CONSIDERATIONS AND GUIDANCE FOR TRAFFIC CONTROL DEVICES FOR HOT LANE NETWORKS

Submitted as Part of the
HOUSTON HOT LANE NETWORK
Value Pricing Project 126XXIA005

Prepared for the
TEXAS DEPARTMENT OF TRANSPORTATION
Houston District

And the
FEDERAL HIGHWAY ADMINISTRATION

Prepared by
Susan T. Chrysler & Alicia Nelson
TEXAS TRANSPORTATION INSTITUTE
College Station, Texas

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Executive Summary

Communicating effectively to HOT lane users is important for safety, operational efficiency, and revenue. HOT lanes have been operating for several years across the US, but standards for traffic control devices have not yet been established. The Federal Manual on Uniform Traffic Control Devices is currently under revision, with a new edition expected in late 2009. The Notice of Proposed Amendments was published in January 2008 with a 6 month public comment period. Through our involvement in the National Committee on Uniform Traffic Control Devices we are aware that the sections on toll and managed lanes facilities is undergoing extensive revision from what was in the NPA. The material presented here from the NPA should be reviewed with reservations as it will likely be changed in the final MUTCD revision expected in late 2009. Within 2 years of the issuing of the Federal MUTCD, TxDOT will have to adopt it in part or in full. Again, it is not clear at this time what changes to the pertinent sections will be made.

This technical memorandum presents information on applicable state and Federal standards for traffic control devices. It also provides a summary of state of the practice for static and dynamic signing on other HOT lane facilities. The recommendations presented in this technical memorandum are based on the driver information needs framework developed in TxDOT project 0-4160, results from limited research on toll and managed lane signing, current practice, and standards under development.

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Introduction

Managed lanes offer drivers a choice. The potential benefit of using a managed lane is a faster trip or more reliable trip time. The costs of using a managed lane include the inconvenience and greater distance if the driver's particular destination is not served directly by the facility or the cost of the toll for priced facilities.

In previous work conducted for the Texas Department of Transportation, TTI conducted focus groups with Texas drivers to gauge their understanding of managed lanes operations and to discover what information people need in order to make their choice whether or not to use the managed lane. TTI developed a general framework identifying the pieces of information a driver needs in order to make a decision about whether or not to enter a managed lane (*1*). This process is shown below in flow-chart form in Figure 1. Descriptions of the individual pieces of information are provided in Table 1. As the original TTI report points out, "this information list is highly dependent on the specific managed lane design and operational strategy, and thus these needs would not likely exist at all facilities. For example, information regarding tolls or payment methods would not apply at a facility that is only for HOV traffic. This information is needed in addition to the other information drivers must access and use to operate their vehicle, such as speed limits, geometric changes, and the flow of traffic immediately surrounding the driver."

The category of "Driver Information" contains driver-specific states and preferences that will affect how each individual driver seeks and uses information from the roadside and other sources concerning the managed lane operation. This category is included to reinforce the idea that it's impossible to build a traveler information system of signs and markings that will satisfy each individual driver on each trip.

The idea of a network of HOT lanes poses challenges to a driver information and signing system. In order to sign a true network of HOT lanes, one must consider:

- Choice of destination names and exits served
- Selection of which destination's prices to display
- Guide signs for direct connect ramps
- Trailblazers for surface street connections among HOT facilities on the network
- Differences of occupancy requirements, contraflow status, and pricing among the HOT facilities on the network

Currently, the Houston HOT lane network cannot function as a true network because of the reversible flow nature of each of the legs of the network. So, for instance, a driver arriving

downtown in the morning from Spring on I-45N cannot continue south on the Gulf Freeway (I-45S) because that facility is in reverse-flow and the HOT lane is running north only. This reverse-flow simplifies the signing process considerably because guide and trailblazer signs are not needed to lead people from the exit of one HOT lane to the entrance of another. In the future, however, if the lanes are re-constructed to be bi-directional, careful thought must be given to this interconnectedness and how the design addresses the issues in the bullet list above.

The recommendations presented in this technical memorandum are based on the driver information needs framework presented above, limited research results on toll and managed lane signing, current practice, and standards under development.

Standards and Regulatory Activity

Texas Department of Transportation

As toll facilities and managed lanes become more common in Texas, the Traffic Operations Division of TxDOT has been working to develop new standards and guidelines for the traffic control devices for these new facilities. Previous TxDOT research on toll facility signing presents a detailed state of the practice and literature review of related work (*2*, *3*).

Since those reports were written there have been several key developments which impact the development of traffic control devices. The first is the creation, by TxDOT, of draft policy guidelines for toll roads and managed lanes (*4*, *5*). These documents were developed to provide TxDOT districts with interim guidance for managed lane and toll projects under development. Some of the recommendations in these policies are based on the earlier research by TTI (*2*, *3*). The other recent shift in Texas is the universal use of license-plate video tolling on TxDOT toll facilities. This practice, called "Pay by Mail," allows drivers who do not possess a Texas toll tag to use electronic toll collection (ETC) facilities and receive a bill in the mail via the vehicle registration data linked to their license plate. Pay by Mail offers drivers a convenience, but created issues with the existing Texas Manual on Uniform Traffic Control Devices (TMUTCD) guidance for signs in Chapter 2J*6*. This 2006 document specified the use of the phrase "TxTAG Only" on signs for ETC roadways. With the advent of Pay by Mail this "tag only" message is no longer valid, and the signing specifications have had to be modified.

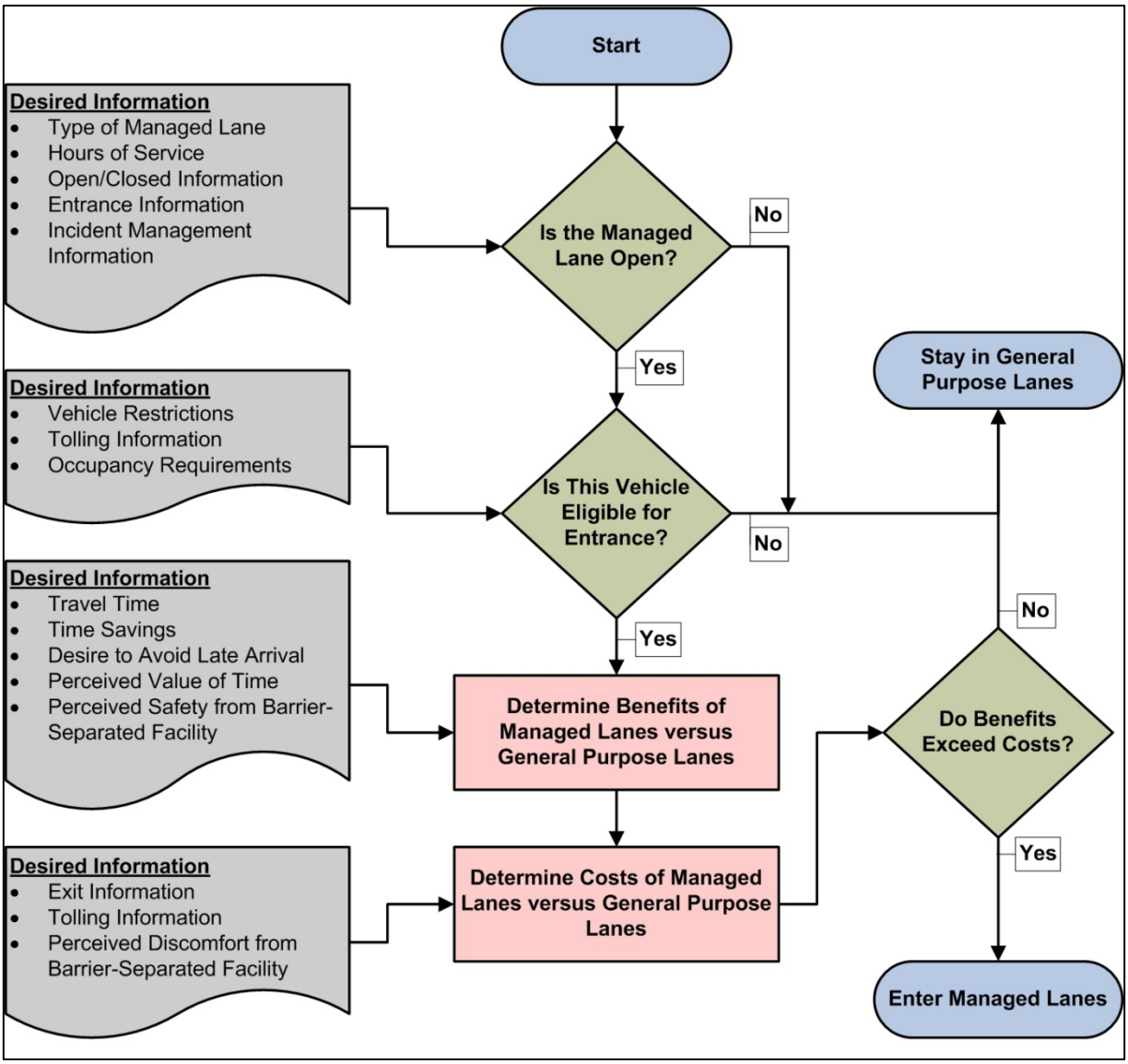

Figure 1. Driver Decision Making Process (1).

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Table 1. Information Types and Categories (1).

o **General Information Category**	o **Types of Information That May Be Needed**
o **Managed Lane Information**	o Type of managed lane (HOV, fixed toll, variable toll, transit only, some combination of these) o What vehicles are allowed o Hours of operation o Open/closed information o Entrance information o Managed lane final destination o Intermediate exit locations for the managed lane o Toll structure (if any) o Required method of payment (if any) o Penalty for improper use
o **Traffic Condition Information**	o Current traffic congestion in general purpose lanes o Presence of incidents in either general purpose or managed lanes o Estimated time savings for use of managed lane
o **Vehicle Information**	o Proper number of occupants o Presence of transponder or cash (if required) o Specific prohibitions on certain vehicles (trucks, towed trailers)
o **Driver Information**	o Need to save time o Penalty for late arrival at destination o Desire to spend the money for a toll o Perceived value of time o Comfort level with barrier-separated facilities o Comfort level with concurrent-lane facilities if there is a large speed differential between managed lanes and general purpose lanes

TxDOT Terminology for HOT Lanes

TxDOT has created *Draft Guidelines for Managed Lanes Signing and Markings* which is available from TxDOT Traffic Operations Division (TRF) on request (5). They also have draft guidelines for toll roads (4). These guidelines are interim until the next revision of the state and federal MUTCD's. In this document, TRF defines terms to be applied to different types of managed lanes:

> **Types of Managed Lanes**
>
> **HOV LANE.** A managed lane designated for exclusive use by HOV for all or part of the day. HOVs, buses and motorcycles can use the HOV lane for free. Single occupant vehicles (SOV) are not allowed.
>
> **HOV/TOLL LANE.** A managed lane where HOVs are free for all or part of the day and SOVs are allowed if they pay a toll.
>
> **TOLL LANE.** A managed lane where all vehicles pay a toll at all times. Toll rates for HOVs may be discounted all or part of the day.

Federal Managed Lane and Toll Facilities Standards

The Federal Manual on Uniform Traffic Control Devices (MUTCD) provides standards and guidance for all signs and markings used on roadways in the United States (*7*). The Code of Federal Regulations states that "traffic control devices on all streets and highways open to public travel in each State shall be in substantial conformance with standards issued or endorsed by the Federal Highway Administrator."(*8*) The Code defines public roads as follows:

> For the purpose of MUTCD applicability, open to public travel includes toll roads and roads within shopping centers, parking lot areas**,** airports, sports arenas, and other similar business and/or recreation facilities that are privately owned but where the public is allowed to travel without access restrictions.

The MUTCD addresses the issue of applicability in Section 1A.07 in a Support statement

> **The "Uniform Vehicle Code" (see Section 1A.11) has the following provision in Section 15-104 for the adoption of a uniform Manual:**
>
> **"(a) The [State Highway Agency] shall adopt a manual and specification for a uniform system of traffic control devices consistent with the provisions of this code for use upon highways within this State. Such uniform system shall**

correlate with and so far as possible conform to the system set forth in the most recent edition of the Manual on Uniform Traffic Control Devices for Streets and Highways, and other standards issued or endorsed by the Federal Highway Administrator."
"(b) The Manual adopted pursuant to subsection (a) shall have the force and effect of law."

Additionally, States are encouraged to adopt Section 15-116 of the "Uniform Vehicle Code," which states that, "No person shall install or maintain in any area of private property used by the public any sign, signal, marking or other device intended to regulate, warn, or guide traffic unless it conforms with the State manual and specifications adopted under Section 15-104."(*9*)

The applicability of the MUTCD to private roads was further clarified in a 2004 Interpretation Letter issued by the Federal Highway Administration to the American Traffic Safety Services Association in which the language in Section 1A.07 was reiterated (*10*).

The MUTCD is currently under revision, with a new edition expected in late 2009. The Notice of Proposed Amendments was published in January 2008 with a 6 month public comment period (*11).* Through our involvement in the National Committee on Uniform Traffic Control Devices (NCUTCD), we are aware that the sections on toll and managed lanes facilities are undergoing extensive revision from what was in the NPA. The material presented here from the NPA should be reviewed with reservations as it will likely be changed in the final MUTCD revision expected in late 2009. Within 2 years of the issuing of the Federal MUTCD, TxDOT will have to adopt it in part or in full. Again, it is not clear at this time what changes to the pertinent sections will be made.

In the interest of explaining the general thinking present in the Federal Notice of Proposed Amendment, key sections are reproduced in this technical memorandum.

NPA Section 2B.21 Regulatory Signs for Toll Plazas:

The ETC (pictograph) ONLY – NO CASH (R3-16) sign shall incorporate a top header panel with a purple background and white border. Within the header panel, the pictograph adopted by the toll facility's ETC payment system (such as E-Z Pass or SunPass) shall be on a white rectangular or square underlay panel and the black legend ONLY shall be on a separate rectangular white panel. The bottom portion of the sign shall have a white background and black border with the black legend NO CASH and one black down arrow for each applicable lane.

Figure 2. NPA Figure 2B.9, Example of R3-16 regulatory sign for ETC lanes at a conventional toll plaza, with adjacent cash lanes.

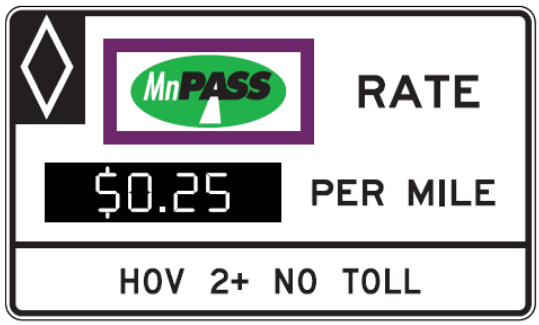
This sign is referenced in another section of the NPA that pertains directly to managed lanes:

> **NPA Section 2B.32 Regulatory Signs for Managed Lanes and ETC Only Lanes**
>
> **Support:**
>
> **A managed lane is a highway lane (or set of lanes) or a highway facility for which one or more variable operational strategies, such as tolling, pricing, vehicle type and/or occupancy requirements, and direction of travel, are implemented and managed in real time in response to changing conditions.**
>
> **A managed lane might be on a separate alignment, might be barrier-separated or buffer-separated from the general purpose lanes, or might be contiguous with the general purpose lanes.**
>
> **Under certain operational strategies, a managed lane is a special type of Preferential lane (see Sections 2B.26 through 2B.30).**
>
> **Standard:**
>
> **The provisions of Sections 2B.26 through 2B.30 regarding regulatory signs for Preferential lanes shall apply to managed lanes operated at all times or at certain times with fixed or variable vehicle occupancy requirements (HOV), vehicle type restrictions, and/or a toll fee payment requirement to use the lane(s). Such managed lanes shall use changeable message signs or changeable message elements within static signs to display the appropriate regulatory sign messages only when they are in effect.**

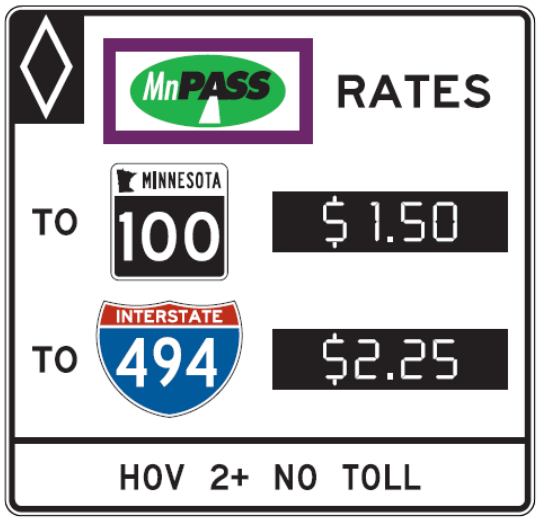
When a single-occupant vehicle equipped with an ETC transponder is allowed to use an HOV lane by paying a toll fee, the Vehicle Occupancy Definition (R3-13 or R3-13a) signs (see Section 2B.27) shall be modified to include the pictograph adopted by the facility's ETC payment system (such as E-Z Pass or SunPass) to indicate the allowable use (see Figure 2B-10). Also in this case, regulatory signs shall be used to indicate the toll fee charged for such vehicles. If the toll fee varies, regulatory signs that include changeable message elements, such as the R3-31 and R3-32 signs that are illustrated in Figure 2B-10, shall be used to display the actual toll amount or rate in effect at any given time.

Figure 2B-10. Special Regulatory Signs for Managed Lanes

Vehicle Occupancy Definition Sign Allowing Single-Occupant ETC-Equipped Vehicles



R3-31



R3-32

Notes:
1. The electronic toll collection (ETC) pictograph that is shown is only an example. The pictograph for the toll facility's adopted ETC system shall be used.
2. Changeable message sign elements shall be used for the numerals displayed for the variable toll fees.

Figure 3. NPA Figure 2B-10, illustrates how to incorporate a toll system pictograph on a purple panel into a white regulatory sign.

When only vehicles equipped with an ETC transponder are allowed to use a managed lane or any tolled facility, regulatory signs to indicate such a restriction shall be provided and shall incorporate the pictograph adopted by the toll facility's ETC payment system and the word ONLY. If incorporated within the white background of a regulatory sign or within the green background of a guide sign, the ETC pictograph shall be on a white rectangular or square panel set on a purple backplate with a white border as shown in Figures 2B-10 and 2E-54. If used on a header panel within a regulatory or guide sign, the ETC pictograph shall have a white border and the header panel shall have a purple background with a white border as shown on the R3-16 signs in Figure 2B-9.

When certain types of vehicles (such as trucks or motorcycles) are prohibited from using a managed lane or when a managed lane is restricted to use by only certain types of vehicles during certain operational strategies, regulatory signs or regulatory panels within the appropriate guide signs that include changeable message elements shall be used to display the open/closed status of the managed lane for such vehicle types. When the vehicle occupancy required for use of an HOV lane is varied as a part of a managed lane operational strategy, regulatory signs that include changeable message elements shall be used to display the required vehicle occupancy in effect.

Referenced figures 2B-10 and 2E-54:

Figure 2E-54. Example of a Comparative Travel Time Information Sign for Preferential or Managed Lanes

Notes:

1. The ETC pictograph that is shown is only an example. The pictograph for the toll facility's adopted ETC system shall be used.
2. CMS elements shall be used for the numerals displayed for the estimated travel times.

Figure 4. NPA Figure 2E.54, illustrates how to incorporate a toll system pictograph on a purple panel into a green guide sign. Also present an option for travel time sign.

Useful Guidance in the NPA

The NPA does include some useful guiding principles concerning the priority of regulatory and guide signs and the placement of guide signs. These include:

NPA 2E.51 Preferential Lane Guide Signs- General

Guidance:

On conventional roads, guide signs applicable only to preferential lanes are ordinarily not needed, but if used they should conform to the provisions for guide signs in Chapter 2D and any principles for Preferential Lane guide signs in Sections 2E.51 through 2E.54 that engineering judgment finds to be appropriate for the conditions. *(Note: this applies to the surface street and Park & Ride lot entry points).*

Guidance

If overhead signs applicable only to a preferential lane are located in approximately the same longitudinal position along the highway as overhead signs applicable only to the general purpose lanes, the signs for the preferential lane should be separated laterally from the signs for the general purpose lanes to the maximum extent practical to minimize conflicting information.

The Preferential Lane signs should be designed and located to avoid overloading the road user. Based on the importance of the sign, regulatory signs should be given priority over guide signs. The order of priority of guide signs should be: Advance Guide, Preferential Lane Entrance Direction, and finally Preferential Lane Exit Destination supplemental guide signs.

New MUTCD Terminology Definitions

Chapter 1 of the MUTCD contains a glossary of terms used in the document. Several new definitions concerning managed lanes and tolling have been added in the NPA. These are listed below, along with counterparts from the 2003 edition where available. Note that there is no definition in the NPA for "Express Lane" even though this is the term shown in many of the figures for managed lane signs. The Toll Road Task Force of the NCUTCD requested that a definition of Express Lane be added to the 2009 MUTCD. The Task Force also requested extensive changes to the definition for Electronic Toll Collection (ETC) to remove references to specific technology and billing systems and to allow for license plate capture to fall under the general heading of ETC.

ETC terms

31.(NPA-new) Electronic Toll Collection (ETC)—a system for collection of toll fees via equipment that communicates wirelessly with transponders mounted in vehicles (moving or stopped) to automatically deduct the toll fee from a pre-paid toll account.

68. (NPA – new) Open Road Electronic Toll Collection—a system designed to allow electronic toll collection (ETC) from vehicles traveling at normal highway speeds.

HOV and Managed Lane Terms

41. (NPA) High-Occupancy Vehicle (HOV)—a motor vehicle carrying at least two or more persons, including carpools, vanpools, and buses.

31. (2003 MUTCD) High Occupancy Vehicle (HOV)—a motor vehicle carrying at least two or more persons, including carpools, vanpools, and buses.

46. (NPA) HOV Lane—any preferential lane designated for exclusive use by high-occupancy vehicles for all or part of a day—including a designated lane on a freeway, other highway, street, or independent roadway on a separate right-of-way.

35. (2003 MUTCD) HOV Lane—any preferential lane designated for exclusive use by high-occupancy vehicles for all or part of a day—including a designated lane on a freeway, other highway, street, or independent roadway on a separate right-of-way.

20. (NPA) Concurrent Flow Preferential Lane—a preferential lane that is operated in the same direction as the adjacent mixed flow lanes, separated from the

adjacent general purpose freeway lanes by a standard lane stripe, painted buffer, or barrier.

13. (2003 MUTCD) Concurrent Flow HOV Lane—an HOV lane that is operated in the same direction as the adjacent mixed flow lanes, separated from the adjacent general purpose freeway lanes by a standard lane stripe, painted buffer, or barrier.

21. (NPA – new) Contiguous Lane—a lane, preferential or otherwise, that is separated from the adjacent lane(s) only by a normal or wide lane line marking. The 2003 MUTCD did not contain a definition of contiguous lane.

60. (NPA – new) Managed Lane—a highway lane or set of lanes, or a highway facility, for which variable operational strategies such as direction of travel, tolling, pricing, and/or vehicle type or occupancy requirements are implemented and managed in real-time in response to changing conditions.

7. (NPA-new) Barrier-Separated Lane—a preferential lane or other special purpose lane that is separated from the adjacent general purpose lane(s) by a physical barrier.

12. (NPA –new) Buffer-Separated Lane—a preferential lane or other special purpose lane that is separated from the adjacent general purpose lane(s) by a pattern of standard longitudinal pavement markings that is wider than a normal or wide lane line marking. The buffer area might include channelizing devices such as tubular markers or traversable curbs, but does not include a physical barrier.

Banner Design

The NPA uses the term "header panel" to refer to the area of the sign above the main body legend, while most sign designers have used "banner". The recently opened Miami 95 Express lanes had the benefit of input from FHWA throughout the development of their signing plan. Also, one of their key signing consultants has been active on the NCUTCD Toll Road Task Force. The signs used in Miami are the closest to being compliant with the NPA of any other HOT lane facility operating today. The photo in Figure 5 shows an entrance sign from July 2008. The banner design incorporates the HOV diamond, the transponder logo, and the ONLY, all on a purple background. It also uses the term "Express Lanes" in the body of the guide sign.

Figure 5. Entrance signs used on Miami's 95 Express Lanes (www.transitmiami.org)

The NPA implies that if HOV operations are incorporated into the managed lane, the HOV diamond should also be displayed on the sign and that the banner should be white. Throughout the multiple illustrations in the Regulatory (Section 2B) and Guide (Section 2E) Sections, the HOV diamond appears in different places. This is one area of great inconsistency concerning HOV sign design. Two examples are given below. Since so few examples of managed lane sign design for HOT lanes are provided it is difficult to read the intent of the NPA.

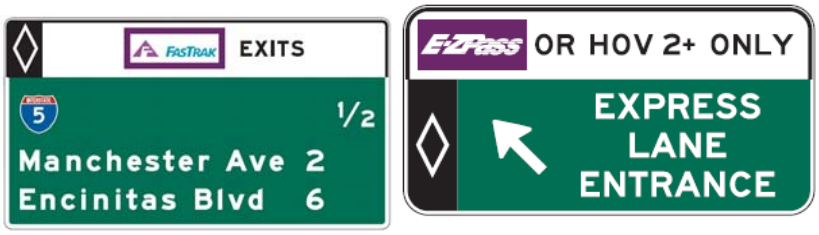


Figure 6. NPA Figure 2E-53 and 2E-49, example of white banner and inconsistent placement of HOV symbol.

State of the Practice

Pricing Strategies and Signs

Pricing strategies for toll lanes, with or without discounts for HOV's, include flat-rate, variable schedule, and dynamic congestion-based. Each method offers a compromise between flexibility, traffic management effectiveness, and complexity of the detection-billing-signing system.

Flat-rate pricing regardless of time of day or point of entry is the simplest method. This system has been in use in the Houston area on I-10 and US 290 since 1998 through the QuickRide program (*12*). On this facility a $2.00 toll is collected from registered participants through transponders at all entry points into the lane during the specified peak hours only. As part of a recent Federal Highway Administration (FHWA) Value Pricing Pilot project, The Texas Transportation Institute (TTI) worked to develop hybrid dynamic message signs which could support dynamic pricing operations in the future. These signs were designed based on sound human factors principles, but no thorough motorist comprehension or placement testing was completed. The photo in Figure 7shows an example of a pricing sign located in a Park and Ride lot on US 290 in Houston. The signs currently installed have the capability to expand to four lines to accommodate differential pricing and hours of operation for 2+ and 3+ HOVs. For instance, currently at peak of the peak periods, 3+ HOVs are free and 2+ HOVs pay the QuickRide toll. Future operations may include shoulder peak and off-peak operations where 2+ HOVs are free and SOVs are allowed to use the lane for a toll.

Variable schedule pricing adjusts price by time of day but on a fixed schedule. Prices and time periods are set based on historic lane volume data in order to optimize flow at peak hours. The Denver I-25 HOT lane uses a variable schedule pricing strategy (*13*). The posting of the variable toll schedule was a particular challenge in the downtown street grid serving the entrance ramp to the lane. Use of ground-mounted electronic dynamic message signs in these areas is often ill- advised due to concerns over vandalism as well as power and communications problems in a dense urban environment. The Colorado Department of Transportation (CDOT) decided to post signs displaying the entire toll schedule near two signalized intersections where a turning movement leads directly to the managed lane ram as shown in Figure 8. An auxiliary plaque announcing "NO CASH" is mounted below the sign shown in the photo on the right. CDOT felt that drivers could absorb this much information on a sign due to low speeds and frequent queuing at traffic signals.

Figure 7. US 290 Park & Ride lot sign for Quickride program in Houston.

Figure 8. Variable price schedule sign on downtown street in Denver.

Dynamic, congestion-based pricing is currently in use in only a few facilities in the U.S. California was the first state to use variable pricing on its State Route 91 outside of Los Angeles (*14*). This facility is a single-entry/ single-exit parallel toll lane through a narrow mountain pass. A sign such as that shown in Figure 9 is located in advance of the slip-ramp entrance to the facility. Since it is a barrel facility, with no intermediate access, a single price applies for the entire trip length.

Figure 9. Dynamic Message Price Sign Used on SR 91 in California.

Figure 10. Dynamic Price Sign Used on I-394 in Minnesota

The other facility that has used dynamic pricing for a few years is the I-394 HOT lane in Minneapolis, Minnesota (*15*). This facility has independent pricing for two segments: a diamond-lane buffer-separated section from the outer loop (I-494) to the inner loop (SH 100); and a reversible-flow barrier-separated segment from the inner loop (SH 100) to downtown (I-94). The sign shown in Figure 10**.** is located at the far terminus and displays the price for the two segments. One issue that arises with this type of segmental pricing is whether or not the total trip price should be shown (i.e. from point of sign to end of lane at I-94) or whether the segment prices should be shown independently. This latter decision would require drivers to mentally add the segment prices for those traveling the entire length of the lane. This segmental pricing offers great demand-response possibilities for congestion management by posting higher prices for the same length of travel in the highly congested inner ring of the downtown area. Minnesota Department of Transportation (MnDOT) did a particularly good job of public information and education prior to the opening of their HOT lane.

Two facilities under development in the San Diego area carry this segmental pricing to an extreme (*16*,*17*). The proposed I-5 North Coast project will travel 26 miles and have multiple access points. San Diego authorities are faced with how to provide dynamic, congestion-based pricing information for multiple destinations. One approach they considered was to display dynamic prices per mile of travel, but this idea was eventually rejected because of concerns over driver understanding of the signs. They have recently installed signs which show a minimum toll (the price to the next exit) in addition to the price to the next major interchange (see Figure 11). An analysis of this sign shows it contains at least 10 units of information. This clearly exceeds all recommendations concerning driver information overload. Another concern is that this sign is located immediately at the diverge point (and contains the diagonal up arrow to exit). Presenting such an information-rich sign at a location where drivers have to maneuver their vehicles could pose safety hazards.

Figure 11. Dynamic Price Sign Installed in 2008 on I-15 in San Diego.

New modular dynamic message sign equipment such as this has allowed hybrid signs to be applied to managed lanes. These systems allow a conventional retroreflective static sign to be coupled with an inserted panel with a dynamic message capability. These hybrid signs provide good conspicuity and legibility of the full sign while providing some flexibility for changeable messages.

Often Dynamic Message Signs (DMSs) are used in conjunction with fixed managed lane signage. The only standards that the MUTCD provides concerning managed lanes are that when DMSs 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.

Large, overhead DMSs are commonly used along managed lanes as shown in Figure 9. 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 at full height on the sign to mimic the design of an overhead regulatory sign. Full matrix DMS can be used to provide pricing information in addition to other traveler information. Two-phase DMS messages alternating between current travel time and current price are currently being considered by several Texas districts. The full-matrix signs provide the flexibility for the sign to be used for

incident management messages and emergency evacuation. These signs, though expensive, offer the maximum flexibility.

One thing that drivers have mentioned repeatedly in focus groups is their desire to have comparative travel times to aid their decision making. This information can be provided through the use of real-time traffic information. Research into driver response to this type of traveler information has been limited to applications in general purpose lanes thus far.

Dynamic information such as pricing and real-time travel information needs to be provided at a distance upstream from entry and exit points to the facility. This distance is also the point where pricing information should be provided so drivers can make a cost/benefit decision as to whether they want to pay for perceived travel time savings and reliability.

The exact distance needed for the complex decisions required for managed lanes is not known and will be the topic of future research. The Manual on Uniform Traffic Control Devices calls for advance guide signs of freeway exits to be typically placed ¼ mile in advance of the exit. The placement of dynamic information with these advance guide signs would be a simple standard for agencies to implement.

Sign Sequencing

The NPA does not contain any typical layout drawings for managed lanes facilities. As mentioned earlier, the I-95 HOT lanes in Miami had the benefit of being under development around the time the NPA was released. Their sign sequence, shown in Figure 12, is a reasonable approximation to the sign sequence one would construct if all of the individual managed lanes guidance pieces in the NPA were followed. The TxDOT Draft Guidelines do contain several drawings for freeway entrance slip-ramp sign sequencing and these are included later in this report.

The sequence recommended in the NPA consists of guide signs at 1 mile, ½ mile, and at the gore point of the entry. Regulatory signs, including price, are interspersed at spacings of approximately 800 feet, which follow general sign principles represented in the MUTCD.

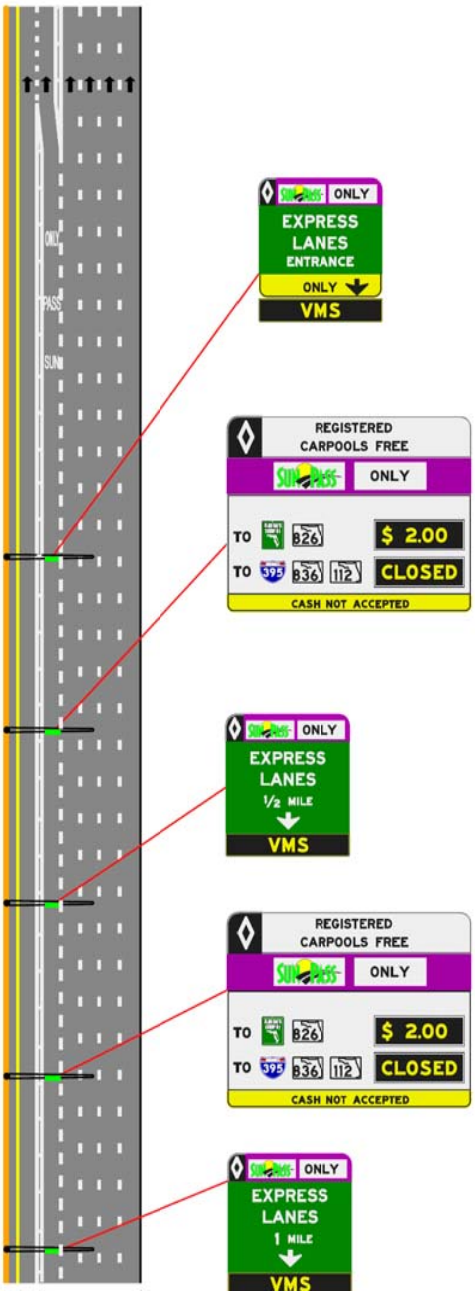


Figure 12. Miami I-95 HOT Lane Signs which follow NPA recommendations closely (*Note: VMS indicates locations for Variable Message Sign elements)*

Sign Design Issues

Font

The current standard font for TxDOT signs is Clearview –HWY-5W. This font is available in Truetype™ form from Terminal Design, Inc. or is incorporated into the Texas version of SignCad™ software (*18*, *19*). Texas is one of the few states that has adopted this font as allowed as an option by FHWA (*20*). This font has been shown to have superior legibility when compared to standard FHWA Highway Gothic letters.

Color

The MUTCD specifies colors by referencing an ASTM (formerly American Society for Testing and Materials) document specifying retroreflective material characteristics. The traffic industry uses color boxes defined by the CIE (Commission Internationale de L'eclairage). Retroreflective materials behave differently under direct headlamp illumination than do indoor signs, either matte or glossy finish. For this reason, other color referencing systems common in the design world, such as Pantone™, do not have a one-to-one correspondence to standard highway sign color specifications. Most retroreflective material vendors offer some information on the Pantone™ color that most closely matches the centroid of the CIE color box under daylight illumination.

The uses of each color category are strictly defined by the MUTCD as follows:

A. Black—regulation
B. Blue—road user services guidance, tourist information, and evacuation route
C. Brown—recreational and cultural interest area guidance
D. Coral—unassigned
E. Fluorescent Pink—incident management
F. Fluorescent Yellow-Green—pedestrian warning, bicycle warning, playground warning, school bus and school warning
G. Green—indicated movements permitted, direction guidance
H. Light Blue—unassigned
I. Orange—temporary traffic control
J. Purple—unassigned *
K. Red—stop or prohibition
L. White—regulation
M. Yellow—warning

** Note that the 2008 Notice of Proposed Amendment assigns Purple to use on toll facilities*

The actual shade of purple to be used is specified in the Code of Federal Regulations (23 CFR Part 655, Appendix to Subpart F). The last time these color specifications were updated was in 2002 (*21*):

> *The ‘‘purple’’ color specifications have been modified to reflect the colors actually in use. Several commenters pointed out that specifying precise color regions for unassigned colors may be premature. Accordingly, a revised color region, incorporating both the hues from the initial proposal in the NPRM and the existing commercial materials, are recommended. As use of the materials is further refined, the purple color box may be optimized or even separated into two distinct colors.*

At the time of the revision to the color boxes, there was only one manufacturer (3M) making a purple overlay film. It is not clear if 3M is still manufacturing this material because of low demand. It is possible to meet the color box using custom mixed screened inks designed specifically for retroreflective materials. The authors caution, however, that other vinyl purple overlay films that may be on the market likely do not meet the FHWA color box, or are very close to its edge.

The whole issue of color specification is currently also under review by FHWA. The process has been somewhat of a chicken-and-egg situation. No manufacturer made much purple material because there wasn’t an official use approved for it in the 2003 MUTCD. So the material that FHWA tested to develop the color specifications released in 2002 were all experimental materials, not production materials. With the release of the 2009 manual where a use for purple is specified for tolled facilities, we anticipate that more manufacturers will respond with conforming products.

TxDOT and the Use of Purple

The current TxMUTCD and draft Guidelines for Toll Facilities do not allow for the use of purple in any form on signs. It is not clear what TxDOT Traffic Operations Division (TRF) will do when the new federal manual is released later this year. Up to this point, TRF is still recommending the black-on-white banner designs for use on Toll Lanes and HOV/Toll Lanes.

In Houston, HCTRA does use purple currently on their toll plaza signs, in banners on the Katy Tollway, and as a guide sign background color on the Westpark Tollway. These signs were all placed at a time when the Federal and Texas MUTCD's did not address toll facilities. A TTI study sponsored by HCTRA showed that the purple materials were durable, were understood well by drivers, and were equal to or better than a green background sign for daytime and nighttime legibility (*22*, *23*).

Internet Addresses and Phone Numbers

Some HOT lane operators may wish to place phone numbers or internet address information on roadway signs directing drivers to call for enrollment information. This practice is expressly forbidden by the MUTCD out of safety concerns. The mental effort required to read and remember web addresses is more than for typical traffic sign words. These materials are permitted in an Option statement for locations that are low speed or for signs designed to be viewed only by pedestrians or occupants of parked vehicles. This means that signs such as this can only be placed in low-speed areas, such as Park and Ride lots, not on arterials or freeways.

> **Section 2A.06**
>
> **Standard: 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 sign.**
>
> 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.

Pictographs and Route Markers

A pictograph is a pictorial representation of a governmental entity that was originally allowed by FHWA for cities to use on street name signs to provide regional identity. The intent was that the unique pictograph would aid navigation in contiguous cities and suburbs by providing drivers a cue that they had crossed a jurisdictional line. In recent years, some agencies have tried to extend the use of pictographs to designate entertainment districts and other points of interest and to extend the use of pictographs to freeway guide signs. FHWA has issued an interpretation which prohibits the use of these pictographs on guide signs because they do not provide additional information beyond a simple text legend and because they are often hard to recognize at high speeds (*24*). This interpretation letter includes a table of allowable pictographs and their applications.

In the NPA, *pictograph* is further defined as:

> **Pictograph—a pictorial representation used to identify a governmental jurisdiction, an area of jurisdiction, a governmental agency, a military base or branch of service, a governmental approved university or college, or a government-approved institution.**

The example they provide is shown in Figure 13 which is the ETC logo for Florida Department of Transportation's SunPass™.

Figure 13. Example application of toll tag pictograph.

Currently, on US 290 Metro uses the QuickRide logo on its signs as shown in Figure 14. TTI believes that this logo would be considered to meet the definition of pictograph as defined in the NPA and could be continued to be used on signs in the region.

Figure 14. Houston METRO QuickRide logo currently used on US 290 signs.

Clearly, in the Houston area, HCTRA uses its own route markers on guide signs as shown in Figure 15. It is unclear whether these would be interpreted as pictographs under the Texas MUTCD. The letter size of the TOLL ROAD legend on the HCTRA markers is 4 inches which does not meet the minimum letter size requirement for signs used on high speed facilities. It is not clear if shields such as this would be considered to be route markers or pictographs.

Figure 15. Example of HCTRA route marker

Recommendations

In the work TTI conducted for the US290 Value Pricing Pilot Program, three categories of signs were identified. The sign categories identified were:

1. Program Information
    - Provides enrollment contact information through a website
    - Installed away from critical decision points because the information contained is not relevant to time-critical go/no go decisions and may serve to distract drivers
2. Regulatory Signs

- Operating hours
- Vehicle restrictions (e.g. no towed trailers)
- Occupancy requirements
- Installed in advance of entrance points
- Other regulatory signs such as Speed Limit and Fine Postings should follow same design principles

3. Price Signs
    - Hybrid signs with conventional static portion showing occupancy classes and electronic variable message component showing lane status and price
    - Large version for high-speed main lane slip ramps points
        - Installed at least ¼ mile upstream to allow adequate decision time
    - Small version for low-speed Park and Ride lot and surface street entry points
        - Installed in location in parking lot where a safe exit is still possible if driver decides not to enter

These three general categories of signs are appropriate for application to all of the HOT facilities that will become part of the network in Houston.

In addition to these three, regular advance guide and guide signs are needed for slip-ramp entrances at terminals and intermediate access points. Standard guide sign spacing should be followed for these applications on high speed facilities.

Destination / Distance Signs

Destination / Distance signs should be placed before the entrance to the HOT lane so users can judge whether the lane will serve their destination. The distance also helps users gauge the costs and benefits of using the lane. METRO included these signs, sometimes called Interchange Sequence Signs, as part of their User-Friendly sign program. Unfortunately, these signs are installed on the HOV lanes after a driver has entered and cannot leave the lane.

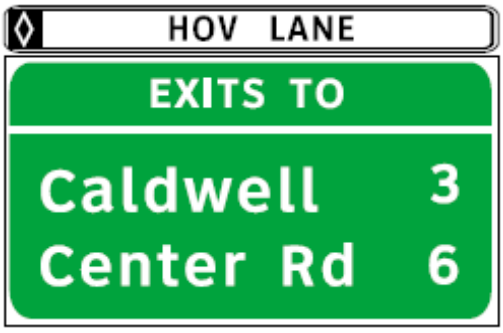


Figure 16. Distance / Destination Sign example from TxDOT Managed Lanes Guidelines. (*Note: Example shows sign for a traditional HOV lane as indicated in the banner*).

Banners

The purpose of the banner is to differentiate signing for the HOT lane from signing for the GP lane. The HOT lane banner should be used on all signs pertaining to the HOT lane. This includes advance entrance signs, trailblazers, signs in the lane, and signs marking exits from the lane.

TTI recommends, as does the NPA, that the banner be used on all regulatory and guide signs with messages aimed at those about to enter the managed lanes and for those currently in the managed lanes. Following current TxDOT guidance and definitions of facilities, the phrase TOLL LANE should be used for those facilities that only give an HOV discount during peak hours as shown in Figure 17.

Figure 17. TxDOT recommended banner for HOT facilities that only give HOV discounts during peak hours.

Route Markers

The TxDOT draft guidelines call for the designation of HOT and Toll Lanes through the use of modified route markers as shown in Figure 18. These serve to confirm to drivers that the special lanes do indeed parallel the main lanes and generally serve the same destinations. Since many of the HOT lanes in the Houston area are elevated, it is even more important to convey this "parallel route" to drivers. It may be difficult for drivers to be certain that these elevated lanes really do follow the main freeway routes. For this reason, we recommend that these route markers be used on both guide and trailblazer signs.

Figure 18. Toll route markers from the Texas MUTCD

Payment Plaques

In both draft guidelines documents, TxDOT Traffic Operations division specifies what pictographs should be used for payment options on toll facilities as shown in Figure 19. These plaques are to be placed above the guide sign as shown in Figure 20. It is not clear from the current drafts of these guidelines where payment information should be placed on small ground-mounted signs as would be used in Park & Ride lots and surface street locations.

Figure 19. Payment plaques provided in TxDOT Draft Guidelines for Toll Roads and Managed Lane signing.

Figure 20. Example sign from TxDOT Draft Guidelines illustrating route markers and payment plaques.

Program Information Signs

The TxDOT Guidelines do not include specific guidance on program information signs that might include details about tag operations, enrollment, or benefits. They do provide guidance on signs for the Pay by Mail program which is the term they use for video tolling as shown in Figure 21. Since this sign concerns payment, TRF considers it to be regulatory in nature and thus has used a white background.

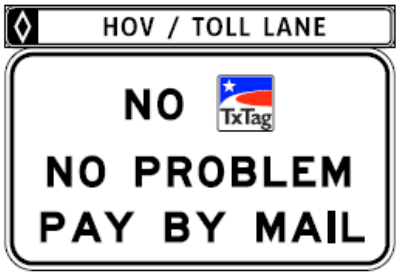


Figure 21. TxDOT Pay by Mail sign.

It is not clear if a more general program information sign that would contain enrollment information should even be treated as a traffic control device at all. Some agencies have reported in standards committee meetings that they consider these types of signs to be advertising and will not allow them to be placed in the right of way.

In spirit, a program information sign is a motorist information sign and it could be argued that it have a blue background. If the information conveyed concerns occupancy, violation fees, and form of payment, a white regulatory sign may be more appropriate. TTI has drafted an example of such a sign and presents it here with several cautions:

- This sign has not been reviewed by TxDOT TRF
- The HOV symbols currently used by METRO and shown in this sign are not approved symbols in the Federal or state MUTCD
- The fonts shown are not standard highway fonts
- This sign has not been tested for comprehension or legibility

Figure 22. Program Information sign developed by TTI to illustrate what types of infmration might be shown on such a sign (*see caveats in above bullet list*)

HOV Tag Requirement

One issue that is not at all clear on the Katy Tollway is whether or not HOV's must have a tag to enter the lane. The signs currently on the Katy Tollway make no mention of it, and the use of EZ TAG ONLY on these signs could be interpreted to mean that all vehicles, including peak hours HOVs, do indeed need to have a tag. This problem has been recognized on other facilities as well. As part of a current TxDOT research project on Congestion Pricing Signs, TTI is testing alternative regulatory sign design which attempt to convey the message that HOV's must have a tag in order to enter the facility (see Figure 23). Signs like this could be used for a facility that uses declaration lanes in tolling areas. If HOV's are not required to have a tag, a similar sign could be developed to convey this message.

This project, 0-6173, is scheduled to continue through FY10 with TTI working in collaboration with Texas Southern University. Flor Tamez of Traffic Operations Division serves as project director and Stuart Corder of the Houston District is a panel member. It may be possible to have candidate signs tested in the second year of this project by having Mr. Corder suggest this to the panel.

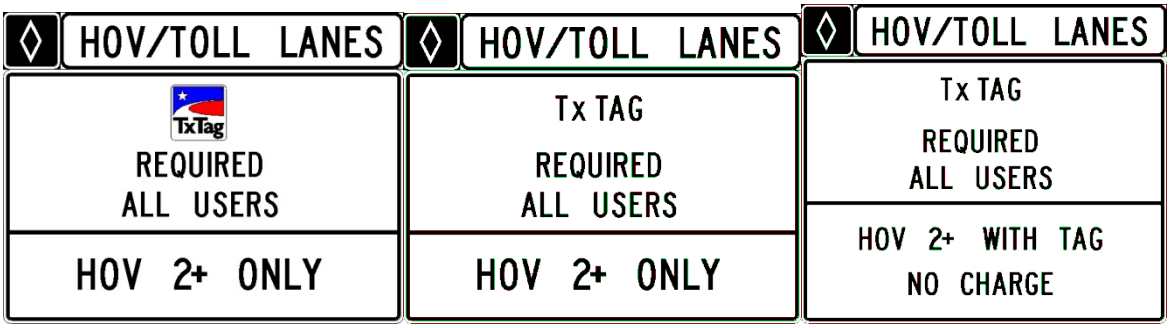


Figure 23. HOV Tag requirement signs being tested in current TxDOT research project 0-6173.

Regulatory Signs

Most regulatory signs for HOT lanes concerning occupancy, hours of operation, and vehicle restrictions follow the HOV sign formats which have been in the MUTCD for years. The TxDOT Draft Guidelines have little coverage of regulatory signs specific to managed lanes, but do include an hours of operation sign in one example. The Federal NPA, as well, has few regulatory signs specific to HOT lanes. Figure 24 shows the different approaches taken by the two documents concerning hours of operation signs.

Figure 24. Example regulatory signs from the TxDOT Draft Guidelines (left) and the Federal NPA (right).

Freeway Slip-Ramp Entrances

TTI conducted survey and focus group research into managed lane signs in project 0-5446. As part of that project, additional drawings for the TxDTO Draft Managed Lanes Signs and Markings Guidelines were developed (*25*). These included the drawing for a lane-drop slip ramp as shown in Figure 25. This figure also illustrates the application of Destination/Distance signs. The price signs shown in this drawing are static, but a dynamic price sign could be substituted. Figure 26 shows an example sign sequence for a slip-ramp entrance to a reversible-lane facility taken from the TxDOT *Draft Guidelines for Managed Lanes Signs and Markings (5)*.

A sign sequence such as this should be developed for the terminus slip-ramp entrances on all the HOT lanes in the Houston network. Consistent use of sign design, route marker design, sign sequence and arrow placement will help drivers enter the facilities smoothly. Keeping these HOT lane entrance areas as close as possible to other left freeway exits will help drivers use their stereotypes and expectations from previous experience to apply to these new entrance ramps.

Wishbone Ramps from Frontage Roads

Several of the access points to the Houston HOT lanes are from direct connect ramps from freeway frontage roads. This situation was addressed in the recently completed 0-5446 project and a typical signing layout drawing was submitted as part of that report as shown in Figure 27. It should be noted that this drawing has not yet been officially incorporated into the TxDOT Guidelines.

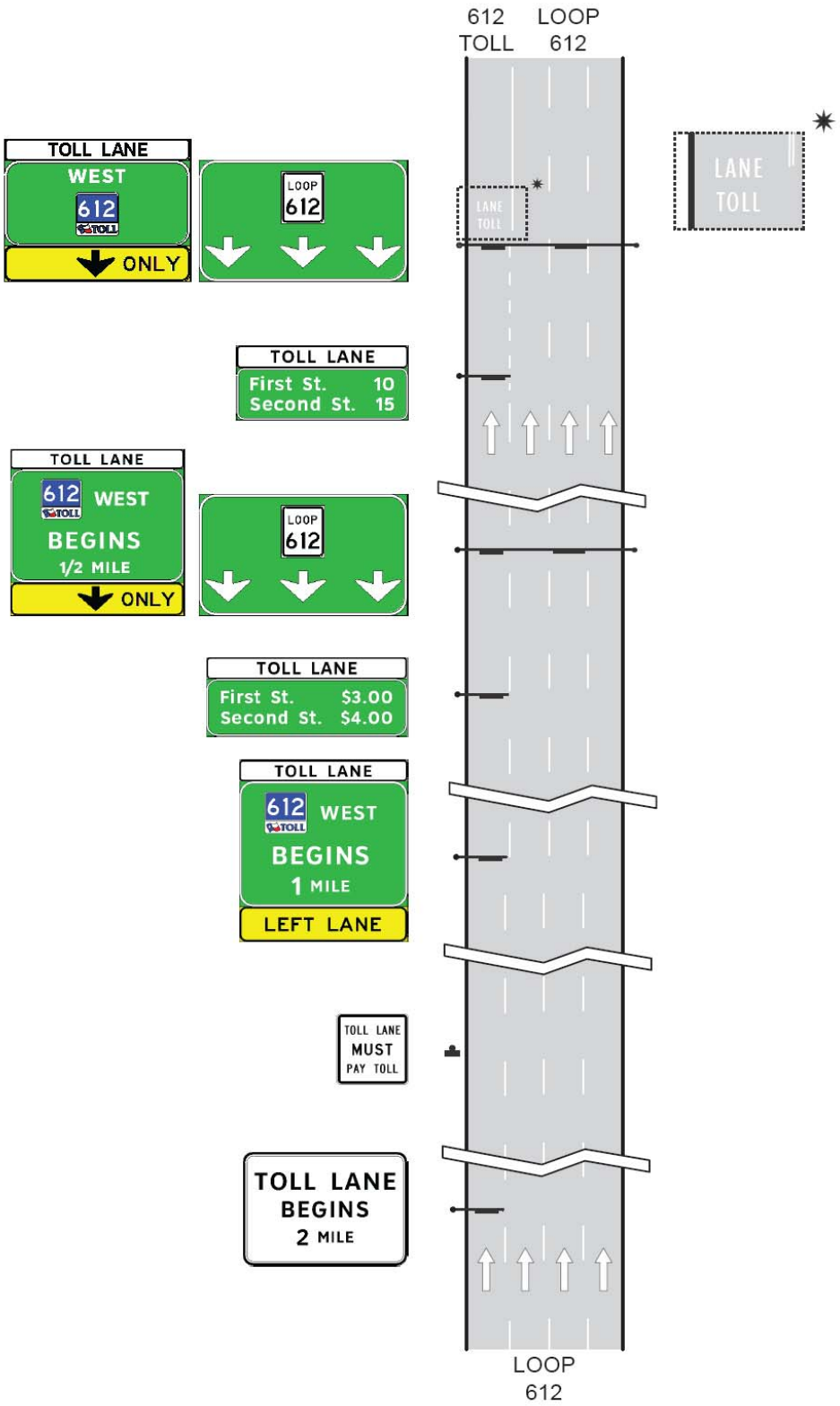


Figure 25. Sign sequence for a lane-drop slip-ramp HOT lane entrance (25).

Figure 2J-11A. Reversible (OPEN) Managed Lane Approach Signing

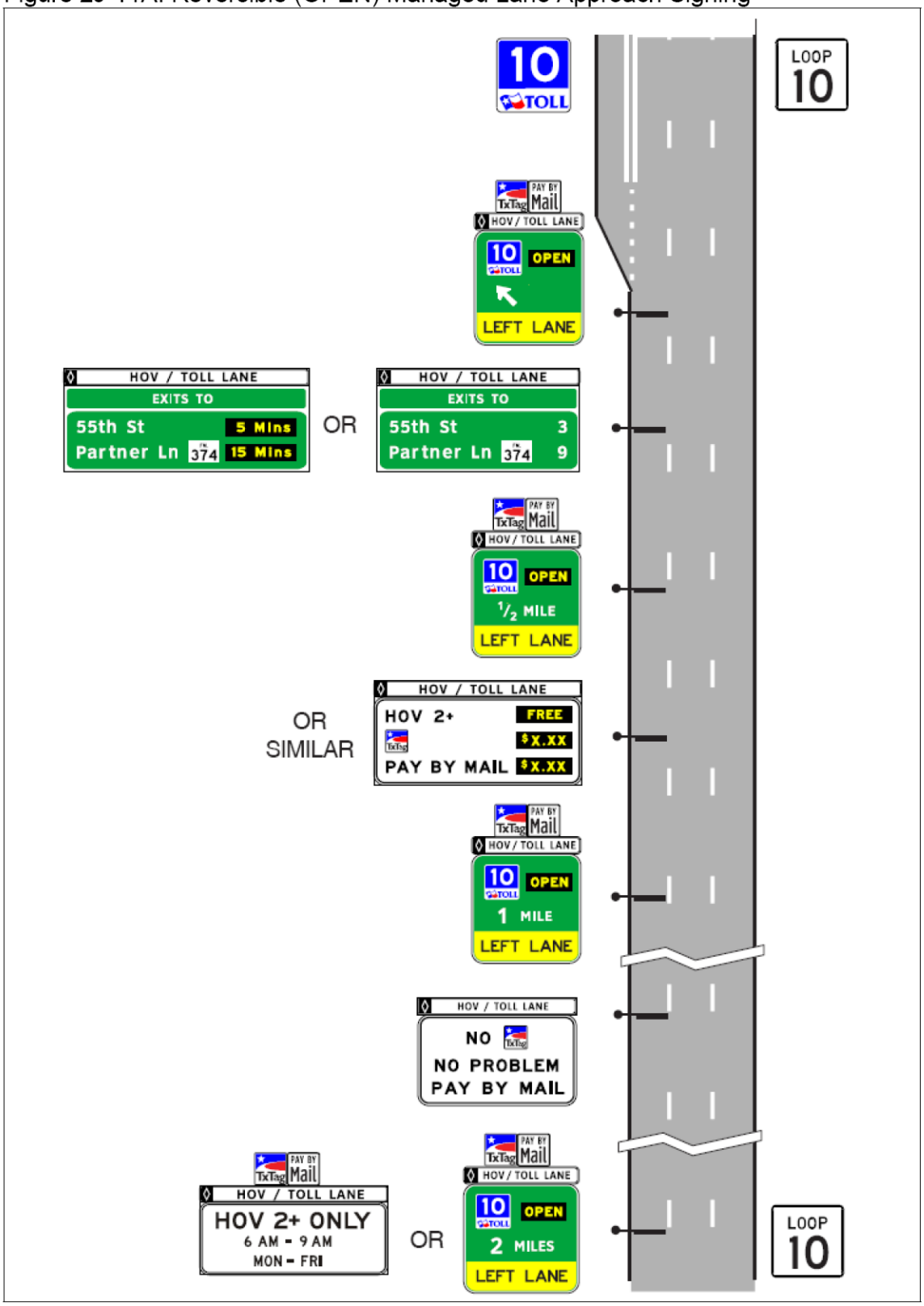


Figure 26. Sample sign sequence from TxDOT Draft Guidelines for Managed Lanes Signs and Markings (*5*).

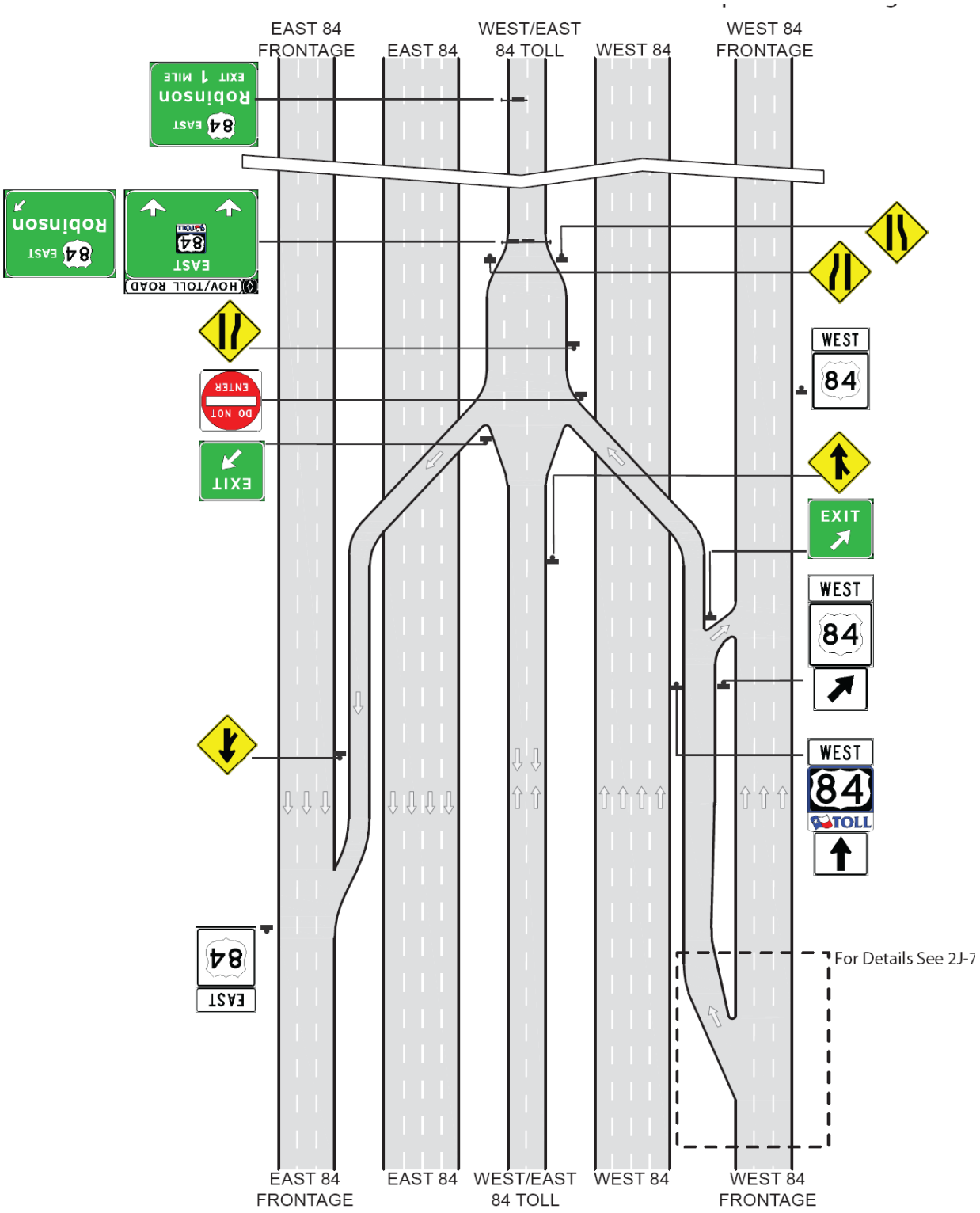


Figure 27. Drawing submitted by TTI to TxDOT for inclusion in the Draft Guidelines document (*25*).

Exits from the HOT Lanes

Whenever there is an exit from the HOT lane, there must be an accompanying sign over the thru lanes indicating that the HOT lane continues. This pull-through sign can be an advance guide sign for the next HOT lane exit or can be a traditional pull through sign (with appropriate HOT lane banner) as shown in Figure 28. This is based on a FHWA Interim Policy memo subsequent to a bus crash in Atlanta HOV lanes (*26*).

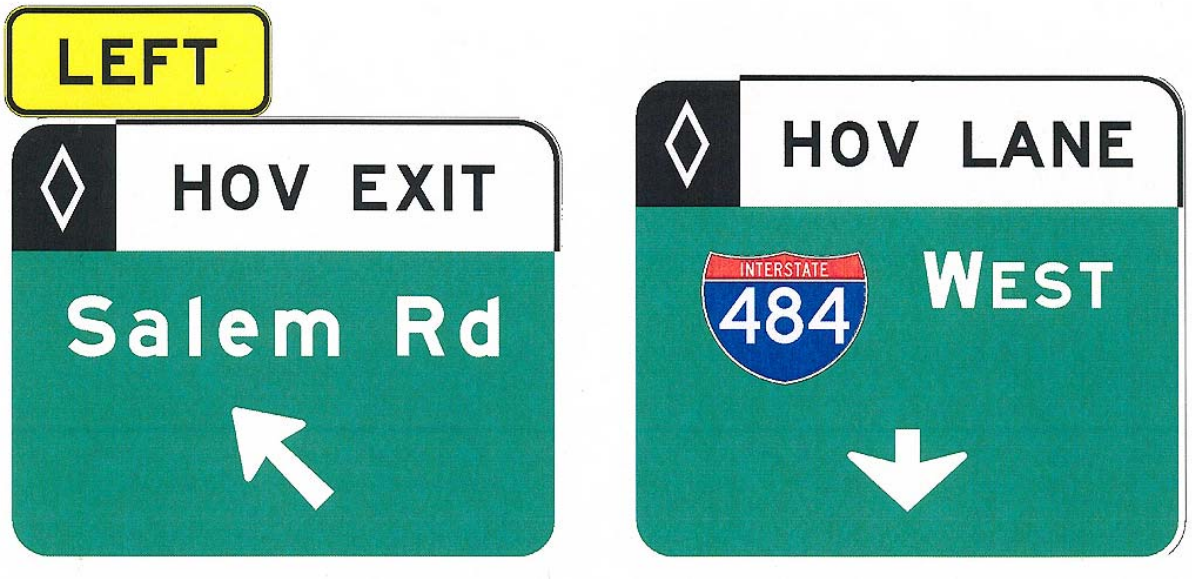


Figure 28. Example Exit and Pull-Through signs for exits from Preferential Lanes

End of Lane

The TxMUTCD, Federal MUTCD, and the TxDOT Draft Guidelines all include guidance on signing for the end of lanes. This includes a ½ mile advance sign and a sign at the end of the area where HOV enforcement and / or toll collection legally ends. TxDOT considers these signs to be regulatory in nature and shows them as black-on-white. There has been much discussion within the Toll Road Task force of the NCUTCD as to whether these signs should be yellow to warn of an upcoming merge area or should be white regulatory signs to aid enforcement.

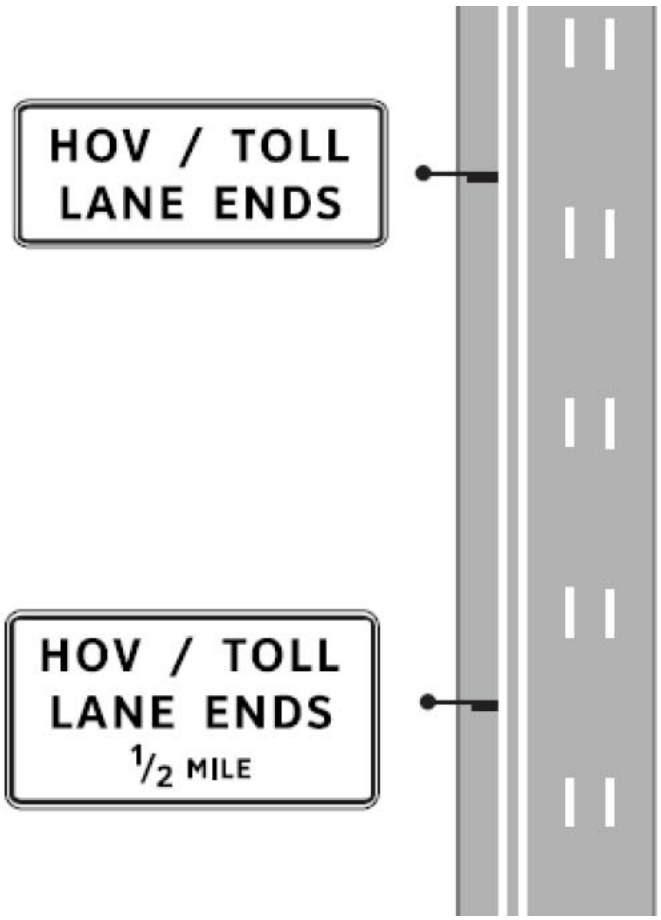


Figure 29. Figure 2J15 from the TxDOT Draft Guidelines.

Park & Ride and Surface Street Entrances

For approaches to entrance locations from surface streets, frontage roads, and Park & Ride lots, a simplified signing approach must be taken. In these locations, there is typically not enough longitudinal space to position program information, regulatory, and price signs in advance of every entrance. In addition, this extent of signing can pose a distraction to the vast majority of drivers on the surface streets who are not interested in the HOT lane information. On the other hand, drivers who are interested in the HOT lanes would like to know whether the lane is open or not and what the current price is before leaving the arterial or frontage road. Therefore, we recommend incorporating a single price into trailblazer signs currently in place as part of METRO's User Friendly sign program. We recommend that a single price be shown to keep the signs simple. This price should be to the end of the lane or final destination, such as downtown. Over time, users will learn to use this price as a barometer of overall system pricing and will likely deduce the price to their particular destination accordingly. If a single price scheme is adopted, this will make the signing simpler. An example of such a sign, as developed by TTI, is shown in Figure 30. This sign could be used in locations where the existing METRO User Friendly trailblazer signs are located with appropriate directional arrow plaques as shown in Figure 30.

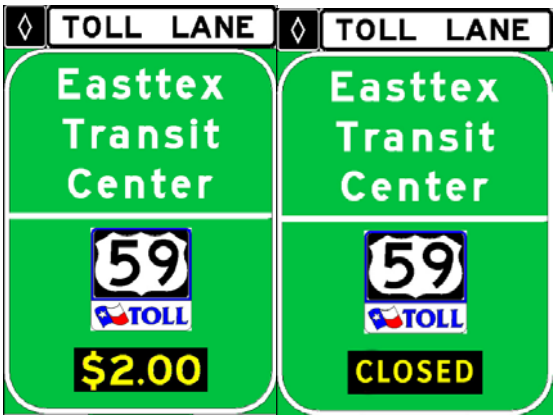


Figure 30. Example trailblazer with price sign developed by TTI. The DMS portion can indicate price or LANE CLOSED.

Figure 31. . Example of surface street signing approaching a Park & Ride Lot.

The program information and regulatory messages should be put in the Park & Ride lots to ensure they are viewed at lower speeds, since they are rich with information. Placing the program information signs here in a lower speed setting will also allow the inclusion of phone numbers and internet addresses. Ideally, these signs will be placed in locations prior to the last bail-out point before the ramp to the HOT lane. In our review of each Park & Ride lot, we did note that this will be difficult in some facilities. For example, at the Easttex Transit Center shown above, the distance from the surface street to the ramp terminal is very short. If the driver decides to not enter the HOT lane after seeing the regulatory information, the bus loading area is the only option for bailing out and returning to the street to reach the main lanes freeway entrance. Site specific engineering will have to be conducted in each Park & Ride lot to locate these signs properly.

References

1. Schrock,S.D., G. L. Ullman, A. Williams, and S.T. Chrysler (2004). Identification of Traveler Information and Decision-Making Needs for Managed Lane Users. Research Report 4160-13, Texas Transportation Institute, College Station TX.

2. Chrysler, S.T., A. Williams, and K. Fitzpatrick (2007). *Preliminary Guidelines for Signing for Toll Facilities*. Research Report 5446-1, Texas Transportation Institute, College Station, TX.

3. Chrysler, S.T., A. Williams, and K. Fitzpatrick (2008). *Driver Comprehension of Signing and Markings for Toll Facilities*. FHWA/TX-07/0-5446-2, Texas Transportation Institute, College Station, TX.

4. TxDOT Traffic Operations Division, *Toll Road Signing Guidelines*, Draft Policy, Aug. 8, 2008. Available from Michael Chacon, TxDOT.

5. TxDOT Traffic Operations Division, *Managed Lane Signing Guidelines*, Draft Policy, June 22, 2008. Available from Michael Chacon, TxDOT.

6. Texas Department of Transportation Manual on Uniform Traffic Control Devices, 2006 Edition. http://www.dot.state.tx.us/publications/traffic.htm Accessed August 15, 2008.

7 . U.S. Department of Transportation. *Manual on Uniform Traffic Control Devices for Streets and Highways, 2003 Edition*. Washington, D.C.: Federal Highway Administration.

8. US Code of Federal Regulations (23 CFR 655.603) Federal Higway Administration http://edocket.access.gpo.gov/cfr_2008/aprqtr/pdf/23cfr655.603.pdf

9. US DOT Manual on Uniform Traffic Control Devices, 2003. Section 1A.07, Support statement page 1A—3. Federal Highway Administration, Washington DC. http://mutcd.fhwa.dot.gov

10. US DOT Federal Highway Administration Request for Interpretation I-44(Intr.)—Applicability of MUTCD to Private Property Open to Public Travel http://mutcd.fhwa.dot.gov/resources/interpretations/1_44.htm

11 . US DOT Federal Highway Administration, Notice of Proposed Amendment to the MUTCD, January, 2008. FHWA Docket No. FHWA-2007-28977 http://wwwcf.fhwa.dot.gov/exit.cfm?link=http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=2008_register[amp]docid=fr02ja08-27.pdf

12. Stockton, W.R., M. Burris, S.T. Chrysler, V.D. Goodin, M. Hoelscher.(2007). Houston Value Pricing Project: Final Report. Technical Report to Texas Department of Transportation and U.S. Federal Highway Administration, College Station, TX, 2007

13. Colorado Department of Transportation. I-25 HOT Lane Plans. March 21, 2005.

14 . Orange County Transportation Authority. http://www.91expresslanes.com/, Accessed June 2009

15. Nookala, M. I-394 MnPass Express Lanes. Paper Presented at the 85th Annual Meeting of the Transportation Research Board, Session 369, January 24, 2006.

16. Fuhs, C. I-5 North Coast Managed Lanes Value Pricing Study: Technology and Systems Operation Concept Task 2.3 Draft Report. PB Consult, Houston, Texas, September 2005

17. Traynor, R. Traffic Control Device Plans for San Diego: I-15 and I-5. Paper Presented at the 85th Annual Meeting of the Transportation Research Board, Session 369, January 24, 2006.

18. Clearview-Hwy font, Terminal Design, Inc. http://www.terminaldesign.com/fonts/sets/?CID=3

19. SignCad Systems. http://www.signcad.com/

20 . US DOT Federal Highway Administration Interim Approval IA-5 Clearview font, September 2004. http://mutcd.fhwa.dot.gov/pdfs/ia_clearview_font.pdf

21 . Federal Register / Vol. 67, No. 147 / Wednesday, July 31, 2002 / Rules and Regulations 49571

22. Chrysler, S.T. & Pezoldt, V. (2008). Driver Understanding of Toll Road Signing Colors, Symbols, and Terminology. *Paper presented at 87th Annual Meeting of the Transportation Research Board*, Session 530, Paper Number 08-1599, January 15, 2008.

23. Funkhouser, D., Chrysler S.T., Nelson, A. and Park E.S. (2008). Traffic Sign Legibility for Different Sign Background Colors: Results of an Open-Road Study at Freeway Speeds. *Paper presented at the 52nd Annual Meeting of the Human Factors and Ergonomics Society, Session ST2, Sept 23, 2008, New York.* Proceedings available from HFES, Santa Monica, CA

24. US DOT Federal Highway Administration Request for Interpretation 2-466(I) – Pictograph Use on Guide Signs. http://mutcd.fhwa.dot.gov/resources/interpretations/pdf/2_646.pdf

25 . Chrysler, S.T. & A. Nelson (*2009*). *Driver Comprehension of Signing and Markings for Managed Lanes.* FHWA/TX-08/0-5446-3, Texas Transportation Institute, College Station TX.

26 . Traffic Control Devices for Preferential Lane Facilities , August 2007. http://mutcd.fhwa.dot.gov/resources/policy/tcdplfmemo/index.htm