation
In Cooperation with the
U.S. Department of Transportation
Federal Highway Administration

April 2004

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

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. This project was conducted in cooperation with the Texas Department of Transportation (TxDOT) and the U.S. Department of Transportation, Federal Highway Administration (FHWA). The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation. The engineers in charge were Beverly T. Kuhn (Texas P.E. #80308) and Ginger Daniels Goodin (Texas P.E. #64560).

The U.S. government and the state of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the contributions of numerous persons who made the successful completion of this report possible. Thanks are extended to the Texas Transportation Institute (TTI) Advisory Team: Dennis Christiansen, Katie Turnbull, Ed Seymour, Bill Stockton, and Tim Lomax. The research discussed herein could not have been accomplished without the exhaustive efforts of Carol Lewis, director of the Center for Transportation Training and Research at Texas Southern University; her staff; and the following TTI individuals: Gene Hawkins, Garry Ford, and John Mounce. The authors would like to thank the project director, Carlos Lopez from the Traffic Operations Division of TxDOT, for his leadership and guidance. The authors are grateful to the following individuals from TxDOT who make up the Project Monitoring Committee: Michael Behrens, Bill Garbade, John Kelly, Jay Nelson, Mary Owen, and Richard Skopik, and RTI engineer Wade Odell.

TABLE OF CONTENTS

	Page
List of Figures.....	viii
Chapter 1: Introduction	1
Chapter 2: Literature Review.....	3
Current Signing Standards and Practice	3
Current Standards.....	3
Sign Color and Banners	5
Symbols.....	8
Terminology.....	12
Sign Placement.....	24
Changeable Message Signs.....	26
Lane Control Signals.....	28
Current Pavement Marking Standards and Practice for Managed Lanes	29
Lane Line Markings.....	29
Horizontal Signing.....	30
Chapter 3: Signing and Pavement Marking Discussion Issues	33
Color Coding.....	33
Symbols and Terminology	33
Allowed Vehicle Symbols	33
Access Point Terminology.....	34
Allowable Exits.....	34
Supplemental Information	35
Sign Placement.....	35
Changeable Message Signs.....	36
Pavement Markings	36
Chapter 4: Conclusions and Recommendations	39
Recommendations for Future Work.....	39
References.....	41

LIST OF FIGURES

	Page
Figure 1. HOV Merge Sign in California.	5
Figure 2. Guide Sign with Full-Span Banner across Top as Used on Houston HOV Lanes.	8
Figure 3. Diamond Symbol as Used on California Facilities.	9
Figure 4. Occupancy Symbols Used in Houston.	10
Figure 5. HOV Sign Used on Eastside HOV Lanes in Washington State (15).	11
Figure 6. Long Island Expressway Defines “Carpool” (16).	11
Figure 7. HOV Symbols Used in Ontario (19).	12
Figure 8. HOT Lane on I-15 in San Diego.	14
Figure 9. Toll Symbols on E-470 in Colorado.	15
Figure 10. Toll Plaza Signing on Sam Houston Tollway in Houston.	15
Figure 11. EZ Pass Sign on State Route 1 in Delaware.	15
Figure 12. Ground-Mounted Occupancy Requirement Sign.	17
Figure 13. Overhead Occupancy Requirement Sign.	18
Figure 14. Motorcycle Allowed Sign in Phoenix.	18
Figure 15. Allowed Vehicle Sign in the United Kingdom.	19
Figure 16. Sign Used to Define HOV Term.	19
Figure 17. Vehicle Exclusion Sign in Houston.	20
Figure 18. Vehicle Segregation on the New Jersey Turnpike.	21
Figure 19. Phone Numbers and Internet Addresses in Use on Signing.	23
Figure 20. Trailblazer Sign on Suburban Arterial in Houston.	23
Figure 21. Example of Cantilevered Signs in California.	25
Figure 22. Hybrid Static-Changeable Message Sign Used in California.	27
Figure 23. Overhead Changeable Message Sign.	28
Figure 24. Yellow Lane Lines Used in California.	30
Figure 25. HOV Lane Pavement Marking Symbols in Houston.	31
Figure 26. Horizontal Signing in California.	31
Figure 27. Horizontal Signing in Offenburg, Germany.	32

CHAPTER 1: INTRODUCTION

Managed lanes facilities may present drivers with unfamiliar access, geometries, and operating rules. Conveying information concerning these features requires effective use of standard and novel traffic control devices. As managed lanes facilities continue to evolve, new operational strategies and geometric designs may require new traffic control devices. The current federal *Manual on Uniform Traffic Control Devices* (MUTCD) contains information on preferential lanes which is spread across several different sections (1). The Texas MUTCD offers guidance on HOV and other preferential lanes in sections on regulatory signs and pavement markings (2).

Designers and operators of managed lanes facilities must consider traffic control device needs early in the planning process. The initial costs of communicating with drivers include the cost of the following: right-of-way for signing and supporting structures; the structures; dynamic message signs and accompanying power and communications; designing, fabricating, and installing static signs including any lane closures required; and pavement markings including standard lane striping plus any horizontal signs and symbols required or desired to augment guide or warning information contained in the signs. The ongoing costs of traveler information include maintenance of signs and markings, communications fees such as monthly cell phone charges for wireless networks, and maintenance of power supplies and other electronic components of dynamic message signs.

Beyond the cost of traffic control, early consideration of driver information needs in the planning process will assure that an operating scheme is not implemented which requires overly complex signs. Variable tolls based on occupancy or time of day with dynamic pricing based on current conditions can result in complex toll schedules. Conventional toll roads often have a full menu of prices posted at toll plazas. With vehicles moving at slow speeds, and in most cases stopping completely, it is safe to present this large amount of information. But with electronic toll collection at high speed, it becomes dangerous to overload drivers with complex toll rules. For such complex operations, planners may have to accept that “one big sign” is not appropriate. With a subscription-based electronic toll system, it is possible to communicate with subscribers through the mail or other means in order to provide the full toll schedule off-road. With a wider audience, other methods of presenting the information must be considered such as the use of

multiple, sequential signs. Or, a small amount of information which applies to the largest number of users, such as the minimum toll for a passenger vehicle, could be presented. Other mechanisms, such as two-way transponders, which would present information in-vehicle, are on the horizon and may lessen the need for numerous traffic control devices in the future.

In addition to operating strategies, planners need to consider traffic control devices in the geometric design as well. Access points which violate driver expectancy, such as left exits, will require good advance signing. Buffer-separated facilities pose a particular problem because space constraints may preclude the use of the desired signing in managed lanes.

The managed lanes concept is still in its relative infancy. Traffic control device standards are lagging behind current practice and current need. This report reviews the new standards and current practices across a variety of managed lane facilities. Contradictions, omissions, and flaws of the current standards and practices are presented in light of interviews with Texas drivers conducted as part of this project. The need for future research and standardization efforts are presented in the [final chapter](#).

CHAPTER 2: LITERATURE REVIEW

CURRENT SIGNING STANDARDS AND PRACTICE

Current Standards

Current managed lanes facilities, including HOV lanes and toll facilities, use a variety of traffic control devices. This is, in part, due to the lack of guidance and standardization in the MUTCD. In addition, the course of development for many of these facilities has led planners to feel that theirs is a “one of a kind” facility where standard signs don’t apply. The attitude of some toll facility operators is that since theirs is a private road, the federal MUTCD does not apply. This is clearly erroneous as the MUTCD does apply to any road that is open to the public. Toll operators, for marketing purposes, often want their road to look and feel different than free roads and strive to have unique signs, structures, or terms. While, for the most part, existing signing for all managed lane facilities has been developed with guidance from and in the spirit of the MUTCD, there is little consistency currently in this area.

The Texas MUTCD (2) contains a section on regulatory signs for HOV facilities. There is no information provided concerning guide or warning signs specifically related to HOV or other managed lanes facilities. The 1978 U.S. MUTCD (3) contained a single section on preferential lane signing, which introduced the use of the white outline diamond shape on a black background. These signs applied to any type of restricted lane and followed general regulatory sign principles of a vertical rectangle and black-and-white color. This manual also included the elongated diamond symbol for pavement markings. The 1988 revision of the MUTCD (4) expanded these sections and included a few example layouts of HOV facility entrances.

The current MUTCD (1) contains eight pages of example layouts for both barrier- and buffer-separated facilities (Section 2E.59). These examples show green advance guide signs, exit plaques, and distance/destination signs all with a small diamond symbol in the upper left corner. They also include special lane drop symbol warning signs. Trailblazer signs from park-and-ride facilities and local streets are also illustrated. Direct access ramp diagrammatic guide signs are also shown.

Guidance is provided to avoid overloading the road users. The MUTCD suggests the importance of signs following this priority:

1. regulatory,
2. advance regulatory,
3. guide, and
4. next exit supplemental.

Several “shall” conditions have been added to the MUTCD concerning preferential lanes which merit individual mention (see Section 2E.59) (*I*). These are:

- minimum of one advance guide sign at least 800 m (0.5 mi) prior to the entry, ground mounted;
- overhead signs to be used as supplement to ground mounted only, unless engineering study identifies that ground mounted are not appropriate;
- HOV abbreviation or diamond symbol to appear on all signs at entry and exit points and on signs showing times of vehicle occupancy requirements; and
- median-mounted signs for advance exit and other guide signs for both barrier- and buffer-separated facilities (twisting of sign up to 45 degrees where lateral clearance is limited is allowed).

Warning signs and pavement markings are also addressed in the new MUTCD (*I*). Section 2C.52 allows for the option of augmenting a warning sign with a small yellow plaque which reads “HOV.” This plaque “may be used to differentiate a warning sign specific for HOV lanes when the sign is also visible to traffic on the adjoining general purpose roadway.” It suggests using this plaque for advisory speeds for curves and exits, lane adds, and lane drops. Some agencies, in practice, have added either the word HOV or the diamond symbol to warning signs. [Figure 1](#) shows the symbol for merging traffic on a yellow rectangular sign with the diamond symbol across the top as a banner. This sign is non-compliant because it should be a diamond-shaped sign as is the standard for this warning symbol sign. It does illustrate, however, that agencies have had to improvise by applying older versions of the MUTCD to situations unique to managed lanes facilities.



Figure 1. HOV Merge Sign in California.

The new MUTCD has more comprehensive coverage of pavement markings for preferential lanes as well. Sections 3B.22 and 3B.23 provide specific guidance on longitudinal pavement markings and symbols for all types of preferential lanes. A clear table, with illustrations, is provided for edge line markings for buffer- and barrier-separated facilities with both concurrent and reversible operations (1).

These improvements will help develop standardization as future facilities are built, and as existing facilities are upgraded and maintained.

Sign Color and Banners

The MUTCD utilizes a color code for signs to assist drivers in finding the type of information they seek (1). Section 1A.12 of the current MUTCD states:

The general meaning of the 13 colors (that have been identified as being appropriate for use in conveying traffic control information) shall be as follows:

- Black – regulation
- Blue – road user services guidance, tourist information, and evacuation route
- Brown – recreational and cultural interest area guidance
- Coral – unassigned
- Fluorescent Pink – incident management

- Fluorescent Yellow-Green – pedestrian warning, bicycle warning, playground warning, school bus and school warning
- Green – indicated movements permitted, direction guidance
- Light Blue – unassigned
- Orange – temporary traffic control
- Purple – unassigned
- Red – stop or prohibition
- White – regulation
- Yellow –warning

While the MUTCD contains no guidance particular to *managed* lanes, there are sections which pertain to preferential only or restricted lanes. These include bicycle, HOV, bus, light rail, or taxi lanes. Regulatory signs for preferential only lanes are described in Section 2B.26. These signs convey information on operating hours, occupancy requirements, and allowed vehicle types. They are all black lettering on a white background. Other signs in this section include “HOV LANE AHEAD” and “HOV LANE ENDS” (R3-15, R3-15a), which are also black on white regulatory signs.

For yellow-series signs, the new MUTCD contains an option to use a supplementary plaque, black letters on a yellow background with the letters “HOV” (W16-11). This option also allows for the use of the diamond symbol instead of the word message “HOV” on the supplementary plaque and for the addition of the words “ONLY” or “LANE” to the plaque.

For green-series signs, all of the illustrations in Section 2E.59 show guide signs with white letters on a green background. These guide signs also contain the diamond symbol in white outline on a black background either in the upper left or across the top of all guide signs related to the HOV lane.

These are the new standards; the current practice varies considerably from these standards. California uses black-on-white signs for advance guide signs and some allowable movement signs (5). In a 1997 article reviewing current practices, Fendrick states that the reasoning behind California’s use of a white background is that “because of the numerous white signs on the approach to the HOV lane, drivers associate white with HOV-lane operation in general. In addition, general-purpose traffic may mistakenly interpret the HOV-lane guide signs

as applying to its operation. This problem is a particular concern for concurrent-flow HOV lanes since all signs are visible to both HOV and general-purpose traffic” (6). Virginia conducted an evaluation of motorists’ impressions of HOV signs shortly after the I-66 lane opened in 1982 (7). Several respondents suggested the use of a color other than white for advance signs, or a flashing light mounted on the sign, to increase its conspicuity.

The Houston area HOV system, managed by the Houston METRO transit agency, is undergoing a facelift to improve driver communication. A series of focus groups tested “user-friendly” signs for trailblazer signs leading drivers toward HOV lanes and freeway connector ramps, and signing in both buffer- and barrier-separated facilities (8). The results of these focus groups were used to guide the design of new signs which placed the standard HOV diamond in the upper left corner and the addition of colored stripes across the top line of all guide and regulatory signs. These stripes are the METRO logo and also appear on buses, light rail, and other METRO signage and publications. Figure 2 shows an example drawing of these signs. The base signs generally do follow the color code laid out in the current MUTCD, with guide signs having a green background and regulatory signs having a white background.

In Virginia, the term “RESTRICTED LANES” is added to the right of the diamond symbol on all static and changeable message signs (9). This is done in situations where the signs are visible to traffic in the general purpose lanes. Washington Department of Transportation (DOT) suggests using the diamond symbol for all lanes, with a black banner heading across the full width on white signs (10). A study of transitway signing needs also supports the use of the diamond symbol in the upper left corner (11). This 1988 report also suggested an evaluation of guide sign colors as an area of future research.

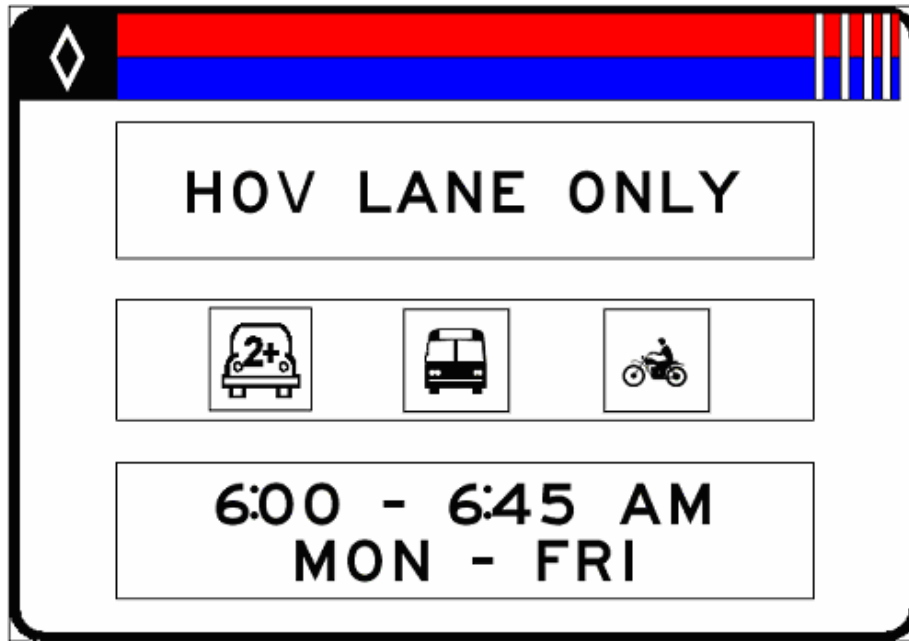


Figure 2. Guide Sign with Full-Span Banner across Top as Used on Houston HOV Lanes.

Symbols

Diamond Symbol

The MUTCD sets the standard that all HOV signs must use the diamond symbol. According to the manual, when the diamond symbol or HOV acronym is used on ground-mounted signs without corresponding text, the symbol should be centered on the top line of the sign. If the symbol or HOV acronym does have adjacent text, the symbol should appear to the left of the text. This standard applies to both the regulatory and guide signs. Concerning overhead signs, if used, the diamond symbol should appear in the top left quadrant, unless it is the “LANE ENDS” sign. For this sign, the diamond should appear on the entire left side of the sign. Again, this applies for regulatory and guide signs.

As this is new guidance in the MUTCD, the current practice, not surprisingly, varies considerably across jurisdictions.

The three photographs in [Figure 3](#) show three different locations for the diamond symbol on California facilities. All of these variants in position and size for the diamond symbol for regulatory signs are illustrated in the MUTCD, though the exact wording of these signs is not entirely consistent with the new manual.

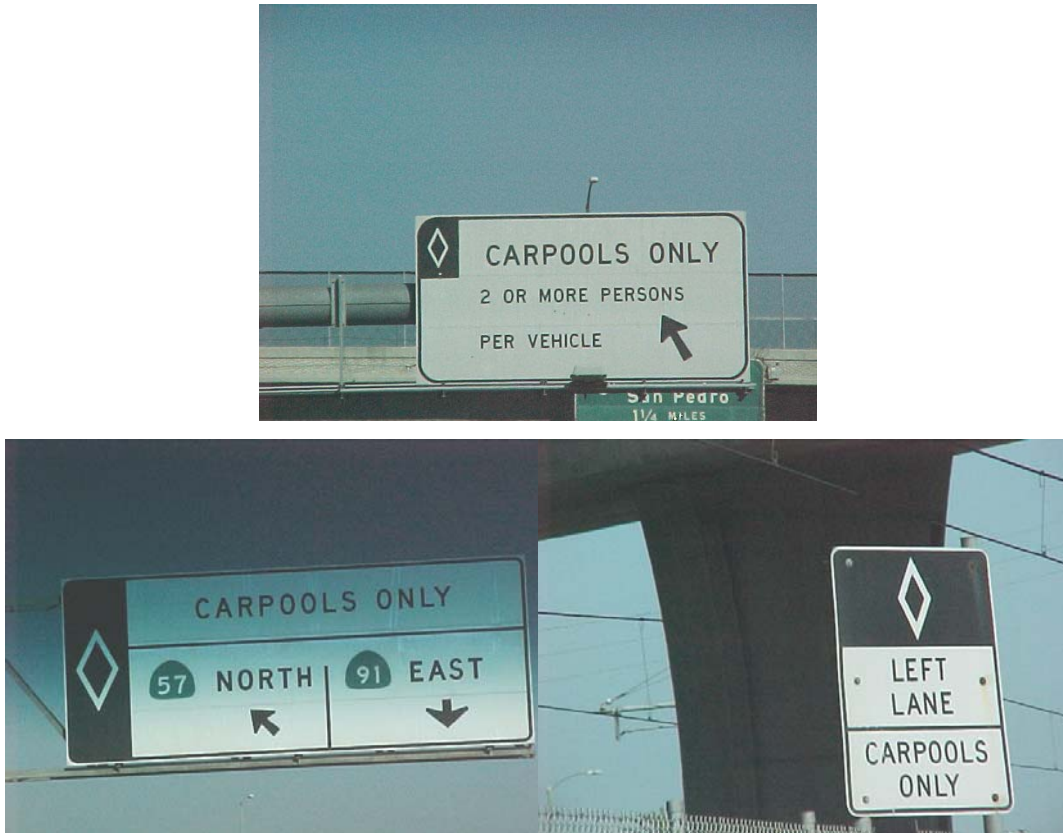


Figure 3. Diamond Symbol as Used on California Facilities.

Occupancy Symbols

The new MUTCD uses text to convey occupancy requirements (see Section 2B.26). Many existing facilities use variants of the “carpool” symbol, which shows the outline of a vehicle with a numeral inside the image indicating the required number of occupants. Other types of symbols that have been seen on managed lanes signs are outlines of taxis, motorcycles, or buses to indicate additional vehicle classes that are allowed in the lane. [Figure 4](#) illustrates the occupancy requirements used on the Houston area HOV lanes. METRO staff reports that these symbols were created in-house and were based on signs seen at other facilities (12).



Figure 4. Occupancy Symbols Used in Houston.

Washington and Texas use a symbol with a number to distinguish the number of passengers. A 1988 Texas Transportation Institute (TTI) study concluded that a word message should be used to indicate occupancy requirements, as the vehicular symbols are “confusing to the motorist” (11). The Houston area HOV facilities currently use a mix of text and symbol signs, with the symbol becoming the predominant usage. In the Dallas area, text is used for occupancy requirements although a few symbol signs were used in the first HOV applications (13). The Ohio MUTCD has adopted the new federal MUTCD practice of using the text “2 or more persons” and/or “2+” (14). The same is true for Minnesota and Georgia. Throughout the country, older style signs that use symbology will remain in place as new signs are phased in over the next 10 years to be brought into compliance with the new manuals.

In Seattle, the Washington DOT tested signs with the diamond symbol only versus the exact sign with a car symbol with silhouettes with the number three on it. They concluded that the car symbol did not reduce the number of violations in the lanes, but when doing on-site

interviews, they determined the effects were excellent for sign detection, recognition, and user acceptance (10). This report recommends that if signs will use symbols, they should be of the front view of a vehicle. The Washington DOT is now using symbols, similar to those used by Houston METRO, to convey occupancy requirements (15), as shown in Figure 5. The Long Island Expressway in New York uses a word message to convey occupancy by defining a carpool as “2 OR MORE PERSONS PER VEHICLE” (16), as shown in Figure 6.



Figure 5. HOV Sign Used on Eastside HOV Lanes in Washington State (15).



Figure 6. Long Island Expressway Defines “Carpool” (16).

In the United Kingdom, the A647 in Leeds uses a symbol with two silhouettes and the numeral “2+” inside a front view of a car (17). Ontario uses symbols, in conjunction with the

diamond symbol, on their signs in the Toronto area (18), as shown in Figure 7. One reason cited for using the symbols is the Ontario requirement to provide signage in both English and French. The authors point out that the “CARPOOLS ONLY” text sign would be unworkable in a bilingual format. For this reason, they use the diamond symbol without accompanying HOV ONLY text on other regulatory signs.



Figure 7. HOV Symbols Used in Ontario (19).

Terminology

Operational Times

All HOV facilities reviewed posted their operating times and days of the week at least once in advance of the entrance. In Houston, where variable occupancy requirements are in place on I-10 and U.S. 290, the phrase “ALL OTHER TIMES” is used. This phrase also encompasses times when the lane is closed, which may result in driver confusion. The only indication that the lane is closed is the presence of cones at the slip ramp entry and the access

gate being closed. This information is not available to drivers until they are at the access area. For facilities that operate continuously, times and days are generally not posted.

For managed lanes that operate along shoulders or on regular freeway lanes during certain periods, there is a need to communicate that during non-peak times all vehicles are allowed in the lane regardless of occupancy or vehicle class. A common application of this is found in bus-only lane operations along shoulders. These facilities are generally signed using ground-mounted signs displaying “BUSES ONLY” along with hours and days posted (see MUTCD Sign R3-11b) (1). In northern Virginia, when the inside travel lane is used as an HOV-2 lane, the right shoulder becomes an allowable travel lane for all vehicles. Signs are placed overhead above the shoulder with the word “SHOULDER” in black letters on a white background as a banner across the top. A dynamic message sign then displays the current status of shoulder use. Other ground-mounted signs refer to the shoulder by stating “USE RIGHT LANE” with the hours and days posted (9). It should be noted that the use of the term “RIGHT LANE” to refer to the shoulder could be confusing to drivers, especially since overhead signs use the term “SHOULDER.” Research has not been performed to confirm this potential confusion problem, however.

Lane Name

For many managed lanes projects, particularly for toll facilities, a program name is used to refer to the facility in marketing materials. This name is often derived from the electronic toll collection system used. Examples of this are *FasTrak* (I-15 San Diego), *FAST Lane* (proposed I-394 in Minneapolis), *EXPress Toll* (Denver), and *Katy Tolllanes* (proposed in Houston). On the I-15 San Diego high occupancy toll (HOT) lane facility, signs indicate the facility is for carpools and those with the FasTrak transponder (see Figure 8). Obviously, the use of terms such as this can benefit drivers by identifying the facility as something different than the general purpose lane. There are also benefits by linking marketing, enforcement, and signing graphics to aid drivers in understanding a toll facility’s system. However, as electronic toll collection software and hardware interoperability increases, these unique names may eventually cause confusion for motorists who are not familiar with the local terminology but who desire to access the managed lane as well. The fact that the program names are all similar (e.g., MnPass, I-Pass,

E-Pass, EZ Pass, EZ Tag, Smart Tag) may further add to driver uncertainty about interoperability.

The use of the trademarked names of the transponder on toll plaza signing is widespread (see [Figure 9](#) and [Figure 10](#)). Throughout the Northeast United States the EZ Pass system can be used on 15 different toll facilities in seven states. At toll collection sites, the EZ Pass logo is generally displayed above the appropriate lane. These facilities all have cash-payment options as well (see [Figure 11](#)). The future direction of managed lanes is toward parallel lanes which use electronic toll collection exclusively. In common parlance, it is likely that these lanes will be referred to by average drivers as “the EZ Pass lane” (or appropriate toll transponder). Signing practices need to weigh the need for uniformity across regions and states with the local commuter benefits of using the local “slang” for the facility.



Figure 8. HOT Lane on I-15 in San Diego.



Figure 9. Toll Symbols on E-470 in Colorado.



Note: The left most sign is yellow, center sign is green, and right most sign is blue with yellow panels.

Figure 10. Toll Plaza Signing on Sam Houston Tollway in Houston.



Figure 11. EZ Pass Sign on State Route 1 in Delaware.

Focus groups conducted as part of this study (20) provide evidence that drivers still consider themselves to be “on” the route number served by the general purpose lanes when they are using the parallel managed lane facility. For instance, when shown a drawing of a buffer-separated concurrent flow facility on I-10, drivers reported that they would describe themselves as “being on I-10,” not “in the toll lane.” The signing referring to managed lanes should support this preconceived notion of route names by using the route number or name in references to the managed lane. It also has implications for access point signing as discussed in a later section of this report.

Earlier studies of special use and preferential lanes showed that many drivers were unaware of the meaning of HOV (11, 14). More recent research shows that, through use, over the last 20-30 years most motorists who are exposed to the term as part of their regular driving experience do understand the meaning (7, 8, 9). A 1984 survey in Virginia showed that virtually everyone knew what HOV meant and also asked how they found out about it. Most respondents, however, preferred the word “carpool” to be located somewhere on the signs. In that study, 26.5 percent of the respondents surveyed also commented that HOV restrictions were a problem for tourists, out-of-state, and non-local drivers, and others suggested immunity or warnings for these violators.

Access Points

TxDOT practice and the new MUTCD standards call for placing an “EXIT” sign at the gore to mark the movement from the general purpose lane into a managed lane. The MUTCD further specifies that signs at exit and entry points shall have the HOV abbreviation or the diamond symbol somewhere in the legend. Meanwhile, lanes designated for bus or taxi traffic shall not use the diamond symbol on guide and exit signs. For barrier-separated facilities only, an exit direction sign is specified; the diagrams show the diamond symbol in the upper left corner of the “EXIT” direction sign (See MUTCD Figure 2E-47). Unfortunately, this recommendation appears contrary to the preference stated by the majority of focus group participants who recommended the sign say “ENTER HOV” to reflect their conception of *entering* the managed lane facility rather than *exiting* the general purpose lane (20).

Signing at the transition from a managed lane back to the general purpose lane also uses “EXIT” terminology. Advance exit and exit direction signs using the route shield and the word

“EXIT” are called for to mark this transition for barrier-separated lanes (Figure 2E-47). While these signs alert drivers that a transition point is nearing which will require a merge maneuver, the use of the word “EXIT” and the use of the concurrent route number is in opposition to the opinions expressed in the focus groups. For buffer-separated facilities that do not require a lane change at entrance and exit points, the “HOV LANE ENDS” (R3-15a) sign is specified (1).

Lane merging warning signs (W4-2) are illustrated at merge points at the end of HOV lanes but are not referred to in the text of Section 2E.59. These signs are placed on the left median as a warning to drivers in the managed lane that they must merge right. It is not clear in the MUTCD whether these merge signs should have the HOV plaque as recommended as an option in Section 2C.52.

Allowed Vehicles

Advance regulatory signing for preferential lanes calls for a particular format to be used for the signs, as stated in Section 2B.26. This section states that the HOV signs shall display the minimum allowable vehicle occupancy requirement established for each HOV lane. The vehicle occupancy requirement for an HOV lane shall be referenced immediately after the word message HOV of the diamond symbol. [Figure 12](#) and [Figure 13](#) illustrate these signs and requirements.

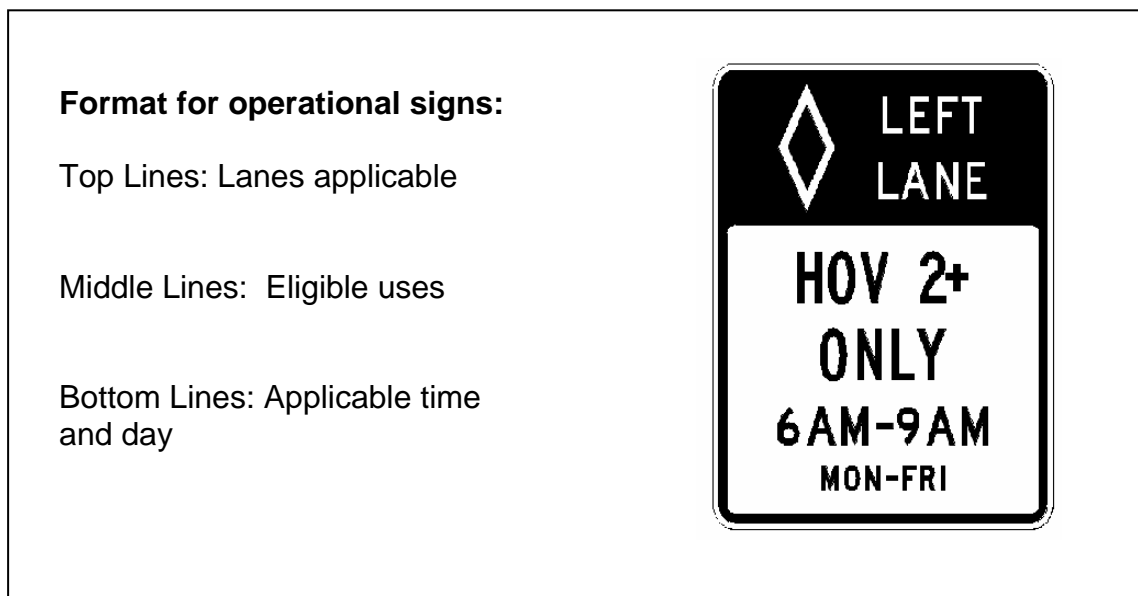


Figure 12. Ground-Mounted Occupancy Requirement Sign.

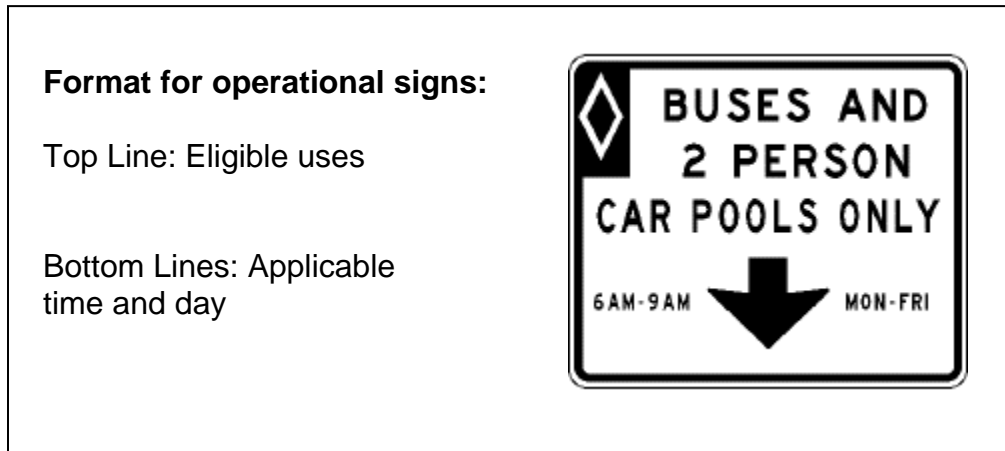


Figure 13. Overhead Occupancy Requirement Sign.

In addition to HOVs, buses, and taxis, other vehicle types may need to be included or excluded. Some facilities explicitly indicate the inclusion of motorcycles on managed lanes by use of the word “MOTORCYCLES” or a symbol. [Figure 14](#) shows an example of a supplemental regulatory sign allowing motorcycles. In the United Kingdom, motorcycles are often allowed in bus lanes. [Figure 15](#) shows a sign used there to indicate allowed vehicles on a surface street managed lane. Notice the use of a side view of a bus.



Figure 14. Motorcycle Allowed Sign in Phoenix.



Figure 15. Allowed Vehicle Sign in the United Kingdom.

Inherently low-emission vehicles (ILEVs) are allowed with a single occupant on many managed lanes facilities. Various symbols for ILEVs have been proposed, but the MUTCD has adopted a sign (R3-10b) with the full term spelled out (1). As these vehicles become more widespread, an abbreviation or symbol may come into use that could shorten these signs. In the 1970s as HOV lanes started, many agencies used the full term “HIGH OCCUPANCY VEHICLE” along with the abbreviation to educate drivers as to the meaning of the abbreviations. Figure 16 illustrates this sign in Virginia.



Figure 16. Sign Used to Define HOV Term.

Agencies often wish to exclude certain vehicles from managed lanes based on weight or length. Regulatory signs stating these exclusions are used upon approach to the entrance to the managed lane. Early research encourages the separation of these exclusions from signs containing allowed vehicles. [Figure 17](#) shows an example of a truck and trailer exclusion sign used in Houston. Meanwhile, an earlier TTI report recommended that the prohibited-vehicles sign be displayed in advance of the permitted-vehicles sign ([11](#)). This work also recommended that words only, not symbols, be used for prohibition with the word “NO” appearing before each vehicle class name. The researchers preparing that report also recommend no more than four lines of text on the prohibition signs.



Figure 17. Vehicle Exclusion Sign in Houston.

In contrast to vehicle exclusion efforts, some managed lanes facilities have established separate carriageways based on vehicle type for which signing is designed to guide motorists to the appropriate carriageway rather than restrict them from the lanes for which they are not intended. The New Jersey Turnpike, for example, has an exclusive lane for passenger vehicles. They use green guide signs at the entry points to divert traffic to the proper lanes (see [Figure 18](#)).



Figure 18. Vehicle Segregation on the New Jersey Turnpike.

A 1999 study for the Massachusetts Highway Department examined entry signing for HOV lanes (21). This study tested 20 college students in a driving simulator and measured the time to decide whether or not they would choose the HOV lane based on the type of sign presented and whether or not the drivers were told they were eligible for the lane. They found that the alternative signs resulted in faster decision times. The alternative signs reduced the amount of information on each sign by separating occupancy (“2 + Person Vehicles Only”) from hours of service (“6:30 AM – 9:30 AM Mon-Fri”) onto two signs. The alternative signs also used a consistent full-width black banner with the diamond symbol and the words “CARPOOL LANE” in white letters. The existing signs used the white diamond symbol on a black field, with the same term in black letters on a white background.

In previous MUTCD versions, the word “Rider” was recommended in phrases such as “4 Rider Car Pools Only.” Fendrick notes that many states, including Washington, California, New York, and Florida had moved away from this term because of driver confusion over whether the driver of the vehicle counted as a “rider” (6). The term “2 Person” or “2 + Persons” is now preferred and was recommended by the Institute of Transportation Engineers (ITE) in 1992 (22). The current MUTCD uses the terms “HOV 2+” and “2 OR MORE PERSONS PER VEHICLE” (1).

Supplemental Information

Some agencies wish to promote ridesharing or electronic toll tag subscription along their managed lanes facilities. The MUTCD has new standards concerning Internet addresses and telephone numbers appearing on traffic control devices. Section 2A.06 states:

Except as stated in the Option below, Internet addresses shall not be shown on any sign, supplemental plaque, sign panel (including logo panels on specific service signs), or changeable message signs.

Guidance:

Unless otherwise stated in this Manual for a specific sign, and except as stated in the Option below, phone numbers of more than four characters should not be shown on any sign, supplemental plaque, sign panel (including logo panels on specific service signs), or changeable message sign.

Option:

Internet addresses or phone numbers with more than four characters may be shown on signs, supplemental plaques, sign panels, and changeable message signs that are intended for viewing only by pedestrians, bicyclists, occupants of parked vehicles, or drivers of vehicles on low-speed roadways where engineering judgment indicates that drivers can reasonably safely stop out of the traffic flow to read the message.

State and local highway agencies may develop special word message signs in situations where roadway conditions make it necessary to provide road users with additional regulator, warning, or guidance information.

These prohibitions are intended to minimize driver distraction and short-term memory load. The allowance of phone numbers and Internet addresses on low-speed roadways, such as parking lots, provides for this information to be displayed on access roads and in park-and-ride lots. Despite these recent prohibitions, many agencies continue to display information like phone numbers and Internet addresses on guide signs and at toll plazas (see [Figure 19](#)).



Figure 19. Phone Numbers and Internet Addresses in Use on Signing.

Trailblazer signs which lead motorists from arterial streets to managed lanes facilities are an important part of a way-finding system. The MUTCD states as guidance that route and access information should be in the form of printed literature and strip maps, but that trailblazer signing may be installed on a highway with the approval of the appropriate transportation agency.

Houston METRO recently implemented a sign upgrade program which involves extensive use of trailblazer signs on arterials leading to park-and-ride lot entrances and along freeway frontage roads (8). Figure 20 shows an example of a trailblazer sign leading drivers to a park-and-ride lot that allows access to a barrier-separated HOV lane in the Houston area. Trailblazers on freeway connectors ramps are also being deployed, which advise drivers on appropriate exits to enter the managed lanes facilities on intersecting roadways.



Figure 20. Trailblazer Sign on Suburban Arterial in Houston.

Sign Placement

Sign placement is always a challenge for transportation agencies. In general, overhead signs are often preferable on freeways because they are visible to all lanes and will not be blocked by large vehicles. Overhead signs, however, are extremely expensive to install and often require lane closures for maintenance activities. A common practice is to erect a large sign structure that spans the full width of the roadway. Guide signs for general purpose and managed lanes are then all placed on the same structure. An earlier TTI study recommended that signing on a single structure should be designated for the transitway or the freeway, but not both, so that users will not get confused (11). Focus group participants in the current project also expressed concern that drivers would be uncertain as to which sign applied to which lane when shown on full-span sign installations. Focus group participants also expressed concern that general purpose lane drivers would become unnecessarily distracted by the information meant for the managed lane users (20).

One study conducted on city streets in San Francisco looked at overhead versus shoulder sign placement and determined that overhead mounting and redesigned signs resulted in a 25-40 percent reduction in violations and intrusions into special use lanes. The authors also note that the higher mounting also contributed to drivers in other parts of the street becoming more aware of the special use lane (24).

On some facilities, conflicting information regarding distances to exits may need to be displayed. For example, the distance to a particular cross street (e.g., Oak Street) may be one mile away for the general purpose lanes, but the egress point from the managed lane to the general purpose lane to then access to that cross street may be much closer (e.g., ¼ mile). If the exit sign for the managed lane stated “OAK ST ¼ MILE” and the advance guide sign for the general purpose lane stated “OAK ST 1 MILE,” motorist confusion would likely arise.

Current practice of sign placement is mixed. Fendrick (6) discussed various states’ use of ground and overhead mounting. For non-separated HOV lanes, Washington, New Jersey, and California use a combination of sign placements. Florida uses overhead signs almost exclusively on non-separated facilities in order to be visible to both lanes of traffic. Rather than using a full-span sign structure, some facilities in California use a pair of cantilever structures that place signs over the appropriate lane (see Figure 21). This arrangement was preferred in the Texas

focus groups, as compared with a full span sign structure. Respondents felt that the physical separation of the two supports led to less distraction by irrelevant signs (20).



Figure 21. Example of Cantilevered Signs in California.

Right-shoulder ground mounting is generally more cost effective, except in cases of very limited right of way. For managed lanes facilities that use the right shoulder or right lane, this is an appropriate location for the signs. For median or left-lane facilities, however; it is not recommended to place signs on the right shoulder. The MUTCD makes no statements concerning which side of the road to place ground-mounted signs. All of the figures for preferential lane use illustrate all signs as being on the left side of the road, for left-side preferential lanes. Meanwhile, a report from Virginia discourages ground mounting, stating, “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” (9). The Virginia article recommended that whenever possible the HOV signing should be mounted directly over the HOV lane.

Unfortunately, placing the sign on the left side of the road poses problems for facilities with a narrow median or concrete barrier separating two carriageways. The MUTCD does make allowances for these situations with limited lateral clearance in Section 2E.59 (1). It provides an option to skew signs up to 45 degrees for signs that are 72 inches or less in width in order to fit within the barrier width.

The MUTCD is difficult to interpret regarding ground-mounted and overhead signs. There seems to be an attempt to distinguish between barrier-separated lanes and other types of facilities, but some of the *shall* conditions seem to contradict each other. The *shall* conditions in

Section 2E.59 regarding ground and overhead mounting are as follows (numbers and list format by the authors):

1. Ground-mounted advance guide signs shall be provided at least 0.5 mi prior to the beginning or initial entry point to all types of preferential only lanes (including barrier-separated, buffer-separated, and concurrent flow) (p. 2E-64).
2. Ground-mounted guide signs shall be provided at the beginning or initial entry point and at intermediate access points to all types of preferential only lanes (p. 2E-64).
3. Overhead preferential only lane guide signs shall be used only as a supplement to ground-mounted preferential only lane guide signs unless an engineering study identifies that ground-mounted guide signs are not appropriate for a particular situation or location (p. 2E-64).
4. For barrier-separated preferential only lanes, overhead advance guide and overhead guide signs shall be provided in advance of and at the beginning or initial entry point to the preferential only lanes (p. 2E-65).

The requirements laid out in standards 1-3 call for ground-mounted signs, while condition 4 mandates an overhead sign. These only reconcile if one assumes that the engineering study called for in number 3 necessarily will result in the conclusion that a ground-mounted sign is never appropriate for barrier-separated facilities, thus producing standard number 4. The rest of the Guidance and Options statements are similarly confusing and contradictory. This section of the manual does cover a good variety of facility types and is comprehensive in that regard. Future revisions of the U.S. manual and any supplemental material specific to managed lanes would do well to clarify the language in Section 2E.59.

Changeable Message Signs

Often changeable, or dynamic, message signs (CMSs) are used in conjunction with fixed managed lane signage. The only standards that the MUTCD provides concerning managed lanes are that when CMSs are used for preferential only lanes, they should have the appropriate sign size, letter height, and legend format for that type of roadway facility and speed. It allows agencies the option of using the diamond symbol or the HOV abbreviation on CMSs.

New York uses overhead signs almost exclusively on buffer lanes, as well as changeable message signs at major decision points (6). Similarly, Virginia uses a combination of static and changeable message signs. Many HOT lane facilities use a hybrid of static and changeable signs, with the changeable component used to display dynamic pricing information. This combination can yield significant cost savings due to the reduced hardware and power consumption of using a small changeable panel as part of a larger static sign. Figure 22 illustrates such a sign along SR 91 in California. As long as the amount of information being presented at one time remains limited and the size of the characters presented meet necessary legibility requirements, this approach can be expected to work well.



Figure 22. Hybrid Static-Changeable Message Sign Used in California.

Large, overhead changeable message signs are commonly used along managed lanes. These signs allow for traffic conditions, incident notification, travel times, and tolls to be displayed dynamically. With newer electronic technology, the diamond symbol can be displayed full height on the sign to mimic the design of an overhead regulatory sign. Figure 23 illustrates such a sign on SR 91 in California.



Figure 23. Overhead Changeable Message Sign.

Lane Control Signals

The MUTCD allows the use of overhead lane control signals that permit or prohibit the use of specific lanes. They are often applied to reversible flow lanes and at toll plazas to indicate payment lane status. Research has shown good driver comprehension of the red X and green arrow lane control signal symbols (23). An FHWA study in 1982 reports that lane control signals may be better understood if accompanied by an advance sign stating “LANE CONTROL SIGNALS AHEAD” (10). A project on transitway signing conducted by TTI contains an example of an educational sign to be used in advance of an area using lane control signals (11). They also recommend including information pertaining to lane control signals in the *Texas Drivers Handbook*.

Lane control signals can also be applied to shoulder lane operations to indicate allowable travel on the shoulder. The MUTCD contains guidance on placement and visibility of these signals.

Another study, conducted in 1978, compared fixed lane-occupancy schedules to changeable message signs and lane control signals with regards to parking. The study concluded that “fixed schedule lane-occupancy signs such as those now in use are ineffective and perhaps dangerous.” The study showed that subjects missed more than seven times the judgment questions concerning the fixed signs than the changeable message signs presented. The report

stated that the subjects took almost twice as long to interpret the data. The most successful signs used the MUTCD approved red X and green arrow lane control signals (24).

CURRENT PAVEMENT MARKING STANDARDS AND PRACTICE FOR MANAGED LANES

Lane Line Markings

Longitudinal pavement markings can play a very important role in the driver's understanding of allowable movements in managed lanes. The MUTCD distinguishes the appropriate markings for the different types of managed lanes based on whether lanes are reversible, physically separated, and on the right or left side of the general purpose lanes. These requirements are summarized in the MUTCD in Section 3B.23. In all cases, whether physically separated or not, the right edge line should be white. The manual recommends "wide" white lines where crossing is prohibited but does not define the width. In industry terminology, standard edge lines are generally 4 inches in width, and wide lines are 8 inches. Carroll et al. report that some HOV projects are not meeting the minimum requirements set by the MUTCD regarding a "wider" stripe (25).

In practice, some agencies have also used yellow lines to separate concurrent flow lanes (see Figure 24 where the far two right pavement lines are yellow). It is presumed that this decision was made to add emphasis to the "do not cross this line" message of the solid double line. Other efforts to emphasize the difference between lane types using pavement treatments have also been taken by some agencies. A recommended practice in Virginia for concrete roadways is to install a thin layer of bituminous pavement to the shoulder area used as an HOV lane in order to better delineate the shoulder/part-time travel lane from the general purpose lanes. The bituminous pavement stops at the beginning of the deceleration lane, and starts again at the end of the acceleration lane of the right shoulder (9).

The MUTCD also discusses that all pavement markings associated with the preferential lane, including longitudinal pavement markings, word and symbol, should end where the "LANE ENDS" sign is installed.



Figure 24. Yellow Lane Lines Used in California.

For concurrent flow lanes, it is desirable to delineate areas where changing lanes in or out of the managed lanes is allowed. The MUTCD recommends using a single broken wide white or single dotted normal-width white line in areas where crossing is permitted. In areas where crossing is prohibited, a double solid white line is specified. For those sections where crossing is discouraged but not prohibited, a single solid wide white line is the standard.

Horizontal Signing

Word and symbol pavement markings (also called horizontal signing) can also coincide with proper signage to convey the roles and rules of the managed lane. The MUTCD states that preferential markings should be used whether the lane is assigned full or part time a specific class or classes of vehicles. It recommends that the markings consist of white lines forming the standard diamond symbol, or the word HOV. The manual also states that all of the preferential lane word and symbol markings shall be white and positioned laterally in the center of the lane. An example of the diamond symbol lane marking is shown in [Figure 25](#). The MUTCD recommends a longitudinal spacing of 300 m, allowing for engineering judgment. In practice, a 1997 review found variations in the spacing of the diamond symbol on the ground ranging from 150 m in Washington State to 1000 m in California (6).



Figure 25. HOV Lane Pavement Marking Symbols in Houston.

Other practices in the area of horizontal signing include use of the word “ONLY” or “LANE” in conjunction with the diamond symbol. Other facilities may place the name of the allowed vehicle class in text on the road, typically “BUS” or “CAR POOL,” as shown in [Figure 26](#). This practice is used in Europe, as illustrated in [Figure 27](#).



Figure 26. Horizontal Signing in California.



Figure 27. Horizontal Signing in Offenburg, Germany.

CHAPTER 3: SIGNING AND PAVEMENT MARKING DISCUSSION ISSUES

COLOR CODING

Toll roads have been an area where agencies have been more willing to utilize banners, logos, and unique colors throughout their traffic control devices. Technically, toll roads are obligated to conform to the MUTCD since the document applies to all roads open to travel by the public. Toll road operators, however, have sought ways to “brand” their roads. While some in the transportation engineering community scoff at this branding as using traffic signs as advertisements, the use of a consistent and unique symbol or color may benefit travelers in navigating. This is an area where more research is needed.

Recently, a panel made up of experts from 13 toll operators recommended the adoption of consistent use of color at toll plazas (26). They report that several agencies are using unique colors for each payment method: electronic, manual, and automatic coin machines. These authors recommend the adoption of uniform symbols for electronic toll collection and uniform colors for these applications.

Recently, in Texas, the Harris County Toll Road Authority has requested permission to experiment with a purple background (with white letters) for guide signs along connector ramps leading to its roads (MUTCD Request 1-39-EX, November 2002). Currently, this request has been withdrawn, but the agency has installed purple guide signs along its Westpark Toll Road, due to open in 2004. An evaluation of the effectiveness of these signs is planned.

SYMBOLS AND TERMINOLOGY

Allowed Vehicle Symbols

The use of symbols to indicate which vehicles are allowed on a managed lane facility has not yet been standardized in the MUTCD but are used frequently. A consistent symbol set for buses, motorcycles, and ILEVs needs to be developed. In addition, occupancy symbols for carpools should be standardized. No visibility or comprehension research has been found on any of the symbols in use today. From a sign design perspective, symbols are preferred because they occupy less space and can be used in a modular fashion whereby the overall footprint of the symbol is a standard size. In addition, for areas with non-English-speaking drivers, symbols may

be preferred as long as research supports their use. Research and design work is needed on these symbols to assure good legibility and comprehension. A symbol for ILEV could be particularly difficult to develop.

For subscription-based programs that allow registered vehicles to pay a toll to be exempt from occupancy requirements, such as the QuickRide program in Houston, a symbol could be used to identify to subscribers when they are allowed in the lane. Symbols may also be desirable to indicate forms of payment accepted or excluded. These symbols may be similar or identical to icons or logos used for electronic payment systems and in other marketing materials. The consistency in message gained by repeated use of these types of symbols will lessen the information-processing load of regular road users, but symbols may cause confusion to unfamiliar users who may have trouble comprehending novel symbols.

The use of symbols may also be extended into signs indicating excluded vehicles. The use of the red circle slash may need to be avoided on vehicle symbols because of the fine detail present in these icons, which could be obscured by the prohibition markings.

Access Point Terminology

Focus groups conducted as part of this overall project (reported in Report 4160-13) indicated that the vast majority of drivers thought of the access area as “entering” the managed lane, not “exiting” the general purpose lane. Yet, all signs in the MUTCD indicate the movement from the general purpose lane to the managed lane with an “EXIT” sign. Clearly, a disconnect exists between the average driver’s conceptualization of the roadway network and the signing practices in this area. Likewise, signing for the parallel general purpose lanes with the use of route shields may be confusing to drivers accessing the managed lanes because it appears that motorists associate the managed lanes with the identical route number or name as the general purpose lanes.

These issues are particularly relevant to signing for facilities with parallel managed lanes. More research is needed to understand inherent driver understanding of routes and other global navigational issues so that the signing system can support the driver’s natural understanding.

Allowable Exits

Another, impediment to HOV lane use cited in the focus groups (20) was that drivers were uncertain as to where they would be able to exit from the system, particularly for barrier-

separated facilities. One study tested driver acceptance of signs placed before entry to a managed lane that warned of no access to major destinations and roads (21). They found that research participants in a simulated driving task were able to comprehend these messages, even though they added to the information load of the sign. Focus group participants in the current project expressed a desire and expectation to be notified at least of the next exit point and preferred to be notified if a major interchange was not accessible from the managed lane.

The new MUTCD does illustrate some advance exit signing in Figure 2E-46, which places exit names and distances on green guide signs mounted on the left side of the road. These exits and distances are intended for the managed lane users only. Caution needs to be exercised in sign design and placement to avoid presenting managed lane exit information that conflicts with that for the general purpose lanes.

Supplemental Information

Information related to electronic toll tag subscriptions, transit information, carpool registries, and other programs is often presented along a roadway. This is even more true for managed lanes, due to their restrictive nature and the possible revenue enhancement from promoting these programs. The MUTCD currently prohibits the placement of Internet addresses on traffic control devices, yet examples are provided in this report that document their use. As Internet usage nears universality, the use of web addresses may be preferred to telephone numbers for these applications. Web addresses can be selected that are easier to remember than telephone numbers, thus lessening the information load on drivers.

Supplemental information should always come second to the necessary warning, guidance, and regulatory functions of traffic control devices. Care must be exercised in placing supplemental information to avoid installing signs near decision points or where they may direct attention away from necessary maneuvers.

SIGN PLACEMENT

Sign placement is a difficult issue for managed lanes facilities. The MUTCD provides somewhat confusing information as to when signs should be placed overhead, on the right shoulder, or on the left-side median barrier. Particularly for concurrent-flow facilities with limited access areas, conflicting information regarding distances to exit points for the managed

lanes and general purpose lanes may exist. In these situations, it is critical that signing displays be designed so as to clearly separate the information for the managed lanes from that intended for the general purpose lanes. Separate cantilevers rather than full-span sign structures are preferred (see [Figure 21](#)). If separate cantilevers are not possible, managed lanes signs should be as far left as possible, preferably with a noticeable gap between them and signs for the general purpose lanes.

Placing signs on the left median is desirable, but lateral clearance restrictions may prevent this application in many instances. Furthermore, on multiple-lane managed lanes, left-side placement may not be the best solution since larger vehicles in the inside lane may block the left-mounted signs from vehicles on the outside managed lane.

CHANGEABLE MESSAGE SIGNS

Changeable message signs can be an important instrument to display traffic alerts, construction updates, and other real-time information. Existing guidelines concerning message construction and message phasing should be followed for managed lanes applications. Agencies may wish to consider placing a static plaque identifying the applicable lane above changeable message signs if the information in the sign applies only to the managed lanes.

Information overload may occur if complex operating schedules and variable pricing based on vehicle class and occupancy are conveyed through multiple-phase changeable message signs. Other communication means, such as highway advisory radio or mailings to subscribers, should be considered to convey this information.

PAVEMENT MARKINGS

The use of the diamond symbol in special use lanes is encouraged to discourage violators. Other horizontal signing applications such as speed limits or route numbers may also be beneficial. The MUTCD section on longitudinal markings makes specific recommendations for a variety of managed lanes facilities but does not cover all possibilities. There has been little research on driver understanding of the use of broken white lines where crossing is permitted. Some focus group participants did indicate an understanding of the prohibitive nature of double white lines and the permissive nature of broken white lines. Many respondents, however, were

not aware of these meanings. Other respondents reported witnessing frequent violations of these markings in concurrent flow HOV lanes in Dallas.

CHAPTER 4: CONCLUSIONS AND RECOMMENDATIONS

The new U.S. MUTCD has several improved sections on preferential lanes. These recommendations are scattered throughout the sections on warning signs, guide signs, lane control signals, and pavement markings. Managed lane planners, designers, and operators may be better served if all relevant standards, options, and guidance were contained in a single chapter. This consolidation would provide an opportunity for consistency to be improved across and within the current piecemeal approach. Managed lanes facilities currently in operation have had to interpret and improvise to develop traffic control plans. These efforts have produced some good practices, but also some that may confuse drivers. In addition, managed lane use may not be reaching its full potential because facilities are perceived as confusing and difficult to use.

RECOMMENDATIONS FOR FUTURE WORK

Future editions of the MUTCD, and any amendments to the Texas MUTCD, should consider the following areas as needing improvement, clarification, and additional research:

- Sign placement recommendations in Section 2E.59 are particularly confusing and contradictory. Clear guidance, based on research, is needed regarding when to place signs overhead or on the ground.
- Information regarding the method of payment needs to be presented before vehicles enter the managed lane facility. It is not clear whether signs like “EZ TAG ONLY,” which display the permissive message regarding which type of electronic toll tag is allowed, adequately convey the message that cash is not accepted. As toll tags become more universal, symbols and terminology need to be standardized within and across states to allow for interoperability of all toll tags.
- The terminology used to demarcate access points and weave areas needs to be researched and standardized. The practice of marking entrances to managed lanes facilities with “EXIT” signs seems to be counter to most drivers’ notions of access. Advance exit signs from managed lanes to general purpose lanes are also not well understood.

- The terminology used to refer to the managed lane and the concurrent, parallel general purpose lane also needs to be researched and standardized. Drivers do not consider themselves to be on a different road and thus find signs referring to the mainline route as a separate entity to be confusing.
- Design and testing of symbols for allowed vehicles, and other operational aspects, are needed.
- A more comprehensive set of pavement marking recommendations that encompasses a wider variety of managed lanes designs is needed. There has been little research on driver understanding of the use of broken white lines where crossing is permitted.
- The use of color coding or distinctive banners on guide signs intended for managed lanes vehicles should be considered and tested.

REFERENCES

1. U.S. Department of Transportation. *Manual on Uniform Traffic Control Devices for Streets and Highways, 2003 Edition*. Washington, D.C.: Federal Highway Administration.
2. Texas State Department of Highways and Public Transportation. *Manual on Uniform Traffic Control Devices for Streets and Highways*. Texas Department of Transportation, Austin, TX, 1980.
3. U.S. Department of Transportation. *Manual on Uniform Traffic Control Devices for Streets and Highways, 1978 Edition*. Washington, D.C.: Federal Highway Administration.
4. U.S. Department of Transportation. *Manual on Uniform Traffic Control Devices for Streets and Highways, 1988 Edition*. Washington, D.C.: Federal Highway Administration.
5. *High-Occupancy Vehicle Guidelines for Planning, Design, and Operations, 2003 Edition*. California Department of Transportation, Sacramento, CA.
6. Fendrick, M.J. Signing and Pavement Marking for Concurrent-Flow High-Occupancy Vehicle Lanes: Summary of Current Practice. *Transportation Research Record 1603*, Transportation Research Board, Washington, D.C., 1997, p. 64-71.
7. Perfater, M.A. *Final Report: Motorists' Impression of the HOV Signs on I-66*. VHTRC 84-R29, Virginia Highway and Transportation Research Council, Charlottesville, VA, 1984.
8. Carroll, C.G. *Developing User-Friendly HOV Signage*. Paper presented at ITE 2000 Annual Meeting and Exhibit, Nashville, TN, 2000.
9. McGhee, C.C. *Traffic Control for High Occupancy Vehicle Facilities in Virginia*. Virginia Transportation Research Council, Charlottesville, VA, 1998.
10. Pain, R., B. Knapp, R. Hostetter, and D. Mace. *Signing and Delineation of Special Usage Lanes*. Report No. FHWA/RD-81/063. Washington, D.C.: Federal Highway Administration, 1982.
11. Hawkins, G., J. Mounce, and S. Albert. *Evaluation of Motorist Information Requirements for Transitways*. Research Report 1113-1, Texas Transportation Institute, College Station, TX, 1988.
12. Personal Communication, Y. Patel, METRO, June 2003.
13. Personal Communication, L. Burgess, TxDOT Dallas District, March 2004.
14. Ohio Department of Transportation. *Manual on Uniform Traffic Control Devices for Streets and Highways, 2003 Edition*. Columbus, OH.

15. Washington State Department of Transportation. Most Eastside HOV Lanes Open to All Traffic at Night; Evaluation Underway. <http://www.wsdot.wa.gov/projects/eastsidehov>. Accessed 1/14/2004.
16. LIRoads. <http://www.mysticmobius.com/liroads/index.asp?id=715> Photo taken August 2002. Accessed 1/14/2004.
17. Leeds City Council, Department of Highways and Transportation. HOV Lane Info Sheet Issue 6 - June 2002 Update. http://www.leeds.gov.uk/pageView.asp?style=0&identifier=200272_843578518. Accessed 1/14/2004.
18. Schijns, S., and A. Cataford. *High Occupancy Vehicle (HOV) Best Practices*. Paper presented at the 68th Annual Meeting of the Institute of Transportation Engineers, Toronto, Canada, 1998.
19. Miscellaneous Ontario Photos. <http://www.lordsutch.com/roads/ontario/misc.html>. Accessed 1/14/2004.
20. Schrock, S.D., G.L. Ullman, A. Williams, and S.T. Chrysler. *Identification of Traveler Information and Decision-Making Needs for Managed Lane Users*. Research Report 4160-13, Texas Transportation Institute, College Station, TX, 2004.
21. Mourant, R.R., B.K. Jaeger, Y. Shen, and J. Li. *Dynamic Evaluation of Pre-entry Signing for a HOV Lane*. Final Report, Virtual Environments Laboratory, Northeastern University, Boston, MA, 1999.
22. Institute of Transportation Engineers. *Design Features of High-Occupancy Vehicle Lanes*. ITE Information Report, Washington, D.C., 1992.
23. Ullman, G.L., S. Wohlschlaeger, C.L. Dudek, and P.B. Wiles. *Driver Interpretations of Existing and Potential Lane Control Signal Symbols for Freeway Traffic Management*. Research Report 1298-1, Texas Transportation Institute, College Station, TX, 1993.
24. Gordon, D.A. *Regulatory Signs for Lane Occupancy and Parking: Final Report*. FHWA-RD-78-689, Washington, D.C.: Federal Highway Administration, 1978.
25. Carroll, C.G., C.A. Fuhs, and J. Obenberger. High Occupancy Vehicle Signing and Pavement Markings: Current and Future Trends. *Transportation Research Record 1781*, Transportation Research Board, Washington, D.C., 2002.
26. Stammer, R., and D. McDonald. Tollway Sign and Pavement Markings – Recommended Design Guidelines. *Transportation Quarterly*, Vol. 54, No. 3, Summer 2000, pp. 67-84.