POTENTIAL USE OF MANAGED LANES BY TEXAS RESIDENTS

A Thesis

by

MANEESH MAHLAWAT

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2007

Major Subject: Civil Engineering

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Approved by:

Chair of Committee,	Mark Burris
Committee Members,	Dominique Lord
	Katherine F. Turnbull
Head of the Department,	David Rosowsky

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ABSTRACT

Potential Use of Managed Lanes by Texas Residents. (December 2007)
Maneesh Mahlawat, B.Tech., Indian Institute of Technology Guwahati
Chair of Advisory Committee: Dr. Mark Burris

Traffic congestion is a serious problem in the United States and is likely to get worse. A number of strategies encompassing increasing supply and managing demand have been suggested to mitigate the problem of traffic congestion. These strategies seek to reduce travel time and/or make travel time more reliable. The use of managed lanes is one such strategy.

Faced with successful implementation of a managed lane strategy, it is important to understand potential public perception of the managed lane as well as estimate the number of travelers willing to use managed lanes. Such an estimate would help estimate the toll rates for optimal usage of managed lanes by carpoolers and toll paying travelers.

An online survey augmented by paper and laptop survey was conducted in Houston and Dallas to collect information about travelers' travel behavior, socio-economic characteristics, managed lane perception, and potential use of managed lanes. A comparison of interest in using managed lanes revealed that in majority of cases there was no difference in interest in using managed lanes across user groups. Travel time reliability and ability to travel faster were indicated as top two reasons for interest in managed lanes. This was true for all travelers regardless of mode.

Mode choice model using multinomial logit modeling were estimated for Houston and Dallas. Simulation studies were conducted using these mode choice models to estimate the percentage of Single Occupant Vehicle (SOV) travelers on managed lane (ML), High Occupancy Vehicle with two travelers (HOV2) on ML, High Occupancy Vehicle with

three or more travelers (HOV3+) on ML, SOV travelers on general purpose lane (GPL), HOV2 travelers on GPL, and HOV3+ travelers on GPL. These scenarios compared the managed lane usage for different speeds on GPL (25 miles per hour, 30 miles per hour, and 35 miles per hour). For the case when general purpose lane speed is 25 miles per hour, an increase of $11.75 in SOV tolls ($18 from $6.25) decreases the modal share of SOV travelers on Houston ML from 23.3 percent to 16.9 percent. A similar increase in Dallas tolls decreases the modal share of SOV ML travelers from 22.0 percent to 16.3 percent.

ACKNOWLEDGEMENTS

I want to take this opportunity to thank my advisor, Dr. Mark Burris. He was always ready to help me when I had questions. Long meetings with him helped me in fine tuning my thought process and kept me motivated toward my work. I also would like to thank my committee members, Dr. Dominique Lord and Dr. Katherine Turnbull, who spent time reading my draft and giving me valuable suggestions.

This research work uses the data collected for the Texas Transportation Institute (TTI) Project entitled "The Role of Preferential Treatment for Carpools in Managed Lane Facilities." I would like to thank the TTI research team led by Matt MacGregor from TxDOT as Project Director and Ginger Goodin from TTI as Research Supervisor for conducting and funding the survey to collect necessary data and helping with the data analysis. I would especially like to mention Dr. David Ungemah for programming the online survey and Dr. Mark Burris for leading survey development.

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NOMENCLATURE

Term	Definition
HOV lanes	High Occupancy Vehicle Lanes. HOV lanes are expressway lanes restricted to vehicles with set minimum number of occupants.
HOV2	Vehicle in which there are two occupants.
HOV3+	Vehicle in which there are at least three occupants.
LOV	Low occupancy vehicle. Vehicle in which there are lower number of occupants than the required minimum
ML	Managed Lanes. A set of lanes within a freeway that are actively managed by pricing and vehicle occupancy.
GPL	General Purpose Lanes. Freeway lanes meant for all vehicles without vehicle occupancy, price or other such constraint.
SOV	Single occupant vehicle. A vehicle in which there are no passengers.
SRS	Simple random sampling is the sampling technique where a sample for study is selected from a larger group (a population). Each individual is chosen entirely by chance and each member of the population has an equal chance of being included in the sample. Every possible sample of a given size has the same chance of selection.
VOT	Value of Travel time. It is the toll an individual is willing to pay to save a particular amount of time.
WTP	Willingness to Pay. A traveler’s WTP is the price at which he or she is indifferent between paying for one option or foregoing it and taking another option
VTTS	Value of Travel Time Savings. The VTTS is the value the traveler places on time saved using a faster (but more expensive) mode. The VTTS includes both monetary and non-monetary costs incurred in the journey.

CHAPTER I

INTRODUCTION

1.1 Background

Traffic congestion is a serious problem in the United States and is getting worse. To quantify the extent of traffic congestion, the 2005 Texas Transportation Institute (TTI) Mobility Report divided the nation's urban areas into four groups: very large urban areas, large urban areas, medium urban areas, and small urban areas. A 20-minute off-peak trip took, on average, 29.6 minutes in very large urban areas and 22 minutes in small urban areas during the peak period in 2003 (*1*). If a hypothetical average urban area had been considered, the same trip would have taken 27.4 minutes during peak time. This is an increase of five minutes compared to 1982 *(1)*. The average delay per traveler over an entire year in 2003 was 47 hours *(1)*. Measured in any way, traffic congestion is a worsening problem. An alarming fact is that traffic congestion will continue getting worse. A medium urban area in 2013 is projected to have same congestion levels as that of a large urban area in 2003 *(1)*.

The problem of traffic congestion may be tackled by a multipronged approach focusing on both increasing road supply and managing traffic demand. However, in congested urban areas, new road facilities are often congested not long after they are constructed. This is usually attributed to the phenomena of triple convergence. Many drivers formerly using alternate routes during peak hours use the new facility (spatial convergence), many drivers who avoided traveling in peak period to avoid congestion start traveling at peak time (time convergence), and some travelers using public transportation or carpooling start driving alone (modal convergence) *(2)*. The end result is that although the new facility is helpful in reducing congestion, it does not relieve congestion to the desired

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This thesis follows the style of *Transportation Research Record.*

extent. Another problem is that the public is generally unreceptive to construction of new facilities near their own community. Since adding new facilities in urban areas implies building near some community, large urban roadway projects often have many opponents *(1)*.

Another issue with construction of new facilities is the lack of available funding. Urban road construction is exceedingly expensive and the revenues from the gasoline tax are not adequate to finance current transportation needs *(3)*. One of the reasons for this is the method of gasoline tax collection. State gasoline tax of 20 cents per gallon in Texas has been fixed since 1991. Adjusting for inflation, 20 cents in 2007 is only equivalent to 13 cents in 1991 *(4)*. One can conclude that the real value of the gasoline tax for funding transportation infrastructure has decreased. Increasing the gasoline tax is not politically feasible at the moment. Therefore, other alternatives to the problem of congestion must also be examined.

Transportation professionals have examined a number of strategies with the potential to manage congestion. These strategies include demand management, provision of modal options other than driving alone, operational improvements on the supply side, and adding more capacity. The concept of managed lanes uses one or more of these strategies. The Texas Department of Transportation (TxDOT) has developed the following definition of managed lanes *(5)*.

> A managed lane facility is one that increases freeway efficiency by packaging various operational and design actions. Lane management operations may be adjusted at any time to better match regional goals.

Managed lane strategies can include time-of-day price adjustments, value pricing, incentives to carpool, and/or vehicle access restrictions. One advantage of using pricing as managed lane strategy is that it does not suffer from the problem of triple convergence.

The Federal Highway Administration (FHWA) has identified different kinds of facilities falling under the umbrella of the managed lane definition (see *Figure 1*) (*6*).

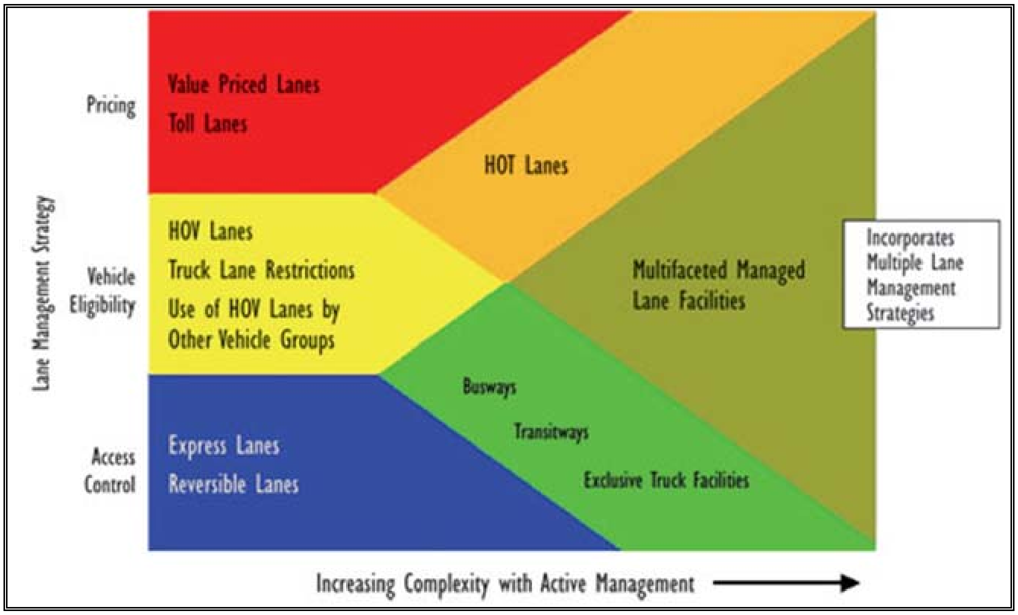

Figure 1: Managed lane strategies (*6*)

On the left side in *Figure 1*, pricing, vehicle eligibility and access control are indicated as possible strategies. Both traditional toll roads and toll lanes using congestion pricing fall under pricing as a managed lane strategy. Allowing only HOV3+ vehicles such as on HOV lanes is an example of using vehicle eligibility as a criterion. Access control is used on Express lanes where access is limited for long stretches of the facility in order to reduce turbulence from vehicle merging. Moving from left to right in *Figure 1*, the strategies of pricing, vehicle eligibility, and access control are combined. Strategies of pricing and vehicle eligibility are combined in HOT lanes. Vehicle eligibility and access control are combined in facilities such as truck-only lanes and bus-only lanes. Multifaceted managed lane facilities combine all the three strategies (*6*).

1.2 Problem Statement

Managed lanes can serve as an important strategy to manage congestion. However, managed lanes cannot be used at all locations with equal success. Travelers are an important part of the success of any managed lane strategy. Travelers can be divided into different groups based on income, ethnicity, trip purpose, length of the trip, gender, among others. The potential usage of managed lanes may vary based on these traveler groups. Researchers examining I-15 High Occupancy Toll (HOT) lanes in San Diego found that travelers on commute trips, individuals from high income households, women, individuals between age 35 and 45, individuals with a higher education, and homeowners were more likely to use HOT lanes (*7*). The trip length of these travelers was greater than eight miles *(7)*. Researchers found a direct correlation between price to use the HOT lanes and the usage of these lanes. The willingness to pay to reduce travel time was found to be $31 per hour *(7)*. A similar study on HOT corridors in Houston, TX found that travelers who paid to use the managed lanes were more likely to be individuals over 65 years of age, had a post-graduate degree, had an annual-household income greater than $100,000, and were more likely to be on a trip to school (dropping off children in most cases) *(8)*. The same survey estimated that males, individuals between ages 25 and 34, and those living alone were less likely to use the managed lanes *(8)*.

As the usage of managed lanes may be different by different traveler groups based on income, it may lead to some potential equity issues. Additionally, a cross-section of travelers may think of tolls on managed lanes as double taxation. Another cross-section of travelers, carpoolers, do not have much to gain from an HOV facility being converted to a tolled managed lane facility. The acceptability and usage of managed lanes will depend on the opinion of all of these travelers.

Public input on policy issues is a major part of project implementation. Therefore, it is important to understand potential traveler response to the concept of managed lanes in

Texas. The Texas Transportation Institute (TTI) project, “The Role of Preferential Treatment for Carpools in Managed Lane Facilities”, sought to address this question for Houston and Dallas. However, even if the public opinion is overwhelmingly in favor of managed lanes implementation, it is important to know the total number of travelers willing to use managed lanes under different traffic conditions and toll rates. The number of potential travelers is important for managed lane project feasibility, congestion reduction, as well as for estimating revenues generated from managed lane implementation. The TTI project, and this research, provides additional insight into this issue.

1.3 Research Objectives

The objective of this research is to gauge the interest and potential usage of managed lanes by different traveler groups. This research will estimate whether the interest is significantly different for different traveler groups. Specifically, this research will:

1. Understand how different groups of travelers (based on income, ethnicity, household size, etc.) react to the concept of managed lanes. Then, quantify whether this difference in interest between the traveler groups is statistically significant.
2. Develop a model to estimate the potential use of managed lanes based on traveler socio-economic characteristics, trip purpose, trip length and other criterion of interest.
3. Estimate the travelers’ willingness to pay to use the managed lanes in both Houston and Dallas.
4. Estimate the percentage of travelers willing to travel on managed lanes under different traffic and toll scenarios.

1.4 Thesis Organization

Chapter I contains background information on the concept of managed lanes, defines the problem and states the thesis objectives. Chapter II includes a review of the available literature on interest and usage of managed lanes. The chapter begins with an introduction to the problem of congestion, reasons why congestion is expected to get worse and the basis for managed lanes as a solution to the problem of congestion. Chapter II continues with an overview of existing managed lanes and any research conducted to estimate interest in managed lanes. The last part of Chapter II deals with mode choice models and the concept of willingness to pay. It examines different motivating factors for travelers to choose a particular mode, particularly carpooling.

Chapter III includes a review of the process of survey design, survey data collection and data reduction. It contains a description of the process of weighting the data. It contains details about the census and other data used for weighting and the methodology used for weighting. It includes methodology of replicate weight design.

Chapter IV includes a review of the findings from the analysis of the survey data. It contains a description of the survey findings regarding respondents' interest in using managed lanes and a detailed summary of differences in interest in using managed lanes based on traveler groups.

Chapter V contains a description of the results from mode choice modeling of the traveler survey data. The first part of chapter provides details of the best mode choice model, the willingness of travelers to pay a toll to save travel time on managed lane, along with other parameters of interest. The second part of the chapter describes various simulated scenarios based on the mode choice model. A quantitative analysis of the percentage of travelers likely to choose each mode under different traffic and toll conditions is performed. Chapter VI is the final chapter and contains conclusions from this thesis along with recommendations for future research.

CHAPTER II

LITERATURE REVIEW

2.1 Traffic Congestion

The United States Department of Transportation (USDOT) mission includes the goal of having a "fast, reliable, efficient, accessible, and convenient transportation system that meets the vital national interests and enhances the quality of life of American people today and into the future" *(9)*. Unfortunately, the transportation system is not poised to fulfill this USDOT mission.

The impediments to the system in providing fast, safe, and efficient transportation include increasing congestion levels and lack of available funds to meet future demands. The 2005 TTI Urban Mobility Study on congestion estimated that congestion caused 3.7 billion hours of travel delay and 2.3 billion gallons of wasted fuel *(1)*. Another factor which is responsible for the system not being able to provide fast and efficient service is the increase in daily vehicle miles traveled on the major US roads. The daily vehicle miles of travel (VMT) has increased from 1.53 billion miles in 1980 to 2.99 billion miles in 2005 *(10)*. At the same time, the total lane miles of highways have only increased from 7.92 million miles in 1980 to 8.37 million miles in 2005 *(11)*. In other words, the VMT increased by 96 percent but total lane miles only increased by six percent (though urban lane miles increased by 62 percent) *(Figure 2)*. The increase in vehicle miles traveled has tripled the increase in population and has been sixteen times the increase in total lane miles (*Figure* 2). The vehicle miles traveled in Texas has increased at a faster rate than the overall rate in the United States (*Figure 3*) *(12)*.

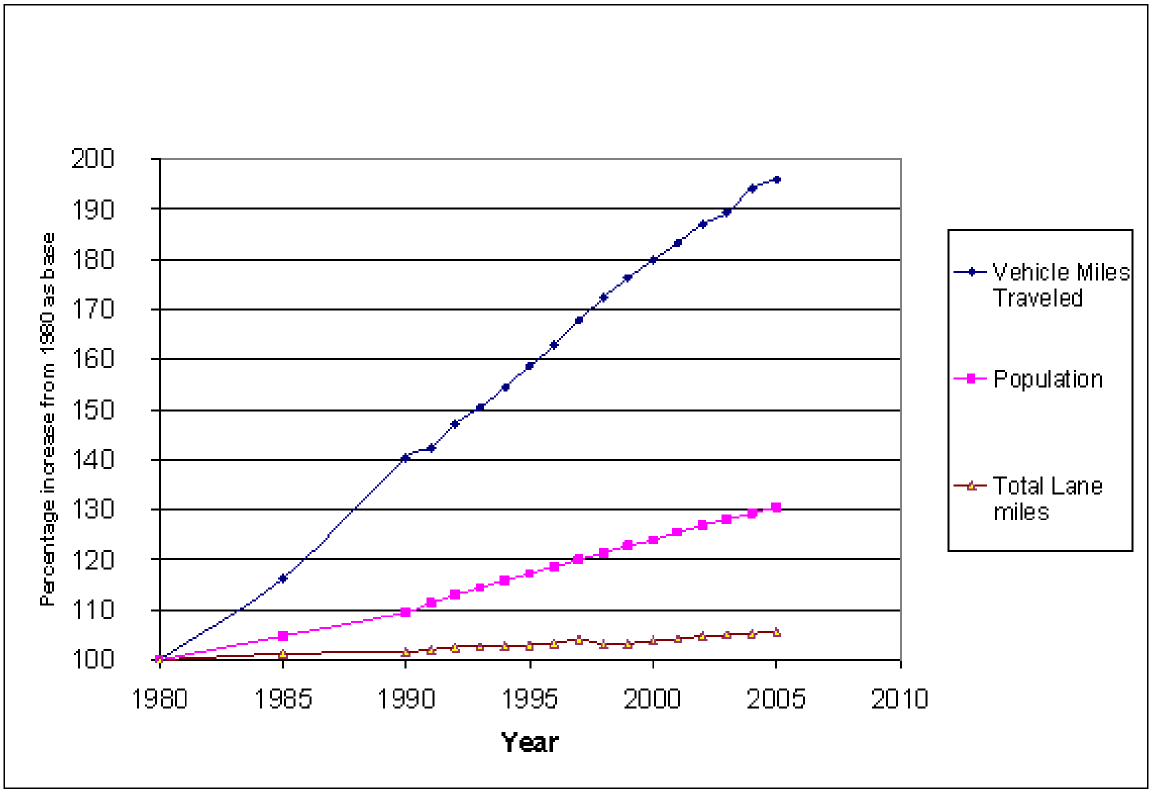

Figure 2: Comparison of total vehicle miles traveled, population, and total lane miles available (assuming 1980 as base year) (*10, 11*)

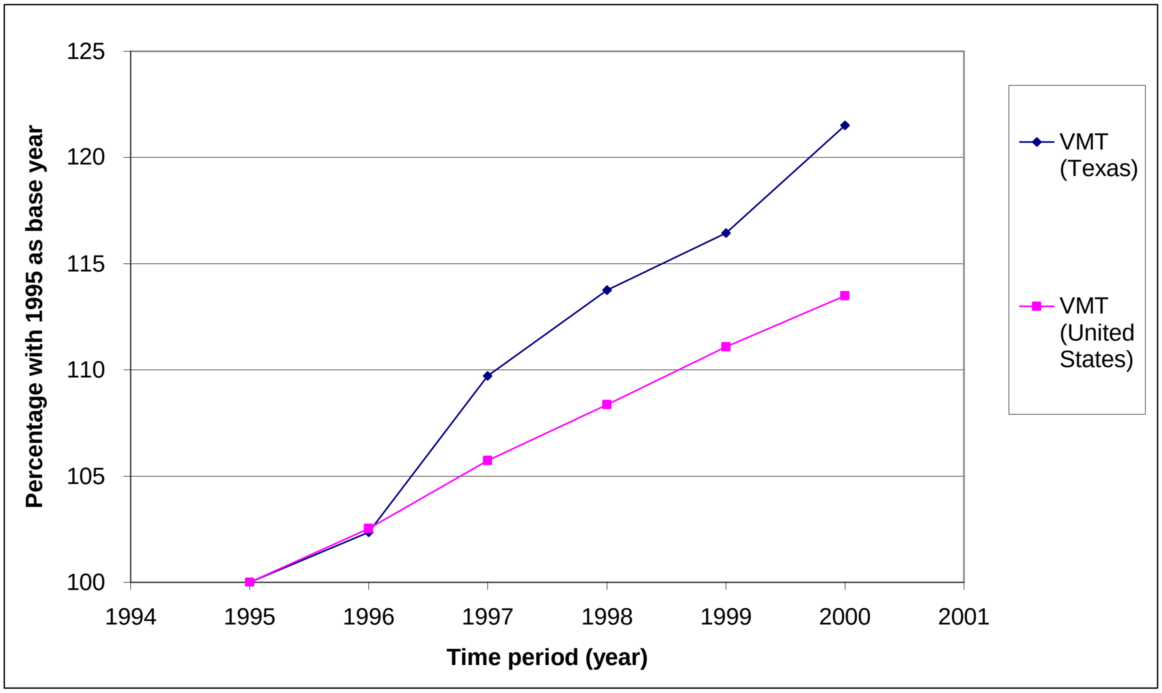

Figure 3: Comparison of vehicle miles traveled in Texas and the United States (with 1995 as the base year) (*12*)

The rapid increase in vehicle miles of travel has led to increasing congestion. The Texas Department of Transportation (TxDOT) and other state departments of transportation are faced with the problem of traffic congestion. The Texas Transportation Institute, in its report on congestion, examined methods to manage congestion (*1*). Some of the suggested solutions included adding capacity, adding more travel options, managing demand, increasing the efficiency of the system, and using pricing as a strategy, among others. However, the report has cautioned against adding capacity as the only solution. Adding capacity suffers from funding constraints and the issue of project approval. Many Americans do not approve of major transportation projects near their homes or neighborhoods *(1)*. Unfortunately, the revenue from the gasoline tax is not adequate to finance new transportation projects plus maintain current infrastructure, nor is the revenue expected to be adequate in the future *(13)*. In fact, in real dollar terms, the gasoline tax funds have declined, as gasoline taxes are not inflation-adjusted. The Texas state gasoline tax is collected as 20 cents per gallon sold and it has not increased since 1991 (see *Figure 4*) *(4)*.

Therefore, it is important that other strategies such as adding more travel options, managing demand, increasing system efficiency, and using pricing are explored as partial solutions to the problem of increasing congestion. Implementation of High Occupancy Vehicle (HOV) lanes, High Occupancy Toll (HOT) lanes, and development of transit options combines some of the above strategies. Another method which combines the above mentioned strategies is the concept of managed lanes. TxDOT defines managed lanes as "*a facility that increases freeway efficiency by packaging various operational and design actions. Lane management operations may be adjusted at any time to better match regional goals*." *(5)*

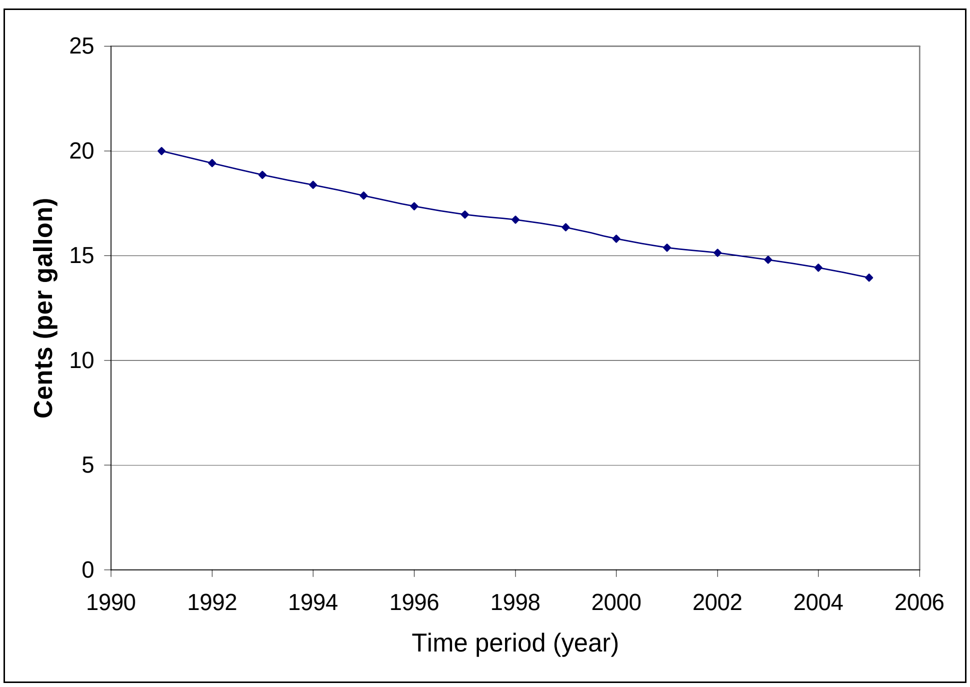

Figure 4: Real value of gasoline tax in Texas (inflation adjusted) with 1990 as base (*4*).

In this thesis the definition of managed lane will be narrowed to "*a set of lanes within a freeway that are actively managed by pricing and vehicle occupancy*" (*14*). By managing demand it is possible to keep the facility from becoming congested and thus ensuring a high flow of vehicles as discussed in the following section.

U.S. Transportation Secretary Mary E. Peters concurs with opinion of finding newer strategies to deal with congestion: "*The daily frustration of drivers on our roadways is ample evidence that our current transportation model is broken, and that bold thinking and leadership are needed. We're never going to solve congestion with higher federal gas taxes or additional earmarks; instead, we need fresh approaches like new technology, congestion pricing and greater private sector investment to get America moving again*." (*15*)

2.2 Speed-Flow Relationships

It has been revealed from highway speed-flow studies that throughput of a highway decreases dramatically once demand exceeds capacity (see *Figure 5*). Thereafter, the corridor vehicle throughput in the highway is significantly lower than the throughput just before attaining capacity (*Figure 5*). For example, on the Eisenhower Expressway in Chicago the flow decreased from a maximum of 2200 vehicles per hour per lane (with a mean of 2100 vehicles per hour per lane) to a maximum of less than 1800 vehicles per hour per lane (with a mean of 1600 vehicles per hour per lane) after the site exceeded optimum density. This sudden drop in traffic flow was due to a large decrease in vehicular speeds (*Figure* 5) *(16)*. Researchers tried fitting different models to the speed-density data. Though none of the models gave an exact fit, Edie's Discontinuous Exponential Model gave the best fit among all the models explored. The flow-density relationship in the Edie model is discontinuous at density equal to 50 vehicles per mile per lane *(17)*. Therefore, a strategy aimed at keeping traffic density less than 50 vehicles per mile per lane can help in congestion mitigation. In recent times, 3-dimensional models have been used to model traffic flow. Researchers have suggested a 'cusp' catastrophe model as most appropriate for modeling traffic near congestion conditions *(18).* The model is based on the assumption that two of the three variables (flow and density) exhibit smooth continuous change near congestion but speed undergoes a 'catastrophic' jump (sudden drop) in its value. This model has been found to be more effective than two-dimensional models *(19).* A variable toll that increases with traffic volume can achieve this goal of not letting speed undergo catastrophic change by keeping traffic flow less than a certain level. Toll incentives for carpools/vanpools when variable tolls are implemented can lead to even greater person throughput.

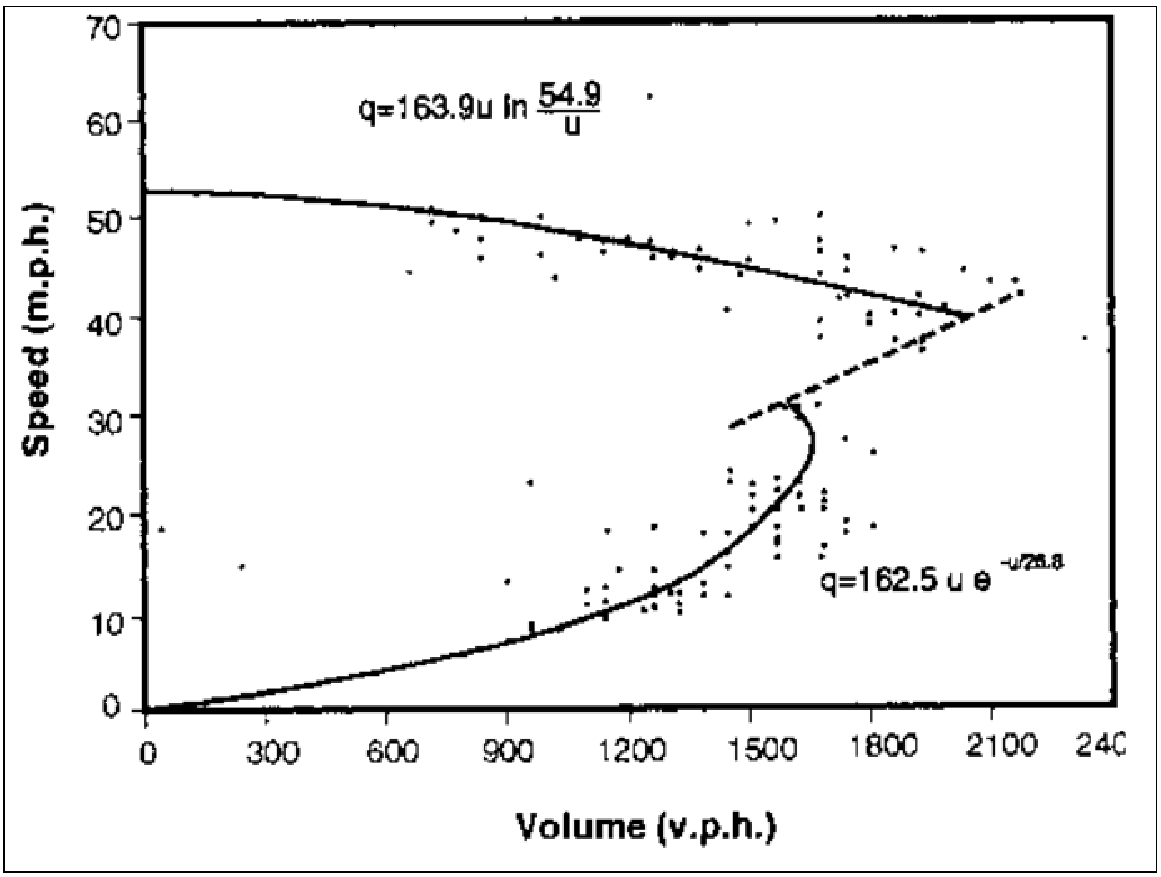

Figure 5: Speed-flow relationship on Eisenhower freeway in Chicago (Edie's discontinuous model has been fit to the data) (*17*).

2.3 Managed Lanes

Managed lanes can combine variable tolls (to limit demand to a point before congestion occurs) with incentives for carpools/vanpools to increase the person carrying capacity of the highway even more. Managed lanes have been implemented on a few highways across the United States, and are being examined for implementation on many other highways. Since many highways in Texas are congested during peak periods, adding managed lanes may provide great benefits in the areas of congestion mitigation and increasing person throughput.

Managed Lanes (using the broader, TxDOT, definition) have existed in Texas for many years. In Houston, HOV lanes (which meet the TxDOT definition of managed lanes) are operational on Katy, Gulf, Southwest, Northwest, North, and Eastex freeways *(Table 1, Figure 6) (20, 21).* In Dallas they are operational on I-35E (Stemmons Freeway), I-635 (LBJ Freeway), I-30 (East R.L. Thornton Freeway), and I-35E/US 67 (South RL Thornton/ Marvin D. Love Freeway) *(Figure 7) (21).*

Table 1: HOV lanes in Houston (*20*)

Corridor name	Days of operation	Timings	Direction	Vehicle occupancy requirements
I-45 North (North Freeway)	Mon.-Fri.	5-11 a.m.	Inbound	2+
		2-8 p.m.	Outbound	2+
US 59 North (Eastex Freeway)	Mon.-Fri.	5-11 a.m.	Inbound	2+
		2-8 p.m.	Outbound	2+
I-45 South (Gulf Freeway)	Mon.-Fri.	5-11 a.m.	Inbound	2+
		2-8 p.m.	Outbound	2+
US 59 South (Southwest Freeway)	Mon.-Fri.	5-11 a.m.	Inbound	2+
		2-8 p.m.	Outbound	2+
I-10 West (Katy Freeway)	Mon.-Fri.	5-6:45 a.m.	Inbound	2+
		6:45-8 a.m.		3+
		8 a.m. - Noon		2+
		1-5 p.m.	Outbound	2+
		5-6 p.m.		3+
		6-8 p.m.		2+
	Saturday	5 a.m.-8 p.m.	Outbound	2+
	Sunday	5 a.m.-8 p.m.	Inbound	2+
US 290 West (Northwest Freeway)	Mon.-Fri.	5-6:45 a.m.	Inbound	2+
		6:45-8 a.m.		3+
		8-11 a.m.		2+
		2-8 p.m.	Outbound	2+

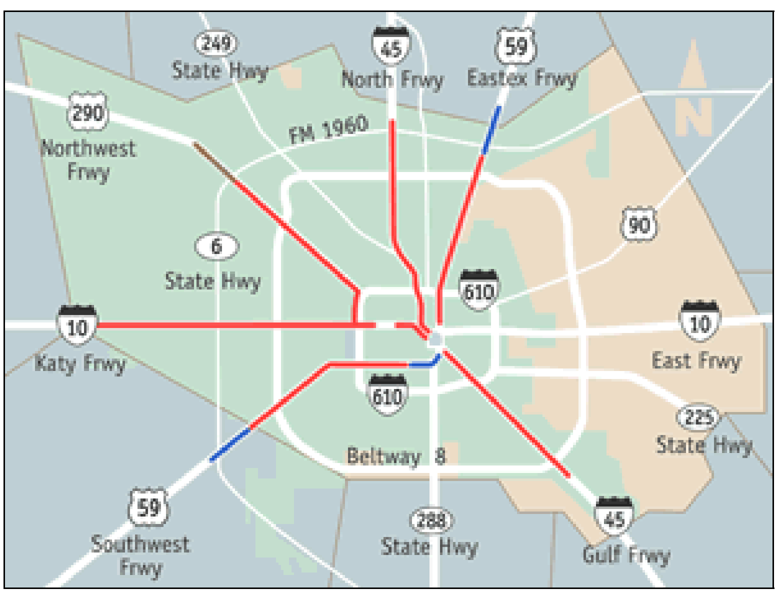

Figure 6: HOV corridor map in Houston (*21)*

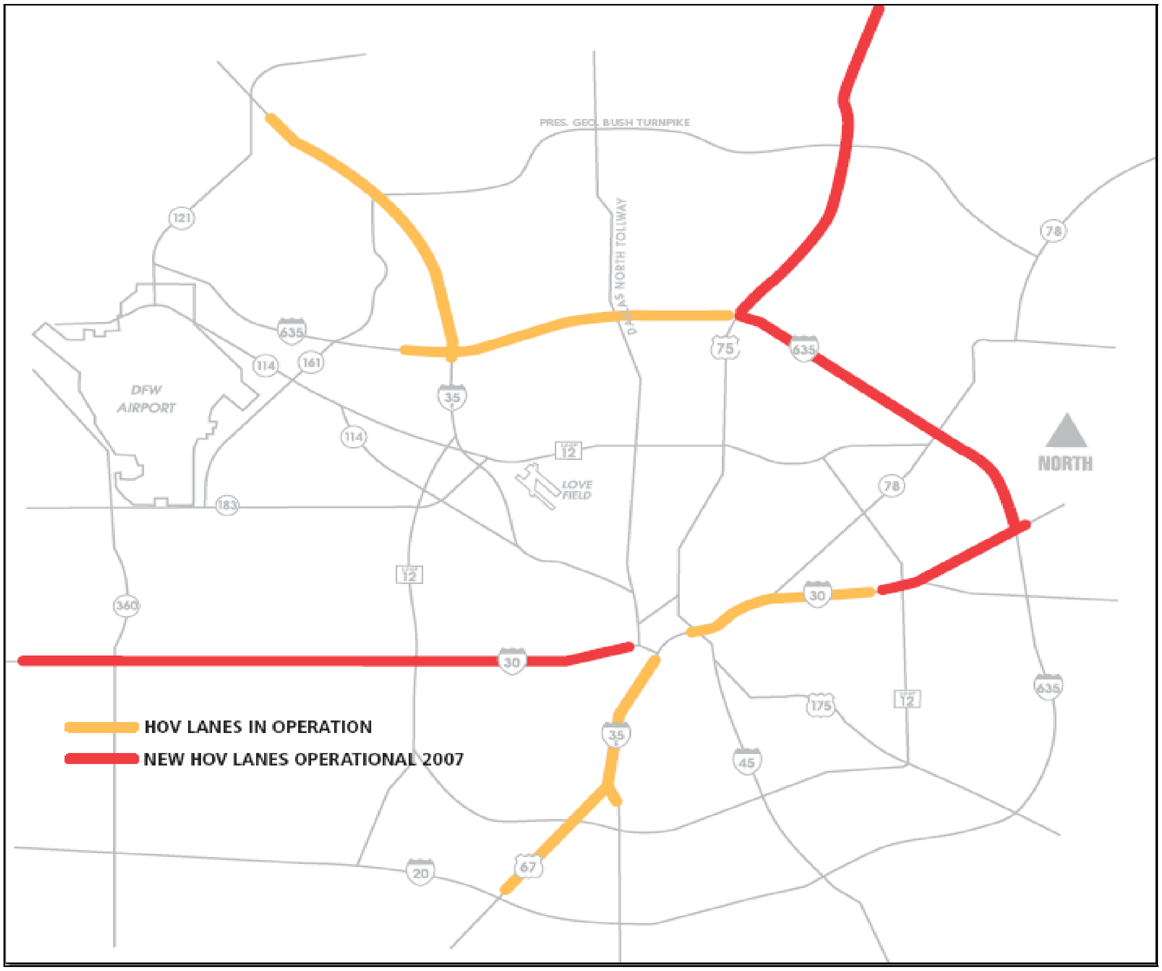

Figure 7: HOV map in Dallas (*21)*

The primary purpose of HOV lanes has been to increase the total person movement in the freeway corridor. Other objectives of the HOV lanes include: increasing the average number of persons per vehicle, preserving the people-moving capacity of the freeway, improving bus operations, and enhancing mobility options for travelers *(22)*. Carpoolers save travel time by using the HOV corridor, though they may compromise on travel flexibility in order to be a part of a carpool. Transit vehicles also travel on the HOV corridors. Therefore, many HOV lanes have a higher person throughput than a general purpose lane, even when there are fewer vehicles on the HOV lane. HOV lanes can provide a highly efficient use of a freeway lane by moving more peak hour travelers than one or more regular freeway lanes. Another important benefit of HOV lanes is creating travel alternatives for people with flexibility. In Houston, HOV lanes facilitate almost 118,000 person trips each weekday, and result in 36,400 fewer vehicle trips on the main lanes during peak periods (*23*). HOV travelers on Katy and Northwest Freeways typically save between 12 to 22 minutes per trip as the speed on the HOV lanes is close to 55 miles per hour whereas the average speed on the main freeway lanes frequently decreases to 24 miles per hour *(20)*.

High Occupancy/ Toll (HOT) lanes fall under the more restrictive definition of managed lanes used in this research. Capacity of HOV lanes may not be fully utilized by carpools/ vanpools and transit vehicles. In such a case, restrictions on vehicle occupancy are changed to allow lower occupancy vehicles (LOVs). These LOVs are required to pay a toll to use the HOV lane. This facility is called a HOT lane. The QuickRide program in Houston is such a facility. The QuickRide program allows HOV2 carpoolers to use Katy Freeway and US-290 HOT lanes by paying a $2 toll when the lanes are normally restricted to vehicles with three or more occupants (HOV3+). The QuickRide program is the only operational managed lane program in Texas satisfying the definition of a managed lane as defined in this thesis.

The I-15 Express Lanes in San Diego, the I-394 HOT lane in Minneapolis, and the I-25 HOT Express Lanes in Colorado are other HOT lanes in operation in the United States. SR-91 Express lanes in California are similar as they offer a toll discount for HOVs. There are a number of facilities existing in the United States which use variable tolls or vehicle occupancy requirements as a strategy to manage demand. Facilities, most like managed lanes are described in the following section.

2.3.1 The QuickRide Program in Houston

The QuickRide program operates along the IH-10 west (Katy) Freeway in Houston during the morning and evening peak hours and on the Northwest Freeway (US-290) in the morning peak period (see *Figure 8*) (*27*). HOV lanes opened along Katy Freeway in Houston for transit riders and vanpools in 1984. As the capacity was not fully utilized, occupancy restrictions were relaxed in 1988 to allow HOV2+ carpools to use the Katy Freeway. This led to excess demand during peak hours on weekdays. Thereafter, only HOV3+ carpools were allowed to use the lanes during the peak times. Not surprisingly, this led to excess capacity on the lanes. In January 1998, the QuickRide program was implemented, which allowed two-person carpools to travel in the peak period by paying a two dollar toll *(24)*. HOV-3+ and transit riders continued to ride for free. In 2002, the total demand was 182 trips per day, significantly below the targeted demand of 600 QuickRide travelers per day *(25)*. In a study to estimate the potential SOV demand for HOV lanes, it was estimated that approximately 2000 SOV travelers would use the Katy Freeway and Northwest Freeway facility during off-peak periods for reasonable toll levels *(26)*.

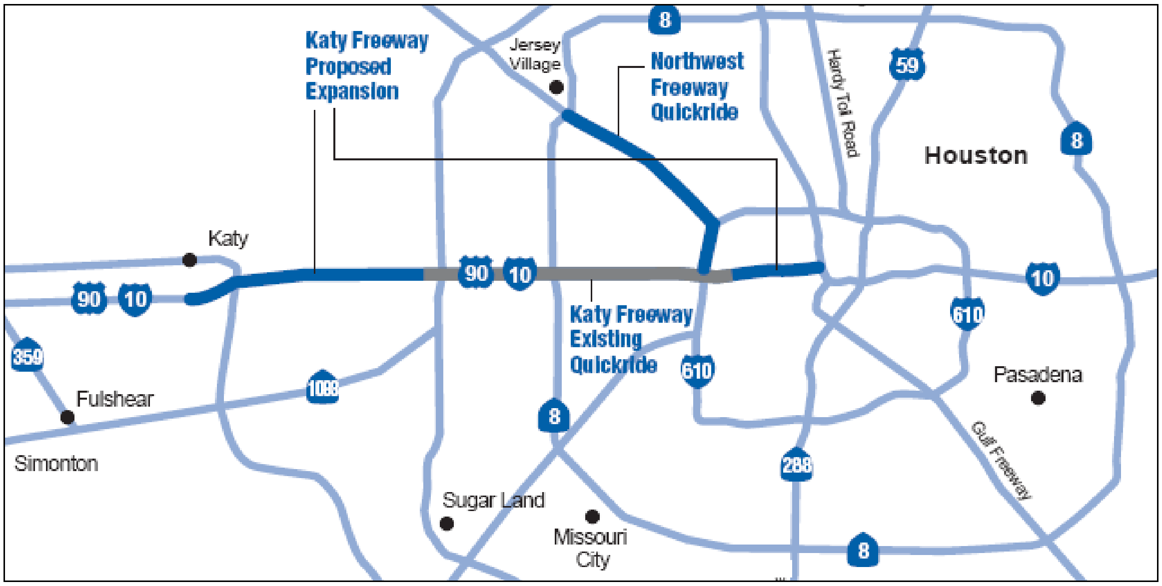

Figure 8: QuickRide program map (*27*)

Based on survey data, travelers who chose to pay the $2 toll for QuickRide program usage were more likely to have a high income (annual household income greater than $100,000), older (greater than 65 years of age), highly educated (had a post-graduate degree), and were on a school related trip. It was found that males, travelers between ages 25 and 34 years and those living alone were less likely to use the QuickRide program *(25)*. These results were partially influenced by many parents using QuickRide to take a child to a private school near the terminus of the US 290 HOT lane.

2.3.2 San Diego Interstate -15 (I-15) Express Lanes

Presently, the interstate-15 (I-15) express lane facility in San Diego is a HOT lane facility (*see Figure 9*) (*27*). From its inception in 1988 until 1996, it existed as an 8-mile, reversible HOV facility. The HOV facility only allowed carpools, vanpools, buses and motorcycles to use the facility. Faced with resource constraints and increasing congestion, the San Diego Association of Governments (SANDAG), in association with the California Department of Transportation and the Federal Highway Administration implemented a managed lane program in 1996 *(28)*. Since the HOV lanes were underutilized by these categories of vehicles, single occupant vehicle (SOV) travelers were allowed to use these lanes under a program called ExpressPass. Under this program, 500 monthly permits for $50 each were sold in January 1997. These permits allowed SOVs to use the lanes an unlimited number of times per month. In June 1997, transponders were introduced to the facility. In March 1998, variable-priced per-trip tolls were introduced (these variable tolls have a maximum amount *(Table 2)*). Later the facility was designated as FasTrak toll facility and travelers from other FasTrak programs could also use this facility (*27*). The rider ship in the I-15 Express Lanes has increased from 5,000 vehicles a day in 1998 to 13,600 vehicles per day in 2002 *(29)*.

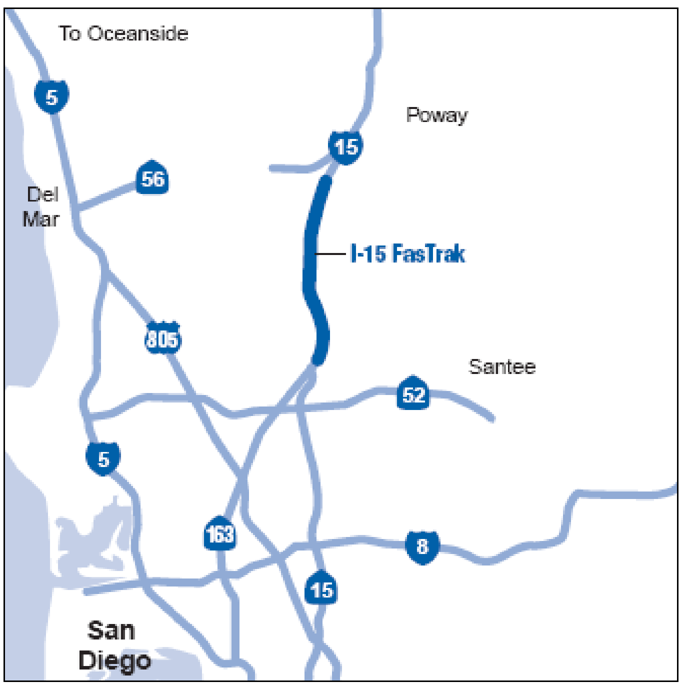

Figure 9: Map of I-15 San Diego Express lanes (*27*)

A weekday maximum toll varies from $0.50 to $4.00 (*Table 2*) (*30*). However, in event of severe congestion tolls may be revised to $8.00 per trip. Tolls are adjusted every six minutes in response to existing traffic conditions.

Table 2: I-15 Express lane toll schedule (*30*)

<table>
<tr><th rowspan="2">Time</th><th colspan="2">Weekday</th><th colspan="2">Friday</th><th colspan="2">Weekend</th></tr>
<tr><th>Direction</th><th>Max toll</th><th>Direction</th><th>Max toll</th><th>Direction</th><th>Max toll</th></tr>
<tr><td>12:00 am - 5:45 am</td><td>--</td><td>--</td><td>--</td><td>--</td><td>NB</td><td rowspan="4">$1</td></tr>
<tr><td>5:45 am - 6:15 am</td><td>SB</td><td>$2</td><td>SB</td><td>--</td><td>NB</td></tr>
<tr><td>6:15 am - 6:45 am</td><td>SB</td><td>$3</td><td>SB</td><td>--</td><td>NB</td></tr>
<tr><td>6:45 am - 8:00 am</td><td>SB</td><td>$4</td><td>SB</td><td>--</td><td>NB</td></tr>
<tr><td>8:00 am - 8:30 am</td><td>SB</td><td>$3</td><td>SB</td><td>--</td><td>NB</td><td rowspan="2">$2</td></tr>
<tr><td>8:30 am - 9:00 am</td><td>SB</td><td>$2</td><td>SB</td><td>--</td><td>NB</td></tr>
<tr><td>9:00 am - 11:00 am</td><td>SB</td><td>$1</td><td>SB</td><td>--</td><td>NB</td><td rowspan="11">$4</td></tr>
<tr><td>11:00 am - 12:00 pm</td><td>--</td><td>--</td><td>--</td><td>--</td><td>NB</td></tr>
<tr><td>12:00 pm - 1:00 pm</td><td>NB</td><td>$1</td><td>NB</td><td>$1</td><td>NB</td></tr>
<tr><td>1:00 pm - 2:00 pm</td><td>NB</td><td rowspan="2">$2</td><td>NB</td><td>$2</td><td>NB</td></tr>
<tr><td>2:00 pm - 2:30 pm</td><td>NB</td><td>NB</td><td rowspan="2">$3</td><td>NB</td></tr>
<tr><td>2:30 pm - 3:00 pm</td><td>NB</td><td rowspan="2">$3</td><td>NB</td><td>NB</td></tr>
<tr><td>3:00 pm - 4:00 pm</td><td>NB</td><td>NB</td><td rowspan="2">$4</td><td>NB</td></tr>
<tr><td>4:00 pm -5:30 pm</td><td>NB</td><td>$4</td><td>NB</td><td>NB</td></tr>
<tr><td>5:30 pm - 6:00 pm</td><td>NB</td><td>$3</td><td>NB</td><td>$3</td><td>NB</td></tr>
<tr><td>6:00 pm - 6:30 pm</td><td>NB</td><td>$2</td><td>NB</td><td>$2</td><td>NB</td></tr>
<tr><td>6:30 pm - 7:00 pm</td><td>NB</td><td>$1</td><td>NB</td><td rowspan="3">$1</td><td>NB</td></tr>
<tr><td>7:00 pm -8:00 pm</td><td>NB</td><td>--</td><td>NB</td><td>NB</td><td>$2</td></tr>
<tr><td>8:00 pm - 12:00 am</td><td>NB</td><td>--</td><td>NB</td><td>NB</td><td>$1</td></tr>
</table>

Focus group studies were conducted prior to implementing ExpressPass project and twice after implementation. According to the focus group study conducted before the project implementation, public opinion for the project was generally favorable, the opinion of existing carpoolers was less favorable, and the opinion of SOV travelers interested in using the program was more favorable. In the study conducted after the implementation of phase I (500 permits), ExpressPass users were enthusiastic, there was a general support for pricing, and carpoolers did not report any negative impacts. After implementation of phase II (variable tolls), in addition to the focus group study, telephone interviews were also conducted. According to the telephone survey, 87 percent of the respondents indicated that program was fair to both Express Lane travelers and general purpose lane travelers, while 89 percent of the ExpressPass users viewed the project as success *(29, 31)*.

In 2001, a study was conducted to determine public opinion regarding an extension of the HOT lane program. The study found 66 percent of the respondents approved of the HOT lane program, while all income-groups had at least a 60 percent approval rating for the FasTrak program. There was a greater support for tolling (77 percent) than the FasTrak program (66 percent). The respondents considered the FasTrak program as fair to general purpose lane travelers (71 percent) and HOT lane travelers (75 percent) *(29, 31)*.

In a telephone survey conducted by Wilber Smith Associates, it was found that the overall impression of the program, by groups, resulted in no statistical difference when examined by age, sex, income, or occupation categories. In the same survey, travelers' impression of the automatic fee program did not vary by age, income, sex, or occupation (*32*).

Researchers examined the traveler profile of I-15 Express lanes. They found that travelers on commute trips, individuals from high income households, women, individuals between ages 35 and 45, individuals with high education, and homeowners were more likely to use managed lanes. The willingness to reduce travel time was found to be $31 per hour (*7*).

2.3.3 State Route (SR) - 91 Express Lanes

The SR 91 Express Lanes are a ten mile long HOT lane facility in Orange County, California (*Figure 10*) (*27*). During most hours of the day; buses, motorcycles, and travelers with three or more people in the vehicle (HOV3+) can travel for free. Other vehicles (SOV and HOV2) must pay a toll (see *Figure 11*) (*32*). During the evening peak time (4pm to 6pm) HOV3+ vehicles must pay a discounted toll. The tolls are collected using a FasTrak transponder. The tolls are variable, based on the time of the day and are published on the SR-91 Express Lanes web site http://www.91expresslanes.com/ tollschedules.asp (*33*). The tolls help maintain the free flow of traffic *(34)*. During the peak period, SR-91 express lanes accommodate 1400-1600 vehicles per hour per lane, which is more than the general purpose lanes *(35)*.

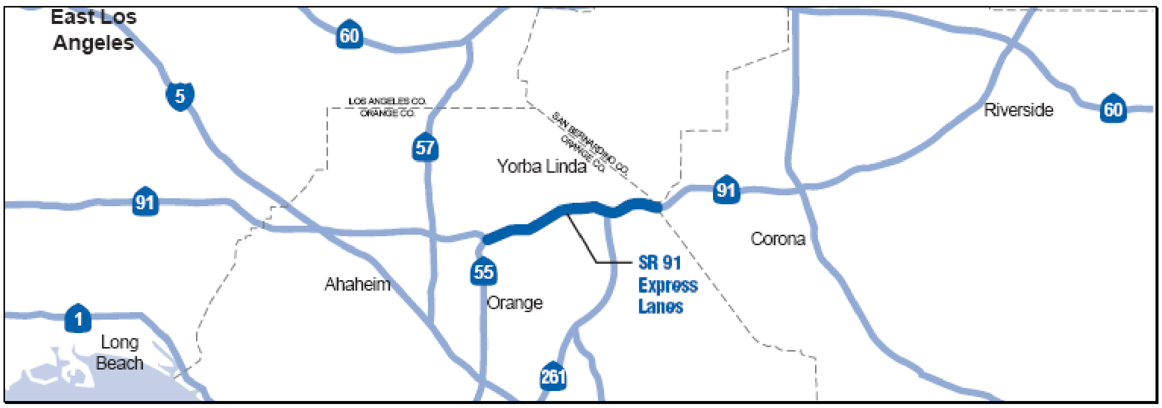

Figure 10: SR-91 Express lanes map (*27*)

Toll Schedule Effective April 1, 2007 — **Eastbound** SR-55 to Riverside Co. Line (91 Express Lanes)

	Sun	M	Tu	W	Th	F	Sat
Midnight	1.15	1.15	1.15	1.15	1.15	1.15	1.15
1:00 am	1.15	1.15	1.15	1.15	1.15	1.15	1.15
2:00 am	1.15	1.15	1.15	1.15	1.15	1.15	1.15
3:00 am	1.15	1.15	1.15	1.15	1.15	1.15	1.15
4:00 am	1.15	1.15	1.15	1.15	1.15	1.15	1.15
5:00 am	1.15	1.15	1.15	1.15	1.15	1.15	1.15
6:00 am	1.15	1.85	1.85	1.85	1.85	1.85	1.15
7:00 am	1.15	1.85	1.85	1.85	1.85	1.85	1.15
8:00 am	1.50	1.85	1.85	1.85	1.85	1.85	1.85
9:00 am	1.50	1.85	1.85	1.85	1.85	1.85	1.85
10:00 am	2.30	1.85	1.85	1.85	1.85	1.85	2.30
11:00 am	2.30	1.85	1.85	1.85	1.85	1.85	2.30
Noon	2.70	1.85	1.85	1.85	1.85	2.80	2.70
1:00 pm	2.70	2.55	2.55	2.55	2.80	4.35	2.70
2:00 pm	2.70	3.70	3.70	3.70	3.80	4.35	2.70
3:00 pm	2.30	3.95	3.95	4.95	4.95	9.25	2.70
4:00 pm	2.30	6.65	8.00	8.50	9.25	9.50	2.70
5:00 pm	2.30	6.65	8.50	8.50	9.25	8.00	2.70
6:00 pm	2.30	3.95	5.45	4.95	5.75	4.75	2.30
7:00 pm	2.30	2.80	2.80	2.80	4.00	4.40	1.85
8:00 pm	2.30	1.85	1.85	1.85	2.55	4.00	1.85
9:00 pm	1.85	1.85	1.85	1.85	1.85	2.55	1.85
10:00 pm	1.15	1.15	1.15	1.15	1.15	1.85	1.15
11:00 pm	1.15	1.15	1.15	1.15	1.15	1.15	1.15

Toll Schedule Effective April 1, 2007 — **Westbound** Riverside Co. Line to SR-55 (91 Express Lanes)

	Sun	M	Tu	W	Th	F	Sat
Midnight	1.15	1.15	1.15	1.15	1.15	1.15	1.15
1:00 am	1.15	1.15	1.15	1.15	1.15	1.15	1.15
2:00 am	1.15	1.15	1.15	1.15	1.15	1.15	1.15
3:00 am	1.15	1.15	1.15	1.15	1.15	1.15	1.15
4:00 am	1.15	2.20	2.20	2.20	2.20	2.20	1.15
5:00 am	1.15	3.60	3.60	3.60	3.60	3.45	1.15
6:00 am	1.15	3.70	3.70	3.70	3.70	3.60	1.15
7:00 am	1.15	4.05	4.05	4.05	4.05	3.95	1.60
8:00 am	1.60	3.70	3.70	3.70	3.70	3.60	1.85
9:00 am	1.60	2.95	2.95	2.95	2.95	2.95	2.30
10:00 am	2.30	1.85	1.85	1.85	1.85	1.85	2.30
11:00 am	2.30	1.85	1.85	1.85	1.85	1.85	2.60
Noon	2.30	1.85	1.85	1.85	1.85	1.85	2.60
1:00 pm	2.60	1.85	1.85	1.85	1.85	1.85	2.60
2:00 pm	2.60	1.85	1.85	1.85	1.85	1.85	2.60
3:00 pm	2.60	1.85	1.85	1.85	1.85	2.30	2.60
4:00 pm	2.75	1.85	1.85	1.85	1.85	2.30	2.75
5:00 pm	2.75	1.85	1.85	1.85	1.85	2.30	2.75
6:00 pm	2.75	1.85	1.85	1.85	1.85	2.70	2.30
7:00 pm	2.30	1.15	1.15	1.15	1.15	1.85	1.85
8:00 pm	2.30	1.15	1.15	1.15	1.15	1.15	1.15
9:00 pm	2.30	1.15	1.15	1.15	1.15	1.15	1.15
10:00 pm	1.15	1.15	1.15	1.15	1.15	1.15	1.15
11:00 pm	1.15	1.15	1.15	1.15	1.15	1.15	1.15

Figure 11: SR-91 toll schedule (effective April 1, 2007) (*32*)

Several travel surveys have been conducted to explore SR-91 express lane traveler characteristics. Large surveys were conducted in 1996 and 1999. In both the surveys, the researchers found that the socio-economic profile of the Express lane travelers was similar to the general purpose lane travelers *(35)*. Even though higher income groups (annual household income greater than $100,000) used the Express lanes more often, 25 percent of the lowest income group (annual household income less than $25,000) used the Express lanes frequently. Approximately half of the highest income group indicated that they did not use the Express lanes *(35)*. Clearly, there are factors other than income responsible for travelers' proclivity to use the HOT lanes. More females than males were likely to use the express lanes. When examining the travel behavior of people with annual household incomes between $40,000 and $60,000, it was found that percentage of this income group in the trips on the express lane decreased from 40 percent to 25 percent from 1996 to 1999*(35)*. Age is also an important factor for express lane usage. The youngest and the oldest travelers were less likely to use the Express lanes as compared to the intermediate age category *(35)*.

2.3.4 I-394 HOT Lane in Minneapolis, Minnesota

The I-394 HOT lanes operate eastbound for a distance of 10.4 miles and westbound for a distance of 8.8 miles. It is a 1-lane reversible section. The eastbound lanes are open from 6:00 am to 1:00 pm and westbound lanes are open from 2:00 pm to 5:00 pm. Lanes are closed from 1:00 pm – 2:00 pm for directional change. The hours of operation may be adjusted for special events *(36)*.

Carpools and transit riders can use the lanes for free. The tolls for SOV travelers vary based on real-time traffic levels. An attempt is made to keep traffic flowing at 50-55 mph in the HOT lane. Tolls average from $1 to $4 during rush hour with a maximum of $8. The lanes are not tolled during off-peak hours. The toll rate is posted on the variable message signs before the entrances to the HOT lane. The studies in the corridor have suggested that speeds are above 50 mph 90 percent of the time.

A panel survey was conducted six months before the opening of the I-394 HOT lane in May 2005 and six months after opening the lane. The panel survey findings indicated a strong support for the HOT lane concept among all income groups (higher among the highest income group). Carpoolers as well as SOV travelers were supportive of the concept, though transit riders were less supportive of the concept. In the survey conducted in December 2004, 64 percent of the respondents thought the HOT lane was a good idea *(37)*.

A survey was conducted in November and December 2005, six months after opening of MnPASS Express Lane Project. The survey opinion results after implementation of the Express Lane project were not very different from the opinion results obtained from a survey conducted before implementation of the project. Respondents remained favorable to allowing SOVs to use carpool lanes by paying toll. Before project implementation, 61 percent of respondents were in favor and after project implementation 59 percent of respondents were in favor of the concept (*Table 3*). The percentage of people who thought it as a bad idea also remained almost the same (*Table 3*). When this opinion was classified according to the income groups, it was found that 71 percent of high-income (annual household income greater than $125,000) travelers, 60 percent of mid-income (annual household income between $50,000 and $125,000) travelers, and 62 percent of low-income (annual household income less than $50,000) travelers were in favor of allowing SOV travelers to use the lanes for a toll (*Table 4*). When the same opinion was classified by travel mode, SOV travelers were most likely to support the concept (70 percent), followed by carpoolers (45 percent), and transit riders (45 percent) (*Table 5*) (*38*).

Table 3: Opinion results before and after implementation of I-394 MnPASS Express Lane project (*38*)

		Good idea	Bad idea	No opinion	Total
Before implementation	Number	334	157	58	549
	Percentage	61%	28%	11%	
After implementation	Number	323	158	58	549
	Percentage	59%	29%	12%	

Table 4: Opinion results (classified by income) after implementation of I-394 MnPASS Express Lane project *(38)*

Opinion across income groups (total respondents = 950)			
	Good idea	**Bad idea**	**No opinion**
Low income (Less than $50,000)	62%	23%	15%
Mid-income ($50,000 to $125,000)	60%	28%	12%
High-income (More than 125,000)	71%	23%	6%

Table 5: Opinion results (classified by travel mode) after implementation of I-394 MnPASS Express Lane Project (*38*)

Opinion by travel mode (total respondents = 810)			
	Good idea	**Bad idea**	**No opinion**
SOV (total=524)	70%	20%	10%
Carpoolers (total=144)	64%	29%	7%
Transit (total=142)	45%	39%	16%
Total (total=810)	64%	25%	11%

VOT was estimated for the different income groups. There was no significance difference in VOT for groups with annual household incomes below $50,000 and those with annual household incomes between $50,000 and $100,000. The VOT for travelers with annual household incomes less than $100,000 was $9.63 per hour. However, the VOT value rises sharply for groups with annual household incomes over $100,000 and is $16.08 per hour for group with annual household incomes above $125,000. When VOT was compared across different age groups, it was found that on an average, younger people had a higher VOT and older people had a lower VOT then age group 45-65. When the VOT was compared by trip purpose, it was found that the VOT for morning commute and for work-related non-commute trips was $3 per hour higher than off-peak social and recreational trips, and the VOT for afternoon commute trip was $1 higher than off-peak social and recreational trips. The value for non-work related trips in the PM peak is $2 lower than off-peak social and recreational trip. When the VOT was compared by trip distance, it was found that for trips less than 10-miles; travelers had significantly lower VOT than medium distance trips and for trips greater than 20-miles; travelers had significantly higher VOT (*39*).

2.3.5 I-25 HOT Express Lanes, Denver, Colorado

The I-25 HOV/Tolled Express Lanes are 7-miles of I-25 HOV lanes between downtown Denver and US 36 (see *Figure* 12) (*27*). The lanes became operational in June 2006. The tolls vary by time of day. The prices are higher during the peak time to maintain high travel speeds in the HOV/Express lanes. The tolls vary from $0.50 to a maximum of $3.25. The lanes operate from 5:00 am to 10:00 am in the morning and 12:00 pm to 3:00 am during the rest of the day.

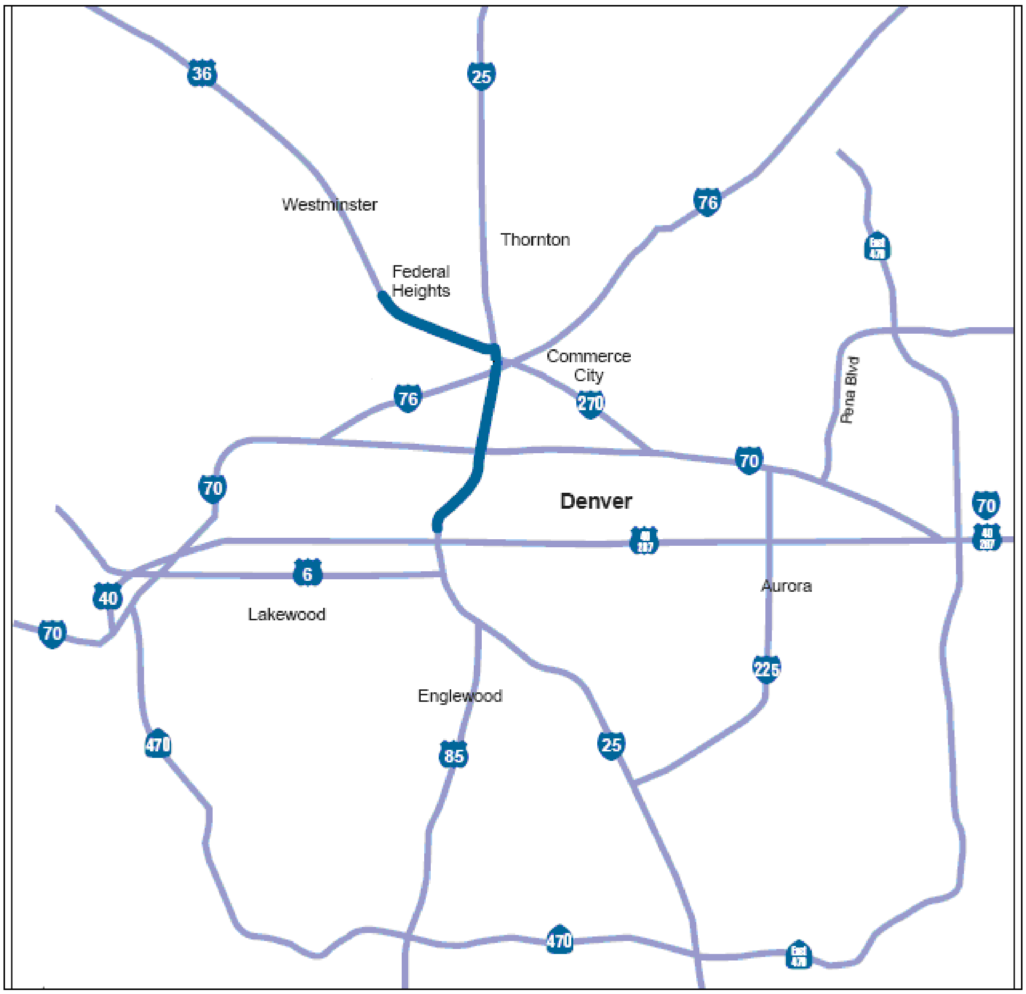

Figure 12: I-25 HOT Express lanes, Denver map (*27*)

A stated preference survey was conducted for Corridor-470 (C-470) travelers in April 2004 in Denver. Approximately 67 percent of the travelers surveyed thought that idea of express lanes on C-470 was an excellent, good, or an ok idea. Approximately 70 percent of the travelers indicated that they would consider using express lanes in case of congestion. Approximately 81 percent of the travelers indicated that they would pay 20 to 30 cents per mile to use express lanes in case of an emergency or if they were late for appointment *(40)*.

Unfortunately Surveys detailing traveler characteristics have not been conducted on I-25 Express lanes in Denver.

2.3.6 I-15 Express Lanes, Utah

I-15 Express Lanes in Utah are 38 miles of lanes from Salt Lake City to University Parkway in Orem (see *Figure 13*) (*28*). Before September 2006 they were HOV lanes, which were then converted to HOT lanes. Carpools, vanpools, transit riders, motorcyclists, and clean fuel vehicle owners are allowed to use the facility without any charge. A maximum of 1350 SOV travelers are allowed to travel on these lanes by paying a 50 dollar toll per month. The decision to make the lanes to HOT lanes was taken because the demand was only 650 to 750 vehicles per hour in the peak period. However, the facility could easily handle 1500 vehicles per hours while providing speeds exceeding 55 miles per hour (*41*). The socio-economic information about I-15 Express Lanes, Utah was not available.

Figure 13: I-15 Express lanes Utah map (*27*)

2.3.7 Other Managed Lane Programs

Managed Lanes as a strategy for congestion management has been adopted across different regions in the United States. A few of these facilities have been described in detail earlier. All the existing, under construction, and under development managed lanes (based on pricing) are documented by the TTI managed lane website *(Table 6) (42)*.

Table 6 : Managed lanes (with pricing component) in the United States (*42*)

Existing Managed Lanes (with pricing component)			
Location	Name	Length (Miles)	Total lanes
Houston (TX)	Katy I-10 QuickRide	13	1
	Northwest US 290 QuickRide	13.5	1
Minneapolis, MN	I- 394 MnPASS	11	2
San Diego, CA	I-15 FasTrak	8	2
Orange County, CA	SR 91 Express Lanes	10	4
Denver, CO	I-25 HOT Lanes	6.5	2
Salt Lake City, UT	I-15 Express Lanes	38	2
Under Construction Managed Lanes (With pricing component)			
Houston (TX)	Katy Freeway I-10	23	4
Maryland	I-95 Kennedy Expressway Express Toll Lanes	9	4
Under Development Managed Lanes (With Pricing component)			
Austin, TX	Loop 1 (MoPac)	11	2
Dallas / Fort Worth, TX	I-635 LBJ Managed Lanes	24	4
	I-30 Managed Lanes	60	2
	I-820/SH183 Managed Lanes	27	2
	I-35W Managed Lane	20	2
Houston, TX	SH 288 Managed Lane	18	4
Seattle, WA	I-405 Managed Lane	30	4
	SR 167 HOT Lanes	9	2
San Diego, CA	I-15 FasTrak Expansion	20	4
	I-5 HOT Lanes	32	4+
	I-805 Managed Lanes	27	4
San Francisco Bay Area, CA	I-680 HOT Lane	14	2

Table 6 continued:

Under Development Managed Lanes (With Pricing component)			
Location	Name	Length (Miles)	Total lanes
Denver, CO	US 36 Express Toll Lanes	25	4
	I-70 Express Toll Lanes	10	4
	C-470 Express Toll Lanes	14	4
	I-25 North Express Toll Lanes	26	2 to 4
	I-70 Mountain Corridor	35	2
Miami, FL	I-95 HOT to HOT Express Toll Lanes	12	3
Ft. Lauderdale, FL	I-595 Express Lane	13	2
Atlanta, GA	I-285 HOT Lanes	14	2
	I-75/I-575 HOT Lanes	36	4
	GA 400 HOT Lanes	20	4
Maryland	Intercounty Connector (ICC)	18.8	6
	I-270 Express Toll Lanes	23	2 to 4
	I-495 Capital Beltway Express Toll Lanes	42	2
Raleigh/Durham, NC	I-40 HOT Lanes	20	1
Portland, OR	Highway 217 Express Toll Lanes	8	2
Salt Lake City, UT	I-15 Express Lane Extension	9.5	2
Virginia	I-495 Capital Beltway HOT Lanes	12	4
	I-95/I-395 HOT Lanes	54	3 and 2

2.3.8 Summary

Managed lanes are in operation in a number of cities and many more are planned. The specific strategy for managed lane operation varies by location. However, the success of the operational managed lane programs and the large number of managed lane programs under consideration and implementation point to the fact that managed lanes are increasingly seen as an important congestion mitigation tool.

A number of studies have examined travel behavior on managed lanes. Studies examining the characteristics of travelers using managed lanes include studies from the QuickRide program in Houston, I-394 MnPASS program in Minneapolis. These studies, as have been described here, indicate that travelers are in favor of managed lane implementation; though not to same degree at all locations. One of the most detailed studies was carried out for the San-Diego I-15 Express Lanes. Focus group studies and other studies were carried out for these express lanes at different stages of express lane implementation: before the implementation of the program, after completion of phase 1, after completion of phase 2, and for extension of these lanes. Similar studies, though less detailed in scope, have been carried out in SR-91 Express Lanes, the QuickRide program in Houston, I-394 Minneapolis HOT lanes, and on the Corridor-470 program in Denver. These studies have identified different aspects of managed lane programs such as interest in managed lanes, traveler groups most interested in managed lanes, etc.

The managed lanes programs described in the previous sections were based on vehicle and/or toll restrictions. They are functional for certain times of day and certain days of the week. The carpool travelers either do not pay a toll or pay a discounted toll. Most of these managed lane programs have evolved from HOV lane programs, when the capacity of the HOV lanes was not fully utilized by the HOVs.

Opinion surveys conducted to analyze public opinion for managed lane programs have indicated a few commonalities. The public opinion before implementation of the managed lanes was generally favorable towards allowing SOVs to travel on these lanes by paying a toll. The opinion of carpooling travelers was less favorable than that of the general population. Public opinion remained favorable after implementation of the managed lane programs.

Analysis of socio-economic characteristics of travelers involved in these managed lane programs indicated some common characteristics. High-income groups used these lanes more often. High-income travelers used SR-91 Express Lanes more often, however 25 percent of low-income groups also frequently used these lanes, while 50 percent of highest income groups did not use these lanes. In general, more females than males used these lanes.

The major difference in the managed lane programs is that their goals differ across locations. The goals for a particular managed lane program could include any or all of the following: increasing vehicle occupancy, improving bus operations, increasing people-moving capacity of the freeway, and enhancing mobility options of the travelers. A different managed lane program may have different set of goals or it may have same goals as listed above, but with different set of priorities.

2.4 Mode Choice and Mode Choice Modeling

2.4.1 Mode Choice

Different factors influence route, mode, and time of travel choice of travelers. Travelers choose their route, mode, and time of travel to maximize their utility (or more accurately, to minimize their disutility) of the trip to be undertaken *(43)*. A number of factors influence this choice. These factors include: socio-economic characteristics of travelers, characteristics of the available modes, trip purpose, trip length, trip time (peak or off-peak), and characteristics of commute alternatives, along with other trip characteristics. Other variables influencing mode choice could be behavioral, attitudinal, and value characteristics of the traveler. All these variables may enter a mode choice model. Researchers have identified following as the most important characteristics influencing a travel mode and route choice *(44)*:

- Direct monetary cost of the trip (tolls, fares, parking)
- Travel time
- Travel time reliability.

A traveler will choose a particular mode which best satisfies his or her travel needs from the choice set. For a choice between traveling on a managed lane versus a general purpose lane, it is often the choice between travel time savings and reliability on the managed lane versus monetary savings on the general purpose lane. When the option for using a carpool for a lower or no toll exists, the choice is often between waiting for passenger pickup and delivery (and curtailment of travel freedom) versus monetary savings. To estimate how travelers may react to these options mode choice models are developed.

The following section describes the literature regarding traveler choice for different modes as carpooling with one passenger, carpooling with more than one passenger, or driving alone.

2.4.2 HOV2 and HOV3+ Mode Choice

Cost sharing is not the most important reason for people to carpool. A study of travelers using the SR-91 Express lanes found that the most frequent reason given for carpooling was that carpoolers belonged to the same household and used the HOV lanes to reduce travel time *(Figure 14) (35)*.

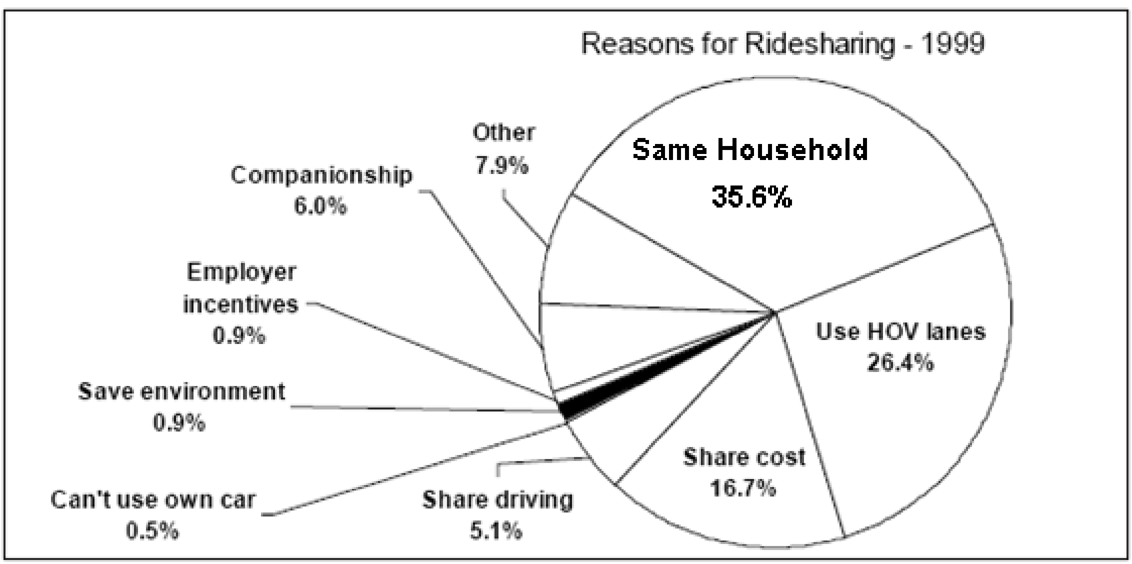

Figure 14: Primary reason for carpooling (HOV-2 and HOV-3+), 1999 (*35*)

It is also important to evaluate reasons for travelers to continue to drive alone instead of carpooling. A telephone study survey by Urban Research Center at the University of Wisconsin (Milwaukee) identified the factors responsible for people not to carpool or vanpool in a seven-county region in Southeastern Wisconsin *(Figure 15) (45)*.

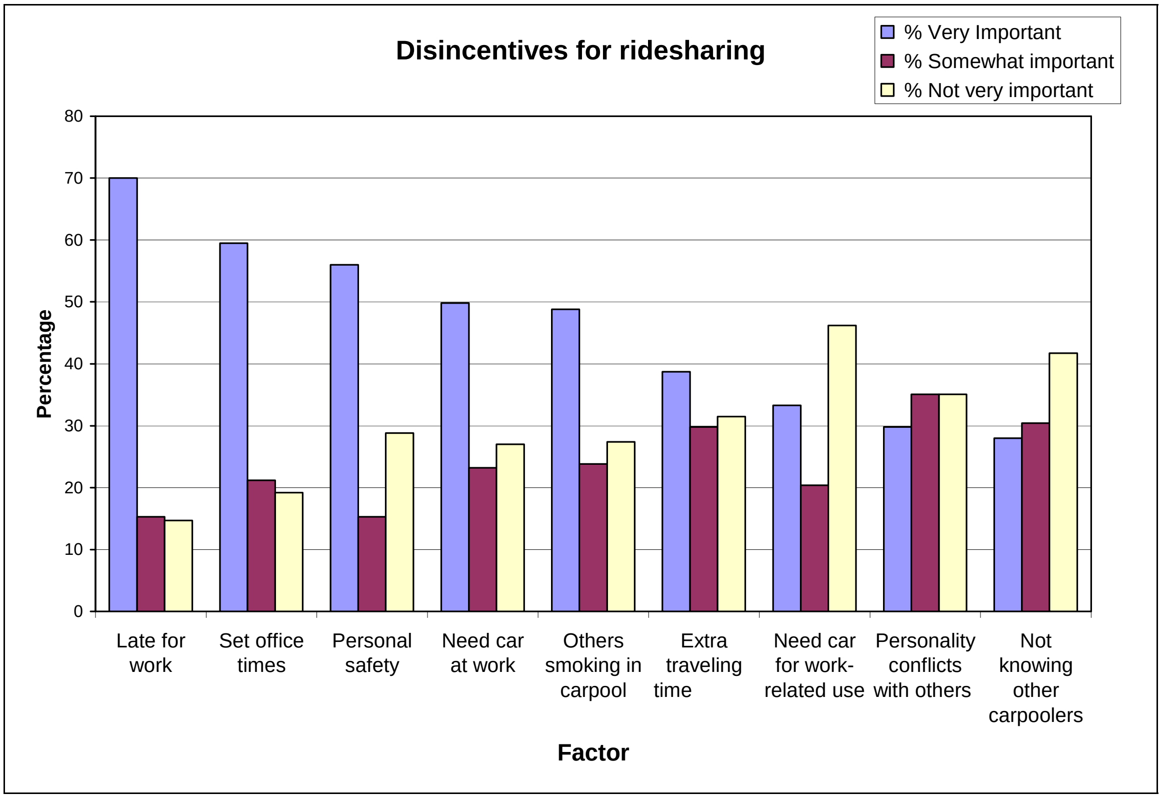

Figure 15: Disincentives for carpooling (*45)*

Travelers need for a vehicle during the work hours was found to be critical barrier in carpooling or vanpooling. Travelers needed a vehicle during the day to be able to pick up kids, run an errand, or for emergency use. Therefore, some employers participating in ridesharing programs provide vehicles for common errands (such as going to day care centers, restaurants, or going to dry cleaners).

Although knowing whether the respondent carpools is desirable, it is even more important to know with whom was the carpool formed. Fampools do not always take cars off the street *(46)*. Therefore the goal of throughput increase, reducing emissions, reducing fuel usage, maximizing use of existing infrastructure, or relieving congestion are not met by formation of fampools. At the same time, the goal of revenue generation is also compromised. Only 26.3 percent of all 2001 work trip carpools involved a non-household member *(47)*.

The previous analysis points to a few factors that motivate travelers to use a particular mode. These factors are used in conjunction with socio-economic characteristics and stated preference data to derive mode choice models. The following section describes mode choice modeling theory and methodology.

2.4.3 Mode Choice Models

Mode choice analysis is the third step in the traditional four step transportation planning process. In this step, a traveler's decision regarding mode choice of travel; for example auto, bus, train, HOV, Managed Lanes, and so on, is estimated.

The development of mode choice models began with the perceived need for behavioral models. Choice models are considered good because they permit comparison of more than two alternatives and let us know the relative importance of these alternatives. The roots of choice models lie in consumer behavior theory, in random utility theory, and modern statistical methods.

Random utility theory assumes that trip maker has perfect discrimination capability. However the analyst is assumed to have incomplete information and therefore uncertainty must be taken into account. The utility is included as a random variable in order to reflect this uncertainty. The utility equations such that an individual t chooses an alternative i from choice set C_t is given as

$$U_{it} = V_{it} + \varepsilon_{it} \ ; \quad i \in C_t \tag{1}$$

where V_{it} is systematic portion of utility,

ε_{it} is random portion of utility.

The alternative with highest utility is chosen. The probability that an alternative *i* is chosen by trip maker *n* from choice set C_t is given as

$$P(i\,|C_t) = P[U_{it} \geq U_{jt} \ \forall \ j \in C_t \,] \tag{2}$$

where i, j are alternatives

P(A) is probability of occurrence of event A

For resolution of importance an individual gives to a particular alternative, psychology is tapped. Psychological experiments reveal that probability of choosing an alternative is dependent on perceived importance of both the alternatives (48). Assuming the random portion of utility to be normally and identically distributed gives binary probit model.

An alternative method is to assume that error terms are independently distributed with Weibull, Gumbel Type I, or double exponential distribution (these distributions are similar but differ in kurtosis value, which is a measure of fatness of tail). This yields a multinomial logit model, which is widely used in transportation mode choice models. The logit model is log ratio of choosing a mode to not choosing a mode. The probability that an individual chooses alternative i within the choice set C_t is given by (*43*)

$$P(i|C_t) = \frac{e^{V_{it}}}{\sum_{j \in C_t} e^{V_{jt}}} \tag{3}$$

For estimation of utility values of different modes by an individual, travel diaries have to be studied or surveys have to be conducted. The data used is both revealed-preference and stated-preference. Socio-economic factors, modes available in the choice set, and mode actually chosen are some of the factors required for developing a mode choice model. Regression analysis of these values may not give probability values to be between 0 and 1; therefore maximum likelihood estimate is used to estimate parameters. The function used is

$$L^*(\beta_1, \beta_2, .., \beta_k) = \prod_{n=1}^{t} P_{iN}^{yiN} P_{jN}^{yjN} \tag{4}$$

$L^*(.)$ is maximum likelihood function of the variables (.)

$\beta_1, \beta_2, ..., \beta_k$ are the coefficients for variables included in the utility equations

yiN = 1 if the mode *i* is chosen, otherwise it is zero.

yjN = 1 if mode *j* is chosen, otherwise it is zero.

Coefficients that maximize that likelihood that the model predicts trip maker's choices correctly are then estimated using equation 4.

A simple discrete choice model, for example, might be used to predict the probability of taking a trip to work by single occupant vehicle (SOV) or by carpooling, based on three factors:

1. Travel time difference between the two modes for the trip
2. Waiting time for carpooling and time taken after parking the vehicle to the destination
3. The relative cost by each mode

In this thesis, different choice models were developed for Houston and Dallas travelers. The mode choice models included socio-economic characteristics of the travelers, trip characteristics, and costs associated with the trip. Logit models were developed for the six modes (alternatives) available to the travelers: drive alone in a managed lane, carpool with one passenger in a managed lane, carpool with two or more passengers in a managed lane, drive alone in a general purpose lane, carpool with one passenger in a managed lane, and carpool with two or more passengers in a general purpose lane. Utility equations were developed for each mode.

2.5 Willingness to Pay

A traveler’s Willingness to Pay (WTP) is the price at which he or she is indifferent between paying for one option or foregoing it and taking another option. In this case, WTP is the maximum amount a traveler will pay to use a faster but more expensive mode when the traveler has the option to use both a faster, more expensive mode and a slower, cheaper mode. WTP for a traveler is directly related to his or her Value of Travel Time Savings (VTTS). The VTTS is the value the traveler places on time saved using a faster (but more expensive) mode. The VTTS includes both monetary and non-monetary costs incurred in the journey. There are different methods to measure VTTS. Using revealed preference and stated preference data is one of the most common methods. Revealed preference and stated preference data is often obtained by surveying travelers. In a revealed preference survey, the mode choice of the traveler is recorded along with other information such as the traveler’s socio-economic characteristics. In the stated preference surveys, respondents are presented with detailed description of hypothetical travel scenarios, and the description of mode choices being evaluated. The respondents are asked which mode they would select given these options. This research used stated preference questions to obtain travelers WTP for using managed lanes.

In the survey used for this research, for the first scenario, the toll was an average toll a traveler would be expected to pay for the travel time saved using a managed lane. Contingent on the first response, the second toll was presented. If the traveler chose to travel by paying the toll in the first scenario, the toll was increased in the second scenario. If the traveler selected a non-toll option the toll was reduced. The third and fourth scenarios were framed in similar manner: increasing or decreasing the toll based on second and third response, respectively. The tolls were higher for SOV travelers in general. However, for a few cases tolls for HOV2 and HOV3+ could be as high as tolls for SOV travelers. Four such scenarios were presented. The VTTS was estimated by the logit models estimated by using the choices indicated by respondents in the stated preference questions.

2.6 Summary of the Literature Review

2.6.1 Findings from Managed Lanes Study

A number of managed lanes are presently in operation in the United States. Many more are in different stages of implementation. This chapter has summarized existing managed lane programs. The emphasis has been to describe the operational characteristics as well as traveler profiles of these managed lanes. An attempt has been made to survey the traveler opinion for these managed lanes.

As the section 2.3 on different managed lanes illustrates, the travelers are in favor of managed lanes implementation. The respondents have a favorable view for allowing SOV travelers to use carpool lanes. This support is high among all traveler groups characterized by age, income, mode, or any other characteristics.

2.6.2 How Models Will Be Used to Understand Travelers Potential Use of Managed Lanes

Mode choice modeling is used to estimate the number of travelers likely to use different modes under given traffic and toll conditions. If the speeds on the general purpose lanes are close to free flow speeds, there is little reason that travelers will choose to pay to travel under similar characteristics in the managed lanes. However, the speeds are usually much slower on the general purpose lanes than the managed lanes at peak times. Under these circumstances, a certain percentage of travelers will choose to pay to save travel time. A multinomial logit mode choice model is a common technique used to estimate the number of travelers willing to pay a particular amount of toll to travel on managed lanes. This technique will be used in this research and is detailed in the following chapters.

CHAPTER III

DATA COLLECTION

3.1 Survey Design

The survey questionnaire was formulated with the goals and the objectives of managed lanes in mind (see *Table 7 for details*) (*49*). In this way, researchers could be assured that the information on how well/poorly the managed lanes may operate (including potential usage) could be estimated. The final questionnaire was a trimmed version of the initial survey questionnaire and it reflected the goals and objectives of managed lanes in general and of this research in particular.

Table 7: Managed lane goals (*49*)

Goals	Objectives	Measures of Effectiveness
1. Improve operational efficiency of the transportation system	Reduce congestion	Reduce average travel time
		Compare average travel time of an HOV lane versus a ML
		Percentage time GPL is LOS D or worse
		Percentage of time HOV or ML is LOS D or worse
		Average speeds (Number of vehicles?)
		Travel time index (TTI)
	Improve travel time reliability	% of veh. (ML & GPL) travel time <= 1.2 * Free flow travel time
		Difference between 95th percentile travel time and 50th percentile travel time
		Percentage of time vehicles achieve free flow speeds
	Maximize throughput and person carrying capacity	Number of vehicles per hour (ML and GPL)
		Number of persons per hour (ML and GPL)
		Increase in AVO and/or transit usage

Table 7 Continued:

Goals	Objectives	Measures of Effectiveness
2. Provide more travel options to the users	Provide additional travel options	Count number of travel options (count number of vehicles/persons selecting new options)
		Increase in AVO and/or transit usage
3. Generate revenue	Generate net revenues	Calculate difference between revenue and costs for conversion
4. Develop a sustainable transportation system	Reduce emissions	Calculate emissions (Nitrous oxides (NOx), VOC, Carbon monoxide (CO), Particulate matter) for both MLs and GPLs
	Reduce fuel usage	Calculate fuel usage for both MLs and GPLs
	Maximize use of existing infrastructure	Vehicle counts
		Increase in Average Vehicle Occupancy (AVO) and/or transit usage
	Pay for itself (operations and maintenance covered)	Revenue versus costs
		Acceleration of construction
5. Improve net societal benefits	Improve benefits to society	Calculate net societal benefits and costs. Costs include construction costs, O&M costs, and capital costs. Benefits include travel time savings, fuel savings, and emissions savings.
		Acceleration of construction.
	Improve social equity	Benefits of the lane to different income/ethnic groups.
6. Enhance and support emergency management operations	Enhance and support emergency management operations	Reduced response time to emergencies
		Additional evacuation route

The survey could be designed to capture information for a typical trip of a respondent on one of the major roads in Houston and Dallas, or it could be designed to gather data on the most recent trip by the survey respondent on a major road in Houston and Dallas. It was assumed that capturing typical trip information would be more representative of the traveler and their behavior than the most recent trip. Therefore, questions were asked the respondent's typical trip. Asking about a typical trip was also helpful in knowing the respondent's usage of toll roads and payment for parking.

The first section of survey contained questions relating to trip purpose, trip time, trip origin and destination, trip length, vehicle mode, and number of trips undertaken. Based on the vehicle mode chosen (SOV, carpool, vanpool, transit, or motorcycle) the remainder of the trip related questions were asked appropriately. For example, the carpoolers were asked to rank various factors affecting carpooling. Additional information about carpool formation was also collected. SOV travelers were asked the reasons for not carpooling (see *Appendix B* for the survey instrument).

The second group of survey questions was designed to gather information about the respondents' opinion of managed lanes. The managed lane opinion questions asked about factors affecting likely usage or non-usage of the managed lanes. Other questions in the managed lanes opinion section were asked to gauge the opinion of traveler's regarding managed lane options such as variable tolls, SOVs being allowed to use managed lane after paying toll, and other factors which might encourage travelers to use managed lanes more often.

The third group of survey questions consisted of stated preference questions. In the stated preference questions, the respondent was given four scenarios, each with six modes: SOV in the ML, HOV2 in the ML, HOV3+ in the ML, SOV in the general purpose lane (GPL), HOV2 in the GPL, and HOV3+ in the GPL.

The fourth group of survey questions was designed to gather information about travelers' socio-economic characteristics including: age, gender, ethnicity, household type, number of people in the household, number of vehicles in the household, occupation, education level, and annual household income. At the end of the survey, respondents had an option of supplying their information so that they could become part of future transportation research. They could also include general comment on MLs or transportation in general.

3.1.1 Selection of Target Respondents

The target group of respondents was focused on potential travelers of the managed lanes. The survey target group could be HOV travelers, carpoolers/vanpoolers, frontage road travelers, transit riders, or SOV travelers on the general purpose lanes of freeways. Since all these travelers could potentially switch to Managed Lanes, all these travelers comprised the target group. Travelers in Houston and Dallas were targeted since these cities already have HOV lanes and have plans for multiple managed lanes.

3.1.2 Selection of Mode Choice Factors

The literature search revealed three main reasons for SOV travelers to switch to carpooling or vanpooling:

Travel Time Savings: Travel time savings is an important factor in mode selection. Driving alone is attractive to travelers because they save time as they don't have to spend time forming (picking up or dropping off a passenger) a carpool *(50, 51, 52).*

Convenience: In absence of any carpooling incentive on the part of employers or any other agency, driving alone is often seen as the most convenient mode in Houston and Dallas. However, this can change if any external agency intervenes to make carpooling or transit more convenient *(50, 51, 52, 53).*

*Cost***:** Carpooling becomes cost-effective as the travelers can share costs of using the vehicle. Government or employer subsidies may lower the cost even further. This induces travelers to carpool and vanpool *(51, 52)*. Parking cost, however, is even more important determinant of the single occupant travelers switching to a carpool *(53)*.

However, trying to include all of these factors in a stated preference question would result in an overly complex question. Therefore respondents chose mode based on travel time and toll cost only.

The researchers also wanted to identify reasons why current Houston and Dallas SOV travelers choose not carpool. Respondents were provided a list of potential reasons, including:

- Not able to find someone with the same location and schedule
- The person with an option to carpool with having non-matching traits (such as a being a smoker, excessive talker, etc.)
- Flexibility of time and car usage if not having to carpool
- Vehicle need during the day
- Having other stops to make, like shopping or picking up kids
- Incompatibility in listening to radio
- Value solitude while traveling
- Other

The information gathered from both the stated preference questions and the reasons for not carpooling would help researchers understand the respondents' current mode choice. After the survey questionnaire was formulated; the next task was to conduct the survey. The following sections describe this task in detail.

3.2 Survey Technique Selection

The survey could be administered by different techniques. Various techniques considered for survey distribution included:

- Laptop survey

- Mail (paper) survey to travelers
- Telephonic survey
- Online web-based survey
- Mail paper survey to travelers after license plate capture
- Household interviews
- Email survey

To decide the most appropriate technique for survey administration, the following issues were considered:

- The ability to ask stated preference questions
- The cost of conducting the survey
- The expected response rate
- The potential sampling error
- The time required to conduct the survey
- The interactivity of the survey technique
- The privacy of the survey respondent
- Any training needed for the personnel
- The number of resources required for conducting the survey

Based on the above criteria, an online survey followed by a targeted paper and laptop survey was found to have maximum utility. The reason for this was that an online survey would be useful for stated preference questions but certain travelers, particularly low income travelers, may not have easy access to the internet. Laptop surveys and paper surveys were used to gain additional responses from the unrepresented groups. Institutional Review Board (IRB) at Texas A&M University approved the survey.

3.3 Survey Advertisement and Data Collection

The internet survey was advertised using newspaper articles, TV news, push cards given at tollbooths and links on different websites. The North Texas Tollway Authority

(NTTA), the North Central Texas Council of Governments (NCTCOG), the Harris County Toll Road Authority (HCTRA), the Metropolitan Area Transit Authority (METRO), the TREK (Houston TMA), the Dallas/Houston TTI offices, and six Houston Libraries handed out push-cards. In all, over 32,000 cards were provided for handout. An analysis of survey respondents indicated that majority of the Houston survey respondents learned of survey from a newspaper article, while in Dallas they learned of the survey from a link on a website *(Table 8).*

Table 8: Source from which respondents learned about the survey

Source of survey knowledge	Percentage of survey respondents	
	Dallas	Houston
News Article	4.4	36.8
TV News Report	0.1	2.6
Tollbooth Card	2.4	0.6
Bus / Train Card	0.1	0.1
Employer Email	7.8	5.7
Website Link	50.6	35
Family / Friend	5.1	8.3
Other / No Answer	29.5	10.7

When it was found that over-all sample size had met the requirements of the data collection, but the sample sizes for low income Hispanics and African-American were too small, it was decided to conduct paper surveys and laptop surveys by visiting Department of Public Safety (DPS) offices in Houston and Dallas. Paper and laptop surveys were also conducted at a community center in Houston. These sites were selected based on the ethnic and economic status of the surrounding neighborhood. For administering the paper and laptop surveys, researchers approached people at driver license offices and asked them to complete the surveys. They hung posters in Spanish and English to publicize the survey at the survey sites.

In both Houston and Dallas, the majority of the respondents completed the survey online *(Table 9).*

Table 9: Survey administration source

Survey Type	Dallas	Houston	Total
Web Based (Online)	1852	2405	4257
Laptop survey	49	85	134
Paper	135	85	220
Total	2036	2575	4611**
**Location of 46 surveys was unknown and 23 surveys were duplicates. Therefore, total number of surveys was 4611+23=4634			

After survey data has been collected, the next step was to reduce the survey data for analysis. The following section describes the process in detail.

3.4 Survey Data Reduction

The online survey was designed to reduce the potential for erroneous answers to many of the survey questions. One way to do this was to use radio buttons and checkboxes as design tools. Radio buttons allow only one alternative to be chosen. Therefore, it was very useful in questions when only one alternative should be selected. Checkboxes were useful for multiple choice answers. In the answers where text entries were made, the answers were checked for logical consistency. For example, extremely high values for typical trip length, typical toll paid per day, number of trips per week, number of vehicles in the household were carefully examined and frequently discarded.

The survey was designed such that only relevant questions were asked of each respondent based on their mode of travel. For example, questions posed to SOV travelers were different from carpoolers, vanpoolers and transit riders. A different set of questions were received by those travelers who indicated an interest in using managed lanes than from the travelers who did not want to use managed lanes. This helped to keep errors to a minimum, and shorten the survey length for respondents.

All the respondents did not answer all the questions. Socio-economic information such as income, age, gender, ethnicity, household type, number of people in the household, number of vehicles in the household, education level, and occupation type was not answered by some of the respondents. Other critical information such as location, trip purpose and whether interested in using managed lanes was also missing. 403 respondents did not answer question regarding income, 160 respondents did not provide ethnicity information, and 310 respondents did not provide information about number of people in the household. Among socio-economic information, the least answered question was the question about household income. 325 respondents did not answer whether or not they would be interested in using managed lanes. The responses with missing values were not deleted from the survey. However, 23 responses were deleted from the original survey because they were duplicate entries of other questions.

After cleaning and reducing the data it was found that the socio-economic profile of the respondents was not same as socio-economic profile of Dallas and Houston travelers. A simple analysis of survey responses would not have been representative of Dallas and Houston travelers. The next section describes the weighting process by which the survey responses were adjusted to become more representative of the population.

3.5 Weighting the Data

Weighting is the procedure to adjust the distributions of respondents in the sample data to approximate those of the target population. The aim is to make the sample data better reflect the answers of the target population, and to reduce the non-response bias in the survey estimates. This process reduces non-response error (error which arises because characteristics of the respondents are different from the non-respondents). One of the ways in which a non-response error could have been introduced in the survey is that low income travelers do not have easy access to the internet. This could result in too few taking the survey, causing overall survey results to improperly reflect their opinion. An effort was made to minimize this problem by using paper surveys administered in low income neighborhoods, but even including these surveys their response rate was still lower than their portion of the population.

Another issue with weighting is that the stratification of the survey respondents has to be done such that each category contains at least the required minimum number of responses. If a category has very few respondents than the responses of those travelers cannot be extrapolated to represent the population responses of that category. Therefore, some ethnicity categories such as Asians, Native Americans, and others were combined into single category of ‘Others’. This was done even though there were responses in each individual category.

The weights were derived using an iterative technique that simultaneously balances the distributions of two weighting parameters – the income and ethnicity parameter and toll road usage parameter. The process was similar to a raking procedure *(54, 55)*. The only difference between raking procedure and the one adopted in the survey involved multiplying each weight by the previous weight in each step. It was observed that this led to a faster convergence of the sample to the population as compared to a simple raking procedure. Details of the procedure are provided in section 3.5.1.

3.5.1 General Weights

The following steps were used to weight the survey data: To begin, an estimate of the entire traveler population was performed. Dallas, Tarrant, Collin, and Denton counties were considered to be the entire traveling population in Dallas. Population estimates were obtained from the American Community Survey *(56)*. *Table 10* contains a breakdown of the population of these four counties by income and ethnicity. *Table 11* contains the percentages of survey respondents in Dallas broken into those same categories.

Table 10: Dallas population

	Caucasian	African-American	Hispanic	Others
Less than $25,000	11.27%	10.10%	2.09%	4.39%
$25,000 to $49,999	11.42%	10.85%	2.38%	5.51%
$50,000 to $99,999	14.47%	6.63%	2.40%	4.10%
$100,000 or more	9.79%	1.77%	1.21%	1.63%

Table 11: Dallas survey respondents

	Caucasians	African-American	Hispanic	Others
Less than $25,000	2.34%	2.17%	1.56%	0.95%
$25,000 to $49,999	9.58%	2.34%	2.34%	0.95%
$50,000 to $99,999	29.90%	2.51%	1.61%	2.28%
$100,000 or more	35.52%	1.34%	1.61%	3.01%

In Houston, Harris County was considered to be the entire traveling population. *Table 12* contains the percentage within each income and ethnicity category in the Houston population. The source of data was the American Community Survey. *Table 13* contains percentage within each category in the survey for Houston respondents.

Table 12: Houston population

	Caucasian	African-American	Hispanic	Others
Less than $25,000	7.23%	7.14%	9.89%	4.32%
$25,000 to $49,999	8.75%	5.25%	9.44%	4.64%
$50,000 to $99,999	13.43%	3.88%	5.94%	3.86%
$100,000 or more	11.99%	1.06%	1.50%	1.68%

Table 13: Houston sample

	Caucasians	African-American	Hispanic	Others
Less than $25,000	2.28%	1.37%	2.15%	0.47%
$25,000 to $49,999	10.13%	2.06%	3.22%	0.77%
$50,000 to $99,999	29.67%	2.49%	3.22%	3.13%
$100,000 or more	32.67%	1.63%	2.15%	2.58%

The second step was to develop initial weighting factors. The formula for the weighting factor was:

Weighting factor = % *census / % sample* (5)

where

% census was the percentage of people within a category of ethnicity and income in the population, and

% sample is the percentage of survey respondents within a particular category of ethnicity and income in the survey

The initial weighting factors for Dallas (*Table 14*) and Houston (*Table 15*) were obtained using Equation 5.

Table 14: Dallas weighting factors

	Caucasians	African-American	Hispanic	Others
Less than $25,000	4.82	4.65	1.34	4.64
$25,000 to $49,999	1.19	4.64	1.02	5.82
$50,000 to $99,999	0.48	2.64	1.48	1.8
$100,000 or more	0.28	1.32	0.75	0.54

Table 15: Houston weighting factors

	Caucasians	African-American	Hispanic	Others
Less than $25,000	3.18	5.19	4.61	9.16
$25,000 to $49,999	0.86	2.55	2.93	6.00
$50,000 to $99,999	0.45	1.56	1.84	1.23
$100,000 or more	0.37	0.65	0.70	0.65

The second step was to weight the survey data using the weighting factors from *Table 14, and Table 15*.

The third step was to reweight the weighted survey data based on toll road usage. Annual Average Daily Traffic (AADT) data for toll and non-toll roads were obtained from Dallas and Houston AADT maps. The total AADT for toll and non-toll roads used here is listed in *Table 16*. *Table 17* contains the number of toll road and non-toll road survey respondents. The weighting factors were obtained using Equation 6.

$$Weighting\ Factor_{Toll} = \frac{\%\ AADT_{toll\ road\ traffic\ data}}{\%\ AADT_{toll\ road\ survey}} \quad (6)$$

where $\%\ AADT_{toll\ road\ traffic\ data}$ is the percentage of AADT on toll roads (the AADT on toll roads divided by the AADT on both toll and non-toll roads). $\%\ AADT_{toll\ road\ survey}$ is the percentage of toll road travelers in the weighted survey sample. Similarly, weighting factors for non-toll road travelers was obtained using Equation 7.

$$Weighting\ Factor_{Non-Toll} = \frac{\%\ AADT_{general\ road\ traffic\ data}}{\%\ AADT_{general\ road\ survey}} \quad (7)$$

where $\%\ AADT_{general\ road\ traffic\ data}$ is the percentage of AADT on non-toll roads (the AADT on non-toll roads divided by AADT on both toll and non-toll roads). $\%\ AADT_{general\ road\ survey}$ is the percentage of non-toll road travelers from the survey sample. The derived weights are summarized in Table 18.

Table 16: Total AADT data (in thousands) and percentage AADT data from Houston and Dallas

Population	Number	Percentage
Toll road travelers	342	8.2%
Non-toll road travelers	3807	91.8%

Table 17: Weighted survey sample number respondents and percentages in each category

Population	Number	Percentage
Toll Road travelers	945	20.6%
Non-toll road travelers	3643	79.4%

Table 18: Toll road, non-toll road weights

Category	Weighting factor
Toll road	0.422
Non-toll road	1.14

The fourth step was to find the combined weight for each survey respondent using weights from income and ethnicity in step 1 and toll road and non-toll road travelers in step 3. This weight was multiplication of weights in Step 1 and Step 3.

The fifth step was to weight the sample by weights derived in step 4. Steps 1 to 3 are repeated with the weighted samples iteratively. This iterative procedure is terminated when the sample percentages were very close to the population percentages in each income and ethnicity category for both Houston and Dallas and the percentage of toll road usage is same as given by AADT. The sample percents converged to population percent after nine steps. The final weights are depicted in *Tables 19, 20, 21, and 22*.

Table 19: Weighting factors for Dallas respondents who used a toll road

	Caucasians	African-American	Hispanic	Others
Less than $25,000	1.963	1.634	0.481	1.674
$25,000 to $49,999	0.515	1.677	0.373	2.387
$50,000 to $99,999	0.225	0.965	0.616	0.796
$100,000 or more	0.133	0.509	0.296	0.247

Table 20: Weighting factors for Dallas respondents who did not use a toll road

	Caucasians	African-American	Hispanic	Others
Less than $25,000	5.540	4.611	1.357	4.723
$25,000 to $49,999	1.454	4.730	1.054	6.736
$50,000 to $99,999	0.636	2.723	1.739	2.247
$100,000 or more	0.375	1.435	0.834	0.698

Table 21: Weighting factors for Houston respondents who used a toll road

	Caucasians	African-American	Hispanic	Others
Less than $25,000	1.315	2.111	1.841	3.637
$25,000 to $49,999	0.356	1.082	1.146	2.328
$50,000 to $99,999	0.183	0.671	0.754	0.496
$100,000 or more	0.148	0.279	0.294	0.270

Table 22: Weighting factors for Houston respondents who did not use a toll road

	Caucasians	African-American	Hispanic	Others
Less than $25,000	3.712	5.958	5.194	10.261
$25,000 to $49,999	1.003	3.054	3.234	6.568
$50,000 to $99,999	0.516	1.894	2.127	1.398
$100,000 or more	0.417	0.788	0.831	0.762

Using the procedure outlined in this section, weights were derived for each of the income and ethnicity categories for Houston and Dallas. The weights listed in *Tables 19, 20, 21, 22* are the general weights created from the iterative procedure described here.

3.5.2 Replicate Weights

Obtaining the general weights was only the beginning. Additional weighting, using replicate weights was necessary for portions of the data analysis. The need for additional steps is outlined in the following paragraphs.

Survey sampling design is generally not simple random sampling (SRS). Surveys using SRS will require much greater financial resources to obtain the same amount of required data. In addition, other sampling methodologies have benefits in terms of data analysis (they can reduce standard errors). In the ML survey conducted in Houston and Dallas, the collected data was stratified based on income and ethnicity. In other words, the sampling design for the ML survey was SRS followed by post-stratification.

Due to this data collection method, the statistical formulas and methods developed for SRS to perform survey analyses were inappropriate. SRS would imply that for each stratum, the proportion of respondents in the sample was the same as the proportion in the entire population. For example, if the surveying sampling plan was SRS and the proportion of Caucasians with annual household incomes less than twenty-five thousand dollars was 10 percent in the population then it would need to be 10 percent in the survey sample as well. The ML survey sample proportions were not equal to population proportions for each stratum. Post-stratification adjustment using weighting was carried out to adjust the sample proportions to equal the population proportions. Therefore, one has to use appropriate formulas and methods for analyzing data from this survey design and not use the formulas and methods developed for SRS.

The sampling weights are random if the sampling plan is not SRS. They cannot be used like fixed weights to conduct tests of proportions or for testing other hypotheses. This is because a non-SRS methodology results in higher standard errors (SE) for the estimates. An assumption of fixed weights (with SRS) would imply lower SE. Thus, using fixed weights may lead to some results from non-SRS surveys being found statistically significant when in fact they are not. Therefore different analyses are required for survey data collected using a non-SRS method.

To correct for the estimation of standard errors in non-SRS survey data two methods are often used: Taylor series linearization and creation of replicate weights (*57*). Common software packages such as SPSS and SAS do not include all the methodologies for replicate weight creation and analysis. Therefore, specialized software packages such as WesVar, or STATA (Version 9.0 and higher for Jackknife-n functionality) are necessary. The paragraphs below outline the process of creation of replicate weights for data analysis in this research.

3.5.3 Replicate Weights Creation

Replicate weights are used to get a better approximation of the standard error of the full sample estimates. The method used to calculate replicate weights begins with dividing the sample into sub-strata. Next, the estimate of interest is calculated from the sub-strata and the full sample. The difference between the estimates of interest in the full sample and each of the sub-strata is used to get the standard error of the estimate.

Suppose $\hat{\theta}$ is the full-sample estimate of some population parameter θ, for example, the mean. The variance estimation $\sigma^2(\hat{\theta})$, is given by Equation 8 (*58*)

$$\sigma^2(\hat{\theta}) = c\sum_{g=1}^{G} (\hat{\theta}_g - \hat{\theta})^2 \qquad (8)$$

Where

$\hat{\theta}_g$ is the estimate of θ based on the observations included in the g^{th} replicate,

G is the total number of replicates formed, and

c is a constant depending on the replication method *(56)*. For Jackknife-n c = 1.

Different methods of creating sub-samples yield different kinds of replicate weights. The replicate weight design includes balanced repeated replication (BRR), jackknife (JK-1, JK-2, JK-n), and successive differences. The selection of methodology depends on the sample design. Since the ML survey had more than 2 Primary Sampling Units (PSU) per strata (Houston road, Dallas road, neither of given roads in Houston or Dallas, or missing location), JK-n method was the only appropriate method. Therefore, JK-n replicate weights were created for the ML survey.

For the JK-n method, the formula for variance estimation is modified. The formula for the variance estimate is given in Equation 9 (*59*).

$$\sigma^2(\hat{\theta}) = c\sum_{g=1}^{G} f_g\, h_g\, (\hat{\theta}_g - \hat{\theta})^2 \tag{9}$$

where:

f_g is the Finite Population Correction (FPC) factor.

The formula for the FPC is:

$$FPC \;=\; [\,(N-n)\,/\,(N-1)\,]^{1/2} \tag{10}$$

where N is total population and n is total sample size *(57)*. For the ML survey FPC values were:

Houston: 0.999103

Dallas: 0.999480

In both cases the FPC was close to 1. The FPC is always less than or equal to 1 (equals one only if all the elements of the population are sampled).

h_g is a factor specific to JK-n methodology

The number of replicates, *G,* is equal to

$$G = \sum_{h=1}^{L} n_h \tag{11}$$

where L is number of strata (12 in our case) and n_h (varies from 2 to 4) is number of PSU in the stratum h.

The methodology for replicate weight creation is given in detail in WesVar Manual (*60*). The following paragraph is adapted from the manual.

> For computation of first replicate weight, the full sample of observations in the first stratum and first PSU are given a weight of zero and the weights associated with the other PSU in the same stratum are adjusted by $n_h / (n_h - 1)$ (in our case often 2) to account for reducing the sample. The weights for observations in all

the other strata are not changed. The remaining replicates for the stratum (weights and θ_g) are formed in the same manner by systematically dropping each of the remaining PSUs for that stratum and computing the replicate weights in a manner similar to computation of the first replicate weight. (60). Then all the stratum are done in the similar manner.

STATA was used to create 39 JK-n replicate weights (G = 39) for the ML survey.

The general weights (discussed in section 3.5.1) were used as initial weights in the Jackknife process.

3.6 Check of Weighted Data

The weighted survey data should have same proportions of respondents as the entire population for the categories considered in the weighting process. For example, the proportions for income and ethnicity for weighted survey data should be the same as the census data. This was accomplished with the weighting process outlined in this chapter. In addition, if the weighting procedure adjusts the proportions of other socio-economic categories, such as gender to equal the census data, one can deduce that procedure was very successful. To test this, gender distribution in the survey data was examined before and after weighting. The results seemed reasonable. In the unweighted survey data, females constituted 40 percent of the respondents while census data revealed this should be 50 percent. In the weighted survey data females constitute 48 percent of the respondents.

3.7 Summary Section

Survey data collection was a challenging task as an adequate number of travelers from each socio-economic category were needed. Since online survey was not successful in collecting adequate number of responses for low-income travelers, paper and infield laptop survey was conducted.

The survey data was weighted by general weights to make it representative of the traveler population.

The weighted data was used for survey analysis. Replicate weights were developed for computation of differences in interest in using managed lanes. The result from this analysis is summarized in Chapter IV. The normal weights were used for mode choice modeling, the results from which have been summarized in Chapter V.

CHAPTER IV

RESULTS*

Chapter IV reviews the findings from survey data analysis. To begin, general results from the survey are listed (see *Table 23*). These results are weighted using the weights developed in previous Chapter (see Tables *19*, *20*, *21*, *22*).

Table 23: Survey results (weighted)

Descriptive Analysis			
Variables	**Dallas**	**Houston**	**Over all**
Age (years)	41.5	37.3	39.0(12.7) +
Age (Percent travelers)			
25 to 34	13.6	8.4	11.4(0.36) +
35 to 44	35.2	26.5	31.7(0.45) +
45 to 54	22.7	24.9	23.7(0.38) +
55 to 64	19.2	22.5	20.6(0.35) +
16 to 24	7.6	13.5	10.0(0.26) +
65 and over	1.7	4.3	2.7(0.15) +
Income (Thousand dollars)	63.0	59.1	61.0(49.2) +

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* Part of the data reported in this chapter is reprinted with permission from "Reaction to the Managed Lane Concept by Various Groups of Travelers" by Mark W. Burris, Kaveh F. Sadabadi, S. Mattingly, Maneesh Mahlawat, J. Li, I. Rasmidatta, and A. Saroosh, 2006, *TRB 86th Annual Compendium of Papers CD-ROM*. 22p, 2006.

Table 23 continued:

Descriptive Analysis			
Variables	**Dallas**	**Houston**	**Over all**
What was your annual household income before taxes in 2005? (Percent travelers)			
Less than $10,000	10.4	8.3	9.1(0.32) +
$10,000 to $15,000	4.0	9.4	7.2(0.29) +
$15,0000 to $25,000	9.4	10.5	9.9(0.33) +
$25,000 to $35,000	9.0	10.4	9.8(0.25) +
$35,0000 to $50,000	18.9	17.4	18.0(0.25) +
$50,000 to $75,000	15.0	14.3	14.6(0.19) +
$75,000 to $100,000	15.1	12.8	13.7(0.19) +
$100,000 to $150,000	11.9	10.8	11.3(0.09) +
$100,000 to $150,000	11.9	10.8	11.3(0.09) +
$150,0000 to $200,000	3.8	3.6	3.7(0.08) +
More than $200,000	2.7	2.5	2.6(0.06) +
Gender (Percent travelers)			
Female	41.1	53.7	48.4(0.47) +
Male	58.9	46.3	51.6(0.47) +
Occupation type (Percent travelers)			
Professional	44.9	40.4	42.2(0.38) +
Technical	12.3	11.4	11.7(0.28) +
Sales	5.7	3.5	4.3(0.20) +
Administrative	11.0	17.5	14.9(0.35) +
Service	1.6	1.1	1.3(0.14) +
Manufacturing	2.4	2.8	2.6(0.18) +
Stay at home	1.7	3.6	2.9(0.19) +
Student	4.9	7.8	6.7(0.30) +
Self employed	5.6	5.0	5.2(0.25) +
Unemployed	2.6	1.9	2.2(0.19) +
Retired	4.1	1.8	2.7(0.16) +
Others	3.1	3.3	3.2(0.19) +
Including yourself, how many people live in your household	2.6	2.9	2.7(1.39) +
How many motor vehicles are available for use by members of your household?	2.1	2.1	2.1(1.04) +
How many miles is your typical trip on the selected road?	19.8	21.6	20.8(0.89) +

Table 23 continued:

Descriptive Analysis			
Variables	**Dallas**	**Houston**	**Over all**
Ethnicity (Percent travelers)			
Caucasian	55.8	43.8	48.6(0.01) +
Hispanic	14.4	16.4	15.6(0.01) +
Afro-American	17.9	25.7	22.5(0.01) +
Asian	4.4	8.2	6.7(0.14) +
Others	2.5	1.0	1.6(0.12) +
Native American	5.0	5.0	5.0(0.15) +
Household type (Percent travelers)			
Single	29.9	27.3	28.4(0.45) +
Unrelated adult	7.3	6.3	6.7(0.25) +
Married without a child	20.4	17.9	18.9(0.33) +
Married with children	32.5	34.8	33.9(0.40) +
Single parent	6.9	9.8	8.6(0.28) +
Others	3.0	3.9	3.5(0.19) +
Education level (Percent travelers)			
Less than High School	4.2	4.0	4.1(0.24) +
High School Graduate	12.2	15.4	14.1(0.35) +
Vocational	27.3	33.1	30.8(0.44) +
College Graduate	35.1	32.6	33.6(0.40) +
Post Graduate	21.3	14.9	17.5(0.31) +
Do you have to pay to park at your destination?			
Yes (Percent)	14.7	17.3	16.3(1.90) +
If you do pay for parking; how much does parking at destination cost per day?	4.8	5.5	5.3(0.44) +
Percent people who pay toll	26.0	25.0	25.4(2.1) +
Percent people who use bus	4.8	11.7	8.9(1.3) +
How much is the toll or bus/train fare?	1.9	2.7	2.4(0.17) +
How many trips do you make during a full week (Monday to Sunday) on the selected road for the same trip purpose?	7.9	8.4	8.2(0.40) +
How much extra time does it take you to pick up and drop off the passenger(s) in your carpool?	6.2	10.3	9.0(1.82) +
Of your trips per week on the selected road, how many trips do you carpool?	5.0	5.5	5.4(0.55) +
How much extra time does it take you to pick up and drop off the passenger(s) in your vanpool?	24.1	11.6	14.0(2.27) +
Of your trips per week on the selected road, how many trips do you vanpool?	2.3	4.6	4.2(0.46) +

Table 23 continued:

Descriptive Analysis			
Variables	**Dallas**	**Houston**	**Over all**
What is the main purpose of most (or all) of these trips? (Percent travelers)			
Commute	58.1	62.3	60.6(2.5) +
Recreational (includes social, shopping, errands, entertainment),	21.1	15.2	17.6(2.1) +
Work (work related, not commuting)	15.8	15.6	15.7(1.9) +
School	2.6	4.7	3.9(1.2) +
Other	2.3	2.3	2.3(0.8) +
What is your primary reason for traveling by bus or train? (Percent travelers)			
Cheaper than driving a car	23.3	14.3	17.7(5.4) +
Convenient to use bus/train	46.7	50.2	48.8(5.6) +
Bus/train runs frequently	9.5	5.1	6.8(4.1) +
Trip takes less time than by car	1.6	9.2	6.3(3.4) +
No car available	9.5	9.0	9.2(3.9) +
Other	9.4	12.2	11.1(5.3) +
Who do you generally carpool with? (Percent travelers)			
Co-worker / person in nearby office	25.1	21.4	22.7(4.3) +
Neighbor	1.5	2.4	2.1(1.3) +
Adult family member	56.1	44.3	48.4(5.4) +
Casual carpool	2.4	6.0	4.8(2.3) +
Child	12.5	20.2	17.5(3.7) +
Other	2.4	5.7	4.6(1.9) +
(.) + is standard error calculated using Replicate weights			

4.1 Respondents Interest in Using Managed Lanes

The survey data was analyzed using the replicate weights created using Jackknife procedure outlined in Chapter III. In this section, the difference in interest in using managed lanes was analyzed for both Houston and Dallas travelers based on socio-economic characteristics such as income, ethnicity, travel mode, number of vehicles in the household, education levels, gender and other characteristics such as trip purpose.

Standard deviation needed for calculation of p-value was estimated using replicate weights.

4.1.1 Toll-road Travelers' and Non-toll-road Travelers' Interest in Using Managed Lanes

There was considerable interest in using managed lanes across both the toll-road travelers and non-toll-road travelers. For all travelers, a significantly higher percentage of Dallas travelers (72.0 percent) were interested in using managed lanes than Houston travelers (68.4 percent) (statistically significant at 0.05 level (see *Table 24*)).

Table 24: Interest in using managed lanes for both toll-road and non-toll-road travelers

Toll road traveler	Number of respondents (weighted)		Interested in using ML? (Yes)				
			Number(weighted)		Percentage		
	Dallas	Houston	Dallas	Houston	Dallas	Houston	p-value
Yes	421	526	324	376	76.9%	71.4%	0.300
No	1202	1614	845	1088	70.3%	67.4%	0.283
Total	1623	2140	1169	1464	72.0%	68.4%	0.039

4.1.2 Interest in Using Managed Lanes across Income Categories

When the interest in managed lanes is compared across different income levels, it was found that travelers with household incomes greater than $100,000 per year had significantly higher interest in using managed lanes than travelers with annual household incomes less than $25,000 and travelers with annual household incomes between $50,000 and $100,000 (see *Table 25).*

Table 25: Comparison of interest in managed lanes across income categories

Household Income Group	Number of Responses (weighted)	Interested in ML (weighted)		p-value			
		Number	%	<$25K	$25K-$50K	$50K-$100K	>$100k
<$25k	1075	721	67.10%	--	0.384	0.399	0.030
$25k-$50k	1132	778	68.70%	0.384	--	0.374	0.109
$50k-$100k	989	671	67.90%	0.399	0.374	--	0.003
>$100k	623	490	78.70%	0.030	0.109	0.003	--

There was no statistically significant difference in interest in using managed lanes among all income categories in Dallas toll-road travelers compared to Houston toll-road travelers (see *Table 26*). There was no statistically significant difference in interest in using managed lanes among Dallas non-toll road travelers compared to Houston non-toll road travelers (see *Table 26*).

Table 26: Interest in using managed lanes for toll-road and non-toll-road travelers across different income categories in Houston and Dallas

Characteristic	**Percentage Interested in Using Managed Lanes**					
	Toll road traveler		**p-value**	**Non-toll road traveler**		**p-value**
Household Income	Dallas	Houston		Dallas	Houston	
Less than $25,000	74.60%	70.40%	0.367	62.20%	69.20%	0.27
$25,000 - $50,000	76.70%	76.60%	0.399	74.70%	64.60%	0.07
$50,000 - $100,000	72.90%	69.90%	0.348	69.10%	65.10%	0.23
Greater than $100,000	86.80%	83.90%	0.275	76.50%	76.30%	0.398

4.1.3 Interest in Using Managed Lanes among Different Ethnicities

When the interest in using managed lanes was compared across different ethnicities, it was found that travelers in “Others” category had a lower interest in using managed lanes than Caucasians, African-Americans, and Hispanics (see *Table 27*).

Table 27: Comparison of interest in managed lanes across ethnicity categories

Ethnicity	Number of Responses (weighted)	Interested in ML		p-value by Ethnicity			
		Number	%	Caucasian	African-American	Hispanic	Others
Caucasian	1966	1409	71.7%	---	0.146	0.717	0.000
African-American	794	547	68.9%	0.146	---	0.322	0.000
Hispanic	1022	726	71.0%	0.717	0.322	---	0.000
Others**	262	122	46.6%	0.000	0.000	0.000	---
Others** ethnicity category consists of travelers who did not belong to Caucasian, African-American, or Hispanic ethnicity categories							

There was no statistically significant difference in interest in using managed lanes for toll-road travelers compared with non-toll-road travelers for ethnicity categories, such as Caucasians, Hispanics, and others in both Houston and Dallas (see *Table 28*).

Table 28: Interest in managed lane concept for Dallas and Houston toll-road and non-toll lane travelers based on ethnicity

Characteristic	**Percentage Interested in Using Managed Lanes**					
	Toll road traveler		**p-value**	**Non-toll road traveler**		**p-value**
Ethnicity	Dallas	Houston		Dallas	Houston	
Caucasians	76.20%	75.30%	0.39	72.20%	71.40%	0.381
African-American	58.60%	68.80%	0.299	69.50%	72.40%	0.373
Hispanic	83.00%	70.50%	0.173	73.80%	68.30%	0.303
Others**	92.40%	84.60%	0.099	58.10%	52.20%	0.334
Others** ethnicity category consists of travelers who did not belong to Caucasian, African-American, or Hispanic ethnicity categories						

4.1.4 Interest in Using Managed Lanes by Trip Purpose

There was no statistically significant difference in interest between Dallas and Houston travelers for using managed lanes based on trip mode. This was true for travelers traveling on toll roads as well as non-toll roads (*see Table 29*).

Table 29: Interest in using managed lanes in Houston and Dallas based on trip purpose

Characteristic	Percentage Interested in Using Managed Lanes					
	Toll road traveler		p-value	Non-toll road traveler		p-value
Trip Purpose	Dallas	Houston		Dallas	Houston	
Commute	77.7%	76.1%	38.8%	73.3%	70.1%	0.320
Recreational	71.0%	78.0%	38.0%	65.3%	63.9%	0.396
Work	79.5%	74.3%	38.7%	69.5%	61.2%	0.318
School	96.0%	49.4%	23.6%	49.8%	69.1%	0.320
Other	72.2%	57.0%	38.4%	72.0%	78.3%	0.395

4.1.5 Interest in Using Managed Lanes Based on Mode Choice

When interest in using managed lanes was compared across different travel modes, it was found that there was no statistically significant difference in managed lane interest based on mode (see *Table 30*).

Table 30: Interest in Using managed lanes across mode

Mode	Total Respondents (weighted)	Number Interested (weighted)		p-value					
				SOV	**HOV 2**	**HOV 3+**	**Transit**	**Motorcycle**	**Vanpool**
SOV	2499	1777	71.1%	---	0.398	0.399	0.194	0.373	0.382
HOV-2	557	393	70.5%	0.398	---	0.398	0.275	0.370	0.385
HOV-3+	283	198	70.1%	0.399	0.398	---	0.312	0.376	0.383
Transit	474	281	59.3%	0.194	0.275	0.312	---	0.310	0.318
Motorcycle	78	64	82.4%	0.373	0.37	0.376	0.310	---	0.397
Vanpool	88	72	82.4%	0.382	0.385	0.383	0.318	0.397	---

There was no statistically significant difference in interest in using managed lanes between Dallas and Houston toll road users (see *Table 31*). There was no statistically significant difference in interest in using managed lanes between Dallas and Houston non-toll road users as well (see *Table 31*).

Table 31: Interest in Using managed lanes based on mode choice for both Houston and Dallas

Characteristic	Percentage Interested in Using Managed Lanes					
	Toll road traveler		p-value	Non-toll road traveler		p-value
Mode	Dallas	Houston		Dallas	Houston	
SOV	82.30%	81.40%	0.396	73.20%	67.30%	0.172
HOV-2	85.00%	89.50%	0.395	74.70%	65.30%	0.311
HOV-3+	94.70%	66.60%	0.33	57.80%	68.40%	0.354
Transit	55.10%	57.70%	0.393	61.10%	64.10%	0.395
Motorcycle	89.90%	59.50%	0.317	86.60%	78.00%	0.391
Vanpool	90.30%	91.00%	0.399	75.50%	79.50%	0.397

4.1.6 Interest in Using Managed Lanes Based on Number of Vehicles in the Household

When interest in using managed lanes was compared in different categories based on number of vehicles in the household, it was found that there was no statistically significant difference in using managed lanes across categories (see *Table 32*). Among categories based on number of vehicles in the household, there was no statistically significant difference in interest in using managed lanes between Houston and Dallas toll-road and non-toll road travelers (see *Table 33*).

Table 32: Comparison of interest in managed lanes across category based on number of vehicles in the household

Number of vehicles in the household	Number Responded (weighted)	Number Interested (weighted)		p-value				
				0	1	2	3	4+
0	38	24	63.4%	---	0.379	0.388	0.375	0.399
1	1172	810	69.1%	0.379	---	0.362	0.389	0.399
2	1734	1263	72.8%	0.388	0.362	---	0.384	0.366
3	628	445	71.0%	0.375	0.389	0.384	---	0.393
4+	384	231	60.2%	0.399	0.399	0.366	0.393	---

Table 33: Interest in using managed lanes in Houston and Dallas in different categories based on number of vehicles in the household

Characteristic	**Percentage Interested in Using Managed Lanes**					
	Toll road traveler		**p-value**	**Non-toll road traveler**		**p-value**
Number of Vehicles	Dallas	Houston		Dallas	Houston	
1	75.4%	64.0%	0.273	69.1%	70.3%	0.395
2	78.1%	82.4%	0.355	74.2%	68.3%	0.253
3	78.2%	70.0%	0.363	63.5%	73.7%	0.254
4+	78.8%	76.8%	0.397	71.0%	55.6%	0.240

4.1.7 Interest in Using Managed Lanes for Respondents Based on Respondent's Major Road

Respondents used different roads for traveling. However they had to indicate one road as major road which they used more often than other roads. The interest in using managed lanes for each road was variable, only 45.7 percent of the travelers on I-45 were interested in using managed lanes while all the travelers (100 percent interest) on Loop-12 were interested in using managed lanes (*Table 34*).

Table 34: Interest in using managed lanes on different roads

		Total number (weighted)	Interested in using MLs (weighted)	
	Houston Roads			
1	BW-8 Sam Houston	100	80	79.9%
2	I-10 East	126	81	64.1%
3	I-10 Katy	519	380	73.3%
4	I-45 Gulf	237	164	69.3%
5	I-45 North	301	178	59.3%
6	I-610 Loop	177	115	65.2%
7	SH-225 LaPorte	16	12	77.1%
8	SH-288 South	77	49	64.0%
9	US-59 Eastex	128	70	54.4%
10	US-59 Southwest	283	208	73.6%
11	US-290 Northwest	259	179	69.2%
12	None (Houston)	72	48	65.9%
	Dallas Roads			
12	None (Dallas)	136	91	66.6%
13	Dallas North Toll way	132	112	84.9%
14	East Loop 820	8	8	89.6%
15	I-20	86	62	72.0%
16	I-30	168	137	81.6%
17	I-35E	250	174	69.4%
18	I-45	16	7	45.7%
19	I-635	193	139	71.9%
20	Loop-12	22	22	100.0%
21	Pres. George Bush Turnpike	110	89	81.3%
22	SH-114	36	28	79.1%
23	SH-121	68	45	65.8%
24	SH-161	17	12	72.6%
25	SH-183	53	39	73.9%
26	SH-360	25	19	76.2%
28	US-175	16	10	61.3%
29	US-67	59	37	61.9%
30	US-75	341	219	64.1%
31	US-80	9	7	77.4%

4.2 Analysis of Factors for Indicating Interest in Managed Lane Usage

Comparative analysis of the reasons for being interested in using managed lanes for travelers using different modes indicated that travel time reliability was always among top three factors for Dallas travelers except the HOV3+ riders (vanpoolers have too small a sample size to derive any conclusion) (see *Table 35*). Probably time is not a significant constraint for HOV3+ riders. Ability to travel faster on a managed lane compared to a general purpose lane had a high score and was always chosen among the top three reasons for being interested in using managed lanes by travelers using different modes in Dallas (see *Table 35*). The third most important reason selected was unique for each mode. The SOV travelers ranked the ability to use the managed lanes without having to carpool or vanpool as the third most important characteristic while HOV 2, HOV3+, motorcyclists, and transit riders chose the reason that Managed lanes would be less stressful. The 'Other' factor always had a high score when it was chosen by the respondents; however it was chosen by very few travelers.

The reasons Houston travelers provided for using managed lanes were generally similar to reasons given by Dallas travelers. The SOV travelers value travel time reliability and ability to travel faster, while still being able to use managed lanes without having to carpool more than other characteristics of managed lanes. Travel time reliability was an important factor for travelers using any mode and scores consistently in top two reasons for all the travelers irrespective of the mode (*Table 36*).

Comparative analysis of all travelers (regardless of mode) indicating an interest to use managed lanes pointed to the fact that travel time reliability and the ability to travel faster on managed lanes were consistently among the top two reasons for the choice to use managed lanes (*Table* 37). SOV travelers indicated the ability to use managed lanes without having to carpool or use transit as third most important reason to use managed lanes. Not surprisingly, this feature of managed lane was not among top three reasons to use the managed lanes by travelers using any other mode. HOV2 and HOV3+ travelers indicated managed lanes being less stressful as third most important reason (*Table 37*). The HOV3+ travelers did not choose travel time savings among top three reasons (pointing to the fact that travel time savings were not as important to HOV3+ travelers). Analysis of ‘Other reason’ indicated that top three reasons in the ‘Other reason’ category could be categorized into travel time savings, reliability and safety in managed lane usage. The travelers seemed to be happy with the fact that there would not be trucks on the managed lanes.

Table 35: Comparative analysis of reasons to use managed lanes for Dallas travelers

	SOV		HOV2		HOV3+		Transit		Motorcycle		Vanpool		All	
Reason	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean
Able to travel alone and still use ML	994	4.3	150	4.1	41	4.2	76	3.8	23	3.4	8	4.8	1292	4.2
Able to use transit on the ML	16	2.8	1	5	2	3.8	76	3.8	.	.	.	.	95	3.6
Able to travel faster than GPL	997	4.5	149	4.6	43	4.4	77	4.4	23	4.5	8	4.8	1297	4.5
Travel time reliability	993	4.5	150	4.7	42	4.4	77	4.4	23	4.3	8	4.6	1293	4.5
Able to use carpool / vanpool on ML	970	2.4	146	4.2	41	3.6	77	3.6	23	2.2	8	3.6	1265	2.7
No large trucks on ML	994	4	149	4.5	42	4.5	76	4.3	23	3.9	8	4.8	1292	4.1
ML less stressful	992	4.1	150	4.6	41	4.6	77	4.3	23	4.1	8	4.5	1291	4.2
Other factor	121	4.3	21	4.3	3	5	12	4.2	5	5	4	3.1	166	4.3

#obs* is total number of respondents (weighted)

Rating scale: 1 (not at all important), 3 (somewhat important), 5 (very important)

Table 36: Comparative analysis of reasons for using managed lanes for Houston travelers

Reason	SOV		HOV2		HOV3+		Transit		Motorcycle		Vanpool		All	
	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean
Able to travel alone and still use ML	1105	4.3	220	4.0	75	3.8	138	3.9	34	4.3	61	4.1	1633	4.2
Able to use transit on the ML	19	2.2	3	4.4	2	3.3	137	4.2	.	.	1	5.0	162	4.0
Able to travel faster than GPL	1105	4.6	219	4.6	76	4.3	140	4.6	34	4.8	61	4.8	1635	4.6
Travel time reliability	1103	4.6	219	4.6	75	4.5	138	4.5	34	4.6	61	4.6	1630	4.6
Able to use carpool / vanpool on ML	1078	2.5	215	4.0	76	4.2	136	3.6	32	2.5	61	4.6	1598	3.0
No large trucks on ML	1097	4.2	220	4.4	76	4.6	136	4.4	34	4.0	61	4.5	1624	4.3
ML less stressful	1103	4.3	221	4.3	75	4.5	137	4.5	34	4.0	61	4.6	1631	4.3
Other factor	126	4.6	28	4.7	15	4.2	14	4.5	13	4.9	8	5	204	4.6
#obs* is total number of respondents (weighted)														
Rating scale: 1 (not at all important), 3 (somewhat important), 5 (very important)														

Table 37: Comparative analysis of reasons to use Managed lanes for all the travelers

Reason	SOV		HOV2		HOV3+		Transit		Motorcycle		Vanpool		All	
	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean
Able to travel alone and still use ML	2099	4.3	370	4.0	116	3.9	214	3.8	57	3.9	69	4.2	2925	4.2
Able to use transit on the ML	35	2.5	4	4.5	4	3.5	213	4.1	0	0	1	5	257	3.9
Able to travel faster than GPL	2102	4.6	368	4.6	119	4.3	217	4.5	57	4.7	69	4.8	2932	4.6
Travel time reliability	2096	4.6	369	4.7	117	4.5	215	4.5	57	4.5	69	4.6	2923	4.6
Able to use carpool / vanpool on ML	2048	2.4	361	4.0	117	4	213	3.6	55	2.4	69	4.5	2863	2.8
No large trucks on ML	2091	4.1	369	4.4	118	4.6	212	4.4	57	4.0	69	4.5	2916	4.2
ML less stressful	2095	4.2	371	4.4	116	4.5	214	4.4	57	4.9	69	4.6	2922	4.3
Other factor	247	4.4	49	4.5	18	4.3	26	4.4	18	4.9	12	4.4	370	4.4
#obs* is total number of respondents (weighted)														
Rating scale: 1 (not at all important), 3 (somewhat important), 5 (very important)														

4.3 Analysis of Travelers for Indicating Interest in Not Using Managed Lanes

Toll payment was the main reason cited by Dallas travelers for not being interested in using managed lanes. This was regardless of their current mode. The second reason cited by Dallas SOV travelers was that they have flexibility to travel at an uncongested time. The third most important reason cited by Dallas SOV travelers was that the ML program was complicated and confusing and the fourth reason was that they did not want toll transponder in their vehicles. Toll transponder usage was cited as important reason by Dallas HOV2 and HOV3+ travelers as well. The second most important reason cited by HOV2 travelers was that they had flexibility to travel at non-peak time (*Table 38*).

Houston travelers cited similar reasons for not using managed lanes. Houston SOV travelers cited the same reasons as Dallas travelers as top four reasons: toll payment, flexibility to travel at uncongested time, ML program being confusing, and not interested in having a toll transponder in using managed lanes. Carpoolers (HOV2 and HOV3+) cited unwillingness to switch to drive alone and flexibility to travel during uncongested times as top two and three reasons for not carpooling. Transit riders did not want to switch from using transit and cited that as second most important reasons for not being interested in managed lane usage. Motorcyclists and vanpool travelers did not have enough respondents to draw meaningful conclusions (*Table 39*).

Overall, toll payment was the main deterrent for traveler interest in using managed lanes, regardless of the mode. SOV travelers cited flexibility to travel at uncongested time as second most important reason. Carpoolers cited unwillingness to drive alone on managed lanes as second most important reason. Transit riders cited unwillingness to change mode as second most important reason (*Table 40*).

Analysis of 'Other reason' indicated that it was toll payment phrased in different ways. The top reason was that toll payment was double taxation as travelers had paid for road construction with gas taxes.

Table 38: Comparative analysis of reasons not to use managed lanes for Dallas travelers

	SOV		HOV2		HOV3+		Transit		Motorcycle		Vanpool		All modes	
	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean
Do not have a credit card to establish account	263	1.6	39	1.8	9	2.4	40	1.6	6	2.3	3	3.2	360	1.7
Use bus or train, and will not change	4	1.8	1	5.0	1	4.0	41	4.2	.	.	.	.	47	4.0
Do not want a toll transponder in my car	266	1.9	39	1.9	10	3.9	39	2.2	6	2.3	3	4.7	363	2.0
ML is complicated or confusing	265	2.3	39	2.3	9	3.2	37	2.6	6	1.9	3	2.1	359	2.3
I have flexibility to travel at less congested times	272	3.0	38	3.5	9	2.2	38	2.7	6	2.8	3	3.0	366	3.0
Do not want to pay the toll cost	276	4.2	41	3.8	10	3.9	39	3.8	6	4.4	3	5.0	375	4.1
Carpool. Will not switch to drive alone	.	.	35	3.0	8	2.4	.	.	.	.	.	.	43	2.9
Travel on uncongested roads. Will not switch to ML	7	3.9	2	3.2	.	.	1	3.0	.	.	.	.	10	3.7
Other factor	113	4.7	9	4.2	2	5.0	12	4.2	3	5.0	1	5.0	140	4.6
#obs* is total number of respondents (weighted)														
Rating scale: 1 (not at all important), 3 (somewhat important), 5 (very important)														

Table 39: Comparative analysis of reasons not to use managed lanes for Houston travelers

Reason	SOV		HOV2		HOV3+		Transit		Motorcycle		Vanpool		All modes	
	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean
Do not have a credit card to establish account	346	1.7	92	2.1	35	1.7	69	2.4	17	2.3	17	1.7	576	1.9
Use bus or train, and will not change	4	1.2	2	1.5	3	1.6	70	3.1	.	.	.	.	79	2.9
Do not want a toll transponder in my car	348	1.9	91	2.2	34	1.8	70	2.4	16	1.4	17	2.4	576	2.0
ML is complicated or confusing	345	2.2	91	2.4	36	2.4	69	3.0	17	2.3	18	2.5	576	2.4
I have flexibility to travel at less congested times	347	3.0	90	2.8	33	3.0	67	2.9	18	1.9	17	2.6	572	2.9
Do not want to pay the toll cost	366	4.4	91	4.3	36	4.2	74	4.0	18	4.8	18	4.6	603	4.3
Carpool. Will not switch to drive alone	.	.	89	3.7	33	3.2	.	.	.	.	.	.	122	3.6
Travel on uncongested roads. Will not switch to ML	9	4.4	1	3.0	1	2.0	1	1.0	1	1.0	.	.	11	4.0
Other factor	113	4.4	28	4.4	13	3.7	21	4.9	10	4.9	8	5.0	193	4.5
#obs* is total number of respondents (weighted)														
Rating scale: 1 (not at all important), 3 (somewhat important), 5 (very important)														

Table 40: Comparative analysis of reasons not to use managed lanes for all the travelers

Reason	SOV		HOV2		HOV3+		Transit		Motorcycle		Vanpool		All modes	
	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean	# obs*	Mean
Do not have a credit card to establish account	609	1.6	131	2	44	1.8	109	2.1	23	1.5	20	1.9	936	1.8
Use bus or train, and will not change	8	1.5	3	2.6	4	2.2	111	3.5	0	0	0	0	126	3.3
Do not want a toll transponder in my car	614	1.9	130	2.1	44	2.3	109	2.3	22	1.4	20	2.8	939	2
ML is complicated or confusing	610	2.2	130	2.4	45	2.5	106	2.9	23	1.3	21	2.4	935	2.3
I have flexibility to travel at less congested times	619	3	128	3	42	2.8	105	2.8	24	1.5	20	2.6	938	2.9
Do not want to pay the toll cost	642	4.3	132	4.2	46	4.1	113	3.9	24	2.1	21	4.7	978	4.2
Carpool. Will not switch to drive alone	0	0	124	3.5	41	3	0	0	0	0	0	0	165	3.4
Travel on uncongested roads. Will not switch to ML	16	4.2	3	3.1	1	2	2	2	1	1	0	0	23	3.6
Other factor	226	4.6	37	4.4	15	3.8	33	4.6	13	2.3	9	5	333	4.4

#obs* is total number of respondents (weighted)

Rating scale: 1 (not at all important), 3 (somewhat important), 5 (very important)

4.4 Analysis of Stated Preference Questions

The travelers could choose one among six modes in four stated preference questions. Each stated preference question was termed as a scenario, from which the travelers could choose one mode. The stated preference question methodology has been summarized in Section 2.5. The travelers chose to use different modes for different values of toll and travel time savings. For different toll values (greater than $0), 35.8 percent to 44.2 percent of travelers were willing to use managed lanes (*Table 41*). However, when the toll was greater than $10 per hour, this percentage was reduced between 23.8 percent and 33.9 percent (*Table 42*). 67.2 percent of Dallas travelers and 63 percent of Houston travelers chose to use managed lanes for at least one scenario (*Table 43*).

Table 41: Travelers willing to use one of the ML options (drive alone or carpool) for different scenarios

	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	Use one of ML options	Not use any ML option	Use one of ML options	Not use any ML option	Use one of ML options	Not use any ML option	Use one of ML options	Not use any ML option
Dallas	589	1057	619	983	663	907	688	869
Dallas	35.8%	64.2%	38.6%	61.4%	42.2%	57.8%	44.2%	55.8%
Houston	1082	1483	1060	1484	1244	1288	1212	1302
Houston	42.2%	57.8%	41.7%	58.3%	49.1%	50.9%	48.2%	51.8%

Table 42: Travelers willing to use one of the ML options (drive alone or carpool) for different scenarios when VOT> $10 per hour

	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	Drive alone in ML	Drive alone in GPL	Drive alone in ML	Drive alone in GPL	Drive alone in ML	Drive alone in GPL	Drive alone in ML	Drive alone in GPL
Dallas	259	828	110	335	137	306	150	292
Dallas	23.8%	76.2%	24.7%	75.3%	30.9%	69.1%	33.9%	66.1%
Houston	404	1162	152	516	200	424	215	456
Houston	25.8%	74.2%	22.8%	77.2%	32.1%	67.9%	32.0%	68.0%

Table 43: Number of travelers willing to pay a toll > $0 at least in one scenario

	ML pay toll		Total
	Yes	No	
Dallas	1361	664	2025
Houston	1532	898	2430
Dallas	67.2%	32.8%	
Houston	63.0%	37.0%	

4.5 Summary

A total of 72 percent of Dallas travelers and 68.4 percent of Houston travelers were interested in using managed lanes. When the interest in managed lane usage was compared across different socio-economic categories, it was found that in majority of the cases, interest in managed lane usage was not significantly different across the categories. There was no statistically significant difference in interest in using managed lanes based on travel mode, or number of people in the household. However, when the interest in using managed lanes was compared across income, it was found that travelers with annual household incomes greater than $100,000 had significantly higher interest than travelers with annual household incomes less than $25,000 or travelers with household incomes between $50,000 and $100,000. When the interest was compared across ethnicities, it was found that ‘Others’ category had significantly lesser interest in using managed lanes compared to Caucasians, African-Americans, or Hispanics.

Travel time reliability and ability to travel faster were indicated as top two reasons for interest in using managed lanes. This was true for all travelers regardless of mode. Toll payment was cited as important deterrent for interest in using managed lanes. SOV travelers cited flexibility to travel at uncongested time as second most important reason not to use managed lanes. Carpoolers cited an unwillingness to drive alone on managed lanes as second most important reason. Transit riders cited continuity to use transit as second most important for not being interested in managed lane usage.

Analysis of stated preference questions indicated that 67.2 percent of Dallas travelers and 63 percent of Houston travelers chose to use managed lanes for at least one scenario. For tolls greater than VOT of $10 per hour, 23.8 percent to 33.9 percent of travelers were willing to use managed lanes in each of the scenarios.

The stated preference questions have been analyzed in detail in Chapter V. The simple analysis (Section 4.5), though useful is not predictive. For mode prediction under different modes, one needs to build mode choice models and estimate mode choice under different scenarios.

CHAPTER V

MODE CHOICE MODEL

The first part of this chapter describes the mode choice models estimated using multinomial logit modeling. The second part of this chapter uses these mode choice models to estimate the percentage of travelers interested in driving alone, carpooling with a passenger, or carpooling with more than one passenger on the managed lanes or the general purpose lanes.

5.1 Mode Choice Model for Houston Travelers

A multinomial logit model was estimated for mode choice modeling using the maximum likelihood method in LIMDEP (*61*) using weighted survey data (the weighting procedure was explained in Chapter IV). Several utility equations, with different combinations of parameters were examined. In addition, nested models were attempted. The utility function given in *Table 44* was found to have best fit and explanatory ability. The utility equation for driving alone was the base mode. The mode choices included: drive alone in a managed lane, drive with one passenger in a managed lane, drive with two or more passengers in a managed lane, drive alone in a general purpose lane, drive with one passenger in a general purpose lane, and drive with two or more passengers in a general purpose lane.

Table 44: Multinomial logit choice mode model for Houston

Mode	Variable	Coefficient	p-value
All	Time	-0.015	0.000
	Cost	-0.037	0.000
SOV on ML	Constant	-1.182	0.000
	Caucasian	0.433	0.000
HOV2 on ML	Constant	-1.650	0.000
HOV3+ on ML	Constant	-1.543	0.000
	Education: Graduate degree	-0.912	0.000
	Trip purpose: Commute	-0.381	0.000
	Income: $35,000 to $50,000	-0.320	0.015
SOV on GPL	Base mode		0.000
HOV2 on GPL	Constant	-3.084	0.000
	Household type: Married with children	1.122	0.000
	Household type: Married without children	1.104	0.000
	Income: $50,000 to $75,000	-0.710	0.000
HOV3+ on GPL	Constant	-4.401	0.000
	Gender: Male	-0.810	0.008
	Trip distance (miles)	0.025	0.000
Number of cases		2724	
ρ^2		0.299	

All the variables used in the Houston model were significant at the 95 percent confidence level (see *Table 44*). Apart from the statistical significance of each variable in the model, each coefficient was examined for its sign and magnitude. A negative coefficient for a variable for a particular mode indicates that particular coefficient's impact is to lessen the likelihood of a traveler to use the mode. A positive coefficient for a variable for a particular mode will make it more likely a traveler will use the mode. Coefficients of time and cost were negative, indicating that an increase in cost and time led to decreasing utility of using the mode. The coefficient for ethnicity as Caucasian for driving alone in a managed lane was positive, indicating that Caucasians were more likely to drive alone in a managed lane. The other coefficients can be interpreted similarly. The mode specific coefficients for carpooling in GPL (HOV2 and HOV3+ in GPL) were large and negative compared to mode specific coefficients for other modes, indicating that travelers were less likely to carpool in general purpose lanes. They were more likely to use other modes.

The mode specific coefficient for carpooling (HOV2 and HOV3+ in ML) in the managed lanes were not as large and negative as the mode specific coefficients for carpooling in general lanes, indicating that carpoolers were more likely to use managed lanes.

From the model, the value of time (VOT) for Houston travelers was found to be $24.07 per hour. VOT values for Houston and Dallas were estimated by finding the ratio of generic coefficient of ‘Time’ to generic coefficient of ‘Cost’ and multiplying the ratio by 60 (see *Table 44*, *45*). The VOT value was multiplied by 60 to convert it to VOT per hour. All the parameters used in the model were justified based on their statistical and physical significance. The overall model provided an acceptable ρ^2 value of 0.299.

5.2 Mode Choice Model for Dallas Travelers

Similar to the development of the Houston mode choice model, different factors were examined for the Dallas traveler mode choice model. All the variables used in the Dallas model were significant at the 95 percent confidence level (see *Table 45*). Coefficients of time and cost were negative, indicating that an increase in cost and time led to decreasing utility of using the mode.

Table 45: Multinomial logit mode choice model for Dallas

Mode	Variable	Coefficient	p-value
All	Time	-0.013	0.000
	Cost	-0.035	0.000
SOV on ML	Constant	-1.145	0.000
	Education: Vocational training	-0.211	0.004
	Ethnicity: Caucasian	0.416	0.000
HOV2 on ML	Constant	-1.649	0.000
	Ethnicity: African-American	0.309	0.009
	Age: 25-35	0.219	0.016
HOV3+ on ML	Constant	-2.985	0.000
	Trip distance	0.019	0.000
	Ethnicity: Hispanic	1.323	0.000
SOV on GPL	Base mode		0.000
HOV2 on GPL	Constant	-2.523	0.000
	Income: $50,000 to $75,000	-0.694	0.000
	Income: Greater than $100,000	-0.679	0.003
	Household type: Married with no children	1.315	0.000
HOV3+ on GPL	Constant	-2.986	0.000
	Education: High School	3.413	0.000
	Gender: Male	-1.062	0.000
Number of cases		1864	
ρ^2		0.290	

Mode specific constants for SOV (managed lanes or general purpose lanes are highest), whereas mode specific constants for HOV3+ (in managed lanes or general purpose lanes are lowest); indicating that travelers were more likely to be SOV travelers compared to carpool with more than two passengers.

In both Houston and Dallas, Caucasians were more likely to travel alone on a managed lane. If the household type was married, the travelers were more likely to carpool. If the trip distance increased, travelers were more likely to carpool; indicating that benefits of carpooling overcomes the negatives as trip distance increases.

From the model, the value of time (VOT) for Dallas travelers was found to be \$21.76 per hour. All the parameters used in the model were justified based on their statistical ad physical significance. The overall model provided and acceptable ρ^2 value of 0.290.

The VOT values for Houston and Dallas closely matched with the VOT values reported from other studies. In a study which compared the VOT values from various studies done on SR-91 Express lane and I-15 Express Lane, it was found that VOT values in most of the studies were in \$20-\$25 range (two studies had VOT values in \$40-45 range) (*64*).

The mode choice models for Houston and Dallas results in two single average values of time for Houston and Dallas travelers. However, VOT varies by traveler. An analysis, described in next section, was performed to gain a better insight into the VOT for the travelers.

5.3 Value of Travel Time Savings for Both Houston and Dallas Travelers

If a hypothetical scenario is considered where the travelers have an option of traveling on a managed lane without paying any toll and a congested general purpose lane; all the travelers should choose the option of traveling on the managed lane. Conversely, if travelers had the option of paying a toll for traveling on a free-flow managed lane or traveling toll free on a free-flow general purpose lane then most (or all) would chose the general purpose lane. Somewhere between these two extremes lies an equilibrium point – where the toll on the managed lanes convinces just enough travelers to use it such that speeds on the managed lanes are faster than the general purpose lanes.

The survey conducted for Houston and Dallas travelers identified the amount of toll they were willing to pay to save specific amount of travel time. Histograms of VOT of the travelers have been summarized in *Figures* 16, 17, and 18. The VOT curves indicated that many travelers were willing to pay a low toll but few would pay higher tolls. VOT for SOV travelers (see *Figure 16*) did not follow the same pattern for low values of VOT.

This was because very few survey respondents were asked if they would be willing to pay a small toll to use the managed lanes. Given that travelers were willing to pay a higher toll, they would pay lower toll as well. The VOT for HOV2 (see *Figure 17*) and HOV3+ (see *Figure 18*) show the expected behavior for traveler VOT.

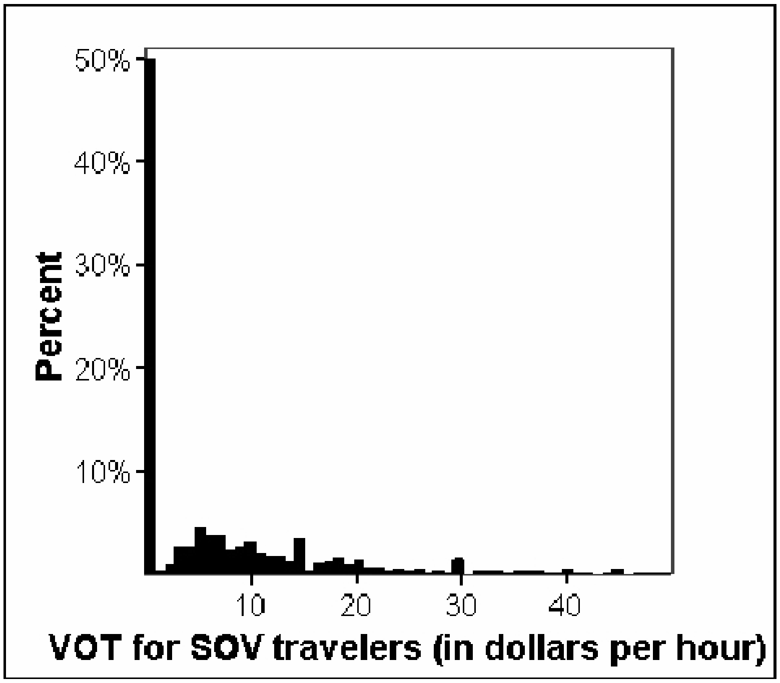

Figure 16: Histogram for VOT of SOV travelers

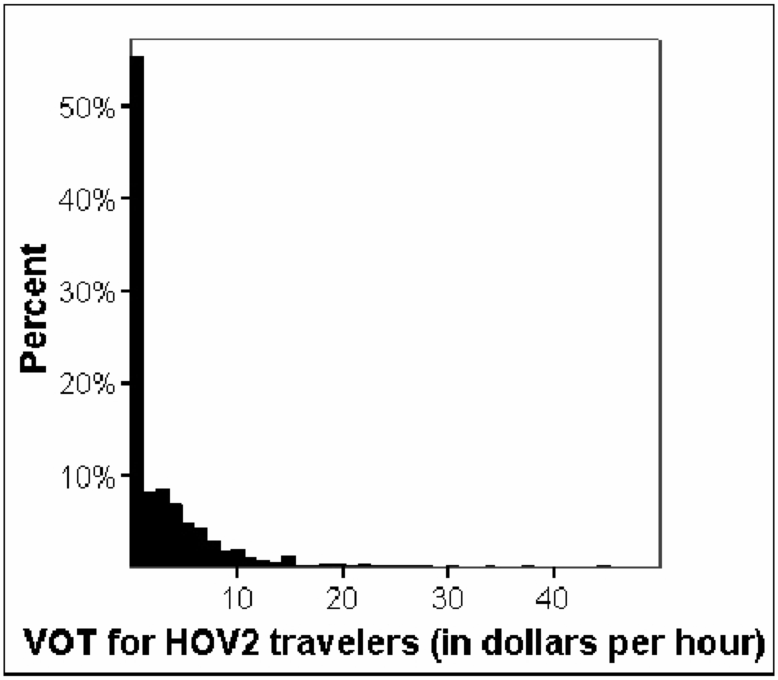

Figure 17: Histogram of VOT for HOV2 travelers

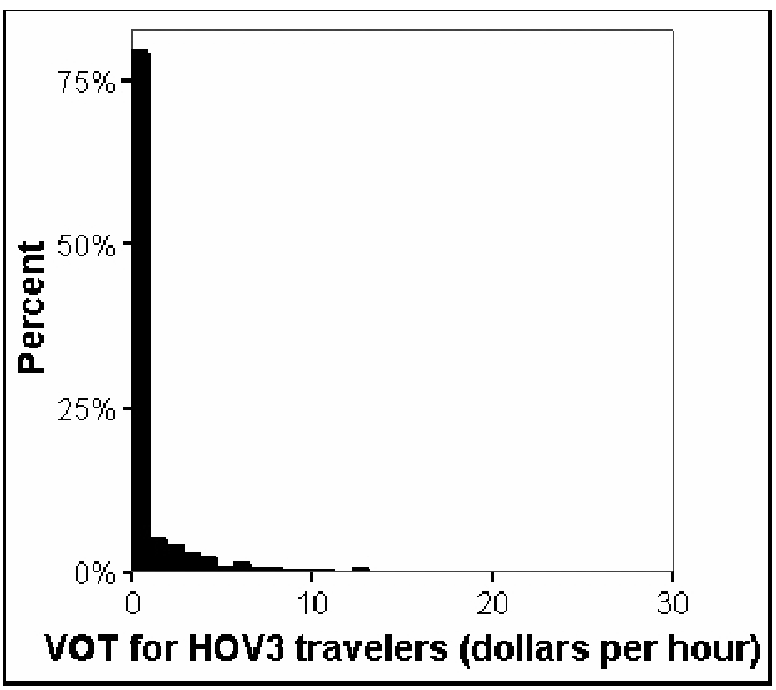

Figure 18: Histogram for VOT of HOV3+ travelers

A graphical comparison of the distributions of VOT for SOV, HOV2 and HOV3+ travelers indicates that SOV travelers were willing to pay a higher toll compared to HOV2 and HOV3+ travelers (*Figure* 19). This fact is borne by statistical analysis as well. The SOV travelers had a greater mean VOT than HOV2 travelers, who in turn had greater mean VOT than HOV3+ travelers (see *Table* 46). One-fourth of the SOV travelers were willing to pay a toll of $18.00 per hour, while one-fourth of HOV2 travelers were willing to pay $7.50 per hour, and one-fourth HOV3+ travelers were willing to pay $4.55 per hour (see *Table* 46).

Table 46: Statistical analysis of VOT

Statistical analysis of VOT ($/hour)				
Mode		SOV	HOV2	HOV3+
Mean		15.16	6.60	3.59
Percentile	75	18.00	7.50	4.55

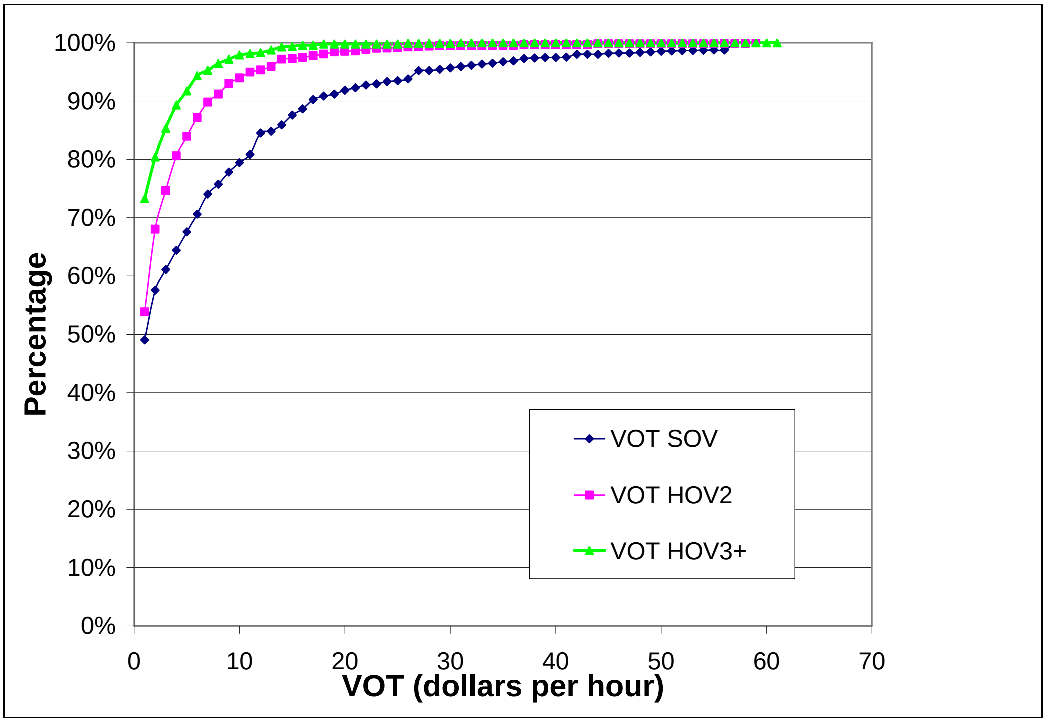

Figure 19: Cumulative VOT for SOV, HOV2, and HOV3+ travelers

The VOT distribution indicates that the percentage of travelers interested in using managed lanes will depend on the toll and travel time savings. Managed lanes would be used by top 15 to 25 percent of travelers based on their value of travel time. However, the VOT distribution only gives a partial indication of the managed lane travelers and their mode. To estimate the percentage of managed lane travelers it was necessary to use the mode choice models under various scenarios. The following section describes results from such a simulation study.

5.4 Simulation Results for Travelers Using Managed Lanes

The mode choice models described in the previous section were used to estimate the percentage of travelers willing to use managed lanes under realistic toll and travel time savings. To develop realistic toll levels, the VOT of both Houston and Dallas travelers was used. In addition, the fact many agencies use toll incentives to encourage carpooling influenced the toll rates chosen. Therefore, in many scenarios the toll rate for HOV3+ was the smallest, then HOV2, and most expensive was SOV travel.

5.4.1 Assumptions Used in the Simulation

1. The time to pick-up one passenger was assumed to be 2.90 minutes. This value used since travelers indicated that it took them 5.77 minutes on an average to pick-up and drop off the passenger.
2. The time for carpool formation for a HOV3+ carpool was assumed to be 5 minutes.
3. The maximum toll modeled for SOV travelers was $45, for HOV2 travelers it was $25, and for HOV3+ travelers it was $15. These values were assumed because very few travelers chose to pay tolls which were higher than these values as indicated in VOT analysis in previous section.
4. Tolls for each scenario were randomly chosen between $0 and the maximum indicated in Assumption 3.
5. The trip length was assumed to be 10 miles and the managed lane speed was assumed to be 70 miles per hour.

5.4.2 Cases Simulated

A total of 6 cases were simulated for the study conducted for this thesis. This included three cases for Houston and three for Dallas. The cases varied based on the speed on general purpose lane. The speeds were 25 miles per hour, 30 miles per hour, or 35 miles per hour.

5.4.3 Simulation Results for Houston Travelers

Results from the simulation study validate the VOT data that show that SOV travelers were willing to pay a greater toll than HOV2 and HOV3+ travelers for the same amount of travel time savings. For example, we examine Houston scenario with general purpose lane speeds of 25 miles per hour and tolls of $6.25 for SOV on managed lanes, $2.75 for

HOV2 on managed lanes and \$1.00 for HOV3+ on managed lanes. In this case, 23.3 percent of all travelers chose to be SOV travelers on managed lane, 10.3 percent HOV2 travelers on managed lanes, 5.9 percent as HOV3+ travelers on managed lanes. The rest of the travelers used general purpose lanes as SOV travelers, HOV2 travelers, and HOV3+ travelers. At maximum realistic toll levels (\$18 for SOV, \$7.5 for HOV2, and \$4.50 for HOV3+), close to 16.9 percent of all travelers would be SOV travelers, 9.6 percent would be HOV travelers and 5.8 percent would be HOV3+ travelers on the managed lanes (see *Figure 20*). If the vehicle speeds on the general purpose lanes increased by 5 miles per hour to 30 miles per hour, fewer travelers chose to travel on the managed lanes for each mode (SOV, HOV2, and HOV3+) (see *Figure 21*). If the speed of the vehicles increases by 10 miles per hour to 35 miles per hour, the number of travelers willing to travel on the managed lane decreased even more for each of the modes (see *Figure 21*). In general, one can conclude the following from the simulation study:

1. If the speed on the managed lanes increases, assuming the speed on the general purpose lanes remains the same and the trip distance remains the same, greater percentage of travelers chose to travel on the managed lanes.
2. If the speed on the managed lanes remains constant but the speed on the general purpose lanes increases, a smaller percentage of travelers will choose to pay to travel on the managed lanes.
3. If the trip distance increases, assuming everything else to remain the same, greater percentage of travelers choose to travel on the managed lanes.

Graphs for all three Houston cases in the study are found in *Appendix A*.

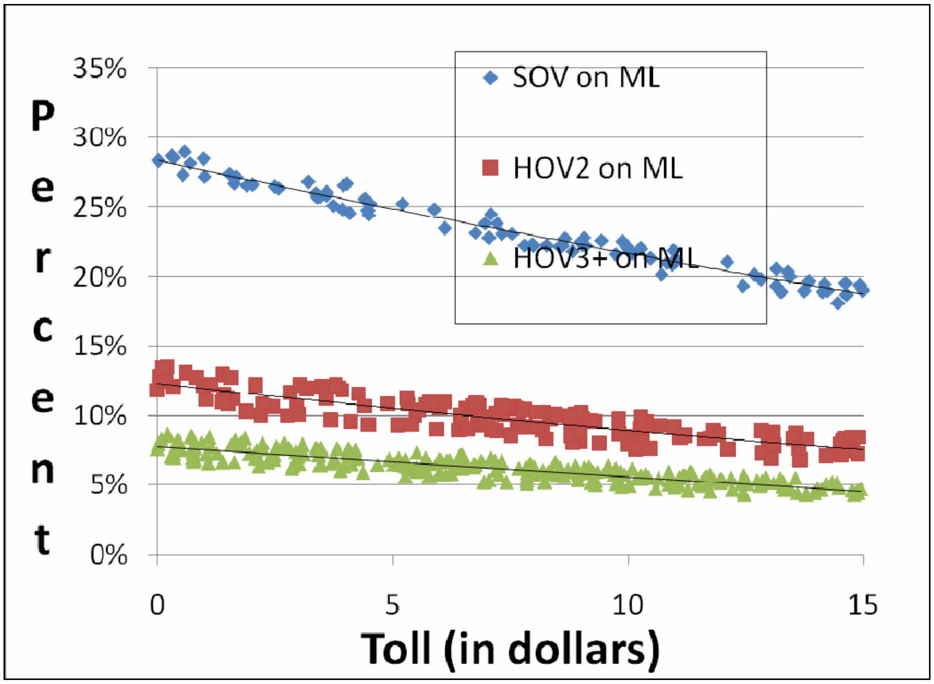

Figure 20: Percentage of Houston travelers choosing different modes in ML for 250 different toll levels assuming trip length is 10 miles, ML speed is 70 mph, and the GPL speed is 25 mph

5.4.4 Simulation Results for Dallas

The VOT for Dallas travelers was lower than for Houston travelers. This can be observed by comparing the Houston scenario described above (GPL speed 25 miles per hour, ML SOV toll of $6.25, ML HOV2 toll of $2.75, ML HOV3+ toll of $1.00). A total of 40.5 percent travelers chose to use managed lanes in Houston and only 38.1 percent in Dallas. If the percentage of travelers choosing to use managed lanes in Dallas and Houston are compared for each case, a greater percentage of travelers choose to use managed lanes in Houston. For simulation results from other cases, please refer to *Appendix A.*

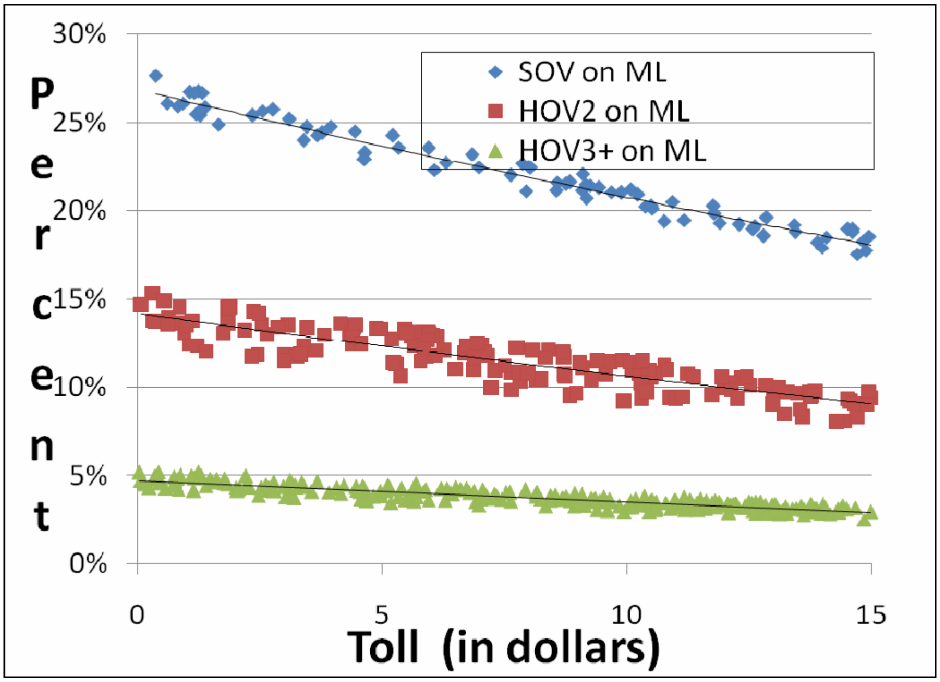

Figure 21: Percentage of Dallas travelers choosing different modes in ML for 250 different toll levels assuming trip length is 10 miles, ML speed is 70 mph, and the GPL speed is 25 mph

Salient simulation results have been summarized in Tables 54 to 57. These tables contain the percentage of travelers interested in traveling on the managed lanes under different tolls and speeds on general purpose lanes (25 miles per hour, 30 miles per hour and 35 miles per hour). A $11.75 increase in tolls for SOV travelers decreases the percentage of Houston SOV travelers on managed lanes to 16.9 percent from 23.3 percent. A similar increase for Dallas travelers decreases the percentage to 16.3 percent from 22.0 percent (*Table 47 and 48*). However, if the speed on Houston general purpose lanes increases to 35 miles an hour, the same increase in tolls changes the percentage of SOV travelers to 15.3 percent from 20.9 percent. In Dallas, the same change decreases the SOV travelers on managed lanes to 15.7 percent from 21.9 percent.

Table 47: Simulation results for percentage of travelers choosing to use different modes for given tolls in Houston when general purpose lane speed is 25 miles per hour

Toll (in dollars)			Percentage of travelers								
			Managed Lane				General Purpose Lane				Total HOV
SOV	HOV2	HOV3+	SOV	HOV2	HOV3+	Total	SOV	HOV2	HOV3+	Total	
6.25	2.75	1.00	23.3%	10.3%	5.9%	39.5%	54.8%	5.2%	0.6%	60.5%	21.9%
8.50	3.50	1.50	21.9%	10.2%	5.9%	38.1%	56.1%	5.3%	0.6%	61.9%	22.0%
10.50	4.50	2.25	20.8%	10.1%	5.9%	36.8%	57.3%	5.4%	0.6%	63.2%	21.9%
10.50	2.25	1.00	20.6%	10.8%	6.1%	37.5%	56.6%	5.3%	0.6%	62.5%	22.8%
10.50	0.00	0.00	20.3%	11.6%	6.3%	38.2%	56.0%	5.3%	0.6%	61.8%	23.7%
18.00	7.50	4.50	16.9%	9.6%	5.8%	32.3%	61.3%	5.7%	0.6%	67.7%	21.8%
27.00	16.50	12.25	13.3%	7.6%	4.8%	25.7%	67.3%	6.3%	0.7%	74.3%	19.4%

Table 48: Simulation results for percentage of travelers choosing to use different modes for given tolls in Dallas when general purpose lane speed is 25 miles per hour

Toll (in dollar)			Percentage of travelers								
			Managed Lane				General Purpose Lane				Total HOV
SOV	HOV2	HOV3+	SOV	HOV2	HOV3+	Total	SOV	HOV2	HOV3+	Total	
6.25	2.75	1.00	22.0%	11.9%	4.1%	38.1%	53.7%	6.3%	1.9%	61.9%	24.3%
8.50	3.50	1.50	20.8%	11.8%	4.2%	36.8%	54.8%	6.5%	2.0%	63.2%	24.4%
10.50	4.50	2.25	19.8%	11.6%	4.1%	35.6%	55.8%	6.6%	2.0%	64.4%	24.4%
10.50	2.25	1.00	19.6%	12.4%	4.3%	36.3%	55.2%	6.5%	2.0%	63.7%	25.2%
10.50	0.00	0.00	19.4%	13.3%	4.4%	37.0%	54.6%	6.4%	2.0%	63.0%	26.1%
18.00	7.50	4.50	16.3%	11.2%	4.1%	31.5%	59.4%	7.0%	2.1%	68.5%	24.3%
27.00	16.50	12.25	13.0%	8.9%	3.4%	25.3%	64.8%	7.6%	2.3%	74.7%	22.2%

5.5 Comparison with Field Data

Mode share data was collected on the I-394 HOT lanes in Minneapolis, Minnesota. The data was collected between 7:00 am and 9:00 am. The share of ML vehicles was 25.2 percent. Approximately 38 percent of the vehicles in the MLs were SOVs. (see Table 49) (62). For mid-range SOV toll levels and free HOV travel (as in I-394), the simulation study predicts the share of ML vehicles to be close to 37 percent in Dallas and 38 percent in Houston. The share of SOVs on the MLs was predicted to be just over 50 percent.

Table 49: Mode share data on I-394 HOT lanes in Minneapolis (7:00 am to 9:00 am) ***(62)***

Mode	Total number of vehicles in all GPL (3 lanes)	Total number of vehicles in all ML (2 lanes)	Percent share	
			GPL	ML
SOV	11373	1480	73.58%	9.58%
HOV2	195	2283	12.60%	14.77%
Buses	0	125	0.00%	0.81%

5.6 Elasticity of Managed Lane Demand

One method to measure the percentage of travelers willing to use managed lanes at different toll levels is measuring the elasticity of managed lane demand with increase in toll level using Equation 12.

$$E_{ML\ Demand} = \frac{\%\ change\ in\ managed\ lane\ usage}{\%\ change\ in\ toll} \qquad (12)$$

where $E_{ML\ Demand}$ is demand elasticity of managed lane

$$\%\ change\ in\ managed\ lane\ usage = \frac{(\%\ initial\ ML\ usage) - (\%\ final\ ML\ usage)}{\%\ ML\ usage\ at\ inital\ toll\ level} \qquad (13)$$

and $\%\ change\ in\ toll = \dfrac{initial\ toll - final\ toll}{initial\ toll}$ (14)

The elasticity of demand for Dallas managed lane travelers, the case when speeds on managed lanes is 25 miles per hour, varies between -15.4 percent to -40.1 percent for SOV travelers. For HOV2 travelers it is much lesser. It varies between -2 percent to -16.8 percent. It is even lower for HOV3+ travelers. It varies between 0.5 percent and -9.6 percent (see *Table 49)*.

The elasticity of demand for Houston managed lane travelers, the case when speeds on managed lanes is 25 miles per hour, varies between -16.2 percent to -42.4 percent for SOV travelers. For HOV2 travelers it is much lower, varies between -1.8 percent to -17.7 percent. It is even lower for HOV3+ travelers. It varies between 0.8 percent and -10.1 percent. The managed lane demand elasticity for both Houston and Dallas travelers can be termed as relatively inelastic (see *Table 50, 51, 52)*.

The values of elasticity of managed lane demand for different toll rates are within the range found in the literature. A study which summarized the elasticity of demand for facilities with variable pricing component or with a fixed pricing component found that elasticity varies between almost perfectly inelastic (-2 percent) to unit elastic (-100 percent) (63). This simulation study predicts a value between -15.4 percent and -43.4 percent for SOV travelers in Houston and Dallas.

Table 50: Elasticity of managed lane demand for the case when speed on GPL is 25 miles per hour

Toll level	Toll (in dollars)			Elasticity					
				Dallas			Houston		
	SOV	HOV2	HOV3+	SOV	HOV2	HOV3+	SOV	HOV2	HOV3+
Initial	6.25	2.75	1.00	-15.4%	-2.0%	0.5%	-16.2%	-1.8%	0.8%
Final	8.50	3.50	1.50						
Initial	8.50	3.50	1.50	-20.6%	-5.4%	-1.4%	-21.7%	-5.5%	-1.3%
Final	10.50	4.50	2.25						
Initial	10.50	4.50	2.25	---	-13.8%	-5.8%	---	-14.9%	-6.3%
Final	10.50	2.25	1.00						
Initial	10.50	2.25	1.00	---	-6.8%	-2.3%	---	-7.4%	-2.5%
Final	10.50	0.00	0.00						
Initial	10.50	0.00	0.00	-22.4%	---	---	-23.7%	---	---
Final	18.00	7.50	4.50						
Initial	18.00	7.50	4.50	-40.1%	-16.8%	-9.6%	-42.4%	-17.7%	-10.1%
Final	27.00	16.50	12.25						

Table 51: Elasticity of managed lane demand for the case when speed on GPL is 30 miles per hour

Toll level	Toll (in dollars)			Elasticity					
				Dallas			Houston		
	SOV	HOV2	HOV3+	SOV	HOV2	HOV3+	SOV	HOV2	HOV3+
Initial	6.25	2.75	1.00	-15.6%	-2.3%	0.4%	-16.4%	-2.1%	0.6%
Final	8.50	3.50	1.50						
Initial	8.50	3.50	1.50	-20.9%	-5.6%	-1.5%	-22.1%	-5.8%	-1.5%
Final	10.50	4.50	2.25						
Initial	10.50	4.50	2.25	---	-13.8%	-5.9%	---	-15.0%	-6.4%
Final	10.50	2.25	1.00						
Initial	10.50	2.25	1.00	---	-6.9%	-2.3%	---	-7.5%	-2.6%
Final	10.50	0.00	0.00						
Initial	10.50	0.00	0.00	-22.7%	---	---	-24.1%	---	---
Final	18.00	7.50	4.50						
Initial	18.00	7.50	4.50	-40.6%	-17.0%	-9.8%	-43.0%	-18.0%	-10.3%
Final	27.00	16.50	12.25						

Table 52: Elasticity of managed lane demand for the case when speed on GPL is 35 miles per hour

Toll level	Toll (in dollars)			Elasticity					
				Dallas			Houston		
	SOV	HOV2	HOV3+	SOV	HOV2	HOV3+	SOV	HOV2	HOV3+
Initial	6.25	2.75	1.00	-15.7%	-2.4%	0.3%	-16.6%	-2.4%	0.5%
Final	8.50	3.50	1.50						
Initial	8.50	3.50	1.50	-21.0%	-5.7%	-1.6%	-22.3%	-6.0%	-1.6%
Final	10.50	4.50	2.25						
Initial	10.50	4.50	2.25	---	-13.9%	-5.9%	---	-15.0%	-6.4%
Final	10.50	2.25	1.00						
Initial	10.50	2.25	1.00	---	-6.9%	-2.4%	---	-7.5%	-2.6%
Final	10.50	0.00	0.00						
Initial	10.50	0.00	0.00	-22.9%	---		-24.4%	---	---
Final	18.00	7.50	4.50						
Initial	18.00	7.50	4.50	-41.0%	-17.1%	-9.9%	-43.4%	-18.2%	-10.4%
Final	27.00	16.50	12.25						

5.7 Summary

To summarize, development of mode choice models have been useful in estimating value of travel time savings for Houston and Dallas. In addition, the mode choice models have helped estimate the percentage of travelers for different scenarios. The HOV users stay HOV for the most part. These scenarios are helpful in estimating demand elasticity of managed lanes. The managed lane demand elasticity was found to be relatively inelastic as the demand elasticity lies between -.43 and 0. Dallas managed lane travelers are relatively more inelastic than Houston managed lane travelers.

CHAPTER VI

CONCLUSIONS

6.1 General Conclusions

A number of studies have been conducted on the six operational managed lanes to gauge the traveler's interest in using these managed lanes. Chapter II of this thesis has summarized the literature regarding interest in existing managed lanes. The majority of travelers, in each case, have a positive impression of managed lanes and are interested in using them. Profiles of managed lane travelers have also been summarized in Chapter II. Travelers from all income categories are interested in managed lane usage, with high income travelers tending to use them more often.

This thesis has summarized the potential use of managed lanes in Houston and Dallas based on responses to a 2006 survey. Travel behavior, socio-economic characteristics, and stated preference data was collected through an online survey augmented by a paper and laptop survey. The survey data collection methodology and weighting of the collected data was provided in Chapter III. Survey results were provided in Chapter IV. Chapter IV contains documentation of the interest in managed lanes by different socio-economic groups. The interest in managed lanes was compared between groups, with the groups categorized by income, ethnicity, trip purpose, mode, number of vehicles in the household, and toll road usage. There was no significant difference in interest in using managed lanes across Houston and Dallas for all categories (*Table 53*). However, when the toll-road travelers were compared to non toll-road travelers, high income toll road travelers in Dallas and Houston (annual household incomes greater than $100,000) had greater interest in using managed lanes. In Houston, toll road travelers with annual household incomes between $25,000 and $50,000 also had greater interest than corresponding non-toll road travelers. Across ethnicity, travelers in the 'Others' category who use a toll road had higher interest in using managed lanes than non-toll road using travelers in the ‘Others’ category. Across all modes; toll-paying Houston travelers had a greater interest in using managed lanes than non-toll paying Houston travelers (*Table 52*).

Table 53: Difference in interest in using managed lanes between toll road and non-toll road travelers

Category	Location	Difference in interest for each location
Income	Dallas	Yes, toll road travelers with annual household income greater than $100,000 had higher interest than non-toll road travelers in the same category. Difference in interest for other travelers was not significant.
Income	Houston	Yes, toll road travelers with annual household income greater than $100,000 and between $25,000 and $50,000 had higher interest than non-toll road travelers in the same category. Difference in interest for other travelers was not significant.
Ethnicity	Dallas and Houston	Yes, toll road traveler in Others category had a higher interest in using managed lanes. Difference in interest for other travelers for different ethnicities was not significant.
Trip purpose	Dallas and Houston	Difference in interest for travelers for different trip purposes was not significant.
Mode choice	Dallas	Difference in interest for travelers for different modes was not significant.
Mode choice	Houston	Yes, toll road SOV travelers had higher interest than non-toll SOV travelers. Difference in interest for other travelers was not significant.
Number of vehicles in the household	Dallas and Houston	Difference in interest for travelers for categories based on number of vehicles in the household was not significant.

Overall, there was a high level of interest in using managed lanes. 68.4 percent of Houston travelers and 72 percent of Dallas travelers were interested in using managed lanes.

Chapter V detailed the mode choice models estimated for Houston and Dallas travelers. The value of travel time for Houston travelers was estimated to be $24.07 per hour and Dallas travelers was estimated to be $21.76 per hour. values were in the range found in literature (64).

Next a simulation study was done using these models to estimate the percentage of travelers in Houston and Dallas who would likely use managed lanes under different toll rates and travel speeds. Simulation study indicated that impact of tolls on number of HOV2 and HOV3+ travelers on managed lanes was smaller compared to impact of tolls on SOV travelers on the managed lanes. A small number of carpoolers always used general purpose lanes, irrespective of toll levels on the managed lanes.

Although sample size was large, the number of travelers in some categories, for example vanpoolers was small. The small sample size limited the ability to draw meaningful conclusions about difference in interest in using managed lanes in such cases. This was due to large standard deviation for interest in using managed lanes for categories with small sample size.

The mode choice model returns reasonable predictions for a range of realistic toll levels for managed lanes. This would be as high as a toll of $18 for SOV travelers, $7 for HOV2 travelers and $4 for HOV3+ travelers. The model should not be used to estimate the percent of travelers for higher tolls.

6.2 Future Research and Recommendations

Future research can be focused on VTTS and relationship between trip length and propensity to use managed lanes.

The value of travel time savings (VTTS) may be variable for different socio-economic groups based on income, ethnicity, household-type, number of vehicles in the household, etc. These VTTS may also be based on trip length and trip purpose. Future research could be focused on estimating percentage of travelers from each such group interested in using managed lanes, their VTTS, and how their VTTS varies/is distributed within each group.

Future research could explore the relationship between trip length and propensity to use managed lanes. The simulation study conducted for this thesis has indicated that greater trip length induces travelers to use managed lanes more often. Research focused on both qualitative data collection along with quantitative analysis would be helpful in exploring this relationship.

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APPENDIX A

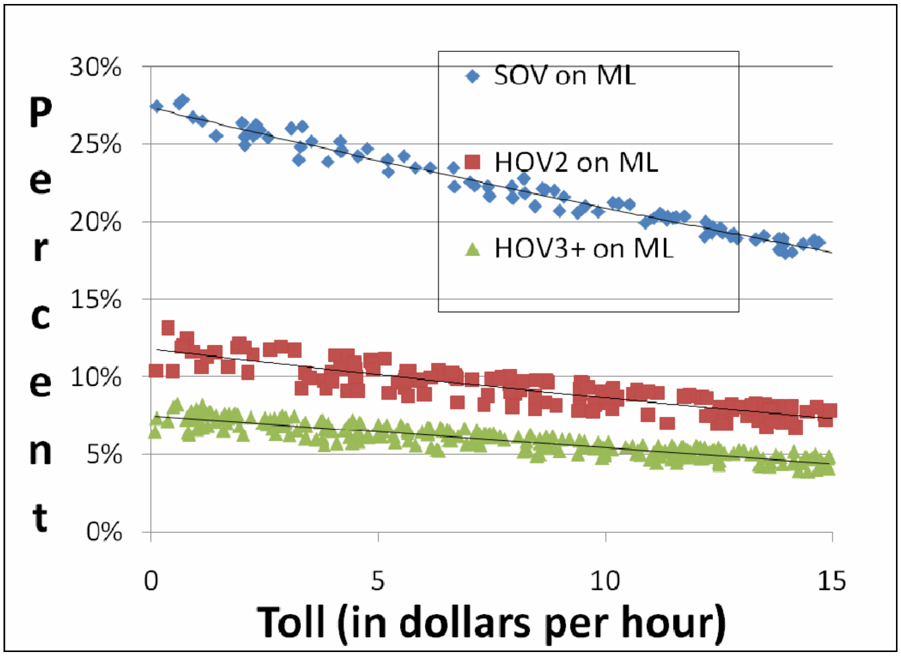


Figure 22: Percentage of Houston travelers choosing different modes in ML for 250 different toll levels assuming trip length is 10 miles, ML speed is 70 mph, and the GPL speed is 30 mph

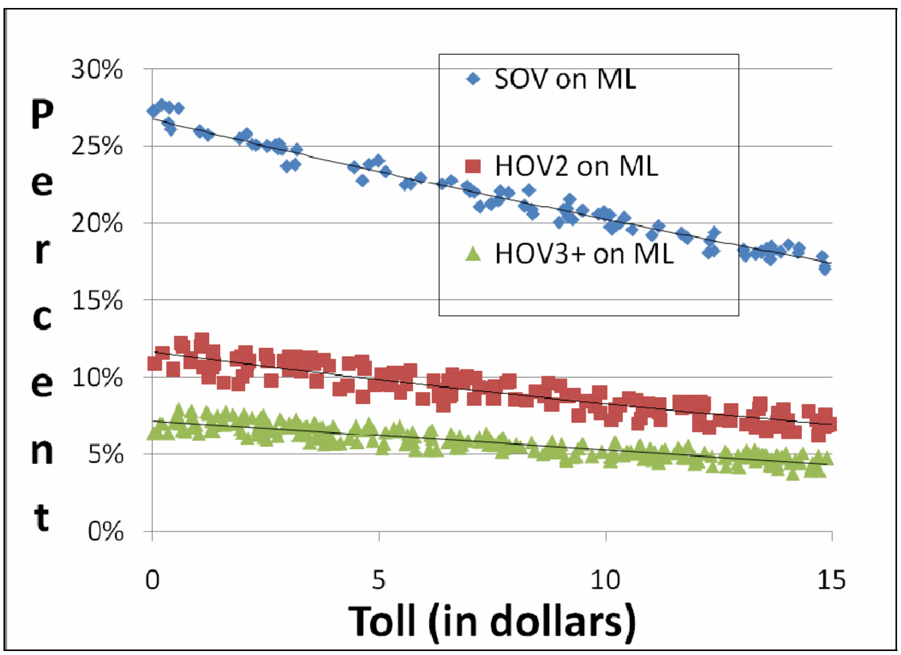


Figure 23: Percentage of Houston travelers choosing different modes in ML for 250 different toll levels assuming trip length is 10 miles, ML speed is 70 mph, and the GPL speed is 35 mph

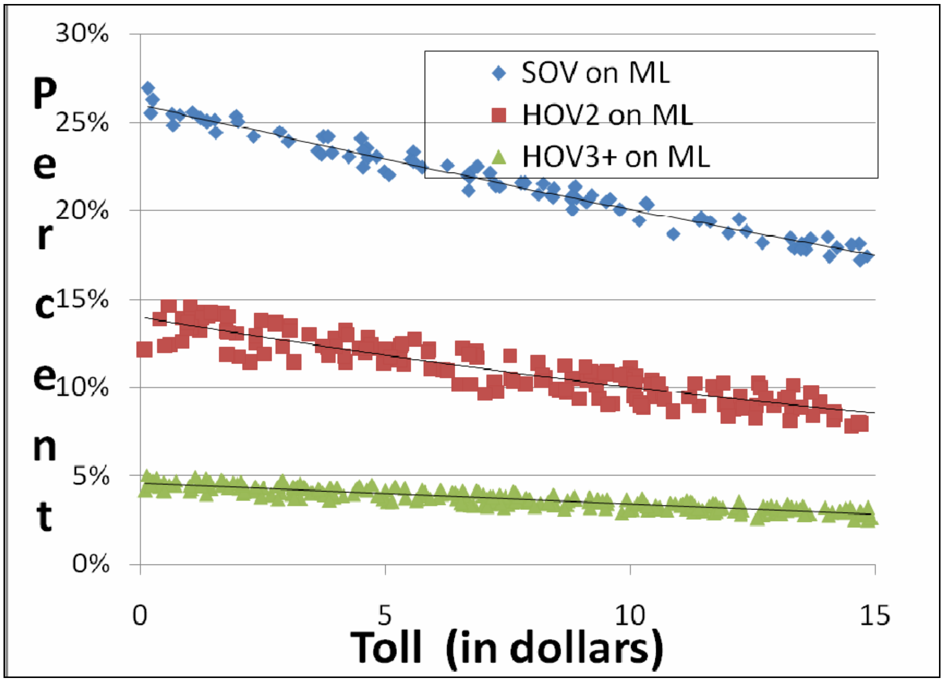


Figure 24: Percentage of Dallas travelers choosing different modes in ML for 250 different toll levels assuming trip length is 10 miles, ML speed is 70 mph, and the GPL speed is 30 mph

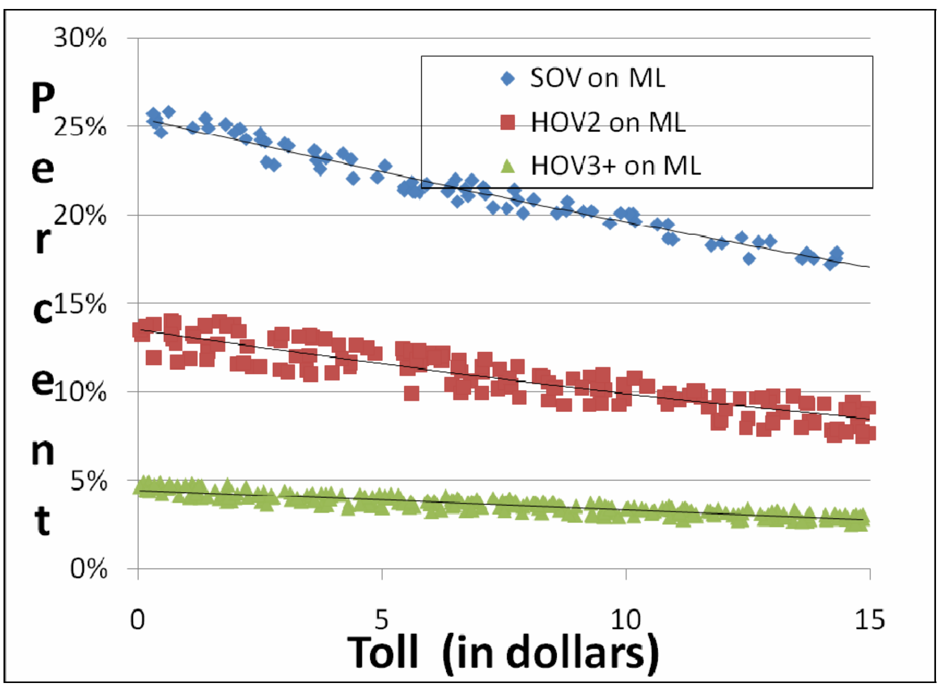


Figure 25: Percentage of Dallas travelers choosing different modes in ML for 250 different toll levels assuming trip length is 10 miles, ML speed is 70 mph, and the GPL speed is 35 mph

Table 54: Simulation results for percentage of travelers choosing to use different modes for given tolls in Dallas when the general purpose lane speed is 30 miles per hour

Toll (in dollar)			Percentage of travelers								
			Managed Lane				General Purpose Lane				Total HOV
SOV	HOV2	HOV3+	SOV	HOV2	HOV3+	Total	SOV	HOV2	HOV3+	Total	
6.25	2.75	1.00	21.4%	11.5%	4.0%	36.9%	54.7%	6.4%	2.0%	63.1%	24.0%
8.50	3.50	1.50	20.2%	11.5%	4.0%	35.6%	55.8%	6.6%	2.0%	64.4%	24.1%
10.50	4.50	2.25	19.2%	11.3%	4.0%	34.4%	56.8%	6.7%	2.0%	65.6%	24.0%
10.50	2.25	1.00	19.0%	12.0%	4.1%	35.1%	56.2%	6.6%	2.0%	64.9%	24.8%
10.50	0.00	0.00	18.8%	12.9%	4.2%	35.9%	55.6%	6.5%	2.0%	64.1%	25.7%
18.00	7.50	4.50	15.7%	10.8%	3.9%	30.4%	60.3%	7.1%	2.2%	69.6%	23.9%
27.00	16.50	12.25	12.5%	8.6%	3.3%	24.4%	65.6%	7.7%	2.3%	75.6%	21.9%

Table 55: Simulation results for percentage of travelers choosing to use different modes for given tolls in Dallas when the general purpose lane speed is 35 miles per hour

Toll (in dollar)			Percentage of travelers								
			Managed Lane				General Purpose Lane				Total HOV
SOV	HOV2	HOV3+	SOV	HOV2	HOV3+	Total	SOV	HOV2	HOV3+	Total	
6.25	2.75	1.00	20.9%	11.3%	3.9%	36.1%	55.4%	6.5%	2.0%	63.9%	23.7%
8.50	3.50	1.50	19.7%	11.2%	3.9%	34.8%	56.5%	6.7%	2.0%	65.2%	23.8%
10.50	4.50	2.25	18.7%	11.0%	3.9%	33.6%	57.5%	6.8%	2.1%	66.4%	23.7%
10.50	2.25	1.00	18.5%	11.8%	4.0%	34.3%	56.9%	6.7%	2.0%	65.7%	24.6%
10.50	0.00	0.00	18.3%	12.6%	4.1%	35.0%	56.3%	6.6%	2.0%	65.0%	25.4%
18.00	7.50	4.50	15.3%	10.5%	3.8%	29.7%	61.0%	7.2%	2.2%	70.3%	23.7%
27.00	16.50	12.25	12.2%	8.4%	3.2%	23.7%	66.2%	7.7%	2.3%	76.3%	21.6%

Table 56: Simulation results for percentage of travelers choosing to use different modes for given tolls in Houston when the general purpose lane speed is 30 miles per hour

Toll (in dollar)			Percentage of travelers								
			Managed Lane				General Purpose Lane				Total HOV
SOV	HOV2	HOV3+	SOV	HOV2	HOV3+	Total	SOV	HOV2	HOV3+	Total	
6.25	2.75	1.00	22.5%	9.9%	5.7%	38.1%	56.1%	5.3%	0.6%	61.9%	21.4%
8.50	3.50	1.50	21.1%	9.8%	5.7%	36.7%	57.3%	5.4%	0.6%	63.3%	21.5%
10.50	4.50	2.25	20.0%	9.7%	5.7%	35.4%	58.5%	5.5%	0.6%	64.6%	21.5%
10.50	2.25	1.00	19.8%	10.4%	5.9%	36.1%	57.9%	5.4%	0.6%	63.9%	22.3%
10.50	0.00	0.00	19.6%	11.2%	6.0%	36.8%	57.2%	5.4%	0.6%	63.2%	23.2%
18.00	7.50	4.50	16.2%	9.2%	5.6%	31.0%	62.5%	5.9%	0.6%	69.0%	21.3%
27.00	16.50	12.25	12.7%	7.2%	4.6%	24.6%	68.3%	6.4%	0.7%	75.4%	18.9%

Table 57: Simulation results for percentage of travelers choosing to use different modes for given tolls in Houston when the general purpose lane speed is 35 miles per hour

Toll (in dollar)			Percentage of travelers								
			Managed Lane				General Purpose Lane				Total HOV
SOV	HOV2	HOV3+	SOV	HOV2	HOV3+	Total	SOV	HOV2	HOV3+	Total	
6.25	2.75	1.00	21.9%	9.6%	5.6%	37.1%	57.0%	5.4%	0.6%	62.9%	21.1%
8.50	3.50	1.50	20.6%	9.6%	5.6%	35.7%	58.2%	5.5%	0.6%	64.3%	21.2%
10.50	4.50	2.25	19.5%	9.4%	5.5%	34.4%	59.4%	5.6%	0.6%	65.6%	21.1%
10.50	2.25	1.00	19.3%	10.1%	5.7%	35.1%	58.8%	5.5%	0.6%	64.9%	22.0%
10.50	0.00	0.00	19.1%	10.9%	5.9%	35.8%	58.1%	5.5%	0.6%	64.2%	22.8%
18.00	7.50	4.50	15.7%	9.0%	5.4%	30.1%	63.3%	5.9%	0.6%	69.9%	21.0%
27.00	16.50	12.25	12.3%	7.0%	4.5%	23.8%	69.0%	6.5%	0.7%	76.2%	18.6%

APPENDIX B

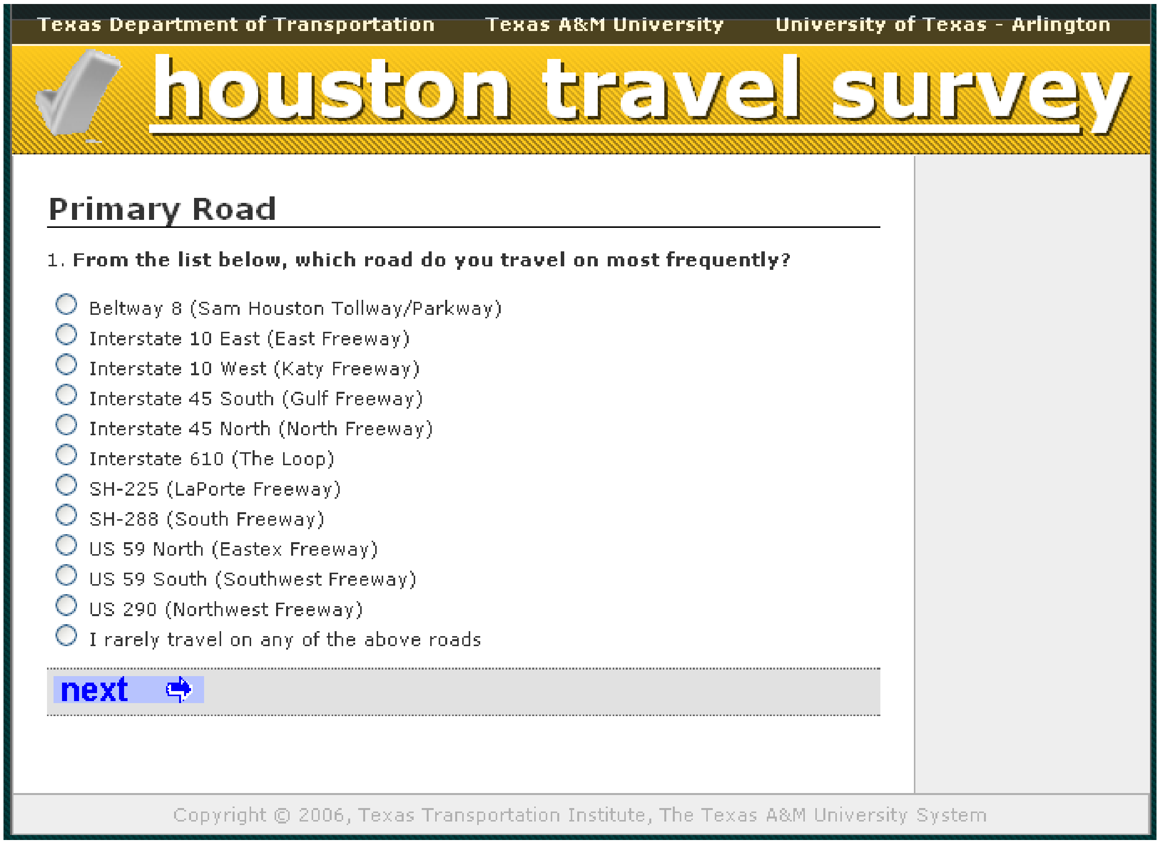


Figure 26: Selection of primary road for a typical trip.

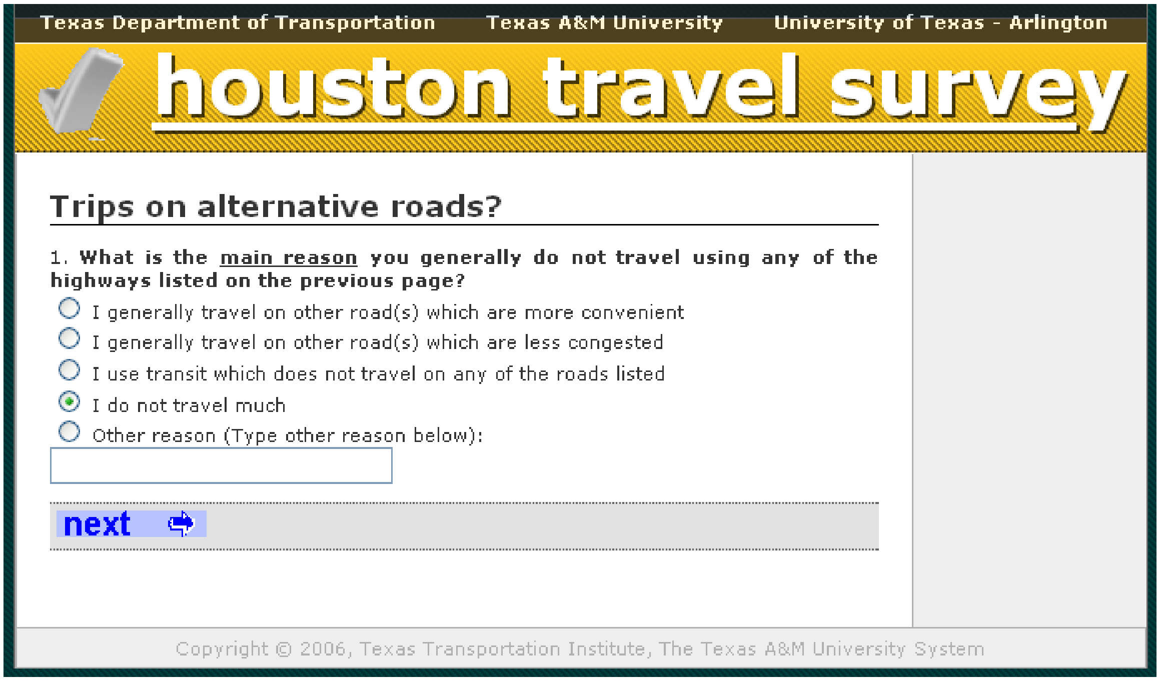
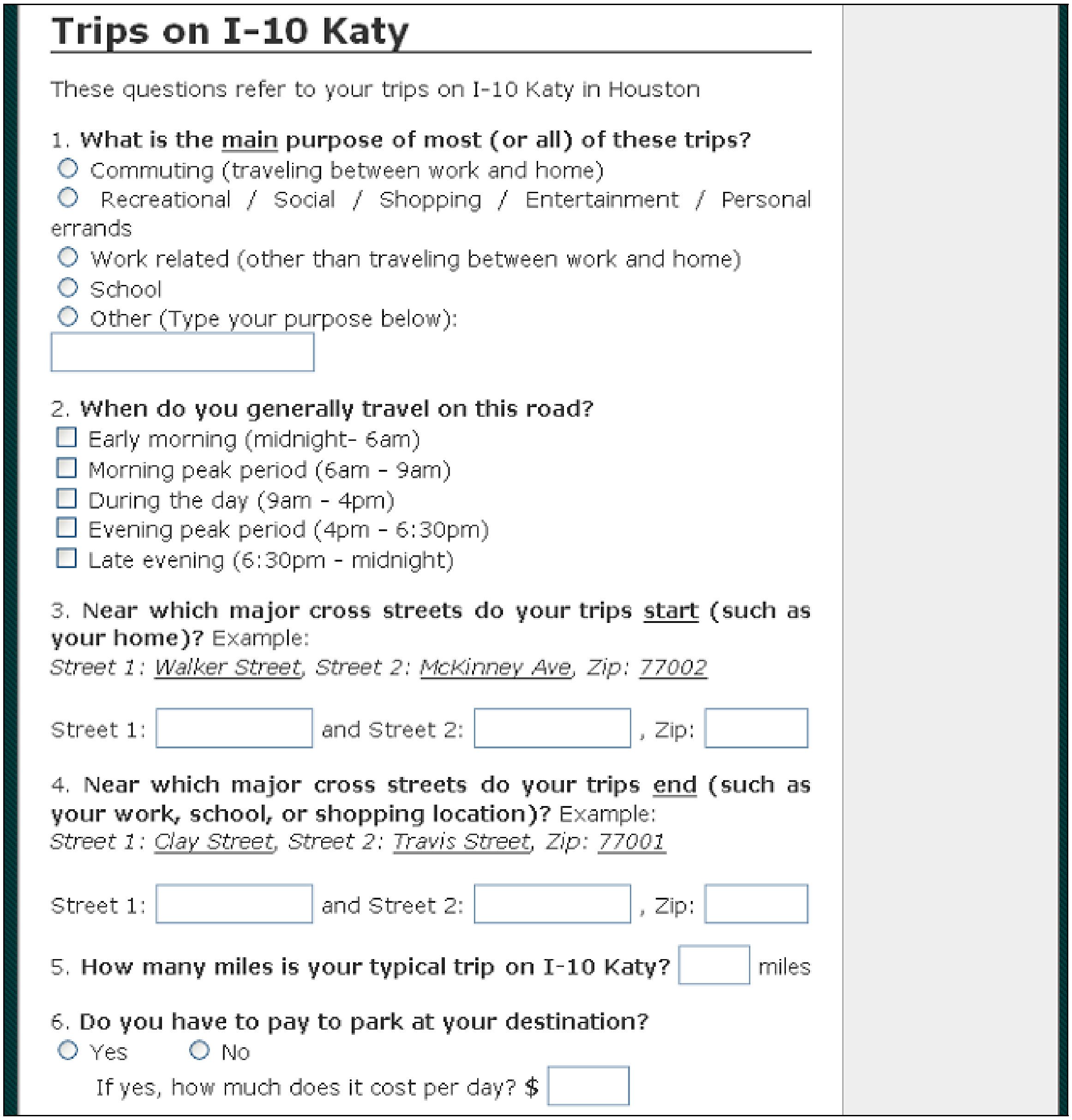


Figure 27: Question asked to the respondent, if none of the major roads are selected.



Trips on I-10 Katy

These questions refer to your trips on I-10 Katy in Houston

1. **What is the main purpose of most (or all) of these trips?**
- ○ Commuting (traveling between work and home)
- ○ Recreational / Social / Shopping / Entertainment / Personal errands
- ○ Work related (other than traveling between work and home)
- ○ School
- ○ Other (Type your purpose below):

2. **When do you generally travel on this road?**
- ☐ Early morning (midnight- 6am)
- ☐ Morning peak period (6am - 9am)
- ☐ During the day (9am - 4pm)
- ☐ Evening peak period (4pm - 6:30pm)
- ☐ Late evening (6:30pm - midnight)

3. **Near which major cross streets do your trips start (such as your home)?** Example:
Street 1: Walker Street, Street 2: McKinney Ave, Zip: 77002

Street 1: ____ and Street 2: ____ , Zip: ____

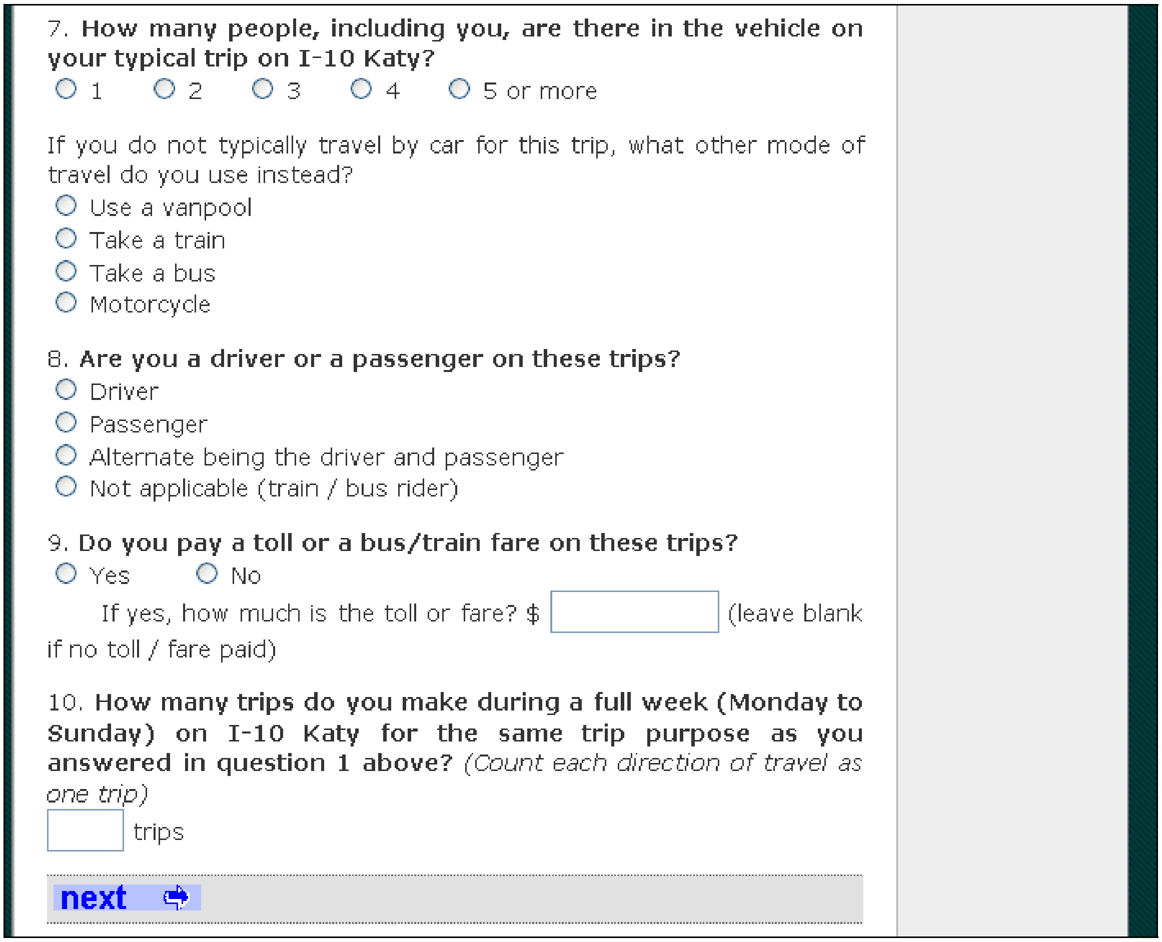
4. **Near which major cross streets do your trips end (such as your work, school, or shopping location)?** Example:
Street 1: Clay Street, Street 2: Travis Street, Zip: 77001

Street 1: ____ and Street 2: ____ , Zip: ____

5. **How many miles is your typical trip on I-10 Katy?** ____ miles

6. **Do you have to pay to park at your destination?**
○ Yes ○ No
If yes, how much does it cost per day? $ ____

Figure 28: Trip related questions asked to respondents after selecting the major road, question 1 to 6.



7. **How many people, including you, are there in the vehicle on your typical trip on I-10 Katy?**

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 or more

If you do not typically travel by car for this trip, what other mode of travel do you use instead?

○ Use a vanpool
○ Take a train
○ Take a bus
○ Motorcycle

8. **Are you a driver or a passenger on these trips?**

○ Driver
○ Passenger
○ Alternate being the driver and passenger
○ Not applicable (train / bus rider)

9. **Do you pay a toll or a bus/train fare on these trips?**

○ Yes ○ No

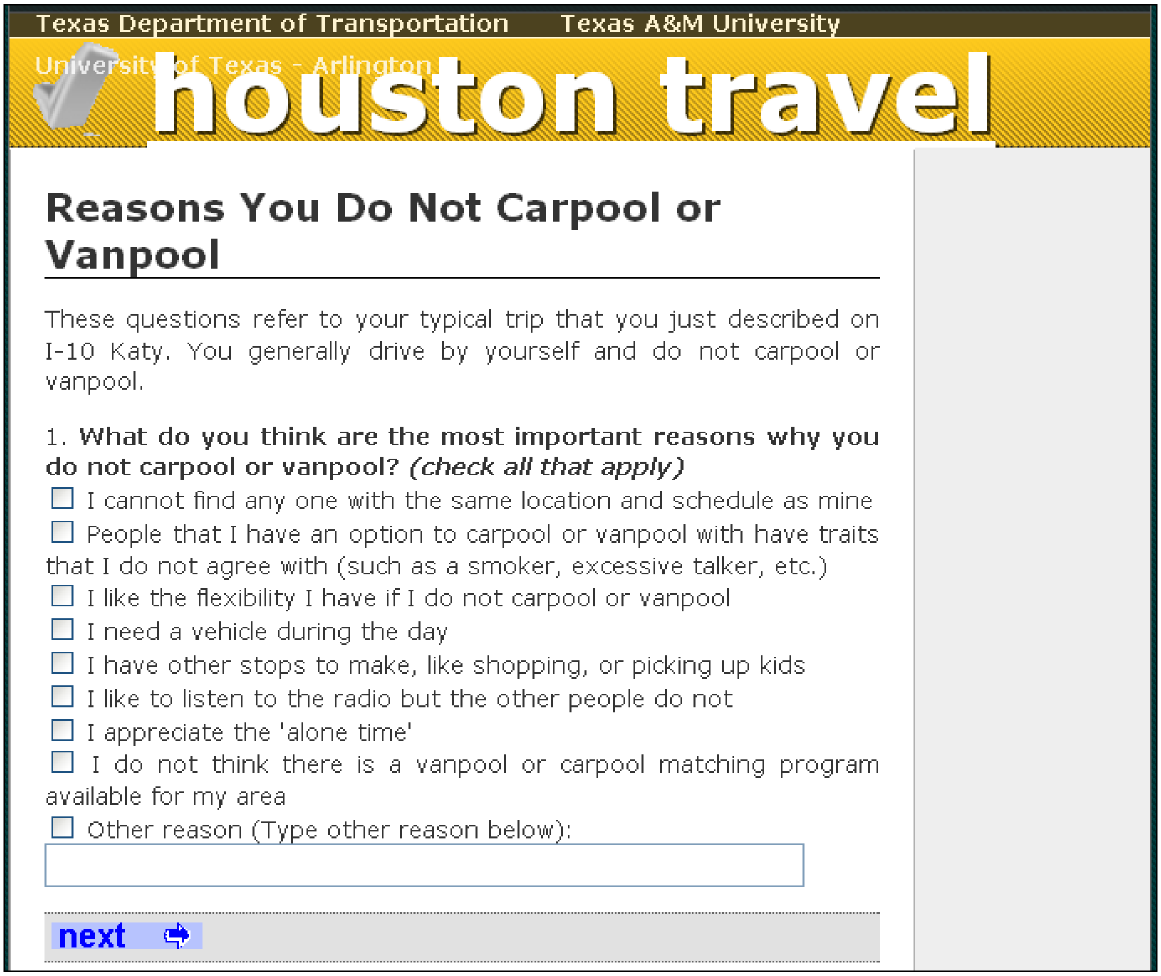
If yes, how much is the toll or fare? $ [ ] (leave blank if no toll / fare paid)

10. **How many trips do you make during a full week (Monday to Sunday) on I-10 Katy for the same trip purpose as you answered in question 1 above?** *(Count each direction of travel as one trip)*

[ ] trips

next

Figure 29: Trip related question asked to respondents after selecting road on a typical trip, question 7 to 10.



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Reasons You Do Not Carpool or Vanpool

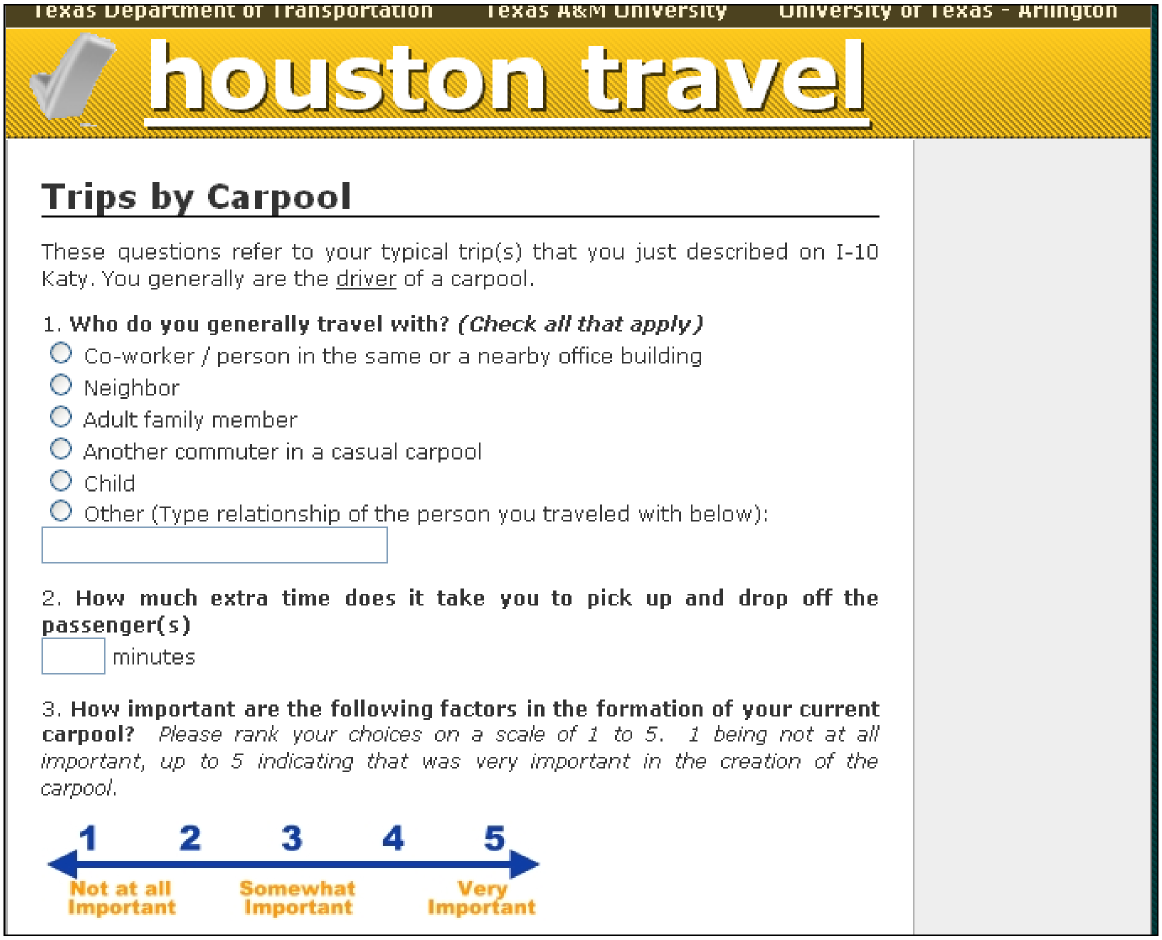
These questions refer to your typical trip that you just described on I-10 Katy. You generally drive by yourself and do not carpool or vanpool.

1. **What do you think are the most important reasons why you do not carpool or vanpool?** ***(check all that apply)***

- ☐ I cannot find any one with the same location and schedule as mine
- ☐ People that I have an option to carpool or vanpool with have traits that I do not agree with (such as a smoker, excessive talker, etc.)
- ☐ I like the flexibility I have if I do not carpool or vanpool
- ☐ I need a vehicle during the day
- ☐ I have other stops to make, like shopping, or picking up kids
- ☐ I like to listen to the radio but the other people do not
- ☐ I appreciate the 'alone time'
- ☐ I do not think there is a vanpool or carpool matching program available for my area
- ☐ Other reason (Type other reason below):

next

Figure 30: Question asked to SOV respondents for their reasons to not carpool / vanpool.



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Trips by Carpool

These questions refer to your typical trip(s) that you just described on I-10 Katy. You generally are the driver of a carpool.

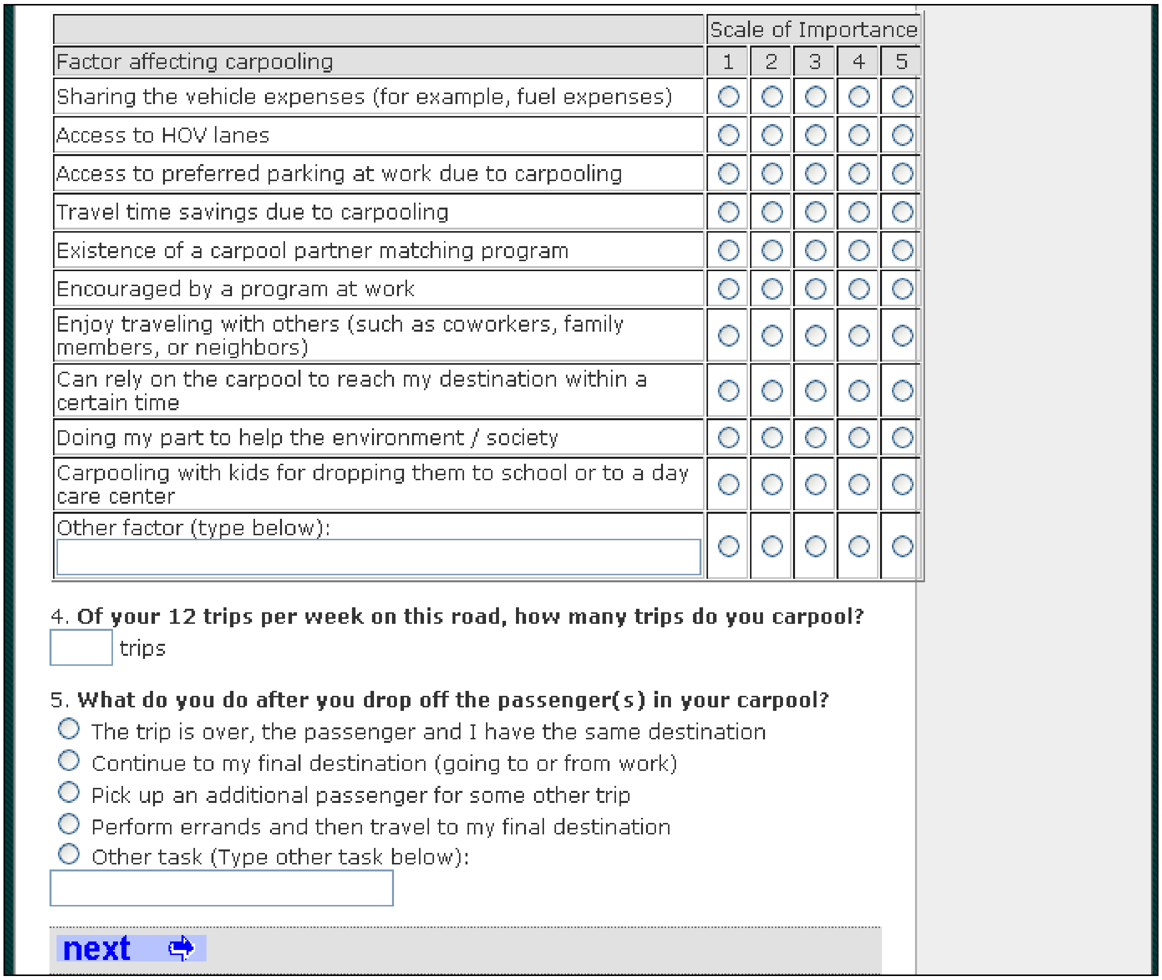
1. **Who do you generally travel with? *(Check all that apply)***
- Co-worker / person in the same or a nearby office building
- Neighbor
- Adult family member
- Another commuter in a casual carpool
- Child
- Other (Type relationship of the person you traveled with below):

2. **How much extra time does it take you to pick up and drop off the passenger(s)**

minutes

3. **How important are the following factors in the formation of your current carpool?** *Please rank your choices on a scale of 1 to 5. 1 being not at all important, up to 5 indicating that was very important in the creation of the carpool.*

Figure 31: Questions asked regarding carpool: questions 1 to 3.



	Scale of Importance				
Factor affecting carpooling	1	2	3	4	5
Sharing the vehicle expenses (for example, fuel expenses)	○	○	○	○	○
Access to HOV lanes	○	○	○	○	○
Access to preferred parking at work due to carpooling	○	○	○	○	○
Travel time savings due to carpooling	○	○	○	○	○
Existence of a carpool partner matching program	○	○	○	○	○
Encouraged by a program at work	○	○	○	○	○
Enjoy traveling with others (such as coworkers, family members, or neighbors)	○	○	○	○	○
Can rely on the carpool to reach my destination within a certain time	○	○	○	○	○
Doing my part to help the environment / society	○	○	○	○	○
Carpooling with kids for dropping them to school or to a day care center	○	○	○	○	○
Other factor (type below):	○	○	○	○	○

4. **Of your 12 trips per week on this road, how many trips do you carpool?**

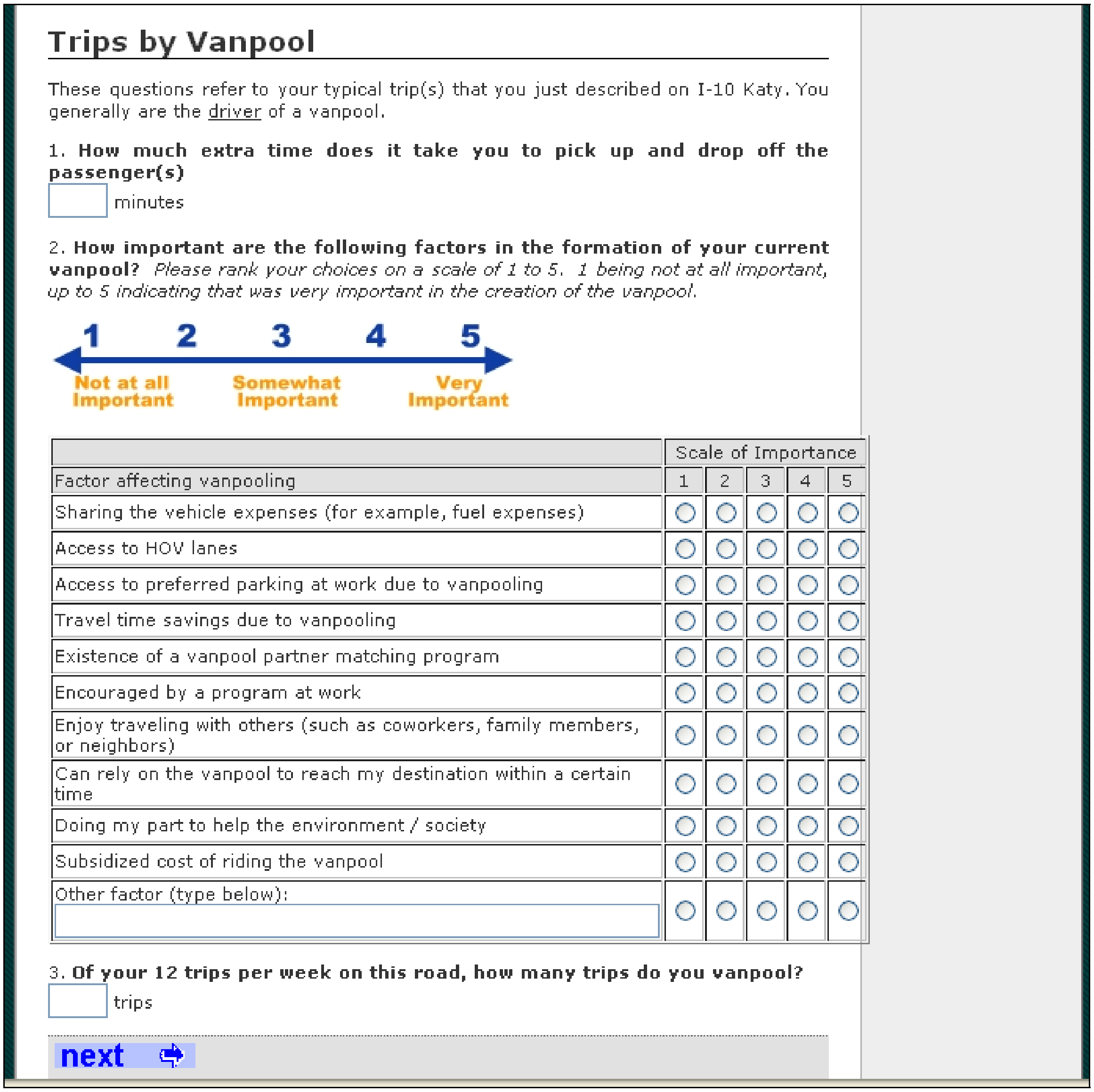
[ ] trips

5. **What do you do after you drop off the passenger(s) in your carpool?**

○ The trip is over, the passenger and I have the same destination
○ Continue to my final destination (going to or from work)
○ Pick up an additional passenger for some other trip
○ Perform errands and then travel to my final destination
○ Other task (Type other task below):

next

Figure 32: Questions asked regarding carpool, questions 3 to 5.



Trips by Vanpool

These questions refer to your typical trip(s) that you just described on I-10 Katy. You generally are the driver of a vanpool.

1. **How much extra time does it take you to pick up and drop off the passenger(s)**

[ ] minutes

2. **How important are the following factors in the formation of your current vanpool?** *Please rank your choices on a scale of 1 to 5. 1 being not at all important, up to 5 indicating that was very important in the creation of the vanpool.*

1 2 3 4 5
Not at all Important
Somewhat Important
Very Important

	Scale of Importance				
Factor affecting vanpooling	1	2	3	4	5
Sharing the vehicle expenses (for example, fuel expenses)	○	○	○	○	○
Access to HOV lanes	○	○	○	○	○
Access to preferred parking at work due to vanpooling	○	○	○	○	○
Travel time savings due to vanpooling	○	○	○	○	○
Existence of a vanpool partner matching program	○	○	○	○	○
Encouraged by a program at work	○	○	○	○	○
Enjoy traveling with others (such as coworkers, family members, or neighbors)	○	○	○	○	○
Can rely on the vanpool to reach my destination within a certain time	○	○	○	○	○
Doing my part to help the environment / society	○	○	○	○	○
Subsidized cost of riding the vanpool	○	○	○	○	○
Other factor (type below):	○	○	○	○	○

3. **Of your 12 trips per week on this road, how many trips do you vanpool?**

[ ] trips

next

Figure 33: Questions asked regarding vanpool.

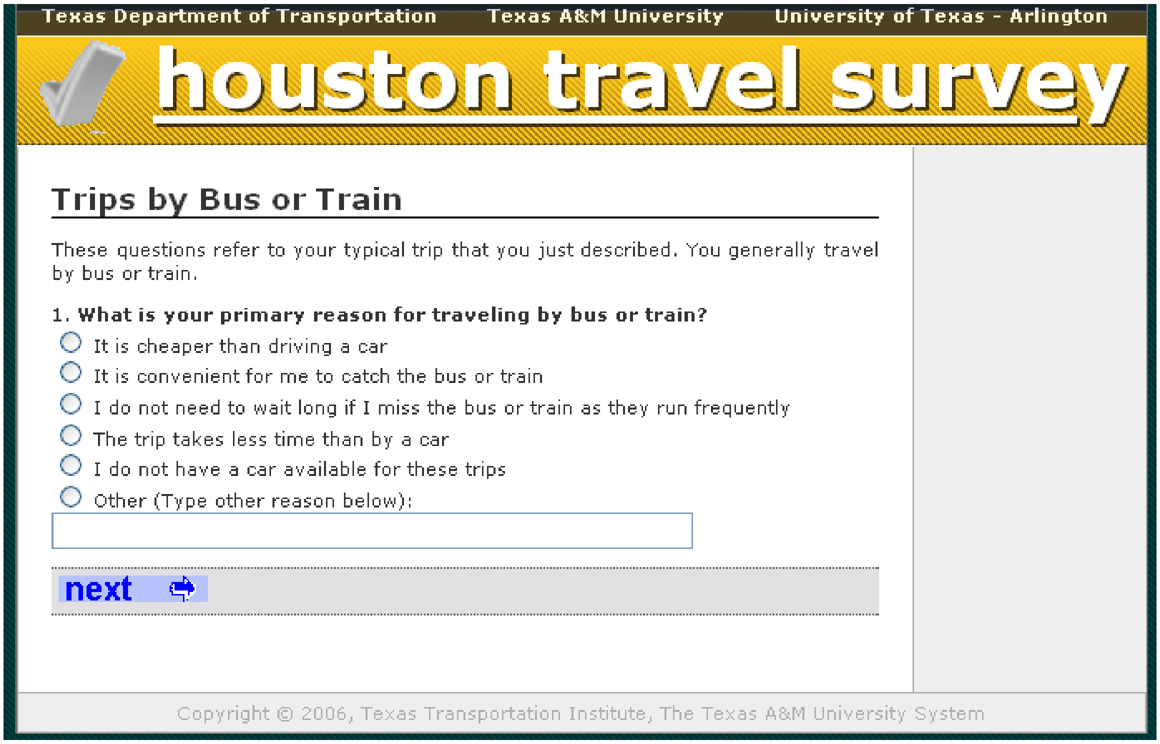
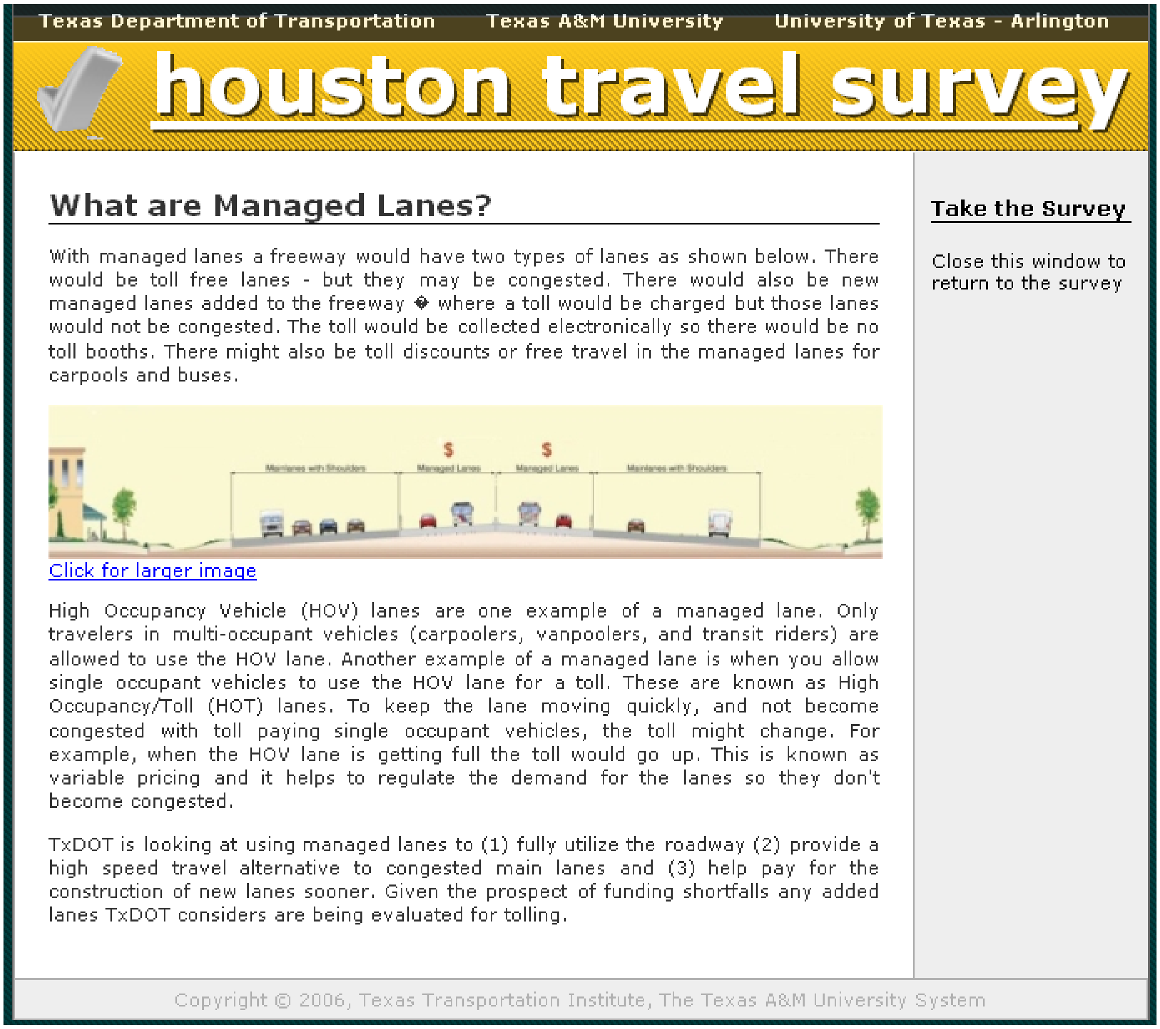


Figure 34: Questions asked regarding trips by transit.



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What are Managed Lanes?

With managed lanes a freeway would have two types of lanes as shown below. There would be toll free lanes - but they may be congested. There would also be new managed lanes added to the freeway � where a toll would be charged but those lanes would not be congested. The toll would be collected electronically so there would be no toll booths. There might also be toll discounts or free travel in the managed lanes for carpools and buses.

Click for larger image

High Occupancy Vehicle (HOV) lanes are one example of a managed lane. Only travelers in multi-occupant vehicles (carpoolers, vanpoolers, and transit riders) are allowed to use the HOV lane. Another example of a managed lane is when you allow single occupant vehicles to use the HOV lane for a toll. These are known as High Occupancy/Toll (HOT) lanes. To keep the lane moving quickly, and not become congested with toll paying single occupant vehicles, the toll might change. For example, when the HOV lane is getting full the toll would go up. This is known as variable pricing and it helps to regulate the demand for the lanes so they don't become congested.

TxDOT is looking at using managed lanes to (1) fully utilize the roadway (2) provide a high speed travel alternative to congested main lanes and (3) help pay for the construction of new lanes sooner. Given the prospect of funding shortfalls any added lanes TxDOT considers are being evaluated for tolling.

Take the Survey

Close this window to return to the survey

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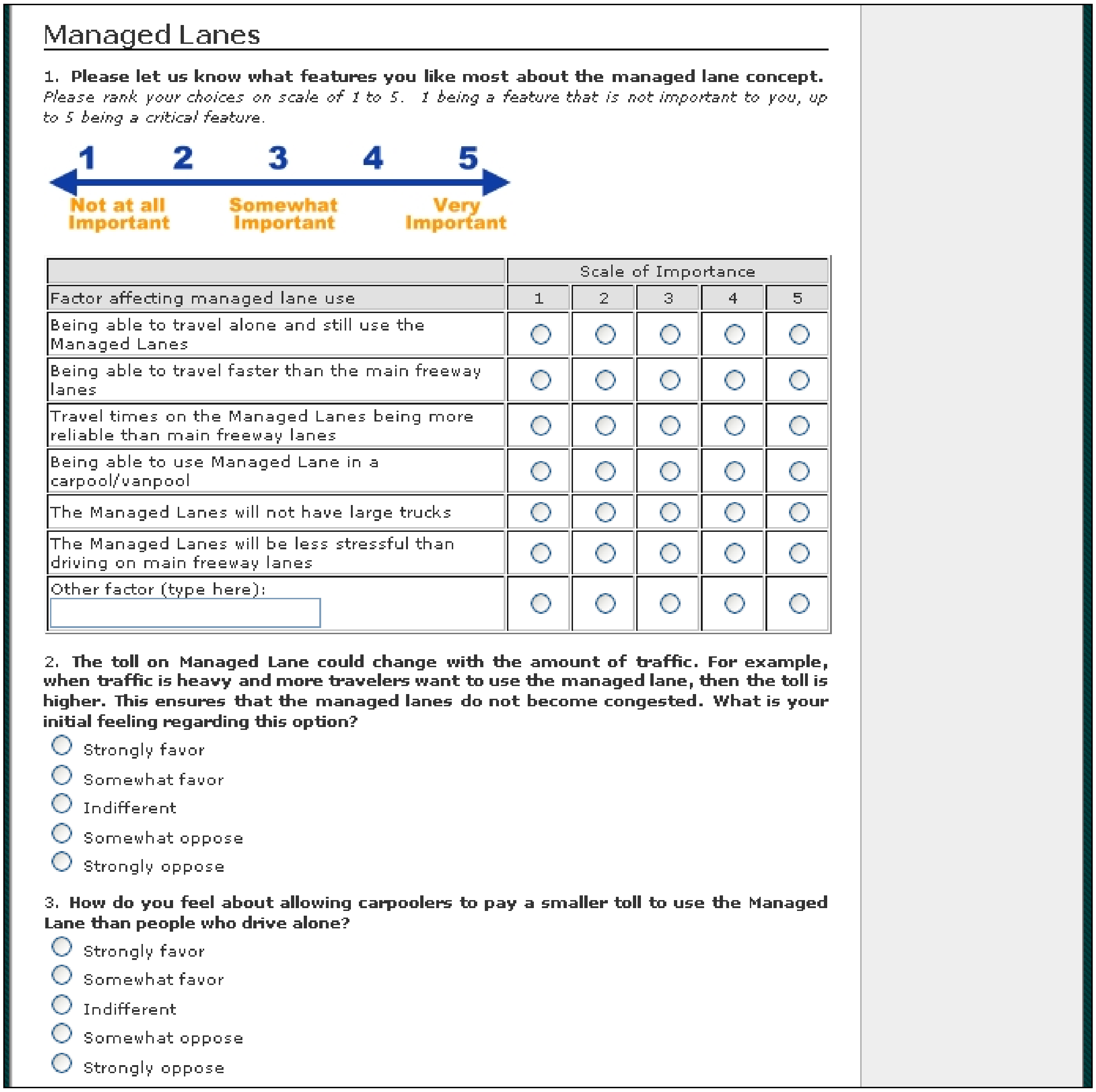
Figure 35: Explanation of concept of managed lanes to the survey respondents.



Managed Lanes

1. Please let us know what features you like most about the managed lane concept.
Please rank your choices on scale of 1 to 5. 1 being a feature that is not important to you, up to 5 being a critical feature.

1 2 3 4 5
Not at all Important   Somewhat Important   Very Important

	Scale of Importance				
Factor affecting managed lane use	1	2	3	4	5
Being able to travel alone and still use the Managed Lanes	○	○	○	○	○
Being able to travel faster than the main freeway lanes	○	○	○	○	○
Travel times on the Managed Lanes being more reliable than main freeway lanes	○	○	○	○	○
Being able to use Managed Lane in a carpool/vanpool	○	○	○	○	○
The Managed Lanes will not have large trucks	○	○	○	○	○
The Managed Lanes will be less stressful than driving on main freeway lanes	○	○	○	○	○
Other factor (type here):	○	○	○	○	○

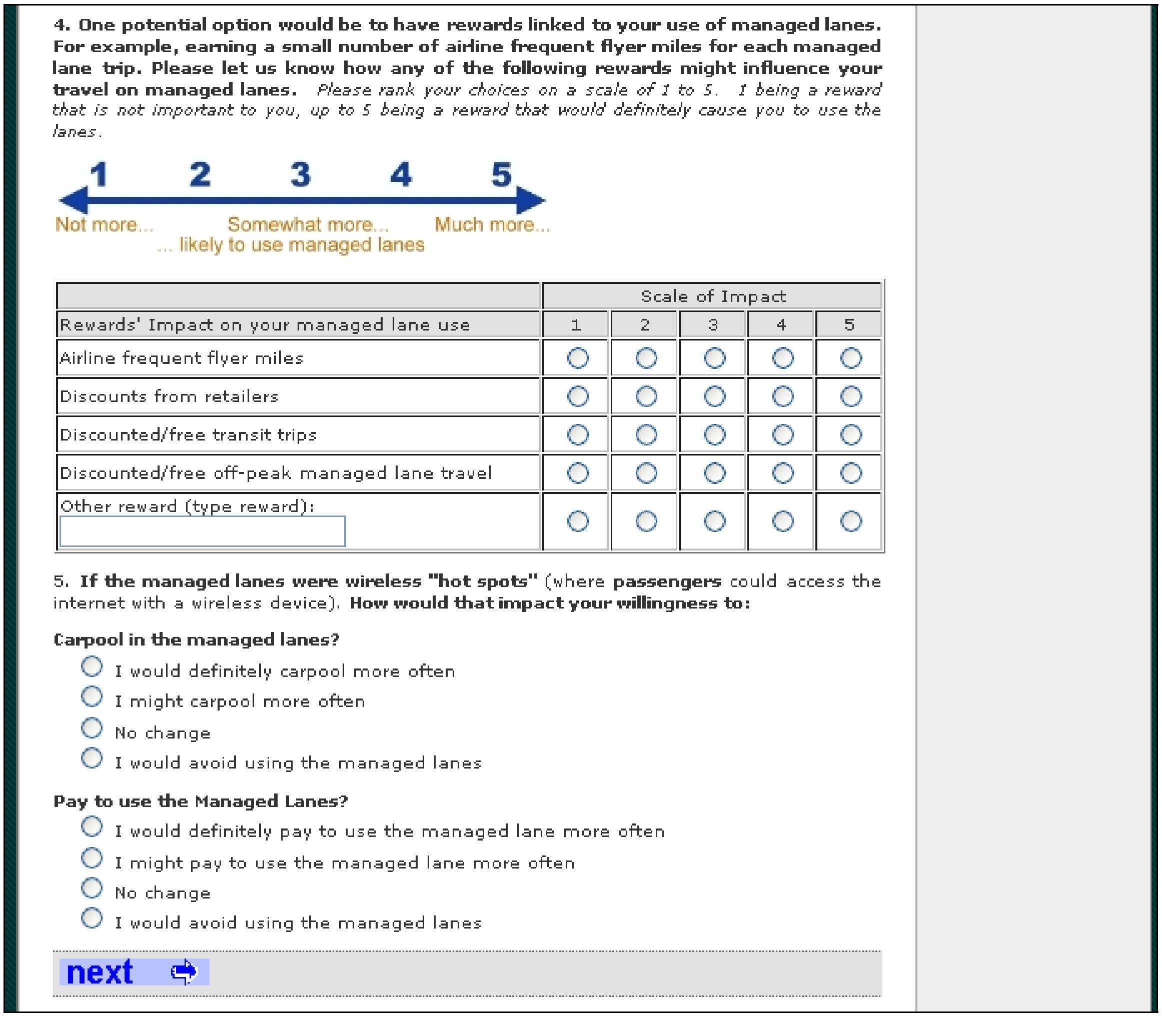
2. The toll on Managed Lane could change with the amount of traffic. For example, when traffic is heavy and more travelers want to use the managed lane, then the toll is higher. This ensures that the managed lanes do not become congested. What is your initial feeling regarding this option?

- ○ Strongly favor
- ○ Somewhat favor
- ○ Indifferent
- ○ Somewhat oppose
- ○ Strongly oppose

3. How do you feel about allowing carpoolers to pay a smaller toll to use the Managed Lane than people who drive alone?

- ○ Strongly favor
- ○ Somewhat favor
- ○ Indifferent
- ○ Somewhat oppose
- ○ Strongly oppose

Figure 36: Questions asked to survey respondents who indicated interest in using managed lanes; questions 1 to 3.



4. One potential option would be to have rewards linked to your use of managed lanes. For example, earning a small number of airline frequent flyer miles for each managed lane trip. Please let us know how any of the following rewards might influence your travel on managed lanes. *Please rank your choices on a scale of 1 to 5. 1 being a reward that is not important to you, up to 5 being a reward that would definitely cause you to use the lanes.*

	Scale of Impact				
Rewards' Impact on your managed lane use	1	2	3	4	5
Airline frequent flyer miles	○	○	○	○	○
Discounts from retailers	○	○	○	○	○
Discounted/free transit trips	○	○	○	○	○
Discounted/free off-peak managed lane travel	○	○	○	○	○
Other reward (type reward):	○	○	○	○	○

5. **If the managed lanes were wireless "hot spots"** (where **passengers** could access the internet with a wireless device). **How would that impact your willingness to:**

Carpool in the managed lanes?

- ○ I would definitely carpool more often
- ○ I might carpool more often
- ○ No change
- ○ I would avoid using the managed lanes

Pay to use the Managed Lanes?

- ○ I would definitely pay to use the managed lane more often
- ○ I might pay to use the managed lane more often
- ○ No change
- ○ I would avoid using the managed lanes

next

Figure 37: Questions asked to survey respondents who indicated interest in using managed lanes; questions 4 and 5.

Managed Lanes

1. **Please let us know what features of managed lanes are the most important in your decision not to use them.** *Please rank your choices on scale of 1 to 5. 1 being a feature that is not important to you, up to 5 being a feature that would definitely cause you not to use managed lanes.*

	Scale of Importance				
Factor affecting managed lane use	1	2	3	4	5
I do not have a credit card needed to set up an account for electronic toll collection	○	○	○	○	○
I do not want a toll transponder (toll tag) in my car	○	○	○	○	○
The Managed Lane program is complicated or confusing	○	○	○	○	○
I have the flexibility to travel at less congested times on the toll-free lanes	○	○	○	○	○
I do not want to pay the toll cost of using Managed Lanes	○	○	○	○	○
Other factor (type here):	○	○	○	○	○

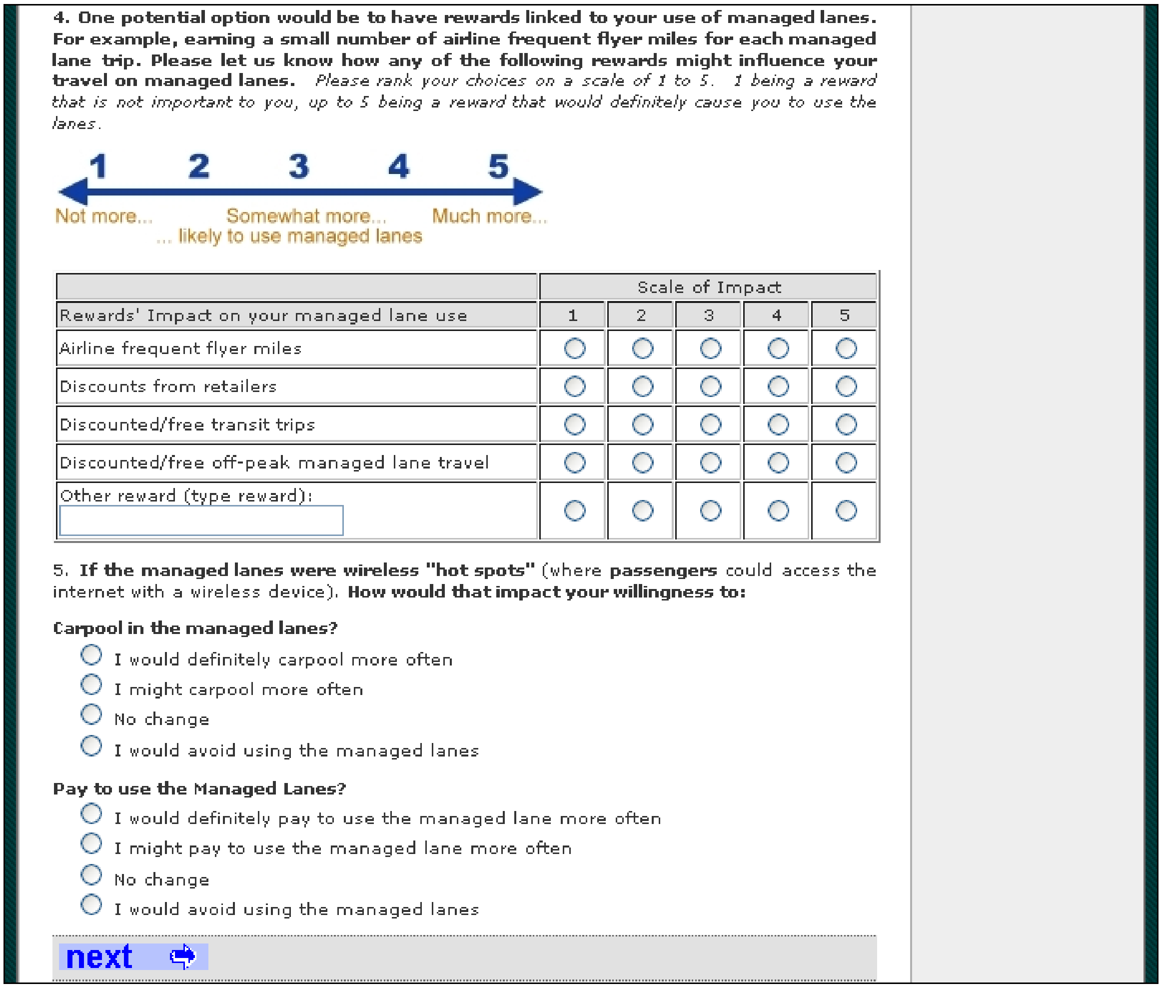
2. **The toll on Managed Lane could change with the amount of traffic. For example, when traffic is heavy and more travelers want to use the managed lane, then the toll is higher. This ensures that the managed lanes do not become congested. What is your initial feeling regarding this option?**

○ Strongly favor
○ Somewhat favor
○ Indifferent
○ Somewhat oppose
○ Strongly oppose

3. **How do you feel about allowing carpoolers to pay a smaller toll to use the Managed Lane than people who drive alone?**

○ Strongly favor
○ Somewhat favor
○ Indifferent
○ Somewhat oppose
○ Strongly oppose

Figure 38: Questions asked to survey respondents who did not indicate interest in using managed lanes; questions 1 to 3.



4. One potential option would be to have rewards linked to your use of managed lanes. For example, earning a small number of airline frequent flyer miles for each managed lane trip. Please let us know how any of the following rewards might influence your travel on managed lanes. *Please rank your choices on a scale of 1 to 5. 1 being a reward that is not important to you, up to 5 being a reward that would definitely cause you to use the lanes.*

	Scale of Impact				
Rewards' Impact on your managed lane use	1	2	3	4	5
Airline frequent flyer miles	○	○	○	○	○
Discounts from retailers	○	○	○	○	○
Discounted/free transit trips	○	○	○	○	○
Discounted/free off-peak managed lane travel	○	○	○	○	○
Other reward (type reward):	○	○	○	○	○

5. **If the managed lanes were wireless "hot spots"** (where **passengers** could access the internet with a wireless device). **How would that impact your willingness to:**

Carpool in the managed lanes?

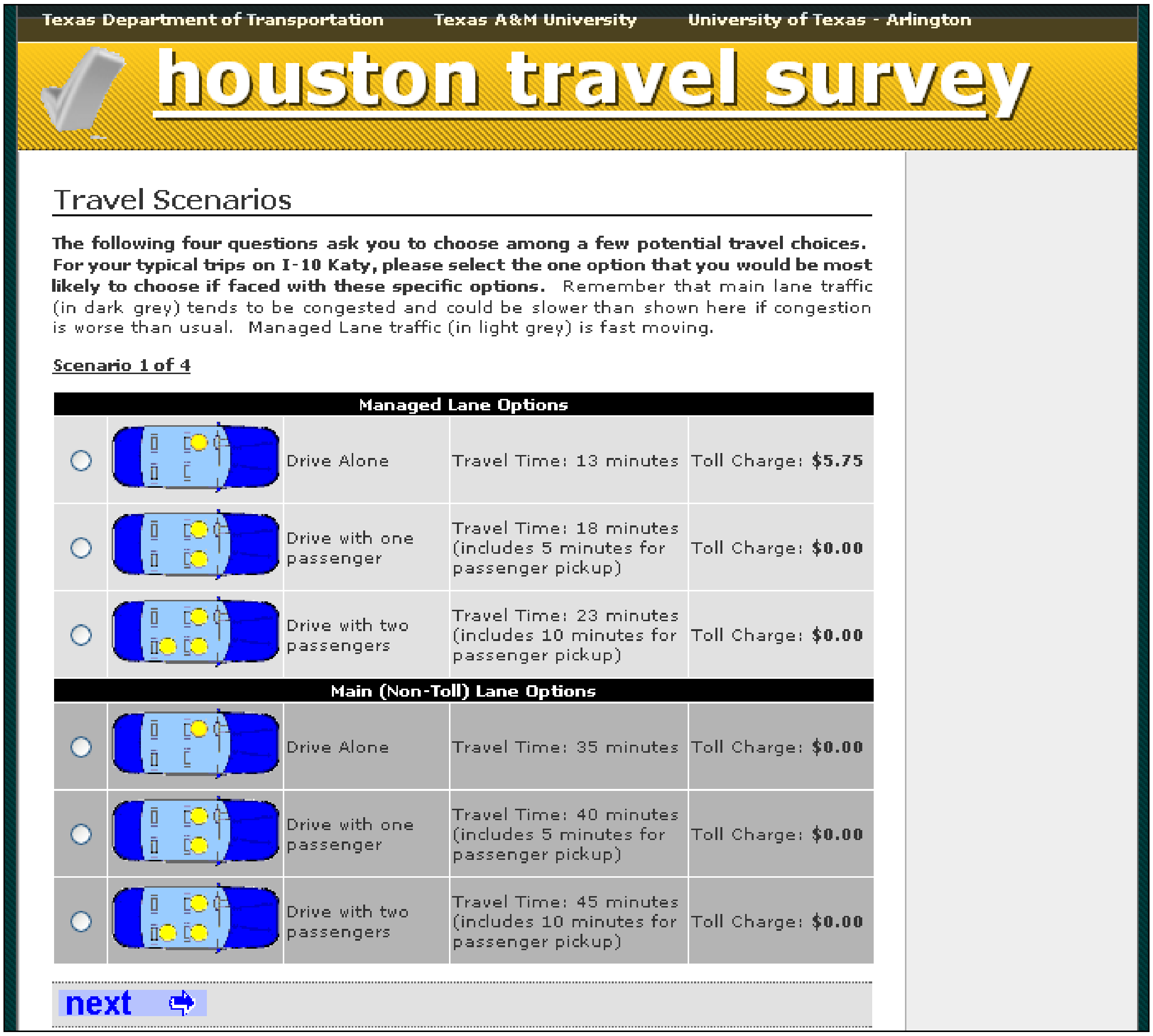
- ○ I would definitely carpool more often
- ○ I might carpool more often
- ○ No change
- ○ I would avoid using the managed lanes

Pay to use the Managed Lanes?

- ○ I would definitely pay to use the managed lane more often
- ○ I might pay to use the managed lane more often
- ○ No change
- ○ I would avoid using the managed lanes

next

Figure 39: Questions asked to survey respondents who did not indicate interest in using managed lanes; questions 4 and 5.



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Travel Scenarios

The following four questions ask you to choose among a few potential travel choices. For your typical trips on I-10 Katy, please select the one option that you would be most likely to choose if faced with these specific options. Remember that main lane traffic (in dark grey) tends to be congested and could be slower than shown here if congestion is worse than usual. Managed Lane traffic (in light grey) is fast moving.

Scenario 1 of 4

Managed Lane Options		
Drive Alone	Travel Time: 13 minutes	Toll Charge: **$5.75**
Drive with one passenger	Travel Time: 18 minutes (includes 5 minutes for passenger pickup)	Toll Charge: **$0.00**
Drive with two passengers	Travel Time: 23 minutes (includes 10 minutes for passenger pickup)	Toll Charge: **$0.00**
Main (Non-Toll) Lane Options		
Drive Alone	Travel Time: 35 minutes	Toll Charge: **$0.00**
Drive with one passenger	Travel Time: 40 minutes (includes 5 minutes for passenger pickup)	Toll Charge: **$0.00**
Drive with two passengers	Travel Time: 45 minutes (includes 10 minutes for passenger pickup)	Toll Charge: **$0.00**

next

Figure 40: First scenario in the stated preference questions.

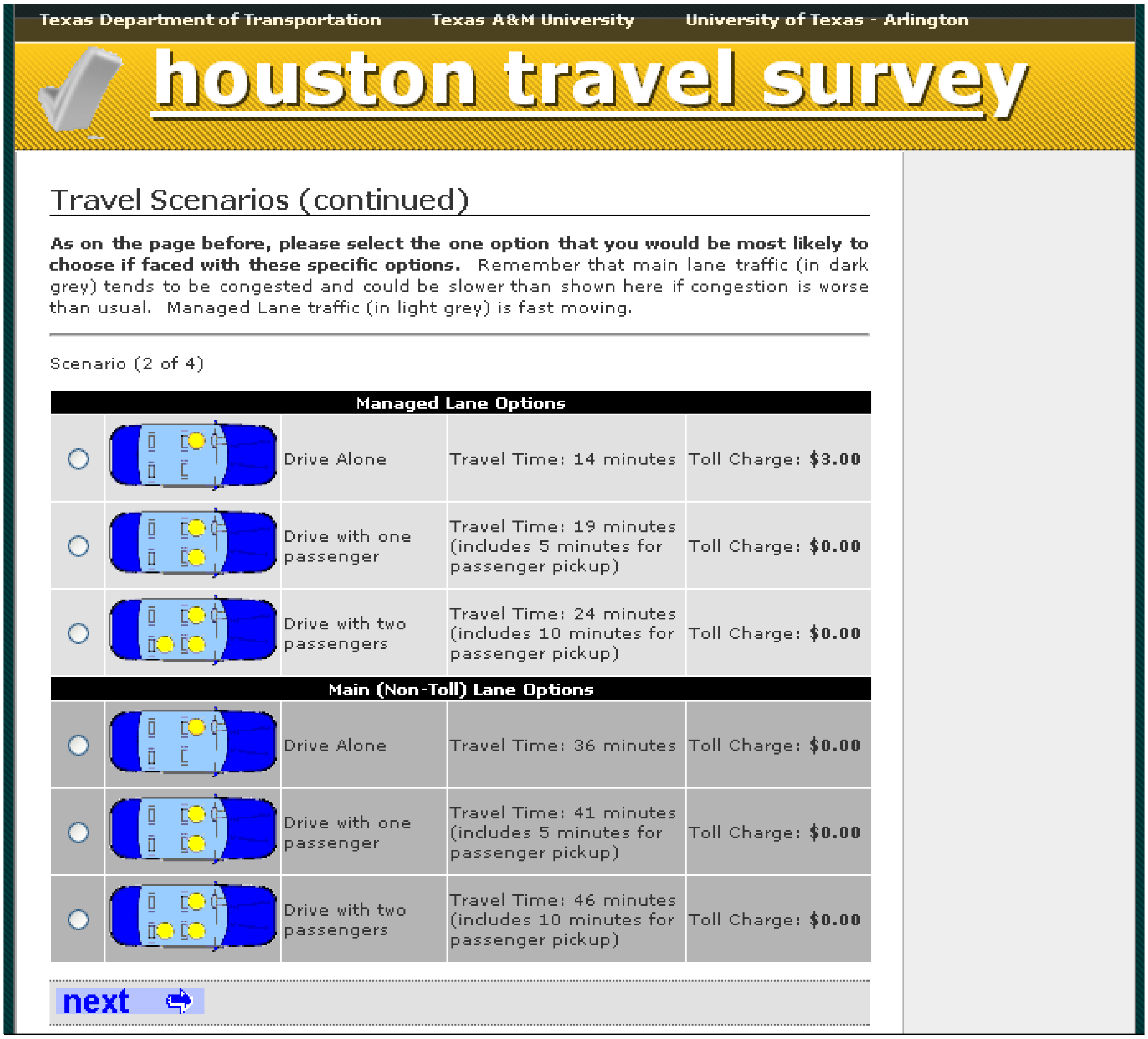
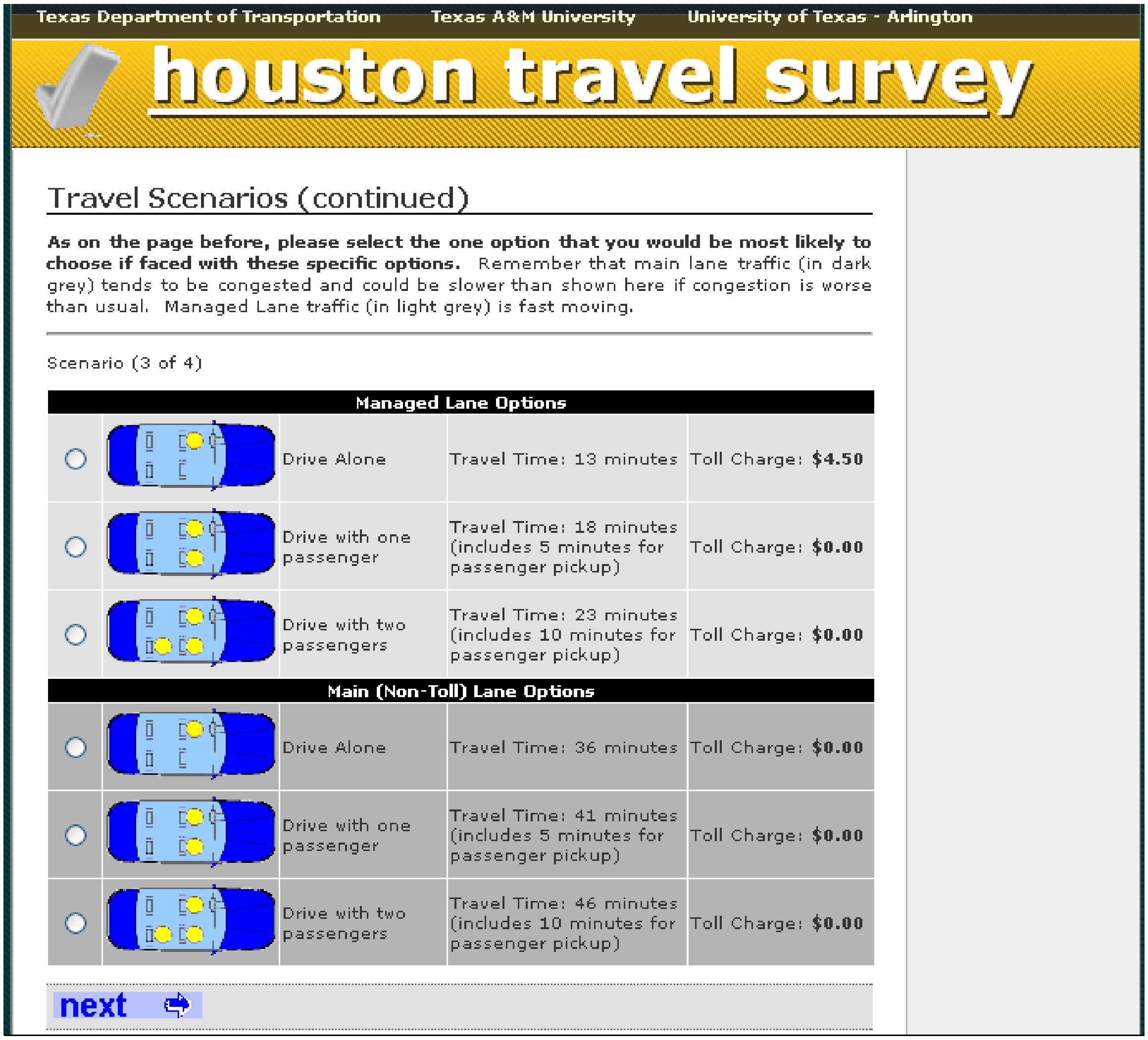


Figure 41: Second scenario in the stated preference questions.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Travel Scenarios (continued)

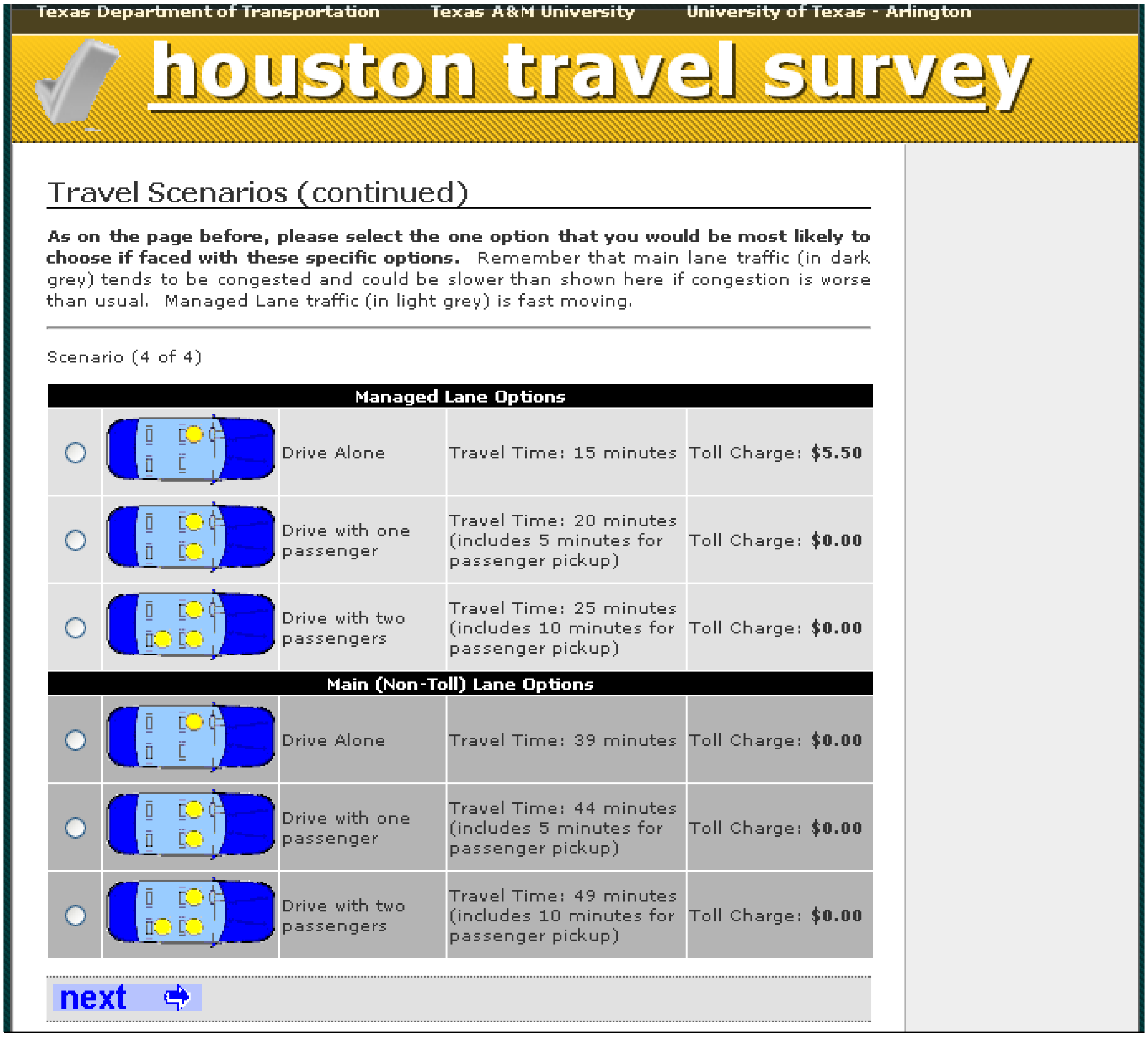
As on the page before, please select the one option that you would be most likely to choose if faced with these specific options. Remember that main lane traffic (in dark grey) tends to be congested and could be slower than shown here if congestion is worse than usual. Managed Lane traffic (in light grey) is fast moving.

Scenario (3 of 4)

Managed Lane Options				
○		Drive Alone	Travel Time: 13 minutes	Toll Charge: **$4.50**
○		Drive with one passenger	Travel Time: 18 minutes (includes 5 minutes for passenger pickup)	Toll Charge: **$0.00**
○		Drive with two passengers	Travel Time: 23 minutes (includes 10 minutes for passenger pickup)	Toll Charge: **$0.00**
Main (Non-Toll) Lane Options				
○		Drive Alone	Travel Time: 36 minutes	Toll Charge: **$0.00**
○		Drive with one passenger	Travel Time: 41 minutes (includes 5 minutes for passenger pickup)	Toll Charge: **$0.00**
○		Drive with two passengers	Travel Time: 46 minutes (includes 10 minutes for passenger pickup)	Toll Charge: **$0.00**

next

Figure 42: Third scenario in the stated preference questions.



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Travel Scenarios (continued)

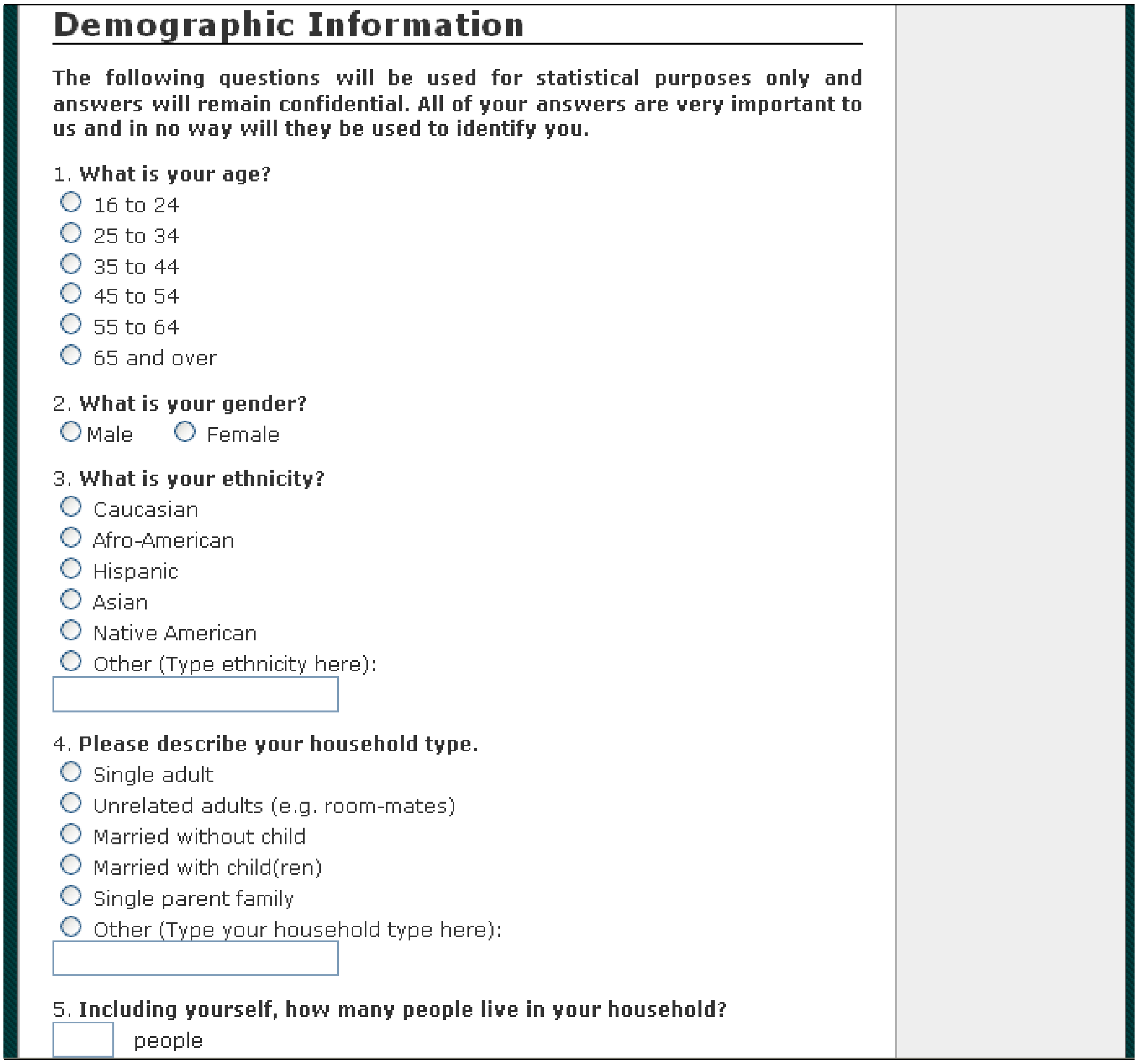
As on the page before, please select the one option that you would be most likely to choose if faced with these specific options. Remember that main lane traffic (in dark grey) tends to be congested and could be slower than shown here if congestion is worse than usual. Managed Lane traffic (in light grey) is fast moving.

Scenario (4 of 4)

Managed Lane Options				
○		Drive Alone	Travel Time: 15 minutes	Toll Charge: **$5.50**
○		Drive with one passenger	Travel Time: 20 minutes (includes 5 minutes for passenger pickup)	Toll Charge: **$0.00**
○		Drive with two passengers	Travel Time: 25 minutes (includes 10 minutes for passenger pickup)	Toll Charge: **$0.00**
Main (Non-Toll) Lane Options				
○		Drive Alone	Travel Time: 39 minutes	Toll Charge: **$0.00**
○		Drive with one passenger	Travel Time: 44 minutes (includes 5 minutes for passenger pickup)	Toll Charge: **$0.00**
○		Drive with two passengers	Travel Time: 49 minutes (includes 10 minutes for passenger pickup)	Toll Charge: **$0.00**

next

Figure 43: Fourth scenario in the stated preference questions.



Demographic Information

The following questions will be used for statistical purposes only and answers will remain confidential. All of your answers are very important to us and in no way will they be used to identify you.

1. **What is your age?**
   - 16 to 24
   - 25 to 34
   - 35 to 44
   - 45 to 54
   - 55 to 64
   - 65 and over

2. **What is your gender?**
   - Male
   - Female

3. **What is your ethnicity?**
   - Caucasian
   - Afro-American
   - Hispanic
   - Asian
   - Native American
   - Other (Type ethnicity here):

4. **Please describe your household type.**
   - Single adult
   - Unrelated adults (e.g. room-mates)
   - Married without child
   - Married with child(ren)
   - Single parent family
   - Other (Type your household type here):

5. **Including yourself, how many people live in your household?**
   people

Figure 44: Socio-economic information related questions asked to the survey respondents; questions 1 to 5.

6. **All together, how many motor vehicles (including cars, vans, trucks, and motorcycles) are available for use by members of your household?**

[ ] vehicles

7. **What category best describes your occupation?**

- ○ Professional / Managerial
- ○ Technical
- ○ Sales
- ○ Service Industry (restaurants, retail, etc.)
- ○ Administrative / Clerical
- ○ Manufacturing / Construction
- ○ Stay-at-home homemaker / parent
- ○ Student
- ○ Self employed
- ○ Unemployed / Seeking work
- ○ Retired
- ○ Other (Type your occupation here):

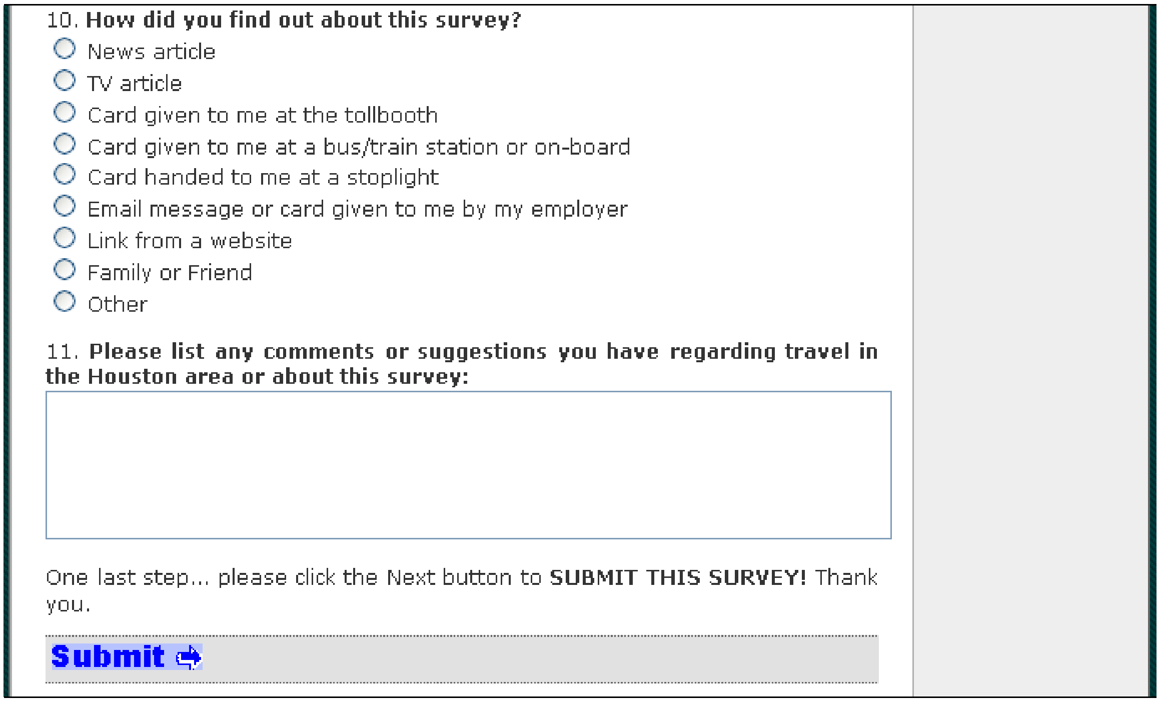
8. **What is the last year of school you have completed?**

- ○ Less than high school
- ○ High school graduate
- ○ Some college / Vocational
- ○ College graduate
- ○ Postgraduate degree

9. **What was your annual household income before taxes in 2005?**

- ○ Less than $10,000
- ○ $10,000 to $14,999
- ○ $15,000 to $24,999
- ○ $25,000 to $34,999
- ○ $35,000 to $49,999
- ○ $50,000 to $74,999
- ○ $75,000 to $99,999
- ○ $100,000 to $149,999
- ○ $150,000 to $199,999
- ○ $200,000 or more

Figure 45: Socio-economic information related questions asked to the survey respondents; questions 6 to 9.



10. **How did you find out about this survey?**

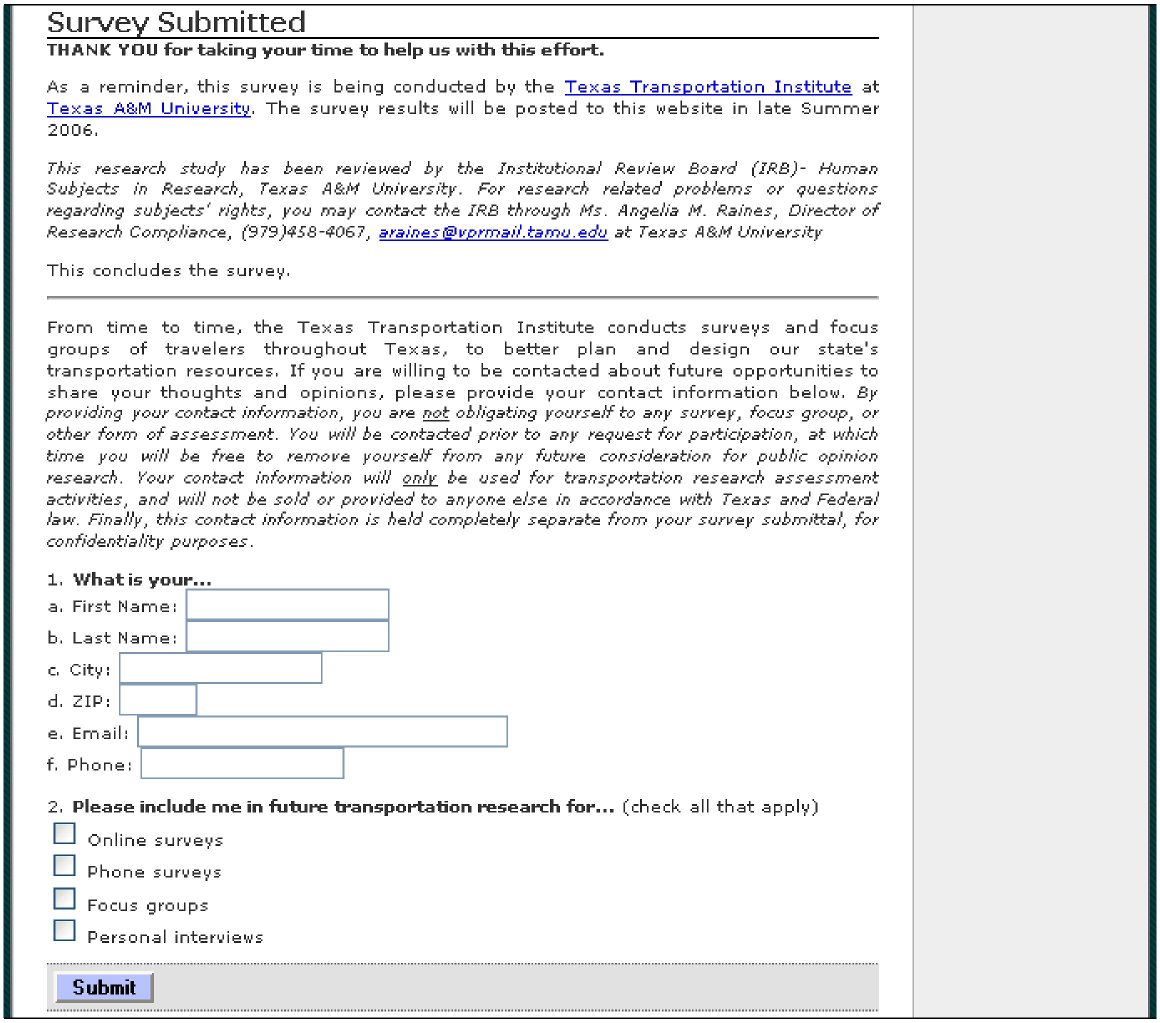
- News article
- TV article
- Card given to me at the tollbooth
- Card given to me at a bus/train station or on-board
- Card handed to me at a stoplight
- Email message or card given to me by my employer
- Link from a website
- Family or Friend
- Other

11. **Please list any comments or suggestions you have regarding travel in the Houston area or about this survey:**

One last step... please click the Next button to **SUBMIT THIS SURVEY!** Thank you.

Submit

Figure 46: Socio-economic information related questions asked to the survey respondents; questions 10 and 11.



Survey Submitted

THANK YOU for taking your time to help us with this effort.

As a reminder, this survey is being conducted by the Texas Transportation Institute at Texas A&M University. The survey results will be posted to this website in late Summer 2006.

This research study has been reviewed by the Institutional Review Board (IRB)- Human Subjects in Research, Texas A&M University. For research related problems or questions regarding subjects' rights, you may contact the IRB through Ms. Angelia M. Raines, Director of Research Compliance, (979)458-4067, araines@vprmail.tamu.edu at Texas A&M University

This concludes the survey.

From time to time, the Texas Transportation Institute conducts surveys and focus groups of travelers throughout Texas, to better plan and design our state's transportation resources. If you are willing to be contacted about future opportunities to share your thoughts and opinions, please provide your contact information below. *By providing your contact information, you are not obligating yourself to any survey, focus group, or other form of assessment. You will be contacted prior to any request for participation, at which time you will be free to remove yourself from any future consideration for public opinion research. Your contact information will only be used for transportation research assessment activities, and will not be sold or provided to anyone else in accordance with Texas and Federal law. Finally, this contact information is held completely separate from your survey submittal, for confidentiality purposes.*

1. **What is your...**

a. First Name:

b. Last Name:

c. City:

d. ZIP:

e. Email:

f. Phone:

2. **Please include me in future transportation research for...** (check all that apply)

- [ ] Online surveys
- [ ] Phone surveys
- [ ] Focus groups
- [ ] Personal interviews

Submit

Figure 47: Information gathered from the respondents, if they wished to be part of future transportation related online surveys, telephone surveys, focus group surveys, or surveys by conducting personal interviews.

VITA

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B.Tech., Civil Engineering, Indian Institute of Technology Guwahati, 2004

Work Experience: Texas Transportation Institute, TAMU, College Station, TX
Graduate Research Assistant

- Helped in conceptualization and development of Managed Lane survey in Houston and Dallas
- Conducted data cleaning to input data into SPSS, STATA, and Limdep for statistical analysis. Weighted the survey date and conducted descriptive statistics of the data. Developed multinomial logit mode choice models

Conferences:

- Maneesh Mahlawat, S. Rayan, S. Kuchangi, S. Patil, Mark W. Burris. Examination of Student Travel Mode Choice. Presented at TRB 2007 Annual Meeting Session 343 (Poster)
- Mark W. Burris, Kaveh F. Sadabadi, S. Mattingly, Maneesh Mahlawat, J. Li, I. Rasmidatta, and A. Saroosh. Reaction to the Managed Lane Concept by Various Groups of Travelers. Presented at TRB 2007 Annual Meeting Session 439 (Paper presentation)