UNDERSTANDING THE BEHAVIOR OF TRAVELERS USING MANAGED LANES – A STUDY USING STATED PREFERENCE AND REVEALED PREFERENCE DATA

A Dissertation

by

PREM CHAND DEVARASETTY

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Approved by:

Co-Chairs of Committee,	Mark Burris
	Douglass Shaw
Committee Members,	Yunlong Zhang
	Thomas E. Wehrly
Head of Department,	John Niedzwecki

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ABSTRACT

This research examined if travelers are paying for travel on managed lanes (MLs) as they indicated that they would in a 2008 survey. The other objectives of this research included estimating travelers' value of travel time savings (VTTS) and their value of travel time reliability (VOR), and examining the multiple survey designs used in a 2008 survey to identify which survey design better predicted ML traveler behavior.

To achieve the objectives, an Internet-based follow-up stated preference (SP) survey of Houston's Katy Freeway travelers was conducted in 2010. Three survey design methodologies—D_b-efficient, random level generation, and adaptive random—were tested in this survey. A total of 3,325 responses were gathered from the survey, and of those, 869 responses were from those who likely also responded to the previous 2008 survey.

Mixed logit models were developed for those 869 previous survey respondents to estimate and compare the VTTS to the 2008 survey estimates. It was found that the 2008 survey estimates of the VTTS were very close to the 2010 survey estimates.

In addition, separate mixed logit models were developed from the responses obtained from the three different design strategies in the 2010 survey. The implied mean VTTS varied across the design-specific models. Only the D_b-efficient design was able to estimate a VOR. Based on this and several other metrics, the D_b-efficient design outperformed the other designs. A mixed logit model including all the responses from all three designs was also developed; the implied mean VTTS was estimated as 65 percent ($22/hr) of the mean hourly wage rate, and the implied mean VOR was estimated as 108 percent ($37/hr) of the mean hourly wage rate.

Data on actual usage of the MLs were also collected. Based on actual usage, the average VTTS was calculated as $51/hr. However, the $51/hr travelers are paying likely also includes the value travelers place on travel time reliability of the MLs. The total (VTTS+VOR) amount estimated from the all-inclusive model from the survey was

\$59/hr, which is close to the value estimated from the actual usage. The D_b-efficient design estimated this total as \$50/hr.

This research also shows that travelers have a difficulty in estimating the time they save while using a ML. They greatly overestimate the amount of time saved. It may well be that even though travelers are saving a small amount of time they value that time savings (and avoiding congestion) much higher – possibly similar to their amount of perceived travel time savings.

The initial findings from this study, reported here, are consistent with the hypothesis that travelers are paying for their travel on MLs, much as they said that they would in our previous survey. This supports the use of data on intended behavior in policy analysis.

DEDICATION

To Lord Venkateswara

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1. INTRODUCTION

The use of managed lanes (MLs) is increasing, particularly in Texas, where there are 8 MLs planned (Managed-Lanes, 2011). Frequently, MLs are newly constructed toll lanes in the middle of an existing freeway. The toll is set to be large enough to ensure congestion does not occur on the MLs. Thus, the toll increases during periods of peak demand and drops during off-peak periods. The tolls are also frequently reduced or eliminated for vehicles engaged in carpooling, thereby encouraging ride-sharing. In this way, MLs offer a revenue stream to (1) support the financing of their construction, and (2) pay for their operations and management. This provides an innovative financing mechanism to widen congested urban freeway corridors—where congestion relief is most needed. In addition, MLs offer a guaranteed high-speed alternative and provide significant mobility benefits and can even offer incentives to carpool. Research has shown many ML travelers use MLs infrequently, most often when travel time is more important or more urgent than usual (see Patil et al., 2011b). Thus, the value of travel time savings on MLs may be exceptionally high, but this is unknown.

This research takes advantage of the new Katy Freeway (I-10) MLs in Houston to better understand travelers who use the MLs, including the value they place on their ML travel. A survey was previously conducted in 2008, just as the new high occupancy vehicle (HOV) lanes opened on the Katy Freeway, prior to them allowing single occupant vehicles (SOVs) on the lanes for a fee. The travelers were asked about their prospective travel on the forthcoming MLs in both typical travel scenarios and unusual (urgent or hurried) circumstances. It was found that travelers thought that their value of travel time savings would be significantly higher for unusual trips (see Patil et al., 2011a, b). When the lanes opened to paying SOVs in 2009, this provided a great opportunity to find out how much actual users of the new MLs are willing to pay—and to compare that to their 2008 survey responses.

It is very common to use stated preference (SP) surveys to conduct travel behavior studies and develop discrete choice models to estimate traveler behavior. There is enough evidence in the literature suggesting that the design of the survey has a strong influence on the statistical significance of the parameter estimates of the discrete choice models. Hence survey design is a critical component in these studies.

To accomplish the comparison, a follow-up survey was conducted in 2010. This provides a unique opportunity to better understand how travelers answer survey questions and how their actions today do or do not match those previous answers in the 2008 study, and it also provides opportunities to learn how to design surveys to better reflect actual travel behavior. This all becomes increasingly important as more projects look at MLs as a critical source of revenue but must do so prior to construction. In this era of tight state and federal resources, all desired projects cannot be funded. Without accurate estimates of travelers' maximum willingness to pay (WTP) through improved surveys, the scarce transportation funds might not get allocated to the most needed projects.

The survey conducted in 2008 gathered information from 3,077 interested respondents who stated that they were willing to take a follow-up survey. A link to the 2010 survey was emailed to those respondents and was widely advertised. The 2010 survey responses are compared here to the responses from the 2008 survey, for those who participated in both. This study will help us understand how travelers respond to surveys and analyze ways to improve survey designs.

1.1 Problem Statement

Increasing traffic congestion in many major cities in the United States have many Departments of Transportation (DOTs) examining the potential of MLs. The operational benefits of MLs are well documented in the literature, but research still lacks in the areas of understanding the behavior of the travelers using these lanes. Critical questions such as who are the potential users of those lanes, how much they the travel time savings and travel time reliability of MLs, need to be answered.

MLs not only offer travel time savings but also promise users more reliable travel times, promote ridesharing, promote transit use, and provide a safer travel alternative to travelers (Collier and Goodin 2002). Literature suggests that travelers value travel time reliability at least as much as they value travel time savings (Concas and Kolpakov, 2009). Accessing this value is critical in estimating the true benefits of the MLs and needs additional research. Estimating the value of travel time savings and travel time reliability for MLs is complicated by the variable pricing strategies. This research will estimate the value travelers are willing to pay for travel time savings and travel time reliability.

SP surveys are commonly used to study travel behavior. In SP surveys, respondents are usually asked to choose a travel option from a set of travel scenarios for a typical trip. In some cases the travel scenarios might be on a facility or mode that does not exist. Partially, based on the results from these surveys, critical decisions regarding constructing the facility are made. In such cases it is very important to know if respondents actual travel choices match with their SP survey responses once the facility is constructed. This study will examine if respondents stated travel behavior matched with their actual behavior on the Katy Freeway.

This research will also examine three different SP survey design strategies for their efficiency in estimating the discrete choice model parameters.

1.2 Research Objectives

The primary purpose of this research is to better understand the behavior of travelers using the MLs and to examine how to improve the ability of SP surveys to estimate demand for MLs. The specific objectives of this research are as follows:

1) Examine if Katy Freeway travelers did what they said they would regarding the use of MLs in a previous survey just before the MLs opened.
2) Estimate the value of travel time savings and the value of travel time reliability for ML travelers.
3) Compare willingness to pay estimates of the respondents from various survey design techniques from the before and after surveys and identify the design technique that best predicted actual willingness to pay.
4) Estimate the willingness to pay from actual ML usage data and compare with those obtained from SP and RP survey data.
5) Examine the differences between RP travel time savings and actual travel time savings.

1.3 Dissertation Outline

The remainder of this dissertation is organized as follows. Literature on the MLs, stated preference (SP) survey designs, and other critical aspects of this research effort are reviewed in the second section. Data collection efforts for the 2010 study are described in the third section. In the fourth section, the data analysis performed on the 2010 survey data is presented and compared to the 2008 survey data. The data analysis includes a description of the various discrete choice models developed, an estimation of value of travel time savings along with a comparison to the related estimates from the previous (2008) survey, an estimation of value of travel time reliability, and a comparision of these values with those obtained from actual ML usage data. The last section concludes the research, suggesting the best survey design strategy, reporting on whether the travelers essentially did what they said they would, and presenting the value of travel time savings and value of travel time reliability.

2. BACKGROUND LITERATURE REVIEW

The objectives of this research included understanding the travel behavior of travelers in different situations (normal vs. urgent), comparing their predicted managed lanes usage (as estimated from the previous survey in 2008) to their actual usage, and finding the survey design that best predicted their usage. Literature reviewed on related aspects of this research is presented in this section.

2.1 Value of Travel Time Savings

The value of travel time savings (VTTS), often referred to as value of time (VOT), has been an important area of research in transportation studies. It is one of the main benefits of transportation infrastructure investments. The earliest studies on VOT date back to the 1960s (Becker, 1965; Beesley, 1965; Oort, 1969). VTTS represents the travelers’ willingness to pay to reduce their travel time (Jara-Diaz and Guevara, 2003). Travelers’ VTTS is often estimated using SP surveys. It is calculated from the discrete travel choice models and is derived as the marginal rate of substitution (MRS) between travel time and cost in the choice models (De Jong et al., 2007). Conveniently, the MRS can typically be estimated using the ratio of two coefficients, the travel time coefficient divided by the cost coefficient, yielding the marginal WTP for travel time savings.

According to Mackie et al. (2001), any travel time reduction stimulates changes in the utility of travel, as the travel time saved can be used in a more pleasurable or a more useful activity. Travel time reductions may also improve the gross domestic product of society if the travel time saved is translated to work.

Cherlow (1981) listed various studies conducted on the evaluation of VTTS. The estimated VTTS varied from as low as 9 percent of the wage rate to as high as 140 percent of the wage rate. He suggested that there is no single VTTS that can be applicable to all people in all circumstances. A more recent study by Lam and Small (2001) estimated the average VTTS to be $22.87 per hour, or 72 percent of the average wage rate. Feather and Shaw (1999) considered travel for leisure rather than commuting and found support for the fact that travel time values can exceed the wage rate.

There have been few studies in the recent literature trying to estimate the VTTS on the MLs. A study by GDOT using SP survey estimated the VTTS of passenger car users to be in the range of $7 to $15 per hour. They have also observed that VTTS varied with the type of vehicle, truck users with 6-axle value travel time savings at a higher price than passenger cars (GDOT, 2010). A more recent study on I-25 travelers in Miami by FDOT estimated the VTTS as 49 percent of the hourly wage, with a range of $2.27 to $79.32 per hour with a mean value of $32 per hour (Perk et al., 2011).

Both revealed preference (RP) data and SP have been used in the past to estimate the VTTS. RP data is generated when one has knowledge on actual commuting choices that individuals make. The two types of data were originally blended in the study by Ben-Akiva and Morikawa (1990). Additionally, a few researchers have tried to find any differences in the estimates between these approaches. Interestingly, they found out that the values estimated using the SP data were approximately half the values estimated using RP data (see Ghosh, 2001; Small et al., 2005). Although the SP approach yielded these lower estimates as compared to RP data, by its design, it is capable of controlling for different levels of attributes and can give very precise estimates of VTTS (Ghosh, 2001).

The value individuals place on travel time savings is influenced by six main factors: the time of day of the trip, the purpose of the trip, the characteristics of the trip (routine, congested, or free-flow), the length of the trip, the mode of travel, and the size of travel time savings (Mackie et al., 2001). Apart from these above-mentioned factors, the travel time savings value may also depend on socio-economic characteristics of the travelers. In the same context, Patil et al. (2011b) tried to estimate the VTTS for different situations including one normal and six urgent situations. They found that travelers place a higher value for travel time savings when in an urgent travel situation than in a normal situation. Among several different urgent situations tested, the situation when travelers were running late for an appointment/event had the highest value of travel time savings. This makes perfect intuitive sense; if one is at risk of losing a job or income, the timing of the trip is especially important and of high value. They also found that travelers from the low- and middle-income groups had, on average, higher VTTS in urgent situations than travelers in the higher-income groups had in normal situations.

Aside from the travel time savings, another important benefit of transportation infrastructure is the value of travel time reliability, which is discussed briefly in the next section.

2.2 Value of Travel Time Reliability

According to Barry et al. (2005), in the presence of substantial road congestion, the travel time variability is valued more than travel time savings. Value of reliability (VOR) indicates the value travelers place on the reliability of estimated travel time. VOR is the travelers' willingness to pay to reduce the variability of travel time by one unit. It is calculated from the discrete travel choice models and is derived as the MRS between travel time variability and cost in the choice models. This variability in travel time is defined differently by different researchers. Several researchers have defined variability to be the difference between the 90th percentile and 50th percentile travel time (Ghosh, 2001; Lam and Small, 2001), whereas, some have assumed it to be the difference between the 75th and the 25th percentile travel time (Small et al., 2005). Some have defined it as the standard deviation of the travel time. In this dissertation, variability is defined as a percentage of the average travel time. There have been several studies in the past trying to estimate the VOR. Earlier studies on VOR used RP data. However, more recent studies have used stated preference survey data or a combination of both SP and RP data for its estimation.

Empirical estimates of VOR have varied considerably, ranging from as low as 0.55 times (Black and Towriss, 1993) to 3.22 times (Small et al., 1999) the VOT. Brownstone and Small (2005), using the data from SR-91 and I-15 high occupancy toll (HOT) lanes, estimated the VOR to be 95 to 140 percent of the median travel time.

Small et al. (2005) calculated the median VOR using RP data of travelers in Los Angeles and estimated it be 85 percent of the average wage rate ($19.56/hr). A recent study by Tilahun and Levinson (2010) found that the travelers value travel time reliability very close to their value of time. The data for the study were collected using a stated preference survey. Concas and Kolpakov (2009) reviewed the literature on VOT and VOR and recommended that the VOR be estimated at 80 to 100 percent of the VOT under ordinary travel circumstances with no major travel constraints. However, under the constraint of non-flexible arrival/departure, they recommended that the VOR be valued up to three times that of the VOT.

Studies have found that VOR is influenced by socio-economic characteristics of the travelers, such as sex, income, etc. A study by Lam and Small (2001) using RP survey data and travel time data on SR-91 found that the VOR for women was almost twice that of the VOR for men. Similar results were also found by Small et al. (2005). Their findings indicated that women, middle-aged motorists, and motorists in smaller households were more likely to use toll lanes, implying that the travelers in those categories either value reliability at a higher level than other travelers or value travel time savings higher than reliability. Risk aversion of the travelers is also expected to influence the VOR. According to the expected utility theory, a risk-averse traveler will be willing to pay a higher cost to reduce the un-reliability of travel time than a risk-taking or a risk-neutral traveler (Concas and Kolpakov, 2009).

Managed lanes are a type of facility that promises the users reliable and lower travel times. The concept of MLs and their benefits are discussed in the next section.

2.3 Managed Lanes

Traffic congestion is a major problem in metropolitan cities such as Houston, Texas. According to a recent study by the Texas Transportation Institute (TTI), traffic congestion caused Americans to spend 4.8 billion hours more on travel in 2010 and to purchase an extra 1.9 billion gallons of fuel. This resulted in losses of approximately $101 billion (Schrank and Lomax, 2011). The additional cost in pollution from emissions is not included in this figure. The concept of MLs is an operational strategy to reduce this problem of congestion by intelligently allocating traffic capacity in different lanes.

2.3.1 Managed Lanes Definition and Types of Facilities

ML facilities include HOV lanes (usually two or more people per vehicle), HOT lanes, and exclusive special use lanes (e.g., express lanes, bus only lanes) (Federal Highway Administration [FHWA], 2004). The FHWA defines managed lanes as "a limited number of lanes set aside within an expressway cross section where multiple operational strategies are utilized, and actively adjusted as needed, for the purpose of achieving pre-defined performance objectives" (FHWA, 2004). A managed lane facility is defined in several ways, including:

- A freeway-within-a-freeway.
- A set of lanes physically separated from the general purpose lanes.
- A facility with high-degree operational flexibility.
- A facility actively managed to respond to growth and changing need.
- A facility managed in order to continuously achieve an optimal condition (free-flow speeds).
- A facility managed through pricing, vehicle eligibility, and access control strategies.

The operational strategies across various types of MLs are shown in Figure 1.

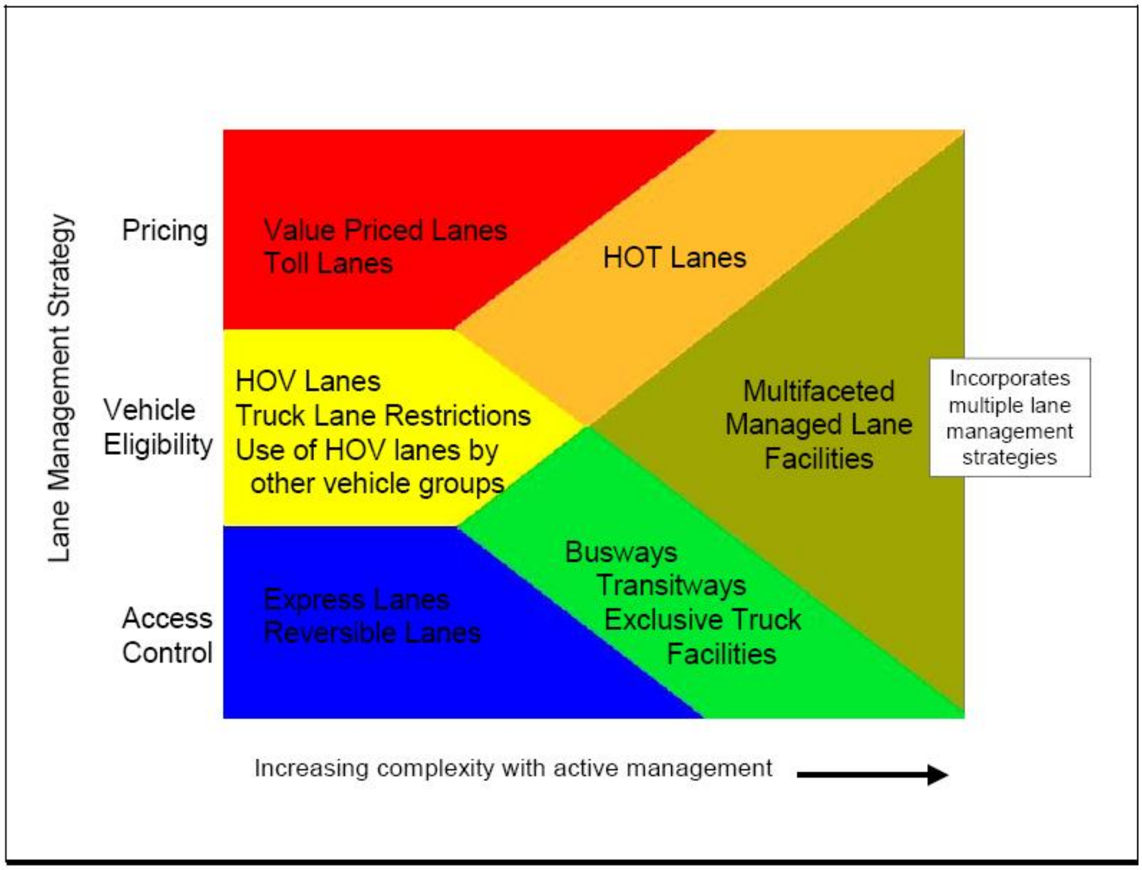


Figure 1: Operational Strategies and Types of Facilities in Managed Lane Concept (FHWA, 2004)

2.3.2 Benefits of Managed Lanes

As defined in the previous section, MLs are expected to provide a more reliable and/or a faster travel alternative for travelers. Unlike the general purpose lanes, which are often quite congested during the peak hours, ML facilities are operated at speeds close to or at free-flowing (i.e., no congestion) speeds. Speed variations on eastbound Katy Freeway MLs and GPLs during peak hours (7:00 AM to 9:00 AM) are shown in Figure 2. These data were from all weekdays (except holidays) for the year 2009. The GPL curve is flatter, and the speeds are widely spread. On the other hand, the ML curve has one peak in between 60 and 70 mph. Nearly 70 percent of the travelers are able to drive between 60 and 70 mph, while only 40 percent of GPL travelers are able to travel at these speeds. This indicates that MLs are more reliable than GPLs.

Since the tolls on MLs often vary with the vehicle occupancy (lower tolls for HOVs), MLs encourage ride-sharing or carpooling. They also encourage transit use, as most facilities allow transit vehicles to use the lane for free. According to Burris and Patil (2009), an efficiently operated ML can carry more traffic than a general purpose lane. Thus, MLs provide travel time savings to users and reduce fuel consumption. By reducing the congestion, MLs are expected to cause less pollution and fewer traffic crashes (Collier and Goodin, 2002).

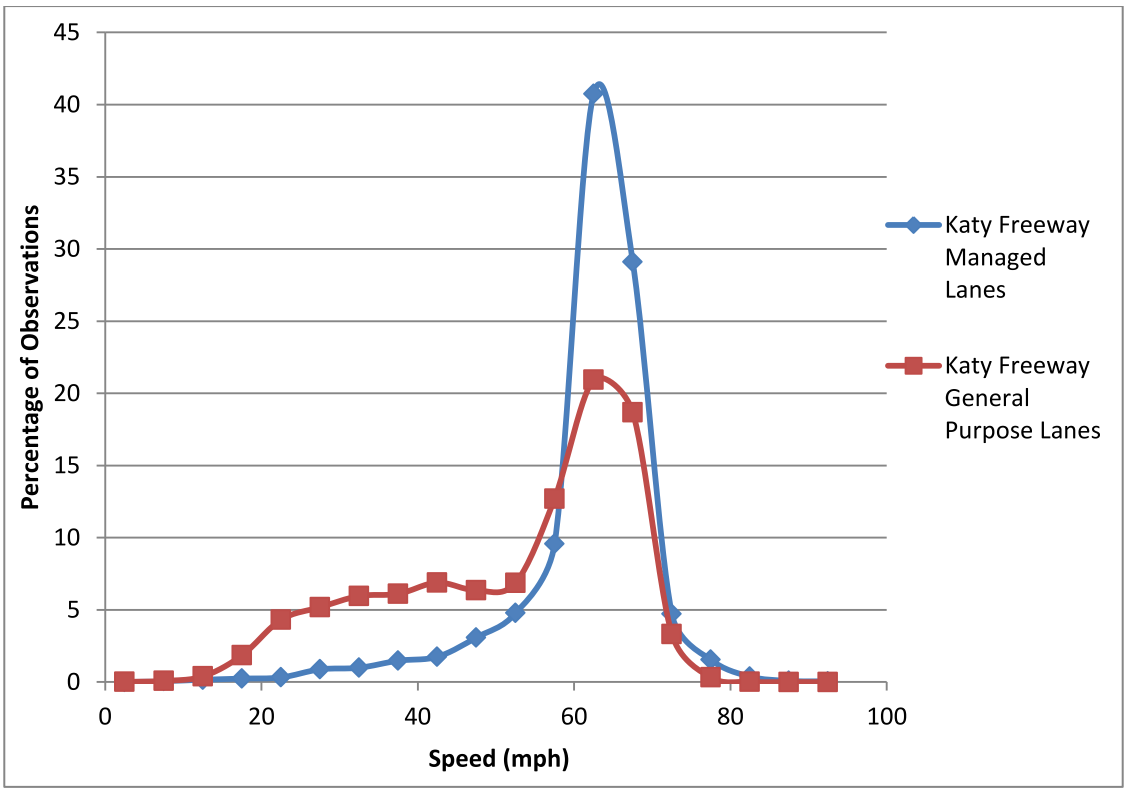


Figure 2: Speed Variation on Katy Freeway (Eastbound) during Peak Hours (7:00 AM to 9:00 AM)

2.3.3 Managed Lane Facilities in the United States

Managed lanes are becoming more and more popular in the United States, partially due to the FHWA value pricing program efforts. The ML facilities that are currently in operation (as of August 2012) in the United States are listed in Table 1. Houston's Katy Freeway is one of these facilities and is the focus in this current study. Details about the Katy Freeway are presented in Section 3.1 of this dissertation.

Table 1: Existing Managed Lane Facilities in the United States (Burris, 2010; FHWA, 2012)

	Name of Facility	Location	Type
1	Katy Tollway/Managed Lanes	Houston, Texas	HOT lanes, tolls vary by time of day
2	Northwest Freeway/US 290 QuickRide	Houston, Texas	HOT lanes with flat fee during the AM peak period
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 and I-35W 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, tolls vary dynamically based on the level of congestion
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

Table 1: Continued

	Name of Facility	Location	Type
12	Dulles Greenway	Virginia	Tolls vary by time of day
13	I-680 near San Francisco	California	HOT lane with dynamic pricing
14	Tappan Zee Bridge	New York	Peak period surcharges for trucks, HOV (3+) discounts
15	Port Authority of New York and New Jersey Crossings	New Jersey and New York	Cash toll, peak toll, off-peak toll, night toll, and an HOV discount
16	State Road 520	Seattle, Washington State	Bridge, tolls vary by the day and time of travel
17	State Road 895, Pocahontas Parkway	Richmond, Virginia	Highway, tolls vary by the day and time of travel.
18	Interstate 85	Georgia, Atlanta	HOT lane with dynamic pricing
19	Maryland Route 200	Montgomery County, Maryland	Highway, tolls vary by time of day
20	Interstate 45	Houston, Texas	HOT lane, tolls vary by time of day

2.4 Stated Preference Survey Designs

As noted in the introductory section, SP surveys are often used in transportation research to estimate or forecast the behavior of travelers. SP survey methods allow researchers to study the travelers' response to different potential travel alternatives, where the alternatives may currently exist or may not (i.e., they may be reasonable but hypothetical alternatives). A typical SP survey consists of several choice sets, where each choice set contains a set of two or more alternatives. Each alternative in the choice set is in turn defined by a set of attributes. The values of the attributes vary in their levels. The respondents of the survey are asked to choose an alternative in each choice set that best suits their travel. For example, consider the following situation where the traveler has two routes to choose for travel between destinations A and B. The alternative routes are described by two attributes. Suppose that route 1 has a travel time of 10 minutes and a toll of $1, and route 2 has a travel time of 15 minutes and a toll of $0.50. Using the standard stated choice modeling jargon, the alternatives for this choice set are route 1 and route 2 and the attributes are the respective travel time and toll rates for each (travel time: 10, 15 minutes; toll: $0.50, $1). The values of these attributes allow the respondent to consider trade-offs between the alternatives. The levels of attributes allocated across the different alternatives in an SP experiment are chosen by the researcher in the design process and have a direct influence on the statistical significance of the estimates of the mode choice model (Dellaert et al., 1999; Ohler et al., 2000; Hensher, 2004; Rose et al., 2008). Hence, choice of attribute levels to be presented to describe the alternatives is an essential aspect in the design of an SP survey.

2.4.1 Survey Design Basics

A choice design can be viewed as a matrix of attribute values. The values in the matrix represent the levels of attributes for the alternatives. The columns and rows of the matrix represent the choice situations, attributes, and alternatives of the choice experiments (see Rose et al., 2008). Traditionally, the layout of the matrix is set up in two ways. Some researchers set up the matrix in such a way that each row represents a choice set and each alternative of the choice set is represented by a group of columns (Bliemer and Rose, 2006; Rose and Bliemer, 2007; see Table 2). This form of representation is also called a linear design. The values of the matrix are populated, or assigned, using the attribute levels. Each row of the matrix (choice experiment) is also referred to as a “run” of the experiment.

Table 2: Choice Experiment Design in Linear Form (Burris et al., 2009)

Experiment Number	Drive Alone on General Purpose Lanes (Toll Free)	Drive Alone on Managed Lanes		Carpool on General Purpose Lanes (Toll Free)	Carpool on Managed Lanes	
	Time (minutes)	Time (minutes)	Toll	Time (minutes)	Time (minutes)	Toll
1	40	15	$2.00	40	15	$0.50
2	35	20	$1.25	35	20	$0.00
…	…	…	…	…	…	…
…	…	…	…	…	…	…

Other researchers set up the design matrix such that each column represents one attribute and each row represents one alternative of the choice set. In this case, a group of rows forms a choice set (Carlsson and Martinsson, 2002; Huber and Zwerina, 1996; Kanninen, 2002; Kessels et al., 2006; Sándor and Wedel, 2001; Sándor and Wedel, 2002; see Table 3). Irrespective of how the matrix is set up, the function of experimental design remains the same, assigning various levels of attributes across the choice sets of the experiment (Rose et al., 2008). Both these designs in Tables 2 and 3 can be represented in choice design form, as shown in Table 4.

Table 3: Choice Experiment Design in Alternate Form (Burris et al., 2009)

Experiment Number	Alternatives \ Attributes	*Time (minutes)*	*Toll*
1	Drive Alone on General Purpose Lanes (Toll Free)	40	N/A
	Drive Alone on Managed Lanes	15	$2.00
	Carpool on General Purpose Lanes (Toll Free)	40	N/A
	Carpool on Managed Lanes	15	$0.50
2	Drive Alone on General Purpose Lanes (Toll Free)	35	N/A
	Drive Alone on Managed Lanes	20	$1.25
	Carpool on General Purpose Lanes (Toll Free)	35	N/A
	Carpool on Managed Lanes	20	$0.00
…	…	…	…
…	…	…	…

Table 4: Choice Experiment Design in Choice Design Form (Burris et al., 2009)

Experiment Number	Alternatives / Attributes	Drive Alone on General Purpose Lanes (Toll Free)	Drive Alone on Managed Lanes	Carpool on General Purpose Lanes (Toll Free)	Carpool on Managed Lanes
1	*Time (minutes)*	40	15	40	15
	Toll	N/A	$2.00	N/A	$0.50
2	*Time (minutes)*	35	20	35	20
	Toll	N/A	$1.25	N/A	$0.00
…	…	…	…	…	…
…	…	…	…	…	…

Almost all of the choice experiments constrain the number of choice situations to be presented to the respondent. This is because human beings have some limit to which they will go to coherently respond to information. If too many choices are presented to an individual, then he/she will sooner or later tune out and lose focus. Hence, there is a need to design the experiment such that the combination of the levels of attributes used yields maximum information. Traditionally, studies relied on the principality of orthogonality to design the choice experiment (Rose et al., 2008). The concept behind orthogonal designs and their shortcoming are discussed in the next section.

2.4.2 Orthogonal Designs

The concept behind orthogonal experimental design relates to the correlation structure between the attributes of the design. Orthogonality of a design is achieved by selecting the levels of the attributes such that they are statistically independent of each other. These designs allow the researcher to estimate independently the influence of each attribute on the choice outcomes (Rose et al., 2008).

Orthogonal designs are generally generated from a “full factorial” design. A full factorial design is a design where all of the possible combinations of attribute levels are used. These designs are resource-expensive and are very often simply not practical to be used for choice experiments. The size of the full factorial design depends on the number of attributes and possible levels each attribute can take. For example, consider a design with five attributes, two attributes taking four levels and three taking three levels. The possible number of choice situations for this design will be $4 \times 4 \times 3 \times 3 \times 3 = 4^2 \times 3^3 = 432$. Imagine an individual trying to cope with that many different combinations of attributes in any conceivable presentation format.

Even though the full factorial designs allow both main effects and interaction effects between attributes to be estimated (Rose et al., 2008), it is most often neither practical nor economical (in terms of time resource) to use these designs. Whether or not it is practical or economical depends greatly on the number of alternatives, attributes, and levels of the attributes. Only in the case where it can be argued that a very small number of each covers the spectrum of motives for making a choice can the full factorial design be used.

One possible way around the problem is to choose a fraction of the full factorial design and construct the choice survey. These designs are called fractional factorial designs. As a result of choosing a fraction of a full factorial design, some attribute effects become confounded and cannot be distinguished from each other. Hence, orthogonal fractional factorial designs are only orthogonal in some of the effects of the design (Rose et al., 2008).

Another way to reduce the number of choice situations presented to respondents without reducing the size of the design is by “blocking” the design. Blocking refers to selecting subsets of a full factorial or fractional factorial design. These blocks are then presented to subsets of respondents; in block designs the different subjects taking the survey do not each see all of the subsets. More discussion on orthogonal fractional factorial design can be found in Louviere et al. (2000) or Bliemer and Rose (2006).

Note that orthogonal designs are mainly used for linear utility function models. These designs were preferred in many studies in the past. Some of the reasons for their use are they are easy to construct and they allow independent estimation of influence of attributes on choice. Most researchers have relied on linear models in cases where orthogonality of data is thought to be important (Rose et al., 2008). Orthogonality ensures that the linear models do not suffer from multi-collinearity problems. Multi-collinearity (MC) describes the situation when two or more attributes vary with each other in some distinct and linear relationship. MC problems lead to failures to minimize the variances of the parameter estimates (Rose et al., 2008), which is required to obtain efficiency in estimation.

Discrete choice models such as the ones used here are not estimated using the linear regression method that is the work-horse in statistical analysis, ordinary least squares (OLS). However, the MC problem using the OLS framework is illustrated here to ease the difficulty in discussion. The variance-covariance (VC) matrix for the linear regression (OLS) model is given by Equation 1. The VC matrix is directly proportional to $[X'X]^{-1}$, when σ^2 (the variance) of the model is fixed. It is apparent that for a linear model, the elements of the VC matrix are minimized when matrix X is orthogonal, i.e., the design is orthogonal. This is preferable because orthogonal designs produce the smallest variances and hence maximize the t-ratios produced by the model.

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

where, σ^2 is the model variance and X is the matrix of attribute levels in the design or data.

Although orthogonal designs are easy to construct, maintaining orthogonality is certainly not guaranteed in many situations, nor is it even desirable. Orthogonal designs are just not a viable option in certain modeling situations (Kuhfeld, 2005). The parameters of the model are estimated from the data obtained from the SP experiments and may depart from what was intended from the original designs. In most cases, orthogonality will not be preserved in the data actually used to estimate the discrete choice models, even when the underlying design was orthogonal (Rose et al., 2008).

Several reasons supporting the above statement can be given (see Rose et al., 2008). To begin, when respondents are given a fraction of a full factorial orthogonal design, the orthogonality can be lost in the fractional data. This is particularly true when the subsets of the design matrix are unevenly distributed over the survey. Some blocks may be over- and some under-represented in the data, leading to loss in orthogonality in the data.

Second, it is common in surveys to collect data on certain socio-economic characteristics and other related variables. These non-design attributes (such as age and gender) do not vary over the alternatives and choice situations for a respondent, introducing correlations among these variables and other design attributes. Third, it is highly probable to have some choice situations in which one alternative is preferred to other alternatives, and it is also possible that some choice situations make no sense economically. In those cases, the analyst may delete such choice situations, as there is no information to gain from the responses on those choice situations (Bates, 1988). In such designs, the orthogonality is not preserved (see Rose et al., 2008; Lancsar and Louviere, 2006). Last, it simply may not make sense to rule out collinearity between two attributes. For example, one might logically expect that travel routes that have a toll associated with them, such as MLs, also have lower travel times involved in their use. Orthogonality would rule this out.

From the above discussion, one can see that orthogonal designs are not an option in many situations. Although orthogonal designs are still preferred for some linear models, discrete choice models such as the members of the logit family (like ours below) are not linear models. Toner et al. (1998) concluded that fractional factorial orthogonal designs do not necessarily improve the efficiency of estimation of the model parameters of the disaggregate logit models. Designs more appropriate for the logit and other discrete choice models are discussed in the next section.

2.4.3 Efficient Designs

Efficiency means that the parameters have been estimated using an approach that results in the smallest standard errors for the parameters, ensuring the largest possible t statistics that indicate significant difference from a zero influence on the choices. For generating efficient designs, the attribute levels across various choice sets are chosen based on an appropriate efficiency criterion. The fundamental concept behind the efficiency criterion for generating choice designs is to therefore minimize the asymptotic standard errors (the square roots of the diagonal elements of the asymptotic variance-covariance [AVC] matrix) of the parameter estimates of the discrete choice models (Bliemer et al., 2008). Huber and Zwerina (1996) showed that efficient designs either improve the reliability of the parameters estimated from the stated choice experiment data at a fixed sample size or reduce the sample size requirements for a chosen level of reliability of parameter estimates for a given experimental design. There are several efficiency criteria described in literature; of those, most commonly used are A-efficiency and D-efficiency criterion.

Both these efficiency criterion are based on minimizing some kind of error statistic calculated from the AVC matrix. A-efficiency criterion tries to minimize the A-error of the AVC matrix, while D-efficiency criterion tries to minimize the D-error of the AVC matrix. The A-error statistic is calculated by taking the trace of the AVC matrix (see Equation 2). The D-error statistic is calculated by taking the determinant of the AVC matrix (see Equation 3). Both these values are calculated using the AVC matrix from one complete design assuming a single respondent (Rose et al., 2008).

$$A - error = \frac{Trace(AVC)}{K}, \text{ and} \tag{2}$$

$$D - error = \det(AVC)^{1/K} \tag{3}$$

where, K = number of parameters.

Relative A-error of any two designs changes with the type of coding used for the design matrix, i.e., the relative A-efficiency of any two design matrices depends on the type of coding scheme used for the attribute levels in the design (Kuhfeld, 2005; Rose and Bliemer, 2008), whereas the relative D-error is invariant to different types of coding of the design matrix and is computationally efficient to update (Huber and Zwerina, 1996). Because of these reasons, use of D-efficiency criterion is more commonly found in the literature.

Many researchers in the past used efficient linear design because it was relatively easy and convenient, and they then converted the design to the choice designs appropriate to estimate discrete choice models (Louviere and Woodworth, 1983; Louviere, 1988; Batsell and Louviere, 1991; Lazari and Anderson, 1994; Kuhfeld et al., 1994; Huber and Zwerina, 1996; Bateman et al., 2007). However, for the discrete choice model, unlike the continuous linear model, the asymptotic variance-covariance matrix is equal to the inverse of the Fisher information matrix (see Equation 4). So choosing a linear design to generate a discrete choice design may not be an appropriately efficient method. An alternative way for searching an efficient design for a discrete choice model involves estimating the variance-covariance matrix for a particular choice model.

$$AVC = -\frac{1}{N}\left[\frac{\partial^2 LL(\boldsymbol{\beta})}{\partial\boldsymbol{\beta}\partial\boldsymbol{\beta}'}\right]^{-1} \tag{4}$$

where, N = 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 discrete choice model, and

$\boldsymbol{\beta}$ is a vector of parameters used in the model.

The Fisher information for the logit model is shown in Equation 5. From Equation 5, it is apparent that to estimate the AVC matrix for the choice model, it is required to know the design and also the estimated parameter values ***(β)***.

$$E[I(\beta|X)] = \frac{\partial^2 L(\beta|X)}{\partial\beta\partial\beta'} = \sum_{s=1}^{S} X_s'(P_s - p_s p_s')X_s \tag{5}$$

where, $X_s = [x_{1s,} .... x_{Js}]',\ p_s = [p_{1s,} ..., p_{Js}]', and\ P_s = diag(p_{1s,} ..., p_{Js})$.

x_{js} is a k-vector of the attributes of alternative *j* in choice set *s* (see Section 2.5.1), and

p_{js} is the probability of choosing alternative *j*, in choice set *s* (see Section 2.5.1).

Since the parameter values are not known in advance of conducting the survey and estimating the choice models, an educated guess based on literature is often made for those values. Using these guesses is consistent with Bayesian statistical analysis. Based on how the priors of the parameters are assumed to look, minor modifications to the D-error statistic have been proposed in the literature. For example, we might assume that toll rates are negative influences on choice, holding other factors or attributes constant, and thus assign a negative value to the toll coefficient, as a prior. When the priors are assumed to be all zeros, the resulting designs are called D_z-efficient designs (see Equation 6). When non-zero priors are assumed, the resulting designs are called D_p-efficient designs (see Equation 7). Many researchers have concluded that the assumption of the priors has a direct influence on the efficiency of the design. Hence, choosing the right priors is very important to generate an efficient design.

$$D_z - error = \det(AVC(X,0))^{1/\mathrm{K}} \tag{6}$$

$$D_p - error = \det(AVC(X,\beta))^{1/\mathrm{K}} \tag{7}$$

Recently, Bayesian techniques have been used by some stated choice modelers when the priors were not known with certainty (Scarpa and Rose, 2008; Ferrini and Scarpa, 2007; Sándor and Wedel, 2001). The designs generated using Bayesian techniques are called D_b-efficient designs. These Bayesian designs are discussed in the next section.

2.4.4 Bayesian Efficient Designs

As discussed before, to calculate D-error, we need information not only on the design but also on the parameter estimates. However, the parameter estimates are unknowns which are estimated from the stated preference experiment data. In some cases, it is possible to obtain priors from previous literature. However we obtain those priors, there will always be some uncertainty in the values. The experimental design thus generated will only be efficient for the specified priors assumed. If the priors are incorrectly specified, the efficiency of the designs may be lowered (Bliemer et al., 2008). In order to increase the efficiency of the design from the assumed values, Bayesian techniques were proposed by Sándor and Wedel (2001). In this approach, instead of taking a fixed value for priors, a random distribution is assumed for the priors. The designs thus obtained are known as Bayesian efficient designs.

The Bayesian D_b-error can be calculated using Equation 8.

$$D_b - error = \int_{\tilde{\beta}} \det AVC(\tilde{\beta}|X)^{1/K}\, \phi(\tilde{\beta}|\theta) d\tilde{\beta} \tag{8}$$

where, $\phi(\tilde{\beta}|\theta)$ is the joint distribution of the assumed parameter priors,

θ are the corresponding parameters of the distribution, and

K is the number of parameters in the model.

The computation of the integral in Equation 8 is complicated, as it cannot be calculated analytically. The integral is approximated using several methods. One of the most common approximation method used in literature is the Pseudo-Random Monte Carlo simulation. In this method, R independent draws are taken from each of the prior distributions of the K-parameters. D_b-error is calculated for each of the designs for each of the R draws. Finally the D_b-error of the design is approximated as the average of all the computed D_b-errors. The computed D_b-error can be written as Equation 9.

$$\widehat{D}_b - error = \sum_{r=1}^{R} \det AVC(\tilde{\beta}^r|X)^{1/K} / R \tag{9}$$

where, $\tilde{\beta}^r = [\tilde{\beta}_1^1, ..., \tilde{\beta}_k^r]$, and r denotes the draw (1,2,…,R).

To generate R pseudo random numbers, we first generate R random numbers (u_k^r), which are uniformly distributed in the interval [0, 1], and compute the draws using Equation 10.

$$\tilde{\beta}_k^r = \Phi_k^{-1}(u_k^r) \tag{10}$$

where, $\Phi_k(\tilde{\beta}_k \mid \theta_k)$ denotes the cumulate distribution function of $\tilde{\beta}_k$.

2.5 Discrete Choice Modeling

The responses from the stated preference survey were modeled using several discrete choice models. Various discrete choice models used for the analysis are described in this section.

2.5.1 Multinomial Logit Model

The multinomial logit (MNL) model was first developed by McFadden to model choice behavior (McFadden, 1974). In transportation planning, these models are used to model mode choice behavior of the travelers. Standard random utility theory suggests that the utility of an individual *i* (*i = 1,2,…n*) choosing an alternative *j* (*j = 1,2,…J*) in a given choice set *s* (*s = 1,2,…S*) can be written as Equation 11. Each individual chooses an alternative in a choice set that maximizes his/her utility (U), illustrated below in linear form.

$$U_{i,j,s} = \boldsymbol{\beta}'\mathbf{X}_{ijs} + \boldsymbol{\gamma}_j'\boldsymbol{Z}_{is} + \epsilon_{i,j,s} \tag{11}$$

where, $\mathbf{X}_{ijs}$ = vector of attributes of alternative *j* as perceived by individual *i*,

$\mathbf{Z}_{is}$ = vector of characteristics of individual *i*,

$\boldsymbol{\beta}$ = vector of coefficients weighing the alternative specific attributes,

$\boldsymbol{\gamma}_j$ = vector of alternative specific coefficients weighing individual characteristics, and

$\epsilon_{i,j,s}$ = 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 first two terms of Equation 11 are called the systematic part of utility function. The last term is called the stochastic part or random (error) part. The standard assumption in the random utility model is that the individual knows the value of the error term while the researcher does not. This implies that there is no risk or uncertainty on the part of the choice maker. Consider the following example of the systematic part of the utility function (see Equation 12).

$$V_{ij} = \beta_0 + \beta_1 * \mathrm{TravelTime}_{ij} + \beta_2 * \mathrm{Reliability}_{ij} + \beta_3 * \mathrm{TravelCost}_{ij} + \gamma_j * \mathrm{Income}_i \tag{12}$$

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

γ_j = the estimated coefficient of income for mode j,

$TravelTime_{ij}$ = the travel time for mode j for individual i,

$Reliability_{ij}$ = the travel time reliability for mode j for individual i,

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

$Income_i$ = the income of individual i.

Because utility is linear in the specification, the VOT can be easily estimated for this example by taking the ratio of the partial derivative of utility function with respect to travel time to the partial derivative of utility function with respect to travel cost, which yields the ratio of coefficients. Similarly, VOR can be estimated as the ratio of the partial derivative of utility function with respect to travel time reliability to the partial derivative of utility function with respect to travel cost. For this linear utility function, the VOT can be derived as β_1/β_3, and VOR as β_2/β_3.

The structure of the MNL assumes that the error terms are identically and independently distributed as type I extreme value distribution. Under this assumption, the probability that individual *i* chooses alternative *j* in a given choice set is given by Equation 13.

$$\text{Prob (choice } j \text{ |individual i, s, } \boldsymbol{\beta}, \mathbf{X}_{ij}, \boldsymbol{\gamma}_{\mathbf{j}}, \mathbf{Z}_{\mathbf{i}}) = \frac{\exp\left(\boldsymbol{\beta}'\mathbf{X}_{ijs}+\boldsymbol{\gamma}_j'\boldsymbol{Z}_{is}\right)}{\sum_{\mathrm{j=1}}^{J}\exp\left(\boldsymbol{\beta}'\mathbf{X}_{ijs}+\boldsymbol{\gamma}_j'\boldsymbol{Z}_{is}\right)} \tag{13}$$

The independence assumption implies that the ratio of choice probabilities of a pair of alternatives is independent of other alternatives. This property of MNL is called the independence of irrelevant alternatives (IIA). Although this property simplifies the estimation process, it may not be desirable in many cases. A classic transportation example illustrates this undesirable property: this is commonly known as the blue bus, red bus problem. Consider that travelers have two options for travel: a car and a red bus. When only these two travel options are available and assuming that the travel time on both these modes is equal, travelers are equally likely to choose any alternative with a probability of 0.5. Now, suppose a blue bus is introduced as a third possible mode of transportation. The IIA property implies that the relative probability of choosing alternatives car and red bus is independent of the introduction of a third mode, the blue bus. Presuming that attributes of the modes do not matter, individuals choose as if they made the choice randomly, and the new probabilities according to the IIA property are 0.33 for car, 0.33 for red bus, and 0.33 for blue bus. However, in reality, the probability of choosing a car should not change, as the alternatives blue bus and red bus are very similar and are not independent. The new probabilities should be 0.5 for car, 0.25 for red bus, and 0.25 for blue bus (see Koppelman and Bhat, 2006). To overcome the IIA problem of the conventional MNL model, nested logit models were introduced (see Section 2.5.2), but there are in fact now several other approaches to breaking or relaxing the IIA assumptions.

MNL models are thus appropriate when modeling what are truly independent alternatives. However, in the stated preference survey conducted for this research, we had alternatives such as driving alone, carpooling on general purpose lanes, and traveling on the MLs with tolls that vary with the time of day and the mode of travel. In such cases, there may be a possibility that the unobserved information required to make a choice may allow for correlations across alternatives and also across choice situations (Hensher and Greene, 2003). This may cause a violation of the IIA assumption of the MNL model. Also, in the 2010 SP survey, multiple observations from the same individual were obtained. To model such responses, mixed logit models are now commonly used (see the discussion in Section 2.5.3).

2.5.2 Nested Logit Model

As one of the first steps to overcome the IIA property of the MNL model, nested logit (NL) models were introduced in the literature. The NL model allows for correlations between alternatives within one level of the nest; they do not need to hold at other levels. The basic idea behind NL models is that it groups similar alternatives within a nest level, thereby creating a hierarchical structure of the alternatives (Ben-Akiva and Lerman, 1994; Train, 2003). The alternatives' error terms within a nest are correlated with each other, but the error terms of alternatives in different nests are not correlated (Silberhorn et al., 2008; Hensher et al., 2005). The NL model can be viewed as a combination of different standard logit models. One of the major differences between a standard logit and NL is that for a NL model, the error component of the alternatives need not necessarily have the same distribution. An example of a two-level nested structure for driving a vehicle is shown in Figure 3. At the "top" level of the nest, the individual chooses whether to drive alone or carpool. At the second level, or "bottom" level, the drivers choose whether to travel on MLs or GPLs. Note, however, that these choices could be made simultaneously; there is no requirement that one decision be made "before" the other one, although that too is a possible implication of a NL model.

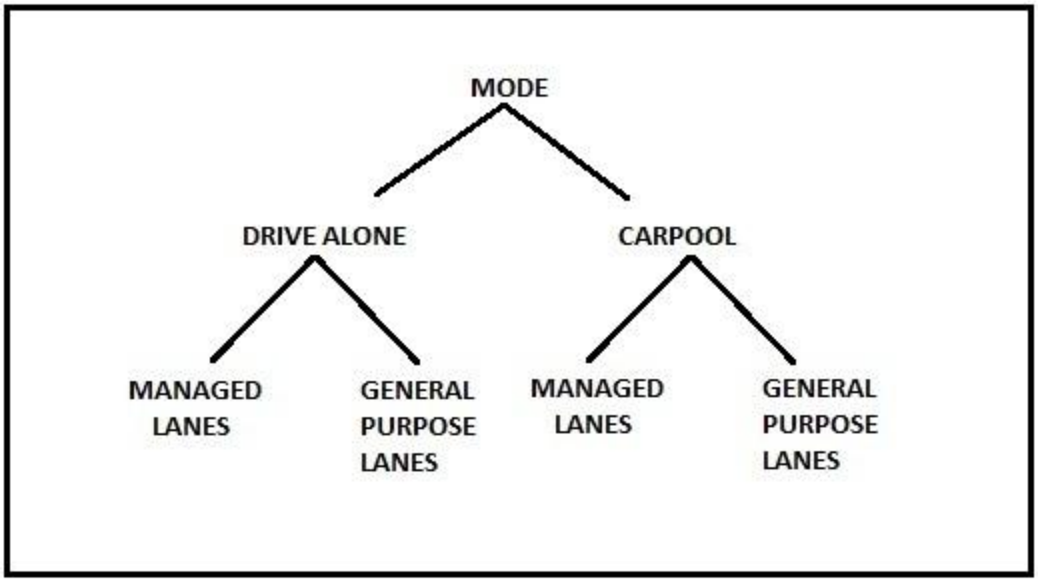


Figure 3: Tree Structure of Nested Logit Model

The probability that an individual i ($i = 1,2,...n$) chooses an alternative j ($j = 1,2,...J$) of nest m ($m = 1,2,...M$) in a choice set s ($s = 1,2,...S$) is given by Equation 14. It is obtained by taking the product of the conditional probability of choosing alternative j in nest m with the probability of choosing nest m (Greene, 1997; Knapp et al., 2001).

$$\text{Prob}\left(\text{alternative j, nest m}|\text{individual i,s, } \boldsymbol{\beta}, \mathbf{X}_{ij}, \boldsymbol{\gamma}_\mathbf{j}, \mathbf{Z}_\mathbf{i}\right) = \mathrm{P}_{\mathrm{jm}} = \mathrm{P}_{\mathrm{j|m}}\mathrm{P}_{\mathrm{m}} \qquad (14)$$

where, $\mathrm{P}_{\mathrm{j|m}} = \frac{\exp(\boldsymbol{\beta}'\mathbf{X}_{ijs|m})}{\sum_{\mathrm{j}=1}^{Jm}\exp(\boldsymbol{\beta}'\mathbf{X}_{ijs|m})}$ = conditional probability of choosing alternative j in nest m,

$\mathrm{P}_{\mathrm{m}} = \frac{\exp\left(\boldsymbol{\gamma}_j'\boldsymbol{Z}_{ism}+\boldsymbol{\tau}_m\boldsymbol{I}_m\right)}{\sum_{\mathrm{m}=1}^{M}\exp\left(\boldsymbol{\gamma}_j'\boldsymbol{Z}_{ism}+\boldsymbol{\tau}_m\boldsymbol{I}_m\right)}$ = probability of choosing nest m,

$\mathrm{I}_{\mathrm{m}} = \ln\sum_{\mathrm{j}}^{\mathrm{Jm}}\exp\left(\boldsymbol{\beta}'\mathbf{X}_{ijs|m}\right)$ = inclusive value (IV), and

$\boldsymbol{\tau}_{\boldsymbol{m}}$ = a measure of correlation between alternatives in nest m.

The VOT and VOR can be estimated using the same concept described for the MNL model. Alternatively, more general, non-marginal WTP measures can be derived by appealing to economic theory of consumers' surplus measures (e.g., see Shaw and Ozog, 1999).

2.5.3 Mixed Logit Model

The mixed logit model, or random parameter logit model, is a later innovation in discrete choice modeling than the NL approach. It is considered by many researchers as the most promising tool for modeling discrete choice data (Hensher and Greene, 2003). A mixed logit model allows the researcher to account for both observed and unobserved heterogeneity of individuals in the models (Greene et al., 2006). With the mixed logit model, it is also possible to model repeated responses from individuals (panel data), scale differences in data sources (although this is also possible with more basic models), modify error structures, and accommodate heteroscedasticity (non-constant variance) from various sources (Brownstone and Train, 1998; Ben-Akiva et al., 2001; Bhat and Castelar, 2002; Greene et al., 2006; Greene and Hensher, 2007; Hensher et al., 2008).

In a mixed logit model, the parameters in the random utility function (Equation 11) are assumed to be random and may vary across individuals to introduce heterogeneity among individuals. The parameters can be specified as in Equation 15.

$$\boldsymbol{\beta_{ik} = \bar{\beta}_k + \sigma_k \upsilon_{ik}} \tag{15}$$

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

υ_{ik} = the individual specific heterogeneity with mean 0 and standard deviation (scaled to) 1, and

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

For each or all of the parameters or coefficients, various empirical distributions can be assumed, although in practice, the possibilities are usually limited to a few well-known families (the normal, the log normal, and the triangular). In our case, the travel time, toll, and travel time variability parameters can all be assumed to be random parameters and have different distributions. However, in this research, estimating the value of travel time savings and value of travel time reliability are of interest, both of which are estimated as ratios of two parameters. Hence, assuming random distributions for travel time, travel time variability, and toll may add complexity in estimating the VTTS and the VOR (Patil et al., 2011b). Choosing the right distribution is also critical for drawing meaningful inferences from the estimates. For example, if a normal distribution is assumed for any of the parameters, then the parameter can take positive values or negative values; this is counterintuitive, as it implies that respondents like higher travel times or tolls. Positive values for certain parameters can potentially be avoided by assuming the lognormal distribution. The log of any number less than 1 but greater than 0 is, of course, a negative number. However, this distribution has a longer tail than the normal distribution, which may yield unrealistically large values (Patil et al., 2011b).

One of the more commonly used distributions in practice is the triangular distribution for the travel time parameter. This triangular distribution is generated using a uniform distribution of the variable U(0,1), and the probability density is given by Equation 16 (Hensher et al., 2005). The triangular distribution takes values from −1 to 1.

$$t = \begin{cases} \sqrt{2U} - 1, & \text{for U} < 0.5 \\ 1 - \sqrt{2(1-U)}, & \text{otherwise} \end{cases} \tag{16}$$

Individual specific estimates can be simulated from a triangular distribution with mean and standard deviation estimated from a mixed logit model using Equation 17 (Hensher et al., 2005).

$$\hat{t} = \hat{\mu} - \hat{\sigma} \times t \tag{17}$$

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

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

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

Preference heterogeneity in the mean and heteroscedasticity relating to the variance can be introduced in the mixed logit by specifying the random parameters, as in Equation 18 (Patil et al., 2011b; Greene and Hensher, 2007).

$$\beta_{ik} = \bar{\beta}_k + \boldsymbol{\delta}'_k \mathbf{z}_i + \gamma_{i,k} \upsilon_{i,k} \tag{18}$$

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

$\upsilon_{i,k}$ = the vector that contains individual and choice-specific, unobserved random disturbances with $E[\upsilon_{i,k}] = 0$ and $\text{Var}[\upsilon_{i,k}] = a_k^2$, a known constant; and

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

The results from the model specified using Equation 18 can be used to estimate the values of VTTS and VOR for different groups (see Hensher et al., 2005). Patil et al. (2011b) demonstrated this by calculating the VTTS for six different urgent situations and one normal situation.

In addition to the above random parameter specifications, mixed logit models can also be specified to include individual heterogeneity in the form of the error components that capture influences that are related to alternatives (Hensher et al., 2008). The utility function is specified as in Equation 19 with this extension.

$$\mathrm{U}_{i,j,s} = \boldsymbol{\beta}'_i \mathbf{x}_{i,j,s} + \epsilon_{i,j,s} + \sum_{m=1}^{M} c_{jm} \mathrm{W}_{i,m} \tag{19}$$

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

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

To account for unobserved heterogeneity, $\mathrm{W}_{\mathrm{i,m}}$ are assumed to be normally distributed with 0 mean such that variance of $\mathrm{W}_{\mathrm{i,m}}$ is given by Equation 20 (Patil et al., 2011b).

$$\mathrm{Var}\left[\mathrm{W}_{\mathrm{m,q}}\right] = \left[\theta_{\mathrm{m}} \times \exp(\tau'_{\mathrm{m}} \mathrm{h}_{\mathrm{q}})\right]^2 \tag{20}$$

where, θ_{m} = the scale factor for error component m,

τ_{m} = parameters in the heteroscedastic variances of the error components, and

h_{i} = the data vector which contains individual choice invariant characteristics that produce heterogeneity in the variances of the error components.

The conditional probability with the above specification of utilities is given by Equation 21 (Greene and Hensher, 2007; Hensher et al., 2008; Patil et al., 2011b).

$$\mathrm{Prob}_{i,s}(\mathrm{j_s}|\mathbf{X}_{\mathrm{is}},\boldsymbol{\Omega},\mathbf{z}_{\mathrm{i}},\mathbf{h}_{\mathrm{i}},\mathbf{v}_{\mathrm{i}},\mathbf{W}_{\mathrm{i}}) = \frac{\exp\left(\boldsymbol{\beta}'\mathbf{x}_{ijs} + \sum_{m=1}^{M} c_{jm} \mathrm{W}_{im}\right)}{\sum_{j=1}^{J} \exp\left(\boldsymbol{\beta}'\mathbf{x}_{ijs} + \sum_{m=1}^{M} c_{jm} \mathrm{W}_{im}\right)} \tag{21}$$

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

The conditional probabilities (Equation 21) are functions of the unobserved individual specific random terms; because of this, these cannot be used to form the likelihood function for the estimation of the parameters (Hensher et al., 2008). By integrating the heterogeneity out of the conditional probabilities, the unconditional choice probability can be formed. The unconditional probability estimation is given in Equation 22.

$$\mathrm{Prob}_{i,s}(j_s) = \int_{v_i}\int_{W_i} \mathrm{Prob}_{i,s}(j_s|\mathbf{X}_{is},\mathbf{\Omega},\mathbf{z}_i,\mathbf{h}_i,\mathbf{v}_i,\mathbf{W}_i)f(\mathbf{v}_i,\mathbf{W}_i)d\mathbf{W}_i d\mathbf{v}_i \tag{22}$$

The integral of Equation 22 does not exist in a closed form; in other words, it is not integrable in elementary mathematical functions. So, the integral has to be approximated using simulation (see Bhat, 2003; Revelt and Train, 1998; Train, 2003). Random draws are taken from each of the random parameters, and the utilities are calculated for each of these draws. The calculated utilities are used to calculate the probabilities and finally are averaged to estimate the unconditional probabilities. The simulated probabilities are calculated as shown in Equation 23.

$$\text{Simulated Prob}_{i,s}(j_s) = \frac{1}{R}\sum_{r=1}^{R}\frac{\exp(\boldsymbol{\beta}'\mathbf{x}_{ijs}+\sum_{m=1}^{M}c_{jm}W_{im,r})}{\sum_{j=1}^{J}\exp(\boldsymbol{\beta}'\mathbf{x}_{ijs}+\sum_{m=1}^{M}c_{jm}W_{im,r})} \tag{23}$$

where, the subscript *r* represents the r^{th} random draw, and R = number of random draws.

The simulated probabilities are used to form the simulated likelihood function. The estimation procedure is affected by the number of draws taken during the estimation process and the sample size. Halton draws are more efficient and give more precise results than random draws (Bhat, 2001; Hensher, 2001b). Too few draws will require less computation time but may result in less precise results. On the other hand, too many draws may yield good results but require a high amount of computational time. Some complex models may even take days for estimation. It is very common to find 100 to 500 Halton draws being used for the model estimation (Greene et al., 2006; Greene and Hensher, 2007; Hensher et al., 2008). In this research, 200 Halton draws were used to estimate the mixed logit models.

2.6 Summary

A Literature review was conducted to understand the current state of art of travel behavior studies. One of the objectives of the research was to estimate value of travel time savings and value of travel time reliability of the ML users using stated preference surveys. Existing literature on efficient survey designs was extensively reviewed. Literature on the operation and policy of MLs was also reviewed. The data from the surveys are typically modeled using discrete choice models to obtain willingness to pay estimates. Literature on different discrete choice models, multinomial logit, nested logit, and mixed logit models was reviewed. Mixed logit models will be used in this research to models the survey responses as they can accommodate a variety of extensions to incorporate different effects and to better estimate the travelers' willingness to pay for travel time savings and travel time reliability.

3. DATA COLLECTION

One of the goals of this research was to determine if travelers use the Katy Freeway MLs as they predicted they would in a survey conducted in 2008. Another goal was to compare the various survey designs tested in the 2008 survey and to identify if any of the survey designs was better able to predict ML use and estimate the value of travel time savings. We also wanted to estimate travelers' value of travel time reliability. To achieve these goals, it was necessary to conduct a follow-up stated preference survey of Katy Freeway travelers in 2010. The following sections provide details of the 2010 survey.

3.1 Katy Freeway Introduction

Construction of the Katy Freeway started in the early 1960s. It was originally designed as a six-lane freeway with a two-lane one-way frontage road in each direction. It is the Texas section of I-10 west, extending from the I-610 interchange to the city of Katy, spanning 23 miles (see Figure 4). It was designed for a capacity of 79,200 vehicles per day. However, the population in this area grew rapidly over the years and by the 1990s, traffic counts showed that the freeway was being used by more than 200,000 vehicles per day (Texas Department of Transportation [TxDOT], 2009). To cater to the increasing traffic demand, it was decided to reconstruct the freeway with a new design. The new freeway has at least four general purpose lanes (GPLs) and a three-lane one-way frontage road in each direction. In addition to these lanes, a portion (12 mile stretch) of the Katy Freeway near downtown was designed with two managed lanes in each direction (TxDOT, 2009). The construction of the Katy Freeway was completed in October 2008. The MLs were initially opened as HOV lanes in November 2008. They then opened for paid SOV use in April 2009.

The 12 mile Katy Freeway MLs extend from west of SH6 to the I-10/I-610 interchange (see Figure 4). The MLs were fully operational beginning April 10, 2009. Unlike HOV lanes, which are only for people traveling with two or more passengers, the

MLs are open to both SOVs and HOVs. The SOVs pay a higher toll compared to HOVs during peak hours. The current tolls for SOVs are $4.00, $2.00, and $1.00 for 12 miles during peak, shoulder, and off-peak hours, respectively. For HOVs, the toll is $1.00 during off-peak and free during peak and shoulder hours. The ML facility is operated and maintained by the Harris County Toll Road Authority (HCTRA). These lanes are operated to maintain a minimum travel speed of 45 mph.

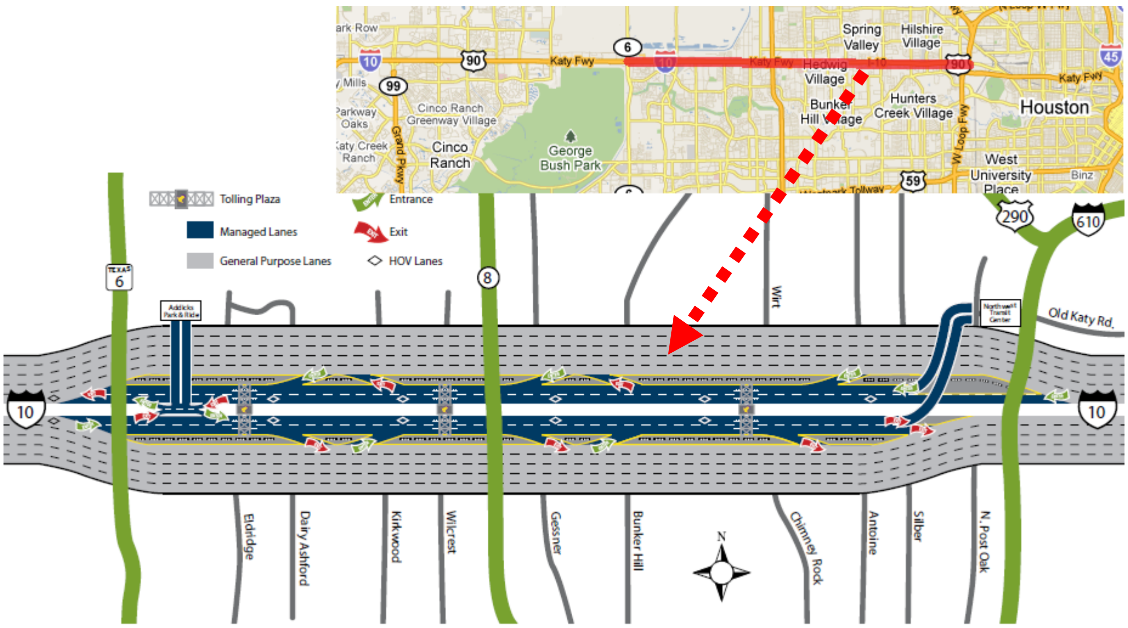


Figure 4: Katy Freeway Managed Lanes (Google Maps, and TxDOT [2009])

3.2 Previous (2008) Katy Freeway Managed Lanes Survey

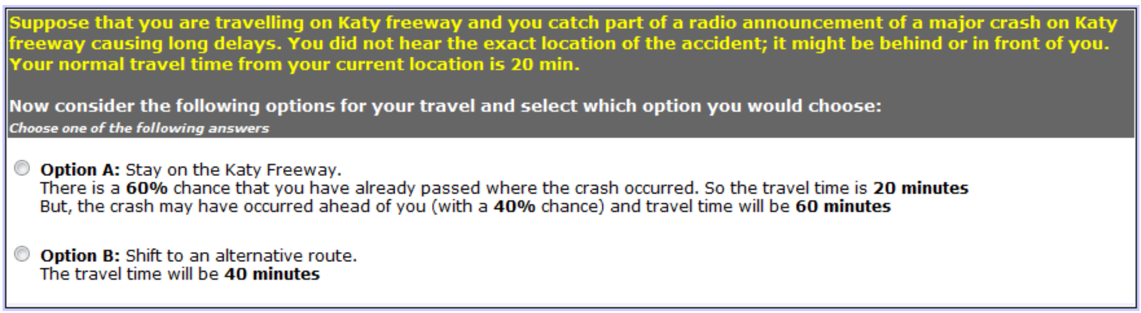
An earlier survey was conducted in 2008 just before opening the MLs to obtain people's opinions regarding the MLs, to understand travelers' behavior, and to estimate the value travelers place on travel time savings for their trips in normal and urgent situations. Respondents were also asked if they would consider using the MLs for their future travel on the Katy Freeway. That survey garnered 3,990 completed responses. During that survey, the respondents were also asked if they would be willing to take a follow-up survey after the MLs opened at a later date. A total of 3,077 people responded that they would take the follow-up survey. The 2008 survey was created using limesurvey, an open-source survey designing tool which can be freely downloaded from www.limesurvey.org. Data from it are used in the Patil et al. studies cited throughout this dissertation (2011a, 2011b).

3.3 Description of the Current (2010) Katy Freeway Survey

The 2010 survey developed for this research consisted of five sections. The first section asked the respondents about their most recent trip on the Katy Freeway. About half of the respondents were asked about their actual trip toward downtown Houston and the other half about their trip away from downtown. Questions included information about the purpose of the trip, day of the week of the trip, when the trip began, when it ended, where the respondent got on and off the Katy Freeway, the type of vehicle, the number of passengers in the vehicle, if the respondent used MLs, etc. (Appendix A includes the actual survey questions).

In the second section, respondents were introduced to the new MLs. Respondents were then asked if they ever used them. If they had used the lanes, the reasons for using them were requested. If they had not used these lanes, the survey sought their reasons for not doing so. Then they were asked about the number of actual trips they took on the Katy Freeway in a week, how many of those were on MLs, the average toll the respondent paid, and the travel time he or she saved. The section ended with questions regarding trips where they were unusually pressed for time and had a tight schedule for travel and how often they used MLs for those types of trips.

The third section was intended to identify the risk-taking behavior or preferences of the respondents. The risk-aversion question presented in the survey is shown in Figure 5. In this question, the respondents were put in a hypothetical situation where they were to think of traveling on a highway and while doing so, hear a part of a radio announcement regarding a crash that might have occurred well ahead of them or, alternatively, they might have passed the location where the crash occurred. Although in the survey this scenario was hypothetical, it is quite likely that many respondents had been in exactly such a situation before on actual trips. They were then given two travel options. Option one was the riskier travel time option, which had some probability (20 to 40 percent) of being significantly delayed. Option two had a known, higher travel time than the regular route. Respondents who chose option one were considered to be more risk-taking travelers in this study and, in comparison, the ones who chose option two were considered more risk averse. It should be noted here the risk-taking behavior of an individual towards choosing travel options may be different from his/her risk behavior in a financial context.


Suppose that you are travelling on Katy freeway and you catch part of a radio announcement of a major crash on Katy freeway causing long delays. You did not hear the exact location of the accident; it might be behind or in front of you. Your normal travel time from your current location is 20 min.

Now consider the following options for your travel and select which option you would choose:
Choose one of the following answers

Option A: Stay on the Katy Freeway.
There is a **60%** chance that you have already passed where the crash occurred. So the travel time is **20 minutes**
But, the crash may have occurred ahead of you (with a **40%** chance) and travel time will be **60 minutes**

Option B: Shift to an alternative route.
The travel time will be **40 minutes**

Figure 5: Question on Risk Aversion

In the fourth section, the respondents were presented with stated preference questions, which are discussed in detail in the next sections. The last section of the survey consisted of questions regarding socio-economic characteristics of the respondents (see Appendix A).

3.4 Survey Administration

The survey was posted on a Texas Transportation Institute server and was made available for public access through the www.katysurvey.org website. The data collection process started on June 1, 2010, and continued until July 15, 2010. Residents of Houston who use the Katy Freeway on a regular basis or have used it recently were encouraged to participate in the survey. The existence of the survey was advertised to the public through online and news media. To increase the participation in the survey, two gas cards worth $250 each were given to two randomly chosen respondents. The contact information for the drawing was stored separately and could not be linked to the survey responses. The list of websites where the survey was advertised is given below. Some of the websites charged a fee for advertising; the fee charged (if any) is also mentioned in the list below:

1. Houston-Galveston area council (http://www.h-gac.com/taq/)—free.
2. Harris County Toll Road Authority (https://www.hctra.org/)—free.
3. KHOU news website and KHOU TV (http://www.khou.com/)—free.
4. Houston newspaper website (http://www.chron.com), and also shown in the Houston Chronicle on Sunday June 13, 2010, in Katy and Memorial areas—$436.
5. Houston Transtar website (http://www.houstontranstar.org/)—free.
6. Houston online news website (http://www.click2houston.com/index.html)—$500.

In addition to the website ads, HCTRA added a brief note regarding the existence of the survey to its monthly HCTRA account e-notices. Emails were also sent to the 3,077 respondents from the previous (2008) survey who had indicated an interest in participating in a follow-up survey. The ads were published on the websites at different dates in order to have a constant flow of responses and also to have a rough idea of responses generated by each source. Since we wanted to match the responses from the previous survey to the responses from the current survey, identifying the responses from the previous respondents was very important, which is also why the ads were published and emails were sent at different dates. It should be noted that both 2008 and 2010 surveys were anonymous, so even if there was a common respondent for both the surveys, his/her exact responses could not be matched.

The survey enabled data collection from June 1, 2010, until July 15, 2010. During this period, there were 4,919 responses. However, only 3,325 of those 4,919 responses were completed to a point where they were useful for analysis. The percentages of total responses obtained on each day during the survey period are shown in Figure 6. It can be observed from the plot that the responses on June 17 correspond to nearly one-fourth of the total responses. On that morning, emails requesting participation in the current survey were sent to the 3,077 previous survey respondents who had indicated their interest in a follow-up survey. Therefore, almost all of those 734 responses on June 17 were likely coming from travelers who had completed the prior survey.

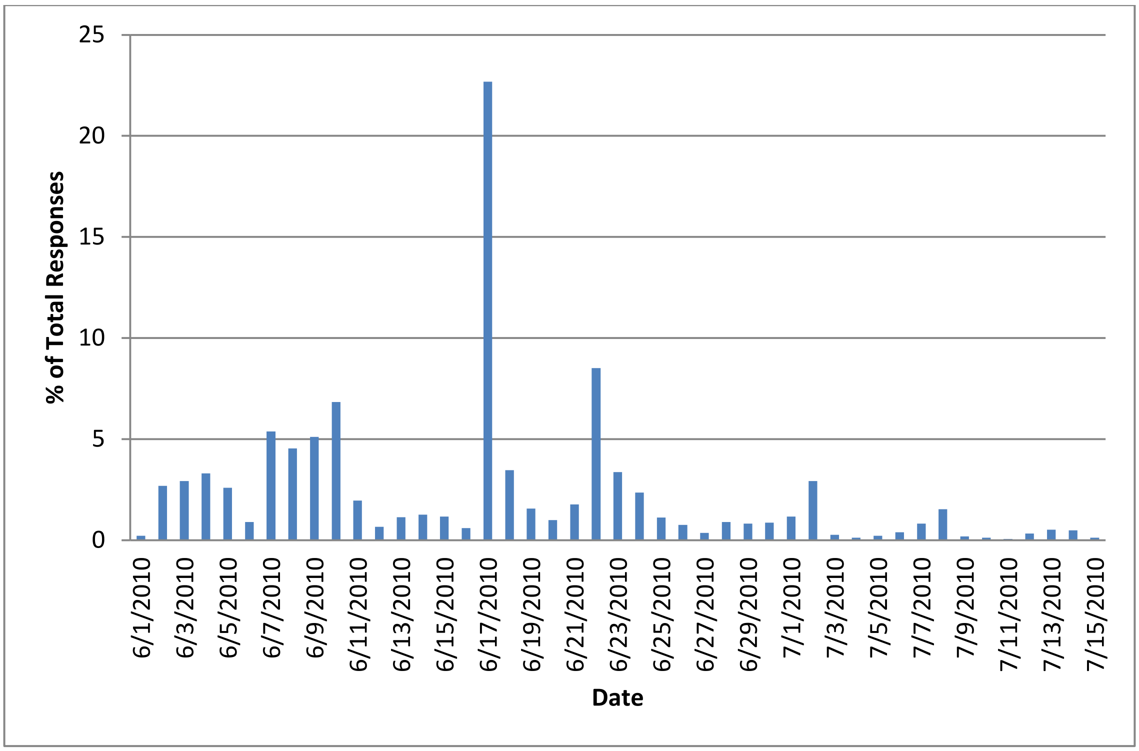


Figure 6: Percentage of Total Responses Obtained on Each Day

3.5 Stated Preference Question Design

A total of six stated preference questions were presented to each survey respondent. In each question, the respondent was asked to consider a realistic travel scenario on the Katy Freeway with four different modes of travel available. The modes included SOV and HOV and varied based on travel time, travel time variability, and toll values. The respondent was asked to choose the mode that best suited his/her travel. Approximately half of the respondents received a question in picture format, while the other half received a question in word format (see Figure 7 and Figure 8).

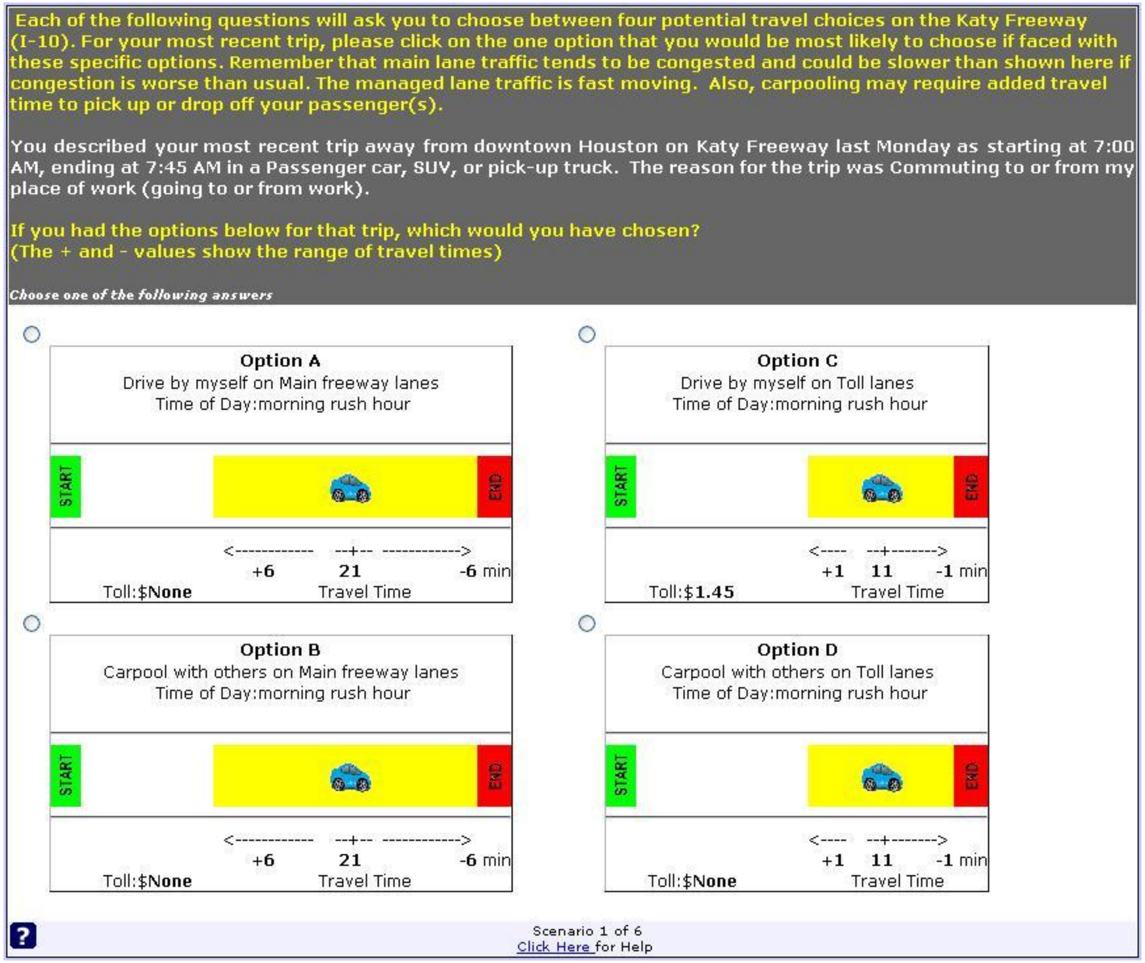
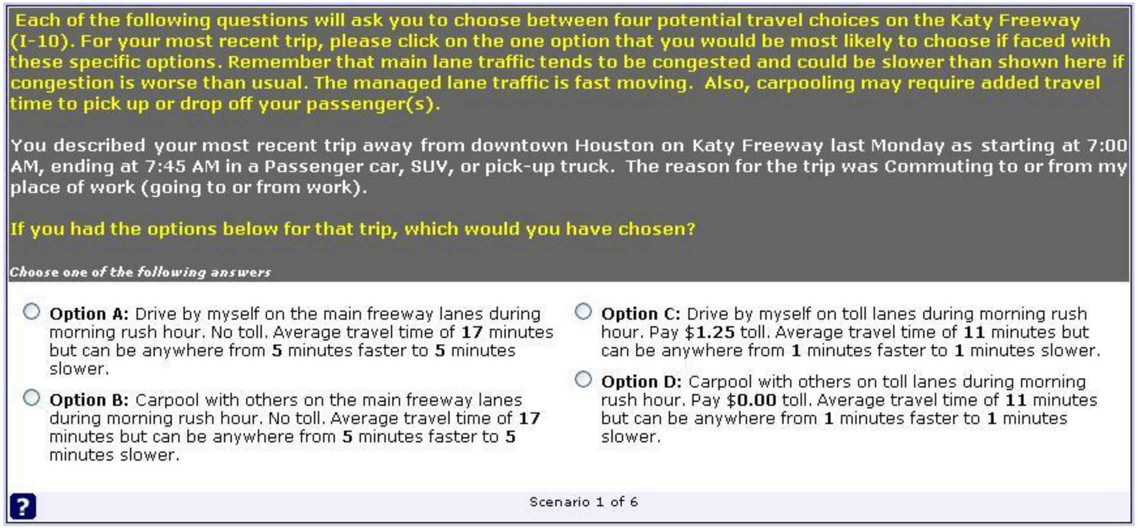


Figure 7: A Typical Scenario in Picture Format with Different Modes of Travel



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 managed 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 7:00 AM, ending at 7:45 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

- **Option A:** Drive by myself on the main freeway lanes during morning rush hour. No toll. Average travel time of **17** minutes but can be anywhere from **5** minutes faster to **5** minutes slower.
- **Option B:** Carpool with others on the main freeway lanes during morning rush hour. No toll. Average travel time of **17** minutes but can be anywhere from **5** minutes faster to **5** minutes slower.
- **Option C:** Drive by myself on toll lanes during morning rush hour. Pay **$1.25** toll. Average travel time of **11** minutes but can be anywhere from **1** minutes faster to **1** minutes slower.
- **Option D:** Carpool with others on toll lanes during morning rush hour. Pay **$0.00** toll. Average travel time of **11** minutes but can be anywhere from **1** minutes faster to **1** minutes slower.

Scenario 1 of 6

Figure 8: A Typical Scenario in Word Format with Different Modes of Travel

Of the six SP questions, three were those in which the respondent was put in an urgent situation. Some of those situations were such that the respondent was unusually pressed for time and had to reach his destination very soon. The descriptions of the urgent situations used in the survey are given in Table 5. Each respondent was randomly given one of the urgent situations presented in Table 5 for all three of his/her SP questions regarding urgent trips.

Table 5: Urgent Situation Categories Presented in the SP Questions (Patil et al., 2011b)

Urgent Situation	**Survey Wording**	**Description/Implication**	**% of Respondents Presented with This Scenario**
Situation 1 *ImpAppt*	You are headed to an important appointment/meeting/event.	The traveler may not necessarily have started late; however, he/she needs to arrive on time.	16.9
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.	17.6
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.	16.3
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.	16.2
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 that are higher or lower than the usual.	16.3
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.	16.7

Travel scenarios were largely created based on the details of the respondent's most recent trip on the Katy Freeway toward/away from downtown Houston. As noted above, roughly half of the respondents were asked about their recent trip toward downtown Houston and the other half about their trip away from downtown. Trip details include the day of the trip, purpose of the trip, when it started, when it ended, where they got on and off the Katy Freeway, the type of vehicle they used for the trip, and the number of people in the vehicle.

The new Katy Freeway has at least six lanes in each direction, of which four are general purpose lanes and two are MLs. It also has a three-lane one-way frontage road in each direction. General purpose lanes are non-toll lanes, and MLs are toll lanes where the toll changes with the time of day (higher during peak hours and lower during other times). Travelers have the option of either driving alone or forming a carpool with others for travel on these lanes (other options, such as transit, are also available but were not examined in this research). With these available options, four modes of travel were used in the SP survey questions:

1) Drive Alone on the General Purpose Lanes (DA-GPL).
2) Carpool on the General Purpose Lanes (CP-GPL).
3) Drive Alone on the Managed Lanes (DA-ML).
4) Carpool on the Managed Lanes (CP-ML).

The toll values were initially based on the current tolls along the Katy Freeway, but tolls vary considerably based on the survey design; this is an advantage of SP models over RP models. Often, in an RP setting, there is simply not enough variation in tolls to be able to ascertain the influence of the toll on choices.

Several relationships were maintained in the design. First, the toll for mode CP-ML was set lower than the toll for DA-ML. Second, the travel time on the MLs was set lower than or equal to the travel time on the general purpose lanes. Because the main idea of MLs is also to provide more reliable and faster travel, the travel time variability (the percentage variation of travel time from the average travel time) on the MLs was set lower than that of the general purpose lanes.

Despite the lower, or eliminated, toll for carpoolers, carpool may still have significant disadvantages for some travelers. Some people just like privacy in their vehicle, and for others the hassle to form a carpool factor is considerable. Thus, each scenario informed the respondent that the additional time taken to engage in a carpool (i.e., picking up another party at some location) should be added to the travel time shown for the carpool mode. The following sections more carefully describe how the values of travel time, toll, and travel time variability were designed based on the recent trip information supplied by each respondent.

3.5.1 Time of Day

The toll values on the Katy Freeway vary according to the time of day. Therefore time of day is a very important variable in determining the tolls for the travel scenarios. Based on the respondent's recent trip start time toward/away from downtown, the time of day for the travel scenarios was determined (see Table 6).

Table 6: Time of Day Based on Trip Start Time

Trip Start Time	Time of Day	% of Respondents
12:00 AM to 6:00 AM	Night	7.2
6:00 AM to 7:00 AM	Morning Shoulder Period	13.1
7:00 AM to 9:00 AM	Morning Peak Period	20.3
9:00 AM to 10:00 AM	Morning Shoulder Period	7.2
10:00 AM to 4:00 PM	Mid-Day	27.2
4:00 PM to 5:00 PM	Evening Shoulder Period	9.9
5:00 PM to 7:00 PM	Evening Peak Period	12.5
7:00 PM to 8:00 PM	Evening Shoulder Period	1.1
8:00 PM to 12:00 AM	Night	1.5

If a respondent chose not to answer the start time of his/her recent trip, he/she was assigned a travel scenario that occurred during the peak period. If that respondent was asked about his/her trip toward downtown Houston, then the travel scenario was described as being during the morning peak or rush hour periods. Conversely if the trip was traveling away from downtown then it would have occurred during the afternoon peak period. The toll values during night and mid-day were lower than during shoulder hours which, in turn, were lower than the tolls during peak hours. Note that the actual Katy Freeway ML tolls are a little different from those provided in the hypothetical scenarios. The actual tolls for HOVs are free during peak and a standard price during off-peak.

3.5.2 Trip Distance

The respondents were also asked the point where they entered and exited the Katy Freeway. Based on this information, the traveler’s trip distance was calculated. It was also important to calculate what portion of the trip distance was along the section of the Katy Freeway where MLs actually existed. For this purpose, the Katy Freeway was divided into two sections and the distance traveled on each section was calculated. The section of the Katy Freeway from the city of Katy to the start of the MLs was defined as section one, and the section where the MLs exist was defined as section two. Only the distance traveled on section two was considered when calculating the toll. If this distance was less than 4 miles, then it was increased by 4 miles to ensure that some difference in travel times between the MLs and GPLs would be generated. If a respondent did not answer the entrance and/or exit locations, then he/she was assigned a trip distance of 12 miles on section two. This distance allocation should not induce any bias in our analysis, as the toll values are calculated based on toll per mile values that are generated using different design strategies.

3.5.3 Calculation of Toll, Average Travel Time, and Maximum/Minimum Travel Time

From the calculated trip distance (distance on section one and two) and the time of day, the toll, average travel time, and maximum and minimum travel times for each individual’s trip could be calculated. However, to finish the calculation, it is necessary to incorporate average speeds, the toll per mile, and the variability of the travel time on the lanes of each of the sections. The average speed on section one was assumed to be 60 mph irrespective of the time of day, as this section is far from downtown and often has free-flow speeds.

Next, consider the following example where a respondent answered that he traveled 15 miles on the Katy Freeway during peak hours, 5 miles on section one and 10 miles on section two. Assume the following values for the speed, toll rate, and travel time variability for the lanes on section two: average speed on GPLs is 45 mph and the variability of travel time is −30 percent to +30 percent of the mean travel time. Let average speed on MLs be 65 mph, the toll for SOVs is 30 cents/mile, there is no toll for HOVs, and the variability of travel time is −10 percent to +10 percent of the mean travel time. Using these assumed values for the example, the average travel time, toll, and maximum and minimum travel time for each mode are calculated, and the example calculations are shown in Table 7.

Table 7: Calculation of Travel Time, Toll, and Maximum/Minimum Travel Time for Each Mode

	DA-GPL	CP-GPL	DA-ML	CP-ML
Travel Time on Section 1 (rounded to the nearest minute)	(5/60)*60 = 5	(5/60)*60 = 5	(5/60)*60 = 5	(5/60)*60 = 5
Travel Time on Section 2 (rounded to the nearest minute)	(10/45)*60 = 13	(10/45)*60 = 13	(10/65)*60 = 9	(10/65)*60 = 9
Total Travel Time (minutes)	18	18	14	14
Toll	None	None	(0.30*10) = $3.00	$0.00
Variability of Travel Time (calculated based on travel time on section 2) (minutes)	(13*0.3) = 4	(13*0.3) = 4	(9*0.1) = 1	(9*0.1) = 1
Maximum Travel Time (minutes)	18 + 4 = 22	18+4=22	14+1=15	14 + 1 = 15
Minimum Travel Time (minutes)	18 – 4 = 14	18 – 4 = 14	14 – 1 = 13	14 – 1 = 13

In addition to the above calculations, the values of the toll per mile, average speed, and variability of travel time were generated using three types of designs, which are discussed in the next sections. Each respondent had an equal chance of receiving SP questions based on one of these designs.

3.5.4 D_b-Efficient Design

One of the design strategies used in this analysis was the Bayesian efficient design. As noted in Section 2.4, D-efficient are those designs that are obtained by minimizing the D-error of the asymptotic variance-covariance matrix of the parameter estimates of the discrete choice model. D_b-efficient, or Bayesian efficient, designs are found by minimizing the D_b-error. Normal distributions with non-zero means were assumed for the priors. The mean values of priors for the attributes toll and speed were obtained from the discrete choice models estimated from the previous survey conducted in 2008, and from relevant literature for travel time variability. The mean and standard deviation of the priors used for obtaining the D_b-efficient design and the exact levels of attributes used for each mode at different times of day are shown in Table 8.

Table 8: Mean, Standard Deviation of Attribute Priors, and Attribute Levels for Different Times of Day

Attribute	Attribute Levels				Mean Value of Priors	Standard Deviation of Priors
	Mode	Time of Day				
		Peak Hours	Shoulder Hours	Off-Peak Hours		
Toll (cents/mile)	**CP-ML**	0,5,10	0,2.5,5	0,1.3,3.3	-0.19	0.1
	DA-ML	8,17,35	4,8.5,17.5	2.6,5.6,11.6		
	CP-GPL	0	0	0		
	DA-GPL	0	0	0		
Speed (mph)	**CP-ML**	55,60,65	55,60,65	60,65,70	0.1*	0.7
	DA-ML	55,60,65	55,60,65	60,65,70		
	CP-GPL	25,35,45	30,40,50	45,50,55		
	DA-GPL	25,35,45	30,40,50	45,50,55		
Travel Time Variability (% of mean travel time)	**CP-ML**	5,10,15	5,10,15	5,10,15	-0.5	0.5
	DA-ML	5,10,15	5,10,15	5,10,15		
	CP-GPL	20,35,50	20,35,50	20,35,50		
	DA-GPL	20,35,50	20,35,50	20,35,50		

*Prior is the coefficient of travel time estimated from the previous survey.

The N-Gene software package was used to generate the D_b-efficient designs for this survey design strategy. To proceed, an MNL was specified for the discrete choice model, and the priors were simulated using Pseudo-Random Monte Carlo simulation with 1,000 independent draws from the prior distributions. The code used from the N-Gene software is included in Appendix B. The design for peak hours obtained from the software is shown in Table 9. The values shown in Table 9 were used as is with no random variation to calculate the attributes for each mode. The corresponding Bayesian designs for other times of day were obtained by replacing the attribute levels, as shown in Table 8. The design has 24 rows divided into 3 blocks of 8 rows. Each respondent was randomly given a choice set from each block. The D_b-error for the design was found to be 0.0497. As mentioned earlier, the smaller the D_b-error, the more efficient the design. The D_b-error for this design is very close to zero; hence, the design is an efficient design.

3.5.5 Random Attribute Level Generation Design

The second type of design strategy generated for part of the survey was the random attribute level generation method. In this method, the attribute levels of each attribute (toll per mile, average speed, and travel time variability) were generated randomly from a corresponding range of values for each attribute. The attribute levels used for each attribute at different times of day are shown in Table 10. In some choice sets generated by this method, there was a small probability that the toll for DA-ML could be smaller than the toll for CP-ML, and this would likely not appear logical to the respondents and would not give them much incentive to carpool. In those cases, the values were adjusted to maintain the logical relationship. If the random values generated for toll for mode CP-ML were found to be greater than that of mode DA-ML, then the toll for mode CP-ML was reset to 0 cents/mile. If the mean travel time (calculated using randomly generated speed on ML and GPL) for the GPL was found to be lower than that of ML, then the mean travel time of ML was set to be 3 minutes faster than that of the GPL.

Table 9: Db-Efficient Design Generated Using N-Gene Software (for Peak Hours)

Mode	CP-ML			DA-ML			CP-GPL		DA-GPL		
Choice Situation	Speed (mph)	Toll (cents/ mile)	Travel Time Variability	Speed (mph)	Toll (cents/ mile)	Travel Time Variability	Speed (mph)	Travel Time Variability	Speed (mph)	Travel Time Variability	Block
1	60	10	0.05	60	17	0.05	35	0.5	35	0.5	3
2	60	0	0.15	60	35	0.15	35	0.2	35	0.2	1
3	55	5	0.1	55	17	0.1	45	0.35	45	0.35	1
4	55	0	0.15	55	8	0.15	45	0.2	45	0.2	3
5	55	0	0.1	55	8	0.1	45	0.2	45	0.2	1
6	60	10	0.1	60	17	0.1	35	0.35	35	0.35	3
7	60	10	0.05	60	17	0.05	25	0.5	25	0.5	1
8	65	0	0.15	65	17	0.15	35	0.2	35	0.2	2
9	55	5	0.1	55	35	0.1	45	0.35	45	0.35	2
10	65	10	0.05	65	35	0.05	25	0.5	25	0.5	2
11	60	0	0.15	60	17	0.15	35	0.2	35	0.2	3
12	60	0	0.1	60	17	0.1	35	0.5	35	0.5	3
13	65	5	0.15	65	8	0.15	25	0.35	25	0.35	1
14	60	5	0.1	60	8	0.1	45	0.35	45	0.35	1
15	55	0	0.05	55	35	0.05	35	0.5	35	0.5	2
16	55	5	0.05	55	17	0.05	45	0.35	45	0.35	3
17	60	0	0.05	60	35	0.05	35	0.5	35	0.5	3
18	65	5	0.15	65	35	0.15	25	0.2	25	0.2	2
19	55	5	0.15	55	17	0.15	45	0.35	45	0.35	2
20	65	10	0.1	65	35	0.1	25	0.2	25	0.2	2
21	55	0	0.05	55	8	0.05	45	0.5	45	0.5	1
22	65	5	0.1	65	8	0.1	25	0.35	25	0.35	3
23	65	10	0.15	65	35	0.15	25	0.2	25	0.2	2
24	65	5	0.05	65	35	0.05	25	0.5	25	0.5	1

Table 10: Attribute Levels Used for Generating Random Attribute Level Design

Attribute	Attribute Levels			
		Time of Day		
	Mode	Peak Hours	Shoulder Hours	Off-Peak Hours
Toll (cents/mile)	CP-ML	0+(0 to 10)	0+(0 to 7)	0+(0 to 5)
	DA-ML	5+(0 to 28)	5+(0 to 18)	5+(0 to 14.6)
	CP-GPL	0	0	0
	DA-GPL	0	0	0
Speed (mph)	CP-ML	55+(0 to 10)	55+(0 to 10)	60+(0 to 10)
	DA-ML	55+(0 to 10)	55+(0 to 10)	60+(0 to 10)
	CP-GPL	20+(0 to 15)	30+(0 to 15)	40+(0 to 15)
	DA-GPL	20+(0 to 15)	30+(0 to 15)	40+(0 to 15)
Travel Time Variability (% of mean travel time)	CP-ML	5+(0 to 15)	5+(0 to 15)	5+(0 to 15)
	DA-ML	5+(0 to 15)	5+(0 to 15)	5+(0 to 15)
	CP-GPL	25+(0 to 25)	20+(0 to 12.5)	15+(0 to 8.6)
	DA-GPL	25+(0 to 25)	20+(0 to 12.5)	15+(0 to 8.6)

3.5.6 Adaptive Random Design

A third design method was also used and is called the adaptive random level attribute generation method. In this method, the attribute levels for the first choice set were generated using the same method used in the random level generation method (see Section 3.5.5). For the second and third choice set, the attribute levels were generated partially based on the response to the respondent's prior choice sets. The values for speed and travel time variability were generated using the same random method for the second and the third choice set. However, the toll rates were increased by a random percentage anywhere between 15 and 75 if the respondent chose a toll option and decreased between 15 and 50 if the respondent chose a non-toll option for the previous SP question.

3.6 Demographics of Respondents

Attributes of the household may also influence choices that drivers make. For example, wealthy households in the relevant population might make traveling choices that are quite different than low-income households. However, any sampling process might lead to differences between the sample and the population of interest. Note that the population of interest is not the entire Houston area population. Rather, it is the population in the area that travels on the Katy Freeway using automobiles. It is of course difficult to know the characteristics of this population, but we might suspect that they are younger and more affluent, on average, than the general population. Nevertheless, the percentage of respondents in each socio-economic category were compared to the 2010 Census Bureau Survey data of Houston and previous (2003 and 2008) Katy Freeway survey respondents to check for any sampling bias (see Table 11). The current survey sample underrepresents the age groups 16 to 24 and 65 or older; for the remaining age groups, it fairly represents the population of Houston. The survey sample also under represents the low-income group and over represents the higher-income group when compared to the 2010 Census Bureau Survey statistics.

As noted, it may be expected that the population of interest and the general population of Houston may differ. So, although the survey sample differs from the 2010 Census Bureau Survey statistics of Houston in some categories, it may be more similar to Katy Freeway automobile travelers. It is in fact close in comparison with previous survey samples. Recall that the 2008 survey (see Patil et al., 2011a,b for details of this survey) was an online survey similar to the current survey. The 2003 survey (see Burris and Figueroa, 2006, for details of this survey) was both an Internet and mail-based survey. The survey was mailed to the travelers observed on the Katy Freeway; hence, the 2003 survey sample can be assumed to be closer to the Katy Freeway travelers' demographics.

Table 11: Respondent Characteristics Compared to Other Data Sources

<table>
<tr><th colspan="2" rowspan="2">Variable of Comparison</th><th colspan="3">Percentage of Total Respondents</th><th>Percentage of Population</th></tr>
<tr><th>2010 Katy Freeway Survey</th><th>2008 Katy Freeway Survey</th><th>2003 Katy Freeway Survey</th><th>2010Census Survey Statistics</th></tr>
<tr><td colspan="2">Percentage of Males</td><td>54</td><td>58</td><td>63</td><td>50</td></tr>
<tr><td rowspan="6">Age</td><td>16 to 24</td><td>3</td><td>2</td><td>5</td><td>17</td></tr>
<tr><td>25 to 34</td><td>23</td><td rowspan="3">71</td><td rowspan="3">79</td><td>23</td></tr>
<tr><td>35 to 44</td><td>23</td><td>19</td></tr>
<tr><td>45 to 54</td><td>26</td><td>17</td></tr>
<tr><td>55 to 64</td><td>19</td><td rowspan="2">27</td><td rowspan="2">16</td><td>12</td></tr>
<tr><td>65 and older</td><td>6</td><td>12</td></tr>
<tr><td colspan="2">Average number of people in Household</td><td>2.73[a]</td><td>2.73[a]</td><td>NA</td><td>2.64[a]</td></tr>
<tr><td colspan="2">Annual Household Income < $25,000</td><td>5</td><td>3</td><td>2</td><td>29</td></tr>
<tr><td colspan="2">Annual Household Income $25,000 to $75,000</td><td>35</td><td>29</td><td>33</td><td>44</td></tr>
<tr><td colspan="2">Annual Household Income > $75,000</td><td>60</td><td>68</td><td>63</td><td>27</td></tr>
</table>

[a]Average value
NA = not available

3.7 Actual Katy Freeway Usage Data

Other than the data collected using the SP survey, data were also collected on the actual usage of the MLs during the year 2009. Two types of vehicle sensors—wavetronix and automatic vehicle identification (AVI)—are installed along the Katy Freeway by TxDOT. These sensors collect data on the speed and volume on all the lanes on the Katy Freeway. These data were used to estimate the actual VTTS, and these values were compared to the VTTS estimates from the survey.

3.7.1 Traffic Volume

Traffic volume data were collected using the wavetronix sensors. These sensors are located at different locations along east and westbound lanes on the Katy Freeway (see Figure 9). Each of these sensors collects the spot speed data on all the vehicles and also counts the number of vehicles crossing the sensor on each of the lanes. These data are aggregated for every 30 seconds and are then sent to the server. The aggregated data set includes the sensor number, the date, the time of the day of the 30 second interval, the lane number, the number of vehicles on the lane, and the average speed. The aggregated 30 second data were further aggregated to get 15 minute interval data. It was found in our investigation that the AVI data were more accurate than the wavetronix data for average speed estimation. So, only traffic volume data were extracted from the wavetronix data. The 15 minute aggregated traffic volume data were then averaged over the year 2009 to get the annual average 15 minute traffic on each of the lanes. Only the weekday traffic volumes excluding major holidays were used to estimate the annual average traffic patterns.

As mentioned above, there are two MLs in each direction of the Katy Freeway. During peak hours, HOVs are allowed to travel for free on the left ML and the other lane is open to SOVs that pay a toll. The number of general purpose lanes on the Katy Freeway varies from four to seven in each direction. Knowing the lane configuration in each direction, the 15 minute lane volumes were combined based on the lane type (ML [SOVs, HOVs] vs. GPL) to get the total vehicle volumes on GPLs and MLs (HOVs and SOVs). The aggregated data from all the sensors were then added, and the percentage of people traveling on GPLs and MLs (SOVs, HOVs) on the 12 mile section of the Katy Freeway was calculated. This information was used in the estimation of value of travel time savings.

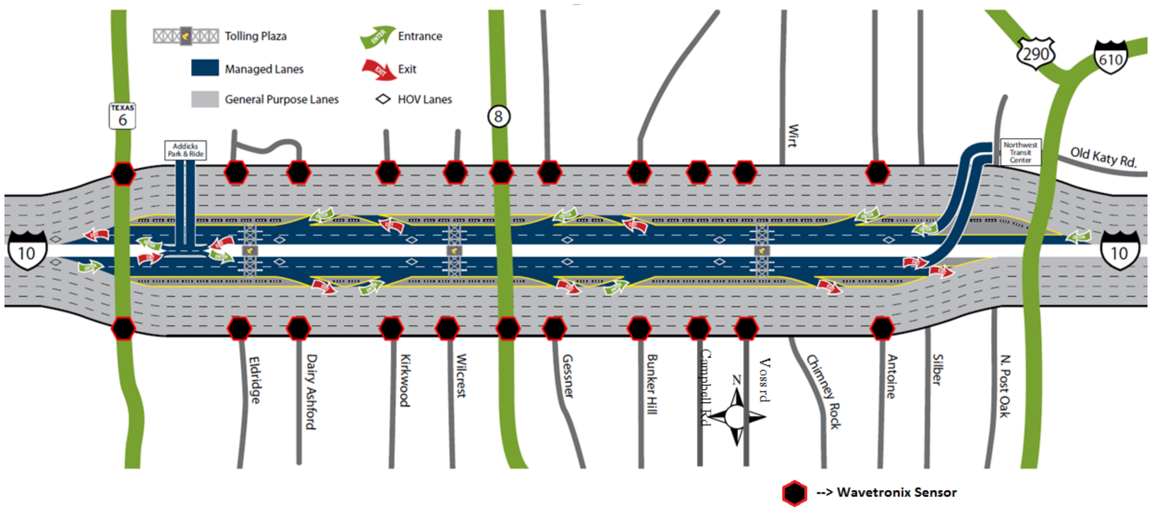


Figure 9: Wavetronix Sensor Locations on Katy Freeway

3.7.2 Travel Time

Time taken to travel the 12 mile section of the Katy Freeway along MLs and GPLs was calculated using the AVI data. AVI sensors are located on the MLs and the GPLs on each direction of the Katy Freeway (see Figure 10). Each AVI sensor identifies each transponder-equipped vehicle based on the vehicle's unique ID and records the time at which the vehicle is identified. The vehicle IDs recorded at an AVI sensor are matched with the adjacent AVI sensor data and the time difference is calculated to find the time each vehicle has taken to cover the distance between those sensors. From the travel time, the average speed is estimated. For each 15 minute period, the recorded travel time and speed data are averaged and sent to the server. The data include the starting AVI sensor ID, ending sensor ID, date, time of day of the 30 second interval, number of vehicles, average speed, and average travel time. When the sensor does not detect any vehicle in any 15 minute period, it records negative values for the speed and the travel time.

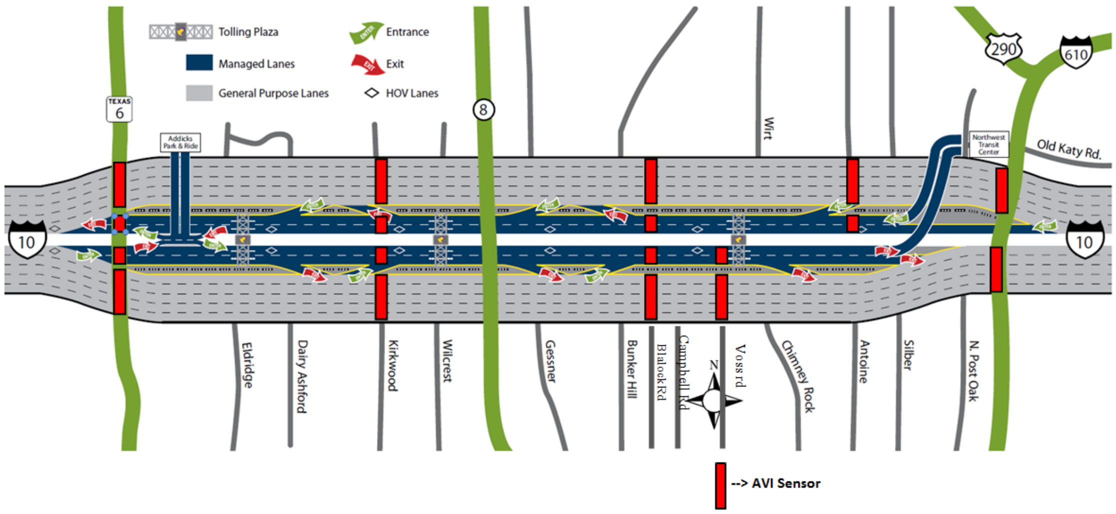


Figure 10: AVI Sensor Locations on Katy Freeway

These negative values were therefore eliminated, and the yearly averages for the year 2009 for speed were obtained for each 15 minute period for all the sections. Only weekday data excluding major holidays were used to estimate the annual average speeds on the MLs and the GPLs. The total travel time on the MLs and the GPLs for each 15 minute period of an average day for the 11.4 mile section with MLs was then estimated by estimating the average travel times in each direction (see Figure 11).

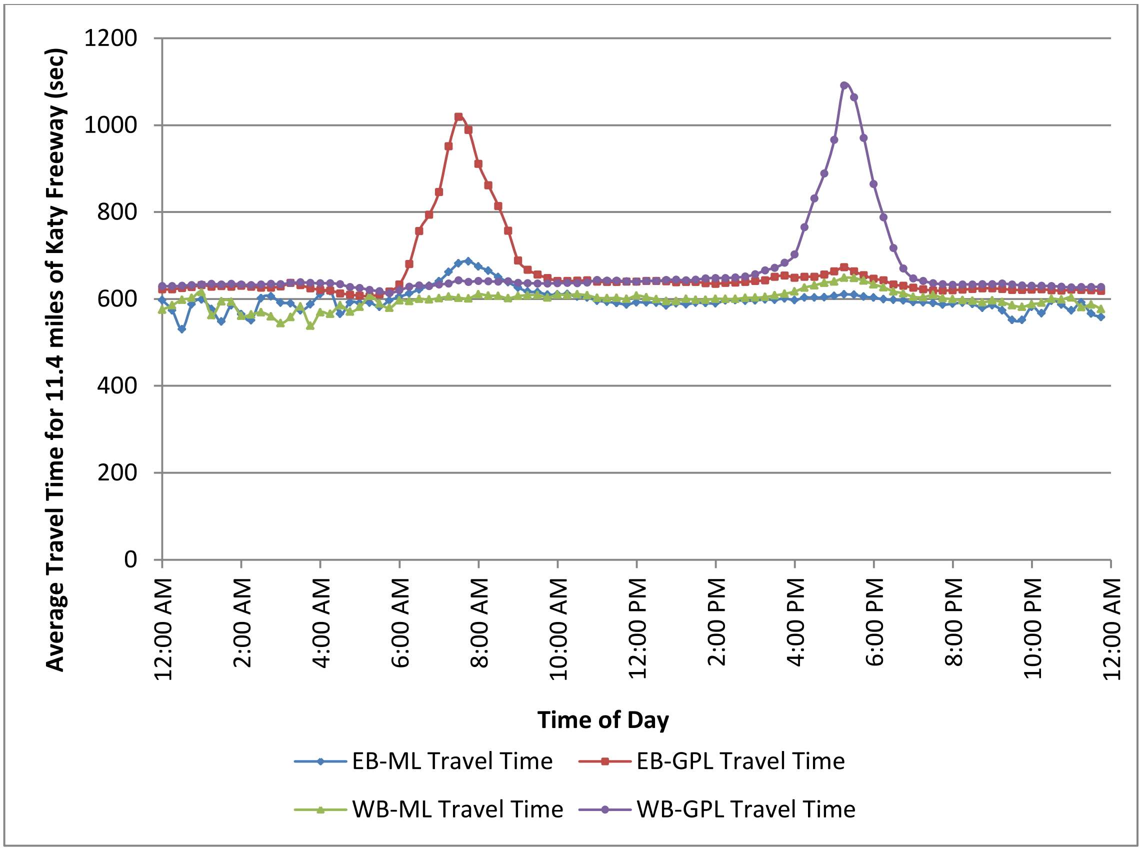


Figure 11: Average Travel Time for 11.4 Miles of Katy Freeway on the MLs and the GPLs by Time of Day

3.8 Summary

An Internet-based travel survey of Katy Freeway travelers was conducted in 2010 to achieve the objectives of this research. The survey gathered 3,325 useful responses, of those 869 were from respondents who also likely participated in 2008 survey. The responses were equally distributed among the three survey design techniques tested in this research. The data from the survey will be used to estimate discrete choice models using mixed logit model methodology described in Section 2.5.3. Models will also be developed for 869 respondents who likely responded to the 2008 survey. Those mode choice models will then be used to estimate travelers' values of travel time and travel time reliability. The values of travel time from the 2010 survey will then be compared with 2008 survey values across various designs to identify the design that better predicted the traveler behavior.

Actual ML usage data is available for the year 2009 from the sensors on the Katy freeway. The value of travel time savings will be calculated from the actual ML usage data and will be compared to the SP data models to identify the survey design that predicted the willingness to pay values closer to the actual values.

4. DATA ANALYSIS

The 3,325 responses obtained through the 2010 survey were first analyzed to check for consistency in responses and to verify if the respondents understood the various formats presented in the survey. A preliminary analysis conducted on the survey responses is presented Section 4.1. This preliminary analysis was helpful in finding sample demographic characteristics that greatly influence ML use and was also helpful in finding additional variables that require further analysis. The later sections present an in-depth analysis of the survey data, which includes estimating various discrete choice models to predict the mode choice, estimating the VTTS, and matching respondents from the current survey to the previous survey and comparing their responses.

4.1 Preliminary Analysis

4.1.1 Descriptive Analysis

The tables in this section contain information on the distribution of responses to the various questions tested in the survey. To begin, the respondents' recent trip characteristics are presented in Table 12 Table 12. Recall that respondents were randomly asked about their actual recent trip either away from or toward downtown Houston. Very few respondents (86, or 2.59 percent) used either a motorcycle or a bus for their recent trip, and thus, their responses were not considered in any analysis. It can be seen from the table that most of the trips were on weekdays. Nearly 35 percent of the respondents carpooled for their recent trip, and in those cases most of them were drivers. Almost 76 percent of carpool trips were with family members.

Table 12: Recent Trip Characteristics

Recent Trip Characteristics	Category	Percentage of Respondents
Toward or Away from Downtown	Away from Downtown	50.8
	Toward Downtown	49.2
Trip Purpose	Commuting to or from my place of work (going to or from work)	48.1
	Recreational/Social/Shopping/Entertainment/ Personal Errands	32.2
	To attend class at school or educational institute	1.1
	Work related (other than to or from home to work)	12.9
	Other	4.0
Day of the Trip	Monday	13.1
	Tuesday	16.3
	Wednesday	18.7
	Thursday	19.8
	Friday	17.7
	Saturday	9.0
	Sunday	5.4
Vehicle Type	Motorcycle	0.6
	Passenger car, SUV, or pick-up truck	97.4
	Bus	2.0
Number of People in the Vehicle	1	64.5
	2	24.4
	3	6.2
	4	3.4
	5 or more	1.5
If Carpooled, Were You Passenger or Driver?	Driver	80.0
	Passenger	20.0
Whom Carpooled with?	Co-worker/person in the same, or a nearby, office building	13.6
	Neighbor	2.8
	Adult family member	53.4
	Another commuter in a casual carpool (also known as slugging)	1.5
	Child	22.6

Table 12: Continued

Recent Trip Characteristics	Category	Percentage of Respondents
	Other	6.1
Carpool Time (minutes)	None	55.9
	0 to 5	16.5
	6 to 10	11.9
	More than 10	15.7
Used ML	Yes	30.4
	No	69.6
Reported Travel Time Savings (min)	none	3.3
	1 to 5	18.6
	6 to 10	22.0
	11 to 15	22.4
	16 to 20	14.3
	20 to 25	2.7
	26 to 30	11.6
	more than 30	5.1

The respondents' use of MLs and the reason for using or not using them are presented in Table 13. It can be seen from the table that nearly 65 percent of the respondents have used the MLs. Nearly 60 percent of those used MLs because of less congestion and predictable travel time. Note that 10 percent of the respondents indicated that MLs do not provide adequate time saved to make their use worthwhile.

The respondents were also asked how often they traveled on the Katy Freeway during the last full work week (Monday to Friday), how many of those trips were on the MLs, and on how many of those trips they were pressed for time and had a tight schedule for their travel. It is important to note that because weekend travel is typically less busy, the bulk of trips on MLs would occur on weekdays. It is also expected that these trips would occur at peak travel times since that is when the GPLs are most congeseted. Respondents were also asked what percentage of all Katy Freeway trips were on the MLs when they were pressed for time (see Figure 12 and Figure 13). It can be seen in Figure 11 that there were a relatively high percentage of respondents with 10 trips during the work week; these respondents were mostly commuting to work using the Katy Freeway. For hurried trips, most of the respondents indicated that they used MLs.

Table 13: Managed Lane Use

Managed Lane Use	Category	Percentage of Respondents
Ever Used Managed Lanes	Yes	65.2
	No	34.8
Reason for Using Managed Lanes	Being able to use the Managed Lanes for free as a carpool	13.0
	During the peak hours the Managed Lanes will not be congested	20.7
	Travel times on the Managed Lanes are consistent and predictable	12.1
	The Managed Lanes are safer/less stressful than driving on the main freeway lanes	17.2
	Travel times on Managed Lanes are less than those on the main freeway lanes	26.0
	Trucks and larger vehicles are not allowed on the Managed Lanes	7.4
	My employer pays for the tolls	1.8
	Other	1.9
Reason for Not Using the Managed Lanes	Participation in a carpool is difficult/undesirable	5.0
	I do not have a credit card needed to set up a toll account	0.9
	I do not want a toll transponder in my car	1.5
	Access to the Managed Lanes is not convenient for my trips	8.7
	The Managed Lanes do not offer me enough time savings	10.6
	Managed Lane use is complicated or confusing	8.2
	I don’t like that the toll changes based on time of day	5.8
	I have the flexibility to travel at less congested times	15.9
	I do not want to pay the toll for this trip	18.8
	I can easily use other routes than the Katy Freeway, so I’ll just avoid it if I think there is a lot of traffic	8.2
	I do not feel safe traveling on Managed Lanes	1.2
	The tolls are too high for me	9.3
	Other	5.9

Table 13: Continued

Managed Lane Use	Category	Percentage of Respondents
Average Toll Paid	$1.00 or less	21.0
	$1.01 to $2.00	21.2
	$2.01 to $4.00	30.9
	More than $4.00	8.3
	Do not Remember	18.6
Average Travel Time Savings	None	2.5
	1–2 minutes	2.3
	2–5 minutes	10.6
	6–10 minutes	22.9
	11–15 minutes	23.7
	16–20 minutes	15.0
	21–30 minutes	9.8
	More than 30 minutes	7.6
	Unsure	5.7

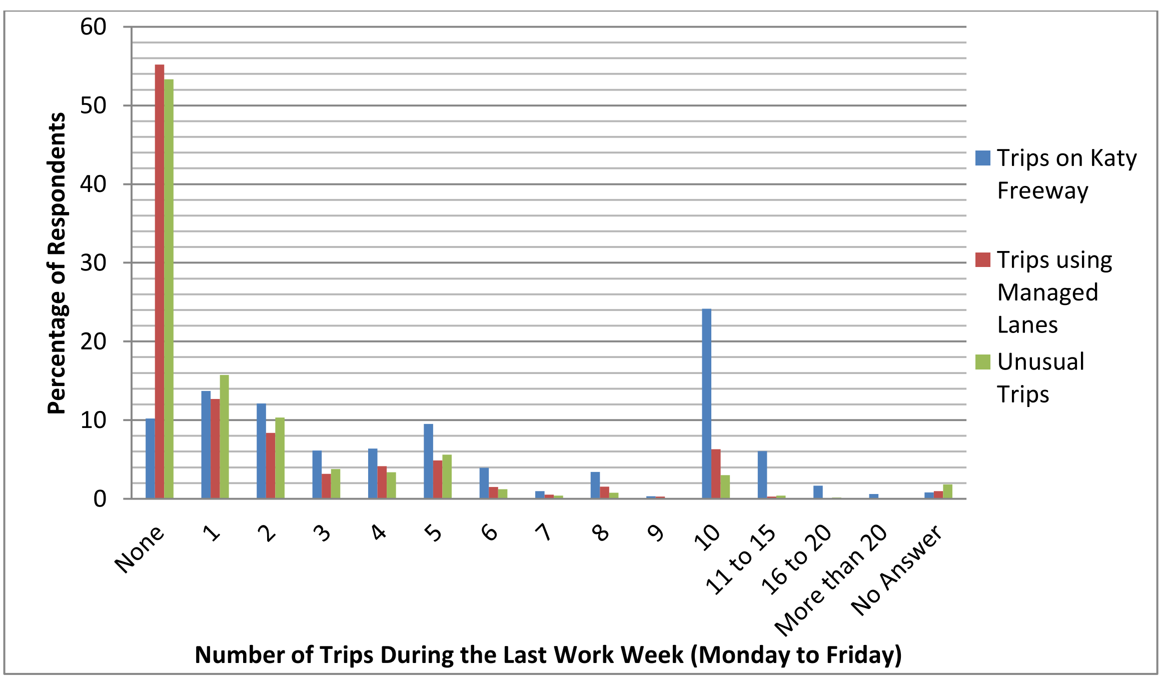


Figure 12: Number of Trips on Katy Freeway during the Last Work Week (Monday to Friday)

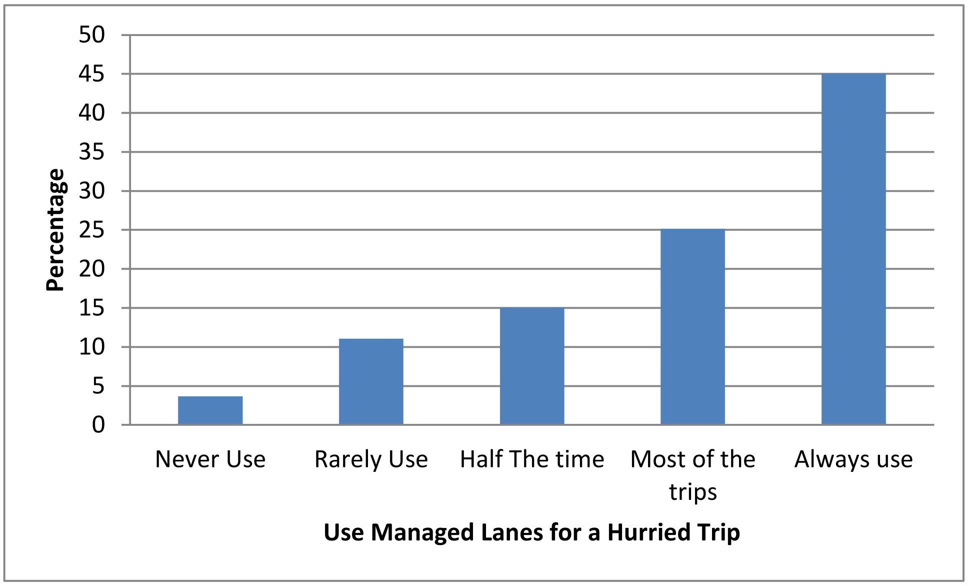


Figure 13: Frequency of Unusual (Hurried) Trips on Managed Lanes

Respondents' socio-economic characteristics and their risk-taking behavior are presented in Table 14. Recall that the risk-averse versus risk-taking question pertains to their trade-off between a trip with a longer fixed time, and one that involves risk in travel time. The riskier option might have a shorter time, but it might not. On this basis, it appears that the sample had many risk takers.

Table 14: Risk-Taking Behavior and Socio-Economic Characteristics of the Respondents

Variable	Category	Percentage of Respondents
Risk-Taking Behavior	Risk Taking	59.9
	Risk Averse	40.1
Occupation	Professional/Managerial	49.1
	Technical	11.1
	Sales	5.9
	Administrative/Clerical	9.4
	Manufacturing	1.2
	Stay-at-home homemaker/Parent	2.7
	Student	1.9
	Self-employed	7.0
	Unemployed/Seeking work	2.0
	Retired	5.7
	Educator	4.1
Education	Less than high school	0.3
	High school graduate	5.7
	Some college or vocational school	26.4
	College graduate	45.5
	Postgraduate degree	22.1

Note: Refer to Table 11 for variables Age, Income, and Gender.

4.1.2 Comparison of Respondents by Groups

Contingency tables (also referred to as cross tabulations) were created between some of the presumably more important variables to get an insight into the data and to check how responses varied across various groups of respondents. Only respondents who used passenger car/SUV or pick-up truck were considered for this analysis. Respondents who used MLs for their recent trip were examined for their socio-economic characteristics, recent trip characteristics, and risk-taking behavior. The results are shown in Table 15 and Table 16.

It can be seen that a slightly higher percentage of respondents in the age group 25 to 54 used MLs compared to other age groups. A higher percentage of respondents who carpooled used the MLs than those who drove alone for their recent trip, as might be expected because of differences in toll costs. A similar trend can also be seen across respondents' household type: a higher percentage of married respondents used the MLs than respondents who were single. For the rest of the variables, the ML use was consistent and did not change much across different categories.

Table 15: Comparison of Recent Trip Characteristics of Respondents Who Used and Did Not Use Managed Lanes

Variable	Category	Percent of Respondents who Used MLs for Their Recent Trip
Recent Trip Purpose	Commuting to or from my place of work (going to or from work)	32.2
	Recreational/Social/Shopping/ Entertainment/Personal Errands	25.0
	To attend class at school or educational institute	34.2
	Work related (other than to or from home to work)	26.8
Drove Alone or Carpooled for Recent Trip	Drive Alone	22.5
	Carpool	41.4
Risk-Taking Behavior	Risk Taking	29.6
	Risk Averse	28.6

Table 16: Demographics of Respondents Who Used and Did Not Use Managed Lanes for Their Recent Trip

Variable	Category	Percent of Respondents Who Used MLs for Their Recent Trip
Age Group	16 to 24	18.8
	25 to 34	29.9
	35 to 44	33.0
	45 to 54	29.6
	55 to 64	26.2
	65 and over	22.0
Gender	Male	28.3
	Female	29.5
Occupation	Professional/Managerial	31.4
	Technical	26.2
	Sales	29.5
	Administrative/Clerical	28.7
	Manufacturing	29.7
	Stay-at-home homemaker/Parent	36.6
	Student	26.8
	Self-employed	22.7
	Unemployed/Seeking work	32.2
	Retired	21.3
	Educator	28.7
Income	Less than $24,999	25.9
	$25,000 to $74,999	27.8
	$75,000 or more	30.3
Education	Less than high school	11.1
	High school graduate	32.8
	Some college or vocational school	32.9
	College graduate	27.0
	Postgraduate degree	28.3
Household Type	Single adult	21.2
	Unrelated adults	22.5
	Married without children	30.0
	Married with children	32.1

Table 16: Continued

Variable	Category	Percent of Respondents Who Used MLs for Their Recent Trip
	Single parent	37.2
Average Number of People in the Household		2.7* (2.9*)
Average Number of Vehicles		2.3* (2.4*)

*Indicates average values. The values in brackets indicate the average values for respondents who did not use MLs for their recent trip.

Respondents who carpooled or drove alone for their recent trip were further examined (see Table 17). As expected, a higher percentage of people carpooled for recreational trips as compared to other trip purposes. Respondents on those recreational trips were mostly accompanied by family members. A higher percentage of married respondents carpooled than respondents who were single. Also, a slightly higher percentage of low-income respondents carpooled compared to medium- and higher-income groups.

Table 17: Comparison of Respondents Who Carpooled (CP) and Who Drove Alone (DA) for Their Recent Trip

Variable	Category	Percent of Respondents who DA for Recent Trip	Percent of Respondents who CP for Recent Trip
Recent Trip Purpose	Commuting to or from my place of work (going to or from work)	82.9	17.1
	Recreational/Social/Shopping/ Entertainment/Personal Errands	36.9	63.1
	To attend class at school or educational institute	63.2	36.8
	Work related (other than to or from home to work)	74.3	25.7
Age	16 to 24	77.1	22.9
	25 to 34	65.5	34.5
	35 to 44	64.3	35.7
	45 to 54	64.1	35.9
	55 to 64	65.3	34.7
	65 and over	54.5	45.5
Gender	Male	67.2	32.8
	Female	61.5	38.5
Household Type	Single adult	78.1	21.9
	Unrelated adults	70.8	29.2
	Married without children	63.1	36.9
	Married with children	59.0	41.0
	Single parent	57.9	42.1
	Average Number of People in Household	2.62[a]	2.90[a]
	Average Number of Vehicles in the Household	2.28[a]	2.31[a]
Education	Less than high school	55.6	44.4
	High school graduate	53.5	46.5
	Some college or vocational school	62.3	37.7
	College graduate	66.4	33.6
	Postgraduate degree	66.5	33.5
Income	Less than $24,999	56.5	43.5
	$25,000 to $74,999	64.5	35.5
	$75,000 or more	65.3	34.7

[a]The values are average values, not percentages.

The responses to SP questions were analyzed to check if the logical relationships implemented in the survey were processed as hoped and also to check if the respondents understood the various formats (refer to Figure 7 and Figure 8) tested in the survey. Failure to provide a response may be an indication of confusion. The analysis of travel scenario 1 in normal and urgent situations is presented in Table 18, and similar results were also obtained for scenarios 2 and 3. It can be seen that all three of the survey designs were presented to respondents in equal percentages. The two question formats were also presented with equal probability. It can also be seen that the percentage of respondents choosing each mode were similar in both of the formats, implying that the respondents likely understood each of the formats to some extent.

Table 18: Summary of Responses to Travel Scenario 1 in Normal and Urgent Situations

	Design Type	DA-GPL	CP-GPL	DA-ML	CP-ML	% of times presented
Travel Scenario 1 (Normal Situation)	D-efficient	57.3	7.6	23.5	11.6	33.2
	Random	51.1	5.5	27.1	16.4	33.9
	Adaptive Random	56.0	4.9	24.2	15.0	32.9
Travel Scenario 1 (Urgent Situation)	D-efficient	34.7	2.6	53.7	8.9	33.2
	Random	31.0	3.2	52.7	13.0	33.9
	Adaptive Random	34.4	2.4	50.9	12.4	32.9
	Question Format					
Travel Scenario 1 (Normal Situation)	Picture Format	53.7	5.6	26.5	14.2	50.4
	Word Format	55.8	6.4	23.3	14.5	49.6
Travel Scenario 1 (Urgent Situation)	Picture Format	32.1	2.7	53.5	11.7	50.5
	Word Format	34.6	2.8	51.4	11.2	49.5

4.2 Estimation of the Value of Travel Time Savings and the Value of Travel Time Reliability

The value of travel time savings estimates from the previous 2008 survey were compared with the current 2010 survey estimates. In this section, discrete choice models developed for each of the survey designs are presented. The estimated VTTS and goodness-of-fit of the models were compared. Nlogit was used for estimating the statistical models that led to the VTTS estimates. Descriptive statistics of some of the variables used for modeling are presented in Table 19.

Table 19: Descriptive Statistics for Important Variables

Variable	**Mean**	**Std. Dev.**
Respondent’s trip purpose was recreation for the last trip on Katy Freeway (dv)	0.34	0.47
Respondent’s trip purpose was commute or work for the last trip on Katy Freeway (dv)	0.48	0.50
Respondent’s trip purpose was work related for the last trip on Katy Freeway (dv)	0.14	0.34
Respondent’s trip purpose was to attend school for the last trip on Katy Freeway (dv)	0.01	0.11
Respondent traveled during peak period (dv)	0.33	0.46
Respondent was risk taking (dv)	0.60	0.49
Respondent was a male (dv)	0.54	0.50
Respondent’s age was between 25 and 54 years (dv)	0.72	0.45
Respondent’s annual household income was less than $25,000 (dv)	0.21	0.41
Respondent’s annual household income was between $25,000 to $75,000 (dv)	0.38	0.48
Respondent’s household type was single adult household (dv)	0.23	0.42
Respondent’s household type was unmarried adults (dv)	0.03	0.17
Respondent’s household type was married (dv)	0.25	0.43
Respondent’s household type was married with children (dv)	0.42	0.49
Respondent’s household type was single parent (dv)	0.06	0.24

dv = dummy variable.

4.2.1 VTTS and VOR Estimation for D_b-Efficient Design Respondents

Of those 3,325 usable responses, 1,100 responses were obtained from respondents who were presented with SP questions developed using the D_b-efficient design. Multinomial logit models were developed, essentially using the probability of mode choice as the dependent variable and the mode attributes, trip characteristics, and socio-economic characteristics as independent variables. A step wise selection procedure was used to identify the significant variables in explaining the choices. The step wise selection method is similar to the forward selection method. In the forward selection method, an initial model is fit with no variables and in each step, variables are added to the model and the contribution of each variable to the model is calculated. The variable with the maximum contribution is added to the model, and the process is repeated until no other remaining variables add any significance to the model. Once a variable is entered in the model, it is never removed in the forward selection method. However, in the step wise selection method, a variable entered in the model may be removed at a later step. So in this method, variables are added one at a time to the model, as in the forward selection method, and in each step the variables already in the model are also tested and removed if found significant below a specified significance level (Ratner, 2003).

Each survey respondent was presented with three normal and three urgent situation SP questions. For estimating the VTTS and the VOR, only the responses from the three normal situations were used. Since multiple responses from the same individual were obtained, mixed logit models were used to model the responses. As explained in Section 3, the mixed logit framework can accommodate possible correlation patterns between the multiple responses that come from the same person. To proceed, significant explanatory variables found from the multinomial logit model were used for the initial mixed logit model. Variables with a significance value less than 0.05 were removed from the final model to yield a parsimonious specification.

200 Halton draws were used for the mixed logit simulation (refer to Equation 23). Travel time, travel time variability parameters, and alternative specific constants

(ASCs) were assumed to be random parameters. A t-distribution was assumed for the travel time and the travel time variability parameters, and a normal distribution was assumed for the ASCs. The toll parameter was assumed to be a constant to simplify the estimation of the VTTS and the VOR and to avoid behaviorally implausible values (see Section 2.5.3). The drive alone on the general purpose lanes' (DA-GPL) mode was set as the base alternative in the model. The mixed logit model estimated results are presented in Table 20. The mean values of the ASCs are all negative, implying that DA-GPL is preferred to other modes, ceteris paribus, which makes sense. The estimated values of the travel time, travel time variability, and the toll/ hourly wage rate coefficients or parameters are negative, which is in accordance with intuition, implying that higher values of these variables are less preferred in choosing a mode of travel.

Note that the hourly wage rate was estimated as the respondents' annual household income divided by 2,000 (approximate number of work hours in a year). This is a standard calculation in such surveys, as many households do not earn a known hourly wage so have difficulty reporting one. The calculation leads to an average hourly income and not a "marginal" wage rate, and thus may be lower than the actual marginal wage. The marginal wage rate reflects the lowest wage at which an individual might be willing to work an additional hour. To the extent that this is true for a given individual, then the calculated cost to their time is actually too low, and thus, may lead to an inaccurate VTTS. However, there is simply no easy and convenient way to recover the marginal wage rate in studies such as ours that focus on other issues such as travel mode choice.

The implied mean VTTS and mean VOR as a percentage of hourly wage rate were estimated by using the coefficients of travel time, travel time variability, and toll/wage rate. The mean VTTS was predicted as 63 percent ($22/hr) of the individuals' hourly wage rate. The mean VOR was predicted as 82 percent ($28/hr) of the individuals' hourly wage rate.

A separate model was developed and estimated including all the variables in Table 20 except travel time variability. This model predicted a VTTS of 97 percent ($33/hr) of the individuals' hourly wage rate. The parameter estimates of these two models were significantly different. The difference in the parameter estimates from these models suggests that there is high correlation between travel time and travel time variability. This might be true, as the travel time variability for the SP questions was estimated as a percentage of the mean travel time. A log-likelihood ratio test between the models with and without travel time variability indicated that the model with travel time variability results in a statistically significant (p-value < 0.01) improvement in model fit.

Table 20: Mixed Logit Model for Db-Efficient Design Respondents

Variable	Alternative(s)	Coefficient	Standard Error	t-ratio
Random Parameters in the Utility Functions				
ASC-CP-GPL	CP-GPL	-4.00*	0.28	-14.55
ASC-DA-ML	DA-ML	-1.41*	0.21	-6.72
ASC-CP-ML	CP-ML	-3.84*	0.33	-11.78
Travel Time (minutes)	All	-0.05*	0.02	-2.53
Travel Time Variability (minutes)	All	-0.06*	0.03	-2.14
Nonrandom Parameters in the Utility Functions				
Toll($)/Wage Rate ($/hr)	All	-4.41	1.58	-2.79
Trip Purpose Recreation (dv)	CP-GPL	0.95	0.24	4.00
Peak Period (dv)	DA-ML	0.66	0.19	3.47
Male (dv) (male = 1, female = 0)	DA-ML	-0.57	0.17	-3.43
Risk Taking (dv) (Risk Taking = 1, Risk Averse = 0)	DA-ML	-0.57	0.16	-3.52
Trip Purpose Commute/Work (dv)	DA-ML	-0.65	0.17	-3.71
Peak Period (dv)	CP-ML	0.63	0.23	2.76
Male (dv) (male = 1, female = 0)	CP-ML	-0.29	0.21	-1.41
Trip Purpose Recreation (dv)	CP-ML	0.66	0.23	2.94
Derived Standard Deviations of Random Parameters				

Table 20: Continued

Variable	Alternative(s)	Coefficient	Standard Error	t-ratio
ASC-CP-GPL	CP-GPL	2.09	0.20	10.62
ASC-DA-ML	DA-ML	1.89	0.15	12.90
ASC-CP-ML	CP-ML	2.07	0.18	11.29
Travel Time+ (minutes)	All	0.22	0.09	2.61
Travel Time Variability+ (minutes)	All	0.48	0.11	4.48
Goodness-of-fit				
Log-likelihood for Constants Only Model		-3386.17		
Log-likelihood at Convergence		-2588.17		
Log-likelihood for Model without TTV		-2591.72		
Adjusted ρ_c^2		0.23		

*Mean of the random parameter estimate.
+Spread of the distribution (standard deviation = spread/√6).
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, K_c = number of parameters in the constants only model; ASC = alternative specific coefficient; dv = dummy or indicator variable.

From the parameter estimates, it can be inferred that carpooling is more common for recreational trips. Male respondents are more likely to choose DA-GPL mode over those modes on MLs. The coefficient of the dummy variable "risk taking" is negative for the DA-ML alternative. This dummy variable relates to risk-taking behavior of the respondent. The negative sign of the coefficient indicates that respondents who are risk taking are more likely to choose GPLs over MLs while driving alone, whereas risk-averse respondents are more likely to choose MLs over GPLs while driving alone.

The triangular distributions used for travel time and reliability parameters were unconstrained and could therefore yield both negative and positive coefficients over the population. The random parameters output for the survey population generated by Nlogit contained less than 5% of the sample with a positive coefficient for the travel time and less than 15% of the sample had a positive coefficient for the reliability parameter. Although one would expect these coefficients to be negative (making the mode less desirable as travel time increases and variation in travel time increases) it is possible that a small percentage of travelers would choose a less desirable option. Data from the I-394 HOT lane in Minnesota reveal (Burris et al., 2012) a small percentage of I-394 drivers choosing to pay for the express lanes even when the GPLs were faster. This is probably due to the perception of better reliability in the express lanes. Similarly, some travelers are paying for ML travel in the off-peak period when travel time reliability may be worse in the MLs. As an additional check to determine the influence of the unconstrained parameters, the model was rerun with constrained distributions for travel time and variability parameters (see Table 21). The resulting coefficients were very similar while the overall model fit was slightly worse. Thus, we felt not artificially forcing the parameter values to be negative was best and may in fact mimic real travel behavior. Therefore, all the models developed hencefoward were left unconstrained.

Table 21: Constrained vs. Unconstrained Mixed Logit Model for Db-Efficient Design Respondents

Variable	**Alternative(s)**	**Unconstrained**		**Constrained**	
		Coefficient	**Standard Error**	**Coefficient**	**Standard Error**
Random Parameters in the Utility Functions					
ASC-CP-GPL	CP-GPL	-4.00*	0.28	-4.01*	0.28
ASC-DA-ML	DA-ML	-1.41*	0.21	-1.45*	0.20
ASC-CP-ML	CP-ML	-3.84*	0.33	-3.91*	0.32
Travel Time (minutes)	All	-0.05*	0.02	-0.05*	0.02
Travel Time Variability (minutes)	All	-0.06*	0.03	-0.06*	0.02
Nonrandom Parameters in the Utility Functions					
Toll($)/Wage Rate ($/hr)	All	-4.41	1.58	-3.80	1.36

Table 21: Continued

Variable	Alternative(s)	Unconstrained		Constrained	
		Coefficient	Standard Error	Coefficient	Standard Error
Trip Purpose Recreation (dv)	CP-GPL	0.95	0.24	0.91	0.24
Peak Period (dv)	DA-ML	0.66	0.19	0.61	0.18
Male (dv) (male = 1, female = 0)	DA-ML	-0.57	0.17	-0.60	0.16
Risk Taking (dv) (Risk Taking = 1, Risk Averse = 0)	DA-ML	-0.57	0.16	-0.55	0.16
Trip Purpose Commute/Work (dv)	DA-ML	-0.65	0.17	-0.60	0.17
Peak Period (dv)	CP-ML	0.63	0.23	0.63	0.23
Male (dv) (male = 1, female = 0)	CP-ML	-0.29	0.21	-0.26	0.20
Trip Purpose Recreation (dv)	CP-ML	0.66	0.23	0.64	0.22
Derived Standard Deviations of Random Parameters					
ASC-CP-GPL	CP-GPL	2.09	0.20	2.11	0.20
ASC-DA-ML	DA-ML	1.89	0.15	1.96	0.13
ASC-CP-ML	CP-ML	2.07	0.18	2.20	0.17
Travel Time+ (minutes)	All	0.22	0.09	0.05	0.02
Travel Time Variability+ (minutes)	All	0.48	0.11	0.06	0.02
Goodness-of-fit					
Log-likelihood for Constants Only Model		-3386.17		-3386.17	
Log-likelihood at Convergence		-2588.17		-2593.37	
Adjusted ρ_c^2		0.23		0.23	

*Mean of the random parameter estimate.

+Spread of the distribution (standard deviation = spread/√6).

4.2.2 VTTS and VOR Estimation for Random Attribute Level Generated Design Respondents

A total of 1,136 responses were obtained from respondents who were presented with SP questions developed using the random attribute generation design. Mixed logit models were developed similar to those in the previous section. For estimating the mixed logit model, 200 Halton draws were used. Travel time, travel time variability parameters, and alternative specific constants were assumed to be random parameters. A t-distribution was assumed for the travel time and the travel time variability parameters, and a normal distribution was assumed for the ASCs. However, it was found that the travel time variability parameter was not significant and was positive; therefore, it was removed from the final model (see Table 22).

The implied mean VTTS was predicted as 137 percent of the individuals' hourly wage rate ($47/hr). The mean values of ASCs were found to be negative, implying the DA-GPL mode was preferred over other modes, ceteris paribus. Similar results were observed as in the model for D_b-efficient design.

Table 22: Mixed Logit Model for Random Attribute Level Generated Design Respondents

Variable	Alternative(s)	Coefficient	Standard Error	t-ratio
Random Parameters in the Utility Functions				
ASC-CP-GPL	CP-GPL	-4.52*	0.37	-12.16
ASC-DA-ML	DA-ML	-2.36*	0.24	-9.99
ASC-CP-ML	CP-ML	-4.69*	0.37	-12.69
Travel Time (minutes)	All	-0.08*	0.02	-4.51
Nonrandom Parameters in the Utility Functions				
Toll($)/Wage Rate ($/hr)	All	-3.53	1.12	-3.16
Trip Purpose Recreation (dv)	CP-GPL	0.82	0.25	3.21
Low Annual Household Income (< $50,000) (dv)	CP-GPL	0.89	0.33	2.71
Medium Annual Household Income ($50-100,000) (dv)	CP-GPL	0.78	0.30	2.65
Peak Period (dv)	DA-ML	0.80	0.18	4.35
Risk Taking (dv) (Risk Taking = 1, Risk Averse = 0)	DA-ML	-0.46	0.14	-3.25
Trip Purpose Commute/Work (dv)	DA-ML	-0.34	0.15	-2.29
Trip Length (miles)	DA-ML	0.06	0.01	5.04
Peak Period (dv)	CP-ML	1.19	0.24	4.99
Trip Length (miles)	CP-ML	0.08	0.02	4.87
Single Adult Household (dv)	CP-ML	-0.64	0.23	-2.79
Trip Purpose Recreation (dv)	CP-ML	1.03	0.20	5.10
Derived Standard Deviations of Random Parameters				
ASC-CP-GPL	CP-GPL	1.97	0.22	8.79
ASC-DA-ML	DA-ML	1.44	0.13	10.91
ASC-CP-ML	CP-ML	2.06	0.16	12.60
Travel Time+ (minutes)	All	0.26	0.05	5.12
Goodness-of-fit				
Log-likelihood for Constants Only Model		-3625.12		
Log-likelihood at Convergence		-2698.38		
Adjusted ρ_c^2		0.25		

*Mean of the random parameter estimate.
+Spread of the distribution (standard deviation = spread/√6).
dv = dummy variable; ASC = alternative specific coefficient.

4.2.3 VTTS and VOR Estimation for Adaptive Random Design Respondents

A total of 1,089 responses were obtained from respondents who were presented with SP questions developed using an adaptive random design. Using the same methodology used for D_b-efficient design, mixed logit models were developed. Two hundred Halton draws were used to estimate the mixed logit model. Travel time, travel time variability parameters, and ASCs were assumed to be random parameters. A t-distribution was assumed for the travel time and the travel time variability parameters, and a normal distribution was assumed for the ASCs. However, it was again found that the travel time variability parameter was not significant and was positive; therefore, it was removed from the final model (see Table 23).

The implied mean VTTS for the responses from this design was estimated as 108 percent ($37/hr) of the sample mean average hourly wage rate. From the parameter estimates, similar inferences can be made as in the models for D_b-efficient design.

Table 23: Mixed Logit Model for Adaptive Random Design Respondents

Variable	Alternative(s)	Coefficient	Standard Error	t-ratio
Random Parameters in the Utility Functions				
ASC-CP-GPL	CP-GPL	-6.84*	0.67	-10.29
ASC-DA-ML	DA-ML	-2.64*	0.33	-7.97
ASC-CP-ML	CP-ML	-8.17*	0.80	-10.18
Travel Time (minutes)	All	-0.10*	0.02	-4.05
Nonrandom Parameters in the Utility Functions				
Toll($)/Wage Rate ($/hr)	All	-5.55	1.30	-4.26
Trip Purpose Recreation (dv)	CP-GPL	1.55	0.48	3.26
Peak Period (dv)	DA-ML	0.90	0.38	2.36
Trip Purpose Commute/Work (dv)	DA-ML	-1.34	0.34	-3.89
Peak Period (dv)	CP-ML	2.01	0.59	3.40
Trip Purpose Recreation (dv)	CP-ML	1.83	0.54	3.40
Single Adult Household (dv)	CP-ML	-1.19	0.61	-1.95
Derived Standard Deviations of Random Parameters				
ASC-CP-GPL	CP-GPL	3.57	0.39	9.27
ASC-DA-ML	DA-ML	3.50	0.26	13.30
ASC-CP-ML	CP-ML	5.66	0.48	11.83
Travel Time+ (minutes)	All	0.26	0.10	2.62
Goodness-of-fit				
Log-likelihood for Constants Only Model		-3265.29		
Log-likelihood at Convergence		-2059.56		
Adjusted ρ_c^2		0.37		

*Mean of the random parameter estimate.
+Spread of the distribution (standard deviation = spread/√6).
dv = dummy variable; ASC = alternative specific coefficient.

4.2.4 VTTS and VOR Estimation for All-Inclusive Sample

A mixed logit model was developed for the overall sample (3,325 responses) to estimate the overall implied mean VTTS and mean VOR (see Table 24). Using the same methodology used for D_b-efficient design, mixed logit models were developed. Two hundred Halton draws were used to estimate the mixed logit model. Travel time, travel time variability parameters, and ASCs were assumed to be random parameters. A t-distribution was assumed for the travel time and the travel time variability parameters, and a normal distribution was assumed for the ASCs.

Table 24: Mixed Logit Model for All-Inclusive Sample

Variable	Alternative(s)	Coefficient	Standard Error	t-ratio
Random Parameters in the Utility Functions				
ASC-CP-GPL	CP-GPL	-6.37*	0.74	-8.66
ASC-DA-ML	DA-ML	-3.79*	0.28	-13.60
ASC-CP-ML	CP-ML	-8.87*	0.46	-19.41
Travel Time (minutes)	All	-0.08*	0.02	-4.50
Travel Time Variability (minutes)	All	-0.14*	0.04	-3.71
Nonrandom Parameters in the Utility Functions				
Toll($)/Wage Rate ($/hr)	All	-7.71	0.78	-9.94
Trip Purpose Recreation (dv)	CP-GPL	1.56	0.26	5.90
Graduate (College Graduate = 1, else 0) (dv)	CP-GPL	-0.81	0.46	-1.75
Trip Length (miles)	CP-GPL	0.03	0.02	1.51
Low Annual Household Income (< $50,000) (dv)	CP-GPL	1.50	0.36	4.18
Medium Annual Household Income ($50-100,000) (dv)	CP-GPL	0.59	0.30	1.96
Single Adult Household (dv)	CP-GPL	-1.21	0.35	-3.48
Married with Children Household (dv)	CP-GPL	-0.40	0.28	-1.42
Peak Period (dv)	DA-ML	1.07	0.21	5.16
Trip Length (miles)	DA-ML	0.10	0.02	6.58
Trip Purpose Commute/Work	DA-ML	-1.18	0.18	-6.46

Table 24: Continued

Variable	Alternative(s)	Coefficient	Standard Error	t-ratio
(dv)				
Single Adult Household (dv)	DA-ML	-0.27	0.22	-1.23
Peak Period (dv)	CP-ML	1.42	0.32	4.49
Trip Length (miles)	CP-ML	0.13	0.02	5.48
Trip Purpose Recreation (dv)	CP-ML	1.44	0.27	5.36
Single Adult Household (dv)	CP-ML	-0.76	0.36	-2.14
Heterogenity in Mean				
Travel Time Variability*Male (dv)	All	0.06	0.03	1.86
Travel Time Variability*Risk Taking (dv)	All	0.09	0.03	2.55
Derived Standard Deviations of Random Parameters				
ASC-CP-GPL	CP-GPL	3.72	0.22	17.02
ASC-DA-ML	DA-ML	1.82	0.20	8.88
ASC-CP-ML	CP-ML	5.02	0.20	25.50
Travel Time+ (minutes)	All	0.50	0.05	9.20
Travel Time Variability+ (minutes)	All	0.19	0.11	1.73
Error Components for Alternatives and Nests of Alternatives Parameters				
Standard Deviation, θ_1	GPL alts	2.82	0.18	15.94
Standard Deviation, θ_2	ML alts	0.87	0.22	3.96
Goodness-of-fit				
Log-likelihood for Constants Only Model		-10339.56		
Log-likelihood at Convergence		-6258.25		
Adjusted ρ_c^2		0.39		

*Mean of the random parameter estimate.
+Spread of the distribution (standard deviation = spread/√6).
dv = dummy variable; ASC = alternative specific coefficient.

The implied mean VTTS for the all-inclusive model was estimated as 65 percent (or \$22/hr) of the sample mean hourly wage rate. The implied mean VOR for the all-inclusive model was estimated as 108 percent (or \$37/hr) of the sample mean hourly wage rate. The values estimated from this model are very close to those values estimated from the D_b-efficient design model. Several variables were also checked to see if there exists preference heterogeneity in the means of the random parameters. Two dummy variables were included in the model to incorporate preference heterogeneity in the means of the travel time variability parameter, with one dummy variable for gender and one for risk-taking behavior. Preference heterogeneity in the means of travel time was also tested in the model but was found insignificant. This implies that travel time savings are equally valued across males and females. The same is also true for people with different risk-taking behaviors with respect to their trip choice. It is interesting to note that the coefficients for preference heterogeneity in the travel time variability are both positive, implying that females value travel time reliability more than males and a risk-averse person values travel time reliability more than a risk-taking person. The resulting marginal utility expression of the parameters for the travel time variability variable is given in Equation 24.

$$\beta_{travel\ time\ variability} = \bar{\beta}_{travel\ time\ variability} + \delta_{1t} \times Male + \delta_{2t} \times Risk\ Taking + \bar{\beta}_{travel\ time\ variability} \times t \quad (24)$$

where, $\bar{\beta}_{travel\ time\ variability}$ is the estimated population means of the triangular distribution corresponding to the travel time variability,

δ_{1t}, δ_{2t} are heterogeneities in the means of travel time variability parameters, and

t is randomly drawn from a triangular distribution (refer to Section 2.5.3).

Using Equation 24, the implied mean VOR for risk-averse males can be estimated as shown in Equation 25. Similarly, the implied mean VOR for other categories can be estimated.

$$\mu_{M,RA} = \frac{\beta_{travel\ time\ variability}}{\bar{\beta}_c} = \frac{\bar{\beta}_{travel\ time\ variability} + \delta_{1t} \times 1 + \delta_{2t} \times 0}{\bar{\beta}_c} = \frac{-0.14+0.06}{-7.71} \times 60 = 62.2\%\ \text{of mean hourly wage rate} \quad (25)$$

where, $\mu_{M,RA}$ is the implied mean VOR for risk-averse males, and

$\bar{\beta}_c$ is the estimated coefficient of the toll/wage rate parameter.

For males who are risk averse, the implied mean VOR was estimated as 62 percent of the sample mean hourly wage rate. Similarly, for females who are risk averse, the implied mean VOR was estimated as 108 percent of the sample mean hourly wage rate.

The GPL and the ML alternatives were further grouped in their error components to account for additional sources of preference heterogeneity not accounted for in the random parameterization and its associate decomposition. The standard deviation parameters ($\theta_1$and θ_2) that capture the heterogeneity profile of additional unobserved effects associated with these two groups of alternatives were therefore additionally estimated and were found to be statistically significant. This suggests that there is a noticeable amount of preference heterogeneity associated with both groups (general purpose and ML alternatives) that is not accounted for by the random parameters (ASCs).

4.2.5 How did Travelers Interpret and Value Travel Time and Travel Time Variability

The travel time attributes for each alternative were described using an average travel time and the range it could vary. It is possible that each respondent might have interpreted the reliability (in terms of travel time) of each alternative in a different way. For example, one traveler might have chosen an alternative in a choice set based on the average travel time and the range of travel times and some might have have made their decision based on minimum travel time and the range of travel time. This interpretation of travel times might also depend on respondent characteristics, such as attitude towards risk, gender etc. Depending on how a traveler might have interpreted the travel time and travel time variability the VTTS and VOT would vary. It is desirable to know how a respondent perceived the travel time attributes in making the mode choice decision. To examine this, three types of discrete choice models were fit to the data, the models differ on how the travel time and travel time variability enter in the model (see Table 25).

Table 25: Variation of Travel Time and Travel Time Variability in the Choice Models

	Travel Time	Travel Time Variability
Model 1	Minimum Travel Time	Range of Travel Time (Maximum Travel Time – Minimum Travel Time)
Model 2	Minimum Travel Time	Range of Travel Time as a Percentage of Average Travel Time (Range / Average Travel Time)%
Model 3	Average Travel Time	Standard Deviation of Travel Time (assuming travel time is uniformly distributed in the given range)

Mixed logit models were developed for the overall sample (3,325 responses) using the same methodology described in earlier models (see Table 26). Two hundred Halton draws were used to estimate the mixed logit models. Travel time, travel time variability parameters, and ASCs were assumed to be random parameters. A t-distribution was used to define the travel time parameter in all the three models. For models 1 and 3, a t-distribution was used to define travel time variability parameter. Unlike the models 1 and 2, the travel time variability in model 2 is a ratio of range of travel times and mean travel time, however, the distribution of this parameter is not known. Several distributions were used to define this parameter in the models, among those normal distribution best defined the parameter, and thus it was used to define travel time variability parameter in model 2.

Table 26: Mixed Logit Models for Different Variations of Travel Time and Travel Time Variability

Variable	Alternative(s)	Coefficient (t-ratio)		
		Model 1	Model 2	Model 3
Random Parameters in the Utility Functions				
ASC-CP-GPL	CP-GPL	-6.36* (-10.98)	-6.06* (-11.23)	-6.87* (-13.80)
ASC-DA-ML	DA-ML	-3.70* (-13.94)	-4.08* (-14.42)	-3.39* (-10.83)
ASC-CP-ML	CP-ML	-9.43* (-15.15)	-9.46* (-15.53)	-8.93* (-14.36)
Travel Time (minutes)	All	-0.09* (-5.15)	-0.13* (-6.67)	-0.09* (-4.43)
Travel Time Variability (minutes)	All	-0.11* (-6.64)	-0.03* (-6.52)	-0.28* (-3.71)
Nonrandom Parameters in the Utility Functions				
Toll($)/Wage Rate ($/hr)	All	-6.89 (-5.75)	-6.71 (-5.80)	-7.94 (-6.78)
Trip Purpose Recreation (dv)	CP-GPL	1.46 (4.68)	1.39 (4.67)	1.47 (5.27)
Trip Length (miles)	CP-GPL			0.05 (2.37)
Low Annual Household Income (< $50,000) (dv)	CP-GPL	0.81 (2.20)	0.86 (2.51)	0.92 (2.79)
Weekday Trip (dv)	CP-GPL	-0.42 (-1.04)	-0.45 (-1.15)	
Single Adult Household (dv)	CP-GPL	-0.90 (-2.58)	-0.85 (-2.55)	-0.84 (-2.59)
Peak Period (dv)	DA-ML	1.21 (5.76)	1.23 (5.76)	1.08 (5.13)
Trip Length (miles)	DA-ML	0.08 (4.94)	0.10 (6.34)	0.08 (4.76)
Trip Purpose Commute/Work (dv)	DA-ML	-1.01 (-5.51)	-1.05 (-5.62)	-1.02 (-5.30)
Single Adult Household (dv)	DA-ML			-0.38 (-1.53)
Married with Children Household (dv)	DA-ML			-0.43 (-2.06)
Peak Period (dv)	CP-ML	1.47 (4.46)	1.51 (4.66)	1.28 (3.72)

Table 26: Continued

Variable	Alternative(s)	Coefficient (t-ratio)		
		Model 1	Model 2	Model 3
Trip Length (miles)	CP-ML	0.16 (6.01)	0.17 (6.48)	0.16 (6.08)
Trip Purpose Recreation (dv)	CP-ML	1.61 (5.23)	1.52 (5.04)	1.46 (4.45)
Single Adult Household (dv)	CP-ML	-0.49 (-1.47)	-0.52 (-1.57)	-0.68 (-1.93)
Heterogenity in Mean				
Travel Time Variability*Male (dv)	All	0.05 (3.48)	0.01 (3.53)	0.22 (3.31)
Travel Time Variability*Risk Taking (dv)	All	0.04 (2.43)	0.01 (3.04)	0.15 (2.14)
Derived Standard Deviations of Random Parameters				
ASC-CP-GPL	CP-GPL	3.91 (14.38)	3.67 (15.67)	3.66 (13.64)
ASC-DA-ML	DA-ML	3.21 (22.50)	3.31 (22.78)	3.07 (18.96)
ASC-CP-ML	CP-ML	5.27 (18.58)	5.18 (18.73)	4.91 (15.97)
Travel Time[+] (minutes)	All	0.41 (4.45)	0.36 (4.21)	0.58 (5.00)
Travel Time Variability[+] (minutes)	All	0.22 (3.94)	0.02 (4.68)	1.19 (2.80)
Goodness-of-fit				
Log-likelihood for Constants Only Model		-10339.56	-10339.56	-10339.56
Log-likelihood at Convergence		-6335.57	-6331.61	-6354.94
Adjusted ρ_c^2		0.38	0.38	0.38
Derived Values				
VTTS (as a Percentage of Hourly Wage Rate)		77 %	114 %	66 %
VOR (as a Percentage of Hourly Wage Rate)		99 %	23[a] %	211 %

[*]Mean of the random parameter estimate.
[+]Spread of the distribution (standard deviation = spread/√6).
[a]Per minute of average travel time savings
dv = dummy variable; ASC = alternative specific coefficient.

It can be seen from Table 26 that the VTTS and the VOR varied across the models. The model fits are comparable among the three models; they fit the data with almost equal goodness-of-fit values. Among the three models, model 1 has the VTTS and the VOR in the range found in literature. Comparing the models in Table 26 with the model in Table 24 it can be said that the model in Table 24 slightly better fit the data. This might suggest that the respondents' mode choice decision was based on average travel time and the range of travel times.

4.3 Comparing Survey Designs for Efficiency in Parameter Estimation

The prediction success (the percentage of correct predictions) for the models developed in Section 4.2 were compared to investigate the influence of design on the prediction capabilities of the models. The percentage of correct predictions for each mode by each design is presented in Table 27. It can be seen from the table that both the random design strategies better predicted the ML travel than the D_b-efficient design strategy. The D_b-efficient strategy was found to be better in predicting GPL travel than the other two design strategies. Burris and Patil (2009) noted that the model that better predicts the smaller trip shares is often more useful to transportation policymakers, as trips by those modes (such as bike, transit, etc.) are often difficult to predict but are critical in our efforts for a more sustainable transportation system.

Table 27: Percent of Correct Prediction for Each Alternative

Design Strategy	CP-GPL	DA-GPL	DA-ML	CP-ML	All Modes
D_b-Efficient	7.2%	60.1%	25.2%	12.4%	43.0%
Random Level Generation	6.5 %	54.9%	30.0%	19.3%	39.6%
Adaptive Random	5.1%	58.3%	25.8%	15.9%	42.6%

When comparing the implied mean VTTS estimated by the three models (Tables 20, 22, 23), it can be seen that the VTTS estimates by the random design strategy (as

136 percent of the sample mean hourly wage rate) and the adaptive random design strategy (as 108 percent of the sample mean hourly wage rate) were nearly twice that estimated by the D_b-efficient design strategy (63 percent of the sample mean hourly wage rate). Similar values as estimated by the D_b-efficient design were also found in literature. The high values estimated by the random level generation design strategy points out that caution needs to be taken while choosing attribute levels in the design. In the adaptive random design strategy, the toll value varied based on the response to previous SP questions, so the implied mean VTTS estimated by this design may be sought as the upper limit of the VTTS. Only the D_b-efficient design strategy was able to estimate the VOR. From the above discussion, it can be said that the D_b-efficient design better predicted the VTTS and the VOR.

D-error and A-error metrics are indicators of the precision of the parameter estimates estimated by a model. The D-error and A-error values depend on the sample size. In this study, we have additionally tested the sample size effect on these values. The D-error and A-error values were calculated for 150, 200, 500, 700, 1000, and 2000 randomly drawn responses from each corresponding design (see Table 28). The D-error and A-error values were calculated from the MNL model developed for each sample. Fifty random draws of each sample were taken from the overall sample, and fifty MNL models were developed. The mean D-error and A-error were calculated by taking the mean of D-error and A-error over the 50 models estimated from the random draws. From the table, it can be seen that all the values are small and similar. Among the three designs tested, D_b-efficient design has the lowest values for D-error and A-error, followed by the adaptive random design and then the random level generation design strategies. The low values by the D_b-efficient design indicate that the D_b-efficient design yields the most efficient parameter estimates, followed by the adaptive random design and then the random level generation design.

Table 28: Efficiency of Designs for Different Sample Sizes

Design Strategy	Sample Size (# choice situations)						Full Sample D_b-Efficient = 3300 Random = 3418 Adaptive Random = 3267
	150	200	500	700	1000	2000	
	D-error*						
D_b-Efficient	0.0241	0.0176	0.0068	0.0048	0.0034	0.0017	0.0011
Random Level Generation	0.0288	0.0211	0.0082	0.0059	0.0041	0.0020	0.0013
Adaptive Random	0.0242	0.0183	0.0071	0.0050	0.0035	0.0017	0.0011
	A-error*						
D_b-Efficient	0.8889	0.8424	0.7188	0.6783	0.6394	0.5694	0.5282
Random	0.9280	0.8805	0.7517	0.7110	0.6689	0.5948	0.5500
Adaptive Random	0.8893	0.8472	0.7251	0.6849	0.6435	0.5730	0.5300

*Based on 50 random draws corresponding to each sample size.

In this section, the design strategies tested in this survey were compared against each other. In the next section, the current 2010 survey responses from those who also completed the previous survey were compared to the previous (2008) survey responses to check which survey design strategy better predicted the VTTS.

4.4 Comparing Current (2010) Survey Responses with the Previous (2008) Survey

On June 17, 2010, emails were sent to the 3,077 previous survey respondents who indicated a willingness to take the follow-up survey alerting them to the new survey and encouraging them to participate. Upon verifying the referral URL to the survey, it was found that almost all of the 869 responses on June 17 and 18 were directed from emails. Therefore, the 869 responses on those dates were all assumed to be responses from the previous survey respondents. Clearly, there may be a few of these 869 respondents who had not participated in the previous survey. However, the evidence (referral URL + responses [see Figure 6]) indicates most would be repeat respondents. In this section, mixed logit models were developed for those 869 respondents (see Table 29), assuming that this group did complete the 2008 survey, and were compared to the 2008 survey estimates of VTTS by different design strategies.

Similar to the models in Section 4.2, 200 Halton draws were used to estimate the mixed logit model for these 869 respondents. Travel time, travel time reliability parameters, and ASCs were assumed to be random parameters. A t-distribution was assumed for the travel time and travel time reliability parameters, and a normal distribution was assumed for the ASCs. Only the travel time, travel time reliability, toll/hourly wage rate, and ASCs were included in the model to mimic the models developed from the 2008 survey responses. The implied mean VTTS for this model was estimated as 48 percent of the sample mean hourly wage rate, and the VOR was estimated as 56 percent of the sample mean hourly wage rate.

From the 2008 survey, the VTTS was estimated as 55 percent, 52 percent, and 40 percent of the hourly wage rate by D_b-efficient, random level generation, and smart random design strategies, respectively. By comparing those values with the current (2010) estimates, it was found that the 2008 values were similar to the current estimates.

Table 29: Mixed Logit Model for Responses from the 869 Previous Survey Respondents

Variable	Alternative(s)	Coefficient	Standard Error	t-ratio
Random Parameters in the Utility Functions				
ASC-CP-GPL	CP-GPL	-9.86*	1.48	-6.67
ASC-DA-ML	DA-ML	-2.93*	0.30	-9.87
ASC-CP-ML	CP-ML	-7.22*	0.62	-11.66
Travel Time (minutes)	All	-0.12*	0.03	-3.81
Travel Time Variability (minutes)	All	-0.14*	0.06	-2.39
Nonrandom Parameters in the Utility Functions				
Toll($)/Wage Rate ($/hr)	All	-15.08	2.24	-6.74
Derived Standard Deviations of Random Parameters				
ASC-CP-GPL	CP-GPL	5.91	0.88	6.73
ASC-DA-ML	DA-ML	3.44	0.30	11.49
ASC-CP-ML	CP-ML	5.86	0.56	10.55
Travel Time+ (minutes)	All	0.17	0.09	1.92
Travel Time Variability+ (minutes)		1.08	0.15	7.36
Goodness-of-fit				
Log-likelihood for Constants Only Model		-2577.79		
Log-likelihood at Convergence		-1736.38		
Adjusted ρ_c^2		0.32		

*Mean of the random parameter estimate.
+Spread of the distribution (standard deviation = spread/√6).
Dv = dummy variable; ASC = alternative specific coefficient.

Since the values estimated from the 2010 survey were similar to those estimated from the 2008 survey, this suggests that travelers' willingness to pay for travel on MLs was similar to what was predicted in the 2008 survey. Further, the 869 responses from the 2010 survey respondents who also responded to the 2008 survey were analyzed to check their use of MLs (see Table 30), and 66.3 percent of those respondents had used MLs. This compares favorably to the percentage who, in 2008, predicted that they would (42.9 percent) or might (34.5 percent) use MLs once they opened. More than 80 percent of them reported that they had saved a travel time of more than 5 minutes. Nearly 59 percent of those who used MLs said that they paid for their travel on the lanes.

Table 30: Managed Lane Usage Found in the 2010 Survey of the 869 Respondents of the 2008 Survey

Managed Lane Use	**Category**	**Percentage of Respondents**
Predicted Interest in Using Managed Lanes*	Yes	42.9
	No	22.5
	Maybe	34.5
Ever Used Managed Lanes+	Yes	66.3
	No	33.7
Paid for Travel on the Managed Lanes+	Yes	58.7
	No	31.3
Average Toll Paid+	$1.00 or less	24.0
	$1.01 to $2.00	20.8
	$2.01 to $4.00	30.7
	More than $4.00	5.0
	Do not Remember	19.6
Average Travel Time Savings+	None	0.6
	1–2 minutes	1.2
	2–5 minutes	11.3
	6–10 minutes	26.9
	11–15 minutes	22.8
	16–20 minutes	14.2
	21–30 minutes	9.5
	More than 30 minutes	7.8
	Unsure	5.8

*Responses from 2008 survey.
+Responses from 2010 survey.

From the reported average toll paid by those 869 survey respondents and the average travel time savings they reported in the survey, the respondents' perceived value of travel time savings was estimated (see Figure 14). The value of travel time savings for those 869 respondents was also estimated from the mixed logit model developed from the SP responses. The SP estimates of VTTS are higher than the travelers' perceived VTTS (see Figure 14). The plot implies that travelers are willing to pay a higher price for travel time savings than what they are actually paying now. The weighted average VTTS was also calculated from the reported and stated responses. The perceived weighted average VTTS from the reported average toll paid and average travel time savings was estimated as $13/hr, and the weighted average VTTS from the SP responses was estimated as $28/hr. The SP survey estimates are nearly twice as much as those perceived by the respondents. This is in contrast with what was found in literature, RP values were twice as much as those estimated from SP survey. The divergence of RP values from SP values might be attributed to traveler's disability to perceive and report the travel time savings they experienced. This will be examined in detail in Section 4.6 of this dissertation.

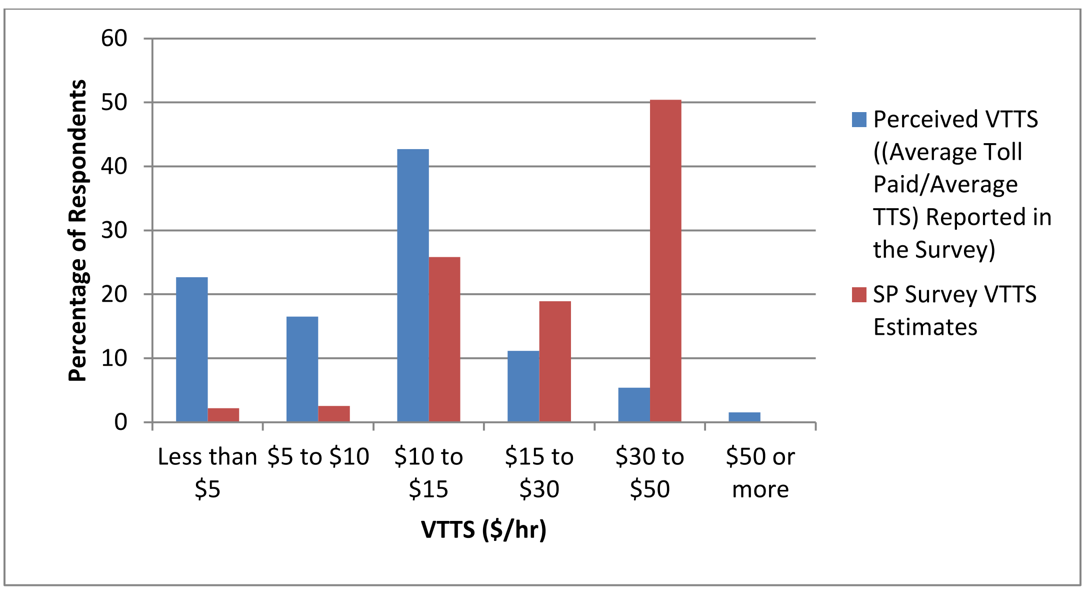


Figure 14: Reported vs. Implied Mean VTTS

4.5 Comparison of SP Trip Survey Results to Actual Trip Patterns

As described in Section 3.6.1, the traffic volume data on MLs and GPLs were collected using independent sources of information. The actual average percentage of travelers using MLs were plotted to see if travelers were taking advantage of the MLs (see Figure 15). One of the two managed lanes in each direction is an HOV lane and allows HOVs to travel for free during peak and shoulder hours (5:00 AM to 11:00 AM and 2:00 PM to 8:00 PM). In Figure 15, ML (HOV) represents the HOV lane and ML (pay) represents the SOV lane. Recall that these data were obtained from sensors which are placed near the toll sensors, so there could be some vehicles which changed lanes after they were recorded and were therefore classified incorrectly. For example, the sensor where the data was obtained might have registered 15 vehicles in the HOV ML and 25 vehicles in the SOV ML. Shortly after passing this sensor, but before the toll sensors, a vehicle could have switched from the HOV ML to the SOV ML. The true volumes would then be 14 HOVs on the ML and 26 SOVs on the ML, but our values would remain 15 and 25. Note that the sensors used here are very close to the toll sensors, so this should cause minimal error.

It can be seen from the plot that the percentage of vehicles using the MLs as SOVs was almost equal to the percentage of vehicles using them as HOVs. During peak hours, almost 20 percent of the Katy Freeway vehicles were using the MLs. Surprisingly, even during off-peak hours, some travelers were paying a toll to use the MLs when the travel time savings are minimal or none. Similar findings were also reported by Cho et al. (2011) based on their study on I-394 in Minnesota. They found that many travelers have shown a willingness to pay to travel on HOT lanes to obtain minimal travel time savings. They indicated that additional factors other than travel time savings are influencing the travelers to pay to use the HOT lanes. The authors have referenced a few surveys on express lane travelers and pointed out that travel time savings, travel time reliability, perceived sense of safety, better enforcement, and better emergency response were major factors for this behavior.

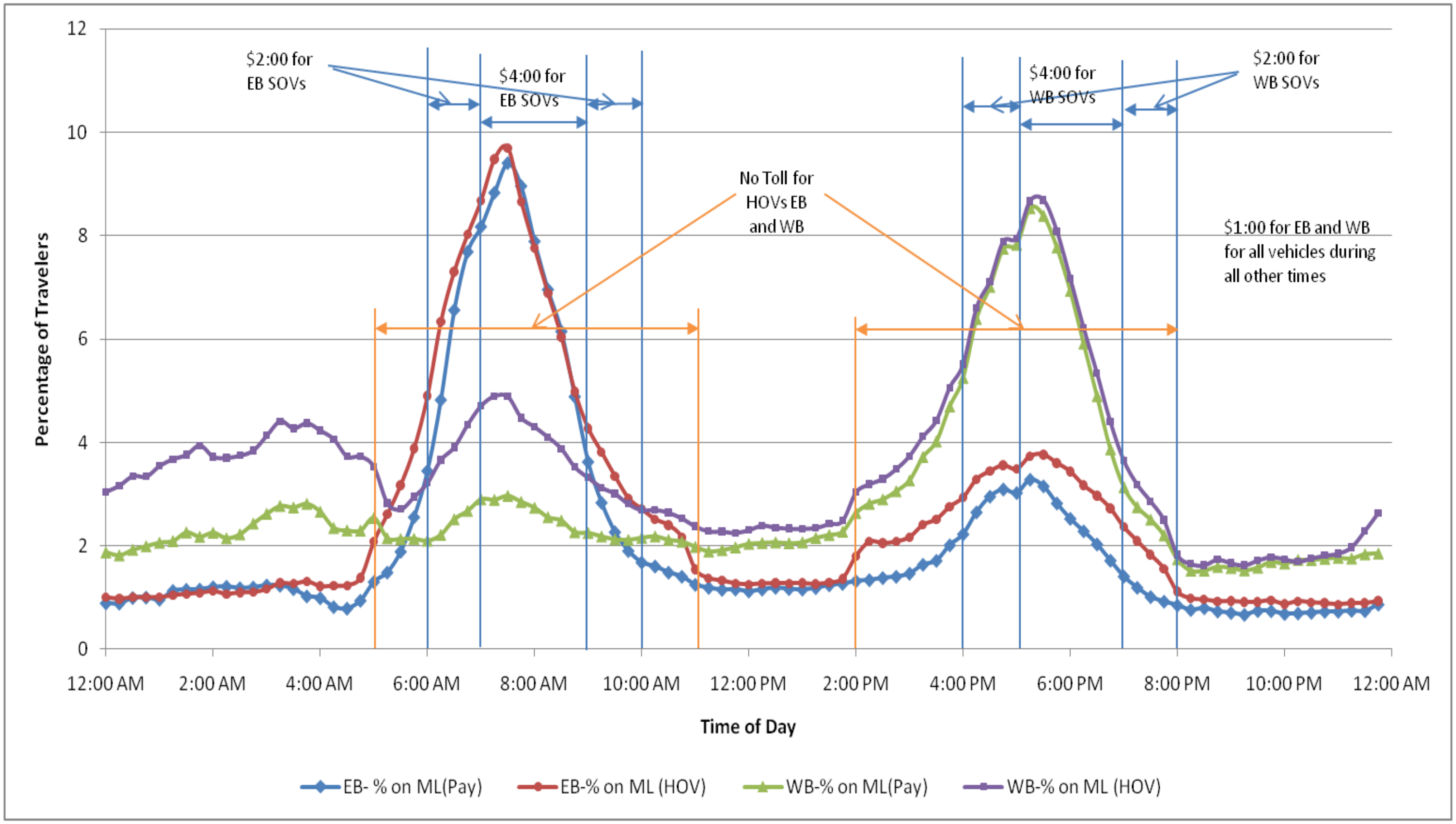


Figure 15: Average Percentage of Travelers on the MLs by Time of Day

The average actual travel times along the MLs and the GPLs were plotted to see if there was any difference between the travel times (see Figure 11). The data used were from the year 2009, excluding holidays and weekends. It can be seen from Figure 11 that the travel time on MLs remained almost constant throughout the day. Conversely, the travel time on the GPLs had two high peaks, one during the morning peak and one during the evening peak hours. During peak hours, the travel time on GPLs was nearly 60 to 80 percent higher than that on MLs.

From the travel time data, the average travel time savings were estimated for the 11.4 mile section of the Katy Freeway for both the east and westbound directions (see Figure 16). The travel time savings were higher for the westbound direction than those for the eastbound direction. During any time of the day, a maximum of only 10 percent of travelers paid a toll to reduce their travel time. While it is appropriate to say that the ML users value travel time savings, it may not be correct to say that only those who use the MLs value travel time savings. The travelers who are using GPLs may also value travel time savings but not enough to pay a toll for their travel. So, it is important to include the GPL travelers while calculating the average VTTS for all Katy Freeway travelers. However, it is not known how much a GPL traveler values his/her travel time savings. For the calculation purpose, it was assumed that a GPL traveler valued his/her travel time savings one-half as much as an ML user. For example, suppose that an ML traveler saved 1 minute of travel time by paying a toll of $1, so his/her VTTS is $60/hr. The GPL traveler's VTTS can range between $0 to $59.99/hr. It was assumed to be the average of these extreme values: $30/hr. Since the percentage of travelers on each of the lanes (GPL, SOV ML, and HOV ML) was known, the average VTTS was estimated as the weighted average of all the travelers. During peak hours, HOVs do not need to pay, so these were excluded in the calculation of the VTTS during peak hours. From the traffic volumes, the travel time savings, and the toll values, the average value of travel time savings for peak, off- peak, and shoulder hour travelers were calculated (see Table 31). It was found that the average VTTS during peak hours was lower than the average VTTS during the off-peak and shoulder hours. This difference may be due to the higher travel time savings during the peak hours. It can be seen that the VTTS not only varied by the time of the day but also by the direction of travel. The average weighted VTTS from Table 31 is $51/hr. From the SP responses from the 2010 survey respondents, the average VTTS was estimated to be $22/hr. Upon comparing these two values, it can be said that the survey estimates are nearly half as much as the actual VTTS values estimated from the actual usage.

Many travelers use MLs not only for travel time savings but also for their travel time reliability. Hence, the average value estimated from the actual usage ($51/hr) may also include the amount travelers are willing to pay for travel time reliability. However, it is not known what percentage of the $51/hr is paying for travel time reliability versus travel time savings. However, this VOR was estimable from the survey and was estimated as $37/hr. So the total amount travelers were willing to pay based on the survey using the D_b-efficient design was $22 + $28 = $50/hr and for the all-inclusive sample was $22 + $37 = $59/hr, both of which are close to the value ($51/hr) calculated from the actual Katy Freeway usage data.

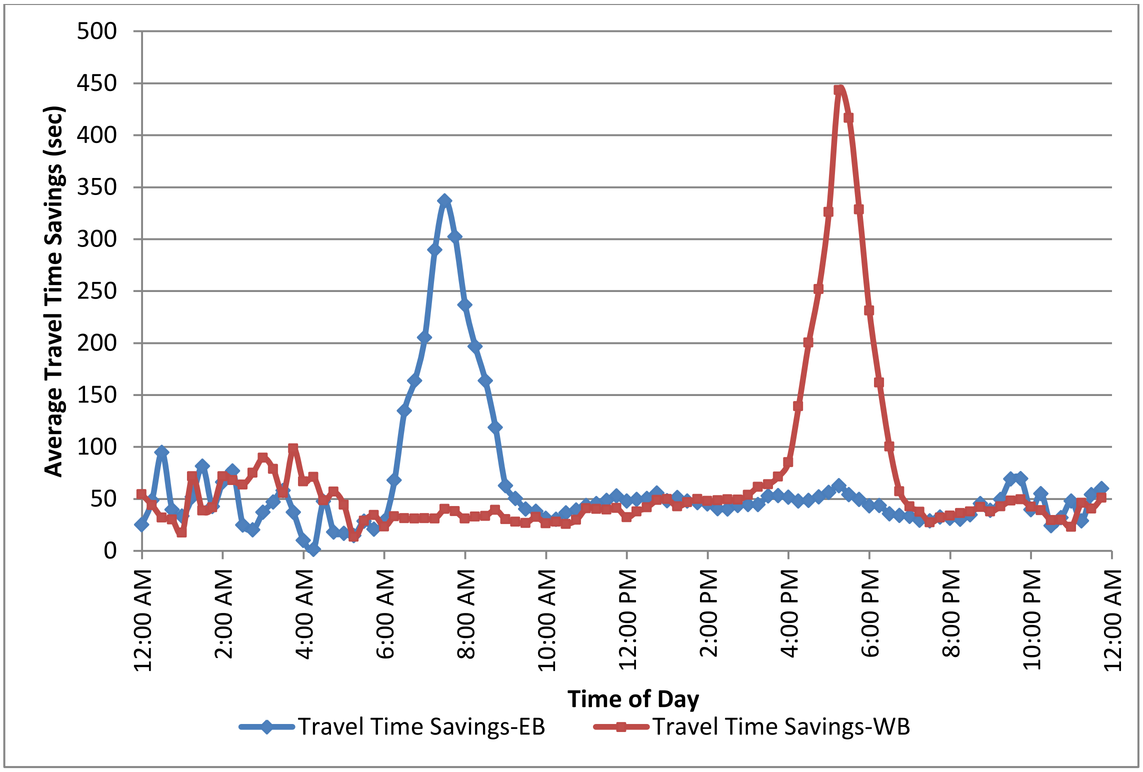


Figure 16: Average Travel Time Savings on the MLs by Time of Day

Table 31: Average VTTS by Time of Day Calculated from Actual Katy Freeway Usage Data

Time Of Day	Average VTTS ($/hr)
Morning Shoulder Hours (EB)	70
Morning Peak Hours (EB)	35
Off-Peak Hours (EB)	48
Evening Shoulder Hours (WB)	65
Evening Peak Hours (WB)	44
Off-Peak Hours (WB)	48
Weighted Average	51

4.6 Comparing Revealed Travel Time Savings with Actual Travel Time Savings

One of the major criticisms against the RP approach is that travelers tend to over- or under- estimate the travel time savings they experienced. In this section, respondents' revealed preference data on reported travel time savings on MLs will be compared to actual travel time savings to examine if there exists such a difference. An effort will also be made to understand if the magnitude of the misperception (over- or under-) of travel time savings is dependent on trip characteristics and/or the traveler characteristics.

The survey data included questions regarding the respondent's most recent trip (day of the week of the trip, when the trip began, when it ended, where the respondent got on and off the Katy Freeway) on the Katy Freeway along with the amount of time they thought the MLs saved them. Since the survey was administered online, the date the survey was taken was also known. Combining these data yielded the most likely date and time of their most recent trip. It is not a certain match since the questionnaire asked travelers to indicate the day of the week of their most recent trip. For many, that would be the most recent matching day of the week. But for infrequent Katy Freeway travelers that may have been 2 or 3 weeks prior. Based on their frequency of use of Katy Freeway (see Table 32) the majority would have traveled on Katy Freeway during the most recent week, and therefore their day and time of travel was known.

Table 32: Survey Respondents' Frequency of Katy Freeway Travel

Frequency of Katy Freeway Travel during the Last Full Week	Percentage of Respondents
0	8.1
1	8.3
2	10.7
3	4.4
4	6.3
5	9.4
6	4.0
7	1.3
8	3.9
9	0.1
10	36.8
12	3.1
14	1.3
15	0.9
16	0.1
18	0.1
19	0.1
20 or more	1.0

The actual travel time savings for that recent trip was obtained by using the respondents' recent trip information (survey date, day of week of the most recent trip, entry and exit location, and start time of the trip) provided in the survey and looking up the actual travel time savings obtained from sensor data. For example, if a respondent had taken the survey on June 16, 2010 and indicated that their most recent trip was on a Friday and it started at 8:00 AM, then the most likely date of his/her recent trip will be the earlier Friday i.e. June 11, 2010. This was based on our assumption that since most of the respondents were frequent users of the Katy Freeway (84 % of the respondents have taken 2 or more trips per week on the Katy Freeway, see Table 32), their most recent trip reported on the survey likely occurred within the past one week since the survey date. In addition, many travelers did not travel the full length of the MLs. Only the travel time savings between the respondents' entry and exit to the ML portion of Katy Freeway was included in the actual time savings.

A scatter plot of the perceived (RP survey data) and the observed (AVI data) travel time savings was plotted (see Figure 17). It can be seen that the perceived travel time savings are much higher than the observed travel time savings. This plot shows the magnitude of the over-estimation of the travel time savings and raises an interesting question, can RP responses be used for policy analysis? It can be seen that few respondents under-estimated travel time savings and a majority of the respondents over-estimated the travel time savings. The weighted average difference between perceived and observed travel time savings was approximately 11 minutes.

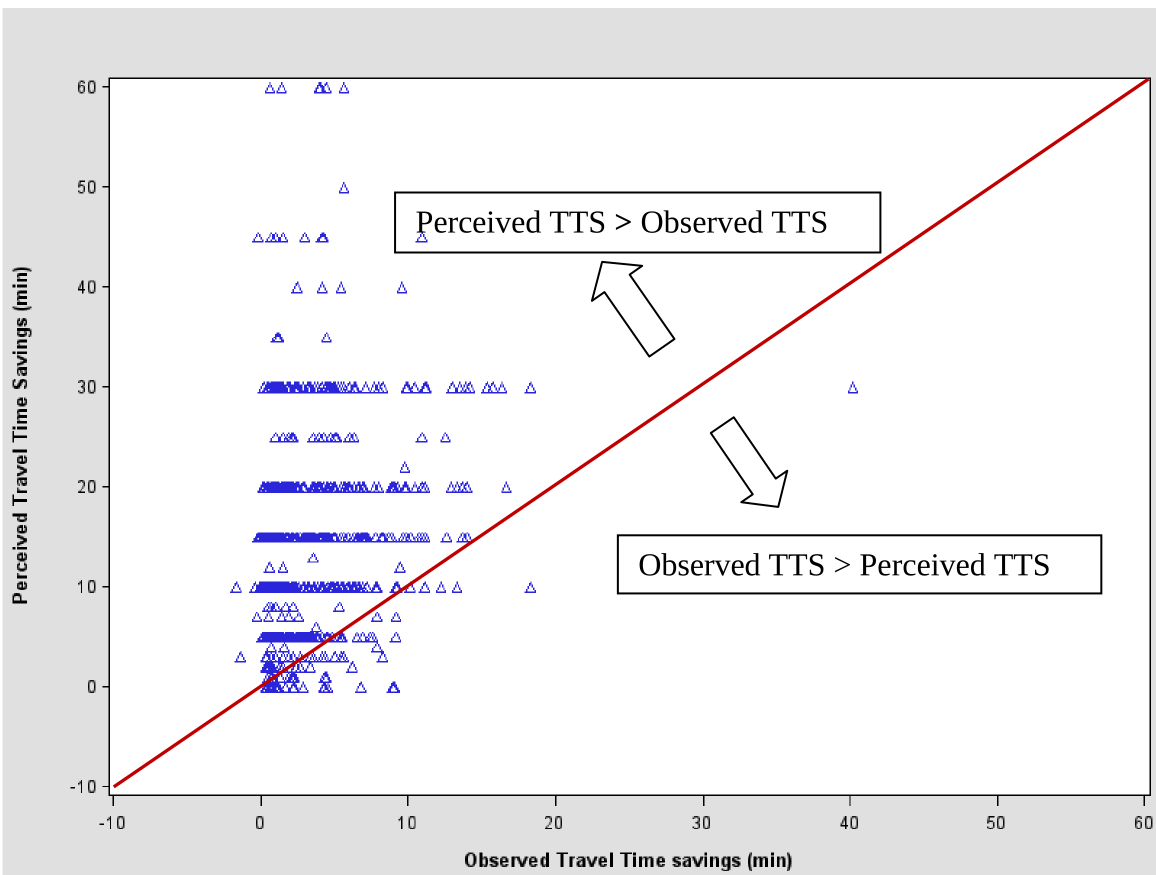


Figure 17: Perceived vs. Observed Travel Time Savings

To examine if the magnitude of over- or under- estimation of travel time savings is related to any of the repondents' trip characteristics or their socio-economic characteristics, a linear regression model was fit (see Table 33 or Equation 26). A small number of respondents (approximately 3 percent) indicated that they saved at least 30 minutes by traveling on the MLs. However, 30 minutes travel time savings for a 12 mile section seems too high, it can also be seen from Figure 3 that 99.9 percent of the time the observed travel time savings were less than 20 minutes, those responses were treated as outliers and were not included in the models. The dependent variable for the model is difference in the perceived and observed travel time savings. Time of day, trip purpose, distance traveled on the MLs, age, gender, income were considered for independent variables. However, time of day was found not to be significant in predicting the magnitude of the difference in travel time savings. Misperception of the travel time savings was higher for female respondents than male respondents. Respondents whose trip purpose was commute to/from work perceived higher travel time savings than those respondents with other trip purposes. This might be because travelers who are travelling to work might be under a constraint of arriving at work at the right time. It is interesting to see that lower income (annual household income less than $25,000) respondents did not over-estimate the travel time savings as much as mid- and high- income respondents.

Table 33: Linear Regression Model for Difference in Perceived and Observed Travel Time Savings

Parameter	Estimate	Standard Error	t Value
Intercept	10.25	1.64	6.26
Male (dv)	-2.72	0.52	-5.23
Age < 35 (dv)	-2.52	1.29	-1.94
35<=Age <55 (dv)	-3.07	1.24	-2.48
55<=Age <64 (dv)	-2.60	1.33	-1.96
Trip Purpose is Commute (dv)	1.28	0.53	2.41
Annual Income < $25,000 (dv)	3.08	1.07	2.87

Note: dv = dummy variable.

$$\begin{aligned}\text{Perceived Travel Time Savings}&\\ = \text{Actual Observed Travel Time Savings} &+ 10.25 - 2.72 \times \text{Male}\\ - 2.52 \times \text{Age}_{<35} - 3.07 \times \text{Age}_{35\text{ to }54} &- 2.60 \times \text{Age}_{55\text{ to }64} + 1.28\\ \times \text{Trip Purpose}_{\text{Commute}} &+ 3.08 \times \text{Annual Income}_{<25{,}000}\end{aligned} \tag{26}$$

Based on the above results it can be said that travelers have difficulty in reporting their travel time savings. In most cases, travelers over-estimated the travel time savings they experienced by using the MLs. This might affect the VTTS estimated from the reported values. This was also reflected in the VTTS estimated from the RP values in Section 4.4, the RP values were around half the values estimated from SP survey. Travelers' misperception of travel time savings should be accounted for while estimating VTTS from RP studies.

5. CONCLUSIONS

The objective of this research was to improve our understanding of traveler behavior, particularly with respect to MLs, to analyze how travelers respond to surveys, and to improve survey design techniques. To achieve these objectives, a stated preference survey was designed using three different survey design methods. The responses from the survey were examined using advanced statistical models.

5.1 The Value of Travel Time Savings and the Value of Travel Time Reliability

The first objective of this study was to estimate the value of travel time savings from travelers of the MLs in the Houston area. To achieve this objective, this study used three different survey design techniques in a single stated preference survey. The designs tested in this survey were D_b-efficient, random level generation, and adaptive random. From each of these designs, responses were gathered and statistical models were developed. In each SP question, the respondent was asked to choose among four modes of travel: drive alone on general purpose lanes, carpool on general purpose lanes, drive alone on managed lanes, and carpool on managed lanes. These modes varied over travel time, travel time variability, and toll values. A total of 3,325 useful responses were gathered from the survey.

A mixed logit modeling technique was used to model the responses from the survey. The average hourly wage rate for the sample was found to be $34/hr. The implied mean VTTS for the all-inclusive sample was estimated as 65 percent of the hourly wage rate ($22/hr). The implied mean VOR was estimated as 108 percent of the hourly wage rate ($37/hr). Preference heterogeneity in these means of travel time and travel time variability were also tested in the models. Preference heterogeneity was only observed in the means of travel time variability. It was found that female travelers valued travel time reliability more than male travelers. Similar results were also observed for risk-taking behavior of the travelers; risk-averse travelers valued travel time reliability higher than risk-taking travelers.

5.2 Best Survey Design for Estimating the VTTS and the VOR

The next objective of this research was to examine the multiple design methods used in the 2008 survey and to verify which method best estimated the actual use of the MLs. The 2008 survey tested four different survey design methods to estimate the VTTS. One among the tested design methods, the reverse smart adjusting design technique, was found to provide poor results, so this method was not examined further.

The multinomial logit models developed from each group of responses obtained by the three design methods—D-efficient, random level generation, and smart adjusting random design—estimated the mean VTTS as 55 percent, 52 percent, and 40 percent of the hourly wage rate, respectively. A total of 869 respondents from the 2008 survey also participated in the current 2010 survey. Since we wanted to examine which survey design method better predicted the VTTS, a mixed logit model for all responses from the 869 respondents was developed to estimate their implied mean VTTS. The implied mean VTTS was estimated as 48 percent of the sample hourly wage rate. The previous survey estimates of VTTS are very close to the 2010 estimate. From this comparison, it can be inferred that travelers' willingness to pay for MLs did not change much from pre- and post-opening of the MLs.

Mixed logit models were developed using all of the current 2010 survey responses. The implied mean VTTS was estimated as 63 percent, 132 percent, and 108 percent of the mean hourly wage using the results from the D_b-efficient, random level generation, and adaptive random designs, respectively. Of the three designs, only the D_b-efficient design was able to estimate the VOR. It estimated the implied VOR as 82 percent of the mean hourly wage rate. Also, the efficiency of parameter estimation (measured by D-efficiency and A-efficiency) was found to be higher for the D_b-efficient and adaptive random strategies as compared to the random design. The percentages of correct predictions were also higher for the D_b-efficient. Based on these results, it can be said that the D_b-efficient design was a more effective technique to capture the key data as compared to the other two design techniques.

5.3 Comparing SP Survey Responses with Actual Usage

AVI and wavetronix sensor data were used to obtain average traffic volumes and travel times along the Katy Freeway for all non-holiday weekdays in 2009. During peak periods, nearly 20 percent of the travelers on the Katy Freeway used the MLs, and this dropped to less than 6 percent in the off-peak. Of those using the lanes during the peak, approximately half of them traveled free as an HOV and half were SOVs who paid a toll. Travelers were paying to use the MLs during off-peak hours when there is often no noticeable travel time savings, although this was less than 6 percent of the total traffic.

During peak hours, the travel time on the GPLs was nearly 60 to 80 percent longer than the travel time on the MLs. The VTTS calculated from the actual data varied by the time of the day and also by direction of travel. Travelers valued their travel time savings higher while driving away from downtown than toward downtown. The average VTTS during peak hours was calculated as $35/hr toward downtown and $44/hr away from downtown. The difference was mainly due to the higher travel time savings during the evening peak hours. Further investigation needs to be done to identify the reasons for these differences.

From all of the 3,325 current (2010) survey respondents, the implied mean VTTS from the mixed logit models (all-inclusive model) was estimated as 65 percent of the mean hourly wage rate. Converting into a dollar amount, it is $22 per one hour of travel time savings. Comparing it with the calculated VTTS ($51/hr) using the actual Katy Freeway usage data, it can be said that survey estimates are nearly half the actual values. However, the $51/hr travelers are paying likely also includes the value travelers place on travel time reliability of the MLs. The total (VTTS+VOR) amount estimated from the all-inclusive model from the survey was $59/hr, which is close to the value estimated from the actual usage. A similar total amount ($50/hr) was also estimated by the D_b-efficient model.

A total of 42.9 percent of 2008 survey respondents indicated that they would use the MLs once they were open, and 34.5 percent indicated that they might use MLs. From the responses from the 869 2010 respondents who also responded to the 2008 survey, it was found that 66.3 percent of them used MLs. From all of the above findings, it can be said that travelers are actually paying for travel as they said they would in the previous 2008 survey.

5.4 Comparing Revealed Travel Time Savings with Actual Travel Time Savings

The perceived travel time savings varied considerably across the respondents. Nearly 97 percent of the respondents indicated that the experienced some travel time savings. Very few respondents under-estimated travel time savings and a majority of the respondents over-estimated the travel time savings. On average, respondents estimated they saved approximately 11 minutes more than they actually did. These results are in-line with the limited literature in the area where perceived travel time savings are approximately twice the average maximum savings in the peak period.

Linear regression models were fit to model the magnitude of over-, under-estimation of the travel time savings. Among the trip characteristics only trip purpose (commute) was found to be a significant predictor of the misperception of travel time savings. Respondents’ characteristics, age, gender, income were also found to be significant in predicting the misperception of travel time savings. This study shows that there is considerable difference between perceived and actual values.

This research has shown that travelers do have difficulty estimating the time they save while using a ML. They greatly overestimate the amount of time saved. VTTS estimated from RP studies should be adjusted for both over- or under- estimation of travel time savings. However, exactly how to incorporate this understanding in mode choice models or traffic revenue estimates in unknown. It may well be that even though travelers are saving a small amount of time they value that time savings (and avoiding congestion) much higher – possibly similar to their amount of perceived travel time savings.

6. RECOMMENDATIONS FOR FUTURE RESEARCH

This study collected data on both revealed and stated preference responses. Better models may be possible by combining both revealed and stated preference data, which may yield more accurate estimates of the value of travel time savings and the value of travel time reliability. Matching techniques can be used to compare the estimates from the 2008 survey to the 2010 survey to identify which survey design technique better predicted the VTTS. It was found that a risk-averse person valued travel time reliability more than a risk-taking person, but further research needs to be done to understand the behavior of travelers using the MLs with respect to risk aversion.

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APPENDIX A. SURVEY QUESTIONNAIRE

Katy Freeway Survey

A. Recent travel on the Katy Freeway

Please tell us about your most recent trip on the Katy Freeway (I-10) traveling towards 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 towards 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 your house or driveway) ?
Choose one of the following answers

Please choose...

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 work / downtown Houston) ?
Choose one of the following answers

Please choose...

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 your answer is Passenger car, SUV, or pick-up truck:

How many people including you, were in the Passenger Car/ SUV/Pick-up Truck?

Choose one of the following answers

- ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 or more

If your answer is not "1":

Were you the driver or a passenger on this recent trip?
Choose one of the following answers

- ○ Driver ○ Passenger

If “Driver” then

How much extra time did it take to pick up and drop off the passenger(s)? (minutes)

Only numbers may be entered in this field

Who did you travel with on this recent trip?
Check any that apply

- ☐ Neighbor
- ☐ Child
- ☐ Co-worker / person in the same, or a nearby, office building
- ☐ Adult family member
- ☐ Another commuter in a casual carpool (also known as slugging)
- ☐ Other:

If the answer is Bus:

How much did you pay to ride the bus?
Check any that apply

- ☐ $ per trip
- ☐ $ per day
- ☐ $ per week
- ☐ $ per month

Did you use the Managed Lanes on the Katy Freeway?

- Yes
- No

How much travel time do you think you *saved* compared to the main lanes? (minutes)

Only numbers may be entered in this field

Did you have to pay to park in Houston?

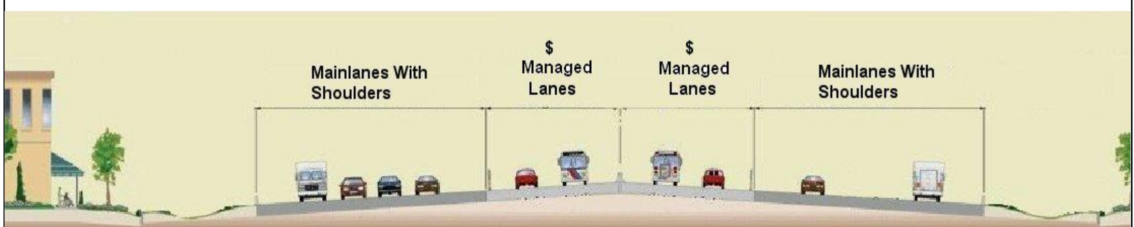
- Yes No

How much does it cost per day (in $)?

Only numbers may be entered in this field

B. Introduction to the New Managed Lanes

The Katy Managed Lanes begin west of SH 6 and end at the I-10/I-610 interchange. The managed lanes are 2 toll lanes in each direction and are being operated by Harris County Toll Road Authority (HCTRA) (See figure below). During the rush hour the toll is higher and during other times the toll is lower. Drivers have multiple entrances and exit locations to get on the managed lanes. The facility is an EZ or TX 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.



Have you ever used the new Managed Lanes ?

Choose one of the following answers

- ○ Yes ○ No

If you answered "yes":

What are the main reasons you used the Managed Lanes?
Check any that apply

- ☐ Being able to use the Managed Lanes for free as a carpool
- ☐ Travel times on the Managed Lanes are consistent and predictable
- ☐ Travel times on Managed Lanes are less than those on the main freeway lanes

- ☐ During the peak hours the Managed Lanes will not be congested
- ☐ The Managed Lanes are safer / less stressful than driving on the main freeway lanes
- ☐ My employer pays for the tolls
- ☐ Trucks and larger vehicles are not allowed on the Managed Lanes
- ☐ Other: ____

If you answered "No":

What are the primary reasons why you did not use the Managed Lanes?
Check any that apply

- ☐ Access to the Managed Lanes is not convenient for my trips
- ☐ I have the flexibility to travel at less congested times
- ☐ The tolls are too high for me
- ☐ I do not want a toll transponder in my car
- ☐ I can easily use other routes than the Katy Freeway, so I'll just avoid it if I think there is a lot of traffic
- ☐ Managed Lane use is complicated or confusing
- ☐ I do not want to pay the toll for this trip
- ☐ The Managed Lanes do not offer me enough time savings
- ☐ I do not have a credit card needed to set up a toll account
- ☐ I don't like that the toll changes based on time of day
- ☐ I do not feel safe traveling on Managed Lanes
- ☐ Participation in a carpool is difficult / undesirable
- ☐ Other: ____

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 managed lanes or main lanes)

Only numbers may be entered in these fields

- Trips per week:

How many of those Katy Freeway trips were using the Managed Lanes?

Only numbers may be entered in these fields

- Trips per week:

If you entered a number greater than "0":

On an average, how much did you pay for the toll for a typical trip?

Choose one of the following answers

- Less than $ 1.00
- $1.01 to $2.00
- $2.01 to 4.00
- More than $4.00
- Do not remember

Approximately how much time did you save by traveling on Managed Lanes?

Choose one of the following answers

- None
- 1-2 minutes
- 2-5 minutes
- 6-10 minutes
- 11-15 minutes
- 16-20 minutes
- 21-30 mintes
- more than 30 minutes
- Unsure

How many of those trips made on Katy Freeway would you consider to be unusually pressed for time and had a tight schedule for your travel ?

Only numbers may be entered in these fields

- Urgent Trips Per Week:

If Unusual trips per week > 0 then

Think about those trips that you were pressed for time. What percentage of the time did you use the Managed Lanes for those trips?
Choose one of the following answers

Never use the Managed Lanes for those urgent trips

Rarely use the Managed Lanes for those urgent trips

About half the time I use the Managed Lanes for those urgent trips

- Most of my urgent trips are on Managed Lanes
- Always use the Managed Lanes for those urgent trips

C. Risk Aversion

Suppose that you are travelling on Katy freeway and you catch part of a radio announcement of a major crash on Katy freeway causing long delays. You did not hear the exact location of the accident; it might be behind or in front of you. Your normal travel time from your current location is 20 min.

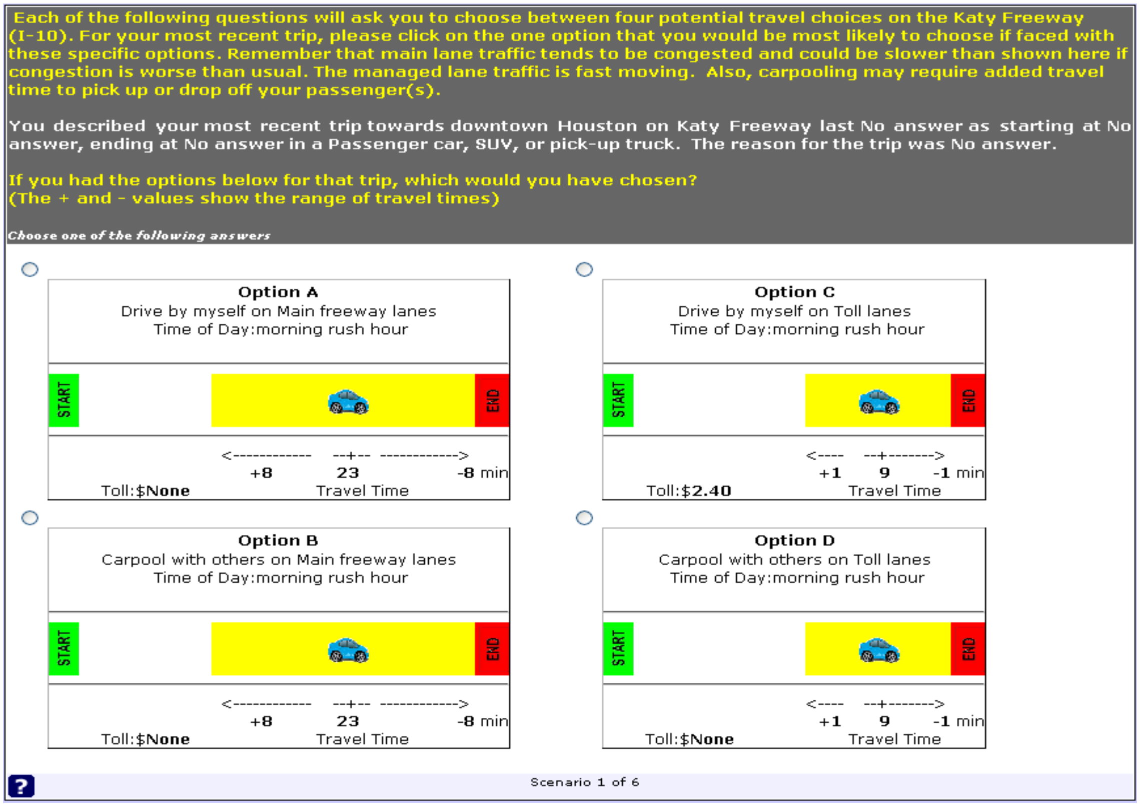
Now consider the following options for your travel and select which option you would choose:

Choose one of the following answers

- **Option A:** Stay on the Katy Freeway.
  There is a **70%** chance that you have already passed where the crash occurred. So the travel time is **20 minutes**
  But, the crash may have occurred ahead of you (with a **30%** chance) and travel time will be **60 minutes**

- **Option B:** Shift to an alternative route.
  The travel time will be **40 minutes**

D. Travel Scenarios



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 managed 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 towards downtown Houston on Katy Freeway last No answer as starting at No answer, ending at No answer in a Passenger car, SUV, or pick-up truck. The reason for the trip was No answer.

If you had the options below for that trip, which would you have chosen?
(The + and - values show the range of travel times)

Choose one of the following answers

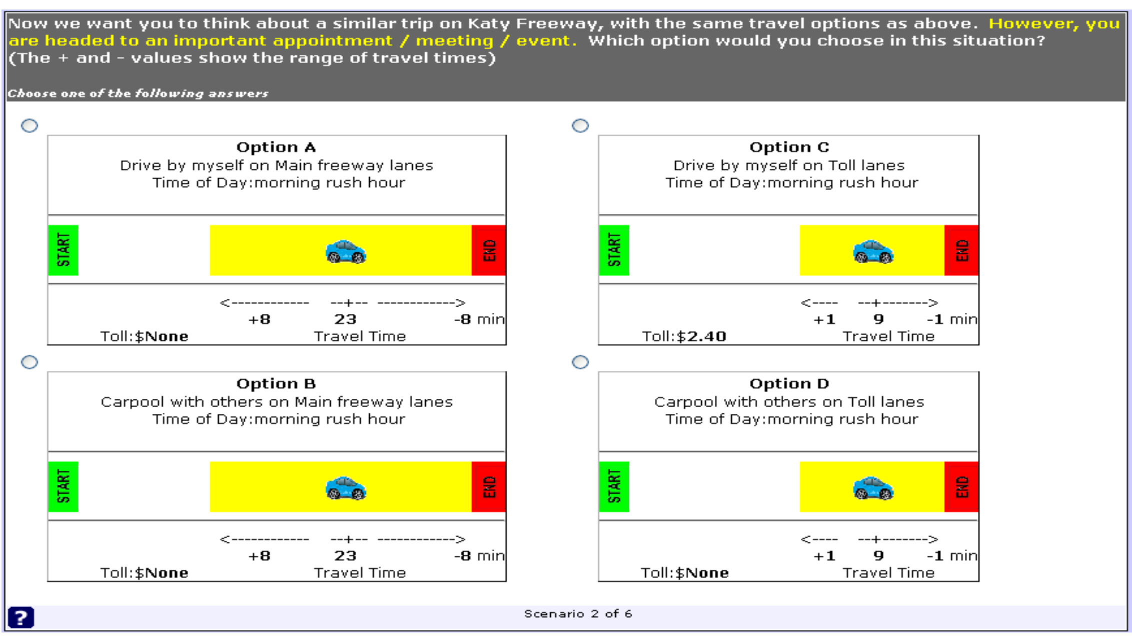
Option A
Drive by myself on Main freeway lanes
Time of Day:morning rush hour
START END
<------------ --+-- ------------>
+8 23 -8 min
Toll:$None Travel Time

Option C
Drive by myself on Toll lanes
Time of Day:morning rush hour
START END
<---- --+-------->
+1 9 -1 min
Toll:$2.40 Travel Time

Option B
Carpool with others on Main freeway lanes
Time of Day:morning rush hour
START END
<------------ --+-- ------------>
+8 23 -8 min
Toll:$None Travel Time

Option D
Carpool with others on Toll lanes
Time of Day:morning rush hour
START END
<---- --+-------->
+1 9 -1 min
Toll:$None Travel Time

? Scenario 1 of 6



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 would you choose in this situation?
(The + and - values show the range of travel times)

Choose one of the following answers

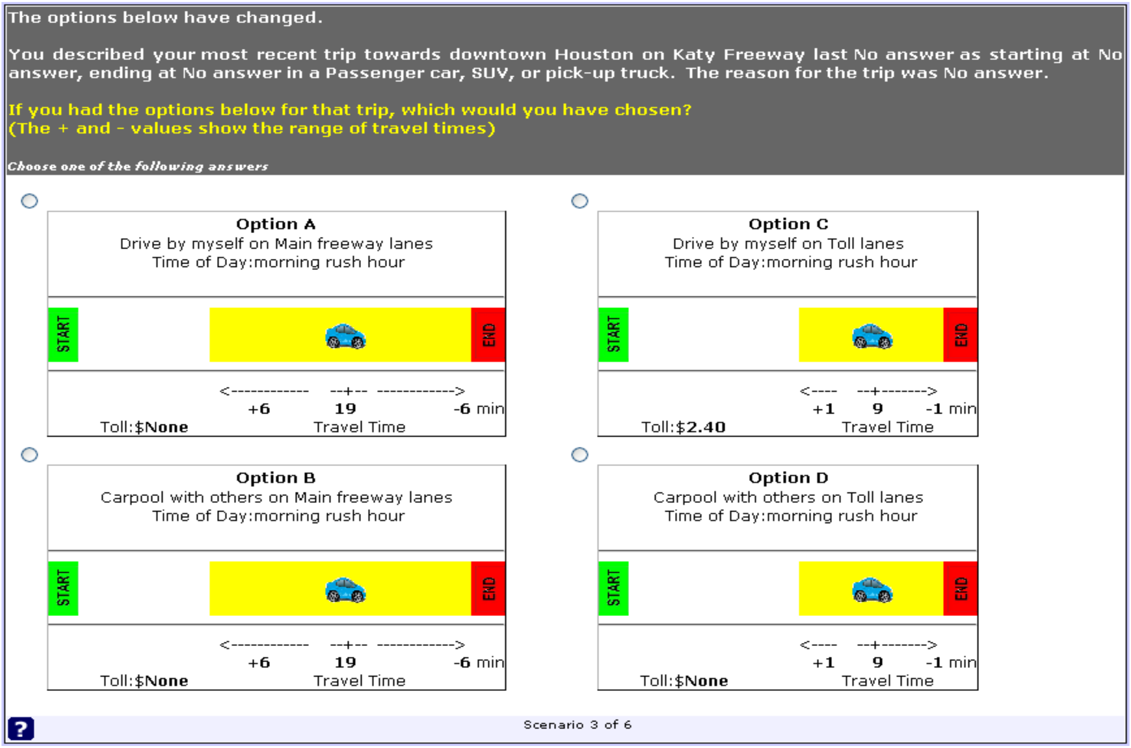
Option A
Drive by myself on Main freeway lanes
Time of Day:morning rush hour
START END
<------------ --+-- ------------>
+8 23 -8 min
Toll:$None Travel Time

Option C
Drive by myself on Toll lanes
Time of Day:morning rush hour
START END
<---- --+-------->
+1 9 -1 min
Toll:$2.40 Travel Time

Option B
Carpool with others on Main freeway lanes
Time of Day:morning rush hour
START END
<------------ --+-- ------------>
+8 23 -8 min
Toll:$None Travel Time

Option D
Carpool with others on Toll lanes
Time of Day:morning rush hour
START END
<---- --+-------->
+1 9 -1 min
Toll:$None Travel Time

? Scenario 2 of 6


The options below have changed.

You described your most recent trip towards downtown Houston on Katy Freeway last No answer as starting at No answer, ending at No answer in a Passenger car, SUV, or pick-up truck. The reason for the trip was No answer.

If you had the options below for that trip, which would you have chosen?
(The + and - values show the range of travel times)

Choose one of the following answers

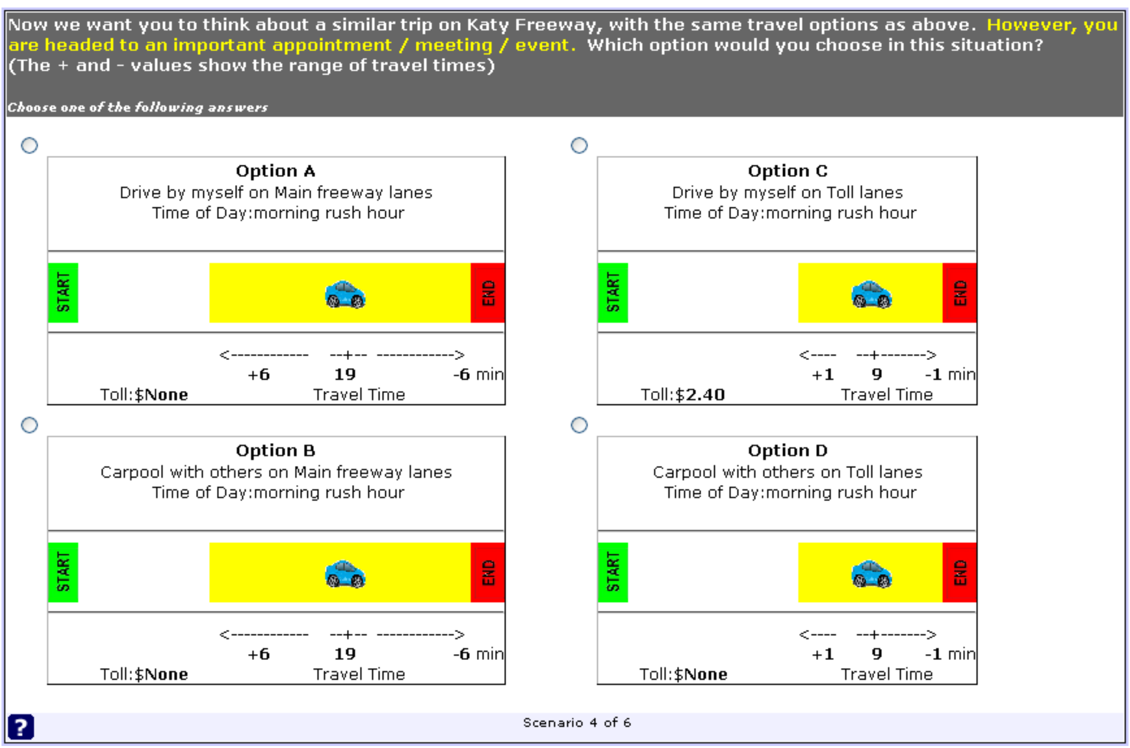
Option A
Drive by myself on Main freeway lanes
Time of Day:morning rush hour
START END
<------------ --+-- ------------>
+6 19 -6 min
Toll:$**None** Travel Time

Option C
Drive by myself on Toll lanes
Time of Day:morning rush hour
START END
<---- --+-------->
+1 9 -1 min
Toll:$**2.40** Travel Time

Option B
Carpool with others on Main freeway lanes
Time of Day:morning rush hour
START END
<------------ --+-- ------------>
+6 19 -6 min
Toll:$**None** Travel Time

Option D
Carpool with others on Toll lanes
Time of Day:morning rush hour
START END
<---- --+-------->
+1 9 -1 min
Toll:$**None** Travel Time

?
Scenario 3 of 6


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 would you choose in this situation?
(The + and - values show the range of travel times)

Choose one of the following answers

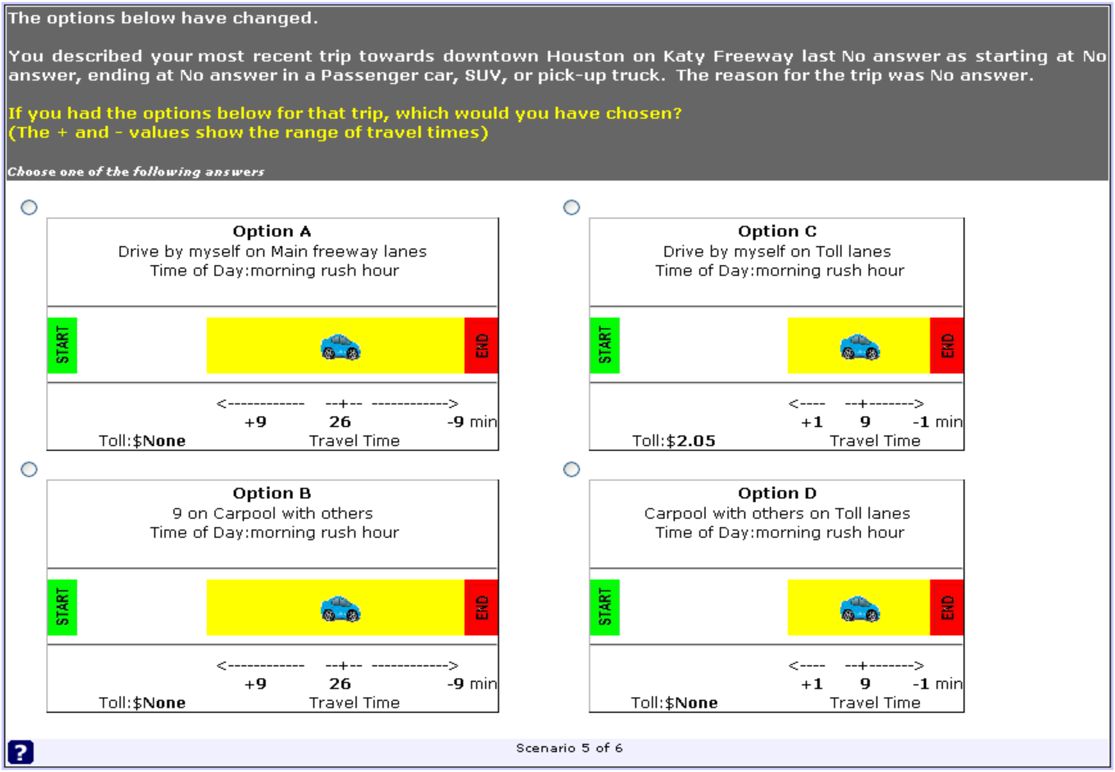
Option A
Drive by myself on Main freeway lanes
Time of Day:morning rush hour
START END
<------------ --+-- ------------>
+6 19 -6 min
Toll:$**None** Travel Time

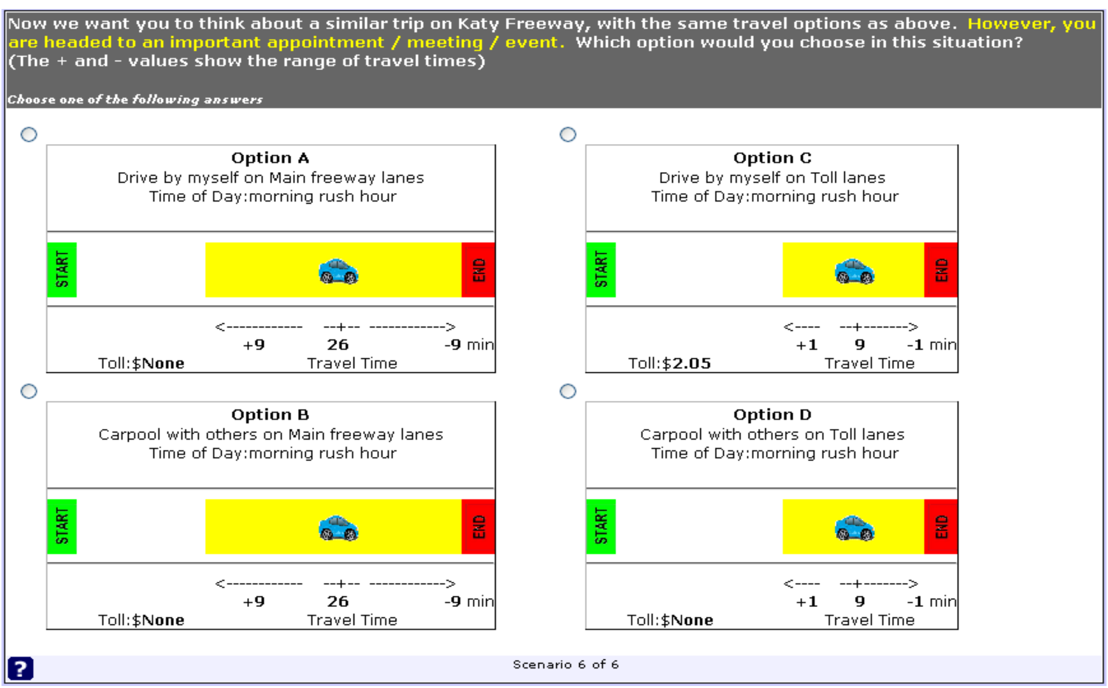
Option C
Drive by myself on Toll lanes
Time of Day:morning rush hour
START END
<---- --+-------->
+1 9 -1 min
Toll:$**2.40** Travel Time

Option B
Carpool with others on Main freeway lanes
Time of Day:morning rush hour
START END
<------------ --+-- ------------>
+6 19 -6 min
Toll:$**None** Travel Time

Option D
Carpool with others on Toll lanes
Time of Day:morning rush hour
START END
<---- --+-------->
+1 9 -1 min
Toll:$**None** Travel Time

?
Scenario 4 of 6


The options below have changed.
You described your most recent trip towards downtown Houston on Katy Freeway last No answer as starting at No answer, ending at No answer in a Passenger car, SUV, or pick-up truck. The reason for the trip was No answer.
If you had the options below for that trip, which would you have chosen?
(The + and - values show the range of travel times)
Choose one of the following answers
Option A
Drive by myself on Main freeway lanes
Time of Day:morning rush hour
START
END
+9 26 -9 min
Toll:$None
Travel Time
Option C
Drive by myself on Toll lanes
Time of Day:morning rush hour
START
END
+1 9 -1 min
Toll:$2.05
Travel Time
Option B
9 on Carpool with others
Time of Day:morning rush hour
START
END
+9 26 -9 min
Toll:$None
Travel Time
Option D
Carpool with others on Toll lanes
Time of Day:morning rush hour
START
END
+1 9 -1 min
Toll:$None
Travel Time
Scenario 5 of 6


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 would you choose in this situation?
(The + and - values show the range of travel times)
Choose one of the following answers
Option A
Drive by myself on Main freeway lanes
Time of Day:morning rush hour
START
END
+9 26 -9 min
Toll:$None
Travel Time
Option C
Drive by myself on Toll lanes
Time of Day:morning rush hour
START
END
+1 9 -1 min
Toll:$2.05
Travel Time
Option B
Carpool with others on Main freeway lanes
Time of Day:morning rush hour
START
END
+9 26 -9 min
Toll:$None
Travel Time
Option D
Carpool with others on Toll lanes
Time of Day:morning rush hour
START
END
+1 9 -1 min
Toll:$None
Travel Time
Scenario 6 of 6

E. 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

Is your child(ren) between 5 to 17 years old (school age)?

- ○ Yes ○ No

Including yourself, how many people live in your household?

Only numbers may be entered in this field

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

Only numbers may be entered in this field

What category best describes your occupational or work status?

Choose one of the following answers

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

What was your gross annual household income before taxes in 2009?

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:

Hourly wage rate ($/hour)

Only numbers may be entered in this field

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. The survey results will be made available at www.KatySurvey.org. 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 B. N-GENE CODE FOR GENERATING D_b-EFFICIENT DESIGN

```
;Design

;alts=dagl,cpgl,daml,cp2ml

;rows=24

;block=8

;eff=(mnl,d)

;rdraws=random(1000)

;cond:

if(cp2ml.spdlvl_m <> daml.spdlvl_m , cp2ml.spdlvl_m = daml.spdlvl_m)

,if(cpgl.spdlvl_g <> dagl.spdlvl_g,cpgl.spdlvl_g=dagl.spdlvl_g)

,if(cp2ml.t2lvl >daml.tlvl, cp2ml.t2lvl <= daml.tlvl)

,if(cp2ml.var_percent_ml <>daml.var_percent_ml, cp2ml.var_percent_ml =
daml.var_percent_ml)

,if(cpgl.var_percent_gl<> dagl.var_percent_gl,cpgl.var_percent_gl=dagl.var_percent_gl)

;model:

U(cp2ml)=c3[-2.30]+spd[n,0.1,0.7]*spdlvl_m[55,60,65]+toll[n,-
0.19,0.1]*t2lvl[0,5,10]+var[n,-0.50,0.5]*var_percent_ml[0.05,0.10,0.15]

/

U(daml)=c2[-1.37]+spd*spdlvl_m+toll*tlvl[8,17,35]+var*var_percent_ml

/

U(cpgl)=c1[-2.02]+spd*spdlvl_g[25,35,45]+var*var_percent_gl[0.2,0.35,0.50]

/

U(dagl)=spd*spdlvl_g+var*var_percent_gl

$
```

APPENDIX C. JAVA SCRIPT CODE FOR SECOND SP QUESTION

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

// Set the time of day
            document.getElementById('answer44745X180X9505').value =
"{INSERTANS:44745X178X9485}"   ;
            document.getElementById('answer44745X180X95011').value =
"{INSERTANS:44745X178X94811}" ;
            document.getElementById('answer44745X180X95017').value =
"{INSERTANS:44745X178X94817}" ;
            document.getElementById('answer44745X180X95023').value =
"{INSERTANS:44745X178X94823}" ;
            document.getElementById('answer44745X180X95029').value =
"{INSERTANS:44745X178X94829}" ;
            document.getElementById('answer44745X180X95035').value =
"{INSERTANS:44745X178X94835}" ;
            document.getElementById('answer44745X180X95041').value =
"{INSERTANS:44745X178X94841}" ;
            document.getElementById('answer44745X180X95047').value =
"{INSERTANS:44745X178X94847}" ;
// Toll Distance, Free Distance, SP Question Type
            document.getElementById('answer44745X180X95050').value =
"{INSERTANS:44745X178X94850}";
            document.getElementById('answer44745X180X95051').value =
"{INSERTANS:44745X178X94851}";
            document.getElementById('answer44745X180X95049').value =
"{INSERTANS:44745X178X94849}";
// Variables
            var TimODay = "{INSERTANS:44745X178X94852}" ;
            document.getElementById('answer44745X180X95052').value =
"{INSERTANS:44745X178X94852}" ;
            var TollDist = "{INSERTANS:44745X178X94850}";
            var FreeDist = "{INSERTANS:44745X178X94851}";

//Set Tolls and Travel Times
            if ("{INSERTANS:44745X178X94849}" == 1)
            { //D-Efficeint
                        var Block = Math.round((Math.floor(Math.random()*80)+5)/10); // Random integer
from 1 to 8
                        switch (Block)
                                    {
case 1:
            document.getElementById('answer44745X180X9501').value = 'Drive by myself';
            document.getElementById('answer44745X180X95025').value = 'Drive by myself';
            document.getElementById('answer44745X180X9502').value = 'Main freeway lanes';
            document.getElementById('answer44745X180X95026').value = 'Main freeway lanes';
                                                            var randomnumber=Math.floor(Math.random()*10) ;
                                                            var speedF = Math.round(60 + randomnumber/10) ;
                                                            var speedT =35;
                                                            if (TimODay == 1)
```

```
                                        { speedT = 35; }
                                        else if (TimODay ==2)
                                        { speedT = 40; }
                                        else { speedT =50;}
                                   var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist *
60/speedF));
                                        var varPerGPL = 20;
                                        var varGPL = Math.round(TollDist *
(60/speedT)*varPerGPL/100);
     document.getElementById('answer44745X180X9503').value = TrvTmGPL;
     document.getElementById('answer44745X180X95027').value = TrvTmGPL;
     document.getElementById('answer44745X180X9504').value = 'None';
     document.getElementById('answer44745X180X95028').value = 'None';
     document.getElementById('answer44745X180X9506').value = varGPL;
     document.getElementById('answer44745X180X95030').value = varGPL;
     document.getElementById('answer44745X180X9507').value = 'Carpool with others' ;
     document.getElementById('answer44745X180X95031').value = 'Carpool with others' ;
     document.getElementById('answer44745X180X9508').value = 'Main freeway lanes';
     document.getElementById('answer44745X180X95032').value = 'Main freeway lanes';
     document.getElementById('answer44745X180X9509').value = TrvTmGPL;
     document.getElementById('answer44745X180X95033').value = TrvTmGPL;
     document.getElementById('answer44745X180X95010').value = 'None' ;
     document.getElementById('answer44745X180X95034').value = 'None' ;
     document.getElementById('answer44745X180X95012').value = varGPL ;
     document.getElementById('answer44745X180X95036').value = varGPL ;
     document.getElementById('answer44745X180X95013').value = 'Drive by myself';
     document.getElementById('answer44745X180X95037').value = 'Drive by myself';
     document.getElementById('answer44745X180X95014').value = 'Toll lanes';
     document.getElementById('answer44745X180X95038').value = 'Toll lanes';
                                        var randomnumber=Math.floor(Math.random()*10) ;
                                        var speedF = Math.round(60 + randomnumber/10) ;
                                        var speedT =25;
                                        if (TimODay == 1)
                                        { speedT = 65; }
                                        else if (TimODay ==2)
                                        { speedT = 65; }
                                        else { speedT =70;}
                              var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
     document.getElementById('answer44745X180X95015').value = TrvTmML;
     document.getElementById('answer44745X180X95039').value = TrvTmML;
                                        var Toll = 17/TimODay;
                                        var TotToll3 = (Math.round(((Toll *
TollDist)/5))/20).toFixed(2);
                                        var varPerML = 15;
                                        var varML = Math.round(TollDist *
(60/speedT)*varPerML/100);
                                        if (varML==0)
                                        { varML =1 ;}
     document.getElementById('answer44745X180X95016').value = TotToll3;
     document.getElementById('answer44745X180X95040').value = TotToll3;
     document.getElementById('answer44745X180X95018').value = varML;
     document.getElementById('answer44745X180X95042').value = varML;
     document.getElementById('answer44745X180X95019').value = 'Carpool with others';
```

```
        document.getElementById('answer44745X180X95043').value = 'Carpool with others';
        document.getElementById('answer44745X180X95020').value = 'Toll lanes';
        document.getElementById('answer44745X180X95044').value = 'Toll lanes';
        document.getElementById('answer44745X180X95021').value = TrvTmML;
        document.getElementById('answer44745X180X95045').value = TrvTmML;
                                        var Toll = 5/TimODay;
                                        var TotToll3 = (Math.round(((Toll *
TollDist)/5))/20).toFixed(2);
        document.getElementById('answer44745X180X95022').value = TotToll3;
        document.getElementById('answer44745X180X95046').value = TotToll3;
        document.getElementById('answer44745X180X95024').value = varML;
        document.getElementById('answer44745X180X95048').value = varML;
        if (TotToll3 == "None" || TotToll3 == 0)
                                        {
                document.getElementById('answer44745X180X95061').value = "0.00" ;
                                        }
                                        else
                                        {
                document.getElementById('answer44745X180X95061').value = TotToll3;
                                        }
                                break;
case 2:

        document.getElementById('answer44745X180X9501').value = 'Drive by myself';
        document.getElementById('answer44745X180X95025').value = 'Drive by myself';
        document.getElementById('answer44745X180X9502').value = 'Main freeway lanes';
        document.getElementById('answer44745X180X95026').value = 'Main freeway lanes';
                        var randomnumber=Math.floor(Math.random()*10) ;
                                        var speedF = Math.round(60 + randomnumber/10) ;
                                        var speedT =35;
                                        if (TimODay == 1)
                                        { speedT = 45; }
                                        else if (TimODay ==2)
                                        { speedT = 50; }
                                        else { speedT =55;}
                                var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist *
60/speedF));
                                        var varPerGPL = 35;
                                        var varGPL = Math.round(TollDist *
(60/speedT)*varPerGPL/100);
        document.getElementById('answer44745X180X9503').value = TrvTmGPL;
        document.getElementById('answer44745X180X95027').value = TrvTmGPL;
        document.getElementById('answer44745X180X9504').value = 'None';
        document.getElementById('answer44745X180X95028').value = 'None';
        document.getElementById('answer44745X180X9506').value = varGPL;
        document.getElementById('answer44745X180X95030').value = varGPL;
        document.getElementById('answer44745X180X9507').value = 'Carpool with others' ;
        document.getElementById('answer44745X180X95031').value = 'Carpool with others' ;
        document.getElementById('answer44745X180X9508').value = 'Main freeway lanes';
        document.getElementById('answer44745X180X95032').value = 'Main freeway lanes';
        document.getElementById('answer44745X180X9509').value = TrvTmGPL;
        document.getElementById('answer44745X180X95033').value = TrvTmGPL;
        document.getElementById('answer44745X180X95010').value = 'None' ;
```

```
document.getElementById('answer44745X180X95034').value = 'None' ;
document.getElementById('answer44745X180X95012').value = varGPL ;
document.getElementById('answer44745X180X95036').value = varGPL ;
document.getElementById('answer44745X180X95013').value = 'Drive by myself';
document.getElementById('answer44745X180X95037').value = 'Drive by myself';
document.getElementById('answer44745X180X95014').value = 'Toll lanes';
document.getElementById('answer44745X180X95038').value = 'Toll lanes';
var randomnumber=Math.floor(Math.random()*10) ;
                    var speedF = Math.round(60 + randomnumber/10) ;
                    var speedT =25;
                    if (TimODay == 1)
                    { speedT = 55; }
                    else if (TimODay ==2)
                    { speedT = 55; }
                    else { speedT =60;}
    var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
document.getElementById('answer44745X180X95015').value = TrvTmML;
document.getElementById('answer44745X180X95039').value = TrvTmML;
                    var Toll = 35/TimODay;
                    var TotToll3 = (Math.round(((Toll *
TollDist)/5))/20).toFixed(2);
                    var varPerML = 10;
                    var varML = Math.round(TollDist *
(60/speedT)*varPerML/100);
                    if (varML==0)
                    { varML =1 ;}
document.getElementById('answer44745X180X95016').value = TotToll3;
document.getElementById('answer44745X180X95040').value = TotToll3;
document.getElementById('answer44745X180X95018').value = varML;
document.getElementById('answer44745X180X95042').value = varML;
document.getElementById('answer44745X180X95019').value = 'Carpool with others';
document.getElementById('answer44745X180X95043').value = 'Carpool with others';
document.getElementById('answer44745X180X95020').value = 'Toll lanes';
document.getElementById('answer44745X180X95044').value = 'Toll lanes';
document.getElementById('answer44745X180X95021').value = TrvTmML;
document.getElementById('answer44745X180X95045').value = TrvTmML;
        var Toll = 5/TimODay;
                    var TotToll3 = (Math.round(((Toll *
TollDist)/5))/20).toFixed(2);
document.getElementById('answer44745X180X95022').value = TotToll3;
document.getElementById('answer44745X180X95046').value = TotToll3;
document.getElementById('answer44745X180X95024').value = varML;
document.getElementById('answer44745X180X95048').value = varML;
        if (TotToll3 == "None" || TotToll3 == 0)
                    {
    document.getElementById('answer44745X180X95061').value = "0.00" ;
                    }
                    else
                    {
    document.getElementById('answer44745X180X95061').value = TotToll3;
                    }
            break;
case 3:
```

```
document.getElementById('answer44745X180X9501').value = 'Drive by myself';
document.getElementById('answer44745X180X95025').value = 'Drive by myself';
document.getElementById('answer44745X180X9502').value = 'Main freeway lanes';
document.getElementById('answer44745X180X95026').value = 'Main freeway lanes';
                                        var randomnumber=Math.floor(Math.random()*10) ;
                                        var speedF = Math.round(60 + randomnumber/10) ;
                                        var speedT =35;
                                        if (TimODay == 1)
                                        { speedT = 25; }
                                        else if (TimODay ==2)
                                        { speedT = 30; }
                                        else { speedT =45;}
          var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
                                        var varPerGPL = 50;
                    var varGPL = Math.round(TollDist * (60/speedT)*varPerGPL/100);
document.getElementById('answer44745X180X9503').value = TrvTmGPL;
document.getElementById('answer44745X180X95027').value = TrvTmGPL;
document.getElementById('answer44745X180X9504').value = 'None';
document.getElementById('answer44745X180X95028').value = 'None';
document.getElementById('answer44745X180X9506').value = varGPL;
document.getElementById('answer44745X180X95030').value = varGPL;
document.getElementById('answer44745X180X9507').value = 'Carpool with others' ;
document.getElementById('answer44745X180X95031').value = 'Carpool with others' ;
document.getElementById('answer44745X180X9508').value = 'Main freeway lanes';
document.getElementById('answer44745X180X95032').value = 'Main freeway lanes';
document.getElementById('answer44745X180X9509').value = TrvTmGPL;
document.getElementById('answer44745X180X95033').value = TrvTmGPL;
document.getElementById('answer44745X180X95010').value = 'None' ;
document.getElementById('answer44745X180X95034').value = 'None' ;
document.getElementById('answer44745X180X95012').value = varGPL ;
document.getElementById('answer44745X180X95036').value = varGPL ;
document.getElementById('answer44745X180X95013').value = 'Drive by myself';
document.getElementById('answer44745X180X95037').value = 'Drive by myself';
document.getElementById('answer44745X180X95014').value = 'Toll lanes';
document.getElementById('answer44745X180X95038').value = 'Toll lanes';
                              var randomnumber=Math.floor(Math.random()*10) ;
                                        var speedF = Math.round(60 + randomnumber/10) ;
                                        var speedT =25;
                                        if (TimODay == 1)
                                        { speedT = 65; }
                                        else if (TimODay ==2)
                                        { speedT = 65; }
                                        else { speedT =70;}
                              var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist *
60/speedF));
document.getElementById('answer44745X180X95015').value = TrvTmML;
document.getElementById('answer44745X180X95039').value = TrvTmML;
                                        var Toll = 35/TimODay;
                                        var TotToll3 = (Math.round(((Toll *
TollDist)/5))/20).toFixed(2);
                                        var varPerML = 5;
                                        var varML = Math.round(TollDist *
(60/speedT)*varPerML/100);
```

```
                                        if (varML==0)
                                        { varML =1 ;}
     document.getElementById('answer44745X180X95016').value = TotToll3;
     document.getElementById('answer44745X180X95040').value = TotToll3;
     document.getElementById('answer44745X180X95018').value = varML;
     document.getElementById('answer44745X180X95042').value = varML;
     document.getElementById('answer44745X180X95019').value = 'Carpool with others';
     document.getElementById('answer44745X180X95043').value = 'Carpool with others';
     document.getElementById('answer44745X180X95020').value = 'Toll lanes';
     document.getElementById('answer44745X180X95044').value = 'Toll lanes';
     document.getElementById('answer44745X180X95021').value = TrvTmML;
     document.getElementById('answer44745X180X95045').value = TrvTmML;
                                        var Toll = 10/TimODay;
                                        var TotToll3 = (Math.round(((Toll *
TollDist)/5))/20).toFixed(2);
     document.getElementById('answer44745X180X95022').value = TotToll3;
     document.getElementById('answer44745X180X95046').value = TotToll3;
     document.getElementById('answer44745X180X95024').value = varML;
     document.getElementById('answer44745X180X95048').value = varML;
                                   if (TotToll3 == "None" || TotToll3 == 0)
                                        {
                    document.getElementById('answer44745X180X95061').value = "0.00" ;
                                        }
                                        else
                                        {
                    document.getElementById('answer44745X180X95061').value = TotToll3;
                                        }
                                   break;
     case 4:

     document.getElementById('answer44745X180X9501').value = 'Drive by myself';
     document.getElementById('answer44745X180X95025').value = 'Drive by myself';
     document.getElementById('answer44745X180X9502').value = 'Main freeway lanes';
     document.getElementById('answer44745X180X95026').value = 'Main freeway lanes';
                    var randomnumber=Math.floor(Math.random()*10) ;
                                        var speedF = Math.round(60 + randomnumber/10) ;
                                        var speedT =35;
                                        if (TimODay == 1)
                                        { speedT = 35; }
                                        else if (TimODay ==2)
                                        { speedT = 40; }
                                        else { speedT =50;}
                                   var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist *
60/speedF));
                                        var varPerGPL = 50;
                                        var varGPL = Math.round(TollDist *
(60/speedT)*varPerGPL/100);
     document.getElementById('answer44745X180X9503').value = TrvTmGPL;
     document.getElementById('answer44745X180X95027').value = TrvTmGPL;
     document.getElementById('answer44745X180X9504').value = 'None';
     document.getElementById('answer44745X180X95028').value = 'None';
     document.getElementById('answer44745X180X9506').value = varGPL;
     document.getElementById('answer44745X180X95030').value = varGPL;
```

```
document.getElementById('answer44745X180X9507').value = 'Carpool with others' ;
document.getElementById('answer44745X180X95031').value = 'Carpool with others' ;
document.getElementById('answer44745X180X9508').value = 'Main freeway lanes';
document.getElementById('answer44745X180X95032').value = 'Main freeway lanes';
document.getElementById('answer44745X180X9509').value = TrvTmGPL;
document.getElementById('answer44745X180X95033').value = TrvTmGPL;
document.getElementById('answer44745X180X95010').value = 'None' ;
document.getElementById('answer44745X180X95034').value = 'None' ;
document.getElementById('answer44745X180X95012').value = varGPL ;
document.getElementById('answer44745X180X95036').value = varGPL ;
document.getElementById('answer44745X180X95013').value = 'Drive by myself';
document.getElementById('answer44745X180X95037').value = 'Drive by myself';
document.getElementById('answer44745X180X95014').value = 'Toll lanes';
document.getElementById('answer44745X180X95038').value = 'Toll lanes';
        var randomnumber=Math.floor(Math.random()*10) ;
                        var speedF = Math.round(60 + randomnumber/10) ;
                        var speedT =25;
                        if (TimODay == 1)
                        { speedT = 55; }
                        else if (TimODay ==2)
                        { speedT = 55; }
                        else { speedT =60;}
                var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist *
60/speedF));
document.getElementById('answer44745X180X95015').value = TrvTmML;
document.getElementById('answer44745X180X95039').value = TrvTmML;
                var Toll = 35/TimODay;
                var TotToll3 = (Math.round((((Toll * TollDist)/5))/20).toFixed(2);
                var varPerML = 5;
                var varML = Math.round(TollDist * (60/speedT)*varPerML/100);
                        if (varML==0)
                        { varML =1 ;}
document.getElementById('answer44745X180X95016').value = TotToll3;
document.getElementById('answer44745X180X95040').value = TotToll3;
document.getElementById('answer44745X180X95018').value = varML;
document.getElementById('answer44745X180X95042').value = varML;
document.getElementById('answer44745X180X95019').value = 'Carpool with others';
document.getElementById('answer44745X180X95043').value = 'Carpool with others';
document.getElementById('answer44745X180X95020').value = 'Toll lanes';
document.getElementById('answer44745X180X95044').value = 'Toll lanes';
document.getElementById('answer44745X180X95021').value = TrvTmML;
document.getElementById('answer44745X180X95045').value = TrvTmML;
        var Toll = 0/TimODay;
        var TotToll3 = (Math.round((((Toll * TollDist)/5))/20).toFixed(2);
document.getElementById('answer44745X180X95022').value = 'None';
document.getElementById('answer44745X180X95046').value = 'None';
document.getElementById('answer44745X180X95024').value = varML;
document.getElementById('answer44745X180X95048').value = varML;
        if (TotToll3 == "None" || TotToll3 == 0)
                        {
        document.getElementById('answer44745X180X95061').value = "0.00" ;
                        }
                        else
```

```
                                        {
          document.getElementById('answer44745X180X95061').value = TotToll3;
                                        }
                              break;
case 5:
document.getElementById('answer44745X180X9501').value = 'Drive by myself';
document.getElementById('answer44745X180X95025').value = 'Drive by myself';
document.getElementById('answer44745X180X9502').value = 'Main freeway lanes';
document.getElementById('answer44745X180X95026').value = 'Main freeway lanes';
                                        var randomnumber=Math.floor(Math.random()*10) ;
                                        var speedF = Math.round(60 + randomnumber/10) ;
                                        var speedT =35;
                                        if (TimODay == 1)
                                        { speedT = 25; }
                                        else if (TimODay ==2)
                                        { speedT = 30; }
                                        else { speedT =45;}
          var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
                                        var varPerGPL = 20;
          var varGPL = Math.round(TollDist * (60/speedT)*varPerGPL/100);
document.getElementById('answer44745X180X9503').value = TrvTmGPL;
document.getElementById('answer44745X180X95027').value = TrvTmGPL;
document.getElementById('answer44745X180X9504').value = 'None';
document.getElementById('answer44745X180X95028').value = 'None';
document.getElementById('answer44745X180X9506').value = varGPL;
document.getElementById('answer44745X180X95030').value = varGPL;
document.getElementById('answer44745X180X9507').value = 'Carpool with others' ;
document.getElementById('answer44745X180X95031').value = 'Carpool with others' ;
document.getElementById('answer44745X180X9508').value = 'Main freeway lanes';
document.getElementById('answer44745X180X95032').value = 'Main freeway lanes';
document.getElementById('answer44745X180X9509').value = TrvTmGPL;
document.getElementById('answer44745X180X95033').value = TrvTmGPL;
document.getElementById('answer44745X180X95010').value = 'None' ;
document.getElementById('answer44745X180X95034').value = 'None' ;
document.getElementById('answer44745X180X95012').value = varGPL ;
document.getElementById('answer44745X180X95036').value = varGPL ;
document.getElementById('answer44745X180X95013').value = 'Drive by myself';
document.getElementById('answer44745X180X95037').value = 'Drive by myself';
document.getElementById('answer44745X180X95014').value = 'Toll lanes';
document.getElementById('answer44745X180X95038').value = 'Toll lanes';
var randomnumber=Math.floor(Math.random()*10) ;
                                        var speedF = Math.round(60 + randomnumber/10) ;
                                        var speedT =25;
                                        if (TimODay == 1)
                                        { speedT = 65; }
                                        else if (TimODay ==2)
                                        { speedT = 65; }
                                        else { speedT =70;}
          var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
document.getElementById('answer44745X180X95015').value = TrvTmML;
document.getElementById('answer44745X180X95039').value = TrvTmML;
                                        var Toll = 35/TimODay;
                    var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
```

```
var varPerML = 15;
var varML = Math.round(TollDist * (60/speedT)*varPerML/100);
if (varML==0)
{ varML =1 ;}
document.getElementById('answer44745X180X95016').value = TotToll3;
document.getElementById('answer44745X180X95040').value = TotToll3;
document.getElementById('answer44745X180X95018').value = varML;
document.getElementById('answer44745X180X95042').value = varML;
document.getElementById('answer44745X180X95019').value = 'Carpool with others';
document.getElementById('answer44745X180X95043').value = 'Carpool with others';
document.getElementById('answer44745X180X95020').value = 'Toll lanes';
document.getElementById('answer44745X180X95044').value = 'Toll lanes';
document.getElementById('answer44745X180X95021').value = TrvTmML;
document.getElementById('answer44745X180X95045').value = TrvTmML;
var Toll = 5/TimODay;
var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
document.getElementById('answer44745X180X95022').value = TotToll3;
document.getElementById('answer44745X180X95046').value = TotToll3;
document.getElementById('answer44745X180X95024').value = varML;
document.getElementById('answer44745X180X95048').value = varML;
if (TotToll3 == "None" || TotToll3 == 0)
{
document.getElementById('answer44745X180X95061').value = "0.00" ;
}
else
{
document.getElementById('answer44745X180X95061').value = TotToll3;
}
break;
case 6:

document.getElementById('answer44745X180X9501').value = 'Drive by myself';
document.getElementById('answer44745X180X95025').value = 'Drive by myself';
document.getElementById('answer44745X180X9502').value = 'Main freeway lanes';
document.getElementById('answer44745X180X95026').value = 'Main freeway lanes';
var randomnumber=Math.floor(Math.random()*10) ;
var speedF = Math.round(60 + randomnumber/10) ;
var speedT =35;
if (TimODay == 1)
{ speedT = 45; }
else if (TimODay ==2)
{ speedT = 50; }
else { speedT =55;}
var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
var varPerGPL = 35;
var varGPL = Math.round(TollDist * (60/speedT)*varPerGPL/100);
document.getElementById('answer44745X180X9503').value = TrvTmGPL;
document.getElementById('answer44745X180X95027').value = TrvTmGPL;
document.getElementById('answer44745X180X9504').value = 'None';
document.getElementById('answer44745X180X95028').value = 'None';
document.getElementById('answer44745X180X9506').value = varGPL;
document.getElementById('answer44745X180X95030').value = varGPL;
document.getElementById('answer44745X180X9507').value = 'Carpool with others' ;
```

```
document.getElementById('answer44745X180X95031').value = 'Carpool with others' ;
document.getElementById('answer44745X180X9508').value = 'Main freeway lanes';
document.getElementById('answer44745X180X95032').value = 'Main freeway lanes';
document.getElementById('answer44745X180X9509').value = TrvTmGPL;
document.getElementById('answer44745X180X95033').value = TrvTmGPL;
document.getElementById('answer44745X180X95010').value = 'None' ;
document.getElementById('answer44745X180X95034').value = 'None' ;
document.getElementById('answer44745X180X95012').value = varGPL ;
document.getElementById('answer44745X180X95036').value = varGPL ;
document.getElementById('answer44745X180X95013').value = 'Drive by myself';
document.getElementById('answer44745X180X95037').value = 'Drive by myself';
document.getElementById('answer44745X180X95014').value = 'Toll lanes';
document.getElementById('answer44745X180X95038').value = 'Toll lanes';
var randomnumber=Math.floor(Math.random()*10) ;
var speedF = Math.round(60 + randomnumber/10) ;
                    var speedT =25;
                    if (TimODay == 1)
                    { speedT = 55; }
                    else if (TimODay ==2)
                    { speedT = 55; }
                    else { speedT =60;}
var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
document.getElementById('answer44745X180X95015').value = TrvTmML;
document.getElementById('answer44745X180X95039').value = TrvTmML;
                    var Toll = 17/TimODay;
var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
                    var varPerML = 15;
var varML = Math.round(TollDist * (60/speedT)*varPerML/100);
                    if (varML==0)
                    { varML =1 ;}
document.getElementById('answer44745X180X95016').value = TotToll3;
document.getElementById('answer44745X180X95040').value = TotToll3;
document.getElementById('answer44745X180X95018').value = varML;
document.getElementById('answer44745X180X95042').value = varML;
document.getElementById('answer44745X180X95019').value = 'Carpool with others';
document.getElementById('answer44745X180X95043').value = 'Carpool with others';
document.getElementById('answer44745X180X95020').value = 'Toll lanes';
document.getElementById('answer44745X180X95044').value = 'Toll lanes';
document.getElementById('answer44745X180X95021').value = TrvTmML;
document.getElementById('answer44745X180X95045').value = TrvTmML;
                    var Toll = 5/TimODay;
var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
document.getElementById('answer44745X180X95022').value = TotToll3;
document.getElementById('answer44745X180X95046').value = TotToll3;
document.getElementById('answer44745X180X95024').value = varML;
document.getElementById('answer44745X180X95048').value = varML;
                    if (TotToll3 == "None" || TotToll3 == 0)
                    {
document.getElementById('answer44745X180X95061').value = "0.00" ;
                    }
                    else
                    {
document.getElementById('answer44745X180X95061').value = TotToll3;
```

```
}
break;
case 7:
document.getElementById('answer44745X180X9501').value = 'Drive by myself';
document.getElementById('answer44745X180X95025').value = 'Drive by myself';
document.getElementById('answer44745X180X9502').value = 'Main freeway lanes';
document.getElementById('answer44745X180X95026').value = 'Main freeway lanes';
var randomnumber=Math.floor(Math.random()*10) ;
var speedF = Math.round(60 + randomnumber/10) ;
var speedT =35;
if (TimODay == 1)
{ speedT = 25; }
else if (TimODay ==2)
{ speedT = 30; }
else { speedT =45;}
var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
var varPerGPL = 20;
var varGPL = Math.round(TollDist * (60/speedT)*varPerGPL/100);
document.getElementById('answer44745X180X9503').value = TrvTmGPL;
document.getElementById('answer44745X180X95027').value = TrvTmGPL;
document.getElementById('answer44745X180X9504').value = 'None';
document.getElementById('answer44745X180X95028').value = 'None';
document.getElementById('answer44745X180X9506').value = varGPL;
document.getElementById('answer44745X180X95030').value = varGPL;
document.getElementById('answer44745X180X9507').value = 'Carpool with others' ;
document.getElementById('answer44745X180X95031').value = 'Carpool with others' ;
document.getElementById('answer44745X180X9508').value = 'Main freeway lanes';
document.getElementById('answer44745X180X95032').value = 'Main freeway lanes';
document.getElementById('answer44745X180X9509').value = TrvTmGPL;
document.getElementById('answer44745X180X95033').value = TrvTmGPL;
document.getElementById('answer44745X180X95010').value = 'None' ;
document.getElementById('answer44745X180X95034').value = 'None' ;
document.getElementById('answer44745X180X95012').value = varGPL ;
document.getElementById('answer44745X180X95036').value = varGPL ;
document.getElementById('answer44745X180X95013').value = 'Drive by myself';
document.getElementById('answer44745X180X95037').value = 'Drive by myself';
document.getElementById('answer44745X180X95014').value = 'Toll lanes';
document.getElementById('answer44745X180X95038').value = 'Toll lanes';
var randomnumber=Math.floor(Math.random()*10) ;
var speedF = Math.round(60 + randomnumber/10) ;
var speedT =25;
if (TimODay == 1)
{ speedT = 65; }
else if (TimODay ==2)
{ speedT = 65; }
else { speedT =70;}
var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
document.getElementById('answer44745X180X95015').value = TrvTmML;
document.getElementById('answer44745X180X95039').value = TrvTmML;
var Toll = 35/TimODay;
var TotToll3 = (Math.round((((Toll * TollDist)/5))/20).toFixed(2);
var varPerML = 10;
var varML = Math.round(TollDist * (60/speedT)*varPerML/100);
```

```
document.getElementById('answer44745X180X95016').value = TotToll3;
document.getElementById('answer44745X180X95040').value = TotToll3;
document.getElementById('answer44745X180X95018').value = varML;
document.getElementById('answer44745X180X95042').value = varML;
document.getElementById('answer44745X180X95019').value = 'Carpool with others';
document.getElementById('answer44745X180X95043').value = 'Carpool with others';
document.getElementById('answer44745X180X95020').value = 'Toll lanes';
document.getElementById('answer44745X180X95044').value = 'Toll lanes';
document.getElementById('answer44745X180X95021').value = TrvTmML;
document.getElementById('answer44745X180X95045').value = TrvTmML;
                                        var Toll = 10/TimODay;
var TotToll3 = (Math.round(((Toll * TollDist)/5))/20).toFixed(2);
                                        if (varML==0)
                                        { varML =1 ;}
document.getElementById('answer44745X180X95022').value = TotToll3;
document.getElementById('answer44745X180X95046').value = TotToll3;
document.getElementById('answer44745X180X95024').value = varML;
document.getElementById('answer44745X180X95048').value = varML;
                                        if (TotToll3 == "None" || TotToll3 == 0)
                                        {
document.getElementById('answer44745X180X95061').value = "0.00" ;
                                        }
                                        else
                                        {
document.getElementById('answer44745X180X95061').value = TotToll3;
                                        }
                              break;
case 8:
document.getElementById('answer44745X180X9501').value = 'Drive by myself';
document.getElementById('answer44745X180X95025').value = 'Drive by myself';
document.getElementById('answer44745X180X9502').value = 'Main freeway lanes';
document.getElementById('answer44745X180X95026').value = 'Main freeway lanes';
                                        var randomnumber=Math.floor(Math.random()*10) ;
                                        var speedF = Math.round(60 + randomnumber/10) ;
                                        var speedT =35;
                                        if (TimODay == 1)
                                        { speedT = 25; }
                                        else if (TimODay ==2)
                                        { speedT = 30; }
                                        else { speedT =45;}
var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
                                        var varPerGPL = 20;
var varGPL = Math.round(TollDist * (60/speedT)*varPerGPL/100);
document.getElementById('answer44745X180X9503').value = TrvTmGPL;
document.getElementById('answer44745X180X95027').value = TrvTmGPL;
document.getElementById('answer44745X180X9504').value = 'None';
document.getElementById('answer44745X180X95028').value = 'None';
document.getElementById('answer44745X180X9506').value = varGPL;
document.getElementById('answer44745X180X95030').value = varGPL;
document.getElementById('answer44745X180X9507').value = 'Carpool with others' ;
document.getElementById('answer44745X180X95031').value = 'Carpool with others' ;
document.getElementById('answer44745X180X9508').value = 'Main freeway lanes';
document.getElementById('answer44745X180X95032').value = 'Main freeway lanes';
```

```
document.getElementById('answer44745X180X9509').value = TrvTmGPL;
document.getElementById('answer44745X180X95033').value = TrvTmGPL;
document.getElementById('answer44745X180X95010').value = 'None' ;
document.getElementById('answer44745X180X95034').value = 'None' ;
document.getElementById('answer44745X180X95012').value = varGPL ;
document.getElementById('answer44745X180X95036').value = varGPL ;
document.getElementById('answer44745X180X95013').value = 'Drive by myself';
document.getElementById('answer44745X180X95037').value = 'Drive by myself';
document.getElementById('answer44745X180X95014').value = 'Toll lanes';
document.getElementById('answer44745X180X95038').value = 'Toll lanes';
                                        var randomnumber=Math.floor(Math.random()*10) ;
                                        var speedF = Math.round(60 + randomnumber/10) ;
                                        var speedT =25;
                                        if (TimODay == 1)
                                        { speedT = 65; }
                                        else if (TimODay ==2)
                                        { speedT = 65; }
                                        else { speedT =70;}
var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
document.getElementById('answer44745X180X95015').value = TrvTmML;
document.getElementById('answer44745X180X95039').value = TrvTmML;
                    var Toll = 35/TimODay;
var TotToll3 = (Math.round((((Toll * TollDist)/5))/20).toFixed(2);
                                        var varPerML = 15;
var varML = Math.round(TollDist * (60/speedT)*varPerML/100);
                                        if (varML==0)
                                        { varML =1 ;}
document.getElementById('answer44745X180X95016').value = TotToll3;
document.getElementById('answer44745X180X95040').value = TotToll3;
document.getElementById('answer44745X180X95018').value = varML;
document.getElementById('answer44745X180X95042').value = varML;
document.getElementById('answer44745X180X95019').value = 'Carpool with others';
document.getElementById('answer44745X180X95043').value = 'Carpool with others';
document.getElementById('answer44745X180X95020').value = 'Toll lanes';
document.getElementById('answer44745X180X95044').value = 'Toll lanes';

document.getElementById('answer44745X180X95021').value = TrvTmML;

document.getElementById('answer44745X180X95045').value = TrvTmML;
                                        var Toll = 10/TimODay;
var TotToll3 = (Math.round((((Toll * TollDist)/5))/20).toFixed(2);
document.getElementById('answer44745X180X95022').value = TotToll3;
document.getElementById('answer44745X180X95046').value = TotToll3;
document.getElementById('answer44745X180X95024').value = varML;
document.getElementById('answer44745X180X95048').value = varML;
          if (TotToll3 == "None" || TotToll3 == 0)
                                        {
document.getElementById('answer44745X180X95061').value = "0.00" ;
                                        }
                                        else
                                        {
document.getElementById('answer44745X180X95061').value = TotToll3;
                                        }
```

```
					break;
					default:
					alert ("Default block");
				}

		}

else if ("{INSERTANS:44745X178X94849}" == 2) //random
		{
		document.getElementById('answer44745X180X9501').value = 'Drive by myself';
		document.getElementById('answer44745X180X95025').value = 'Drive by myself';
		document.getElementById('answer44745X180X9502').value = 'Main freeway lanes';
		document.getElementById('answer44745X180X95026').value = 'Main freeway lanes';
			var randomnumber15=Math.floor(Math.random()*15) ;
			var speedT = Math.round(10+10*TimODay + randomnumber15) ;
			var speedF = Math.round(60 + randomnumber15/3) ;
			var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
			var randomnumber25=Math.floor(Math.random()*25);
			var varPerGPL = Math.round(10+5*(4-TimODay)+randomnumber25/TimODay);
			var varGPL = Math.round(TollDist * (60/speedT)*varPerGPL/100);
			document.getElementById('answer44745X180X9503').value = TrvTmGPL;
			document.getElementById('answer44745X180X95027').value = TrvTmGPL;
			document.getElementById('answer44745X180X9504').value = 'None';
			document.getElementById('answer44745X180X95028').value = 'None';
			document.getElementById('answer44745X180X9506').value = varGPL;
			document.getElementById('answer44745X180X95030').value = varGPL;
		document.getElementById('answer44745X180X9507').value = 'Carpool with others' ;
		document.getElementById('answer44745X180X95031').value = 'Carpool with others' ;
		document.getElementById('answer44745X180X9508').value = 'Main freeway lanes';
		document.getElementById('answer44745X180X95032').value = 'Main freeway lanes';
			document.getElementById('answer44745X180X9509').value = TrvTmGPL;
			document.getElementById('answer44745X180X95033').value = TrvTmGPL;
			document.getElementById('answer44745X180X95010').value = 'None' ;
			document.getElementById('answer44745X180X95034').value = 'None' ;
			document.getElementById('answer44745X180X95012').value = varGPL ;
			document.getElementById('answer44745X180X95036').value = varGPL ;
		document.getElementById('answer44745X180X95013').value = 'Drive by myself';
		document.getElementById('answer44745X180X95037').value = 'Drive by myself';
			document.getElementById('answer44745X180X95014').value = 'Toll lanes';
			document.getElementById('answer44745X180X95038').value = 'Toll lanes';
			var randomnumber10=Math.floor(Math.random()*10) ;
			var randomnumber15=Math.floor(Math.random()*15) ;
			var speedF = Math.round(60 + randomnumber15/3) ;
			var speedT = 25;
			if (TimODay == 1 || TimODay == 2)
			{ speedT = 55 + randomnumber10; }
			else
			{ speedT = 60 + randomnumber10; }
			var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
			if (TrvTmGPL < TrvTmML)
			{
				TrvTmML = TrvTmGPL - 3 ;
			}
```

```
                else
                {
                TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
                }
                document.getElementById('answer44745X180X95015').value = TrvTmML;
                document.getElementById('answer44745X180X95039').value = TrvTmML;
                var randomnumber20=Math.floor(Math.random()*20) ;
                var randomnumber8=Math.floor(Math.random()*8) ;
                var randomnumber10=Math.floor(Math.random()*10) ;
                var TollDA = 5+randomnumber20/TimODay+randomnumber8;
                var TotTollDA = (Math.round(((TollDA * TollDist)/5))/20).toFixed(2);
                var varPerML = 5+randomnumber10;
                var varML = Math.round(TollDist * (60/speedT)*varPerML/100);
                if (varML==0)
                { varML =1 ;}
                document.getElementById('answer44745X180X95016').value = TotTollDA;
                document.getElementById('answer44745X180X95040').value = TotTollDA;
                document.getElementById('answer44745X180X95018').value = varML;
                document.getElementById('answer44745X180X95042').value = varML;
        document.getElementById('answer44745X180X95019').value = 'Carpool with others';
        document.getElementById('answer44745X180X95043').value = 'Carpool with others';
                document.getElementById('answer44745X180X95020').value = 'Toll lanes';
                document.getElementById('answer44745X180X95044').value = 'Toll lanes';
                document.getElementById('answer44745X180X95021').value = TrvTmML;
                document.getElementById('answer44745X180X95045').value = TrvTmML;
                var randomnumber6=Math.floor(Math.random()*6) ;
                var randomnumber4=Math.floor(Math.random()*4) ;
                var TollCP = randomnumber6/TimODay + randomnumber4;
                var TotTollCP = (Math.round(((TollCP * TollDist)/5))/20).toFixed(2);
                if (TotTollDA < TotTollCP || TollCP < 5)
                {
                        TotTollCP = 'None';
                }
                else
                {
                        TotTollCP = (Math.round(((TollCP * TollDist)/5))/20).toFixed(2);
                }
                document.getElementById('answer44745X180X95022').value = TotTollCP;
                document.getElementById('answer44745X180X95046').value = TotTollCP;
                document.getElementById('answer44745X180X95024').value = varML;
                document.getElementById('answer44745X180X95048').value = varML;
                if (TotTollCP == "None")
                {
                        document.getElementById('answer44745X180X95061').value = "0.00" ;
                }
                else
                {
                document.getElementById('answer44745X180X95061').value = TotTollCP;
                }
        }

else if ("{INSERTANS:44745X178X94849}" == 3) // smart adjusting
        {
```

```
// Previous SP Answer and Toll Rate
if ("{INSERTANS:44745X178X94854}"==1)
{
	var SPAns1 = "{INSERTANS:44745X179X949}";
	var SPAnsA = SPAns1.indexOf(".");
	if (SPAnsA == -1)
	{
		var toll1 = 0;
	}
	else
	{
		var toll1 = Number(SPAns1.substring(SPAnsA-1,SPAnsA+3));
	}
	var SPAns2 = "{INSERTANS:44745X179X952}";
	var SPAnsB = SPAns2.indexOf(".");
	if (SPAnsB == -1)
	{
		var toll2 = 0;
	}
	else
	{
		var toll2 = Number(SPAns2.substring(SPAnsB-1,SPAnsB+3));
	}
}
else
{
	var SPAns1 = "{INSERTANS:44745X179X970}";
	var SPAnsA = SPAns1.indexOf("$");
	if (SPAnsA == -1)
	{
		var toll1 = 0;
	}
	else
	{
		var toll1 = Number(SPAns1.substring(SPAnsA+1,SPAnsA+4));
	}
	var SPAns2 = "{INSERTANS:44745X179X971}";
	var SPAnsB = SPAns2.indexOf("$");
	if (SPAnsB == -1)
	{
		var toll2 = 0;
	}
	else
	{
		var toll2 = Number(SPAns2.substring(SPAnsB+1,SPAnsB+4));
	}
}
var TollpMiDAML1 = Number("{INSERTANS:44745X178X94859}");
var TollpMiCPML1 = Number("{INSERTANS:44745X178X94860}");
if (toll1 + toll2 > 0)  // calculate tolls for SP set 2 for smart adjusting random
{
	var randomnumberTfact = (115+Math.floor(Math.random()*60))/100;
	var TollpMiDAML2 = TollpMiDAML1*randomnumberTfact ;
```

```
			var TollpMiCPML2 = TollpMiCPML1*randomnumberTfact ;
		}
		else
		{
			var randomnumberTfact = (50+Math.floor(Math.random()*35))/100;
			var TollpMiDAML2 = TollpMiDAML1*randomnumberTfact ;
			var TollpMiCPML2 = TollpMiCPML1*randomnumberTfact ;
		}

		document.getElementById('answer44745X180X9501').value = 'Drive by myself';
document.getElementById('answer44745X180X95025').value = 'Drive by myself';
document.getElementById('answer44745X180X9502').value = 'Main freeway lanes';
document.getElementById('answer44745X180X95026').value = 'Main freeway lanes';
		var randomnumber15=Math.floor(Math.random()*15) ;
		var speedT = Math.round(10+10*TimODay + randomnumber15) ;
		var speedF = Math.round(60 + randomnumber15/3) ;
		var TrvTmGPL = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
		var randomnumber25=Math.floor(Math.random()*25);
		var varPerGPL = Math.round(10+5*(4-TimODay)+randomnumber25/TimODay);
		var varGPL = Math.round(TollDist * (60/speedT)*varPerGPL/100);
		document.getElementById('answer44745X180X9503').value = TrvTmGPL;
		document.getElementById('answer44745X180X95027').value = TrvTmGPL;
		document.getElementById('answer44745X180X9504').value = 'None';
		document.getElementById('answer44745X180X95028').value = 'None';
		document.getElementById('answer44745X180X9506').value = varGPL;
		document.getElementById('answer44745X180X95030').value = varGPL;
document.getElementById('answer44745X180X9507').value = 'Carpool with others' ;
document.getElementById('answer44745X180X95031').value = 'Carpool with others' ;
document.getElementById('answer44745X180X9508').value = 'Main freeway lanes';
document.getElementById('answer44745X180X95032').value = 'Main freeway lanes';
		document.getElementById('answer44745X180X9509').value = TrvTmGPL;
		document.getElementById('answer44745X180X95033').value = TrvTmGPL;
		document.getElementById('answer44745X180X95010').value = 'None' ;
		document.getElementById('answer44745X180X95034').value = 'None' ;
		document.getElementById('answer44745X180X95012').value = varGPL ;
		document.getElementById('answer44745X180X95036').value = varGPL ;
document.getElementById('answer44745X180X95013').value = 'Drive by myself';
document.getElementById('answer44745X180X95037').value = 'Drive by myself';
		document.getElementById('answer44745X180X95014').value = 'Toll lanes';
		document.getElementById('answer44745X180X95038').value = 'Toll lanes';
		var randomnumber10=Math.floor(Math.random()*10) ;
		var randomnumber15=Math.floor(Math.random()*15) ;
		var speedF = Math.round(60 + randomnumber15/3) ;
		var speedT = 25;
		if (TimODay == 1 || TimODay == 2)
		{ speedT = 55 + randomnumber10; }
		else
		{ speedT = 60 + randomnumber10; }
		var TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
		if (TrvTmGPL < TrvTmML)
		{
			TrvTmML = TrvTmGPL - 3 ;
		}
```

```
            else
            {
            TrvTmML = Math.round((TollDist * 60/speedT) + (FreeDist * 60/speedF));
            }
            document.getElementById('answer44745X180X95015').value = TrvTmML;
            document.getElementById('answer44745X180X95039').value = TrvTmML;
            var randomnumber20=Math.floor(Math.random()*20) ;
            var randomnumber8=Math.floor(Math.random()*8) ;
            var randomnumber10=Math.floor(Math.random()*10) ;
            var TollDA = TollpMiDAML2;
            var TotTollDA = (Math.round(((TollDA * TollDist)/5))/20).toFixed(2);
            var varPerML = 5+randomnumber10;
            var varML = Math.round(TollDist * (60/speedT)*varPerML/100);
            if (varML==0)
            { varML =1 ;}
            document.getElementById('answer44745X180X95016').value = TotTollDA;
            document.getElementById('answer44745X180X95040').value = TotTollDA;
            document.getElementById('answer44745X180X95018').value = varML;
            document.getElementById('answer44745X180X95042').value = varML;
document.getElementById('answer44745X180X95019').value = 'Carpool with others';
document.getElementById('answer44745X180X95043').value = 'Carpool with others';
            document.getElementById('answer44745X180X95020').value = 'Toll lanes';
            document.getElementById('answer44745X180X95044').value = 'Toll lanes';
            document.getElementById('answer44745X180X95021').value = TrvTmML;
            document.getElementById('answer44745X180X95045').value = TrvTmML;
            var randomnumber6=Math.floor(Math.random()*6) ;
            var randomnumber4=Math.floor(Math.random()*4) ;
            var TollCP = TollpMiCPML2;
            var TotTollCP = (Math.round(((TollCP * TollDist)/5))/20).toFixed(2);
            if (TotTollDA < TotTollCP || TollCP < 5)
            {
                        TotTollCP = 'None';
            }
            else
            {
                        TotTollCP = (Math.round(((TollCP * TollDist)/5))/20).toFixed(2);
            }
            document.getElementById('answer44745X180X95022').value = TotTollCP;
            document.getElementById('answer44745X180X95046').value = TotTollCP;
            document.getElementById('answer44745X180X95024').value = varML;
            document.getElementById('answer44745X180X95048').value = varML;
            document.getElementById('answer44745X180X95059').value = TollDA;
            document.getElementById('answer44745X180X95060').value = TollCP;
            if (TotTollCP == "None")
            {
                        document.getElementById('answer44745X180X95061').value = "0.00" ;
            }
            else
            {
            document.getElementById('answer44745X180X95061').value = TotTollCP;
            }
}
document.getElementById('answer44745X180X95055').value = TrvTmGPL+varGPL;
```

```
document.getElementById('answer44745X180X95056').value = TrvTmGPL-varGPL;
document.getElementById('answer44745X180X95057').value = TrvTmML+varML;
document.getElementById('answer44745X180X95058').value = TrvTmML-varML;
 document.getElementById("answer44745X180X9501").style.display='none';
 document.getElementById("answer44745X180X9502").style.display='none';
 document.getElementById('answer44745X180X9503').style.display='none';
 document.getElementById('answer44745X180X9504').style.display='none';
 document.getElementById('answer44745X180X9505').style.display='none';
 document.getElementById('answer44745X180X9506').style.display='none';
 document.getElementById('answer44745X180X9507').style.display='none';
 document.getElementById('answer44745X180X9508').style.display='none';
 document.getElementById('answer44745X180X9509').style.display='none';
 document.getElementById('answer44745X180X95010').style.display='none';
 document.getElementById('answer44745X180X95011').style.display='none';
 document.getElementById('answer44745X180X95012').style.display='none';
 document.getElementById('answer44745X180X95013').style.display='none';
 document.getElementById('answer44745X180X95014').style.display='none';
 document.getElementById('answer44745X180X95015').style.display='none';
 document.getElementById('answer44745X180X95016').style.display='none';
 document.getElementById('answer44745X180X95017').style.display='none';
 document.getElementById('answer44745X180X95018').style.display='none';
 document.getElementById('answer44745X180X95019').style.display='none';
 document.getElementById('answer44745X180X95020').style.display='none';
 document.getElementById('answer44745X180X95021').style.display='none';
 document.getElementById('answer44745X180X95022').style.display='none';
 document.getElementById('answer44745X180X95023').style.display='none';
 document.getElementById('answer44745X180X95024').style.display='none';
 document.getElementById('answer44745X180X95025').style.display='none';
 document.getElementById('answer44745X180X95026').style.display='none';
 document.getElementById('answer44745X180X95027').style.display='none';
 document.getElementById('answer44745X180X95028').style.display='none';
 document.getElementById('answer44745X180X95029').style.display='none';
 document.getElementById('answer44745X180X95030').style.display='none';
 document.getElementById('answer44745X180X95031').style.display='none';
 document.getElementById('answer44745X180X95032').style.display='none';
 document.getElementById('answer44745X180X95033').style.display='none';
 document.getElementById('answer44745X180X95034').style.display='none';
 document.getElementById('answer44745X180X95035').style.display='none';
 document.getElementById('answer44745X180X95036').style.display='none';
 document.getElementById("answer44745X180X95037").style.display='none';
 document.getElementById("answer44745X180X95038").style.display='none';
 document.getElementById('answer44745X180X95039').style.display='none';
 document.getElementById('answer44745X180X95040').style.display='none';
 document.getElementById("answer44745X180X95041").style.display='none';
 document.getElementById("answer44745X180X95042").style.display='none';
 document.getElementById('answer44745X180X95043').style.display='none';
 document.getElementById("answer44745X180X95044").style.display='none';
 document.getElementById("answer44745X180X95045").style.display='none';
 document.getElementById("answer44745X180X95046").style.display='none';
 document.getElementById("answer44745X180X95047").style.display='none';
 document.getElementById("answer44745X180X95048").style.display='none';
 document.getElementById("answer44745X180X95049").style.display='none';
 document.getElementById("answer44745X180X95050").style.display='none';
```

```
        document.getElementById("answer44745X180X95051").style.display='none';
        document.getElementById("answer44745X180X95052").style.display='none';
        document.getElementById("answer44745X180X95053").style.display='none';
        document.getElementById("answer44745X180X95054").style.display='none';
        document.getElementById("answer44745X180X95055").style.display='none';
        document.getElementById("answer44745X180X95056").style.display='none';
        document.getElementById("answer44745X180X95057").style.display='none';
        document.getElementById("answer44745X180X95058").style.display='none';
        document.getElementById("answer44745X180X95059").style.display='none';
        document.getElementById("answer44745X180X95060").style.display='none';
        document.getElementById("answer44745X180X95061").style.display='none';

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