

1. Report No. FHWA/TX-17/0-6907-R1		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle ADVANCING TRAVELER INFORMATION TECHNOLOGIES FOR PRICED MANAGED LANE NETWORKS				5. Report Date Published: October 2018	
				6. Performing Organization Code	
7. Author(s) Nick Wood, Sue Chrysler, Maarit Moran, Chris Simek, Jeff Kaufman, Shawn Turner, Marcus Brewer, Tina Geiselbrecht, and Lisa Green				8. Performing Organization Report No. Report 0-6907-R1	
9. Performing Organization Name and Address Texas A&M Transportation Institute The Texas A&M University System College Station, Texas 77843-3135				10. Work Unit No. (TRAIS)	
				11. Contract or Grant No. Project 0-6907	
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office 125 E. 11 th Street Austin, Texas 78701-2483				13. Type of Report and Period Covered Technical Report: January 2016–August 2017	
				14. Sponsoring Agency Code	
15. Supplementary Notes Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration. Project Title: Communicating Information for Traveling on Managed Lane Networks URL: http://tti.tamu.edu/documents/0-6907-R1.pdf					
16. Abstract Managed lane networks are complex, interconnected facilities that require advancements in traveler information to successfully serve the users of those facilities. Historically, managed lanes were typically developed for single, distinct corridors, providing preferential access for users who travel from one endpoint to another. The success of past managed lane projects has led to planned and constructed networks of managed lanes that expand the concept across most major freeways within a region. Currently, operators rely mostly on signage, websites, and social media to convey information related to pricing and operating rules. Existing communication methods will become ineffective as network complexity increases. New technology, including advancements in traveler information and connected vehicles, may provide a solution to the problem. This research project investigated different ways to communicate operational and pricing rules for managed lane networks. Key parts of this research consisted of (a) a national state-of-the-practice review, (b) system user focus groups and surveys, and (c) an emerging technologies assessment.					
17. Key Words HOT, HOV, Managed Lanes, Tolling, Signage, GTFS, Online Maps			18. Distribution Statement No restrictions. This document is available to the public through NTIS: National Technical Information Service Alexandria, Virginia http://www.ntis.gov		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 200	22. Price

ADVANCING TRAVELER INFORMATION TECHNOLOGIES FOR PRICED MANAGED LANE NETWORKS

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Report 0-6907-R1

Project 0-6907

Project Title: Communicating Information for Traveling on Managed Lane Networks

Performed in cooperation with the
Texas Department of Transportation
and the
Federal Highway Administration

Published: October 2018

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

This report is not intended for construction, bidding, or permit purposes. The engineer in charge of the project was Nick Wood, P.E. #117258.

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

ACKNOWLEDGMENTS

This project was conducted in cooperation with TxDOT and FHWA. The authors thank the TxDOT project manager, Darrin Jensen, and the TxDOT Project Team: David Fink, Theresa Poer, John Nevares, Flor Tamez, Lin Zhou, and Feng-Pin An. Other members of the TxDOT Project Team consisted of Dan Lamers, Natalie Bettger, and Amanda Wilson from the North Central Texas Council of Governments and Nader Mirjamali and Hameed Merchant from Houston METRO.

The project authors would also like to acknowledge other Texas A&M Transportation Institute researchers and support staff who advised or helped with specific tasks. These individuals and their contributions include:

- Beverly Kuhn—project advisor.
- Tony Voigt—project advisor.
- Linda Cherrington—project advisor.
- Jason Crawford—project advisor.
- Stephen Ranft—project advisor.
- Rob Benz—project advisor.
- Mark Burris—project advisor.
- Michelle Benoit—editing and proofreading.
- Joanna Hunt—editing and proofreading.
- Michelle Canton—media outreach.
- Debbie Murillo—graphic design.
- Jim Lyle—photography.
- Michelle Williams—financial management.
- Justin Malnar—contract development.
- Jessie Flasowski—contract management.

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CHAPTER 1—INTRODUCTION

PROJECT GOAL

Managed lanes are facilities designed to improve the operational performance of highways through a combination of strategies that regulate demand for selected lanes on a corridor or network. Historically, managed lanes were typically developed for single, distinct corridors, providing preferential access for users who travel from one endpoint to another. The success of past managed lane projects has led to planned and constructed networks of managed lanes that expand the concept across most major freeways within a region.

Currently, operators rely mostly on signage and online media to convey information related to pricing and operating rules. Existing communication methods will become ineffective as network complexity increases. New technology, including advancements in traveler information and connected vehicles, may provide a solution to the problem. The goal of this research project was to improve the traveler experience, which may lead to enhanced mobility for Texas.

STATE-OF-THE-PRACTICE REVIEW

One of the first tasks was to conduct a state-of-the-practice review about communicating information for navigating a managed lane network. The review used three different techniques for gathering current practices:

- Reviewing existing literature.
- Making in-person site visits.
- Conducting stakeholder interviews.

Overall, key issues were assessed and summarized for specific cross-cutting topics related to signage, operating policies, traveler behavior, and geometric design. Seven detailed case studies examined how traveler information systems were applied and operating within a regional context. Each case study detailed the roles and responsibilities of key stakeholders, the type of pricing system, and the type of pre-trip, en-route, and post-trip information providers to travelers of the managed lane network. In general, the case studies focused only on corridors and related components that are currently priced, or are planned to be priced.

CASE STUDIES

Seven regional managed lane networks were examined as part of the state-of-the-practice review. Overall, direct managed-lane-to-managed-lane connections are currently limited in practice, with some regions only having one or two such connections throughout the network. Direct connections are usually limited by the presence of existing infrastructure, level of anticipated demand, and availability of funding for construction.

FOCUS GROUPS

The research team conducted a series of four focus groups throughout Texas for regions with existing managed lanes (Dallas and Houston), areas with managed lanes under construction (Austin), and areas where occasional travelers may wish to use the managed lanes (College

Station). Researchers recruited a total of 32 participants for four focus groups. The participant pool consisted of travelers who frequently or occasionally used managed lane facilities. An expert facilitator developed a question-based guide for discussion. The key questions for the focus groups consisted of:

- How, when, and why might a traveler choose to use managed lane facilities?
- What information is necessary for a traveler to choose to use managed lane facilities?
- When does a traveler want to receive information?
- How does a traveler want to receive this information?
- What technology do travelers use for navigation and real-time travel information?

TRAVEL SURVEY

Using the findings from the focus groups, the research team developed a questionnaire for a larger respondent pool to provide input with regard to the use of travel information systems for managed lanes. The survey asked respondents about frequent trip purpose, pre-planning activities, navigational tools, and barriers for accessing information. A total of 866 respondents who resided in regions with active managed lanes—Austin, Dallas/Fort Worth (DFW), and Houston—completed the survey. The survey was open for responses for six weeks during February and March 2017. Survey recruitment occurred through a variety of methods including outreach to traditional media (e.g., radio stations, newspapers) and web-based social media.

TECHNOLOGY ASSESSMENT

The research team conducted a technology assessment using the findings gleaned from the state-of-the-practice review and the input received from the focus groups and surveys. The overall goal of the technology assessment was to examine what implementation pathway might be pursued given a near-term timeframe. The primary components of this task consisted of interviews with private, third-party mapping and data providers (e.g., Sidewalk Labs®, HERE, INRIX®) and a proposed framework to improve an existing operational plan. The research team offered suggestions to improve existing route-builder applications that were developed by the Texas Department of Transportation (TxDOT) as well as an outline for a proposed managed lane and toll feed specification. The general transit feed specification (GTFS) used by many transit agencies throughout Texas is proposed as an existing system to build an addendum for static and real-time managed lane data.

CHAPTER 2—STATE-OF-THE-PRACTICE REVIEW

BACKGROUND ON MANAGED LANES

Defining Managed Lanes

Managed lanes is a broad term that describes a variety of facilities designed to improve the operational performance of highways through a combination of strategies that regulate demand for selected lanes on a corridor or network. A typical implementation includes designated lanes within a freeway where traffic is maintained at a faster, more reliable speed by increasing the toll rate as the number of vehicles entering the lane increases and decreasing the toll rate as the number of vehicles decreases. In many implementations, high-occupancy vehicles (HOVs) enjoy reduced toll rates all the time or during peak hours.

The Federal Highway Administration (FHWA) defines a managed lane as “highway facilities or a set of lanes where operational strategies are proactively implemented and managed in response to changing conditions” (1). TxDOT defines a managed lane facility as “one that increases freeway efficiency by packaging various operational and design actions” (2). The concept is that the operation of and demand on a facility can be managed in order to achieve a continuous optimal condition, such as free-flow speeds. Figure 1 shows the westbound direction of the I-635 East TEXpress Lanes® in Dallas, Texas.



Figure 1. Westbound I-635 East TEXpress Lane® in Dallas, Texas.

The managed lane concept may vary in specific definition from one stakeholder to the next, but all the definitions share some common elements. Typically, managed lanes operate as a freeway within a freeway, where one or more lanes are separated from the general-purpose lanes. As such, they are usually an optional alternative to the general-purpose lanes in contrast to a toll road. The principal management strategies used to manage these lanes are pricing, vehicle eligibility, and access control (1). A combination of tools and techniques are used to manage the

operation and demand on a facility. Managed lanes often incorporate a high degree of operational flexibility so that over time operations can be actively managed to respond to growth and changing needs (1).

The original concept of priced managed lanes was introduced in the United States in 1995 on the 91 Express Lanes in Orange County, California. The goal was to use variable road pricing to maintain uncongested travel during peak periods on freeways that operated with HOV lanes or HOV policies for preferential use. The first projects were primarily focused on single corridors within a region and took advantage of opportunities to test the concept in corridors exhibiting favorable characteristics, oftentimes corridors with underutilized volume. Managed lanes were viewed as a success after several pilot projects, and public planning agencies have built off that achievement by seeking to implement more complex projects, including large-scale, regional networks and self-financed express toll lanes.

Evolution of Managed Lane Networks

However, challenges emerge as agencies expand projects on single corridors to larger networks of managed lanes. Operators of managed lane networks have to consider changing user demand across expansive geographic areas and consider how that volatility will impact the volume within merging segments on the system. Some emerging plans for regional managed lane networks call for direct-connect ramps that link managed lanes from different corridors on top of existing interchanges. Other issues may include the difficulty in coordinating partners within the system (if different agencies or private groups own or operate separate components), maintaining consistent operating rules, and communicating travel information to the public. Given the novelty and complexity of the concept, there are many issues with implementing a managed lane network.

Managed lane networks are complex, interconnected facilities that require advancements in traveler information to successfully serve the users of those facilities. Information related to whether those lanes are open or closed and associated costs for priced facilities are typically shown on overhead signs. This type of communication method may not be practical for increasingly complex managed lane networks. Successful project sponsors usually identify effective strategies to communicate the operations, pricing, and benefits for managed lane networks at a system level as well as before and during individual trips.

CURRENT TRAVELER INFORMATION PRACTICE

This project investigated how, where, and when people want to access traveler information. The research team considered the different types of tasks confronted by drivers with the inherent possibility of information overload.

The driving task can be described by three hierarchical levels:

- **Control.** The primary driving task is control, which relates to the physical operation of the vehicle. In normal situations, the control task is highly automated, which frees cognitive resources for other high-level tasks of guidance and navigation.

- **Guidance.** Guidance tasks relate to selecting the longer-distance trajectory of the vehicle and making decisions such as selecting the speed and lane choice for the vehicle.
- **Navigation.** Navigation tasks relate to the choice of the route to get from the trip origin to the trip destination (3).

Most information related to managed lanes is influenced by the navigational tasks based on this hierarchy.

Methods of Conveying Travel Information

The literature addressed several aspects related to the *method* of conveying travel information. This topic includes what information is conveyed, the medium used in conveying information, the amount of information that is conveyed, and when the information is disseminated.

Multiple literature sources cited the radio as the most frequently used medium for acquiring traveler information (4, 5, 6). Other studies cited the radio as an effective medium in conveying information and affecting change in travel behavior (7, 8). Other key findings from the literature included that the young are more likely to use a smartphone application to obtain travel information, while older travelers are more prone to use the radio for traveler information (9), and older drivers are less likely to use traveler information (10). The Internet has the greatest influence on travel plans (11) and is more commonly used in the afternoon (7).

In terms of *when* information is provided, pre-trip information helps decrease uncertainty when travel time variability is encountered (12).

What Information Is Presented

Previous research for TxDOT and FHWA identified traveler information needs for single managed lane facilities. This project expands these information needs to managed lane networks. Table 1 presents the expanded information needs for managed lane networks, building on the work of TxDOT Research Project 0-4160.

FHWA is still in the process of completing a Second Strategic Highway Research Program (SHRP2) project that establishes a preliminary set of terminology and guidelines for conveying travel time reliability information to road users. Specifically, eight terms with detailed guidelines for travel time reliability information have been developed that would most likely be understood and used by travelers. Field tests were conducted in Texas, Ohio, and North Carolina to assess the practicality of assembling terms using three distinct methods: agency website, mobile smartphone application, and traditional interactive voice response 511 system (13). Results from that research project will be publicly disseminated at a future date.

Table 1. Managed Lane Information Needs.

General Information Category	Types of Information That May Be Needed
Managed lane network information	<ul style="list-style-type: none"> • Connector routes • Bail-out points (i.e., entering one managed lane does not commit the driver to using the managed lane on an intersecting roadway) • Predicted travel times • Toll structure (if any) • Required method of payment (if any) • Penalty for improper use • What vehicles are allowed
Managed lane information	<ul style="list-style-type: none"> • Type of managed lane (HOV, fixed toll, variable toll, transit only, or some combination of these types) • Hours of operation • Open/closed information • Segment cost • Access point location information • Managed lane final destination
Traffic condition information	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • Proper number of occupants • Presence of transponder or cash (if required) • Specific prohibitions of certain vehicles (e.g., trucks or towed trailers)
Driver information	<ul style="list-style-type: none"> • Need to save time • Penalty for late arrival at a 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

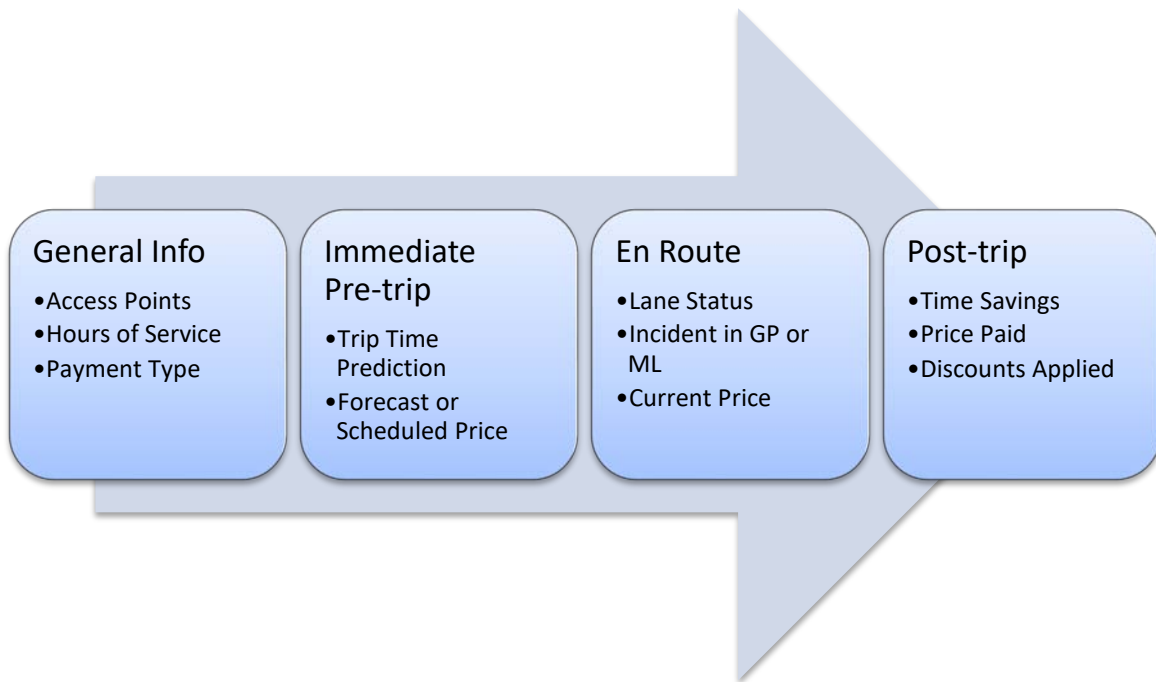
The level of traveler familiarity with a system may dictate traveler information needs (14). More information may be necessary for unfamiliar travelers. Travelers need to be informed of their travel options—which includes knowing when managed lane facilities are open or closed and what the requirements are for their use (e.g., vehicle use restrictions, vehicle occupancy requirements, and required toll rate). Likewise, knowing where to enter and exit managed lane facilities is important. Guidelines for managed lane sign design and placement for this type of information are provided in Chapter 2G of the *Manual on Uniform Traffic Control Devices* (MUTCD) (15).

Travelers are limited by the amount of data they can effectively comprehend. Care should be taken to ensure that travelers are not overburdened with information. Schrock et al. noted that “one of the key facets of positive guidance is the acknowledgement that humans have limits on their ability to scan, process, and react to information as part of their driving activities” (14). This statement reiterates the importance of determining the most effective means of conveying information on a managed lane (and even more so with a managed lane network) without inundating travelers with too much information. One technique that may be employed in properly spacing travel information is being aware of *when* travel information is provided.

Schrock et al. performed focus groups in San Antonio, Houston, and Dallas to determine travelers' opinions of what does and does not work well in conveying information about managed lanes. When asked about their understanding of the car symbol with occupancy numbers, some focus group members from San Antonio were both unfamiliar with the symbol and unable to determine its meaning. One suggested improvement was to include silhouettes or stick figures of the number of people associated with the occupancy requirement. In instances such as off-peak hours or in the case of an incident in an adjacent general-purpose lane, operators may want to open an HOV lane to all vehicles. Focus group members also expressed confusion over the proposed sign to convey this information. Suggestions included either removing the term "HOV" from the sign or providing further detail in the description to help minimize confusion. Focus group members also expressed concern about knowing if they would have to pay to use a managed lane prior to entering the system (14). This sentiment closely aligns with findings cited by Shbaklo et al., who focused on the importance of having accurate toll rate information as travelers enter an expressway (16).

When Information Is Presented

Traveler information can be provided at many points in time, as illustrated in Figure 2. This conceptual model identifies different types of information and when it might be desired. The communication channel used for each of these points in time may vary, and all must be considered when developing a communication framework.



GP = general-purpose lane; ML = managed lane.

Figure 2. Examples of Information Types Desired at Different Points in Time.

When traveler information is presented can also have a significant influence on user behavior. Operators may also consider if different pieces of information and/or different information mediums may be more effective at different times of the day. Petrella et al. found differences in

traveler information use in the morning and afternoon peak periods. Traveler information use was higher in the morning. The authors commonly found that travelers used TV and radio less frequently during the afternoon peak compared to the Internet (5). These differences imply that it may be most effective to convey managed lane network information (at least partially) differently for different times of the day.

Abdel-Aty et al. stated, “In the context of this study traffic information, particularly pre-trip, will help reduce the degree of uncertainty when commuters encounter travel time variation on their routes” (12). Having pre-trip information may help travelers make the decision about whether to use a managed lane for a given trip.

Medium Used to Present Information

Information related to electronic toll tag subscriptions, transit information, carpool registries, and other programs is often presented along a roadway. This presentation is important for managed lanes due to their restrictive nature and the presumed promise of improved performance over adjacent general-purpose lanes.

One central question addressed in the literature is whether traveler information conveyed through different mediums impacts travel behavior to different extents. Related questions include which methods of obtaining travel information are used most frequently and which methods are most influential in affecting travel behavior. While the mediums are diverse, they broadly fall into one of two categories:

- Radio and traditional forms of media.
- Technology and Internet applications.

Radio and Traditional Forms of Media. In a study performed by Tseng et al., the authors noted that the most common reported means of obtaining traffic information among the study participants was radio (4). Though not studying a managed lane setting, Petrella et al. investigated how traveler information impacted travel behavior along the US 75 corridor in Dallas and the I-15 corridor in San Diego, and found that the radio was the most common means of obtaining real-time traveler information (5). Kuhn et al. considered the medium used to convey travel time reliability information as part of a recently completed SHRP2 project. The authors found simple means of communicating reliability information (e.g., text based, graphical, auditory) had similar results, though more complex methods of conveying information were not as effective (6).

As part of an in-depth analysis of the I-85 corridor in Atlanta, Georgia, Petrella et al. used two-stage panel household traveler survey data to assess the impact of pricing on travel behavior. One of the sections within the accompanying report is about traveler information. The authors found that radio was the most common source of traveler information for 42 percent of the respondent pool, followed by 19 percent who indicated electronic message signs (6). The State Road and Tollway Authority observed noticeable changes in volume for the I-85 Express Lanes in Atlanta after a radio traffic reporter remarked that the express lanes were “a great deal” during specific times of the day (8).

Mailings, Paid Advertising, and Public Service Announcements. Information about managed lane operations may be provided to users by means of mailings, paid advertising, and public service announcements, which are often provided free of charge during traffic reports.

Bill Inserts. For electronic transponder customers, home address information is typically required for billing purposes. Agencies may wish to use bill inserts to communicate complicated toll structures, intermediate exit information, and hours of service, particularly for facilities that are exclusively for use by subscription to a local transponder. As interoperability increases and transponders can be used throughout a state, region, or nation, it may become more difficult to use this method of information dissemination.

Enhanced Technology and Interactive Maps. The literature also refers to various more technologically based mediums for conveying travel information. Kristof et al. provided an overview of advanced traveler information systems (ATISs) and different methods of evaluating such systems. They recommended the ITS Deployment Analysis System as the best ATIS evaluation method because it is sponsored by the U.S. Department of Transportation (USDOT) and allows for the evaluation of a range of ITS components. The ATIS methods detailed by Kristof et al. include “highway advisory radio, variable message signs, telephone information services, Web/Internet sites, kiosks with traveler information, personal data assistant-type devices, and in-vehicle devices” (9). The authors found a wide range of mediums available for disseminating travel information.

Different groups of travelers may react differently to different mediums of conveying travel information. Peirce et al. performed an in-depth analysis of variable tolling on the SR 520 corridor in Seattle. The SR 520 project was not a managed lane, but the variable tolls function in a similar manner to many variably priced managed lanes. The authors found that younger survey respondents more commonly reported use of smartphone apps for traveler information and older respondents (those over 45) more commonly reported use of the radio (10). Zhang and Levinson noted that older travelers (over age 55) are less likely to use traveler information (11).

Wang et al. developed a framework for modeling the traveler information acquisition process in two stages: (a) information access and acquisition, and (b) travel decision change. They developed probit models using data from the Triangle area of North Carolina. One finding indicated that “although only 23 percent of respondents acquire travel information from the Internet, it has the greatest influence on changes in travel plans.” At the time when the research was completed. A less commonly used medium to convey travel information may actually be more influential in enacting travel changes than more frequently used mediums (17).

Online, interactive maps were found to be increasingly used by the traveling public compared with other, traditional media. Waze[®] and Google Maps are two frequently used mapping products. Google Maps launched in 2005 and as of 2015 had over 1 billion users (18). Waze[®] was founded in 2008 and is a dynamic mapping service that allows users to anonymously provide information about traffic crashes or speed traps. Waze integrates passive data collected from users who have activated the application. As of 2014, Waze had 50 million users in 200 countries (19). The app now includes Google Street View and is part of the data supplied through Google Maps (20). These types of technologies may be increasingly useful in conveying information in a managed lane network context, given their widespread current use.

Websites. The 2009 MUTCD currently prohibits the placement of Internet addresses on traffic control devices, yet examples of this practice have been found on the road. Web addresses that are easier to remember than telephone numbers can be selected, thus lessening the information load on drivers.

Phone Apps or Website Subscriptions. Some facilities are already using mobile phone apps and website subscriptions to allow managed lane users to self-declare as an HOV in order to receive a discount. The Drive On TEXpress[®] app in the DFW region allows users to self-identify as HOV for specific managed lane trips as far in advance as 7 days and up to 15 minutes from departure. This system also has an option where users are notified post-trip that their HOV discount was applied.

Travelers may also want to know about other forms of transportation. The RideScout[®] application (available in Austin) provides an integrated source of information for transit, bike, taxi, rideshare, and parking. This smartphone application also provides cost comparisons and incident alerts with suggested rerouting. Apps like this one should be able to provide managed lane information as well, but agencies must understand how to provide managed lane information to third-party app developers. The RideScout[®] app for the DFW and Houston regions does not currently include managed lane information.

In-Vehicle Communication Technology

From a safety and cost perspective, providing managed-lane-specific information on demand directly into the vehicle of interested drivers is an excellent answer to the challenges of communicating to the appropriate drivers without distracting general-purpose lane users. The potential safety benefits arise from reducing the amount of distracting information visible on the roadway and by removing additional sign structures, which can pose roadside safety hazards. The cost reductions arise from the elimination of installation and maintenance costs of many static and dynamic signs. Clearly, until in-vehicle technology has significant market penetration, some level of traditional roadside signage will be necessary. As a vision of the future, however, the universal application of in-vehicle communications could realize significant safety and cost benefits for operating agencies (21).

Many vehicles are equipped with navigation systems installed either by the factory or by the user. These systems offer route guidance and information related to services along the roadway such as fuel and food. Information concerning managed lane operations could be provided for vendors of these systems to include in their information packages. Systems that rely on stored maps could not accept dynamic pricing or lane status information but could at least provide basic route and operating rules information on demand. Other vehicle systems, such as OnStar[™] and satellite radio, could provide broadcasts of traffic conditions and managed lane information to specific regions.

FACTORS THAT INFLUENCE TRAVELER INFORMATION

Travelers of managed lanes are influenced by a number of factors that impact their travel behavior. Demographics and trip purpose have been cited as key influences on travel behavior with regard to managed lane use. Several aspects of travel behavior are critical to consider when

planning to effectively convey travel information within a managed lane network. The literature includes studies characterizing different attributes that influence managed lane behavior, including tolling, travel time reliability, and intelligent transportation systems (ITSs). Managed lane networks are a relatively new concept, so prior research on this topic did not center on networks but rather on managed lanes that operate within a single corridor.

Overall, key topics that emerged as recurring trends within existing research include:

- Traveler traits and behavioral response.
- Information valued by travelers.
- Response to travel information.

There is some overlap among these broad listed topics, but the arrangement of these topics helps to categorize key factors that impact managed lane network traveler information systems.

Additionally, geometric design traits such as access and type of separation (e.g., barrier, striped buffer) are known factors as well. This section details the results of a literature review seeking information about traveler information needs, in-vehicle communication technology, connected vehicles, and geometric design.

Traveler Traits and Behavioral Response

Socioeconomic, psychological, and personal attributes are all factors that influence travelers to choose to travel in a managed lane or managed lane network.

Gender Differences

In the research cited previously by Abdel-Aty et al., males were found to select riskier routes (i.e., shorter travel times with more variability) (12). Devarasetty et al. investigated how closely actual and perceived travel times aligned. The authors found that men estimated travel time savings from managed lanes more accurately (22). Carrion and Levinson collected global positioning system (GPS) data and assessed toll transactions to evaluate the importance of travel time reliability associated with using the I-394 MnPASS (an HOV-to-HOT lane conversion project) in the Minneapolis–St. Paul region. As with Abdel-Aty et al., the authors found that males are generally more risk prone (23). Based on the results stemming from these sources, males are generally more prone to select riskier routes and are better at accurately estimating managed lane travel time savings.

Personality and Psychological Traits

Some of the literature provides insights into how personality and psychological traits affect travel behavior. Devarasetty et al. considered the impact that psychological variables may have on travelers' decision to use a managed lane or the adjacent general-purpose lane. The authors also investigated whether the decision to carpool or ride alone in either a managed lane or the adjacent general-purpose lane facility could be more accurately predicted by considering certain traveler psychological traits. The study used data collected from Denver, Miami, and San Diego. The final study sample was comprised of 664 participants. Psychological variables related to conscientiousness, general locus of control, personal need for structure, financial risk tolerance,

driving risk perceptions, risky driving style, and careful driving style were modeled in composite scale form. The authors were trying to investigate the relationship between these traits and managed lane use. The authors found that the connection between psychological variables and choices made in a managed lane context were not as strong as expected. However, they did find, based on Likert scale responses, that “individuals with higher risky driving style scores were less likely to choose carpooling on general purpose lanes” and that “individuals with higher conscientiousness scores were less likely to choose to carpool on the managed lanes” (24).

Further analysis of the same dataset used by Devarasetty et al. was performed on the individual question level by Green and Burris. They found that while psychological variables in their construct form are of minimal use, certain psychological questions, used in tandem with common socioeconomic and trip variables, were useful in better understanding managed lane travel behavior. Select questions from the personal need for structure construct and the driving risk perceptions and driving style construct showed particular promise (25). This finding led to further research by Green and Burris in which additional psychological questions, most of which were framed in a transportation context, were developed. Using multinomial mixed logit models, the authors tested the inclusion of individual psychological items to see if they improved the model’s effectiveness, which was assessed in terms of adjusted rho squared value and percent corrected predicted values. Data were obtained from a stated-preference survey that included questions related to decisions made in a managed lane setting (i.e., managed lane versus general-purpose lane and drive alone versus carpool), and a psychological questions section. The analyses included data collected from managed lane users on I-15 in Salt Lake City, I-394 and I-35W in Minneapolis, and I-495 on the Capital Beltway in the Washington, D.C., area. The authors found that models developed using select psychological items resulted in better models than models involving select psychological scale variables or trip and demographic variables. Furthermore, models that contained select psychological items in tandem with common trip and demographic variables performed even better (26).

Shifan et al. found that sensation seekers were more likely to select routes with lower average travel times but greater travel time variability (less reliability). They used both revealed-preference (in-field) and stated-preference (laboratory) data to assess the travel behavior of persons receiving real-time travel time information. Study participants completed a questionnaire related to personality factors. The authors also noted that trip characteristics and driver socioeconomic characteristics influence travel behavior—not just travel time. Additionally, the study found that having access to travel time information associated with different routes affects route choice, but more so when drivers lack experience with having travel time data available. As trial runs continued, study participants became more likely to choose the route they chose initially (without any travel time information)—seeming to indicate that as drivers gain experience with travel time information, they may begin to value it less than when travel time information is novel (27).

Counterintuitive Travel Behavior

Sometimes, the response to travel information may be unexpected. Janson and Levinson performed a series of three experiments using data collected along HOT lane corridors with dynamic pricing. The HOT lane price was altered every 3 minutes to reflect changes in density in that lane. When density was low, the price decreased, and when density was higher, the price

increased. This methodology tested whether HOV drivers continued to use the express lane and whether the price changes helped control overall congestion. However, the authors found that increases in HOT lane toll prices actually caused increased demand. This anomaly may have occurred because travelers saw the increased toll and believed that congestion was immediately ahead, so paying to use the HOT lane would save them time (28).

Another example of a counterintuitive response to travel behavior was seen in research performed by Du et al., which considered the impact of various variables on single-occupancy vehicle (SOV) HOT lane usage rates using 2008 and 2010 data from SR 167 in Washington. When the toll rate increased, the rate of SOV drivers in the HOT lane also increased. Though seemingly counterintuitive, this result may have occurred because SOV drivers associated higher toll rates with upcoming congestion they wanted to avoid (29).

Information Valued by Travelers

Other studies have considered what information is most important to travelers. Two aspects of information that have been identified as important to managed lane travelers, and are discussed further in this section, are travel time reliability and travel information accuracy.

Travel Time Reliability

Several studies in the literature considered the topic of conveying travel time reliability to managed lane users.

Word Choice to Present Travel Time Information. As noted in the section discussing mediums used to convey travel information, a recent SHRP2 report completed by Kuhn et al. focused on determining the most effective way of informing travelers of reliability. By performing a literature review, expert interviews, technology and innovation scans, focus groups, surveys, and laboratory experiments, the authors developed a lexicon for various technical terms related to travel time reliability. The authors stated, “The goal of this research project was to examine what combination of words, numbers, and other features of user information messages, along with communications methods and technology platforms, best communicates information about travel time and reliability to travelers so that they can make optimal travel choices from their own point of view” (7). They found that the study participants did not always properly understand statistical terms related to reliability. The authors reported that “reliability terms that are commonly used and understood by transportation professionals, such as 95th percentile, buffer time, buffer index, and even average trip time, are not necessarily preferred or consistently understood by travelers” (7). In particular, people did not like statistical-sounding terms and often interpreted their meaning incorrectly. Although no travel time reliability terms appeared to be uniformly effective, the authors recommended one to three terms for eight different travel time reliability categories for pilot testing and/or field studies. The authors found that participants underestimated the benefits associated with improved reliability information, such as “reduced delay, improved on-time reliability, and reduced stress.” Therefore, it may be difficult to convey to travelers the real value of provided travel time reliability information (7).

Impact on Route Choice. Abdel-Aty et al. performed a study that considered the impact of travel time reliability on route choice that included multiple components. The first study

included five stated-preference questions that asked participants to select in each question one of two routes—one route with a longer travel time than another but more consistent travel times. A portion of the study had a mail-back component with a revealed-preference section and a section with questions related to the effects of ATISs. The authors found that travelers generally try to minimize the travel time on their route unless it is associated with too much uncertainty; then, they will switch to selecting a longer route with more certainty. Travel time was not the main criterion used in making route choices, and ATISs should avoid advising travelers to use the route with the shortest travel time if there is a high degree of uncertainty associated with the route (12).

Impact on Decision to Use Managed Lanes. Managed lanes often have access requirements that are contingent on vehicle occupancy. In the case of HOT lanes, vehicle occupancy may dictate whether the vehicle is charged to use the facility—with SOVs (or those not meeting the specified vehicle occupancy for free managed lane use) able to pay a fee to use the managed lane. As mentioned previously, Du et al. considered the impact of various variables on SOV HOT lane usage rates using 2008 and 2010 data from SR 167 in Washington (which was converted from an existing HOV lane to an HOT lane in 2008). They found that reliability was an important factor in the decision of SOV travelers to use the HOT lane (29).

Jin et al. studied both value of time and value of reliability on managed lanes by surveying travelers who had recently used the I-75, I-95, or SR 826 corridors in south Florida. Stated-preference surveys were administered to study participants associated with all three corridors, and revealed-preference data were collected for the I-95 corridor. Speed sensors gathered data for use toward assessing reliability statistics on the I-95 corridor. Survey respondents were less likely to prefer a discount associated with a late shift if they had previously experienced delays (30). These findings present interesting insights into how the penalty for late arrival may impact travel behavior on a managed lane system and support the importance of accurately conveying this information (e.g., vehicle occupancy requirements and discount times) to managed lane users so that they can make an informed decision about whether and/or when to use the managed lane. It follows that the same principle—if anything, magnified to a greater scale—would exist for a managed lane network.

Carrion and Levinson performed a review of travel time reliability research. A framework based on expected utility theory includes the fact that travel time variability is a disutility in addition to travel time. Much travel time reliability research that has been done is qualitative in nature and is based on questionnaire results related to travelers' preferences. Likewise, travel time reliability surveys are much more often stated-preference surveys rather than revealed-preference surveys. The authors indicated, "Most researchers agree that the variability presentation by Small et al. (which is in turn based on Black and Towriss) should be the current preferred presentation of travel time variability" (31). Thus, this questionnaire design is likely the one that should be selected in the event that travel time reliability information is collected via questionnaire relative to conveying information on managed lane networks.

Carrion and Levinson performed an experiment to assess the importance of travel time reliability associated with using the HOT lane by collecting data via GPS and transponders along the I-394 corridor in the Minneapolis–St. Paul region. The study required participants to be involved with the experiment for a period of 7–8 weeks and follow prescribed guidelines about which route to

take. The authors analyzed the revealed-preference data collected in this setting to produce logit models to assess the value of reliability. The reliability measures of standard deviation, shortened right range, and interquartile range were considered. The authors concluded, “Both the centrality measure of travel time and travel time variability are directly linked to the travel time distribution experienced by each traveler. Therefore, the fact that both are statistically significant factors in explaining the route choice variation is likely to translate into an added influence to the behavioral decision-making process of the subjects” (32).

Burris et al. analyzed tolling data obtained from the I-394 MnPASS express lanes in Minneapolis and I-15 express lanes in San Diego to assess travelers’ value of time and the differences between variable tolls—where the rate is preset for different times of the day—and dynamic tolls—where the rate changes based on real-time conditions. The authors noted that during both the peak and off-peak times, the travel time on general-purpose lanes was comparable to that on the HOT lanes on both I-394 and I-15. As stated by the authors, “This finding indicated that users were willing to pay for even a relatively small travel time savings.” This finding, as well as the relatively high value of travel time savings, led the authors to believe that travelers may be paying for more than just travel time savings and that travel time reliability may be one of the other major incentives to paying a toll (33).

From the results of research performed by Peirce et al., of particular note is that the rate of consulting traveler information dropped dramatically for those using SR 520, which may be linked to improved reliability along this route (10). It is unclear how this finding may relate to conveying information on managed lane networks because although routes with improved reliability may lessen the need to convey route information, the complex nature of a new managed lane setting may still call for improved measures to convey complex information that may influence traveler behavior.

Travel Information Accuracy

Research related to travel information accuracy and traveler response shows that less accuracy is associated with travelers being more prone to select more-reliable, less-risky routes (34), and as would be expected, as travel time information becomes less accurate, its demand decreases. Supplying current versus historical travel time information may affect travelers differently (35). Additionally, inclusion of a maximum travel time may influence route selection when there is a penalty for late arrival (34).

An additional finding of the research performed by Tanaka et al. was a mixed response in sensitivity to travel time information when only less-accurate information (i.e., only current travel times) was provided (34). Ben-Elia et al. also considered the importance of travel information accuracy. They performed a stated-preference experiment that had 36 participants select from three potential routes (reliable, useless, or riskier), based on varying levels of accuracy, 30 different times. Less accuracy resulted in study participants being more likely to select the more-reliable or useless alternative than the riskier route. Additionally, the authors found that prescriptive information impacted travel behavior choices more than descriptive information and that risk attitudes played a role in the participants’ choices (35).

Zhang and Levinson did a stated-preference survey with 113 drivers for different routes between select origin-destination pairs in Twin Cities, Minnesota. Before each trip, study participants were provided real-time travel time information but with varying levels of accuracy. They modeled the results using ordinary regression, multinomial, and rank-ordered logit models. The authors found that demand for travel time information decreased with inaccurate information (11).

Tanaka et al. studied not only the effect of travel time information on route selection but also the effect of informing respondents of the maximum travel time associated with a route. In a sense, this method is a form of considering travel time reliability because it relates to the distribution of route travel times. They also considered the effect of data accuracy, with some scenarios containing information only from current travel time estimates (considered less accurate) and other scenarios providing predictive data as well (more accurate). A total of 60 respondents (15 respondents assigned to each of four cases) were each asked to respond to 60 stated-preference questions—20 questions where no information was given, 20 questions where only travel time information was given, and 20 questions where both travel time information and travel time distribution information were given. One significant finding was that providing the inclusion of the maximum travel time may influence route selection when a late-arrival penalty exists. Also, especially in the case of a late-arrival penalty, the accuracy of the information provided (i.e., whether just current travel times or travel times having a historical aspect) may have an impact on route selection (34).

Response to Travel Information

Travelers may respond to travel information in myriad ways including changing their departure time, route selection, vehicle occupancy (i.e., whether to carpool), and/or mode choice. Kristof et al. (9) stated, “The goal of ATIS is to provide travelers with information that will facilitate their decisions concerning route choice, departure time, trip delay or elimination, and mode of transportation.” When communicating traveler information for managed lane networks, it is important to consider which of these decisions is being targeted and how far in advance the information needs to be conveyed.

Koo and Yim (36) performed a study to determine the impact that obtaining traffic information about a traffic incident had on commuter travel behavior and choices. The authors focused on whether obtaining traffic information pre-trip or during the trip had an influence on the decision-making process. Panel survey participants were interviewed about a specific incident that was selected for analysis based on set criteria. Over 100 morning southbound commuters who traveled US 101 were interviewed near Silicon Valley in California on the day of an incident and 3 days after the incident. They found that “despite the benefits of obtaining travel information, only 51.4 percent of respondents obtained information prior to leaving for their commutes, and of those who heard of congestion, 70.8 percent did not alter their departure time, mode of travel, or route.” Those participants who actually experienced congestion related to the incident reported a similar lack of intention to alter travel behavior. Respondents reported relatively low levels of changing departure time (45.3 percent), route (30.2 percent), or mode (14.2 percent) at least once a week. Although traffic information on the incident appears to have had some influence on travel behavior choices, more widespread travel behavior change may be contingent on “informing them of travel time or delay, information sources such as TravInfo, and the

potential benefits of alternative travel options.” Although that study focused on travel behavior associated with traffic information and an incident, similar applications may exist in a managed lane network setting. The study also reiterated the fact that travel information acquisition and travel information use do not necessarily equate to the same thing (36).

Peirce et al. (37) performed a two-stage panel household traveler survey in Seattle and Atlanta. The two-stage panel survey design included surveying households both before and after implementing road pricing in the corridor of interest so that the impacts of the variable tolling programs could be assessed. These studies were part of the Urban Partnership Agreement and Congestion Reduction Demonstration Programs. The Seattle study focused on implementing variable pricing for the SR 520 Bridge, which was previously non-tolled. The Atlanta study focused on the I-85 Express Lanes, a conversion of an existing HOV 2+ lane to an HOT 3+ facility. The authors stated that “one of the fundamental findings of both studies is that congestion pricing, even with relatively modest toll levels, can lead to significant shifts in traffic volumes, in choices of routes and lanes, and to a lesser extent in modes used, vehicle occupancies, and other aspects of personal travel.” However, tolling had little impact on telecommuting or not traveling for work trips. The authors also voiced the need to clearly communicate the motivation for road pricing, how travelers will be affected, and what travel options exist (37).

Another important aspect to consider in traveler response to travel information is that the actual and perceived travel time savings associated with managed lane use may be different. Devarasetty et al. used 2010 Katy Freeway data collected via stated-preference surveys, and, through the collection of travel speeds using vehicle sensors, they determined that on average, travelers overestimate the amount of travel time savings obtained from using the managed lane by roughly four times the actual travel time saving realized (22). Perception is more likely to influence travel behavior responses rather than actual conditions. The extent of the discrepancy in real and perceived managed lane use benefits may be altered if additional managed lane information is provided (e.g., travel times on managed lanes and adjacent routes).

Information Overload

Care must be taken not to overwhelm drivers with information. When a driver is overloaded with information or faces an imminent danger, he or she actively sheds the information load by ignoring the navigational level in order to maintain physical control of the vehicle and keep from colliding with another vehicle or other hazard.

The principles of positive guidance dictate that not all information is needed at all locations (38). Providers of information about managed lanes, both pre-trip and en route, must keep in mind that ramps and merge areas increase the workload of controlling and guiding the vehicle. At these critical places, drivers concentrate on their own speed, headway, and lane position. They may not have the cognitive resources to make complicated decisions about whether or not to use a managed lane. Ideally, drivers make this decision upstream of the point where a maneuver is required to enter or exit the lane. In order for this maneuver to happen, drivers must be provided with the relevant information far upstream of the maneuver point.

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

Geometric Design

The design of managed lanes influences how users perceive and use the facility. Provisions for tolling need to be included for facilities that have a pricing component, and enforcement accommodations must be provided to maintain the integrity of eligibility and/or pricing criteria. A managed lane facility adjacent to general-purpose lanes needs appropriate separation between the two types of lanes. Ideally, all these characteristics must have a degree of consistency between one facility and another within a managed lane network so that driver expectancy can be satisfied when traveling within a region.

Geometric design also has effects on the operations of managed lanes and, subsequently, influences what, how, and where travel information is provided. Electronic toll collection requires a decision on where the toll collection occurs, and such locations are usually in a constrained median environment. Regardless of the choice of tolling system, the design will need to accommodate the necessary infrastructure, which typically involves large structures, such as gantries and signage, as well as hardware such as cameras and electronic readers, roadside controllers, communications equipment, and power.

The use of variable pricing on managed lanes requires additional infrastructure and communication abilities to communicate toll rates, lane restrictions, and other use information. Some facilities, such as the I-10 Katy Freeway Managed Lanes in Houston, use clear signage to inform drivers they can self-declare as an HOV or travel as a tolled SOV by choosing the appropriate lane. Figure 3 shows an example of signage for a declaration area on the I-25 Express Lanes in Denver, Colorado. Other HOT facilities such as the LBJ TEXpress Lanes[®] in Dallas allow the driver to self-declare prior to entering the tolling area to receive a discounted toll rate, so the driver does not have to choose a specific lane. Advance declarations can also be used for HOT operations on single-lane facilities that do not have an available cross-section for a second declaration lane.



Figure 3. HOT Declaration Lane at Toll Gantry on I-25 Managed Lanes in Denver, Colorado.

CHAPTER 3—MANAGED LANE CASE STUDIES

The case studies evaluated several existing managed lane systems for roadway signage and other methods (including but not limited to social media and websites) that communicate operational and pricing rules for traveling on managed lane networks. Researchers conducted in-person site visits and interviews with operating agencies in the case study region.

This chapter presents case studies on managed lane systems in cities across the United States. The case studies include:

- Dallas/Fort Worth, Texas.
- Houston, Texas.
- Minneapolis–St. Paul, Minnesota.
- Miami, Florida.
- Seattle, Washington.
- San Francisco, California.
- Washington, D.C., and Virginia.

DALLAS/FORT WORTH, TEXAS

Description of Network

Overview of Managed Lane System

The DFW region in North Texas contains a complex and expanding network of managed lanes. In 2012, the network of managed lanes was branded TEXpress Lanes[®] with the logo shown in Figure 4 (39). In June 2014, the LBJ Express managed lanes were launched as the first dynamically pricing roadway in the region.

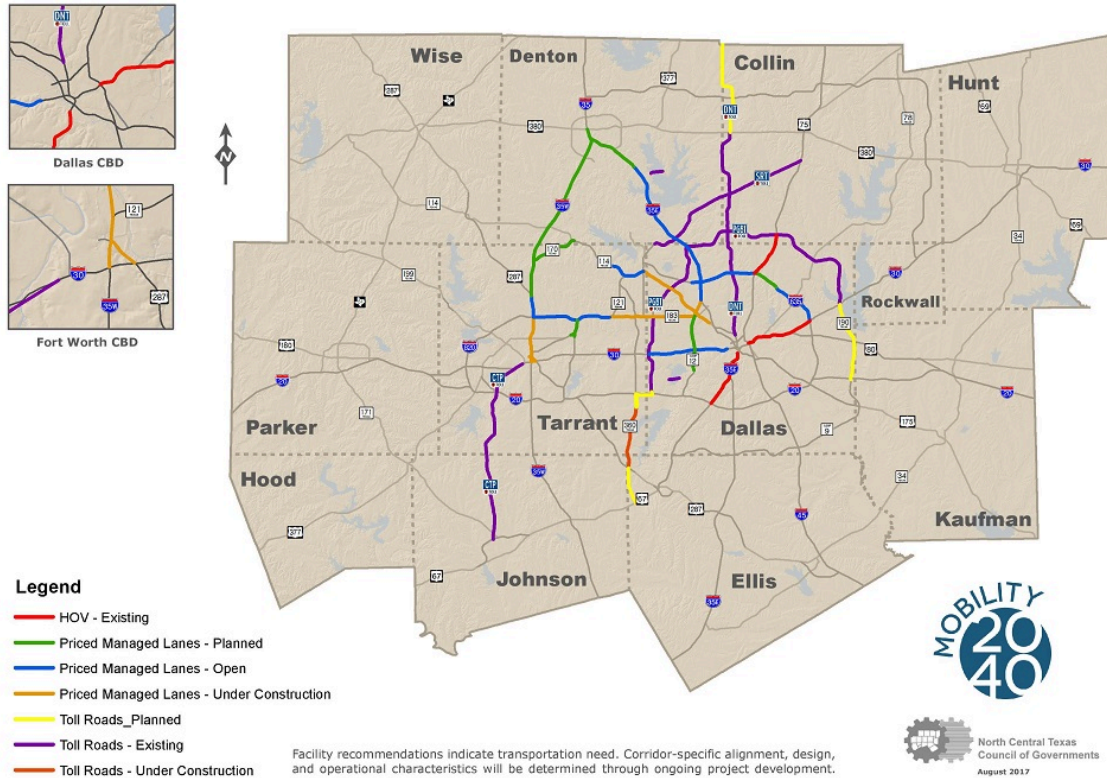


Figure 4. TEXpress Lanes[®] Logo.

As of August 2017, TEXpress Lanes[®] operate within five freeways in DFW, and other corridors will have TEXpress Lanes[®] within the next 5 years. These five priced managed lane facilities—LBJ Express, North Tarrant Express (NTE), DFW Connector, 35Express, and the I-30 TEXpress Lanes[®]—operate in some of the region’s most congested corridors. The TEXpress Lanes[®] are additional lanes adjacent to non-tolled general-purpose lanes.

The DFW roadway network also includes a number of HOV lanes. The TEXpress Lanes[®] (labeled new managed lanes) and the current HOV lanes (labeled express/HOV lanes) are shown in Figure 5. Several HOV lanes are slated to become tolled managed lanes in the future.

Mobility 2040 Toll Road Status



Source: (40)

Figure 5. Dallas/Fort Worth Managed Lane System in 2017.

The three operational managed lanes include multiple segments, and each segment may vary in length, number of lanes, and number and configuration of access points. For example, the LBJ and NTE TEXpress Lanes[®] charge different rate multipliers based on vehicle class, but rates on the DFW Connector are based on axles (41). A summary of the operational TEXpress Lanes[®] is presented in Table 2.

Table 2. Roadways in the Dallas/Fort Worth Managed Lane System in 2017.

Roadways	Roadway Configuration	Rate Set By
LBJ TEXpress Lanes® (I-635)	3 segments, 13.3 miles, includes reversible, direct connect with HOV (US 75)	Segment pricing and vehicle class
NTE TEXpress Lanes®	2 segments, 11 miles	Segment pricing and vehicle class
DFW Connector TEXpress Lanes® (42)	1 segment, 4 miles, two lanes in each direction on SH 114	Segment pricing and number of axles
35Express	3 segments, 18 miles, two reversible lanes	Segment pricing and number of axles
I-30 TEXpress Lanes®	3 segments, 16 miles, part of corridor has concurrent single lanes, other part is reversible	Segment pricing and number of axles

Traveler informational efforts have mainly focused on educating the public on the concept and benefits of managed lanes. TxDOT stated that the TEXpress Lanes® “provide more capacity, reduce congestion and pay for much-needed roadway improvements.” The project sponsors also emphasize that travelers have a choice between using the existing highway lanes and paying for the TEXpress Lanes® (39). TEXpress Lanes® are presented as a new type of toll system that offers commuters “choice, flexibility and convenience” (43). HOV discounts for travelers who carpool or ride motorcycles are highlighted on project websites and are a central feature of available smartphone applications (44).

The TEXpress Lanes® brand was selected through an educational outreach effort designed to familiarize drivers with the concept of managed lanes. Historically, managed lanes in the region have been referred to as HOV/managed lanes, HOV lanes, and express lanes. The differing use of various terms can lead to traveler confusion about what specific terms mean for types of benefits and who can use the facility. Two of the private concessionaires, in partnership with North Central Texas Council of Governments (NCTCOG) and TxDOT, sponsored a “Name the Lanes” contest in which members of the public could submit names for the system (45). An array of public and private partners involved in the managed lane projects, as well as the growing complexity of the system, contribute to challenges in communicating clear and concise information to the public.

Roles and Responsibilities

TxDOT owns the managed lane facilities, and private concessionaires operate a few of those facilities. TxDOT provides oversight for geometric design and access considerations. TxDOT partnered with private developers through comprehensive development agreements, a type of public-private partnership, to fund, develop, and operate the managed lane projects in DFW. Several private consortiums composed of several different entities bid on the rights to develop and run the managed lane facilities and adjacent general-purpose lanes. In addition to operations and maintenance, the private operators, in collaboration with TxDOT, are responsible for public communication about the projects (46). Each of the three active managed lanes is operated by a different public consortium, as follows:

- LBJ Infrastructure Group is the developer and operator of the LBJ Express.
- NorthGate Constructors operates the DFW Connector.
- NTE Mobility Partners operates I-35 North Tarrant Express.

Billing and customer service are managed by the North Texas Tollway Authority (NTTA), a toll road operator responsible for multiple traditional toll road facilities in the DFW region. NTTA handles billing and customer service for all toll fees in the region and customer service related to TollTags. NTTA does not price, operate, or maintain the TEXpress Lanes[®]. Before 2013, Dallas Area Rapid Transit (DART) operated HOV lanes surrounding Dallas, but it has since transferred that responsibility to TxDOT. However, the transit agency continues to operate buses on managed lanes within the region.

NCTCOG, the metropolitan planning organization for the DFW region, provides oversight for all managed lanes. NCTCOG’s Regional Transportation Council (RTC) is an independent policy body that oversees the allocation of transportation funds and has responsibility for setting regional toll rates and managed lane policies (47). In 2012, RTC released updated regional policies on tolled managed lanes and express/HOV lane policies in an effort to clarify the system for the public (48). RTC also announced that the project developers would lead an educational campaign to educate drivers on how to use the new lanes. NCTCOG created a managed lane public information officers’ working group to address the public messaging for managed lane projects in the region. The working group included representatives from NCTCOG, TxDOT, DART, NTTA, and the private contractors developing and operating the corridors.

Pricing System

TEXpress Lanes[®] manage traffic flow with roadside equipment that recalculates prices based on real-time traffic conditions every 5 minutes, 24 hours a day, to maintain a minimum 50 mph speed. This variable congestion-management pricing is designed to manage traffic flow and provide travelers with shorter, more predictable travel when there is congestion in the main lanes (49). Figure 6 shows a summary of the pricing used on TEXpress Lanes[®].

	TEXpress Lanes		Express/HOV Lanes
	Peak Period *	Off-Peak Period	Peak & Off-Peak Period
HOV	50% discount	Posted rate	No toll
SOV	Posted rate	Posted rate	Posted rate
Trucks	Varies**	Varies**	Not allowed
Motorcycles	50% discount	Posted rate	No toll
Transit Vehicles	No toll	No toll	No toll

* Morning peak – 6:30-9:00 am; afternoon peak – 3:00-6:30 pm

** The toll rate for trucks, buses and vehicles with trailers will increase based on shape and size or axle count.

Source: (50)

Figure 6. TEXpress Lanes[®] Payment Summary.

While toll rates vary by time of day and vehicle type, they are controlled by overarching policies set by RTC. RTC policy requires an interim 6-month period with a fixed time-of-day toll

schedule before dynamic pricing is implemented. During the 6-month period, the toll rates incrementally increase or decrease according to a pre-established pattern, allowing the public to become accustomed to sign placement, operation, and the choices they have. NCTCOG and RTC participate in public meetings to communicate about rate-setting policies with the public.

Prices are set for each segment of each priced managed lane roadway. A segment is a fixed distance between two specific access points on a managed lane. The toll rates for a segment-based pricing system are usually dependent upon demand for specific segments. In contrast, per-mile pricing is dependent upon the location with the highest demand, and that location adjusts the toll rate uniformly across the entire facility. Travelers on TEXpress Lanes[®] is presented with the cost for each segment, not the price for the entire priced managed lane. HOV rates apply to HOV 2+ vehicles during peak periods (6:30 a.m. to 9 a.m. and 3 p.m. to 6:30 p.m., Monday to Friday).

TollTag is an electronic payment system in which travelers receive a TollTag transponder sticker that triggers an automatic deduction from a prepaid account. Managed by NTTA, TollTag works on NTTA toll roads and TEXpress Lanes[®]. NTTA also offers a free smartphone app, Tollmate[®], to help manage a TollTag account. To obtain this discount, eligible vehicles must have a TollTag or TxTag[®] and activate their HOV status at least 15 minutes prior to entering the TEXpress Lanes[®]. Activation can be done using the Drive On TEXpress[®] smartphone app or the DriveOnTEXpress.com website (51). Travelers without an electronic toll transponder are billed by mail and pay a higher rate.

On express/HOV lanes, HOVs travel for free at all times of day. SOVs pay a posted rate based on traffic volumes (52).

Existing Traveler Information System

Information for traveling on the managed lanes comes from a variety of sources because many different entities are responsible for operating managed lanes in the region. Websites, smartphone apps, and highway signage are major components of the TEXpress Lanes[®] information system. TxDOT, owner of the roadways, provides project information through its website and media outlets. NCTCOG also produces informational materials, such as fact sheets and policy updates, to educate the public on regional managed lane policies and operations. NCTCOG provides information on both TEXpress Lanes[®] and express/HOV lanes that operate in the region (52).

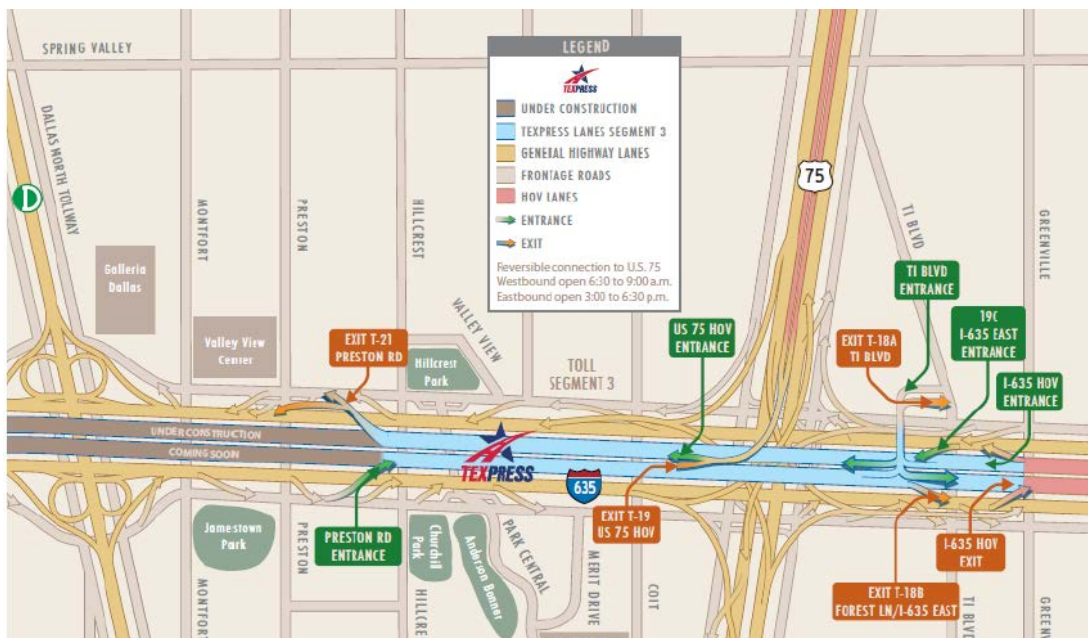
The private concessionaires that operate the TEXpress Lanes[®] use websites, smartphone apps, highway signage, advertising, and media to communicate with and educate the public on managed lanes. Ongoing campaigns include a “Why TEXpress” theme that uses Twitter[®], Facebook[®], and the whyTEXpress.com website to provide general information about how the managed lanes serve travelers. This website’s focus is on basic information needed to use the lane, such as where TEXpress Lanes[®] operate, how to access lanes, cost, pricing methods, payment, and discounts. One of the private partners, Cintra Toll Services, LLC, manages a free smartphone app called Drive On TEXpress[®] and the app currently includes information about the LBJ and the NTE TEXpress Lanes[®]. The app can be used to schedule HOV status, view routes between access points, and track discounts (53). Advertising methods include television ads,

radio spots, billboards, door hangers, and social media. The campaign slogan “Arrive Fashionably Early” was used to communicate the benefits of using managed lanes and alert the public about the opening of completed TEXpress Lanes® (54).

Pre-trip Information

Websites provide the most comprehensive source for information about the purpose, use, pricing, and function of the TEXpress Lanes® system. The TEXpress Lanes® website (<http://www.texpresslanes.com/>) is the primary site that provides traveler information about the managed lane system; it includes payment options, toll rates, carpool discounts, access point locations, and tutorial videos. The TEXpress Lanes® website also provides web-based links to individual websites for each of the three operating managed lanes.

Individual webpages for each roadway are integrated with the TEXpress Lanes® website to provide detailed information about using each roadway. Travelers are advised to print the maps and store them in their car. The website also provides detailed maps of each entrance and exit ramp (55). Figure 7 shows a visualization that details the location of access points to and from the managed lane. These detailed maps can also be accessed on the TEXpress Lanes® smartphone app by selecting specific origin and destination exits.



Source: (55)

Figure 7. Map of LBJ TEXpress Lanes® Access Points.

The LBJ TEXpress Lanes® website includes a trip planner page that will “calculate the price ranges you might pay by using past toll rates for the same entry and exit points, same day of week, time of day and vehicle class” (56). However, efforts by researchers to use this trip planner failed to attain the toll rate estimates that the website claimed it could provide.

The DFW Connector, managed by NorthGate Constructors, has a website that is not branded or styled like the other TEXpress Lanes® webpages and has an independent smartphone app. The

site directs readers to the TEXpress Lanes® page for information on the managed lane system but lists other tools for public outreach that include text message alerts, email alerts, a toll-free hotline, and a physical information storefront (57).

En-Route Information

The DFW region primarily relies upon roadway signage with dynamic panels to show en-route information for navigating the managed lane network. Highway signs inform drivers of upcoming access points, HOV requirements, and payment options. As seen in Figure 8, the signs do not include the TEXpress Lanes® name or logo but refer to the lanes as express lanes. They do include TxTag® and TollTag logos (top of the sign in Figure 8), which help local travelers understand the payment options.



Figure 8. Destination and Price Sign on Westbound I-635 LBJ TEXpress Lanes®.

Current pricing is displayed on highway signs for each segment of the TEXpress Lanes® for both SOVs and HOV 2+. The rates for drivers without a transponder appear on most road signs, but the rates for trucks and buses do not usually show (58). Figure 9 shows highway express lane signage that includes information on roadways, access points, prices, HOV requirements, and NTTA TollTag logos. Figure 10 shows a price sign on the NTE TEXpress Lanes®, with one price for SOVs and another price for HOVs.



Figure 9. Southbound I-35 Sign Bridge for I-635 LBJ and 35E TEXpress Lanes® in Dallas.



Figure 10. Managed Lane Sign with Price Information on NTE Westbound.

Information about tolling is provided on the project websites and on highway message signs that update in real time to reflect current prices. Compared to other regions, toll rates are only shown to the nearest exit, not for following exits or the farthest point on the TEXpress Lanes®.

Post-trip Information

Travelers in the DFW region can primarily access post-trip information through the online toll account management portals and smartphone applications. The Drive On TEXpress[®] smartphone app allows registered users to see trip discounts and carpool history (59). Travelers who use a toll transponder can get information about their account either online or via mailed monthly bills. NTTA provides billing and customer service assistance online and by telephone. In addition to the information already noted, the TEXpress Lanes[®] website includes comprehensive frequently asked questions (FAQs).

Future Possibilities

The number of partners involved in the managed lane system presents a challenge that will only grow as more TEXpress Lanes[®] are built in the next few years. TEXpress Lanes[®] are planned or under construction in four additional corridors in the DFW region and are expected to open by 2018. These include the projects summarized in Table 3 (60).

Table 3. Planned TEXpress Lanes[®] in Dallas/Fort Worth.

Project Name	Estimated Opening Date	Number of Lanes (per direction)	Pay By
NTE 35W (61)	2016 (north segment 2), 2018 (south segment)	Phase 1 and 2: two lanes; Phase 3: one lane; 3 segments (62)	Shape and size
Midtown Express (63)	2017 (Phase 1) and 2018 (Phase 2)	One lane, 3 segments	Axles

The website and smartphone applications for the current TEXpress Lanes[®] are not unified. The TEXpress Lanes[®] website presents a central point for information about every managed lane in the region. However, the TEXpress Lanes[®] brand is not shown on roadway signs.

HOUSTON, TEXAS

Description of Network

Overview of Managed Lane System

Houston's managed lane system consists of a radial HOV/HOT network of roadways that run between Houston's multiple business and commercial districts and the surrounding areas. The four roadways in the system are US 290 Northwest, I-45 North and South, US 59 Eastex and Southwest, and the I-10 Katy Freeway. The managed lanes are designed to provide priority access to transit and HOVs, while HOT functionality allows SOVs to take advantage of underused lane capacity (64). The HOV focus and limited access points for the lanes make the managed lanes most suitable for longer trips.

The Harris County Toll Road Authority (HCTRA) operates the Katy Freeway, which is branded the Katy Freeway Managed Lanes. The Metropolitan Transit Authority of Harris County (METRO) operates the other managed lanes, which are referred to as express lanes or HOV/HOT lanes.

The Katy Freeway Managed Lanes include two lanes in each direction that are divided from the main lanes by candlestick barriers (64). The other corridors in the system, I-45 North, I-45 South, US 59 Southwest, US 59 East, and US 290 Northwest Freeway, have one reversible barrier-separated lane that reverses direction during the midday to serve morning inbound and evening outbound traffic. Over 100 lane-miles of managed lanes currently operate in the Houston region and are summarized in Table 4.

Table 4. Managed Lane Facilities in Houston, Texas.

Roadway	Operator	Lane Design	Pricing Schedule
I-10 W and US 59 (Katy Freeway)	HCTRA	12 miles; four lanes, two in each direction	Open 24 hours, 7 days a week; HOV hours are Monday–Friday: <ul style="list-style-type: none"> • Eastbound—6 a.m. to 10 a.m., HOV 2+ • Westbound—3 p.m. to 7 p.m., HOV 2+ Tolls for SOVs during these periods vary from \$0.30 to \$3.20 (65)
I-45 North (North Freeway)	METRO	Each roadway includes one reversible lane	Only open during designated hours Monday–Friday: <ul style="list-style-type: none"> • Inbound—5 to 11 a.m., HOV 2+ • Outbound—1 to 8 p.m., HOV 2+ Tolls for SOVs during these periods vary
US 59 North (Eastex Freeway)			
I-45 South (Gulf Freeway)			
US 59 South (Southwest Freeway)			
US 290 West (Northwest Freeway)	METRO	One reversible lane	Only open during designated hours Monday–Friday: <ul style="list-style-type: none"> • Inbound—5 to 6:30 a.m., HOV 2+; 6:30 to 8 a.m., HOV 3+; 8 to 11 a.m., HOV 2+ • Outbound—1 to 8 p.m., HOV 2+

Roles and Responsibilities

The two main authorities managing the Houston managed lane system are HCTRA and METRO. The operating agencies have different goals for the system. METRO’s focus is on transit access and overall performance rather than maximizing toll collection. HCTRA emphasizes the improved service options for travelers and the addition of choice for drivers.

HCTRA manages the Katy Freeway Managed Lanes in addition to various other traditional toll roads in the region. Operational responsibility for the Katy Freeway Managed Lanes was transferred from METRO to HCTRA in 2008. In return for the right to operate the HOT lanes and collect tolls, HCTRA provided \$250 million in revenue bonds—backed by toll revenue from its other Houston facilities—to the reconstruction project. HCTRA also provided TxDOT with \$250 million through a 10-year loan to dramatically accelerate the Katy Freeway construction from a 12-year to a 6-year project.

METRO operates several HOV/HOT express lanes. METRO is the regional transit agency for the Houston region and manages a system of multimodal travel options. This includes a park-and-ride system consisting of 29 lots with more than 33,000 parking spots and a wide array of vanpool and carpool options in the region (66). Many of these facilities are designed with direct ramp connections to the HOV/HOT lanes in order to ensure these vehicles have priority access.

Transcore is a private contractor that handles toll operations, toll transponders for METRO (which are interoperable with HCTRA toll tags), and customer complaints.¹

Pricing System

Pricing depends on facility type, congestion level, and traffic demand, but the overarching strategy is to develop a policy that encourages HOV use and uses a toll price that rations the remaining lane capacity to ensure a reliable, high-speed trip for users. The pricing varies on a pre-established time-of-day schedule, with the highest tolls charged during the most congested times in the peak direction.

HCTRA operates the reconstructed Katy Freeway Managed Lanes, which have a different pricing structure than the METRO-operated corridors. The Katy Freeway Managed Lanes operate 24 hours a day, 7 days a week. Pricing along the Katy Freeway is a fixed time-of-day pricing schedule, with prices that adjust according to predetermined congestion estimates. During most of the day on weekdays, the toll is a flat \$0.30–\$0.40 charge. Prices increase during weekday peak travel periods based on a defined set of tiers. HOV drivers can use the managed lanes for free in the designated HOV hours; these HOV hours vary slightly on each corridor and can be adjusted in response to long-term trends. In 2013, a three-or-more-axle charge of \$7.00 per tolling plaza was introduced for truck travelers. Transit vehicles and motorcycles can travel the lanes free of charge at all times (65).

On the Katy Freeway, non-HOV users can only pay for access using a qualifying toll transponder. Toll access for SOVs on the Katy Freeway began in April 2009. Cash payments are not accepted. This is explained on the FAQ page of HCTRA’s Katy Freeway Managed Lane website (67).

METRO express lanes do not take cash payments either, but payment can be made via numerous toll tags: METRO HOT Lanes Toll Tag, Harris County EZ TAG, TxDOT TxTag®, or the Dallas NTTA TollTag. HOT lane rates have been adjusted over time, as shown in Table 5. The I-45, US 59, and US 290 managed lanes operate only during designated hours, typically limited to weekday morning and evening peak periods, with the charge for SOVs ranging from \$1.00 to \$7.00.

Table 5. Houston Managed Lane Toll Price History.

Freeway	Open to Toll (HOT)	Initial Toll Rate	Date of Change	Current Toll Rate
Katy Freeway (I-10)	4/18/2009	\$4.00	9/1/2013	\$7.00
North Freeway (I-45 North)	12/3/2012	\$5.00	1/6/2014	\$7.00
Gulf (I-45 South)	2/20/2012	\$4.50	1/6/2014	\$6.50
NW (US 290)	5/20/2013	\$5.00	1/6/2014	\$7.00
SW (US 59)	7/23/2012	\$4.50	1/6/2014	\$6.50
Eastex (US 59 North)	7/15/2013	\$2.25	1/6/2014	\$4.50

¹ Personal Communication with Metropolitan Transit Authority of Harris County, May 9, 2016.

Existing Traveler Information System

HCTRA and METRO both provide traveler information for Houston's managed lanes. METRO focuses on providing transit, park-and-ride, and other travel options alongside the managed lane information. With a primary focus on providing reliable transit and HOV service and a large existing user base, METRO does not focus on public campaigns or outreach to new users. HCTRA informs travelers about the Katy Freeway.

Pre-trip Information

METRO provides information on the express lanes on its website, a trip planner, and numerous options concerning travel with METRO. The express lane information includes a service map, definitions of access ramp types, HOV schedules and use, and payment policies. METRO introduces and links to the Katy Freeway website and includes discussion of it along with the express lanes it operates.

Due to their original design as HOV lanes, the METRO managed lanes have been developed with direct connections to many park-and-ride lots, transit centers, and other roads. Graphics that present a diagram of each access route that METRO provides to its users are presented on its website (68). Similar graphics are available for other roadway access points. In addition to transit access, openings in the barrier wall adjacent to the general traffic lanes also provide HOT lane access.

An interactive map presents all access points to the HOT lanes and can be combined with bus routes, rail lines, park-and-ride locations, and transit center information. Figure 11 presents a screenshot of a map on a smartphone that can be used by travelers for pre-trip planning purposes. It also provides basic information about how and when to use the HOV lanes. The map is available via smartphone or computer and can be viewed as a text-only version that simplifies the page. Notably, the interactive map is integrated with Bing Translator to offer translations of the site into nine languages (69).

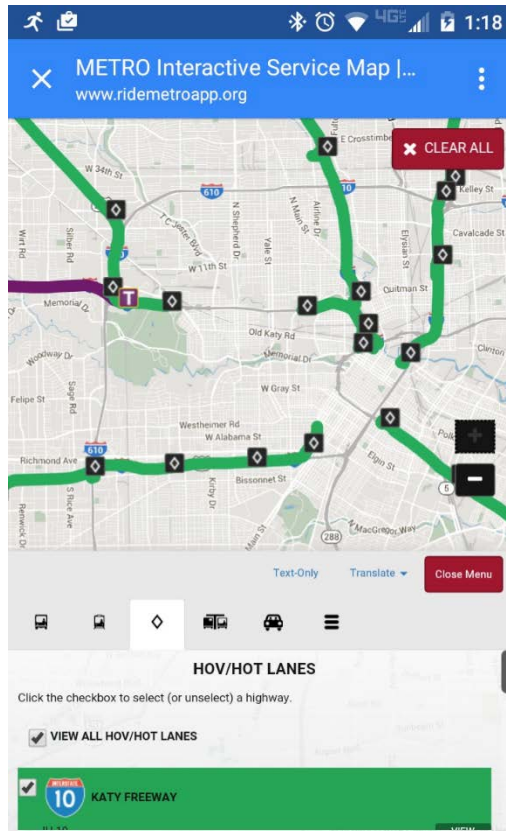
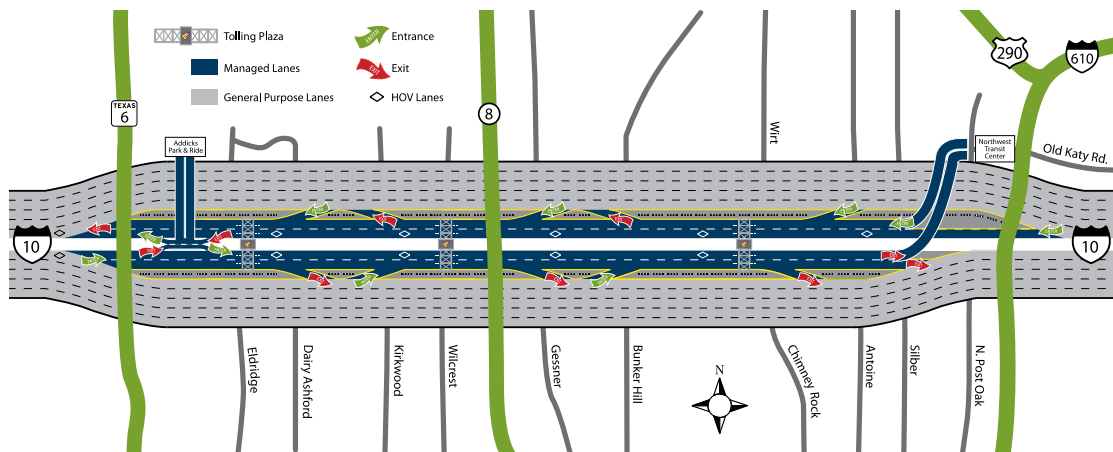


Figure 11. Screenshot from METRO Interactive Map.

HCTRA provides information exclusively about the Katy Freeway Managed Lanes. HCTRA’s website offers guidance for travelers on all its roadways, with a focus on roadway information and closures, toll tags, and payment methods. The Katy Freeway Managed Lanes website introduces the managed lanes concept and its benefits to HOV and SOV drivers, route options, information about toll transponders, and a quick toll guide for different vehicle types. The Katy Freeway Managed Lanes website explains that the managed lanes provide more options by “making underused High Occupancy Vehicle (HOV) lanes available to Single Occupancy Vehicle (SOV) drivers who pay a toll” (70). It also emphasizes that use of the managed lanes is “optional to all motorists” (67). The site explains how the managed lanes function, presents rates and rate schedules, and provides a guide based on the type of ride (e.g., HOV, SOV, or truck).

HCTRA provides a detailed map of the managed lanes that includes entrance and exit points for drivers and details the access available from park-and-ride lots. The map is shown in Figure 12 and is available as a downloadable PDF as well (71).



Source: (71)

Figure 12. Katy Freeway Managed Lanes Map.

HCTRA has a mobile application for smartphone use, but the app currently only offers telephone numbers for assistance, customer service, news, and a map (the map was not functional when researchers attempted to review the application). HCTRA reports that EZ Tag account management will soon be available through the application.

En-Route Information

Traveler information is mainly communicated through signage once travelers are en route. METRO-operated lanes are labeled “Express Lane,” and the Katy Freeway Managed Lanes are labeled “Katy Tollway,” in contrast to the website logo. The access points to the managed lanes are marked by signage that presents the HOV occupancy requirement and the current toll price. Figure 13 presents such a sign from I-45 in Houston. The sign also includes the toll tag logos that can be used to pay the toll.



Figure 13. METRO Express Lanes Entrance Signage.

Upon entering the managed lanes, a driver is given the opportunity to identify himself or herself as a qualified free user (e.g., a bus, vanpool, or carpool with enough occupants) or a toll payer

(depending on the time of day and individual facility) by moving through separate lanes on the HOT facility and/or at one of the access points. These declaration points are identified by the signage shown in Figure 14. Overhead signage at self-declaration points originally stated “HOV Only” and “All Others.” The “All Others” term was replaced with “EZ Tag Only” to clarify better who could use the lanes. HCTRA is also considering an application that can be used for toll declaration on the Katy Freeway.² Roadway signage directs travelers to park and rides, exit ramps, and other roadway connections.

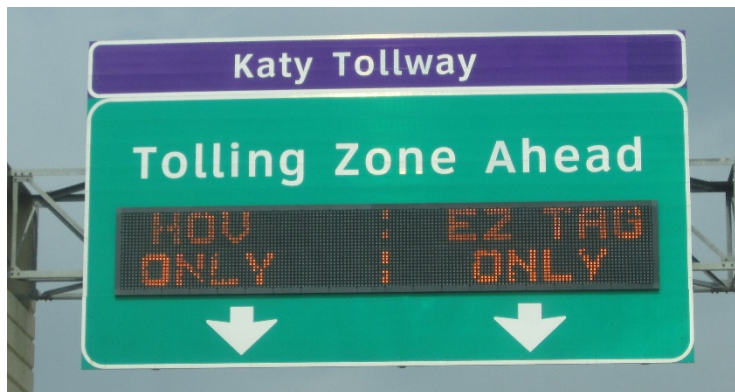


Figure 14. User Declaration Sign on the Katy Freeway.

Post-Trip Information

HCTRA’s Katy Managed Lanes website includes a page for travelers who may have missed a toll (<https://www.hctra.org/MissedAToll>). It informs drivers who use a tolled road without a transponder to avoid a violation fee by reporting the missed toll. Drivers can also search for toll violations by license plate number. This option is only available once per year per driver. Drivers are otherwise encouraged to use an EZ TAG and directed to sign up online (72).

Pricing is presented on the managed lane websites, along with roadway signage. Pricing information is available on METRO’s website for all times of day in the table format shown in Figure 15.

² Personal Communication with the Texas Department of Transportation—Houston District, May 2016.

INBOUND

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
5:00 a.m.	CLOSED	\$1.00	\$1.00	\$1.00	\$1.00	\$1.00	CLOSED
6:00 a.m.	CLOSED	\$4.50	\$4.50	\$4.50	\$4.50	\$4.50	CLOSED
6:30 a.m.	CLOSED	HOV 2+ Only	HOV 2+ Only	HOV 2+ Only	HOV 2+ Only	HOV 2+ Only	CLOSED
8:00 a.m.	CLOSED	\$2.25	\$2.25	\$2.25	\$2.25	\$2.25	CLOSED
9:00 a.m.	CLOSED	\$1.00	\$1.00	\$1.00	\$1.00	\$1.00	CLOSED
10:00 a.m.	CLOSED	\$1.00	\$1.00	\$1.00	\$1.00	\$1.00	CLOSED
11:00 a.m.	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED

Source: (73)

Figure 15. METRO Pricing Table for US 59 North.

Future Possibilities

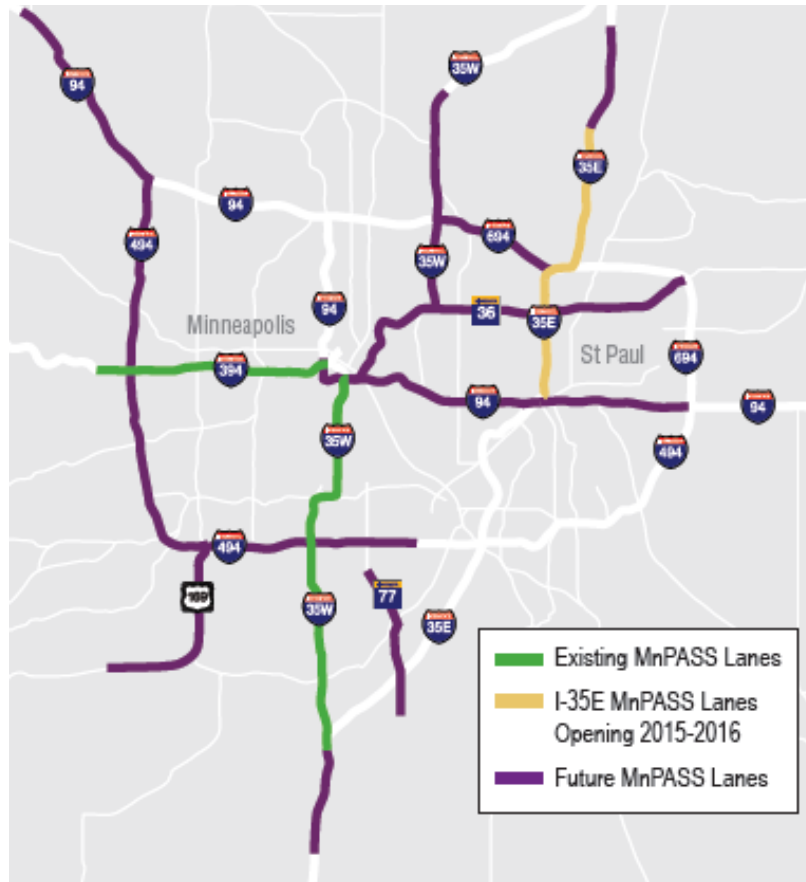
Having evolved from its early efforts to provide improved travel conditions for transit buses and vanpools using HOV lanes, the managed lane system in Houston is uniquely focused on continuing to prioritize these HOVs. Routes serve travelers in the congested corridors between the region’s residential suburbs and its multiple business districts in and around downtown Houston. At the same time, the introduction of variable pricing and tolling technology increases the complexity of this system for users. Looking forward, new express lanes are being planned for SH 288. These lanes would not offer any HOV discount, unlike the existing managed lanes in the Houston region. This may create additional confusion for travelers when the facility opens. Finally, a more complex and more interconnected managed lane network could be increasingly difficult to coordinate, given HCTRA and METRO’s different perspectives and goals.

MINNEAPOLIS–ST. PAUL, MINNESOTA

Description of Network

Overview of Managed Lane System

The managed lane network in the Twin Cities area of Minneapolis–St. Paul, Minnesota, consists of two fully operating express lane corridors (I-394 and I-35W) (74). A third express lane corridor (I-35E) has recently opened (75). There are plans to expand the express lane system in the Twin Cities area in the future. Figure 16 shows the location of express lanes currently operating, under construction, and planned in the Twin Cities area.



Source: (76)

Figure 16. Map of Existing and Future Planned MnPASS Lanes.

HOT lanes on I-394 opened in 2005 and were a conversion from HOV lanes. The I-35W HOT lanes were similarly converted from HOV lanes in 2009 (74). Unlike many other express lanes across the country, vehicles with two or more occupants, motorcycles, and transit buses can use the express lanes for free at all times without having to purchase a MnPASS transponder. SOVs are only permitted to use the express lanes during the designated peak hours of operation if they own a MnPASS.

Two new types of MnPASS tags were made available in 2015—a free sticker tag and a switchable tag with a one-time \$15 fee (77). The switchable tag allows travelers to designate whether they are traveling alone or traveling with at least two total people in the vehicle, thereby avoiding the toll associated with SOV use when the requirements for using the express lane for free are met. In contrast, the sticker version of MnPASS will charge users as if they are SOVs whenever they use the express lane, regardless of the vehicle occupancy (76). Using an older-style transponder allows express lane users to remove it from the windshield when they have two or more persons in their vehicle so that they are not charged a fee (78). Images of the free sticker tag and the switchable tag are provided in Figure 17 and Figure 18, respectively. The MnPass is not currently interoperable with other tolling systems, but there are plans to enact interoperability soon, possibly by 2017 (79). Portable transponders can be moved for use by the same owner in different vehicles (80), and travelers can obtain a sticker tag for each of their vehicles (81).



Source: (76)

Figure 17. Free Sticker Tag.



Source: (76)

Figure 18. Switchable Tag.

SOV travelers who pay to use the express lane are not allowed to use the ramp meter bypass lanes (82). The MnPASS lane is separated from the adjacent general-purpose lane by double white lines. When the lines are solid, it is illegal to enter or exit the MnPASS lane, and violators may be charged a \$142 fine (83). However, when the lines are dashed, it is permissible to enter or exit the MnPASS lane (76).

Roles and Responsibilities

The Minnesota Department of Transportation (MnDOT) is the only agency that does tolling in the Twin Cities area. The MnPASS System has a back-office portion of the system and a customer service aspect of the system. MnDOT has contracted with the state highway patrol to enforce the proper use of the express lanes through the use of enforcement transponders and mobile enforcement readers (84).

Pricing System

In December 2015, MnDOT started using full-color dynamic message signs along the portion of the I-35E express lanes that is currently operational. Figure 19 presents a graphic of the display for the full-color message sign. The MnPASS logo is shown in purple with white lettering, and the rest of the sign has a black background with white lettering. The signs are the only place that toll prices are shown. MnDOT does not display real-time toll information on a website because the price will likely have changed by the time a traveler is actually using the roadway.³

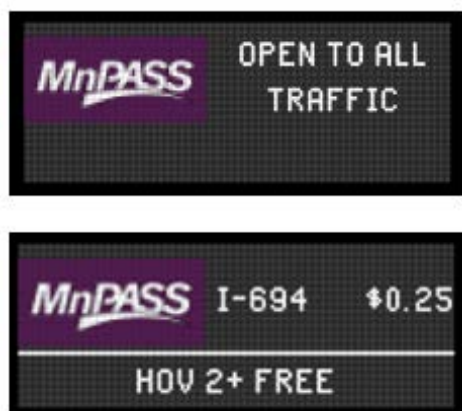


Figure 19. MnPASS Full-Color Dynamic Message Signs for Use on I-35E.

Slight differences exist for hours of operation and type of signage associated with different MnPASS corridors within the Twin Cities area. However, the basic operation for all of the MnPASS lanes in the region is similar. Toll-paying express lane users are locked into the toll they are shown as they enter the express lane. However, MnDOT charges drivers the lowest price shown within a 9-minute range (3). The toll rate varies depending on traffic, with a minimum toll of \$0.25 and a maximum toll of \$8 (84) for a given section (79). Average toll prices during peak periods are in the range of \$1 to \$4 (85). Tolls are set with the goal of keeping the MnPASS lane traveling at 50–55 mph (84).

The toll is shown on overhead signs directly before the MnPASS lane entrance (84). Toll pricing signs show either one or two destinations. The two displayed prices are not additive; rather, the first price is the price to travel from the traveler's current location to the first location, and the second price is the price to travel from the traveler's current location to the second destination (86).

Existing Traveler Information System

Pre-trip Information

Toll rates are not provided to travelers before their trip (3). However, travelers can get information from the online website where MnPASS lanes are operated, hours of operation, and how to set up a MnPASS account prior to their travel on a MnPASS corridor (76).

³ Personal Communication with the Minnesota Department of Transportation, July 7, 2016.

En-Route Information

The most prevalent form of en-route information for the MnPASS lanes is signs. As noted earlier, dynamic message signs are used to convey toll information that changes dynamically. With the planned I-35E express lanes, signs will also be used to delineate entrances and exits associated with the MnPASS lane (84). During off-peak hours of operation, the MnPASS lane will be open to all travelers for free, and the dynamic signs will be changed to say “Open to All Traffic” or “OPEN,” indicating that anyone is allowed to use the lane for free (87). The media may be used to relay information about an incident along the MnPASS lane corridor (3). The dynamic toll rate signs discussed earlier are an innovative approach to sign design.

Post-trip Information

A MnPASS live chat feature is available on the MnPASS website, where persons with a MnPASS account number can ask questions and receive answers Monday through Friday, 8 a.m.–5 p.m. (88). MnPASS recently created a new account management system that requires registration by MnPASS users (76).

Future Possibilities

No connections are planned or programmed for MnPASS lanes (3); however, as Figure 16 shows, there are plans for further extensions of MnPASS lanes. The fully dynamic message signs used to indicate the price on the MnPASS lanes are a novel concept that will provide MnDOT flexibility in its future operation of express lanes in the Twin Cities area.

MIAMI, FLORIDA

Description of Network

Overview of Managed Lane System

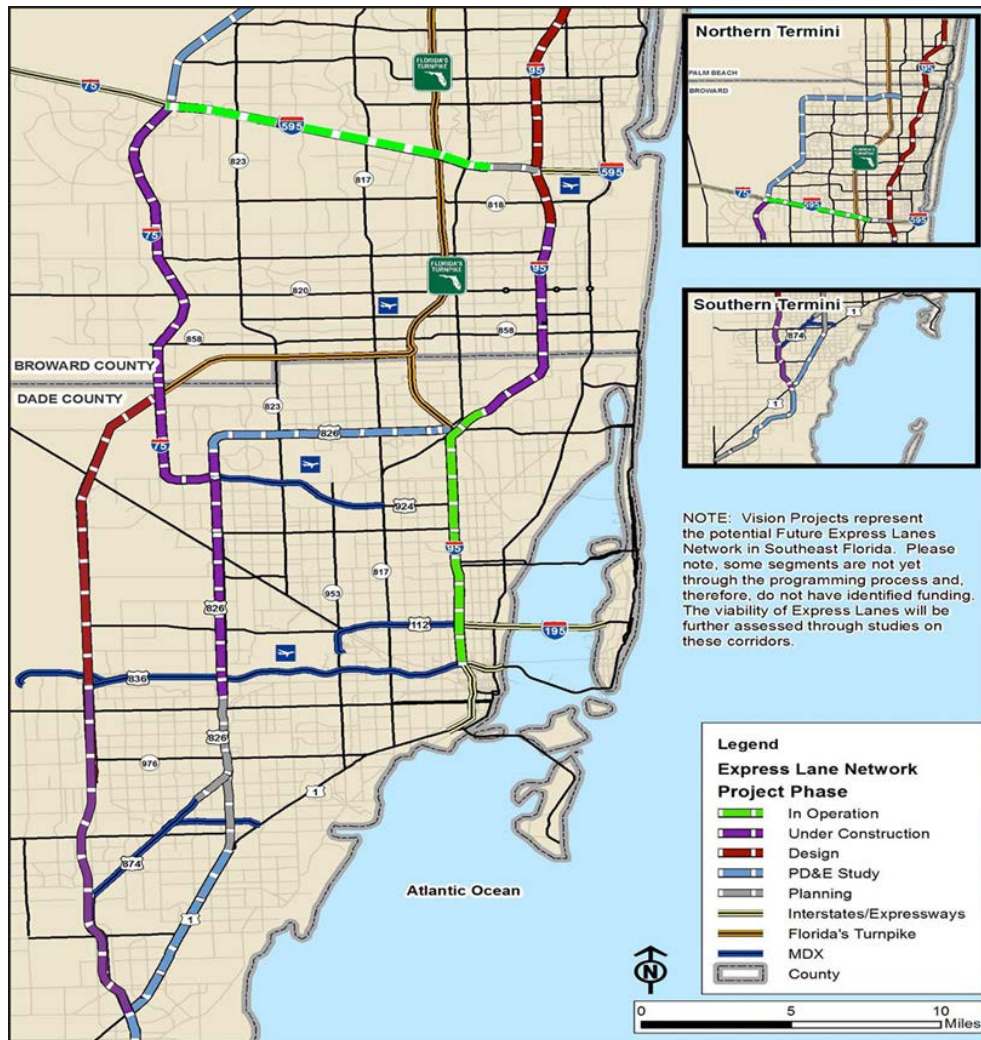
In the Miami, Florida, region, the Florida Department of Transportation (FDOT) currently operates a growing managed lane network. The network is commonly referred to as the south Florida network because the managed lane system extends beyond Miami-Dade County into adjacent Broward County. The south Florida network currently includes two managed lane facilities: the 95 Express and the 595 Express. Figure 20 shows the logo for the South Florida Express Lanes.



Figure 20. South Florida Express Logo.

The 95 Express and 595 Express are congestion-priced managed lanes within their respective freeway corridors. Both roadways are part of a collection of radial and axial corridors that cover a large area of Broward and Miami-Dade Counties. In addition, several extensions and new

routes are in various stages of planning, design, and construction. An extension of the 95 Express that will convert existing HOV lanes north of the 95 Express to express lanes in both directions is currently under construction (89). The 75 Express within the I-75 corridor and the Palmetto Express managed lanes within the SR 826/Palmetto Expressway are currently under construction (90). Each of these managed lane corridors will be part of a large network of interconnected, congestion-priced managed lanes in southeast Florida. Additional facilities are being planned, and studies are underway to consider further expansion of the managed lane network in the future. Current, under construction, and potential future facilities are shown in Figure 21 (91).



Source: (91)

Figure 21. South Florida Express Lanes Network.

A number of other traditional tolled facilities operate in the south Florida roadway network. The Florida's Turnpike Enterprise (FTE) operates the Turnpike Mainline, also designated as SR 91, that begins near Florida City in Miami-Dade County and connects to the central and northern regions of Florida, and the Homestead Extension of Florida's Turnpike (HEFT) located on SR 821 that travels around the west side of the Miami metropolitan area and connects with

US 1 north of the Florida Keys (92). The Miami-Dade Expressway (MDX) Authority also owns five tolled facilities in the region (93):

- SR 112/Airport Expressway.
- SR 836/Dolphin Expressway.
- SR 874/Don Shula Expressway.
- SR 878/Snapper Creek Expressway.
- SR 924/Gratigny Parkway.

The FTE and MDX corridors are exclusively tolled facilities and do not have a general-purpose lane component or any other non-tolled component.

Roles and Responsibilities

FDOT owns and operates the express lane facilities in south Florida. Two FDOT districts are involved in design, construction, operations, and maintenance of the system because the managed lane network extends from Miami-Dade County (District 6) into the adjacent Broward County to the north (District 4); FDOT will own and operate the extensive managed lane system being developed and shown in Figure 21.

Administrative tasks within FDOT are divided into setting tolls, which is performed by one division, and back-office and customer service issues, which are addressed by another division in conjunction with FTE. FTE also owns, operates, and maintains its facilities (SR 91/Turnpike Mainline and HEFT), and Miami-Dade Expressway Authority contracts with FTE to operate MDX facilities.

Transponders for all facilities are issued and administered through the SunPass program, which is also a function of FDOT. SunPass is a prepaid toll program in which tolls are electronically deducted from a prepaid account (94). There are two types of transponders available: the SunPass portable transponder costs \$19.99 plus tax, and the SunPass mini sticker transponder costs \$4.99 plus tax (out-of-state customers are required to pay a 6 percent sales tax). Transponders can be purchased online or at Turnpike service plazas and gas stations, SunPass Service Centers, and a variety of authorized retailers such as Publix supermarkets, CVS pharmacy stores, and Walgreens stores (95).

Pricing System

The 95 Express Lanes facility uses a congestion pricing strategy, which is locally referred to as dynamic tolling (96). Toll rates are set based on congestion, so pricing is variable throughout the day and may vary from one day to the next. The toll amount is displayed on the overhead electronic signs before each of the 95 Express entrances so drivers have time to decide to use the express lanes or stay in the general-purpose lanes.

FDOT explains that toll rates on the 95 Express are based on the traffic conditions of the express lanes only and not on the conditions of the local lanes. Roadway monitors are used to gather volume and speed data that are used to determine whether tolls go up or down to provide the best conditions possible. As the express lanes become more congested, toll rates increase. As the

congestion goes down, toll rates decrease. A similar description of tolling is provided for the 595 Express Lanes (97) and Palmetto Express Lanes (96). Information on the website for the 595 Express Lanes also describes the method by which tolls are calculated for trucks, stating that toll rates for three-or-more-axle vehicles are calculated by taking the current displayed rate for a two-axle vehicle, dividing by two, and multiplying by the number of axles. For example, if the rate displayed is \$0.50, an 18-wheeler with five axles would be charged $\$0.50/2 \times 5 = \1.25 .

Tolling is completely electronic; vehicles displaying a registered SunPass transponder have tolls charged to the corresponding SunPass account, while vehicles without a SunPass transponder are charged by mail based on the information associated with the vehicle's license plate, which is photographed at the toll plaza at the time of travel. Drivers who qualify may use the 95 Express Lanes for free after registering their vehicles (98). Registered vehicles must place their South Florida Commuter Services-issued decal on their windshield. All exempt drivers must shield their SunPass transponders to avoid being charged for using the lanes. Vehicles can qualify under any of the categories below:

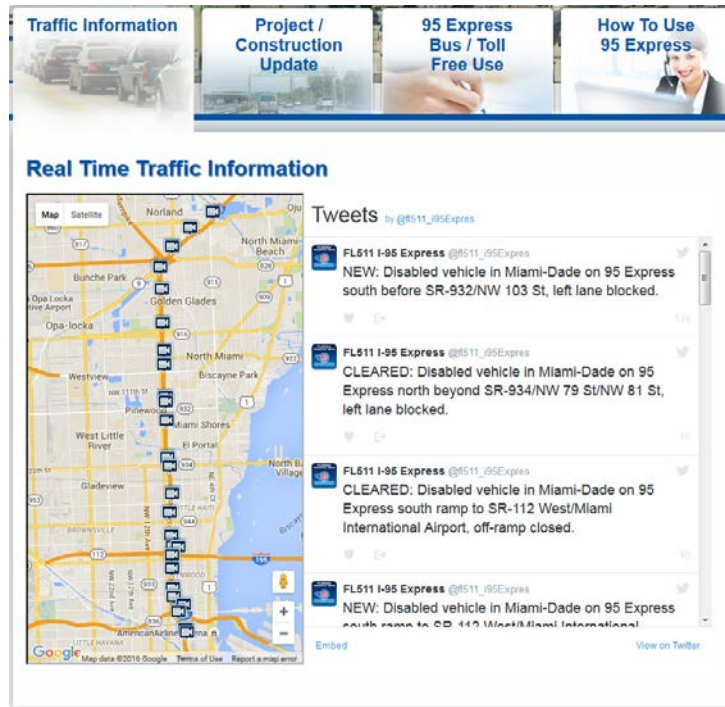
- Registered south Florida vanpools.
- Registered carpools of three or more.
- Registered hybrid vehicles.
- Registered buses.
- Motorcycles (which do not have to register).
- Emergency vehicles (which do not have to register).

Existing Traveler Information System

Pre-trip Information

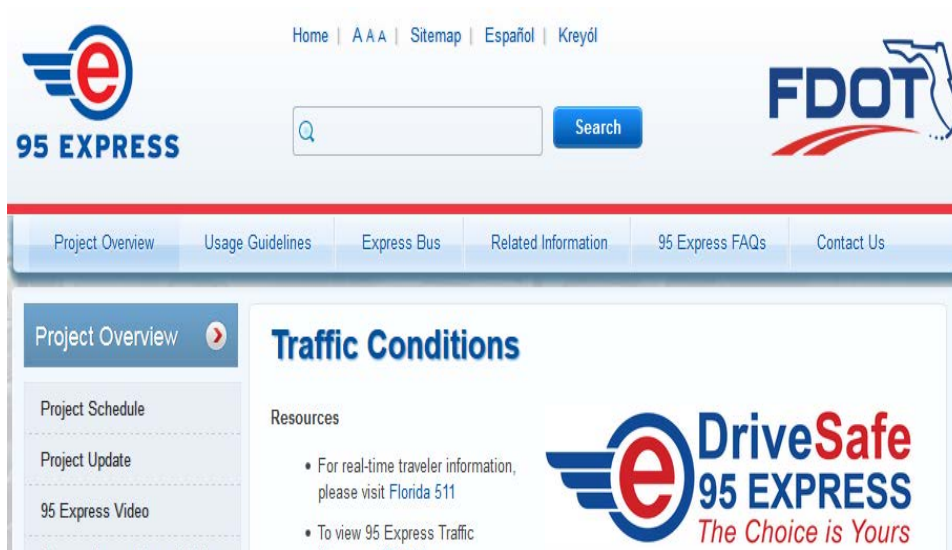
FDOT provides information on the express lanes through a suite of websites, with each site dedicated to a specific facility. The 95 Express Lanes site provides a real-time traffic information display on the homepage; the display includes a map of the facility with clickable icons for traffic camera locations to see real-time camera images. The display also includes the feed for the 95 Express Lanes dedicated Twitter® account. Figure 22 shows a screenshot of this information from the 95 Express Lanes website.

The 95 Express Lanes site also provides additional links under a project overview heading. Users can find information on ongoing project schedules and updates, an informational video about the facility, a diagram of the corridor's entry/access points, links to additional sources of traffic conditions (see Figure 23), construction announcements, and a link to the website's FAQs.



Source: (99)

Figure 22. Real-Time Traffic Information on 95 Express Website.



Source: (100)

Figure 23. Project Overview Section of 95 Express Website.

The Palmetto Express and 595 Express websites do not provide the same detailed real-time travel information as the 95 Express website, but they do provide descriptions and diagrams of access points. The Palmetto Express website has a separate page for scheduled lane closures, and the 595 Express website offers a link to the Florida 511 traffic information website through its homepage.

Guidelines for using the 95 Express Lanes are provided on the websites. The first guideline for using the managed lanes on each website advises potential travelers that the express lanes are intended for long-distance commuting, and shorter trips are probably better served through the general-purpose lanes. In particular, the websites advise motorists that once they have entered the express lanes, they need to continue all the way to the end. The sites also provide general safety procedures for the lanes, information about toll collection and registration, and a telephone number for more information (101).

En-Route Information

Traveler information is mainly communicated through signage once travelers are en route. The most critical item currently communicated is lane status (e.g., open/closed/congested) displayed on changeable message signs. Customers have requested a mobile app or other methods of communicating traffic alerts. As mentioned previously, FDOT has developed a method to filter out alerts for 95 Express from the alerts for other corridors. FDOT puts those alerts on a dedicated Twitter® handle and reposts that feed on the 95 Express website, which would primarily be accessed pre-trip but could be accessed by vehicle passengers en route. As a result of this feature, FDOT reports a large decrease in customer requests for information and that it is looking for ways to add useful pieces of pre-trip information.⁴

FDOT recommends use of changeable message signs during actual travel. Much of the necessary construction and maintenance are done at night whenever possible, though alerts are shared during the day as appropriate. There are no reversible lane strategies at present, so this is not a current communications need.

Toll rates are not shared through the website or other electronic means but through physical signage on the roadway. The reason given by FDOT for this policy is that, to date, the price is subject to change, and FDOT does not want to provide different rates to a person pre-trip and at the point of decision. FDOT has seen an increase in traveler requests for toll information pre-trip and may be more open to explore providing that information in the future (4).

Area transit agencies also communicate their transit route information to transit services that travel through managed lanes. It is useful for passengers to know that their potential transit route may have delays due to incidents on the freeways in general and on the managed lanes in particular. Some community groups market to their constituencies the partnership between transit services and managed lanes to encourage people to use them (including covering their registration with the transit agency to get bus passes or SunPasses) (4).

FDOT noted that some users confuse the 95 Express and MDX routes. FDOT uses 95Express.com in all of its materials, and MDX does try to route users to 95 Express if it receives questions intended for them. There is also some confusion about SunPass and where it is applicable and who administers it; the SunPass statements describe which facilities were traveled on, but travelers do not always understand the distinction. Additionally, there may be some confusion about differences in tolling policies between facilities, particularly with discounts for transponder versus pay by plate (4).

⁴ Personal Communication with the Florida Department of Transportation, July 1, 2016.

Post-trip Information

The 95 Express Lanes website addresses tolling issues for travelers who are not registered users in the tolls section of its FAQs (96). The website informs drivers who use the express lanes without a transponder that they can voluntarily mail a toll payment to FTE, and the website provides the mailing address. The website also includes instructions for calling SunPass Customer Service if the traveler cannot remember the value of the toll in effect at the time. Similar items are shown on the websites for 595 Express and Palmetto Express, but all three websites encourage drivers without SunPasses not to use the express lanes (96).

Future Possibilities

Multiple expansions and extensions of the south Florida managed lane network are already in various stages of implementation. FDOT is implementing Phase 3 of the 95 Express Lanes continuing 29 miles north from Stirling Road in Broward County to Linton Boulevard in Palm Beach County. The first segment started construction in mid-2016, and the third and final segment is scheduled for construction in 2020 (102).

FDOT is implementing express lanes along 28 miles of the I-75 and SR 826 (Palmetto Expressway) corridors, from just south of SR 836 (Dolphin Expressway) in Miami-Dade County to I-595 in Broward County. This project, known as the 75 Express Lanes, will complete another section of the south Florida managed lane network for all motorists and is intended to improve mobility, relieve congestion, provide additional travel options, and accommodate future growth in the area (103).

Florida's Turnpike Enterprise is exploring the implementation of express lanes within its toll facility (toll within a toll) on SR 91 in south Florida (4). The new configuration would be similar to the express lanes on I-95 and other facilities except that the entire facility is tolled, and an additional toll would be charged on the express lanes for long-distance commuters to avoid the local traffic along that portion of the Turnpike Mainline.

SEATTLE, WASHINGTON

Description of Network

Overview of Managed Lane System

The Washington State Department of Transportation (WSDOT) operates HOT and express toll lanes in the Seattle region. The managed lane facilities are shown in Figure 24 and include the following facilities:

- SR 167 HOT Lanes.
- I-405 Express Toll Lanes.

In May 2008, Washington's first HOT lanes, a conversion of the existing HOV lanes, opened on SR 167. SOV drivers can pay an electronic toll to drive in the HOT lane and access "the stress-free, reliable trip the carpool lane offers" (104). I-405 Express Toll Lanes opened in mid-2015 with electronically tolled lanes adjacent to the general-purpose lanes from Lynnwood to Bellevue

(105). These managed lanes are free for HOVs with two or three passengers (depending on time of day) and allow vehicles that do not meet the HOV requirements to pay a dynamically priced toll fee to use the lanes. Currently, each of these managed lanes operates independently and has no direct connections. Table 6 summarizes the operations of these managed lanes.



Source: (106)

Figure 24. Tolled Facilities in Seattle.

Table 6. Operational Managed Lanes in Seattle.

Project Name	Road Number	Pricing Structure	Roadway Configurations	Rate Set By
SR 167 HOT Lanes	SR 167	HOV 2+ use lanes for free Monday–Sunday 5 a.m. to 7 p.m.; lanes are open to all drivers and charge no tolls 7 p.m. to 5 a.m. Rates are between \$0.50 and \$9.00.	One lane in each direction; 9 miles.	Destination-based segment pricing
I-405 Express Toll Lanes	I-405	HOV 3+ use lanes for free Monday–Friday 5–9 a.m. and 3–7 p.m.; HOV 2+ use lanes for free 9 a.m.–3 p.m. The minimum toll rate is \$0.75, and the maximum is \$1. Nights and weekends are always free.	Two lanes in each direction from NE 6th to SR 522; one lane in each direction from SR 522 to I-5. Two direct access ramps; 17 miles.	Destination-based segment pricing

WSDOT also operates a larger network of HOV lanes throughout the state. WSDOT is planning to expand the network of HOT managed lanes, and by 2019, the network will include direct connections from HOV lanes to HOT lanes. Additional tolled facilities exist on the SR 520 Bridge (a fixed time-of-day toll with no discounts for HOVs) and the Tacoma Narrows Bridge south of Seattle (a flat, fixed fee for vehicles traveling eastbound). The SR 520 Bridge operates on a fixed time-of-day pricing scheme that ranges from \$0 from midnight to 5 a.m. up to as much

as \$4.10 during peak daytime periods. Rates are higher for travelers without an electronic pass (107). Characteristics about the two priced managed lane facilities in the Seattle region are shown in Table 6.

Roles and Responsibilities

WSDOT operates and maintains Washington State's highway network, bridges, ferries, and public transportation systems. WSDOT is the only operator of toll roads in the state. It designs, operates, and maintains the managed lanes. In addition, WSDOT manages communications, including public education and marketing efforts related to the managed lanes.

The Washington State Transportation Commission (WSTC) is the state tolling authority appointed to set roles for state highways and bridges and develop a statewide transportation plan. WSTC reviews traffic and revenue annuals to determine if changes to existing toll rates are needed (108). In March 2016, WSTC introduced new rules that modified the hours of operation for the I-405 managed lanes and managed public hearings and feedback on such policy decisions (109). In addition to providing policy guidance, WSTC conducts state outreach on transportation policy, promotes transportation education, and undertakes studies and surveys.

Pricing System

The SR 167 HOT Lanes and I-405 Express Toll Lanes use dynamic pricing designed to ensure free-flowing traffic in the managed lanes when the general-purpose lanes are congested. The state transportation policy board of WSTC dictates pricing policy for the managed lanes and all other tolls in the state. The managed lanes rates have a fixed maximum and minimum cost. Prices fluctuate within this range based on the number of vehicles currently using the facilities in order to maintain free-flow speeds, which are defined as "at least 45 miles per hour 90 percent of the time" (110).

Rates on the SR 167 HOT lanes are based on congestion and range from \$0.50 to \$9.00. Carpools of two or more riders can use the HOT lanes toll free. I-405 toll rates range from \$0.75 to a maximum of \$10.00. Drivers on I-405 are presented with up to three toll rates as they enter the express lanes. Transit, vanpools, and motorcycles can use the managed lanes toll free at all times.

All tolling facilities in Washington use the Good to Go electronic payment system, first introduced in 2007 for the Tacoma Narrows Bridge toll. The Good to Go system allows users to set up an account that offers a lower cost than charged by the photo-enforced pay-by-mail system. Good to Go users can obtain a Flex Pass (shown in Figure 25), which allows users to set their HOV status and receive free access to the facilities on SR 167 HOT Lanes and I-405 Express Lanes (111). For the I-405 Express Lanes, carpools that meet the occupancy requirements to ride toll free must have a Good to Go Flex Pass that can be set to HOV mode (112). In contrast, on SR 167, carpools do not need a pass to prove their HOV status, but travelers who do have a Flex Pass must set it to HOV mode to avoid being charged the toll (113).



Source: (114)

Figure 25. Good to Go Pass Toll/HOV Indicator.

Existing Traveler Information System

WSDOT is the sole operator of managed lanes in Washington State and the main provider of information for traveling on the managed lanes. On-road signage provides the majority of information related to access and pricing. As the central point of information for all transportation activity in the state, WSDOT presents managed lane information alongside information about traffic, weather, public transportation, commute options, construction projects, and planning information. Managed lanes focus more on performance trends, project milestones, and lane closures and less on toll rates. Customer service operations answer questions from the public, and targeted educational campaigns are used to inform users of road openings, transponder sales, and special events.

WSDOT maintains a diverse set of social media outlets, including Facebook[®], Twitter[®], YouTube[®], and a blog (115). The social media outlets are used for all transportation information and do not typically report on toll rates or travel times. WSDOT has a smartphone application that provides access to the traffic map, social media feeds, and static summary information about toll rates.

Pre-trip Information

WSDOT's website is the primary source for pre-trip information about all transportation activities in the state, including tolling and managed lanes. As such, tolling and managed lane information is presented equally alongside traffic information, construction projects, and other general information about highways in the state. Additionally, the WSDOT website includes the managed lane information on a real-time traffic roadmap for the Seattle region as well as some educational and marketing material for the various managed lanes. The traffic map, which includes updates on all roadways in the region, is widely circulated by WSDOT on social media and by local news outlets during traffic reports (115). Figure 26 shows an online map that is accessible to travelers within the Seattle region.

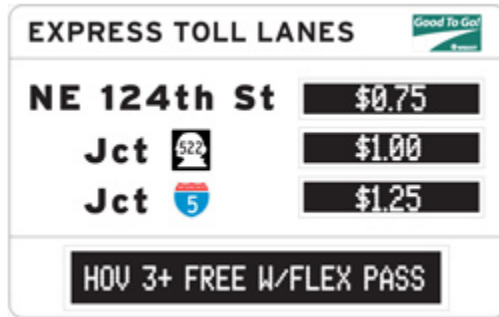


Source: (116)

Figure 26. WSDOT Real-Time Traffic Map.

The WSDOT website offers an example of roadway signage (Figure 27) and a video about how to interpret the signs. The WSDOT website also presents educational videos to help travelers understand issues, with titles including “Why Rates Change” and “How to Read the Signs.” Toll rate ranges and fixed time-of-day schedules are provided on the website, the WSDOT app, and print materials, but real-time price fluctuations are not made available. WSDOT staff are concerned about the confusion that would arise if a price looked up ahead of time differs from the price when a driver reaches the roadway. However, WSDOT is considering providing historical prices on the website.⁵

⁵ Personal Communication with the Washington State Department of Transportation, July 2016.



Source: (117)

Figure 27. Pricing Sign Graphic from the I-405 Express Lanes.

En-Route Information

The region primarily relies upon roadway signage with dynamic panels to show en-route travel information. This includes information about toll lane prices, HOV occupancy requirements, payment requirements, and access points. Real-time prices for the managed lanes are only provided on roadway signs and cannot be looked up in advance on the website.

Rates are posted at each access point, and drivers are charged once for the amount displayed when the vehicle enters the lane (108). SOV drivers on SR 167 pay per trip one toll that is displayed on overhead signage when they first enter the HOT lane. I-405 HOT lanes include three destination zones, which allow for pricing variations tied to end location (118). HOV occupancy requirements, each destination point, and the current charge to that destination are presented on signage above the 405 Express Toll Lanes.

Roadway signage also exists to display hours of operation, use of photo tolling (where applicable), weight restrictions in lanes, customer service information, notices of weight restrictions and legality of crossing the lane buffer strip, and local access information. Local access information alerts drivers to which general lane exits they can access if they exit the managed lanes. Travel times for the general-purpose and managed lanes are presented at decision points as well. Transit and park-and-ride information is not provided on roadway signage.

Real-time toll rates are typically provided only on the roadways themselves in proximity to access opportunities. Pricing is segment based and presented as a single destination price. A traveler who enters I-405 from its southern end will see three prices based on destinations. These prices are not additive but a total rate to each of those destinations. WSDOT staff reported some customer confusion as to whether rates were additive. Some local roadways that link directly to the managed lanes have signage to show pricing, but typically WSDOT avoids presenting prices far in advance to avoid traveler frustration with price changes (5).

Post-trip Information

The WSDOT website includes a webpage focused on tolling and toll payments. There is a Good to Go website where users can open and manage their accounts, pay bills, and look up penalties. Customer service is also offered by phone and at three locations in Washington (119). WSDOT marketing staff monitor all social media for public feedback and reply to every comment (5).

Future Possibilities

In 2016, WSDOT released an application program interface (API) to access the tolling data from the managed lanes. This open data access allows developers or individuals to use these data to create applications that present these data for travelers. WSDOT's long-term vision is a 40-mile express toll lane system between SR 167 and the I-405/I-5 interchange. The existing express toll lanes on I-405 will expand north and eventually may include a direct connection between SR 167 and I-405 (120). This connection will be installed as an HOV-to-express lane connection until 2023. In 2023, the HOV lanes will convert to express lanes, creating an all-express-lane system. Signage and traveler information will have to communicate these changes and take into consideration the future configuration of the roadway network.

SAN FRANCISCO, CALIFORNIA

Description of Network

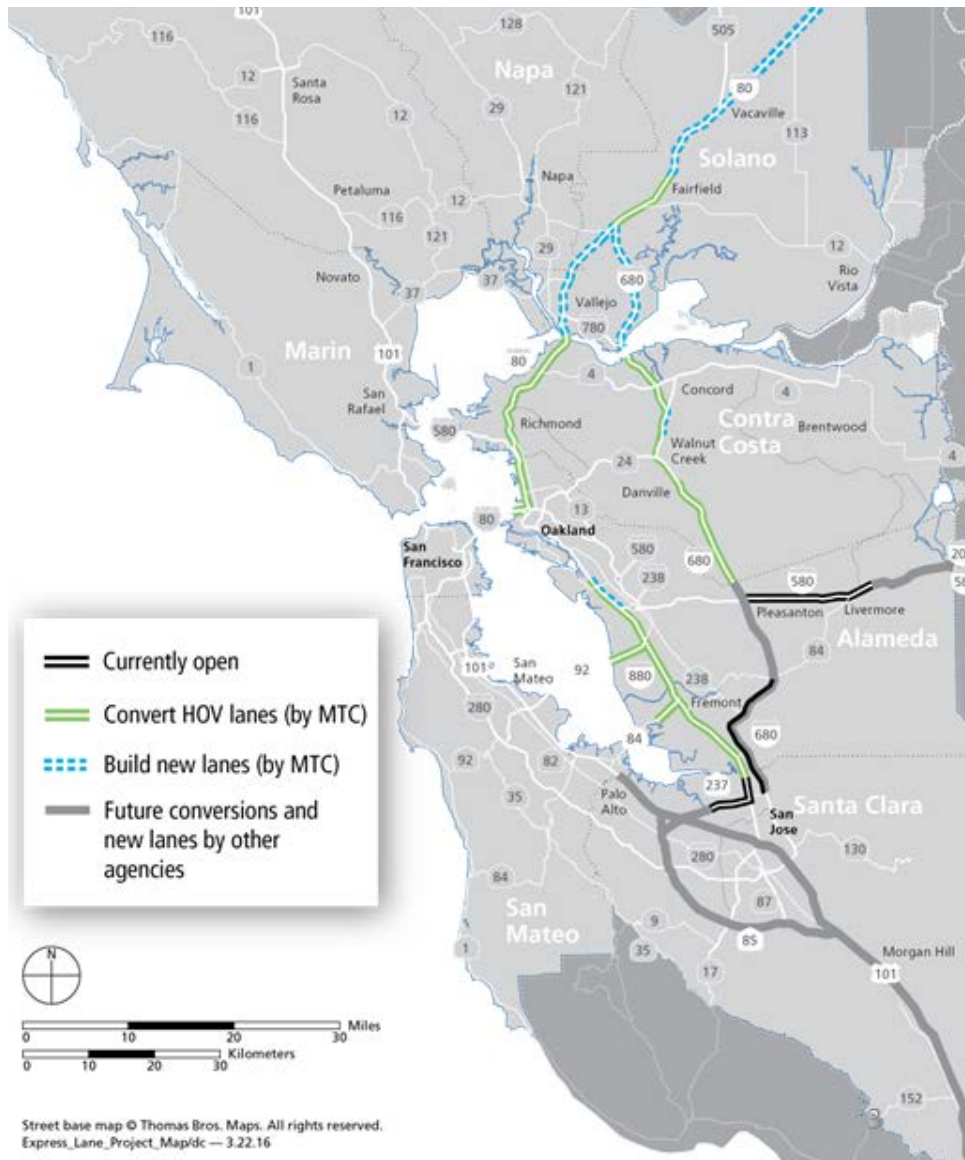
Overview of Managed Lane System

The Bay Area Express Lanes in the San Francisco, California, area include a number of managed lane facilities in various stages of operation, planning, and development. The Bay Area also includes an existing system of HOV lanes. Currently operating managed lane roadways are (121):

- I-580 operated by the Alameda County Transportation Commission (ACTC).
- I-680 operated by ACTC.
- SR 237 operated by the Santa Clara Valley Transportation Authority (VTA).

The Metropolitan Transportation Commission (MTC), the regional transportation planning agency for the nine-county San Francisco region, does not currently operate any functioning managed lanes but will soon become a major express lane operator in the area. In 2011, the California Transportation Commission gave MTC authority to develop and operate 270 miles of express lanes. The 270-mile future system will include 150 miles of HOV-to-HOT conversion and 120 miles of new express lanes. MTC has longer-term plans to develop more express lanes, which include conversions, gap closures, extensions, and interchanges (122).

Figure 28 provides a map showing the status of current and planned express lanes in the Bay Area. By 2035, it is anticipated that the Bay Area Express Lanes system will include 550 miles of express lanes (123).



Source: (124)

Figure 28. Bay Area Express Lane Projects—Operational and In Development.

The system involves numerous operators, roadways with different tolling hours, and different transponder requirements. Although the Bay Area has multiple express lane operators, an MTC goal is to ensure that travelers have a seamless experience using facilities operated by different entities (Figure 28). The unique business rules of each operating agency create some operational hurdles, including the need to develop consistency in hours of operation across facilities owned by different entities.⁶

⁶ Personal Communication with the Metropolitan Transportation Commission, June 24, 2016.

Roles and Responsibilities

Several entities play a role in the operation of the Bay Area Express Lanes network. The Bay Area Express Lanes (planned and operated) stretch over four California counties—Alameda, Contra Costa, Solano, and Santa Clara (122). MTC, ACTC, and VTA can choose to implement different tolling methods. As noted above, MTC has been authorized to develop and operate 270 miles of express lanes in the future. MTC will design, implement, operate, and own the toll system, as well as oversee daily operations, set toll policy, and conduct public outreach for the express lanes.

All of the toll transactions are ultimately handled by the Bay Area Toll Authority (BATA). BATA also operates the Regional Customer Service Center. MTC and BATA created a joint exercise of powers agency called Bay Area Infrastructure Financing Authority to plan, develop, operate, and finance the express lanes.

The California Department of Transportation (Caltrans) owns and manages the state highway system and has control over express lane signage and standards. Caltrans also reviews and approves design and operations plans, operates the traffic management center, and maintains more roadway elements. The California Highway Patrol helps to enforce proper express lane use. FHWA has project-level approval control for all express lane projects. Several other lesser entities play a role in Bay Area Express Lanes, though an exhaustive list is not provided within this report.

Pricing System

The Bay Area Express Lanes use dynamic pricing based on traffic congestion during peak periods. Qualified carpools, vanpools, buses, and other toll-exempt vehicles can use the lanes for free at all times. Outside of peak-hour operating hours, the lanes are open to general traffic and have no charge or transponder requirements (125).

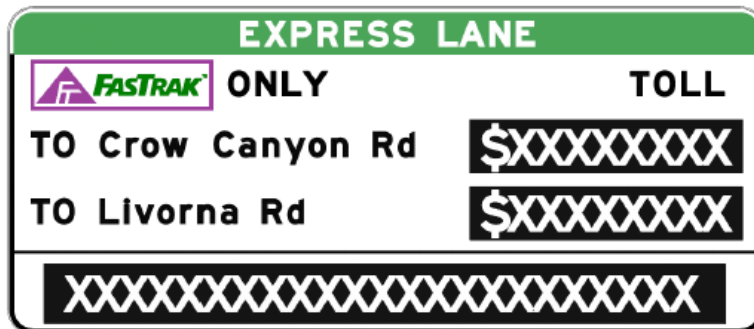
Some of the Bay Area Express Lanes (such as southbound I-680 and I-580) require users to have a FasTrak toll tag to use the lane. Travelers had mixed responses to this requirement. Some saw it as a good method of reducing express lane use cheater rates, and others saw it as unsafe and unneeded bureaucracy (126). On I-580, carpools are required to own a FasTrak Flex tag (127) that allows carpools to designate whether they have 1, 2, or 3+ persons in their vehicle (before their trip) and get assessed the appropriate toll rate (see Figure 29).



Source: (127)

Figure 29. FasTrak Flex Switchable Toll Tag.

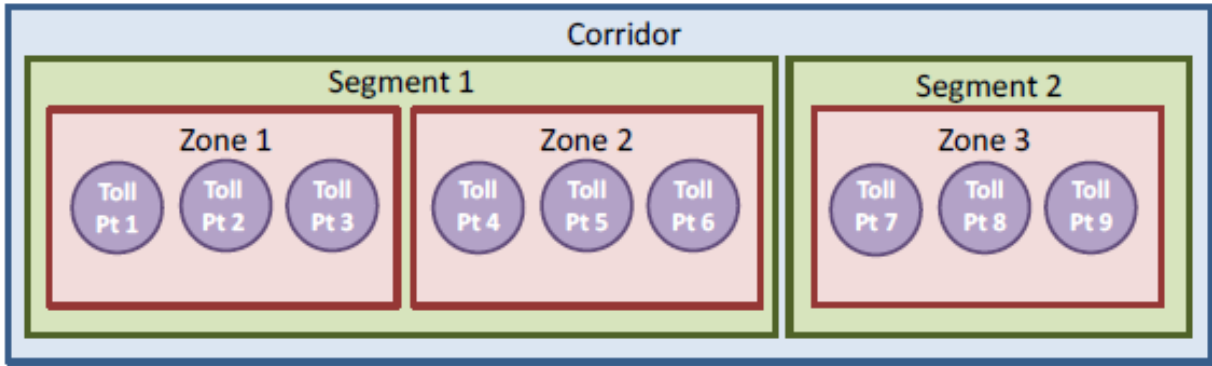
Express lane pricing is displayed using changeable message signs, as directed by the MUTCD. When entering an express lane, travelers are provided pricing information via a sign with changeable message components. In some cases of extreme traffic, instead of listing a toll price, these signs may say “HOV ONLY” to indicate that paying a toll to use the lane is not an option for non-carpoolers. Additionally, during off-peak hours, it may say “OPEN TO ALL” to indicate that no user of the lane will be charged a toll (128). Figure 30 provides an example of these pricing signs.



Source: (128)

Figure 30. Example Express Lane Pricing Sign.

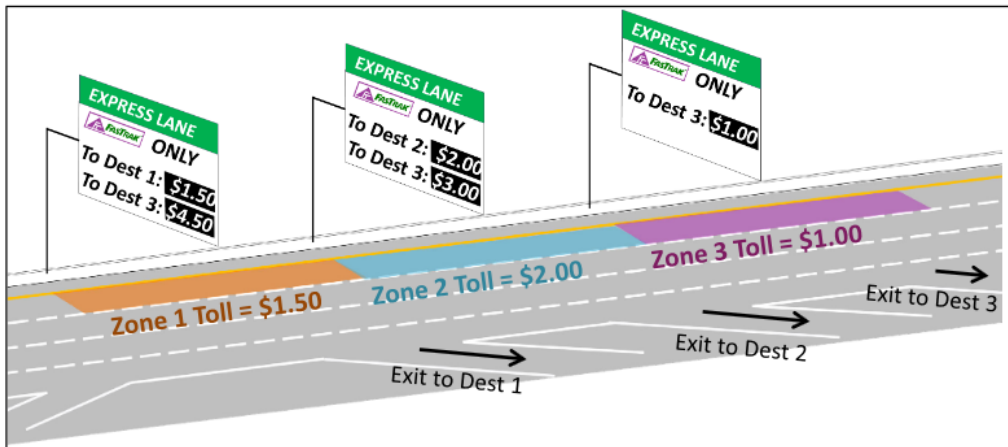
Express lane information is commonly provided for the end of a given zone and the end of a given segment (see Figure 31). Segments are comprised of two or three zones, with each zone being 3–5 miles long (6).



Source: (128)

Figure 31. Example Toll Zones and Segments.

The prices displayed are dynamic and vary based on the congestion level. During congested periods, the toll rate increases. According to the MTC express lane concept, users are locked into the prices shown when they enter a tolled zone. This practice ensures that the price express lane users see will not change between the time they choose to enter the express lane and when they get to their destination. Figure 32 provides a zone-based pricing example and illustrates the toll pricing information provided on any given sign. The toll prices listed are not additive, and the toll associated with a zone is the same regardless of the distance traveled within the zone (128).



Source: (128)

Figure 32. MTC Express Lane Zone-Based Pricing Example.

MTC express lanes will operate under a pricing system similar to a transit fare zone, but ACTC and VTA have a per-mile pricing policy. The express lane on I-580 in Alameda County uses tolling read points to track vehicles and calculate toll fees. The express lane is primarily open access, with some double white striping near the end of the express lane. At each read point, travelers get assigned an increment of the toll. The VTA website recently started providing the current toll prices in real time; it is the only operating agency/location in the Bay Area that provides this service (6).

Existing Traveler Information System

The Bay Area Express Lanes use several methods of conveying traveler information, including pre-trip information, en-route information, and post-trip information. Various websites related to the Bay Area Express Lanes exist and contain a lot of information duplication because the entities are not sure where users will go to find travel information. While duplication of data can be a good thing, it carries the potential risk of inconsistency and lack of consistent updates across related sources (6).

Pre-trip Information

The Bay Area Express Lanes website presents pre-trip information (128). Travelers can use the site to read about express lanes and how they work and about the functionality of FasTrak and FasTrak Flex toll tags. It includes maps of operating express lanes and lanes that will be opening soon. A link to announcements of important express lane events provides information about construction and closures. It also provides a link to the 511 website maintained by MTC. Google provides the map and data platform to support the 511 system (6).

Additionally, VTA has a website that explains express lane use requirements (129), and ACTC has a website that discusses the express lanes it operates and the toll tag requirements associated with their use (130).

A local newspaper columnist, known as Mr. Road Show, publishes reader questions and responses about transportation, including questions about navigating the express lanes. The author asks MTC for the answer, and MTC coordinates with VTA to provide answers (6).

En-Route Information

Signs along the express lane corridors are an important method of conveying en-route information. Caltrans stipulates that the only permissible website to include on express lane signs is 511.org. Every express lane in California has signage that contains the FasTrak logo, and all HOT lane signs have a white-on-purple express lane banner (6). The MTC Express Lanes Concept of Operations provides the following description of information that may be provided at the start of an express lane: “Signing for the start of an express lane includes advance overhead signs to let drivers know that they are approaching an express lane, the price to travel in the express lane, the FasTrak account requirement and the hours of operation” (122).

Overhead signs are the single biggest cost in converting from HOV lanes to HOT lanes, largely due to the structures needed to support them (6).

Post-trip Information

FasTrak toll tag owners can choose to receive account statements summarizing the tolls they paid and their account balance. They can also retrieve this information online or by contacting a customer service center with questions (131).

Future Possibilities

Over the next couple of decades, the express lanes system in the San Francisco Bay area is expected to increase to more than 500 lane-miles. This includes different tolling methods and anticipated express lane connectors that are converted from HOV direct connectors. As part of this anticipated growth, it will be critical to evaluate traveler information needs and determine how to most effectively integrate this information across facilities and operators (6, 132). With all the information they must convey to travelers using express lanes in the region, MTC staff are currently looking toward new solutions beyond relying on using signs to convey information (6).

WASHINGTON, D.C., AND VIRGINIA

Description of Network

Overview of Managed Lane System

In Washington, D.C., and northern Virginia, a network of tolled express lanes is expanding through the conversion of HOV lanes to HOT lanes. Figure 33 shows the logo for the 495 and 95 Express Lanes. The 43-mile managed lane facilities in the region include the following:

- I-95 Express Lanes.
- I-495 Express Lanes.



Figure 33. Express Lanes Logo.

In November 2012, I-495, also called the Capital Beltway, became the first managed lanes in the region. Four new lanes were constructed along the corridor. In 2014, the I-95 Express Lanes replaced the existing reversible HOV lanes with HOT lanes. For the first 2 weeks of the launch, the lanes were open to all, tolls were not enforced, and the message signs presented the HOV rules for the express lanes to familiarize users with the system. After 2 weeks, an all-electronic tolling system was activated, and a transponder is now required for all users (133).

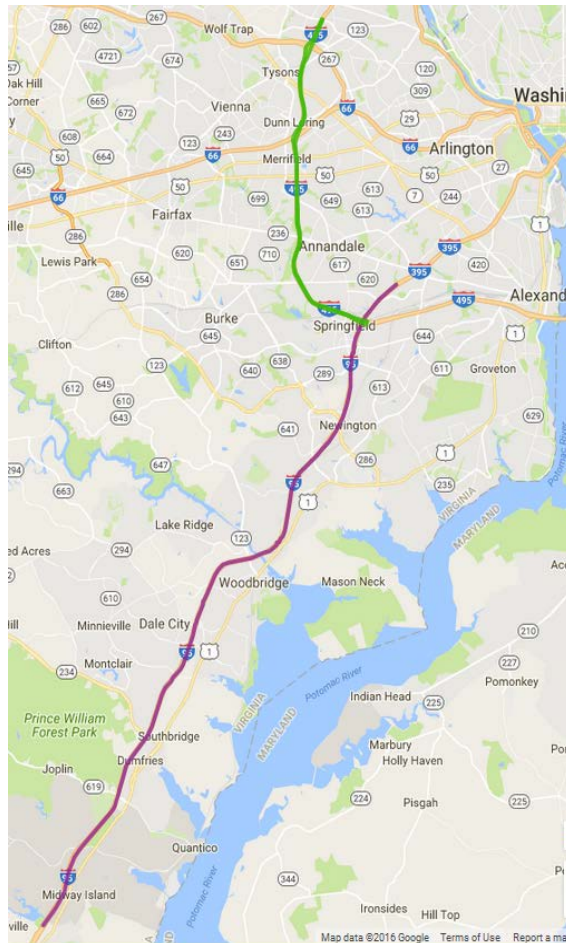
The express lanes operate in a region that also includes a network of toll roads and HOV lanes. Northern Virginia has reversible HOV lanes on I-395, I-66, and the Dulles Toll Road. The I-395 HOV lanes connect directly to the 95 Express Lanes, and I-495 Express also has connections to HOV lanes. Figure 34 shows the location of the express lanes within the region. The 95 and 495 Express Lanes operate 24 hours a day, 7 days a week, and tolling is always active. HOV restrictions are always in effect, and all users must have a transponder to use the lanes. To qualify as an HOV, a vehicle must include three or more individuals. Table 7 summarizes the operational characteristics of the regional Washington, D.C., managed lane network for specific corridors. Figure 34 shows a map of the managed lane network in the Washington, D.C., region.

Roles and Responsibilities

The Virginia Department of Transportation (VDOT) owns managed lane roadways, general-purpose roadways, HOV lanes, and several toll roads in the state. VDOT partnered with private consortiums, or concessionaires, to develop the managed lane systems. VDOT also provides oversight for all aspects of the express lane operations.

Several private companies partnered with VDOT to design, develop, and operate the managed lane system. The Capital Beltway Express, LLC, is a consortium led by Transurban that designed, built, operates, finances, and maintains the HOT lane project on I-495. Transurban is a toll road owner headquartered in Alexandria, Virginia. VDOT entered into a comprehensive agreement with the 95 Express Lanes, LLC, a consortium of Transurban and Fluor, to develop the 95 Express Lanes. This private concessionaire designed, built, maintains, and operates the express lane project (134).

The Virginia Department of Rail and Public Transportation (DRPT) is the state agency responsible for programs related to rail and transit options in the state. In conjunction with the 95 Express conversation, DRPT developed a travel demand management plan for the corridor. The goals are to maintain transit and HOV ridership and to attract new transit and HOV riders to the new HOT lanes (135).



Source: (136)

Figure 34. Managed Lanes in Northern Virginia.

Table 7. Operational Managed Lanes in Washington, D.C.

Project Name	Road Numbers	Pricing Structure	Roadway Configurations	Rate Set By
95 Express	I-95 and I-395	HOV 3+ travel free; others pay toll	29 miles of reversible lanes. Direct connection to HOV 3 lanes in I-395, which has HOV 3 requirements during rush hours (137).	Link-based segment pricing
495 Express	I-495	HOV 3+ travel free; others pay toll	Two lanes in each direction, running about 14 miles. Open 24 hours a day, 7 days a week.	Link-based segment pricing

Pricing System

The express lanes use dynamic pricing to provide a more predictable trip and manage the flow of traffic on the roadways. Rates on the express lanes are based on congestion and range from \$0.20 per mile to \$1.00 per mile, but the express lane website emphasizes that toll rates can range significantly due to heavy congestion or incidents. Pricing is presented on highway signage as a set of three prices to travel to upcoming exits. At decision points along the lanes, drivers are presented with additional pricing signs (138). The website also provides a historic-rate

calculator that allows users to see estimated total prices based on a trip's entrance and exit points, date, and time of day (139).

Hybrid and clean fuel vehicles are not exempt from the occupancy requirements on the express lanes, although these vehicles are allowed to use HOV lanes in Virginia without meeting occupancy requirements. Buses, motorcycles, and law enforcement vehicles can use the express lanes for free. Vanpools, carpools, taxis, and trucks with two axles can use the lanes with an EZ Pass transponder and can benefit from HOV discounts if they meet the three-occupant requirement (140).

All tolling facilities in the region use EZ Pass transponders for the electronic payment system. EZ Pass Flex, shown in Figure 35, is a transponder developed specifically for the Virginia HOT lanes with a switchable feature to allow HOV travelers on the 95 and 495 Express Lanes to indicate that they are traveling with three or more people. An EZ Pass website hosted by VDOT informs users about account maintenance, toll violations, options for payment, and automatic account replenishment. The EZ Pass website also offers online account management and customer service phone numbers and locations (141). EZ Pass transponders are used on roadways in over a dozen states, from Maine to North Carolina, but the Flex Pass is designed for the 95 and 495 Express Lanes. Owners of EZ Passes from other states can use them in the HOT lanes, but only Virginia and Maryland users can order the EZ Pass Flex.



Source: (142)

Figure 35. EZ Pass Flex HOV Indicator.

Existing Traveler Information System

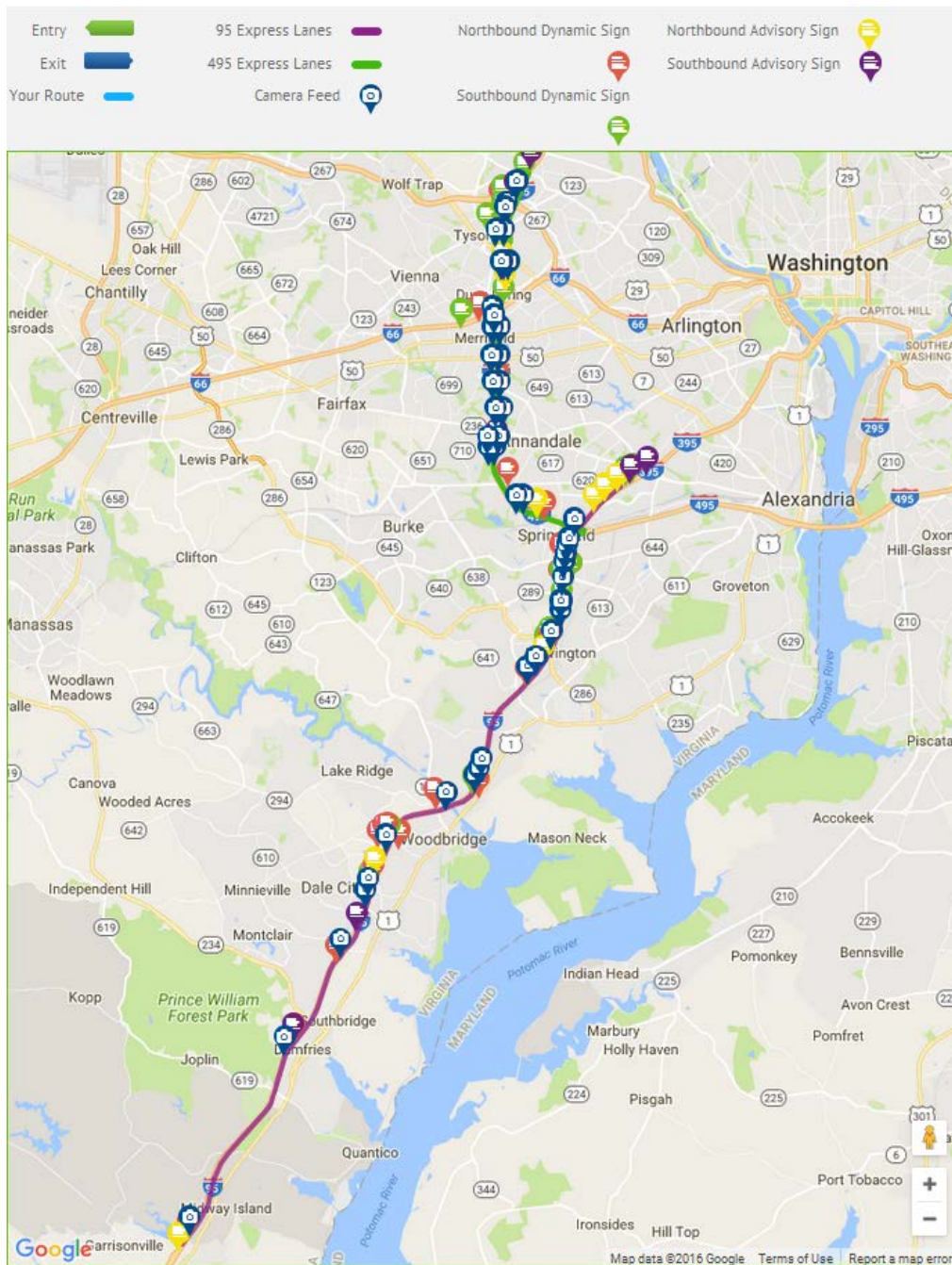
Managed lane information for the system is provided by VDOT, Transurban, EZ Pass, regional newspapers, and other media outlets. Transurban, the private operator of the express lane system, maintains the express lane website—a primary source of information that conveys express lane function, access information, payment information, and FAQs. The website also offers a mobile application and a customer service telephone number. Pricing signage and marketing materials are the responsibility of concessionaires, but VDOT collaborates to ensure compliance with signage requirements.⁷

⁷ Personal Communication with the Virginia Department of Transportation, August 9, 2016.

Pre-trip Information

The express lane website is the primary source for pre-trip information about managed lanes in the region. Transurban includes on the website detailed information about how the managed lanes operate, future developments, pricing and payment options, travel options available, and how to understand and use the system. Travelers can also download an express lane mobile app that offers real-time toll estimates, live traffic cameras, advisories, and a tool to pay missed tolls.

The express lane website includes a map that provides clear and detailed information to help travelers understand and prepare for a trip on the managed lanes (Figure 36). The interactive map provides trip price and time estimates based on user-provided entry and exit points. The map also allows users to view every sign and every traffic camera along the network by clicking on icons on the map. Traffic cameras show real-time traffic feeds as well as simple explanations for what the user is looking at. Similarly, graphics of dynamic message signs are displayed, and the type of information that a driver would see is explained (143). A static map of entry and exit points is also provided as a PDF with the slogan “Map out a course to get your time back” (136).



Source: (143)

Figure 36. On the Road Map.

VDOT also operates a robust 511 program, providing weather, traffic alerts, real-time road conditions, traffic speeds, message sign contents, and construction and incident updates. HOV and express lane information can be viewed alongside transit and park-and-ride options. The 511 online map also includes graphics of the information presented on highway message signs along the roadways, including HOV lane signs. Travelers can create accounts to customize traffic alerts, use a 511 mobile application, or call for more information (144).

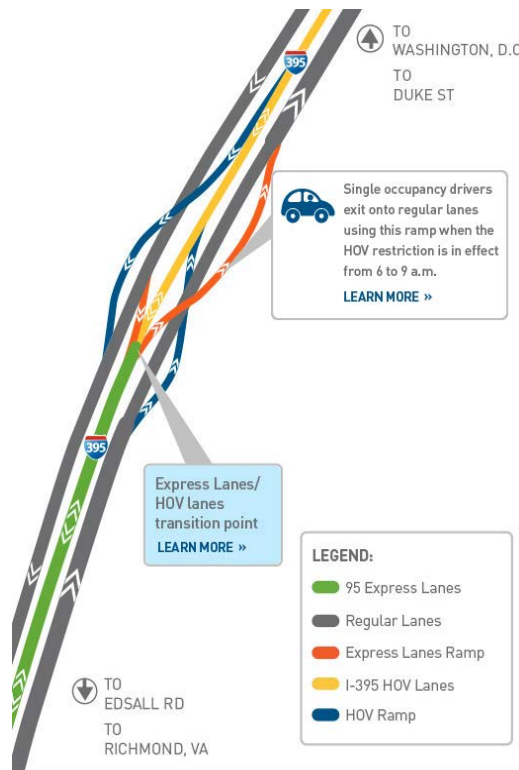
VDOT's website presents information about the managed lanes along with information about traffic, construction projects, safety information, and all other travel information for Virginia. This includes webpages about HOV lanes, toll roads, park and rides, carpooling, and vanpooling. A map of all park-and-ride lots in the state is provided. The map does not display HOT or HOV roadways but does inform travelers about the HOV-to-HOT conversation on I-95 (145).

En-Route Information

Roadway signage, including electronic message signs, provides en-route information to travelers about HOV rules, pricing, and exits. Toll prices are posted before all express lane entrances and at decision points within the express lanes. At decision points, travelers can decide whether to pay the next toll rate or exit the express lane (138).

Electronic message signs are placed before each express lane entrance showing the current toll prices, with several prices presented that are associated with upcoming exits.

Information is also provided about the transition point between the 95 Express Lanes and adjacent and connecting HOV lanes. When the HOV restriction is in effect on I-395 (which continues from the north end of the I-95 Express Lanes), drivers traveling with fewer than three occupants must exit the express lanes before the lanes convert to HOV. Figure 37 displays a graphic used to show travelers this transition zone.



Source: (140)

Figure 37. Express Lane/HOV Lane Transition Point Map.

Post-trip Information

The express lane website includes prominent links to pay an invoice, pay for a missed toll, or sign up for an EZ Pass® (146). Each of these links connects to a webpage with detailed information on how to address the issue. Travelers can also register on the website to create a free account that provides customized price alerts, express lanes news, and traffic alerts (147). Users can set price alerts for a particular entrance and exit, time of day, and day of week to have a price alert along with the price of a trip at that time emailed or texted. Customer service is also offered by phone and at three physical locations in the Washington, D.C., metro region (146).

The Washington Post presents a regular column written by Robert Thomson, called Dr. Gridlock, who answers questions about transportation activities in the Washington region. This column offers an additional outlet for travelers to receive updates and ask questions about the express lanes. When the 95 Express Lanes opened in 2014, Dr. Gridlock's column offered a "quick-study guide on how the 95 Express Lanes will work" (133). The article explained the terms *HOT* and *HOT lanes*, roadway locations and connections, pricing structure, toll collection, occupancy rules, and transponder requirements.

Future Possibilities

Additional HOV-to-HOT lane conversions are being planned for I-66 and I-395 in the northern Virginia region. These roadways will connect to the existing express lanes and create a larger network of dynamically priced roadways in the region. Construction began on I-66 in August 2016 and, when operational, will connect to the existing lanes and will add significant new capacity to the express lane system. By 2021, the region is expected to have an 84-mile network of managed lanes. Challenges in communication with travelers may be complicated by the fact that VDOT will have partnerships with at least three concessionaires operating different legs of the system (7). The I-66 project also includes significant investments in transit, park and rides, and travel demand management efforts to encourage HOV and bus use that will have specific communication needs (148). A growing number of facilities in close proximity may lead to issues with sign compression, multiple websites and sources of information, and information overload as drivers make decisions about each facility (7).

CHAPTER 4—FOCUS GROUPS

INTRODUCTION

In 2006, Texas became the first state to include standards and guidance concerning signs for managed lanes in its Texas MUTCD. TxDOT recognized early in the development of managed lanes that traveler information would be one of the keys to success. Federal guidance followed in the 2009 MUTCD but did not include any guidance on areas where managed lanes intersected. The purpose of the human factors activities of this project was to identify what information drivers desire and by what means they would like it to be communicated.

Managed lane facilities within or across jurisdictions may have different objectives and different operational policies. This means that roadways within the same region may have different operating schedules, different pricing structures, and different eligibility requirements. The managed lane concept itself is often difficult for the general public to understand because it represents a significant departure from the traditional freeway travel model of free and open access for all vehicle types. As such, the development of managed lane networks comprised of facilities with different operational policies poses a challenge in terms of communicating to the public how, when, and why to use these types of facilities.

Technology advancements, particularly in the area of smartphones, are opening new avenues for transportation agencies to inform the public about managed lane operation. This research assesses what kinds of information the public wishes to receive on travel on managed lane networks and when and how they would like to receive the information. Researchers conducted four focus groups to determine:

- What the participants know about managed lanes and managed lane networks.
- What travel information they currently use to make travel decisions.
- What information they would like to have to use managed lanes.
- What type of communication mechanisms they would prefer to use to receive that information.

An online survey was developed based on the findings of these focus groups and deployed to a larger audience as described in Chapter 5.

METHODOLOGY

The research team conducted four focus groups with 32 people total. Sessions were conducted in Texas A&M Transportation Institute (TTI) offices in the cities listed in Table 8.

Table 8. Locations of Focus Groups and Description of Managed Lanes in Operation in Those Areas.

City	Managed Lanes in the Area
Houston	Katy Tollway less than ½ mile from TTI office. Several other grade- and barrier-separated HOT lanes operated in the region by METRO Transit. Long history of HOV lanes in region.
Dallas	LBJ TEXpress Lanes® (I-635 HOT) and US 75 HOV lanes less than ½ mile from TTI office. Other HOT and tolled express lanes operate in Fort Worth area by TxDOT and concessionaires. Long history of HOV lanes in region.
Austin	No existing managed lanes. Texas Loop 1 (MoPac Expressway) HOT lanes under construction at time of focus group, with some roadway signs already installed and visible to passing traffic.
Bryan/College Station	No managed lanes, but residents were expected to be familiar with the other three metropolitan areas due to occasional personal and work trips there.

Participants and Recruiting

Each session lasted approximately 2 hours and was held at 5:30 p.m. Participants for the sessions were recruited through two primary channels:

- **Email list:** TTI maintains a list of participants from past research projects that indicated an interest in participating in future projects. These individuals were forwarded an email with information about the opportunity and a link directing them to a website where they provided additional information.
- **Social media:** TTI posted a notice of the focus group sessions to its main Facebook® page with instructions directing potential participants to the website noted above.

The link took the focus group candidate to a TTI-maintained and administered recruitment website containing a questionnaire aimed at:

- Commuting habits (typical roads used; frequency of commuting, carpooling, and transit usage).
- Use of managed lanes (frequency and purpose).
- Use of toll tags.
- Socioeconomic indicators (gender, age, ethnicity, household income, education).

Using the information collected, the research team selected participants for each session that would result in the following composition of participants:

- Austin—mostly toll tag owners and toll road users (N=7).
- Bryan/College Station—mostly infrequent managed lane users (N=10).
- Dallas—frequent commuters and managed lane users (N=5).
- Houston—frequent commuters and managed lane users (N=10).

During the selection process, researchers chose participants representing the above characteristics while also ensuring that the sessions were evenly represented in terms of gender, age, ethnicity, household income, and education. Participants were notified of their selection via email, and follow-up phone calls were placed prior to each session to confirm attendance.

Upon arrival, participants signed an informed consent document. Then, the facilitator initiated the session with introductions. Participants were reimbursed \$50. All of the sessions were conducted in June 2016. One TTI staff member served as discussion facilitator, and two other staff members took notes. Appendix B includes the focus group discussion guide.

Discussion Guide Development

The facilitator's discussion guide and group exercise underwent several revisions leading up to the focus groups. The research team wanted an opportunity to gather both qualitative and quantitative information, so an individual ranking worksheet was ultimately selected to use in conjunction with the group discussions. Initially, the ranking of the types of information was going to be done as a group, with the facilitator using pre-labeled index cards on a wall chart indicating communication mechanism. A pilot focus group with TTI employees unfamiliar with the project or managed lanes was conducted to test the draft discussion guide and group exercise. In the pilot test, it became clear that a group ranking of so many individual items would be very long, complicated, and confusing. Following the pilot test, the discussion guide was revised again and the group exercise became the individual worksheets described in the following section.

KNOWLEDGE AND PERCEPTIONS OF MANAGED LANES

The facilitator initiated each focus group with a discussion on managed lanes, express lanes, managed HOV lanes, and managed lane networks. For each of these terms, the moderator asked participants if they knew what the term referred to, and if so, to explain what the term meant in their own words.

Managed Lanes

Participants in all four sessions were initially asked what the term *managed lanes* meant to them. All of the Houston participants, five of the seven Austin participants, and six of the 10 Bryan/College Station participants indicated that they knew what a managed lane was. Only two participants in the Dallas session indicated such knowledge. Follow-up questions from the facilitator indicated that the actual level of understanding of managed lanes varied significantly between participants, in spite of their perceived knowledge of managed lanes. No participant in any of the sessions provided a comprehensive operational definition of managed lanes, but a few participants noted that such facilities are controlled differently, while others noted that they have eligibility restrictions. For the most part, participants who were familiar with managed lanes cited specific examples of what might constitute a managed lane. The following are example responses provided by participants:

- Houston—"You either use the HOV or the toll lanes, and I think they are managed by TxDOT. I think you have to stay in your lane once you get in."
- Houston—"I think they are controlled differently, and not by TxDOT. I think that they are restricted in terms of where you can access them. When I'm coming down 45, I only have a few areas where I can get in, but on the Katy Freeway, there are a lot of areas to access."
- College Station—"They have occupancy requirements."

- College Station—“I think HOV lanes are managed lanes.”
- College Station—“They are toll roads.”
- Dallas—“It means an HOV lane.”
- Dallas—“It could also be an HOV with an express lane.” (Note: This comment was made prior to discussion on express lanes.)
- Dallas—“It could be an HOV lane where you need at least one more passenger than yourself.”

As can be seen in the examples provided above, participants were generally aware of facility types that might be classified as a managed lane but were not sure why those facilities would be considered managed lanes. The closest to an operational definition that any participant came was one participant in Austin who stated, “I think it is something similar to a toll road, but it is broader like an HOV. There may not be a toll, but there is some sort of managed access. I think that’s where the managed term comes from. It may be free, but there are requirements and restrictions on who can use the road.”

Express Lanes

Participants were next asked if they knew anything about *express lanes*, to which very few participants responded yes. Only one participant in any session was able to identify a specific express lane facility in Texas: 635 in Dallas (provided by an Austin participant who had formerly lived in Dallas). No other participants in any session were able to identify an example of an express lane facility, and no participant was able to articulate an accurate operational definition. When further questioned by the facilitator, participants’ thoughts on what might constitute an express lane facility varied significantly. The following are some examples of participant responses:

- Austin—“There is one here in Austin going southbound on I-35. There’s lot of access points on the lower deck versus the upper deck.”
- Bryan/College Station—“Once you get on, you can’t go out. It’s separated like what we had when I lived in Chicago, and the direction of flow reverses in the morning and the afternoon.”
- Bryan/College Station—“It’s a fast version of a road to get you to a central location.”
- Bryan/College Station—“There are no traffic lights.”
- Bryan/College Station—“I would have thought it was just the left lane that goes faster.”
- Bryan/College Station—“It’s a type of toll road and you have to have a tag or you’ll get something in the mail. It’s the special lane you have to go through so you don’t have to slow down to pay.”
- Dallas—“It could be an HOV lane where you need at least one more passenger than yourself.”
- Houston—“It’s like a diamond lane, where you have to have more people in the car to use it.”
- Houston—“It depends on how you define, like on 45 where they don’t allow trucks to use the lane.”
- Houston—“I think they have one in San Antonio where there is one lane where you can cut straight through the city. It’s like straight shot.”

As can be seen in the responses above, participants generally focused on the term *express* and interpreted it to mean any number of things. To some it meant a road that gets them to their destination faster, while to others it meant a road with fewer exits and on ramps. Others took the term to mean that there are certain restrictions on the types of vehicles that may use the lanes (such as truck restrictions). However, the common element was that express lanes provide a quicker, perhaps less congested route for travelers. However, not all participants linked this faster trip with pricing.

Managed HOV Lane

The facilitator next asked participants to discuss what the term *managed HOV lane* meant to them. As with managed lanes and express lanes, participants generally had issues with identifying what a managed HOV lane actually entails. The following are examples of responses:

- Austin—“It’s an HOV that has its own entity to manage it. It has its own enforcement and maintenance, and it is likely tolled in order to pay for that.”
- Austin—“I think TxDOT handles all that. I don’t think you are getting any superior pavement, but you are getting expedited access.”
- Bryan/College Station—“It’s one that changes direction like in Dallas. It is limited access in terms of occupancy. Sometimes it’s HOV 2 and sometimes it’s HOV 4.”
- Bryan/College Station—“I think there is something in Denver that is one of these, but I never used it when I was there.”
- Bryan/College Station—“I think we have got on one in Houston. We got on it one time and then couldn’t get off of it.”
- Dallas—“I don’t recall seeing signs about these. I’m guessing it costs money because it has the word ‘managed’ in it. And I wouldn’t think you can use it unless you have a passenger.”
- Houston—“That’s where you have to have an EZ TAG to travel on them. There are some facilities where you don’t have to have a tag, but on a managed HOV like I-10 you do.”
- Houston—“In a managed HOV lane there are designated times you can get on and off and there are certain times you can use it.”
- Houston—“I-45 South is like that. In the morning you are heading in and in the afternoon you are heading out.”
- Houston—“I thought ‘managed’ related to the times it was open.”

As can be seen in the examples above, many participants believed that a managed HOV lane is an HOV lane with different operational policies and operating times, which in many cases is true. Several participants thought that the term meant that pricing may be employed, which is also true.

Managed Lane Network

Finally, participants were asked about their perception of the term *managed lane network*. Example responses include the following:

- Austin—“It’s probably a system of cameras so they can view the system and see what the other lanes are doing and provide information on travel times or let you know when there

is a wreck. I think they would have to monitor all the lanes because the free lanes can impact the managed lanes. I think a network would involve putting in a lot more cameras and you would have to have the means for conveying that information, so they might have a radio station or something similar.”

- Austin—“I was thinking it would be connections between managed lanes.”
- Austin—“It’s like traveling from Houston to Dallas on a toll road network.”
- Austin—“I used to live in Dallas, and it seems like that is where they were going. You can just take toll roads to get all over the region.”
- Bryan/College Station—“That sounds like a cluster of roads where you would need a tag to use them.”
- Bryan/College Station—“It’s all a bunch of toll roads that use the same tag.”
- Dallas—“Maybe it’s where people communicate with each other in the event of a traffic jam.”
- Houston—“I would think it is where several roads or lanes intersect and you have choices on which one you take.”
- Houston—“Maybe it’s where you have a choice in terms of the companies? Like there is EZ TAG and TxTag®.”
- Houston—“I think of different entities coming together in the same spot.”
- Houston—“I see it as central management of the HOV and managed lanes. One entity is controlling the flow of traffic. It’s not that 290 and 45 are acting independently, but instead they are all working together.”
- Houston—“It could also apply to between I-10 and 290, where you can manage traffic flowing between the facilities. Those corridors are being created by studies showing that traffic is flowing one way or another, and you could manage the flow between those facilities as part of a network.”

As can be seen in the examples provided above, many participants correctly assumed that the term referred simply to a network of managed lanes that would allow a driver to make expedited trips across a region. However, a number of participants latched on to the term *managed* as having more to do with responsibility for the roadway as opposed to managing access. Participants appeared to view the term as meaning a “network of lanes that is managed” as opposed to a “network of managed lanes.”

USE OF AND PREFERENCES FOR TRANSPORTATION-RELATED INFORMATION

Focus group participants were asked about the delivery mechanisms and types of information they would like to receive about managed lanes and specifically hypothetical future managed lane networks. This information was obtained in two primary ways:

- **General Discussion:** Prior to conducting the worksheet exercise discussed below, the facilitator led the group in a discussion on their general use of transportation-related information. Following the completion of the worksheet exercise, the facilitator led a second discussion on what participants had selected as their preferred options for receiving information on managed lanes and their motivations/reasoning in making their selections.

- **Worksheet Exercise:** Participants were provided with a two-page worksheet that featured information communication mechanisms (such as text messaging, digital message signs, in-vehicle navigation, etc.) and specific pieces of information that might be transmitted with those mechanisms (incident location, route travel time, delay, etc.). Participants were asked to rank in priority order the top five pieces of information they would like to receive using each mechanism and then to circle their most preferred information communication mechanism. The facilitator then engaged the group in a discussion about their preferences. The worksheet pages are shown in Figure 38 and Figure 39.









Cell Phone Text Message	Smartphone Application	Website, e.g. TranStar, My35.org, TransVision, etc.	Roadway Signs (Limit 3)	Electronic Message Sign	In-car Navigation System	TV	Radio
							
	How do I pay? Do I need a tag? Can I pay my bill mail?	How do I pay? Do I need a tag? Can I pay my bill mail?	How do I pay? Do I need a tag? Can I pay my bill mail?	How do I pay?	How do I pay? Do I need a tag? Can I pay my bill mail?	How do I pay? Do I need a tag? Can I pay my bill mail?	How do I pay? Do I need a tag? Can I pay my bill mail?
	How do I sign up for a toll tag? Do I need to sign up for an HOV discount program ahead of time? Is it any cheaper for an HOV on either leg?	How do I sign up for a toll tag? Do I need to sign up for an HOV discount program ahead of time? Is it any cheaper for an HOV on either leg?	How do I sign up for a toll tag? Do I need to sign up for an HOV discount program ahead of time? Is it any cheaper for an HOV on either leg?		How do I sign up for a toll tag? Do I need to sign up for an HOV discount program ahead of time? Is it any cheaper for an HOV on either leg?	How do I sign up for a toll tag? Do I need to sign up for an HOV discount program ahead of time? Is it any cheaper for an HOV on either leg?	How do I sign up for a toll tag? Do I need to sign up for an HOV discount program ahead of time? Is it any cheaper for an HOV on either leg?
	Recommendation/Guidance that shows route (free or ML) for the lowest cost and least amount of time How much time will my total trip home take in the ML?	Recommendation/Guidance that shows route (free or ML) for the lowest cost and least amount of time How much time will my total trip home take in the ML?			Recommendation/Guidance that shows route (free or ML) for the lowest cost and least amount of time How much time will my total trip home take in the ML?	Recommendation/Guidance that shows route (free or ML) for the lowest cost and least amount of time How much time will my total trip home take in the ML?	How much time will my total trip home take in the ML?

Figure 38. Page 1 of Worksheet Exercise (Printed on 11x17 in. Paper).









Cell Phone Text Message	Smartphone Application	Website, e.g. TranStar, My35.org, TransVision, etc.	Roadway Signs (Limit 3)	Electronic Message Sign	In-car Navigation System	TV	Radio
							
How do I pay?	How do I pay?	How do I pay?	How do I pay?	How do I pay?	How do I pay?	How do I pay?	How do I pay?
Do I need a tag?	Do I need a tag?	Do I need a tag?	Do I need a tag?	Do I need a tag?	Do I need a tag?	Do I need a tag?	Do I need a tag?
Can I pay my bill mail?	Can I pay my bill mail?	Can I pay my bill mail?	Can I pay my bill mail?	Can I pay my bill mail?	Can I pay my bill mail?	Can I pay my bill mail?	Can I pay my bill mail?
How do I sign up for a toll tag?	How do I sign up for a toll tag?	How do I sign up for a toll tag?	How do I sign up for a toll tag?	How do I sign up for a toll tag?	How do I sign up for a toll tag?	How do I sign up for a toll tag?	How do I sign up for a toll tag?
Do I need to sign up for an HOV discount program ahead of time?	Do I need to sign up for an HOV discount program ahead of time?	Do I need to sign up for an HOV discount program ahead of time?	Do I need to sign up for an HOV discount program ahead of time?	Do I need to sign up for an HOV discount program ahead of time?	Do I need to sign up for an HOV discount program ahead of time?	Do I need to sign up for an HOV discount program ahead of time?	Do I need to sign up for an HOV discount program ahead of time?
Is it any cheaper for an HOV on either leg?	Is it any cheaper for an HOV on either leg?	Is it any cheaper for an HOV on either leg?	Is it any cheaper for an HOV on either leg?	Is it any cheaper for an HOV on either leg?	Is it any cheaper for an HOV on either leg?	Is it any cheaper for an HOV on either leg?	Is it any cheaper for an HOV on either leg?
Recommendation/Guidance that shows route (free or ML) for the lowest cost and least amount of time	Recommendation/Guidance that shows route (free or ML) for the lowest cost and least amount of time	Recommendation/Guidance that shows route (free or ML) for the lowest cost and least amount of time	Recommendation/Guidance that shows route (free or ML) for the lowest cost and least amount of time	Recommendation/Guidance that shows route (free or ML) for the lowest cost and least amount of time	Recommendation/Guidance that shows route (free or ML) for the lowest cost and least amount of time	Recommendation/Guidance that shows route (free or ML) for the lowest cost and least amount of time	Recommendation/Guidance that shows route (free or ML) for the lowest cost and least amount of time
How much time will my total trip home take in the ML?	How much time will my total trip home take in the ML?	How much time will my total trip home take in the ML?	How much time will my total trip home take in the ML?	How much time will my total trip home take in the ML?	How much time will my total trip home take in the ML?	How much time will my total trip home take in the ML?	How much time will my total trip home take in the ML?

Figure 39. Page 2 of Worksheet.

General Use

After discussion on knowledge and use of managed lanes, the facilitator transitioned to a discussion on how session participants are currently receiving information about traffic congestion and to what extent they are using that information to make travel decisions. Participants reported a range of information sources that generally fell into four categories:

- Smartphone applications.
- Websites.
- In-vehicle devices.
- Traditional media.

Smartphone Applications

All sessions with the exception of Dallas reported using various mobile phone apps to get traffic information. None of the Dallas participants indicated that they use an app to make routing and other travel decisions, but most were aware of these apps. The most popular apps among participants in the other three sessions were Waze[®], Google Maps, and Apple Maps. In general, participants indicated confidence that these apps provide accurate information and subsequent routing services. The fact that systems such as Waze[®] and Google Maps use crowdsourced data was cited by participants in all four sessions as a reason to trust the data. As one participant in Austin stated, “Waze is crowdsourced, so the more people there are on the road, the more data there is.”

However, participants do not necessarily follow routing suggestions provided by these apps in all cases. For example, participants in the Houston and Austin sessions stated that these apps often ask them to exit a major highway and use the access road, which some participants found to be too inconvenient relative to the perceived small time savings. Furthermore, participants reported that they are less likely to follow the recommended route if they are closer to home or are in a familiar area. Conversely, participants in all sessions indicated that they usually follow the recommended route if they are taking a longer (non-local) trip or are in an unfamiliar area. Some participants also indicated that mobile apps often lack information on new roadways. One participant in the Austin session discussed getting lost in Cedar Park while using the Google Maps app because his/her destination was in a new development that was apparently not showing up on the app.

A small number of participants reported using mobile-phone-based navigation apps but not to get routing recommendations. These participants used the apps primarily to determine their arrival time. In most cases, these participants used the app during their daily commute or other familiar trips. In these cases, the participants indicated that they either check the app before leaving in order to estimate their arrival time or look at the app while traveling in order to determine if they are going to be early or late.

The most commonly used apps were those that provide data for any location, as opposed to apps focused on the region. As such, the facilitator asked if any participants used local-based apps, but such use was minimal to non-existent. None of the participants in the Austin session had heard of the local travel apps RideScout[®] or Metropia[®]. A couple of participants in the Dallas session

indicated that they had tried to use the TEXpress Lanes[®] app but found it too difficult and confusing. None of the Dallas participants was aware of an NTTA app. One of those participants stated the following: “I have a lot of apps on my phone, but I don’t use them to look at traffic. I don’t want to have to look at my phone every five minutes while I’m traveling. I’ve heard of the TEXpress Lanes[®] app, but to me it sounds so confusing. Everything about it is confusing, and I cannot figure it out. There are different fares and discounts, and you have to do everything 15 minutes before you leave, and I’m not sure if it’s worth it.” One participant in the Houston session indicated that he/she used the web interface for the Houston TranStar[®] system via mobile phone to look at traffic conditions while traveling.

Participants who did not use mobile phone apps for travel decisions (including the whole Dallas session) stated that they either used other means (such as traditional media or websites) or simply knew the roads well enough to not require assistance. This was particularly true for participants in the Dallas session. Dallas participants tended to take the same roads on a regular basis and indicated that they were often able to tell by looking at traffic conditions while driving when they should take an alternate route.

Websites

A few participants in every session reported using websites to get traffic condition information. The most commonly cited website was Google Maps, which can also be accessed through a smartphone app. Participants who reported website usage stated that they generally use them in cases where they are unfamiliar with the area in which they are traveling or if they want to simply check traffic conditions on the route that they typically use. Two participants in the Houston session noted that they look at the Houston TranStar[®] website, but one of them noted that he/she accesses Houston TranStar[®] via phone while checking it against Google Maps. A participant in the Austin session also stated that he/she uses TxDOT’s traffic website when traveling to an unfamiliar area, particularly on long trips, and when wanting to gauge traffic conditions prior to leaving.

In-Vehicle Devices

The use of in-vehicle devices, such as Garmin navigation units or OnStar[®], was reported in both the Bryan/College Station and Dallas sessions. In most cases, it appeared that these participants use these systems because they have relied on them for so long and view them as being dependable, even with the continual development and refinement of mobile-phone-based systems. In the Bryan/College Station session, there were several exchanges between a couple of users of Garmin[®] and users of Waze[®] and/or Google Maps, with the app users extolling the benefits and advantages of their systems. However, the Garmin[®] users were generally not swayed in their support for their existing devices, even if they expressed interest in the mobile phone apps. The reliability of satellite-based navigation units in rural areas with poor cell phone coverage was cited as a reason for favoring them over apps.

Traditional Media (Television and Radio)

Participants in the Bryan/College Station area were more likely to look at the news or listen to the radio to get travel information, particularly for trips into Houston. Participants in Dallas and

Houston also reported watching the local news prior to leaving on a particular trip. Two participants in the Dallas session stated that they also got traffic reports from the radio station they listen to. One participant noted that the station he/she listens to provides estimated clearance time for incidents, which he/she found very useful. In fact, others in the session found this interesting and potentially useful and asked the participant what station it was. Two Austin participants watched morning traffic reports on the television. A few participants in each session got traffic information from television and radio. Other participants indicated that television is only useful for getting information prior to beginning a trip, and that in areas like Houston and Dallas, traffic conditions can change very quickly. Furthermore, participants indicated that traffic reports on the radio are useful for information on the locations of incidents but generally do not provide any information on the severity of the incident or the estimated delay. Several participants commented on how traditional media traffic coverage is not available on demand and requires remembering to tune in at a particular time for the traffic report.

Preferences for Travel Information

Participants indicated their preference for the type of travel information and the means by which it is received by using the worksheets described earlier. For each communication mechanism (columns on worksheet), participants were asked to rank the pieces of information that they believed would be most useful to them in terms of making the decision to use a managed lane. Due to time limitations and the large number of possible information types, participants were asked to indicate only their top five preferences. They were also instructed to write in a new item that the research team may not have anticipated when developing the worksheets. In addition, participants were asked to circle their most preferred communication mechanism of the ones listed across the column headings of the worksheet. Table 9 shows the number of participants in each session that selected the given communications mechanisms as their most preferred. Each of the mechanisms that received a most preferred ranking is explored in more detail within the following subsections of this report.

Table 9. Number of Participants Choosing Each as Their Most Preferred Method of Receiving Information.

Most Preferred Method	Total	Austin	Bryan/College Station	Dallas/Fort Worth	Houston
Cell phone text message	1				1
Smartphone application	16	5	5		6
Website	3			1	2
Roadway signs	0				
Electronic message sign	1				1
In-car navigation	8		5	3	
Television	1	1			
Radio	1			1	

From the sessions, the preferred mechanism and associated information about traveling on managed lane networks was likely to depend on whether the participant was en route or had not yet started the trip. Information such as how to pay, hours of operation, and how to sign up for a toll tag was generally seen as being much more valuable prior to initiating a trip. Information on incidents (including location and estimated delay) was viewed as being much more valuable once the trip had been initiated because it would allow participants to change their initially

selected route in response to traffic conditions. Incident and travel time information were seen as being valuable prior to the initiation of a trip, but participants noted that it would be more useful to have that information provided while they are driving. Participants generally indicated that static information, such as information on how and where to purchase toll tags or facility hours of operation, could be provided by websites, television and radio, or roadway signs. Real-time traffic information, such as routing recommendations, cost information, and exit locations, was seen as being more suitable to smartphone apps.

Recommendations on routing that show free lanes versus managed lanes with the lowest cost and amount of time were among the most popular pieces of information, regardless of the mechanism employed. As such, the facilitator on several occasions asked for additional input on what this information might look like. One participant noted that he/she would like to receive a notification whenever the price for access to a managed lane facility has increased. Another noted that, in the future, he/she would like to see a “heads-up display in my car to show me recommended routes.” Another stated, “I want to be given options, like it could give you three choices with miles and routes and cost for each of the three routes.”

This focus on providing routing options, and not simply providing an alternate route, was a recurring theme. Many participants know the areas they travel very well and might make travel decisions outside of what is recommended, and being given several options was seen as providing even more valuable information in that decision-making process. The facilitator also asked if participants would want to receive information on a segment basis or trip basis. When asked to choose between the two options, participants almost universally agreed that segment-related information would be preferred, although many felt that having information on both a segment and trip basis would be valuable. The overall preference among participants was simply to have an app provide them with an estimated cost and estimated travel time while having the option to view more detailed data.

Cell Phone Text Message

Only one person in all of the sessions indicated that he/she would prefer to get information on managed lanes through a cell phone text message. The individual noted that this mechanism could be provided at no cost and ranked the following (in order of priority) as pieces of information he/she would like to receive via text message:

1. How much will my total trip home cost?
2. What is the expected delay?
3. Where is the incident?
4. How much time will my total trip home take in the managed lane?
5. Recommendation/guidance that shows route (free or managed lane) for the lowest cost and least amount of time.

Smartphone Apps

Table 10 shows the participant rankings of information that could be received through a smartphone app. Only pieces of information that received a ranking from at least one participant

are shown in the table. Information that was not selected by any participant (who selected smartphone apps as the preferred communication mechanism) include:

- Can I pay my bill by mail?
- How do I sign up for a toll tag?
- Do I need to sign up for an HOV discount program ahead of time?
- Is the lane open 24/7?
- Do you need to know that you can only go one direction on an intersecting road?

The participant ID columns in Table 10 show the rankings provided by individual participants who selected smartphone apps as their preferred mechanism for receiving travel information. The numbers refer to the priority each participant assigned to that particular piece of information. For example, the first participant ID column shows a participant who believed that recommendation/guidance that shows route (free or managed lane) for the lowest cost and least amount of time was the most important piece of information he/she would want provided by a smartphone app. Expected delay was ranked as being the second most important, followed in order by total trip home cost, crashes or construction on the route, and location of incidents. There are 16 columns in the table, meaning that 16 participants out of all four sessions selected smartphone apps as their preferred communications medium.

Table 10. Ranking of Preferred Travel Information by the 16 Participants Who Selected Smartphone Apps as Their Preferred Communication Mechanism.

Information Desired (Selected from List)	Participant Identification Number															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
How do I pay?			1						1	4						
Do I need a tag?		5							2				2	2		2
Is it any cheaper for an HOV on either leg?								1				3			5	
Recommendation/guidance that shows route (free or ML) for the lowest cost and least amount of time.	1	1		1	1	1	1	2		1	1	1		1		1
How much time will my total trip home take in the ML?								3			2	2	1			
How much will my total trip home cost?	3	2	5	2	4					2	3	4				4
Can I tow my trailer?																5
Which direction is the exit (left or right)?													3		4	
Can I get directly from one ML to another ML?					5				5		5					
Can I get from the free lanes of the first leg to the ML on the second leg and vice versa?					3	5		4						4		
Can I get to a major destination like the airport or shopping center from the lane?																3
What exits can I get to from the ML?				5		4	4		4	3		5		5		
When will I have a chance to get out of the ML?			2								4		5			
What is the expected delay?	2		3	3			5	5								3
Where is the incident?	5	3	4	4		3	3		3							2
Are there any crashes or construction on my route?	4	4			2	2	2		3	5			4	3	1	

Note: Information items from the exercise worksheet not shown in the table were not ranked in the top five by any of the participants.

As can be seen in the table, “recommendation/guidance that shows route (free or managed lane) for the lowest cost and least amount of time” was the most preferred piece of information to receive through a smartphone app. Of the 16 participants who selected smartphone apps as their preferred communication mechanism, all but five ranked this number one in terms of importance. Participants also indicated a strong preference for information that would be valuable during the trip. For example, information on the locations of incidents and expected delay received many top-five rankings. Furthermore, participants also tended to rate information related to the cost of a trip home as very desirable.

Several participants in the sessions stated that they do not like using their phones when driving as their primary reason for not wanting to receive information through a cell phone app.

Website

Three participants indicated websites as their preferred communication channel. In preliminary discussions about how and why people would use traffic information from a website, participants had indicated they would be most likely to use websites in a pre-trip planning mode to check conditions. Table 11 shows the rankings.

Table 11. Ranking of Preferred Travel Information by Participants Selecting Websites as Their Preferred Communication Mechanism.

Information Desired (selected from list)	Participant Identification Number		
	17	18	19
How do I pay?	4		
Do I need a tag?	5		
Is it any cheaper for an HOV on either leg?			3
Recommendation/guidance that shows route (free or ML) for the lowest cost and least amount of time.	1	4	5
How much time will my total trip home take in the ML?			
How much will my total trip home cost?			2
What is the expected delay?		3	1
Where is the incident?	3	1	4
Are there any crashes or construction on my route?	2	2	
Write-In: What is expected time to clear incident?		5	

Note: Information items from the exercise worksheet not shown in the table were not ranked in the top five by any of the participants.

Only one of the three people who preferred websites ranked the route recommendation/guidance item as their most important information type. This person was from Houston and made the comment that if there was a construction project affecting a route, it would be there for a long time and a website could capture that, whereas incident information changes rapidly and may be better captured on a smartphone app. Another participant in Houston added that he/she would use a website for a future trip because it might contain construction schedule information, but for a more imminent trip, he/she would use a smartphone, thinking it was more up to date. Participants in other locations offered comments on website content that indicated they would seek static program information concerning occupancy requirements and HOV discounts on a website.

Electronic Message Sign

Only one person in all four sessions selected electronic message signs as his/her preferred mechanism for receiving information on managed lane facilities. This participant was in the Houston session and ranked the following (in order of priority) as pieces of information he/she would like to receive from these signs:

1. How much time will my total trip home take in the managed lane?
2. Are there any crashes or construction on my route?
3. Where is the incident?
4. What is the expected delay?
5. How much will my total trip home cost?

This participant stated that he/she preferred having information presented on an electronic sign because he/she was already used to seeing information on tolls on Houston area toll roads and using the estimated travel time information on those signs to gauge congestion. This participant is familiar enough with the area's roads that he/she knows what typical travel times are and can estimate how bad congestion is on those facilities by just looking at the travel times.

Furthermore, this participant stated that he/she would not want to get information through a cell phone app or text message because using the phone is too distracting. The participant stated the following: "I don't have my cell phone out while I'm driving. I'm a bad enough driver as it is. When I want to get home, I just want to get home, so I'm not going to pay attention to a text message; I will get the information I need on the sign. The only time I might use a cell phone app is when I don't know where I'm going."

In the Dallas and Houston sessions, the facilitator asked participants how information on digital message signs might be presented and the issues associated with this medium since both regions have extensive managed lane facilities and drivers are presumably familiar with the message signs used on those facilities. For example, much of the discussion about smartphone apps revolved around the conveyance of routing information, and the facilitator asked how routing information might be displayed for all drivers given that signage for that system would not display origin or destination. Participants in both sessions noted that route information is already displayed on a segment basis and that similar information could be provided for a managed lane network.

In-Car Navigation System

Eight participants selected in-car navigation systems as their preferred communication method. Table 12 shows participant ranking of information that could be received through an in-car navigation device. The only two pieces of information that received no ranking from participants selecting this communications option were:

- Can I get from the free lanes of the first leg to the managed lane on the second leg and vice versa?
- Can I tow my trailer?

The participant ID columns in Table 12 show the rankings provided by participants who selected in-car navigation units as their preferred mechanism for receiving travel information. As with the previous tables, the numbers in each column refer to the priority each participant assigned to that particular piece of information. The first participant ID column shows a participant who believed crashes or construction on his/her route was the most important piece of information that could be provided by an in-vehicle navigation unit, followed by expected delay and incident location. There are eight columns in the table, meaning that eight participants out of all four sessions selected in-car navigation devices as their preferred communications medium.

Table 12. Ranking of Preferred Travel Information by Participants Selecting In-Car Navigation Units as Their Preferred Communication Mechanism.

Information Desired (selected from list)	Participant Identification Numbers							
	20	21	22	23	24	25	26	27
How do I pay?					1			
Do I need to sign up for an HOV discount program ahead of time?			5					
Is it any cheaper for an HOV on either leg?			4					
Recommendation/guidance that shows route (free or ML) for the lowest cost and least amount of time.			1	1		5		1
How much time will my total trip home take in the ML?		5	2		2		1	
How much will my total trip home cost?		4	3				2	
Is the lane open 24/7?		3			3		3	
Which direction is the exit (left or right)?							4	2
Can I get directly from one ML to another ML?					4			
Can I get to a major destination like the airport or shopping center from the lane?	4							
What exits can I get to from the ML?	5				5	1		3
When will I have a chance to get out of the ML?		2				2		4
Do you need to know that you can only go one direction on an intersecting road?						3	5	
What is the expected delay?	2							
Where is the incident?	3							
Are there any crashes or construction on my route?	1	1				4		5

Note: Information items from the exercise worksheet not shown in the table were not ranked in the top five by any of the participants.

As the table shows, the distribution of preferred information was wider for in-vehicle navigation units than for other preferred methods. Recommendations/guidance on routing was still ranked highly by some participants, but others indicated a preference for information on crashes and construction. Travel time and cost-related information also ranked highly.

Traditional Media

Only one person in all of the sessions selected television as the mechanism from which he/she would most like to receive information on managed lanes. However, this person did not complete the exercise correctly and did not rank any of the individual pieces of information in priority order. Furthermore, only one person in all of the sessions indicated that he/she would most like to receive information via radio and ranked the following (in order of priority) as pieces of information he/she would like to receive:

1. Are there any crashes or construction on my route?
2. Where is the incident?
3. What is the expected delay?
4. How much time will my total trip home take in the managed lane?
5. How much does it cost? (added by the participant)

MANAGED LANE NETWORK SCENARIOS

Participants in each session were presented with a hypothetical managed lane network specific to their area. The Bryan/College Station session was given a network for the Dallas/Fort Worth area

because the research team felt this would represent a plausible business trip scenario and that these participants would be less familiar with the Dallas/Fort Worth area than the Houston area. The Bryan/College Station participants were intended to be representative of unfamiliar drivers who may be visiting an area and wanting to access a managed lane network. Participants were asked to provide input on these future systems and specifically the type and method of information they would like to receive in order to facilitate their use of these new networks.

While each of the scenarios and participants' responses to them are discussed separately in this section, in general, participants had trouble visualizing these networks. Discussion often focused on current roadways and the issues associated with them—not how technology might enable new means of communicating travel information.

Many expressed concerns about being locked in to a managed lane network. The congestion pricing element contained within each scenario was a particular area of concern. Participants in each of the sections expressed concerns about getting on one facility within the network, finding out that rates on another segment had increased due to traffic congestion, and then not being able to egress the facility.

Austin

The hypothetical managed lane network presented to participants in the Austin session was as follows: The traffic congestion in Austin is similar to what it is in 2016. Improvements have been made on some facilities around town. There are express lanes completed on MoPac (one lane in each direction). Imagine in the future, US 183 has two express lanes in each direction, also in the median, which run north from MoPac to the 183A tollway. The tolls on both the MoPac Express and US 183 Express change dynamically. That means it adjusts with the traffic in the lane—the more cars in the lane, the higher the toll. Imagine you work downtown and live in Leander. You are at your office getting ready to leave for home at 5:30 p.m.

The facilitator asked participants what sort of information they would like to have when deciding whether to use the managed lanes or use some other roadway or mode. Participants provided the following responses:

- Where to get a TxTag®.
- Occupancy requirements for the facilities.
- Time savings/travel time on the free lanes versus the managed lanes.
- Current price on the managed lanes.

Participants were asked to discuss how they would like to receive information on the priced roadways. In the ensuing discussion, it became apparent that price and travel times were the most critical information from the listing provided above since most of the participants' discussion focused on how they would like to receive those two pieces of information (as opposed to occupancy requirements or how to get a TxTag®). Participants generally preferred receiving this information through some sort of smartphone app, and specifically push notifications. As one participant stated, "I would like my phone or car to, at some point, tell me it'll cost \$5 and take 20 minutes." This participant noted, however, that there is the potential for information overload,

stating, “I don’t want to make a lot of decisions while I drive, and with all these choices and prices changing all the time, I just want to know what it will cost to get from A to B.”

Some of the participants noted that much of the discussion was centered on current technologies, and that the scenario was for 2030. One participant stated that, in the future, he/she would expect some sort of technology that would allow users to input their origin and destination and provide updated toll rates as they travel. This participant stated that he/she would like to receive an estimate or dollar range to determine the prices and associated travel times for several different potential routes, including the managed lanes. Another participant stated that, in the future, he/she would like to see price and travel time information projected on the windshield, perhaps with route information also being displayed in the form of a map overlay.

Participants stated that they would like to have more information about how cost is being determined. The group was aware that prices would be set dynamically, which would introduce a lot of uncertainty in trip planning. If an algorithm is used, participants would like for it to be available to others for inclusion in apps and other third-party services and not simply used to place a price on a flashy sign. One participant indicated that if the computerized algorithm was not transparent and available, he/she would not take the priced roads because he/she did not trust that the price would be set fairly and would boycott the road on principle.

Participants also indicated a desire for options to leave the managed lane network when needed and feared being trapped on the roadway and subject to ever-escalating toll rates. All participants indicated that a managed lane network in the Austin area would need a bail-out option that would allow travelers to get off a priced segment if they deem that the price has gotten too high. One participant observed that “you are just asking for a disaster if you don’t allow people to get in and out of those facilities,” to which another participant responded that people might need to exit for reasons other than price, such as being able to refuel their vehicle.

Bryan/College Station

There are currently no managed lane projects within the Bryan/College Station area. As such, the hypothetical managed lane network presented to participants in that session asked them to think about a situation in which they were temporarily working in Dallas/Fort Worth and would be using that network of managed lanes. The actual scenario was presented follows: Your job is taking you to the Dallas/Fort Worth area for several weeks. You will be working near the race track on I35W north of Fort Worth and your hotel is in Euless near the DFW airport. The traffic congestion in Fort Worth is similar to what it is in 2016. Improvements have been made on some facilities around town. There are express lanes completed on I35W (one lane in each direction). This is the toll lane that is being built in the median of I35W in the section north of downtown. The Express Lanes on 820/183 are still operating like they are today. The tolls on both the I35W Express and on 820/183 TEXpress Lanes[®] change dynamically. That means it adjusts with the traffic in the lane—the more cars in the lane, the higher the toll.

The participants initially had difficulty visualizing the scenario, with one participant (who travels frequently in the metroplex region) eventually explaining the current roadway network in the area. Participants had additional questions about current occupancy requirements and the status of tolls on certain roadways in the region. Even with additional explanation by the moderator,

many participants had trouble with the ensuing discussion because they were not familiar with the specific roadways.

The facilitator asked participants what sort of information they would like to have to facilitate decision making on whether to use the managed lanes presented in the scenario. Two participants indicated that in the future, there are likely to be automated vehicles operating on the roadway and that there will be a significant amount of information piped into onboard systems. Another participant stated that automated vehicles could enable decision making by allowing drivers to input their origin and destination and providing routes, travel times, cost, and current traffic conditions. Another participant stated that he/she would like to see more signs displaying information such as occupancy requirements and associated costs.

At the end of the discussion, the moderator asked, “If you went to Dallas and didn’t know about these lanes, would you go in?” All of the participants answered no.

Dallas/Fort Worth

The hypothetical managed lane network presented to Dallas session participants was as follows: The traffic congestion in Fort Worth is similar to what it is in 2016. Improvements have been made on some facilities around town. There are express lanes completed on I35W (one lane in each direction). This is the toll lane that is being built in the median of I35W in the section north of downtown. The Express Lanes on 820/183 are still operating like they are today. The tolls on both the I35W Express and on 820/183 TEXpress Lanes[®] change dynamically. That means it adjusts with the traffic in the lane—the more cars in the lane, the higher the toll. Imagine you work at Alliance Airport and live in Euless. You are at your office getting ready to leave for home at 5:30 p.m. Your normal route is to go south on I35W to 820/183 East.

The facilitator asked what information participants would want to decide which route to take. Participants provided the following examples:

- Traffic conditions.
- Location of accidents.
- Travel time on alternate routes.

Traffic conditions and accident locations were often discussed together for Dallas-area participants as information they would like to receive. For example, one participant stated that he/she would only use the managed lanes if there was an accident in the general-purpose lanes that would significantly increase travel time. This participant stated that travel time alone and accident information alone are not necessarily sufficient by themselves, stating that accidents can be cleared quickly and that he/she could sit out slow-moving traffic (that is not the result of an accident). However, some accidents can bring traffic to a dead stop, in which case it is important to have both pieces of information (travel time and incident status) in order to decide whether to use the managed lanes. At a later point in the discussion, the facilitator turned back to this discussion, asking about other pieces of information that Dallas-area participants would need in deciding to use managed lanes, with the unanimous answer again being traffic conditions.

One Dallas participant stated that he/she did not really need routing information because he/she would infer traffic conditions in the general-purpose lanes based on the displayed price. This participant stated that he/she knows the area well enough to make routing decisions and that seeing an elevated price would indicate that the general-purpose lanes are congested ahead. Another participant agreed but stated that he/she would want to know why the price is going up and reiterated the need for signage to convey information on accidents.

One participant wondered aloud why roadside signs showing the location of accidents are not more common. The facilitator pushed the group to provide more insight on the issue of roadway signs because they had not been brought up much by participants in other sessions, with the exception of some discussion in Houston. Another participant stated that signs displaying accident information should be placed “maybe three miles back” from the entrance of a managed lane facility and display whether there is an accident ahead. The facilitator asked the group what they thought about using roadway signs to convey routing information. One participant responded that signs would not know the destination of travelers and therefore would not be able to recommend routes.

Another participant stated that signs would likely be the best method for conveying information to travelers who are not familiar with the area. When asked what information should be provided to unfamiliar drivers, participants responded with the following: signs should indicate distance to the next exit and identify the name of that exit, price for access to the managed lanes, a map showing lanes, and traffic conditions. However, two participants noted that having too much information on a sign or attempting to show a map of the managed lane network might cause confusion and could potentially make traffic worse.

Participants in the Dallas session did not use mobile phone apps for routing as much as participants in other sessions but did indicate that they are open to using them in the future. One participant stated that he/she would like to see an app that is capable of knowing a user’s regular commute and issuing notifications when events (such as traffic incidents) occur along that route, which may include multiple roadways and associated segments. The potential for more dynamically priced facilities in the area was also seen as a possible opportunity for app development. Several participants indicated that dynamic pricing is difficult to predict and that they would consider using an app that gave them current rates for managed lane access while they were driving. Participants also expressed a desire for information on incidents and specifically estimated time to clear incidents. Several noted that the mere presence of an incident might not require a departure from the preferred route, but that an accident with significant clearing time would likely require rerouting.

Houston

The hypothetical managed lane network presented to Houston session participants was as follows: The traffic congestion in Houston is similar to what it is in 2016. Improvements have been made on some facilities around town. There are express lanes completed on 610 through the Galleria area (one lane in each direction). The express lanes on I-10 to Katy are still operating like they are today. The tolls on both the 610 and Katy Express Lanes change dynamically. That means it adjusts with the traffic in the lane—the more cars in the lane, the higher the toll.

Imagine you work in Bellaire and live in Katy. You are at your office getting ready to leave for home at 5:30 p.m. Your normal route is to go north on 610 West to I-10 West.

The facilitator first asked what would influence participants' decision to use the priced facilities in this network. Responses included the following:

- The time of day (peak versus off-peak).
- The cost to use the facilities.
- The amount of traffic on the facilities.
- The need to make additional stops while en route to the final destination.
- The need to be at the final destination by a certain time.

The facilitator next asked the participants to discuss specific information that they would like to have to make the decision to use the facilities. Travel time and cost were the most commonly cited answers. However, participants were cognizant of the fact that in a dynamically priced environment, both of these pieces of information are likely to change on a frequent basis, perhaps even after they have begun their trip. One participant stated that if he/she was heading home and "the price doubles, I might just get off the road and get a beer and wait things out."

This statement prompted the facilitator to ask if participants would be interested in having information about the potential cost of trips on the network and how they would like to receive that information. Most of the participants in the session indicated that this information would be desirable. Several participants noted that if prices are set based on traffic volume, then having information on the cost of their trips would allow them to deduce how bad traffic is without having to have that information directly or look at other sources. As one participant stated, "If I see a higher rate, then I'm going to know traffic is bad and I'm going to just wait it out."

All of the participants (with the exception of one) indicated a preference for cost information to be provided on a segment-by-segment basis as opposed to giving a total cost of the whole trip. (The one other participant actually had no preference on how cost information was presented.) One participant noted that facilities in the area tend to have varying levels of congestion. For example, I-10 was noted as often running smoothly while 610 was backed up. Having segment-based price information would allow travelers to make more detailed travel decisions in response to conditions. Several other participants agreed with this assessment.

There was no strong consensus on how participants in the Houston session would like to receive cost information. Some participants indicated that they would like to receive that information from a smartphone app, while others preferred a website. One participant noted that a map of the area showing current segment-by-segment pricing would be beneficial. More participants preferred roadway signs to convey this information in the Houston session relative to others, but it was not a majority sentiment.

Participants noted that they would prefer cost information to be as current as possible, with some wanting to receive real-time information. However, a few participants stated that such real-time information could pose problems. For example, one participant said he/she would be upset if someone traveling a short distance behind him/her got charged a lower rate, which could be a distinct possibility depending on how often rates are updated. In response to this, another

participant noted that updating the rates every two minutes or less might be too frequent, but at the same time, that level of fluctuation would be unlikely to deter him/her from using the roadways.

Several Houston participants expressed concerns about being locked into any potential managed lane network once they are on. They stated that since the price is being set based on travel volumes, there is a chance that the price for the current facility may change, and subsequent priced segments are likely to change once they enter the network. All of the participants agreed that they would like to have a bail-out option that would allow them to exit the network prior to the start of any new priced segment if the price had risen.

Several participants in the Houston session indicated that they would want to have more information about who is determining the price for managed lane access and how they are making that determination. One participant stated that he/she would like to “look and see traffic numbers and see if they match up with the rates being charged.” Another participant replied that as a business owner, he/she is likely to pass the cost of tolls on to customers and would like to be able to tell them how toll rates are being calculated if asked. One participant stated that if price information is conveyed through an app, then it might be possible to embed information about the pricing algorithm within the app itself, perhaps as part of the terms of service agreement. Another participant responded that he/she would prefer to see the algorithm itself since it is unlikely that in the year 2030, these types of decisions would be made by “a person pushing a button” and transparency would be the best policy. A participant in the Houston session went on to state that “unless the technology is transparent, how do you know you can trust it? I work in technology, and you should never trust anything that’s out there unless it’s published. If you are telling me that I am dependent on the system, then I need to know what the system is being fed.”

SUMMARY

In June 2016, TTI researchers conducted four focus groups in Austin, Bryan/College Station, Dallas, and Houston to assess what sort of information travelers would like to have and the means by which they would prefer to receive information about traveling on managed lanes and managed lane networks. Initial discussions showed that many participants were aware of the managed lane concept itself but could not articulate an operational definition. Responses to questions aimed at identifying participant knowledge of these types of facilities indicated that participants view them as having eligibility requirements or using pricing, but the two aspects were not generally merged. Furthermore, some participants could identify types of managed lane facilities or specific managed lane facilities, but they were unsure of what it was that made the facility a managed lane. General confusion about the terms *express lanes*, *managed HOV lanes*, and *managed lane networks* was also common. In several cases, participants thought the term *managed* referred to the operating entity and the agencies responsible for the lanes themselves.

Participants reported currently using many different sources of travel information in making travel decisions, the most common being smartphone apps, websites, and in-vehicle devices like navigation units. These resources are most commonly used for routing purposes. Participants who use smartphone apps and navigation units generally do so because they want to monitor traffic conditions on their usual trips or obtain routing information on trips in unfamiliar areas.

Participants indicated a high level of trust in the capabilities of smartphone-based apps and their associated data systems and algorithms to provide reliable information. Much of this trust is based on their previous experience with these systems since participants felt that they have proven themselves to be a reliable tool. However, for pricing technologies, there was a certain level of distrust. Participants noted that they would prefer the algorithms setting prices for managed lane facilities to be transparent and available for review by the public.

For receiving information about managed lane networks in the future, respondents most frequently preferred smartphone apps, although some participants looked to automated vehicle systems to provide information to the driver. Participants indicated that the information available through other sources such as websites and in-vehicle navigation units can be provided through a smartphone app. The information that participants indicated would be most useful when deciding to use a managed lane network was recommendation/guidance that shows route (free or managed lane) for the lowest cost and least amount of time. Information on the location of incidents and their impact on travel time was also highly rated by participants.

CHAPTER 5—SURVEYS

BACKGROUND

TxDOT and other operators of managed lanes in Texas rely on signage, websites, and social media to convey information related to pricing, occupancy requirements, and hours of information. Using existing methods for operational and planned systems may prove ineffective as network complexity grows. This research task, along with the focus groups described in the previous chapter, assessed how to improve traveler information for TxDOT and partnering agencies for the operation of regional managed lane networks throughout the state.

The purpose of the focus groups was to gather input from a small number of drivers in depth about identified key issues to include in a survey deployed statewide to a larger group. The focus groups demonstrated that it was important to ask the questions in the context of a familiar roadway network. For this reason, the survey sorted people by geographic region and provided example facility names based on where the respondent traveled most frequently. The focus groups also showed that if a person had never used managed lanes, it was difficult for them to answer questions about traveler information systems pertaining to them. Therefore, the survey asked questions specific to managed lane information only of people who had used them. The survey flow diagram shown in Figure 40 illustrates the branching logic used in the survey.

Based on the focus group findings, the online survey addressed the following research questions:

1. What communication mechanisms (i.e., maps, websites, apps) do people use to plan a route? Answers to these questions will help TxDOT know where to direct resources for providing routing information that includes managed lane options.
2. What features of trip planning systems do drivers prefer? Answers to these questions will help TxDOT know trip planning system features to include (e.g., point to point routing, registered accounts to store regular trips). These answers will also illustrate where managed lane options need to be included in trip planner systems.
3. How does the preferred communication mode and mechanism vary by whether a user seeks the information pre-trip or en-route?
4. What specific type of regulatory and guide information would drivers like to see on road signs compared to in-vehicle devices?

SURVEY DEVELOPMENT

The primary goal of the web survey was to identify what information travelers use and desire for planning trips that may use managed lanes. The initial survey instrument was drafted collaboratively, with all members of the project team having an opportunity to provide input on content, wording, response options, and skip logic. The focus group findings summarized from Chapter 4 provide a strong foundation for the questionnaire. Results from previous TTI surveys also helped form the survey design.

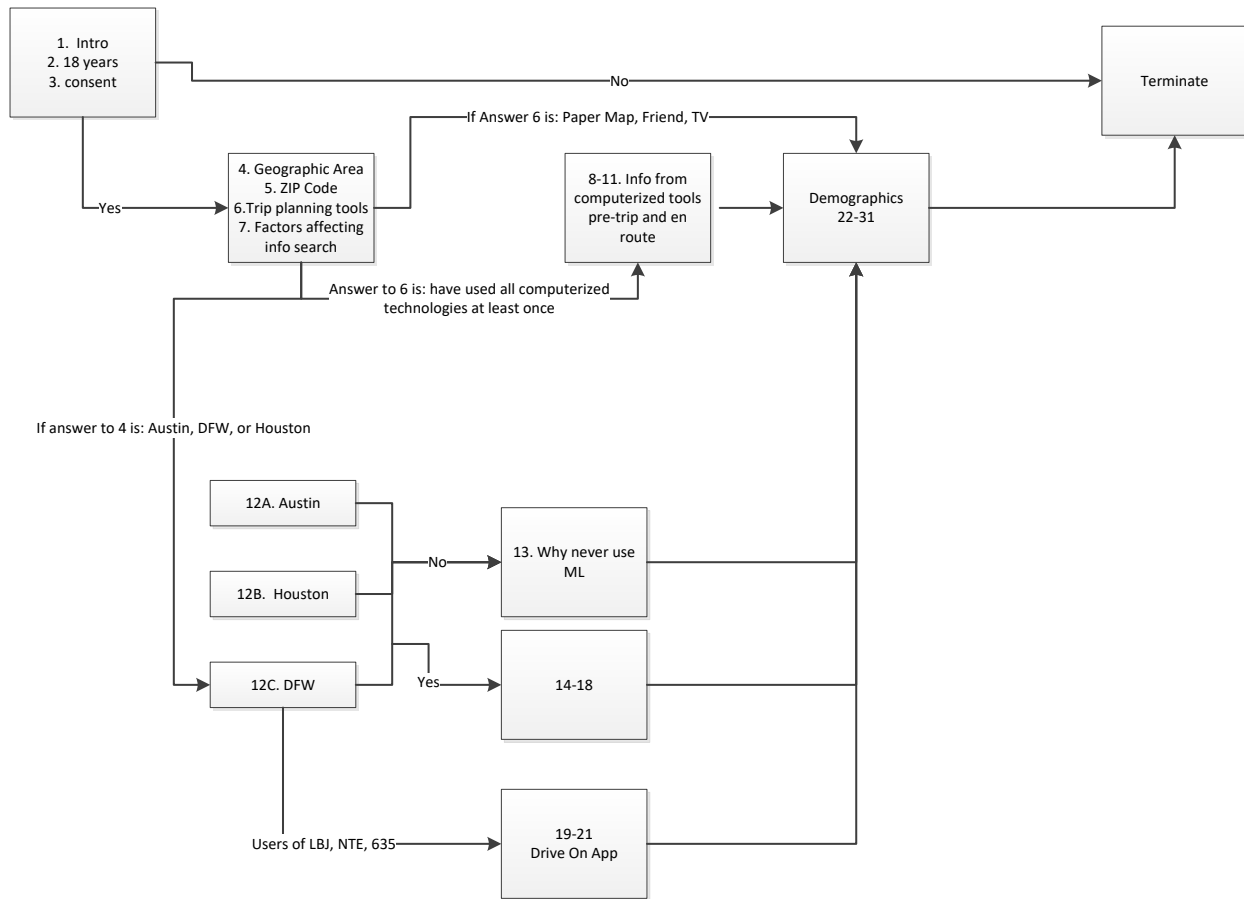


Figure 40. Flow of Questions Illustrating Survey Skip Logic.

TTI programmed the web-based survey using the Qualtrics software (149). The final, self-administered questionnaire contained approximately 30 questions, partitioned into the following modules:

- **Background.** This section determined respondent eligibility, including age verification and acquisition of informed consent.
- **Geography.** This section identified the geographic area where the respondents did most of their driving.
- **Trip Planning Activities.** This section queried the respondents on their use of travel information for the purpose of planning a trip. This included information on specific platforms and information on trip attributes.
- **Managed Lane Use.** This section collected information on respondent use of managed lanes, including facility used, frequency of use, motivations for using and not using managed lanes, opinion of technologies used to disseminate managed lane information, and overall opinion of managed lanes.
- **Demographics.** This final section collected person- and household-level sociodemographic characteristics of the respondents.

The survey was only administered in English.

Prior to data collection, all members of the project team tested the instruments and provided comments. This testing process helped to debug the program and streamline the order of questions as they appeared to the respondents. Appendix C contains the final questionnaire.

As noted in Appendix C, a slight modification was made for an option listed within Question 6 after approximately 100 people had completed the survey. The question asked about websites people may use for traveler information. The original wording did not include the names of very popular sites (Houston TranStar[®] and TransGuide) that respondents may find more familiar than the previous generic phrase “toll road agency website.”

SURVEY FLOW

The survey divided questions into sets, as defined by the earlier noted modules. Respondents saw specific questions based on their answers to the first series, which asked where respondents made most of their trips and whether they took trips on managed lanes. Using this survey flow logic, the research team reduced the amount of survey time by only asking questions that pertained to their travel. For example, respondents did not see questions about Austin-based managed lanes if they indicated they primarily traveled in Houston. Other examples included use of specific technologies such as in-vehicle navigation systems and smartphone devices. Figure 40 shows the overall flow logic.

Screening and Sorting Questions, Demographic

Questions 1–3 introduced the purpose of the survey and asked if the respondent was at least 18 years old and agreed to participate in the survey. The Human Subjects Protection Office at Texas A&M University required the inclusion of the first three questions. Participants answered a small set of demographic questions at the end of the survey. The demographic categories were those used by the American Community Survey of the U.S. Census Bureau. Questions 4 and 5 asked for zip code and the geographic region in Texas where the respondents did most of their driving. The answers helped determine what specific managed lane examples the respondents saw for later questions.

Pre-trip Planning Activity Questions

All participants saw Questions 6 and 7. Question 6 asked how often respondents used specific trip planning tools. If participants indicated they used every type of listed technology at least once, they saw Questions 8–11 about different pre-trip and en-route formats of information. If respondents indicated they never used a technology-based trip planning tool from Question 6, they saw the demographics section and the survey ended for those respondents after that question (our results indicate that this never happened). Question 7 asked about what factors affect their decision to seek out traveler information of any kind.

Respondents saw Questions 8–11 if they indicated that they use all of the technology types (e.g., websites, apps, navigation systems). Questions 8–11 addressed tool use in terms of entering destinations, registering accounts, and feature desirability.

Managed Lane Use Questions

Question 12 asked about use of specific managed lanes. The options offered were pre-selected based on the answer to the zip code and frequent travel location questions. Question 13 appeared if the respondent answered a prior question with the response of never using a managed lane. That question asked why the respondent never traveled on a managed lane and the survey ended for those respondents with that question. Questions 14–18 appeared if respondents indicated use of a managed lane. These questions asked about trip purpose, factors affecting the decision-making process, and how they learned about managed lanes. Question 16 listed specific types of information and asked respondents to indicate whether they felt this information should appear on a road sign or in a vehicle. An explanation prefaced Question 16 to describe a scenario when participants should consider a future system, not currently in operation. Any implementation of in-vehicle systems would need to consider issues of driver distraction within system design.

Questions Specific to the DFW Region Drive On TEXpress® App

Question 19 asked respondents only from the DFW region whether they used the Drive On smartphone application. Respondents answered follow-up questions about specific features of the Drive On app if they answered affirmatively. This app, branded with the TEXpress Lanes® logo, provides users with information about managed lanes and enables HOV declaration for reduced tolls (*150*).

SURVEY DEPLOYMENT

The survey launched on February 2, 2017. The primary method of advertising the survey was through social media, including LinkedIn®, Facebook®, and Twitter®. Promotion of the survey consisted of posting on TTI social media pages and hashtagging a diverse set of organizations within the Austin, DFW, and Houston regions. These organizations included major employers, transportation agencies, and media outlets. The survey remained open for public responses from February 2 through March 12, 2017.

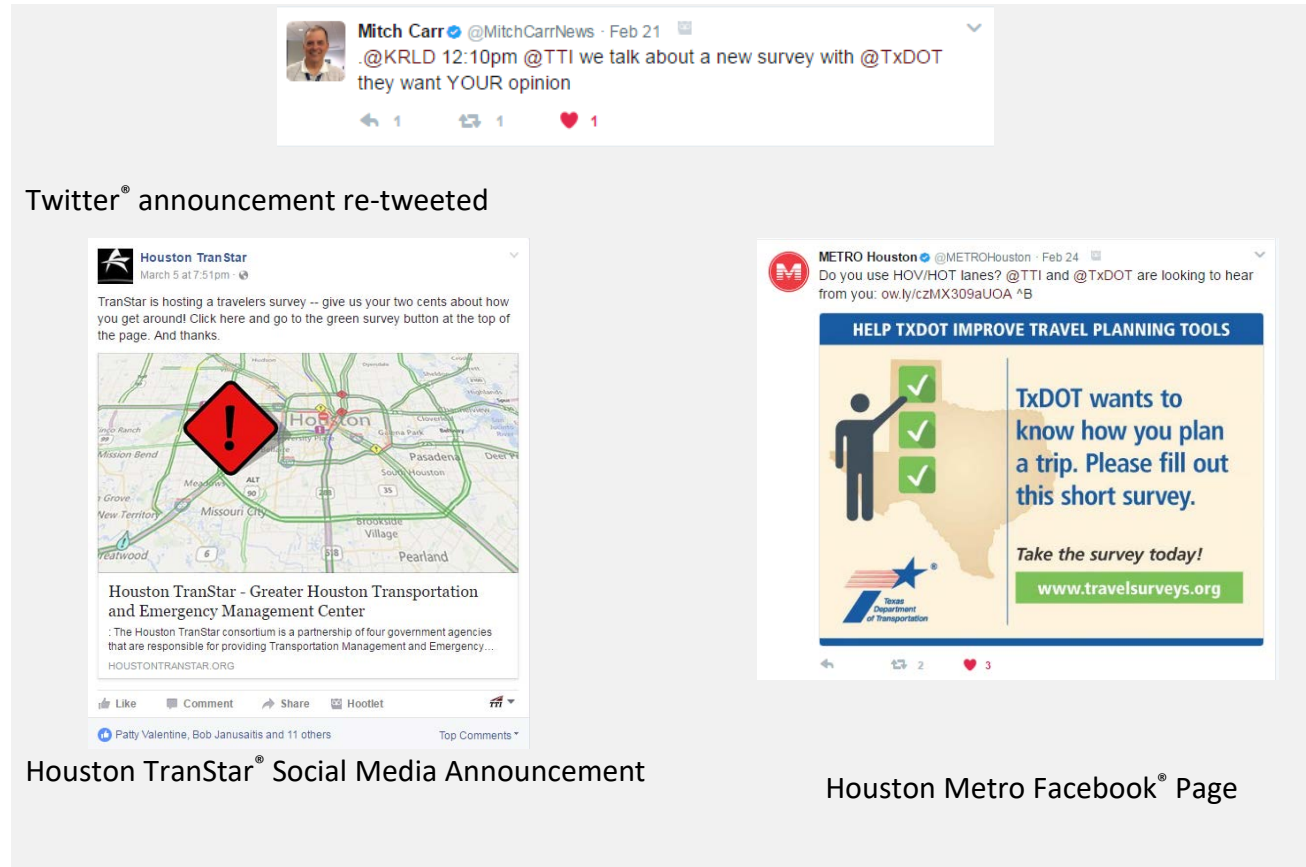
Distribution of a press release to Texas media occurred on February 10. The research team also promoted the survey through social media. Facebook® indicated that 7,590 users of the system saw a promotion of the survey during the open response period. In the DFW region, paid Facebook® advertisements generated 44 clicks and 20 shares to other Facebook® pages. The research team also used the Twitter® account maintained by TTI to make 80 Twitter® posts, and Twitter® indicated that 58,953 users saw those posts. Additionally, the Twitter® posts garnered 48 retweets and 109 clicks to the survey web address. Houston TranStar® also advertised the survey on its main webpage by using a small clickable green button that appeared in the upper right-hand corner.

Key dates for survey publicity included the following:

- TTI Press Release: February 16.
- Community Impact News (social media posting): February 17.
- The Eagle Online (Bryan/College Station): February 17.
- Mt. Pleasant Daily Tribune Newspaper: February 20.

- Houston TranStar® website posting and social media posting: February 24–March 5.
- Paid Facebook® advertisement for the DFW region: March 2–6.

Figure 41 presents snapshots of a few social media adverts used for promoting the survey.



Twitter® announcement re-tweeted

Houston TranStar® Social Media Announcement

Houston Metro Facebook® Page

Figure 41. Examples of Social Media Advertising.

Other outlets for promoting the survey included newsletters for metropolitan planning organizations, radio interviews, local newspapers, press releases, and the TTI website. Figure 42 provides a screenshot image of the advertisement on the TTI website. Figure 43 provides a screenshot image of the advertisement in the Community Impact Newsletter.

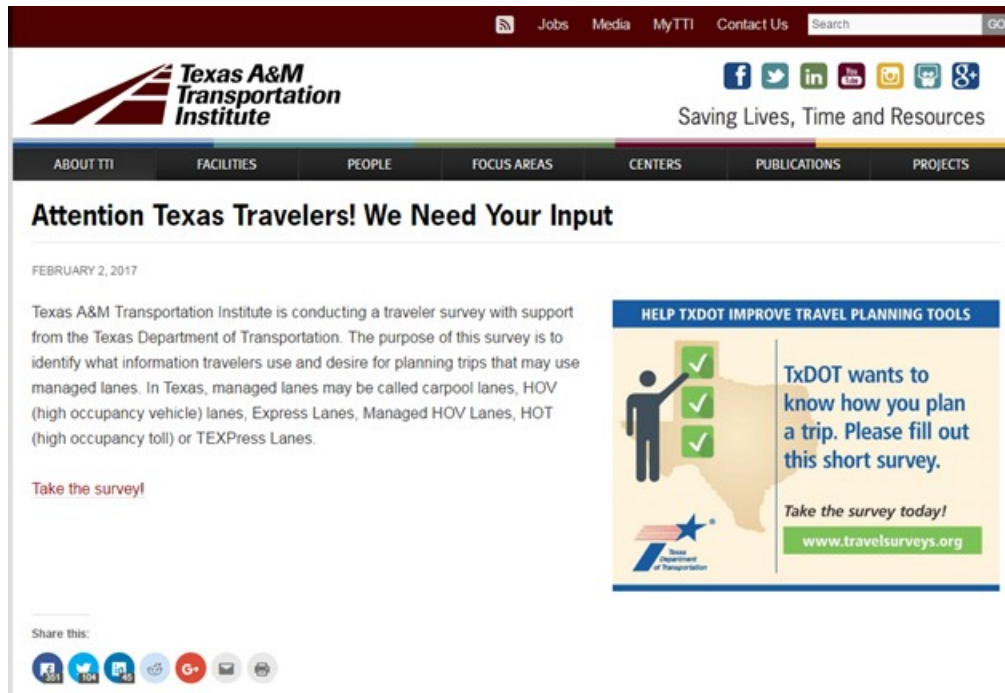


Figure 42. Survey Advertisement on TTI Website.



Figure 43. Survey Advertisement on Community Impact News Website.

Researchers did not have ready access to a database of all individuals driving in major Texas metro areas, so a non-probability sampling method was used. The budget did not support a probability sampling approach.⁸ Researchers implemented non-probability sampling techniques,

⁸ A probability sampling method is any method of sampling that uses some form of random selection of units from a defined population. Probability sampling provides the ability to quantify sampling error and estimate confidence intervals for detection of statistically significant differences between groups. More information can be found at <https://www.socialresearchmethods.net/kb/sampprob.php>.

a commonly used methodology when dealing with undefined populations and/or limited sampling resources. Significant downsides of this method of sampling include the inability to quantify sampling error and the inability to extrapolate meaningful inferences to a larger population.

RESULTS

The survey opened for responses from February 2 to March 12, 2017. After examining 1,128 responses, researchers identified 190 surveys that were only partially complete and thus removed them from further analysis. The remaining 938 survey responses formed the basis for interpreting results. Overall, the median time to complete the survey was approximately 7 minutes. Figure 44 shows the number of completed surveys by geographic region.

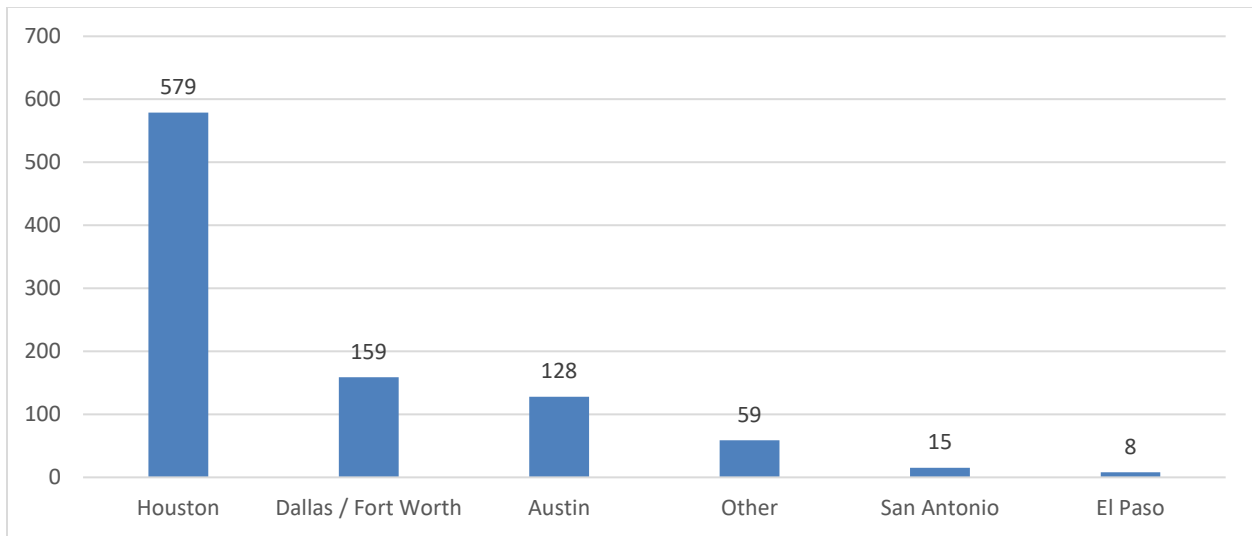


Figure 44. Distribution of Completed Surveys by Geography (Q4, N=938).

Figure 45 presents the proportional distribution of respondents within the Houston, Dallas/Fort Worth, and Austin regions that reported using specific facilities. The question that supported Figure 45 was a multiple-choice question that enabled respondents to choose more than one managed lane facility. Respondents from regions such as Houston and Dallas/Fort Worth with multiple managed lane facilities may have used more than one facility. As such, regional proportions may sum to greater than 100 percent.

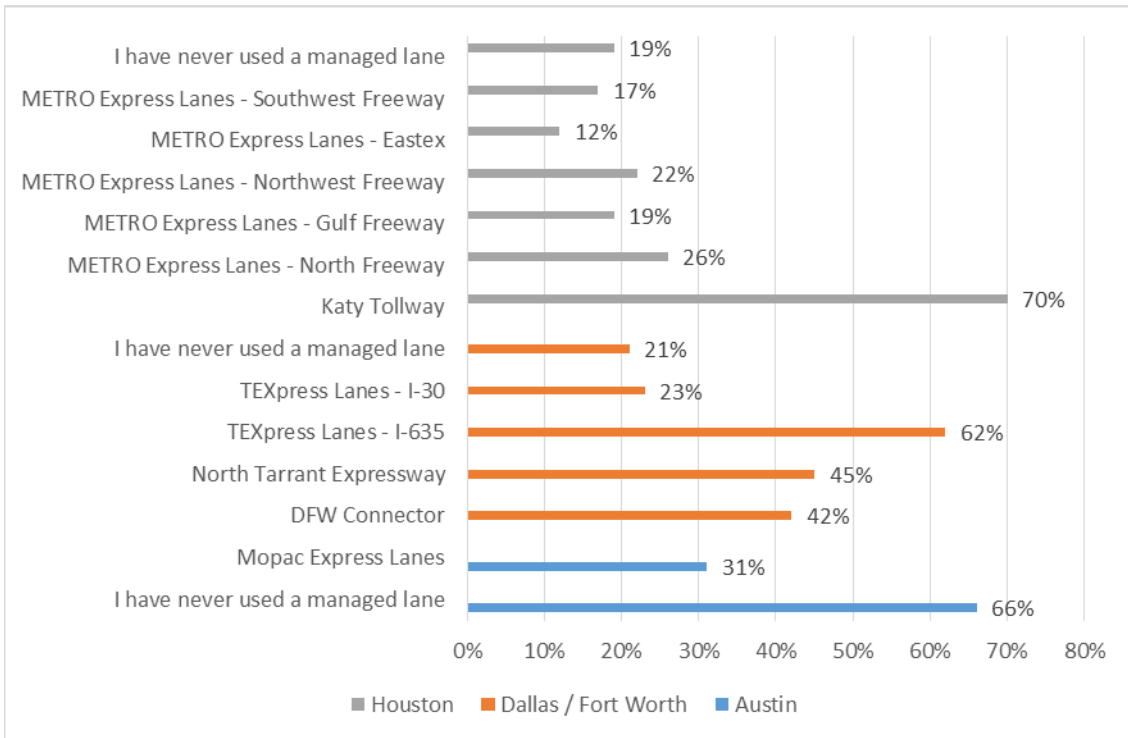


Figure 45. Proportion of Regional Respondents by Use of Managed Lane Facility (Q12, N=938).

Figure 46 provides a summary of completed surveys by weekly field period.

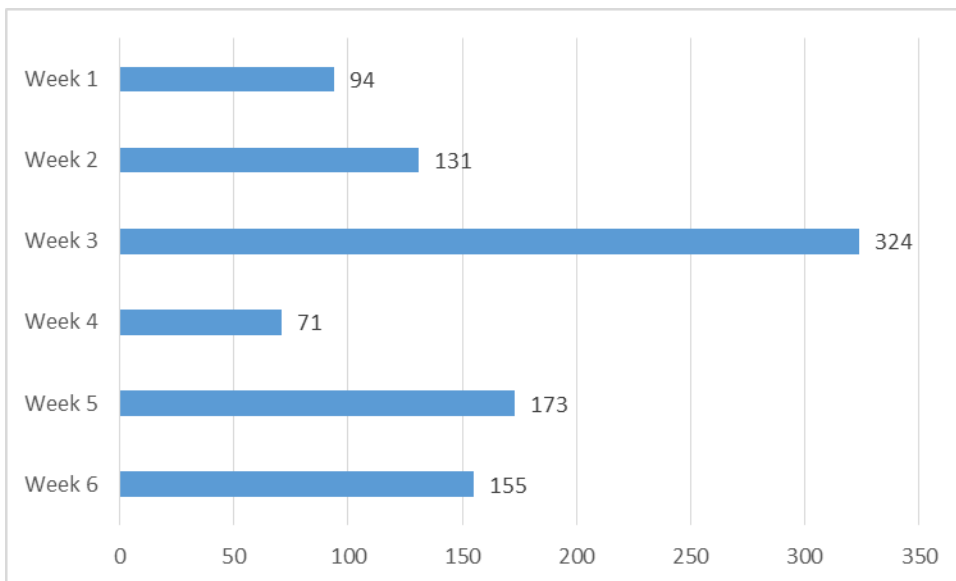


Figure 46. Distribution of Completed Surveys by Weekly Field Period (N=938).

After data collection concluded, data editing began. This process involved reviewing the data for completeness, subjecting it to a variety of logic checks, and post-coding variables for analytical purposes.

Responses to Individual Questions

Respondents were initially provided a list of traveler information sources (such as TV or radio reports, smartphone apps, etc.) and asked how frequently they used each in the process of selecting routes in major metropolitan regions. Figure 47 through Figure 54 present a proportional distribution for each source by frequency of use and geography. Figure 55 presents the proportional distribution of all sources by geography for those that used each source often or very often. The data suggest that, in total, smartphone apps and mapping websites are the sources of traveler information used most frequently (151). These were the only two sources of traveler information consistently used often or very often across all geographies. These findings are very much in line with those suggested by a 2016 Traveler Information Survey conducted in the Austin TxDOT District. In that study, a majority of commuters (68 percent) preferred to use smartphone apps to obtain traveler information for commute trips. This proportion increased to 73 percent for non-commute work or school trips.

Fifty-one percent of respondents who reported most of their trips in Houston noted using road agency websites either often or very often. This estimate should be interpreted with caution since the survey was advertised on the Houston TranStar[®] website, and respondents from other regions reported significantly lower usage of road agency websites. Overall, paper maps were the noted source of traveler information used least frequently, with 84 percent of all respondents reporting using this source rarely or never.

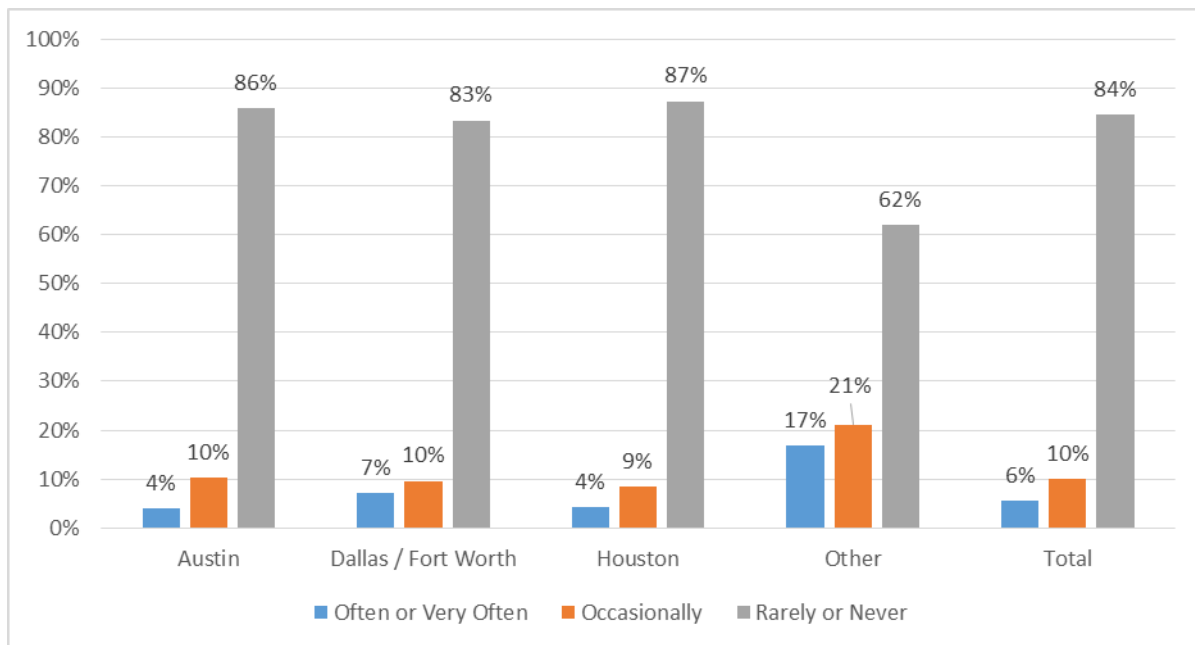


Figure 47. Use of Paper Maps to Help Respondent Select Route (Q6, N=928).

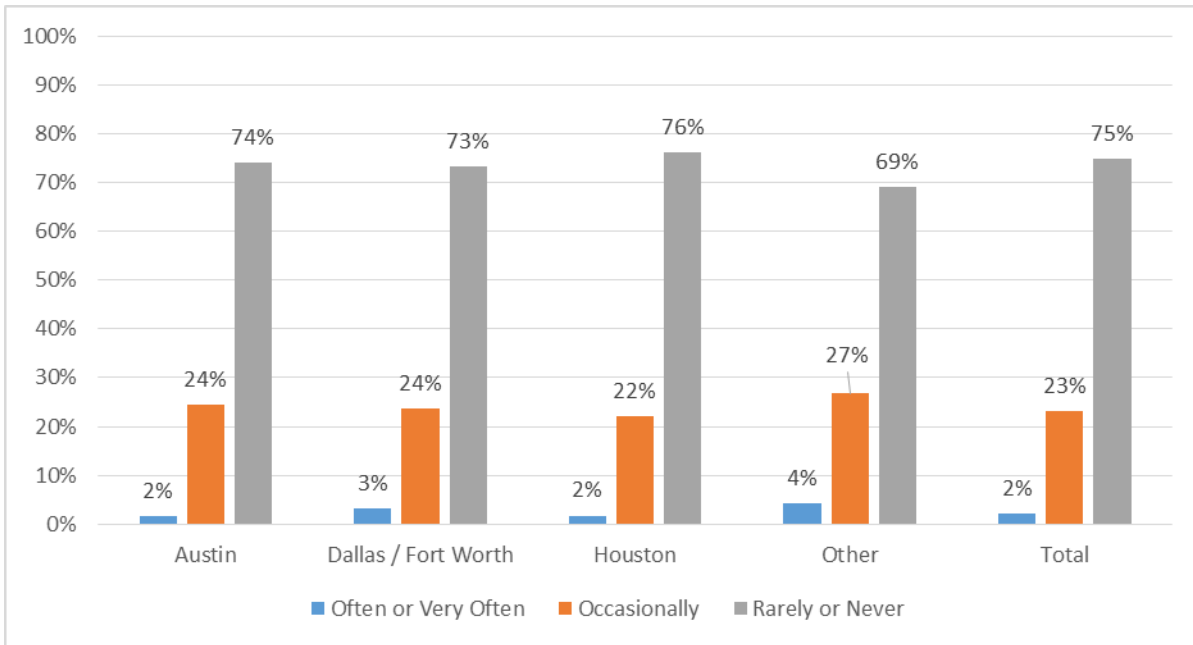


Figure 48. Use of Directions from a Friend to Help Respondent Select Route (Q6, N=929).

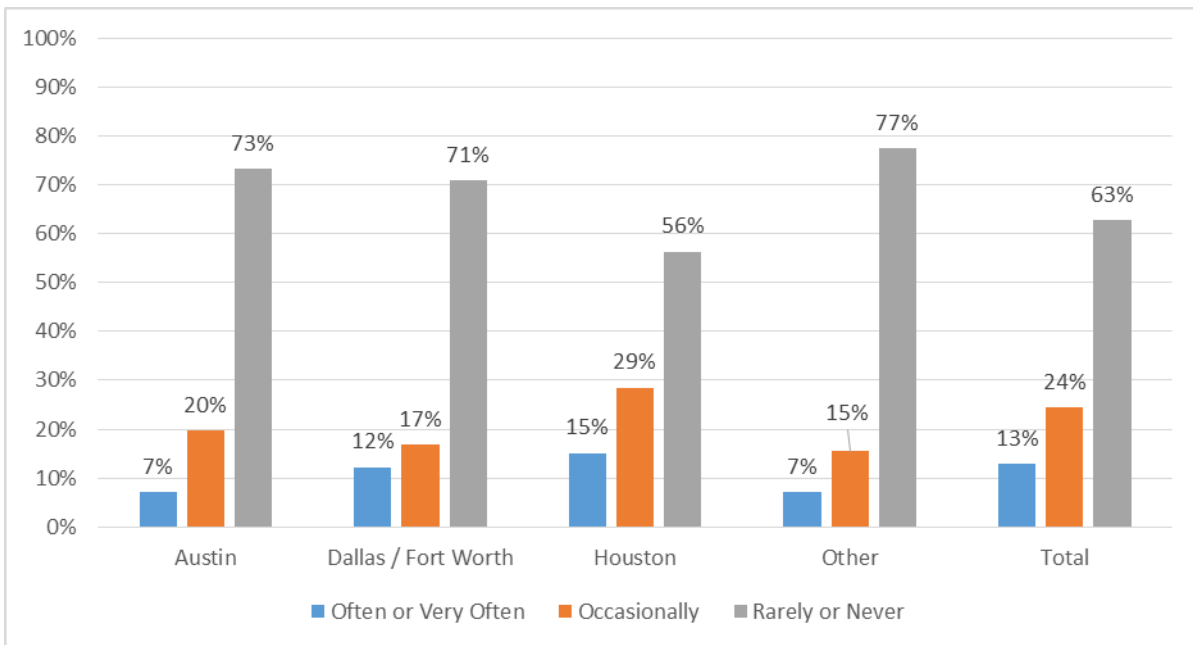


Figure 49. Use of TV or Radio Reports to Help Respondent Select Route (Q6, N=928).

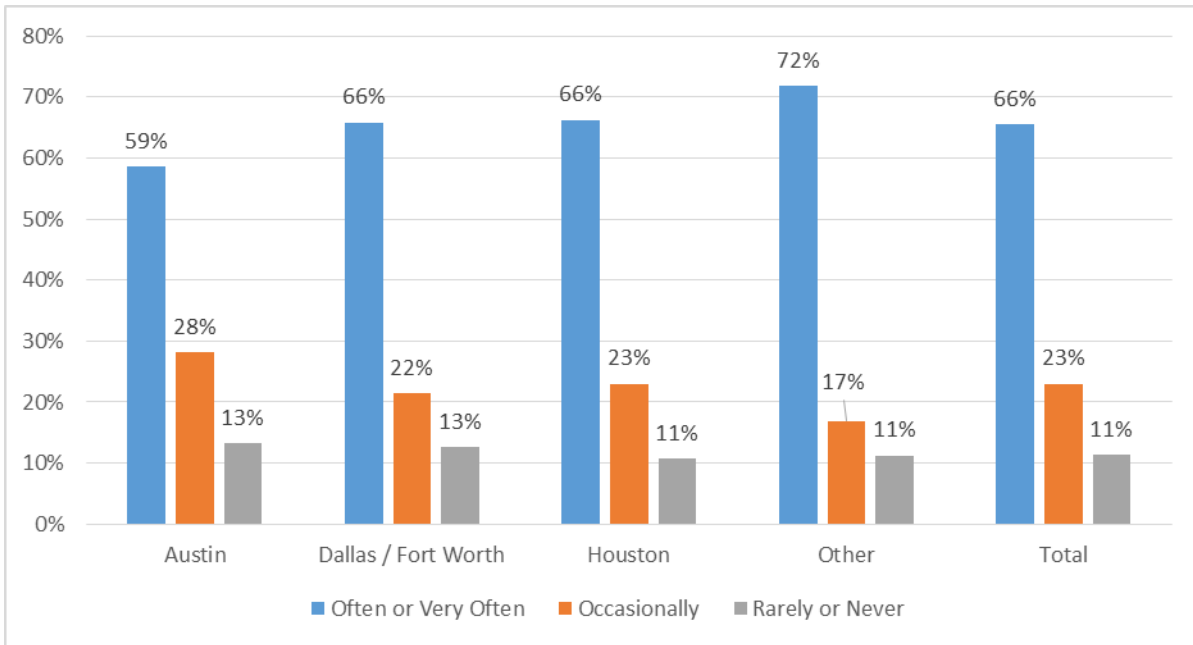


Figure 50. Use of Mapping Website to Help Respondent Select Route (Q6, N=935).

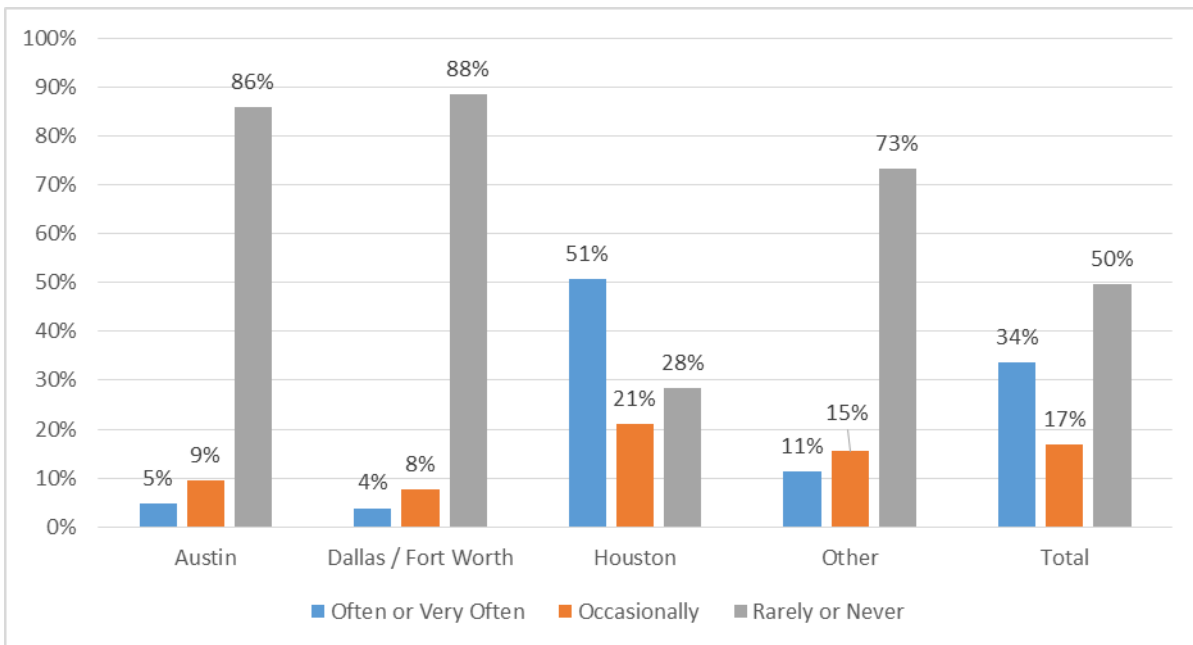


Figure 51. Use of Road Agency Website to Help Respondent Select Route (Q6, N=930).

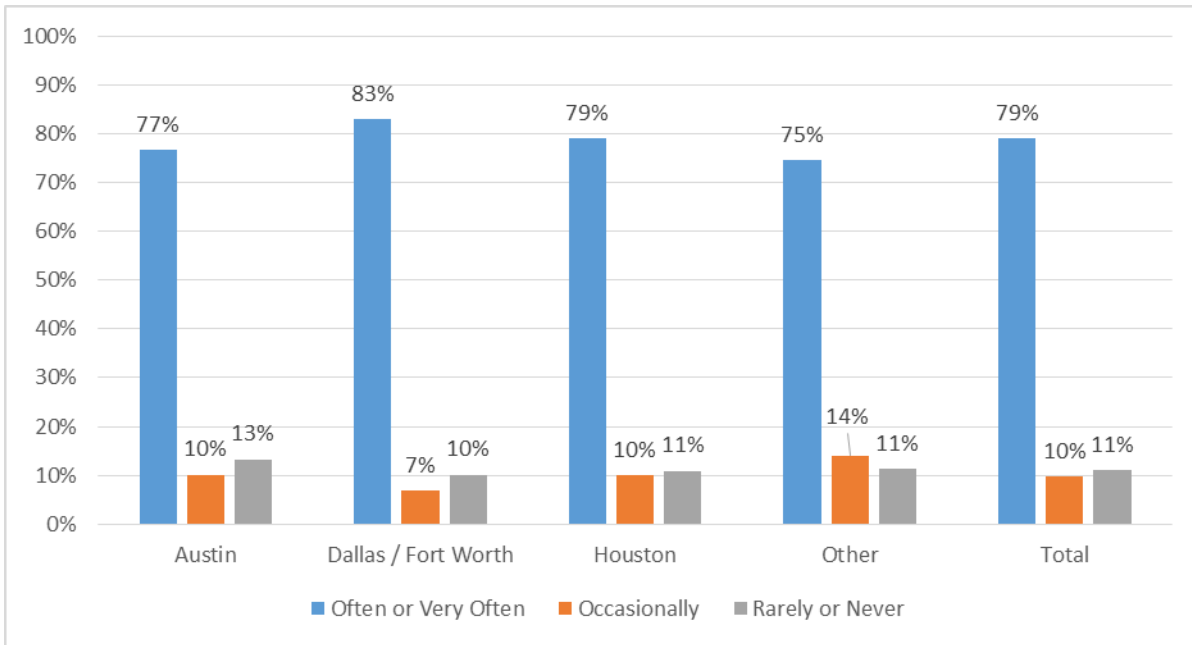


Figure 52. Use of Smartphone App to help Respondent Select Route (Q6, N=935).

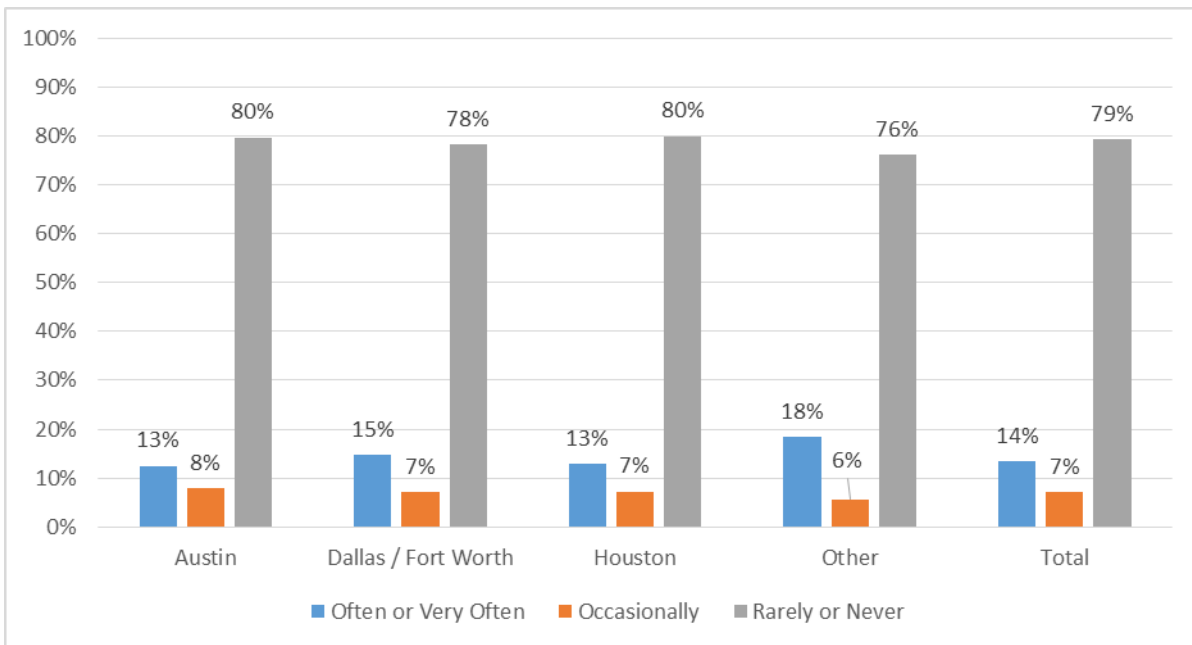


Figure 53. Use of GPS Navigation System to Help Respondent Select Route (Q6, N=933).

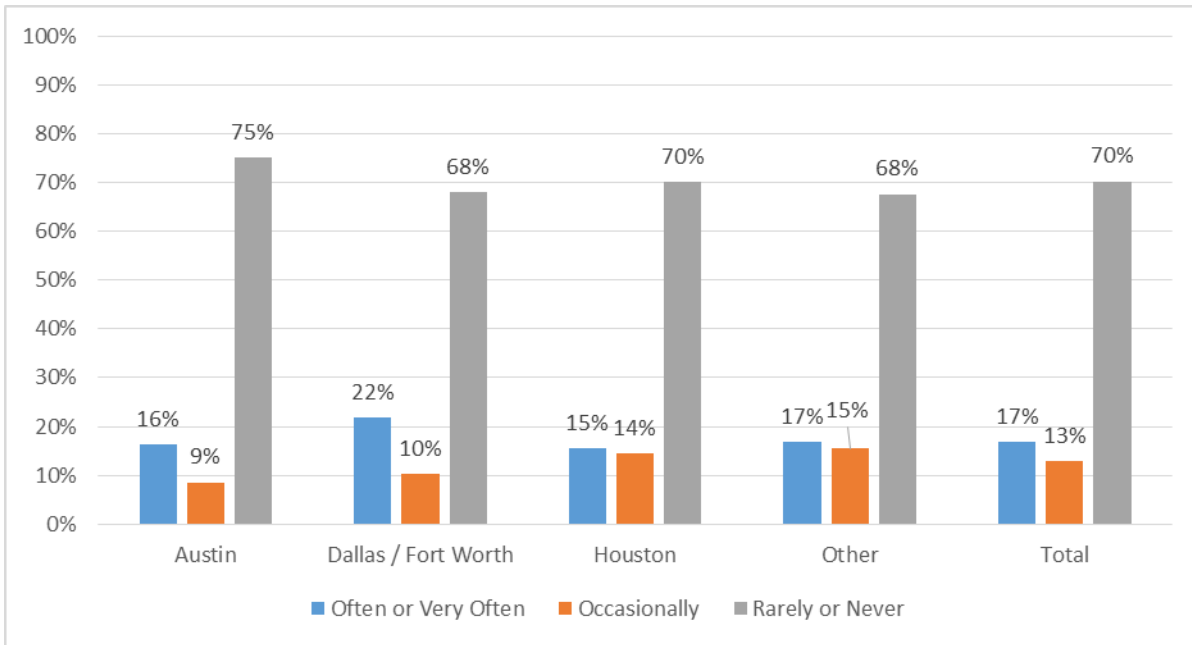


Figure 54. Use of In-Vehicle Navigation System to Help Respondent Select Route (Q6, N=931).

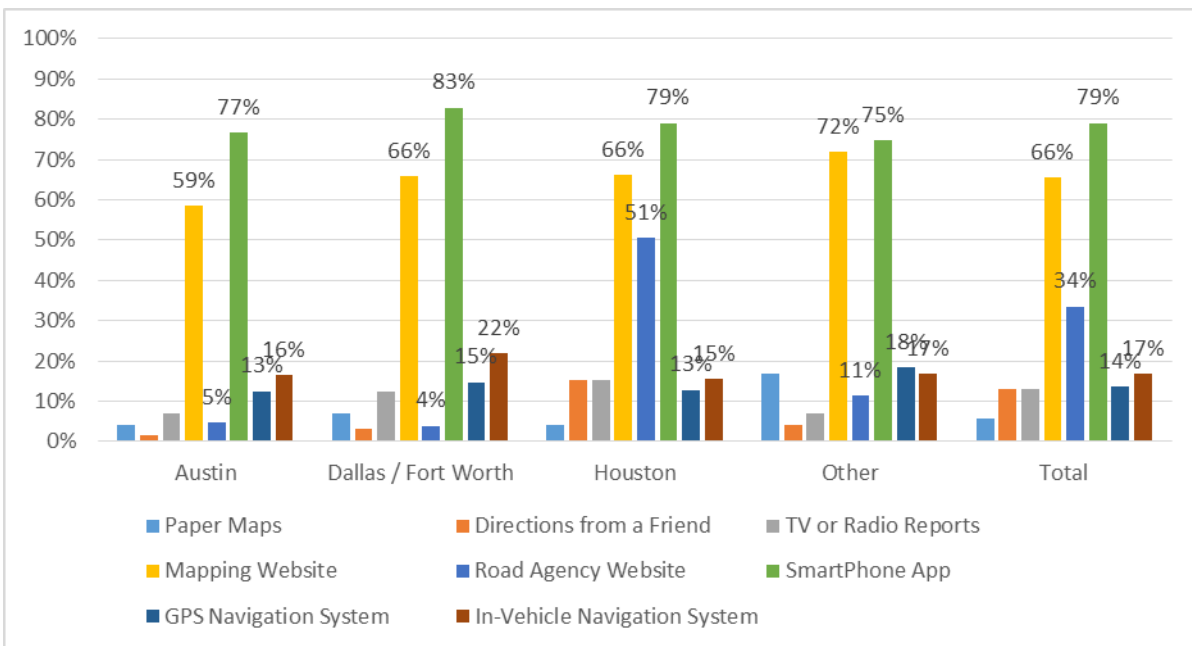


Figure 55. Use of Traveler Information Often or Very Often to Help Respondent Select Route (Q6, N=928).

Many factors may influence decisions to seek out traveler information. Using a scale from 1 to 5, where 1 is a factor that is *extremely unimportant* and 5 is a factor that is *extremely important*, respondents were asked to assign a score to a series of factors regarding their importance in the decision to seek out traveler information. Figure 56 presents the mean scores of these factors by geography. Overall, travel party size and composition received the lowest mean score of all

factors (2.7, or between *somewhat important* and *neutral*). Conversely, route familiarity received the highest mean score of all factors (4.0, *somewhat important*), followed closely by weather conditions (3.9) and trip distance (3.9).

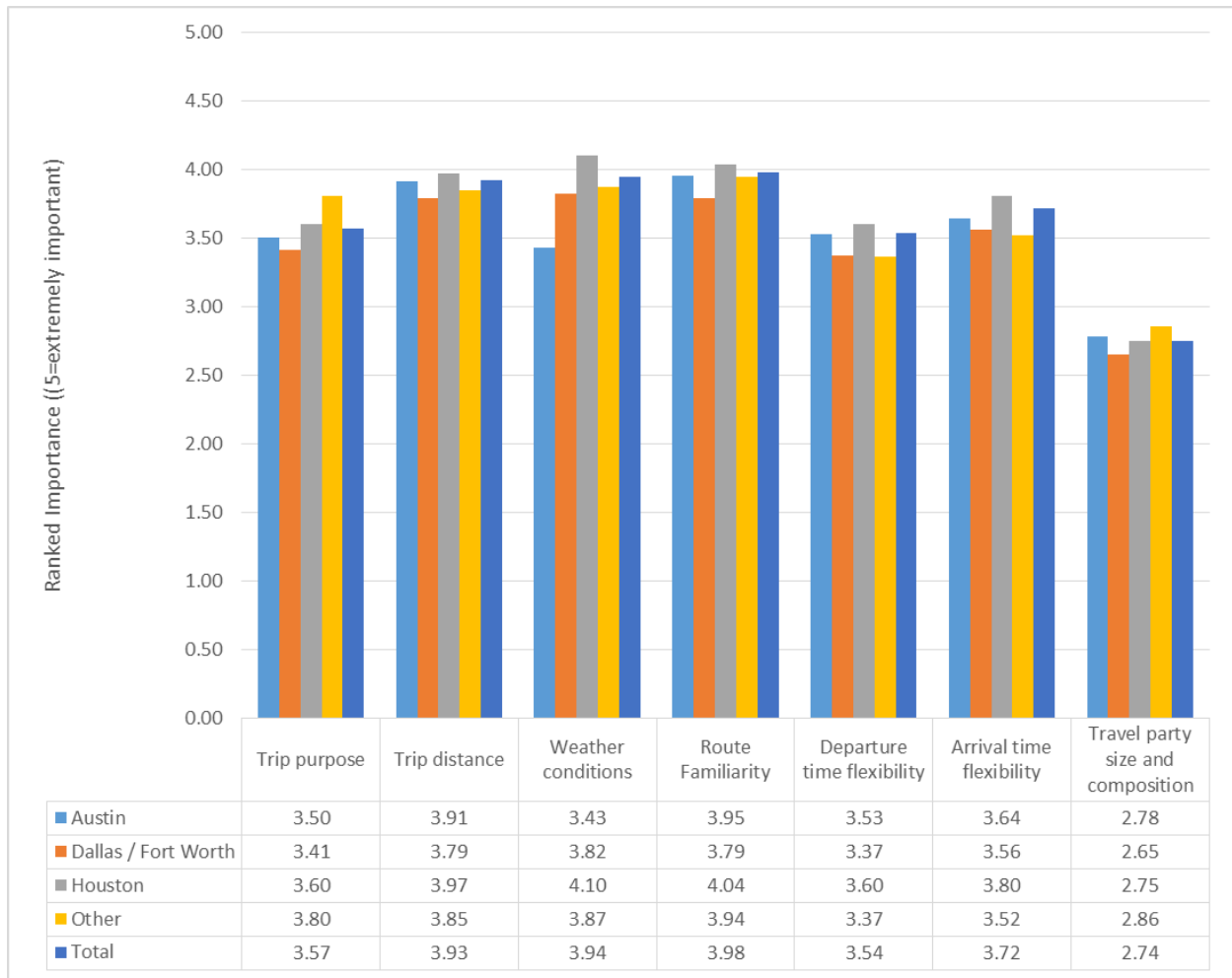


Figure 56. Importance of Factors That May Influence Decisions to Seek Out Traveler Information (Q7, N=936).

The trends across geographies were fairly consistent with a few exceptions, the most noteworthy of which concerns weather conditions. The mean scores reported by respondents from each of the three major metro areas (Austin, 3.4; Dallas/Fort Worth, 3.8; Houston, 4.1) were significantly different from one another.

Respondents with at least some level of familiarity with all routing technology options offered in the survey (as shown in Figure 50 through Figure 55) were asked to think about the computerized tools they use and to identify preferences on how to use them for making trips to areas they have visited before. Overall, a majority (55 percent) of respondents preferred to enter their origin and destination and have the tool present different routes. Slightly more than one-fourth (28 percent) preferred to enter their origin and destination and have the tool present the best route. Cumulatively, slightly more than eight of 10 respondents (83 percent) preferred

interacting with mapping technology by entering origin and destination. Figure 57 presents the details.

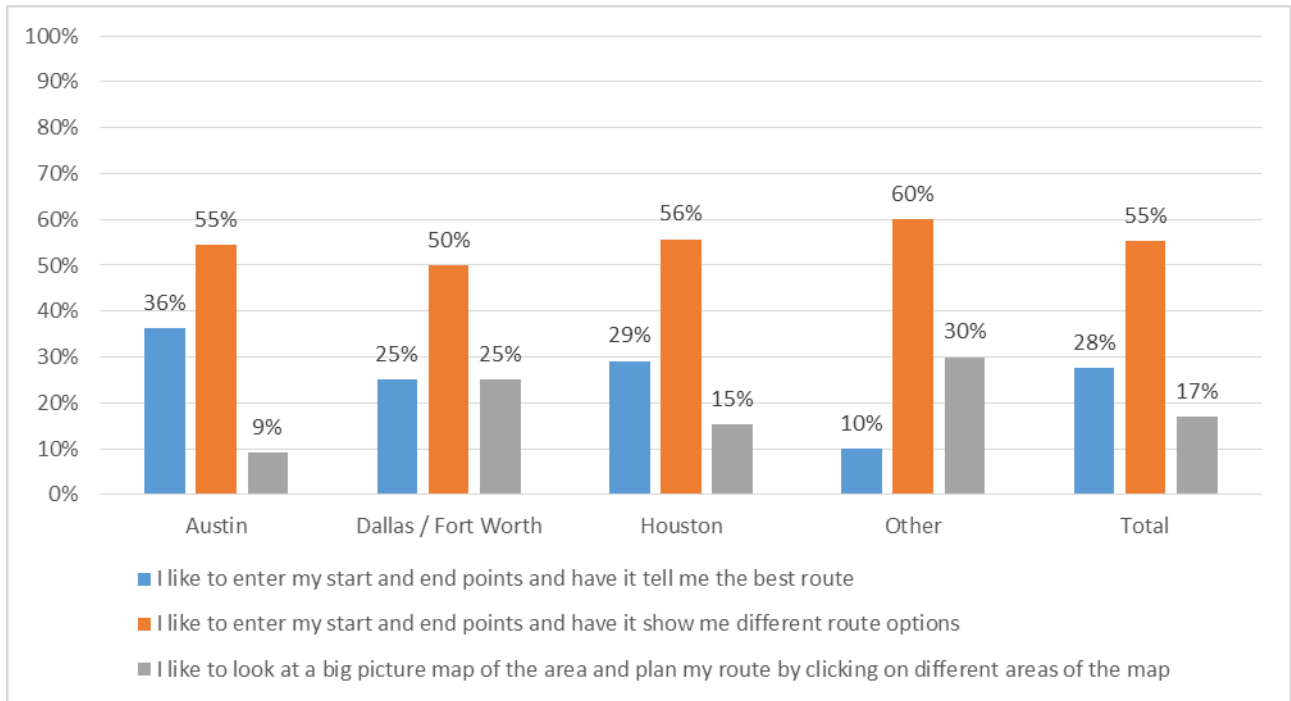


Figure 57. Preferred Ways to Use Computerized Tools for Planning Routes to Familiar Destinations (Q8, N=112).

Respondents were next asked if they would be willing to register for a free account on an app or website and store frequent trips so that they could consult them again in the future. As shown in Figure 58, nearly three-fourths (72 percent) of respondents said yes.

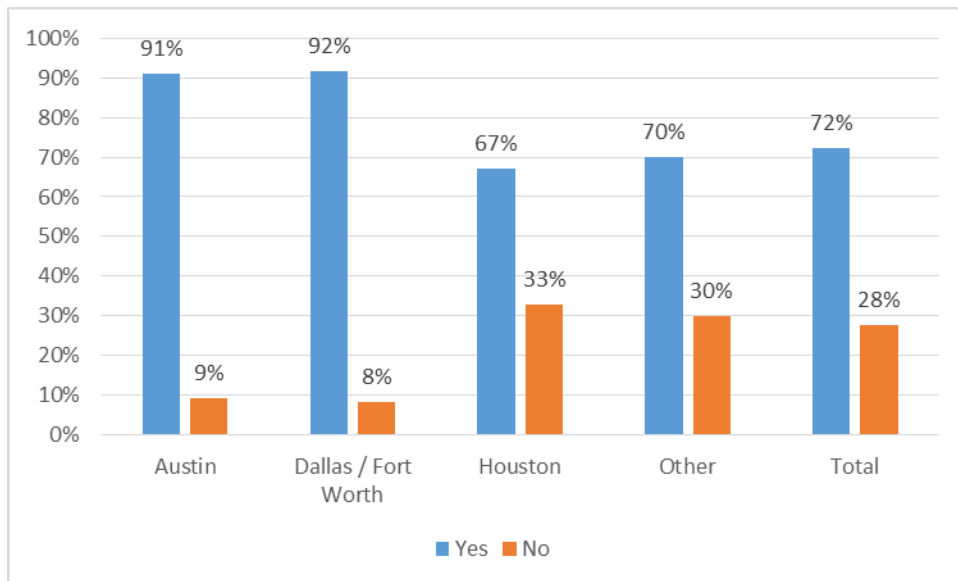


Figure 58. Willingness to Register for a Free Account (Q9, N=112).

For Question 10, respondents imagined they were planning a trip for either that day or later in the week. They saw a list of various types of traveler information and were asked to indicate the relative importance that a travel planning tool provide that information. Figure 59 through Figure 66 present a proportional distribution for each piece of information by importance and region. Figure 67 presents the proportional distribution of all elements of information by geographic region for elements signified as critical or important.

A significant share of respondents (93 percent) indicated that information on “expected delays” and “rerouting advice” was critical or important. Conversely, fewer respondents (23 percent) felt that “bus or train information” was critical or important.

Interestingly, a majority of respondents who reported most of their driving in Austin identified “cost of any tolls” and “information on how I can pay tolls” as either important or critical. This finding contrasted with respondents who reported most of their driving in the Dallas/Fort Worth or Houston regions. The difference may be a function of the length of time that managed lanes or toll roads have operated within those regions and thus overall driver familiarity.

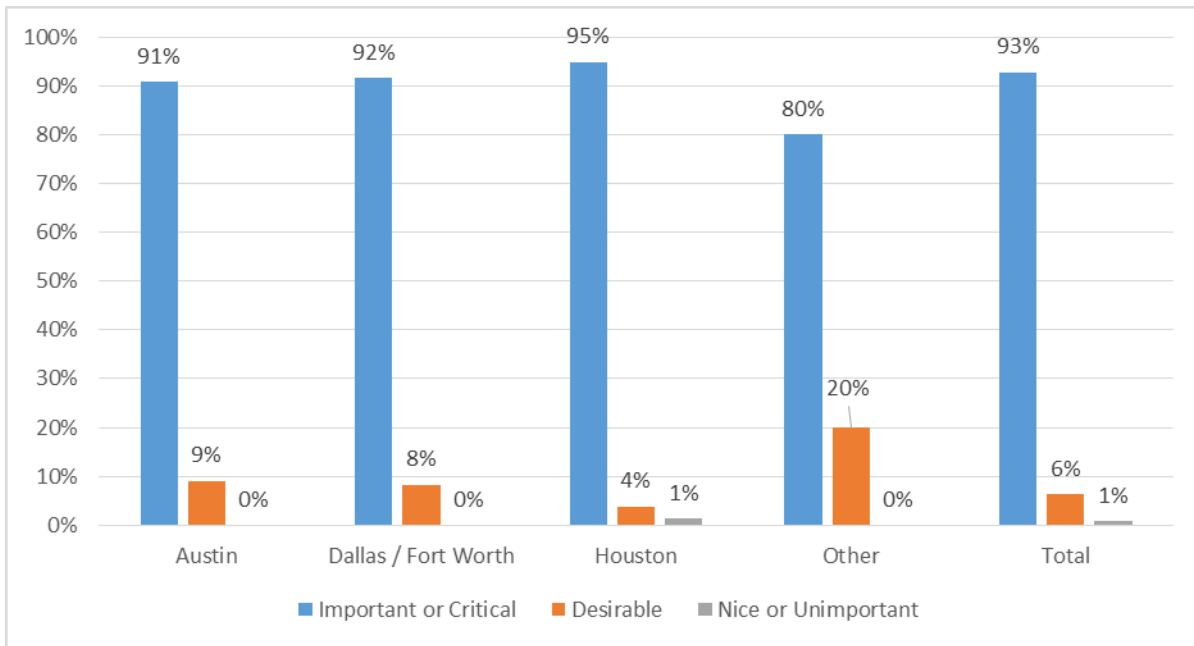


Figure 59. Importance of Information on Expected Delays in Trip Planning (Q10, N=111).

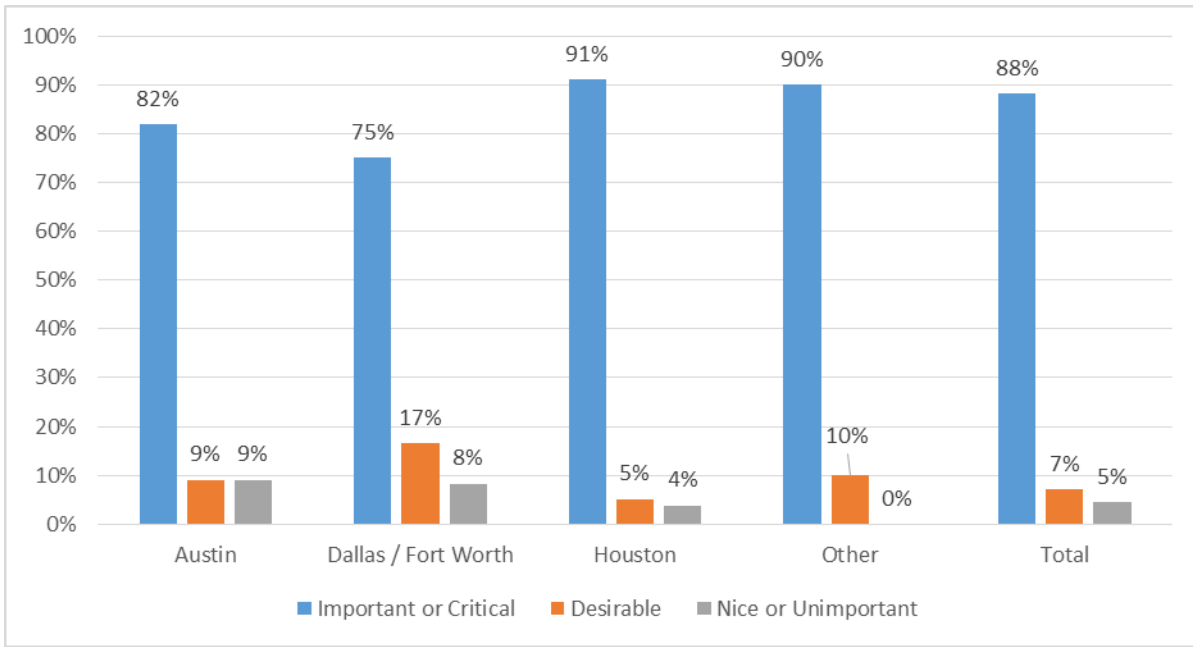


Figure 60. Importance of Information on Rerouting Advice in Trip Planning (Q10, N=111).

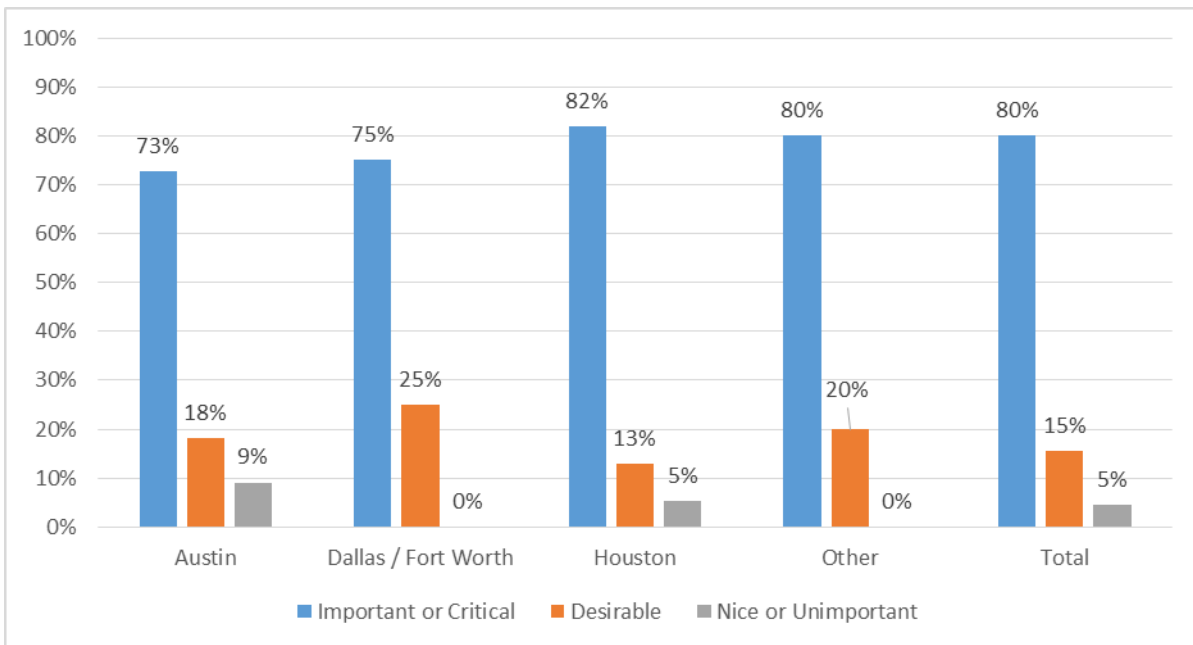


Figure 61. Importance of Information on Alternate Routes in Trip Planning (Q10, N=110).

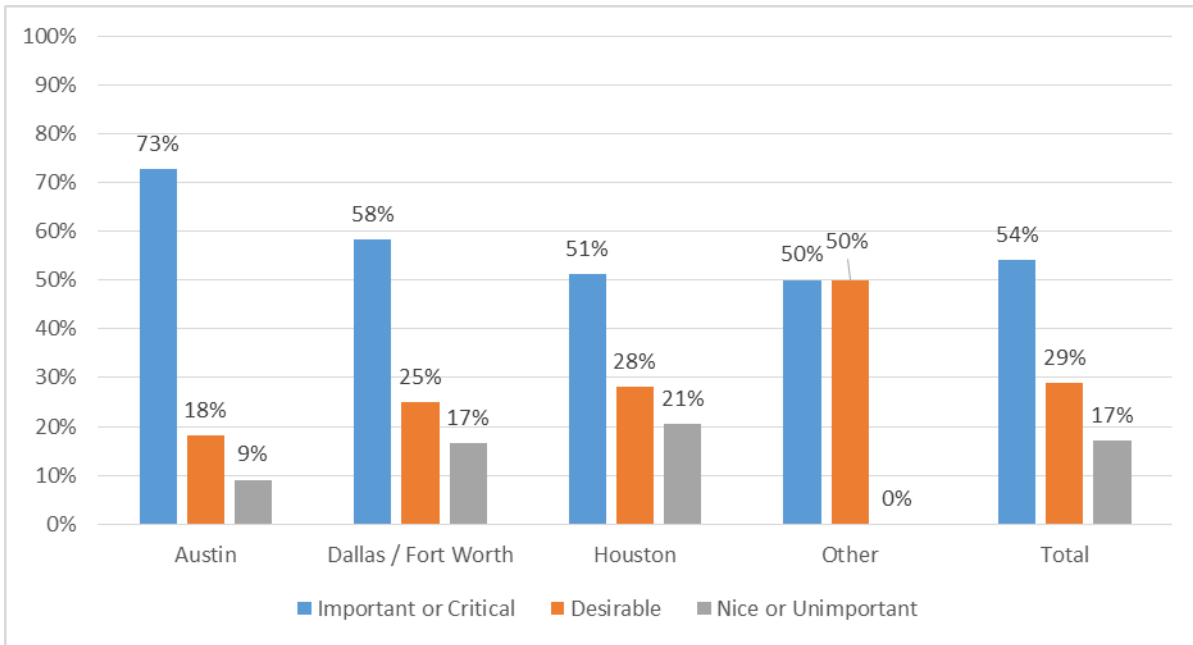


Figure 62. Importance of Information on Managed Lanes in Trip Planning (Q10, N=111).

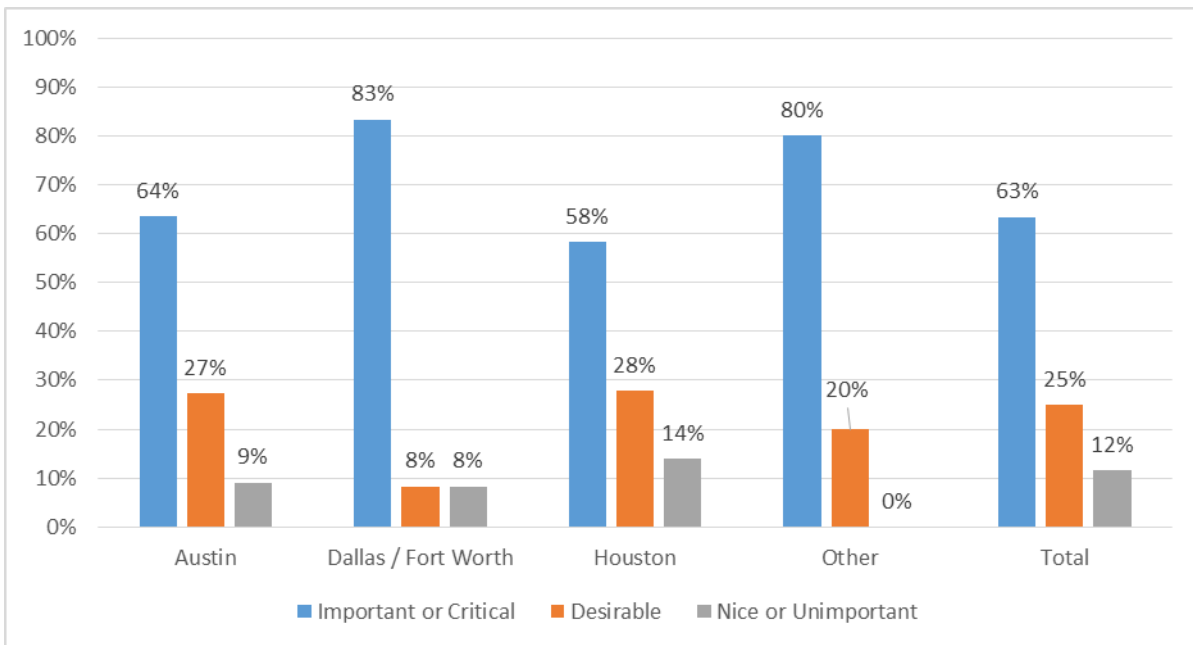


Figure 63. Importance of Information on Trip Distance in Trip Planning (Q10, N=112).

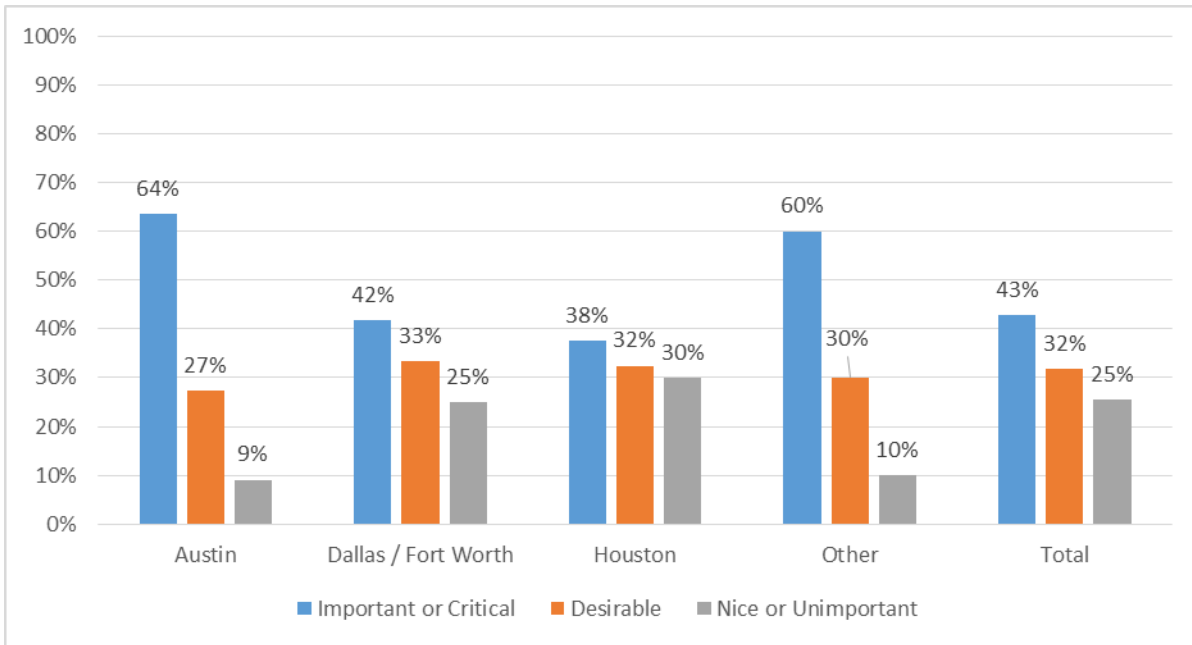


Figure 64. Importance of Information on Toll Cost in Trip Planning (Q10, N=110).

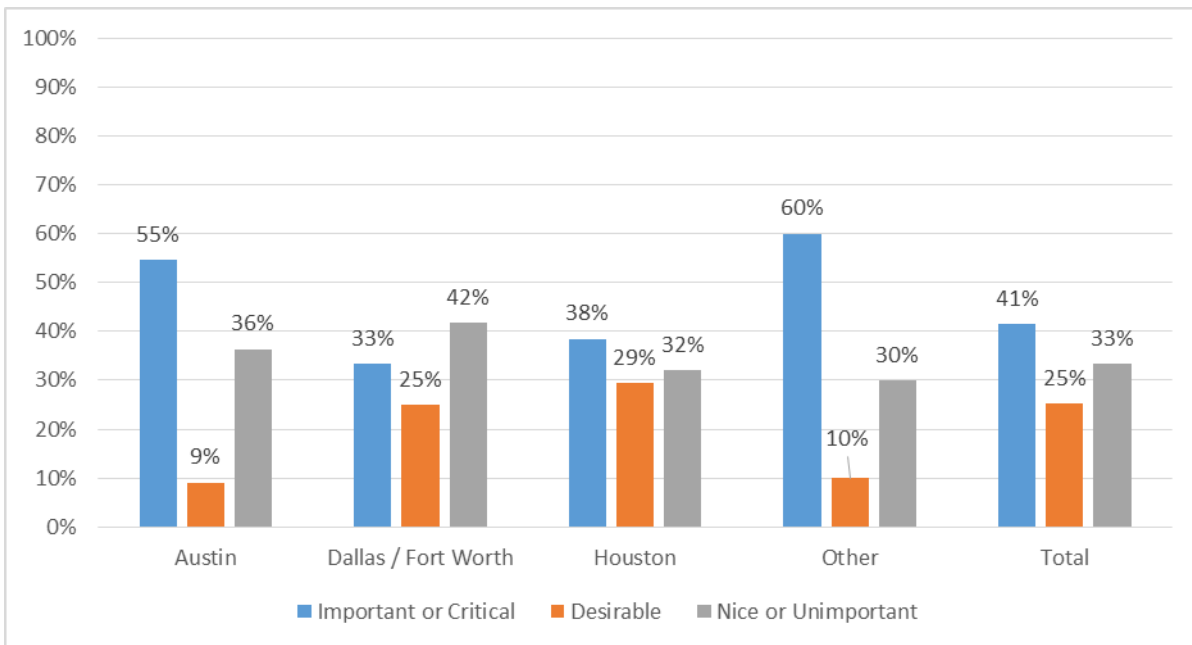


Figure 65. Importance of Information on Toll Payment Options (Q10, N=111).

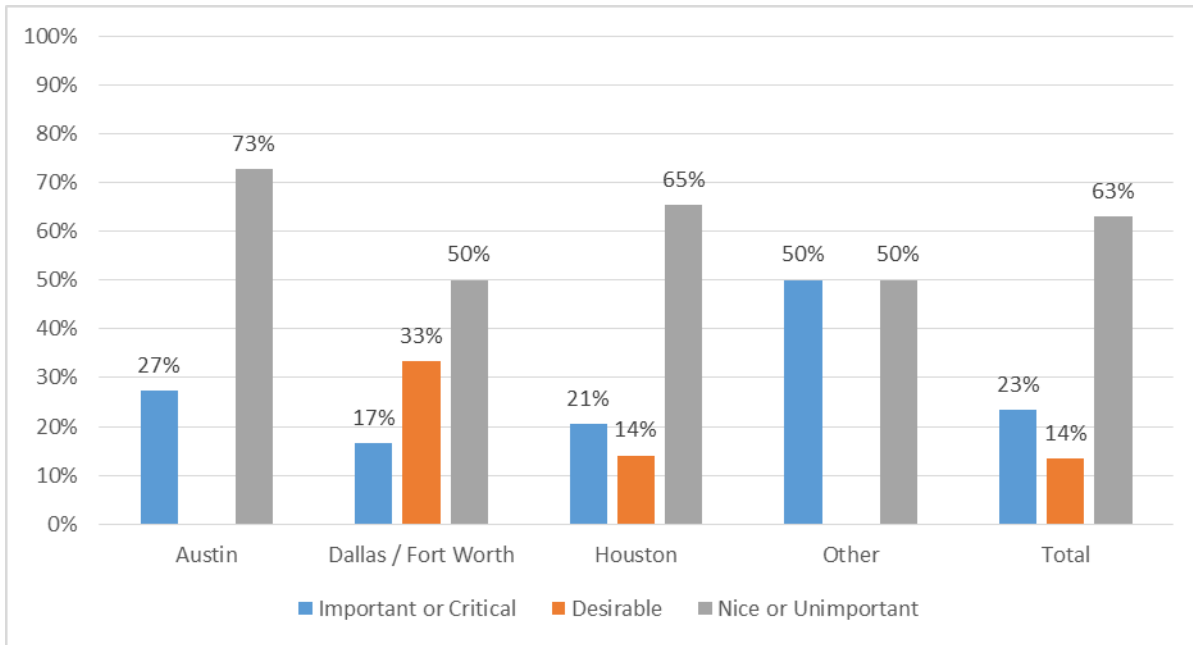


Figure 66. Importance of Information on Bus or Train Options in Trip Planning (Q10, N=111).

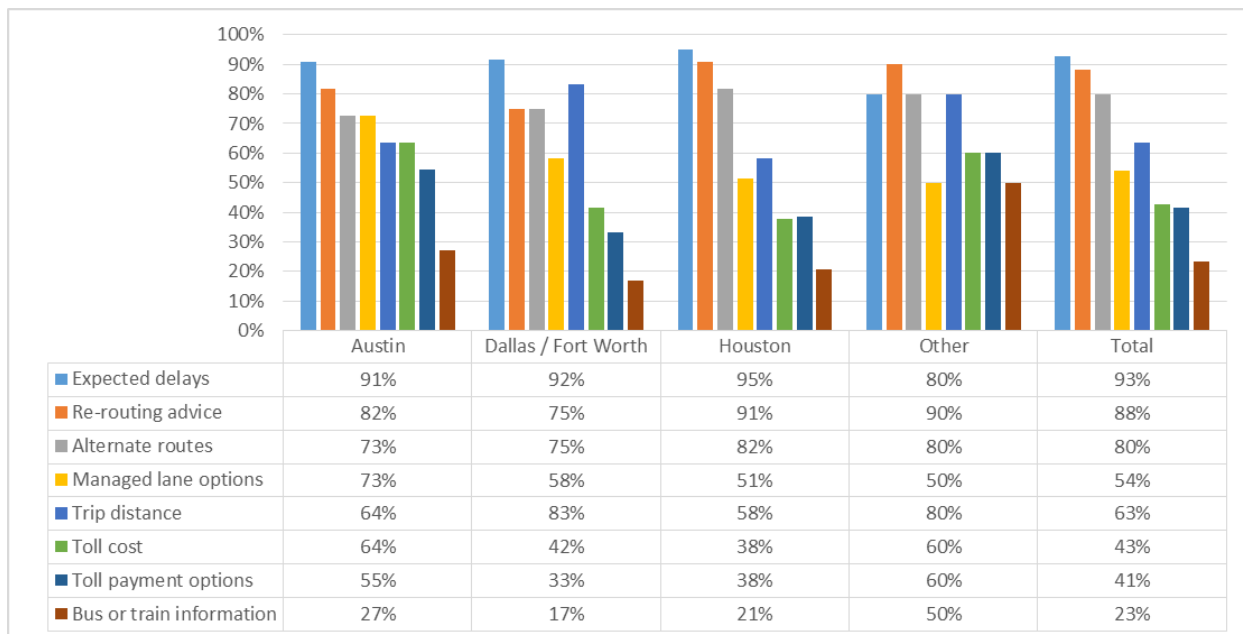


Figure 67. Travel Planning Tool Provided Elements of Information—Important or Critical (Q10, N=111).

For Question 11, respondents identified the most valuable navigation tool features they use when planning a trip. Figure 68 presents results by geographic region. A large share of respondents indicated that “information about slowed or stopped traffic locations” and “rerouting advice to avoid traffic jams or wrecks” was the most valuable of all offered features (76 percent and 75 percent, respectively). A majority of respondents also deemed “travel time to destination” as valuable (65 percent of all respondents). Interestingly, a higher proportion of respondents who

reported most of their driving in Austin deemed “travel time to destination” as valuable (73 percent of Austin respondents) compared to respondents who reported most of their driving in either Dallas/Fort Worth or Houston (66 percent and 63 percent, respectively). The least valuable features indicated from Question 11 were “options to use special lanes on my route like carpool, express, or toll lanes” and “current toll rates for toll lanes or roads for my route.”

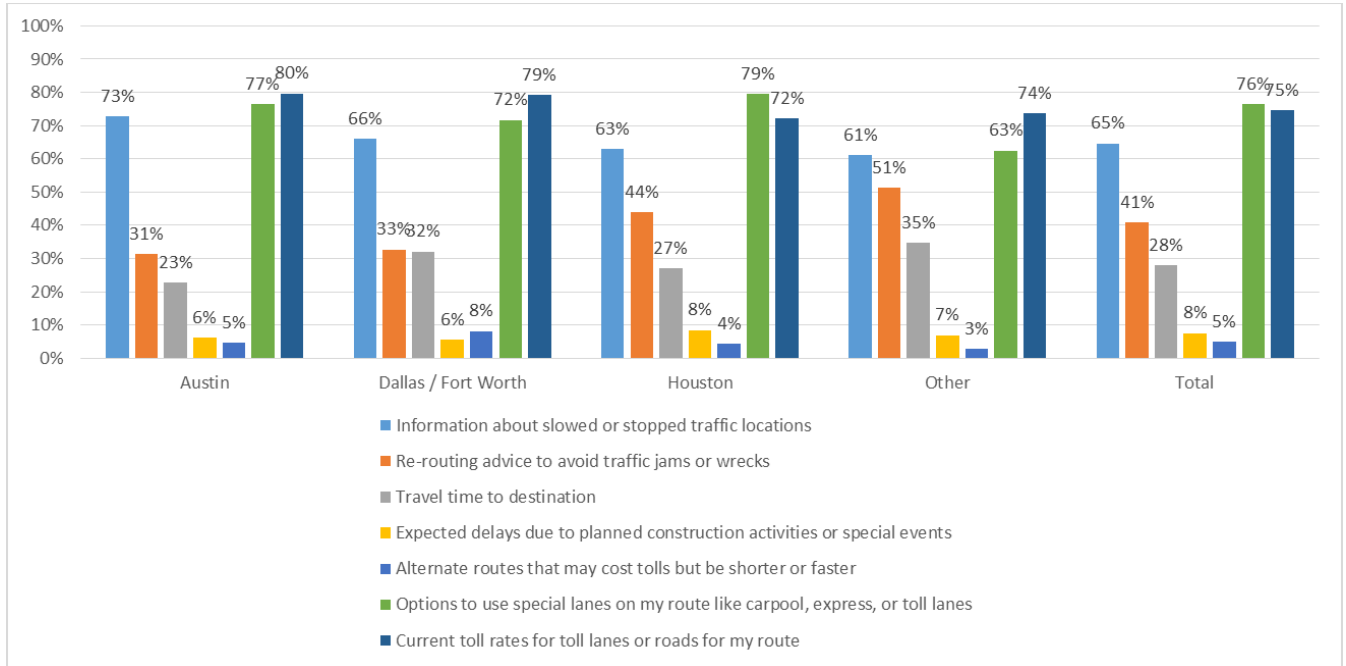


Figure 68. Most Valuable Features of Trip Planning Tools Used While Taking a Trip (Q11, N=515).

Question 12 was a multiple-choice question that allowed respondents from regions such as Dallas/Fort Worth with multiple managed lane facilities to indicate using more than one facility. Table 13 presents the proportional distribution of regional drivers who used various regional managed lanes. As such, columns may sum to greater than 100 percent. Overall, these data suggest that use of managed lanes in Austin, where the only facility recently opened, is much lower than use of managed lanes in Dallas/Fort Worth and Houston.

Table 13. Use of Managed Lanes by Regional Drivers (Q12, N=515).

Facility	Austin	Dallas/Fort Worth	Houston
I have never used a managed lane	69%	21%	19%
MoPac Express Lanes	31%	n/a	n/a
DFW Connector	n/a	42%	n/a
North Tarrant Express	n/a	45%	n/a
TEXpress Lanes®—I-635	n/a	62%	n/a
TEXpress Lanes®—I-30	n/a	23%	n/a
Katy Tollway	n/a	n/a	70%
METRO Express Lanes—North Freeway	n/a	n/a	26%
METRO Express Lanes—Gulf Freeway	n/a	n/a	19%
METRO Express Lanes—Northwest Freeway	n/a	n/a	22%
METRO Express Lanes—Eastex	n/a	n/a	12%
METRO Express Lanes—Southwest Freeway	n/a	n/a	17%

Note: “n/a” indicates that a facility does not service a specific region.

For Question 13, respondents who reported never using a managed lane identified the most important reason for making that decision. Figure 69 shows the existence of a substantial amount of variation across geographies. A significantly higher proportion of respondents who reported most of their driving in Austin selected the reason “the lane doesn’t go where I need it to go” as the most prominent barrier (50 percent of managed lane non-users) compared to the other regions. A near equal proportion of respondents who reported most of their driving in Houston selected the reason “I am not sure when I will be able to exit the lane” or “The lane doesn’t go where I need to go” as the most significant barriers (24 percent and 23 percent of managed lane non-users, respectively).

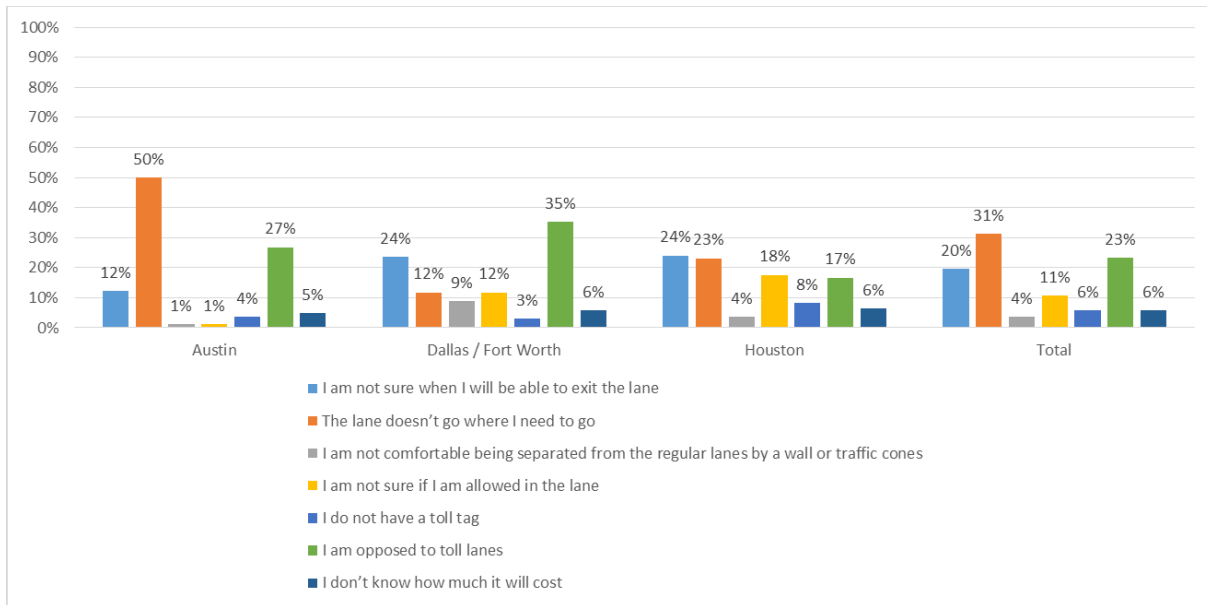


Figure 69. Reasons Managed Lanes Not Used (Q13, N=140).

Table 14, Table 15, and Table 16 present the distribution of managed lane users by both trip purpose and frequency of use for respondents who reported most of their driving in either the Austin, Dallas/Fort Worth, or Houston regions, respectively. Data from those tables suggest some common themes across geographic regions. Survey findings indicate the majority of

managed lane travelers use managed lanes less than two times per month, regardless of trip purpose. Figure 70 presents a slightly different finding by only showing the types of trips for those who reported using managed lanes at least twice per month. For instance, data suggest that 43 percent of managed lane users who reported most of their driving in Houston travel on managed lanes more than twice per month for work commute trips. This finding was significantly higher than managed lane trips from survey respondents who primarily traveled in either the Dallas/Fort Worth or Austin regions.

Table 14. Frequency of Managed Lane Use by Trip Purpose—Austin (Q14, N=41).

Trip Purpose	More than 5 times per week	2–5 times per week	3–4 times per month	Less than 2 times per month
Work Commute	5%	14%	5%	77%
School Activities	0%	2%	5%	93%
Leisure Activities	2%	7%	18%	73%
Personal Appointments	2%	7%	16%	74%
Special Events	2%	7%	9%	81%

Table 15. Frequency of Managed Lane Use by Trip Purpose—Dallas/Fort Worth (Q14, N=113).

Trip Purpose	More than 5 times per week	2–5 times per week	3–4 times per month	Less than 2 times per month
Work Commute	2%	5%	11%	82%
School Activities	0%	1%	2%	97%
Leisure Activities	1%	1%	29%	70%
Personal Appointments	2%	4%	25%	70%
Special Events	2%	2%	17%	80%

Table 16. Frequency of Managed Lane Use by Trip Purpose—Houston (Q14, N=149).

Trip Purpose	More than 5 times per week	2–5 times per week	3–4 times per month	Less than 2 times per month
Work Commute	13%	18%	12%	57%
School Activities	1%	2%	2%	96%
Leisure Activities	1%	4%	24%	71%
Personal Appointments	1%	5%	20%	74%
Special Events	1%	3%	15%	81%

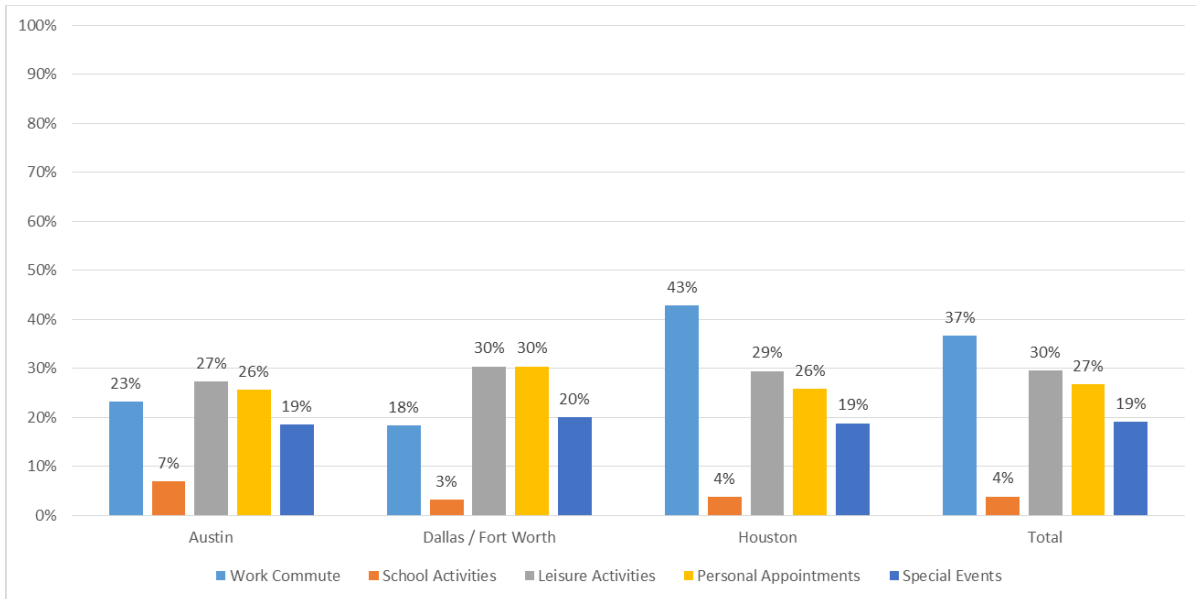


Figure 70. Type of Trips for Which Managed Lanes Are Used More Than Twice per Month (Q14, N=90).

Question 15 asked respondents to identify the most important factor in their decision to use managed lanes. More than a third of all managed lane travelers (35 percent) stated that “traffic conditions that I observe in the regular lanes” was the most important factor. Slightly less than one-quarter of managed lane users (23 percent) stated that “traffic reports on a smartphone or in-vehicle GPS” was the most important factor. Radio traffic reports were the least important (2 percent). Figure 71 provides details about the level of significance for eight different factors as indicated by respondents from the three regions.

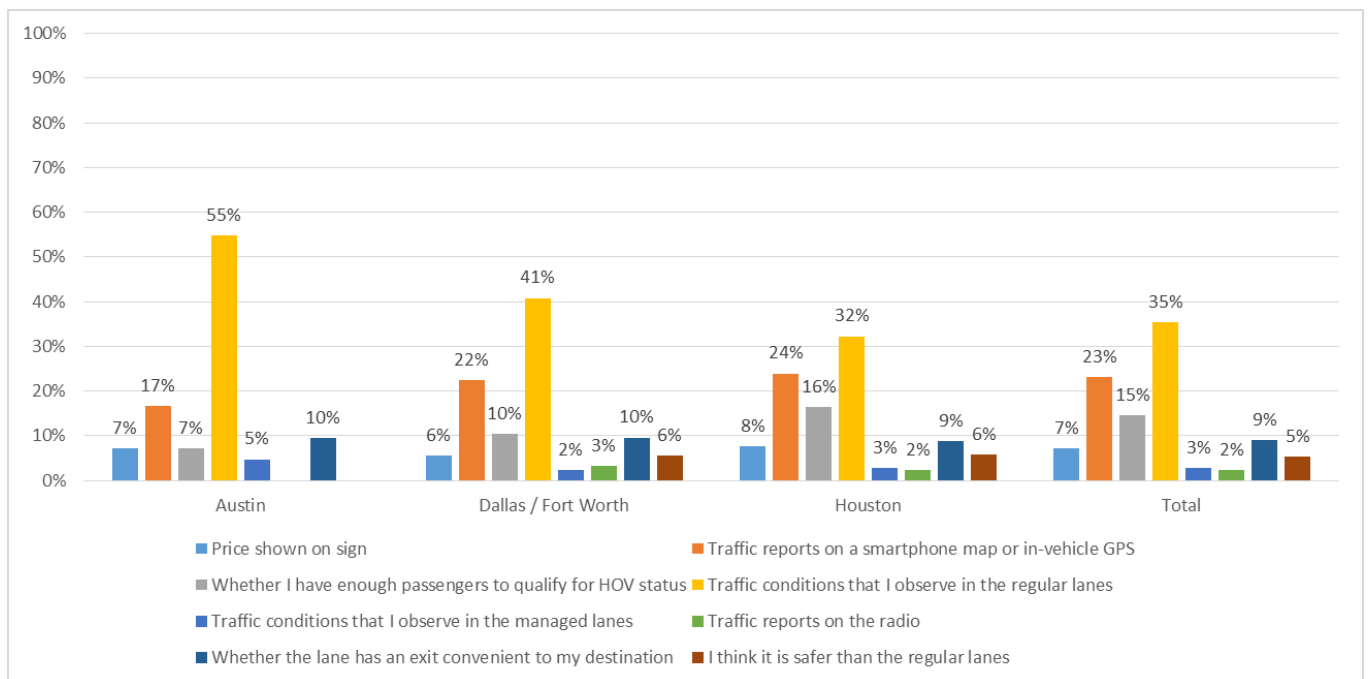


Figure 71. Single Most Important Factor in Decision to Use Managed Lane (Q15, N=308).

Question 16 asked respondents to imagine a future scenario when some traveler information would appear on their smartphone, navigation system, or other in-vehicle device. Technology-enhanced traveler information devices might allow for fewer installations of road signs. Question 16 presented several travel information elements and asked respondents to indicate whether they thought specific elements should appear on a roadway sign or on an in-vehicle device. Figure 72 shows a summary of responses to this question. A significant share of the total respondents indicated the elements “entrance location to the managed lane” and “number of occupants required” were best suited for display on road signs. Conversely, “alerts about crashes, construction, or other accidents” and “traffic condition status” were elements suggested by the greatest proportion of respondents as being best suited for display on in-vehicle devices. The figure illustrates that respondents desire traffic condition and travel time information in vehicle, but the remainder on road signs. This mirrors existing operations where most information is on road signs but an in-vehicle app may provide traffic condition updates and travel time for a specific route that was entered into a navigation tool. One interesting result was the mixed responses to the “list of intersecting roads the managed lane connects to” item. People were evenly split as to where this information should appear. For managed lane networks, information concerning intersecting roads could quickly become quite overwhelming, and perhaps some respondents recognized that.

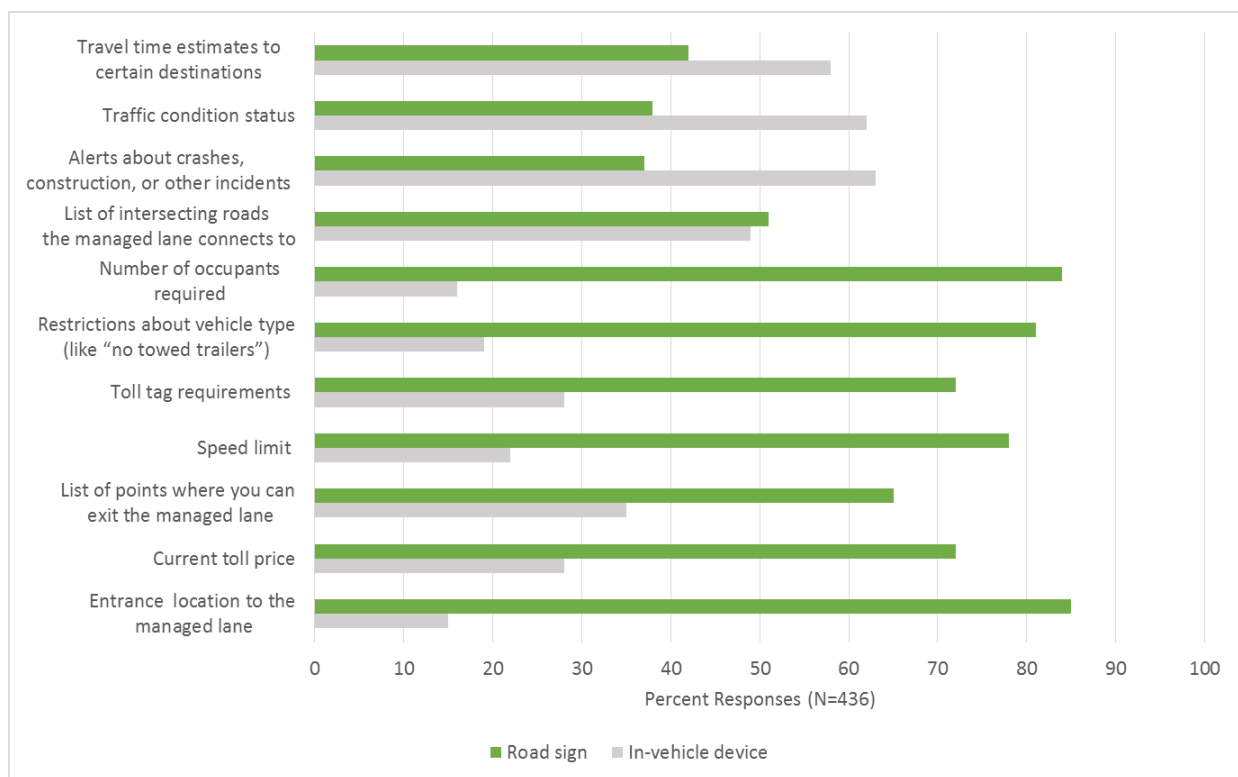


Figure 72. Preference for Where Information Should Be Displayed (Q16, N=436).

Questions 17 and 18 focused on first use of a managed lane. Figure 73 shows that a majority of respondents described their initial trip within a managed lane as being influenced by a decision to seek out managed lane information after physically seeing signs for the managed lane while traveling in the corridor.

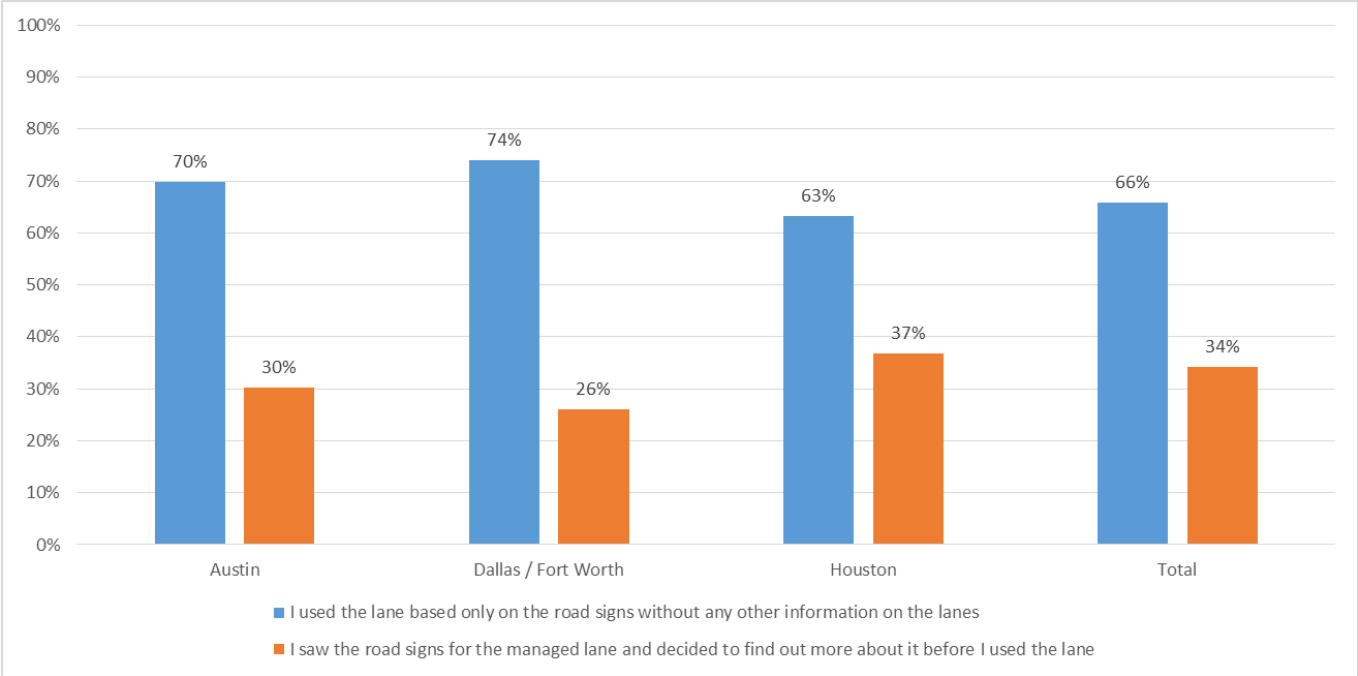


Figure 73. Description of Initial Managed Lane Use (Q17, N=306).

The largest proportion of responses indicated that managed lane travelers learned of the facility by seeing it while driving in the corridor. However, those responses varied considerably by region, ranging from 23 percent for Austin travelers to 64 percent for Houston travelers. As suggested by Figure 74, both Dallas/Fort Worth and Houston managed lane travelers are significantly more likely than Austin travelers to learn about managed lanes while driving in the region.

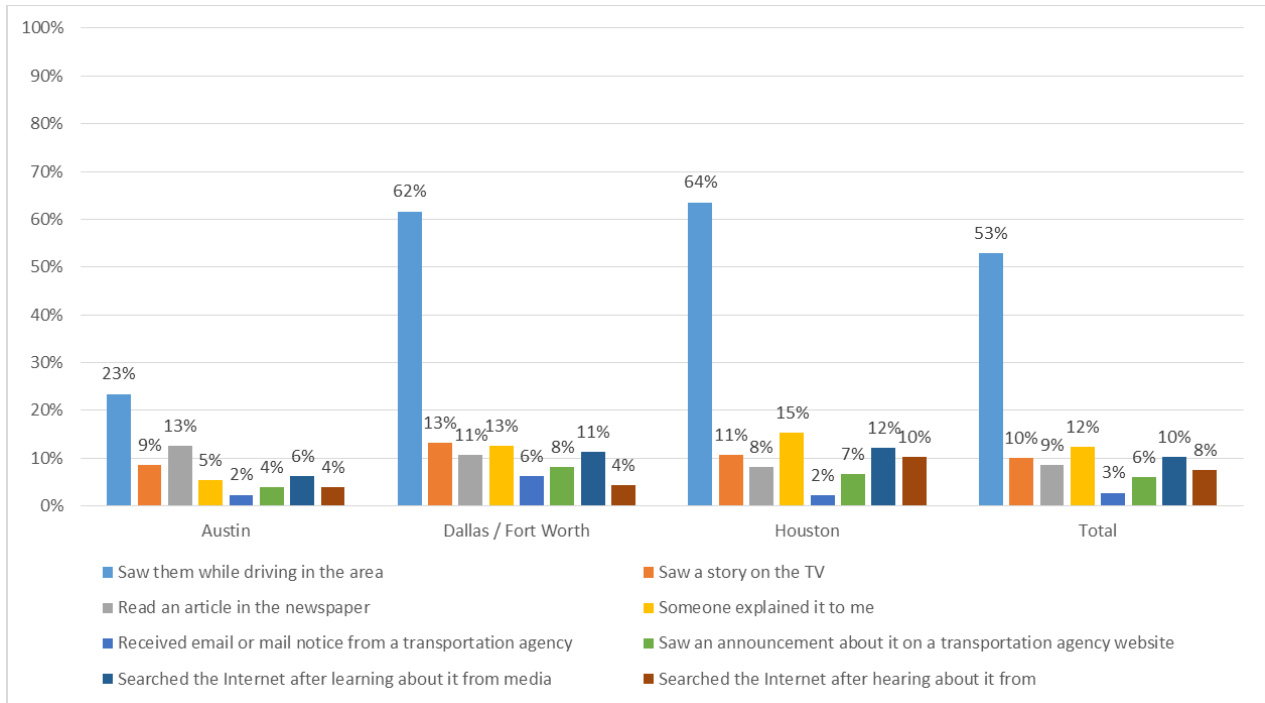


Figure 74. How Respondent Learned of Managed Lane (Q18, N=309).

Questions 19 and 20 asked Dallas/Fort Worth regional managed lane users about the Drive On smartphone app that allows drivers to indicate the number of vehicle occupants and view discounted toll rate information. Eleven respondents had used the app, and of those, 10 had used the app to declare HOV status. This feature was, by far, the most popular feature. Checking managed lane traffic conditions was the feature least often used (9 percent of app users). Figure 75 provides details on the proportion of travelers who used select features of the Drive On app.

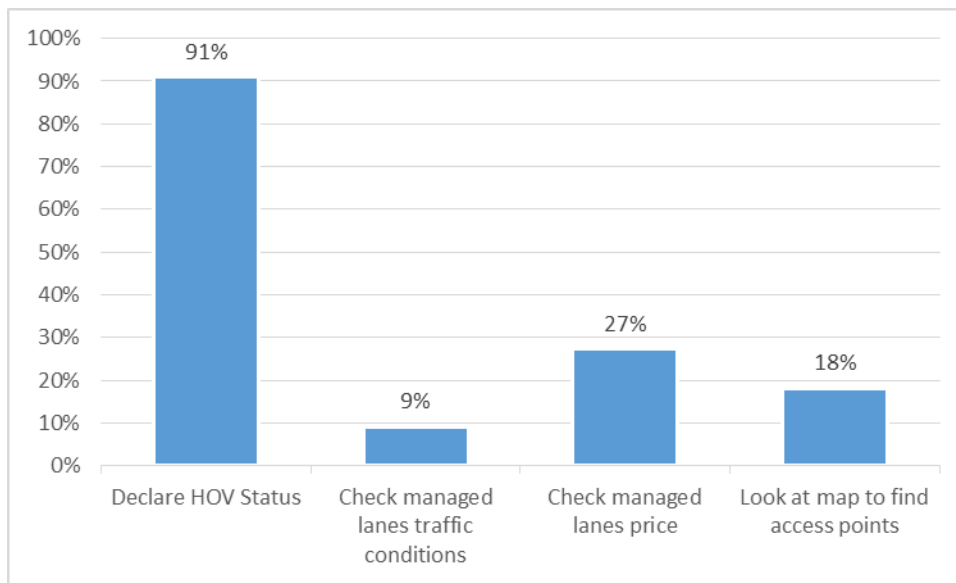


Figure 75. Drive On App Features Used (Q20, N=11).

The final section of the survey gathered personal and household demographic statistics about the respondent pool. The following figures detail the respondents' demographics. Figure 76, using data from Question 22, shows the reported employment status of the respondents. Question 22 allowed respondents to select multiple options, so the statuses grouped for Figure 76 can sum to values greater than 100 percent.

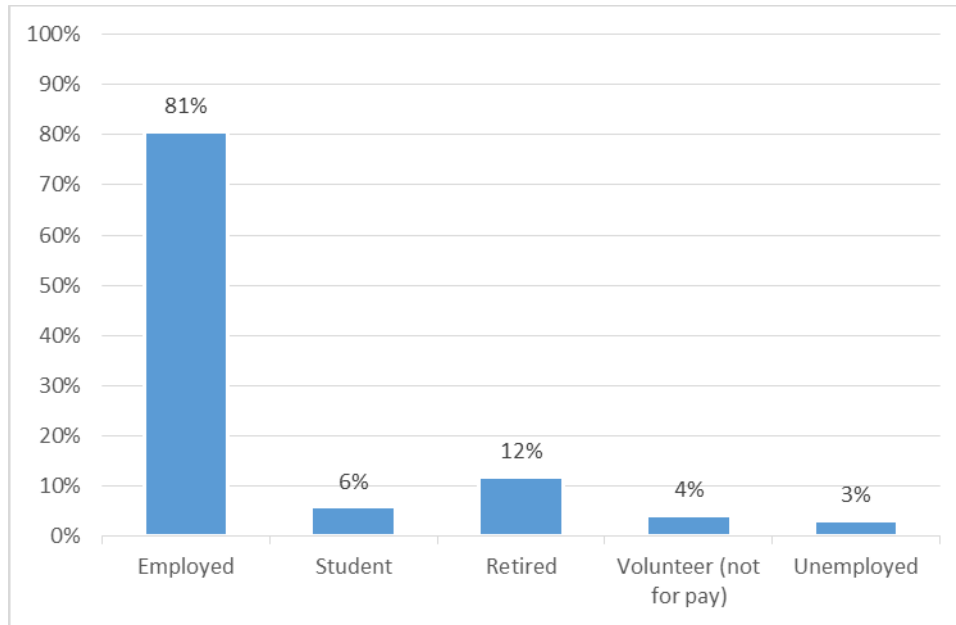


Figure 76. Employment Status (Q22, N=515).

Figure 77 shows that approximately one-fourth of respondents (24 percent) were under 35 years old, while almost half (45 percent) were between 35 and 54. Nearly one-third (31 percent) were 55 or older. Only 1 percent refused to provide age.

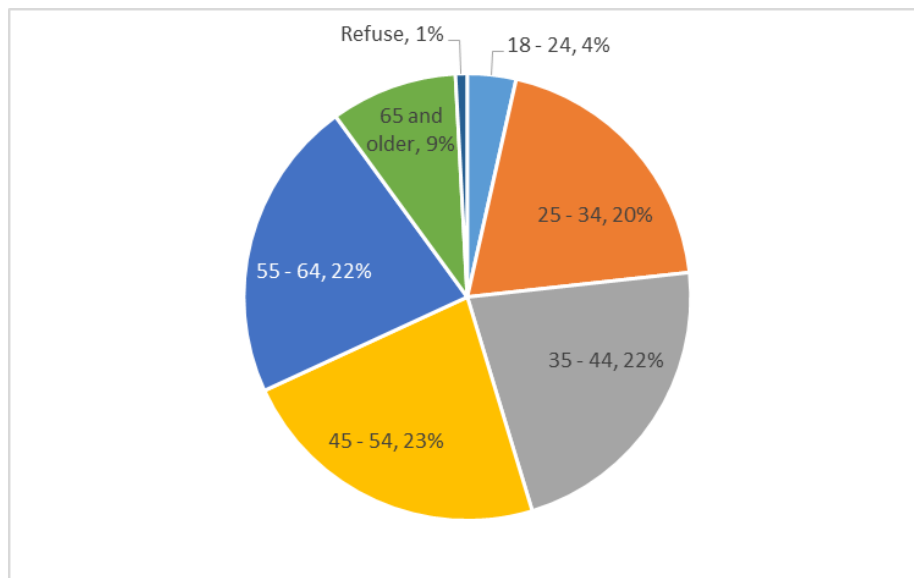


Figure 77. Age (Q25, N=504).

Two-thirds of respondents (67 percent) were married, while 16 percent were never married. Figure 78 shows the details. Figure 79 illustrates that nearly three-fourths of respondents had either a bachelor's degree (44 percent) or a graduate or professional degree (30 percent).

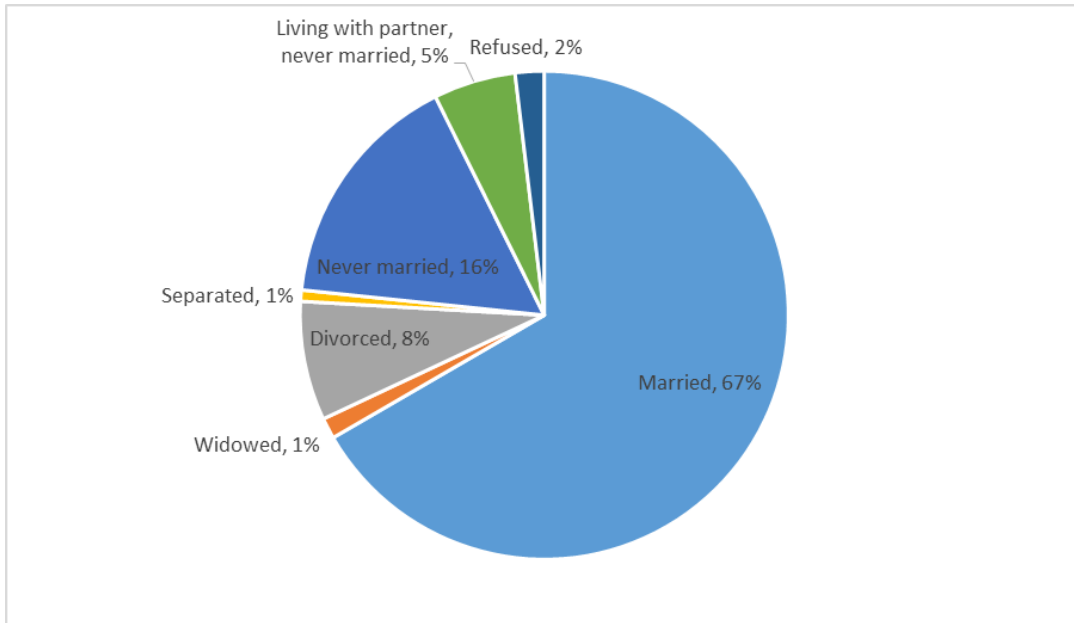


Figure 78. Relationship Status (Q26, N=497).

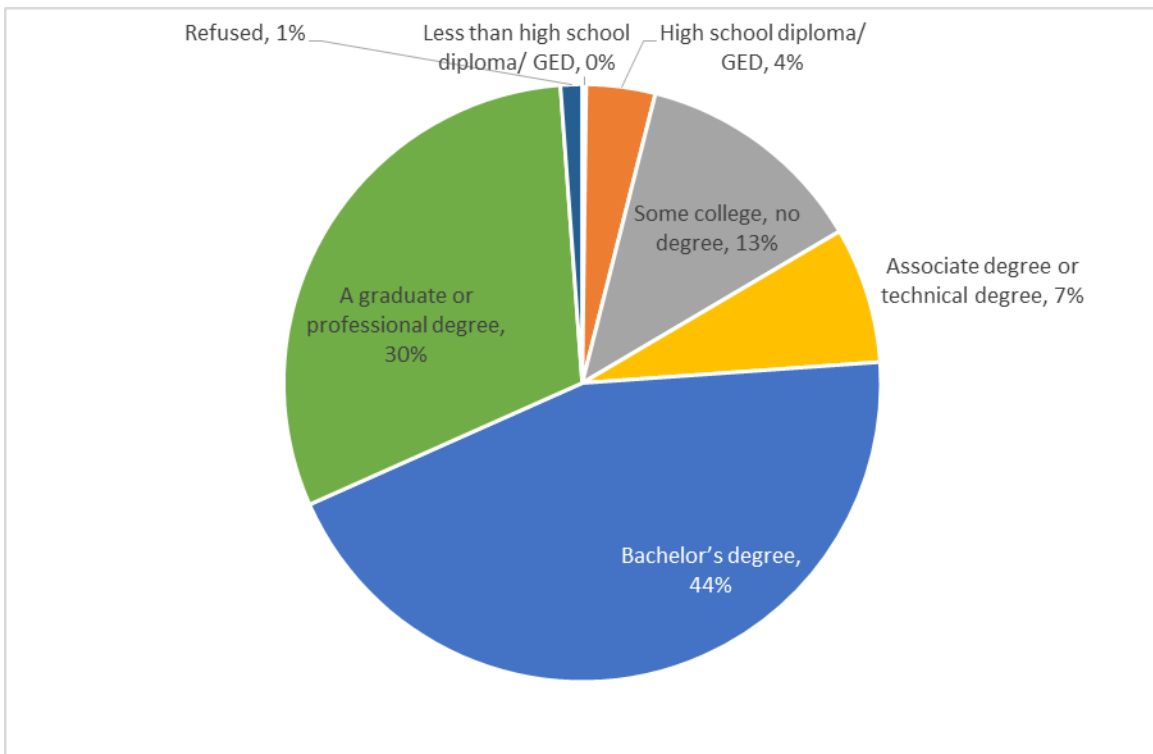


Figure 79. Education (Q27, N=503).

More than eight of 10 respondents (82 percent) reported white or Caucasian as their ethnicity. About 11 percent reported Hispanic as their ethnicity (not shown in the corresponding figure). Figure 80 graphically displays the respondent pool by race.

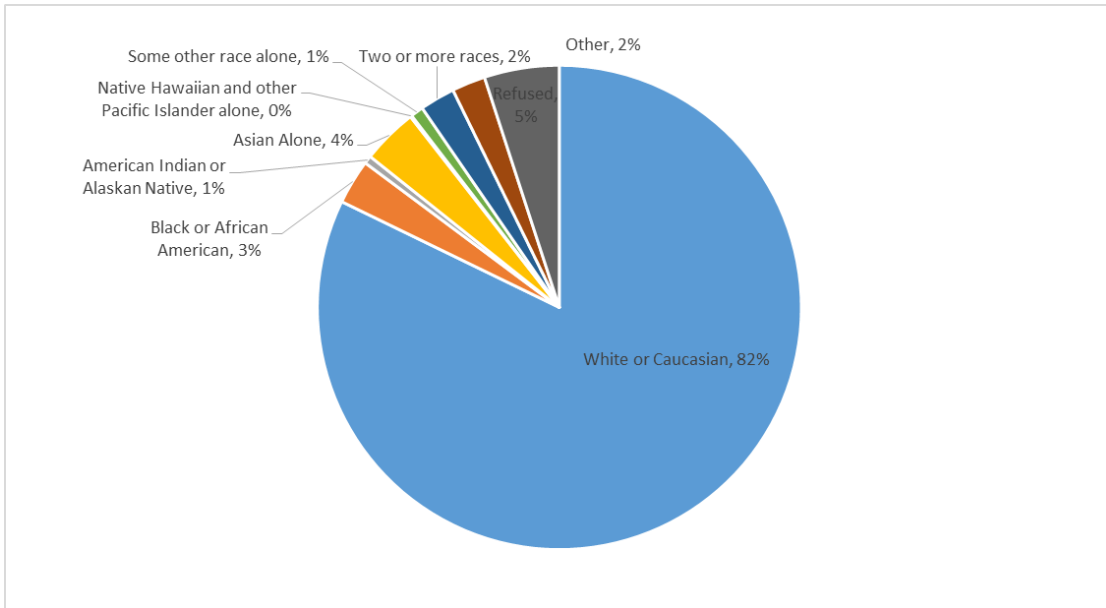


Figure 80. Race (Q27, N=515).

Nearly half of all respondents (46 percent) reported annual household incomes of \$100,000 or more, while approximately one-fourth (27 percent) reported annual household incomes between \$50,000 and \$99,999. About one in five respondents (19 percent) refused to provide this information. Figure 81 illustrates the respondent pool by household income.

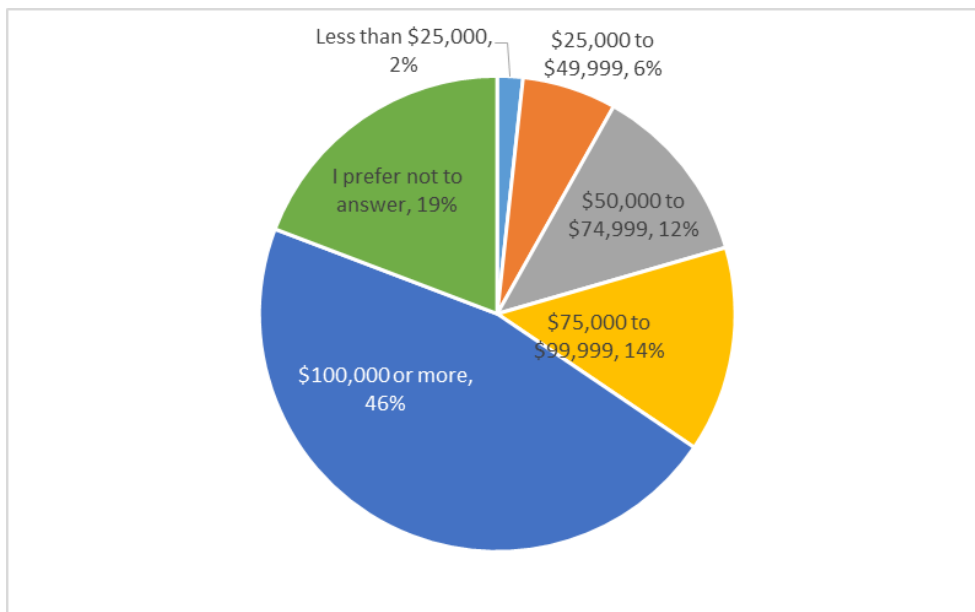


Figure 81. Annual Household Income (Q30, N=498).

Figure 82 shows the distribution of male and female respondents and those who refused to answer this question.

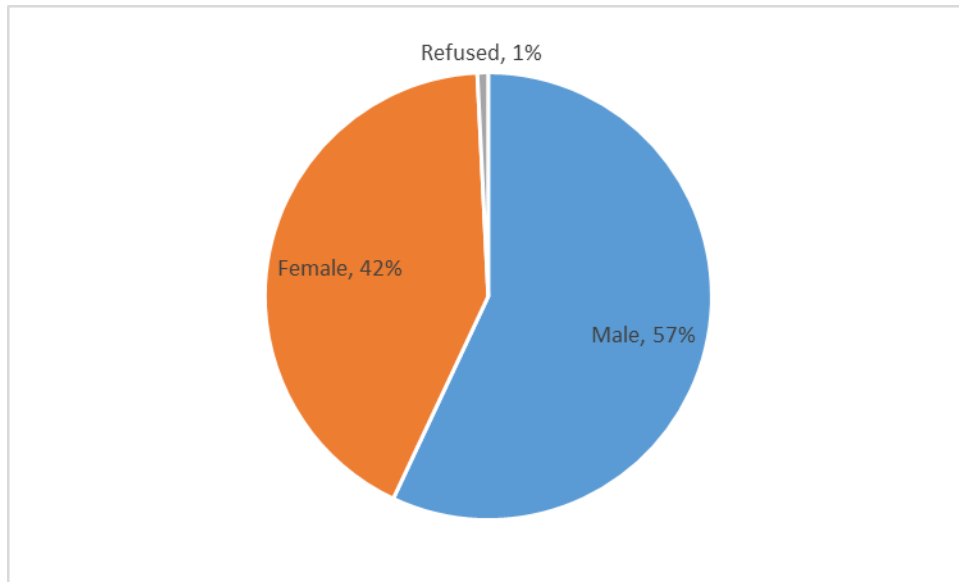


Figure 82. Gender (Q31, N=500).

DISCUSSION

The survey results show that drivers desire information to reduce their trip time and avoid congestion. Route options, delays, and rerouting options were all very high on desired information. This includes providing information about managed lanes in routing options—as long as cost information is provided.

Responses to questions on whether information should be provided in-vehicle or on road signs showed that drivers accept existing operations where most information is on road signs but an in-vehicle app may provide traffic condition updates and travel time for a specific route entered into a navigation tool. Notably, drivers did not desire in-vehicle information about current toll prices. This may reflect the relatively small number of dynamically priced toll facilities in Texas, which almost all operate in the Dallas/Fort Worth region.

The three regions of Dallas/Fort Worth, Houston, and Austin varied based on system maturity and type of pricing schedule (e.g., dynamic or fixed). The DFW region experienced a number of recent, significant changes to the managed lane network with the opening of a number of high-capacity priced facilities and the introduction of dynamic pricing. Most of the managed lanes in Houston had operational policy modifications to incorporate SOV, toll-paying drivers as new users, without an increase to physical capacity (the I-10 Katy Freeway Managed Lanes are an exception). In October 2016, Austin started to operate the first managed lane in the region by opening a small 5-mile priced section of the MoPac Express Lanes. Comparatively, many travelers in the Austin region are new to managed lanes, relative to the decades-long history in DFW and Houston.

Depending on the question, survey responses between the three regions were either similar or exhibited notable differences. Austin drivers expressed a higher inclination to demand toll cost information compared to the other regions (64 percent compared to 38–42 percent in Houston and DFW), likely due to initial interest generated from the recent opening of the first managed lane in the region. Houston respondents (51 percent compared to 4–5 percent in Austin and DFW) were far more likely to use an agency website (e.g., Houston TranStar®) to help select a route. However, survey advertising on the Houston TranStar® website likely influenced that finding since respondents accessed the survey through the road agency website. The Central Texas Regional Mobility Authority (based in Austin) and North Central Texas Council of Governments (based in the DFW region) helped to advertise the survey but did not use a website primarily to disseminate travel information. Generally, most other findings tended to be similar for the three regions, including use of a mapping website (66 percent often or very often), smartphone app (79 percent often or very often), and in-vehicle GPS navigation system (70 percent rarely or never).

Overall, respondents indicated that data elements related to travel reliability were important or critical for planning to take or not take a managed lane. For example, travelers want to know any information about unique events that may cause considerable delay, such as a large event (e.g., Rodeo Houston, South by Southwest® Conference, football game), vehicle crash, or inclement weather. The specific elements designed as important or critical included expected delays (93 percent), rerouting advice (88 percent), and alternative routes (80 percent). Bus or train information was the lowest-rated element, with only 23 percent of total respondents noting it as important or critical.

The results show that smartphone applications are a dominant method of obtaining traveler information. Designers of traveler information systems must always be cognizant of the potential for driver distraction due to these devices. Interfaces for smartphones in vehicles are emerging that will likely mitigate some driver visual distraction. Bluetooth pairing to audio systems allows voice commands and information to be broadcast. Other systems, such as Apple Car, link to a vehicle's center stack console video screen and offer a simplified user interface designed with drivers in mind. These systems provide larger text, limited operations, and lock-out features to prevent activities on the phone that have been shown to be distracting. While systems like these reduce visual distraction, the cognitive distraction of the traveler information persists. Decisions about using managed lanes can involve complex reasoning weighing delay, comfort, and cost. The cognitive distraction of the decision will be the same whether the information is presented in-vehicle or roadside. One advantage of in-vehicle presentation is that the information can remain visible and retrievable through audio systems on demand. The same is not true for roadside signs.

Transportation agencies working with developers of apps and mobile-friendly websites must ensure that the app minimizes the risk for driver distraction. The National Highway Traffic Safety Administration (NHTSA) offers guidelines for developers and metrics to assess potential distraction. The Phase 1 guidelines published in 2013 apply to original equipment infotainment systems in vehicles (152). The Phase 2 guidelines apply to portable and aftermarket devices. These entered a public comment period in November 2016 and will be issued as a final rule later in 2017 (153).

The results of the survey must be interpreted in the context of the likely bias in the sample of people who responded. By its very nature of being a computerized survey, individuals who are not comfortable with technology likely did not respond. In addition, an Internet connection was necessary, so individuals who do not have or cannot afford Internet access did not respond. All of the advertising for the survey also took place through Internet and social media placement. More than half the respondents came from Houston, most likely as a result of a link to the survey placed on the Houston TranStar[®] site. This site gets 900,000 unique visitors per month. With these considerations, the researchers feel that this sample may represent a group of first adopters of new technology. The results clearly showed frequent use of technology for trip planning purposes. For future systems, such as managed lane networks and advanced traveler information systems, this sample of respondents likely is representative of future travelers as technology use continues to spread.

CHAPTER 6—TECHNOLOGY ASSESSMENT

INTRODUCTION

The technology assessment considered and proposed methods, or pathways, to advance traveler information practices for managed lanes and managed lane networks. Current methods of displaying elements related to pricing, access, hours of operation, and direction of travel require the use of overheads signs. Signs can often lead to scenarios with driver distraction and overloading of information. At times, agencies have placed information about operating rules online, but users have limited access to and knowledge of those websites. Additionally, as evidenced by the preceding focus groups and travel survey, users have more of a desire to use third-party applications that integrate many aspects of the traveler experience—beyond managed lanes.

This chapter details key considerations for enhancing technology-based traveler information systems for managed lanes and managed lane networks. The first section provides an overview of regional traffic operations with respect to media for conveying information and refinements to existing Concept of Operations (ConOps) documents. The second section outlines the communicative data, standards, and technologies likely to be incorporated within an improved traveler managed lane traveler information system. These technologies include the integration of private-sector data providers (e.g., INRIX[®], HERE), transit service data standardization, and connected vehicles. The last section proposes an implementation pathway that (a) improves existing toll calculators and route builders as developed by Texas-based agencies, and (b) provides a managed lane and toll feed specification with a common standard for sharing static and real-time data with third-party users. A separate document, entitled *Framework for Inclusion within a Regional Concept of Operations*, summarizes the proposed implementation approach within an organized specification format.

CONSIDERATIONS FOR REGIONAL OPERATIONS

Many technologies and strategies provide traveler information for managed lane facilities. In many cases, the context of those technologies and strategies (e.g., in their testing, their marketing, or their application) has been within a single facility. As managed lane facilities become more prevalent, the success of facilities depends on how these technologies and strategies apply for multiple facilities within a region. This section describes some items that influence regional traveler information, with emphasis on managed lanes.

When implementing a regional traveler information system, operators should consider the characteristics of the facilities in question. This includes providing information to travelers about specific entrances, exits, and delays for each facility but also applies for interactions between facilities across a region. As a regional managed lane network grows, the likelihood of trips using multiple facilities also grows. This creates a need to provide information to those users who travel on more than one facility during their trip.

If all of the managed lane facilities within a regional network are similar (e.g., all facilities are HOV lanes), then the information sought by travelers will be more consistent across facilities. If differences exist in operations or restrictions (e.g., part-time use, HOT versus HOV-only), those

differences will need to also be communicated to travelers so that they can make informed decisions about their route choices. For example, a single-occupant vehicle traveling on an HOT lane is approaching a connector to an HOV lane on another freeway; that driver needs to know that he or she does not meet the eligibility requirement to enter that HOV lane.

Similarly, if there is only one regional operator, then policies and procedures for sharing information can be directly implemented throughout the region by that operator; however, if there is more than one operator, then providing traveler information will require some level of coordination. The various operators need to understand the components of their respective systems and how they differ so that accurate information can be consistently provided to users traveling on each facility and between facilities. Regardless of the number of facilities or the number of operators, the goal should be to provide consistent information across the region that contributes to a seamless managed lane network.

Concept of Operations

A regional ConOps specifies the necessary steps for implementation, who is responsible for each step, the way that those steps will be completed, the measures of effectiveness used to describe the objectives that the system is intended to meet, and the way information will be collected to quantify measures of effectiveness. The specifics of a regional ConOps vary by region and by operator, but some elements are suitable for any application. The FHWA publication *Systems Engineering for Intelligent Transportation Systems (154)* describes the technical process of developing a ConOps for an ITS project and provides an example that a regional managed lane operator should consider when implementing a managed lane travel information system.

The existing ITS architecture is an important component for a regional ConOps. FHWA (154) states that “when an ITS project is initiated, there is a natural tendency to focus on the programmatic and technical details and to lose sight of the broader regional context.” Any changes or improvements need to be consistent with the regional ITS architecture, if a regional ITS architecture exists. If there is just one operator, then there is quite likely only one architecture, but if there are multiple operators, then they may need to make some changes and agreements about what hardware to use within a single regional network. FHWA says, “The architecture is most valuable as a scoping tool that allows a project to be broadly defined and shown in a regional context. The regional ITS architecture step and the concept exploration step that is described in the next section may iterate since different concepts may have different architecture mappings. The initial architecture mapping may continue to be refined and used as the Concept of Operations and system requirements are developed” (154).

Staff and Data Collection Needs

On a managed lane system, key traveler information may need to be collected in real time from the roadway. This may require hardware to collect the information to be shared with travelers. Cameras to monitor operations, sensors to collect speed and headway data, and equipment to generate volume counts are all commonly used components of a managed lane facility, and the output from those components provides the basis of traveler information. Crash advisories and dynamic toll rates are two specific examples of traveler information that require a robust system of data collection hardware.

Whether information is provided through dynamic signs, smartphone applications, or radio messages, the operator must have sufficient staff to generate and manage traveler information. Staff requirements may include programmers for apps and websites, a narrator for radio messages or other verbal communications, technicians to monitor the feeds from cameras and sensors to receive the information to be shared with travelers, and others to update and maintain dynamic signs. As vehicle-to-infrastructure (V2I) technologies become more common, the importance of having staff dedicated to their consistent operation will also increase.

COMMUNICATION TECHNOLOGIES AND STANDARDS

Successful managed lane systems have operators that consider how to convey information after determining what elements to provide. This section introduces a number of relevant technologies, standards, and data systems that regional operators should consider as they devise managed lane network information systems. Traveler information is conventionally provided through roadway signs. More often, data aggregated by outside, third-party private providers are being used more by travelers for informational purposes. Use of connected vehicle systems will likely grow over time given the increased adoption of the technology in newer vehicles. This section details the considerations for advancing communicative practices given specific technologies and systems, with emphasis on detailing the existing practice of sharing transit data with private entities.

Roadway Signs

Changing facility and network design may lead to changes in sign formatting. Operators have the choice of using either static or dynamic signs, with inherent capabilities for each type. Static signs can be used for information that does not change, such as the distance to the next exit. Dynamic signs have myriad potential uses for communicating dynamic information such as travel time, toll rates, hours of operation, lane restrictions, and variable speed limits. The content and overall visual appearance of the sign typically are factors that influence the decision on where to place a roadway sign.

Many common static signs and messages are specified in the MUTCD and applicable state or regional standards. Some static signs and all dynamic signs are not specified in existing design standards. As new information needs are identified, consideration should be given to the amount of information a driver can process, what items are of highest priority, and how that information is displayed. For example, Chapter 6F of the MUTCD provides guidance on changeable message signs, including the maximum number of information units (three lines of text) to show on a single message and how many messages (two phases) can be shown on a portable changeable message sign used in temporary traffic control. Minimum letter heights, display time for each phase, and other features used to improve legibility and comprehension should be considered for dynamic signs. Research continues on information processing as the number and type of traveler information items changes to accommodate new situations such as those found on managed lane facilities.

In-Vehicle Systems

In-vehicle information systems are an increasingly common technology used to convey traveler information. Currently, in-vehicle navigation devices can take several basic forms:

- Embedded system: permanently installed in the dash.
- Aftermarket system: typically portable and quickly mounted to the dash or windshield.
- Smartphone: either independent or tethered (via communications) to an in-dash system.

The exact details for each type of navigation device vary, and the consumer product offerings are dramatically improving as mobile technology becomes more commonplace. For example, several years ago many of these navigation devices had static highway maps that were pre-loaded, and the maps could only be updated by either installing a map update via CD/DVD (embedded in-dash system) or by plugging the portable navigation device into an Internet-connected computer. Given the prevalence and low consumer cost of high-speed cellular data networks, most navigation devices now retrieve map, navigation, and other traffic information in real time via cellular communications.

Smartphones have become much more common for travelers, especially those who are highly mobile. A Pew Research Center survey in late 2016 found that 77 percent of U.S. adults own a smartphone (155). Similarly, the 2016 Texas Transportation Poll conducted by TTI found that 70 percent of survey respondents had recently used a smartphone app for navigation or route guidance (156). As mentioned earlier, smartphones can be used independently of a vehicle, or can be tethered to an in-dash system (which can provide a larger touch screen as well as enhanced dashboard or audio control). The integration of smartphones with in-dash infotainment systems is also changing dramatically on a year-to-year basis as automakers compete with each other to provide the latest technology at the greatest convenience.

Private-Sector Data

Private-sector data providers are companies that provide real-time traffic information and analytics using data collected from a wide variety of location-based sources. This service is based on the widespread, and increasing, availability of location-based data, from sources such as mobile phones, GPS devices, Bluetooth sensors, and connected vehicles. Private-sector data providers collect, analyze, and transform these data to, in turn, provide information about traffic conditions on roadways. Examples of private data providers include:

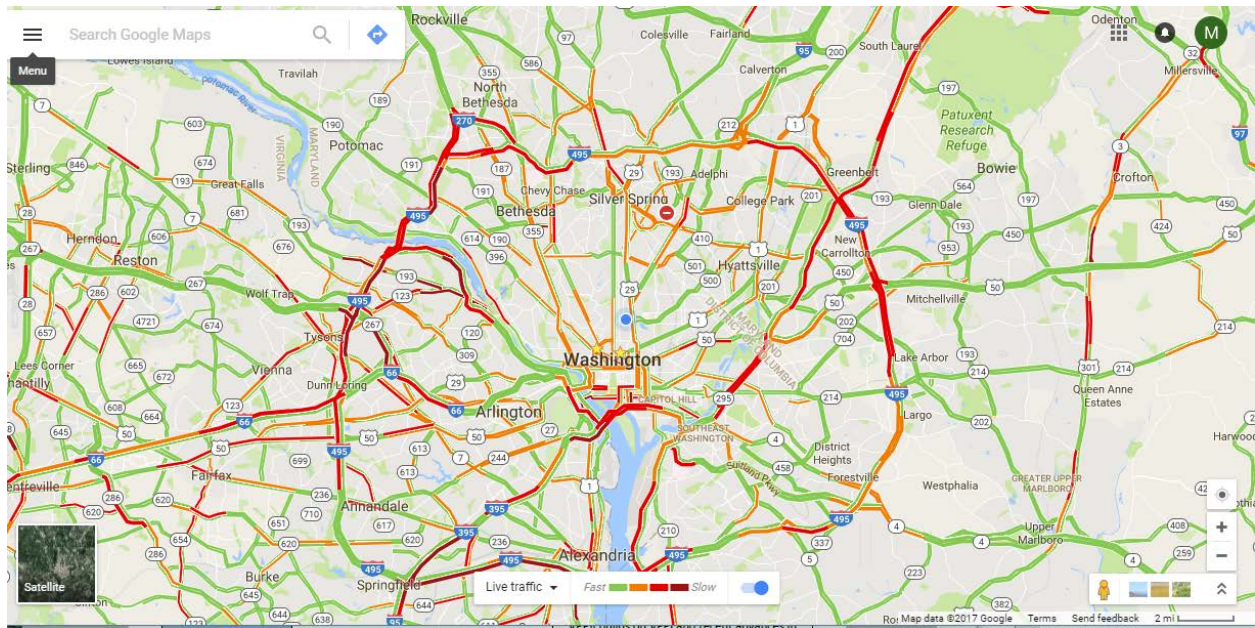
- Air Sage[®].
- American Trucking Research Institute.
- HERE.
- INRIX[®].
- TomTom[®].
- Trafficcast.

Often, the private data provider does not provide hardware or public maps. Instead, the company provides data that can be distributed to different outlets, including transportation agencies and third-party partners (such as MapQuest[®] or Google Maps). Departments of transportation

(DOTs) and transportation agencies use private data sources for applications including traffic monitoring, congestion management, and traveler information. The primary data provided by private-sector data providers include:

- Traffic flow (speed and travel times).
- Traffic incidents.

Traffic flow data include speed, congestion, and roadway geometry. Traffic incident data can include the location, type of incident, status (whether the incident is active), start time, end time, and other information. In addition, private data providers offer analytics, create APIs, and provide other targeted services such as tools specific to trucking customers or fleet managers. Services based on the data collected include traffic hotspot analysis, road performance, autonomous vehicle deployment studies, parking tools, and road weather. Figure 83 shows an example of a user interface conveying traffic flow and incident data.



Source: (157)

Figure 83. Example of Live Traffic Data Provided by Private Data Provider.

Most managed lane activity is not a roadway feature commonly captured by private-sector data providers. Some maps show some managed lane facilities, particularly those facilities with a wide separation from the general-purpose lanes. However, managed lane information may be an applicable extension of private data services if the roadway and vehicle data can be incorporated. One provider noted that if it did partner on a managed lane application, its likely role would be providing the travel information but not communicating that information to the public. Part of this is because critical travel information is still expected to have to be presented on the roadway, and not exclusively on smartphones.

Data Sources

Private-sector data providers gather input data from multiple sources, and those data are then blended to produce an estimate of current traffic conditions (158). Data can include private and public sources. Probe sources include cell phones, GPS devices installed in vehicles, Bluetooth sensors, cameras on roadways, and source data from car manufacturers that have integrated sensor technology. In addition to probe and sensor data, some companies supplement that information with field and local data. For example, INRIX[®] incorporates construction, road closures, sporting and entertainment events, and hazardous weather conditions (159). DOT-related data can provide information for planned events, while unplanned events can be picked up by Twitter[®] feeds, TV stations, and radio stations. The private data provider may have to assess the quality and update frequency of different datasets to determine usefulness for speed and closure updates. The amount of detail in any given application is dependent on the quality of source information.

Providers also supplement more standard data with locally sourced field data and local activities and events. Field staff will follow local construction projects, connect with local agencies, and monitor for temporary roadway closures. Cameras on vehicles can also be used to compare road sign and lane marking data from a database to confirm accuracy. Data are constantly monitored because accuracy for routing and travel time is a priority. Lane closure data, for example, are not always accurate or up to date. Providers do not always rely on agency data because those data are not always up to date.⁹ Different sources can have different levels of reliability and data quality, so the approach can be different for each location.

Data Applications

Providers typically provide their data to numerous map providers and other third parties. It is map providers that choose which information is presented to the end user. The private data providers offer many different attributes that can be transmitted and communicated to end users, including reversible lanes and the flow of traffic. Priority data for private data providers include information that determines routing directions. For example, lane closures are a priority data point because they can require detours or change travel times. Other efforts are underway to include lane-specific information. One type of lane-specific information is the number of lanes and, if known, lane splitting at junctions on a roadway. Providers also report working on incorporating lane widths into future maps, which can be used for future automated vehicle applications. There is research being done on lane-specific traffic conditions and travel times, but this is not currently available commercially.

Toll rates are also included in private data feeds, which are reportedly used more often by trucking customers. Dynamically priced congestion pricing is not widespread, according to HERE, and it works on applications and data that are of interest to its customers. If shoulder use becomes more common, at least one provider suggested that it can be incorporated into these data.¹⁰

⁹ Personal Communication with HERE, March 2017.

¹⁰ Confidential Communication with Private Data Provider, March 2017.

Interviews with Map and Traveler Information Companies

Researchers contacted several private-sector mapping and traveler information companies (HERE, INRIX[®], Waze[®], and Sidewalk Labs[®]) to identify current practices and explore the potential for transportation agencies to provide them with some type of structured data feeds about managed lanes. The key findings from the interviews are described in the following sections:

- Finding 1: When considering implementation, it is useful to differentiate between relatively static information (e.g., presence of a managed lane that is open to traffic) and dynamic information (e.g., current toll rate, occupancy requirement).

The foundation for most map and traveler information companies is a routable digital map that can be used for navigation purposes. This routable map digitally encodes what roads exist and are open for public travel. Various other layers of information (i.e., road attributes) are then encoded on these digital maps, like speed limits, height restrictions, presence of tolls, current real-time speeds, etc. The existence of roads is fairly static, whereas other information like real-time speeds is very dynamic. Therefore, map and traveler information companies are much more likely to have up-to-date routable maps because they change much less often than the dynamic information. Also, for these companies, having an accurate routable map is their core business, whereas the other traveler information is considered nice to know but not absolutely essential for wayfinding.

- Finding 2: Map and traveler information companies are including the presence of some types of managed lanes, but other, more-dynamic information is lacking.

Most map companies include the presence of managed lanes in their routable maps when a managed lane has a separate and distinct travel way from other nearby travel paths. However, if a managed lane is separated from other travel lanes by only a lane marking or buffer, and does not provide a distinct travel path to a different destination than other lanes, then the managed lane is not likely to be encoded in digital maps. For example, buffer-separated carpool lanes are not included on most commercially available maps.

Dynamic information like toll rates or occupancy requirements are not provided in any commercial maps. Several companies said that as managed lanes become more common for urban travel, they are likely to try to include this dynamic information in their map and navigation products. Waze is working to include HOV lanes in its products in the near future, such that “Wazers” can use routing that includes HOV lanes. Like HERE, INRIX[®] provides traveler information for certain types of managed or tolled lanes that have sufficient separation from other lanes. Several of the companies indicated that the implementation (and timing) of lane-specific information in their consumer products will depend upon market and customer demand and needs.

- Finding 3: Data exchange standards are ideal, but at a minimum, transportation agencies need to provide timely, accurate, and structured managed lane information if they want private companies to help distribute this information to in-vehicle devices.

All of the companies emphasized the importance of having transportation agencies (i.e., those responsible for managing and operating the roadways) provide accurate, up-to-date managed lane information. Several of the companies indicated that data exchange standards are ideal and can help them expand their information products to a national or global scale. However, existing traveler information and traffic control standards (such as SAE J2540 and SAE J2735) either were not recognized or were considered but not adopted. In regard to standardization, Waze mentioned the KISS principle (Keep it Simple, Stupid) and has developed its own Closure and Incident Feed Specification (https://blog.waze.com/p/blog-page_19.html) for transportation agencies that participate in its Connected Citizen Program (<https://www.waze.com/ccp>). Waze hopes that, because of its simplicity, this specification is broadly adopted by many transportation agencies, the same way that GTFS has been widely adopted by public transit agencies for providing transit routes, schedules, and information. HERE mentioned its Open Location Platform (<https://here.com/en/innovation/here-open-location-platform>) and how it is working to standardize both the data received from connected vehicles as well as the warning message sent to connected vehicles. However, all four companies indicated that they can ingest any easily accessible, online structured data feed, and that a standard is not absolutely necessary but would be helpful.

General Transit Feed Specification

The GTFS is a consistent data format used to convey public transportation service information. Its typical application is to display scheduled transit information in an online trip planner, such as Google Maps. Although it would require the development of a specification that captures the data needs of managed lane communications, GTFS offers a model format and process to share travel data with developers and stakeholders in a low-cost, open format.

There are two types of GTFS—*GTFS static* and *GTFS realtime extension* (161). *GTFS static* is an open data specification developed for use by transit agencies, developers, and other stakeholders to convey and transmit routes, schedules, and associated geographic information about public transportation services. *GTFS realtime* allows agencies to supplement the static data with live service updates such as latest departure and arrival times, service alerts, and vehicle locations. Travelers can easily interpret and use data from a GTFS feed by looking at online maps and other interfaces.

GTFS Static

GTFS static contains routes, stops, trips, and published schedules, which are relatively consistent—only changing as routes or schedules are updated (162). *GTFS feeds* are a set of data organized in a common format that let public agencies publish their transit data. A *GTFS feed* includes a series of text (.txt) files. Each file provides information about one aspect of the transit service, including stops, routes, trips, and other schedule data. Developers or other users can easily use the feeds to create applications based on data. Table 17 summarizes both required and optional files, along with their associated content, that comprise a static *GTFS* file. Figure 85 shows an example of a *GTFS* file for a system calendar. This file identifies different service periods using a weekly schedule. Figure 86 maps the relationship between the various files included in a static *GTFS* feed.

Table 17. GTFS File Summary.

Filename	Minimum Requirement	Defines
agency.txt	Required	One or more transit agencies that provide the data in this feed.
stops.txt	Required	Individual locations where vehicles pick up or drop off passengers.
routes.txt	Required	Transit routes. A route is a group of trips displayed to riders as a single service.
trips.txt	Required	Trips for each route. A trip is a sequence of two or more stops that occur at a specific time.
stop_times.txt	Required	Times a vehicle arrives at and departs from individual stops for each trip.
calendar.txt	Required	Dates for service IDs using a weekly schedule. Specify when service starts and ends, as well as days of the week where service is available.
calendar_dates.txt	Optional	Exceptions for the service IDs defined in the calendar.txt file. If calendar_dates.txt includes ALL dates of service, this file may be specified instead of calendar.txt.
fare_attributes.txt	Optional	Fare information for a transit organization's routes.
fare_rules.txt	Optional	Rules for applying fare information for a transit organization's routes.
shapes.txt	Optional	Rules for drawing lines on a map to represent a transit organization's routes.
frequencies.txt	Optional	Headway (time between trips) for routes with variable frequency of service.
transfers.txt	Optional	Rules for making connections at transfer points between routes.
feed_info.txt	Optional	Additional information about the feed itself, including publisher, version, and expiration information.

Source: (163)

```

service_id,monday,tuesday,wednesday,thursday,friday,saturday,sunday,start_date,end_date
WE,0,0,0,0,0,1,1,20060701,20060731
WD,1,1,1,1,1,0,0,20060701,20060731

```

Source: (164)

Figure 85. Example of Fare Attributes File.

Other features of GTFS static include:

- The use of text files produces small data files that do not necessitate significant storage space or hosting costs for an agency.
- GTFS feeds can provide trip suggestions with multiple segments operated by different agencies. Transfer points require identification.

Limitations of static GTFS data include the following:

- Schedules form the basis for providing transit-related information and require updates when changes occur for bus stops, routes, or schedules.
- GTFS static does not include different fare rates for the same trip, so it does not lend itself to fare payment integration.
- GTFS static is not capable of supporting share demand-response and flex-route transit services. However, efforts are underway to develop a GTFS-flex specification for flexible route transit (165).

GTFS Realtime

In 2011, GTFS realtime was added as an extension of GTFS static to provide transit updates to users in real time. This feed specification allows public transit agencies to convey information about deviations in service and schedules. GTFS realtime currently provides information on:

1. Trip Updates—Fluctuations from the scheduled timetable through messages like “on-time” or “two minutes late.” These data help to update estimated trip travel times.
2. Service Alerts—Updates about service delays, rerouting, and other disruptions to normal service. Alerts target particular stops, routes, and days based on attributes in the GTFS static data.
3. Vehicle Positions—Information on the location of a vehicle based on GPS data. This feed can even include updates about travel speed, congestion level, and occupancy status (the latter is still experimental) (166).

Each type of information requires a separate feed that is sent via HTTP. Unlike static data, agencies have to host data used to support GTFS realtime feeds. For example, vehicle position data would come from new data gathered by an agency’s automatic vehicle location (AVL) system. Transit agencies commonly have AVLs to track vehicle locations. Unlike the static feed, GTFS realtime requires agencies to store the feed within a location available for third parties to retrieve data. These data constitute live information. Furthermore, an agency may be responsible for more complex real-time formatting of information such as data gathered from AVLs to supply a GTFS realtime feed.

GTFS realtime facilitates the communication of information via web browsers and mobile applications. This includes live departure and arrival times to transit stations and service alerts. The third-party company publishing the information is constantly “pinging” the agency server for trip updates to provide updates every 30 to 90 seconds. GTFS realtime is “designed for ease of implementation, good GTFS interoperability, and a focus on passenger information” (167).

Data for GTFS Realtime

GTFS realtime data are a data exchange format based on protocol buffers—a “language-neutral, platform-neutral, extensible mechanism for serializing structured data,” similar to XML. This means a user can define the data structure once and use a number of different programming languages (e.g., C++, Java, Python) to read and write structured data (168). Compared to XML, protocol buffers are simpler, smaller, faster, and less ambiguous (169).

Developing a GTFS Feed

To create a GTFS feed, a public agency has to collect and format agency data into the specified format and make them available for applications. As an open data standard, there is no required proprietary technology necessary, and information and guidance on the process are available and free online. Transit agencies can work with third-party developers to build their own GTFS feed to publish and share routes and scheduling information with customers. For example, Google Transit, the service that shares transit information via Google Maps, works with agencies to develop and publish transit data that meet the following criteria (170):

- Be a transit agency.
- Provide publicly accessible service.
- Operate fixed routes and schedules.

Agencies sign terms and conditions agreements with Google to participate, open an account, and then work with the company to clarify data issues. GTFS data are managed through a partner dashboard where agencies can upload and test a feed and receive online technical assistance. This process involves the following steps:

1. Access the transit partner dashboard.
2. Create your data feed.
3. Publish your GTFS feed data.
4. Review your feed.
5. Test using private preview.
6. Launch your feed.

A number of validation tools as well as reference guides to create a feed are available publically online. A feed validator tool verifies that the data files match the specification. Possible errors include missing files, missing values, and invalid field values. Schedule viewer is a Python program that allows agencies to see their data feed on a map to review whether routes and schedules correctly represent the system (171). Private companies provide setup and administration of GTFS feed development and ongoing maintenance for a fee (172). TTI researchers have provided technical assistance to Texas transit agencies on the development of GTFS feeds as well.

Connected Vehicles

The implementation of traveler information technologies encompasses many considerations of traffic control devices, roadway design, communication methods, supporting infrastructure, and

staffing. In addition, however, operators need to consider the implications of connected vehicles and, by extension, automated vehicles. The previous discussion focused on communicating information to human drivers. As vehicle design increasingly incorporates connected and automated vehicle technology, the focus may shift away from travelers as human drivers and more to travelers as human passengers inside vehicles, and to some extent, the vehicles themselves. An operator that is implementing a regional traveler information system in the near future would be prudent to consider a system that can adapt to those vehicles as they join the public fleet. This section discusses some of those considerations.

Privacy will be a high priority for implementation with connected vehicles. Connected vehicles communicate wirelessly with other vehicles and roadway infrastructure, sharing safety and mobility information and generating new data about how, when, and where vehicles travel. While the data generated will provide input for strategies to help prevent crashes and improve mobility, the unprecedented level of detailed data raises questions about privacy and security. USDOT is enacting standards for sharing information so that the vehicle information communicated does not identify the driver or vehicle, and technical controls are put in place to help prevent vehicle tracking and tampering with the system. Traveler information systems must be compatible with USDOT's privacy restrictions. Some restrictions (173) specifically related to vehicle-to-vehicle systems include:

- The system will not collect or store any personally identifiable information about individuals or vehicles.
- The safety messages exchanged by vehicles cannot be used by law enforcement or private entities to identify a speeding or erratic driver.
- The system will not permit tracking through space or time of specific owners, drivers, or passengers.
- Third parties attempting to use the system to track a vehicle would find it extremely difficult to do so, particularly in light of simpler and cheaper means available for that purpose.
- The system will not collect financial information, personal communications, or personally identifiable information about individuals or vehicles. It will enroll enabled vehicles automatically, without collecting any information identifying specific vehicles or owners.
- The system will not provide a "pipe" into the vehicle for extracting data. It will enable NHTSA and motor vehicle manufacturers to find lots or production runs of potentially defective equipment without use of vehicle identification numbers or other information that could identify specific drivers or vehicles.

USDOT (174) has pursued a security-by-design approach to developing the connected vehicle environment, which means that the entire connected vehicle system (vehicles, roadside components, and communications media) has been designed with the critical goal of cybersecurity in mind. USDOT has several research programs dedicated to ensuring a secure connected transportation environment, and future traveler information systems will have to consider these elements as they are designed and implemented:

- Vehicle Cybersecurity—Focuses on mitigating the safety impacts of potential cyber-attacks into vehicle systems and components.
- Infrastructure Cybersecurity—Focuses on protecting against threats and vulnerabilities to the nation’s roadside equipment, devices, and systems.
- Dedicated Short-Range Communications Security—Focuses on ensuring trusted communications between vehicles and between infrastructure and vehicles.
- ITS Architecture and Standards Security—Focuses on the development of architecture and standards required to ensure security in the connected vehicle environment.

As mentioned previously, considerations for the physical infrastructure have to be included within the deployment plan of a traveler information system. FHWA, in discussing V2I requirements, supports that guidance, stating that early deployments of connected vehicle field infrastructure are likely to be installed in conjunction with existing ITS equipment (e.g., dynamic message signs, close-captioned television cameras, vehicle detection stations, etc.) and existing traffic signal controllers. One reason for this is that ITS deployments are already located in areas where V2I communications are likely to be most needed and beneficial. Also, these locations provide an opportunity to leverage existing power sources, cabinet space, and backhaul communications, which will minimize deployment costs. Installation of connected vehicle (CV) field infrastructure is conceptually no different than installation of other ITS equipment. FHWA says that the “same considerations of siting, foundations, mounting points, power, physical accessibility and security, backhaul networks, and so forth that have become standardized and accepted in ITS practice, will be considerations in connected vehicle infrastructure deployments. In addition, new requirements may need to be considered for connected vehicle infrastructure deployments; such as, ensuring adequate line of sight for antennas and conducting mapping surveys of the surrounding roadway geometry” (175).

FHWA states that “in many ways, one can think of connected vehicle infrastructure as the next generation of ITS equipment being installed in the field with the potential to have a transformational impact on transportation operations and safety. As such, it is important to start considering V2I communications requirements and standards when new ITS equipment and traffic signal controllers are purchased and installed. FHWA highly recommends that for any ITS equipment and traffic signal controllers, purchased in the future, and the deploying agency follow the systems engineering process and deploy the equipment in an environment that is CV ready.”

For further support, as part of FHWA’s Connected Vehicles Pilot Deployment Program, it has developed a series of documents on concepts and assessments for EnableATIS (Advanced Traveler Information System 2.0), which includes enhanced traveler information services that record or infer user decisions and other contextual trip data that, when suitably processed, can improve or transform system management functions (176).

IMPLEMENTATION PATHWAYS

Using the ConOps framework, the technologies and standards introduced in the previous section can inform a pathway forward to implementing a traveler information system for managed lane networks. This section proposes a foundation for a pathway that incorporates two key features:

- An agency-derived toll calculator.
- A route-builder concept.

Currently, travelers of managed lanes lack comprehensive and readily accessible tolling information. Rates are generally found on agency websites and on roadway signage. However, potential travelers may have to read a table and calculate total toll charges based on their trip. For example, a driver in Houston would have to sum three tolling fees to estimate the cost of a trip from Telephone Road to the Katy Freeway. A trip that includes two or more tolls, such as Highway 183A, SH 45, and SH 130 in Cedar Park and Lockhart, require the identification of tolling points from several different tables. While some agencies have developed origin-destination matrices that allow users to identify costs based on a defined entrance and exit point, most do not currently do so because it is not a requirement. NTTA has developed matrices for each of its toll roads to assist users with assessing costs (177). However, this system requires travelers to query information from multiple matrices—one for each facility—for a trip using more than one road.

Additionally, users may also use multiple toll facilities managed by different entities. Traveler information systems need to query data from multiple agencies to build trips and create relevant statistics. For example, a Dallas/Fort Worth trip that utilizes both the Dallas North Tollway and the I-635 TEXpress Lanes® would require the user to access both the NTTA and TEXpress Lanes® sites. In the Houston area, a trip on the Westpark Tollway from IH 610 to SH 99 in Fort Bend County would require the user to access both the HCTRA and Fort Bend County Toll Road Authority websites since ownership of the tollway switches at the county line.

Dynamic systems become complicated to display for users because rates may change every 5 minutes. Current dynamically tolled facilities, such as the LBJ TEXpress Lanes® (I-635) in Dallas and the MoPac Express Lanes in Austin, do not display prevailing toll rate information on their websites, only providing that information on or before entry to the managed lane system.

Agency-Derived Toll Calculators

Two tolling agencies in Texas developed toll calculators that provide users toll information based on their proposed trips. The NTTA Tollmate® app for Android and iPhone provides users a toll calculator to assess the costs of traveling on toll roads (178). The user enters the origin, destination, and vehicle class based on the number of axles. The calculator assesses a set of proposed routes using the given information, both tolled and non-tolled, and calculates the toll cost if toll roads are used. Figure 87 presents screenshots of the Tollmate® app.

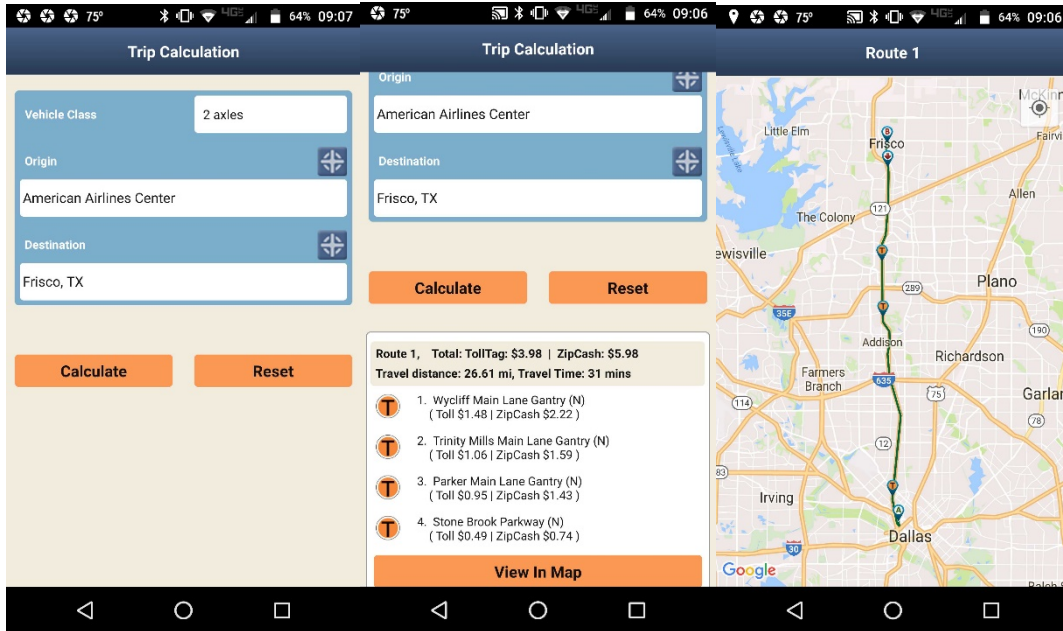


Figure 87. Screenshots of NTTA’s Tollmate® Application with Entry Fields and Results.

The calculator operates using data and the roadway network as defined by Google’s Map Service. NTTA identifies toll-assessment locations using latitude and longitude coordinates and assigned toll rates. Tollmate® utilizes a proprietary algorithm created by NTTA’s contractor that calculates a toll amount from a database if an identified route passes through a toll gantry. The calculator sums the toll costs identified on the route and provides the user a total toll assessment for the route.¹¹ The results for the user include a set of itemized toll charges for the route, with both toll tag and ZipCash® (the pay-by-mail service for NTTA facilities) amounts, as well as mapping of the route.

TxDOT developed a toll calculator for SH 130, SH 45, Highway 183A, and a section of MoPac on a TxTag® website that operates in a similar manner to NTTA’s Tollmate® calculator (179). Users can enter origins, destinations, and the number of vehicle axles. The TxTag® calculator uses Google’s Map Service to provide the base map and routing calculation. The calculator also provides an itemized set of toll charges for the route, for both toll tag and pay-by-mail amounts. Figure 88 presents a screenshot of the TxTag® calculator. TxDOT’s calculator accesses toll data stored in a SQL database and uses JSON and JavaScript to interface with PHP/HTML website code for data transfer.¹² The route builder captures the toll values at the individual points and calculates the total amount for the trip.

¹¹ Personal Communication with North Texas Tollway Authority, June 12, 2017.

¹² Personal Communication with Erica Ramirez, TxDOT Toll Road Division. July 5, 2017.

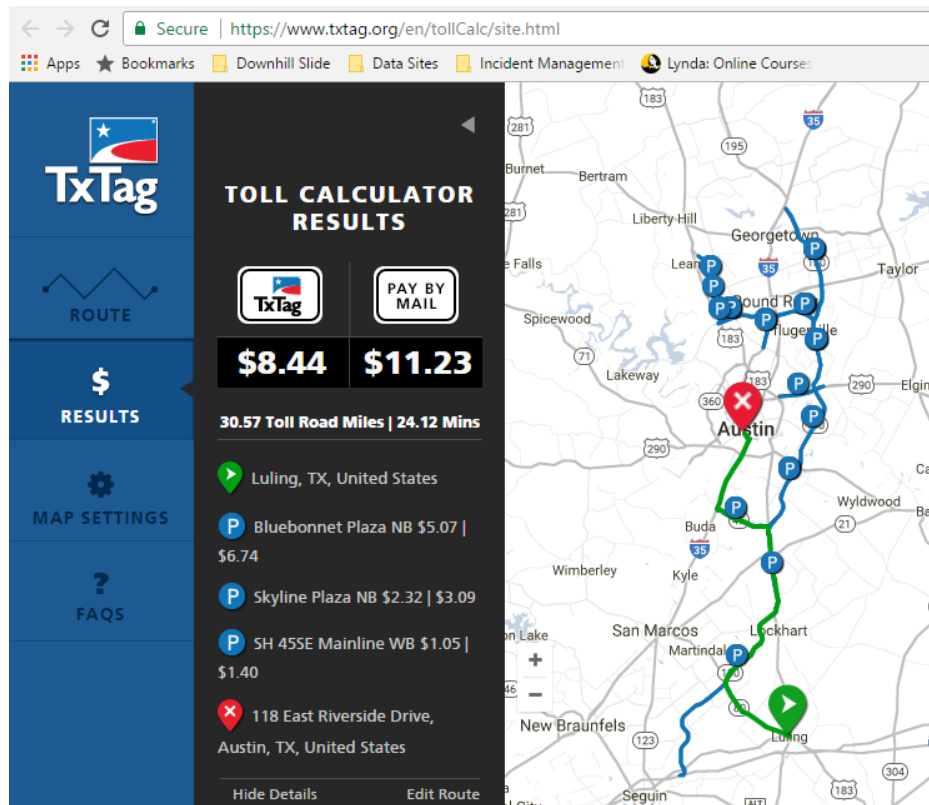


Figure 88. TxTag® Toll Calculator Routing Example.

Route-Builder Concept

A managed lane and toll information system for Texas should consider (a) the ability of the road user to obtain information from the agency, and (b) the agency’s ability to easily provide and maintain the information. A potential approach for a dynamic, real-time priced managed lane information system could utilize a route-builder application, similar to NTTA and TxDOT’s, to identify travel options and calculate the costs of taking different routes, including those with and without tolls.

A relatively uniform approach to tolling within Texas would help with the implementation of a route-builder system. Texas-based toll entities all assess tolls for vehicles that pass at specific points. These tolling points predominantly consist of gantries with transponder readers, or antennae, that capture passing transponders on the system. Systems with a pay-by-mail option also contain cameras at these locations to capture license plate information for billing purposes. The Sam Houston Tollway in Houston remains the only toll facility in the state that still accepts cash payment for tolls. These cash-accepting tollbooths are located in the same areas as the electronic toll gantries.

A route-builder approach essentially mimics an actual trip on the facility. When a vehicle passes a tolling point on the system, the vehicle’s transponder communicates its presence to the toll system. The toll system accesses a database to determine the amount to be charged and assesses the charge to the account associated with the vehicle. For the route builder, the calculated route would reach a tolling point on the map. The intersection with this tolling point would trigger

communication to the toll system database, which instead of charging the toll to an account, would charge the toll amount to the calculator. A trip involving multiple tolling points would accrue multiple charges. The route builder would tally the charges and provide a total cost for use of the facility.

The route builder would operate as follows:

1. The user enters the start and end locations of the proposed trip, as well as the vehicle class.
2. The route builder calculates the route location.
3. If the route builder calculates a route utilizing a toll facility, the route builder captures all of the associated tolling amounts from the real-time toll feed for each tolling point passed.
4. The route builder sums the values from all the passed tolling points and provides an overall toll calculation for the trip.
5. The route builder also includes a time stamp to qualify the results in terms of accuracy for each point passed and for the entire trip.

A route builder could also capture toll amounts for trips that use facilities operated by multiple participating agencies and potential trips in multiple metropolitan areas. This approach would additionally provide comprehensive, door-to-door trip information. In the future, connected vehicle technologies could provide the ability for communication between vehicles and road infrastructure to broadcast cost information to a vehicle navigation system.

The success of this approach would partially depend on the accuracy of the map layer that the route builder utilizes. Tolling agencies would need to review the mapping of their systems to ensure accuracy and notify the mapping service of the required modifications.

Proposed Managed Lane and Toll Feed Specification

One potential solution for conveying managed lane traveler information combines elements of existing route builders and feed specifications like GTFS. Online toll calculators have the functionality to provide basic toll rate information to the public, for facilities where all freeway lanes have tolls. The incorporation of managed and priced lanes within an existing toll calculator would require modifications based on the unique operational aspects of those types of facilities. This proposed methodology would use a similar approach to a GTFS, based on a standardized data format for supplying and transmitting managed lane and related toll information to private, third-party mapping services. Similar to GTFS, static and real-time feeds would need an established definition to correlate with the transfer of static and dynamic tolling rate data.

The data to support a managed lane and toll rate feed for Texas facilities does not need to be as complex as data to support GTFS for transit services. GTFS requires six to 13 tables to appropriately communicate agencies, route locations, bus stops, estimated times of arrival, and other transit-related information. In contrast, the managed lane and toll feed specification would only require one single table that contains pertinent information for the route builder and toll calculating components. This provides a simpler approach compared to toll systems outside of Texas that operate based on entrance-exit rate structures and their associated origin-destination

(O-D) matrices. Figure 89 provides a theoretical visual of the toll feed specification table. The toll feed specification table would contain the following information:

- Operating agency.
- Facility name.
- Direction of flow.
- Tolling location name.
- Latitude/longitude of tolling location (to line up with the toll route on the mapping platform).
- Time stamp of toll data (with day and time).
- Charge per number of axles (if not charged by number of axles, state “N/A”).
- Charge by vehicle classification (if not charged by classification, state “N/A”).
- HOV charge (if HOV is not operational, state “CLOSED”; if no HOV exists, state “N/A”).
- Cash charge (if toll road does not accept cash, state “N/A”).
- Pay-by-mail charge (if toll road does not have a pay-by-mail feature, state “N/A”).

Agency	Facility Name	Direction	Gantry	Toll Point	TimeStamp	Latitude	Longitude	HOV	2AxleCash	PayByMail	2Axle	3Axle	4Axle
HCTRA	Hardy Toll	NB	Tidwell	Exit	9/1/2016 0:00	29.8394	-95.3568	N/A	N/A	\$1.00	\$0.90	\$2.00	\$3.00
HCTRA	Hardy Toll	NB	Little York	Exit	9/1/2016 0:00	29.86233	-95.3625	N/A	N/A	\$1.25	\$1.20	\$2.75	\$3.75
HCTRA	Hardy Toll	NB	Aldine Mail	Exit	9/1/2016 0:00	29.89595	-95.3709	N/A	N/A	\$1.25	\$1.20	\$2.75	\$3.75
HCTRA	Hardy Toll	NB	Hardy South Plaza	Toll Plaza	9/1/2016 0:00	29.92999	-95.3788	N/A	N/A	\$1.75	\$1.50	\$3.50	\$5.25
HCTRA	Hardy Toll	NB	Central Greens	Exit	9/1/2016 0:00	29.95725	-95.3783	N/A	N/A	\$1.00	\$0.90	\$2.00	\$3.00
HCTRA	Hardy Toll	NB	Airport Connector	Toll Plaza	9/1/2016 0:00	29.95739	-95.3667	N/A	N/A	\$1.25	\$1.20	\$2.75	\$3.75
HCTRA	Hardy Toll	NB	Rankin	Exit	9/1/2016 0:00	29.96425	-95.3798	N/A	N/A	\$1.00	\$0.90	\$2.00	\$3.00
HCTRA	Hardy Toll	NB	Richey	Exit	9/1/2016 0:00	29.99485	-95.3964	N/A	N/A	\$1.25	\$1.20	\$2.75	\$3.75

Figure 89. Sample Toll Feed Specification Table.

Static Toll Feed Specification

Most of the tolled facilities in Texas operate off a static toll rate system, with the agency assigning fixed rates for each tolling location. Both Tollmate[®] and TxDOT’s toll calculators operate for static toll rate facilities. The static toll feed specification would allow other agencies to transfer their managed lane and toll rate information into the database. The hosting entity would use its data-transfer protocol to add the information to the mapping API for the route builder.

Preparing data in the static toll feed specification would be relatively simple, requiring minor modification and minimal effort from the operating agencies. Agencies currently have most of the required information for the table in a similar format to the proposed requirements, including facility name, direction, tolling location, and toll rates by axle count/vehicle classification. Agencies post these data for their websites or contain them in an action item by the agency’s decision-making body approving the rate structures. Agencies would have to enter some information into the table, including exact latitude-longitude coordinates to correspond with the route builder, special HOV toll rates and exemptions, vehicle classifications, and a time stamp to show when the tolling agency approved the rates.

Dynamic Toll Feed Specification

Dynamic tolling differs from static tolling in that the toll rates change in real time given the current demand for a facility. The complexity of integrating a dynamic-rate toll feed would be considerably greater than a static toll feed. The TEXpress Lanes[®] system in the Dallas/Fort Worth region alters toll rates on its system based on real-time traffic every 5 minutes, 24 hours per day with the intent of maintaining a minimum speed of 50 mph (180). The managed lanes under construction on SH 288 in the Houston area currently have plans to start dynamic tolling. In addition, both the Katy Managed Lanes and METRO's HOV/HOT lanes use a dynamic tolling hybrid, where the toll rates vary by time of day but to an established amount for that time period regardless of traffic.

A set table with a fee schedule would not suffice for a toll system that uses changeable dynamic tolling. The challenge to this approach would be the transmission of real-time toll amounts to the route-builder system. Transmission to a route builder could work similarly; however, it would require programming for the integration between platforms. Assuming multiple back-office systems available for dynamic tolling systems, each back-office system could potentially require separate programming for integration.

A possible solution might incorporate a data-transfer protocol similar to real-time GTFS services currently used for transit. Real-time GTFS allows transit providers to display present locations of buses and estimated times of arrival at transit stops, as well as service updates for the system. The transit provider receives the vehicle geo-coordinates, and the position transmits to the map as defined by the feed specification (181). The mapping program can also display additional information based on the feed specification including estimated arrivals to upcoming stops and time stamp to qualify the vehicle position. Figure 90 shows a sample display of real-time bus information based on its utilization of Google's real-time GTFS feed.

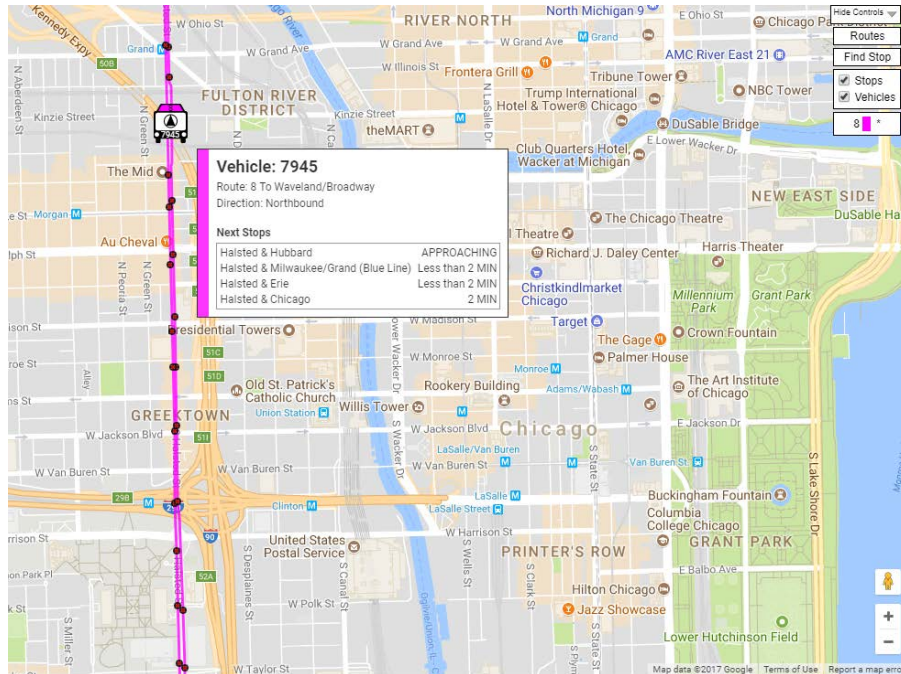


Figure 90. Real-Time Vehicle Location Display from Chicago Transit Authority Bus Tracker.

A critical component of GTFS involves the options for real-time transit data transmission: fetch and push (182). With the fetch approach, the transit agency can either host its GTFS real-time feed on its server or use a web application server, and the mapping service provider can pull the data every 30 seconds. The push approach allows the transit agency to set up automatic uploads of its GTFS real-time feeds and specify the timing of these uploads (recommended at 30-second intervals).

A dynamic toll feed specification protocol—based off GTFS—could serve as the data transmission medium for the tables used by the route builder to determine managed lane and toll costs. Agencies that operate dynamically priced facilities currently transmit their toll rate information in real time to overhead signage. In a similar manner, agencies can transmit these same data elements within a real-time toll feed specification format, via push or fetch, to upload into the route builder. Agencies would need to include similar information as contained in the static toll feed specification format, including exact geo-coordinates, carpool (HOV) discounts, and vehicle classifications. A time stamp dynamic provides a critical element for transmitting data within the feed. While the static feed requires the agencies to enter a time stamp reflecting when rates went into effect, the time stamp for a real-time feed would notify users at the time of posting and would only be valid for that time of posting.

Feed Hosting

A single entity needs to be recruited to serve as the host and manager of the toll feed specification. This entity’s responsibilities would include the development of the data-transfer programming and the integration of the data into the map API. Private mapping services provide hosting of GTFS for both static and real-time feeds. However, these platforms display primarily static aspects of transit, including route information, bus stops, and schedules. Those services do

not display real-time locational data for transit. While mapping providers have not provided a direct explanation, a concern may exist given the possible liability of providing incorrect information to travelers when the mapping service does not control the information. Transit agencies that utilize real-time GTFS, such as Chicago Transit Authority in Chicago, TriMet in Portland, and Muni in San Francisco, use one of the mapping services to host their own real-time transit data maps on their websites.

Private mapping services would need convincing to develop and host a toll feed specification. If a service does develop such a feed specification, it is uncertain the service would display real-time toll information that would feed into the mapping service's route builder. If a private mapping service does not take on the responsibility, an agency, such as TxDOT, may best serve as the hosting entity for this system. TxDOT mobility interests cover the entirety of the state, while other tolling agencies, such as HCTRA, NTTA, and Central Texas Regional Mobility Authority, predominantly focus on transportation issues within their respective metropolitan areas. Also, TxDOT's TxTag[®] Toll Calculator, with appropriate modifications, could serve as the platform for a comprehensive statewide system.

Implementation Challenges

A challenge becomes evident in the development of a national toll information system that extends beyond Texas. Not all toll roads throughout the country operate on a location-based toll assessment. Systems such as the Ohio Turnpike, New York Thruway, and Pennsylvania Turnpike use an O-D-based toll assessment where tolls are calculated based on where a vehicle enters and exits the toll facility. These toll systems charge based on an O-D matrix reflecting these two points. A separate route-builder-based calculation process would need developing that reflects an O-D facility. Unlike the point-based toll assessment, where the toll system ascribes a rate when the route passes the tolling point, the O-D route builder would need to (a) identify the toll road entrance location, (b) identify the toll road exit location, and (c) access an O-D trip matrix to calculate a toll amount.

Creating a uniform toll information feed specification could prove challenging. An O-D toll-assessment methodology for a route-builder application cannot convert to a tolling point-based approach because the O-D approach depends specifically on entrance and exit points. One can modify a tolling point-based system into an O-D approach. This would require agencies to calculate the tolling costs for every potential O-D pairing on the system. However, agencies in Texas would most likely not engage in the time and effort to convert the data to the appropriate format, especially when it is not required for their operations.

A potential solution involves the merging of the two different toll assignment approaches into a single system. This would require both systems to have some type of identification within their datasets to inform the route-building program about the specific calculator to use for each facility. However, the issue of hosting for this system would need addressing, especially on a national level. Either an agency like USDOT or private mapping services would need to take on that responsibility.

APPENDIX A—CONCEPT OF OPERATIONS FOR A ROUTE-BUILDER-BASED TOLL ROAD/MANAGED LANE INFORMATION SYSTEM

The following is a Concept of Operations for utilizing a route builder, similar to route builders on mapping platforms like Google and Bing, to provide users comprehensive information about the tolled and managed lane facilities, operational nature of these systems, and costs of a proposed trip. This approach would allow multiple tolling agencies throughout Texas to provide their information to a single system, which users could utilize to plan trips and identify costs for routes that traverse multiple facilities and multiple tolling agencies.

THE ROUTE-BUILDER APPROACH

A route-builder approach would essentially mimic an actual trip on the facility. When a vehicle passes a tolling point on the system, the vehicle's transponder communicates its presence to the toll system. The toll system accesses a database to determine the amount to be charged and assesses the charge to the account associated with the vehicle. For the calculator, the route builder would reach a tolling point on the map. The intersection with this tolling point would trigger communication to the toll system's database, which instead of charging the toll to an account, would charge the toll amount to the calculator. A trip involving multiple tolling points would accrue multiple charges. The calculator would tally the charges and provide a total cost for use of the facility.

The route builder would operate as follows:

- The map API has tolled facilities mapped and included in the mapping platforms.
- The tolling agency has transmitted rate and facility information via feed specifications (discussed below) to the hosting entity associated with the tolling locations.
- The tolling agency provides exact locations of tolling locations that line up with the toll route.
- Based on user-entered start and end points, the route builder API establishes a route.
- If a route passes a tolling point, the route builder captures information associated with that point, including toll costs by payment method and HOV availability, based on the user's inputs.
- The route builder calculates all of the individual toll amounts captured on the route and provides the total amount for the trip.
- The route builder displays a map of the route with tolling points highlighted.
- The route builder displays a set of directional instructions for the trip, which also contain tolling points passed with their associated toll amounts.

This approach would allow capture of toll information from multiple participating agencies for trips utilizing more than one tolling agency's systems, including potential trips utilizing tolled facilities in multiple metropolitan areas. This proposed route-builder approach would not only provide cost figures for a proposed route, it would also provide comprehensive trip information, including door-to-door route information. In addition, with future communications between vehicles and road infrastructure, routing cost information could broadcast into a vehicle's navigation system.

USER INTERFACE AND OUTPUT

The proposed system would utilize a simple user interface requiring minimal inputs:

- The start and end points of the trip.
- The number of axles for the vehicle.
- The vehicle classification type.

The route builder would provide the user the following information after running its calculations:

- The total cost of the trip based on payment options.
- A list of all individual tolling point assessments on the trip route.
- Information about HOV availability on the system.
- Complete trip routing information, including non-tolled facilities.
- A corresponding map displaying the route.

DEVELOPMENT OF A TOLL FEED SPECIFICATION FOR DATA TRANSFER

A set of toll feed specifications, similar to a general transit feed specification (GTFS), would need to be developed to allow for the transfer of toll road information between the tolling agency's system and the route builder. These feeds would consist of a static toll feed specification for static rates and a dynamic toll feed specification for dynamic toll facilities.

Data Table

Participating tolling agencies would need to provide data for the feed specifications in a single table format that contained pertinent information for the route builder and toll calculating components. The toll feed specification table would contain the following information:

- Tolling agency operating toll facility.
- Toll facility name.
- Direction of flow.
- Tolling location name.
- Latitude/longitude of tolling location (to line up with the toll route on the mapping platform).
- Time stamp of toll data (with day and time).
- Charge by vehicle classification (if not charged by classification, state "N/A").
- HOV charge (if HOV is not operational, state "CLOSED"; if no HOV exists, state "N/A").
- Cash charge (if toll road does not accept cash, state "N/A").
- Pay-by-mail charge (if toll road does not have a pay-by-mail feature, state "N/A").

Static Feed

The static feed specification would allow tolling agencies operating with static rate structures to upload data tables to the hosting entity's system for integration into the route builder. A tolling agency would only need to load a new table when its policy board approved new rates.

Dynamic Feed

The dynamic feed specification would allow tolling agencies to transmit toll rate data to the route builder similar to how it transmits toll rate data from its back-office system to its road signage. The dynamic specification would include programming that translates the toll rate data from the back-office system into the feed specification format and facilitate the data transfer to the route builder's hosting agency via one of two protocols:

- Fetch—the tolling agency hosts its data on its web server and the hosting entity pulls the data every 30 seconds.
- Push—the tolling agency automatically uploads its data and specifies the timing of these uploads (recommended at 30-second intervals).

The data, when provided to the route builder via one of the feed specifications, would feed the route calculations with the toll amounts and other route information that would display on the results screen. Figure A-1 displays the flow of the route-builder concept with feed specifications.

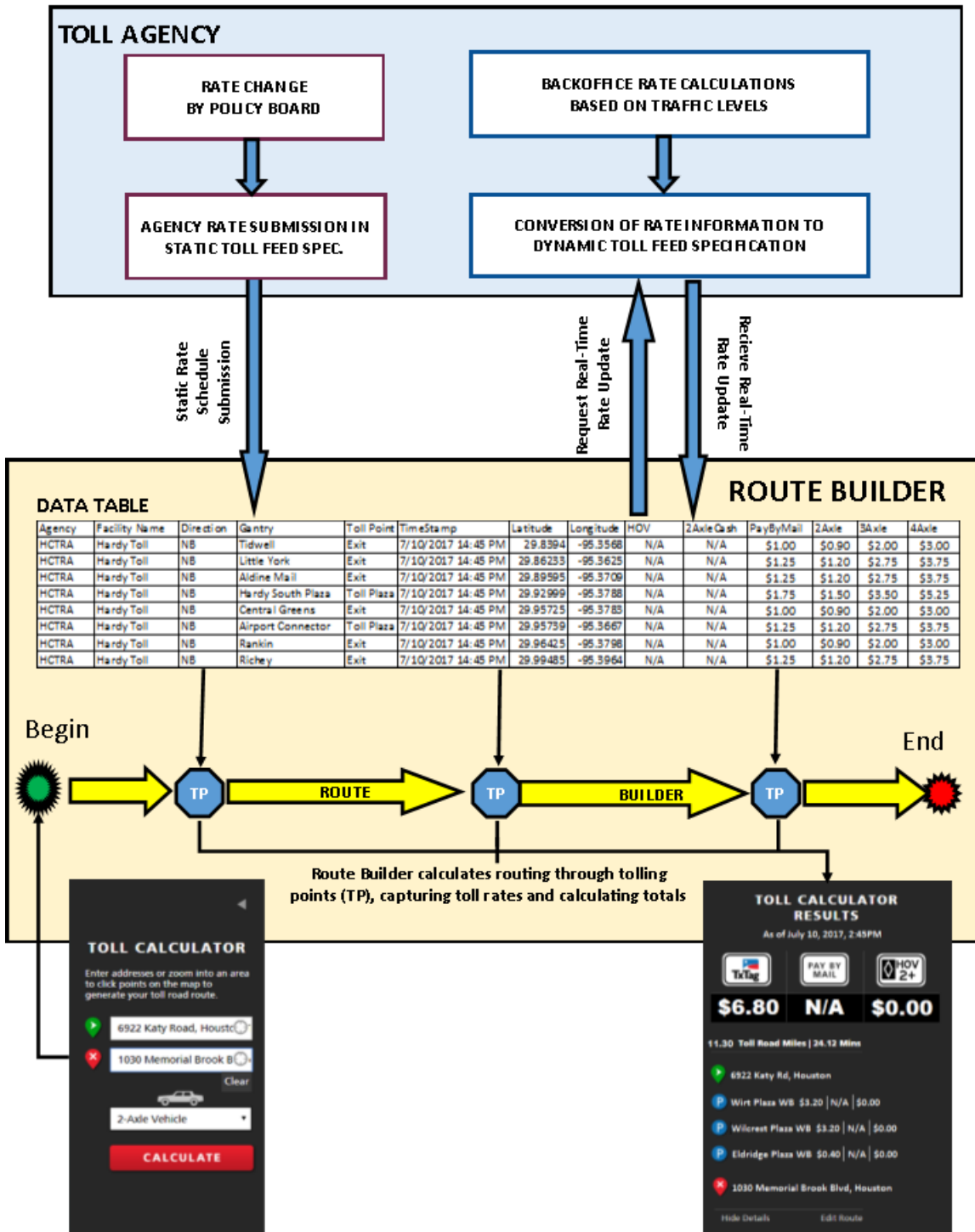


Figure A-1. Flow of Route-Builder Concept with Feed Specifications.

APPENDIX B—FOCUS GROUP DISCUSSION GUIDE USED BY FACILITATOR

Communicating Information for Travelers on Managed Lane Networks

1. Introduction—20 minutes

Welcome to the focus group today. Thank you for taking time out of your busy schedules to talk with us. I'd like to begin by telling you about how the group will work and then we'll get down to the specifics of our topic for the day.

How many of you have participated in a focus group before?

The success of the group depends quite a bit on how willing you are to share with us what you think. So, I'm asking you right up front to be open and forthcoming, and not to worry about what I might think, or what others in the group might think about what you say, or even if you are giving a viewpoint that disagrees with someone else's. We're not really talking today about matters that would be considered very sensitive, but the topic is one that we would expect people to have differing opinions on, so I do want to encourage lots of dialogue.

We will be audio and video recording this session but only for note taking purposes. We will keep the recording to ourselves and will destroy the file once our report is completed. Please let me assure you that we will always keep everything you say as anonymous.

Having said that, I want you to relax and enjoy the conversation. But I do have to ask that you talk one-at-a-time, that you not have any side conversations, and that you speak loudly so that everyone can hear what each person has to say. I don't expect our discussion to last more than about an hour and a half. If you need to get more refreshments or use the facilities around the hall, please feel free to get up at any time.

First I'd like us to have some brief introductions. I'll start with us.

Now, let's go around the room and tell everyone your first name only, what part of town you live in, what you do, or anything else that you want us to know about you.

Let's get to the topic at hand. TTI is doing a research study for TxDOT about how and what to communicate to travelers that are using managed lane networks.

Show of hands, how many people know what a managed lane is? What do you think it means? What do you think express lane means? What do you think managed HOV lanes means?

What about a managed lane network? What do you think it means?

Managed lane is a general term that describes special lanes that operate differently than the general purpose lanes. Managed lanes can be managed by requiring a certain number of passengers in the car (this is a high occupancy vehicle [HOV] lane) or by limiting when you can use the lane or by charging a toll. Some managed lanes charge a toll that changes based on the traffic conditions in the lane. This is an effort to guarantee a reliable trip time and a minimum

speed in that lane. So if the lane gets crowded or there's a crash in the lane, the price will go up to discourage any more people from getting in the lane.

What do they call them here?

2. Current travel—20 minutes

Before we get too far into the topic, let's talk a little bit about how you currently travel around the region.

How many of you commute to work? Do you travel in the peak hours? Do you travel on the toll roads? Describe a typical day commuting.

Do you carpool or take transit? If you carpool, who do you carpool with? How much extra time does it take you to pick up a person? Do you meet in the park and ride lot? Do you take the HOV/managed lane?

Do you have options you could take to work? (alternate routes, transit, HOV)

Do you feel like you save time and/or money taking transit or carpooling? What about if you use the toll road? Do you feel like you save time?

For College Station

Tell me about the kinds of trips that would take you to Houston, Dallas, and Austin. Would you typically be driving alone? Do you take toll roads? Have you ever taken the HOV lane? Why or why not?

For Everyone

Do you have a toll tag? Why? If you don't have a toll tag, does that prevent you from taking the toll roads or lanes in those metro areas?

What happens if you go on a toll road that doesn't take cash and you don't have a tag?

Does your route take you from one HOV/managed lane to another? Tell me about navigating that.

Do you ever have to backtrack to get to an HOV/managed lane?

Are you aware of the occupancy/toll requirements on different HOV/managed lanes?

Are you aware when you can use the managed lanes?

3. Traveler Information Systems—30 minutes

How do you know if the roads are congested? Do you listen to radio/TV/look at the Internet? Which source do you use? Do you regularly get traffic information before you leave? If so, how? If not, why not? What about when you're already on the road? How do you get that information?

How frequently do you think these sources are updated?

How far in advance of your trip do you check traffic conditions?

Do you use these sources to compare routes or just to estimate the trip on the route you want to take? Do you follow the route given to you by the app (e.g., Google Map) or by your car's navigation system? If the app offers you a route that is different than your usual route, would you take it? If the recommended route includes a toll road, do you try to find out what the toll will be?

Show of hands, who takes two or more different freeways to work? Do you check on the conditions on the final leg of your trip before you leave? Does the condition on the final leg change anything about your route decision? (use local example here)

Do you think the information you get is beneficial in your trip planning? Do you think it's reliable?

What source of information do you trust the most? (prompt for app vs. TV vs. radio vs. local TMC vs. CMS)

What source do you think is easiest to use or would you recommend to a friend? (prompt—is one better on a home computer vs. an app)

Dallas: Have you used the Drive On TEXPress[®] app or any other app specific to this region? (COG app, NTTA TollMate[®]). Do you know the difference between TEXPress Lanes[®] and other express or managed HOV lanes in the area?

Austin: Have you heard of or used an app specific to Austin traffic like Metropia[®], RideScout[®]?

Houston: Have you heard of or used an app specific to Houston traffic?

4. Travel from one managed lane to another managed lane—Scenarios and Worksheet Exercise—40 minutes

Now, let's imagine a scenario where many of the current HOV and/or managed lanes are connected into a network.

Austin 2025—The traffic congestion in Austin is similar to what it is in 2016. Improvements have been made on some facilities around town. There are express lanes completed on MoPac (one lane in each direction). This is the toll lane that is being built in the median of MoPac. Imagine in the future, US 183 has two express lanes in each direction, also in the median, which run north from MoPac to the 183A tollway.

The tolls on both the MoPac Express and US 183 Express change dynamically. That means it adjusts with the traffic in the lane—the more cars in the lane, the higher the toll.

Imagine you work downtown and live in Leander. You are at your office getting ready to leave for home at 5:30 PM.

Dallas/Fort Worth 2020—The traffic congestion in Fort Worth is similar to what it is in 2016. Improvements have been made on some facilities around town. There are express lanes completed on 35W (one lane in each direction). This is the toll lane that is being built in the median of 35W in the section north of downtown. The Express Lanes on 820/183 are still operating like they are today.

The tolls on both the 35W Express and on 820/183 TEXpress Lanes[®] change dynamically. That means it adjusts with the traffic in the lane—the more cars in the lane, the higher the toll.

Imagine you work at Alliance Airport and live in Euless. You are at your office getting ready to leave for home at 5:30 PM. Your normal route is to go south on 35W to 820/183 East.

Houston 2030—The traffic congestion in Houston is similar to what it is in 2016. Improvements have been made on some facilities around town. There are express lanes completed on 610 through the Galleria (one lane in each direction). The express lanes on I-10 to Katy are still operating like they are today.

The tolls on both the 610 and Katy Express Lanes change dynamically. That means it adjusts with the traffic in the lane—the more cars in the lane, the higher the toll.

Imagine you work in Bellaire and live in Katy. You are at your office getting ready to leave for home at 5:30 PM. Your normal route is to go south on 610 North to I-10 West.

College Station—Your job is taking you to the Dallas/Fort Worth area for several weeks. You will be working near the race track on 35W north of Fort Worth and your hotel is in Euless near the DFW airport. The traffic congestion in Fort Worth is similar to what it is in 2016. Improvements have been made on some facilities around town. There are express lanes completed on 35W (one lane in each direction). This is the toll lane that is being built in the median of 35W in the section north of downtown. The Express Lanes on 820/183 are still operating like they are today.

The tolls on both the 35W Express and on 820/183 TEXpress Lanes[®] change dynamically. That means it adjusts with the traffic in the lane—the more cars in the lane, the higher the toll.

Imagine you work at Alliance Airport and live in Euless. You are at your office getting ready to leave for home at 5:30 PM. Your normal route is to go south on 35W to 820/183 East.

EXERCISE

Now, I want to pass around a handout that includes some of the information (or the questions you might ask or need to know in order to decide whether or not to use the managed lane). For each column please go in and rank the top 5 items of importance to you. This is the information that you really want and/or need to know to decide whether or not to travel on the managed lane. Then circle the column heading that is your most preferred method of communication, if you could only receive information one way.

Additional Questions if time:

How do you determine what route you're going to take home and if you are going to use the managed lanes or not?

Now imagine you're considering using the managed lanes.

What information do you need to make this trip? (*prompt for toll rate from point to point, prompt for access points*)

How do you want to receive this information? (*prompt for dynamic message signs, text message, via website, via traffic app/GPS*)

When do you want to receive this information? (*prompt for just prior to my trip, en route, etc.*)

What would happen if you didn't get that information? (would you still use the lane?)

Do you expect there to be a ramp directly connecting the express lanes? What if there isn't? Does this affect your decision to use either one or both express lanes?

Imagine the toll rates for the Express Lanes on the second segment of your trip are more than double the rates for the first segment Express Lanes. Do you need to know this before you get on them? Or have you committed to this route before you start your trip? What do you need to know? When do you need to know it?

Would any of this change if there was a reduced price for HOVs and you were in a carpool?

5. Wrap up (5 minutes)

Summarize

Hanging Issues

Thanks

Compensation

APPENDIX C—TRAVELER INFORMATION NEEDS SURVEY

Q1 Welcome to the Traveler Information Needs Survey. The survey is being conducted by the Texas A&M Transportation Institute with support from the Texas Department of Transportation. The purpose of this research is to identify what information travelers use and desire for planning trips that may use managed lanes. In Texas, managed lanes may be called carpool lanes, HOV (high occupancy vehicle) lanes, Express Lanes, Managed HOV Lanes, HOT (high occupancy toll), or TEXpress Lanes[®]. This survey reflects questions developed by the researchers at Texas A&M Transportation Institute and does not reflect any policies of or endorsement by the Texas Department of Transportation. Your participation in this survey is greatly appreciated and completely voluntary. Your answers on the survey will be confidential to the extent permitted or required by law. This survey should take about 10 minutes to complete and your responses are anonymous. All records of the survey are confidential and accessible only to members of the research team. There is minimal risk involved in answering the questions and there is no risk greater than that which you would come across in everyday life. Participation in this research will provide no direct benefit to you but you will be helping to improve travel information systems provided to you by Texas transportation agencies. If you have questions, concerns or complaints regarding this study, you may contact Sue Chrysler at 979-845-4443, s-chrysler@tti.tamu.edu. This research study has been reviewed by the Human Subjects' Protection Program and/or the Institutional Review Board at Texas A&M University. For questions about your rights as a research participant, to provide input regarding research, or if you have questions, complaints, or concerns about the research, you may call the Texas A&M University Human Subjects Protection Program office by phone at 1-979-458-4067, toll free at 1-855-795-8636, or by email at irb@tamu.edu.

Q2 Are you at least 18 years of age?

- Yes (1)
- No (2)

Q3 Do you agree to participate in this survey?

- Yes (1)
- No (2)

Q4 Please select the general geographic area where you do your most frequent driving.

- Austin (1)
- Dallas/Fort Worth (2)
- El Paso (3)
- Houston (4)
- San Antonio (5)
- Other (6)

Q5 Please identify the area in which you do your most frequent driving by location or zip code.

Q6 When you are planning a trip in a major metropolitan area, what tools do you use to select your route?

	Very often - Nearly every trip (1)	Often - Most Trips (2)	Occasionally - Some trips (3)	Rarely - Few trips (4)	Never (5)
Paper maps (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ask a friend for directions (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
TV or radio reports (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Mapping website like Mapquest or Google Maps (4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Website of a toll road agency like NTTA or HCTRA (5)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
App on a smartphone or tablet like Apple Maps or Google Maps or Waze (6)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
GPS Navigation system like a TomTom or Garmin that I hook up in my car (7)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Navigation system built into my car (8)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Note: Option 5 was re-worded slightly after the first 100 people took the survey and before advertising heavily in Houston. The rewording was: Website of a road agency like TxDOT, NTTA, or HCTRA (e.g., Houston TranStar®, TransGuide)

Q7 Many factors may influence your decision to seek out traveler information. Using a scale from 1 to 5, where 1 is a factor that is extremely unimportant and 5 is a factor that is extremely important, please assign a score to each of the following factors regarding their importance in your decision to seek out traveler information.

	1 - Extremely unimportant (1)	2 - Somewhat unimportant (2)	3 - Neutral (3)	4 - Somewhat important (4)	5 - Extremely important (5)
Trip purpose (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Trip distance (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Weather conditions (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Familiarity with the route you plan to take (4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Flexibility regarding time of departure (5)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Flexibility regarding time of arrival (6)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The number and type of people you are traveling with (7)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q8 Thinking about the computerized tools you use, please tell us how you most prefer to use them for most trips to an area you have visited before:

- I like to enter my start and end points and have it tell me the best route (1)
- I like to enter my start and end points and have it show me different route options (2)
- I like to look at a big picture map of the area and plan my route by clicking on different areas of the map (3)

Q9 Thinking about the computerized trip planning tools you use, would you be willing to register a free account in an app or website and store frequent trips so that you can consult them again in the future?

- Yes (1)
- No (2)

Q10 Imagine you are planning for a trip you are going to take later today or later this week – a trip you won't leave on for at least an hour. Please indicate in the list below how important it is that a travel planning tool provide that piece of information. You may assume that a basic route will be provided.

	Critical - I would not use the tool if it did not provide functionality (1)	Important - Having this functionality would make me want to use the tool frequently (2)	Desirable - I might use that piece of information occasionally (3)	Nice, but not necessary - I might use this piece of information rarely (4)	Not at all important - Having this would not make me want to use the tool any more or less (5)
Expected delays due to congestion, construction, or special events (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Rerouting advice to avoid unusual traffic jams or wrecks (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Alternate routes that may cost tolls but are shorter distance or faster time (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Options to use special lanes designed for carpools or toll payers (4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Distance of the trip in miles (5)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cost of any tolls (6)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Information on how I can pay tolls (7)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Information on bus or train options to my destination (8)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other (9)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q11 Thinking about other navigation tools you use just before taking a trip or while taking a trip (like GPS systems and smartphones) click on the three most valuable features of this tool?

- Information about slowed or stopped traffic locations (1)
- Rerouting advice to avoid traffic jams or wrecks (2)
- Travel time to destination (3)
- Expected delays due to planned construction activities or special events (4)
- Alternate routes that may cost tolls but be shorter or faster (5)
- Options to use special lanes on my route like carpool, express, or toll lanes (6)
- Current toll rates for toll lanes or roads for my route (7)
- Other (8) _____

Q12 Which of the following $\{q://QID4/ChoiceGroup/SelectedChoices\}$ area managed lanes have you ever used? Select all that apply.

- Express Lanes on MoPac (Loop 1), which opened in October 2016 (1)
- Katy Tollway (I-10 from 610 West to SH 6) (2)
- METRO Express Lanes (paying a toll to use HOV lanes) on the North Freeway (I-45 North) (3)
- METRO Express Lanes (paying a toll to use HOV lanes) on the Gulf Freeway (I-45 South) (4)
- METRO Express Lanes (paying a toll to use HOV lanes) on the Northwest Freeway (US - 290) (5)
- METRO Express Lanes (paying a toll to use HOV lanes) on the Eastex (US 59/I-69 North) (6)
- METRO Express Lanes (paying a toll to use HOV lanes) on the Southwest Freeway (US 59/I-69 South) (7)
- State Highway 114 near Grapevine, sometimes called the DFW Connector (8)
- Northeast Loop 820 and State Highway 121 northeast of downtown Fort Worth, sometimes called the North Tarrant Expressway (9)
- TEXpress Lanes[®] on I-635 (LBJ Freeway) between I-35E and US 75 north of Dallas (10)
- TEXpress Lanes[®] on I-30 in Arlington (11)
- I have never used a managed lane in the $\{q://QID4/ChoiceGroup/SelectedChoices\}$ region (12)

Q13 You responded that you have never used any of the $\{q://QID4/ChoiceGroup/SelectedChoices\}$ regional managed lanes. Click on the most important reason for not using the managed lane?

- I am not sure when I will be able to exit the lane (1)
- The lane doesn't go where I need to go (2)
- I am not comfortable being separated from the regular lanes by a wall or traffic cones (3)
- I am not sure if I am allowed in the lane (4)
- I do not have a toll tag (5)
- I am opposed to toll lanes (6)
- I don't know how much it will cost (7)

Q14 Please indicate how frequently you use managed lanes for each of the types of trips listed below.

	Less than 2 times per month (1)	3–4 times per month (2)	2–5 times per week (3)	More than 5 times per week (4)
Regular commute (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
School activities (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Leisure activities (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Personal appointments (4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Special events (5)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q15 What is the single most important factor in your decision to use managed lanes?

- Price shown on sign (1)
- Traffic reports on a smartphone map or in-vehicle GPS (2)
- Whether I have enough passengers to qualify for HOV status (3)
- Traffic conditions that I observe in the regular lanes (4)
- Traffic conditions that I observe in the managed lanes (5)
- Traffic reports on the radio (6)
- Whether the lane has an exit convenient to my destination (7)
- I think it is safer than the regular lanes (8)

Q16 This research project is considering roadways and technologies that are still being developed. Imagine that in the future, some traveler information will be sent to your smart phone, navigation system, or other in-vehicle device. This might allow fewer road signs to be installed. For each piece of information shown below, please indicate whether you think it should appear on a roadway sign or on an in-vehicle device.

Entrance location to the managed lane (1)	<input type="radio"/> In-vehicle device (1)	<input type="radio"/> Road sign (2)
Current toll price (2)	<input type="radio"/> In-vehicle device (1)	<input type="radio"/> Road sign (2)
List of points where you can exit the managed lane (3)	<input type="radio"/> In-vehicle device (1)	<input type="radio"/> Road sign (2)
Speed limit (4)	<input type="radio"/> In-vehicle device (1)	<input type="radio"/> Road sign (2)
Toll tag requirements (5)	<input type="radio"/> In-vehicle device (1)	<input type="radio"/> Road sign (2)
Restrictions about vehicle type (like “no towed trailers”) (6)	<input type="radio"/> In-vehicle device (1)	<input type="radio"/> Road sign (2)
Number of occupants required (7)	<input type="radio"/> In-vehicle device (1)	<input type="radio"/> Road sign (2)
List of intersecting roads the managed lane connects to (8)	<input type="radio"/> In-vehicle device (1)	<input type="radio"/> Road sign (2)
Alerts about crashes, construction, or other incidents (9)	<input type="radio"/> In-vehicle device (1)	<input type="radio"/> Road sign (2)
Traffic condition status (10)	<input type="radio"/> In-vehicle device (1)	<input type="radio"/> Road sign (2)
Travel time estimates to certain destinations (11)	<input type="radio"/> In-vehicle device (1)	<input type="radio"/> Road sign (2)

Q17 Which statement best describes the first time you used managed lanes?

- I used the lane based only on the road signs without any other information on the lanes (1)
- I saw the road signs for the managed lane and decided to find out more about it before I used the lane (2)

Q18 How did you learn about the managed lanes you use? Select all that apply.

- Saw them while driving in the area (1)
- Saw a story on the TV (2)
- Read an article in the newspaper (3)
- Someone explained it to me (4)
- Received email or mail notice from a transportation agency (5)
- Saw an announcement about it on a transportation agency website (6)
- Searched the Internet after learning about it from media (7)
- Searched the Internet after hearing about it from someone (8)

Q19 Have you ever used the Drive On smartphone app that allows you to indicate the number of passengers in your car for a possible discounted toll rate on Dallas/Fort Worth regional managed lanes?

- Yes (1)
- No (2)

Q20 What features of the Drive On smartphone app do you use? Select all that apply.

- Declare HOV status (1)
- Check managed lane traffic conditions (2)
- Check managed lane price (3)
- Look at map to find access points (4)

Q21 What one new feature would be the most valuable to you?

- Traffic condition updates for that corridor (both regular and managed lanes) (1)
- Look at map to find where to exit and enter the managed lane (2)
- Traffic condition updates for intersecting roadways (3)
- Ability to set a maximum toll price you're willing to pay, and receive text or email alert if that price is reached (4)
- Ability to set up a daily text notification that would tell you the toll price at the same time each day (5)
- Ability to get current toll prices on intersecting roadways (6)

Q22 The survey is almost over. The last section focuses on collecting information about you. Which of the following describes your current situation? Select all that apply.

- Employed (1)
- Student (2)
- Retired (3)
- Volunteer (not for pay) (4)
- Unemployed (5)

Q23 What is your home zip code?

Q24 What is your work zip code?

Q25 Which of the following categories best describes your age?

- 18–24 (1)
- 25–34 (2)
- 35–44 (3)
- 45–54 (4)
- 55–64 (5)
- 65 and older (6)

Q26 What is your current relationship status?

- Married (1)
- Widowed (2)
- Divorced (3)
- Separated (4)
- Never married (5)
- Living with partner, never married (6)

Q27 What is the highest level of education you have completed?

- Less than high school diploma/GED (1)
- High school diploma/GED (2)
- Some college, no degree (3)
- Associate degree or technical degree (4)
- Bachelor's degree (5)
- A graduate or professional degree (6)

Q28 Are you of Hispanic, Latino, or Spanish origin?

- Yes (1)
- No (2)

Q29 What is your race? Select all that apply.

- White or Caucasian (1)
- Black or African American (2)
- American Indian or Alaskan Native (3)
- Asian alone (4)
- Native Hawaiian and other Pacific Islander alone (5)
- Some other race alone (6)
- Two or more races (7)
- Other (8) _____

Q30 What category best describes your yearly household income? By yearly household income we mean pre-tax earnings from jobs that you or other household members have had during the past 12 months.

- Less than \$25,000 (1)
- \$25,000 to \$49,999 (2)
- \$50,000 to \$74,999 (3)
- \$75,000 to \$99,999 (4)
- \$100,000 or more (5)
- I prefer not to answer (6)

Q31 What is your gender?

- Male (1)
- Female (2)

Q32 Respondents must be at least 18 years old to participate in this study. While we appreciate your willingness to participate, the survey will now end.

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