Technical Report Documentation Page

1. Report No. FHWA/TX-04/0-4160-13	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle IDENTIFICATION OF TRAVELER INFORMATION AND DECISION-MAKING NEEDS FOR MANAGED LANE USERS		5. Report Date April 2004 6. Performing Organization Code
7. Author(s) Steven D. Schrock, Gerald L. Ullman, Alicia A. Williams, and Susan T. Chrysler		8. Performing Organization Report No. Report 0-4160-13
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: September 2002 - 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: Operating Freeways with Managed Lanes

16. Abstract
Researchers conducted focus groups in Dallas, Houston, and San Antonio to better determine what information drivers believe they need and how well they understand current and proposed message formats. Participants disagreed with the standard of marking the entrance to the managed lane from the general-purpose lanes with an EXIT sign, as they considered themselves still on the overall facility. Participants were also receptive to using a different color sign or at least a different colored banner to help differentiate between managed lane and general-purpose lane information.

The research team develop a conceptualized driver decision-making model to help managed lane designers understand the type of information that drivers need in order to make informed decisions about whether or not to use the managed lane facility. Recommendations are made for further research into which types of information could be moved off of the roadway and presented in other formats, such as the Internet or highway advisory radios.

17. Key Words Managed Lanes, Driver Information Needs	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 74	22. Price

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

IDENTIFICATION OF TRAVELER INFORMATION AND DECISION-MAKING NEEDS FOR MANAGED LANE USERS

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Report 0-4160-13
Project Number 0-4160
Research Project Title: Operating Freeways with Managed Lanes

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

April 2004

TEXAS TRANSPORTATION INSTITUTE
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ACKNOWLEDGMENTS

This project was conducted in cooperation with TxDOT and FHWA. The researchers also acknowledge the following members of the project monitoring committee, both past and present, for their leadership, time, efforts, and contributions: Program Coordinator Gary K. Trietsch, P.E.; Project Director Carlos Lopez, P.E.; Current Technical Panel Members Ken Bohuslav, P.E., Chuck Berry, P.E., Maribel Chavez, P.E., Bill Garbade, P.E., Clint Jumper, P.E., John Kelly, P.E., James Kratz, P.E., Jay Nelson, P.E., Mary Owen, P.E., Jim Randall, P.E., Carol Rawson, P.E., Phil Russell, P.E., Amadeo Saenz, P.E., Richard Skopik, P.E.; Previous Technical Members Mike Behrens, P.E., Alvin Luedecke, Jr., P.E., Steven Simmons, P.E., and Robert Wilson, P.E.; and our Research and Technology Implementation Office engineer, Wade Odell, P.E.

The research reported herein was performed by the Texas Transportation Institute as part of a project entitled “Operating Freeways with Managed Lanes” and was sponsored by the Texas Department of Transportation in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

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CHAPTER 1: INTRODUCTION

OVERVIEW OF MANAGED LANES

Managed lanes, as defined by the Texas Department of Transportation (TxDOT), have an extremely broad operational definition:

> "A facility that increases freeway efficiency by packaging various operational and design actions. Lane management operations can be adjusted at any time to match regional goals" (*1*).

The theory behind managed lanes is to set aside certain freeway lanes and to employ various operational strategies of those lanes to move traffic more efficiently. Examples of strategies that can be used as part of managed lane operations include the following (*2*):

- allowing lane access only to certain vehicle groups by time of day,
- charging a toll for access to the lanes to manage demand, or
- otherwise controlling access points.

Additional strategies and combinations thereof are also possible. Whatever strategies designers use, the idea is to modify them as needed over time to meet regional goals. These regional goals may involve encouraging changes in modal shift, departure times, or use of other routes in the region, reduction in environmental emissions, generation of revenues, and other issues. This is in stark contrast to historical goals of freeway facilities to provide and maintain high levels of service for all traffic on the facility.

RAMIFICATIONS OF THE MANAGED LANE CONCEPT UPON TRAVELER INFORMATION REQUIREMENTS

An implied goal of the managed lane concept is to offer additional choices to motorists on a section of freeway. These choices can vary by time of day or possibly in response to changing traffic conditions on either the managed lane or the other general-purpose lanes in the corridor or region. The extent to which travelers can and will accommodate such operational flexibility hinges on getting the right information to travelers, at the right time, and in the right format so that they can make effective decisions pertaining to their trip.

Some users of managed lanes will make decisions prior to the start of their trip. However, others may make such decisions en route to their destination. The information needed to support such decisions must be safely and effectively interwoven with that information required for motorists to safely control, guide, and navigate their vehicles into and along the managed lanes. To further complicate matters, this information must often also be interwoven with similar control, guidance, and navigation information required for motorists operating in adjacent general-purpose lanes. Obviously, in such a complex information environment the potential for information conflicts and overload exists. How, where, and when such conflicts and overload can occur, as well as what can be done to help alleviate these conditions, are the focus of this report.

CONTENTS OF THIS REPORT

The research team performed several activities as part of this task investigation:

- reviewed previous literature and available analysis tools relevant to traveler information overload and positive guidance in a freeway and/or managed lane environment,
- conducted a series of focus groups to investigate motorist understanding of several managed lane operational issues and information concepts, and
- undertook critical analysis to assess information needs that support key decisions by motorists attempting to use various managed lane operational strategies.

Chapters 2 through 4 of this report summarize the results of these activities. The final chapter summarizes the principal findings and conclusions from these analyses, and provides basic recommendations on addressing traveler information requirements on future managed lane facilities.

CHAPTER 2:
LITERATURE REVIEW

HISTORICAL DEVELOPMENT OF MANAGED LANE SIGNING AND MARKING

Early applications of managed lanes consisted primarily of transit-only lanes. Specific examples reported by Carroll, Fuhs, and Obenberger include Route 495 Exclusive Bus Lane in New Jersey (1969) and Interstate 395 Exclusive Bus Lane Demonstration Project in Washington D.C. (1969) (*3*). These earliest projects used existing traffic control intermixed with simple devices such as traffic cones or vertical tube markers to delineate the managed lane from the general-purpose lanes. Because the drivers in the managed lanes were experienced transit operators, designers made little concerted effort to systematize information dissemination for the managed lane users. Rather, they focused the effort on getting the general public to realize that passenger cars and other vehicles were prohibited from these lanes.

It was not until the 1975 revisions of the *Manual on Uniform Traffic Control Devices* (MUTCD) that standardization was attempted in managed lane environments (*4*). These signs were still focused primarily on identifying the managed lanes as restricted in some manner from general traffic. By this time there were high-occupancy vehicle (HOV) lanes in place in New Jersey, New York, Washington D.C., Los Angeles, San Francisco, and Seattle, each with their own information systems. Transportation officials in locations that did not have managed lanes were often confused as to what these signs were for (*3*).

Carroll, Fuhs, and Obenberger also point out gaps that exist (or existed at the time of their publication date) in the practice of HOV signing. These gaps include a lack of MUTCD guidance in the areas of:

- terminology nationally or even regionally (HOV lane, carpool lane, diamond lane, etc.),
- systematic signing practices for different types of managed lanes (HOV, toll lanes, hybrid systems, etc.),
- guidance for signing and marking for part-time managed lanes (such as some reversible HOV systems),

- guidance for managed lane warning signs (the authors noted a lack of consistency in the use of managed lane "diamonds"),
- consistency in the use of "diamond" pavement symbols to identify managed lanes, and
- consistency of managed lane sign sizing and guidelines of varying sign size (*3*).

Although the latest update of the MUTCD addresses some of these and other issues regarding consistency of the use of traffic control devices, there are still obvious gaps and questions remaining as to what treatments are most effective (*4*).

POSITIVE GUIDANCE

Positive guidance is a principle that combines highway/traffic engineering with human factors methods to produce a highway information system matched to driver attributes and situational demands (*5*). Drivers gather information from many sources, including tactile vibrations through the vehicle, auditory input of road noise, and predominantly visual input of the roadway ahead. According to the positive guidance model, all of this information is processed at three different levels of control actions. As depicted in Figure 1, the most important of these is the control level, which relates to the physical operation of the vehicle. A higher level of control is required for guidance of the vehicle, which relates to the safe speed and lane choice for the vehicle. Finally, above that is the navigation level of control, in which the driver chooses the route to get from the trip origin to the trip destination. When a driver is overloaded with information, the driver actively sheds the information load by ignoring the navigational level in order to maintain the physical control of the vehicle and keep from colliding with another vehicle or other hazard.

A procedure based on positive guidance principles was developed to serve as a countermeasure technique to address known traffic problem locations that were identified through high accident frequencies, motorist complaints, and other methods. One of the key facets of positive guidance is the acknowledgment that humans have limits on their ability to scan, process, and react to information as part of their driving activities. The principles of positive guidance have been used in the traffic engineering community for almost 30 years.

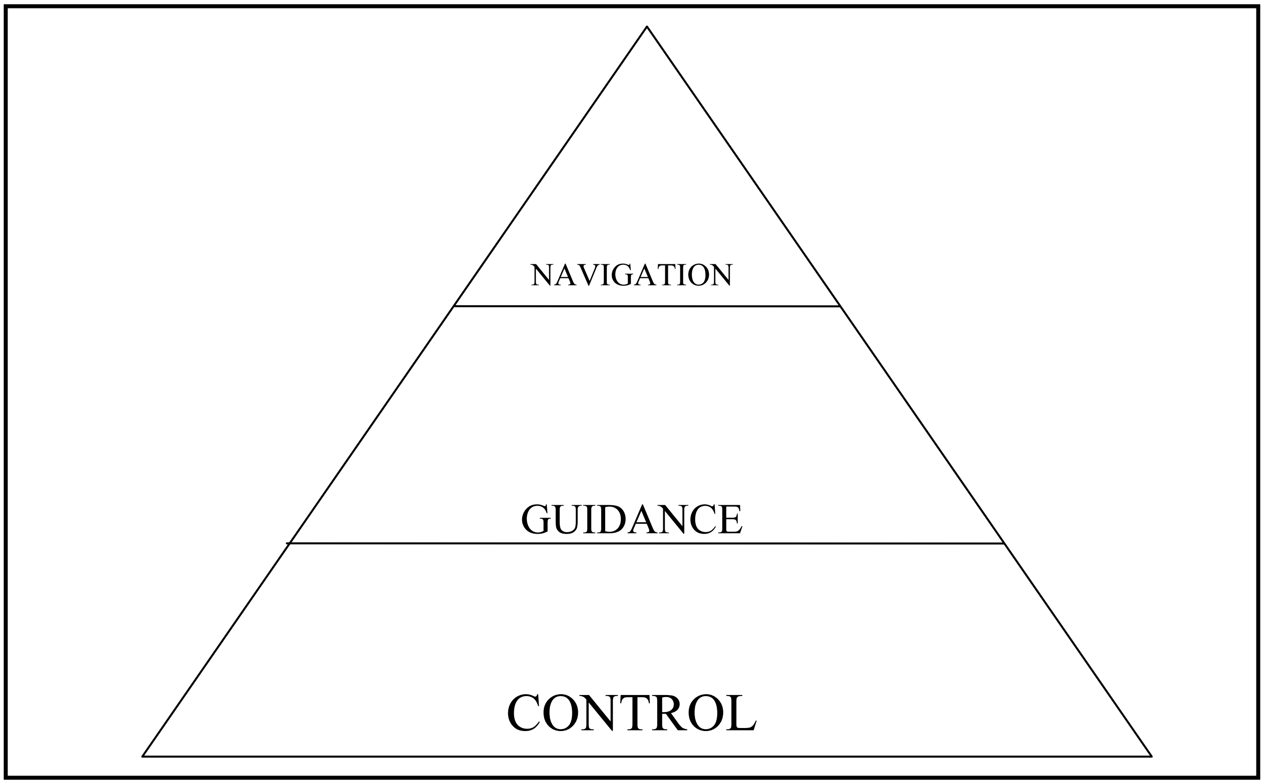

Figure 1. Levels of the Driving Task (5).

Evaluating a location with the positive guidance procedure requires evaluation of eight steps:

- site definition,
- problem description,
- hazard identification,
- hazard visibility assessment,
- expectancy violation determination,
- information load analysis,
- information needs specification, and
- current information system evaluation.

The last three steps are of interest for this research, and they are discussed in further detail in the following sections.

Information Load Analysis

When using positive guidance to improve an existing roadway location, the information load is determined by a drive-through of the site. The objectives of such an investigation would be to determine in a general sense how much information is presented to drivers in all areas, not only from traffic control devices. The factors considered are merely categorized as low, medium, or high information load, with no attempt made to further quantify the data. Factors where information may be presented to drivers that should be considered include:

- adjacent land use,
- traffic volume,
- traffic speed,
- the required driving task,
- the amount and location of any hazards,
- sight distance,
- violations of what typical drivers were expecting, and
- the clutter and complexity of the information (*5*).

There are methods other than drive-throughs that may be valid for determining information load. Current methods for determining the information load of as-yet unbuilt facilities include information load models (*6*) and testing using driving simulators (*7*,*8*). This process was merely intended to get the engineer conducting the site investigation to determine locations where a relatively large amount of information is presented to drivers.

Information Needs Specification

Positive guidance also helps traffic engineers understand that not all information is needed at the same locations. When a driver is far upstream from a decision point, such as a managed lane entrance or exit, there is little information required by the driver. As the driver approaches the decision point, more information is required for the driver to understand that there may be maneuvering required, that other drivers may be maneuvering in that area, and that drivers can select alternate paths. As the driver reaches the location, little information other than speed and implementation information is needed, as the driver should be focused on acting on the path choice he or she made. After the decision point, the information needs are reduced to minimal guidance information.

Required information may come from:

- signing information about laws and regulations,
- signing about hazard warnings,
- speed advisories,
- surrounding traffic behavior,
- advance guide signs,
- roadway geometric information, and
- previous experience by the driver about the area *(5)*.

Current Information System Evaluation

In the final step of the positive guidance process, the analyst uses judgment to compare the need for information with that information that is actually provided. If the analyst determines that there is a deficiency in the traffic control plan (either from information that is not provided or not legibly provided, or if too much information is provided at a specific location), then steps are recommended to remedy the specific problem.

Adding missing information is obviously a fairly straightforward process. However, if the analyst judges too much information is present at the specific location, one of two steps is recommended. First, the information being presented is analyzed to identify if some of the information is superfluous, and if so that material is removed from the roadway. If no superfluous material is present, then attempts should be made to spread the information farther upstream or downstream from the location as appropriate.

INFORMATION LOADING

Several areas of research relate to how motorists read and understand traffic signs. These areas include issues related to vision, mental information loading, and specific research of the composition and placement of traffic signs. These areas are discussed in more detail below.

Mental Information Loading

Zeitlin researched how drivers allocate their mental processing ability during actual driving situations (*9*,*10*). Observers evaluated vanpool drivers in the New York metropolitan area during 36,000 miles of daily commute driving. During the drive, the observers would direct the driver to orally repeat a string of digits using delayed-digit recall. In this method, a series of single digits would be played from a tape recorder, with a one-second gap between digits. The driver would be required during the one-second gap to say aloud the digit that preceded the one just played. The observers would record the ability of the drivers to successfully complete the task, and record the locations where they made errors. Zeitlin was then able to compare locations where the drivers had a lower likelihood of success. He found that inner-city locations and intersections were more likely to lead to more mistakes or omissions from the drivers, serving as an example that drivers do indeed shed lower-priority tasks in order to successfully complete their main task of driving.

Sign Reading Research

McNees and Messer conducted research in the 1980s to better understand how varying amounts of information on freeway guide signs were processed by drivers (*11*). In their study, the researchers tested 750 subjects by showing them 35 mm slides representing freeway guide sign bridges. The signs on these slides provided information that the subjects were to use in order to select a particular route. To reflect urban driving conditions, up to five sign panels were present on each slide.

The available reading time and the amount of information presented on the sign panels were varied in the study. The subject's ability to correctly select the appropriate path through the study was measured. A correct response implied that the subject had enough time to identify the pertinent information from the signs and make a decision based on that information. The researchers found that as the amount of information on each sign panel and as the number of panels increased, the time required to identify the route information increased.

Recommendations were made based on these results to limit the information on large sign bridges (four sign panels or more) to less than six units of information per sign. Additionally, when the reading time for these sign arrays was fixed to shorter and shorter intervals, subjects were less and less likely to be able to correctly find their desired information.

Smiley, MacGregor, Dewar, and Blamey researched the use of innovative tourist guide signing in Ontario (*12*). These messages were placed at two test locations and were evaluated based on legibility, information load, comprehension, conspicuity, and driver response to the signs. These innovative signs used different types of arrows and used a distinctive banner to help the signs stand out more than previous tourist signing. The researchers found that when shown signs large enough to provide 2.5 seconds of reading time, 94 percent of the target destinations were correctly recognized. This dropped to 79 percent for 1.5 seconds of reading time. Correct responses also were lowered when more information-intensive signing was used (in this case up to five destinations on a single sign).

Interestingly, these researchers also found that correct responses were lowered when subjects were asked to search for a particular type of facility rather than the name of a specific facility. In this study, subjects could find facility types by either reading the text of the location or by reading the adjacent pictograph. The researchers found that only 58 percent of subjects could correctly identify if a certain type of facility was present, which indicated to the researchers that information load was more severe when subjects were searching for general items. This seems to make intuitive sense, as this type of search would require a motorist to read all available information.

Pictographs were also studied in isolation from the remaining sign information. The pictographs studied were general tourist information such as campground, skiing, and golf information symbols. Eleven pictographs in all were tested, and the researchers found that five of the eleven had comprehension responses below the 85th percentile. In general, comprehension scores were higher when the pictograph showed a person in action. For example, the golf and skiing symbols showed a stick person performing those actions, and these pictographs had the highest comprehension scores, 96 and 95 percent, respectively. The more passive pictographs, such as the Conservation Area sign (which showed some trees inside a large letter "C") scored much lower at 73 percent of subjects comprehending the message. In general then, when a symbol is simple and easily identified, it proves to be a good candidate for use on signing. This could indicate improved information dissemination for managed lanes if an identifying symbol or banner is used and easily associated with a managed lane or other special roadway feature by the driving public.

Information Overload

As previously discussed, when drivers are loaded with too much information to process at one time, they "load shed" as a way of coping. Drivers will focus on that information that they believe will successfully help them traverse the immediate section of roadway ahead, and will not process higher level information such as navigational or general information signing. To date, it has been difficult to quantify how much is "too much" information for a traveler to accommodate. Several factors come into play, including the type and content of information, traffic and environmental conditions, and the alertness and information processing ability of the driver.

Under most driving situations, overload is not a factor as driving is usually undemanding (*13*). But as information demand increases, drivers need to spend more and more energy attending to and processing that information. Pietrucha states this process succinctly:

> "In the simplest situation, the driver has to perform only vehicle control tasks and has little problem attending to and processing information on traffic signs. However, as driving becomes more complex or conditions outside the vehicle degrade and obscure the visual cues needed for vehicle control, the driver's attention becomes focused on these other tasks, and attending to certain types of traffic signing becomes less important. As the driving task becomes more complex or conditions degrade further, the task load increases and becomes progressively difficult for the driver to handle" (*13*).

Agg reviewed the effect of large amounts of guide sign information presented simultaneously on British roadways by conducting a photographic survey of guide signing sampled over a three-day driving tour (*14*). She analyzed the number of destinations that were visible on signs in individual pictures. In other words, how much information about various destinations was being presented to drivers at a specific location? She found that while the median number of destinations was four, about 5 percent of the signing arrays presented information for from eight to fifteen destinations. Agg categorized the information into units, and found that for the more heavily loaded signs, up to 23 units of information were presented to drivers. Agg recommended replacing the highest information load sign arrays with map diagrams to reduce the searching and reading tasks for drivers.

Messer and McNees evaluated guide signs on 1053 miles of freeway in ten major metropolitan areas in the Unites States (*15*). They reported their findings as the number of signs per mile that was in the sample area for each city, and found that while the average number of signs per mile was just about two, Houston and Fort Worth, Texas, both had around three signs per mile. In addition, they determined that Dallas, Fort Worth, San Antonio, and Houston all had at least 14 instances where their sign arrays provided more than 15 bits of information, which was considered undesirable and potential areas of driver information overload. No other cities in the study had so many instances of this. The conclusions of their research pointed out that out-of-state drivers may not be prepared for the additional information load in these cities, and certainly not at the locations where more than 15 bits of information were presented.

Messer, Mounce, and Brackett researched driver expectancies on rural roadways to determine how drivers reacted to unexpected events (*16*). The researchers found that when drivers were surprised by unexpected geometric features, there was an increased probability of potentially unsafe driving decisions. While the surprise might shock a person into an unwise physical reaction, it is also likely that a portion of this reason comes from the unpreparedness of a driver to be ready to process the information that is presented. In the information overload context, when the critical information of an unexpected geometric feature is presented, a driver may be slow to react because of the slow information processing time. This is consistent with previous research indicating that it takes drivers longer to detect and react to events that are unexpected (*17*). This basis is also recognized in current engineering design policies (*18*).

ATTEMPTS TO QUANTIFY INFORMATION OVERLOAD CONDITIONS

In 2003, the Transportation Research Board published the National Cooperative Highway Research Project (NCHRP) Report 488, entitled *Additional Investigations on Driver Information Overload*. The goal of the authors of this report was to “develop a model of driver information load for freeway applications and to translate that model into a practical tool so traffic and safety professionals could analyze information load" (*6*). In essence, this research was intended to provide a way of quantifying the amount of information presented to drivers, at least as presented on freeway guide signs. To accomplish this, the researchers attempted to identify information dissemination problems, limitations of human processing in short time intervals, and the amount of information presented on freeway guide signs.

The authors of the NCHRP report started with a conceptual model that included the assumption of a novice, older, or otherwise unfamiliar driver who would require more time to successfully process roadway information. These drivers would be assumed to be traveling on a freeway or expressway, and be actively searching for information that would allow them to arrive at their proper destination. Once one or more information sources are located, the driver must immediately determine how to allocate his or her attentional resources in order to successfully process the new information while still maintaining the safe operation of the automobile, following positive guidance principles of driver information processing. The factors that interact with this process are presented in Figure 2.

Additionally, the researchers believed that the driving task demand component of the information load model was dependent on the distance the driver was upstream from the maneuver point, which could be considered an exit gore, freeway split, or other geometric feature denoting the last point where a choice can still be made in the driving path. Further, it was believed that the point of maximum workload would come at some point upstream from this decision point, and gradually drop as the gore point was reached. Conceptually, this is shown in terms of driver workload in Figure 3.

The researchers of the NCHRP report developed a methodology for quantifying the driver mental workload of a given highway guide sign by quantifying the units of information that are presented by various types of signing, as well as the information provided from roadway geometric configurations. In order to manipulate the measure of complexity of a particular sign, the user can input a complexity rating on the sign that would increase the quantified workload value. Workload for a given sign was also designed to be dependent on the distance from the sign and the observation point, as conceptualized in Figure 3.

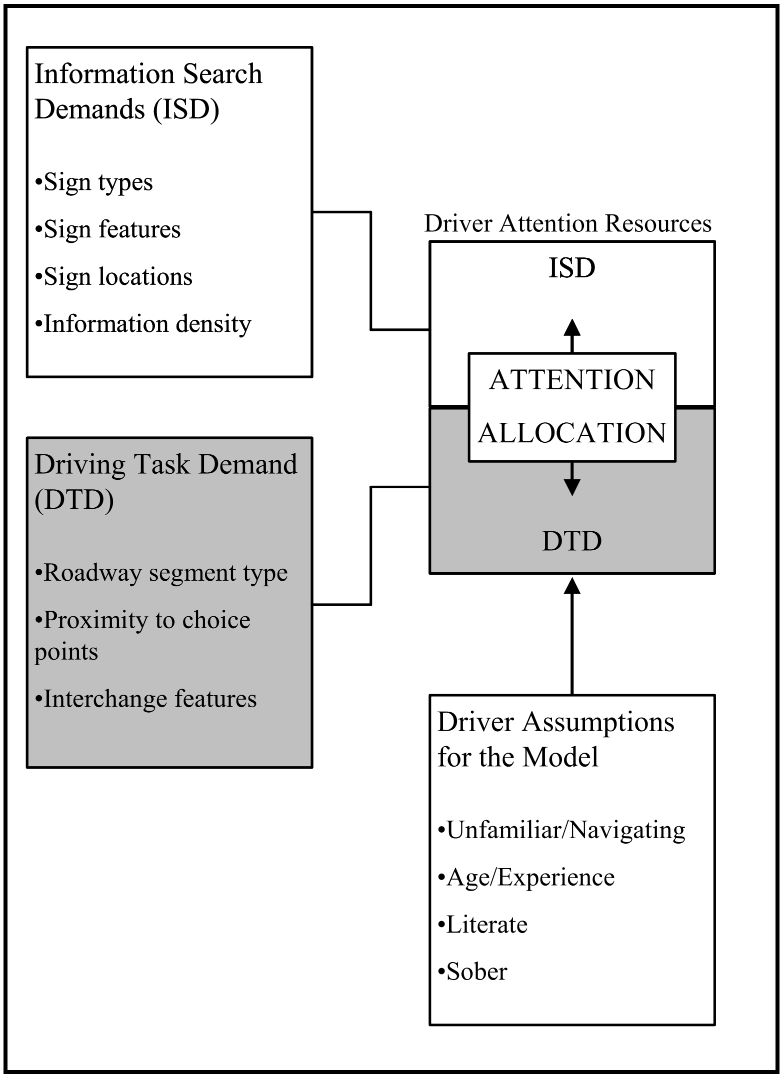

Figure 2. Driver Information Load Model Components (*6*).

Critique of Driver Information Load Model Conceptual Tool for Use in Managed Lane Environments

TTI researchers in this project believed that the model had potential application in assessing information load for complex environments such as will exist in many managed lane applications. Therefore, a set of preliminary signing plans for the reconstruction of Interstate 10 between Houston, Texas, and Katy, Texas, was reviewed to gather realistic guide signs for both managed lanes and the general-purpose lanes, as well as geometric features and distances for the proposed reconstruction. This information was input for a 10.2 mile distance. As expected

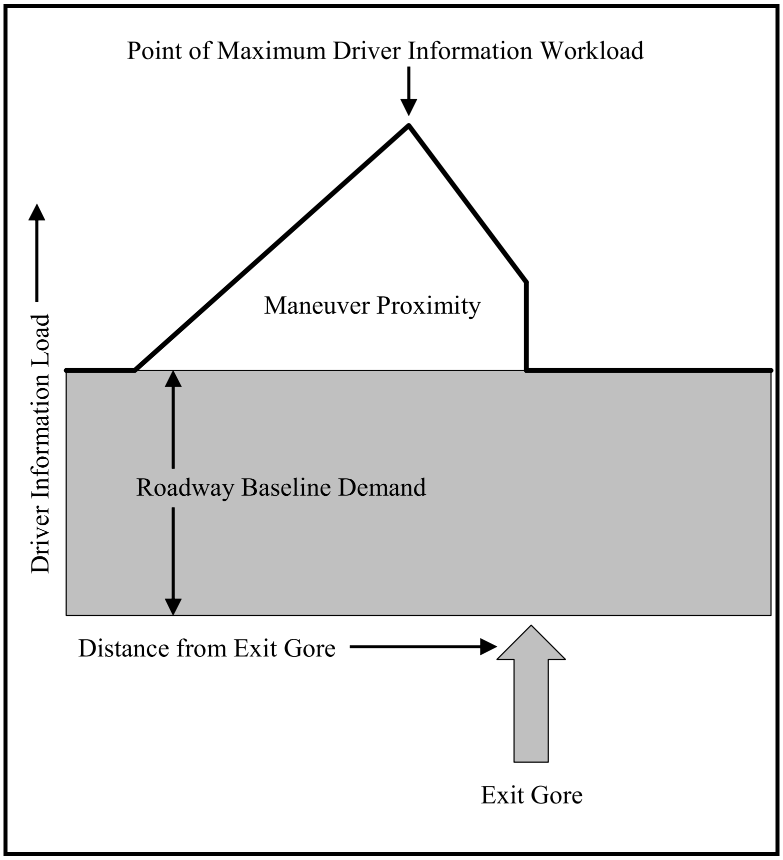

Figure 3. Information Load Conceptual Diagram for Driving Task Demand (*6*).

from the conceptual model, the computed workload increased in locations where drivers would be required to read significant amounts of sign information or when geometric changes occurred.

Although the researchers were able to generate model outputs of the Katy managed lane and general-purpose lane system, they found several shortcomings with the model itself. Specifically:

- There was no method of differentiating whether a sign was for the managed lanes or the general-purpose lanes. This lack of a method for differentiating the type of information led to extremely high information load computations at several of the major sign structures.
- There was no way to differentiate between driver decision points for the managed lanes and the general-purpose lanes.

- No determination or guidance was given in the program to help determine when a specific location had "too much" information. The model only indicated where there are relatively higher levels of load (which will often be intuitively obvious simply by examining the set of signing plans themselves).

One possible method for using this tool would be to develop two databases for each section of the roadway (one for managed lanes and one for general-purpose lanes). This method would be problematic because some information presented on a sign array may be for both groups of traffic, and could not easily be split between the two groups, and it would be doubtful that anyone would choose to do this.

It should be stated plainly that the authors of the model never intended their software to address the specific need of managed lane information directly. In fact, they stated that while a vast array of environments could benefit from a model such as theirs, "absent any existing model of [driver information overload] and the lack of empirical data upon which to develop a model, it would be unrealistic to address such diverse applications under an initial project of limited scale" (*6*). A managed lane situation, in combination with adjacent general-purpose lanes, would clearly be one of the diverse applications to which they were referring. Regardless, the general methods of determining locations where workload is higher can still be of value in practical engineering terms to aid traffic engineers and highway planners in understanding that some locations are more information rich, which could hinder proper decision making by drivers. These principles, however, would not provide anything that would be of specific use for managed lanes.

The authors of the model provided several suggestions for what to do when engineers find the density of signing information they believe to be too "intense." These include:

- consider signing needs early and throughout the road design process,
- follow guidelines of the MUTCD,
- increase font sizes for increased reading distance,
- maintain a high level of nighttime sign legibility,
- redesign the roadway to minimize complex configurations that require closely spaced decision points or decision points that violate driver expectancies,

- repeat critical signs when possible, and
- spread the information load rather than placing it all at one location (*6*).

Following these suggestions can help minimize locations where drivers are presented with more information than they can reasonably process while driving. However, these general statements do not offer much in the way of specific techniques to address potential traveler information overload conditions in managed lane applications.

CONCLUDING CONSIDERATIONS

For managed lane environments, five points are clear from this literature review.

- First, it should be realized that although there are no hard-and-fast numbers, ***there are limits to human information processing***. Some general recommendations exist, such as McNees' and Messer's recommendation that no more than six units of information be used per sign on large sign arrays. But even in that research, some drivers were able to successfully process much larger amounts of information (*11*).
- Second, when this finite information processing is allocated by a driver to deal with critical driving maneuvers and attend to the control of the vehicle, ***a driver may not have the capacity to deal with yet more information***, such as additional managed lane information signs, and will not be able to process that information. This could occur during times of driving in heavy traffic, at unexpected geometric features, or when many sources of information are presented simultaneously. It is difficult to effectively assess the extent to which such overload conditions might occur simply by examining a proposed set of signing plans.
- Third, ***proper placement and presentation of managed lane information will alleviate some of these limitations***. By spreading the information from demanding driving locations, it is possible to increase the time and mental processing a driver can use to attend to the managed lane information. This information could be spread by shifting the message upstream – or in certain instances downstream – from the present location. The MUTCD and other engineering references provide minimum

separation guidelines between the signing and the location being signed for, and these should govern any load spreading considerations.

- Fourth, information requirements are usually governed by geometric design considerations that have already been made in most instances. By ***considering the information needs earlier in the design process (prior to exit ramp and managed lane entrance location selection, for example)*** the information needs of drivers can be more easily addressed.
- Fifth, despite their initial attractiveness, newly developed tools for analyzing driver workload conditions do not have the capabilities to effectively capture the nuances and special situations that arise in managed lane applications. Using the model, analysis of all signs and markings used to address managed lane and general-purpose lane information needs (some displayed together on the same structure) does generate very high information load levels. However, it is not apparent if (and how much) such load levels can be reduced through use of banners or symbols that delineate managed lane information, separation of managed lane and general-purpose lane decision points, or even with slightly different terminology for certain managed lane components and maneuvers that might have better recognition and recall among travelers.

Positive guidance principles indicate that efforts to design facilities and information systems to be consistent with driver expectancies will minimize their overall driving workload, minimize errors, and maximize the consistency of the resulting driving behaviors. Presently, very little is known as to how the traveling public understands both design and informational concepts being used or proposed for managed lane use. To address this limitation, researchers conducted a series of focus group analyses in several Texas cities. The methodology and results of these focus group analyses are discussed in the next chapter.

CHAPTER 3: FOCUS GROUP ANALYSIS OF MANAGED LANE INFORMATION

DEMOGRAPHICS

The research team held six focus group sessions to get input from Texas drivers regarding key issues in managed lanes traveler information. The sessions were held in Houston, Dallas, and San Antonio. In total, 62 people participated in the focus groups. Overall, 94 percent of the sample reported doing some driving each day, and 56 percent of the drivers in this sample reported driving on urban freeways 20 or more days a month. Overall, 39 percent of the subjects included in the focus groups reported they had utilized HOV lanes.

The Houston metropolitan area contains nearly 100 miles of HOV lanes, both barrier and buffer separated (*19*). It also has an extensive toll road network covering 83 miles, which allows electronic and cash payments (*20*). The locations of the Houston groups drew participants mainly from an urban area, with a few regular commuters in the mix. The Dallas area HOV system encompasses 31 miles of buffer-separated and barrier-separated facilities (*21*). There are also toll roads in the area that allow electronic and cash payments. The Dallas HOV facilities have a two-person occupancy requirement at all times, while in Houston during peak hours some facilities require three people.

The San Antonio area did not have any HOV facilities or toll roads at the time of the focus group, though several such facilities were under discussion in the press. Therefore, none of the drivers in the San Antonio groups reported driving in an HOV lane. Table 1 provides information about the demographics and driving history of the sample.

Participants were recruited by contacting community service agencies and by placing flyers in office complexes and other major employers. Sessions were held at various times of day in an effort to get people who worked at various times. In Houston, one session was held in the TTI office at I-10 and Post Oak, and the other session was held at the Ripley House community center in the eastside neighborhood. In Dallas, one session was held at the TTI office on the LBJ Freeway (IH-635) on the northeast side of town, and another at the Jeffery Learning Center just southeast of downtown. In San Antonio, one session was held at the TTI

Table 1. Demographic Characteristics of Focus Group Sample.

Demographic Category	Dallas	San Antonio	Houston	Total
Number of People	20	21	21	62
Gender				
Male	6	7	10	23
Female	14	14	11	39
Age				
Minimum Age	19	18	19	18
Maximum Age	64	59	61	64
Median Age	37	36	29	35
Race				
White	4	10	2	16
African American	16	2	8	26
Hispanic	0	9	11	20
Other	0	0	0	0
Employment				
Full Time	15	9	16	40
Part Time	3	7	1	11
Retired	0	1	0	1
Student	1	1	3	5
Homemaker	0	0	0	0
Unemployed	1	1	1	3
Not Reported	0	2	0	0
Highest Educational Attainment				
Some High School	0	1	1	2
High School Graduate	2	7	6	15
Some College / Vocational School	10	7	11	28
College Graduate	7	6	3	16
Some Graduate Work	0	0	0	0
Graduate Degree	1	0	0	1
Residence				
City	13	18	18	49
Suburb	7	2	3	12
Rural	0	1	0	1
Percent Driving 20 or More Days a Month on Freeway	50%	67%	52%	56%
Percent of People Driving Daily	90%	90%	100%	94%
Percent of People Who Drive in HOV Lane	70%	0%	48%	39%

office at Castle Hills in the northwest suburbs, and the other at the Benavides Learning Center on the west side of the city. All participants were paid $50.00 for their participation in the two-hour session.

After reading and signing an informed consent form, and filling out a demographic questionnaire, the session began with introductions and a discussion of the roads on which the participants generally travel. All sessions were audio taped, and a note taker from the TTI staff was present as well. Figure 4 illustrates the actual conduct of a focus group held at the TTI office in Houston.

Figure 4. Conduct of One Houston Focus Group.

The facilitator presented large photographs and drawings on poster board to provide a discussion aide. The potential signs shown in the drawings were created from several sources. Some illustrations were created based on signs found on Houston-area facilities, while the majority were alternatives designed by the research team based on a preliminary driver information needs analysis of managed lane facilities.

PARTICIPANTS' UNDERSTANDING OF MANAGED LANE CONCEPTS

The facilitator began the focus group with a discussion of what terms the participants used to describe the various types of managed lanes. When asked what they would call the type of road that is used for buses and carpools only, Houston, Dallas, and the majority of the San Antonio participants responded with "*HOV" (pronounced H-O-V)*. It should be noted though that there were several at the Benavides Learning Center in San Antonio who had never heard of the term *HOV* before. When asked, participants agreed that the same term can be used to refer to a special lane separated by a wall, separated by special paint, or is elevated above the rest of the freeway. When asked, most of the participants expressed that the term "HOV" would also be appropriate for a special lane that reversed directions at some point in the day. Again, though, there was some discussion from the San Antonio groups that this type of lane was different, and maybe should be called something different. Alternate terms given were *inbound/outbound lane* and the *fast lane*.

The same question was asked about lanes that only buses were allowed on, and also lanes that you must pay to drive on. All of the groups except the Ripley House in Houston believed that separate terms were needed for these lanes. Almost unanimously, the groups suggested *bus lane* for the bus-only lane, and *toll lane* or *toll way* for the lane you must pay to use. A few participants suggested attaching the word *HOV* to *toll* or *toll lane* for lanes where HOVs are free and others must pay. One Houston group believed that if you must pay in addition to carpooling in the special lane, then a separate term was not necessary.

Although the majority of the participants refer to these special lanes as *HOV* lanes, the facilitator also requested other possible names be suggested. The participants provided the following alternatives:

- bus lane,
- carpool lane,
- environmentally friendly lane,
- fast lane,
- hub lane,
- special access lane,
- special lane,

- speedway, and
- toll bridge.

The most suggested alternative among the various focus groups was the *fast lane*. When the facilitator inquired about the term *diamond lane*, none of the participants recognized the term, but many were familiar with the diamond symbol.

DISCUSSION OF THE TEXAS MANAGED LANE TERMINOLOGY

Before moving any further into the discussion on managed lanes, the facilitator passed out a handout containing the following definitions:

- Barrier separated – An HOV lane that is separated from the general-purpose lanes of traffic by a concrete wall.
- Buffer separated – An HOV lane that is separated from the general-purpose lanes only by a double white line on the road with a little extra space (the "buffer") between it and the general-purpose lanes. Small traffic cones or delineator posts may also be used to create a buffer.
- Concurrent flow – The lane always goes in the same direction as the neighboring general-purpose lanes. There are generally two special purpose lanes, one for each direction of travel.
- Diamond lane – An HOV lane that has a white diamond painted on the road to indicate that it is for special vehicles only. Diamond lanes are usually separated only by a buffer.
- General-purpose lanes – The main, free lanes used by everyone. Also called general-purpose lanes.
- HOV lane – High-occupancy vehicles only. Buses, vanpools, carpools.
- Managed lane – Any special use lane that is managed by a road authority by limiting access or hours of operation, or by charging a fee to use the lanes.
- Reverse flow – The lane reverses direction, going downtown in the morning and out to the suburbs in the afternoon.

- Slip ramp – A left-side entrance “gateway” on the freeway into a buffer-separated HOV lane. These are typically used on reverse flow facilities.
- Truck lane – Special lane for trucks to use, often found on uphill sections of road usually on the right-hand side.

The facilitator used Figures 5 and 6 as illustrations to explain the definitions.

Figure 5. Example of a Concurrent Flow Buffer-Separated Facility (photo taken in Dallas).

Entrance vs. Exit Terminology

One issue that was explored in these focus groups was the drivers’ concepts of the different roadway types and what terms they used to refer to different facility types. The first question in this area probed whether drivers would use the same route name to refer to travel in the HOV lane. When the facilitator asked, “When you move from the general-purpose lanes into the HOV lane, do you still consider yourself on the main road?” all of the participants but one answered yes. The one participant said he considered it something different, while others discussed that it felt different than the main road.

Figure 6. Example of a Reverse Flow Barrier-Separated Facility (photo taken in Houston).

Expanding on this topic, the facilitator asked, "When you choose to move from the general-purpose lanes into the HOV lane, are you exiting the freeway or entering the HOV lane?" All but one answered, "Entering the HOV lane." The one who answered, "Exiting the freeway," expressed that he could see it being called either option.

These responses have direct implications for signing. The current Texas practice and current national MUTCD standards are to mark transition areas between general-purpose lanes and managed lanes as freeway exits, as opposed to managed lane entrances (*4*). The responses of these 62 drivers indicate a nearly unanimous pre-conceived notion that the movement is thought of as an entrance to the managed lane, not an exit from the general-purpose lane.

Merge Area Terminology

Merge areas were one area of research where a consistently understood term was not found among the focus group participants. For buffer-separated facilities especially, it is not readily apparent what term should be used to refer to an upcoming roadway segment with skip-line pavement markings that will allow traffic to move between the general-purpose lanes and the managed lane(s). The MUTCD refers to this area as the area where crossing or enter/exit movements are permitted. At the present time, the manual does not label the area by a specific term.

Referring to Figure 7 the facilitator asked the participants what they would call the region of the managed lane that allowed you to pass to and from the general-purpose lanes. Suggestions included:

- access area/lanes,
- bumper lanes,
- change or changing lanes,
- dotted area,
- entrance/exit,
- exchange,
- general-purpose lane entrance,
- HOV exit,
- interchange,
- merging area/field,
- open area,
- passing area/lanes,
- pit stop, and
- transition.

The most common responses were some form of access area/lane and HOV entrance/exit. Also, change or changing lanes was mentioned by several people.

SIGN DESIGN AND PLACEMENT DISCUSSION

Another key issue that was investigated in the focus groups was how to segregate driver information intended for the managed lanes from information for the general-purpose lanes. With some geometric designs, the potential exists for conflicting exit information for managed and general-purpose lanes.

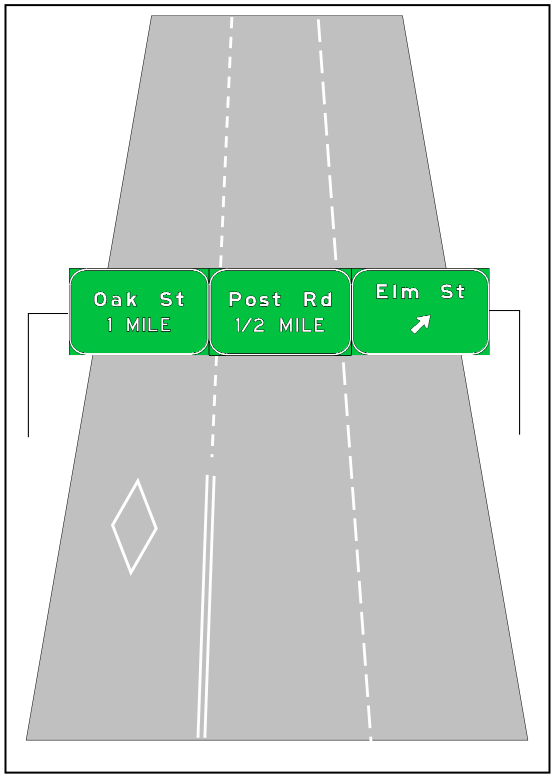

Figure 7. Area Where Crossing to and from the General-Purpose Lanes is Permitted.

Using Figure 8, the facilitator asked if the signs intended for the managed lanes should look like the signs for the general-purpose lanes. All of the participants responded that the managed lane signs should "look different." Suggestions for improvement by the focus group participants included:

- adding the HOV diamond on the sign,
- adding the term HOV to the sign,
- changing the color,
- moving the sign to the left side or separating the general-purpose lane signs from the managed lanes, and/or
- placing the sign at the exit location.

The most common suggestion given, without prompting from the facilitator, was to change the color of the sign.

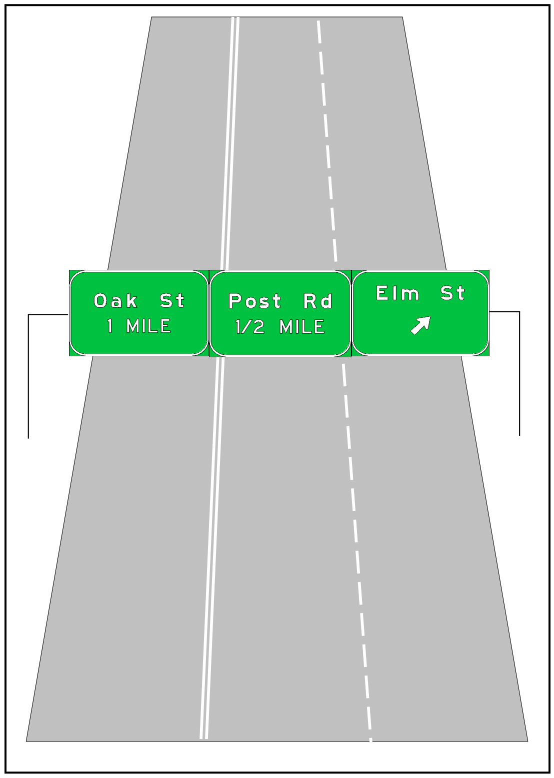

Figure 8. Standard Green HOV Guide Sign.

Many of the participants were especially confused by the meaning of the Oak St. sign. One subject asked, "Does that [sign] tell you that the [Oak St] exit is in one mile, or the [general-purpose lanes] access is?" In other words, the subject was unsure if the Oak St. exit off of the general-purpose lanes was one mile ahead, or if the chance for the managed lane to exit into the general-purpose lanes (in order to exit at Oak St. at some point farther down the roadway) was one mile ahead. Another subject was confused by the Oak St. panel being located over the far left lane and asked "Shouldn't the people in the right be able to exit Oak St. too?"

When participants expressed this confusion, the facilitator explained that the sign represented the second case. One of the Houston groups did offer suggestions to alleviate this confusion, such as rewording the sign to say Exit *HOV 1 Mile to Oak St*, or to leave off *Oak St* and say *HOV Exit Only*.

Sign Color and Banner Alternatives

TTI researchers hypothesized that some of the potential confusion pertaining to the intended audiences for different guide signs would be to use color coding as a means of distinguishing among different user groups. In order to examine the potential understanding and perception of this approach, the facilitator presented Figure 9 to focus group participants. Note that the guide sign for the managed lane sign was altered to a bright, contrasting color. The purple color is currently on the reserved color list for the MUTCD, but was used in this instance for discussion purposes. When asked what they thought of this alternative, most participants stated they liked it. However, one participant was concerned that someone who is colorblind would not be able to distinguish the difference.

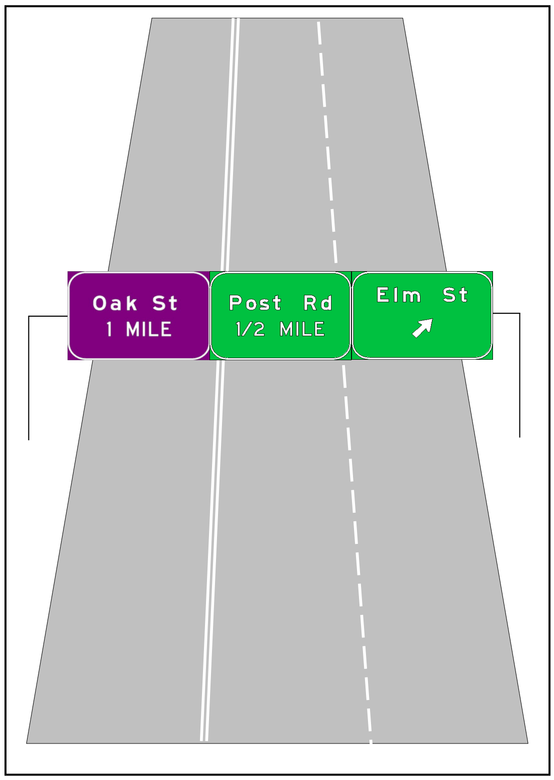

Figure 9. Colored HOV Guide Sign.

Another alternative coding approach examined is depicted in Figure 10, which shows the managed lane sign as a standard green with a red and blue banner across the top and the black and white HOV symbol. The banner is similar to that currently used by the Metropolitan Transit Authority of Harris County (METRO). When shown this alternative, the participants expressed mixed opinions concerning its effectiveness. Several believed that there was not enough of a

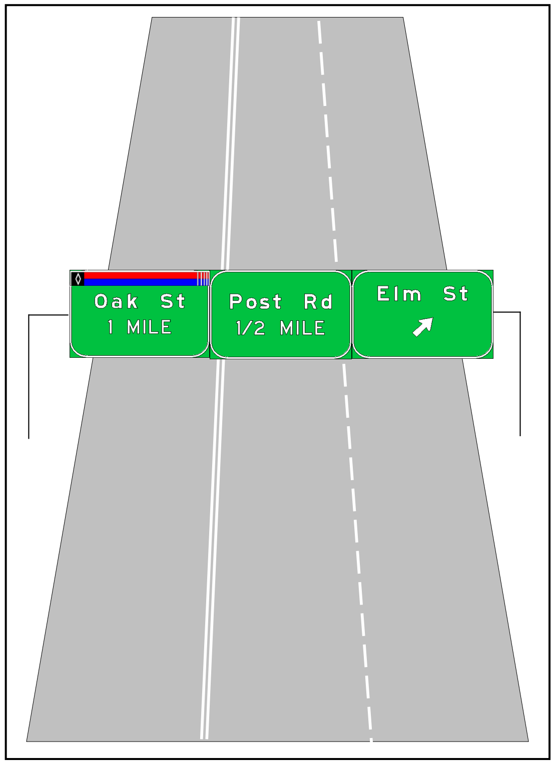

Figure 10. HOV Guide Sign with Banner.

contrast to catch the HOV driver's eyes, but when prompted by the facilitator, some said it would be easier than a plain green sign for the drivers in the general-purpose lanes to ignore. A subject from San Antonio mentioned that the banner was not a large contrast from the green sign, but that if you recognized it as an HOV lane (from previous driving or media), it would be enough. With further discussion, the group reached consensus that because the banner was not so contrasting with the other guide signs on the structure, general-purpose lane travelers would be able to "tune the sign out." Although many participants liked that the banner was at the top of the sign, they were not fond of the colors. Houston participants immediately recognized the METRO logo, but expressed confusion on whether or not the sign indicated an exit to a METRO Park & Ride, and were also concerned that the sign meant the lane was for buses only. Specifically, Houston participants commented that, "[The banner] would confuse me, is that a [METRO] exit only?" or, "Is that an exit to a METRO lot?" A couple of participants from the other groups mentioned that they liked the banner, but that dual colors were not necessary. With group agreement, a Dallas woman said, "I don't like the two colors; [you] just need one solid strip."

The facilitator further explored the concept of a single color banner, and returned to Figure 5, which showed a black and white banner with the text HOV LANE and the HOV diamond. Some participants expressed interest in the banner as long as the colors were different than the general-purpose lane freeway signs. Many participants liked having the diamond symbol and/or the word HOV on the sign.

Sign Placement Issues

Another potential method to separate information intended for managed lane users from information intended for general-purpose lane motorists is by physically separating the signs themselves. Although a few participants brought up the subject of either moving the sign or placing it on its own pole without a cue from the facilitator, the facilitator introduced the discussion in the other focus groups by returning to look at Figure 5. The vast majority of the participants expressed approval with the managed lane sign being on its own, and not on a structure that contains signs for the general-purpose lanes. As a participant from San Antonio stated, "If you're in the HOV lane, then you only have one sign to look at to find your exit instead of all three." Participants also saw value in this approach from the perspective of a general-purpose lane driver. Again, a San Antonio participant said, "If it's on its own [sign structure] and I know I won't go in there, then I won't pay attention to it." A couple of other participants suggested that merely separating the general-purpose lane signs from the managed lanes on the structure would be beneficial. The facilitator took the isolated sign idea further by asking the groups if they preferred the small sign on a pole to the left of the lane, as shown in Figure 5. Although almost everyone agreed that the small sign would not be a distraction to the general-purpose lane motorists, there was concern that the sign would not be large enough, or that the sign would be missed if you were driving in the managed lane. In San Antonio, when asked if placing the sign on its own structure would be enough, everyone agreed that a change of color was still needed. One man said if there wasn't a color change, then it at least needs to have something different on it. Finally, two participants mentioned the idea of placing the HOV information on the pavement in the lane through the use of pavement markings, or horizontal signing.

Another possibility for identifying information as intended for managed lane patrons is to add a small panel across the top of a standard sign. The design shown in Figure 11 is one proposed for the Katy Tollway in Houston. When asked what they thought about Figure 11, the majority of the participants expressed approval. The facilitator responded by asking if this was because of the color yellow, or because the panel itself stood outside of the guide sign panel rectangle. The participant responses were mixed, but most believed it was the combination of the color and the raised panel. A couple of participants also mentioned they liked the yellow color because they were taught that color meant warning or caution, whereas another participant was concerned about the use of yellow for the same reason. Expanding on the concept of the yellow color, the facilitator asked if the sign panel would be misunderstood as an EXIT ONLY indication, but there seemed to be little concern from the participants that this would be a problem.

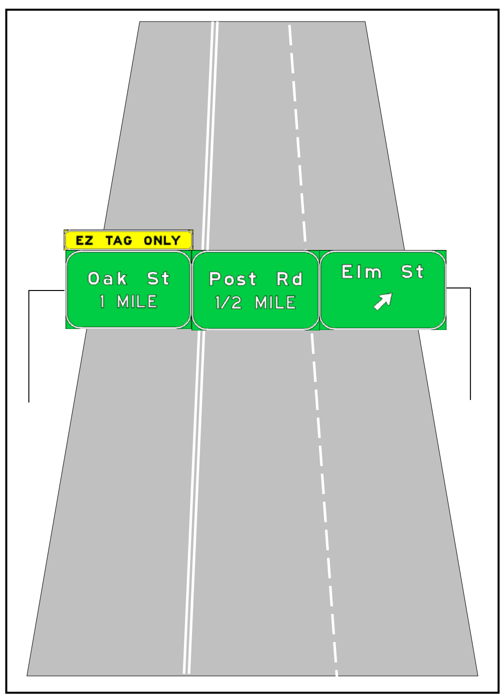

Figure 11. HOV Sign with Added Panel.

Ultimately, various combinations of the different features examined in this section are possible as well. Therefore, TTI researchers also explored a few potential combinations, such as in Figure 12. For that particular configuration of an auxiliary panel with a unique background color for the guide sign, only a few people in each city thought that the sign was effective. Several participants provided disapproving comments, such as: “It’s too much,” “It’s not necessary,” “Too colorful,” and “Too busy.” A few approving comments were also provided, such as: “It identifies the sign as different from the other two,” “It distinguishes it,” and “At 70 mph, you want the sign busy.” Although the concept of redundancy in information provision and even coding is often cited as a potential tool in the highway engineer’s arsenal, the general trend of focus group participant opinions was away from coding combinations to distinguish between managed lane and general-purpose lane information.

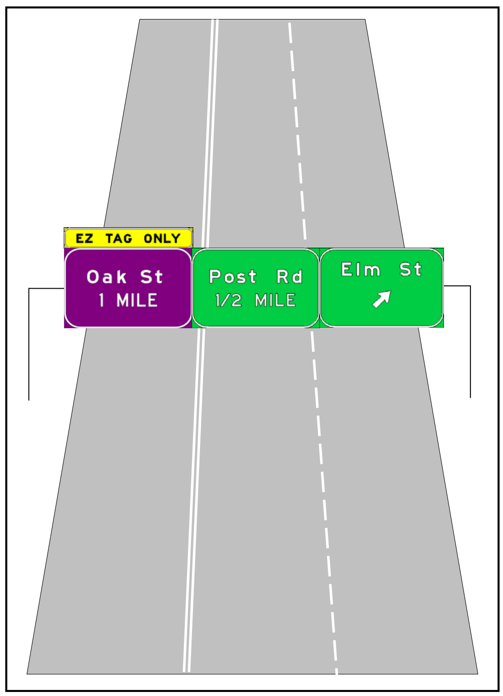

Figure 12. Colored HOV Sign with Panel.

Managed Lane Use during Off-Peak Times and during Incidents

During off-peak hours or possibly even during incidents on an adjacent general-purpose lane, an agency may wish to open a managed lane facility to all vehicles regardless of occupancy and toll payment capabilities. If the facility normally has some types of occupancy restriction, it may be difficult to convey to drivers that the facility now allows single-occupant vehicles. Therefore, TTI researchers included some discussion of potential methods of conveying such information to travelers approaching a managed lane entrance. Figure 13 is a proposed HOV sign for the Houston HOV system. Its three panels can electronically be rotated during the day to display different messages. The message shown in the figure would be displayed during those operating periods when single-occupant vehicles are allowed.

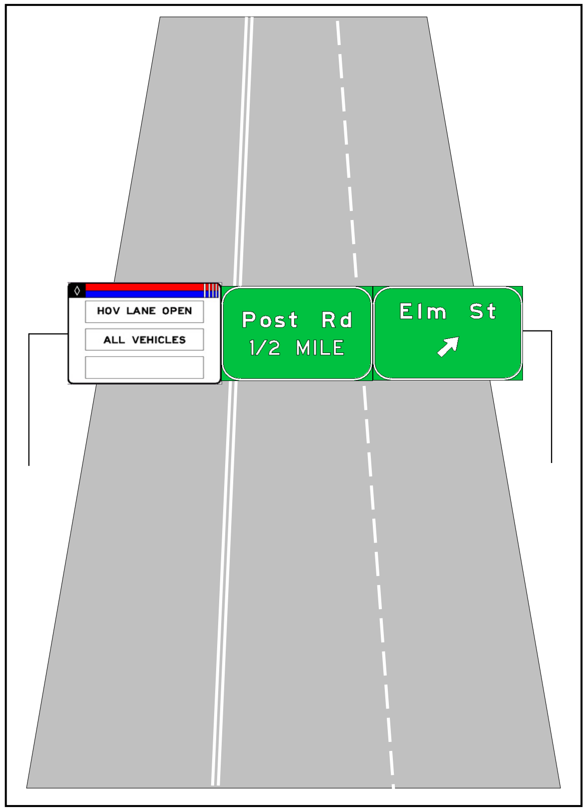

Figure 13. HOV LANE OPEN, ALL VEHICLES Sign.

The facilitator presented the scenario that the participants were to envision themselves alone in their vehicles on a weekend day, and asked if they were allowed to drive in the HOV lane shown in Figure 13. Interestingly, every participant believed that the information presented on the sign was confusing. Ultimately, participants split fairly evenly between those who believed they were allowed to drive in the lane and those who believed they were not. The participants who said they were allowed in said it was because the sign said "All Vehicles" and that the sign did not specify a specific number of occupants required in the vehicle. Meanwhile, those who believed they could not enter the managed lane made their decision from the term *HOV* used in the sign, the diamond symbol, and the double white pavement lines. Several participants specifically mentioned that they had been taught that HOV meant two or more people, and therefore they would not ever be allowed in a lane designated for HOV use. When participants seemed conflicted over the existence of the double white lines, the facilitator asked which would take precedence, the sign or the pavement markings. One participant stated that since the lines were permanent and the sign message could vary, the sign would take precedence. However, another participant stated that one should wait for the broken lines before attempting to cross.

Eventually, the TTI facilitator explained that the intended meaning of the sign was to allow all vehicles into the lane regardless of the number of occupants in the vehicle. The facilitator then asked the groups for ways in which the sign could be improved. The most common suggestion was to take the term "HOV" off the sign. Other common suggestions included rewording the sign to say "Lane Open to All Vehicles," or adding some indication of time such as, "HOV Lane Open to All Vehicles Today" or "HOV Lane Now Open to All Vehicles." Even with these concerns, the groups seemed open to the idea of having the managed lane accessible to all drivers in the case of an accident or a special event.

The TTI facilitator then turned the discussion to the topic of methods of informing travelers about changes in access requirements (such as occupancy requirements, toll schedules, etc.). When asked for suggestions on other ways they would expect to be informed of such changes, the participants identified the following combined list:

- dynamic HOV signs well in advance of the managed lane entrances,
- dynamic message signs,
- handouts in the mail (although it was not apparent how this approach could be used in an incident situation),
- Internet,
- phone number to call,
- radio, and
- TV traffic news.

Some participants expressed concerns that some people may not have radio or Internet access. Another difficulty explicitly identified by participants was those situations where carpoolers arrive who believe they can get in the lane with two people in the vehicle, but find that the schedule has been changed to require three occupants before accessing the lane.

ADDITIONAL OPERATIONAL AND REGULATORY ISSUES

Figure 14 is a photograph taken at the entrance of a reversible flow, managed lane from a side street in Houston. The facilitator focused on the HOV sign, the red and green signal lights, and the electronic DO NOT ENTER Sign. The electronic sign will display in white HOV LANE OPEN with a diamond symbol when the entrance ramp is open. When asked if this was too much information to absorb at once, the majority of the participants said yes, although they liked certain aspects of the HOV signage.

Figure 14. HOV Regulatory Sign with Symbols.

When asked if they thought the lights and the electronic sign were enough, most participants said yes, although some were concerned about not knowing the specific times the lane was open and how many occupants were required. It was suggested by some to keep a sign containing a schedule, such as the one in Figure 14, but to move it much farther in advance of the entrance ramp. Still others suggested that you could display the occupant requirements electronically, with green 2+ or 3+ lights. Although there were some conflicting responses on whether or not the sign was necessary, everyone liked the familiarity of the red and green lights. There was some concern that they may be confused with traffic lights.

Occupancy Information

When the facilitator asked what the meaning of the car symbols containing the occupant numbers meant, the different cities had various responses. In Houston, where the picture sign in Figure 14 is located, all of the participants recognized the symbols and understood their meaning. In Dallas, the participants were unfamiliar with the symbol, but were quick to determine its meaning. In San Antonio, the participants were also unfamiliar with the symbol, but unlike Dallas, several participants were unable to determine its meaning. One participant thought the symbol meant that two or three lanes were available. Suggestions for improving the symbol included putting the number of silhouettes inside the car instead of the number, or using "gingerbread" stick figures to display the number of occupants required.

Continuing the discussion on how to relay the number of participants required, the facilitator showed two other text versions in Figure 15, which were modified versions of signing proposed by Mourant et al. (*22*). Houston preferred the symbol over "2+ PERSON" or "Min 2 Persons." In San Antonio and Dallas, the majority of the participants preferred some sort of symbol, although several participants in Dallas preferred one of the options seen in Figure 15. In each group, the point was brought up that some people may not be able to read English, and therefore the symbols might be the best option.

Referring to Figure 15, the facilitator asked the groups if they preferred the time written above the day, or vice versa. Almost all of the participants responded they prefer time before day. They also believed that drivers would understand the abbreviation "MON-FRI." When asked, some participants preferred the vertical layout of the signs in Figure 14, and others the horizontal layout in Figure 15. The common concern was that the signs should be simple and easy to read at a fast pace.

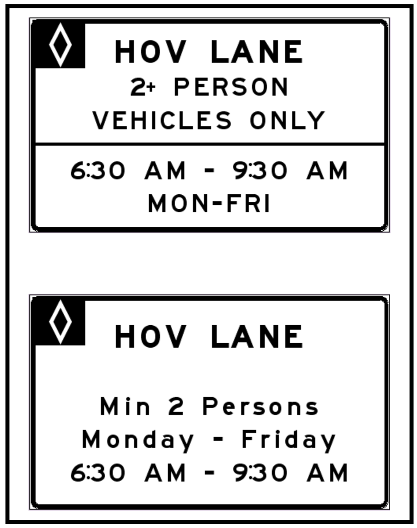

Figure 15. Regulatory Signs.

Dynamic Pricing Information

Managed lane facilities offer the opportunity to vary occupancy and price dynamically. Communicating this dynamic information is challenging. QuickRide is an enrollment program in Houston that allows, for a fee, two-person carpools during the three-plus restricted times. The driver must be pre-registered and display the appropriate hang tag and electronic toll transponder. Currently, the program is open only to two-person carpools, but other facilities have been proposed that would allow single-occupant vehicles during off-peak times. The signs for the QuickRide program must differentiate between non-enrolled HOV2 vehicles, which are allowed free-of-charge at off-peak times, and QuickRide-enrolled HOV2 vehicles ("QuickRide2"), which pay during the peak. In addition, single-occupant vehicles must be registered ("QuickRide1") for billing purposes and constitute a separate user category.

The Houston groups were asked if they had ever heard of QuickRide. Only one of the Houston participants had heard of the program. The facilitator explained the concept of the program and the signs shown in Figure 16 to all of the groups. During each group, confusion arose on whether or not you could enter the lane, and then there would be someone there to take your money. Some believed this defeated the purpose of the lane and would slow it down if you

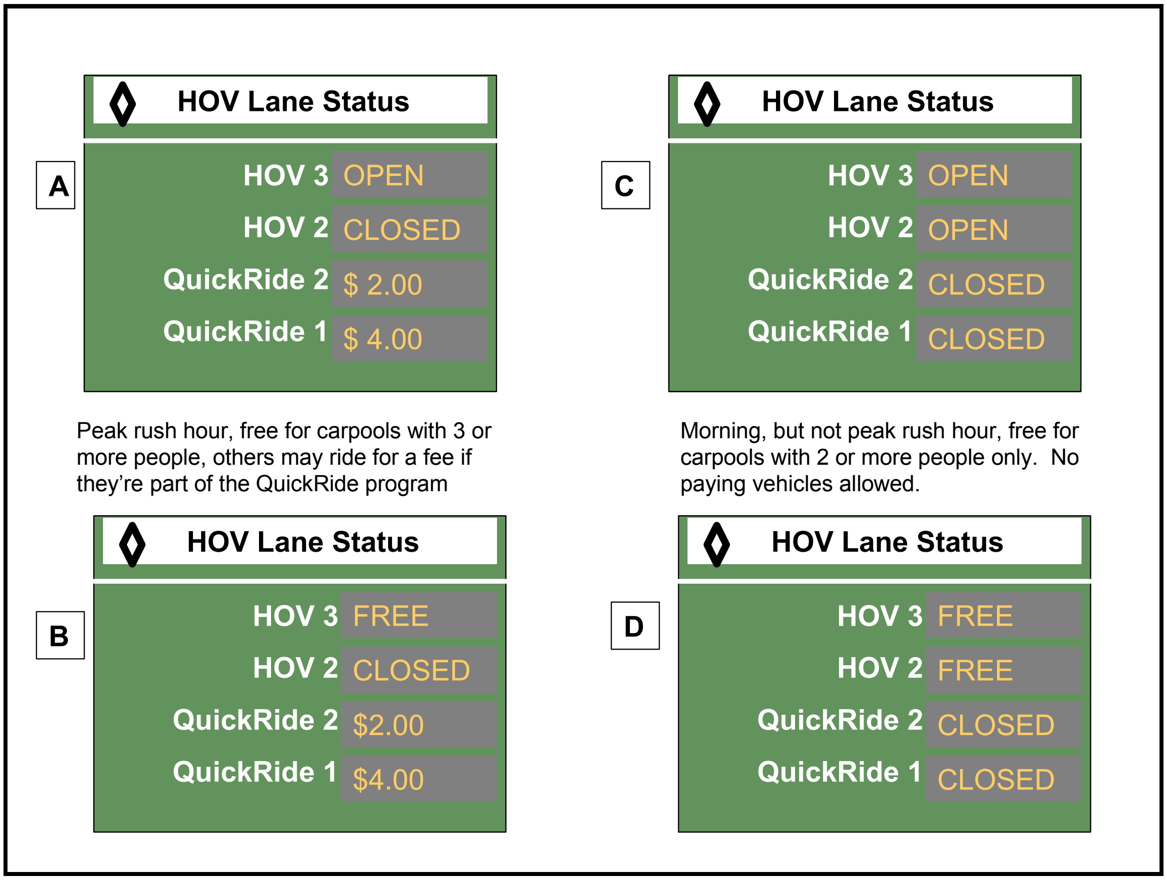

Figure 16. HOV Variable Status Signs.

had to stop and pay. In each case, the facilitator explained that only pre-registered drivers could use the lane and would be charged electronically. This confusion argues for the method of payment information to be clearly displayed at all entrance points.

When asked if they preferred the word "OPEN" or "FREE" from Signs A and B, most of the groups preferred "FREE," although some people in Houston believed it sounded "cheesy." Several people in San Antonio thought that "HOV3" or "HOV2" referred to a specific lane number, incorrectly interpreting this designation to mean that there would be two or three lanes dedicated to HOV users. When asked if they would prefer to replace the terms with symbols, most participants approved.

Either by volunteering, or when asked by the facilitator, many participants expressed that they would prefer a fixed schedule for the managed lanes. Several even believed that there should be a fixed minimum of necessary occupants for the lanes.

PERSONAL DECISIONS AND EXPECTATIONS

The final discussion of the groups involved the decisions the participants would make about utilizing managed lanes, and their expectations of them. When asked at what point they decide to use the HOV lane, the responses were a combination of how much traffic there is, and whether or not they are running late. One concern was expressed with regard to barrier-separated facilities; a Houstonian stated, "In Houston, one problem with the HOVs is that if you're not familiar with them, you'll miss some exits when there's the barrier." Another responded with, "Why get on when you can't get off?" Concerning their expectations about how often they can exit an HOV lane, when asked, the majority of the participants did not expect to be able to exit as often as the general-purpose lanes, but did expect to be told if there was <u>not</u> an exit to a major interchange. When asked what they expected as a minimum, subjects said they would like exits at the major interchanges, or every five exits, and would at least like to know the next exit available. As a maximum, it was suggested to have the same exits available from the HOV lane as the general-purpose lanes have, and a sign with the next three exits. Several subjects said that with a combination of the name of the next exit and the number of miles to the access area, then the driver can use that sign as well as the general-purpose lane signs to determine when they should get on and off the HOV lanes. When asked if there was not an HOV lane exit for their destination, if they would be more likely to get off early or go past and turn around, most participants said they would get off early, but a few said they would try turning around depending on the traffic.

OTHER PARTICIPANT CONCERNS REGARDING MANAGED LANES

Participants vocalized some concerns during the focus groups that did not specifically relate to the questions the facilitator was asking. In each city, a few people were concerned about the safety of the barrier-separated lanes. Their concerns included:

- being afraid of going the wrong way,
- getting stuck behind someone who's stopped,
- not knowing where you'll be able to get out,
- not knowing if you'll have to pay if you get in, and
- the lanes being too narrow.

When asked, many of these participants said they would prefer cones or a wider separation from the general-purpose lanes of the walls. On the other hand, some participants stated that the wall protects you from the general-purpose lanes.

Another issue that arose in one of the Dallas focus groups was regarding large trucks in the HOV lanes. Although the group did not want the trucks in the HOV lane, group members did believe trucks need their own lane, or should only drive at night.

CHAPTER 4: DECISION ANALYSIS DEVELOPMENT OF MANAGED LANE DRIVER INFORMATION FRAMEWORK

DRIVER INFORMATION MODELS

In order to better understand the information needs of drivers in a managed lane environment, researchers performed a critical assessment of typical driving needs and how those needs can be met via traveler information sources. This process incorporated the lessons learned from the literature review and focus groups, and the research team used it to develop a framework to aid traffic engineers and highway planners when considering how, when, and where to provide managed lane information to drivers.

Managed lane facilities are more likely to present unfamiliar decision-making needs for drivers that have not experienced them before. Additionally, with the newer combinations of managed lane types, users that may be familiar with more traditional managed lane types (i.e., HOV-only lanes) may still be confused by newer types such as combination HOV/toll lanes (HOT lanes) or toll lanes with dynamic pricing. They may not have knowledge of the hours of operation, enforcement regulations, or how and when to pay, or even if payment is necessary.

Pain, Knapp, Hostetter, and Mace examined how drivers make a decision to use a managed lane facility in a report published in 1982 (*23*). At that time, these types of special lanes were referred to as Special Use Lanes (SULs), and consisted primarily of HOV lanes, some bus-only lanes, and toll facilities. As part of their work, the researchers developed a driver decision-making paradigm for the process of how a driver makes the decision of whether or not to enter a managed lane, or SUL. This paradigm is presented in Figure 17.

This paradigm was a useful starting point for this research, in that it correctly identified that the decision to use a managed lane is a multi-step process, and it also implies that in order to make a properly informed decision, the driver must be able to take in several different types of pertinent information. However, the specific informational units needed at each point were not included in that initial effort. Therefore, TTI researchers expanded upon that paradigm to

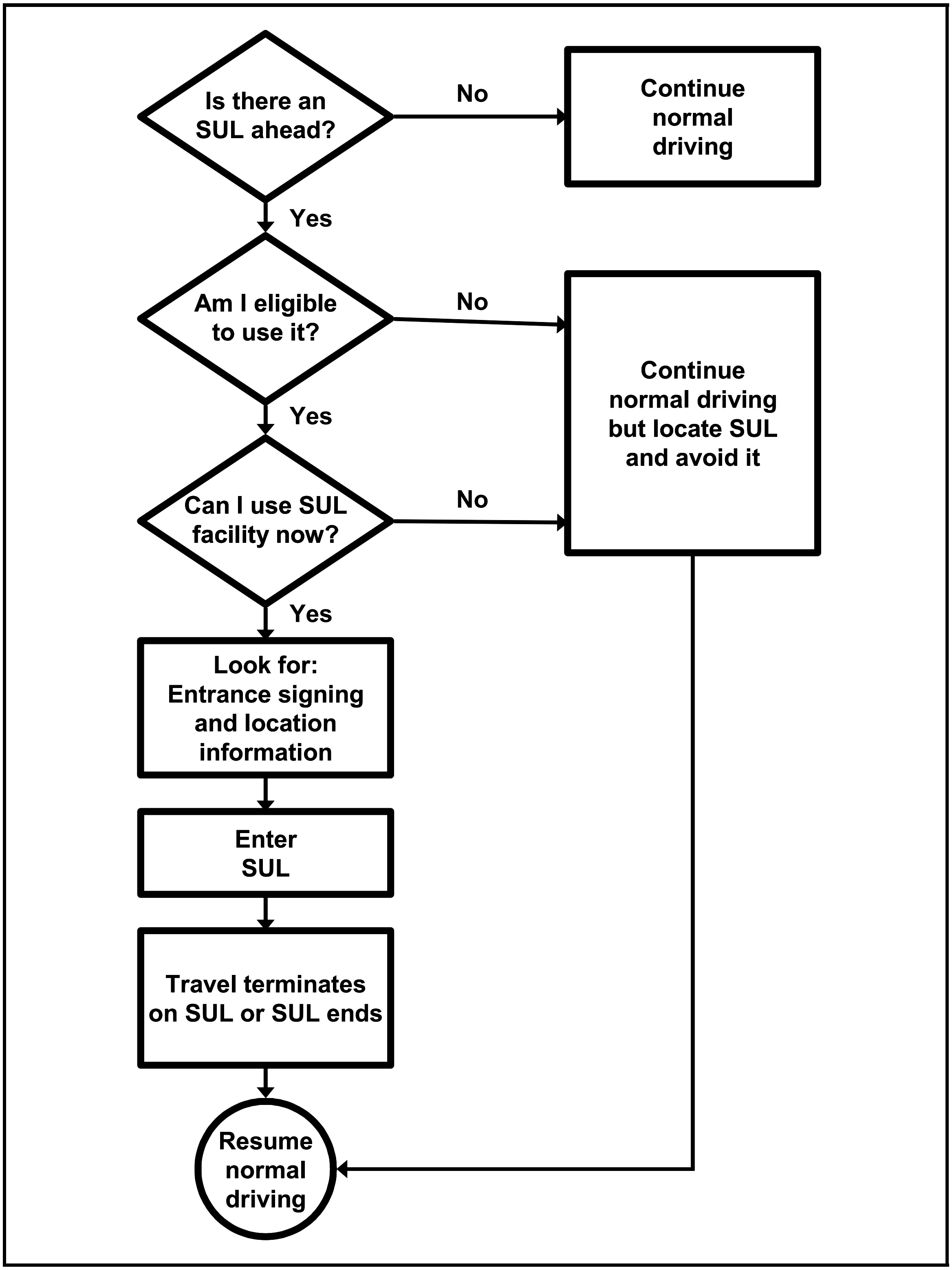

Figure 17. Driver Decision-Making Paradigm for Special Use Lanes (*23*).

generate a list of information that drivers would likely need. This information is presented in Table 2. 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 information categories are defined below:

- Entrance information – This category includes information such as how a driver can enter the managed lane facility, and subsequent entrance information. Information such as whether this is the only chance for a driver to enter the managed lane or whether subsequent opportunities exist downstream can be useful in helping a driver make an informed decision.
- Exit information – Knowing where to exit. Being able to understand potential exit points will help a driver better understand if the managed lane could be useful in completing his/her trip and if it would require a longer driving distance than would be the case if he or she remained in the general-purpose lanes.
- Hours of service – For some managed lane facilities that are only open certain times of day, this type of information would typically be the hours that the facility is open. This is also true for managed lanes that reverse direction at different times of day.
- Incident management information – This type of information includes real-time information on the presence of any downstream crashes or other unexpected delays in either the managed lanes or the general-purpose lanes.
- Occupancy requirements – This category includes the minimum number of occupants that must be in a vehicle in order to properly use the managed lane. This information is typically related to HOV or HOT facilities.
- Open/closed information – This information is similar to hours of service but may be simplified to only show “OPEN” or “CLOSED” with no other information such as when and how long the facility will be open or closed.

Table 2. Information Needs for Managed Lane Decision-Making Process.

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

- Time savings – The amount of time less that it takes to reach the terminal destination of the managed lane (such as "downtown" for example) when using the managed lane instead of the general-purpose lanes.
- Tolling information – This information may be fixed, or it may vary by time of day in an attempt to shift some drivers from peak times to off-peak times.
- Travel time – The total amount of time it takes to travel to a downstream location using either the managed lane or the general-purpose lanes. An example of this is "23 MINUTES TO DOWNTOWN."
- Type of managed lane – This type of information helps drivers understand if they are even eligible to use the managed lane. Examples include "BUS ONLY LANE," "TOLL LANE," or "HOV LANE."
- Vehicle restrictions – If certain vehicles are not allowed into the managed lane this should be conspicuously displayed to prevent confusion. Common examples of restricted vehicles on existing managed lane facilities include trucks, vehicles with trailers, and wide loads.

Ultimately, these informational units interact with individual driver perceptions and desires as part of the decision-making process. Some of those perceptions/desires are listed and described below:

- Desire to avoid late arrival – Getting fired or losing pay at work, or needing to pick up children from daycare before the daycare closes, are some examples of what would be considered by drivers to evaluate their desire to avoid a late arrival.
- Perceived discomfort from barrier-separated facility – Some drivers perceive discomfort or even fear when traveling immediately next to a concrete barrier wall, such as exists in some barrier-separated facilities. Furthermore, some drivers may feel "trapped" in the managed lane if they cannot move back to the general-purpose lanes easily in the event of managed lane congestion. Such perceptions will reduce the likelihood of managed lane use, all other factors held constant.
- Perceived safety from barrier-separated facility – In contrast to the previous bullet, it is also possible that some drivers feel safer when driving next to a concrete barrier

wall, such as may exist in some barrier-separated facilities. This type of perception increases the likelihood of managed lane use, holding all other factors constant.

- Perceived value of time – Factors that affect a driver's perceived value of time include whether he or she is late and for what event or activity they are late for, driver income level, etc.

Combining the informational units with the driver perceptions and desires yields the modified conceptualized decision model shown in Figure 18. This model incorporates what information a driver needs to correctly answer each of the questions required in the process of deciding whether a managed lane facility is a better choice than the general-purpose lanes. It also takes into account not only the specifics of the managed lane facility and traffic conditions, but also the qualitative specifics of the individual driver. The assessment is alluded to as a benefit-cost analysis, but it is not performed with numbers and mathematics. Rather, this information is processed in the mind of the driver in real time or just prior to the trip, and may be thought more as a perceptual assessment rather than a precise computation.

With this revised information, a new conceptualized model of the decision process for whether or not a driver decides to access a managed lane was developed, showing each step in the process and the information that the driver would need to make an informed decision.

At this point, it should be acknowledged that each driver ultimately makes a decision on whether or not to use the managed lane, regardless of whether he or she has complete or incomplete information. If the information set is incomplete, one of three results will occur. As one possibility, the driver may make a decision that ultimately benefits him or her (i.e., either by choosing to enter the managed lane when it is advantageous to do so, or deciding not to enter when it is not). An example of this might be a driver approaching a managed lane for the first time, realizing that he or she is eligible to use the managed lane, and deciding to take it without any detailed understanding of downstream traffic congestion in the general-purpose lanes or the managed lanes. But in choosing the managed lane he or she manages to avoid general-purpose lane congestion and saves 20 minutes from his or her trip time. In this situation, the driver receives the same benefit of the time savings as if he or she had fully understood the benefits of using the managed lane.

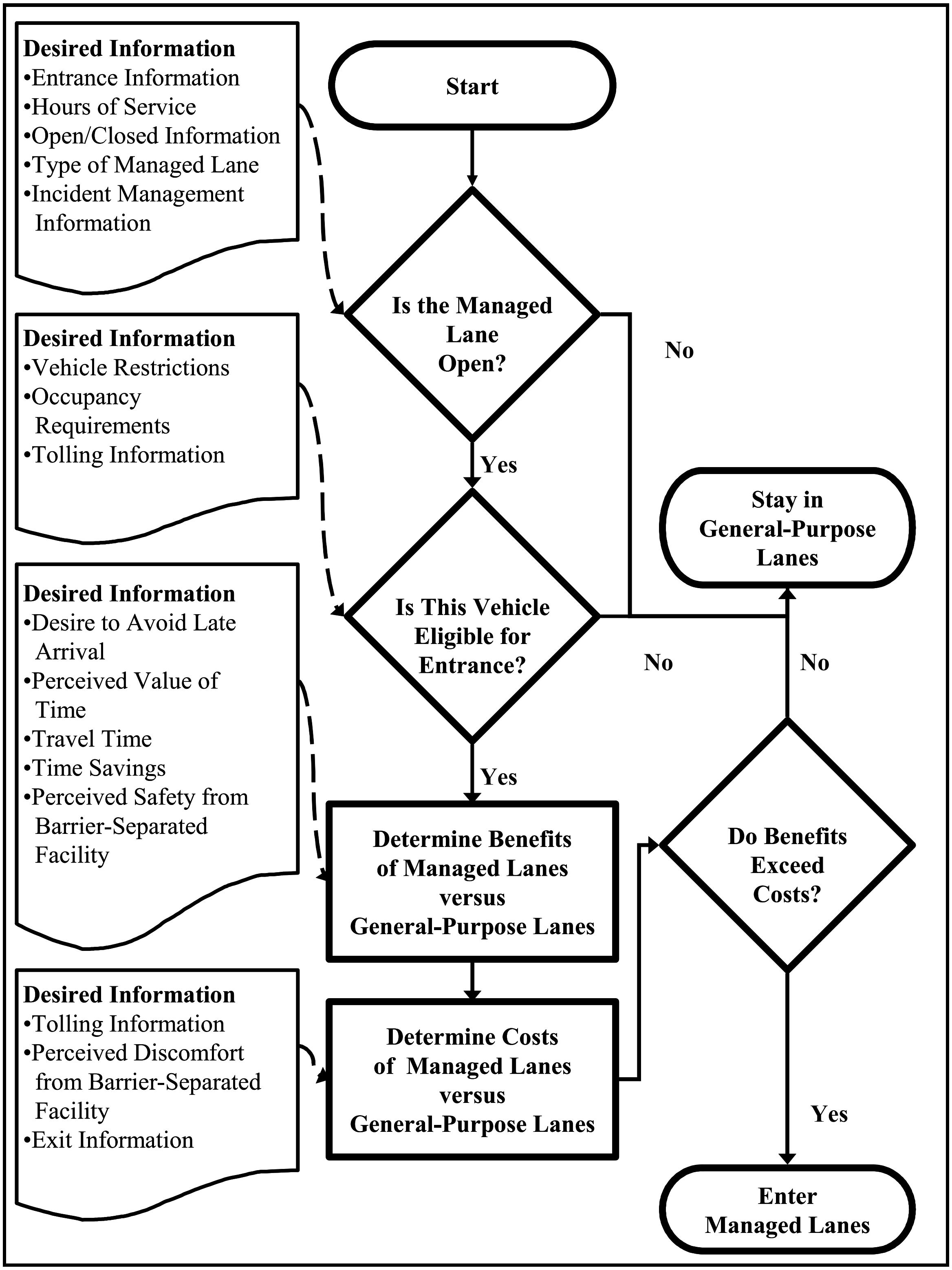

Figure 18. Conceptualized Model of Decision Whether or Not to Access a Managed Lane.

On the other hand, the other two outcomes possible from a set of incomplete information have negative consequences. A motorist could choose to enter the managed lane even though the benefits of doing so do not exceed the costs of additional travel time, toll charges, inconvenience, and added travel distances to exit the lane, or other costs. There may even be adverse legal ramifications if, for example, the vehicle being driven did not meet the current occupancy requirements for the facility. Ultimately, this type of outcome is likely to leave the driver somewhat disgruntled and less likely to use the lane again under similar circumstances. In contrast, the incompletely-informed driver could also make a wrong choice by staying in the general-purpose lanes when he or she could have used the managed lanes and reaped the benefits of so doing. In this scenario, the highway agency operating the facility has lost out on a potential user of the managed lane facility, and so loses out on potential revenue in a tolling situation or at least a reduction in the congestion of the general-purpose lanes in other cases. However, such an outcome does not have the same negative influence on future decisions by the driver. In fact, such an outcome may ultimately increase the likelihood of future managed lane use by the driver, as long as he or she is made aware of the benefits that were missed by not previously using the lane.

From the above discussion, it should be evident that driver familiarity and prior experiences are another factor in the decision-making process. An understanding of driver familiarity and how it relates to the information requirements discussed earlier can further shed insights into the decision-making process. In the next section, the relation between driver familiarity (experience) and information requirements is presented and analyzed.

CONCEPTUAL DRIVER MODELS REGARDING MANAGED LANE USE

In that managed lane facilities represent a tremendous number of design options and operational strategies that influence traveler information requirements, an exhaustive accounting of all possible combinations would prove unwieldy and have limited benefit to practitioners. Therefore, several examples of typical interactions between driver familiarity and common managed lane facilities are provided as instructional illustrations of information requirements for these facilities and how the requirements change as a function of driver familiarity.

TYPES OF DRIVERS

One of the more important considerations that arose from this assessment process is the recognition that managed lane information needs are also highly dependent upon traveler experience and other individual factors. Certainly, not all of the information needed to make an informed decision must come from the highway agency in terms of information dissemination devices (overhead and shoulder-mounted static signs, overhead and shoulder-mounted dynamic message signs, pavement markings, etc.); some of the information required is internal to each individual driver, such as the perceived value of time and the level of comfort with entering a barrier-separated facility. Other information, such as geometric features or specific sign locations and content, can be learned over time through repeated trips through a corridor. Drivers experienced with a particular roadway would also be likely to have some expectations of typical traffic conditions during their trips, including speed and congestion at different times of day as well as areas where additional attentional demand is required such as at interchanges with weave areas. Drivers who have been through a specific corridor before could likely be considered to need to acquire less information and will rely more heavily on information stored in the driver's mind.

Researchers developed a general classification of drivers who might reasonably be confronted with the decision of whether or not to enter a managed lane. At one extreme is the unfamiliar driver, in the middle is what is called a semi-familiar driver, and at the other extreme is the very familiar driver. While it should be stated plainly that the entire driving population would fill the continuum between the extremes of a completely unfamiliar driver and a completely familiar driver, the three examples presented are for planning considerations and are considered examples of the wider distribution of drivers. The general classifications of the types of drivers are detailed in the following sections.

Several assumptions were made in the development of these example drivers. First, an unfamiliar driver was considered a driver that knew very little about the specific managed lane or managed lanes in general. Unfamiliar drivers should not, however, be assumed to be bad drivers or novice drivers in the sense of their ability to drive. Rather, it is just that this driver would not know much about the managed lane or managed lanes in general. Likewise, familiar drivers should not be assumed to be expert drivers, just that they know much more about the details of the managed lane in question.

Unfamiliar Driver

An unfamiliar driver has little or no experience on the roadway in question. In the extreme case, this driver may have never driven on this particular roadway before, may not be aware that a managed lane is ahead, and may not have encountered a managed lane of this type before. In order to make an informed decision on the proper path to take, this driver would need to acquire all of his or her knowledge from the roadway environment en route (or have researched the potential use of the facility beforehand). This type of driver would need the highest amount of information presented to him or her, and would be at highest risk of experiencing information overload from the information presented, particularly at locations where control and guidance tasks are more severe. A conceptual example of an unfamiliar driver is shown in Figure 19.

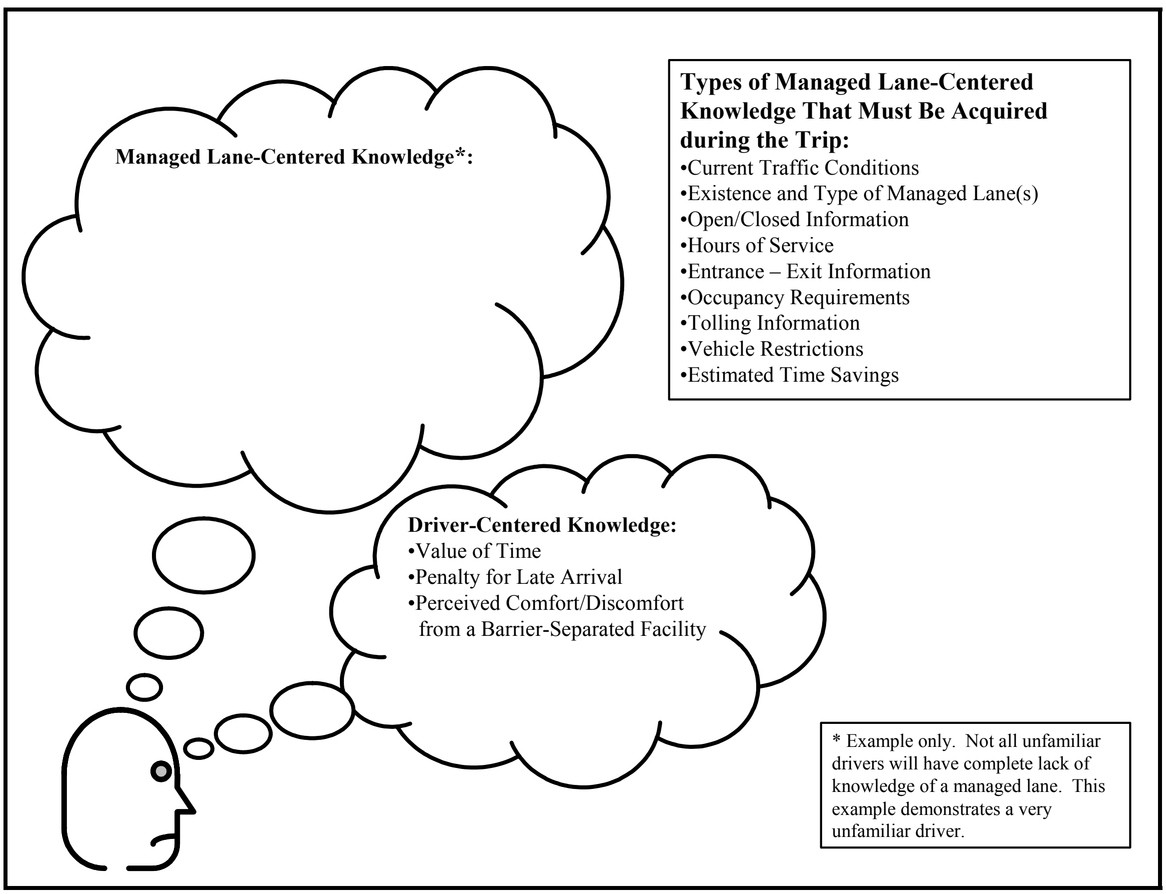

Figure 19. Example of an Unfamiliar Driver's Managed Lane Knowledge Base.

Semi-familiar Driver

A semi-familiar driver is one who fits between the other classifications. This driver could be considered one who has occasionally used the facility, or one who may have driven on the general-purpose lanes adjacent to the managed lanes and is considering using the managed lanes for the first time. This driver would know some information, such as geometry, speed, and direction of the roadway, but may need to determine additional information, such as tolling information and potential time savings en route. Depending on the type and amount of information needed by this type of driver, the amount of information that must be acquired from the roadway could be extensive and could result in a driver who is overloaded with information. The specific information needed would likely vary widely between drivers. A conceptual example of a semi-familiar driver is shown in Figure 20.

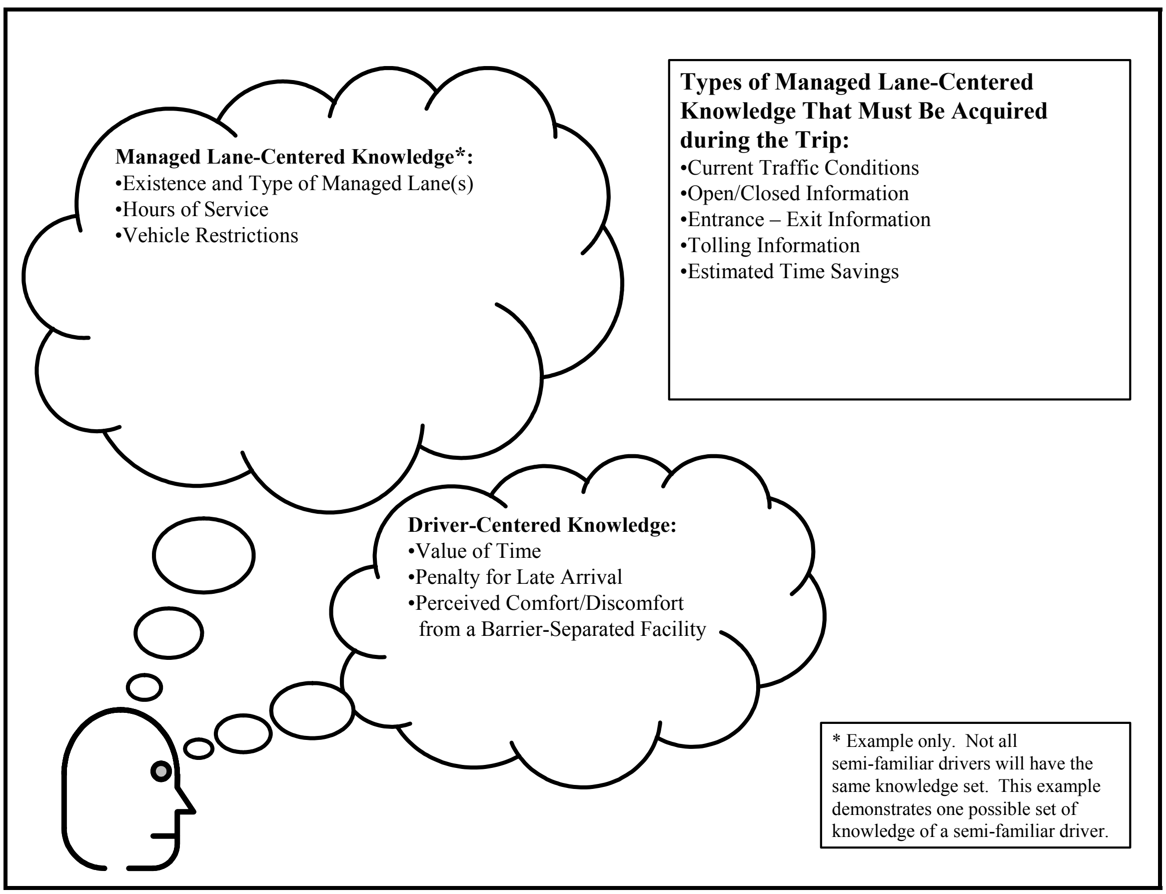

Figure 20. Example of a Semi-Familiar Driver's Managed Lane Knowledge Base.

Familiar Driver

The familiar driver can be considered one who is intimately acquainted with the roadway in question. This driver may be a daily user, such as a commuter who drives the route daily at the same time. Alternatively, this may be a driver who is an experienced driver in a general sense, and who may have extensive knowledge of other managed lanes, and who has taken the effort to learn about this managed lane prior to the trip. This driver would need relatively little information about the geometry of the roadway, and little signing information. In fact, in the extreme case, this type of driver could successfully maneuver through the route in question without even looking at a single sign, hearing a radio broadcast, reviewing a navigational aid, etc. This group of drivers would be least likely to be burdened with information overload. A conceptual example of a familiar driver is shown in Figure 21.

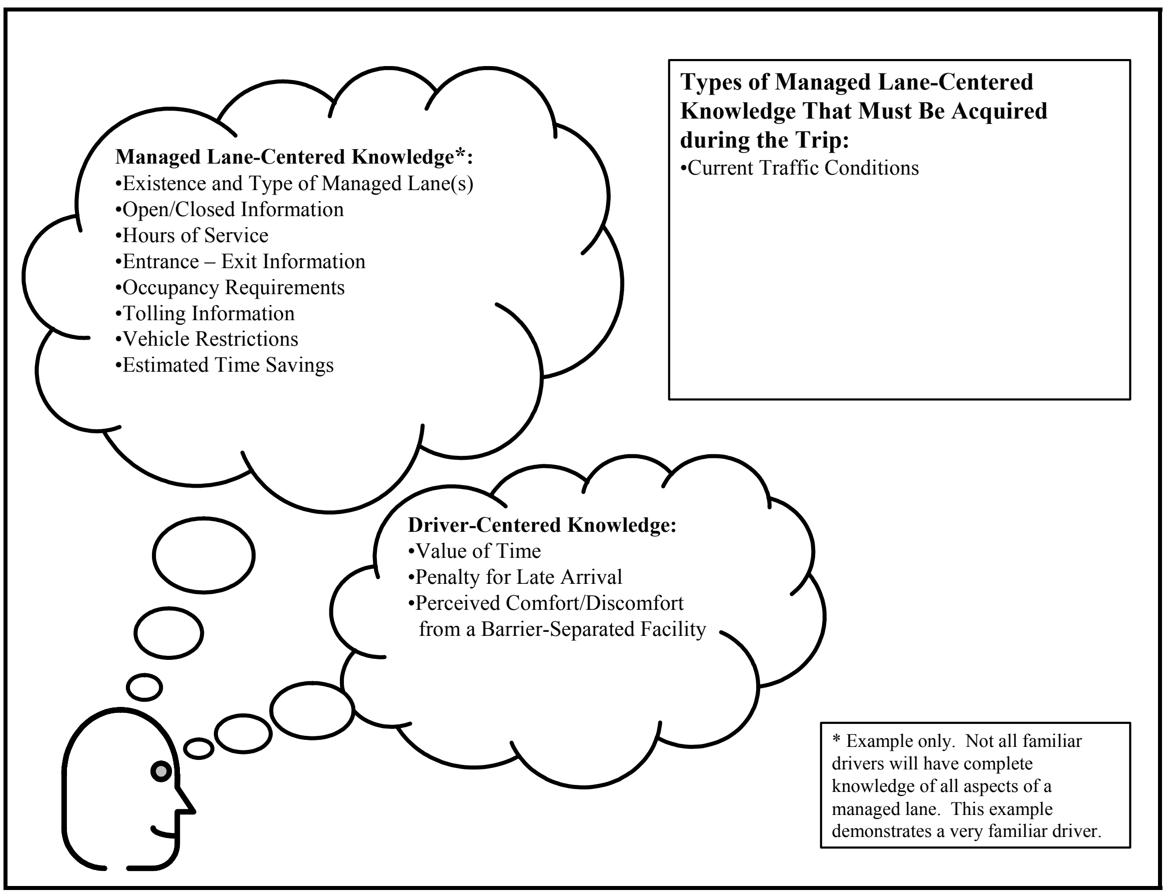

Figure 21. Example of a Familiar Driver's Managed Lane Knowledge Base.

USER FAMILIARITY AND ITS ROLE IN THE MANAGED LANE TRAVELER INFORMATION ASSESSMENT PROCESS

As described above, user familiarity has a significant influence upon traveler information needs for a managed lane facility. Over time, such familiarity often reduces the need for certain types of information such as where to enter a facility, what legal and financial requirements exist for entry, where exits are located, etc. The most familiar users of a facility could reasonably be expected to travel the facility successfully even without any external sources of information, but completely unfamiliar drivers need to acquire virtually all of the information from the roadway signs or other information sources.

While common practice for general-purpose lanes and all other roadways requires the highway agency to plan for the completely unfamiliar driver, a review of the informational requirements listed in Table 2 and Figure 18 suggests that it may not always be possible to accommodate this type of driver for all types of managed lane scenarios. In other words, an operating agency may choose to design the facility (and the information system supporting it) for "familiar users." However, if such a decision is made, focus must turn toward ensuring that unfamiliar users are not misled or confused into using the managed lane when they do not wish to do so.

The interaction between driver familiarity and information requirements implies that information requirements should be considered early in the managed lane design process, as choices are being made regarding access and egress points, types of tolling facility, and type and amount of vehicle occupancy adjustments to accommodate. Tables 3, 4, and 5 have been generated to help guide practitioners in considering which facility types require more en route information than other facilities, and to highlight the types of information that should be considered (at least in general terms) in the managed lane design process. These tables reiterate that different user groups require different information. One noteworthy point from Table 5 is that more complex managed lane facilities (such as variable-priced HOT lanes) require even familiar drivers to acquire a substantial amount of en route information. If this cannot be effectively accommodated into the overall information system via static and dynamic signing then other mechanisms such as the mobile Internet, two-way transponder communications, or other in-vehicle communications with the motorists may be necessary.

Table 3. Typical Information Needs for HOV Lane Users.

	HOV Lanes	
	Concurrent-Flow	**Barrier-Separated**
Unfamiliar Drivers	• Entrance Information • Hours of Service and/or Open/Closed Information • Incident Information • Occupancy Requirements • Travel Time and/or Time Saving • Vehicle Restrictions	• Entrance Information • Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Occupancy Requirements • Travel Time and/or Time Saving • Vehicle Restrictions
Semi-Familiar Drivers	• Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Occupancy Requirements • Travel Time and/or Time Saving	• Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Occupancy Requirements • Travel Time and/or Time Saving
Familiar Drivers	• Incident Information • Occupancy Requirements • Travel Time and/or Time Saving	• Incident Information • Occupancy Requirements • Travel Time and/or Time Saving

Note: The information categories shown in this table are typical examples shown merely for illustrative purposes. It is entirely likely that specific managed lane facilities may exhibit different information-dissemination needs and/or capabilities.

Table 4. Typical Information Needs for Toll Lane Users.

	Toll Lanes	
	Static Pricing or Pricing That Changes by Time of Day	**Dynamic Pricing**
Unfamiliar Drivers	• Entrance Information • Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Tolling Information • Travel Time and/or Time Saving • Vehicle Restrictions	• Entrance Information • Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Tolling Information • Travel Time and/or Time Saving • Vehicle Restrictions
Semi-Familiar Drivers	• Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Tolling Information • Travel Time and/or Time Saving	• Entrance Information • Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Tolling Information • Travel Time and/or Time Saving • Vehicle Restrictions
Familiar Drivers	• Hours of Service and/or Open/Closed Information • Incident Information • Travel Time and/or Time Saving	• Hours of Service and/or Open/Closed Information • Incident Information • Tolling Information • Travel Time and/or Time Saving

Note: The information categories shown in this table are typical examples shown merely for illustrative purposes. It is entirely likely that specific managed lane facilities may exhibit different information-dissemination needs and/or capabilities.

Table 5. Typical Information Needs for HOT Lane Users.

	HOT Lanes	
	Static Pricing or Pricing That Changes by Time of Day	**Dynamic Pricing**
Unfamiliar Drivers	• Entrance Information • Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Occupancy Requirements • Tolling Information • Travel Time and/or Time Saving • Vehicle Restrictions	• Entrance Information • Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Occupancy Requirements • Tolling Information • Travel Time and/or Time Saving • Vehicle Restrictions
Semi-Familiar Drivers	• Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Occupancy Requirements • Tolling Information • Travel Time and/or Time Saving	• Entrance Information • Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Occupancy Requirements • Tolling Information • Travel Time and/or Time Saving • Vehicle Restrictions
Familiar Drivers	• Hours of Service and/or Open/Closed Information • Incident Information • Travel Time and/or Time Saving	• Hours of Service and/or Open/Closed Information • Incident Information • Tolling Information • Travel Time and/or Time Saving

Note: The information categories shown in this table are typical examples shown merely for illustrative purposes. It is entirely likely that specific managed lane facilities may exhibit different information-dissemination needs and/or capabilities.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

There are limits to human information processing. Not all drivers are able to process information at the same capacity, and it is possible in some driving instances to provide so much information that some drivers are not able to process it all. Additionally, as many types of managed lane driver information are complicated and must come in addition to the general-purpose lanes, these drivers with lowered information-processing capabilities will be hard-pressed to correctly read and process the information provided. Presenting information in such a way to minimize driver information overload will allow more drivers to understand managed lane information, and they may be more likely to use the facility if eligible. While there is no upper limit on information that can be presented to drivers on roadway signing, previous researchers recommended not exceeding four sign panels of information with more than six units of information on each panel (*11*). If general-purpose and managed lane information is presented on the same overhead guide sign or on separate sign structures but are still readable at a single point, then this recommendation should be considered. A review of the information may reveal that some of the information can safely be shifted upstream or downstream to spread the information load.

As drivers traverse a roadway again and again, they become familiar with the signs and information that is required to properly travel the managed lane or general-purpose lanes in that area. Because the needs of drivers change over time, and each driver has a different threshold of information processing, the designers of the information dissemination for a managed lane facility need to determine which members of the driving population they are targeting (or can target) to use the managed lane. This step needs to happen early in the design process so the designers can make rational decisions about what levels of information need to be presented.

Determination of who the target audience really is (familiar, semi-familiar, or unfamiliar) can help determine how much information must be presented within the managed lane corridor regarding the managed lane. Additionally, if the target audience can be defined specifically, such as toll users who have electronic transponders, other options for information dissemination become available. The target audience is a factor that should be explicitly determined in the design process, as it directly relates to the dissemination alternatives available for certain kinds of information.

In the above example, the users with transponders have provided their mailing information, and some information regarding the managed lanes can be mailed to them in regular newsletters and, thus, removed from signing. Examples of possible information that could be removed from signs and put into mailings could include hours of service, toll structure, average time savings, and any planned uses for the managed lane facility. In this manner the information acquisition activity would move from during the trip to prior to the trip. Internet information pages can also serve a similar purpose for unfamiliar drivers who desire to learn more during pre-trip planning. Even other traffic devices such as highway advisory radios could be used to great effect for certain information.

Based on current trends and results of focus groups conducted for this research, several innovative methods of managed lane information dissemination are recommended for further research to determine their usefulness and applicability. These include:

- Color-coding signs would provide better differentiation between information intended for managed lane traffic and that intended for general-purpose lane traffic. This coding could take the form of banners across the top of the sign, or the color of the entire sign. Further research is needed to determine the manner that would aid drivers the most in understanding the information presented, and the amount of benefit that can be achieved through this type of coding process.
- Consideration should be given to removing from signs managed lane information that can be effectively presented in other formats to drivers. Examples of other dissemination methods include highway advisory radio, Internet, and direct mailing to electronic transponder carriers. It is unclear at the present time which kinds of information can be best moved or repeated on these alternate formats, and further research is needed to address this.
- Focus group participants varied in their understanding of managed lane terminology. Participants were more likely to understand a term if they were from an area that currently had some type of managed lanes. Drivers disagreed with some standard types of information, such as referring to the entrance to a managed lane as an "exit." Further research needs to be conducted to find a more appropriate way of differentiating between the managed lane entrance and the general-purpose lanes.

Some examples of different signing include simply showing an arrow with the words describing the type of managed lane, such as "HOV LANE." Such a change in terminology could improve driver understanding while showing the difference between the lane types. Further research would be needed to find the optimal wording that would satisfy both drivers and highway agencies.

- By considering the intended target user group for the managed lane earlier in the design process, decisions of how much and what type of managed lane-specific information can be better assessed. This early consideration can allow for innovative information dissemination strategies, such as direct mailings to transponder subscribers. Further, designers will be better able to design the facility with the information needs fully addressed rather than as an afterthought at the end of the project.

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