UNDERSTANDING AND ESTIMATING THE VALUE TRAVELERS PLACE ON THEIR TRIPS ON MANAGED LANES

A Dissertation

by

SUNIL NARAYAN PATIL

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

DOCTOR OF PHILOSOPHY

December 2009

Major Subject: Civil Engineering

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Approved by:

Chair of Committee,	Mark W. Burris
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ABSTRACT

Understanding and Estimating the Value Travelers Place on Their Trips on Managed Lanes. (December 2009)

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Chair of Advisory Committee: Dr. Mark W. Burris

Travelers' value of travel time savings (VTTS) are often used to estimate the benefits of transportation facilities, including managed lanes (MLs). With various eligibility criteria and time of day pricing on the MLs, the VTTS estimation is complicated. This is evident by the underestimation of VTTS on MLs in many of the previous studies. This study investigates stated preference (SP) survey design strategies and differentiating the VTTS for ordinary and some common urgent situations faced by the travelers in an attempt to improve on VTTS estimation on MLs.

This study used three different survey design strategies (including a D-efficient design) in an internet based survey of Katy Freeway travelers. It was found that a random attribute level generation strategy, where the VTTS presented in the alternative was adjusted based on the answer to a previous SP question, performs better than the other two designs with respect to VTTS estimation and other survey design efficiency criteria.

The analysis to differentiate the VTTS for ordinary and urgent trips was carried out using the state of art in the mixed logit model estimation. It was found that travelers value their travel time savings much more when facing most of these urgent situations rather than ordinary situations. Both peak and off-peak period travelers' VTTS were also found to be significantly greater when on urgent trips. Survey design attribute level ranges were found to significantly affect the VTTS estimation.

Further, in order to understand the policy implications of these findings it was demonstrated that classifying all trips as ordinary can significantly underestimate the VTTS benefits offered by the MLs. Additionally, the VTTS of any urgent trips would be greatly underestimated. The study also demonstrated that many of the low and medium income group travelers on urgent trips can have VTTS greater than that of the highest VTTS traveler from the high income group on an ordinary trip. These findings have significant policy implications since the benefits of MLs (and of most transportation investments) are primarily derived from travel time savings. Underestimating the VTTS and hence the benefits for MLs can result in reducing the likelihood of funding such facilities. This study provides an important first step in the proper estimation of these benefits by suggesting modifications to SP surveys to better capture the influence of urgent trips on the value of a ML facility.

DEDICATION

To my parents: Laxmi and Narayan, brothers: Sandeep and Shrikant, and my lovely wife: Bhavna

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1. INTRODUCTION

1.1. Background and Motivation

Understanding travel behavior is critical to the process of planning and policy making. Travel behavior analysis is a vast concept that includes study of travel by all the modes of transportation. It also includes the study of travelers in order to analyze their mode choice, destination choice, time of departure, and number of trips made by the travelers. Further, travel behavior analysis can be used in various studies including demand estimation and for operation of existing transportation facilities. It is also used for understanding the transportation needs of various traveler groups. Despite numerous studies carried out to understand the travel behavior, travel behavior analysis remains an active research area due to its complex nature. One of the important components of travel behavior analysis is estimation of the value travelers assign to travel time savings on various toll facilities including managed lanes (MLs).

Managed lanes such as High Occupancy Vehicle (HOV) lanes and High Occupancy/Toll (HOT) lanes tend to offer a reliable and faster alternative to travelers, often encourage drivers to travel during less congested periods, and/or increase their vehicle occupancy (ride sharing). Findings from a few implemented pilot projects in the United States conclude that managed lanes indeed offer a faster and reliable travel alternative, promote ridesharing, transit use, and offer a safer alternative (Collier and Goodin, 2002). Thus, one of the important benefits offered by managed lanes is the value of travel time savings (VTTS) for travelers on MLs. Stated preference (SP) studies are often conducted to estimate these VTTS and hence the benefits of managed lanes to travelers. Accurate estimation of the area travelers' VTTS also plays an important role in the efficient operation of a toll facility. The toll rates are typically set using the estimated VTTS from one or more survey studies, but too high or too low of a toll rate can cause

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This dissertation follows the style of Transportation Research Part A.

underutilization or congestion of these lanes, respectively. In addition, adjusting the rate after implementing an initial rate can upset the area travelers especially if it is raised. Hence, it is critical to accurately estimate the VTTS. This study focuses on two measures to better estimate and understand the value travelers place on their trips on managed lanes.

The first measure is to develop a better stated preference survey design for VTTS estimation. A stated preference survey utilizes the underlying survey design(s) to present the time and toll tradeoffs to the respondents in SP questions. These survey designs affect estimation of the parameters of choice models and hence estimation of the VTTS. This dissertation analyzes three different survey designs as one of measures to improve the VTTS estimation and overall goodness of fit of the choice models.

Additionally, estimation of VTTS on managed lane facilities using stated preference studies is complex as travelers on these facilities can change their mode of transportation from driving alone to carpooling and/ or they may change their time of departure to lower or eliminate need to pay the toll. These complexities may be one reason that, typical stated preference studies developed to estimate ML travelers' VTTS tend to underestimate their VTTS when compared to studies using the revealed preference approach (see Ghosh, 2001; Brownstone et al., 2003, Brownstone and Small, 2005). Another possible reason for this underestimation is given by Brownstone and Small (2005) who explain that:

> People display time inconsistency in their actual behavior, but not in their hypothetical behavior. In their actual travel they may intend to choose the cheaper roadway, but then neglect to allow sufficient time and so be forced by a scheduling constraint to take the express lanes. It is entirely plausible that they would not account for such errors in implementing their own plans when answering SP questions. Thus, they make the higher-cost choice more often in real life than on hypothetical surveys. (p. 288).

Further, many of the studies of existing managed lanes have concluded that while the vast majority of travelers use MLs only occasionally, they also show that travelers from all income groups use these MLs (Sullivan et al., 2000; Collier and Goodin, 2002; Burris and Stockton, 2004). These findings indicate that travelers may be assigning different values to their travel time savings on different trip occasions, which is in part supported by the findings of the studies indicating that the VTTS changes depending on the time of day (Small et al., 1999; Tseng and Verhoef, 2008). This hypothesis was recently supported by a study of the Minnesota I-394 MnPASS HOT lanes project, which focused on the change in VTTS due to unexpected delay (Tilahun and Levinson, 2008). Using a SP survey, Tilahun and Levinson (2008) compared the maximum willingness to pay (WTP) of travelers who were delayed with that of travelers who were not delayed for their last trip. They found that the travelers (subscribers to MnPASS) who were late in the afternoon rush hour for their last (most recent) trip had a higher average WTP than those who were not delayed.

A considerable gap still exists in the understanding of travel behavior for managed lanes especially for those with both variable pricing and occupancy discounts. This dissertation research continues the line of investigation started by Tilahun and Levinson (2008) by focusing on possible variation in the VTTS that may be due to a traveler's sense of urgency for a given trip. Hence, the second measure to improve VTTS estimation examined here is the inclusion of urgent trips in stated preference studies. The study investigates whether an individual attaches more value to his/her travel time savings when faced by some of the commonly faced urgent situations, as might seem logical.

1.2. Research Objectives and Tasks

As discussed in the previous section, the goal of this dissertation is to add to the understanding of travel behavior, specifically to better estimate and understand travelers' VTTS on MLs. To obtain this goal, two research objectives were identified. The first research objective was to analyze the effects of survey designs on estimation of mode choice models and VTTS of travelers on MLs with variable pricing. The second objective was to estimate and compare the value travelers place on travel time savings when on urgent versus ordinary trips.

To achieve these objectives many tasks were required. The primary ones are briefly mentioned here. The first research task was to conduct an extensive literature review to guide efforts in developing an improved survey designing and mode choice modeling for managed lanes with variable pricing. This task also included a brief review of literature related to the estimation of value of travel time savings. The second task involved survey designing and hosting of an internet based survey which incorporated various survey designs. Three survey design approaches were used to present the travel time and toll tradeoffs in the stated preference questions. The internet based survey was implemented to collect information related to general travel and demographics apart from the answers to stated preference questions related to urgent and regular/ordinary travel situations. The third task was to analyze the stated preference survey data for above objectives and present the results and conclusions. Detailed analyses were carried out to study effects of survey designs and to compare and understand the VTTS for travelers on urgent trips and on regular trips. This task also included analysis for VTTS estimation for peak and off-peak period travelers.

1.3. Dissertation Outline

The rest of this dissertation is organized as follows. In Section 2 the concept of managed lanes and the benefits of managed lanes are described. This section also contains literature review of stated preference survey methodology and stated preference survey designs, followed by the review of discrete choice models and estimation of value of travel time savings. This research used the stated preference survey data collected from Katy Freeway travelers for mode choice modeling. The survey designs used for Katy Freeway traveler survey, survey methodology and questionnaire are described in Section 3. Preliminary analysis of the survey responses is presented in Section 4. Logit models estimated for these data are presented in Section 5 with focus on suggesting the best survey design strategy and VTTS estimation for ordinary and urgent situations. In order to investigate more about the travel behavior in urgent situation, the research also included analysis of urgent situation VTTS estimation for peak and off-peak traveler groups; results of which are also presented in Section 5. This is followed by estimation of benefits of managed lanes and policy implication demonstration. Section 6 includes the conclusions drawn from this dissertation research followed by recommendations for future research.

2. LITERATURE REVIEW

The goal of this dissertation was to improve the understanding of travel behavior through specific research objectives that included study of effects of survey designs and comparison of travelers' value of travel time savings on managed lanes for urgent and regular trips. One of the tasks in this dissertation included the review of literature that can support the analysis carried out to achieve these objectives. The review of literature related to travel behavior, managed lanes, survey designs, discrete choice models and estimation of VTTS is presented in this section.

2.1 Study of Travel Behavior and Its Importance

Travel behavior analysis is the study of peoples' activities and movements. It encompasses study of travel by all modes including walking, biking, driving, riding the bus, air travel etc. These studies are typically undertaken to predict one or more of the following- travelers' destination(s), mode choice, route choice, ride sharing, time of departure, and number of trips.

Travel plays an important role in any economy. Hence, travel behavior analysis can be very important in regional or area wide planning even in the planning at the national level. Travel behavior analysis is used for various purposes some of which are described in the following paragraphs.

Being able to predict traveler's mode or destination is a key in demand estimation for a link (such as highway/freeway), network and region (see example, McFadden, 1974b). Hence, travel behavior studies can also contribute to design and planning of travel facilities. These studies can also be carried out to estimate the number of trips produced at a household level (see example, Lan and Hu, 2000).

Travel behavior analysis can have significant policy implications and it can also include travel safety analysis. It can include study of various traveler groups understanding their travel behavior and analysis for equity offered by a proposed facility such as a toll road. The most often studied traveler groups include groups based on gender, income, age and ethnicity. For example, Collia et al. (2003) analyzed travel patterns of elderly drivers. Pucher and Renne (2003) analyzed the socioeconomics of urban travel. Such studies contribute to understanding of travel behavior and transportation needs of various traveler groups and most of these studies have important consequences for public policy.

Travel behavior analysis is also used to estimate travelers' perceived value of travel time savings and reliability. This value is a very important statistic and is typically used to estimate the monetary cost of traffic congestion (see example, Schrank and Lomax, 2007), cost and benefits of traffic/roadway improvements or construction, etc. Numerous studies have been carried out to estimate the travel time savings offered by toll facilities such as toll roads and toll bridges (see examples, Burris and Pendyala, 2002, Brownstone et al. 2003). Managed lane facilities such as high occupancy/toll lanes are some of the newer facilities to join the list of toll facilities. This research focused on estimation of value of travel time savings offered by managed lanes. The concept of managed lanes and their benefits are described in next section.

2.2. Managed Lanes and Their Benefits

A managed lane is a broad concept and it includes various types of facilities. Different managed lane facilities that exist in the United States and the details of the Katy Freeway and managed lanes are also presented in this section.

2.2.1. Concept of Managed Lanes

The Federal Highway Administration defines managed lanes as "highway facilities or a set of lanes where operational strategies are proactively implemented and managed in response to changing conditions" (FHWA, 2005). Managed lanes typically represent the facilities which are:

- located within a freeway,
- separated from the general purpose lanes,
- operated in order to actively manage the traffic,
- respond to growth, and

- targeted to maintain a level of service through tools of pricing, vehicle eligibility and/or access control.

Managed lanes include a broad range of facilities and typically use one or more of the three operational strategies to achieve the targeted level of service; pricing, vehicle eligibility and access control. Various types of facilities such as HOV lanes, HOT lanes, toll lanes, express lanes, busways, etc. are possible by implementing these operation strategies as shown in Figure 1. For example, when pricing and vehicle eligibility are used as the operation strategy, the facility type is generally known as a HOT lane. Managed lanes thus include a wide range of facility types and offer various benefits to travelers.

2.2.2. Benefits of Managed Lanes to Travelers

One of the goals of managed lanes is to provide a more reliable and/or faster alternative to general purpose lanes, which are normally congested during peak hours. Managed lanes with vehicle eligibility as an operating strategy (HOV or HOT lanes) also have an objective of increasing ride sharing and, frequently, promoting transit use. An efficiently operated managed lane can carry more traffic and serve more travelers than a general purpose lane. Thus managed lanes are expected to offer travel time savings along with fuel savings for those who use them. Managed lanes are also expected to cause less pollution and vehicle crashes due to less congestion (Collier and Goodin, 2002). Since most managed lanes allow the transit to use the lanes for free of charge, they also tend to increase efficiency of the transit by savings in travel time and improved reliability. Initially, managed lanes that allow vehicles to use them for a toll were thought to cause an equity issue and were seen as favoring wealthier travelers. However, the latest research findings prove that managed lanes are used by travelers from all income categories and most of travelers use them infrequently when in need of a reliable and fast alternative (Sullivan et al., 2000, Collier and Goodin, 2002).

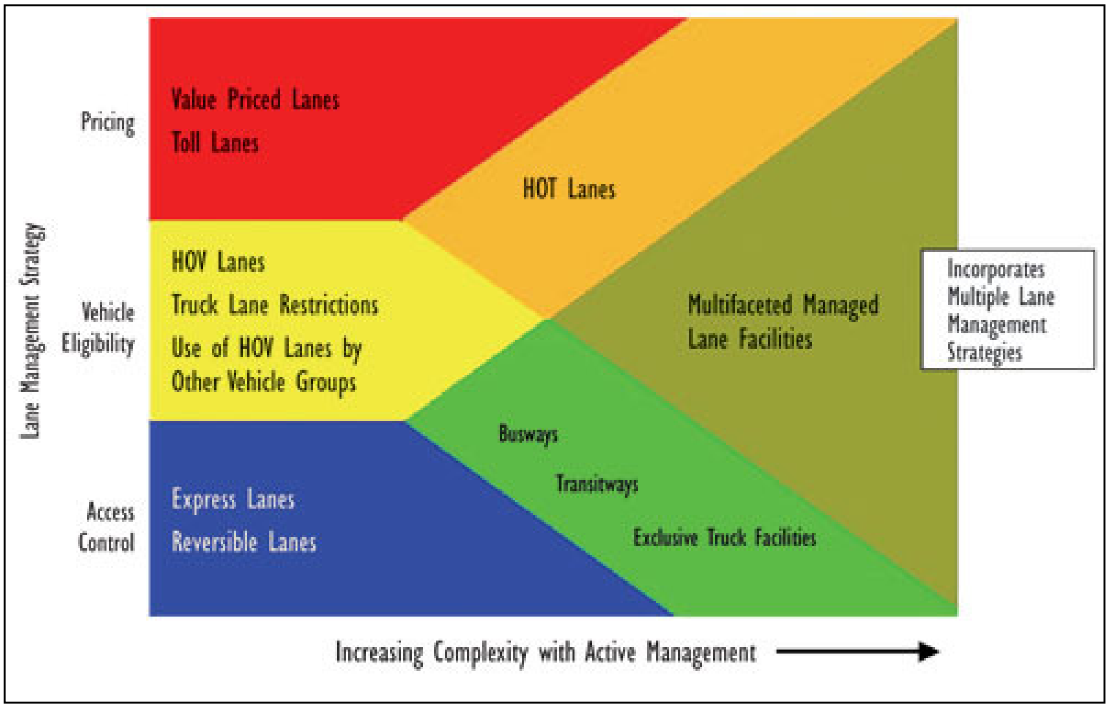

Figure 1 Operational Strategies and Types of Facilities in Managed Lane Concept.
(*Source: FHWA, 2005*)

2.2.3. Existing Facilities in the United States

Due in part to early Federal Highway Administration (FHWA) Value Pricing Pilot Program efforts, managed lanes are becoming more and more popular in the United States. As a result more managed lane facilities than ever are being planned and constructed. Managed lane facilities in operation in the United States as of August 2009 are listed in the Table 1. Katy Freeway, Houston is one of the earliest freeways to include the managed lanes. This research uses data collected from travelers of the Katy Freeway. Hence, various details of Katy Freeway and its managed lanes are presented in the next section.

Table 1 Existing Managed Lane Facilities in the United States (Source: Burris, 2009)

	Name of Facility	Location	Type
1	Katy Tollway/Managed Lanes	Houston, Texas	HOT lanes, tolls vary by time of day
2	Northwest US 290 QuickRide	Houston, Texas	HOT lanes with flat fee
3	State Route 91 Express Lanes	Orange County, California	Toll Express Lanes, tolls vary by time of day
4	Interstate 15 Express Lanes	San Diego, California	HOT lanes, tolls vary dynamically based on level of congestion
5	Interstate 394 MnPASS Express Lanes	Minneapolis, Minnesota	HOT lanes, tolls vary dynamically based on level of congestion
6	Interstate 25 HOV/Tolled Express Lanes	Denver, Colorado	HOT lanes, tolls vary by time of day
7	Interstate 15 Express Lanes	Salt Lake City, Utah	HOT lanes with flat fee
8	State Route 167 -HOT Lanes Pilot Project	Washington State	HOT lanes, tolls vary dynamically based on level of congestion
9	Interstate 95 Express Lanes	Miami-Dade County, Florida	HOT lanes, tolls vary dynamically based on level of congestion
10	San Joaquin, Foothill, and Eastern Toll Roads	California	Tolls vary by time of day
11	New Jersey Turnpike Authority Roads (except Garden State Parkway)	New Jersey	Tolls vary by time of day
12	Dulles Greenway	Virginia	Tolls vary by time of day

2.2.4. Katy Freeway and Managed Lanes

Houston, Texas is one of the largest cities in the United States with a 2007 U.S. Census population estimate of over 5.7 million people living in the Houston metropolitan area (Census, 2007). Houston has an extensive network of freeways with an outer freeway loop (Beltway 8) of about 25 miles in diameter (Figure 2).

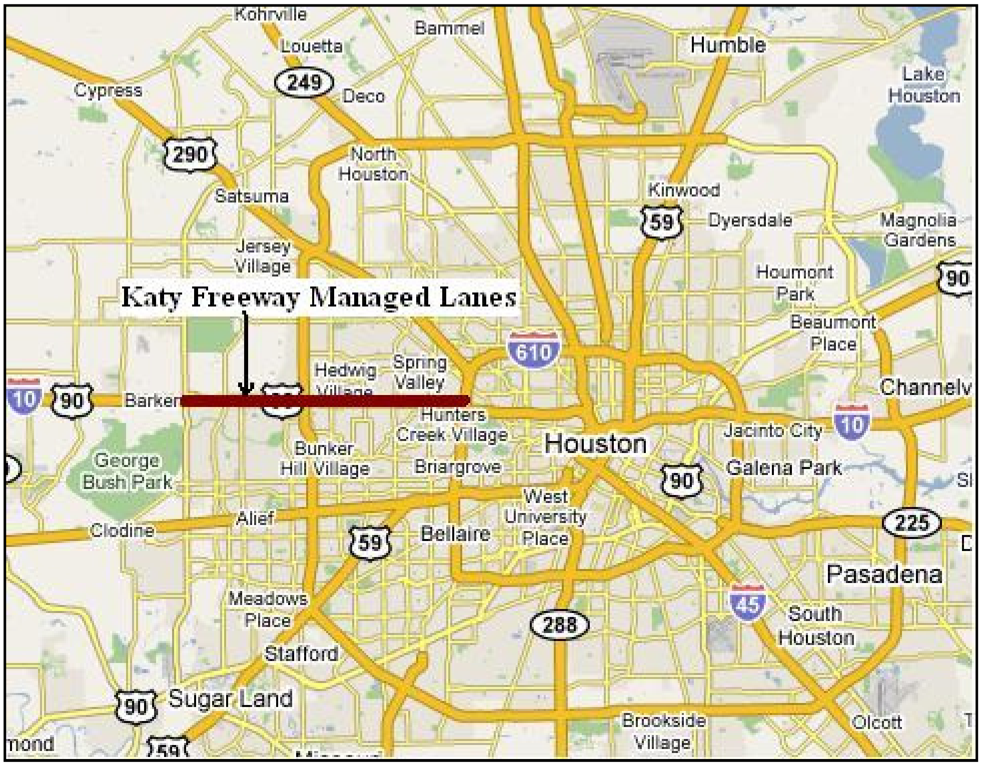

Figure 2 Freeway Network in and Around City of Houston, Texas.

Katy Freeway is one of a few key travel corridors in this network. It is located on the west side of the downtown Houston and is owned and operated by the Texas Department of Transportation (TxDOT). This 23 mile stretch of Interstate 10 connects the city of Katy with Interstate 610 west (inner loop) (TxDOT, 2009). Katy Freeway had three main lanes (or general purpose lanes) and two frontage-road lanes for most of its length in each direction. When constructed in 1960s, it was designed to carry 79,200 vehicles per day: however in 2008 the freeway served more than 219,000 vehicles per day (TxDOT, 2009). It also has the highest daily truck volumes of any roadway in the state of Texas (FHWA, 2003). In the FHWA report, A Guide for HOT Lane Development (2003) traffic delays costing $85 million a year were reported for the Katy Freeway.

In 1984 a HOV lane, constructed with support from Federal Transit Administration (FTA) funds, was opened by TxDOT and Houston Metro. The HOV lane was a reversible single lane in the middle of the freeway separated by a concrete barrier. In the beginning only buses and authorized vanpools were allowed to use the HOV lane. Later, eligibility requirements were relaxed to allow carpools of four or more, then three or more and then two or more people. Allowing two-plus person carpools caused a large increase in traffic on the HOV lane; hence, more restrictive carpool rules were eventually reinstated. From 6.45 a.m. to 8.00 a.m. and from 5.00 p.m. to 6.00 p.m. the lane was restricted to carpools with three or more occupants. However, even with this restriction significant excess capacity existed on the HOV lane.

In 1998, Houston Metro and TxDOT launched the value pricing pilot program known as QuickRide on the existing 13 mile HOV lane, funded as an FHWA Priority Corridor Program. The HOV lane was converted into a HOT lane, which allowed registered two-person carpools to use the lane for a $2 fee during its greatest peaks (from 6:45 a.m. to 8.00 a.m. and from 5.00 p.m. to 6.00 p.m. Monday through Friday) and for free during other times. The QuickRide facility allowed buses and three-plus carpools for free while continuing to restrict the single occupant vehicles (SOVs) at all times. QuickRide featured a fully automatic toll collection system, where the toll was paid by windshield-mounted electronic transponders issued by either Houston Metro or transponders issued by the Harris County Toll Road Authority (HCRTA).

In 2003, an expansion of Katy Freeway started in order to build four continuous through-lanes and as many as eight freeway lanes at entrance and exit ramps, with the project costing approximately $2.7 billion (U.S.). The new project also added four MLs in the middle of the freeway separated by flexible “candlestick” barriers. These MLs were designed to better manage the congestion using peak-period pricing. The MLs are 12 miles long and run from Highway 6 to Interstate 610. The MLs opened to traffic in November 2008, operating as HOV lanes in which two-plus person carpools, motorcycles, and buses could travel for free. In April 2009, the MLs started operating as HOT lanes with the addition of time of day pricing for SOVs. The toll rate is set to vary by time of day ($4, $2, and $1 for peak, shoulder, and off-peak hours, respectively, for the 12 mile stretch); HOVs, and motorcycles pay only during off-peak hours, and the toll can be paid by EZTag or TxTag only (HCTRA, 2009a). This provided an excellent testbed to determine how travelers value their trips on MLs using the latest techniques in survey design.

2.3. Stated Preference Survey Designs for Mode Choice Modeling

Surveying travelers is a critical component of travel behavior analysis. While travelers' survey can be very useful in gaining useful information, the survey needs to consider various sampling issues and the survey methodology to gain meaningful information related to the travel behavior. Travel behavior analysis mostly involves study of travelers using one of the surveys such as travel diaries, household travel surveys and stated preference surveys. The type of survey needed for a study is decided based on the type of data required to model the travel behavior under consideration in that study.

SP surveys are a popular tool in the studies of mode choice modeling and estimation of value of travel time savings. Stated preference surveys allow researchers to study traveler response/behavior toward various travel alternatives which can be existing, future or imaginary alternatives. A typical stated preference experiment consists of presenting some alternatives in stated preference questions to the respondent. The alternatives are described by means of attributes. For example, travel time and toll can be the attributes to describe the travel alternatives car, bus, and train. Respondents are asked to choose one of the presented alternatives. The values of attributes presented (levels of attributes) in a SP question help the respondent to consider the trade-offs between the alternatives and are used to estimate mode choice models. The levels of attributes used in the SP experiment affect the estimation precision and the inferences drawn from mode choice model (Dallaer et al., 1999, Ohler et al., 2000, Hensher, 2004). Hence, choosing the combination of attribute levels to be presented using the underlying survey design is one of the important factors of SP surveying.

2.3.1. Survey Design Basics

A choice design is made up of choice sets composed of several alternatives, each defined as a combination of different attribute levels (Zwerina et al., 1996). The researcher, through the experimental design, specifies attribute levels in each stated preference experiment, which is evaluated by the respondent. Cumulative data from all the stated preference experiments are then used to model individual preferences by estimating the parameters corresponding to each of the attributes used to model the choice. Thus, the researcher can control certain factors within the study which affect parameter identification, model flexibility, and statistical efficiency of the estimators (Johnson et. al. 2006). The experimental design can therefore influence the estimation of each attribute's contribution to the observed choices.

Experimental design in its linear form (a linear design) can be visualized as a matrix with columns representing different attributes of all the alternatives and rows representing choice situations (see Table 2). A choice situation or a stated preference question is also referred to as a "run" of an experiment. The attribute levels are used to populate the matrix.

Table 2 Survey Design in Linear Form (Linear Design)

Experiment Number	Drive Alone on General Purpose Lanes (Toll Free)	Drive Alone on Managed Lanes		2-Person Carpool on Managed Lanes		3-Person Carpool on Managed Lanes	
	Time (min)	Time (min)	Toll	Time (min)	Toll	Time (min)	Toll
1	45	27	$1.50	30	$0.75	30	$0.25
2	35	20	$1.25	25	$0.25	27	$0.00
3	30	20	$1.50	23	$0.50	25	$0.25

Similarly, a choice design can be described as a matrix in which each column represents an alternative and each choice situation is represented by multiple rows corresponding to different attributes as shown in Table 3 (see, Bliemer and Rose, 2006).

Table 3 Survey Design in Choice Design Form

Experiment Number	Alternatives Attributes	Drive Alone on General Purpose Lanes (Toll Free)	Drive Alone on Managed Lanes	2-Person Carpool on Managed Lanes	3-Person Carpool on Managed Lanes
1	*Time (min)*	45	27	30	30
	Toll	N/A	$1.50	$0.75	$0.25
2	*Time (min)*	35	20	25	27
	Toll	N/A	$1.25	$0.25	$0.00
3	*Time (min)*	30	20	23	25
	Toll	N/A	$1.50	$0.50	$0.25

Some researchers also use a different form of choice design, in which the rows represent alternatives and columns represent attributes (see, Huber and Zwerina, 1996, Kanninen, 2002). This type of design is shown in Table 4. It is a transposition of the matrix presented in Table 3. Irrespective of the representation, a choice design is different than a linear design when model estimation is considered.

Almost all the studies have a constraint on the number of choice situations that can be used to gain information; hence, the researcher has to populate the design matrix such that the combination of the levels used in each choice situation will yield the maximum information.

When all possible combinations of attribute levels are listed in a design it becomes a full-factorial design, which is resource expensive and most of the time impractical to present to respondents. For example, even for a simple study with five factors, three at five levels and two at four levels (denoted as $5^3 4^2$), there are (5 x 5 x 5 x 4 x 4 =) 2,000 combinations in the full-factorial design. The large number of choices makes it very difficult to use the full-factorial design, even though with the full-factorial design all the main effects, all two-way and higher order interactions are estimable.

Table 4 Survey Design in Choice Design Form- Alternate Representation

Experiment Number	Alternatives / Attributes	*Time (min)*	*Toll*
1	Drive Alone on General Purpose Lanes (Toll Free)	45	N/A
	Drive Alone on Managed Lanes	27	$1.50
	2-Person Carpool on Managed Lanes	30	$0.75
	3-Person Carpool on Managed Lanes	30	$0.25
2	Drive Alone on General Purpose Lanes (Toll Free)	35	N/A
	Drive Alone on Managed Lanes	20	$1.25
	2-Person Carpool on Managed Lanes	25	$0.25
	3-Person Carpool on Managed Lanes	27	$0.00

A fractional factorial design is any design that has fewer rows than the full-factorial design. As a result of using fewer rows (choice situations) some attribute effects become confounded and they cannot be distinguished from each other. However, the (smaller) design size makes it possible to present all the choice situations to individuals (see Kuhfield, 2005, for details). Blocking of a design is one more way to reduce the number of choice situations per respondent, without changing the design size. Blocking refers to presenting the design (full or fractional factorial) to different respondents in sets which finally add up to the whole design.

It is recommended that a good fractional factorial survey design should possess the properties of level balance and orthogonality, while the converse may not always be true (see Kuhfield, 2005, Rose and Bliemer, 2008). Level balance is achieved in a design when all the levels occur equally within each factor. Orthogonality is achieved by selecting the levels such that the attributes become statistically independent. Orthogonality thus reduces the possibility of inducing correlations in attributes due to design error (higher order correlations may still remain in an orthogonal design). The full-factorial design is an orthogonal design, even for higher order correlations. Orthogonal designs are mainly used for linear models, as they are easy to construct. When used for estimating linear models, orthogonal designs were found to remove multicollinearity and minimize variance of parameter estimates (Louviere et al., 2000, Rose and Bliemer, 2008).

Despite their ease of construction, orthogonal designs are not an option in certain situations (Kuhfeld, 2005). It is not possible to use orthogonal designs when all the factor level combinations are not feasible or they do not make sense. For example, in the survey used for this dissertation, the speeds (hence the travel times) of all managed lane alternatives cannot be greatly different. Hence, the level combinations with extreme low and high speed levels for two managed lane alternatives would not be a feasible combination. Orthogonal designs are characterized by specific numbers of runs for specific numbers of factors with specific numbers of levels. Hence, when the desired number of runs is not available, using an orthogonal design is not an option. For example, for the survey used in this research the size of the design was limited by the number of characters in the survey code, which allowed only designs with up to 21 runs. Hence, an orthogonal design can be used only if it is available in that size. Further, in the case of discrete choice modeling the orthogonality of the design may not be preserved when the design is presented as a block (subset) to each respondent. Certain blocks are either over- or under- represented in the data (for example, due to non-response), which makes it difficult to retain the orthogonality of the design (Rose and Bliemer, 2008).

Choice studies differ from most of the studies involving linear models in one more ways which may limit the advantage of using an orthogonal design. Choice studies typically use additional attributes apart from those used to select the design. These non-design attributes (such as age, gender) in choice studies may also remain constant over the alternatives for each of respondent, creating correlations between themselves and other attributes (Rose and Bliemer, 2008).

Apart from these issues, in discrete choice studies, researchers also desire choice situations which do not have an extreme imbalance in the utilities of the alternatives presented to a respondent. Thus researchers avoid the situation where one alternative is very attractive in comparison to all others, as this does not help to gain much information about the trade-offs between the alternatives (Bates, 1998). This is similar to the problem of infeasible factor level combinations mentioned above, which may limit the use and advantage of orthogonal designs.

Conversely, marginal choices (with comparable utilities of the alternatives) are not desirable for efficiency (Toner et al., 1998). Studies such as the one carried out by Toner et al. (1998) have concluded that fractional factorial orthogonal designs do not necessarily improve the efficiency of the parameter estimation of the disaggregate logit models. Thus an experimental design for discrete choice models needs special considerations in order to better estimate the parameters as well as model the choice and estimate of value of travel time savings.

An efficient design is one of the recent survey designs used to overcome most of the disadvantages of orthogonal designs. This dissertation research uses an efficient design to achieve one of the objectives-studying the effect of survey designs on mode choice models and estimation of VTTS. The basic concept of an efficient design and details of the method used for searching an efficient design are presented in the next section.

2.3.2. Efficient Survey Designs

Selecting a fractional factorial design for a survey out of numerous possibilities from a full-factorial design typically is done using an efficiency criterion. An efficient survey design is characterized as a design that minimizes variance (thus the standard error) of the estimated parameters and hence maximizes the t-ratios produced by that model. The variances of parameter estimation are drawn from the variance-covariance

(VC) matrix of the model. For a linear model the variance-covariance matrix is given by Equation (1).

$$VC = \sigma^2 [X'X]^{-1} \tag{1}$$

where σ^2= the model variance and

X = the matrix of attribute levels in the design or data.

The model variance (σ^2) acts as the scaling factor, hence the VC matrix is proportional to $[X'X]^{-1}$. Most of the efficiency criteria (statistics) are based on the eigenvalues of $[X'X]^{-1}$. Two of the efficiency measures are A-efficiency and D-efficiency, both based on averaging the variance (Equations 2 and 3).

$$\text{A-efficiency} = 100 \times \frac{1}{N_D\, trace([X'X]^{-1})/p} \tag{2}$$

$$\text{D-efficiency} = 100 \times \frac{1}{N_D |(X'X)^{-1}|^{1/p}} \tag{3}$$

where N_D = number of runs (rows in a linear design),

p = number of parameters (different attributes in the design), and

$trace([X'X]^{-1})$ = sum of the diagonal elements of the matrix $[X'X]^{-1}$.

Thus, A-efficiency is a function of the arithmetic mean, while D-efficiency is a function of the geometric mean of eigenvalues. Hence D-efficiency is not sensitive to the parameter scaling (weighing the standard errors of larger parameters heavily as they tend to be larger than those of smaller parameters) in minimization. Use of D-efficiency criteria also has advantages in ease of incorporating it into programming and the fact that the relative D-efficiency (ratio of D-efficiency) of any two designs is not dependent on the coding scheme (Kuhfeld, 2005, Rose and Bliemer, 2008). Hence, use of D-efficiency criteria dominates the research literature.

Finding an efficient design specifically for a discrete choice model is done in two ways. The first approach is based on the assumption that the design which is good for a general linear model is also good for the discrete choice model. Many researchers in the past have used efficient linear designs for estimating discrete choice models using this assumption (Louviere and Woodworth, 1983, Louviere, 1998, Batsell and Louviere, 1991, Lazari and Anderson, 1994, Kuhfeld et al., 1994, Huber and Zwerina, 1996, Kuhfeld, 2005, Johnson et al., 2007). The efficient linear design which is finally unfolded into a choice design tends to possess the qualities of level balance and orthogonality. Macros for searching this type of design are readily available in SAS software and are described in sub-section 2.3.3 (Kuhfeld, 2005).

A second and more recent approach of searching an efficient design for a discrete choice model involves estimating the variance-covariance matrix for a particular choice model (Bliemer and Rose, 2006, Bliemer et al., 2009, Rose and Bliemer, 2008, Hess et al., 2008). The main argument in using this second approach is that, unlike in a linear model, the asymptotic variance-covariance matrix of a discrete choice model is based on the second derivative of the log-likelihood function underlying the estimation of the model (McFadden, 1974a, Bliemer and Rose, 2006), which in turn is driven by the assumption of the error structure in the model. For example, the formal relevant probabilities of the simple multinomial logit model relate to the fact that the underlying error (random) terms follow the extreme value distribution, while the probit model assumes that the error terms follow a distribution that is cumulative-normal. In neither case is the error term generated by assuming a linear model and a normal distribution, as is the case in use of ordinary least squares estimation. The variance-covariance matrix for a multinomial logit model (VC) is given by:

$$\mathrm{VC} = \frac{1}{\mathrm{M}}\left[\frac{\partial^2 \mathrm{LL}(\beta)}{\partial\beta\,\partial\beta'}\right] \tag{4}$$

where M = number of respondents, usually only one complete design for a single respondent is considered for estimation of the D-error while searching for the D-efficient design,

LL = log-likelihood function for the multinomial logit model (refer to the sub section 2.4.1 for details), and

β = the parameters used in the model.

As stated earlier, this approach uses design criteria specific to the specification of a choice model (such as multinomial logit, nested logit or mixed logit). D-efficiency for a specific model thus depends on the asymptotic VC matrix for that particular model. Also, ideally, this approach requires knowledge of the estimated parameter values (or assumption of parameter priors) to estimate the log-likelihood function, LL. This suggests the use of Bayesian methods, or at least approaches that allow feedback between design and estimation. Several researchers have concluded at this point that the assumption about the parameter priors affects the efficiency, and they have recommended using pilot studies and prior knowledge about the parameter values (Huber and Zwerina, 1996, Kanninen, 2002, Carlsson and Martinsson, 2003, Rose and Bliemer, 2008). Bayesian techniques are also being used to provide the parameter values needed in finding the efficient design (Ferrini and Scarpa, 2007, Scarpa and Rose, 2008, Rose and Bliemer, 2008, Hess et al., 2008).

This research follows the first approach in which an efficient design is searched assuming a linear model for generating one of the designs used in the Katy Freeway traveler survey. However, a design obtained using the second approach is also compared to investigate if it had better efficiency. These two approaches to search for an efficient design are explained in the sub sections 2.3.3 and 2.3.4.

2.3.3. Efficient Design Searching Using SAS Macros

Macros for searching a D-efficient design are readily available in SAS software and are explained in detail in Kuhfeld (2005). A series of macros is run in order to search for an efficient design. The procedure is described in the following paragraphs (see, Appendix A for detailed SAS codes).

First %MktRuns macro is run by specifying the number of attributes and the corresponding number of levels. This macro suggests the recommended sizes of the design. The macro also specifies the saturated design size which is the minimum size needed for estimation of the parameters and is equal to the number of parameters in the linear model. Next, another macro called %ResMac is used to specify the restriction during the design search. The restrictions are typically the level combinations corresponding to two or more attributes which are not feasible in the survey. For example, a restriction may be specified that in any given run, level four cannot be present in more than one of the attributes.

Next, the %MktEx macro is run by specifying the number of levels for each attribute, the size of the design to be searched, the restriction macro to be used and the random number seed to be used in case the results need to be replicated later. The %MktEx macro searches and returns an efficient design along with its D-efficiency and A-efficiency. The levels in the design returned are specified as integers 1,2,3,.., etc. In order to run basic checks against this design the macro %MktEval is run. This macro first prints a matrix of canonical correlations between the attributes (such as travel time and toll). This matrix will be an identical matrix in case the design is an orthogonal design. Next, the macro prints all one-way frequencies for all attributes, all two-way frequencies, and all n-way frequencies. Equal or at least nearly equal one-way and two-way frequencies are desired, and we want to see that each combination occurs only once. Equal one-way frequencies is an indication that the design is balanced. Equal two-way frequencies indicates that the design is orthogonal. The n-way frequencies, all equal to one, means that there are no duplicate profiles. This type of design is a perfect design for a main-effects model.

In the next step the macro %MktLabs is used to assign the variable names and actual values to the levels. This is followed by use of the %MktRoll macro to turn the linear design into the choice design. Finally, the macro %ChoicEff is used to evaluate efficiency of the design for a multinomial logit model.

A list of commands to obtain an efficient survey design of 24 runs/rows (24 questions in eight blocks of three ordinary situation questions) is given in Appendix A. A second approach used to search for a D-efficient design assuming a choice model is described in the next section.

2.3.4. Efficient Design Searching Assuming Choice Model- MS Excel Macros

The search for a D-efficient SP survey design assuming a choice model can be carried out using MS-Excel macros[1]. As discussed in the previous section this approach requires assumption of priors. Additionally, a fixed design size (number of runs) is used

[1] An example worksheet containing macros was provided by Dr. Riccardo Scarpa, Professor in Environmental Economics at the Waikato Management School, New Zealand.

to search for the D-efficient design. In each of the iterations, the macro randomly selects levels for each of the attributes and each run of the design is developed using these levels. Using these levels and the assumed priors the value of the utility function for each of the alternative in each run is estimated. These utilities are then used to calculate the probability for each run of the design which is further used to estimate the variance covariance matrix and the D-error for the design generated in that iteration. The macro is written to carry out a large number of iterations (over 1000) to search for the design with the least D-error.

A D-efficient design was obtained using MS Excel macros as well as using the SAS macros to compare their D-errors. The design with a lower D-error should be used to generate the stated preference questions. Details of this comparison and the designs finally implemented in the survey are presented in Section 3.

The first objective of this dissertation was to analyze the effects of survey designs on estimation of mode choice models and VTTS of travelers on MLs with variable pricing. To achieve this objective it was necessary to analyze the survey responses. As is common with mode choice modeling, discrete choice models such as multinomial logit model and mixed logit model were developed. These models are explained in the next section.

2.4. Mode Choice Modeling

In this section two discrete choice models often used for mode choice modeling are described. These models are also used to estimate the implied value of travel time savings.

2.4.1. Multinomial Logit Model

In transportation planning, multinomial logit (MNL) models are typically used to predict the mode choice for an individual and are based on the concept of random utility maximization. The multinomial logit model is the most popular form of discrete choice model in which the utility of an alternative j =1,..., J for a individual q = 1,..,Q in a choice situation t =1,…,T is specified in Equation (5). It consists of a systematic part and a random (error) component.

$$U_{q,j,t} = \boldsymbol{\beta}'\mathbf{x}_{qjt} + \epsilon_{q,j,t} \tag{5}$$

where β = the coefficients to be estimated,

$\mathbf{x}_{qjt}$ = vector (K×1) of K independent variables which include alternative specific constants, characteristics of the individuals, characteristics of the alternative and other descriptive variables affecting the choice, and

$\epsilon_{\mathrm{q,j,t}}$ = the error components which may be due to unaccounted measurement error, correlation in the parameters, unobserved individual preferences and other similar unobserved characteristics of the choice-making.

The error components ($\epsilon_{q,j,t}$) are assumed to be distributed as identical independent type 1 extreme value which gives a closed-form multinomial logit model probability equation (Equation 6). This assumption, however, comes at a cost as it assumes that the model has the independence from irrelevant alternatives (IIA) property. The IIA property of the MNL restricts the ratio of choice probabilities for any pair of alternatives to be independent of the existence and characteristics of other alternatives in the choice set. This restriction implies that the introduction of a new alternative (mode) or improvements to any existing alternative will affect all other alternatives proportionately. That is, in the case of mode choice study the new or improved mode will reduce the probability of existing modes in proportion to their probabilities before the change (Train, 2003). Not being able to account for individual heterogeneity (as the parameters are assumed to be fixed) is seen as another shortcoming of this model.

$$\text{Prob (choice } j \text{ |individual } q, \mathbf{X}_{q,t}, \text{choice setting } t) = \frac{\exp(\boldsymbol{\beta}'\mathbf{x}_{qjt})}{\sum_{j=1}^{J_i} \exp(\boldsymbol{\beta}'\mathbf{x}_{qjt})} \tag{6}$$

An example of the systematic part of the utility function is given in Equation (7) indicated as V_{qj}.

$$V_{qj} = \beta_0 + \beta_1 * \text{TravelTime}_{qj} + \beta_2 * \text{TravelCost}_{qj} + \beta_3 * \text{Income}_{q} \tag{7}$$

where β_k = the estimated coefficient of each independent variable x,

$TravelTime_{qj}$ = the travel time for mode j for individual q,

$TravelCost_{qj}$ = the cost of travel on mode j for individual q, and

$Income_q$ = the income of individual q.

This equation can be used to estimate the value of travel time savings for travelers if the coefficients β_1 and β_2 are included in the utility equations for all modes. The VTTS will then be given by the partial derivative of the utility equation with respect to time divided by the partial derivative of the utility equation with respect to cost; in this case this results in the ratio β_1/β_2.

Use of the multinomial logit model can be justified in the case of very basic travel options such as driving alone, taking a bus and carpooling. However, increased use of, and examination of, concepts such as managed lanes and HOT lanes with variable pricing has complicated both an individual's travel options and the models necessary to estimate which mode an individual will choose. The options such as traveling alone on managed lanes during peak hours at a higher toll, traveling alone on the managed lanes during non peak hours at a lower toll, and carpooling on managed lanes during peak hours with or without passengers at discounted tolls must be included in the new global choice set. The travel alternatives are similar to each other due to shared attributes which are not included in the measured part of the utility functions. The presence of such highly similar options may cause violation of the IIA assumption. In such instances it is increasingly common to use a random parameter logit model (mixed logit model).

2.4.2. Mixed Logit Models

The mixed logit (or random parameter logit) model is one of the latest developments in the choice modeling which has a very unrestrictive specification (see Train, 1998, Revelt and Train, 1998, Train, 2003). The mixed logit model is very flexible and it can approximate any random utility model (McFadden and Train, 2000). With developments in computational abilities and the theoretical framework, the mixed logit model has evolved from a basic specification which allows only the parameters to be distributed randomly to the model which can now accommodate repeated responses (as panel data or autocorrelation), scale differences in data sources, error structures, heteroscedasticity, and heterogeneity from various sources (see Brownstone and Train, 1999, Ben-Akiva et al., 2001, Bhat and Castelar, 2002, Greene et al., 2006, Greene and Hensher, 2007, Hensher et al., 2008). This research follows the notations and the specification used in Greene and Hensher (2007).

The simplest specification of the mixed logit model which allows the parameters to be distributed randomly specifies:

$$\beta_{qk} = \bar{\beta}_k + \sigma_k \upsilon_{qk}; \tag{8}$$

where $\bar{\beta}_k$ = the population mean for the k^{th} attribute,

υ_{qk} = the individual specific heterogeneity with mean zero and standard deviation (scaled to) one, and

σ_k = the standard deviation of the (assumed) distribution of the β_{kq}'s around $\bar{\beta}_k$.

Various empirical distributions can be assumed for one or all coefficients in the model including travel time and toll or travel cost coefficients. Assuming both travel time and toll as random parameters however adds complexity in estimation of their ratio, the VTTS. Inferences about the VTTS in such cases become complicated due to the fact that the travel cost coefficient drawn from the distribution may contain a zero, making the ratio inestimable. Using a distribution such as lognormal is one of the ways to ensure that the coefficient remains on one side of zero. The drawback of using lognormal distribution is that it has a very long tail which corresponds to unrealistically large values. Using a normal distribution also presents the problems of long tails and inclusion of zero. Further, part of a normal distribution can take positive values, which are counterintuitive for time and toll parameters. The time and toll parameters are expected to take negative values, as travelers dislike longer trips and higher travel costs.

Triangular distribution is another distribution which is often used. The triangular distribution is generated from a uniform distribution U (0, 1). The probability density function for the triangular distribution (Hensher et al. 2005) is given in Equation (9).

$$\begin{aligned} t &= \sqrt{2U} - 1, \text{ for U<0.5} \\ &= 1 - \sqrt{2(1-U)}, \text{ otherwise} \end{aligned} \tag{9}$$

where t is the variable with triangular distribution and, U is a random number from distribution U(0,1). The resulting triangular distribution thus takes values from -1 to 1. In order to simulate individual specific parameter estimates from a triangular distribution with mean and standard deviation estimated in mixed logit model Equation (10) is used (Hensher et al. 2005).

$$\hat{t} = \hat{\mu} - \hat{\sigma} \times t \quad (10)$$

where $\hat{t}$ is the individual specific parameter estimate,

$\hat{\mu}$ is the estimated mean of the distribution,

$\hat{\sigma}$ is the estimated standard deviation of the distribution and t is as defined earlier.

Additionally, distributions which have estimated standard deviations greater than the estimated mean present behaviorally implausible inferences. One of the ways to handle this issue is to specify additional restrictions on the standard deviation of the distribution, making it a constrained distribution (Hensher and Greene, 2003, Hensher et al., 2005). The standard deviation can be restricted to take a value equal to a multiple of the mean, the multiple taking a value between zero and one (for example, standard deviation = 0.5 x mean).

These random parameters β_{qk} can be further specified to accommodate the heterogeneity in the mean and the heteroscedasticity as given in Equation (11). The heterogeneity of the mean refers to the case in which the mean is not homogeneous or equal for all the segments (groups) in the sample. By contrast, heteroscedasticity indicates that the variances of these means corresponding to each segment are different.

$$\beta_{qk} = \bar{\beta}_k + \boldsymbol{\delta}'_k \mathbf{z}_q + \gamma_{q,k} \upsilon_{q,k}; \quad (11)$$

where $\boldsymbol{\delta}'_k \mathbf{z}_q$ = the observed heterogeneity around the mean of the k^{th} random parameter ($\boldsymbol{\delta}_k$ is to be estimated and $\mathbf{z}_q$ is a data vector which may contain individual specific characteristics such as the socio-demographic factors),

$\upsilon_{q,k}$ = the vector which contains individual and choice specific, unobserved random disturbances with $E[\upsilon_{q,k}] = 0$ and $\mathrm{Var}[\upsilon_{q,k}] = a_k^2$, a known constant, and

$\gamma_{q,k} = \sigma_k \exp[\boldsymbol{\eta}'_k \mathbf{h}_q]$ with $\exp[\boldsymbol{\eta}'_k \mathbf{h}_q]$ as the observed heterogeneity in the distribution of $\beta_{q,k}$ ($\boldsymbol{\eta}_k$ is to be estimated and $\mathbf{h}_q$ is a data vector which may contain individual specific characteristics).

This ability of specifying the heterogeneity around the mean can also be used for estimating the VTTS for different groups. For example, Hensher et al. (2005 p. 660-667) demonstrate how this specification can be used to estimate the preference heterogeneity around the means of the travel time and travel cost parameters for travelers in different cities. Similar logic can be used for investigating the preference heterogeneity around the mean of travel time and toll parameters for ordinary and six urgent travel situations.

Further, extension in the mixed logit model can account for the autocorrelation (which may exist in panel data or repeated choice situations) is specified as:

$$v_{q,k,t} = \rho_k v_{q,k,t-1} + w_{q,k,t}, \tag{12}$$

where ρ_k = the autocorrelation parameters to be estimated, and

$w_{q,k,t}$ = the new underlying structural random variable.

Correlation in the error patterns in this way would likely arise if the questions asked over "time" are essentially identical. For example, the usual panel model obtains the answer to a question such as household income at various points in time. It is easy to see in this case that the same household may have unobservables that lead to patterns in household income.

While the above extensions are related to random parameters only, the following extension can be specified to incorporate additional unobserved heterogeneity through effects that are associated with preferences within the alternatives. The utility function with this extension is specified as Equation (13) as in the kernel logit model (see Brownstone and Train, 1999, Ben-Akiva et al., 2001, Greene and Hensher, 2007, for details).

$$\mathrm{U}_{q,j,t} = \boldsymbol{\beta}'_q \mathbf{x}_{q,j,t} + \epsilon_{q,j,t} + \sum_{m=1}^{M} c_{jm} \mathrm{W}_{q,m}, \tag{13}$$

where $c_{jm} = 1$ if error component m appears in the utility function of alternative j, and

$\mathrm{W}_{q,m}$ = effects associated with individual preferences within choices (alternatives).

$W_{q,m}$ are assumed to be normally distributed with zero mean and can account for unobserved heterogeneity such that

$$\mathrm{Var}[W_{m,q}] = [\theta_m \times \exp(\tau'_m h_q)]^2 \tag{14}$$

where θ_m = the scale factor for error component m,

τ_m = parameters in the heteroscedastic variances of the error components, and

h_q= the data vector which contains individual choice invariant characteristics that produce heterogeneity in the variances of the error components.

The conditional choice probability with above extensions is given by Equation (15).

$$\mathrm{Prob}_{q,t}(j_t|\mathbf{X}_{it},\boldsymbol{\Omega},\mathbf{z}_q,\mathbf{h}_q,\mathbf{v}_q,\mathbf{W}_q) = \frac{\exp(\boldsymbol{\beta}'\mathbf{x}_{qjt}+\sum_{m=1}^{M} c_{jm}W_{mq})}{\sum_{j=1}^{J}\exp(\boldsymbol{\beta}'\mathbf{x}_{qjt}+\sum_{m=1}^{M} c_{jm}W_{mq})} \tag{15}$$

where $\boldsymbol{\Omega}$ = the parameter set which collects all the structural parameters (the underlying parameters in the model/equation).

These probabilities cannot be calculated exactly and hence are replaced by simulated probabilities. Thus the unconditional probability for this model has to be estimated by the maximum simulated likelihood method (see Train, 2003 for more information). As explained in Train (2003) in the mixed logit simulator: “the draws of the random terms are taken, utility is calculated for these draws, the calculated utilities are inserted into the logit formula, and the results are averaged.” The number of draws taken during the estimation and the sample size affect the estimation procedure. Further, the speed of estimation is affected by the method of taking these draws from densities. Using Halton draws instead of random draws has proven effective in the simulation. Bhat,(2001) found that 100 Halton draws provided more precise results than 1000 random draws for the mixed logit model he used. Similar findings from other studies confirmed the advantage of using Halton draws (Train, 2000, Munizaga and Alvarez-Daziano, 2001, Hensher, 2001).

The discrete choice models such as the mixed logit model are often used for whole data which represents all groups in the population. However, sometimes it is of interest to study these groups (such as low, medium and high income groups of travelers) separately to analyze the travel behavior for each of these groups. Market segmentation techniques described in next section are then used to separately analyze those groups.

2.5. Market Segmentation

When a discrete choice model is fitted to the whole data set, it is essentially assumed that the impacts of all variables are similar for the whole group. However, sometimes researchers are more interested in comparing two or more groups of travelers. For example, one might be interested in comparing the impact of travel cost for peak and off peak traveler groups. When a single model (pooled model) is fitted to all the data (combining peak and off peak traveler groups) the estimated travel cost coefficient is assumed to be the same for both the groups (segments). One of the ways to compare the effect of travel cost for these two groups will be to include the interaction of the dummy variables for peak period travel groups and the travel cost. However, inclusion of dummy variable is not useful when the researcher is interested in studying impact of other variables (other trip and traveler characteristics such as travel time and gender) for these segments. Market segmentation technique allows the researchers to separately estimate models for each segment and compare the effects of variables for each of them (Koppelman and Bhat, 2006).

In this approach the sample is divided into mutually exclusive and collectively exhaustive segments. Different choice models are estimated for each of these segments and the estimation results are compared with that of the pooled model that is the model for whole sample (Koppelman and Bhat, 2006). Different checks are performed to check if separating the segments has significant gains in terms of estimation and comparison. Koppelman and Bhat (2006) list three comparison criteria:

1. Market segmentation test,
2. Reasonableness and statistical significance of parameters in each of the segments, and
3. Evaluating if the relationships between the parameters intra and inter segments are reasonable.

The market segmentation test is based on the likelihood ratio test and is carried out to evaluate the goodness-of-fit differences between the group of segmented models and the pooled models. As in the likelihood ratio test, the test statistic of the market segmentation test also has the asymptotic χ^2distribution (Equation 16).

$$-2\times\left[\mathrm{LL}(\beta)-\sum_{\mathrm{s}=1}^{S}\mathrm{LL}(\beta_{\mathrm{s}})\right] \geq \chi^2_{\mathrm{n,(p)}} \tag{16}$$

where LL(β) is the log-likelihood for the pooled model,

LL(β_s) is the log-likelihood for the model for the sth segment

S is the number of segments,

n is the number of restrictions, and

p is the level of significance.

The pooled model is considered as the restricted model; hence the null hypothesis tests whether the coefficients for each market segment model and the pooled model are equal (Koppelman and Bhat, 2006). The number of restrictions is thus calculated as: $\sum_{s=1}^{\mathrm{S}} \mathrm{K_s} - \mathrm{K}$, where Ks is the number of coefficients in the sth market segment and K is the number of coefficients in the pooled model.

This market segmentation test was used in this study to analyze the travel behavior of peak and off-peak traveler groups. This dissertation focused on estimation of VTTS to add to the understanding of travel behavior. The literature related to estimation of VTTS and the factors affecting VTTS are presented in the next section.

2.6. Value of Travel Time Savings

Each traveler has to sacrifice time spent traveling, which could otherwise be utilized for earning income, for some leisure activities, or many other options. This sacrifice imposes an opportunity cost equal to the individual's value of time in the activity forgone. The value of travel time savings refers to the value of a change in the time duration of a given journey which is not necessarily marginal or infinitesimal (Bruzelius, 1979). The analyses carried out in the dissertation depend heavily on the estimation of VTTS on managed lanes. Hence the literature review was conducted for estimation of VTTS and factors affecting VTTS. This is presented in the next section.

2.6.1. Estimation of Value of Travel Time Savings

Travelers' VTTS are typically estimated by conducting stated preference studies. In these studies an opinion survey of travelers is conducted to elicit information as to how much extra money they would be willing to pay for a reduction in travel time. As per Kroes and Sheldon (1988), the "stated preference methods refer to a family of techniques which use individual respondent's statements about their preferences in a set of transport options to estimate utility functions". Stated preference survey methods identify values of relative utilities for different options; therefore, they are immune to the errors due to respondents overestimating and underestimating their actual travel times and costs (Kroes and Sheldon, 1988). These methods are generally used along with revealed preference (RP) methods because in that case the revealed preference data can be used to scale the utility function and generate the model. Combining SP and RP data potentially allows the consistency of the SP data with the RP data to be determined (see Adamowicz et al., 1994, Brownstone et al., 2000, Dosman and Adamowicz, 2006).

To analyze the data obtained by stated preference methods, the discrete choice models described in the sub section 2.4 are widely used. Route choice, mode choice or speed choice models (see Chui and McFarland, 1985, McFarland and Chui, 1987, for examples) are occasionally used to evaluate the travel time and cost trade-offs studied for estimation of the implied VTTS. The dissertation focused on estimation of VTTS for freeway travelers with an option of using the managed lanes. Hence the use of a mode choice study was the most appropriate compared to route or speed choice studies.

SP surveys used for VTTS estimation can benefit by including variables which affect the travelers' VTTS. Numerous factors which affect the VTTS are discussed in the next section.

2.6.2. Factors Affecting the Value of Travel Time Savings

Various travelers' characteristics affect their value of travel time savings. For example, the age of the traveler has an effect on their value of time. For example, a study carried out by Algers et al. (1998) concluded that people aged 45 or older seem less sensitive to travel time than younger travelers. Gender of the traveler also plays an important role in deciding some travel characteristics, such as commuting patterns and criteria for mode choice. It is observed that women were less likely to choose public transit but more likely to carpool than men. Commuting women were often less time sensitive than men (Patterson et al., 2005). Trip purpose is another factor which affects value of travel time savings. Value of travel time savings was generally found to be greater for commuting than leisure travel (Wardman, 1998).

It was also observed that the value of travel time savings frequently depends on the income of the individual (Fosgerau, 2005). On average, the value of travel time is estimated to be between 20 percent to 50 percent of the wage rate for work trips (Small et al., 1999, Calfee and Winston, 1998). Travel time and its variability also affect the value of time; Senna (1994) and Davis et al. (2009) reported that value of time does not only depend on (average) travel time but also on variability of travel time (reliability). Small et al. (1999) found that the travel time savings for congested travel was valued much higher than the travel time savings in uncongested conditions. They also found that the travel time reliability was valued highly and it can be more than the value of travel time savings.

These findings are critical in understanding the decision-making of travelers with the option of using variably priced managed lanes and estimation of their value of travel time savings under different travel scenarios. Highway project evaluations and travel behavior studies frequently use the estimates of value of travel time savings. VTTS estimates are also used in various calculations such as estimating the benefit-cost ratio of a transportation project, estimating cost of traffic congestion (see Schrank and Lomax, 2007) and finding the base for fixing the toll rates on a tolled facility. Demand estimation for toll roads and managed lanes greatly benefit by a more detailed knowledge of VTTS of the travelers rather than just a number representing the average VTTS for all travelers. Understanding the distribution of the VTTS across users of the facility helps to set the toll rates so that a required flow (level of service) can be maintained on the facility. Researchers are now focusing on estimation of the distribution of the VTTS (Hess et al., 2005, Fosgerau, 2006).

Further, it can also be expected that an individual will attach different values of travel time savings based on the occasion. For example a traveler may place more value on the travel time savings when he/she is late for work than that for a usual work trip when he/she is not delayed. This study attempts to better estimate the VTTS by separating the situations under which the travel decision is made. The study focuses on differentiating the VTTS for ordinary and urgent situations. This study also tries to estimate the effect of survey design technique on estimation of the VTTS and its distribution in order to understand traveler decision-making when using variably priced managed lanes are a travel option.

2.7 Summary

The literature review indicates that managed lanes offer various benefits to travelers including travel time savings. Travelers' VTTS depends on various socio-demographics characteristics apart from the characteristics of the trip. Estimation of VTTS for managed lane travelers can be challenging and there is a possibility that travelers may be attaching different values to travel time savings in different travel situations.

The VTTS is typically estimated using mode choice models such as multinomial logit and mixed logit models. The mixed logit model can accommodate a variety of extensions to incorporate different effects and to better estimate the VTTS. The estimation of VTTS is also affected by underlying survey design used in the stated preference surveys. The orthogonal designs even though simple to obtain have many disadvantages most of which can be overcome by using a D-efficient design.

The next section describes the data collection efforts and presents the details of survey designs used in the internet based survey.

3. DATA COLLECTION

The research goal was to add to the understanding of travel behavior, specifically to better estimate and understand travelers' VTTS on MLs. This required data collected from travelers using MLs or those with an option of using MLs. Further, the objectives of research included study of effects of survey designs on mode choice model estimation and estimation of VTTS for urgent trips. Thus a stated preference survey was necessary to collect data which can implement multiple survey designs and can present ordinary and urgent travel situations to the respondent.

This dissertation used the data collected from travelers who used the Katy Freeway in Houston. The Katy Freeway was recently widened and additional variably priced managed lanes (HOT lanes) were added in the middle of the freeway. The study used the advantage of collecting the choice data just when the Katy Freeway managed lanes opened. The surveys were conducted in November of 2008 using the internet, which has disadvantages and advantages over mail or telephone surveys. Details of the survey administration and possible sampling bias are presented in this section followed by the details of survey questionnaire and survey designs used.

3.1. Survey Administration

The traveler survey used to collect data for this dissertation was aimed at understanding the travel behavior and hence it was designed to gain information related to general travel and stated preferences. The survey also focused on estimation the value of travel time savings of travelers considering general purpose lanes (GPL) and ML options. Hence, the sampling strategy targeted travelers who used the Katy Freeway (travelers who use the Katy Freeway regularly or have at least used it in the past week). People living in proximity to the Katy Freeway were encouraged to take the survey online. The survey text was available in either Spanish or English.

The availability of the survey and its web address (www.katysurvey.org) were publicized through radio (www.sunny99.com), news web sites (Houston Chronicle, www.chron.com, My Fox Houston, www.myfoxhouston.com, News Katy, http://instantnewskaty.com), and web sites of Houston TranStar (www.houstontranstar.org) and West Houston Association (www.westhouston.org). Additionally, e-mails were sent to randomly selected travelers in Harris County who owned an electronic toll transponder.

In order to increase the survey participation, two awards of $250 gas cards selected by a lottery were announced for those who completed the survey. Incentives to participate are often used in recruiting for surveys. The online survey was made available from October 29, 2008 to November 30, 2008. As the survey was an internet based survey it may have created some sampling issues as discussed next.

3.2. Possible Sampling Issues for the Internet Based Survey

Every survey sample has potential sampling bias because respondents may volunteer or refuse to participate, or answer specific questions. And nearly every survey questionnaire involves potential errors in response, as the respondents may not understand concepts or questions.

Since the survey was administrated over the internet, it naturally requires that the respondents have access to a computer to take the survey. Thus the data collection method may have created a sampling bias as it required that the sample members had at least some temporary, if not permanent, internet access to take the survey. However, the percentage of people having internet access is increasing and 60 percent of all the Texans used internet in the year 2007 (Austin Business Journal, 2009). Since the target population for this survey consisted of people living nearby Katy Freeway, in the metropolitan area of Houston, having at least one vehicle, it can be assumed that the percentage of people with internet access would be even higher than in the general population at large. Hence, the potential bias from using an internet based survey will, in this case, be smaller, as compared to some other large sampling and survey approaches done using the internet as the means to conduct the survey.

Alternative approaches have potential biases too. For example, mail surveys sent to correct addresses do not have the initial selection problem, but mail surveys often suffer from poor response rates because households throw away what they perceive to be junk mail. Telephone surveys have become increasingly problematic as many households have caller-ID phones and do not answer unrecognized calls. Many other households switched to the use of mobile phone service only, and thus potential bias exists with this approach because listings of cell-phone numbers are not available and random digit dial approaches are precluded.

In addition, stated choice surveys can involve complex tasks. The more complex the task, the less likely some types of respondents will be to complete the survey, or participate at all. An internet survey can aid the respondent in these tasks by allowing helpful visual materials, and connections between responses that the respondent can more easily see than in a lengthy mail survey. These techniques were employed in this survey in an effort to maximize response rate while minimizing any confusion. The internet survey was also designed such that consistency checks on responses were conducted, or which required the respondent to answer a question before she can move on to the next question, thus potentially reducing item-response bias. The details of this internet based survey questionnaire are given in the next section.

3.3. Survey Questionnaire

The survey questionnaire begins by asking the respondent questions about their most recent trip on the Katy Freeway. These types of questions are known as revealed preference (RP) questions. These questions were followed by questions on respondent's general travel behavior on Katy Freeway, an introduction to the managed lanes concept, questions regarding their feelings toward this ML concept, stated preference questions, and finally key socio-economic questions (see Appendix B for the complete questionnaire).

In the fifth section of the survey questionnaire respondents were presented with three pairs of stated preference questions. In SP designs involving hypothetical questions that are outside of experiences respondents have, consistency checks can be invaluable. However, in this case it was expected that most of the choices provided to respondents were familiar to them as the survey was made available after the Katy MLs were already opened to traffic. Each pair of SP questions asked the respondent about their choice of travel mode for a trip in the case of an ordinary situation and also for an urgent travel scenario. In all three SP question pairs, one of six reasons was used to describe the urgent situation that a traveler may be facing. These reasons were worded so that they were somewhat generic and therefore applicable to numerous other similar urgent situations, applicable to either direction of travel (toward/away from downtown), all days of the week (weekday/weekend) and all times of departure (peak/shoulder of the peak/off-peak). Note that not all of the situations used below occurred unexpectedly to the traveler, as some of them may be known in advance. The six urgent reasons and their implications are given in Table 5.

The travel time and toll (if any) related to the trip were the key attributes that define the alternatives in each SP scenario. Apart from travel time savings managed lanes also offer increased reliability in travel times than the GPLs. Stated preference surveys can accordingly be modified to estimate the value of reliability separately. However, to keep the choice tasks simple and to focus on the study objectives a parsimonious specification was purposefully chosen. The stated preference questions included only two key attributes of the travel choices, the travel time and toll. This means that the estimated VTTS will also include the effect of travel time reliability.

A typical presentation of the stated preference question presented in the survey is shown in Figure 3.It should be noted that labels inform the respondent if the mode of travel they would chose involves driving alone or carpooling, the use of a managed lane or a general purpose lane. These labels provide more information about the alternative, in the same way that labeling a soft-drink a “cola” or a “orange” would aid respondents in their choices among soft drink beverages. The specific levels or values of travel time and toll presented in the stated preference questions were determined using one of four experimental designs. These experimental designs are discussed in more detail in the next section.

Table 5 Urgent Situations Categories Presented in the SP Survey

Urgent Situation	Survey Wording	Description/Implication
Situation 1 *ImpAppt*	You are headed to an important appointment/meeting/event	The traveler may not necessarily have started late: however he/she especially needs to arrive on time.
Situation 2 *LateAppt*	You are running late for an appointment or meeting	The traveler knows that he/she is already late and hence is in need of the fastest travel alternative.
Situation 3 *WorryTime*	You are worried about arriving on time	The traveler needs to arrive on time (as in Situation-1): however, now the word worry has been added in the description to analyze if the behavior is any different due to the underlined urgency. People worried might leave earlier than normal or they may plan to use the managed lanes. Also, this situation may or may not include an important appointment/meeting/event.
Situation 4 *BadWeather*	You expect potential traffic problems due to bad weather	The travel times may be longer than usual (for both GPLs and MLs) with possible additional unreliability in the travel time on the GPLs.
Situation 5 *LateML*	You left late knowing you could take advantage of the toll lanes	Even though similar to Situation-2 the traveler in this situation is expected to have a higher value of travel time savings than that presented by the usual toll rates. Additionally, analysis of this situation may provide an interesting insight into travel behavior with respect to a dynamically priced facility and may help to understand how the traveler reacts when faced by tolls which are higher or lower than the usual.
Situation 6 *ExtraStops*	You need to make extra stops on the trip but still need to arrive on schedule	The traveler could make up the time using the MLs or leave earlier depending on flexibility of schedule.

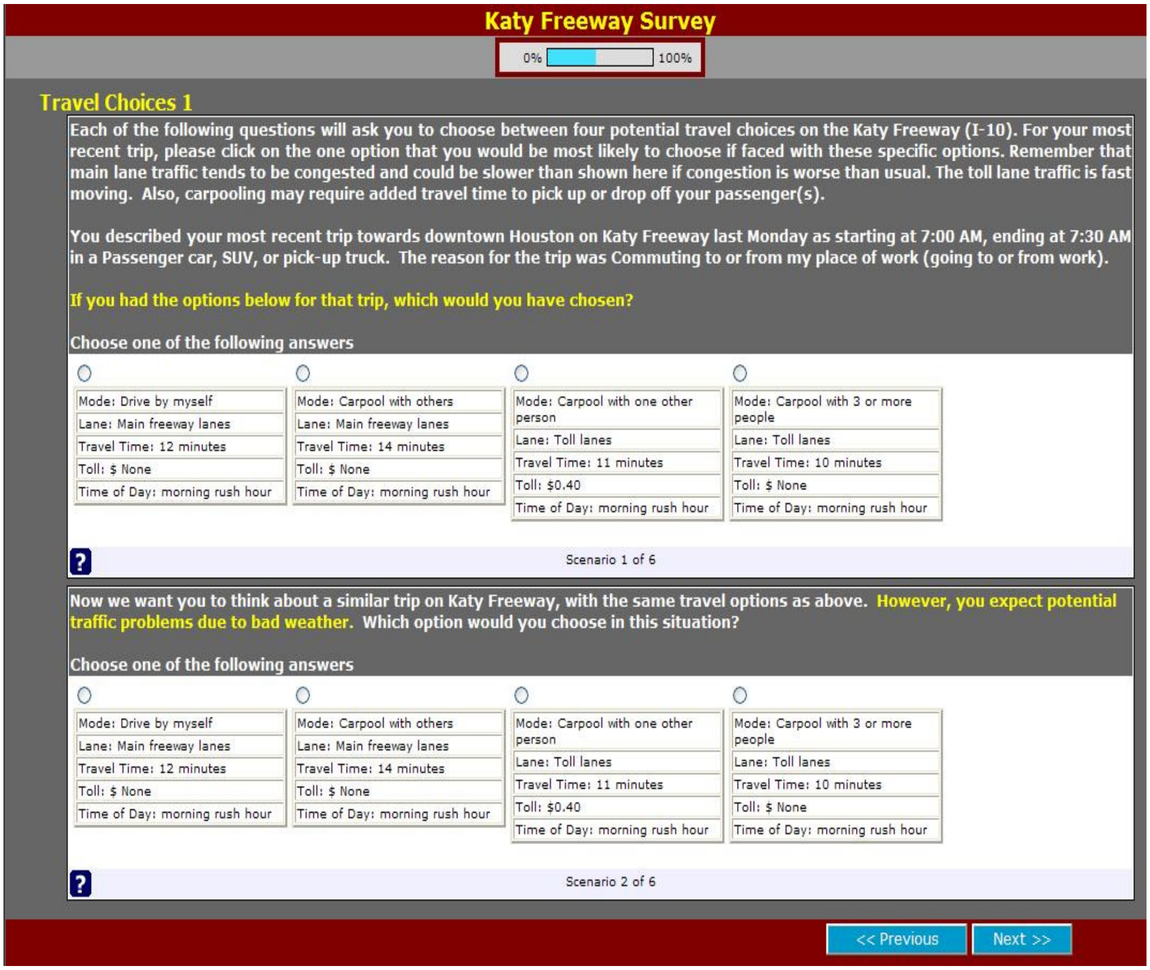

Figure 3 Typical Stated Preference Question in the Survey.

3.4. Survey Design Details

Three different approaches were used to determine the specific levels of travel time and toll to be presented in the stated preference questions. Ideally, one wishes to provide the respondent with a wide range of realistic levels for the travel time and toll that they might face in a commuting or traveling situation. In all three of these approaches the respondents were presented with four out of five travel options (design alternatives) as follows:

1. Driving alone on general purpose lanes (DA-GPL),

2. Carpooling on general purpose lanes (CP-GPL),
3. Driving alone on managed lanes (DA-ML),
4. Carpooling with one other person on managed lanes (HOV2-ML), and
5. Carpooling with three or more people on managed lanes (HOV3+-ML).

The travel time and toll were presented in the SP questions to describe each alternative; however, the levels of these attributes in turn depended on the trip length for each respondent. In other words, it was recognized that, realistically, a total package of the trip that the respondent would choose might well depend on the length of the total trip he or she took as part of their actual travel. Hence, the speed of the vehicle and the toll rate per mile were used as the specific design attributes to calculate the levels of travel time and toll by using the reported actual trip length for each respondent. The respondent's specific trip length was calculated based on the Katy Freeway on and off-ramps the respondent indicated they had used on a recent trip. Also, if the trip length of the respondent was more than 12 miles (the length of the MLs), then an additional component of travel time on the highway section beyond the ML section was included in the individual's travel time. This was calculated using speed equal to 60 miles per hour since travel this far from downtown Houston was often free flow.

For example, if a respondent's trip length exceeded 15 miles then the travel time was calculated for two sections, the uncongested section and the congested section. The uncongested section in this example was (15 – 12 =) 3 miles long and the corresponding travel time was 3 minutes (calculated using the speed of 60 mph). Further, the congested section travel time for this example was calculated for the remaining 12 mile length using the GPL and ML speed levels obtained from the design. Hence, if the GPL speed level was 40 mph and ML speed level was 60 mph, the travel time for the congested section was(60 * 12/40 =) 18 minutes. The total travel times presented for GPL and ML alternatives for both sections were (3 + 18 =) 21 minutes and (3 + 12 =) 15 minutes respectively. Only the congested section length was used to calculate the toll presented in a ML alternative. For example, if the toll rate as obtained from the design was $0.15 /mile for the travel alternative DA-ML, then the toll presented in the question was

15*12/100=$1.8 (along with travel time of 15 minutes) for the respondent in above example.

In all the designs the travel alternatives that involve the GPLs were presented with no toll and with longer travel times than the ML travel alternatives (MLs with variable pricing are operated such that they provide a faster and more reliable travel option than the GPLs). One of the three design approaches described in the following sections was randomly assigned to each respondent. The specific levels used for speed and toll rate are also described in the following sections. An extensive java code was developed to present a respondent with one of the design and the corresponding attribute levels. The java code for the second SP question is given in Appendix C.

3.4.1 D-efficient Design

SAS macros were used to search for a D-efficient design which was generated used for the SP portion of the survey. Additionally, a D-efficient design was also generated using MS Excel macros. The SAS macros assume a linear model and the MS Excel macro assumes a multinomial logit model when searching for a D-efficient design. The D-errors of the design obtained using SAS macro were smaller (SAS macro- 0.1616, MS Excel macro- 0.1903 assuming zero priors) for a Multinomial Logit Model specification. Thus the use of SAS macros was justified for this study.

The D-efficient survey design generated using SAS consisted of 24 runs/rows (24 questions in eight blocks of three ordinary situation questions). The SP questions were presented such that each respondent who received this version of the survey (with D-efficient design) was always presented with the alternative of driving alone on the general purpose lanes, which was the travel mode used by most of the respondents.

The survey design was structured to present only three out of the remaining four travel alternatives to each respondent. This mixture of alternatives was achieved by adding an additional level of availability (not available NA) in the travel times (attributes) of these four modes so that the attribute level combination in the full-factorial design with level “NA” represents that the corresponding alternative is not available in that design row (question). In addition, a constraint was added during the search of the efficient design such that the total number of alternatives in any given run was equal to four. Thus the runs with travel time level NA present as one of the travel time attributes of more than one travel mode were not considered in searching for the D-efficient design. While this strategy will limit the size of the choice set to four, it also adds a bias in the estimation of the mode choice model, as the frequency of each alternative in the choice sets of all the respondents will not be equal. The attributes and levels used for this design for peak and off-peak period travelers are given in Table 6.

Table 6 Attributes and Levels Used for The D-efficient Design

Alternative (Travel Mode)	Attributes	Peak Period Levels	Off-Peak Period Levels
Drive alone on GPLs	Speed (mph)	25, 35, 45	45, 50, 55
	Toll Rate (cents/mile)	0	0
Carpool on GPLs	Speed (mph)	25, 35, 45, NA	45, 50, 55, NA
	Toll Rate (cents/mile)	0	0
Drive alone on MLs	Speed (mph)	55, 60, 65, NA	55, 60, 65, NA
	Toll Rate (cents/mile)	10, 20, 35	5, 10, 17.5
Carpool with one other person on MLs	Speed (mph)	55, 60, 65, NA	55, 60, 65, NA
	Toll Rate (cents/mile)	5, 10, 20	2.5, 5, 10
Carpool with three or more people on MLs	Speed (mph)	55, 60, 65, NA	55, 60, 65, NA
	Toll Rate (cents/mile)	0, 5, 10	0, 2.5, 5

There were, two additional and alternative design strategies were used to generate the values of travel time and toll in stated preference questions. These are the random attribute level approach and the smart adjusting random attribute level generation approach described next.

3.4.2 Random Attribute Level Generation (Random)

In the random attribute level generation design approach the choice alternatives and attribute levels were generated differently than using the D-efficient design approach. Every respondent was presented with two fixed travel alternatives: their current actual travel mode (drive alone [SOV] or carpool [HOV] on GPLs) and a similar occupancy travel mode (SOV/HOV) on MLs. They were also presented two other alternatives that were randomly chosen from the remaining three travel modes.

For example, if the respondent's current actual travel mode was to drive alone on GPLs, they were always presented with the modes: drive alone on GPLs and drive alone on MLs. In the case where the respondent's current actual travel mode was to carpool on GPLs (first fixed alternative for the respondent) the respondent was always presented with the ML option to carpool with two more people (50 percent of the time) or carpool with three or more people (50 percent of the time) as the second fixed alternative. This approach of choosing the four alternatives out of five as described above made it possible to make use of a respondent's RP information and make the choice set more realistic for each respondent.

No fixed numbers of experimental design runs or attribute levels were used in this approach (and as will be seen below, in the smart adjusting random approach). Instead, a combination of base rate plus a variable portion was used as specified in Table 7. For toll rates, one of three or four base levels was randomly selected and then the corresponding random part was added to the base level. For example, the toll for the mode, "drive alone on managed lane in peak periods" was a randomly selected base rate from 7, 15 and 28 and the corresponding variable portion was chosen from (0-6), (0-10), or (0-14), depending on the base level selected. If more than one GPL (or ML) alternative was available in the choice set the travel times (speed) presented for those two GPL (or ML) alternatives were the same. In case the randomly selected travel time for GPL alternatives were less than or equal to those presented for ML alternatives, the travel times of the GPL were adjusted to be the travel time on the ML plus an additional 3 minutes.

Table 7 Attributes and Level Ranges Used for the Random Design Approach

Alternative (Travel Mode)	Attributes	Range of Level for Peak Period*	Range of Level for Off-Peak Period*
Drive alone on GPLs	Speed (mph)	20 + (0 to 25)	40 + (0 to 25)
	Toll Rate (cents/mile)	0	0
Carpool on GPLs	Speed (mph)	20 + (0 to 25)	40 + (0 to 25)
	Toll Rate (cents/mile)	0	0
Drive alone on MLs	Speed (mph)	40 + (0 to 25)	50 + (0 to 20)
	Toll Rate (cents/mile)	7 + (0 to 6) 15 + (0 to 10) 28 + (0 to 14)	3.5 + (0 to 3) 7.5 + (0 to 5) 14 + (0 to 7)
Carpool with one other person on MLs	Speed (mph)	40 + (0 to 25)	50 + (0 to 20)
	Toll Rate (cents/mile)	0 4 + (0 to 2) 8 + (0 to 4) 17 + (0 to 6)	0 2 + (0 to 1) 4 + (0 to 2) 8.5 + (0 to 3)
Carpool with three or more people on MLs	Speed (mph)	40 + (0 to 25)	50 + (0 to 20)
	Toll Rate (cents/mile)	0 4 + (0 to 2) 8 + (0 to 4) 13 + (0 to 6)	0 2 + (0 to 1) 4 + (0 to 2) 6.5 + (0 to 3)

*numbers in parentheses correspond to range of random part used for creating levels

3.4.3 Smart Adjusting Random Attribute Level Generation (Smart Random)

In this design approach the alternatives to be presented were generated in the same way as they were in the random attribute level generation (the second) design approach. For the first choice question the attribute levels were chosen randomly. In the second and third questions the speed levels were chosen randomly: however, the toll rates were increased or decreased (up to 200 percent) if the choice made in the previous question was a tolled or a toll-free travel mode, respectively. Thus, the VTTS offered for a similar travel mode on the managed lanes was increased or decreased (adaptive) depending on the choice in the previous question. This is akin to the double-bounded contingent valuation approach used by many economists (see Hanemann et al., 1991, Kanninen, 1993), and the discrete response contingent valuation approach is just a special case of a choice modeling exercise.

This approach is little different from the computer adaptive conjoint designs as it does not search for a run from an efficient design after every question. Hence, it does not take as much time to generate the stated preference attribute levels to be presented in next question. However, this approach did not guarantee that the respondent would see a higher (lower) VTTS if they selected a tolled (non-tolled) alternative. It only guaranteed the increase (decrease) in toll rate, but a random change in travel time could result in VTTS that did not increase (decrease) as the toll increased (decreased). Therefore, the respondents who had the smart adjusting random design were split into two groups:

1. Smart Adjusting Random- the toll and VTTS changed as expected,
2. Reverse Smart Adjusting Random- the VTTS did not change in the same direction as the toll did.

3.5 Summary

Travel behavior analysis is largely dependent on the data collected from travelers. For this dissertation research an internet based survey was developed for travelers of the Katy Freeway. Details of the survey administration, sample and possible sampling biases, survey questionnaire used and implemented survey designs were presented in this section. The extensive data collected was used to achieve the objectives of studying the effect of survey designs on mode choice modeling and estimation and comparison of VTTS for ordinary and urgent trips. The preliminary analysis carried out on these data for achieving the research objectives is presented in the next section.

4. PRELIMINARY DATA ANALYSIS

This research had two objectives. The first objective was to analyze the effects of survey designs on estimation of mode choice models and VTTS of travelers on MLs with variable pricing. The second objective was to estimate and compare the value travelers place on travel time savings when on urgent versus ordinary trips. A preliminary analysis carried out to contribute towards achieving these objectives is described in this section. This analysis involved description of sample size, analysis of sampling bias, and descriptive analysis for important variables used in the mode choice modeling. The analysis also included comparison of traveler groups to study their travel behavior.

4.1. Description of Survey Sample and Analysis of Sampling Bias

A total of 6,312 respondents took at least some portion of the online survey. Of these, 3990 respondents fully completed the survey. Each survey was designed to optimally use information obtained for travelers who were traveling by car (either alone or as carpooler), in conjunction with the actual opening of the expanded freeway. However, 119 respondents who traveled by motorcycle or bus also took the survey. Their responses were not used which decreased the sample size to 3871.

Income, age and gender are often the key variables in determining response rates in surveys, and hence it is necessary to check whether there is a biased group in this regard. In order to investigate this sampling bias based on distribution of income, age and percentage of males the survey sample was compared with a sample from a previous survey (mail/post + internet) conducted in 2003 on Katy Freeway travelers and the potential population of Katy Freeway travelers (Table 8).

Table 8 Analysis of Bias in the Sample with Respect to Income, Age, and Gender

Comparison Criterion	Katy Freeway Survey 2008 Sample	Along Katy Freeway Corridor Source: H-GAC, 2009	Katy Freeway Survey 2003 Sample
Annual Household Income < $25000	3 percent	11 percent	4 percent
Annual Household Income $25000 to $75000	29 percent	32 percent	33 percent
Annual Household Income > $75000	68 percent	57 percent	63 percent
Age 16-24 years	2 percent	NA	5 percent
Age 25-54 years	71 percent	NA	79 percent
Age 55 years and over	27 percent	NA	16 percent
Percentage of Males	58 percent	NA	63 percent

The potential population of Katy Freeway was defined as people living in the Traffic Analysis Zones (TAZ) along the Katy Freeway based on the latest household travel survey performed for the Houston-Galveston Area Council of Governments (H-GAC, 2009). Though the current survey oversamples from the higher income group and under-samples from the low income group and age group 16 to 24 years, the (current internet based) survey sample is not very different from the sample of the previous (mail + internet based) study sample based on all the criteria used. This previous survey was mailed to travelers observed on the Katy Freeway and therefore may be closer to true Freeway user demographics than the general population data (see Burris and Figueroa, 2006 for details of this survey).

Apart from age, gender and income variables data related to many other demographic and general travel variables were also collected through survey. Descriptive analysis of these variables is presented in the next section.

4.2. Preliminary Analysis of Key Variables

There are many variables related to travelers' demographics and general travel characteristics which influence their travel behavior. These key variables thus play an important role in estimation of the mode choice models. Descriptive statistics for these variables are presented in Table 9. The descriptive statistics can be used to check the presence of outliers and invalid responses. This analysis can also be used to gauge the general characteristics of the sample respondents.

Table 9 Descriptive Statistics for Important Variables

Variable	Mean	Std. Dev.	Min	Max
Variables Related to General Travel				
Number of people in the vehicle during the last trip	1.55	0.91	1	5
Trip length (miles) for the last trip	13.43	7.35	0.6	31
Traveled toward downtown Houston for last trip (dv)	0.48	0.50	0	1
Last trip was a trip that the traveler regularly takes (dv)	0.56	0.50	0	1
Traveler has an option of taking an alternative route (dv)	0.76	0.43	0	1
Respondent had heard about the new Katy managed lanes before taking the survey (dv)	0.86	0.34	0	1
Respondent’s trip purpose was commute or work for the last trip on Katy Freeway (dv)	0.56	0.50	0	1
Respondent possesses a toll tag (dv)	0.95	0.21	0	1
Respondent needs to pay to park in downtown (dv)	0.14	0.35	0	1
Number of trips on Katy Freeway in last week	4.32	4.18	0	26
Respondent's last trip was on a weekday (dv)	0.82	0.38	0	1
Respondent traveled in peak period (6.00 a.m.-9.00 a.m. or 3.30 p.m. to 6.30 p.m.) for last trip (dv)	0.52	0.50	0	1
Demographic Variables				
Number of vehicles in household	2.40	1.07	0	10
Male respondent (dv)	0.58	0.49	0	1
Respondents age between 25 and 54 years (dv)	0.71	0.45	0	1
Respondents annual household income between $50,000 and $99,000 (dv)	0.37	0.48	0	1
Respondents annual household income over $100,000 (dv)	0.50	0.50	0	1
Respondents household size	2.73	1.32	0	9
Respondents household type is a single adult household (dv)	0.19	0.39	0	1
Respondent's household type was married (dv)	0.27	0.44	0	1
Respondent's household type was married with children (dv)	0.45	0.50	0	1
Respondent's occupation was technical (dv)	0.09	0.29	0	1
Respondent’s occupation was professional (dv)	0.52	0.50	0	1
Respondent's occupation was sales (dv)	0.07	0.26	0	1
Respondent's occupation was administrative/ clerical (dv)	0.08	0.27	0	1
Respondent's education was less than high school graduation (dv)	0.00	0.05	0	1
Respondent was a high school graduate (dv)	0.05	0.22	0	1
Respondent completed some college or vocational school (dv)	0.25	0.43	0	1
Respondent had a post graduate degree (dv)	0.22	0.42	0	1

dv- dummy variable

Further, in order to gain insight into travel behavior of travelers who drove alone and travelers who carpooled for their last trip on the Katy Freeway they were analyzed separately. This comparison is shown in Table 10. These two groups significantly differ based on some of the characteristics which are highlighted in the Table 10. These differences are as expected because travelers are more likely to carpool if they are traveling in off-peak hours, on weekend, for longer trips, for trips related to other than commuting or work, and are married with children. Note that the mean of a dummy variable corresponds to the percentage of respondents in that category.

Table 10 Comparison of Respondents Who Drove Alone and Those Who Carpooled

Variable	DA	CP
Mean of Variables Related to General Travel		
Number of people in the vehicle during the last trip	1.00	2.54
Trip length (miles) for the last trip	**12.74**	**14.63**
Traveled toward downtown Houston for last trip (dv)	0.48	0.46
Last trip was a trip that the traveler regularly takes (dv)	**0.63**	**0.42**
Traveler has an option of taking an alternative route (dv)*	0.76	0.75
Respondent had heard about the new Katy managed lanes before taking the survey (dv)	0.87	0.85
Respondent's trip purpose was commute or work for the last trip on Katy Freeway (dv)	**0.70**	**0.32**
Respondent possesses a toll tag (dv)	0.96	0.94
Respondent needs to pay to park in downtown (dv)*	0.14	0.14
Number of trips on Katy Freeway in last week*	4.89	3.31
Respondent's last trip was on a weekday (dv)	**0.90**	**0.67**
Respondent traveled in peak period (6.00 a.m.-9.00 a.m. or 3.30 p.m. to 6.30 p.m.) for last trip (dv)	**0.55**	**0.46**
Mean of Demographic Variables		
Number of vehicles in household*	2.37	2.46
Male respondent (dv)	0.59	0.56
Respondents age between 25 and 54 years (dv)	0.71	0.72
Respondents annual household income between $50,000 and $99,000 (dv)*	0.37	0.37
Respondents annual household income over $100,000 (dv)*	0.50	0.50
Respondents household size*	2.65	2.87

Table 10 (*Continued*)

Variable	DA	CP
Respondents household type is a single adult household (dv)	0.23	0.12
Respondent's household type was married (dv)	0.26	0.28
Respondent's household type was married with children (dv)	**0.41**	**0.51**
Respondent's occupation was technical (dv)*	0.09	0.09
Respondent's occupation was professional (dv)	0.55	0.46
Respondent's occupation was sales (dv)	0.08	0.05
Respondent's occupation was administrative/ clerical (dv)	0.07	0.09
Respondent's education was less than high school graduation (dv)	0.00	0.00
Respondent was a high school graduate (dv)	0.05	0.06
Respondent completed some college or vocational school (dv)	0.25	0.26
Respondent had a post graduate degree (dv)	0.23	0.22

DA- Respondents who drove alone for last trip,
CP- Respondents who carpooled for last trip, dv- dummy variable
*- Group means (or proportions) are not significantly different at 95% confidence level

The above traveler groups were separated based on their general travel characteristics; however it is also possible to gain some understanding of travel behavior by comparing the SP survey responses. Accordingly, the respondents who selected a ML lane alternative in at least one of the SP questions were compared to the respondents who didn't select any of the ML travel alternatives in any of the SP questions (Table 11). This comparison can be helpful in studying who will be interested in using the MLs. It can be observed from Table 11 that travelers in both categories have similar characteristics. However, travelers who are on longer trips, who traveled in peak hours, who are married and have children (household type), who are professionals by occupation are more likely to chose the MLs.

Table 11 Comparison of Respondents Who Selected MLs and Those Who Never Selected MLs in Any of The SP Questions

Variable	Selected MLs	Never Selected MLs
Mean of Variables Related to General Travel		
Number of people in the vehicle during the last trip	1.64	1.33
Trip length (miles) for the last trip	13.84	12.43
Traveled toward downtown Houston for last trip (dv)*	0.47	0.48
Last trip was a trip that the traveler regularly takes (dv)*	0.55	0.56
Traveler has an option of taking an alternative route (dv)	0.77	0.73
Respondent had heard about the new Katy managed lanes before taking the survey (dv)	0.86	0.86
Respondent's trip purpose was commute or work for the last trip (dv)*	0.56	0.57
Respondent possesses a toll tag (dv)	0.96	0.94
Respondent needs to pay to park in downtown (dv)	0.15	0.12
Number of trips on Katy Freeway in last week	4.26	4.46
Respondent's last trip was on a weekday (dv)	0.81	0.84
Respondent traveled in peak period (6.00 a.m.-9.00 a.m. or 3.30 p.m. to 6.30 p.m.) for last trip (dv)	**0.58**	**0.38**
Mean of Demographic Variables		
Number of vehicles in household	2.37	2.46
Male respondent (dv)	0.59	0.56
Respondents age between 25 and 54 years (dv)	0.71	0.72
Respondents annual household income between $50,000 and $99,000 (dv)	0.37	0.37
Respondents annual household income over $100,000 (dv)*	0.50	0.50
Respondents household size	2.65	2.87
Respondents household type is a single adult household (dv)	0.23	0.12
Respondent's household type was married (dv)	0.26	0.28
Respondent's household type was married with children (dv)	0.41	0.51
Respondent's occupation was technical (dv)	0.09	0.09
Respondent's occupation was professional (dv)	**0.55**	**0.46**
Respondent's occupation was sales (dv)*	0.08	0.05
Respondent's occupation was administrative/ clerical (dv)	0.07	0.09
Respondent was a high school graduate (dv)	0.05	0.06
Respondent completed some college or vocational school (dv)	0.25	0.26
Respondent had a post graduate degree (dv)*	0.23	0.22

dv= dummy variable, * - Group means/ proportions are not significantly different (95% Conf. level)

The data related to SP questions were further analyzed to verify if the survey logic was implemented as expected during the data collection (Table 12). The summary of SP choices (ignoring the unanswered SP questions) is also presented in Table 12. It can be observed that 'driving alone on GPLs' is the most preferred mode of the respondents and in urgent trips more respondents tend to switch from the GPLs to MLs.

The analyses carried out in this section thus provided useful information related to sampling issues. The descriptive analysis provided summary of important variables for the whole sample and traveler groups. This information was used for the model building in the next section. The next section is focused on detailed analysis for investigating the survey designs and the effect of travel urgency on VTTS.

Table 12 Preliminary Analysis of Data Related to SP Questions

	Drive alone on the GPLs	Carpool on the GPLs	Drive alone on the MLs	Carpool with one other person on the MLs	Carpool with three or more people on the MLs	All
Percent of Times the Alternative was Presented to The Respondent						
In first pair of SP questions	23%	22%	20%	15%	20%	100%
In second pair of SP questions	23%	20%	19%	20%	18%	100%
In third pair of SP questions	23%	14%	23%	21%	18%	100%
In all SP question pairs	23%	19%	21%	19%	18%	100%
VTTS ($/hr) Presented for the Alternative in All the Three Pairs of SP Questions						
Mean	NA	NA	21.9	11.3	3.3	NA
Std. Dev	NA	NA	16.6	12.2	5.4	NA
Minimum	NA	NA	0.0	0.0	0.0	NA
Maximum	NA	NA	285.0	216.0	108.0	NA
Percent of Times the Alternative was Selected						
In an ordinary situation	60%	9%	17%	9%	5%	100%
In a urgent situation	46%	6%	33%	11%	4%	100%

5. DATA ANALYSIS

Goal of this dissertation was to add to the understanding of travel behavior, specifically to better estimate and understand the travelers' VTTS on MLs. Detailed analyses of the survey data were carried out in order to investigate effect of various survey designs on estimation of VTTS and to estimate the difference between the VTTS for ordinary and urgent trips. Further, a detailed analysis of VTTS for peak and off-peak period was also carried out. These analyses are presented in this section.

5.1. Comparison of Survey Designs

The analysis of different survey designs used in the Katy Freeway survey is presented in the following section. Apart from VTTS estimation, the responses corresponding to each design were compared for different survey taking behavior and goodness of fit provided for the model.

5.1.1. Descriptive Analysis of Survey Respondents by Survey Design

In order to compare the four design approaches a descriptive analysis was carried out on the data from respondents of each design (see Table 13). Results in Table 13 illustrate that there are no major differences in the samples corresponding to each of the design approaches except for the sample size and the frequency of alternatives presented in the SP questions: these differences were as planned. To check for other differences, the samples corresponding to each of the designs were analyzed for non-trading, lexicographic and other behaviors (see Hess et al., 2008). Non-trading behavior corresponds to the situation when a respondent chooses the same single alternative in all the SP questions. This is consistent with a focus on only one attribute, rather than all of the key attributes that might determine choices. For example, in some choice experiments respondents may ignore all but a dominant attribute, such as price, and always choose an alternative with the cheapest price, no matter what the levels of other attributes are.

Table 13 Descriptive Analysis of Responses by Design Strategies

Data Characteristic	Survey Design			
	D-Efficient	Random	Smart Adjusting Random	Reverse Smart Random
Number of respondents	1240	1303	355	973
Peak period travelers	50%	51%	57%	45%
Morning peak travelers	30%	29%	32%	26%
Evening peak travelers	20%	22%	25%	19%
Average trip length (miles)	11.7	11.9	12.2	11.5
Trip purpose as Commute/work	57%	54%	61%	53%
Male respondents	57%	57%	59%	60%
Carpoolers	36%	36%	36%	39%
Traveling towards downtown	47%	48%	48%	48%
Age < 25 years	2%	2%	2%	1%
Age 25 to 65 years	91%	91%	91%	92%
Age > 65 years	7%	7%	7%	7%
Annual Household Income < $25000	3%	3%	4%	2%
Annual Household Income $25000 to $75000	29%	29%	28%	28%
Annual Household Income > $75000	67%	68%	68%	70%
% of times alternative 1 presented	18%	20%	20%	18%
% of times alternative 2 presented	25%	22%	22%	21%
% of times alternative 3 presented	19%	22%	22%	26%
% of times alternative 4 presented	19%	18%	19%	18%
% of times alternative 5 presented	19%	18%	17%	17%
Non-trading and Lexicographic Behavior				
Non-trading	33.9%	30.8%	22.6%	32.9%
Always choosing fastest alternative	2.2%	3.4%	3.2%	4.1%
Always choosing cheapest alternative	36.6%	32.1%	24.0%	33.4%
Always choosing alternative with lowest occupancy	62.7%	60.4%	60.0%	61.9%

Lexicographic behavior can involve violation of transitivity (Choice A preferred to B, B to C, so choice A should be preferred to choice C) and may also arise when a respondent apparently uses only one attribute to base their decisions in all SP questions. Respondents from each sample were identified as the respondents with apparent lexicographic behavior if they always selected the fastest (with least travel time), the cheapest (no toll) or the alternatives with lowest occupancy (drive alone alternatives).

The results of the non-trading and lexicographic behavior for each of the design approaches are summarized in Table 13. It can be observed that the smart adjusting random approach performs better than other design alternatives in that it results in less non-trading and fewer respondents always choosing the cheapest alternative. The percentage of respondents always choosing same occupancy mode and fastest alternatives were similar for all these designs.

5.1.2. Efficiency in Estimation of Parameters and Comparison of Estimated VTTS

The samples corresponding to each design approach were used to estimate four different simple Multinomial Logit Models (MNL). Since the aim of this part of the study was to compare the survey designs; this simple MNL specification (instead of nested logit or mixed logit specification) with just travel time and toll/hourly wage rate coefficients in the utility functions along with alternate specific constants was used. The hourly wage rate was estimated as the respondents' annual household income divided by 2000 (approximate number of work hours in a year). In all the models the mode- DA-GPL - was set as the base alternative.

After estimating a MNL model for samples corresponding to each design approach the D-error and A-error for each of them was also calculated. Next, using the travel time and toll/hourly wage rate coefficients (β_t and β_c respectively) the implied marginal VTTS as percentage of wage rate for travelers from each sample (VTTS= β_t / β_c , after converting into comparable units) was estimated. The confidence intervals for the VTTS values ($V_{S,I}$) as derived by Armstrong et al. (2001)were also estimated using the t-ratio method equation (Equation 17).

$$V_{S,I} = \left(\frac{\beta_t.t_c}{\beta_c.t_t}\right).\frac{(t_t t_c - \rho t^2)}{(t_c^2 - t^2)} \pm \left(\frac{\beta_t.t_c}{\beta_c.t_t}\right).\frac{\sqrt{(\rho t^2 - t_t t_c)^2 - (t_t^2 - t^2)(t_c^2 - t^2)}}{(t_c^2 - t^2)} \tag{17}$$

where t_t = t-ratio for parameter estimates β_t,

t_c = t-ratio for parameter estimates β_c,

t = cirtical value of the statistic given the degree of confidence required,

ρ = coefficient of correlation between β_t and β_c

The model estimation results and estimated VTTS along with its confidence interval at the 95 percent level of confidence are summarized in Table 14. The log-likelihood value, adjusted ρ_0^2 and adjusted ρ_c^2 are also reported for each model (Equation 18 and 19).

$$\text{Adjusted } \rho_0^2 = 1 - \frac{LL(\hat{\beta}) - K}{LL(0)} \tag{18}$$

where $LL(\hat{\beta})$ =log-likelihood for the estimated model,

K= Number of parameters in the estimated model

$LL(0)$ =log-likelihood with zero coefficients model (which results in equal likelihood of choosing each available alternative)

$$\text{Adjusted } \rho_c^2 = 1 - \frac{LL(\hat{\beta}) - K}{LL(C) - Kc} \tag{19}$$

where $LL(C)$ =log-likelihood for the constants only model,

Kc= Number of parameters in the constants only model

Since the market shares (percentage of trips using each travel mode/alternative) are not exactly equal in this study, it would be appropriate to use the adjusted ρ_c^2 to make inferences about the goodness of fit of the models (Koppelman and Bhat, 2006). Using this criterion the model corresponding to the smart adjusting random strategy provides a better fit than other models.

Table 14 Estimation Results for MNL Models Corresponding to Different Design Strategies

	D-Efficient Design		Random Level Generation		Smart Adjusting Random Level Generation		Reverse Smart Adjusting Random	
Observations (Number of choice situations)	3720		3909		1065		2675	
	Estimate	t-ratio	Estimate	t-ratio	Estimate	t-ratio	Estimate	t-ratio
ASC-Carpool on GPLs	-2.02	-30.38	-1.76	-30.28	-1.96	-16.01	-1.67	-24.97
ASC-Drive alone on MLs	-1.47	-19.96	-1.34	-19.83	-0.96	-7.57	-1.71	-21.61
ASC-Carpool with one other person on MLs	-2.30	-30.02	-2.06	-28.69	-1.98	-14.13	-2.15	-25.51
ASC-Carpool with three or more people on MLs	-3.14	-32.12	-2.73	-33.06	-3.12	-17.20	-2.70	-27.70
Travel Time (minutes)	-0.10	-14.74	-0.10	-14.91	-0.11	-9.27	-0.09	-11.93
Toll/wage rate ($/hr)	-11.17	-6.85	-11.03	-8.81	-16.95	-7.14	-3.86	-3.59
Log-likelihood	-3418.38		-4097.45		-1074.80		-2825.14	
Adjusted ρ_0^2	0.3360		0.2428		0.2679		0.2365	
Adjusted ρ_c^2	0.0924		0.1034		0.1501		0.0916	
D-error	0.0059		0.0043		0.0166		0.0055	
A-Error	1.1794		1.0803		1.3374		1.0289	
VTTS (% of wage rate in $/hr)	55%		52%		40%		145%	
C.I. for VTTS	(41%, 79%)		(41%, 69%)		(28%, 57%)		(93%, 314%)	

All the designs provide estimates of the alternate specific constants (ASCs), travel time and toll coefficients with signs (direction of influence on the choices) as per the prior expectations. A close look at the alternative specific constants (ASCs) reveals that when compared to the mode for DA-GPL, all other modes have negative ASCs, and hence are less attractive (which is as expected), other things being equal. HOV3+-ML appears to be the least attractive travel mode to the sample. This is consistent with added inconvenience travelers face in terms of coordinating a carpool with multiple parties.

The prediction success for these models (predicted versus actual choices) were compared to investigate the influence of design. It was found that all random attribute level generation strategies' models were predicting the market share of the less favorite modes more accurately than D-efficient design model (Table 15). Note that the managed lane modes and CP-GPL mode have smaller trip shares (DA-GPL is the most popular mode), hence a model/design approach which predicts these modes more accurately is often more useful to transportation policy makers.

Table 15 Percent of Correct Prediction for Each Alternative

Design Strategy	CP-GPL	DA-GPL	DA-ML	HOV2-ML	HOV3+-ML	All Modes
D-efficient	10.9%	69.4%	21.9%	12.3%	5.8%	51.9%
Random	17.7%	63.4%	25.8%	18.2%	11.0%	43.9%
Smart Random	17.0%	62.5%	35.6%	22.1%	6.7%	45.4%
Reverse Smart Random	19.4%	64.2%	21.6%	18.6%	10.3%	43.9%

After comparing the implied VTTS (in terms of percent of wage rate) for all three samples it can be seen that the alternative design strategies do affect the estimated VTTS. The exceptionally high (and seemingly implausible) estimate of VTTS for the reverse smart random strategy underscores the need of using attribute levels with caution. Nevertheless, the results here (except for the reverse smart random approach) support the literature that commuting time saved is valued close to 50 percent of the wage rate. The results for the basic random strategy (that predicts a VTTS of approximately 52 percent of the individual's wage rate) and the D-efficient design (predicting a VTTS of 55 percent of wage rate) are higher than the VTTS obtained by the smart adjusting random strategy (predicting a VTTS of about 40 percent of wage rate). An earlier study conducted for the VTTS of Katy Freeway travelers (data collected in 2003) estimated the value as 39 percent of the wage rate (Burris and Patil, 2006).

Specifically, the results here for these three strategies are not dissimilar to other findings like these that indicate a VTTS that is around half of the wage rate. Further, the close estimates of VTTS for the D-efficient and basic random strategy may be due in part to the use of the same attribute level range for the travel time and toll (Refer Table 6 and Table 7). Note that the attribute level range for the toll of the mode with occupancy (SOV or HOV) similar to respondent's current mode was changed by a factor for the smart random approach depending on the answer to previous question. When used in the survey these levels got transformed into the VTTS presented to the respondent as given in Table 16. It can be observed from Table 16 that this does not necessarily change the mean VTTS presented to the travelers in smart random design strategy when compared to the D-efficient and Random design approaches.

Table 16 VTTS ($/hr) Presented Through Various Survey Designs

Travel Alternative	Mean	Std. Dev.	Minimum	Maximum
D-efficient				
DA-ML	22.41	17.18	0	285
HOV2-ML	9.80	7.10	0	78
HOV3+-ML	4.75	5.48	0	78
Random				
DA-ML	21.72	15.06	0	156
HOV2-ML	11.95	14.36	0	147
HOV3+-ML	2.57	4.95	0	93
Smart-Random				
DA-ML	21.78	18.94	0	246
HOV2-ML	12.93	13.36	0	213
HOV3+-ML	3.05	6.59	0	90
Reverse Smart Random				
DA-ML	21.46	16.74	0	228
HOV2-ML	11.94	13.79	0	216
HOV3+-ML	2.40	4.99	0	108

The similarity of average VTTS presented is revealed in the histogram for VTTS presented for mode DA-ML as shown in Figure 4. Another possible confounding influence of the design results pertains to sample sizes for the surveys, which are unequal.

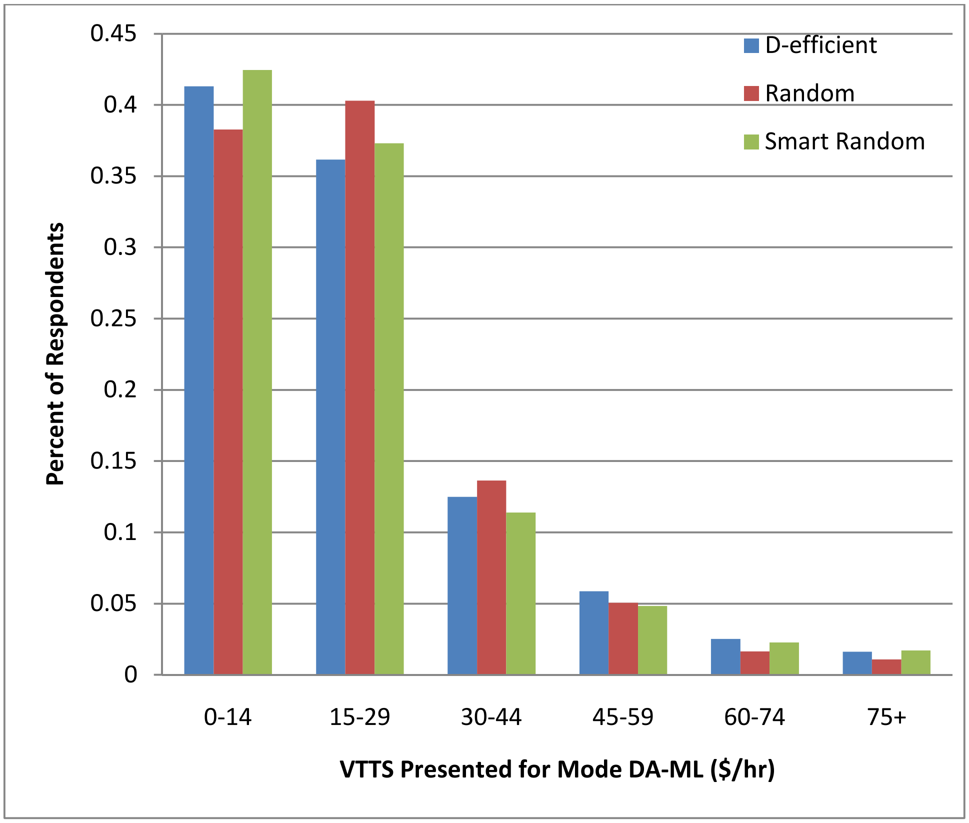

Figure 4 VTTS Presented for Mode DA-ML in Various Designs.

Comparison of the estimated confidence intervals for the VTTS indicates that the confidence intervals for the random design strategies' (except the reverse smart random) models are smaller than those for the D-efficient design model estimate. Since the reverse smart random strategy failed to produce a valid VTTS estimate it was dropped from further investigation of survey designs.

Since the D-error and A-error values depend on the sample size; the study additionally compared the D-error and A-error values for the specific samples corresponding to first three designs, doing so using random draws from each (Table 17). The D-error and A-error was calculated for different sample sizes; using 150, 200, 500, 700 and 1000 randomly drawn responses (choices) from the sample corresponding to each design approach. It should be noted that the sample size of less than 150 SP responses (obtained from 50 respondents in this study) is less likely as most of the studies for VTTS on MLs with internet based sampling are expected to generate larger samples. 50 draws of a given sample size were taken (e.g. 200) to estimate the average value of the D-errors and A-error statistics. Two sample t-tests on the D-error and A-error values were constructed to compare them.

Table 17 Efficiency of Designs for Different Sample Sizes

Design Strategy	Sample Size (# choice situations)					Full Sample D-eff= 3720 Random= 3909 Smart Random= 1065
	150	200	500	700	1000	
*D-error**						
D-efficient design	0.531	0.119	0.048	0.034	0.024	0.006
Random Level Generation	0.127	0.091	0.036	0.026	0.018	0.004
Smart Random	0.138	0.103	0.040	0.028	0.019	0.017
*A-error**						
D-efficient design	4.349	1.946	1.702	1.584	1.491	1.179
Random	1.891	1.776	1.534	1.452	1.383	1.080
Smart Random	1.921	1.832	1.553	1.473	1.376	1.337
*Adjusted Rho Squared**						
D-efficient design	0.083	0.085	0.093	0.097	0.091	0.092
Random	0.107	0.101	0.103	0.103	0.103	0.103
Smart Random	0.144	0.148	0.154	0.151	0.152	0.150

*Based on 50 random draws corresponding to each sample size

For all the sample sizes up to 1000 the D-error and A-error corresponding to the D-efficient design were significantly (alpha=0.05) greater than that corresponding to both the random and smart adjusting random strategies (Table 17). Comparison of the D-error and A-error thus indicates that the random strategy yields most efficient parameter estimates followed by the smart adjusting random strategy and then the D-efficient design.

A similar analysis was carried out for the adjusted ρ_c^2 (Table 17). The smart random strategy model was found to provide a better model fit with statistically significant larger value of adjusted ρ_c^2. The D-efficient design sample model provided the smallest adjusted ρ_c^2 among the samples corresponding to these three design approaches. This may be in part due to the ability of random design strategies to select four out of five alternatives depending on the respondent's current mode as obtained from the RP part of the survey. Note that only DA-GPL mode was present in all the questions for all the respondents presented with D-efficient design. Hence, the respondents who had their current travel mode as CP-GPL may or may not have received their current mode in the SP question depending on the block of design presented to them.

Based on these simple MNL models, the smart adjusting random and D-efficient design both appear to be superior to the random design. The reverse smart random was clearly the worst design strategy. However, implementing a D-efficient design was more restrictive than the random strategies since it wasn't possible to customize the design for a respondent. Additional difficulties were presented by use of SAS macro as it was not possible to use same attribute levels for more than one alternative. For example, the SAS macro method doesn't allow use of same speed (travel time) for both alternatives on GPLs. Hence with D-efficient design it was difficult to make the survey more realistic and make it comparable to the actual travel options a traveler may face.

Nevertheless, the analysis in this section clearly demonstrates the factors that need consideration in survey design and how these designs can affect the VTTS estimation for ML travelers. Next, the effect of travel urgency on VTTS for ML travelers is analyzed.

5.2. Analysis of Ordinary and Urgent Situations

One of the objectives of this dissertation was to compare VTTS of travelers on urgent and regular trips. To begin, a MNL and a mixed logit model were estimated for each mode choice (see Table 18). Each includes the reasons for urgent travel. Key variables including the commuting trip length, trip purpose, the traveler's age, gender, household type, size of household, number of vehicles in the household, and vehicle occupancy for the individual's most recent trip were found to be significant in the basic (MNL) model.

In the employed mixed logit model procedure 350 Halton draws were used to minimize simulation variance. Note that previous studies have concluded that use of Halton sequences rather than random draws decreases the estimation time and smoothens the simulation (Bhat, 2001, Train, 2003). The study used 350 Halton draws[2] primarily because the use of more draws takes multiple days for estimation of this complex model and it is not uncommon to use 200 to 500 Halton draws (Greene et al. 2006, Greene and Hensher, 2007, Hensher et al. 2008).

Typically, all the alternative specific constants (ASCs) and the travel time and toll parameters are specified as random parameters in a mixed logit model for mode choice. In this study the travel time parameter and ASCs were assumed as random parameters. The toll parameter was assumed as a fixed parameter to simplify the VTTS estimation inference and to avoid obtaining behaviorally implausible values for the implied VTTS as described in Section 2.4.

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[2] See, Hensher and Greene, 2003 for discussion on required number of Halton draws for stability in estimation

Table 18 Model Estimation Results for Ordinary and Urgent Situation Data

Attribute	Alternative(s)	MNL Model		Mixed Logit model	
		Coeff.	t-ratio	Coeff.	t-ratio
ASC-CP-GPL	CP-GPL	-0.66	-10.53	R:-2.22	-11.49
ASC-DA-ML	DA-ML	-1.04	-8.20	R:-2.44	-7.66
ASC-HOV2-ML	HOV2-ML	-0.58	-4.45	R:-1.82	-8.74
ASC-HOV3+-ML	HOV3+-ML	-1.95	-14.23	R:-4.64	-21.82
Travel Time (minutes)	All	-0.11	-24.16	R:-0.24	-31.41
Toll ($)	All	-0.90	-19.17	-1.81	-42.02
Drove alone for last trip (dv)	CP-GPL	-2.99	-28.77	-5.59	-23.28
Trip purpose commute/work (dv)	CP-GPL	0.14	1.87		
Male (dv) (male =1, female=0)	CP-GPL	-0.17	-2.40		
Age between 25 and 54 (dv)	CP-GPL			0.53	2.49
Drove alone for last trip (dv)	DA-ML	-0.27	-5.04		
Trip Length (miles)	DA-ML	0.01	4.14	0.04	5.12
Toll tag subscriber (dv) (1= owns a toll tag)	DA-ML	0.57	5.13	1.12	3.75
Drove alone for last trip (dv)	HOV2-ML	-2.41	-30.42	-4.07	-25.33
Trip purpose commute/work (dv)	HOV2-ML	0.22	3.23		
Trip Length (miles)	HOV2-ML	0.02	4.77	0.04	3.81
Age between 25 and 54 (dv)	HOV2-ML	-0.28	-3.80		
Number of people in household	HOV2-ML	0.08	2.80		
Male (dv) (male =1, female=0)	HOV2-ML	-0.49	-7.56	-0.82	-5.68
Single Adult Household (dv)	HOV2-ML	-0.36	-3.40	-0.47	-2.29
Number of vehicles in the household	HOV2-ML	-0.08	-2.39		
Drove alone for last trip (dv)	HOV3+-ML	-2.88	-25.36	-5.26	-20.14
Trip Length (miles)	HOV3+-ML	0.01	2.49		
Male (dv) (male =1, female=0)	HOV3+-ML	-0.22	-2.49		
Age between 25 and 54 (dv)	HOV3+-ML	0.32	3.08		
Standard deviation of Random Parameters					
ASC-CP-GPL	CP-GPL			3.35	30.08
ASC-DA-ML	DA-ML			1.92	25.74
ASC-HOV2-ML	HOV2-ML			2.37	24.54
ASC-HOV3+-ML	HOV3+-ML			3.61	20.71
Travel Time┼ (minutes)	All			0.24	31.41
Urgent to ordinary situations Scale parameter	All			0.64	6.68

Table 18- *Continued*

Attribute	Alternative(s)	MNL Model		Mixed Logit model	
		Coeff.	t-ratio	Coeff.	t-ratio
Interactions in MNL /Heterogeneity in mean in mixed logit					
Travel Time* ImpAppt	All	0.00	-0.40	0	
Travel Time* LateAppt	All	-0.02	-1.72	-0.07	-4.32
Travel Time* WorryTime	All	-0.07	-5.22	-0.11	-5.18
Travel Time* BadWeather	All	-0.03	-2.19	0	
Travel Time* LateML	All	-0.02	-2.04	-0.06	-2.91
Travel Time* ExtraStops	All	0.00	-0.39	0	
Toll ($)* ImpAppt	All	0.54	10.14	1.05	15.21
Toll ($)* LateAppt	All	0.72	15.29	1.28	17.01
Toll ($)* WorryTime	All	0.47	9.10	0.98	11.60
Toll ($)* BadWeather	All	0.36	6.32	0.78	10.42
Toll ($)* LateML	All	0.44	8.06	0.77	8.63
Toll ($)* ExtraStops	All	0.13	1.98	0.21	2.90
Toll ($)* Medium Household Income ($50- 100,000) (dv)	All	0.01	0.33	-0.14	-5.50
Toll ($)*High Household Income(>$100,000) (dv)	All	0.16	3.87	0.14	5.49
Error Components for alternatives and nests of alternatives parameters					
Standard deviation , θ_1	GPL alts.			0.27	3.42
Standard deviation , θ_2	ML alts.			2.10	7.27
Heterogeneity around standard deviation of error components effect					
Male (dv) (male=1, female=0)	GPL alts			1.63	6.03
Number of vehicles in the household	GPL alts			0.16	3.93
Male (dv) (male=1, female=0)	ML alts			-1.06	-5.99
Number of vehicles in the household	ML alts			-0.06	-1.10
Log-likelihood at convergence		-13467.43		-10722.10	
Adjusted ρc2		0.28		0.42	

Notes dv=dummy variable, R: Mean of the random parameter estimates, Adjusted $\rho_c^2 = 1 - \frac{LL(\hat{\beta})-K}{LL(C)-Kc}$ where, $LL(\hat{\beta})$ =log-likelihood for the estimated model, *K*= Number of parameters in the estimated model, $LL(C)$ =log-likelihood for the constants only model, *Kc*= Number of parameters in the constants only model, ┼ = Represents spread of the distribution (std. dev.= spread/√6) , ASC= Alternative Specific Coefficient

A normal distribution was assumed for the ASCs because no priors were available on them being of a particular distribution, and a constrained triangular distribution (spread=mean, $\bar{\beta}_{time}$) was assumed for the travel time parameter. An unconstrained triangular distribution was examined, but it did not provide a behaviorally meaningful sign for travel time parameter for all the population. Note that the travel time parameter is expected to be negative as it represents decreased utility for increased travel time. The positive sign will infer that the traveler actually enjoys longer travel, which is counterintuitive for most travel.

The technique described in Brownstone et al. (2000) and Hensher et al. (2008) was used to estimate a scale parameter (λ_{qt}) for the urgent situation trips (the ordinary situations scale parameter was normalized to 1.0). This is similar to what is done in models that use both SP and RP data and allow for possibility of different sources of random preferences over SP and RP choices (see Small et al. 2005).

Six dummy variables were used to incorporate the preference heterogeneity in the means (refer Section 3.3 for details) of the travel time and toll parameters, with one dummy variable for each of the six situations an ordinary situation corresponded to a zero value for all the six urgent situations dummy variables, and was the base case. The resulting marginal utility expressions of the parameters for the time and toll variables are given in Equations 20 and 21.

$$\begin{aligned}\beta_{time} = \bar{\beta}_{time} &+ \delta_{1t} \times ImpAppt + \delta_{2t} \times LateAppt + \delta_{3t} \times WorryTime \\ &+ \delta_{4t} \times BadWeather + \delta_{5t} \times LateML + \delta_{6t} \times ExtraStops + \bar{\beta}_{time} \times t\end{aligned} \tag{20}$$

$$\begin{aligned}\beta_c = \bar{\beta}_c &+ \delta_{1c} \times ImpAppt + \delta_{2c} \times LateAppt + \delta_{3c} \times WorryTime \\ &+ \delta_{4c} \times BadWeather + \delta_{5c} \times LateML + \delta_{6c} \times ExtraStops \\ &+ \delta_{7c} \times IncMed + \delta_{8c} \times IncHigh\end{aligned} \tag{21}$$

where $\bar{\beta}_{time}$ and $\bar{\beta}_c$ are the estimated population means of the constrained triangular and non-stochastic distributions corresponding to the time and toll/wage rate parameters respectively,

δ_{1t},.., δ_{6t} and δ_{1c},.., δ_{8c} are heterogeneities in the means of travel time and toll parameters respectively,

$ImpAppt$, $LateAppt$, $WorryTime$, $BadWeather$, $LateML$ and $ExtraStops$ are the dummy variables corresponding the six urgent situations (Refer to Table 5 for details),

$IncMed$ and $IncHigh$ are dummy variables for medium ($50,000-100,000) and high (greater than $100,000) annual household income, and

t is randomly drawn from a triangular distribution (refer Section 2.3.2).

Using equations (20) and (21), the implied mean VTTS for the low household income category identified by $IncMed = 0$ and $IncHigh = 0$ can be calculated for the ordinary situations (μ_{ord}) and six urgent situations ($\mu_1, .., \mu_6$) as shown in equation (22) and (23). The implied mean VTTS for the medium and high household categories can be similarly calculated by adding the estimates of δ_{7c} and δ_{8c} respectively in the denominator of (22) and (23).

$$\mu_{ord} = \frac{\bar{\beta}_{time}}{\bar{\beta}_c} \tag{22}$$

$$\mu_i = \frac{\bar{\beta}_{time}+\delta_{it}}{\bar{\beta}_c+\delta_{ic}}, i = 1, .., 6 \tag{23}$$

With the exception of heterogeneities for the variables *ImpAppt*, *BadWeather*, and *ExtraStops* (δ_{1t}, δ_{4t} and δ_{6t}) in travel time all other situations were statistically significant sources of influence on preference heterogeneity for both travel time and toll parameters (p=0.05 for all statistical inferences). The preference heterogeneity variables relating to the medium and high income groups (δ_{7c} and δ_{8c}) were also found to be significant.

The observed heterogeneity around the standard deviation of the travel time parameter (η_k) with respect to gender was added but, it was found to be statistically insignificant. It indicates that male travelers are not heterogeneous in terms of the marginal disutility associated with the travel time of all the modes when compared with female travelers.

To account for additional sources of preference heterogeneity not accounted for by the random parameterization and its associated decomposition, the general purpose lane (GPL) alternatives and the ML alternatives (across both ordinary and the urgent data sets) were further grouped in their error components. An example of such a preference heterogeneity associated with these two groups can be the travel time reliability associated with the travel modes in these two groups. The travel times of two GPL alternatives are expected to be less reliable than those of three ML alternatives. The standard deviation parameters ($\theta_1$and θ_2) which capture the heterogeneity profile of additional unobserved effects associated with these two groups of alternatives were therefore additionally estimated and they were found to be statistically significant. This suggests that there is a noticeable amount of preference heterogeneity associated with both groups (general purpose and managed lanes alternatives), that is not accounted for by the random parameters (ASCs).

Further, male and female travelers can be expected to have different travel behavior and the travel behavior can be expected to be significantly affected by number of vehicles in the household. Hence, these groups can have different preferences due to possible differences in ride sharing abilities. The influence of gender ($\tau_{11}$and τ_{12}) and the number of vehicles in the household ($\tau_{21}$and τ_{22}) on preference heterogeneity was estimated. The corresponding coefficients $\tau_{11}$and τ_{12} were found to be positive and significant, and this suggests that for male travelers and those households with an increasing number of vehicles the standard deviation of the error component associated with GPLs-(θ_1) increases, leading to an increase in preference heterogeneity from these unobserved effects. Similarly, τ_{21} was found to be negative and significant indicating that for male travelers the standard deviation of the error component associated with the managed lanes-(θ_2) decreases, leading to a decrease in the preference heterogeneity for male travelers.

Apart from these random parameters and parameters related to the heterogeneity and heteroscedasticity various non-random or fixed parameters were also included in the model which are reported in Table 18. The estimate of urgent situations to ordinary situations scale parameter was statistically significant (significantly different from 1) and less than one (0.68) suggesting a higher variance on the unobserved effects associated with the urgent situations. The mixed logit model provided overall improvement in the model fit over the simple MNL model as indicated by the higher adjusted ρ_c^2 and the improved log-likelihood value. A likelihood ratio test was carried out to determine if the improvements obtained by the mixed logit specification over the MNL model are statistically significant. The test statistic rejected the MNL model in favor of the mixed logit model with a very high significance (p-value < 0.0001). Hence only the mixed logit model was used for estimation of the individual's VTTS.

The parameter estimates for the mixed logit model from Table 18 were used to estimate the distribution of the implied VTTS for ordinary and urgent situations for the three income groups. The implied mean of VTTS was estimated (Table 19) as the ratio of the travel time to the estimated toll parameter using the heterogeneity in mean corresponding to each urgent situation and to each income group (Equations 18 to 21). For example, for low income group traveler facing the *LateAppt* situation, the implied VTTS distribution will be given by Equation 24.

$$VTTS_2 = \frac{\bar{\beta}_{time}+\delta_{it}+\bar{\beta}_{time}\times t}{\bar{\beta}_c+\delta_{ic}} = 60*\frac{-0.24-0.07-0.24\times t}{-1.81+1.28}=35.2-27.17\times t \tag{24}$$

where t = a variable which is randomly drawn from a triangular distribution.

The variable t takes values from (-1 to 1) as described in Equation 9. Thus implied VTTS of travelers facing this situation will range from (35.2-27.17=) 8.03 to (35.2+27.17=) 62.37.

The estimated VTTS is much higher for all of the six urgent situations than for non-urgent situations (see Table 19). Note that the VTTS estimates here may also include the values perceived by travelers for other benefits offered by the MLs such as safety and reliability as the effects of these attributes were not separated at the survey design stage to keep the choice task simple. The maximum estimate of the mean of VTTS was observed for the situation *LateAppt*, when the traveler is running late for an important appointment or meeting. The mean VTTS for situation *LateAppt* is 3.8 to 5.5 times greater than the mean of the implied VTTS corresponding to an ordinary situation.

The estimates of the mean of VTTS for all other urgent situations, except for the situation *ExtraStops*, were also very high as compared to the mean of VTTS corresponding to the ordinary situation. This suggests that travelers do not value travel time savings very highly (in comparison to the ordinary situation scenario) when they need to make extra stops on the trip, but still need to arrive on schedule. They may be depending more on the possibility of making an early departure, and less on paying/carpooling to use the managed lanes in order to make up for the extra time needed.

Table 19 VTTS for Different Urgent Situations

	Household Income ($/year)		
	Low- < 50,000	Medium 50,000 -100,000	High- >100,000
Situation	Mean VTTS ($/hr)		
Ordinary	7.9	7.4	8.6
Headed to an important appointment/meeting/event (ImpAppt)	18.7	15.9	22.8
Running late for an appointment or meeting (LateAppt)	35.2	27.9	47.5
Worried about arriving on time (WorryTime)	25.0	21.5	30.0
Expecting potential traffic problems due to bad weather (BadWeather)	13.9	12.2	16.0
Left late knowing you could take advantage of the toll lanes (LateML)	17.0	15.0	19.6
Need to make extra stops on the trip but still need to arrive on schedule (ExtraStops)	9.0	8.3	9.8

Implied means of the VTTS are also significantly different for different income groups; the low and high income groups having higher VTTS estimates compared to the medium income group. The higher estimate for the low income group in comparison to the medium income group could possibly be attributed to the schedule inflexibility of people in this group: possibly associated with many lower paying jobs having much less flexibility in work hours.

In order to further illustrate and compare the distributions of the implied VTTS corresponding to all these situations a draw of 1000 sample points was taken from the triangular distribution (the distribution used for the travel time parameter) and the VTTS values for the low income group were estimated. Note that although the spread of the distribution for the travel time parameter was fixed to be equal to the mean; the heterogeneity in the means of travel time and toll parameters gives different shapes to the distributions of VTTS corresponding to different situations (Figure 5). The VTTS for the situation *LateAppt* does not only have a large mean but it also has a large spread as compared the ordinary and other urgent situations (see Figure 5), resulting in the large variability of the VTTS for travelers late for an appointment.

From the analysis in this part of the section it can be concluded that travelers value the travel time savings on MLs very highly when faced by urgencies. Travelers in peak and off-peak period have significantly different travel behavior and hence a separate analysis of these two groups will shed some more light on the VTTS for urgent trips on managed lanes. This analysis is presented in the next section.

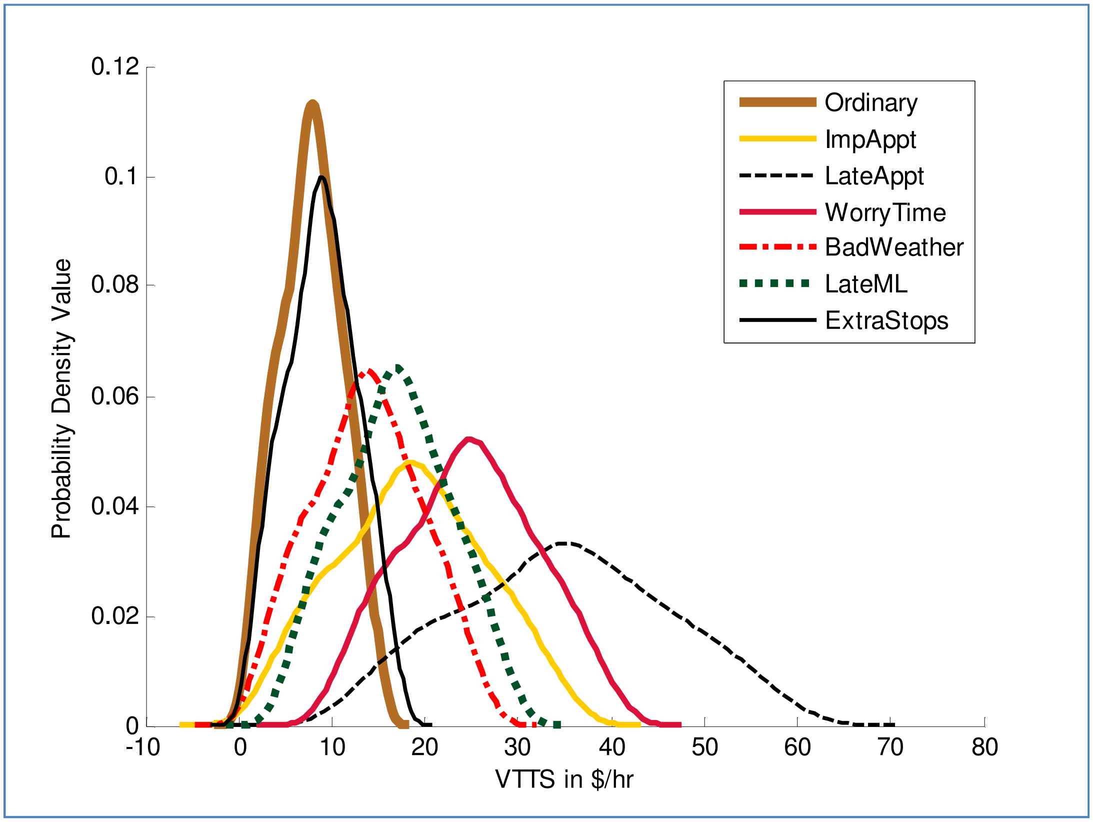

Figure 5 Distribution of the Implied VTTS for Low Household Income Group (less than $50,000 per year).

5.3. Comparison of Peak and Off-peak Traveler Groups

Katy Freeway is a major travel corridor in the Houston area and traffic volumes in peak hours are significantly greater than those in off-peak hours. Even after the Katy Freeway expansion in 2008, the speeds on the GPLs often drop significantly in peak hours as shown in Figure 6 and Figure 7. Travelers in peak and off-peak periods have different characteristics such as trip purpose, travelers' occupations and time budget constraints. Hence, accurately estimating VTTS in both peak and off-peak can be very useful, especially in the case where the managed lane facility has time of day/variable pricing. This section compares travel behavior and VTTS in peak and off-peak hours with respect to ordinary and urgent trips. The effect of survey design attributes on the VTTS estimation for both peak and off-peak travelers was also studied.

In order to analyze the mode choice behavior all respondents were divided into two groups, peak and off-peak travelers. During the survey design phase, the peak periods were identified as 6.15 a.m. to 9.00 a.m. and 3.45 p.m. to 6.30 p.m. using historical speed data on Katy Freeway GPLs such as those shown in Figure 6 and Figure 7. Comparisons of these two groups, with respect to different trip and traveler characteristics were undertaken.

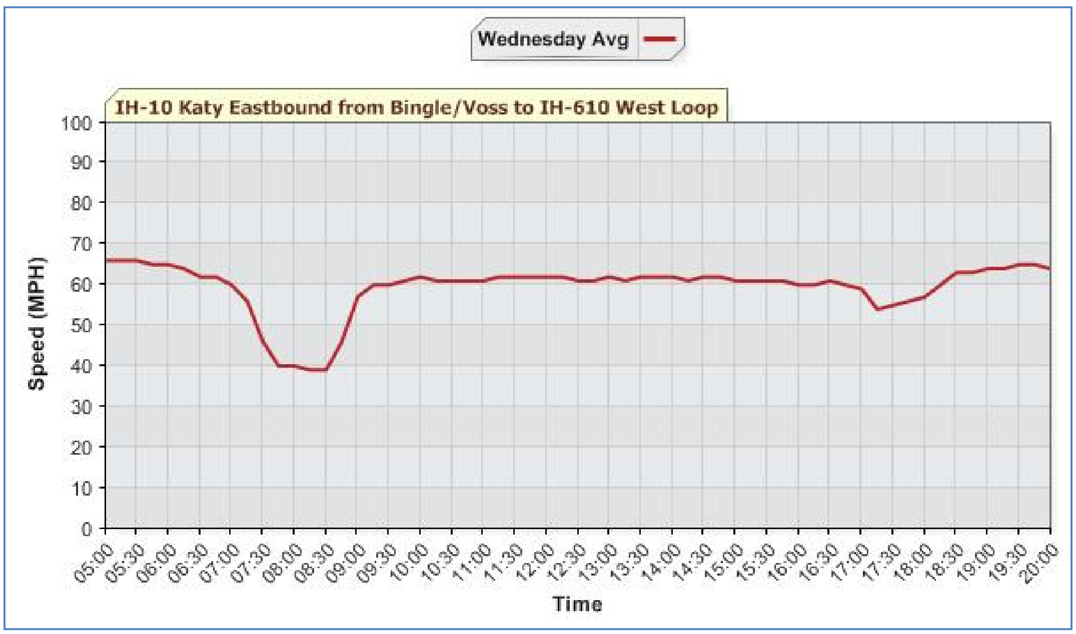

Figure 6 Average Speed for East Bound Katy Freeway General Purpose Lanes.
(Source: Houston TranStar, 2009)

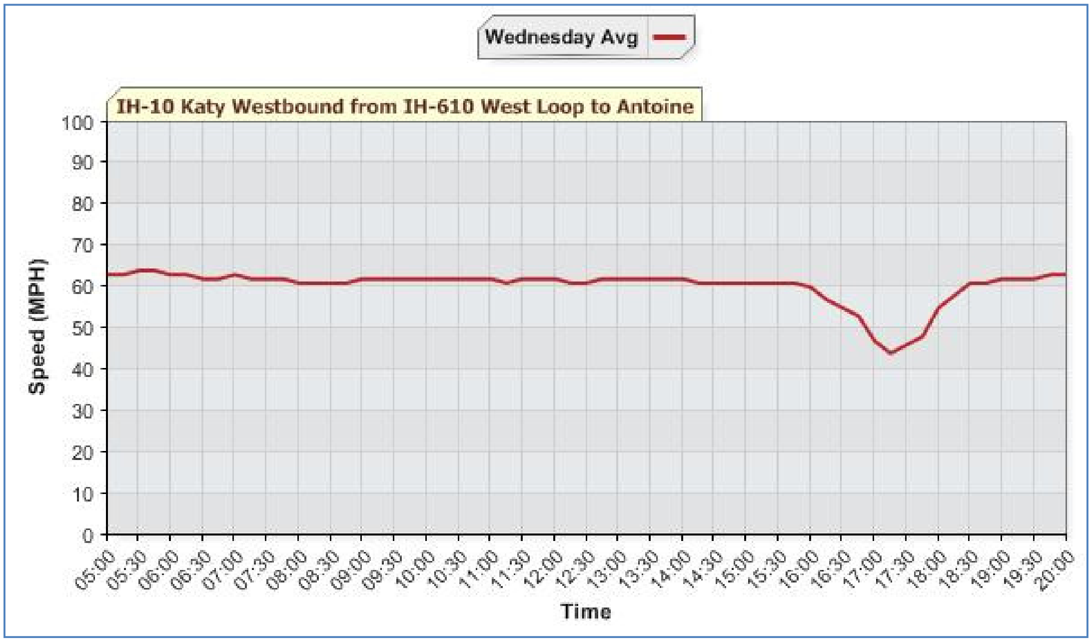

Figure 7 Average Speed for West Bound Katy Freeway General Purpose Lanes.
(Source: Houston TranStar, 2009)

5.3.1. Comparison of Trip and Traveler Characteristics

The samples related to off-peak and peak period traveler groups were compared to study their characteristics (Table 20). As expected the peak period group contained larger percentage of travelers who were commuting. Hence, it also contained more travelers who drove alone, who were between 25 to 54 years old, were in professional or managerial occupation and were on a regular trip. Regular trip was described to survey respondents as the trip they usually take at least once every two weeks.

Similarly, a higher percentage of travelers with occupations stay at home and self employed was found in the off-peak period group. The composition of peak and off-peak traveler groups is thus as expected.

Table 20 Comparison of Off-Peak and Peak Traveler and Trip Characteristics

Variable	Off-Peak Period	Peak Period
Number of respondents	1999	889
Percent of travelers traveling toward downtown	44%	55%
Percent of travelers who drove alone	61%	72%
Percent of travelers who pay for parking in downtown	13%	16%
Percent of male travelers	58%	58%
Percent of travelers on commute or work related trips	47%	78%
Percent of travelers between 25 and 54 years old	69%	77%
Percent of travelers with a graduate or post graduate degree	69%	68%
Percent of travelers on a regular trip	48%	73%
Percent of self employed travelers	10%	5%
Percent of travelers with a professional/managerial occupation	48%	59%
Percent of travelers who do not work (stay-at-home),	4%	2%
Average trip length (miles)	13.4	13.6

5.3.2. Analysis of Travelers Who Shifted from GPL to MLs in Urgent Situations

As one of the ways to better understand the travel behavior in urgent situations for peak and off-peak period groups, the characteristics of the respondents who selected a GPL alternative in an ordinary situation but switched to ML alternative in an urgent situation were studied (Table 21). This group of respondents contained the respondents who switched to MLs in at least one of the three urgent situation stated preference questions. Note that all the four travel modes and corresponding values of travel time and toll presented to a respondent in a pair of ordinary and urgent situation stated preference questions were kept the same. The comparison of travelers who choose the MLs in the peak and the off-peak periods is presented in Table 21.

Table 21 Characteristics of Travelers Who Switched to MLs in Urgent Situations

	Off-Peak Period	Peak Period
Percent of travelers traveling toward downtown	46%	56%
Percent of travelers who drove alone	64%	81%
Percent of travelers who need to pay for parking in downtown	12%	17%
Percent of male travelers	57%	55%
Percent of Travelers with commute or work related trips	46%	80%
Percent of Travelers with age between 25 and 54 years	70%	78%
Percent of travelers on regular trip	47%	75%
Percent of self employed travelers	9%	4%
Percent of travelers with professional/managerial occupation	49%	59%
Percent of travelers who stay-at-home	4%	2%
Average trip length (miles)	13.1	12.9

It can be observed from the comparison of Table 20 and Table 21 that even though most of the characteristics are similar to the corresponding samples of peak and off-peak traveler groups there are some interesting differences as well.

The percentage of travelers who drove alone increases when including only those who chose a ML option. This is even higher in the peak period. This suggests that travelers who drove alone are more likely to switch to managed lanes and more so in the peak period. Similarly, the travelers driving towards downtown are more likely to switch to MLs in urgent situations in both peak and off-peak periods. This can be attributed to an increased likelihood of a penalty for being late for the trips toward downtown.

Travelers who are on a commute or work related trip are more likely to switch to MLs in peak than in off-peak in an urgent situation. Similar split was observed for travelers who are on a regular trip. This may be attributed to high reliability of travel time in off-peak periods than in peak periods.

5.3.3. Mixed Logit Models for Peak and Off-peak Period Traveler Groups

Two mixed logit models were estimated to analyze the data corresponding to peak and off-peak period travelers. The peak period traveler group included only the travelers who traveled in the direction of typical commute: East bound for morning peak period travel and westbound for evening peak period travel (peak model). Travelers who traveled in peak period but opposite the typical commute direction were included in the off-peak group along with the off-peak time period travelers (off-peak period model-1).

Additionally, an alternate model for off-peak period was estimated by excluding the travelers who traveled in the peak period but in the off-peak direction (off-peak model-2). This will help to isolate the effect of attribute levels on implied value of travel time savings (if any). Note, that the peak period travelers (in both east and west bound) received similar attribute levels: higher tolls and greater travel times. The off-peak period travelers received smaller tolls and shorter travel times.

The travel time and toll coefficients for income groups- low (less than$50,000 per year), medium ($50,000 to $100,000 per year) and high (greater than $100,000 per year) and for six urgent situations were estimated using the heterogeneities in the means of travel time and toll respectively. Further, the alternative specific constants (ASCs) and the travel time coefficients were specified as the random parameters. Normal distribution was assumed for distributions of ASCs and constrained (mean= spread) triangular distribution was assumed for the travel time parameter. In order to obtain meaningful signs of the value of travel time savings, the toll coefficient was assumed to follow a non-stochastic (fixed) distribution. These models were estimated using 250 Halton draws.

A market segmentation test was carried out to check if two different models for the peak and off-peak period travelers were superior to a single pooled model for both peak and off-peak groups (combined together). The test statistic rejected the pooled model with high significance (P=0.0000). The model estimation results are given in Table 22.

Table 22 Models for Peak and Off-peak Travelers

Attribute	Alternative	Peak Model	Off-peak Model-1	Off-peak Model-2
		Coeff.	Coeff.	Coeff.
Non-Random Parameters				
Toll ($)	All	-1.91	-1.89	-2.38
Drove alone for last trip (dv)	CP-GPL	-5.89	-4.88	-5.29
Trip Length (miles)	DA-ML	0.03	0.04	0.04
Toll tag subscriber (dv) (1= owns a toll tag)	DA-ML	-	1.28	1.47
Drove alone for last trip (dv)	HOV2-ML	-5.50	-4.03	-4.06
Trip Length (miles)	HOV2-ML	-	0.03	-
Male (dv) (male =1, female=0)	HOV2-ML	-1.24	-	-
Single Adult Household (dv)	HOV2-ML	-1.53	-	-
Drove alone for last trip (dv)	HOV3+-ML	-	-4.63	-4.06
Drove alone for last trip (dv)	HOV3+-ML	-6.25	-	-
Random Parameters				
ASC-CP-GPL	CP-GPL	-1.26	-2.03	-1.84
ASC-DA-ML	DA-ML	-0.38	-2.98	-3.25
ASC-HOV2-ML	HOV2-ML	0.46	-2.64	-2.12
ASC-HOV3+-ML	HOV3+-ML	-4.31	-5.11	-4.73
Travel Time (minutes)	All	-0.20	-0.27	-0.29
Standard deviation of Random Parameters				
ASC-CP-GPL	CP-GPL	3.29	3.01	3.03
ASC-DA-ML	DA-ML	3.01	2.57	2.87
ASC-HOV2-ML	HOV2-ML	3.18	3.21	3.11
ASC-HOV3+-ML	HOV3+-ML	3.96	4.16	3.44
Travel Time† (minutes)	All	0.20	0.27	0.29
Urgent to ordinary situations Scale parameter	All	0.33	0.71	0.44

Table 22 *(continued)*

Attribute	Alternative	Peak Model	Off-peak Model-1	Off-peak Model-2
		Coeff.	Coeff.	Coeff.
Heterogeneity in mean				
Travel Time* *ImpAppt*	All	-	-	-
Travel Time* *LateAppt*	All	-0.05	-0.07	-0.33
Travel Time* *WorryTime*	All	-0.09	-0.11	-0.30
Travel Time* *BadWeather*	All	-	-	-0.18
Travel Time* *LateML*	All	-	-	-0.16
Travel Time* *ExtraStops*	All	-	-	-
Toll ($)* *ImpAppt*	All	1.00	1.21	1.77
Toll ($)* *LateAppt*	All	1.17	1.36	1.76
Toll ($)* *WorryTime*	All	0.91	1.10	1.78
Toll ($)* *BadWeather*	All	0.52	1.15	1.63
Toll ($)* *LateML*	All	0.84	1.13	1.36
Toll ($)* *ExtraStops*	All	0.32	-	0.47
Toll ($)* Medium Household Income ($50- 100,000) (dv)	All	-	-0.17	-0.19
Toll ($)*High Household Income(>$100,000) (dv)	All	-	0.17	0.19
Log-likelihood at convergence		-3258.21	-7578.62	-5073.76
Adjusted ρ_c^2		0.42	0.40	0.39

'-' Not significant at the 90 percent confidence level, ┼ = Represents spread of the distribution (std. dev.= spread/√6) , ASC= Alternative Specific Coefficient

These results were used to estimate the implied value of travel time savings for peak and off-peak travelers and for ordinary and urgent travel situations.

5.3.4. Estimation of VTTS for Peak and Off-peak Period Travelers

Based on the models estimated in the previous section, the estimated implied mean VTTS for peak and off-peak travelers is given in Table 23. For these models the urgent situation VTTS was found to be significantly greater than the ordinary situation

VTTS. The highest implied mean VTTS was observed for the urgent situation: *LateAppt*. The income heterogeneities in the peak model were found to be insignificant indicating insignificant difference in the effect of tolls across the three income groups.

Table 23 Comparison of Mean VTTS ($/hr) for Peak and Off-peak Respondents

	Implied Mean VTTS ($/hr)								
	Peak Model			Off-peak Model-1			Off-peak Model-2		
	LIG	MIG	HIG	LIG	MIG	HIG	LIG	MIG	HIG
Ordinary	6.2	6.2	6.2	8.7	8.0	9.5	7.2	6.7	7.9
ImpAppt	13.1	13.1	13.1	24.2	19.4	32.2	28.3	21.7	40.8
LateAppt	20.5	20.5	20.5	38.6	29.3	57.0	60.0	46.1	85.9
WorryTime	17.3	17.3	17.3	29.3	24.2	37.3	58.5	44.7	84.8
BadWeather	8.6	8.6	8.6	22.1	18.0	28.6	37.1	29.8	49.3
LateML	11.1	11.1	11.1	21.6	17.7	27.8	26.4	22.3	32.3
ExtraStops	7.5	7.5	7.5	8.7	8.0	9.5	9.0	8.2	10.0

LIG- Low Income Group, MIG- Medium Income Group, HIG- High Income Group

Further, it can also be observed that the implied peak VTTS is smaller than the off-peak VTTS, which is against our a priori expectations and the findings of previous studies. This may be due to the attribute levels used in the survey design (Table 24). Note that Table 24 combines the attribute level ranges from all three survey designs. These attribute level values were selected based on observed speeds (on GPLs and HOV lanes) and prevalent toll rates in the United States However, higher speeds in off-peak period resulted in smaller travel time savings on the MLs. This resulted in presenting greater average value of travel time savings to the off-peak period travelers as compared to the peak period travelers (Table 24). For example, for GPL speed of 60 mph and ML speed of 70 mph in the off-peak for a 12 mile (length of ML) long trip the travel time savings would be just 1.7 minutes. Hence, for the toll rate of 21 cents/mile (for mode DA-ML) the presented VTTS in off-peak will be = (12*21/100)/ (1.7/60) = $88.2/hr. Conversely, in the peak hours for the same trip length and for GPL and ML speeds of 40 mph and 65 mph respectively, the VTTS presented with the toll rate of 35 cents/mile will be just = (12*35/100)/(6.92/60)=$36.4/hr. Thus the VTTS presented for the off-peak hours is more than twice the VTTS presented for the peak hours. This resulted in the average VTTS presented to be greater in the off-peak hours when compared to that in the peak hours as shown in Table 24.

Table 24 Survey Design Attributes Used for Off-Peak and Peak Travelers

Alternative (Travel Mode)	Attributes	Off-Peak Period	Peak Period
*Range of levels used for survey design attributes**			
Drive alone on the GPLs	Speed (mph)	40-65	20- 50
	Toll Rate (cents/mile)	0	0
Carpool on the GPLs	Speed (mph)	40-65	20- 50
	Toll Rate (cents/mile)	0	0
Drive alone on the MLs	Speed (mph)	50-70	50- 70
	Toll Rate (cents/mile)	3.5-21	7- 42
Carpool with one other person on the MLs	Speed (mph)	50-70	50- 70
	Toll Rate (cents/mile)	0-11.5	0-24
Carpool with three or more people on the MLs	Speed (mph)	50-70	50- 70
	Toll Rate (cents/mile)	0-8.5	0-17
Average VTTS presented to all the respondents			
Drive alone on the MLs	VTTS ($/hr)	24.3	19.8
Carpool with one other person on the MLs	VTTS ($/hr)	12.2	10.1
Carpool with three or more people on the MLs	VTTS ($/hr)	3.6	3.5

* Travelers who traveled in the direction opposite of the typical commute in peak hours were presented with the peak period attribute levels but classified as off-peak travelers.

Further, in order to demonstrate the effect of VTTS presented in SP questions on estimated VTTS a simple analysis was carried out on a smaller sample using only ordinary travel scenario data of peak period travelers. VTTS presented for the mode DA-ML was estimated as the ratio of toll presented for DA-ML and the difference in travel time of modes DA-GPL and DA-ML. In the cases where the mode DA-GPL was not present in the SP question the travel time of mode HOV-GPL was used in the calculations. Similarly, VTTS presented for mode HOV2-ML (or HOV3+-ML) was estimated as the ratio of toll presented for HOV2-ML (or HOV3+-ML) and the difference in travel time of modes HOV-GPL and HOV2-ML (or HOV3+-ML). If the mode HOV-GPL was not presented in a SP question the travel time of mode DA-GPL was used to estimate the VTTS presented for mode HOV2-ML or HOV3+-ML. In cases where the toll presented for any of the ML alternative was zero, the VTTS presented was estimated as zero. Finally, the average VTTS presented was calculated using values of travel time savings presented for the ML alternatives a SP question.

The SP data were separated into five groups based on the average VTTS presented as VTTS ($/hr) = 0.00 to 5.00, 5.01 to 10.00, 10.01 to 15.00, 15.01 to 20.00, and greater than 20.01. Further, a random draw of 200 observations (SP questions) was taken from the first group with VTTS ($/hr) presented between 0.00 and 5.00. A simple MNL model, using only ASCs, travel time, and toll variable was estimated for the observations in this draw. The implied VTTS was then calculated for this draw as the ratio of travel time and toll coefficient. This procedure was repeated for 50 draws from this group to obtain an average value of the estimated VTTS. Similarly, the average value of the estimated VTTS was calculated for the remaining four groups based on the presented VTTS.

The average estimated VTTS for all the five groups is plotted in Figure 8. Given that the observations were separated into five groups only on the basis of the presented VTTS, it can be concluded from Figure 8 that the estimated VTTS depends on the presented VTTS. This underlines the importance of survey design and dependence of VTTS estimates on the values of underlying attribute levels.

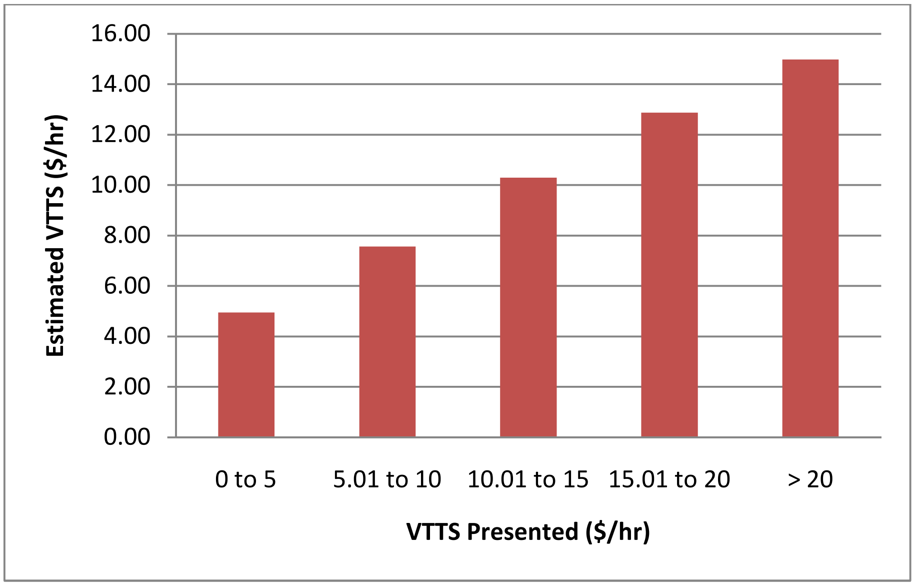

Figure 8 Effect of Presented VTTS on Estimated VTTS for Peak Period Travelers.

Hence, the results of the analysis to study the difference in VTTS for ordinary and urgent situation for peak and off-peak travelers should be interpreted with caution. Nevertheless, these results can be used to conclude that travelers value their time savings highly in urgent travel situations in both peak and off-peak. The policy implications of considering the difference in VTTS for ordinary and urgent travel situations are discussed in the next section.

5.4 Policy Analysis

This research has found a significant difference between a travelers' typical VTTS and a traveler's VTTS in urgent situations. It is the former VTTS (based on typical travel) which generally serves as the basis to calculate travelers' willingness to pay for a ML. Therefore, engineers and planners are missing the added value that MLs have for travelers on urgent trips. Based on previous studies and anecdotal evidence/ quotes from ML travelers it is known that many only use or are interested in using MLs in urgent situations (Zmud and Arce, 2008, HCTRA, 2009b). This added value is therefore unmeasured and the true value of MLs is underestimated. The following scenarios were developed to illustrate this underestimation. These scenarios make a number of assumptions regarding traffic on a freeway with MLs, including:

- Total travelers on the freeway = 8000 veh/hr,
- Percent of travelers facing an urgent situation= 0, 10, 20 and 30. Of these
    - 25 percent face the urgent situation- ImpAppt,
    - 25 percent face the urgent situation- LateAppt,
    - 12.5 percent face the urgent situation- WorryTime,
    - 12.5 percent face the urgent situation-BadWeather,
    - 12.5 percent face the urgent situation- LateML,
    - 12.5 percent face the urgent situation- ExtraStops,
- Percent of ML travelers with low incomes (less than $50,000)= 25 percent,
- Percent of ML travelers with medium incomes ($50,000 to $100,000)= 37 percent,
- Percent of ML travelers with high incomes (greater than $100,000) = 38 percent.

Note that the percentages of travelers on urgent trips used in above assumptions were just plausible guesses. The percentages of travelers in each income group were obtained for people living near Katy Freeway corridor from the study conducted by Houston Galveston Area Council of Governments (H-GAC, 2009). Using the above assumptions and the VTTS estimates from Section 5.2 (Table 19) one can estimate the potential willingness to pay for MLs in variety of scenarios. These willingness to pay estimates can be used to estimated the required toll rate for available space on MLs. The WTP benefits were estimated for an increasing number of toll paying vehicles, which is the number of vehicles that can fit on the managed lanes (see Figure 9).

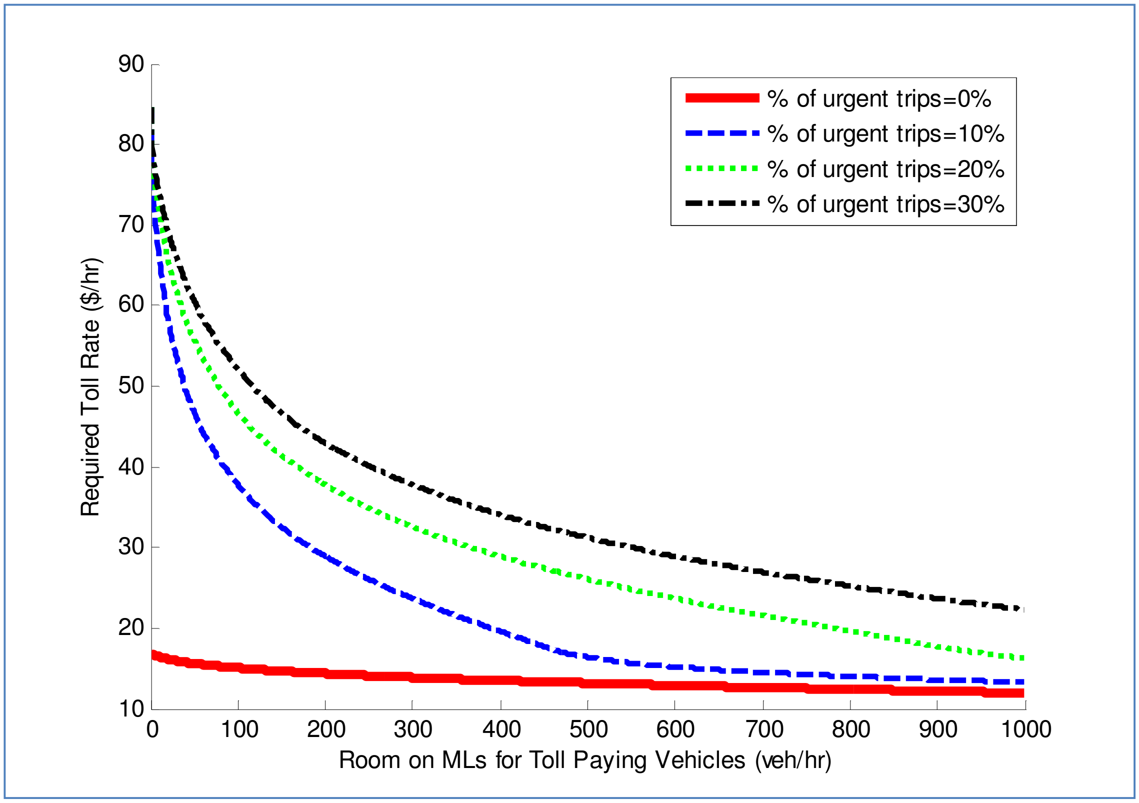

Figure 9 Estimated Toll Rates for Required Number of Vehicles on MLs.

It can be clearly observed from Figure 9 that assuming all travelers are on ordinary trips can lead to great underestimation of the value of travel time savings benefits obtained from the managed lanes. For example, as shown in Figure 10, if there is room for 100 more vehicles on MLs, the assumption that all travelers are facing ordinary trips will yield the hourly benefits marked by area below the curve corresponding to the ordinary situations which is approximately calculated as 15.1*100+(17.6-15.1)*100/2=$1,635.

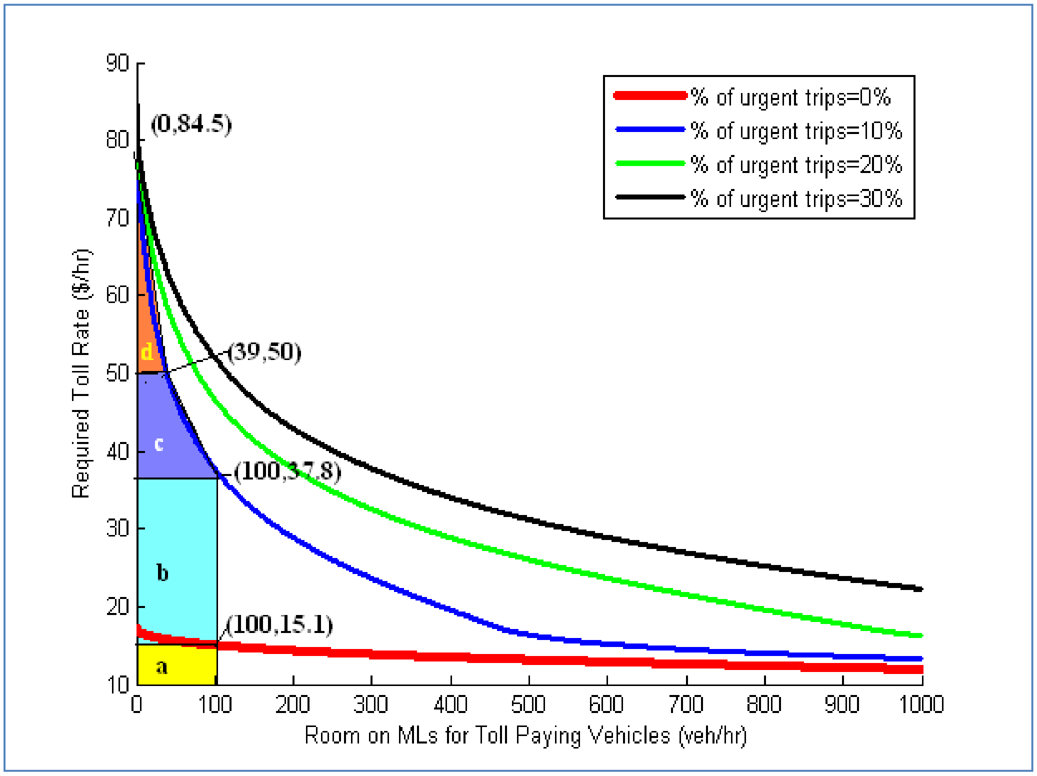

Figure 10 Benefits of Managed Lanes.

However, if we assume just 10 percent of all the travelers are facing urgent trips the hourly benefits increase to area marked by a + b + c + d (c and d are approximated as a triangle for ease of calculation), which is 37.8*100 + (50-37.8)*39+(50-37.8)*(100-39)/2+(84.5-50)*39/2= $5,300.65. Hence, the average value of MLs to travelers assuming no urgent trips will be approximately = 1635/100= $16.35. The average value of MLs to travelers assuming 10 percent are on urgent trips = 5300.65/100= $53.01. Thus if managed lanes saved 10 minutes of travel time, considering all 100 trips to be ordinary trips will yield travelers' benefits = 100*16.35*10/60= $272.50 and with 10 percent urgent trips the benefits will be = 100*53.01*10 / 60=$883.40. Hence, (wrongly) classifying the 10 percent of urgent trips as ordinary trips will miss the value of benefits by (883.40-272.50) / 272.50*100= 224 percent.

These calculations also demonstrate that the percentage of urgent trips affects the value of these benefits; hence it calls for accurate estimation of the percentage of travelers facing urgent trips and the percentage of urgent trips of each type using the traveler surveys. When there is a room for 100 toll paying travelers on MLs and when the there are approximately 10 minutes of travel time savings offered by MLs, the resulting percentage increase in the benefits for various percentages of urgent trips are plotted in Figure 11. Note that the percentage of increase in the managed lanes benefits will increase with an increasing percentage of urgent trips.

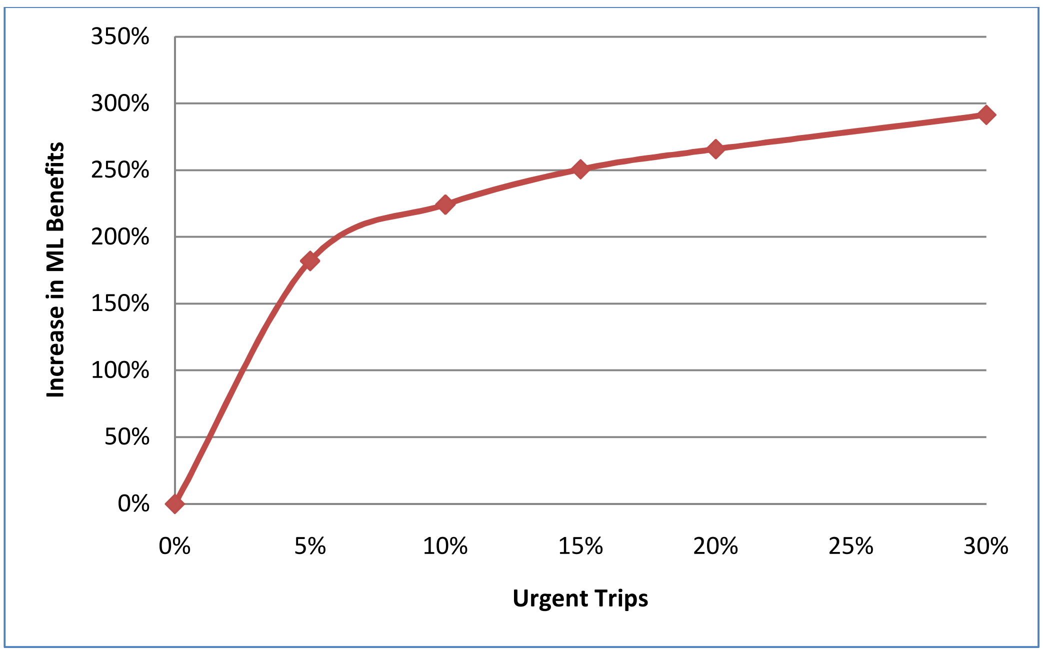

Figure 11 Benefits of Managed Lanes for 100 Toll Paying Vehicles.

Note that the plots in Figure 9 are actually demand curves in each scenario and these can be also be used to set the toll rates on the MLs. When setting the toll rate for MLs it is the travelers with the highest VTTS who use MLs and therefore this group is the one by which the ML toll is set. Based on the estimated VTTS distributions for the low income group travelers, 60 percent of travelers facing the urgent situation-*ImpAppt*, 95 percent facing the urgent situation-*LateAppt*, 87 percent facing the urgent situation-*WorryTime*, 32 percent facing the urgent situation-*BadWeather*, 52 percent facing the urgent situation-*LateML*, and 1 percent facing the urgent situation-*ExtraStops*, will have higher VTTS than the highest VTTS ($16.72/hr) high income group (annual household income >$100,000) traveler in a non-urgent (ordinary) situation (see Figure 12).

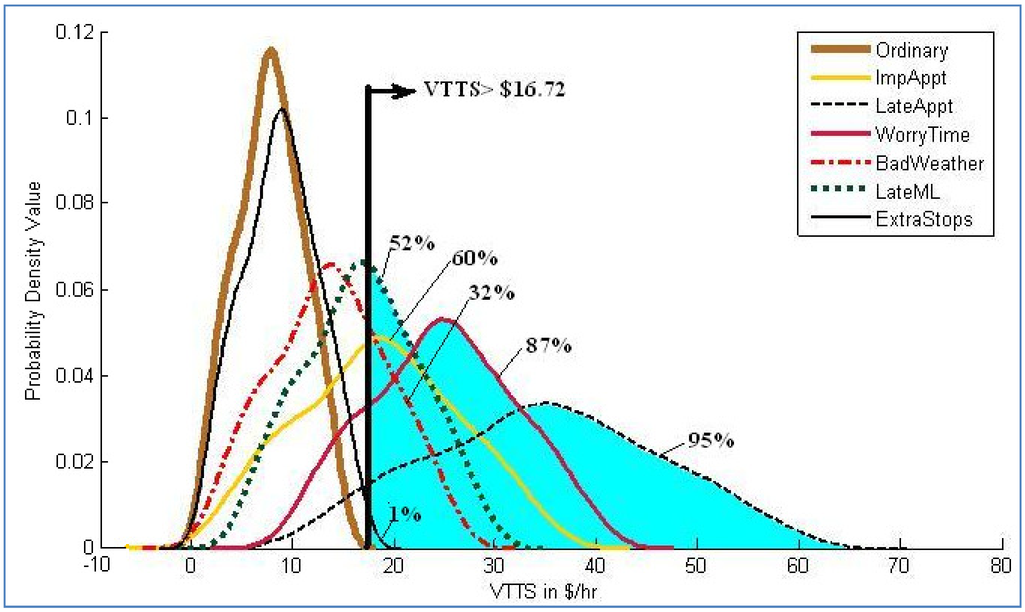

Figure 12 Percent of Low Income Group Travelers with VTTS Greater Than $16.72/hr.

Corresponding percent of travelers in urgent situations from medium and high income groups with VTTS higher than the highest VTTS ($16.72/hr) high income group traveler in a non-urgent (ordinary) situation are shown in Figure 13 and Figure 14. Therefore, depending on the room for toll paying travelers on the managed lanes, the entire group of toll paying travelers could be on urgent trips- which had a significantly higher willingness to pay than typical trips.

From the policy analysis in this section it can be concluded that travelers on urgent trips from all income groups place a significantly higher value on the travel time savings offered by MLs. Further, these travel time saving benefits can be a significant part of the total benefits offered by MLs.

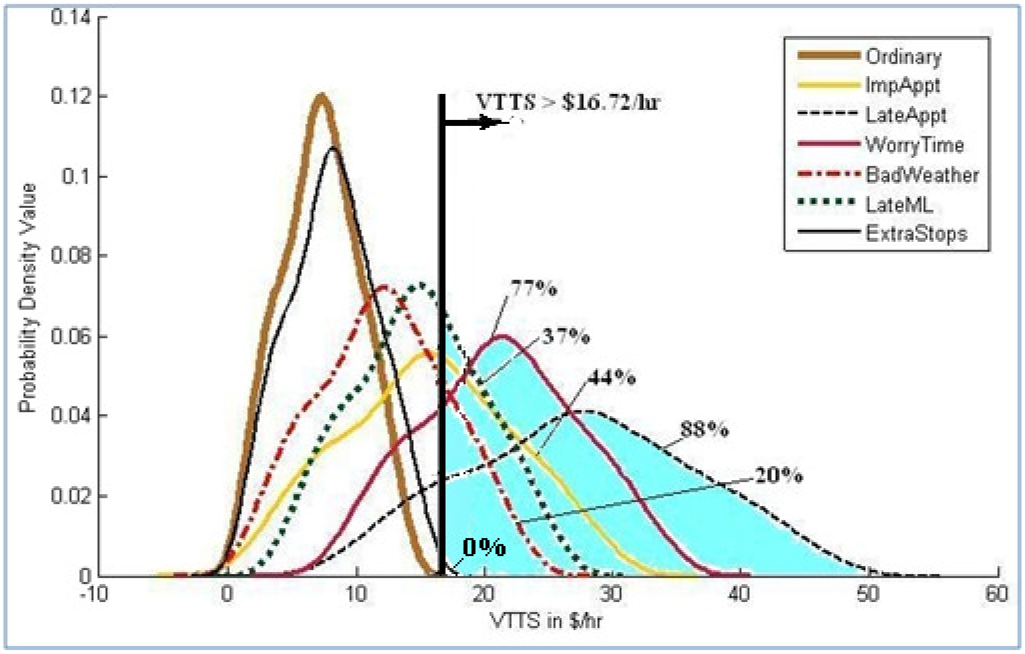

Figure 13 Percent of Medium Income Group Travelers with VTTS Greater Than $16.72/hr.

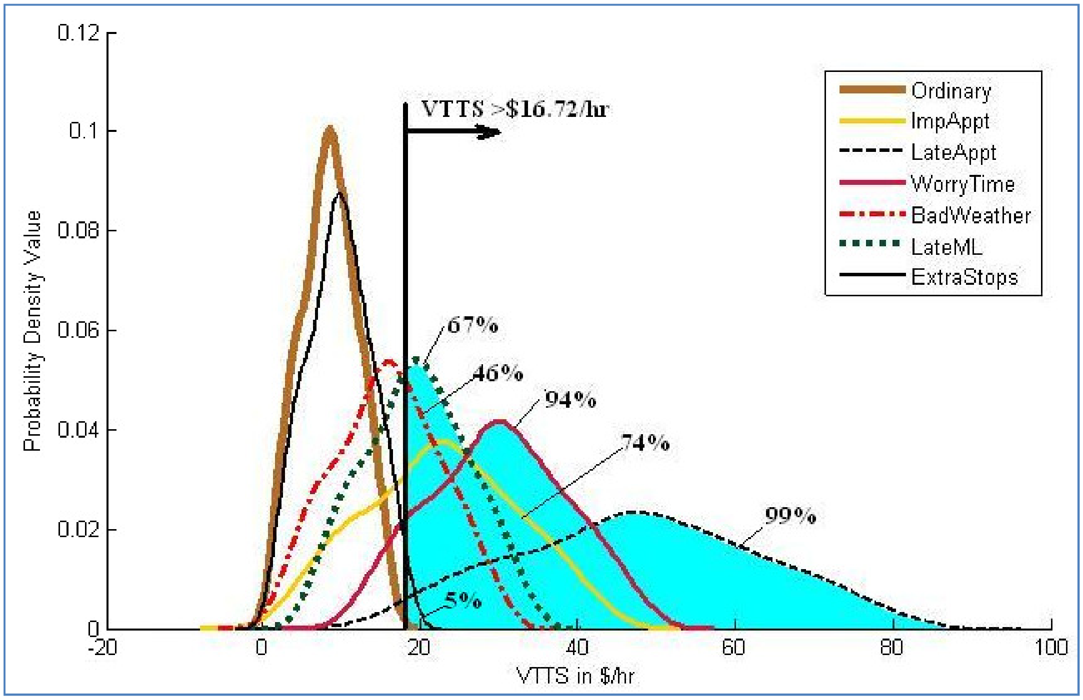

Figure 14 Percent of High Income Group Travelers with VTTS Greater Than $16.72/hr.

6. CONCLUSIONS

This research was aimed at understanding the travel behavior specifically, by studying the value of travel time savings (VTTS) and its estimation for managed lanes (MLs). This issue was investigated mainly by designing stated preference (SP) surveys, first at the survey design stage and later by including the SP questions related to six common urgent situations faced by managed lane travelers. An internet based SP survey was developed and made available to Katy Freeway and managed lane travelers. Survey responses from over 3,800 individuals were analyzed to achieve the research objectives.

6.1. Best Survey Design for Estimation of the VTTS

The first objective of this research was to investigate the influence of survey design strategies on estimation of VTTS for ML travelers. The study used three different experimental designs in a single survey. Each respondent was randomly assigned to one of these designs. The study used a D-efficient design, a random attribute level generation strategy (random), and a smart adjusting random attribute level generation strategy based on VTTS and the respondent's answer to the previous SP question (smart random). As an additional fourth design strategy (reverse smart random) responses which were used that were identified by the VTTS not changing in the same direction as the toll within the smart adjusting method were collected. Thus the toll values presented in the reverse smart random design strategy followed logic that was exactly opposite of smart random design strategy. This strategy was found to provide poor results.

The survey design strategies were also evaluated for choice behaviors such as non-trading and lexicographic behaviors. These behaviors were found to be significantly different for the different survey design strategies. For the large sample sizes used in this study it was found that the two random attribute level generation strategies were less susceptible to the non-trading behavior than the D-efficient design. These strategies were also found to perform better in comparison to the D-efficient design with respect to the lexicographic behavior criteria (based on behavior when the respondent chooses the cheapest and lowest occupancy alternative) except for one criterion in which the respondent always chooses the fastest alternative.

The efficiency of parameter estimation (measured by D-efficiency and A-efficiency) was found to be higher for the random and smart random strategies as compared to the D-efficient design. The gain in efficiency for the random design attributes may be due to the large sample sizes and their ability to adjust the choice set for individual respondent by considering their current travel mode. The random strategies used in this dissertation also offered more flexibility in presenting the desired attribute levels and using the consistency checks. Additionally, the smart random strategy also produced a better model fit (with larger adjusted ρ_c^2) as compared to the D-efficient and random strategy.

The survey design strategies yielded different point estimates for the implied VTTS but all were close to the values estimated in previous studies. The D-efficient design and random strategies (which used a fixed and narrower range for the toll attribute level) yielded higher point estimates of VTTS as compared to the smart random strategy. The confidence intervals for both the random strategies however were narrower than the D-efficient design.

Designing a SP survey using random attribute level generation based on the VTTS presented and answer to the previous SP question seems to be promising. Surprisingly, it out performs D-efficient design in VTTS estimation and in almost every other category (Although the D-efficient design was modified slightly to select only four of five alternatives). Additionally, the random strategies proposed in this study can adjust the SP questions so that they use more information from the revealed preference part of the survey and also the choice sets can handle the availability of alternatives with more ease than the D-efficient design. Better performance of the smart random strategy may be in part due to these abilities. Future studies may help to confirm the findings of this study.

6.2. Difference in the VTTS for Ordinary and Urgent Situations

The second objective of the study was to compare the VTTS for ordinary situations and six different urgent situations commonly faced by ML travelers. An ordinary situation was defined as a typical trip in the week prior to the survey. Urgent situations were represented by expected and unexpected events potentially affecting an ordinary trip which has previously arranged budgeted times and schedules. An urgent situation thus affects both travel time, and the possibility of arriving at a given location within the budgeted time.

The findings of this study indicate that the travelers value their travel time very highly when faced by most of the urgent situations considered in this study. These include: Headed to an important appointment/ meeting/ event, running late for an important meeting/ event/appointment, worried about arriving on time, expecting potential traffic problems due to bad weather and left late knowing they can take advantage of the toll lanes. The mean of VTTS corresponding to most of these urgent situations ranged from $8 to $47.5 per hour as compared to the estimate of $7.4 to $8.6 per hour for the ordinary situations for all income groups. Further, the study found that the implied means of VTTS for low and medium income group travelers facing an urgent situation were higher than the high income group travelers in an ordinary situation.

The findings thus add to the understanding of travel behavior for the managed lanes travelers and help in understanding of the occasional use of the facility by the travelers from all income groups. The study also shows how the stated preference survey can be modified to obtain various estimates of the VTTS for a managed lanes traveler. It should be noted that the VTTS estimated here for the travelers on managed lanes also includes the value travelers attach to the reliability of travel times offered by the managed lanes.

6.3. VTTS Estimation for Peak and Off-peak Traveler Groups

The peak and off-peak period travelers were compared to study their travel behavior in ordinary and urgent travel situations. It was found that travelers who drove alone are more likely to switch to the managed lanes in urgent travel situations and more so in the peak hours. Travelers driving towards downtown are more likely to use the managed lanes in urgent travel situations when compared to travelers driving away from downtown. Similarly in urgent travel situations peak hour travelers who are on commute or work related trips are more likely to use MLs than the off-peak hour travelers on commute or work related trips.

The results of mixed logit models indicated that travelers value time savings very highly when faced by all the urgent travel situations in both peak and off-peak periods. The VTTS values estimated for off-peak travelers was greatly affected by the level ranges used for the speed (travel time) and toll attributes. This may have resulted in greater estimated VTTS for the off-peak hour travelers than that for the peak hour travelers. Nevertheless, these unexpected results highlight the issue related to selection of attribute levels in off-peak period and the complexity of VTTS estimation for travelers on managed lane facilities with the time of day pricing.

6.4. Policy Implications

The contribution of urgent trip VTTS in estimation of benefits of managed lanes and other policy implications were also demonstrated in this dissertation. It was shown that classifying urgent trips as ordinary trips will greatly underestimate the benefits of managed lanes to travelers. One of the demonstrations with just 10 percent urgent trips and 10 minutes of travel time savings estimated the benefits missed (by classifying the urgent trips as ordinary trips) as 200 percent for 100 toll paying vehicles. Under these circumstances the benefits of managed lanes would be more than three times as much as predicted assuming only ordinary trips. Thus, the results of this study can be used to better estimate the benefits offered by managed lanes. Additionally, the findings have a potential to affect the policy decision of construction of new managed lanes.

The study also demonstrated how the knowledge of percentage of travelers facing urgent situation of each type can be useful in estimating the efficient toll rates for managed lanes with variable pricing. These findings can be particularly useful to the agencies operating the managed lanes as they can help to maintain a desired level of service on the facility.

It was also demonstrated that depending on the toll values the whole group of travelers on managed lanes can be the travelers facing urgent situations and hence managed lanes would provide significant travel time savings benefit to travelers from all income groups. Managed lanes thus can cater to high valued trips from all income groups and hence they can be great assets to travelers. Thus the study also helps to project managed lanes as a reliable travel alternative for travelers from all income groups.

6.5 Recommendations for Future Work

Additional survey design techniques which can combine the D-efficient designs and the smart adjusting random attribute level generation strategy can be investigated. A revealed preference study can be carried out to further support the estimation of difference in VTTS for ordinary and urgent situations. The research in this dissertation was carried out on data collected soon after opening of the expanded facility (HOT lanes with variable pricing). Now that travelers have gotten accustomed to the new facility, additional study can be carried out to compare the findings in this study. More urgent trip reasons can be investigated and similar studies can be carried out for other parts of the country or for other freeways with managed lanes.

An additional survey can be conducted to estimate the percentage of infrequent travelers, how often does an average infrequent traveler uses the managed lanes, and to enlist common urgent situations faced by travelers.

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APPENDIX A

SAS commands for searching a D-efficient Design

```
title 'Design for peak with availability';
%mktruns(3 4 4 4 4 3 3 3)
/*4 th level represents availability */

%macro resmac; /*put restrictions so that choice set has only 4 alts*/
navail=((x2<4)+(x3<4)+(x4<4)+(x5<4));
if (navail^=3)then bad=1;
else  bad=0;
%mend;

%mktex(3 4 4 4 4 3 3 3, n=24, restrictions = resmac, seed=1024433)
%mkteval;

%mktlab(data=randomized, vars=x1-x8,out=Peak_LinDes)
/* one can change the variable order through vars to avoid main variables having
interaction*/

data key1;
missing N;
input x1-x8;
datalines;
25 25 55 55 55 10 5  0
35 35 60 60 60 20 10 5
45 45 65 65 65 35 20 10
.  N  N  N  N  .  .  .
;
%mktlab(data= Peak_LinDes, key=key1,out=Peak_LinDes1)
proc print data= Peak_LinDes1 (obs=24);
var x1-x8;
run;

title 'Peak travelers';
data key;
input Mode $ 1-4 (TT Toll) ($);  /*name to be read from columns 1 to4*/
datalines;
SGP  x1  .
HGP  x2  .
SMP  x3  x6
```

```
H2MP x4  x7
H3M  x5  x8

; /* Maintain the column format- spacing is critical*/
%mktroll(design= Peak_LinDes1, key=key, alt=Mode,
out=Peak_ChDes)
proc print data= key;
run; /* Varify if the key is coded correctly*/

proc print data= Peak_LinDes1 (obs=24);
var x1-x8;
run; /* Print the linear design*/
proc print data= Peak_ChDes (obs=30);
id set; by set;
run; /* Print the first 6 questions of rolled design*/

data Peak_ChDes;
set Peak_ChDes;
if Mode = 'SGP' then do; Toll = 0; end;
if Mode = 'HGP' then do; Toll = 0; end;
run;
proc print data= Peak_ChDes (obs=30);
id set; by set;
run;

title2 'Evaluate the Choice Design';
%choiceff(data= Peak_ChDes, init= Peak_ChDes (keep=set),
nsets=24, nalts=5, beta=zero, intiter=0,
model=class(Mode /zero= 'SGP' separators='' ' ')
identity(TT)identity(Toll)
/ lprefix=0 cprefix=0)
/* D-eff=   zero=SGP */

%mktblock(data=Peak_ChDes, nalts=5, nblocks=8, factors=TT
Toll,out=Peak_ChBlckd, seed=472)
/*change the seed for desired frequency of a factor in a block*/

proc print data= Peak_ChBlckd (obs=120);
id Block; by Block;
run;

%mkteval(blocks=block)
```

APPENDIX B

Survey Questionnaire

Welcome Screen
Dear Houston Traveler,

The Texas Transportation Institute is examining ways to improve traffic flow along the Katy (I-10)Freeway. We need your help with this. This survey should take about 15 minutes to complete.
While you are not obligated to answer the questions on the survey, the information you provide will be very valuable as we work to improve travel on the Katy Freeway. Your answers on the survey will be confidential and not used in any way to identify you.
Two randomly selected surveys will win a $250 gas card. To be eligible the survey must be complete and contact information entered in the last question. Your contact information is stored separately and cannot be linked to your responses to these questions. If you have any questions regarding the survey, please contact me at (979) 845-9875 or mburris@tamu.edu.

Thank you for your participation.

Sincerely,

Mark Burris, Ph.D.
Research Director/Associate Research Engineer
Texas Transportation Institute

This research study has been reviewed by the Human Subjects' Protection Program and/or the Institutional Review Board at Texas A&M University. For research-related problems or questions regarding your rights as a research participant, you can contact these offices at (979)458-4067 or irb@tamu.edu.

Recent Travel Section

Please tell us about your most recent trip on the Katy Freeway (I-10) traveling away from downtown Houston during the work week (Monday through Friday). A "trip" is any time you traveled on Katy Freeway.

What was the purpose of your most recent trip? Choose one of the following answers:

- Commuting to or from my place of work (going to or from work)
- Recreational / Social / Shopping / Entertainment / Personal Errands
- Work related (other than to or from home to work)
- To attend class at school or educational institute
- Other

On what day of the week was your most recent trip away from downtown Houston?
Choose one of the following answers:

- Sunday
- Monday
- Tuesday
- Wednesday
- Thursday
- Friday
- Saturday

What time of day did that trip start? (for example, when did you leave work) ?
Choose one of the following answers:
12.00 AM 12.30 AM …11.30 PM

Is this a trip you regularly take (at least once every 2 weeks)?

- Yes
- No

Do you usually start your trip at that time when you travel on the Katy Freeway?

- Yes
- No

Would it have been possible for you to start your trip earlier or later?
Choose one of the following answers:

- Yes, I could have easily made the trip a little earlier or later
- Yes, I could have made the trip at any time that day
- No, I could not take the trip at any other time

Did you allow for extra travel time due to possible traffic congestion on the Katy Freeway (I-10) for your last trip?

- Yes
- No

Where did you get ON and OFF the Katy Freeway (I-10)?

ON OFF

- An exit West of 1463-Katy Road
- 1463 - Katy Road
- Pin Oak Road

- Katy Mills
- Katy Fort Bend Road
- Grand Pkwy
- Mason Road
- Westgreen Blvd.
- Fry Road
- Greenhouse Road / Baker Road
- Barker Cypress Road
- Park Row / Park 10
- Highway 6
- Eldridge Pkwy
- Dairy Ashford
- Kirkwood Road
- Sam Houston Pkwy / Wilcrest Dr.
- Gessner Road
- Blalock Road
- Bingle Road / Campbell
- Wirt Road
- Antonie Drive / Chimney Rock
- Silber Road / N Post Oak Road
- Loop 610
- Washington Ave / Westcott St
- T C Jester Blvd
- Durham Dr. / Shepherd Dr. / Patterson St.
- Studemont St. / Heights Blvd.
- Taylor Street
- I-45 Downtown Houston
- An exit East of I-45 Downtown Houston

What time of day did your trip end (for example, when did you arrive at home) ?
Choose one of the following answers:
12.00 AM 12.30 AM …11.30 PM

What kind of vehicle did you use for your most recent trip?
Choose one of the following answers:

- Motorcycle
- Passenger car, SUV, or pick-up truck
- Bus

If you traveled by Passenger Car/ SUV/Pick-up Truck, how many people including you, were in the vehicle?

Choose one of the following answers:

- 1
- 2
- 3
- 4
- 5 or more

Did you have to pay to park in Houston?

- Yes
- No

We want you to now think about all of your trips on the Katy Freeway during the last full week.

How many total trips did you make during the past full work week (Monday to Friday) on the Katy Freeway either into, or out of Houston? (Each direction of travel is one trip, include trips on the HOV lane or main lanes)

- Trips per week:-

Consider your usual trip into or out of Houston on the Katy Freeway:
On your usual trip, how much do you enjoy the travel?

Choose one of the following answers:

- I do not enjoy it at all
- I usually dislike it
- Neutral - neither dislike or like
- I usually enjoy the trip
- I always enjoy the time during my travel

Which of the following describes your activities during your usual travel on Katy Freeway? Check any that apply:

- I answer/make phone calls or text messages
- I listen to the radio, music, a book on tape, etc.
- I carpool and talk with fellow passengers
- I do not have to drive - so I can get reading or work done on the trip
- I focus only on driving

Do you own an electronic toll collection transponder - for example an EZ-Tag or TxTag?

- Yes
- No

Do you sometimes use a route into the Houston area other than the Katy Freeway to make trips with a similar purpose to your usual trip?

- Yes
- No

Introduction to New Toll Lanes

Prior to this survey, had you heard of the soon to open toll lanes on the Katy Freeway (I-10)?

- Yes
- No

Description of the Proposed Toll Lanes
The new Katy Tollway lanes are scheduled to open in the fall of 2008 and the facility will begin west of SH 6 and end at the I-10/I-610 interchange. The road will include 4 main lanes in each direction, 2 toll lanes in each direction and will be operated by Harris County Toll Road Authority (HCTRA) (See figure below). The tolls for the toll lanes will vary in cost to keep traffic moving quickly. During the rush hour the toll will be higher and during other times the toll will be lower. Drivers will have multiple entrances and exit locations to get on the toll lanes from both the eastbound and the westbound mainlanes of I-10. The facility will probably be in operation 24 hours a day and will probably be an EZ Tag only facility. Qualifying high-occupancy vehicles can travel for free during the peak hours. Metro buses will not be charged with the toll anytime.

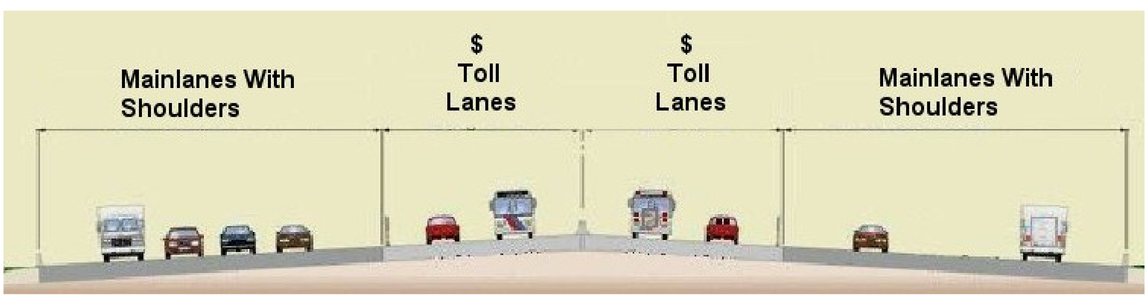

Figure A-1 Schematic Diagram of New Katy Toll Lanes (source www.katyfreeway.org).

Now that you know about the toll lanes on the Katy Freeway do you think you would be interested in using them?

Choose one of the following answers

- Yes
- No
- Maybe

What interests you the most about the toll lanes?
Check any that apply

- The toll lanes are safer / less stressful than driving on the main freeway lanes
- During the peak hours the toll lanes will not be congested
- Being able to use the toll lanes for free as a carpool
- Travel times on the toll lanes are consistent and predictable
- Other

The questions in this part of the survey are to find out your views on a number of potential options for the operation of the proposed toll lanes. The options raised here are for research purposes, and not official policies.

To maintain a smooth traffic flow, the toll that you pay on the toll lanes could change with the time of day you go through the station. As shown in the graph below, lower tolls could be charged for travel at specific times (for example, 6:30 a.m. to 7:00 a.m.) and higher tolls during the most congested times (for example, 7:00 a.m. to 8:00 a.m.).

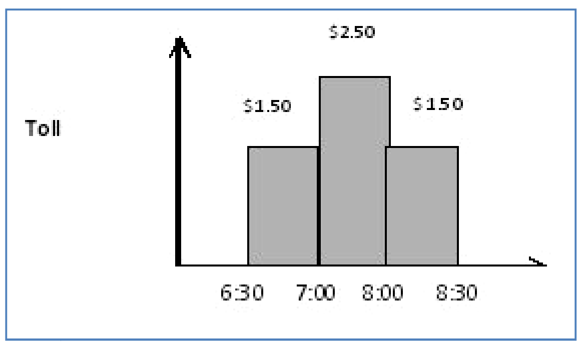

Figure A-2 Concept of Time of Day Pricing.

What is your initial feeling regarding this option?
Choose one of the following answers

- Very unfavorable
- Somewhat unfavorable
- Neutral / No Opinion
- Somewhat favorable
- Very favorable

The toll on the proposed toll lanes could also change with the amount of traffic on the toll lanes. For example, if the toll lanes were not congested then the toll might be lower. However, if the toll lanes were very congested the toll might be higher to maintain the smooth flow of traffic. What is your initial feeling regarding this option?
Choose one of the following answers

- Very unfavorable

- Somewhat unfavorable
- Neutral / No Opinion
- Somewhat favorable
- Very favorable

Travel Choices 1

Each of the following questions will ask you to choose between four potential travel choices on the Katy Freeway (I-10). For your most recent trip, please click on the one option that you would be most likely to choose if faced with these specific options. Remember that main lane traffic tends to be congested and could be slower than shown here if congestion is worse than usual. The toll lane traffic is fast moving. Also, carpooling may require added travel time to pick up or drop off your passenger(s).

You described your most recent trip away from downtown Houston on Katy Freeway last Monday as starting at 8:30 AM, ending at 9:30 AM in a Passenger car, SUV, or pick-up truck. The reason for the trip was Commuting to or from my place of work (going to or from work).

If you had the options below for that trip, which would you have chosen?
Choose one of the following answers

- Mode: Drive by myself

  Lane: Main freeway lanes
  Travel Time: 26 minutes
  Toll: $ None
  Time of Day: afternoon rush hour
- Mode: Drive by myself

  Lane: Toll lanes
  Travel Time: 10 minutes
  Toll: $3.15
  Time of Day: afternoon rush hour
- Mode: Carpool with one other person

  Lane: Toll lanes
  Travel Time: 9 minutes
  Toll: $1.60
  Time of Day: afternoon rush hour
- Mode: Carpool with 3 or more people

  Lane: Toll lanes
  Travel Time: 9 minutes
  Toll: $0.75

Time of Day: afternoon rush hour

Now we want you to think about a similar trip on Katy Freeway, with the same travel options as above. However, you are headed to an important appointment / meeting / event. Which option you would choose in this situation?
Choose one of the following answers:

- Mode: Drive by myself

  Lane: Main freeway lanes
  Travel Time: 26 minutes
  Toll: $ None
  Time of Day: afternoon rush hour
- Mode: Drive by myself

  Lane: Toll lanes
  Travel Time: 10 minutes
  Toll: $3.15
  Time of Day: afternoon rush hour
- Mode: Carpool with one other person

  Lane: Toll lanes
  Travel Time: 9 minutes
  Toll: $1.60
  Time of Day: afternoon rush hour
- Mode: Carpool with 3 or more people

  Lane: Toll lanes
  Travel Time: 9 minutes
  Toll: $0.75
  Time of Day: afternoon rush hour

Travel Choices 2
Contains similar choices as travel choices-1 with different set of travel time and toll values.
Travel Choices 3
Contains similar choices as travel choices-1 with different set of travel time and toll values.

Demographics
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 or released to any other person outside the research team.

What is your age?
Choose one of the following answers

- 16 to 24
- 25 to 34
- 35 to 44
- 45 to 54
- 55 to 64
- 65 and over

What is your gender?
Choose one of the following answers

- Male
- Female

Please describe the type of household you live in.
Choose one of the following answers:

- Single adult
- Unrelated adults
- Married without children
- Married with child(ren)
- Single parent family
- Other

Including yourself, how many people live in your household?

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

What category best describes your occupational or work status?
Choose one of the following answers

- Professional / Managerial
- Sales
- Stay-at-home/ homemaker / parent
- Administrative / Clerical
- Student
- Self employed
- Manufacturing
- Technical
- Retired
- Unemployed / seeking work
- Other

What was the last year of school that you have completed?
Choose one of the following answers

- Less than high school
- High school graduate
- Some college or vocational school
- College graduate
- Postgraduate degree

We know that your income is private and that us asking for it is a sensitive issue. However, we really need to know because we use this information to figure out how much your time is worth to you, which is important in explaining your transportation decisions. Remember, we will never use this information in conjunction with anything that identifies you by name, and all information is kept confidential. What was your gross annual household income before taxes in 2007? Include all sources of income, including wages, payments from retirement accounts, earnings from stocks and bond, etc.

Choose one of the following answers

- 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 $199,999
- $200,000 or more
- Its easier to tell my hourly wage rate:

Thank you for taking the time to fill in this survey. Your responses will be helpful as we work to improve travel in the Houston area. If you have any general comments about travel on the Katy Freeway, or Houston in general, please type them below. Thanks!

Please finish the survey by hitting “Submit” below. You will then have a chance to enter your contact information to be eligible to win one of the $250 gas cards. Your contact information is stored separately and cannot be linked to your responses to these questions.

APPENDIX C

Java Code for the Second pair of Stated Preference Questions

```
<SCRIPT language="JavaScript">
<!--hide from old browsers

// Set the time of day
    document.getElementById('answer95716X143X11974').value =
     "{INSERTANS:95716X139X11364}"   ;
    document.getElementById('answer95716X143X119710').value =
     "{INSERTANS:95716X139X113610}" ;
    document.getElementById('answer95716X143X119715').value =
     "{INSERTANS:95716X139X113615}" ;
    document.getElementById('answer95716X143X119720').value =
     "{INSERTANS:95716X139X113620}" ;
    document.getElementById('answer95716X143X119725').value =
     "{INSERTANS:95716X139X113625}" ;
    document.getElementById('answer95716X143X119730').value =
     "{INSERTANS:95716X139X113630}" ;
    document.getElementById('answer95716X143X119735').value =
     "{INSERTANS:95716X139X113635}" ;
    document.getElementById('answer95716X143X119740').value =
     "{INSERTANS:95716X139X113640}" ;
// Toll Distance, Free Distance, SP Question Type
    document.getElementById('answer95716X143X119742').value =
     "{INSERTANS:95716X139X113642}";
    document.getElementById('answer95716X143X119743').value =
     "{INSERTANS:95716X139X113643}";
    document.getElementById('answer95716X143X119741').value =
     "{INSERTANS:95716X139X113641}";
// Variables
    var TimODay = "{INSERTANS:95716X139X113644}" ;
    document.getElementById('answer95716X143X119744').value =
     "{INSERTANS:95716X139X113644}" ;
    var TollDist = "{INSERTANS:95716X139X113642}";
    var FreeDist = "{INSERTANS:95716X139X113643}";

// Previous SP Answer and Toll Rate
    var TollFact = 1;
    var SPAns1 = "{INSERTANS:95716X113X980}";
    var SPAnsA = SPAns1.indexOf(".");
        if (SPAnsA == -1)
        {
        var toll1 = 0;
        }
        else
```

```
        {
        var toll1 = Number(SPAns1.substring(SPAnsA-1,SPAnsA+3));
        }
var SPAns2 = "{INSERTANS:95716X113X1137}";
var SPAnsB = SPAns2.indexOf(".");
        if (SPAnsB == -1)
        {
        var toll2 = 0;
        }
        else
        {
        var toll2 = Number(SPAns2.substring(SPAnsB-1,SPAnsB+3));
        }
if (toll1 + toll2 > 0)
{
var TollFact = 1.33
}
else
{
var TollFact = 0.667;
}
var SPAnsA = SPAns1.indexOf("minutes");
        if (SPAnsA == -1)
        {
        var minutes1 = 0;
        }
        else
        {
        var minutes1 = Number(SPAns1.substring(SPAnsA-3,SPAnsA));
        }
var SPAnsB = SPAns2.indexOf("minutes");
        if (SPAnsB == -1)
        {
        var minutes2 = 0;
        }
        else
        {
        var minutes2 = Number(SPAns2.substring(SPAnsB-3,SPAnsB));
        }

var HOV2AddTime = 0;
var HOV3AddTime = 0;
var TollPaid = 0;
var BusAddTime = 5;
var usedmodes=new Array(5);
        usedmodes[0]=0;
        usedmodes[1]=0;
        usedmodes[2]=0;
        usedmodes[3]=0;
        usedmodes[4]=0;
        usedmodes[5]=0;
var AddTime = 0;
```

```
//Set Tolls and Travel Times
    if ("{INSERTANS:95716X139X113641}" == 1)
    { //D-Efficeint
        var Block = Math.round((Math.floor(Math.random()*80)+5)/10); // Random integer from 1 to 8
            if (Block == 8)  // switch 1/8 of blocks to # 8 since could not make it on the first SP group
            {
            document.getElementById('answer95716X143X119745').value = 8;
            }
            else
            {
            document.getElementById('answer95716X143X119745').value =
            "{INSERTANS:95716X139X113645}";
            }
        switch ({INSERTANS:95716X139X113645})
            {
            case 1:
                document.getElementById('answer95716X143X11972').value = 'Main freeway lanes' ;
                document.getElementById('answer95716X143X119722').value = 'Main freeway lanes' ;
                document.getElementById('answer95716X143X11973').value = 'Drive by myself';
                document.getElementById('answer95716X143X119721').value = 'Drive by myself' ;
                    var randomnumber=Math.floor(Math.random()*10) ;
                    var speedT = Math.round(20*TimODay + randomnumber) ;
                    var speedF = Math.round(60 + randomnumber/10) ;
                    var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
                document.getElementById('answer95716X143X11975').value = TrvTmGPL;
                document.getElementById('answer95716X143X119723').value = TrvTmGPL;
                document.getElementById('answer95716X143X119724').value = ' None' ;

                document.getElementById('answer95716X143X11976').value ='Carpool with others' ;
                document.getElementById('answer95716X143X119726').value = 'Carpool with others' ;
                document.getElementById('answer95716X143X11977').value = 'Main freeway lanes';
                document.getElementById('answer95716X143X119727').value = 'Main freeway lanes';
                    var randomnumber=Math.floor(Math.random()*10) ;
                    var speedT = Math.round(30 + 10*TimODay + randomnumber) ;
                    var speedF = Math.round(60 + randomnumber/10) ;
                    var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
                document.getElementById('answer95716X143X11978').value = TrvTmGPL ;
                document.getElementById('answer95716X143X119728').value = TrvTmGPL ;
                document.getElementById('answer95716X143X11979').value = ' None' ;
                document.getElementById('answer95716X143X119729').value = ' None' ;

                document.getElementById('answer95716X143X119711').value = 'Drive by myself' ;
                document.getElementById('answer95716X143X119731').value = 'Drive by myself' ;
                document.getElementById('answer95716X143X119712').value = 'Toll lanes' ;
                document.getElementById('answer95716X143X119732').value = 'Toll lanes' ;
                    var randomnumber=Math.floor(Math.random()*10) ;
                    var speedT = Math.round(60 + randomnumber) ;
                    var speedF = Math.round(60 + randomnumber/10) ;
                    var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
                document.getElementById('answer95716X143X119713').value = TrvTmML;
                document.getElementById('answer95716X143X119733').value = TrvTmML ;
```

```
        var randomnumb6 = Math.floor(Math.random()*6);
        var Toll = 7/TimODay + randomnumb6/TimODay;
        var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
    document.getElementById('answer95716X143X119714').value = TotToll3;
    document.getElementById('answer95716X143X119734').value = TotToll3;

    document.getElementById('answer95716X143X119716').value = 'Carpool with one
    other person';
    document.getElementById('answer95716X143X119736').value = 'Carpool with one
    other person';
    document.getElementById('answer95716X143X119717').value = 'Toll lanes' ;
    document.getElementById('answer95716X143X119737').value = 'Toll lanes' ;
        var randomnumber=Math.floor(Math.random()*10) ;
        var speedT = Math.round(50 + randomnumber) ;
        var speedF = Math.round(60 + randomnumber/10) ;
        var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
    document.getElementById('answer95716X143X119718').value = TrvTmML;
    document.getElementById('answer95716X143X119738').value = TrvTmML;
        var randomnumb6 = Math.floor(Math.random()*4);
        var Toll = 8/TimODay + randomnumb6/TimODay;
        var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
    document.getElementById('answer95716X143X119719').value = TotToll3;
    document.getElementById('answer95716X143X119739').value = TotToll3;
break;

case 2:
    document.getElementById('answer95716X143X11972').value = 'Main freeway lanes' ;
    document.getElementById('answer95716X143X119722').value = 'Main freeway lanes' ;
    document.getElementById('answer95716X143X11973').value = 'Drive by myself';
    document.getElementById('answer95716X143X119721').value = 'Drive by myself' ;
        var randomnumber=Math.floor(Math.random()*10) ;
        var speedT = Math.round(20*TimODay + randomnumber) ;
        var speedF = Math.round(60 + randomnumber/10) ;
        var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
    document.getElementById('answer95716X143X11975').value = TrvTmGPL;
    document.getElementById('answer95716X143X119723').value = TrvTmGPL;
    document.getElementById('answer95716X143X119724').value = ' None' ;

    document.getElementById('answer95716X143X11976').value ='Carpool with others' ;
    document.getElementById('answer95716X143X119726').value = 'Carpool with others' ;
    document.getElementById('answer95716X143X11977').value = 'Main freeway lanes';
    document.getElementById('answer95716X143X119727').value = 'Main freeway lanes';
    document.getElementById('answer95716X143X11978').value = TrvTmGPL ;
    document.getElementById('answer95716X143X119728').value = TrvTmGPL ;
    document.getElementById('answer95716X143X11979').value = ' None' ;
    document.getElementById('answer95716X143X119729').value = ' None' ;

    document.getElementById('answer95716X143X119711').value = 'Drive by myself' ;
    document.getElementById('answer95716X143X119731').value = 'Drive by myself' ;
    document.getElementById('answer95716X143X119712').value = 'Toll lanes' ;
    document.getElementById('answer95716X143X119732').value = 'Toll lanes' ;
        var randomnumber=Math.floor(Math.random()*10) ;
```

```
        var speedT = Math.round(50 + randomnumber) ;
        var speedF = Math.round(60 + randomnumber/10) ;
        var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
    document.getElementById('answer95716X143X119713').value = TrvTmML;
    document.getElementById('answer95716X143X119733').value = TrvTmML ;
        var randomnumb6 = Math.floor(Math.random()*14);
        var Toll = 28/TimODay + randomnumb6/TimODay;
        var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
    document.getElementById('answer95716X143X119714').value = TotToll3;
    document.getElementById('answer95716X143X119734').value = TotToll3;

    document.getElementById('answer95716X143X119716').value = 'Carpool with 3 or
    more people';
    document.getElementById('answer95716X143X119736').value = 'Carpool with 3 or
    more people';
    document.getElementById('answer95716X143X119717').value = 'Toll lanes' ;
    document.getElementById('answer95716X143X119737').value = 'Toll lanes' ;
        var randomnumber=Math.floor(Math.random()*10) ;
        var speedT = Math.round(55 + randomnumber) ;
        var speedF = Math.round(60 + randomnumber/10) ;
        var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
    document.getElementById('answer95716X143X119718').value = TrvTmML;
    document.getElementById('answer95716X143X119738').value = TrvTmML;
        var randomnumb6 = Math.floor(Math.random()*2);
        var Toll = 4/TimODay + randomnumb6/TimODay;
        var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
    document.getElementById('answer95716X143X119719').value = TotToll3;
    document.getElementById('answer95716X143X119739').value = TotToll3;
break;

case 3:
    document.getElementById('answer95716X143X11972').value = 'Main freeway lanes' ;
    document.getElementById('answer95716X143X119722').value = 'Main freeway lanes' ;
    document.getElementById('answer95716X143X11973').value = 'Drive by myself';
    document.getElementById('answer95716X143X119721').value = 'Drive by myself' ;
        var randomnumber=Math.floor(Math.random()*10) ;
        var speedT = Math.round(20*TimODay + randomnumber) ;
        var speedF = Math.round(60 + randomnumber/10) ;
        var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
    document.getElementById('answer95716X143X11975').value = TrvTmGPL;
    document.getElementById('answer95716X143X119723').value = TrvTmGPL;
    document.getElementById('answer95716X143X119724').value = ' None' ;

    document.getElementById('answer95716X143X11976').value ='Carpool with others' ;
    document.getElementById('answer95716X143X119726').value = 'Carpool with others' ;
    document.getElementById('answer95716X143X11977').value = 'Main freeway lanes';
    document.getElementById('answer95716X143X119727').value = 'Main freeway lanes';
    document.getElementById('answer95716X143X11978').value = TrvTmGPL ;
    document.getElementById('answer95716X143X119728').value = TrvTmGPL ;
    document.getElementById('answer95716X143X11979').value = ' None' ;
    document.getElementById('answer95716X143X119729').value = ' None' ;
```

```
        document.getElementById('answer95716X143X119711').value = 'Carpool with one
        other person';
        document.getElementById('answer95716X143X119731').value = 'Carpool with one
        other person';
        document.getElementById('answer95716X143X119712').value = 'Toll lanes' ;
        document.getElementById('answer95716X143X119732').value = 'Toll lanes' ;
            var randomnumber=Math.floor(Math.random()*10) ;
            var speedT = Math.round(60 + randomnumber) ;
            var speedF = Math.round(60 + randomnumber/10) ;
            var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
        document.getElementById('answer95716X143X119713').value = TrvTmML;
        document.getElementById('answer95716X143X119733').value = TrvTmML ;
            var randomnumb6 = Math.floor(Math.random()*6);
            var Toll = 17/TimODay + randomnumb6/TimODay;
            var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
        document.getElementById('answer95716X143X119714').value = TotToll3;
        document.getElementById('answer95716X143X119734').value = TotToll3;

        document.getElementById('answer95716X143X119716').value = 'Carpool with 3 or
        more people';
        document.getElementById('answer95716X143X119736').value = 'Carpool with 3 or
        more people';
        document.getElementById('answer95716X143X119717').value = 'Toll lanes' ;
        document.getElementById('answer95716X143X119737').value = 'Toll lanes' ;
            var randomnumber=Math.floor(Math.random()*10) ;
            var speedT = Math.round(50 + randomnumber) ;
            var speedF = Math.round(60 + randomnumber/10) ;
            var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
        document.getElementById('answer95716X143X119718').value = TrvTmML;
        document.getElementById('answer95716X143X119738').value = TrvTmML;
            var randomnumb6 = Math.floor(Math.random()*2);
            var Toll = 4/TimODay + randomnumb6/TimODay;
            var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
        document.getElementById('answer95716X143X119719').value = ' None';
        document.getElementById('answer95716X143X119739').value = ' None';
    break;

    case 4:
        document.getElementById('answer95716X143X11972').value = 'Main freeway lanes' ;
        document.getElementById('answer95716X143X119722').value = 'Main freeway lanes' ;
        document.getElementById('answer95716X143X11973').value = 'Drive by myself';
        document.getElementById('answer95716X143X119721').value = 'Drive by myself' ;
            var randomnumber=Math.floor(Math.random()*10) ;
            var speedT = Math.round(15 + 15*TimODay + randomnumber) ;
            var speedF = Math.round(60 + randomnumber/10) ;
            var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
        document.getElementById('answer95716X143X11975').value = TrvTmGPL;
        document.getElementById('answer95716X143X119723').value = TrvTmGPL;
        document.getElementById('answer95716X143X119724').value = ' None' ;

        document.getElementById('answer95716X143X11976').value ='Drive by myself';
        document.getElementById('answer95716X143X119726').value = 'Drive by myself';
        document.getElementById('answer95716X143X11977').value = 'Toll lanes';
```

```
document.getElementById('answer95716X143X119727').value = 'Toll lanes';
    var randomnumber=Math.floor(Math.random()*10) ;
    var speedT = Math.round(60 + randomnumber) ;
    var speedF = Math.round(60 + randomnumber/10) ;
    var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
document.getElementById('answer95716X143X11978').value = TrvTmML ;
document.getElementById('answer95716X143X119728').value = TrvTmML ;
    var randomnumb6 = Math.floor(Math.random()*10);
    var Toll = 15/TimODay + randomnumb6/TimODay;
    var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
document.getElementById('answer95716X143X11979').value = TotToll3;
document.getElementById('answer95716X143X119729').value = TotToll3;

document.getElementById('answer95716X143X119711').value = 'Carpool with one
other person';
document.getElementById('answer95716X143X119731').value = 'Carpool with one
other person';
document.getElementById('answer95716X143X119712').value = 'Toll lanes' ;
document.getElementById('answer95716X143X119732').value = 'Toll lanes' ;
    var randomnumber=Math.floor(Math.random()*10) ;
    var speedT = Math.round(55 + randomnumber) ;
    var speedF = Math.round(60 + randomnumber/10) ;
    var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
document.getElementById('answer95716X143X119713').value = TrvTmML;
document.getElementById('answer95716X143X119733').value = TrvTmML ;
    var randomnumb6 = Math.floor(Math.random()*2);
    var Toll = 4/TimODay + randomnumb6/TimODay;
    var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
document.getElementById('answer95716X143X119714').value = TotToll3;
document.getElementById('answer95716X143X119734').value = TotToll3;

document.getElementById('answer95716X143X119716').value = 'Carpool with 3 or
more people';
document.getElementById('answer95716X143X119736').value = 'Carpool with 3 or
more people';
document.getElementById('answer95716X143X119717').value = 'Toll lanes' ;
document.getElementById('answer95716X143X119737').value = 'Toll lanes' ;
    var randomnumber=Math.floor(Math.random()*10) ;
    var speedT = Math.round(60 + randomnumber) ;
    var speedF = Math.round(60 + randomnumber/10) ;
    var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
document.getElementById('answer95716X143X119718').value = TrvTmML;
document.getElementById('answer95716X143X119738').value = TrvTmML;
    var randomnumb6 = Math.floor(Math.random()*2);
    var Toll = 4/TimODay + randomnumb6/TimODay;
    var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
document.getElementById('answer95716X143X119719').value = TotToll3;
document.getElementById('answer95716X143X119739').value = TotToll3;
break;

case 5:
document.getElementById('answer95716X143X11972').value = 'Main freeway lanes' ;
document.getElementById('answer95716X143X119722').value = 'Main freeway lanes' ;
```

```
document.getElementById('answer95716X143X11973').value = 'Drive by myself';
document.getElementById('answer95716X143X119721').value = 'Drive by myself' ;
    var randomnumber=Math.floor(Math.random()*10) ;
    var speedT = Math.round(20*TimODay + randomnumber) ;
    var speedF = Math.round(60 + randomnumber/10) ;
    var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
document.getElementById('answer95716X143X11975').value = TrvTmGPL;
document.getElementById('answer95716X143X119723').value = TrvTmGPL;
document.getElementById('answer95716X143X119724').value = ' None' ;

document.getElementById('answer95716X143X11976').value ='Carpool with others' ;
document.getElementById('answer95716X143X119726').value = 'Carpool with others' ;
document.getElementById('answer95716X143X11977').value = 'Main freeway lanes';
document.getElementById('answer95716X143X119727').value = 'Main freeway lanes';
    var randomnumber=Math.floor(Math.random()*10) ;
    var speedT = Math.round(15 + 15*TimODay + randomnumber) ;
    var speedF = Math.round(60 + randomnumber/10) ;
    var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
document.getElementById('answer95716X143X11978').value = TrvTmGPL ;
document.getElementById('answer95716X143X119728').value = TrvTmGPL ;
document.getElementById('answer95716X143X11979').value = ' None' ;
document.getElementById('answer95716X143X119729').value = ' None' ;

document.getElementById('answer95716X143X119711').value = 'Carpool with one
other person';
document.getElementById('answer95716X143X119731').value = 'Carpool with one
other person';
document.getElementById('answer95716X143X119712').value = 'Toll lanes' ;
document.getElementById('answer95716X143X119732').value = 'Toll lanes' ;
    var randomnumber=Math.floor(Math.random()*10) ;
    var speedT = Math.round(50 + randomnumber) ;
    var speedF = Math.round(60 + randomnumber/10) ;
    var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
document.getElementById('answer95716X143X119713').value = TrvTmML;
document.getElementById('answer95716X143X119733').value = TrvTmML ;
    var randomnumb6 = Math.floor(Math.random()*2);
    var Toll = 4/TimODay + randomnumb6/TimODay;
    var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
document.getElementById('answer95716X143X119714').value = TotToll3;
document.getElementById('answer95716X143X119734').value = TotToll3;

document.getElementById('answer95716X143X119716').value = 'Carpool with 3 or
more people';
document.getElementById('answer95716X143X119736').value = 'Carpool with 3 or
more people';
document.getElementById('answer95716X143X119717').value = 'Toll lanes' ;
document.getElementById('answer95716X143X119737').value = 'Toll lanes' ;
    var randomnumber=Math.floor(Math.random()*10) ;
    var speedT = Math.round(55 + randomnumber) ;
    var speedF = Math.round(60 + randomnumber/10) ;
    var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
document.getElementById('answer95716X143X119718').value = TrvTmML;
document.getElementById('answer95716X143X119738').value = TrvTmML;
```

```
            var randomnumb6 = Math.floor(Math.random()*4);
            var Toll = 8/TimODay + randomnumb6/TimODay;
            var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
        document.getElementById('answer95716X143X119719').value = TotToll3;
        document.getElementById('answer95716X143X119739').value = TotToll3;
break;

case 6:
        document.getElementById('answer95716X143X11972').value = 'Main freeway lanes' ;
        document.getElementById('answer95716X143X119722').value = 'Main freeway lanes' ;
        document.getElementById('answer95716X143X11973').value = 'Drive by myself';
        document.getElementById('answer95716X143X119721').value = 'Drive by myself' ;
            var randomnumber=Math.floor(Math.random()*10) ;
            var speedT = Math.round(20*TimODay + randomnumber) ;
            var speedF = Math.round(60 + randomnumber/10) ;
            var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
        document.getElementById('answer95716X143X11975').value = TrvTmGPL;
        document.getElementById('answer95716X143X119723').value = TrvTmGPL;
        document.getElementById('answer95716X143X119724').value = ' None' ;

        document.getElementById('answer95716X143X11976').value ='Carpool with others' ;
        document.getElementById('answer95716X143X119726').value = 'Carpool with others' ;
        document.getElementById('answer95716X143X11977').value = 'Main freeway lanes';
        document.getElementById('answer95716X143X119727').value = 'Main freeway lanes';
            var randomnumber=Math.floor(Math.random()*10) ;
            var speedT = Math.round(30 + 10*TimODay + randomnumber) ;
            var speedF = Math.round(60 + randomnumber/10) ;
            var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
        document.getElementById('answer95716X143X11978').value = TrvTmGPL ;
        document.getElementById('answer95716X143X119728').value = TrvTmGPL ;
        document.getElementById('answer95716X143X11979').value = ' None' ;
        document.getElementById('answer95716X143X119729').value = ' None' ;

        document.getElementById('answer95716X143X119711').value = 'Drive by myself';
        document.getElementById('answer95716X143X119731').value = 'Drive by myself';
        document.getElementById('answer95716X143X119712').value = 'Toll lanes' ;
        document.getElementById('answer95716X143X119732').value = 'Toll lanes' ;
            var randomnumber=Math.floor(Math.random()*10) ;
            var speedT = Math.round(55 + randomnumber) ;
            var speedF = Math.round(60 + randomnumber/10) ;
            var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
        document.getElementById('answer95716X143X119713').value = TrvTmML;
        document.getElementById('answer95716X143X119733').value = TrvTmML ;
            var randomnumb6 = Math.floor(Math.random()*14);
            var Toll = 28/TimODay + randomnumb6/TimODay;
            var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
        document.getElementById('answer95716X143X119714').value = TotToll3;
        document.getElementById('answer95716X143X119734').value = TotToll3;

        document.getElementById('answer95716X143X119716').value = 'Carpool with one
        other person';
        document.getElementById('answer95716X143X119736').value = 'Carpool with one
        other person';
```

```
        document.getElementById('answer95716X143X119717').value = 'Toll lanes' ;
        document.getElementById('answer95716X143X119737').value = 'Toll lanes' ;
            var randomnumber=Math.floor(Math.random()*10) ;
            var speedT = Math.round(60 + randomnumber) ;
            var speedF = Math.round(60 + randomnumber/10) ;
            var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
        document.getElementById('answer95716X143X119718').value = TrvTmML;
        document.getElementById('answer95716X143X119738').value = TrvTmML;
            var randomnumb6 = Math.floor(Math.random()*2);
            var Toll = 4/TimODay + randomnumb6/TimODay;
            var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
        document.getElementById('answer95716X143X119719').value = ' None';
        document.getElementById('answer95716X143X119739').value = ' None';
    break;

    case 7:
        document.getElementById('answer95716X143X11972').value = 'Main freeway lanes' ;
        document.getElementById('answer95716X143X119722').value = 'Main freeway lanes' ;
        document.getElementById('answer95716X143X11973').value = 'Drive by myself';
        document.getElementById('answer95716X143X119721').value = 'Drive by myself' ;
            var randomnumber=Math.floor(Math.random()*10) ;
            var speedT = Math.round(30 + 10*TimODay + randomnumber) ;
            var speedF = Math.round(60 + randomnumber/10) ;
            var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
        document.getElementById('answer95716X143X11975').value = TrvTmGPL;
        document.getElementById('answer95716X143X119723').value = TrvTmGPL;
        document.getElementById('answer95716X143X119724').value = ' None' ;

        document.getElementById('answer95716X143X11976').value ='Carpool with others' ;
        document.getElementById('answer95716X143X119726').value = 'Carpool with others' ;
        document.getElementById('answer95716X143X11977').value = 'Main freeway lanes';
        document.getElementById('answer95716X143X119727').value = 'Main freeway lanes';
            var randomnumber=Math.floor(Math.random()*10) ;
            var speedT = Math.round(20*TimODay + randomnumber) ;
            var speedF = Math.round(60 + randomnumber/10) ;
            var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
        document.getElementById('answer95716X143X11978').value = TrvTmGPL ;
        document.getElementById('answer95716X143X119728').value = TrvTmGPL ;
        document.getElementById('answer95716X143X11979').value = ' None' ;
        document.getElementById('answer95716X143X119729').value = ' None' ;

        document.getElementById('answer95716X143X119711').value = 'Carpool with one
        other person';
        document.getElementById('answer95716X143X119731').value = 'Carpool with one
        other person';
        document.getElementById('answer95716X143X119712').value = 'Toll lanes' ;
        document.getElementById('answer95716X143X119732').value = 'Toll lanes' ;
            var randomnumber=Math.floor(Math.random()*10) ;
            var speedT = Math.round(50 + randomnumber) ;
            var speedF = Math.round(60 + randomnumber/10) ;
            var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
        document.getElementById('answer95716X143X119713').value = TrvTmML;
        document.getElementById('answer95716X143X119733').value = TrvTmML ;
```

```
        var randomnumb6 = Math.floor(Math.random()*4);
        var Toll = 8/TimODay + randomnumb6/TimODay;
        var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
    document.getElementById('answer95716X143X119714').value = TotToll3;
    document.getElementById('answer95716X143X119734').value = TotToll3;

    document.getElementById('answer95716X143X119716').value = 'Carpool with 3 or
    more people';
    document.getElementById('answer95716X143X119736').value = 'Carpool with 3 or
    more people';
    document.getElementById('answer95716X143X119717').value = 'Toll lanes' ;
    document.getElementById('answer95716X143X119737').value = 'Toll lanes' ;
        var randomnumber=Math.floor(Math.random()*10) ;
        var speedT = Math.round(60 + randomnumber) ;
        var speedF = Math.round(60 + randomnumber/10) ;
        var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
    document.getElementById('answer95716X143X119718').value = TrvTmML;
    document.getElementById('answer95716X143X119738').value = TrvTmML;
        var randomnumb6 = Math.floor(Math.random()*4);
        var Toll = 8/TimODay + randomnumb6/TimODay;
        var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
    document.getElementById('answer95716X143X119719').value = TotToll3;
    document.getElementById('answer95716X143X119739').value = TotToll3;
break;

case 8:
    document.getElementById('answer95716X143X11972').value = 'Main freeway lanes' ;
    document.getElementById('answer95716X143X119722').value = 'Main freeway lanes' ;
    document.getElementById('answer95716X143X11973').value = 'Drive by myself';
    document.getElementById('answer95716X143X119721').value = 'Drive by myself' ;
        var randomnumber=Math.floor(Math.random()*10) ;
        var speedT = Math.round(20*TimODay + randomnumber) ;
        var speedF = Math.round(60 + randomnumber/10) ;
        var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
    document.getElementById('answer95716X143X11975').value = TrvTmGPL;
    document.getElementById('answer95716X143X119723').value = TrvTmGPL;
    document.getElementById('answer95716X143X119724').value = ' None' ;

    document.getElementById('answer95716X143X11976').value ='Drive by myself';
    document.getElementById('answer95716X143X119726').value = 'Drive by myself';
    document.getElementById('answer95716X143X11977').value = 'Toll lanes';
    document.getElementById('answer95716X143X119727').value = 'Toll lanes';
        var randomnumber=Math.floor(Math.random()*10) ;
        var speedT = Math.round(60 + randomnumber) ;
        var speedF = Math.round(60 + randomnumber/10) ;
        var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
    document.getElementById('answer95716X143X11978').value = TrvTmML ;
    document.getElementById('answer95716X143X119728').value = TrvTmML ;
        var randomnumb6 = Math.floor(Math.random()*14);
        var Toll = 28/TimODay + randomnumb6/TimODay;
        var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
    document.getElementById('answer95716X143X11979').value = TotToll3;
    document.getElementById('answer95716X143X119729').value = TotToll3;
```

```
            document.getElementById('answer95716X143X119711').value = 'Carpool with one
            other person';
            document.getElementById('answer95716X143X119731').value = 'Carpool with one
            other person';
            document.getElementById('answer95716X143X119712').value = 'Toll lanes' ;
            document.getElementById('answer95716X143X119732').value = 'Toll lanes' ;
                var randomnumber=Math.floor(Math.random()*10) ;
                var speedT = Math.round(55 + randomnumber) ;
                var speedF = Math.round(60 + randomnumber/10) ;
                var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
            document.getElementById('answer95716X143X119713').value = TrvTmML;
            document.getElementById('answer95716X143X119733').value = TrvTmML ;
                var randomnumb6 = Math.floor(Math.random()*6);
                var Toll = 17/TimODay + randomnumb6/TimODay;
                var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
            document.getElementById('answer95716X143X119714').value = TotToll3;
            document.getElementById('answer95716X143X119734').value = TotToll3;

            document.getElementById('answer95716X143X119716').value = 'Carpool with 3 or
            more people';
            document.getElementById('answer95716X143X119736').value = 'Carpool with 3 or
            more people';
            document.getElementById('answer95716X143X119717').value = 'Toll lanes' ;
            document.getElementById('answer95716X143X119737').value = 'Toll lanes' ;
                var randomnumber=Math.floor(Math.random()*10) ;
                var speedT = Math.round(60 + randomnumber) ;
                var speedF = Math.round(60 + randomnumber/10) ;
                var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
            document.getElementById('answer95716X143X119718').value = TrvTmML;
            document.getElementById('answer95716X143X119738').value = TrvTmML;
                var randomnumb6 = Math.floor(Math.random()*4);
                var Toll = 8/TimODay + randomnumb6/TimODay;
                var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
            document.getElementById('answer95716X143X119719').value = TotToll3;
            document.getElementById('answer95716X143X119739').value = TotToll3;
        break;


        default:
            alert ("Default block");
        }

}
else // Random or smart adjusting SP questions
{
    //alert ("SPMode = 2 or 3");   both use same modes and travel times, only tolls are different
    if ("{INSERTANS:95716X139X113641}" == 2)  // random
    {
    var TollFact = 1;
    }
    // Modes 1 and 2 are the same from SP Qs 1 and 2 - respondents current mode
    // Which modes are already used?
```

```
if ("{INSERTANS:95716X139X11363}" == "Drive by myself")
{
usedmodes[1] = 1
usedmodes[2] = 1
document.getElementById('answer95716X143X11972').value = 'Main freeway lanes' ;
document.getElementById('answer95716X143X119722').value = 'Main freeway lanes' ;
document.getElementById('answer95716X143X11977').value = 'Toll lanes' ;
document.getElementById('answer95716X143X119727').value = 'Toll lanes' ;
document.getElementById('answer95716X143X11973').value = 'Drive by myself';
document.getElementById('answer95716X143X119721').value = 'Drive by myself';
document.getElementById('answer95716X143X11976').value = 'Drive by myself';
document.getElementById('answer95716X143X119726').value = 'Drive by myself';
    var randomnumber=Math.floor(Math.random()*25);
    var speedT = Math.round(20*TimODay + randomnumber) ;
    var speedF = Math.round(60 + randomnumber/10);
    var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
    var randomnumber=Math.floor(Math.random()*20);
    var speedT = Math.round(50 + randomnumber);
    var speedF = Math.round(60 + randomnumber/6);
    var TrvTmML = Math.round((TollDist * 60/speedT)+(FreeDist *
    60/speedF)+(AddTime));
        if (TrvTmML > TrvTmGPL)
        {
        var TrvTmML = TrvTmGPL - 3;
        }
document.getElementById('answer95716X143X11975').value = TrvTmGPL;
document.getElementById('answer95716X143X11978').value = TrvTmML;
document.getElementById('answer95716X143X119723').value = TrvTmGPL;
document.getElementById('answer95716X143X119728').value = TrvTmML;
    var randomnumb4=Math.floor(Math.random()*30);
    if (randomnumb4 < 10)
    {
    var randomnumb5=Math.floor(Math.random()*6);
    var Toll = 7/TimODay + randomnumb5/TimODay;
    }
    else if (randomnumb4 > 10 && randomnumb4 <20)
    {
    var randomnumb5=Math.floor(Math.random()*10) ;
    var Toll = 15/TimODay + randomnumb5/TimODay;
    }
    else
    {
    var randomnumb5=Math.floor(Math.random()*14) ;
    var Toll = 28/TimODay + randomnumb5/TimODay;
    }
    var TotToll3 = (Math.round(((Toll * TollDist * TollFact)/5))/20).toFixed(2);
document.getElementById('answer95716X143X11979').value = TotToll3;
document.getElementById('answer95716X143X119724').value = ' None';
document.getElementById('answer95716X143X119729').value = TotToll3;
}
else if ("{INSERTANS:95716X139X11363}" == "Carpool with one other person")
{
usedmodes[3] = 1
```

```
usedmodes[4] = 1
document.getElementById('answer95716X143X11972').value = 'Main freeway lanes' ;
document.getElementById('answer95716X143X119722').value = 'Main freeway lanes' ;
document.getElementById('answer95716X143X11977').value = 'Toll lanes' ;
document.getElementById('answer95716X143X119727').value = 'Toll lanes' ;
document.getElementById('answer95716X143X11973').value = 'Carpool with others';
document.getElementById('answer95716X143X119721').value = 'Carpool with others' ;
document.getElementById('answer95716X143X11976').value = 'Carpool with one other
person' ;
document.getElementById('answer95716X143X119726').value = 'Carpool with one other
person' ;
document.getElementById('answer95716X143X119724').value = ' None';
    var randomnumber=Math.floor(Math.random()*25);
    var speedT = Math.round(20*TimODay + randomnumber) ;
    var speedF = Math.round(60 + randomnumber/10);
    var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
    var randomnumber=Math.floor(Math.random()*20);
    var speedT = Math.round(50 + randomnumber);
    var speedF = Math.round(60 + randomnumber/6);
    var TrvTmML = Math.round((TollDist * 60/speedT)+(FreeDist *
    60/speedF)+(AddTime));
        if (TrvTmML > TrvTmGPL)
        {
        var TrvTmML = TrvTmGPL - 3;
        }
document.getElementById('answer95716X143X11975').value = TrvTmGPL;
document.getElementById('answer95716X143X11978').value = TrvTmML;
document.getElementById('answer95716X143X119723').value = TrvTmGPL;
document.getElementById('answer95716X143X119728').value = TrvTmML;
    var randomnumb4=Math.floor(Math.random()*101);
        if (randomnumb4 < 25)
        {
        document.getElementById('answer95716X143X11979').value = ' None';
        document.getElementById('answer95716X143X119729').value = ' None';
        }
        else if (randomnumb4 > 25 && randomnumb4 <62.5)
        {
            var randomnumb4=Math.floor(Math.random()*30);
            if (randomnumb4 < 10)
            {
            var randomnumb5=Math.floor(Math.random()*6);
            var Toll = 7/TimODay + randomnumb5/TimODay;
            }
            else if (randomnumb4 > 10 && randomnumb4 <20)
            {
            var randomnumb5=Math.floor(Math.random()*10) ;
            var Toll = 15/TimODay + randomnumb5/TimODay;
            }
            else
            {
            var randomnumb5=Math.floor(Math.random()*14) ;
            var Toll = 28/TimODay + randomnumb5/TimODay;
            }
```

```
        var TotToll3 = (Math.round(((Toll * TollDist * TollFact)/5))/20).toFixed(2);
        document.getElementById('answer95716X143X11979').value = TotToll3;
        document.getElementById('answer95716X143X119729').value = TotToll3;
    }
    else if (randomnumb4 > 62.5 && randomnumb4 <75)
        {
        var randomnumb6 = Math.floor(Math.random()*2);
        var Toll = 4/TimODay + randomnumb6/TimODay;
        var TotToll3 = (Math.round(((Toll * TollDist * TollFact)/5))/20).toFixed(2);
        document.getElementById('answer95716X143X11979').value = TotToll3;
        document.getElementById('answer95716X143X119729').value = TotToll3;
        }
    else if (randomnumb4 > 75 && randomnumb4 < 87.5)
        {
        var randomnumb6 = Math.floor(Math.random()*4);
        var Toll = 8/TimODay + randomnumb6/TimODay;
        var TotToll3 = (Math.round(((Toll * TollDist * TollFact)/5))/20).toFixed(2);
        document.getElementById('answer95716X143X11979').value = TotToll3;
        document.getElementById('answer95716X143X119729').value = TotToll3;
        }
    else
        {
        var randomnumb6 = Math.floor(Math.random()*6);
        var Toll = 17/TimODay + randomnumb6/TimODay;
        var TotToll3 = (Math.round(((Toll * TollDist * TollFact)/5))/20).toFixed(2);

        document.getElementById('answer95716X143X11979').value = TotToll3;
        document.getElementById('answer95716X143X119729').value = TotToll3;
        }
}
else
{
usedmodes[3] = 1
usedmodes[5] = 1
document.getElementById('answer95716X143X11972').value = 'Main freeway lanes' ;
document.getElementById('answer95716X143X119722').value = 'Main freeway lanes' ;
document.getElementById('answer95716X143X11977').value = 'Toll lanes' ;
document.getElementById('answer95716X143X119727').value = 'Toll lanes' ;
document.getElementById('answer95716X143X11973').value = 'Carpool with others';
document.getElementById('answer95716X143X119721').value = 'Carpool with others';
document.getElementById('answer95716X143X11976').value = 'Carpool with 3 or more
people';
document.getElementById('answer95716X143X119726').value = 'Carpool with 3 or more
people';
document.getElementById('answer95716X143X119724').value = ' None';
    var randomnumber=Math.floor(Math.random()*25);
    var speedT = Math.round(20*TimODay + randomnumber) ;
    var speedF = Math.round(60 + randomnumber/10);
    var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
    var randomnumber=Math.floor(Math.random()*20);
    var speedT = Math.round(50 + randomnumber);
    var speedF = Math.round(60 + randomnumber/6);
```

```
var TrvTmML = Math.round((TollDist * 60/speedT)+(FreeDist *
60/speedF)+(AddTime));
    if (TrvTmML > TrvTmGPL)
    {
    var TrvTmML = TrvTmGPL - 3;
    }
document.getElementById('answer95716X143X11975').value = TrvTmGPL;
document.getElementById('answer95716X143X11978').value = TrvTmML;
document.getElementById('answer95716X143X119723').value = TrvTmGPL;
document.getElementById('answer95716X143X119728').value = TrvTmML;
    var randomnumb4=Math.floor(Math.random()*101);
        if (randomnumb4 < 75)
            {
            document.getElementById('answer95716X143X11979').value = ' None';
            document.getElementById('answer95716X143X119729').value = ' None';
            }
            else if (randomnumb4 > 75 && randomnumb4 <83.3)
            {
            var randomnumb6 = Math.floor(Math.random()*2);
            var Toll = 4/TimODay + randomnumb6/TimODay;
            var TotToll3 = (Math.round(((Toll * TollDist * TollFact)/5))/20).toFixed(2);
            document.getElementById('answer95716X143X11979').value = TotToll3;
            document.getElementById('answer95716X143X119729').value = TotToll3;
            }
            else if (randomnumb4 > 83.3 && randomnumb4 <91.7)
            {
            var randomnumb6 = Math.floor(Math.random()*4);
            var Toll = 8/TimODay + randomnumb6/TimODay;
            var TotToll3 = (Math.round(((Toll * TollDist * TollFact)/5))/20).toFixed(2);
            document.getElementById('answer95716X143X11979').value = TotToll3;
            document.getElementById('answer95716X143X119729').value = TotToll3;
            }
            else
            {
            var randomnumb6 = Math.floor(Math.random()*6);
            var Toll = 17/TimODay + randomnumb6/TimODay;
            var TotToll3 = (Math.round(((Toll * TollDist * TollFact)/5))/20).toFixed(2);

            document.getElementById('answer95716X143X11979').value = TotToll3;
            document.getElementById('answer95716X143X119729').value = TotToll3;
            }
}

// MODES 3 & 4, 2 of the 5 modes already selected, randomly select the final 2
    var totmodes = usedmodes[5] + usedmodes[4] + usedmodes[3] + usedmodes[2] + usedmodes[1];
    do
    {
    var trymode = Math.round((Math.floor(Math.random()*50)+5)/10); // Random integer from 1 to
    5
    if ( usedmodes[trymode] == 0)
        {
        usedmodes[trymode] = 1
```

```
var totmodes = usedmodes[5] + usedmodes[4] + usedmodes[3] + usedmodes[2] +
usedmodes[1];
switch (trymode)
    {
    case 1:
    var randomnumber=Math.floor(Math.random()*25);
    var speedT = Math.round(20*TimODay + randomnumber) ;
    var speedF = Math.round(60 + randomnumber/10);
    var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
        if (TrvTmGPL < TrvTmML)
        {
        var TrvTmGPL = TrvTmML + 3;
        }
    if (totmodes == 3)
        {
        document.getElementById('answer95716X143X119713').value = TrvTmGPL;
        document.getElementById('answer95716X143X119714').value = ' None';
        document.getElementById('answer95716X143X119712').value = 'Main freeway
        lanes' ;
        document.getElementById('answer95716X143X119711').value = 'Drive by myself'
        ;
        document.getElementById('answer95716X143X119733').value = TrvTmGPL;
        document.getElementById('answer95716X143X119734').value = ' None';
        document.getElementById('answer95716X143X119732').value = 'Main freeway
        lanes' ;
        document.getElementById('answer95716X143X119731').value = 'Drive by myself'
        ;
        }
    if (totmodes == 4)
        {
        document.getElementById('answer95716X143X119718').value = TrvTmGPL;
        document.getElementById('answer95716X143X119719').value = ' None';
        document.getElementById('answer95716X143X119717').value = 'Main freeway
        lanes' ;
        document.getElementById('answer95716X143X119716').value = 'Drive by myself'
        ;
        document.getElementById('answer95716X143X119738').value = TrvTmGPL;
        document.getElementById('answer95716X143X119739').value = ' None';
        document.getElementById('answer95716X143X119737').value = 'Main freeway
        lanes' ;
        document.getElementById('answer95716X143X119736').value = 'Drive by myself'
        ;
        }
    break;

    case 2:
    var randomnumber=Math.floor(Math.random()*20);
    var speedT = Math.round(50 + randomnumber);
    var speedF = Math.round(60 + randomnumber/6);
    var TrvTmML = Math.round((TollDist * 60/speedT)+(FreeDist * 60/speedF));
        if (TrvTmGPL < TrvTmML)
        {
        var TrvTmGPL = TrvTmML + 3;
```

```
        }
var randomnumb4=Math.floor(Math.random()*30);
        if (randomnumb4 < 10)
        {
        var randomnumb5=Math.floor(Math.random()*6);
        var Toll = 7/TimODay + randomnumb5/TimODay;
        }
        else if (randomnumb4 > 10 && randomnumb4 <20)
        {
        var randomnumb5=Math.floor(Math.random()*10) ;
        var Toll = 15/TimODay + randomnumb5/TimODay;
        }
        else
        {
        var randomnumb5=Math.floor(Math.random()*14) ;
        var Toll = 28/TimODay + randomnumb5/TimODay;
        }
var TotToll3 = (Math.round(((Toll * TollDist * TollFact)/5))/20).toFixed(2);
if (totmodes == 3)
        {
        document.getElementById('answer95716X143X119713').value = TrvTmML;
        document.getElementById('answer95716X143X119714').value = TotToll3;
        document.getElementById('answer95716X143X119712').value = 'Toll lanes' ;
        document.getElementById('answer95716X143X119711').value = 'Drive by myself'
        ;
        document.getElementById('answer95716X143X119733').value = TrvTmML;
        document.getElementById('answer95716X143X119734').value = TotToll3;
        document.getElementById('answer95716X143X119732').value = 'Toll lanes' ;
        document.getElementById('answer95716X143X119731').value = 'Drive by myself'
        ;
        }
if (totmodes == 4)
        {
        document.getElementById('answer95716X143X119718').value = TrvTmML;
        document.getElementById('answer95716X143X119719').value = TotToll3;
        document.getElementById('answer95716X143X119717').value = 'Toll lanes' ;
        document.getElementById('answer95716X143X119716').value = 'Drive by myself'
        ;
        document.getElementById('answer95716X143X119738').value = TrvTmML;
        document.getElementById('answer95716X143X119739').value = TotToll3;
        document.getElementById('answer95716X143X119737').value = 'Toll lanes' ;
        document.getElementById('answer95716X143X119736').value = 'Drive by myself'
        ;
        }
break;

case 3:
var randomnumber=Math.floor(Math.random()*25);
var speedT = Math.round(20*TimODay + randomnumber) ;
var speedF = Math.round(60 + randomnumber/10);
var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF) +
HOV3AddTime);
        if (TrvTmGPL < TrvTmML)
```

```
        {
        var TrvTmGPL = TrvTmML + 3;
        }
if (totmodes == 3)
        {
        document.getElementById('answer95716X143X119713').value = TrvTmGPL;
        document.getElementById('answer95716X143X119714').value = ' None';
        document.getElementById('answer95716X143X119712').value = 'Main freeway
        lanes' ;
        document.getElementById('answer95716X143X119711').value = 'Carpool with
        others' ;
        document.getElementById('answer95716X143X119733').value = TrvTmGPL ;
        document.getElementById('answer95716X143X119734').value = ' None';
        document.getElementById('answer95716X143X119732').value = 'Main freeway
        lanes' ;
        document.getElementById('answer95716X143X119731').value = 'Carpool with
        others' ;
        }
if (totmodes == 4)
        {
        document.getElementById('answer95716X143X119718').value = TrvTmGPL ;
        document.getElementById('answer95716X143X119719').value = ' None';
        document.getElementById('answer95716X143X119717').value = 'Main freeway
        lanes' ;
        document.getElementById('answer95716X143X119716').value = 'Carpool with
        others' ;
        document.getElementById('answer95716X143X119738').value = TrvTmGPL ;
        document.getElementById('answer95716X143X119739').value = ' None';
        document.getElementById('answer95716X143X119737').value = 'Main freeway
        lanes' ;
        document.getElementById('answer95716X143X119736').value = 'Carpool with
        others' ;
        }
break;

case 4:
 var randomnumber=Math.floor(Math.random()*20);
 var speedT = Math.round(50 + randomnumber);
 var speedF = Math.round(60 + randomnumber/6);
 var TrvTmML = Math.round((TollDist * 60/speedT)+(FreeDist *
60/speedF)+(HOV2AddTime));
        if (TrvTmGPL < TrvTmML)
        {
        var TrvTmGPL = TrvTmML + 3;
        }
 var randomnumb4=Math.floor(Math.random()*30);
        if (randomnumb4 < 10)
        {
        var randomnumb5=Math.floor(Math.random()*6);
        var Toll = 7/TimODay + randomnumb5/TimODay;
        }
        else if (randomnumb4 > 10 && randomnumb4 <20)
        {
```

```
        var randomnumb5=Math.floor(Math.random()*10) ;
        var Toll = 15/TimODay + randomnumb5/TimODay;
        }
        else
        {
        var randomnumb5=Math.floor(Math.random()*14) ;
        var Toll = 28/TimODay + randomnumb5/TimODay;
        }
    var randomnumb4=Math.floor(Math.random()*101);
        if (randomnumb4 < 25)
        {
        // No Toll
        var Toll = 0 ;
        }
        else if (randomnumb4 > 25 && randomnumb4 <62.5)
        {
        var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
        }
        else if (randomnumb4 > 62.5 && randomnumb4 <75)
        {
        var randomnumb6 = Math.floor(Math.random()*2);
        var Toll = 4/TimODay + randomnumb6/TimODay;
        }
        else if (randomnumb4 > 75 && randomnumb4 < 87.5)
        {
        var randomnumb6 = Math.floor(Math.random()*4);
        var Toll = 8/TimODay + randomnumb6/TimODay;
        }
        else
        {
        var randomnumb6 = Math.floor(Math.random()*6);
        var Toll = 17/TimODay + randomnumb6/TimODay;
        }
    var TotToll3 = (Math.round(((Toll * TollDist * TollFact)/5))/20).toFixed(2);
    if (totmodes == 3)
        {
        document.getElementById('answer95716X143X119713').value = TrvTmML;
        document.getElementById('answer95716X143X119733').value = TrvTmML;
            if (TotToll3 > 0.1)
            {
            document.getElementById('answer95716X143X119714').value = TotToll3;
            document.getElementById('answer95716X143X119734').value = TotToll3;
            }
            else
            {
            document.getElementById('answer95716X143X119714').value = ' None';
            document.getElementById('answer95716X143X119734').value = ' None';
            }
        document.getElementById('answer95716X143X119712').value = 'Toll lanes' ;
        document.getElementById('answer95716X143X119711').value = 'Carpool with one
        other person' ;
        document.getElementById('answer95716X143X119732').value = 'Toll lanes' ;
```

```
        document.getElementById('answer95716X143X119731').value = 'Carpool with one
        other person' ;
        }
if (totmodes == 4)
        {
        document.getElementById('answer95716X143X119718').value = TrvTmML;
        document.getElementById('answer95716X143X119738').value = TrvTmML;
                if (TotToll3 > 0.1)
                {
                document.getElementById('answer95716X143X119719').value = TotToll3;
                document.getElementById('answer95716X143X119739').value = TotToll3;
                }
                else
                {
                document.getElementById('answer95716X143X119719').value = ' None';
                document.getElementById('answer95716X143X119739').value = ' None';
                }
        document.getElementById('answer95716X143X119717').value = 'Toll lanes' ;
        document.getElementById('answer95716X143X119716').value = 'Carpool with one
        other person' ;
        document.getElementById('answer95716X143X119737').value = 'Toll lanes' ;
        document.getElementById('answer95716X143X119736').value = 'Carpool with one
        other person' ;
        }
break;

case 5:
var randomnumber=Math.floor(Math.random()*20);
var speedT = Math.round(50 + randomnumber);
var speedF = Math.round(60 + randomnumber/6);
var TrvTmML = Math.round((TollDist * 60/speedT)+(FreeDist *
60/speedF)+(HOV3AddTime));
        if (TrvTmGPL < TrvTmML)
        {
        var TrvTmGPL = TrvTmML + 3;
        }
var randomnumb4=Math.floor(Math.random()*101);
        if (randomnumb4 < 75)
        {
        var Toll = 0 ;
        }
        else if (randomnumb4 > 75 && randomnumb4 <83.3)
        {
        var randomnumb6 = Math.floor(Math.random()*2);
        var Toll = 4/TimODay + randomnumb6/TimODay;
        }
        else if (randomnumb4 > 83.3 && randomnumb4 < 91.7)
        {
        var randomnumb6 = Math.floor(Math.random()*4);
        var Toll = 8/TimODay + randomnumb6/TimODay;
        }
        else
        {
```

```
                    var randomnumb6 = Math.floor(Math.random()*4);
                    var Toll = 13/TimODay + randomnumb6/TimODay;
                    }
                var TotToll3 = (Math.round(((Toll * TollDist * TollFact)/5))/20).toFixed(2);
                if (totmodes == 3)
                    {
                    document.getElementById('answer95716X143X119713').value = TrvTmML;
                    document.getElementById('answer95716X143X119733').value = TrvTmML;
                        if (TotToll3 > 0.1)
                        {
                        document.getElementById('answer95716X143X119714').value = TotToll3;
                        document.getElementById('answer95716X143X119734').value = TotToll3;
                        }
                        else
                        {
                        document.getElementById('answer95716X143X119714').value = ' None';
                        document.getElementById('answer95716X143X119734').value = ' None';
                        }
                    document.getElementById('answer95716X143X119712').value = 'Toll lanes' ;
                    document.getElementById('answer95716X143X119711').value = 'Carpool with 3 or
                    more people' ;
                    document.getElementById('answer95716X143X119732').value = 'Toll lanes' ;
                    document.getElementById('answer95716X143X119731').value = 'Carpool with 3 or
                    more people' ;
                    }
                if (totmodes == 4)
                    {
                    document.getElementById('answer95716X143X119718').value = TrvTmML;
                    document.getElementById('answer95716X143X119738').value = TrvTmML;
                        if (TotToll3 > 0.1)
                        {
                        document.getElementById('answer95716X143X119719').value = TotToll3;
                        document.getElementById('answer95716X143X119739').value = TotToll3;
                        }
                        else
                        {
                        document.getElementById('answer95716X143X119719').value = ' None';
                        document.getElementById('answer95716X143X119739').value = ' None';
                        }
                    document.getElementById('answer95716X143X119717').value = 'Toll lanes' ;
                    document.getElementById('answer95716X143X119716').value = 'Carpool with 3 or
                    more people' ;
                    document.getElementById('answer95716X143X119737').value = 'Toll lanes' ;
                    document.getElementById('answer95716X143X119736').value = 'Carpool with 3 or
                    more people' ;
                    }
                break;

                }
            }
        }
        while (totmodes < 4)
    }
```

```
        document.getElementById("answer95716X143X11971").style.display='none';
        document.getElementById("answer95716X143X11972").style.display='none';
        document.getElementById('answer95716X143X11973').style.display='none';
        document.getElementById('answer95716X143X11974').style.display='none';
        document.getElementById('answer95716X143X11975').style.display='none';
        document.getElementById('answer95716X143X11976').style.display='none';
        document.getElementById('answer95716X143X11977').style.display='none';
        document.getElementById('answer95716X143X11978').style.display='none';
        document.getElementById('answer95716X143X11979').style.display='none';
        document.getElementById('answer95716X143X119710').style.display='none';
        document.getElementById('answer95716X143X119711').style.display='none';
        document.getElementById('answer95716X143X119712').style.display='none';
        document.getElementById('answer95716X143X119713').style.display='none';
        document.getElementById('answer95716X143X119714').style.display='none';
        document.getElementById('answer95716X143X119715').style.display='none';
        document.getElementById('answer95716X143X119716').style.display='none';
        document.getElementById('answer95716X143X119717').style.display='none';
        document.getElementById('answer95716X143X119718').style.display='none';
        document.getElementById('answer95716X143X119719').style.display='none';
        document.getElementById('answer95716X143X119720').style.display='none';
        document.getElementById('answer95716X143X119721').style.display='none';
        document.getElementById('answer95716X143X119722').style.display='none';
        document.getElementById('answer95716X143X119723').style.display='none';
        document.getElementById('answer95716X143X119724').style.display='none';
        document.getElementById('answer95716X143X119725').style.display='none';
        document.getElementById('answer95716X143X119726').style.display='none';
        document.getElementById('answer95716X143X119727').style.display='none';
        document.getElementById('answer95716X143X119728').style.display='none';
        document.getElementById('answer95716X143X119729').style.display='none';
        document.getElementById('answer95716X143X119730').style.display='none';
        document.getElementById('answer95716X143X119731').style.display='none';
        document.getElementById('answer95716X143X119732').style.display='none';
        document.getElementById('answer95716X143X119733').style.display='none';
        document.getElementById('answer95716X143X119734').style.display='none';
        document.getElementById('answer95716X143X119735').style.display='none';
        document.getElementById('answer95716X143X119736').style.display='none';
        document.getElementById("answer95716X143X119737").style.display='none';
        document.getElementById("answer95716X143X119738").style.display='none';
        document.getElementById('answer95716X143X119739').style.display='none';
        document.getElementById('answer95716X143X119740').style.display='none';
        document.getElementById("answer95716X143X119741").style.display='none';
        document.getElementById("answer95716X143X119742").style.display='none';
        document.getElementById('answer95716X143X119743').style.display='none';
        document.getElementById("answer95716X143X119744").style.display='none';
        document.getElementById("answer95716X143X119745").style.display='none';

 // end hiding code -->
</script>
<p> </p>
```

VITA

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