

**THE IMPACT OF TRAFFIC IMAGES ON MODE CHOICE IN
STATED-PREFERENCE SURVEYS**

A Thesis

by

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ABSTRACT

A difficult aspect of using stated-preference choice experiments to predict travel behavior is properly presenting attributes and characteristics of hypothetical trips to respondents. With the growing in number of transportation choices recently, the task of concisely and accurately communicating trip attributes in the stated-preference setting become increasingly more important. Recent attempts to introduce innovative strategies to the stated-preference setting have yielded techniques to more efficiently summarize trip attributes to respondents. One technique is to use images of traffic conditions as a supplemental means of summarizing average trip speed, travel time reliability, or degree of congestion. However, little research has been performed testing the effect that the use of traffic images has on models of mode choice built from this kind of stated-preference data. In this research, a stated-preference setting was developed in which the influence that images of traffic conditions was measured. Pictures of traffic conditions that correlated to average trip speed were either shown or withheld depending on random assignment to a survey population from Austin, Texas. From the significant differences in respondent preferences across mode choice, a mixed-logit model was built to describe the respondent's choice behavior. Overall model parameters discovered no evidence to support the assertion that traffic image presentation has a statistically significant effect on mode choice with respect to Value of Travel Time Savings, or Value of Travel Time Reliability.

DEDICATION

To Meg, for her patient support, encouragement, and love.

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NOMENCLATURE

SP	Stated-preference
VTTS	Value of Travel Time Savings
VTTR	Value of Travel Time Reliability
RP	Revealed-preference
VOT	Value of Time
D_b -efficient	Bayesian D-efficient
RA	Random Adjusting
ATS	Austin Traveler Survey
MNL	Multinomial Logit
ML	Mixed Logit

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1. INTRODUCTION

In urban transportation planning, understanding and determining the factors that most influence traveler behavior is critical to predicting traveler route choice. For some travelers, the quality of the road may be a deciding factor. For others it may be the degree of congestion and therefore travel time that influences the traveler to use a certain road. For other travelers, the cost of the trip may be the most important factor. In order to determine the degree to which these trip attributes influence traveler behavior, many researchers perform surveys using hypothetical travel scenarios from which respondents can choose. This type of survey is known as a Stated-Preference (SP) survey, and it differs from revealed preference surveys in that it does not measure actual traveler behavior. Therefore, SP surveys are not constrained in presenting choice alternatives that currently exist to survey respondents. One of the challenges that SP surveys present to the researcher is how to best communicate these hypothetical trip alternatives to survey respondents and therefore generate the most accurate data to measure influencing factors in trip choice.

A difficult aspect of using SP choice experiments to predict travel behavior is properly presenting attributes and characteristics of hypothetical trips to respondents. A travel choice scenario can exhibit a wide variety of trip attributes, such as travel time, travel time reliability, or cost variability. However, many respondents to SP choice experiments often have difficulty combining and translating these attributes to a real-world experience (Mazotta and Opaluch 1995, Wang et al. 2001). Recently, research has

indicated that stated-preference experiments incorporating “pivoted” hypothetical alternatives—in which hypothetical trip attributes are closely tied to a respondent’s most recent trip experience—can more closely resemble the respondent’s travel perspective and therefore provide results that most accurately resemble actual travel choice behavior (Rose et al. 2008). Additionally, since expected value of travel time savings (VTTS) increases by approximately 30-50% in congested conditions as compared to free-flow conditions (Rizzi et al. 2012), the ability to communicate hypothetical congested conditions to experiment respondents becomes increasingly more important to obtaining accurate estimates of travel behavior.

Recent research has examined the most effective ways to communicate trip attributes to stated-preference respondents. It is necessary to present respondents with enough information to simulate the level of knowledge that they will have when presented with a real-world travel choice. However, there are indications that increasing the number of trip attributes presented to the respondent adversely affects his/her ability to interpret stated-preference scenarios, adding error noise to resulting utility functions, and creating bias towards trip characteristics on which respondents place the most importance (Arentze et al. 2003). In this respect, it is vital to the effectiveness of any stated-preference survey to simultaneously provide adequate knowledge of travel alternatives to the respondent while communicating such knowledge in a simplistic manner. To this end, Rizzi et al. found that including traffic images to supplement trip attribute information in the presentation of SP questions resulted in more realistic VTTS estimates (Rizzi et al. 2012).

This research evaluates the effectiveness of using the traffic images (seen in Figure 1) to supplement stated-preference trip attribute information and estimate any



Figure 1. Traffic images illustrating light, medium, and heavy traffic

effect on respondents' VTTS and value of travel time reliability (VTTR). This research supplements and expands on the existing literature on SP question design, with the goal of quantifying the impacts of traffic images on mode choice in SP surveys.

1.1 RESEARCH PROBLEM

Travelers' choices are becoming increasingly complex due to a greater amount of mode and route alternatives, such as managed lanes (MLs). Therefore, it is becoming increasingly important to present more complex choice experiments in order to accurately measure the respondent's decision processes in choosing alternatives. The incentive in doing so is to develop travel demand models of traveler utility that can incorporate complex choices while preserving model accuracy. There is, however, a limit to the information that can be processed by the survey respondent in the decision-making process. Additionally, a large amount of information may induce bias in the results as respondents find the stated-preference choice set overly burdensome (Mazotta and Opaluch 1995, Wang et al. 2001). One proposed method to alleviate this burden is through the introduction of supplementary traffic images as an additional means to communicate trip conditions to SP survey respondents.

This thesis evaluates the impact of incorporating supplementary traffic images with SP questions on respondent mode choice behavior. The issues examined in this thesis include the impact of images on lexicographic and non-trading behavior as well as their impact on the performance of multinomial logistic mode choice model behavior derived from survey results. These models assist in understanding the role that simplified information in a mixed lexicographic/pictorial format—as compared to a solely

lexicographic format—can have in altering SP response behavior as well as providing a basis for greater understanding of traveler utility within this context. The research analyzed the models derived from survey responses to evaluate which method provides more accurate results.

1.2 RESEARCH OBJECTIVES

The objectives of the research are as follows:

1. Using sound practices for SP survey design (as established by the literature, see Section 2), develop and administer a real-world survey in which the effects of traffic images on respondent mode choice behavior can be measured.
2. Analyze survey response data by survey design type by identifying significant model parameters, developing an optimal mixed-logit model, and analyzing it to measure the effect of traffic images on those models. Also, determine if the impact of images is beneficial or detrimental to model performance.
3. Using the models generated in Objective 2, estimating VTTS, and VTTR for respondents that were presented surveys with traffic images as well as those that were presented surveys without traffic images.
4. Measure the impact that traffic images have on model parameters, as well as their impact on non-trading and lexicographic behavior, VTTS and VTTR estimates, and model goodness-of-fit measures.

1.3 RESEARCH METHODOLOGY AND SURVEY DESIGN

The goal of this research was to test the impact of traffic images on respondent mode choice in the stated-preference section of a traveler survey. In this survey, respondents in the Austin metropolitan region were asked a series of questions regarding their most recent trip, including time of day, vehicle used, vehicle occupancy, trip purpose, and trip origin/destination. Once trip data was acquired, each respondent was presented with a set of three stated-preference questions with two mode choice alternatives. These were designed to be similar to each respondent's most recent trip, and

each respondent was asked to select which single alternative would best represent the choice the respondent would make if the hypothetical travel scenario were real.

Prior to the presentation of the stated-preference portion of the proposed survey, the respondents were separated into two groups, with one viewing graphic representations of hypothetical trip attributes with no traffic images (a lexicographic strategy, see Figure 2), and the other group viewing traffic images next to the graphic representations of hypothetical trip attributes (a mixed-lexicographic/graphic strategy, see Figure 3). The trip attributes that varied in this experiment were travel time, travel time variability, and cost. The survey assigned attribute distributions according to either a Bayesian D-efficient (D_b -efficient) distribution—in which trip attributes are assigned based on a minimization of the D-error of prior values—or a Random Adjusting distribution, which utilized response feedback to current SP questions to generate subsequent SP trip attributes.

You described your most recent trip on an Austin freeway as occurring on a Monday at 6:45 AM in a passenger car, SUV, or pick-up truck. The reason for your trip was commuting to or from your place of work (going to or from work).


If you had the options below for that trip during the morning shoulder period, which option would you choose?

(The Max and Min values show the range of travel times)

Choose one of the following answers


Option A

Non-toll Road
Begin Trip at (morning shoulder period)
Trip Distance: 20 miles
No Toll




Typical
<--Max--> <--> <--Min-->

Travel Time 37 34 31 minutes



Option B

Toll Road
Begin Trip at (morning shoulder period)
Trip Distance: 20 miles
Toll: \$2.20



Typical
<--Max--> <--> <--Min-->

Travel Time 23 22 21 minutes




Figure 3. Example of SP question with traffic images included

Once data was collected, it was analyzed for similarity of responses across survey design type as well as mode choice to identify significant parameters that may be useful in constructing logit models of the survey results. The data was then analyzed for lexicographic behavior (in which a respondents choose alternatives based on only one trip attribute) and non-trading behavior (in which a respondents choose only one alternative for all SP questions). After this step, mixed-logit models of all responses were

generated to better understand the characteristics of the whole sample and to serve as a control by which to compare models of subsets of the data. The data was then divided by survey design type and a best logit model was estimated and analyzed across different pools of data. This included: 1) respondents who viewed traffic images, 2) respondents who did not view traffic images, 3) respondents who viewed traffic images and the degree in which those traffic images differed, and 4) respondents who did not view traffic images and the degree in which those traffic images would have differed had the respondent viewed images that were generated from the same trip attribute criteria.

1.4 THESIS OUTLINE

This thesis is organized by sections as follows: Section 2 contains an overview of the role of urban planning in predicting future travel behavior and route choice, including a literature review on the standard techniques of SP question design. Section 3 includes an overview of the research methodology, including a description of the survey instrument and how it was developed. Section 3 also presents the method by which SP trip attributes were assigned and the manner in which traffic images were distributed among survey respondents. Section 4 describes the analysis procedure, and the format of the data collected. This section includes a socio-demographic analysis of survey respondents, a descriptive analysis of the response data, and a comparative analysis of mixed-logit models of mode choice by survey design type. Section 5 contains the conclusions drawn from the research and provides recommendations for future research.

2. LITERATURE REVIEW

The purpose of this research is to further the understanding of the effects that images of traffic conditions have on SP response behavior, specifically with regards to mode choice. This section provides relevant background information to better understand the importance that mode and route choice have on urban planning, and how planners use information about traveler preferences to accommodate future growth. This section will also examine the means by which researchers gather information about traveler's preferences, particularly through revealed-preference and stated-preference surveys. This section will then examine the standard techniques of SP survey design, as well as standard methods used to analyze survey data. This section is also a review of recent research that has studied the effect that images have on SP response behavior, with an emphasis on how findings can benefit the urban planning process.

2.1 THE IMPORTANCE OF PREDICTING FUTURE TRAVEL BEHAVIOR

The task of urban planning includes many facets of building efficient and optimum communities. One of the most important tasks in urban planning is the effective design of transportation infrastructure around which a community can be built. In the most desirable case, urban planning plays a pivotal role in developing transportation networks that can be a catalyst for healthy economic growth for a community and region (The American Planning Association 2013). Among the many concerns that face planners are predicting the spatial distribution of future economic growth, the

distribution of travel demand that follows such growth, and determining future transportation infrastructure that can accommodate that growth. A key question for transportation planners then becomes one of how to predict travel behavior for future conditions, and how to prepare to manage that travel demand before growth and subsequent congestion become a detriment to economic growth.

The ability for planners to predict future behavior is rooted in the principle of utility maximization. For centuries economists, psychologists, and sociologists have postulated that individual behavior can be predicted on the basis that any given individual will seek to maximize his or her utility, or benefits, of a choice (Heiner 1983). When a choice is presented to an individual, that individual will consider the possible alternatives, including the attributes of each choice set, and make the decision that maximizes the utility that that individual receives upon making that choice. These principles rely upon the validity of various assumptions, particularly that an individual retains full knowledge and understanding of all choice sets and attributes, and that the individual will make a consistent and rational choice depending on those attributes (Meyer and Miller 2001). The topic of discrete choice analysis remains useful despite the limitations of these assumptions and has been the basis of continuing insight into human behavior and decision theory (Heiner 1983). Due of the principle of utility maximization, researchers are able to replicate real-world scenarios through hypothetical choice experiments, in which a subject may state his or her preference within the constraints of the experiment. In so doing, researchers isolate significant parameters which affect the

discrete choice, thus arriving at a measureable value for each parameter's aggregate influence on choice behavior.

With these principles under consideration, it is important to note that discrete choice analyses and the behavior models it generates are a representation of real choice behavior, and serves to approximate choices that are made in situations similar to those on which model predictions are based (Ortúzar and Willumsen 2011). The derivation of choice models enables planners to perform demand analysis, which is vital in predicting future usage of transportation networks and determine the supply of transportation infrastructure needed to accommodate demand (Meyer and Miller 2001).

Of particular interest to planners is the estimation of traveler's willingness to pay for transportation services. With an approximation of a population's willingness-to-pay for a given trip, planners determine if an infrastructure upgrade or new construction will provide sufficient societal benefits to outweigh project costs (Brownstone and Small 2005). Municipalities or toll road agencies also use this information to derive demand elasticity of toll price or travel demand for future infrastructure (McFadden 1974). It is therefore essential that travel demand models are accurate representations of aggregate choice behavior for a given population; inaccurate or biased data could result in decisions that are based on incorrect assumptions about project benefits and costs.

2.2 PREDICTING TRAVEL DEMAND AND VALUE OF TIME

Given the importance of accurately estimating travel demand for a transportation system, researchers spend a great deal of effort determining the most efficient and accurate ways to predict mode choice. Through discrete choice analysis, researchers are

able to approximate choice behavior, assuming that choosing agents have the capacity to maximize utility. Heiner argues that choice uncertainty is the source of predictable behavior, in that uncertainty forces a choosing agent to examine the consequences of that choice (Heiner 1983). Once choice uncertainty is introduced, decision-making is determined by an agent's flexibility regarding alternative choices and the level of information available to the decision-maker. If Heiner's hypotheses are correct, the benefits of discrete choice analysis should be maximized when there are several available alternatives with varying attributes, which in the case of travel mode choice occurs when one route is cheaper, faster, or more reliable than another route.

For example, some studies that support Heiner's argument researched the ability of decision-makers to assimilate real-time route knowledge in the choice process, as provided by modern Advanced Traveler Information Systems (ATIS). These systems currently provide travelers information through mobile traffic applications or changeable message signs. Levinson studied the ability of travelers to respond to real-time traffic information when faced with recurring or non-recurring congestion. Levinson finds that the benefits of route information are at a maximum when travel conditions are close to congested, and when that congestion is non-recurring (Levinson 2003). Ben-Elia and Shiftan found that advanced knowledge of alternative conditions also expedites the learning process of choosing agents, resulting in an increase in risk-taking behavior indicative of the utility maximization process (Ben Elia and Shiftan 2010). These studies show the ability of travelers to assimilate information about routes in order to optimize the benefits of a given trip. If researchers can therefore measure the effects that trip

characteristics and individual attributes have on individual trip choices, it is possible to simulate the choice agent's decision-making process, and thus their choice behavior, through discrete choice modeling (Walker and Ben-Akiva 2011).

2.3 STATED-PREFERENCE SURVEY PURPOSE AND DESIGN

One useful tool in establishing choice behavior for a population is the stated-preference survey. SP surveys differ from revealed-preference (RP) surveys in that they provide the means by which hypothetical alternatives can be evaluated. For this purpose, many agencies seeking to build new facilities may utilize a SP survey to gather predicted usage for those facilities (McFadden 1974). Hess et al argue that SP data have significant advantages over revealed-preference data in that they encourage respondent trade-off between attributes, which facilitates in the willingness-to-pay (including the value of time [VOT]) measure, where in RP data time and cost attributes are strongly correlated (Hess et al 2010). While the stated-preference survey is a useful tool, it is essential to conduct the survey in such a way as to minimize bias and sampling errors inherent in certain SP design strategies. Researchers have recently examined the effects that many design strategies have on survey responses in an effort to minimize bias and sampling error. These studies seek to establish state-of-the-art practices in stated-preference survey administration to serve as a baseline for further research.

One area that researchers have examined is the relationship between SP survey task complexity and respondent cognitive ability, and the effect that this relationship has on choice behavior. Arentze tested various forms of presentation and attribute levels in order to quantify the bias that is introduced when task complexity increases, and found

no difference between using lexicographic presentation versus other graphical forms, unless there was a significant difference in literacy rates among respondents (Arentze et al. 2003). Arentze also found that while there is no significant difference in presenting the respondent with two versus three choice sets per choice exercise. However, there is a significant difference when the respondent must base their decision on three versus five attribute characteristics (Arentze et al. 2003). In his research, Heiner proposed that the reason for this difference is due to the existence of a gap in the cognitive ability versus the decision-making ability (C-D) of the respondent. This hypothesis described the means by which respondents tend to either pick their preference illogically or base decisions on only a few attributes that they could understand and process (Heiner 1983). Mazotta et al. confirmed the existence and effect of the C-D gap as proposed by Heiner and suggested avoiding using alternatives that differed by 4 or more attributes at any time (Mazotta and Opaluch 1995). Caussade et al. found the number of choice attributes had a clear detrimental effect on a respondent's ability to choose, which contributed to higher model error variance, while the number of levels also had a negative effect, though much smaller (Caussade et al. 2005). For the purpose of this study, the choice experiment is limited to two mode alternatives (toll and non-toll road options) with three attributes: travel time, travel time reliability, and trip cost. The levels within each attribute are also limited to three per attribute.

In their research, Stopher and Hensher also quantified the empirical gains of increasing task complexity, and found that they are marginal. However, they noted that there is little evidence of response fatigue over as many as 32 choice experiments

(Stopher and Hensher 2000, Hensher 2006, Hess et al. 2012). Despite this conclusion, this research is designed to be short to avoid any residual effects that may arise due to response fatigue. The choice experiments in this research are therefore limited to only three questions.

Computers and internet-based surveys can provide the added benefit of functionality to structure experiments around the specific experiences of each respondent (Mazotta and Opaluch 1995). Researchers currently apply this technique by receiving specific information regarding each respondent's most recent experience and attempting to replicate alternatives from that experience (see Rose et al. 2008). This technique is termed "pivoting," and in the realm of transportation research, is used to build stated-preference alternatives with which the respondent can more easily identify, and thus provide a more accurate representation of the respondent's preferences. This research will also utilize the pivoting strategy, in which many trip characteristics, such as time of day and trip length, will be based on the respondent's description of their most recent trip.

In addition to the format and presentation of stated-preference questions, attribute level generation is equally important in optimizing the statistical efficiency of the experiment. Respondents of this survey will be separated into two groups in which attribute levels are generated according to either a Bayesian D-efficient (D_b -efficient) distribution or a random adjusting (RA) distribution. In their research, Rose et al. found that the D_b -efficient design produced significantly improved results over traditional orthogonal designs (Rose et al. 2008). Devarasetty et al. also noted an increase in survey

efficiency as compared to other attribute distribution techniques, including a random and adaptive random attribute level generation technique (Devarasetty et al. 2012). One objective of this research is to compare the results from the D_b -efficient distribution with the RA design, which utilizes the respondent's initial feedback in the first stated-preference question and adjusts for this input in subsequent questions. Richardson argued for the use of these types of adaptive techniques for stated-preference surveys, where each question depends on the previous one (Richardson 2007). He found this method to be easier for respondents while producing unbiased estimates of the distribution and model parameters. Since this experiment is mostly concerned with the traveler's response to trip cost, the toll cost for the toll road alternative in each stated-preference experiment will adjust by either increasing or decreasing by a random amount within a range, depending on the respondent's choice in the previous question. With these two methods, each design strategy can be compared.

Minimizing non-trading and lexicographic response behavior is also a concern to researchers. This response behavior occurs when respondents do not accurately analyze attributes in a consistent manner. In the case of non-trading behavior, respondents choose from the same alternative in the choice experiment (such as always choosing a toll route alternative, regardless of the attributes of that mode). Lexicographic behavior occurs when a respondent's choices are based on only one attribute (such as the fastest, cheapest, or most reliable route). This type of response behavior violates the primary assumption of choice experiments, which is that a choosing agent will choose to maximize their utility, which may or may not occur when respondents do not consider

equally all information presented in the choice experiment. While some of these characteristics may represent actual choice behavior in real-world experience, Hess et al. find that such patterns in response behavior may result in response bias (Hess et al. 2010) while Sælensminde finds that this behavior significantly impacts the critical measure of VOT (Sælensminde 2006). This study examined such non-trading and lexicographic behavior in an attempt to determine its potential effects on the resulting choice model.

Lastly, researchers have determined that through the use of mixed-logit (ML) choice models, response data can be better estimated in choice experiments in which more than one choice observation is generated for each respondent (Hensher et al. 2005, Bliemer and Rose 2010). The effects of user heterogeneity (panel effects)—when such exists—in the response pool yields models with higher parameter errors and lower goodness-of-fit measures (Walker and Ben-Akiva 2011). For this reason, this research utilizes the ML model approach while generating MNL models of the data for points of comparison. This methodology is similar to that used by Patil in his research (Patil 2009).

2.4 SUMMARIZING CHOICE ATTRIBUTES WITH IMAGES

As noted in the previous section, one of the challenges of designing and executing an effective SP survey is the ability to communicate the nuances of choice attributes to survey respondents. Often, any effect that respondent misunderstanding of attributes in the choice experiment may have on the data is attributed to noise in the data, and subsequently explained through the error term of a discrete choice model.

The topic of using images to communicate choice attributes in the stated-preference setting has been heavily researched. For example, recent research evaluated the efficacy of using images of health complications to persuade respondents into choosing healthier food choices (Hollands et al. 2011). They concluded that by pairing adverse health imagery with specific food types they could change implicit attitudes about those foods. Similar research was attempted with cigarettes, with the result that more prominent imagery referring to the health risks of cigarette consumption communicated risks more clearly than less prominent imagery, or no imagery at all (Bansal-Travers et al. 2011). In their research, Lohse and Rosen find that color and graphics in the Yellow Pages draw attention to those advertisements that utilize them, soliciting deeper and more serious consideration from Yellow Pages users in the process (Lohse and Rosen 2001). It is evident that no matter the application, imagery in the SP setting is an effective means to communicate attribute characteristics. It is not much of a stretch, therefore, to assume that imagery has the potential to better facilitate the communication of traffic attributes and conditions to respondents of travel surveys.

While many studies have focused on the format, attribute levels, and alternate characteristics of stated-preference surveys, surprisingly little research has been conducted regarding the use of traffic images to communicate traffic conditions to survey respondents. In one study, Rizzi et al. found that traffic images, however rudimentary, can substantially influence travel-time valuation, which serves as a basis for further research into incorporating them into SP experimental design (Rizzi et al. 2012). In that research, Rizzi placed imagery alongside lexicographic descriptions of trip alternatives,

including congested and non-congested conditions. Half of the survey respondents viewed these images and the other half viewed only lexicographic descriptions of the trip attributes. Through the research, Rizzi found that respondents place a congestion premium on their choice behavior when images are present, since VOT of the respondents increased from \$5.70 per hour to \$7.40 per hour.

While effective and insightful, Rizzi's research was limited in its ability to generate traffic images that varied with travel time. Instead, all respondents who viewed images saw one image of non-congested conditions even though travel time may have varied from 10 minutes to 25 minutes. Instead of basing traffic image generation on a discrete condition of congestion/non-congested traffic, the research in this thesis will base image generation on average trip speed, with images presenting increasingly congested conditions as average trip speed decreases. This research will also attempt to determine how well, if at all, traffic images summarize trip reliability attributes, which has not been previously researched.

This research attempts to utilize not only the techniques presented in this section, but expand on the current knowledge of the effects of these traffic images on SP survey performance and efficiency. In so doing, this research will aid in the increase of efficiency of SP designs so that data generated by SP surveys will more accurately reflect respondent VTTS, VTTR, and choice behavior.

3. SURVEY DEVELOPMENT AND EXECUTION

The following section provides an overview of the process taken to develop and administer the Austin Traveler Survey (ATS), which served as the method of data collection for this research. This section will describe the survey in detail, with a special focus on the development and administration of the stated-preference portion of the survey. It then describes the methods of survey advertising and the website on which the survey was hosted—LimeSurvey v1.91.

3.1 SURVEY OVERVIEW

The Austin Traveler Survey (www.austrintravelsurvey.org) was conducted from August 1, 2012 to September 19, 2012. The survey consisted of four sections designed to understand Austin road users' decision-making process, specifically with regards to toll road usage. The first section asked respondents about details of their most recent trip on major Austin area freeways (see Appendix A for the full survey). Questions in this section were specifically designed to ask respondents about the purpose, the time of day, and the mode of transportation used on that trip. These were the primary trip attributes that were later pivoted to the SP section of the survey. The second section asked the user to consider their most recent trip, and whether the user frequently, occasionally, or never would use a hypothetical toll road alternative to the user's primary route. In this way, the survey objective was to better understand users' motivations in choosing to use or avoid a possible toll road alternative. The third section consisted of a set of SP questions, built

to present a trip option similar to the respondent's most recent trip in trip distance, travel time, and time of day. The survey presented the respondent with a choice between a non-toll option and a toll option in a stated-preference setting. The fourth and final section of the survey contained questions regarding the socio-demographic characteristics of the respondent, including gender, age, ethnicity, level of education, and income.

3.1.1 Details of Respondent's Most Recent Trip

The ATS began with questions to determine characteristics of the respondent's most recent travel behavior on Austin area freeways. Each respondent was asked to recall their most recent trip within the last six months on an Austin area freeway, and note which roadways they traveled on during that trip (see Figure 4). If this question was left blank, the respondent had the option to continue answering questions about his/her most recent trip, but if the respondent marked the box labeled, "I have not used an Austin area freeway in the past six months," the survey skipped the first two sections and jumped to the stated preference questions. By marking multiple boxes, a respondent indicated their most recent trip utilized multiple freeways in the Austin area.

Have you traveled on any of the following freeways in the Austin area in the past six months? If so, on which freeway(s) did you take your most recent trip?

Choose more than one, if your trip included multiple freeways.

Check any that apply

- I-35
- Loop 1 (Mopac Expressway)
- SH-45 (North)
- SH-130 / SH-45 (Southeast)
- US-290 / SH-71
- US-183
- I have not used an Austin area freeway in the past six months

Figure 4. Survey question on recent freeway usage

Once a respondent's usage of Austin area freeways was determined, follow-up questions focused on the respondent's purpose of travel, day of travel, and time of travel. These follow-up questions were then used to determine trip characteristics for the SP portion of the survey (as noted in Section 3.2). The vehicle type that the respondent used in completing their most recent trip was also ascertained; a respondent was asked to choose between a passenger car/SUV/pickup truck, motorcycle, bus, or to fill in another mode of transportation. Modes of transportation other than the options listed were expected to be relatively uncommon, since the question refers to a user's most recent trip on Austin freeways, and does not focus on other roadway facilities. At this point in the survey, several additional questions were presented to the respondent to better understand further the nature of the trip based on their selected mode. If the respondent answered "passenger car, SUV, or pick-up truck," then the respondent was asked how many people were in the vehicle when the trip was made. If the respondent answered "1" person, then the respondent made the trip alone, and questions regarding carpooling were

skipped. If their answer was greater than one, the respondent was asked a series of questions regarding their carpool, including if the respondent was the driver on the referenced trip, and if so, how much extra time did it take to pick up and drop off the passengers. In the final question on carpooling behavior, the respondent was asked to describe their relationship to other people in the car. Lastly, if the respondent indicated that he/she used the bus on their most recent trip, all questions pertaining to number of vehicle occupants and carpooling were skipped, and the respondent was asked about the bus fare on the trip. No follow-up questions are asked if the respondent indicated that a motorcycle or any other mode of transportation was used.

The next questions in the survey asked the respondent to indicate the location of the entrance and exit ramp which he/she used to access the freeway on their most recent trip (Figure 5). The first question asked the respondent to indicate the entrance ramp by clicking and dragging a marker along a Google Maps interface until the marker was placed over the approximate location of the entrance ramp. A separate question asked the user to repeat this process for the exit ramp. The Google Maps interface compatibility with LimeSurvey began with Version 1.91. This enabled a user to input a location graphically, rather than relying solely on descriptive text, such as the names of particular entrance/exit ramps, to determine a user's origin and destination. The Google Maps interface was used with the intention of reducing error or confusion among respondents who, for example, may not remember the name of the entrance/exit ramp they used on their trip, but may be able to locate the position (say, near their home, work, or a shopping center) on a map. This information was also useful in determining approximate

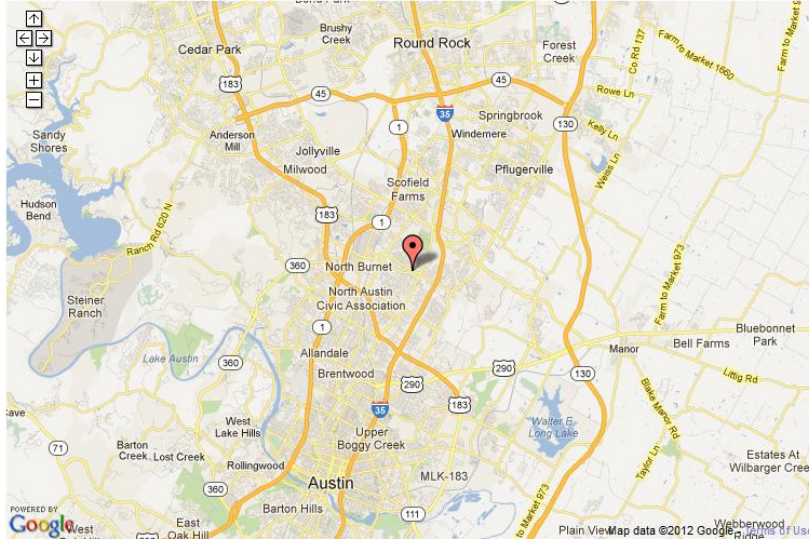
trip length to build a series of stated preference questions similar to the respondent's actual trip. The survey also presented the respondent with a follow-up question regarding the travel time of their most recent trip.

The next section of the survey asked respondents to consider a hypothetical scenario in which a toll road exists as a reasonable alternative route from their origin to their destination. The respondent was then asked the frequency with which he/she would use the toll road for any particular trip. The three possible answers were "frequently," "occasionally," and "never". If the respondent answered "frequently" or "occasionally," a follow-up question appeared asking the respondent to identify the reasons why he/she would consider using a toll road route as an alternative to a non-toll road route. If the respondent answered "never," they were asked to identify the reasons why they would not consider using a toll road route (Figure 6). In this format, it was possible to separate the respondents into two categories, those who had a negative predisposition to using toll roads, and those who had less negative predisposition. The purpose of this question format was to specifically ask respondents who would not under any circumstance use the toll road in order to better understand the reasons for the respondents' avoidance of toll roads. Likewise, the survey asked respondents who do not avoid toll roads to identify which considerations must be made in determining whether the user would elect to travel on the toll road, as opposed to a non-toll road alternative.

Please **click and drag the marker** to move the marker to the location on the map where you **ENTERED** the freeway.

See "Help" section below the map if needed.

30.3835 -97.6918



Map tutorial:

*You may zoom in to the map on a specific location by either double-clicking the spot on the map or by clicking the "+" button in the top left corner of the map

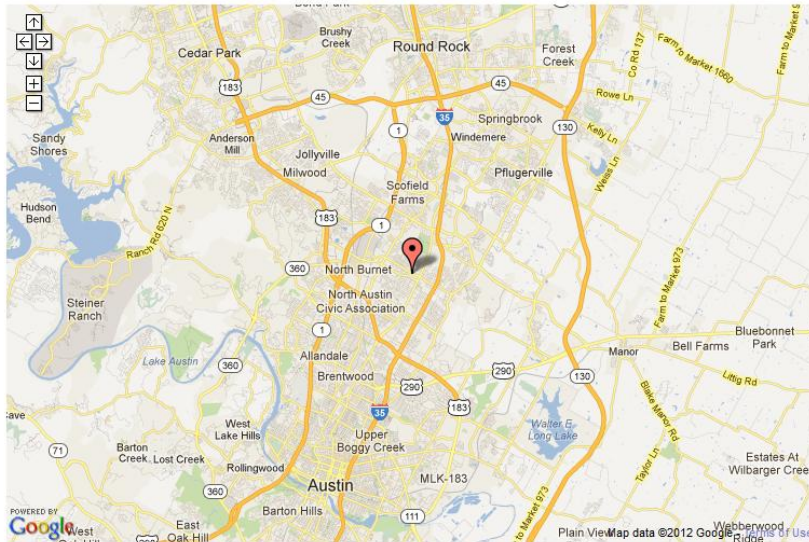
*Zoom out by clicking the "-" button in the top left corner of the map

*You may center the map on a different location by either drag-clicking the mouse at any spot on the map or by clicking on one of the arrow buttons in the top left corner of the map

Please **click and drag the marker** to move the marker to the location on the map where you **EXITED** the freeway.

See "Help" section below the map if needed.

30.3835 -97.6918



Map tutorial:

*You may zoom in to the map on a specific location by either double-clicking the spot on the map or by clicking the "+" button in the top left corner of the map

*Zoom out by clicking the "-" button in the top left corner of the map

*You may center the map on a different location by either drag-clicking the mouse at any spot on the map or by clicking on one of the arrow buttons in the top left corner of the map

Figure 5. Graphical interface to determine respondent's trip origin/destination

What would be important considerations for you to decide to use the toll road for a given trip?

Check any that apply

- Toll roads would need to be safer than alternate routes
- Someone else (like an employer) would need to pay my tolls
- Access to/from the toll road would need to be convenient for my trip
- Travel times on the toll road would have to be consistent and predictable
- Toll roads would need to be less stressful than alternate routes
- The toll road would need to save time
- During peak hours toll roads would not be congested
- None of these reasons
- Other:

What are the primary reasons why you would not use a toll road for a given trip?

Check any that apply

- I generally have the flexibility to travel at less congested times on toll free roads
- I don't have a credit card as needed to set up a toll transponder account
- I do not want to pay the toll for a given trip
- If access to/from the toll road was not convenient for my trip
- I do not feel safe traveling on toll roads
- I don't want to have a toll transponder in my vehicle
- If it is too complicated/confusing to use the toll road
- If the toll road does not save me enough time
- If the toll was too expensive for me
- If I can easily use routes other than the toll road, so I'll just avoid it unless there is a lot of traffic
- None of these reasons
- Other:

Figure 6. Understanding respondent's motivations for using/not using a toll road

The next questions asked the respondent about current toll road usage and the cost of travel.

3.2 STATED-PREFERENCE QUESTION DESIGN

In the SP portion of the survey, a total of three questions were presented to each survey respondent. In each question, the respondent was asked to consider two realistic

travel scenarios on an Austin area freeway, with two different modes of travel available: a non-toll and a toll road option (see Figure 7). The respondent was asked to choose the mode that best suited their travel preferences given a hypothetical set of trip characteristics for travel time, travel distance, trip time of day, trip day of week, and total toll. Some trip characteristics were pivoted directly from respondent's answers to previous questions pertaining to their most recent trip. Trip characteristics that were obtained in this manner included the trip time of day, the trip day of the week, vehicle used, and trip purpose. These elements were used to build the text of all three SP questions. The text of each question was the same for all three questions, and was mostly based on those characteristics (see Figure 7 for an example SP question).

If a respondent did not answer any of the questions required in order to build the SP question text, the survey randomly selected various trip attributes. In the case of a missing week day for the respondent's most recent trip, a day of the week was randomly selected. If a respondent did not answer the question regarding vehicle type used, the survey selected passenger car, SUV, or pickup truck by default. If a respondent did not enter a trip purpose, the text indicating a hypothetical trip purpose for the SP scenario was omitted. If a user did not enter a trip time of day, the survey randomly assigned the hypothetical trip as starting at 8:00 am or 5:00 pm, both of which are during peak commuting hours. See Appendix B for the JavaScript code that built the text and graphics of each of three SP questions.

If the respondent did not interface with the Google Maps origin/destination question, an average trip distance of 14 miles was assigned to the hypothetical trip. The

distance of 14 miles was selected using average trip data for the Austin metropolitan region as derived from data collected by the 2009 National Household Travel Survey (National Household Travel Survey 2009). The respondent was restricted in the possible answers for the Google Maps origin/destination question; if the respondent stated that the origin or destination of the stated trip was outside of Texas, the hypothetical trip would default to the average Austin trip distance of 14 miles. Likewise, if the stated trip was longer than 30 miles, the hypothetical trip length defaulted to 14 miles. Finally, if the stated trip was less than 6 miles, the hypothetical trip length defaulted to 6 miles. These adjustments were made to create an SP setting that the respondent could more easily visualize and comprehend in such a limited survey environment.

All of these trip characteristics laid the foundation for the SP questions. The following sections will explain how the hypothetical SP trip characteristics (travel time, travel time variability, and total toll) were determined.

Each of the following questions will ask you to choose between two potential travel choices in Austin. Thinking about your most recent trip, please select the one option that you would most likely have chosen if you were faced with these options on your trip.

You described your most recent trip on an Austin freeway as occurring on a Monday at 6:45 AM in a passenger car, SUV, or pick-up truck. The reason for your trip was commuting to or from your place of work (going to or from work).


If you had the options below for that trip during the morning shoulder period, which option would you choose?

(The Max and Min values show the range of travel times)

Choose one of the following answers

Option A


Non-toll Road
Begin Trip at (morning shoulder period)
Trip Distance: 20 miles
No Toll



Travel Time <--Max--> Typical <--Min-->
 36 34 32 minutes

Option B

Toll Road
Begin Trip at (morning shoulder period)
Trip Distance: 20 miles
Toll: \$3.00



Travel Time <--Max--> Typical <--Min-->
 20 19 18 minutes

Each of the following questions will ask you to choose between two potential travel choices in Austin. Thinking about your most recent trip, please select the one option that you would most likely have chosen if you were faced with these options on your trip.

You described your most recent trip on an Austin freeway as occurring on a Monday at 6:45 AM in a passenger car, SUV, or pick-up truck. The reason for your trip was commuting to or from your place of work (going to or from work).



If you had the options below for that trip during the morning shoulder period, which option would you choose?

(The Max and Min values show the range of travel times)

Choose one of the following answers

Option A



Non-toll Road
Begin Trip at (morning shoulder period)
Trip Distance: 20 miles
No Toll

Travel Time <--Max--> Typical <--Min-->
 37 34 31 minutes

Option B

Toll Road
Begin Trip at (morning shoulder period)
Trip Distance: 20 miles
Toll: \$2.20

Travel Time <--Max--> Typical <--Min-->
 23 22 21 minutes

Figure 7. Stated preference question graphic, with no-picture and picture variations

3.2.1 Basis of SP Design

In any SP survey, attribute levels are selected by a researcher to provide respondents with a credible set of travel choices. This process can replicate scenarios that already exist for the respondent, or can be hypothetical, as in the case where the designed travel choices do not already exist. In the case of the ATS, the SP section presented respondents with two travel choices: a toll road and a non-toll road option. Each of the two options utilized trip attributes that were designed to present the respondent with characteristics that are unique to each mode of travel. Among these trip characteristics were average mode speed, time of day factor, and mode specific travel time variability. Using average trip speed and a time of day factor, the survey determined travel time from trip length using Equation 1:

$$TT = \frac{(O_{at, ong} - D_{at, ong}) \cdot 1.3}{V / TDF} \quad (1)$$

where: TT = total trip travel time
O_{Lat,Long} = latitude/longitude of trip origin
D_{Lat,Long} = latitude/longitude of trip destination
1.3 = factor to account for increased travel distance over a straight line from origin to destination (see Section 3.2.3)
V = average trip speed (see Sections 3.2.4.2 and 3.2.4.3)
TDF = time of day factor, as noted in Table 1

Once the total trip travel time was determined, travel time variability was determined as a percentage of travel time (see Sections 3.2.4.1 through 3.2.4.3).

Finally, a toll rate in cents per mile was assigned to the toll road mode. The assignment of toll rates was derived following protocol described in Sections 3.2.4.1 through 3.2.4.3.

3.2.2 Trip Time of Day

In a real-world scenario, travel time and travel time reliability vary according to the time of day. Therefore, to present the respondent with a realistic scenario of travel conditions, these attributes must vary in the survey design. Based on the respondent's recent trip start time as answered in the previous section of the survey, the time of day for the travel scenario was determined (see Table 1). The descriptive text for time of day as found in the second column of Table 1 was also included in the SP question text, to provide the respondent with better reference to when the hypothetical trip would occur.

Travel time and travel time reliability vary significantly during the course of a day. Therefore, time of day factors were assigned to each time segment, and according to road choice (see Table 1). For example, because the non-toll road mode had a higher time of day factor of 1.8 for the peak period, travel times for this mode were greater than the toll road alternative.

Table 1. Time of Day Factors Based on Trip Start Time

Trip Start Time	Time of Day	Time of Day Factors	
		Non-toll Road	Toll Road
12:00 AM to 6:00 AM	Night	1.0	1.0
6:00 AM to 7:00 AM	Morning Shoulder Period	1.4	1.1
7:00 AM to 9:00 AM	Morning Peak Period	1.8	1.2
9:00 AM to 10:00 AM	Morning Shoulder Period	1.4	1.1
10:00 AM to 4:00 PM	Mid-Day	1.0	1.0
4:00 PM to 5:00 PM	Evening Shoulder Period	1.4	1.1
5:00 PM to 7:00 PM	Evening Peak Period	1.8	1.2
7:00 PM to 8:00 PM	Evening Shoulder Period	1.4	1.1
8:00 PM to 12:00 AM	Night	1.0	1.0

3.2.3 Trip Distance

Trip distance was calculated as the great-circle distance between a respondent's stated trip origin latitude/longitude and destination latitude/longitude, using the haversine formula for great-circle distance. The haversine formula yields the distance between two points on a sphere, and in the case of this calculation, yields a distance in total miles between two points on Earth. The calculated great-circle distance between a respondent's origin/destination, however, is only an approximation of the total trip distance, since it represents the straight-line distance between the two points on the globe. The great-circle trip distance was therefore multiplied by a factor of 1.3 for the purposes of this study to better approximate the distance between the two points as traveled on roadways, in addition to the distance the respondent traveled off of the freeway.

3.2.4 Other SP Attributes

In order to build a well-designed stated preference question set, the other three attributes (travel time, travel time variability, and toll rate) varied between questions. Of those three attributes, travel time and travel time reliability were dependent on the time of day, as noted in Equation 1. The following sections describe how the values of travel time, travel time reliability, and total toll were determined based on recent trip information as supplied by each respondent.

3.2.4.1 Travel Time, Travel Time Variability, and Toll Rate Selection

Each respondent had values of travel time, travel time variability, and toll rate determined using one of two SP design methods. The design method to be used was

determined randomly prior to the presentation of the questions to the respondent. Due to the random nature of the assignment, approximately half of the respondents were presented with SP questions where the attributes of the questions were determined by a D_b -efficient design, with the other half determined using a Random Adjusting design. Both designs are discussed in the following sections.

3.2.4.2 Bayesian D-efficient Design

One of the design strategies used in this study was the Bayesian D-efficient (D_b -efficient) design. In this case, the attributes in the mode choice models were estimated in a manner that minimizes standard errors of an estimated set of parameters while maximizing the t statistic. The t statistic generally indicates any difference between the attribute design and an attribute design that has zero influence on the choices in the model. In this process, attribute levels were chosen such that the asymptotic standard errors (the square roots of the diagonal elements of the asymptotic variance-covariance [AVC] matrix) are minimized for the discrete choice models (Bliemer et al. 2008). Specifically in this study, D_b -error efficiency criterion was used, where the Bayesian Efficient design was obtained by minimizing the D-error of the AVC matrix of the parameter estimates of the discrete choice model (Bliemer et al. 2008, Huber and Zwerina 1996). For a discrete choice model, the AVC matrix is equal to the inverse of the Fisher information matrix (see Equation 2).

$$AV = -\frac{1}{N} \left[\frac{\partial^2 LL}{\partial \theta^2} \right]^{-1} \quad (2)$$

where: N = number of respondents
 LL = log-likelihood function for the discrete choice model
 θ = a vector of parameters used in the model

From this equation, it is noted that the design and an estimate of the parameter vector (θ) must be known in order to estimate the AV matrix for the choice model. Since the parameter values cannot be known prior to conducting the survey, an educated guess based on literature was necessary in order to obtain prior estimates (priors) of these parameters. By the Bayesian techniques proposed by Sándor and Wedel, the priors were obtained by random distribution in order to increase the efficiency of the design, thus the designs are known as Bayesian efficient designs (Sándor and Wedel 2001). In this way, the Bayesian D_b -error was calculated using Equation 3.

$$D_b\text{-error} = \int \det AV(\theta) \pi(\theta) d\theta \quad (3)$$

where: $\pi(\theta)$ = joint distribution of the assumed parameter priors
 θ = the corresponding parameters of the distribution
 K = the number of parameters in the model

Because the integral in Equation 3 is computationally intense, it can be approximated using several methods, including the use of Halton draws to simulate the distributions, as was the case for this study. Once the distribution was simulated, the following process was used to develop an efficient design: 1) R independent draws were taken from each of the prior distributions of the K-parameters, 2) the D_b -error was calculated for each of the designs for each of the R draws, and 3) the D_b -error of the design was approximated as the average of all D_b -errors, as in Equation 4.

$$D_b\text{-error} = \sum_{r=1}^R \det AV(\tilde{r})^{1/2} / R \quad (4)$$

$$\text{where: } \tilde{r} = \begin{bmatrix} \tilde{r}_1^1 \\ \vdots \\ \tilde{r}_k^r \end{bmatrix}$$

\tilde{r} the draw (1, 2, ..., R)

In the case of this study, normal distributions with non-zero means were assumed for the priors. The mean values of the priors for the speed attributes were obtained from an average trip distance of 14 miles, or the average household trip for the Austin metropolitan region, as found by the data collected by the National Household Travel Survey 2009 (National Household Travel Survey 2009). Also, the attributes of average trip speed, travel time variability, and toll rate, were assigned as seen in Table 2. These values were then used to determine the priors, as described in Equation 1 in section 3.2.1. For example, the toll road has attribute levels of 70, 65, and 60 mph for the average trip speed. In this case, Equation 1 from section 3.2.1 is applied, and a total travel time of 12, 12.92, and 14 minutes are used for the D_b -efficient design process. Likewise, travel time variability and total toll were determined from total travel time and toll rate, per section 3.2.1. The means and standard deviations 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 3.

The Ngene software package was used to generate the D_b -efficient designs for this survey design strategy (ChoiceMetrics 2012) (See Appendix C for Ngene code). To proceed, a random parameter panel logit (rppanel) was specified for the discrete choice model, and the priors were simulated using 400 Halton draws drawn from prior distributions. The design for peak hours obtained from the software is shown in Table 4.

Table 2. Attribute Level Selection

Attribute	Attribute Levels	
Average Trip Speed (mph)	Toll Road	70, 65, 60
	Non-toll Road	55, 50, 45
TT Variability (% of TT)	Toll Road	0, 5, 10
	Non-toll Road	5, 10, 15
Toll Rate (\$/mile)	Toll Road	0.5, 0.10, 0.15
	Non-toll Road	0

Table 3. Attribute Levels, Mean, and Standard Deviation of Attribute Priors

Attribute	Attribute Levels		Mean Value of Priors	Standard Deviation of Priors
Travel Time (minutes)	Toll Road	12, 12.92, 14	-0.05	0.3
	Non-toll Road	15.27, 16.8, 18.67		
TT Variability (minutes)	Toll Road	0, 0.64, 1.28	-0.06	0.5
	Non-toll Road	0.84, 1.68, 2.52		
Total Toll (dollars)	Toll Road	0.7, 1.4, 2.1	-0.12	0.1
	Non-toll Road	0		

The values shown in Table 4 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 3. The design has 24 rows divided into 8 blocks of 3 rows. Each respondent was randomly given all choice sets from one of the blocks. The D_b -error for the design was found to be 0.71, which indicates an efficient design.

Table 4. D_b-Efficient Design Generated Using Ngene Software (for Peak Hours)

Mode		TR		NTR		Block
Choice Situation	Speed (mph)	TT Variability (% of TT)	Toll Rate (cents/mile)	Speed (mph)	TT Variability (% of TT)	
1	60	5	10	50	5	1
2	70	0	5	55	10	6
3	65	10	5	50	15	3
4	70	5	15	45	15	1
5	65	0	5	45	5	5
6	65	10	10	50	5	4
7	70	10	5	45	5	8
8	70	5	15	50	5	7
9	65	10	15	55	5	5
10	60	5	10	45	10	3
11	70	10	5	55	5	2
12	60	5	10	55	10	5
13	70	5	15	55	15	8
14	60	0	15	55	15	6
15	65	0	15	55	10	2
16	70	5	5	55	10	1
17	65	0	10	50	15	4
18	60	0	10	50	15	4
19	60	10	5	45	15	7
20	70	0	15	45	15	2
21	60	5	15	50	10	7
22	65	0	10	50	10	8
23	60	10	10	45	5	3
24	65	10	5	45	10	6

3.2.4.3 Random Adjusting Design

The second type of design strategy generated for the stated preference part of the survey was the adaptive RA attribute level generation method. In this method, for the first SP question the attribute levels of each attribute (travel time, travel time variability, and toll rate) were generated randomly from a corresponding range of values for each

attribute. The attribute levels used for each attribute are shown in Table 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 travel time 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 of anywhere between 30% and 90% if the respondent chose a toll option and decreased between 35% and 70% if the respondent chose a non-toll option for the previous SP question.

Two examples have been generated to illustrate the manner in which the survey presents the stated-preference questions to respondents. The first is an example of the random adjusting level criterion, presented without traffic images, as shown in Figure 8 through Figure 10. Here, a respondent has indicated their most recent trip on an Austin area freeway was a commuting trip in a passenger car, SUV, or pickup truck, and occurred on a Monday at 8:00 am (during the morning peak period). The respondent also indicated that their trip began near Round Rock and ended near downtown Austin, traveling along the I-35 corridor. This trip would amount to approximately 23 miles, and the travel time would be determined per Equation 1.

Table 5. Attribute Levels Used for Generating Random Attribute Level Design

Attribute	Mode	Attribute Level
Speed (mph)	TR	60+(0 to 10)
	NTR	45+(0 to 10)
Travel Time Variability (% of TT)	TR	0+(0 to 10)
	NTR	5+(0 to 10)
Toll Rate (cents/mile)	TR	10+(0 to 10)
	NTR	0

You described your most recent trip on an Austin freeway as occurring on a Monday at 8:00 AM in a passenger car, SUV, or pick-up truck. The reason for your trip was commuting to or from your place of work (going to or from work).


If you had the options below for that trip during the morning peak period, which option would you choose?

(The Max and Min values show the range of travel times)

Choose one of the following answers

Option A


Non-toll Road
Begin Trip at (morning peak period)
Trip Distance: 23 miles
No Toll

START  **END**

Travel Time: Typical <---Max-----+-----Min---> 56 45 34 minutes

Option B

Toll Road
Begin Trip at (morning peak period)
Trip Distance: 23 miles
Toll: \$4.15

START  **END**


Travel Time: Typical <---Max-----+-----Min---> 26 24 22 minutes

Figure 8. SP question 1 for the random adjusting design

Choose one of the following answers

Option A


Non-toll Road
Begin Trip at (morning peak period)
Trip Distance: 23 miles
No Toll

START  **END**

Travel Time: Typical <---Max-----+-----Min---> 59 52 45 minutes

Option B

Toll Road
Begin Trip at (morning peak period)
Trip Distance: 23 miles
Toll: \$2.30

START  **END**


Travel Time: Typical <---Max-----+-----Min---> 27 24 21 minutes

Figure 9. SP question 2 for the random adjusting design

Choose one of the following answers

Option A


Non-toll Road
 Begin Trip at (morning peak period)
 Trip Distance: 23 miles
 No Toll



Travel Time: <---Max---+---Typical---Min---> 49 45 41 minutes

Option B

Toll Road
 Begin Trip at (morning peak period)
 Trip Distance: 23 miles
 Toll: \$4.10



Travel Time: <---Max---+---Typical---Min---> 27 26 25 minutes

Figure 10. SP question 3 for the random adjusting design

At this point, the survey would have enough information to generate the stated-preference choice sets. A random assignment would then be made and the respondent could be assigned to the random-adjusting attribute level selection with no traffic images shown. In the first question, a travel speed between 60 and 70 mph was assigned for the toll road option, with a speed between 45 and 55 mph assigned for the non-toll option. In this example, a travel speed of 68 mph and 55 mph was assigned for the two options, respectively. Because this trip occurred during the morning peak period, a time of day factor of 1.2 and 1.8 was used in calculating a typical travel time (see Table 1) of 24 minutes and 45 minutes, respectively. Travel time variability was also randomly assigned: between 0 and 10 percent of total travel time for the toll option and between 5 and 15 percent of total travel time for the non-toll option. For this example, travel time

variability was assigned as 7 percent and 14 percent travel time variability for their respective modes. Finally, a price for the toll option was assigned a value between 10 and 20 cents per mile. This example was assigned a toll rate of 18 cents per mile, with the total cost being \$4.15 for the toll option. See Figure 8 for an illustration of how the respondent would view this choice set.

Once the respondent has answered the previous SP question, the survey then generates the second choice set based on the answer to the first choice set. The process to generate attributes for the second choice set would be the same as the first, with the exception of the toll rate assignment. If the respondent chooses the non-toll option in the first question, the toll rate would adjust down by a random amount between 35 to 70 percent of the original toll rate assigned in the first SP question. Otherwise, if the toll option was chosen, the toll rate would adjust upward by a random amount between 30 to 90 percent. For this example, since the non-toll option was selected, the toll rate decreased from 18 cents per mile to 10 cents per mile and the total toll was \$2.30, a 56 percent decrease in the toll rate (see Figure 9).

Finally, the attributes for the third SP question would be assigned based on the same procedures as the second SP question. In the case of this example, since the toll option was selected in the second SP question, the toll rate was adjusted upward by 78 percent for a final toll rate of 17.8 cents per mile, and a total of \$4.10 for this hypothetical trip (see Figure 10).

The second example of stated-preference attribute assignment uses the D_b -efficient method to generate SP question attributes. In this process, the Ngene software

package generated a D_b -efficient attribute distribution based on simulated attribute priors as seen in Table 4. From this information, Ngene develops 8 possible “blocks” to which a respondent would be randomly assigned when the survey is taken. Each assignment includes three attribute assignment criteria, each criterion representing the attribute assignment for one question. The blocks are therefore used to calculate a respondent’s total travel time, travel time variability, and toll rate for each SP question. In this example, the respondent was assigned to block 8, which includes a travel speed of 70 and 45 mph (with a time of day factor of 1.2 and 1.8 applied to the toll roads and non-toll road options respectively), and a travel time variability of 10 and 5 percent of the total travel time, for the toll and non-toll options, respectively. The toll rate assignment for question 1 of block 8 is 5 cents per mile, resulting in a total trip cost of \$1.15 for a 23 mile trip (see Figure 11).

The second and third SP questions follow this same process using the attributes for travel speed, travel time variability and toll rate shown for block 8 in Table 4.

3.2.4.4 Other SP Design Considerations

While the SP design usually provides for realistic travel scenarios from which the respondent can choose, several constraints were placed on the attributes to prevent the travel scenario from exceeding certain limits. First, travel speed was constrained, such that if Equation 1 yielded an average trip speed that exceeded 85 mph in the case of the toll road option or 75 mph in the case of the non-toll road option, the SP design defaulted

You described your most recent trip on an Austin freeway as occurring on a Monday at 8:00 AM in a passenger car, SUV, or pick-up truck. The reason for your trip was commuting to or from your place of work (going to or from work).

If you had the options below for that trip during the morning peak period, which option would you choose?

(The Max and Min values show the range of travel times)

Choose one of the following answers

Option A

Non-toll Road
Begin Trip at (morning peak period)
Trip Distance: 23 miles
No Toll

Travel Time 49 45 41 minutes

Option B

Toll Road
Begin Trip at (morning peak period)
Trip Distance: 23 miles
Toll: \$1.15

Travel Time 27 24 21 minutes

Figure 11. SP question 1 for the D_b -efficient design with pictures

to a travel time that would yield an average trip speed of 85 mph and 75 mph for the respective options. This range of speeds was selected to best represent SH 130 in Austin, which during the time of the study, had a speed limit of 85 mph. Second, the maximum travel time as found using Equation 1 that a respondent was presented was 60 minutes. This constraint was placed to present a more realistic travel option to the average respondent. Lastly, in the case of respondents presented with the RA design, the toll rate was limited to a range of 10 to 55 cents per mile. Due to the nature of the Random Adjusting design, it was possible that the survey could present toll rates that exceeded this high a rate unless this constraint was provided.

3.2.4.5 SP Question Graphics

As seen in Figure 2 and Figure 3, each respondent may have been presented with a set of stated preference questions that either included a picture representing traffic conditions typical of the trip characteristics presented, or the stated preference questions did not include such a picture. Each respondent was randomly assigned the picture or no-picture design before the first SP question was presented.

Upon calculation of the trip characteristics (as discussed in Sections 3.2.1 through 3.2.4), a picture was assigned to each option that was based on the option's average mode speed. If a mode speed was greater than or equal to 65 mph, the respondent saw a picture of light traffic (Figure 12) next to the option graphic. If the average speed was between 50 mph and 60 mph, the survey displayed a picture of medium traffic (Figure 13), and if the average speed was less than or equal to 50 mph, the respondent was presented a picture of heavy traffic (Figure 14). The presentation of these pictures provided the basis for study among these results to determine whether the pictures introduced any level of response bias among survey respondents.

3.3 SOCIO-DEMOGRAPHICS

The final section of the survey had standard questions about the socio-demographic characteristics (gender, age, ethnicity, education, and income) of each respondent, including a text box in which the respondent could add any comments within or outside the scope of the survey (see Appendix A).



Figure 12. Survey image representing “light” traffic



Figure 13. Survey image representing “medium” traffic



Figure 14. Survey image representing “heavy” traffic

3.4 SURVEY ADMINISTRATION

This section of the thesis outlines the efforts made to advertise the ATS, including the social media campaign, in addition to an overview of the web engine that hosted the survey.

3.4.1 Survey Advertising

In addition to marketing through traditional media, the survey team led by The Texas A&M Transportation Institute (TTI) included strategies that utilized the tools of social media for advertising the survey. Collecting data and information through social media proved to be a useful method for this survey. Based on staff and advertising budget, efforts to publicize the Austin Traveler Survey included:

- A press release to targeted Austin area media
- Social media posts such as the following:
 - Targeted tweets to more than 40 media and community groups and organizations through Twitter such as local traffic anchors, many who re-tweeted the survey to their followers
 - Facebook posts to more than 25 targeted media, city organization pages such as Austin Chambers of Commerce, local traffic anchors and media as well as community organizations.

In this manner, several sources of publicity were utilized to generate interest and responses to the ATS. Survey advertisement began in earnest on August 6, 2012 with a post by the Texas Department of Transportation and Texas A&M Transportation Institute's profile on Facebook and Twitter. The text advertised the survey as a way for the two institutions to better understand how respondents travel around Austin, specifically with regards to respondent's use of toll roads (see Figure 15). Similar messages were posted on these same sites throughout the course of the survey administration period from early August until early September.

Soon after the posts on Facebook and Twitter, local media outlet and NPR affiliate KUT published a short article citing the advertising efforts of TxDOT and TTI (see Figure 16). This article was published on KUT News' website (found at <http://kutnews.org/post/convincing-central-texans-take-toll-roads>) on August 9, 2012.

On August 30, 2012 TxDOT announced that toll rates would increase by about 50% for certain toll roads beginning January 1, 2013 (see http://www.statesman.com/blogs/content/shared-gen/blogs/austin/traffic/entries/2012/08/30/tolls_going_up_on_three_area_roads.html). Although this announcement provided only indirect publicity, it did increase the media and public attention on toll roads during a time when the survey was still active. Also on August 30, the survey began offering a prize incentive for


respondents. Under the contest rules, each respondent was able to enter their name, email, and phone number to be enrolled in to a drawing for one of two \$200.00 gift cards.

The next day on August 31, 2012, TxDOT published an advertisement for the Austin Travel Survey via The TxDOT Update, which is published every other week and distributed by email. See Figure 17 for an image of the advertising text. The issue of the newsletter can be found at http://www.txdot.gov/txdot_library/newsletters/txdot_update/2012/default.html.

One of the final public advertisements for the survey came on September 14, 2012, when PRWeb published a short article describing the survey and advertising the prize incentive for respondents (see Figure 18, and <http://www.prweb.com/releases/2012/9/prweb9904499.htm>).

3.4.2 Survey Hosting


The Austin Traveler Survey was developed and hosted via LimeSurvey version 1.91 and was active from August 1, 2012 until September 19, 2012 from the website www.austrintravelersurvey.org. LimeSurvey proved to be especially useful in order to create an interactive setting for the stated-preference section of the survey, since it allows the survey designer to manipulate the survey's HTML code for customization purposes, as well as to embed non-native JavaScript in the survey code. In this way, elements of an individual's responses were temporarily stored within each survey and coded to build the SP questions.


 **Texas Department of Transportation**
Yesterday via HootSuite


TxDOT is working with Texas Transportation Institute to learn more about how you travel around Austin. The researchers at TTI want to better understand drivers' use of toll roads. Please tell them your opinion at www.austrintravelssurvey.org. The survey is part of a study directed by the Texas Legislature and the results will be used to build and operate a better transportation system.

Unlike · Comment · Share 2

You and 8 others like this.


 **Jose R Fernandez** There are NO restrooms signs on I-130!
23 hours ago via mobile · Like

 **Elias Leal** whar all our taxes going ?
20 hours ago via mobile · Like


 **Randy Ehresman** it's about disposable income and the amount people are willing to put towards their travel expenses. lower gas prices allow you to compensate for paying tolls. if the gas prices are up then less toll revenue. I drive mop ac north twice a day. keep in mind the city of Austin has a low unemployment rate too.

when school is in session I would pay am arm and a leg to avoid the 2 hr traffic to be home with my family. my work includes my travel time, so having more time at home is why I would pay for tolls!!!
15 hours ago via mobile · Like

People Who Shared This

 **Texas Transportation Institute**
Texas Department of Transportation is working with Texas Transportation Institute to learn more about how you travel around Austin. The researchers at @TTI want to better understand drivers' use of toll roads. Please tell them your opinion at www.austrintravelssurvey.org. The survey is part of a study directed by the Texas Legislature and the results will be used to build and operate a better transportation system.

Like · Comment · Yesterday at 1:21pm

 **Michelle Duncan Hoelscher**
For my Austin friends!
Like · Comment · Yesterday at 1:14pm

 **TxDOT @TxDOT** 6 Aug

TxDOT is working w/ @TTI 2 learn more about how u travel around Austin. Help us out by filling out this survey! ow.ly/cLMJQ

Retweeted by jollypeno

Expand Reply Retweeted Favorited

Figure 15. Facebook and Twitter advertisements for the Austin Travel Survey

Convincing Central Texans to Take Toll Roads


By Laura Rice, KUT News

Choose one of the following answers

Option A

Non-toll Road
Begin Trip at 5:00 PM (afternoon peak)
Trip Distance: 14 miles
No Toll


Travel Time: 33 30 27 minutes



Option B

Toll Road
Begin Trip at 5:00 PM (afternoon peak)
Trip Distance: 14 miles
Toll: \$1.40

Travel Time: 16 16 16 minutes



Credit Texas Transportation Institute

[Enlarge image](#) 

An example question from the survey asks Austinites to compare travel situations.

The Texas Transportation Institute wants Austinites to [fill out a survey](#) about their use of toll roads and freeways. The Texas Legislature mandated TxDOT to have the survey done to evaluate the flow of traffic in the city.

The survey asks about when, where and how much time you spend on area [highways](#).

Figure 16. KUT News' advertisement of the Austin Travel Survey

TAKE THE AUSTIN TRAVEL SURVEY

TxDOT is working with the Texas Transportation Institute (TTI) to learn more about how people travel around Austin. Please tell them your opinion at www.austintravelsurvey.org. The results of this survey will be used to build and operate a better transportation system. The survey closes Saturday, Sept. 8.

[Back to top](#)



MoPac is one of Austin's most important roadways, serving as a key route to downtown and points beyond.

Figure 17. Survey advertisement in TxDOT Update

Seeking Austin Traveler Comments on Area Roadways

TTI study seeks better understanding of how Austin motorists view area roadways.

College Station, Texas (PRWEB) September 14, 2012



The Texas A&M Transportation Institute(TTI) is working with the Texas Department of Transportation to better understand drivers' use of Austin area roadways – what works, what doesn't, and what improvements should be made. If you travel around Austin and have an idea of how to improve the area's roadways, researchers want to hear from you.

The online survey, found at <http://www.austintravelsurvey.org>, takes about 15 minutes to complete. Two randomly selected respondents will each receive a \$200 VISA gift card.

The survey, part of a study requested by state lawmakers to help build and operate a better transportation system, closes on September 19.

Further information is available by contacting Dr. Mark Burris at (979) 845-9875 or by email at mburris@tamu.edu.



Texas Capitol, Austin

“ If you travel around Austin and have an idea of how to improve the area's roadways, researchers want to hear from you. ”

Figure 18. PRWeb's announcement of Austin Travel Survey

The survey advertisement efforts proved successful. There were 748 total responses to the survey over the time that the survey was active, of which 594 were complete responses. See Figure 19 for response rates and distribution across the survey period. Of the incomplete responses, 149 respondents did not complete the stated-preference portion of the survey, and 5 respondents stated that they had not traveled on Austin area freeways in the last 6 months. These responses were considered incomplete for the purposes of this analysis. Furthermore, 11 respondents (1.9% of total complete

responses) stated they used the bus, motorcycle, or another mode on their most recent trip on Austin area freeways. Due to the limited sample size of the modes that were not of the passenger car class, these responses were not included in further analysis. The final number of survey responses available for analysis was 583.

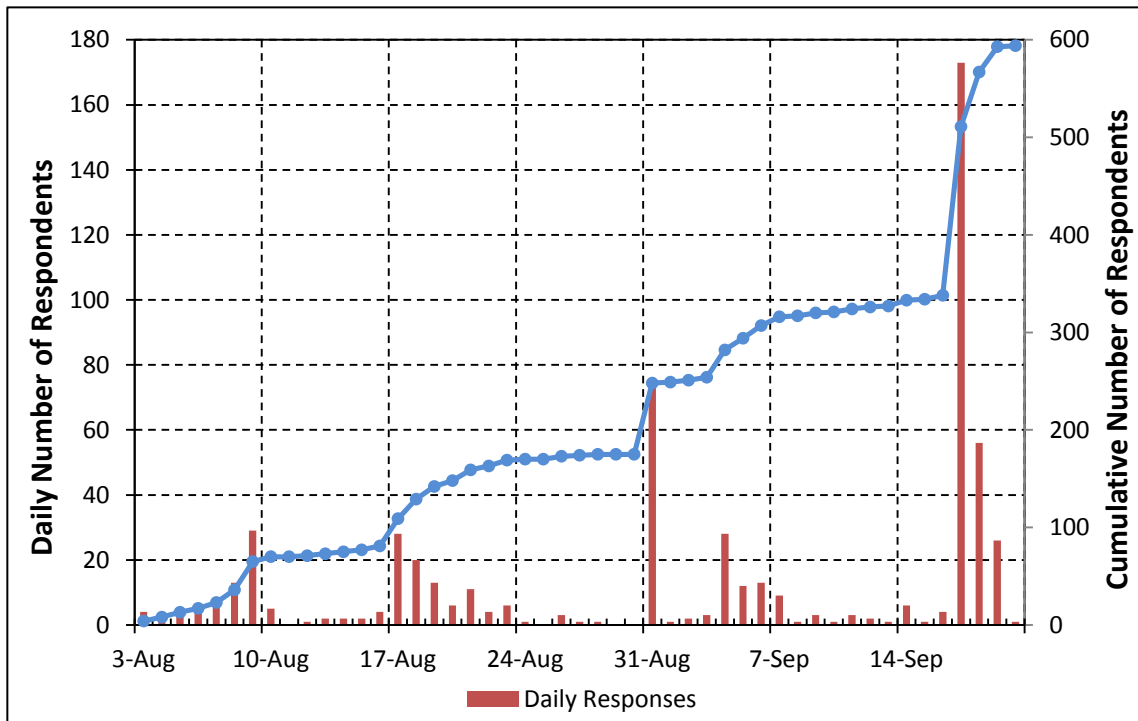


Figure 19. Daily and cumulative number of respondents over active survey period

4. DATA STRUCTURE AND ANALYSIS

Each respondent submitted their answers through LimeSurvey v1.91, which was then transferred into a LIMDEP project file for statistical analysis. Importing the data into a transferable file enabled various statistical tests of significance to be performed through SPSS. Once completed, the data was imported into NLOGIT5 for mixed-logit modeling. The following section describes the structure of the data and the statistical tests performed on the data to identify relevant variables.

4.1 DESCRIPTIVE ANALYSIS

A summary of the socio-demographic characteristics of survey respondents can be found in Table 6. In addition to survey population socio-demographic statistics, Table 6 cites data on the overall population of the Austin Metropolitan Statistical Area as found by the 2011 American Community Survey. The American Community Survey is an annual survey conducted by the U.S. Census Bureau to estimate population statistics for intra-decennial years in which the census is not conducted. This data can provide generalizations about the ability of the survey sample population to represent the overall Austin population. As seen in Table 6, nearly 50% of respondents were male, though slightly more respondents were male than female, which is similar to the Austin population. Nearly 75 percent of survey respondents fell within the ages of 25 to 54, with approximately 25% of respondents representing each of the 25-34, 35-44, and 45-54 age categories. The survey population underrepresented certain age categories, including the

18-24 and 65+ categories, but overrepresented all age categories from 25 years to 64 years old. Nearly half of all respondents described themselves as college graduates, while 98.3 percent of all respondents stated that they have at least some college or vocational school background, including the 31.4 percent of respondents that have attended postgraduate college.

Contrasting the survey demographics with Austin demographics, it is found that the population with no higher education was underrepresented in the survey responses. Likewise, nearly 30 percent of survey respondents described their household income as between \$100,000 to \$199,999 per year, with over 70 percent of respondents earning more than \$50,000 per year. The American Community Survey, however, illustrates that the survey population underrepresented the lower-income categories, with only 15.2 percent of respondents earning less than \$50,000 per year, as compared to 44.1 percent of the Austin population with a household income in the same income bracket. For these reasons, it is evident that the sample population overrepresented the total population in higher education and training as well as high income, which may be due to the nature of the advertising of the survey, as the primary advertising was performed on social networks, public radio, and news websites. Most of the social media advertising involved posts to the social pages of professional organizations, such as TxDOT and the Texas A&M Transportation Institute, in addition to other online news outlets. Considering these findings, it is possible that the sample could have better represented the whole population through a random selection process of all TxTag users, or possibly through DMV registrations which may have a greater likelihood of reaching more of the the

lesser-educated and poor population. Nonetheless, the driving population typically exhibits characteristics that are different from the non-driving population, so some differences between survey respondent socio-demographics and those of the general population are expected.

Table 6. Socio-demographic Characteristics of Survey Respondents as Compared to Austin MSA Population Statistics

Gender	Respondents	Austin MSA¹
Male	53.6%	50.2%
Female	46.4%	49.8%
Age		
18-24	2.1%	11.0%
25-34	21.5%	16.8%
35-44	25.8%	15.3%
45-54	26.5%	13.2%
55-64	16.9%	10.1%
65+	7.2%	8.3%
Education²		
Less than high school	0.0%	12.1%
High school graduate	1.7%	19.2%
Some college or vocational school	19.5%	28.1%
College graduate	47.4%	26.4%
Postgraduate college	31.4%	14.2%
Household Income		
Less than \$10,000	0.7%	6.7%
\$10,000 - \$14,999	0.5%	4.5%
\$15,000 - \$24,999	1.0%	9.4%
\$25,000 - \$34,999	4.3%	9.3%
\$35,000 - \$44,999	8.7%	14.2%
\$50,000 - \$74,999	16.8%	18.4%
\$75,000 - \$99,999	18.2%	12.6%
\$100,000 - \$199,999	29.8%	19.4%
\$200,000 or more	6.0%	5.6%
Prefer not to answer	14.0%	---

¹The current definition (December 2009) of the Austin-Round Rock-San Marcos Metropolitan Statistical Area constitutes Bastrop, Caldwell, Hays, Travis, and Williamson counties. This data originates from the 2011 American Community Survey

²ACS estimates for educational level attained used a sample population of 25 years and older

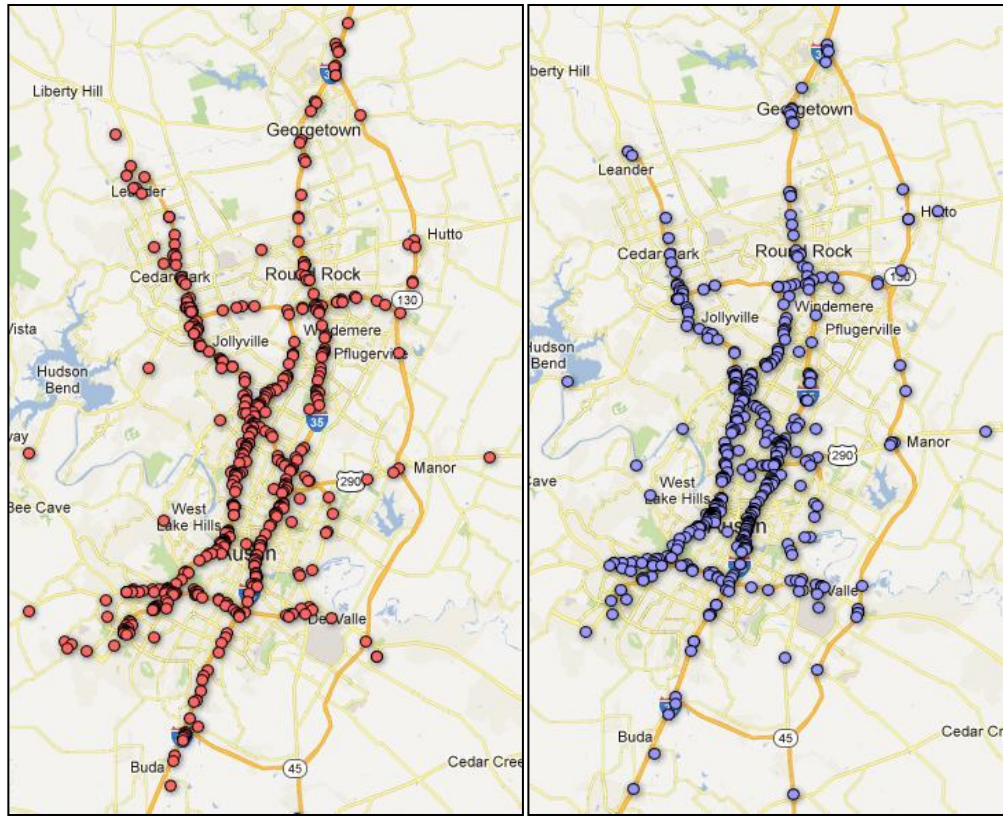


Figure 20. Distribution of origins and destinations of most-recent trips

Figure 20 illustrates the distribution of origins (left) and destinations (right) along many of the major freeways in the Austin area. As mentioned previously, the survey asked respondents to interact with the Google Maps tool by placing a marker on the location that the respondent entered and exited the freeway. From Figure 20, the main routes that were used as entrance and exit points to the freeway infrastructure were US-183, Loop 1, US-290 (between Loop 1 and SH-130), and I-35. There were only a few respondents who stated their freeway trip began along SH-130, or US-290 east of I-35. The time of day that the respondent took their most recent trip is shown in Figure 21. In the first section of the survey regarding the most recent trip, a high percentage of

respondents stated they began their trip during the early morning peak hour (between 7:00 and 9:00 AM). While there is a number of trips beginning at the morning peak hour, there was no large increase in respondents during the afternoon commute. Such a pattern could be characteristic of a subset of respondents that viewed the advertisement at work and completed it during work hours, which may indicate an over-representation of working-class professionals responding to the survey. The subsequent analysis of respondent breakdown by trip purpose also demonstrates that a high percentage of most recent trips were for the purpose of “commuting.”

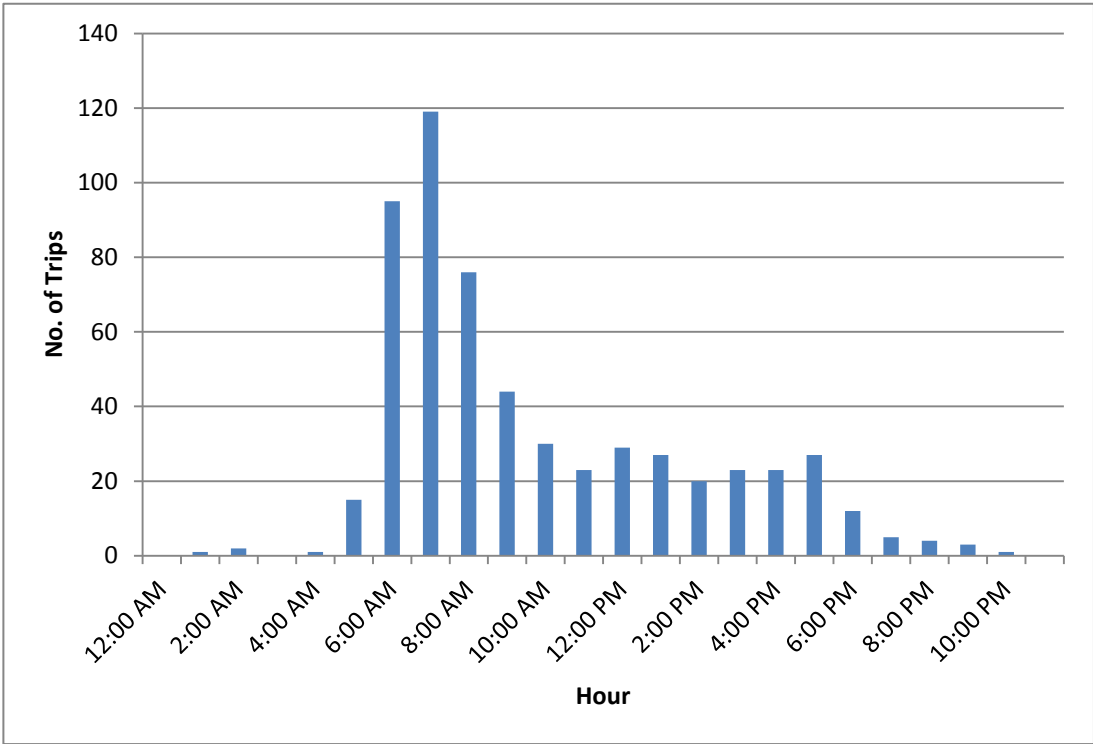


Figure 21. Histogram of respondent’s time of day that the most recent trip began

4.2 PRELIMINARY ANALYSIS

The goal of this thesis is to evaluate the effect that traffic images had on SP choice behavior. The previous sections describe the effort to design and administer an SP survey, which was used to gather response data to be analyzed. This section describes the process by which data was parsed and analyzed, and the models that were generated by this process.

Survey responses were cross-tabulated by the four survey design types (see Table 7) to check for consistency across survey designs, as well as by mode choice (see Table 8). The purpose of cross-tabulating survey responses by design type was to provide reasonable evidence that survey respondents were statistically similar across survey designs and that therefore results that differ by design type are not due to vastly different travelers happening to answer the different survey designs. For these data, several tests were used to check for statistically significant differences in traveler characteristics based on survey design type. If significant differences did exist in the data across survey design apart from those response attributes that were designed to be different, there would be reason to doubt the results of this study. To perform statistical test of significance across survey design type, for those data which were categorical but not ordinal in nature (i.e. day of the week, or time of the day) the chi-squared test was used. Kendall's Tau-b test was used for ordinal data (i.e. how many times the respondent used the toll road in the previous week). For continuous data such as travel time for the respondent's most recent trip, an Analysis of Variance procedure was used. In Table 7, variables which proved significantly different by survey design type were denoted by an asterisk following the

response characteristic. The preliminary analysis of respondent characteristics by mode choice (Table 8) was also crucial in identifying key demographic and response characteristics that might influence traveler mode choice, and thus which characteristics should be further analyzed, and will be discussed in a subsequent section.

Table 7. Survey Response by Survey Design Type

Characteristic Picture/No Picture Attribute Selection Type	Percent of Travelers				
	Picture D _b -eff	No Picture D _b -eff	Picture RA	No Picture RA	All
Freeways used on most recent trip ⁺					
I-35	70.1	69.9	71.7	79.0	72.6
Loop 1 (Mopac Expressway)	70.1	77.1	72.4	73.2	73.2
SH-45 (North)	27.2	29.4	29.7	32.6	29.7
SH-130 / SH-45 (Southeast)	26.5	26.8	25.5	29.7	27.1
US-290 / SH-71	45.6	54.9	52.4	51.4	51.1
US-183	57.1	56.2	66.9	58.0	59.5
Trip purpose					
Commuting to/from work	48.3	51.0	50.3	39.1	47.3
Recreational/Social/Shoppin Entertainment	35.4	28.1	30.3	33.3	31.7
Work related	8.8	14.4	12.4	15.2	12.7
Educational	2.0	0.0	2.1	0.0	1.0
Other	5.4	6.5	3.4	10.9	6.5
Day of the week					
Sunday	10.2	9.8	6.9	8.0	8.7
Monday	21.8	19.0	23.4	21.0	21.3
Tuesday	10.9	15.0	14.5	13.8	13.6
Wednesday	8.8	11.1	10.3	4.3	8.7
Thursday	10.9	13.7	11.7	12.3	12.2
Friday	23.1	19.6	19.3	21.0	20.8
Saturday	14.3	11.1	13.8	18.8	14.4
Vehicle occupancy					
1	61.9	67.3	67.6	60.9	64.5
2	26.5	24.2	24.8	30.4	26.4
3	5.4	4.6	3.4	5.1	4.6
4	2.7	1.3	1.4	2.2	1.9
5+	3.4	2.0	2.8	0.7	2.2

Table 7. Continued

Characteristic Picture/No Picture Attribute Selection Type	Percent of Travelers				
	Picture D _b -eff	No Picture D _b -eff	Picture RA	No Picture RA	All
Was the respondent the driver or passenger?					
Driver	75.0	77.6	76.1	66.7	73.7
Passenger	25.0	22.4	23.9	33.3	26.3
Average time to pick up carpooling passengers (in minutes)	5.5	10.7	13.1	6.8	9.1
Respondent's relationship to other passengers ⁺					
Neighbor	3.6	2.0	6.4	1.9	3.4
Child	35.7	26.5	27.7	26.4	29.3
Co-worker / person in same/nearby building	8.9	14.3	10.6	17.0	12.7
Adult family member	67.9	61.2	51.1	54.7	59.0
Another commuter in casual carpool	3.6	0.0	0.0	0.0	1.0
Other	8.9	12.2	14.9	9.4	11.2
Average respondent-stated trip time (in minutes)	46.7	38.7	37.3	44.5	41.7
Respondent preference for taking toll road					
Frequently	35.4	28.1	32.4	32.6	32.1
Occasionally	40.8	45.8	42.1	39.1	42.0
Never	23.1	25.5	24.8	26.1	24.9
Reasons respondent would take toll road ⁺					
Convenient access	57.8	54.2	46.9	48.6	52.0
Reliable travel time	38.8	42.5	27.6	37.7	36.7
Shorter travel time	62.6	62.1	57.2	58.0	60.0
Less congestion	51.7	52.3	48.3	47.1	49.9
Increased safety	12.9	20.3	13.1	11.6	14.6
Less stressfull	40.8	39.9	34.5	37.7	38.3
Does not pay	8.2	6.5	6.2	6.5	6.9
None of the above reasons	0.0	0.7	0.0	0.0	0.2
Other	7.5	8.5	9.0	8.0	8.2
Reasons respondent would not take toll road ⁺					
No convenient access	6.8	9.2	8.3	5.1	7.4
Avoids congested time periods	2.7	5.9	4.8	5.8	4.8
Does not feel safe	0.0	0.0	1.4	0.0	0.3
Toll road is too expensive	8.8	10.5	9.7	10.9	9.9

Table 7. Continued

Characteristic Picture/No Picture Attribute Selection Type	Percent of Travelers				
	Picture D _b -eff	No Picture D _b -eff	Picture RA	No Picture RA	All
Does not save enough travel time	8.2	9.8	8.3	7.2	8.4
Prefer other alternatives	8.2	12.4	9.0	10.9	10.1
Too complicated	1.4	3.3	4.1	1.4	2.6
Does not want to pay toll	13.6	17.0	18.6	16.7	16.5
Does not want transponder in vehicle	6.1	3.3	5.5	5.1	5.0
Does not have credit card for transponder	0.7	0.7	1.4	0.7	0.9
None of the above reasons	0.0	0.0	0.0	0.0	0.0
Other	5.4	5.2	3.4	6.5	5.1
Toll road usage in the past week					
0 trips	64.6	66.7	65.5	65.9	65.7
1-2 trips	20.4	16.3	14.5	21.0	18.0
3-5 trips	11.6	7.2	8.3	8.0	8.7
6-10 trips	2.0	6.5	6.9	2.2	4.5
More than 10 trips	1.4	3.3	4.8	2.2	2.9
Average cost of 1 trip on toll road*					
Less than \$1.00	7.5	3.9	6.2	4.3	5.5
\$1.01 to \$2.00	13.6	15.0	9.7	8.0	11.7
\$2.01 to \$3.00	6.1	5.2	9.0	7.2	6.9
\$3.01 to \$4.00	2.0	2.6	2.1	1.4	2.1
More than \$4.00	3.4	2.6	4.1	5.1	3.8
I don't remember	2.7	3.9	2.8	7.2	4.1
Average travel time savings when respondent uses the toll road (in minutes)	13.8	16.6	17.2	16.9	16.1
Does respondent pay to park in Austin?					
Yes	8.9	7.8	6.3	5.8	7.2
No	91.1	92.2	93.8	94.2	92.8
Average cost to park in Austin (in dollars/day)	5.9	6.3	6.2	4.2	5.8
Time of day					
Peak	48.3	40.5	53.1	42.0	46.0
Shoulder	22.4	30.7	27.6	23.9	26.2
Off-peak	29.3	28.8	19.3	34.1	27.8

Table 7. Continued

Characteristic Picture/No Picture Attribute Selection Type	Percent of Travelers				
	Picture D _b -eff	No Picture D _b -eff	Picture RA	No Picture RA	All
D _b -eff block assignment					
1	12.2	12.4	0.0	0.0	12.2
2	10.9	12.4	0.0	0.0	11.6
3	11.6	10.5	0.0	0.0	10.9
4	11.6	11.8	0.0	0.0	11.6
5	16.3	10.5	0.0	0.0	13.5
6	10.9	15.0	0.0	0.0	12.9
7	12.9	15.0	0.0	0.0	14.2
8	13.6	12.4	0.0	0.0	13.2
Average calculated trip distance (in miles)	21.6	22.0	17.2	27.7	22.1
Average toll road travel time for SP1 (in minutes)	12.5	13.4	13.0	12.6	12.9
Average non-toll road travel time for SP1 (in minutes)	22.4	23.2	23.1	21.2	22.5
Average toll rate for SP1 (in cents/mile)*	7.5	7.7	15.3	15.0	11.3
Average total toll for SP1 (in \$)*	0.9	1.0	1.9	1.9	1.4
Average toll road travel time variability for SP1 (in minutes)*	1.0	1.0	0.7	0.6	0.8
Average non-toll road travel time variability for SP1 (in minutes)*	2.3	2.4	3.7	3.3	2.9
Image presented to respondent for toll road option, SP1*					
Light traffic	87.8	87.6	52.4	58.0	71.9
Medium traffic	12.2	12.4	47.6	42.0	28.1
Heavy traffic	0.0	0.0	0.0	0.0	0.0
Image presented to respondent for non-toll road option, SP1*					
Light traffic	0.0	0.0	0.0	0.0	0.0
Medium traffic	21.8	27.5	37.2	38.4	31.0
Heavy traffic	78.2	72.5	62.8	61.6	69.0
Answer to SP1					
Non-toll road option	53.1	57.5	55.9	65.2	57.8
Toll road option	46.9	42.5	44.1	34.8	42.2
Average toll road travel time for SP2 (in minutes)	13.0	14.0	13.1	12.6	13.2
Average non-toll road travel time for SP2 (in minutes)	21.9	23.1	23.0	21.0	22.3

Table 7. Continued

Characteristic Picture/No Picture Attribute Selection Type	Percent of Travelers				
	Picture D _b -eff	No Picture D _b -eff	Picture RA	No Picture RA	All
Average toll rate for SP2 (in cents/mile)*	12.6	12.4	16.0	14.9	13.9
Average total toll for SP2 (in \$)*	1.6	1.7	2.0	1.9	1.8
Average toll road travel time variability for SP2 (in minutes)*	0.3	0.3	0.7	0.7	0.5
Average non-toll road travel time variability for SP2 (in minutes)*	2.2	2.3	3.6	3.2	2.8
Image presented to respondent for toll road option, SP2*					
Light traffic	25.9	24.8	46.2	44.9	35.2
Medium traffic	74.1	75.2	53.8	55.1	64.8
Heavy traffic	0.0	0.0	0.0	0.0	0.0
Image presented to respondent for non-toll road option, SP2*					
Light traffic	0.0	0.0	0.0	0.0	0.0
Medium traffic	0.0	0.0	0.0	0.0	0.0
Heavy traffic	100.0	100.0	100.0	100.0	100.0
Answer to SP2					
Non-toll road option	61.6	67.1	64.1	71.7	66.1
Toll road option	38.4	32.9	35.9	28.3	33.9
Average toll road travel time for SP3 (in minutes)	13.19	14.10	13.10	12.57	13.26
Average non-toll road travel time for SP3 (in minutes)	22.28	23.71	22.81	21.36	22.57
Average toll rate for SP3 (in cents/mile)*	10.03	10.00	17.81	16.60	13.51
Average total toll for SP3 (in \$)*	1.27	1.35	2.21	2.08	1.72
Average toll road travel time variability for SP3 (in minutes)	0.26	0.33	0.32	0.22	0.28
Average non-toll road travel time variability for SP3 (in minutes)	1.85	1.91	1.93	1.62	1.83
Image presented to respondent for toll road option, SP3*					
Light traffic	23.1	24.8	42.1	42.8	32.9
Medium traffic	76.9	75.2	57.9	57.2	67.1
Heavy traffic	0.0	0.0	0.0	0.0	0.0
Image presented to respondent for non-toll road option, SP3*					
Light traffic	0.0	0.0	0.0	0.0	0.0
Medium traffic	0.0	0.0	0.0	0.0	0.0
Heavy traffic	100.0	100.0	100.0	100.0	100.0

Table 7. Continued

Characteristic Picture/No Picture Attribute Selection Type	Percent of Travelers				
	Picture D _b -eff	No Picture D _b -eff	Picture RA	No Picture RA	All
Answer to SP3*					
Non-toll road option	61.9	61.2	71.0	78.5	67.9
Toll road option	38.1	38.8	29.0	21.5	32.1
Gender					
Male	53.1	52.3	48.2	60.3	53.4
Female	46.9	47.7	51.8	39.7	46.6
Age					
18-24	1.4	0.7	3.5	2.9	2.1
25-34	24.1	19.9	24.1	19.0	21.8
35-44	25.5	25.8	24.8	25.5	25.4
45-54	24.1	29.1	24.8	27.7	26.5
55-64	17.2	17.9	17.0	15.3	16.9
65+	7.6	6.6	5.7	9.5	7.3
Ethnicity					
White/Caucasian	78.9	77.7	71.7	80.4	77.2
Hispanic/Latino	8.8	7.2	11.0	5.8	8.2
African American	3.4	5.2	2.1	3.6	3.6
Asian American	2.7	3.9	4.8	2.9	3.6
Native American	2.0	0.0	0.7	1.4	1.0
Other	2.0	3.3	6.2	5.1	4.1
Education					
Less than high school	0.0	0.0	0.0	0.0	0.0
High school graduate	2.7	1.3	0.7	2.2	1.7
Some college or vocational school	15.1	19.2	16.9	23.5	18.6
College graduate	45.2	53.0	50.7	42.6	48.0
Post-graduate college	37.0	26.5	31.7	31.6	31.7

Table 7. Continued

Characteristic Picture/No Picture Attribute Selection Type	Percent of Travelers				
	Picture D _b -eff	No Picture D _b -eff	Picture RA	No Picture RA	All
Household Income					
Less than \$10,000	0.0	0.7	1.4	0.7	0.7
\$10,000 - \$14,999	1.4	0.7	0.0	0.0	0.5
\$15,000 - \$24,999	0.7	1.3	0.7	0.7	0.9
\$25,000 - \$34,999	3.4	5.3	4.3	4.4	4.4
\$35,000 - \$49,999	6.8	5.9	12.9	9.6	8.7
\$50,000 - \$74,999	20.5	12.5	15.7	18.4	16.7
\$75,000 - \$99,999	15.1	21.7	19.3	16.9	18.3
\$100,000 - \$199,999	26.7	33.6	29.3	29.4	29.8
\$200,000 or more	6.2	5.9	5.7	5.9	5.9
Prefer not to answer	19.2	12.5	10.7	14.0	14.1

*Significant differences ($p < 0.05$) per tests of significance as described in Section 3

+Sums can total over 100 percent as the respondent could select more than one answer per response

As seen in Table 7 it is evident that the respondents to each of the four survey design types exhibit similar characteristics. First, there are no significant differences between the responses by design type as they relate to respondents' most recent trip characteristics, such as freeway traveled, trip purpose, day of the week, or vehicle occupancy. It is important to note that some characteristics of the respondent's most recent trip were used to illustrate the hypothetical characteristics of a trip in the stated-preference portion of the survey, such as trip time of day, day of week, and trip purpose (see Section 3.2). For this purpose, it was necessary to ensure that there was no statistically significant variation in the distribution of these characteristics over survey design types, in order to ensure control over these variables for the stated-preference section analysis. Also, toll road preference or aversion was not significantly different in the four survey design types. However, respondent-stated average cost of one trip on the

toll road did vary by survey design. Other differences between survey designs as shown in Table 6 are due to inherent differences between the SP design characteristics and are not a result of differences in traveler socio-demographics.

There are several characteristics of this data as evidenced by Table 7 that are worth noting. First, the average toll rate and therefore the average total toll in the SP questions differed significantly between the designs for D_b-efficient and RA survey types (see Table 2 and Table 5). This was due to an error in the code that generated the toll rate assigned to each respondent for the SP questions. The error, though it significantly altered the reported average toll rate when cross-tabulated by survey design type, will not negatively impact VOT and other analysis performed using mixed-logit modeling. Additionally, since the error occurred when comparing attribute distribution designs and not while comparing across the presence of traffic images, the difference is not relevant to the comparison of picture and no-picture surveys.

A second error in the coding of the image distribution resulted in the degree of traffic congestion in the image that the respondent viewed with each SP question. While in the first SP question, respondents were assigned a heavy traffic image when average trip speed was below 50 mph, in the second and third SP questions, respondents viewed the heavy congestion image if the average trip speed was below 55 mph. While this was a small error, because of the distribution of trip speed attributes for the SP questions, 100 percent of respondents that viewed traffic images for the second and third SP questions were presented with the heavy traffic image for the non-toll road option. Fortunately, as each SP question carried equal weight in the analysis, and as in the first SP question a set

of respondents were able to view the medium-congested traffic image as associated with the non-toll road option, there was a control population by which the original survey design could be tested, as will be discussed in subsequent sections.

The data were also analyzed by examining results by mode choice for each respondent. Since each respondent was able to answer three SP questions, each response represented three choices by the respondent, resulting in 1,749 (3 choices multiplied by 583 respondents) available choices from which the data was analyzed. Cross-tabulated results of traveler characteristics with respect to stated mode choice are shown in Table 8. These results provide insight as to which traveler characteristics and preferences may be significant factors in predicting mode choice behavior. First, several key characteristics of a traveler's most recent trip on Austin area freeways were shown to be significantly different by respondent's mode choice, including characteristics such as trip purpose, the day of the week the respondent's most recent trip was executed, and the duration of that trip. In the case of trip purpose, respondents who stated that their most recent trip was for commuting and work-related purposes were more likely to choose a toll road alternative in the SP section of the survey, while recreational travelers tended to choose the non-toll alternative. Since the work-related option was described to the respondent as "not commuting", but trips between one work-related task to another, it is likely that many respondents would not shoulder the cost of the toll in the hypothetical SP exercise, and thus may be more inclined to choose the toll road alternative.

Table 8. Survey Response by Mode Choice

Characteristic Preferred Mode Choice	Percent of Travelers		
	Non-toll road option	Toll road option	All
Freeways used on most recent trip ⁺			
I-35	73.9	70.1	72.5
Loop 1 (Mopac Expressway)	73.9	71.9	73.1
SH-45 (North)	26.2	35.6	29.6
SH-130 / SH-45 (Southeast)	21.4	37.0	27.0
US-290 / SH-71	53.9	45.8	51.0
US-183	60.3	58.0	59.5
Did not use Austin freeways in six months	0.0	0.0	0.0
Trip purpose*			
Commuting to/from work	46.0	50.5	47.6
Recreational/Social/Shopping/Entertainment	35.0	26.6	32.0
Work related	10.6	16.7	12.8
Educational	0.9	1.3	1.0
Other	7.4	5.0	6.5
Day of the week*			
Sunday	10.1	6.4	8.8
Monday	22.1	19.8	21.3
Tuesday	14.1	12.8	13.6
Wednesday	8.5	9.4	8.8
Thursday	12.0	12.8	12.3
Friday	18.7	24.6	20.8
Saturday	14.6	14.1	14.4
Vehicle occupancy			
1	63.3	67.0	64.7
2	27.8	24.2	26.5
3	5.0	4.1	4.7
4	2.1	1.6	1.9
5+	1.8	3.0	2.2
Was respondent the driver or passenger on trip?			
Driver	72.9	75.8	73.9
Passenger	27.1	24.2	26.1
Average time to pick up carpooling passengers (in minutes)			
	8.6	10.0	9.1
Respondent's relationship to other passengers ⁺			
Neighbor	2.5	5.3	3.4
Child*	31.7	25.1	29.5
Co-worker / person in same/nearby building*	9.2	18.4	12.3

Table 8. Continued

Characteristic Preferred Mode Choice	Percent of Travelers		
	Non-toll road option	Toll road option	All
Adult family member	58.4	60.9	59.2
Another commuter in casual carpool	1.2	0.5	1.0
Average respondent-stated trip time (in minutes)*	35.8	52.3	41.8
Respondent preference to taking toll road*			
Frequently	17.7	58.1	32.3
Occasionally	46.4	35.7	42.5
Never	35.9	6.2	25.2
Reasons respondent would take toll road ⁺			
Convenient access*	42.4	68.7	51.9
Reliable travel time*	29.4	49.1	36.5
Shorter travel time*	50.1	77.6	60.0
Less congestion*	41.7	64.5	49.9
Increased safety*	11.3	20.0	14.5
Less stressful*	31.0	50.9	38.2
Does not pay	7.6	5.6	6.9
None of the above reasons	0.3	0.0	0.2
Other	0.1	0.1	0.1
Reasons respondent would not take toll road ⁺			
No convenient access*	10.2	2.4	7.4
Avoids congested time periods*	6.9	1.1	4.8
Does not feel safe	0.4	0.2	0.3
Toll road is too expensive*	14.3	2.4	10.0
Does not save enough travel time*	11.3	3.3	8.4
Prefer other alternatives*	14.5	2.4	10.1
Too complicated*	3.7	0.6	2.6
Does not want to pay toll*	24.4	2.5	16.5
Does not want transponder in vehicle*	7.2	1.1	5.0
Does not have credit card for transponder	0.9	0.8	0.9
None of the above reasons	0.0	0.0	0.0
Other*	5.4	5.2	5.1
Toll road usage in the past week*			
0 trips	75.5	48.6	65.8
1-2 trips	13.7	25.5	18.0
3-5 trips	6.1	13.6	8.8
6-10 trips	2.9	7.3	4.5
More than 10 trips	1.8	4.9	2.9

Table 8. Continued

Characteristic Preferred Mode Choice	Percent of Travelers		
	Non-toll road option	Toll road option	All
Average cost of 1 trip on toll road			
Less than \$1.00	16.8	15.7	16.2
\$1.01 to \$2.00	33.3	35.1	34.3
\$2.01 to \$3.00	18.3	21.9	20.3
\$3.01 to \$4.00	6.6	5.6	6.1
More than \$4.00	12.8	9.7	11.1
I don't remember	12.1	11.9	12.0
Average travel time savings when respondent uses the toll road (in minutes)	15.4	16.7	16.1
Does respondent pay to park in Austin?*			
Yes	6.0	9.6	7.3
No	94.0	90.4	92.7
Average cost to park in Austin (in dollars/day)	5.87	5.61	5.75
Time of day*			
Peak	39.3	57.7	46.0
Shoulder	25.1	28.3	26.3
Off-peak	35.5	14.0	27.8
Picture presented to respondent?*			
Yes	48.1	53.9	50.2
No	51.9	46.1	49.8
Attribute selection criteria*			
D _b -eff	48.7	56.4	51.5
Random adjusting	51.3	43.6	48.5
D _b -eff block assignment			
1	14.0	9.5	12.3
2	10.7	12.6	11.5
3	7.8	15.7	10.9
4	14.0	7.8	11.6
5	14.8	11.5	13.5
6	12.2	13.7	12.8
7	13.7	15.1	14.2
8	12.8	14.0	13.2
Gender			
Male	49.8	59.9	53.5
Female	50.2	40.1	46.5

Table 8. Continued

Characteristic Preferred Mode Choice	Percent of Travelers		
	Non-toll road option	Toll road option	All
Age			
18-24	2.5	1.3	2.1
25-34	22.5	20.7	21.9
35-44	24.6	27.2	25.5
45-54	26.1	26.9	26.4
55-64	17.6	15.5	16.8
65+	6.6	8.5	7.3
Ethnicity			
White/Caucasian	79.4	78.1	78.9
Hispanic/Latino	7.9	9.4	8.5
African American	4.2	2.8	3.7
Asian American	3.3	4.4	3.7
Native American	0.8	1.5	1.1
Other	4.4	3.8	4.2
Education			
Less than high school	0.0	0.0	0.0
High school graduate	1.7	1.8	1.7
Some college or vocational school	19.4	16.8	18.4
College graduate	46.8	50.5	48.1
Post-graduate college	32.1	31.0	31.7
Household Income*			
Less than \$10,000	0.8	0.5	0.7
\$10,000 - \$14,999	0.7	0.2	0.5
\$15,000 - \$24,999	0.5	1.5	0.9
\$25,000 - \$34,999	5.5	2.4	4.4
\$35,000 - \$49,999	10.1	6.3	8.7
\$50,000 - \$74,999	18.3	14.1	16.8
\$75,000 - \$99,999	19.3	16.2	18.2
\$100,000 - \$199,999	26.1	36.2	29.8
\$200,000 or more	3.7	9.9	5.9
Prefer not to answer	14.8	12.8	14.1

*Significant differences per tests of significance as described in Section 3

+Sums can total over 100 percent as the respondent could select more than one answer per response

Travelers on Monday and Tuesday were more inclined to avoid the toll road option in the SP exercise than those who traveled later in the week—the most significant difference in mode choice occurring on Fridays. Lastly, respondents who indicated that their most recent trip was a carpool averaged approximately 9 minutes in picking up the passengers. In the case of this group of respondents, the relationship of the respondent to the other passengers or driver played a role in predicting SP choice behavior. Of those respondents traveling with a child, the larger quantity chose the non-toll road alternative, while those traveling with co-workers or people in the same or nearby office building were more likely to choose the toll road alternative. Those traveling with neighbors, other adult family members, or other commuters in a casual carpool showed no significant difference in SP choice behavior. Survey responses also showed a significant difference between average trip time for the respondents' most recent trip and SP choice behavior. This trip time was respondent-stated and reflects the average time it takes for a respondent to travel from origin to destination, including time to travel both on and off of the freeway. The average time for those who chose the non-toll road option was 35.8 minutes, and the average time for the toll road option was 52.3 minutes, indicating that as travel time increased, a respondent's willingness to pay additional costs to reduce that travel time increased.

As expected, the research found there was a strong relationship between a respondent's predisposition to toll roads and their SP choice behavior. Respondents who frequently would take a toll road alternative, if it existed, chose the toll road alternative in the SP exercise 76.6 percent of the time, with those who occasionally would take the

toll road choosing that alternative in the SP exercise only 43.5 percent of the time. Interestingly, the strongest indicator of SP choice behavior were those who chose to never take the toll road even if one existed as a legitimate alternative; of this group of respondents, only 14.7 percent chose the toll road option in SP questions. In a follow-up question, respondents were also asked to check reasons which would make the toll road option attractive, if the respondent chose the “frequent” or “occasionally” response to the previous question. Of the responses, most of the listed reasons in the survey proved significant, including convenience of access, reliable travel times, shorter travel times, less congestion, increased safety, and a less stressful experience. For those who would “never” take the toll road, significant influences included lack of convenient access to the toll roads, the respondent’s ability to avoid the most congested time periods, respondents feeling that the toll road is too expensive, does not save enough travel time, is too complicated, does not want to pay the toll or have a transponder in the vehicle, or generally prefers other alternatives to the toll road.

Of those respondents who used the toll road in the past week, many were more inclined to choose the toll road option in the SP exercise. Those who did not use the toll road in the past week were strongly inclined to choose the non-toll road alternative. This is good evidence that recent behavior can strongly influence choice behavior in the SP setting, even for those respondents who only occasionally (1 to 2 times in a week) use the toll road. Such a characteristic of the SP behavior may indicate the existence of a barrier to entry to use of the toll road infrastructure.

The time of day that the respondent took their most recent trip on Austin freeways was also recorded and grouped together into one of three categories, including peak, off-peak, and shoulder periods (see Section 3.2.2). The survey found that there was a significant effect of travel time of day on SP choice behavior. Since the trip time of day of the respondent's most recent trip in Austin was used to formulate the hypothetical SP setting, the trip time of day should have directly influenced choice behavior in the SP section. 59.5 percent of respondents that traveled during the peak hours in their actual trip chose the toll road alternative in their SP question, while those traveling in the off-peak hours chose the toll road alternative 28.3 percent of the time.

Finally, certain socio-demographic characteristics were significantly different by respondent SP mode choice, including respondent gender and household income. First, household income plays a significant role in influencing travel choices. Since much of the decision regarding toll road usage is based on travel cost, it makes sense that the income of the respondent would affect mode choice. Indeed, as respondent income increases, the likelihood of choosing the toll alternative also increases. Moreover, there is a clear divide in the degree of influence once income reaches the \$100,000 limit and above. For all incomes below this level, the non-toll alternative is the more preferred, but if a respondent earns more than \$100,000, this relationship changes and the toll road option is preferred. Creating a multinomial logit model (as will be discussed in the next section) will further aid in dissecting the relationship between income, cost, and willingness to pay. Second, male respondents chose toll road alternatives more often than non-toll road alternatives. The female respondents chose non-toll road alternatives more

often. Upon initial investigation it is difficult to determine the precise cause of this discrepancy, since various factors may go in to influencing male versus female SP choice behavior. The next step in the analysis (developing the MNL model) will help analyze the effects that certain parameters such as trip purpose or income may have on travel choices.

4.3 LEXICOGRAPHIC AND NON-TRADING BEHAVIOR ANALYSIS

A lexicographic and non-trading behavior analysis was performed on the data to determine if survey design type influenced how respondents interacted with choice alternatives. Lexicographic behavior occurs when a respondent focuses on only one attribute of the choice set instead of all attributes in the aggregate. For example, if a respondent chose the fastest route for every alternative, there is evidence that the respondent may not have been considering all possible attributes of the trip. A similar behavior could be manifested also by a respondent who chose the most or least reliable option only, or the cheapest option only. Non-trading behavior is similar in nature, but occurs when a respondent chooses only one alternative, regardless of the attributes of other alternatives. The purpose of this type of analysis is to identify in which survey design types this type of behavior might have occurred and to determine which design was best at minimizing this type of behavior.

From Table 9 it was apparent that all design types had a very high percentage of respondents exhibiting non-trading behavior. This was expected as each respondent was given only two alternatives to choose from, and the number of choice sets was limited to only three. Of all the survey designs, the Random Adjusting with Pictures design was the

best at reducing non-trading behavior. With respect to lexicographic behavior, the Random Adjusting attribute distribution method performed the best overall, with the exception of lexicographic behavior focusing on reliability.

Table 9. Lexicographic and Non-trading Choice Behavior Analysis

	Percent of Travelers				All
	Picture D _b -eff	No Picture D _b -eff	Picture RA	No Picture RA	
Non-trading Behavior	68.03	64.05	52.41	62.32	61.75
Lexicographic Behavior					
Fastest Travel Time	25.17	20.92	11.72	6.52	16.30
Most Reliable	3.40	1.31	14.48	7.97	6.69
Cheapest Option	42.18	42.48	40.69	54.35	44.77

4.4 MULTINOMIAL LOGIT MODELS OF MODE CHOICE

Section 4.1 and 4.2 described many of the characteristics of survey participants grouped by survey design type and mode choice. In the analysis, certain respondent characteristics were significantly different based on mode chosen and may affect mode choice. While useful, this type of analysis considers characteristics individually and does not evaluate the influence of each variable in the context of other parameters. Therefore, one goal of this research was to derive a multinomial logit (MNL) model that best describes the influence that these characteristics have on mode choice in the aggregate. In the stated-preference section of the survey, each respondent was asked to complete three stated-choice experiments, of which they must choose one of two alternatives.

Therefore, from this data it is possible to generate 3 observations from each respondent's completed survey.

Several MNL models of respondent mode choice were developed using the mixed (or random parameters) logit modeling technique in order to better understand what variables most influence mode choice. The mixed-logit modeling technique is ideal for this data due to the presence of respondent heterogeneity in the error terms of the results. Respondent heterogeneity potentially violates the assumption of independent and identically distributed (IID) observations, which is the foundation of the simpler multinomial logit model (Hensher et al. 2005). Such preference heterogeneity presents itself when response error may correlate across choice situations. In this case, it is introduced as respondents are asked to answer multiple SP questions each. To account for respondent heterogeneity in the models, the parameter for toll (γ_{TOLL}) and the toll road alternative-specific constant (ASC) parameter (γ_{ASC_TR}) were randomized using a Halton sequence, simulating a random selection process to vary the distribution of those parameters (Hensher et al. 2005). The Halton sequence for these data used a triangular distribution for the toll and toll road ASC parameters. For these data, it was determined to use a Halton sequence with a total of 500 draws to account for heterogeneity across respondents' six choice observations, as this number of draws presented the model with the best goodness-of-fit across a range of possible draws that were tested (Hensher et al. 2005). The best model that was generated used these parameters for the Halton estimation, which proved to perform superior than any other number of draws or any other distribution. In this process, variables which were found to be significant in the

previous descriptive analysis were all included in early generations of the model to determine their influence in mode choice. Certain respondent characteristics were omitted from later analysis, such as the respondents' predisposition to toll road usage. While this may be a strong indicator of respondent behavior through the SP exercises, a respondents' opinion towards toll road usage is a data point that is often not available, which would diminish the transferability of the MNL model.

All other significant parameters were subsequently included in model trials, and many of them were determined to be significant in predicting mode choice behavior, though several decisions were made in the parameter selection that helped generate the most efficient MNL model. Table 10 provides the coefficients and significance (in parentheses) of each parameter as it pertains to the model, as well as the relative statistics indicating goodness-of-fit and predictive ability of the model. This table also includes the statistics on the alternative specific constant only model, which is a good basis for comparison of more complex model performance.

One model in particular had the best results for goodness-of-fit and predictive ability. This model yielded results that indicated that most of the parameters that were determined to be significant individually were also significant in the aggregate. Model 2 in Table 10 displays the model parameters, the parameter coefficients, and the parameter p-values for the best model.

As expected, trip purpose had a significant impact on mode choice. Specifically, work-related trips (trips involving work that are not commuting trips) proved to significantly help the model successfully predict behavior. For this reason, a dummy

parameter indicating whether the trip was work-related or not was added to the toll road utility model, with β_{work} equal to a value of 0.91 for Model 2 as seen in Table 10. This indicated that travelers on work trips had a higher likelihood of choosing the toll road, possibly due to tolls on some work-related trips being paid for by the employer and not the driver.

The day of the week of the trip was a strong indicator of toll road choice behavior. β_{weekday} is a dummy parameter and indicates whether the hypothetical SP trip would occur on a weekday (Monday through Friday). Users prefer non-toll alternatives for trips that occur on weekdays. Additionally, the time of day was also a significant influence on mode choice. For peak hour trips—between 7:00 to 9:00 am and 4:00 to 6:00 pm—respondents were more likely to choose a toll road alternative.

Income was also a strong influence on the model. It was found that by parsing income into a dummy parameter indicating whether or not the traveler's household income was more than \$100,000 per year was the best indicator of mode choice, as those travelers had a higher likelihood of choosing the toll road alternative.

The value of travel time savings (VTTS) and value of travel time reliability (VTTR) were also calculated from model parameters. VTTS for any of the models in this setting is equal to $(\beta_{\text{TT}} / \beta_{\text{TOLL}}) 60$, and VTTR was calculated by $((\beta_{\text{TTV}} / \beta_{\text{TOLL}}) * 60)$. Model 2 yields a VTTS of \$14.04/hour, with a VTTR of \$1.40/hour.

Table 10. Mode Choice Models – All Data

Mode	Variable	Model 1:	Model 2:	Model 3:	Model 4:
		Constant only (n=1734)	Non-user Indicator (n=1728)	Frequent User Indicator (n=1728)	Neither frequent or non-user indicator included (n=1728)
All	Travel Time (TT)		-0.30(.000)	-0.31(.000)	-0.33(.000)
Non-toll Road	Travel Time Variability (TTV)		-0.03(.629)	-0.04(.478)	-0.04(.506)
	Weekday ($WKDAY$)		1.38(.004)	1.25(.008)	0.90(.064)
	Non-User (0x /week) ($NO-USE$)		3.25(.000)		
Toll Road	ASC	-0.57(.000)	-0.66(.295)	-3.32(.000)	-3.44(.000)
	Toll ($TOLL$)		-1.29(.000)	-1.21(.000)	-1.22(.000)
	Time of Day (peak) ($PEAK$)		0.84(.105)	0.56(.274)	0.62(.233)
	Male ($MALE$)		0.81(.043)	0.76(.056)	0.81(.050)
	High Income (>\$100,000) (INC)		1.43(.001)	1.42(.001)	1.46(.001)
	Trip purpose (work related) ($WORK$)		0.91(.159)	1.26(.050)	1.32(.043)
	Frequent User (+3x /week) ($FREQ-USE$)			2.62(.000)	
Standard Deviations	Travel Time		0.29(.021)	0.24(.088)	0.31(.011)
	ASC_TR		8.13(.000)	8.61(.000)	8.79(.000)
Model Results	Log Likelihood	-1136.17	-833.11	-854.16	-866.32
	Adjusted ρ_c^2		0.26	0.24	0.23
	Value of Travel Time Savings (\$/hr)		14.04	15.14	16.07
	95% C.I. on VTTS (\$/hr)		(9.63, 18.46)	(10.44, 19.83)	(11.25, 20.88)
	Value of Travel Time Reliability (\$/hr)		1.40	2.13	2.00
	95% C.I. on VTTR (\$/hr)		(-4.26, 7.06)	(-3.76, 8.03)	(-3.90, 7.91)
	Percent Correct Predictions		71.2	68.6	68.0

The model's predictive ability, ρ_c^2 , and log-likelihood increased significantly with the inclusion of one of two parameters: the frequent user parameter or the non-user parameter. These parameters are derived from a previous question in the survey concerning the frequency of usage of a toll road in the past week. If the respondent indicated use of the toll road more than three times in the past week, they were designated a "frequent user" (see Model 3). Similarly, if the respondent indicated that they did not use a toll road in the past week, they were designated a "non-user" (see Model 2). In the generated models, both of these indicators strongly influenced mode choice, and the non-user indicator (Model 2) provided the best results. If both of these parameters are removed from the model, all of the relevant statistics for goodness-of-fit and predictive ability worsen. However, as discussed previously, the data that may indicate whether a specific proportion of a given population used the toll road in the previous week may not be readily available, thus affecting the transferability of those models. While they are useful to illustrate the importance of a user's prior experience and habits regarding toll road usage, the model without these parameters may be able to best describe choice behavior from readily available trip and user characteristics. Therefore, subsequent analysis in this study focused solely on the comparisons of Model 4 from Table 10 across the different survey design types.

When the data is analyzed by survey design type, the models demonstrate certain characteristics worthy of discussion (see Table 11). First, all survey designs yielded a predictive ability very similar to other design types, with the exception of the RA with

Pictures design, which was worse than the predictive ability of the other designs. The adjusted ρ^2 measure is higher for the D_b -efficient designs than for the RA designs.

With regards to specific model parameters, there are certain characteristics of the data worth discussion. There is consistent disutility associated with travel time, which is the result expected for such a parameter. However, there is inconsistency in the sign for utility of the travel time variability parameter. In the case of the D_b -efficient survey designs, VTTR has a positive coefficient, indicating that a user prefers a non-toll route alternative with increasing travel time variability. The opposite was true for those respondents who viewed the RA design type. Survey design types consistently demonstrated disutility for the toll road alternative, as ASC_{TR} was always a negative value.

The calculated values of VTTS were similar across designs, though the value of VTTR was inconsistent in this breakdown of responses by survey design type. From this analysis as well as the lexicographic analysis performed previously in this study, it is possible that the level of information being presented to the respondent led to disregard for this attribute in the decision-making process of the respondent. Regardless, these models are a great starting point in understanding respondent behavior as it correlates to different designs in attribute distribution and graphic presentation of the alternatives.

Table 11. Mode Choice Model 4 Across All Survey Design Types

Mode	Variable	All Survey Design Types (n=1728)	D _b -efficient with Picture (n=438)	D _b -efficient without Picture (n=447)	RA with Picture (n=435)	RA without Picture (n=408)
All	Travel Time (τ_{TT})	-0.33(.000)	-0.42(.000)	-0.48(.000)	-0.38(.006)	-0.22(.108)
Non-toll Road	Travel Time Variability (τ_{TV})	-0.04(.506)	0.05(.846)	0.15(.162)	-0.19(.286)	-0.12(.407)
	Weekday (τ_{WKDAY})	0.90(.064)	0.98(.295)	0.31(.759)	0.48(.758)	2.38(.072)
Toll Road	ASC	-3.44(.000)	-4.85(.000)	-3.10(.012)	-1.26(.471)	-3.35(.052)
	Toll (τ_{TOLL})	-1.22(.000)	-0.88(.004)	-1.76(.000)	-2.00(.758)	-1.28(.002)
	Time of Day (peak) (τ_{PEAK})	0.62(.233)	1.19(.252)	0.09(.929)	-1.93(.003)	1.62(.213)
	Male (τ_{MALE})	0.81(.050)	0.72(.358)	-0.12(.893)	1.45(.217)	1.60(.172)
	High Income (>\$100,000) (τ_{INC})	1.46(.001)	2.46(.006)	1.31(.113)	1.85(.290)	1.09(.303)
	Trip purpose (work related) (τ_{WORK})	1.32(.043)	1.78(.171)	1.60(.110)	1.25(.194)	0.85(.622)
Standard Deviations	Travel Time	0.31(.011)	0.45(.025)	0.87(.000)	0.48(.513)	0.23(.655)
	ASC_TR	8.79(.000)	6.94(.000)	5.54(.004)	13.11(.001)	10.50(.002)
Model Results	Log Likelihood	-866.32	-199.05	-207.77	-241.37	-198.77
	Adjusted ρ_c^2	0.23	0.29	0.27	0.11	0.14
	Value of Travel Time Savings (\$/hr)	16.07	28.78	16.53	11.37	10.12
	95% C.I. on VTTS (\$/hr)	(11.25, 20.88)	(14.89, 42.66)	(7.99, 25.08)	(3.35, 19.40)	(-2.23, 22.48)
	Value of Travel Time Reliability (\$/hr)	2.00	-3.47	-5.04	5.62	5.69
	95% C.I. on VTTR (\$/hr)	(-3.90, 7.91)	(-38.39, 31.46)	(-12.10, 2.02)	(-4.71, 15.94)	(-7.76, 19.14)
	Percent Correct Predictions	68.0	70.8	69.6	62.1	72.5

Table 12 shows the same MNL model (Model 4 from Table 10) as it applies to the subset of D_b -efficient and RA survey design types. This table demonstrates that the data in the D_b -efficient subset of the response pool had more convincing results with regards to model predictive ability, adjusted ρ^2 , and VTTR. Interestingly, the VTTS calculation for both pools of data were different to the full response set at \$20.85/hr and \$11.21/hr for the D_b -efficient and RA designs, respectively. These differences, however, were inside of the 95% confidence interval for the VTTS and VTTR estimate, suggesting there is no statistical evidence to show that attribute distribution design had a significant effect on VTTS and VTTR estimates.

In Table 13, model results for the design types with and without pictures are summarized. An effort was made with this data to discover the best model for this subset of data. Therefore, Table 13 shows the results from both the base model and another model that was optimized for the Pictures design dataset and the No Pictures design data set. From these models it was most plain to see the impact that the presence of traffic images had on SP choice behavior. While the predictive ability of the Pictures dataset decreased relative to the No Pictures dataset, the adjusted ρ^2 of the Pictures dataset was higher than that of the No Pictures dataset, suggesting better goodness-of-fit measures for the Pictures dataset. With the models established, the VTTS was calculated and found to be higher by \$1.26/hr for the responses in the Pictures dataset. Much like the analysis performed on the dataset by attribute distribution, this increase in VTTS for the Pictures dataset lied well within the 95% confidence interval for the VTTS estimates for both datasets. Therefore, these results regarding the VOT calculation for respondents

viewing traffic images lacks any strong evidence that the presence of images induces a significant influence on mode choice behavior in this setting. Likewise, the VTTR figure is higher in the Picture dataset by \$0.96/hr, which is also well within the 95% confidence interval for the VTTR estimate.

Table 12. Mode Choice Models – D_b-efficient v. Random Adjusting

Mode	Variable	All Survey Design Types (n=1728)	D _b -efficient (n=885)	RA (n=843)
All	Travel Time (τ_{TT})	-0.33(.000)	-0.46(.000)	-0.28(.000)
Non-toll Road	Travel Time Variability (τ_{TTV})	-0.04(.506)	0.10(.282)	-0.13(.183)
Toll Road	Weekday (τ_{WKDAY})	0.90(.064)	0.66(.316)	1.63(.071)
	ASC	-3.44(.000)	-3.92(.000)	-2.42(.025)
	Toll (τ_{TOLL})	-1.22(.000)	-1.33(.000)	-1.48(.000)
	Time of Day (peak) (τ_{PEAK})	0.62(.233)	0.60(.381)	0.44(.619)
	Male (τ_{MALE})	0.81(.050)	0.24(.646)	1.23(.098)
	High Income (>\$100,000) (τ_{INC})	1.46(.001)	1.71(.003)	1.88(.076)
Standard Deviations	Trip purpose (work related) (τ_{WORK})	1.32(.043)	1.83(.016)	0.89(.444)
	Toll	0.31(.011)	0.66(.000)	0.26(.368)
Model Results	ASC_TR	8.79(.000)	6.31(.000)	11.31(.000)
	Log Likelihood	-866.32	-410.32	-444.91
	Adjusted ρ_c^2	0.23	0.29	0.14
	Value of Travel Time Savings (\$/hr)	16.07	20.85	11.21
	95% C.I. on VTTS (\$/hr)	(11.25, 20.88)	(13.98, 27.73)	(5.02, 17.40)
	Value of Travel Time Reliability (\$/hr)	2.00	-4.39	5.39
	95% C.I. on VTTR (\$/hr)	(-3.90, 7.91)	(-12.39, 3.61)	(-2.54, 13.32)

Table 13. Mode Choice Models – Pictures v. No Pictures

Mode	Variable	Pictures (n=873)		No Pictures (n=855)	
		Base model	Best model	Base model	Best model
All	Travel Time (TT)	-0.33(.000)	-0.34(.000)	-0.35(.000)	-0.36(.000)
Non-toll Road	Travel Time Variability (TTV) Weekday ($WKDAY$)	-0.05(.671)	-0.05(.665)	-0.01(.868)	-0.04(.628)
Toll Road	ASC	-3.44(.000)	-3.42(.000)	-3.18(.001)	-3.37(.000)
	Toll ($TOLL$)	-1.12(.000)	-1.17(.001)	-1.44(.000)	-1.32(.000)
	Time of Day (peak) ($PEAK$)	0.15(.834)		0.97(.224)	
	Male ($MALE$)	0.86(.154)		0.77(.245)	
	High Income (>\$100,000) (INC)	1.99(.002)	2.16(.001)	1.08(.100)	1.00(.103)
	Trip purpose (work related) ($WORK$)	1.43(.135)	1.58(.102)	1.42(.134)	1.32(.130)
Standard Deviations	Toll ASC_TR	0.24(.220)	0.32(.042)	0.54(.004)	0.61(.001)
Model Results	Log Likelihood	-448.86	-450.24	-413.93	-422.38
	Adjusted ρ_c^2	0.21	0.21	0.23	0.22
	Value of Travel Time Savings (\$/hr)	17.42	17.54	14.79	16.28
	95% C.I. on VTTS (\$/hr)	(10.40, 24.43)	(11.24, 23.84)	(7.73, 21.86)	(9.17, 23.39)
	Value of Travel Time Reliability (\$/hr)	2.64	2.62	0.54	1.66
	95% C.I. on VTTR (\$/hr)	(-9.54, 14.82)	(-9.24, 14.47)	(-5.81, 6.89)	(-5.04, 8.35)
	Percent Correct Predictions	66.4	67.1	67.3	68.8

Finally, an analysis was completed that investigated the effect that the difference between the degrees of congestion of the alternatives. In this portion of the study, the data was again separated into two groups, one viewing traffic images and the other not viewing traffic images. For both sets of data, each alternative was assigned a number representing which image would be shown given the traffic conditions the alternative suggested. In this way, if an alternative suggested heavy traffic conditions, that alternative would be given a “3”, while an alternative that suggested light traffic conditions would be given a “1”. Thus, the data was further separated into three groups: 1) those that viewed images that were separated by a factor of 2, 2) those that viewed images separated by a factor of 1, and 3) those that viewed the same images for both alternatives. Since the only SP question in which respondents could have viewed the same traffic image for both alternatives was the first SP question, there was no respondent heterogeneity in the error terms that occurred, and therefore the mixed-logit model was not necessary for that subpopulation of responses. Table 14 and Table 15 show the results of this MNL model analysis. Due to the small sample size of the models based on SP questions in which the respondent viewed the same traffic picture, these models do not converge to reliable parameter estimates of VTTS, VTTR, or any of the other parameter estimates. As evidenced by the data in these tables, VTTS for those who did not view traffic images was lower than those who did view traffic images when the pictures differed by two degrees of congestion by \$10.81/hr. However, again, due to the width of the 95% confidence interval for the VTTS estimate, this data does not provide

strong enough evidence that the presentation of pictures influenced mode choice for even the largest differences in trip attributes between alternatives.

Table 14. Mode Choice Models – How Picture Differences Influence Choice (When Pictures are Presented)

Mode	Variable	Pictures (all data, n=873)	Same Picture (n=32)		1 Degree of Difference (n=491)	2 Degrees of Difference (n=350)
			(MNL)	(ML)		
All	Travel Time (T_T)	-0.40(.000)	-0.14(.472)	-1.36(.363)	-0.31(.000)	-0.22(.000)
Non-toll Road	Travel Time Variability (T_{TV})	-0.12(.389)	-0.50(.613)	2.40(.560)	-0.03(.795)	-0.19(.079)
Toll Road	ASC	-3.60(.000)	0.31(.504)	-3.59(.610)	-3.58(.000)	-2.52(.000)
	Toll (T_{OLL})	-1.93(.000)	0.08(.877)	1.01(.664)	-1.20(.000)	-1.15(.004)
	High Income (>\$100,000) (I_{NC})	2.74(.000)	-100.58(1.000)	-7.20(.474)	-2.08(.000)	0.94(.042)
	Trip purpose (work related) (W_{ORK})	1.99(.065)	-0.98(.279)	-50.58(.902)	1.42(.014)	1.22(.067)
Standard Deviations	Toll	2.89	---	3.22(.308)	1.80	3.51
	ASC_TR	9.61	---	0.04(1.000)	7.47	5.87
Model Results	Log Likelihood	-450.24	-17.70	-16.29	-268.41	-219.13
	Adjusted ρ_c^2	0.21	---	-0.21	0.13	0.06
	Value of Travel Time Savings (\$/hr)	17.54	-101.05	-80.47	24.53	26.34
	95% C.I. on VTTS (\$/hr)	(11.24, 23.84)	(-376.65, 174.55)	(-253.78, 92.85)	(11.14, 37.92)	(8.69, 44.00)
	Value of Travel Time Reliability (\$/hr)	2.62	-365.14	141.77	2.96	-1.18
	95% C.I. on VTTR (\$/hr)	(-9.24, 14.47)	(-1024.86, 294.57)	(-129.32, 412.87)	(-26.82, 32.74)	(-32.06, 29.71)
	Percent Correct Predictions	67.1	---	71.9	72.1	62.29

Table 15. Mode Choice Models – How Picture Differences Influence Choice (When Pictures are Not Presented)

Mode	Variable	Pictures (all data, n=873)	Same Picture (n=32)		1 Degree of Difference (n=491)	2 Degrees of Difference (n=350)
			(MNL)	(ML)		
All	Travel Time (T_T)	-0.36(.000)	-0.55(.098)	-1.98(.989)	-0.43(.007)	-0.12(.146)
Non-toll Road	Travel Time Variability (T_{TV})	-0.04(.628)	-2.69(.212)	0.37(.989)	0.07(.763)	-0.32(.086)
Toll Road	ASC	-3.37(.000)	0.07(.914)	-9.69(.989)	-4.23(.001)	-2.56(.001)
	Toll (T_{OLL})	-1.32(.000)	-1.55(.404)	-5.09(.989)	-1.28(.001)	-0.48(.050)
	High Income (>\$100,000) (I_{NC})	1.00(.103)	-0.14(.932)	6.66(.989)	1.81(.027)	0.71(.237)
	Trip purpose (work related) (W_{ORK})	1.32(.130)	1.90(.181)	-0.59(.989)	1.64(.103)	0.42(.591)
Standard Deviations	Toll	0.61(.001)		0.15(.996)	0.99(.001)	0.86(.003)
	ASC T_R	7.93(.000)		13.28(.990)	6.83(.009)	0.00(1.000)
Model Results	Log Likelihood	-422.38	-9.04	-8.87	-250.91	-195.26
	Adjusted ρ_c^2	0.22		-0.10	0.19	0.05
	Value of Travel Time Savings (\$/hr)	16.28	21.37	23.26	20.04	15.53
	95% C.I. on VTTS (\$/hr)	(9.17, 23.39)	(-3.91, 46.65)	(-3259.46, 3305.98)	(5.39, 34.70)	(-5.39, 36.45)
	Value of Travel Time Reliability (\$/hr)	1.66	103.92	-4.41	-3.19	39.89
	95% C.I. on VTTR (\$/hr)	(-5.04, 8.35)	(56.28, 151.57)	(-624.46, 615.64)	(-23.93, 17.54)	(-5.69, 85.47)
	Percent Correct Predictions	68.8		70.8	69.4	68.0

5. CONCLUSIONS

In this research, a stated-preference survey was developed to measure the influence of traffic images on mode choice. The Austin Travel Survey was used to collect information about the most recent trip of each respondent, which was then pivoted to develop base trip characteristics for the SP portion of the survey. Trip attributes were developed for each respondent using either a D_b -efficient or RA design. In order to test the impact that traffic images had on mode choice, half of the respondents were assigned a SP question set in which they were shown an image of traffic in their SP questions alongside of a lexicographic description of trip attributes. The study design allowed for four survey design types: D_b -efficient with pictures, D_b -efficient without pictures, RA with pictures, and RA without pictures.

Descriptive analysis of survey responses was performed to determine if significant differences in respondent characteristics existed between survey design types. There was no evidence of differences in responses between survey design types. Survey responses were then cross-tabulated to determine any significant differences in respondent trip preferences across mode choice. From this analysis, several factors were determined to be significant influences on mode choice. To determine the influence that trip attributes had on mode choice in the aggregate, a mixed-logit model was built to estimate the respondent's choice behavior. Responses were also analyzed to determine the effect that each survey design type had on lexicographic and non-trading behavior.

5.1 CONCLUSIONS

A lexicographic and non-trading behavior analysis was performed on the data to determine if survey design type influenced how respondents interacted with choice alternatives. It was apparent that all design types had a very high percentage of respondents exhibiting non-trading behavior. Such a result is not surprising in SP choice experiments with only two alternatives to choose from. Of all the survey designs, the Random Adjusting with Pictures design was the best at reducing non-trading behavior. With respect to lexicographic behavior, the Random Adjusting attribute distribution method performed the best overall, with the exception of lexicographic behavior focusing on reliability. It was not clear, however, whether the presence of traffic images reduced the occurrence of non-trading or lexicographic behavior for this data.

Several MNL models of respondent mode choice were developed using the mixed (or random parameters) logit modeling technique in order to better understand what variables most influence mode choice. One model in particular had the best results for goodness-of-fit and predictive ability, though this model relied on an indicator of past toll road usage as a predictor of future usage. Since past usage is typically not available, further analysis included model estimation without this parameter. In addition to travel time, travel time variability, and total toll parameters, model parameters that significantly improved the ML model estimation were trip purpose (for a work-related trip), the day of the week, gender, time of day, and high income (>\$100,000/year). It was noted that there was consistent disutility in the data associated with travel time, which is the result expected for such a parameter. However, there was inconsistency in the data in

the sign for utility of the travel time variability parameter, suggesting a weakness in the reliability of the travel time reliability parameter estimate across survey design type. Data parsed by trip attribute distribution (D_b -efficient versus RA) showed no significant differences in VTTS and VTTR estimates, while model goodness-of-fit parameters increased for the D_b -efficient design.

From the models separating respondents by the presentation of pictures it was most plain to see the impact that the presence of traffic images had on SP choice behavior. While the predictive ability of the Pictures dataset decreased relative to the No Pictures dataset, the adjusted ρ^2 of the Pictures dataset was higher than that of the No Pictures dataset, suggesting better goodness-of-fit measures for the Pictures dataset. With the models established, the VTTS was calculated as \$17.54/hr for the Pictures dataset, and \$16.28 for the No Pictures dataset—a difference of \$1.26/hr. Much like the analysis performed on the dataset by attribute distribution, this increase in VTTS for the Pictures dataset lied well within the 95% confidence interval for the VTTS estimates for both datasets. Therefore, these results regarding the VTTS calculation for respondents viewing traffic images lacks any strong evidence that the presence of images induces a significant influence on mode choice behavior in this setting. Likewise, the VTTR figure is higher in the Picture dataset by \$0.96/hr, which is also well within the 95% confidence interval for the VTTR estimate.

An analysis was also completed that investigated the effect that the difference between the degrees of congestion of the alternatives. While model parameters were not adequate to draw conclusions on the effect of viewing the same picture for both

alternatives, VTTS for those who did not view traffic images was lower than those who did view traffic images when the pictures differed by two degrees of congestion by \$10.81/hr. However, due to the width of the 95% confidence interval for the VTTS estimate, this data does not provide strong enough evidence that the presentation of pictures influenced mode choice for even the largest differences in trip attributes between alternatives.

5.2 RESEARCH LIMITATIONS

While this study was able to present images that roughly corresponded to trip characteristics (via the average trip speed attribute), this research was limited in its ability to study the effect of image presentation in the context of a pictorial format with minimal text. Due to the format of the SP questions, it is possible that a respondent viewed the traffic images as being a supplemental piece of information, secondary to the lexicographic description of trip attributes. Therefore, it is possible that respondents did not base their decisions on the traffic image, since trip attributes were summarized in the text. In future studies, a greater disparity could be introduced in how heavily a respondent must rely on traffic pictures to understand trip characteristics of the mode choice.

This study was also limited in the variety of pictures used to convey trip attributes. With only three possible images that respondents saw to convey trip attributes, this study may not have been able to relate trip conditions to every respondent's own travel experience. By providing pictures with a greater variety of

facilities across a greater range of average travel speeds, it is possible that more respondent's will relate SP trip conditions with actual travel experience.

Finally, due to the error in the code that generated the picture assignment for the SP questions, instances in which respondents viewed the same pictures for both the toll road and the non-toll road option were limited. Because there were so few SP questions that displayed the same pictures for both modes, the analysis comparing the influence that the degree of picture differences was particularly lacking. Since this part of the analysis yielded differences (although statistically insignificant) in the mixed-logit models, further research could be justified in determining the effect, if any, picture differences have on influencing mode choice.

5.3 RECOMMENDATIONS FOR FURTHER RESEARCH

This topic remains a source for valuable future research. Most specifically, research into the impact of traffic images on SP mode choice behavior should focus on more accurately reflecting experimental conditions of SP surveys in other disciplines. For example, when testing the effect that images have on SP choice behavior in the health setting, researchers tested the effect of a variety of presentation designs, including such things as the prominence of the images in the SP question. Such a strategy could be valuable in this setting in addressing the limitations discussed previously. Research could study the effects of presenting a picture with trip attributes in a caption and presenting a picture aside a lexicographic description of trip conditions (similar to what was done in this survey). If this type of study still yields no evidence that traffic imagery influences mode choice or VTTS estimates, the case for using such imagery in SP travel

surveys would be more doubtful, as there will be little evidence that such survey design strategies provide any benefit to mode choice models.

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APPENDIX A

SURVEY INSTRUMENT



Traveler Survey

This is a survey of people who have recently traveled on Austin area freeways. The survey should take approximately 10 to 15 minutes to complete.

Dear Austin Traveler,

The Texas Transportation Institute is examining ways to improve traffic flow along freeways in Austin. We need your help with this. This survey should take about 15 minutes to complete. While you are not obligated to answer the questions on the survey, the information you provide will be very valuable as we work to improve travel. Your answers on the survey will be confidential and not used in any way to identify you. Please use the next and previous buttons at the bottom of the page.

If you have any questions regarding the survey, please contact me at (979) 845-9875 or mburris@tamu.edu. Thank you for your participation.

Sincerely,

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

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

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Have you traveled on any of the following freeways in the Austin area in the past six months? If so, on which freeway(s) did you take your most recent trip?

Choose more than one, if your trip included multiple freeways.

Check any that apply

- I-35
- Loop 1 (Mopac Expressway)
- SH-45 (North)
- SH-130 / SH-45 (Southeast)
- US-290 / SH-71
- US-183
- I have not used an Austin area freeway in the past six months

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 an educational institute
- Other:

On what day of the week was your most recent trip?

Choose one of the following answers

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

What time of day did that trip start?

Choose one of the following answers

▼

What kind of vehicle did you use for your most recent trip?

Choose one of the following answers

- Passenger Car, SUV, or Pick-up Truck
- Motorcycle
- Bus
- Other:

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+

Were you the driver or a passenger on this recent trip?

Choose one of the following answers

- Driver
- Passenger

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 nearby, office building
- Adult family member
- Another commuter in a casual carpool (also known as slugging)
- Other:

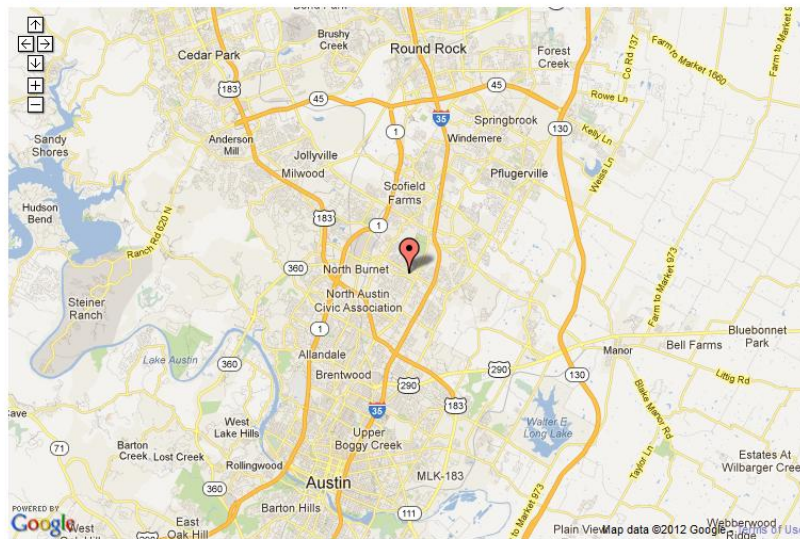
How much did you pay to ride the bus?

\$ per trip

Only numbers may be entered in this field

Please **click and drag the marker** to move the marker to the location on the map where you **ENTERED** the freeway.

See "Help" section below the map if needed.



Map tutorial:

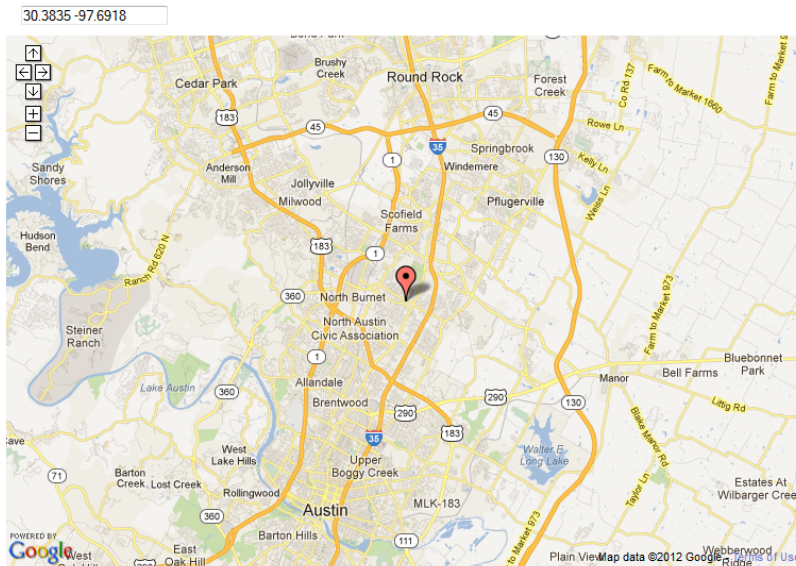
*You may zoom in to the map on a specific location by either double-clicking the spot on the map or by clicking the "+" button in the top left corner of the map

*Zoom out by clicking the "-" button in the top left corner of the map

*You may center the map on a different location by either drag-clicking the mouse at any spot on the map or by clicking on one of the arrow buttons in the top left corner of the map

Please **click and drag the marker** to move the marker to the location on the map where you **EXITED** the freeway.

See "Help" section below the map if needed.



Map tutorial:

*You may zoom in to the map on a specific location by either double-clicking the spot on the map or by clicking the "+" button in the top left corner of the map

*Zoom out by clicking the "-" button in the top left corner of the map

*You may center the map on a different location by either drag-clicking the mouse at any spot on the map or by clicking on one of the arrow buttons in the top left corner of the map

How long was your most recent trip on the freeway?

(this is the amount of time from when you got in your car to the time you arrived at your destination)

minutes

Only numbers may be entered in this field

If a toll road exists as a reasonable alternative route to your destination (for example, in the case of SH-130 as an alternative to I-35), how often would you use the toll road for any given trip?

Choose one of the following answers

- Frequently
- Occasionally
- Never

What would be important considerations for you to decide to use the toll road for a given trip?

Check any that apply

- Toll roads would need to be safer than alternate routes
- Someone else (like an employer) would need to pay my tolls
- Access to/from the toll road would need to be convenient for my trip
- Travel times on the toll road would have to be consistent and predictable
- Toll roads would need to be less stressful than alternate routes
- The toll road would need to save time
- During peak hours toll roads would not be congested
- None of these reasons
- Other:

What are the primary reasons why you would not use a toll road for a given trip?

Check any that apply

- I generally have the flexibility to travel at less congested times on toll free roads
- I don't have a credit card as needed to set up a toll transponder account
- I do not want to pay the toll for a given trip
- If access to/from the toll road was not convenient for my trip
- I do not feel safe traveling on toll roads
- I don't want to have a toll transponder in my vehicle
- If it is too complicated/confusing to use the toll road
- If the toll road does not save me enough time
- If the toll was too expensive for me
- If I can easily use routes other than the toll road, so I'll just avoid it unless there is a lot of traffic
- None of these reasons
- Other:

Thinking about the last work week (from Monday through Friday):

How many trips did you make on Austin area toll roads (each direction counts as one trip)?

Choose one of the following answers

- 0
- 1-2
- 3-5
- 6-10
- more than 10

On average, how much is the total toll for one trip on the toll road (each direction counts as one trip)?

Choose one of the following answers

- Less than \$1.00
- \$1.01 to \$2.00
- \$2.01 to \$3.00
- \$3.01 to \$4.00
- more than \$4.00
- I don't remember

On average, approximately how much time do you save when you use the toll road?

minutes

Only numbers may be entered in this field

On an average day, do you have to pay to park in Austin?

- Yes
- No

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

\$ per day

Only numbers may be entered in this field

Stated Preference Questions without Picture:

Each of the following questions will ask you to choose between two potential travel choices in Austin. Thinking about your most recent trip, please select the one option that you would most likely have chosen if you were faced with these options on your trip.


You described your most recent trip on an Austin freeway as occurring on a Monday at 6:45 AM in a passenger car, SUV, or pick-up truck. The reason for your trip was commuting to or from your place of work (going to or from work).

If you had the options below for that trip during the morning shoulder period, which option would you choose?


(The Max and Min values show the range of travel times)

Choose one of the following answers

Option A

Non-toll Road Begin Trip at (morning shoulder period) Trip Distance: 20 miles No Toll		
<input type="radio"/>		
Typical <---Max-----Min--->		
Travel Time	36 34 32	minutes

Option B

Toll Road Begin Trip at (morning shoulder period) Trip Distance: 20 miles Toll: \$3.00		
<input type="radio"/>		
Typical <---Max-----Min--->		
Travel Time	20 19 18	minutes

Stated Preference Questions with Picture:

Each of the following questions will ask you to choose between two potential travel choices in Austin. Thinking about your most recent trip, please select the one option that you would most likely have chosen if you were faced with these options on your trip.



You described your most recent trip on an Austin freeway as occurring on a Monday at 6:45 AM in a passenger car, SUV, or pick-up truck. The reason for your trip was commuting to or from your place of work (going to or from work).

If you had the options below for that trip during the morning shoulder period, which option would you choose?



(The Max and Min values show the range of travel times)

Choose one of the following answers

Option A

Non-toll Road Begin Trip at (morning shoulder period) Trip Distance: 20 miles No Toll		
<input type="radio"/>		
Typical <---Max-----Min--->		
Travel Time	37 34 31	minutes

Option B

Toll Road Begin Trip at (morning shoulder period) Trip Distance: 20 miles Toll: \$2.20		
<input type="radio"/>		
Typical <---Max-----Min--->		
Travel Time	23 22 21	minutes

Please state your gender.

Choose one of the following answers

- Male
- Female

Which of the following age categories best represents your age?

Choose one of the following answers

- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65 and over

What is your race/ethnicity?

Choose one of the following answers

- White/Caucasian
- Hispanic/Latino
- African American
- Asian American
- Native American
- Other:

What is your highest level of education?

Choose one of the following answers

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

What is your annual HOUSEHOLD income?

Choose one of the following answers

- Less than \$10,000
- \$10,000 - \$14,999
- \$15,000 - \$24,999
- \$25,000 - \$34,999
- \$35,000 - \$49,999
- \$50,000 - \$74,999
- \$75,000 - \$99,999
- \$100,000 - \$199,999
- \$200,000 or more
- Prefer not to answer
- It is easier to note wages per hour (\$/hr)

Feel free to provide any comments or suggestions related to transportation and travel here:

Thank you for completing this survey! We appreciate your feedback.

Please follow this [link](#) to register for your chance to win one of two \$200 gift cards!

Prize Enrollment:



Traveler Survey Prize Enrollment

Thanks! We appreciate the time you took to fill in this survey. The next page will ask for contact information so that you can be entered into a drawing for one of two \$200 gift cards. The rules of the contest are below:

1. Contest is void where prohibited by law. No purchase necessary to win, but the survey must be fully completed by September 19, 2012. Late or duplicate entries will not be accepted.
2. All contestants must be 18 or older.
3. Two winners will be chosen. Each prize is a gift card worth \$200. The winner will be selected on September 26, 2012 at CE/TTI tower on the campus of Texas A & M campus. Winner need not be present.
4. The winner is responsible for all applicable federal, state and local taxes including income tax.
5. Employees of the Texas Transportation Institute and the Texas Department of Transportation and members of their families are not eligible to enter to win.
6. Contest is void where prohibited by law.

Next>>

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This survey is currently not active. You will not be able to save your responses.

Traveler Survey Prize Enrollment

***Please enter your name.**

First name
Last name

***Please enter your phone number.**

Phone number

***Please supply your e-mail so we can notify you of the results when they are ready. Your e-mail will not be used for any other purpose or given to anyone else.**

Email

Submit

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This survey is currently not active. You will not be able to save your responses.

APPENDIX B

STATED-PREFERENCE QUESTION CODE

SPQ #1:

```
//Set default question type to 0.
var questype = 0;

//Pull values from survey for presentation in SP questions.
var dayofweek = "{INSERTANS:22858X29X1341}"
  if (dayofweek == "")
    //User did not select the day of the week. Generate a
    weekday randomly.
    {
    var questype = 1;
    var random4 = (Math.floor(Math.random()*5))+1;
    switch (random4)
    {
    case 1:
      var dayofweek = "Monday";
      document.getElementById('answer22858X38X102528
        ').value = "Monday";
      break;

    case 2:
      var dayofweek = "Tuesday";
      document.getElementById('answer22858X38X102528
        ').value = "Tuesday";
      break;

    case 3:
      var dayofweek = "Wednesday";
      document.getElementById('answer22858X38X102528
        ').value = "Wednesday";
      break;

    case 4:
      var dayofweek = "Thursday";
      document.getElementById('answer22858X38X102528
        ').value = "Thursday";
```



```

        break;

        case 5:
            var dayofweek = "Friday";
            document.getElementById('answer22858X38X102528
                ').value = "Friday";
            break;
        }
    }
else
//User did select a day of the week. Use this in SPQ.
{
    document.getElementById('answer22858X38X102528').value
        = dayofweek;
}

//Assign a vehicle to the SPQ presentation
var vehicle = "{INSERTANS:22858X29X1343}";
if (vehicle == "")
{
    //User did not select a vehicle. Use passenger car,
    etc.
    var vehicle = ""
    document.getElementById('answer22858X38X102529').value
        = "";
}
else
//User specified vehicle. Use in SPQ.
{
    var vehicle = vehicle.toLowerCase();
    var vehicle = vehicle.replace("suv", "SUV");
    var vehicle = " in a " + vehicle;
    document.getElementById('answer22858X38X102529').value
        = vehicle;
}

//Assign a trip purpose to the SPQ presentation
var trippurpose = "{INSERTANS:22858X29X1339}"
if (trippurpose == "")
//User did not select a trip purpose. Do not refer to
trip purpose in SPQ text.
{
    var trippurpose = "";
}

```

```

        document.getElementById('answer22858X38X102533').value
            = "";
    }
else
    {
    //User specified trip purpose. Use in SPQ.
    var trippurpose = trippurpose.toLowerCase();
    var trippurpose = trippurpose.replace("my", "your");
    var trippurpose = " The reason for your trip was " +
        trippurpose + ".";
    document.getElementById('answer22858X38X102533').value
        = trippurpose;
    }

// Determine the time of day - influences the toll rate and
// travel speeds
var TripTime = "{INSERTANS:22858X29X1342}";
if (TripTime == "")
    {
    //User did not provide response. Force into AM or PM
    // peak. Randomly select 8:00 AM or 5:00 PM.
    var questype = 1;
    var TimeOfDay = 1;
    var random1 = Math.floor(Math.random()*100);
    if (random1 < 50)
        {
        var TripTime = "8:00 AM";
        document.getElementById('answer22858X38X102527').va
            lue = "8:00 AM";
        document.getElementById('answer22858X38X10251').val
            ue = TimeOfDay;
        document.getElementById('answer22858X38X10252').val
            ue = "morning peak" ;
        }
    else
        {
        var TripTime = "5:00 PM";
        document.getElementById('answer22858X38X102527').va
            lue = "5:00 PM";
        document.getElementById('answer22858X38X10251').val
            ue = TimeOfDay;
        document.getElementById('answer22858X38X10252').val
            ue = "afternoon peak" ;
        }
    }

```

```

    }
else
    //Determine if trip time of day was during Peak,
    Shoulder, or Off-peak hours.
    {
    //create an hours after midnight variable
    var x = TripTime.split(" ");
    var y = x[0].split(":");
    var hours = Number(y[0]);
    if (x[1] == "AM" && hours == 12)
        {
        var HAM = hours - 12;
        }
    else if (x[1] == "AM")
        {
        var HAM = hours;
        }
    else
        {
        var HAM = hours + 12;
        }

    if (HAM < 6 || HAM >= 19)
        {
        var TimeOfDay = 3;
        document.getElementById('answer22858X38X10251').val
            ue = TimeOfDay ;
        document.getElementById('answer22858X38X10252').val
            ue = "night time" ;
        }
    else if (HAM >= 10 && HAM < 15)
        {
        var TimeOfDay = 3 ;
        document.getElementById('answer22858X38X10251').val
            ue = TimeOfDay ;
        document.getElementById('answer22858X38X10252').val
            ue = "mid-day period" ;
        }
    else if (HAM >= 6 && HAM < 7)
        {
        var TimeOfDay = 2 ;
        document.getElementById('answer22858X38X10251').val
            ue = TimeOfDay ;
        }

```

```

        document.getElementById('answer22858X38X10252').value = "morning shoulder period" ;
    }
else if (HAM >= 9 && HAM < 10)
    {
        var TimeOfDay = 2 ;
        document.getElementById('answer22858X38X10251').value = TimeOfDay ;
        document.getElementById('answer22858X38X10252').value = "morning shoulder period" ;
    }
else if (HAM >= 15 && HAM < 16)
    {
        var TimeOfDay = 2 ;
        document.getElementById('answer22858X38X10251').value = TimeOfDay ;
        document.getElementById('answer22858X38X10252').value = "afternoon shoulder period" ;
    }
else if (HAM >= 18 && HAM < 19)
    {
        var TimeOfDay = 2 ;
        document.getElementById('answer22858X38X10251').value = TimeOfDay ;
        document.getElementById('answer22858X38X10252').value = "afternoon shoulder period" ;
    }
else if (HAM >= 7 && HAM < 9)
    {
        var TimeOfDay = 1 ;
        document.getElementById('answer22858X38X10251').value = TimeOfDay ;
        document.getElementById('answer22858X38X10252').value = "morning peak period" ;
    }
else if (HAM >= 16 && HAM < 18)
    {
        var TimeOfDay = 1 ;
        document.getElementById('answer22858X38X10251').value = TimeOfDay ;
        document.getElementById('answer22858X38X10252').value = "afternoon peak period" ;
    }
}

```

```

// Find TT peak factors(TravTime) for non-toll (NTR) and
toll roads (TR)
if (TimeOfDay == 1)
//assigns value of PeakFactor for peak travel
{
    var PeakFactorNTR = 1.8 ;
    var PeakFactorTR = 1.2 ;
}
else if (TimeOfDay == 2)
//assigns value of PeakFactor for shoulder travel
{
    var PeakFactorNTR = 1.4 ;
    var PeakFactorTR = 1.1 ;
}
else if (TimeOfDay == 3)
//assigns value of PeakFactor for off-peak travel
{
    var PeakFactorNTR = 1.0 ;
    var PeakFactorTR = 1.0 ;
}
document.getElementById('answer22858X38X10253').value =
    PeakFactorTR ;
document.getElementById('answer22858X38X10254').value =
    PeakFactorNTR ;

// Create variables pos1 (lat & long) and pos2 (lat & long)
based on user input
var position1 = "{INSERTANS:22858X33X1014}" ;
var position2 = "{INSERTANS:22858X53X1352}" ;
var check1 = position1.search("TX") ;
var check2 = position2.search("TX") ;
if (check1 == -1 || check2 == -1)
//one of the user inputs is outside of Texas. Default
TripDist to 14 miles.
{
    var TripDist = 14 ;
}
else
//User input is inside of Texas. Convert answer string
to number.
{
    var pos1 = position1.split(";");
    var pos2 = position2.split(";");

```

```

var pos1Lat = pos1[0];
var pos1Long = pos1[1];
var pos2Lat = pos2[0];
var pos2Long = pos2[1];
}

// Calculate trip distance from map interface.
if (pos1Lat == undefined || pos1Long == undefined ||
    pos2Lat == undefined || pos2Long == undefined)
//User did not input one of their positions. Default
  TripDist to 14 miles.
  {
    var TripDist = 14 ;
  }
else
//User input is valid. Calculate trip dist from Lat/Long
  and use as SP trip distance
  {
    var radpos1Lat = Math.PI * pos1Lat/180 ;
    var radpos2Lat = Math.PI * pos2Lat/180 ;
    var radpos1Long = Math.PI * pos1Long/180 ;
    var radpos2Long = Math.PI * pos2Long/180 ;
    var theta = pos1Long-pos2Long ;
    var radtheta = Math.PI * theta/180 ;
    var TripDist = Math.sin(radpos1Lat) *
      Math.sin(radpos2Lat) + Math.cos(radpos1Lat) *
      Math.cos(radpos2Lat) * Math.cos(radtheta) ;
    TripDist =
      Math.round(1.3*(Math.acos(TripDist)*(180/Math.PI)*6
        0*1.1515)) ;
    document.getElementById('answer22858X38X102534').value
      = TripDist ;
    if (TripDist > 30)
      {
        var TripDist = 14 ;
      }
    else if (TripDist < 6)
      {
        var TripDist = 6 ;
      }
  }

document.getElementById('answer22858X38X10255').value =
  pos1Lat ;

```

```

document.getElementById('answer22858X38X10256').value =
    pos1Long ;
document.getElementById('answer22858X38X10257').value =
    pos2Lat ;
document.getElementById('answer22858X38X10258').value =
    pos2Long ;
document.getElementById('answer22858X38X10259').value =
    TripDist ;

// Determine if pictures will be included in questions
var random2 = Math.floor(Math.random()*100);
if (random2 < 50)
{
    // include picture in SPQs
    document.getElementById('answer22858X38X102510').value =
        1 ;
    var tablewidth = 750;
}
else
{
    // do not include picture in SPQs
    document.getElementById('answer22858X38X102510').value =
        2 ;
    var tablewidth = 600;
}
document.getElementById('answer22858X38X102530').value =
    tablewidth;

//Write question text to output
if (questype == 0)
{
    document.getElementById('answer22858X38X102535').value =
        "You described your most recent trip on an Austin
        freeway as occurring on a " + dayofweek + " at " +
        TripTime + vehicle + "." + trippurpose ;
}
else
{
    document.getElementById('answer22858X38X102535').value =
        "Consider you need to travel in Austin on a " +
        dayofweek + " at " + TripTime + vehicle + "." +
        trippurpose ;
}

```

```

// Select survey attribute distribution
var random3=Math.floor(Math.random()*100);
if (random3 < 50)
{
// Method 1 - D-Efficient
document.getElementById('answer22858X38X102511').value =
1;
var Block =
Math.round((Math.floor(Math.random()*80)+5)/10); //
Random integer from 1 to 8
document.getElementById('answer22858X38X102512').value =
Block;
switch (Block)
{
case 1:
// Explanatory comments are the same and apply for
each case, but are not repeated after the first
case.
// Check if average trip speeds are reasonable.
Correct if not.
// Assign TR/NTR speeds.
var SpeedTR = 60;
var SpeedNTR = 50;
var TravTimeTR = Math.round((TripDist * 60) /
(SpeedTR / PeakFactorTR));
if (TravTimeTR > 60)
{
var TravTimeTR = 60;
}
var TravTimeNTR = Math.round((TripDist * 60) /
(SpeedNTR / PeakFactorNTR));
if (TravTimeNTR > 60)
{
var TravTimeNTR = 60;
}
// Assign toll rate.
var TollRate = 10 ;
var TotToll = (Math.round((TollRate *
TripDist)/5)/20).toFixed(2) ;
// Assign TT variability factors.
var VarFactorTR = 5/100 ;
var VarFactorNTR = 5/100 ;

```



```

var TravTimeVarTR =
    Math.round(VarFactorTR*PeakFactorTR*TravTimeTR
    ) ;
var TravTimeVarNTR =
    Math.round(VarFactorNTR*PeakFactorNTR*TravTime
    NTR) ;
// Calculate trip characteristics from
    attributes.
var MinTravTimeTR = TravTimeTR - TravTimeVarTR ;
var MaxTravTimeTR = TravTimeTR + TravTimeVarTR ;
    var MinTravTimeNTR = TravTimeNTR -
        TravTimeVarNTR ;
var MaxTravTimeNTR = TravTimeNTR +
    TravTimeVarNTR;
// Check if average trip speeds are reasonable.
    Correct if not.
var MinSpeedTR = (TripDist/MaxTravTimeTR)*60 ;
var MaxSpeedTR = (TripDist/MinTravTimeTR)*60 ;
if (MaxSpeedTR > 85)
    {
        var MaxSpeedTR = 85 ;
        var MinTravTimeTR = (TripDist/MaxSpeedTR)*60 ;
    }
var MinSpeedNTR = (TripDist/MaxTravTimeNTR)*60 ;
var MaxSpeedNTR = (TripDist/MinTravTimeNTR)*60 ;
if (MaxSpeedNTR > 75)
    {
        var MaxSpeedNTR = 75 ;
        var MinTravTimeNTR =
            (TripDist/MaxSpeedNTR)*60;
    }
break;

case 2:
    var SpeedTR = 70;
    var SpeedNTR = 55;
    var TravTimeTR = Math.round((TripDist * 60) /
        (SpeedTR / PeakFactorTR));
    if (TravTimeTR > 60)
        {
            var TravTimeTR = 60;
        }
    var TravTimeNTR = Math.round((TripDist * 60) /
        (SpeedNTR / PeakFactorNTR));

```

```

if (TravTimeNTR > 60)
{
    var TravTimeNTR = 60;
}
var TollRate = 5 ;
var TotToll = (Math.round((TollRate *
    TripDist)/5)/20).toFixed(2) ;
var VarFactorTR = 10/100 ;
var VarFactorNTR = 5/100 ;
var TravTimeVarTR =
    Math.round(VarFactorTR*PeakFactorTR*TravTimeTR
    ) ;
var TravTimeVarNTR =
    Math.round(VarFactorNTR*PeakFactorNTR*TravTime
    NTR);
var MinTravTimeTR = TravTimeTR - TravTimeVarTR ;
var MaxTravTimeTR = TravTimeTR + TravTimeVarTR ;
var MinTravTimeNTR = TravTimeNTR -
    TravTimeVarNTR;
var MaxTravTimeNTR = TravTimeNTR +
    TravTimeVarNTR;
var MinSpeedTR = (TripDist/MaxTravTimeTR)*60 ;
var MaxSpeedTR = (TripDist/MinTravTimeTR)*60 ;
if (MaxSpeedTR > 85)
{
    var MaxSpeedTR = 85 ;
    var MinTravTimeTR = (TripDist/MaxSpeedTR)*60;
}
var MinSpeedNTR = (TripDist/MaxTravTimeNTR)*60;
var MaxSpeedNTR = (TripDist/MinTravTimeNTR)*60;
if (MaxSpeedNTR > 75)
{
    var MaxSpeedNTR = 75 ;
    var MinTravTimeNTR =
        (TripDist/MaxSpeedNTR)*60;
}
break;

case 3:
    var SpeedTR = 65;
    var SpeedNTR = 50;
    var TravTimeTR = Math.round((TripDist * 60) /
        (SpeedTR / PeakFactorTR));
    if (TravTimeTR > 60)

```

```

        {
            var TravTimeTR = 60;
        }
        var TravTimeNTR = Math.round((TripDist * 60) /
            (SpeedNTR / PeakFactorNTR));
        if (TravTimeNTR > 60)
        {
            var TravTimeNTR = 60;
        }
        var TollRate = 5 ;
        var TotToll = (Math.round((TollRate *
            TripDist)/5)/20).toFixed(2) ;
        var VarFactorTR = 10/100 ;
        var VarFactorNTR = 15/100 ;
        var TravTimeVarTR =
            Math.round(VarFactorTR*PeakFactorTR*TravTimeTR
                );
        var TravTimeVarNTR = Math.round(VarFactorNTR *
            PeakFactorNTR * TravTimeNTR);
        var MinTravTimeTR = TravTimeTR - TravTimeVarTR ;
        var MaxTravTimeTR = TravTimeTR + TravTimeVarTR ;
        var MinTravTimeNTR = TravTimeNTR -
            TravTimeVarNTR;
        var MaxTravTimeNTR = TravTimeNTR +
            TravTimeVarNTR;
        var MinSpeedTR = (TripDist/MaxTravTimeTR)*60 ;
        var MaxSpeedTR = (TripDist/MinTravTimeTR)*60 ;
        if (MaxSpeedTR > 85)
        {
            var MaxSpeedTR = 85 ;
            var MinTravTimeTR = (TripDist/MaxSpeedTR)*60 ;
        }
        var MinSpeedNTR = (TripDist/MaxTravTimeNTR)*60 ;
        var MaxSpeedNTR = (TripDist/MinTravTimeNTR)*60 ;
        if (MaxSpeedNTR > 75)
        {
            var MaxSpeedNTR = 75 ;
            var MinTravTimeNTR =
                (TripDist/MaxSpeedNTR)*60;
        }
    }
    break;

case 4:
    var SpeedTR = 65;

```

```

var SpeedNTR = 50;
var TravTimeTR = Math.round((TripDist * 60) /
    (SpeedTR / PeakFactorTR));
if (TravTimeTR > 60)
{
    var TravTimeTR = 60;
}
var TravTimeNTR = Math.round((TripDist * 60) /
    (SpeedNTR / PeakFactorNTR));
if (TravTimeNTR > 60)
{
    var TravTimeNTR = 60;
}
var TollRate = 10 ;
var TotToll = (Math.round((TollRate *
    TripDist)/5)/20).toFixed(2) ;
var VarFactorTR = 10/100 ;
var VarFactorNTR = 5/100 ;
var TravTimeVarTR =
    Math.round(VarFactorTR*PeakFactorTR*TravTimeTR
    );
var TravTimeVarNTR =
    Math.round(VarFactorNTR*PeakFactorNTR*TravTime
    NTR);
var MinTravTimeTR = TravTimeTR - TravTimeVarTR ;
var MaxTravTimeTR = TravTimeTR + TravTimeVarTR ;
var MinTravTimeNTR = TravTimeNTR -
    TravTimeVarNTR;
var MaxTravTimeNTR = TravTimeNTR +
    TravTimeVarNTR;
var MinSpeedTR = (TripDist/MaxTravTimeTR)*60 ;
var MaxSpeedTR = (TripDist/MinTravTimeTR)*60 ;
if (MaxSpeedTR > 85)
{
    var MaxSpeedTR = 85 ;
    var MinTravTimeTR = (TripDist/MaxSpeedTR)*60 ;
}
var MinSpeedNTR = (TripDist/MaxTravTimeNTR)*60 ;
var MaxSpeedNTR = (TripDist/MinTravTimeNTR)*60 ;
if (MaxSpeedNTR > 75)
{
    var MaxSpeedNTR = 75 ;
    var MinTravTimeNTR =
        (TripDist/MaxSpeedNTR)*60;
}

```

```

    }
break;

case 5:
    var SpeedTR = 65;
    var SpeedNTR = 45;
    var TravTimeTR = Math.round((TripDist * 60) /
        (SpeedTR / PeakFactorTR));
    if (TravTimeTR > 60)
    {
        var TravTimeTR = 60;
    }
    var TravTimeNTR = Math.round((TripDist * 60) /
        (SpeedNTR / PeakFactorNTR));
    if (TravTimeNTR > 60)
    {
        var TravTimeNTR = 60;
    }
    var TollRate = 5 ;
    var TotToll = (Math.round((TollRate *
        TripDist)/5)/20).toFixed(2) ;
    var VarFactorTR = 0/100 ;
    var VarFactorNTR = 5/100 ;
    var TravTimeVarTR =
        Math.round(VarFactorTR*PeakFactorTR*TravTimeTR
        );
    var TravTimeVarNTR =
        Math.round(VarFactorNTR*PeakFactorNTR*TravTime
        NTR) ;
    var MinTravTimeTR = TravTimeTR - TravTimeVarTR ;
    var MaxTravTimeTR = TravTimeTR + TravTimeVarTR ;
    var MinTravTimeNTR = TravTimeNTR -
        TravTimeVarNTR;
    var MaxTravTimeNTR = TravTimeNTR +
        TravTimeVarNTR;
    var MinSpeedTR = (TripDist/MaxTravTimeTR)*60 ;
    var MaxSpeedTR = (TripDist/MinTravTimeTR)*60 ;
    if (MaxSpeedTR > 85)
    {
        var MaxSpeedTR = 85 ;
        var MinTravTimeTR = (TripDist/MaxSpeedTR)*60 ;
    }
    var MinSpeedNTR = (TripDist/MaxTravTimeNTR)*60 ;
    var MaxSpeedNTR = (TripDist/MinTravTimeNTR)*60 ;

```

```

    if (MaxSpeedNTR > 75)
    {
        var MaxSpeedNTR = 75 ;
        var MinTravTimeNTR =
            (TripDist/MaxSpeedNTR)*60;
    }
break;

case 6:
    var SpeedTR = 70;
    var SpeedNTR = 55;
    var TravTimeTR = Math.round((TripDist * 60) /
        (SpeedTR / PeakFactorTR));
    if (TravTimeTR > 60)
    {
        var TravTimeTR = 60;
    }
    var TravTimeNTR = Math.round((TripDist * 60) /
        (SpeedNTR / PeakFactorNTR));
    if (TravTimeNTR > 60)
    {
        var TravTimeNTR = 60;
    }
    var TollRate = 5 ;
    var TotToll = (Math.round((TollRate *
        TripDist)/5)/20).toFixed(2) ;
    var VarFactorTR = 0/100 ;
    var VarFactorNTR = 10/100 ;
    var TravTimeVarTR =
        Math.round(VarFactorTR*PeakFactorTR*TravTimeTR
        );
    var TravTimeVarNTR =
        Math.round(VarFactorNTR*PeakFactorNTR*TravTime
        NTR) ;
    var MinTravTimeTR = TravTimeTR - TravTimeVarTR ;
    var MaxTravTimeTR = TravTimeTR + TravTimeVarTR ;
    var MinTravTimeNTR = TravTimeNTR -
        TravTimeVarNTR;
    var MaxTravTimeNTR = TravTimeNTR +
        TravTimeVarNTR;
    var MinSpeedTR = (TripDist/MaxTravTimeTR)*60 ;
    var MaxSpeedTR = (TripDist/MinTravTimeTR)*60 ;
    if (MaxSpeedTR > 85)
    {

```

```

        var MaxSpeedTR = 85 ;
        var MinTravTimeTR = (TripDist/MaxSpeedTR)*60 ;
    }
    var MinSpeedNTR = (TripDist/MaxTravTimeNTR)*60 ;
    var MaxSpeedNTR = (TripDist/MinTravTimeNTR)*60 ;
    if (MaxSpeedNTR > 75)
    {
        var MaxSpeedNTR = 75 ;
        var MinTravTimeNTR =
            (TripDist/MaxSpeedNTR)*60;
    }
break;

case 7:
    var SpeedTR = 70;
    var SpeedNTR = 50;
    var TravTimeTR = Math.round((TripDist * 60) /
        (SpeedTR / PeakFactorTR));
    if (TravTimeTR > 60)
    {
        var TravTimeTR = 60;
    }
    var TravTimeNTR = Math.round((TripDist * 60) /
        (SpeedNTR / PeakFactorNTR));
    if (TravTimeNTR > 60)
    {
        var TravTimeNTR = 60;
    }
    var TollRate = 15 ;
    var TotToll = (Math.round((TollRate *
        TripDist)/5)/20).toFixed(2) ;
    var VarFactorTR = 5/100 ;
    var VarFactorNTR = 5/100 ;
    var TravTimeVarTR =
        Math.round(VarFactorTR*PeakFactorTR*TravTimeTR
        );
    var TravTimeVarNTR =
        Math.round(VarFactorNTR*PeakFactorNTR*TravTime
        NTR);
    var MinTravTimeTR = TravTimeTR - TravTimeVarTR ;
    var MaxTravTimeTR = TravTimeTR + TravTimeVarTR ;
    var MinTravTimeNTR = TravTimeNTR -
        TravTimeVarNTR;

```

```

var MaxTravTimeNTR = TravTimeNTR + `
    TravTimeVarNTR;
var MinSpeedTR = (TripDist/MaxTravTimeTR)*60 ;
var MaxSpeedTR = (TripDist/MinTravTimeTR)*60 ;
if (MaxSpeedTR > 85)
{
    var MaxSpeedTR = 85 ;
    var MinTravTimeTR = (TripDist/MaxSpeedTR)*60 ;
}
var MinSpeedNTR = (TripDist/MaxTravTimeNTR)*60 ;
var MaxSpeedNTR = (TripDist/MinTravTimeNTR)*60 ;
if (MaxSpeedNTR > 75)
{
    var MaxSpeedNTR = 75 ;
    var MinTravTimeNTR =
        (TripDist/MaxSpeedNTR)*60;
}
break;

case 8:
    var SpeedTR = 70;
    var SpeedNTR = 45;
    var TravTimeTR = Math.round((TripDist * 60) /
        (SpeedTR / PeakFactorTR));
    if (TravTimeTR > 60)
    {
        var TravTimeTR = 60;
    }
    var TravTimeNTR = Math.round((TripDist * 60) /
        (SpeedNTR / PeakFactorNTR));
    if (TravTimeNTR > 60)
    {
        var TravTimeNTR = 60;
    }
    var TollRate = 5 ;
    var TotToll = (Math.round((TollRate *
        TripDist)/5)/20).toFixed(2) ;
    var VarFactorTR = 10/100 ;
    var VarFactorNTR = 5/100 ;
    var TravTimeVarTR =
        Math.round(VarFactorTR*PeakFactorTR*TravTimeTR
        );

```



```

    var TravTimeVarNTR =
        Math.round(VarFactorNTR*PeakFactorNTR*TravTime
            NTR);
    var MinTravTimeTR = TravTimeTR - TravTimeVarTR ;
    var MaxTravTimeTR = TravTimeTR + TravTimeVarTR ;
    var MinTravTimeNTR = TravTimeNTR -
        TravTimeVarNTR;
    var MaxTravTimeNTR = TravTimeNTR +
        TravTimeVarNTR;
    var MinSpeedTR = (TripDist/MaxTravTimeTR)*60 ;
    var MaxSpeedTR = (TripDist/MinTravTimeTR)*60 ;
    if (MaxSpeedTR > 85)
        {
            var MaxSpeedTR = 85 ;
            var MinTravTimeTR = (TripDist/MaxSpeedTR)*60 ;
        }
    var MinSpeedNTR = (TripDist/MaxTravTimeNTR)*60 ;
    var MaxSpeedNTR = (TripDist/MinTravTimeNTR)*60 ;
    if (MaxSpeedNTR > 75)
        {
            var MaxSpeedNTR = 75 ;
            var MinTravTimeNTR =
                (TripDist/MaxSpeedNTR)*60;
        }
    break;

    default:
        alert ("Default");
    }

}
else
{
    // Method 2 - adaptive random.
    document.getElementById('answer22858X38X102511').value =
        2;
    // Randomly assign TR/NTR speeds within range.
    var SpeedTR = 60 + Math.floor(Math.random()*11);
    var SpeedNTR = 45 + Math.floor(Math.random()*11);
    var TravTimeTR = Math.round((TripDist * 60) / (SpeedTR /
        PeakFactorTR));
    if (TravTimeTR > 60)
        {
            var TravTimeTR = 60;

```

```

    }
    var TravTimeNTR = Math.round((TripDist * 60) / (SpeedNTR
    / PeakFactorNTR));
    if (TravTimeNTR > 60)
    {
        var TravTimeNTR = 60;
    }
    // Randomly assign toll rate within range.
    var TollRate = 10 + (Math.floor(Math.random()*11)) ;
    var TotToll = (Math.round((TollRate *
    TripDist)/5)/20).toFixed(2) ;
    // Randomly assign variability factors within range.
    var VarFactorTR = (Math.floor(Math.random()*11))/100 ;
    var VarFactorNTR = (5 +
    Math.floor(Math.random()*11))/100 ;
    var TravTimeVarTR =
    Math.round(VarFactorTR*PeakFactorTR*TravTimeTR) ;
    var TravTimeVarNTR =
    Math.round(VarFactorNTR*PeakFactorNTR*TravTimeNTR) ;
    // Calculate trip characteristics from attributes.
    var MinTravTimeTR = TravTimeTR - TravTimeVarTR ;
    var MaxTravTimeTR = TravTimeTR + TravTimeVarTR ;
    var MinTravTimeNTR = TravTimeNTR - TravTimeVarNTR ;
    var MaxTravTimeNTR = TravTimeNTR + TravTimeVarNTR ;
    // Check if average trip speeds are reasonable. Correct
    if not.
    var MinSpeedTR = (TripDist/MaxTravTimeTR)*60 ;
    var MaxSpeedTR = (TripDist/MinTravTimeTR)*60 ;
    if (MaxSpeedTR > 85)
    {
        var MaxSpeedTR = 85 ;
        var MinTravTimeTR = (TripDist/MaxSpeedTR)*60 ;
    }
    var MinSpeedNTR = (TripDist/MaxTravTimeNTR)*60 ;
    var MaxSpeedNTR = (TripDist/MinTravTimeNTR)*60 ;
    if (MaxSpeedNTR > 75)
    {
        var MaxSpeedNTR = 75 ;
        var MinTravTimeNTR = (TripDist/MaxSpeedNTR)*60 ;
    }
}

//Determine which pictures will be displayed.
//For Toll Road:

```

```

if (SpeedTR >= 65)
  { //Light traffic
  var picturerefTR = 1;
  }
else if (SpeedTR < 65 && SpeedTR > 50 )
  { //Medium heavy traffic
  var picturerefTR = 2;
  }
else
  { //Heavy traffic
  var picturerefTR = 3;
  }

//For Non-Toll Road:
if (SpeedNTR >= 65)
  {
  //Light traffic
  var picturerefNTR = 1;
  }
else if (SpeedNTR < 65 && SpeedNTR > 50 )
  {
  //Medium heavy traffic
  var picturerefNTR = 2;
  }
else
  {
  //Heavy traffic
  var picturerefNTR = 3;
  }

// Store SPQ 1 variables in LimeSurvey.
document.getElementById('answer22858X38X102513').value =
  SpeedTR ;
document.getElementById('answer22858X38X102514').value =
  SpeedNTR ;
document.getElementById('answer22858X38X102515').value =
  TravTimeTR ;
document.getElementById('answer22858X38X102516').value =
  TravTimeNTR ;
document.getElementById('answer22858X38X102517').value =
  TollRate ;
document.getElementById('answer22858X38X102518').value =
  TotToll ;

```

```
document.getElementById('answer22858X38X102519').value =
    VarFactorTR ;
document.getElementById('answer22858X38X102520').value =
    VarFactorNTR ;
document.getElementById('answer22858X38X102521').value =
    TravTimeVarTR ;
document.getElementById('answer22858X38X102522').value =
    TravTimeVarNTR ;
document.getElementById('answer22858X38X102523').value =
    MaxTravTimeTR ;
document.getElementById('answer22858X38X102524').value =
    MinTravTimeTR ;
document.getElementById('answer22858X38X102525').value =
    MaxTravTimeNTR ;
document.getElementById('answer22858X38X102526').value =
    MinTravTimeNTR ;
document.getElementById('answer22858X38X102531').value =
    picturerefTR ;
document.getElementById('answer22858X38X102532').value =
    picturerefNTR ;
```

SPQ #2:

```
// Get values from question set 1
// TimeOfDay (in words)
document.getElementById('answer22858X74X16052').value =
    "{INSERTANS:22858X38X10252}";
// Pictures (y=1, n=2)
document.getElementById('answer22858X74X160510').value =
    "{INSERTANS:22858X38X102510}";
// Attribute selection (d-eff=1, RA=2)
document.getElementById('answer22858X74X160511').value =
    "{INSERTANS:22858X38X102511}";
// D-eff Case No. (1 through 8)
document.getElementById('answer22858X74X160512').value =
    "{INSERTANS:22858X38X102512}";

// Variables imported from previous SPQ.
var TimeOfDay = Number("{INSERTANS:22858X38X10251}") ;
var PeakFactorTR = Number("{INSERTANS:22858X38X10253}") ;
var PeakFactorNTR = Number("{INSERTANS:22858X38X10254}") ;
var TripDist = Number("{INSERTANS:22858X38X10259}") ;
var Block = Number("{INSERTANS:22858X38X102512}") ;
var TollRate1 = Number("{INSERTANS:22858X38X102517}") ;

//Set Tolls and Travel Times by the same method as SPQ1.
if ("{INSERTANS:22858X38X102511}" == 1)
{
    //D-Efficeint
    switch (Block)
    {
        // See explanatory comments for d-efficient attribute
        // distribution in SPQ 1 for more information.
        case 1:
            var SpeedTR2 = 70;
            var SpeedNTR2 = 45;
            var TravTimeTR2 = Math.round((TripDist * 60) /
                (SpeedTR2 / PeakFactorTR));
            if (TravTimeTR2 > 60)
            {
                var TravTimeTR2 = 60;
            }
            var TravTimeNTR2 = Math.round((TripDist * 60) /
                (SpeedNTR2 / PeakFactorNTR));
            if (TravTimeNTR2 > 60)
```

```

        {
            var TravTimeNTR2 = 60;
        }
    var TollRate2 = 15 ;
    var TotToll2 = (Math.round((TollRate2 *
        TripDist)/5)/20).toFixed(2) ;
    var VarFactorTR2 = 5/100 ;
    var VarFactorNTR2 = 15/100 ;
    var TravTimeVarTR2 =
        Math.round((VarFactorTR2*PeakFactorTR*TravTimeTR2
            )/2) ;
    var TravTimeVarNTR2 =
        Math.round((VarFactorNTR2*PeakFactorNTR*TravTimeN
            TR2)/2) ;
    var MinTravTimeTR2 = TravTimeTR2 - TravTimeVarTR2 ;
    var MaxTravTimeTR2 = TravTimeTR2 + TravTimeVarTR2 ;
    var MinTravTimeNTR2 = TravTimeNTR2 -
        TravTimeVarNTR2 ;
    var MaxTravTimeNTR2 = TravTimeNTR2 +
        TravTimeVarNTR2 ;
    var MinSpeedTR2 = (TripDist/MaxTravTimeTR2)*60 ;
    var MaxSpeedTR2 = (TripDist/MinTravTimeTR2)*60 ;
    if (MaxSpeedTR2 > 85)
    {
        var MaxSpeedTR2 = 85 ;
        var MinTravTimeTR2 = (TripDist/MaxSpeedTR2)*60 ;
    }
    var MinSpeedNTR2 = (TripDist/MaxTravTimeNTR2)*60 ;
    var MaxSpeedNTR2 = (TripDist/MinTravTimeNTR2)*60 ;
    if (MaxSpeedNTR2 > 75)
    {
        var MaxSpeedNTR2 = 75 ;
        var MinTravTimeNTR2 = (TripDist/MaxSpeedNTR2)*60;
    }
    break;

case 2:
    var SpeedTR2 = 65;
    var SpeedNTR2 = 55;
    var TravTimeTR2 = Math.round((TripDist * 60) /
        (SpeedTR2 / PeakFactorTR));
    if (TravTimeTR2 > 60)
    {
        var TravTimeTR2 = 60;
    }

```

```

    }
    var TravTimeNTR2 = Math.round((TripDist * 60) /
        (SpeedNTR2 / PeakFactorNTR));
    if (TravTimeNTR2 > 60)
    {
        var TravTimeNTR2 = 60;
    }
    var TollRate2 = 15 ;
    var TotToll2 = (Math.round((TollRate2 *
        TripDist)/5)/20).toFixed(2) ;
    var VarFactorTR2 = 0/100 ;
    var VarFactorNTR2 = 10/100 ;
    var TravTimeVarTR2 =
        Math.round((VarFactorTR2*PeakFactorTR*TravTimeTR2
            )/2);
    var TravTimeVarNTR2 =
        Math.round((VarFactorNTR2*PeakFactorNTR*TravTimeN
            TR2)/2);
    var MinTravTimeTR2 = TravTimeTR2 - TravTimeVarTR2 ;
    var MaxTravTimeTR2 = TravTimeTR2 + TravTimeVarTR2 ;
    var MinTravTimeNTR2 = TravTimeNTR2 -
        TravTimeVarNTR2 ;
    var MaxTravTimeNTR2 = TravTimeNTR2 +
        TravTimeVarNTR2 ;
    var MinSpeedTR2 = (TripDist/MaxTravTimeTR2)*60 ;
    var MaxSpeedTR2 = (TripDist/MinTravTimeTR2)*60 ;
    if (MaxSpeedTR2 > 85)
    {
        var MaxSpeedTR2 = 85 ;
        var MinTravTimeTR2 = (TripDist/MaxSpeedTR2)*60 ;
    }
    var MinSpeedNTR2 = (TripDist/MaxTravTimeNTR2)*60 ;
    var MaxSpeedNTR2 = (TripDist/MinTravTimeNTR2)*60 ;
    if (MaxSpeedNTR2 > 75)
    {
        var MaxSpeedNTR2 = 75 ;
        var MinTravTimeNTR2 = (TripDist/MaxSpeedNTR2)*60;
    }
    break;

case 3:
    var SpeedTR2 = 60;
    var SpeedNTR2 = 45;

```

```

var TravTimeTR2 = Math.round((TripDist * 60) /
    (SpeedTR2 / PeakFactorTR));
if (TravTimeTR2 > 60)
    {
    var TravTimeTR2 = 60;
    }
var TravTimeNTR2 = Math.round((TripDist * 60) /
    (SpeedNTR2 / PeakFactorNTR));
if (TravTimeNTR2 > 60)
    {
    var TravTimeNTR2 = 60;
    }
var TollRate2 = 10 ;
var TotToll2 = (Math.round((TollRate2 *
    TripDist)/5)/20).toFixed(2) ;
var VarFactorTR2 = 5/100 ;
var VarFactorNTR2 = 10/100 ;
var TravTimeVarTR2 =
    Math.round((VarFactorTR2*PeakFactorTR*TravTimeTR2
    )/2) ;
var TravTimeVarNTR2 =
    Math.round((VarFactorNTR2*PeakFactorNTR*TravTimeN
    TR2)/2) ;
var MinTravTimeTR2 = TravTimeTR2 - TravTimeVarTR2 ;
var MaxTravTimeTR2 = TravTimeTR2 + TravTimeVarTR2 ;
var MinTravTimeNTR2 = TravTimeNTR2 -
    TravTimeVarNTR2 ;
var MaxTravTimeNTR2 = TravTimeNTR2 +
    TravTimeVarNTR2 ;
var MinSpeedTR2 = (TripDist/MaxTravTimeTR2)*60 ;
var MaxSpeedTR2 = (TripDist/MinTravTimeTR2)*60 ;
if (MaxSpeedTR2 > 85)
    {
    var MaxSpeedTR2 = 85 ;
    var MinTravTimeTR2 = (TripDist/MaxSpeedTR2)*60 ;
    }
var MinSpeedNTR2 = (TripDist/MaxTravTimeNTR2)*60 ;
var MaxSpeedNTR2 = (TripDist/MinTravTimeNTR2)*60 ;
if (MaxSpeedNTR2 > 75)
    {
    var MaxSpeedNTR2 = 75 ;
    var MinTravTimeNTR2 = (TripDist/MaxSpeedNTR2)*60;
    }
break;

```



```

case 4:
  var SpeedTR2 = 65;
  var SpeedNTR2 = 50;
  var TravTimeTR2 = Math.round((TripDist * 60) /
    (SpeedTR2 / PeakFactorTR));
  if (TravTimeTR2 > 60)
  {
    var TravTimeTR2 = 60;
  }
  var TravTimeNTR2 = Math.round((TripDist * 60) /
    (SpeedNTR2 / PeakFactorNTR));
  if (TravTimeNTR2 > 60)
  {
    var TravTimeNTR2 = 60;
  }
  var TollRate2 = 10 ;
  var TotToll2 = (Math.round((TollRate2 *
    TripDist)/5)/20).toFixed(2) ;
  var VarFactorTR2 = 0/100 ;
  var VarFactorNTR2 = 15/100 ;
  var TravTimeVarTR2 =
    Math.round((VarFactorTR2*PeakFactorTR*TravTimeTR2
    )/2) ;
  var TravTimeVarNTR2 =
    Math.round((VarFactorNTR2*PeakFactorNTR*TravTimeN
    TR2)/2) ;
  var MinTravTimeTR2 = TravTimeTR2 - TravTimeVarTR2 ;
  var MaxTravTimeTR2 = TravTimeTR2 + TravTimeVarTR2 ;
  var MinTravTimeNTR2 = TravTimeNTR2 -
    TravTimeVarNTR2 ;
  var MaxTravTimeNTR2 = TravTimeNTR2 +
    TravTimeVarNTR2 ;
  var MinSpeedTR2 = (TripDist/MaxTravTimeTR2)*60 ;
  var MaxSpeedTR2 = (TripDist/MinTravTimeTR2)*60 ;
  if (MaxSpeedTR2 > 85)
  {
    var MaxSpeedTR2 = 85 ;
    var MinTravTimeTR2 = (TripDist/MaxSpeedTR2)*60 ;
  }
  var MinSpeedNTR2 = (TripDist/MaxTravTimeNTR2)*60 ;
  var MaxSpeedNTR2 = (TripDist/MinTravTimeNTR2)*60 ;
  if (MaxSpeedNTR2 > 75)
  {

```

```

    var MaxSpeedNTR2 = 75 ;
    var MinTravTimeNTR2 = (TripDist/MaxSpeedNTR2)*60 ;
    }
break;

case 5:
    var SpeedTR2 = 65;
    var SpeedNTR2 = 55;
    var TravTimeTR2 = Math.round((TripDist * 60) /
        (SpeedTR2 / PeakFactorTR));
    if (TravTimeTR2 > 60)
    {
        var TravTimeTR2 = 60;
    }
    var TravTimeNTR2 = Math.round((TripDist * 60) /
        (SpeedNTR2 / PeakFactorNTR));
    if (TravTimeNTR2 > 60)
    {
        var TravTimeNTR2 = 60;
    }
    var TollRate2 = 15 ;
    var TotToll2 = (Math.round((TollRate2 *
        TripDist)/5)/20).toFixed(2) ;
    var VarFactorTR2 = 10/100 ;
    var VarFactorNTR2 = 5/100 ;
    var TravTimeVarTR2 =
        Math.round((VarFactorTR2*PeakFactorTR*TravTimeTR2
            )/2) ;
    var TravTimeVarNTR2 =
        Math.round((VarFactorNTR2*PeakFactorNTR*TravTimeN
            TR2)/2) ;
    var MinTravTimeTR2 = TravTimeTR2 - TravTimeVarTR2 ;
    var MaxTravTimeTR2 = TravTimeTR2 + TravTimeVarTR2 ;
    var MinTravTimeNTR2 = TravTimeNTR2 -
        TravTimeVarNTR2 ;
    var MaxTravTimeNTR2 = TravTimeNTR2 +
        TravTimeVarNTR2 ;
    var MinSpeedTR2 = (TripDist/MaxTravTimeTR2)*60 ;
    var MaxSpeedTR2 = (TripDist/MinTravTimeTR2)*60 ;
    if (MaxSpeedTR2 > 85)
    {
        var MaxSpeedTR2 = 85 ;
        var MinTravTimeTR2 = (TripDist/MaxSpeedTR2)*60 ;
    }

```

```

var MinSpeedNTR2 = (TripDist/MaxTravTimeNTR2)*60 ;
var MaxSpeedNTR2 = (TripDist/MinTravTimeNTR2)*60 ;
if (MaxSpeedNTR2 > 75)
{
var MaxSpeedNTR2 = 75 ;
var MinTravTimeNTR2 = (TripDist/MaxSpeedNTR2)*60;
}
break;

case 6:
var SpeedTR2 = 60;
var SpeedNTR2 = 55;
var TravTimeTR2 = Math.round((TripDist * 60) /
(SpeedTR2 / PeakFactorTR));
if (TravTimeTR2 > 60)
{
var TravTimeTR2 = 60;
}
var TravTimeNTR2 = Math.round((TripDist * 60) /
(SpeedNTR2 / PeakFactorNTR));
if (TravTimeNTR2 > 60)
{
var TravTimeNTR2 = 60;
}
var TollRate2 = 15 ;
var TotToll2 = (Math.round((TollRate2 *
TripDist)/5)/20).toFixed(2) ;
var VarFactorTR2 = 0/100 ;
var VarFactorNTR2 = 15/100 ;
var TravTimeVarTR2 =
Math.round((VarFactorTR2*PeakFactorTR*TravTimeTR2
)/2) ;
var TravTimeVarNTR2 =
Math.round((VarFactorNTR2*PeakFactorNTR*TravTimeN
TR2)/2) ;
var MinTravTimeTR2 = TravTimeTR2 - TravTimeVarTR2 ;
var MaxTravTimeTR2 = TravTimeTR2 + TravTimeVarTR2 ;
var MinTravTimeNTR2 = TravTimeNTR2 -
TravTimeVarNTR2 ;
var MaxTravTimeNTR2 = TravTimeNTR2 +
TravTimeVarNTR2 ;
var MinSpeedTR2 = (TripDist/MaxTravTimeTR2)*60 ;
var MaxSpeedTR2 = (TripDist/MinTravTimeTR2)*60 ;
if (MaxSpeedTR2 > 85)

```

```

        {
            var MaxSpeedTR2 = 85 ;
            var MinTravTimeTR2 = (TripDist/MaxSpeedTR2)*60 ;
        }
        var MinSpeedNTR2 = (TripDist/MaxTravTimeNTR2)*60 ;
        var MaxSpeedNTR2 = (TripDist/MinTravTimeNTR2)*60 ;
        if (MaxSpeedNTR2 > 75)
        {
            var MaxSpeedNTR2 = 75 ;
            var MinTravTimeNTR2 = (TripDist/MaxSpeedNTR2)*60;
        }
    break;

case 7:
    var SpeedTR2 = 60;
    var SpeedNTR2 = 45;
    var TravTimeTR2 = Math.round((TripDist * 60) /
        (SpeedTR2 / PeakFactorTR));
    if (TravTimeTR2 > 60)
    {
        var TravTimeTR2 = 60;
    }
    var TravTimeNTR2 = Math.round((TripDist * 60) /
        (SpeedNTR2 / PeakFactorNTR));
    if (TravTimeNTR2 > 60)
    {
        var TravTimeNTR2 = 60;
    }
    var TollRate2 = 5 ;
    var TotToll2 = (Math.round((TollRate2 *
        TripDist)/5)/20).toFixed(2) ;
    var VarFactorTR2 = 10/100 ;
    var VarFactorNTR2 = 15/100 ;
    var TravTimeVarTR2 =
        Math.round((VarFactorTR2*PeakFactorTR*TravTimeTR2
        )/2) ;
    var TravTimeVarNTR2 =
        Math.round((VarFactorNTR2*PeakFactorNTR*TravTimeN
        TR2)/2) ;
    var MinTravTimeTR2 = TravTimeTR2 - TravTimeVarTR2 ;
    var MaxTravTimeTR2 = TravTimeTR2 + TravTimeVarTR2 ;
    var MinTravTimeNTR2 = TravTimeNTR2 -
        TravTimeVarNTR2 ;

```

```

var MaxTravTimeNTR2 = TravTimeNTR2 +
    TravTimeVarNTR2 ;
var MinSpeedTR2 = (TripDist/MaxTravTimeTR2)*60 ;
var MaxSpeedTR2 = (TripDist/MinTravTimeTR2)*60 ;
if (MaxSpeedTR2 > 85)
    {
    var MaxSpeedTR2 = 85 ;
    var MinTravTimeTR2 = (TripDist/MaxSpeedTR2)*60 ;
    }
var MinSpeedNTR2 = (TripDist/MaxTravTimeNTR2)*60 ;
var MaxSpeedNTR2 = (TripDist/MinTravTimeNTR2)*60 ;
if (MaxSpeedNTR2 > 75)
    {
    var MaxSpeedNTR2 = 75 ;
    var MinTravTimeNTR2 = (TripDist/MaxSpeedNTR2)*60;
    }
break;

case 8:
    var SpeedTR2 = 70;
    var SpeedNTR2 = 55;
    var TravTimeTR2 = Math.round((TripDist * 60) /
        (SpeedTR2 / PeakFactorTR));
    if (TravTimeTR2 > 60)
        {
        var TravTimeTR2 = 60;
        }
    var TravTimeNTR2 = Math.round((TripDist * 60) /
        (SpeedNTR2 / PeakFactorNTR));
    if (TravTimeNTR2 > 60)
        {
        var TravTimeNTR2 = 60;
        }
    var TollRate2 = 15 ;
    var TotToll2 = (Math.round((TollRate2 *
        TripDist)/5)/20).toFixed(2) ;
    var VarFactorTR2 = 5/100 ;
    var VarFactorNTR2 = 15/100 ;
    var TravTimeVarTR2 =
        Math.round((VarFactorTR2*PeakFactorTR*TravTimeTR2
            )/2) ;
    var TravTimeVarNTR2 =
        Math.round((VarFactorNTR2*PeakFactorNTR*TravTimeN
            TR2)/2) ;

```

```

var MinTravTimeTR2 = TravTimeTR2 - TravTimeVarTR2 ;
var MaxTravTimeTR2 = TravTimeTR2 + TravTimeVarTR2 ;
var MinTravTimeNTR2 = TravTimeNTR2 -
    TravTimeVarNTR2 ;
var MaxTravTimeNTR2 = TravTimeNTR2 +
    TravTimeVarNTR2 ;
var MinSpeedTR2 = (TripDist/MaxTravTimeTR2)*60 ;
var MaxSpeedTR2 = (TripDist/MinTravTimeTR2)*60 ;
if (MaxSpeedTR2 > 85)
    {
    var MaxSpeedTR2 = 85 ;
    var MinTravTimeTR2 = (TripDist/MaxSpeedTR2)*60 ;
    }
var MinSpeedNTR2 = (TripDist/MaxTravTimeNTR2)*60 ;
var MaxSpeedNTR2 = (TripDist/MinTravTimeNTR2)*60 ;
if (MaxSpeedNTR2 > 75)
    {
    var MaxSpeedNTR2 = 75 ;
    var MinTravTimeNTR2 = (TripDist/MaxSpeedNTR2)*60;
    }
break;

default:
    alert ("Default");
}
}

else if ("{INSERTANS:22858X38X102511}" == 2)
{
// Random adjusting
var SP1Ans = "{INSERTANS:22858X78X1720}";
// Determine if toll option was selected in SPQ1
var SP1AnsA = SP1Ans.search("Toll:");
// If toll option was not selected, adjust toll rate
down by 35 to 70 percent.
if (SP1AnsA == -1 || SP1AnsA == "")
{
var randomNumberTfact =
    (35+Math.round(Math.random()*35))/100;
var TollRate2 = TollRate1*randomNumberTfact ;
document.getElementById('answer22858X74X160527').value
    = "downward" ;
}
}
else

```

```

{
// Toll road was selected, adjust toll rate up by 30
  to 90 percent.
var randomNumberTfact =
  (130+Math.round(Math.random()*60))/100;
var TollRate2 = TollRate1*randomNumberTfact ;
document.getElementById('answer22858X74X160527').value
  = "upward" ;
}
// Check to make sure toll rate is between 10 and 55
cents per mile after adjustment. Correct if not.
if (TollRate2 > 55)
  {
  var TollRate2 = 55;
  }
else if (TollRate2 < 10)
  {
  var TollRate2 = 10;
  }
// Randomly assign new speeds for toll/non-toll roads
and check for reasonableness of new trip speeds.
var SpeedTR2 = 60 + Math.floor(Math.random()*11);
var SpeedNTR2 = 45 + Math.floor(Math.random()*11);
var TravTimeTR2 = Math.round((TripDist * 60) / (SpeedTR2
  / PeakFactorTR));
if (TravTimeTR2 > 60)
  {
  var TravTimeTR2 = 60;
  }
var TravTimeNTR2 = Math.round((TripDist * 60) /
  (SpeedNTR2 / PeakFactorNTR));
if (TravTimeNTR2 > 60)
  {
  var TravTimeNTR2 = 60;
  }
var TotToll2 = (Math.round((TollRate2 *
  TripDist)/5)/20).toFixed(2) ;
var VarFactorTR2 = (Math.floor(Math.random()*11))/100 ;
var VarFactorNTR2 = (5 +
  Math.floor(Math.random()*11))/100 ;
var TravTimeVarTR2 =
  Math.round(VarFactorTR2*PeakFactorTR*TravTimeTR2) ;
var TravTimeVarNTR2 =
  Math.round(VarFactorNTR2*PeakFactorNTR*TravTimeNTR2) ;

```

```

var MinTravTimeTR2 = TravTimeTR2 - TravTimeVarTR2 ;
var MaxTravTimeTR2 = TravTimeTR2 + TravTimeVarTR2 ;
if (MaxTravTimeTR2 > 60)
{
    var MaxTravTimeTR2 = 60 ;
}
var MinTravTimeNTR2 = TravTimeNTR2 - TravTimeVarNTR2 ;
var MaxTravTimeNTR2 = TravTimeNTR2 + TravTimeVarNTR2 ;
var MinSpeedTR2 = (TripDist/MaxTravTimeTR2)*60 ;
var MaxSpeedTR2 = (TripDist/MinTravTimeTR2)*60 ;
var MinSpeedNTR2 = (TripDist/MaxTravTimeNTR2)*60 ;
var MaxSpeedNTR2 = (TripDist/MinTravTimeNTR2)*60 ;
if (MaxSpeedNTR2 > 75)
{
    var MaxSpeedNTR2 = 75 ;
    var MinTravTimeNTR2 = (TripDist/MaxSpeedNTR2)*60 ;
}
}

// Determine which pictures will be displayed.
// For toll road:
if (SpeedTR2 > 65)
{ //Light traffic
    var picturerefTR2 = 1;
}
else if (SpeedTR2 <= 65 && SpeedTR2 > 55 )
{ //Medium heavy traffic
    var picturerefTR2 = 2;
}
else
{ //Heavy traffic
    var picturerefTR2 = 3;
}

// For non-toll road:
if (SpeedNTR2 > 65)
{ //Light traffic
    var picturerefNTR2 = 1;
}
else if (SpeedNTR2 <= 65 && SpeedNTR2 > 55 )
{ //Medium heavy traffic
    var picturerefNTR2 = 2;
}
else

```



```

    { //Heavy traffic
      var picturerefNTR2 = 3;
    }

// Store SPQ 2 variables in LimeSurvey.
document.getElementById('answer22858X74X160513').value =
  SpeedTR2 ;
document.getElementById('answer22858X74X160514').value =
  SpeedNTR2 ;
document.getElementById('answer22858X74X160515').value =
  TravTimeTR2 ;
document.getElementById('answer22858X74X160516').value =
  TravTimeNTR2 ;
document.getElementById('answer22858X74X160517').value =
  TollRate2 ;
document.getElementById('answer22858X74X160518').value =
  TotToll2 ;
document.getElementById('answer22858X74X160519').value =
  VarFactorTR2 ;
document.getElementById('answer22858X74X160520').value =
  VarFactorNTR2 ;
document.getElementById('answer22858X74X160521').value =
  TravTimeVarTR2 ;
document.getElementById('answer22858X74X160522').value =
  TravTimeVarNTR2 ;
document.getElementById('answer22858X74X160523').value =
  MaxTravTimeTR2 ;
document.getElementById('answer22858X74X160524').value =
  MinTravTimeTR2 ;
document.getElementById('answer22858X74X160525').value =
  MaxTravTimeNTR2 ;
document.getElementById('answer22858X74X160526').value =
  MinTravTimeNTR2 ;
document.getElementById('answer22858X74X160528').value =
  picturerefTR2 ;
document.getElementById('answer22858X74X160529').value =
  picturerefNTR2 ;

```

SPQ #3:

```
// Get values from question set 1
// TimeOfDay (in words)
document.getElementById('answer22858X76X16062').value =
    "{INSERTANS:22858X38X10252}" ;
// Pictures (y=1, n=2)
document.getElementById('answer22858X76X160610').value =
    "{INSERTANS:22858X38X102510}" ;
// Attribute selection (d-eff=1, RA=2)
document.getElementById('answer22858X76X160611').value =
    "{INSERTANS:22858X38X102511}" ;
// D-eff Case No. (1 through _)
document.getElementById('answer22858X76X160612').value =
    "{INSERTANS:22858X38X102512}" ;

// Variables
var TimeOfDay = Number("{INSERTANS:22858X38X10251}") ;
var PeakFactorTR = Number("{INSERTANS:22858X38X10253}") ;
var PeakFactorNTR = Number("{INSERTANS:22858X38X10254}") ;
var TripDist = Number("{INSERTANS:22858X38X10259}") ;
var Block = Number("{INSERTANS:22858X38X102512}") ;
var TollRate2 = Number("{INSERTANS:22858X74X160517}") ;

//Set Tolls and Travel Times
if ("{INSERTANS:22858X38X102511}" == 1)
{
    //D-Efficeint
    switch (Block)
    {
        // See explanatory comments for d-efficient attribute
        // distribution in SPQ 1 for more information.
        case 1:
            var SpeedTR3 = 70;
            var SpeedNTR3 = 55;
            var TravTimeTR3 = Math.round((TripDist * 60) /
                (SpeedTR3 / PeakFactorTR));
            if (TravTimeTR3 > 60)
            {
                var TravTimeTR3 = 60;
            }
            var TravTimeNTR3 = Math.round((TripDist * 60) /
                (SpeedNTR3 / PeakFactorNTR));
            if (TravTimeNTR3 > 60)
```

```

        {
            var TravTimeNTR3 = 60;
        }
    var TollRate3 = 5 ;
    var TotToll3 = (Math.round((TollRate3 *
        TripDist)/5)/20).toFixed(2) ;
    var VarFactorTR3 = 5/100 ;
    var VarFactorNTR3 = 10/100 ;
    var TravTimeVarTR3 =
        Math.round((VarFactorTR3*PeakFactorTR*TravTimeTR3
            )/2) ;
    var TravTimeVarNTR3 =
        Math.round((VarFactorNTR3*PeakFactorNTR*TravTimeN
            TR3)/2) ;
    var MinTravTimeTR3 = TravTimeTR3 - TravTimeVarTR3 ;
    var MaxTravTimeTR3 = TravTimeTR3 + TravTimeVarTR3 ;
    var MinTravTimeNTR3 = TravTimeNTR3 -
        TravTimeVarNTR3 ;
    var MaxTravTimeNTR3 = TravTimeNTR3 +
        TravTimeVarNTR3 ;
    var MinSpeedTR3 = (TripDist/MaxTravTimeTR3)*60 ;
    var MaxSpeedTR3 = (TripDist/MinTravTimeTR3)*60 ;
    if (MaxSpeedTR3 > 85)
    {
        var MaxSpeedTR3 = 85 ;
        var MinTravTimeTR3 = (TripDist/MaxSpeedTR3)*60 ;
    }
    var MinSpeedNTR3 = (TripDist/MaxTravTimeNTR3)*60 ;
    var MaxSpeedNTR3 = (TripDist/MinTravTimeNTR3)*60 ;
    if (MaxSpeedNTR3 > 75)
    {
        var MaxSpeedNTR3 = 75 ;
        var MinTravTimeNTR3 = (TripDist/MaxSpeedNTR3)*60;
    }
    break;

case 2:
    var SpeedTR3 = 70;
    var SpeedNTR3 = 45;
    var TravTimeTR3 = Math.round((TripDist * 60) /
        (SpeedTR3 / PeakFactorTR));
    if (TravTimeTR3 > 60)
    {
        var TravTimeTR3 = 60;
    }

```

```

}
var TravTimeNTR3 = Math.round((TripDist * 60) /
    (SpeedNTR3 / PeakFactorNTR));
if (TravTimeNTR3 > 60)
    {
    var TravTimeNTR3 = 60;
    }
var TollRate3 = 15 ;
var TotToll3 = (Math.round((TollRate3 *
    tripDist)/5)/20).toFixed(2) ;
var VarFactorTR3 = 0/100 ;
var VarFactorNTR3 = 15/100 ;
var TravTimeVarTR3 =
    Math.round((VarFactorTR3*PeakFactorTR*TravTimeTR3
    )/2) ;
var TravTimeVarNTR3 =
    Math.round((VarFactorNTR3*PeakFactorNTR*TravTimeN
    TR3)/2) ;
var MinTravTimeTR3 = TravTimeTR3 - TravTimeVarTR3 ;
var MaxTravTimeTR3 = TravTimeTR3 + TravTimeVarTR3 ;
var MinTravTimeNTR3 = TravTimeNTR3 -
    TravTimeVarNTR3 ;
var MaxTravTimeNTR3 = TravTimeNTR3 +
    TravTimeVarNTR3 ;
var MinSpeedTR3 = (TripDist/MaxTravTimeTR3)*60 ;
var MaxSpeedTR3 = (TripDist/MinTravTimeTR3)*60 ;
if (MaxSpeedTR3 > 85)
    {
    var MaxSpeedTR3 = 85 ;
    var MinTravTimeTR3 = (TripDist/MaxSpeedTR3)*60 ;
    }
var MinSpeedNTR3 = (TripDist/MaxTravTimeNTR3)*60 ;
var MaxSpeedNTR3 = (TripDist/MinTravTimeNTR3)*60 ;
if (MaxSpeedNTR3 > 75)
    {
    var MaxSpeedNTR3 = 75 ;
    var MinTravTimeNTR3 = (TripDist/MaxSpeedNTR3)*60;
    }
break;

case 3:
    var SpeedTR3 = 60;
    var SpeedNTR3 = 45;

```

```

var TravTimeTR3 = Math.round((TripDist * 60) /
    (SpeedTR3 / PeakFactorTR));
if (TravTimeTR3 > 60)
    {
    var TravTimeTR3 = 60;
    }
var TravTimeNTR3 = Math.round((TripDist * 60) /
    (SpeedNTR3 / PeakFactorNTR));
if (TravTimeNTR3 > 60)
    {
    var TravTimeNTR3 = 60;
    }
var TollRate3 = 10 ;
var TotToll3 = (Math.round((TollRate3 *
    TripDist)/5)/20).toFixed(2) ;
var VarFactorTR3 = 10/100 ;
var VarFactorNTR3 = 5/100 ;
var TravTimeVarTR3 =
    Math.round((VarFactorTR3*PeakFactorTR*TravTimeTR3
    )/2) ;
var TravTimeVarNTR3 =
    Math.round((VarFactorNTR3*PeakFactorNTR*TravTimeN
    TR3)/2) ;
var MinTravTimeTR3 = TravTimeTR3 - TravTimeVarTR3 ;
var MaxTravTimeTR3 = TravTimeTR3 + TravTimeVarTR3 ;
var MinTravTimeNTR3 = TravTimeNTR3 -
    TravTimeVarNTR3 ;
var MaxTravTimeNTR3 = TravTimeNTR3 +
    TravTimeVarNTR3 ;
var MinSpeedTR3 = (TripDist/MaxTravTimeTR3)*60 ;
var MaxSpeedTR3 = (TripDist/MinTravTimeTR3)*60 ;
if (MaxSpeedTR3 > 85)
    {
    var MaxSpeedTR3 = 85 ;
    var MinTravTimeTR3 = (TripDist/MaxSpeedTR3)*60 ;
    }
var MinSpeedNTR3 = (TripDist/MaxTravTimeNTR3)*60 ;
var MaxSpeedNTR3 = (TripDist/MinTravTimeNTR3)*60 ;
if (MaxSpeedNTR3 > 75)
    {
    var MaxSpeedNTR3 = 75 ;
    var MinTravTimeNTR3 = (TripDist/MaxSpeedNTR3)*60;
    }
break;

```

```

case 4:
  var SpeedTR3 = 60;
  var SpeedNTR3 = 50;
  var TravTimeTR3 = Math.round((TripDist * 60) /
    (SpeedTR3 / PeakFactorTR));
  if (TravTimeTR3 > 60)
  {
    var TravTimeTR3 = 60;
  }
  var TravTimeNTR3 = Math.round((TripDist * 60) /
    (SpeedNTR3 / PeakFactorNTR));
  if (TravTimeNTR3 > 60)
  {
    var TravTimeNTR3 = 60;
  }
  var TollRate3 = 10 ;
  var TotToll3 = (Math.round((TollRate3 *
    TripDist)/5)/20).toFixed(2) ;
  var VarFactorTR3 = 0/100 ;
  var VarFactorNTR3 = 15/100 ;
  var TravTimeVarTR3 =
    Math.round((VarFactorTR3*PeakFactorTR*TravTimeTR3
    )/2) ;
  var TravTimeVarNTR3 =
    Math.round((VarFactorNTR3*PeakFactorNTR*TravTimeN
    TR3)/2) ;
  var MinTravTimeTR3 = TravTimeTR3 - TravTimeVarTR3 ;
  var MaxTravTimeTR3 = TravTimeTR3 + TravTimeVarTR3 ;
  var MinTravTimeNTR3 = TravTimeNTR3 -
    TravTimeVarNTR3 ;
  var MaxTravTimeNTR3 = TravTimeNTR3 +
    TravTimeVarNTR3 ;
  var MinSpeedTR3 = (TripDist/MaxTravTimeTR3)*60 ;
  var MaxSpeedTR3 = (TripDist/MinTravTimeTR3)*60 ;
  if (MaxSpeedTR3 > 85)
  {
    var MaxSpeedTR3 = 85 ;
    var MinTravTimeTR3 = (TripDist/MaxSpeedTR3)*60 ;
  }
  var MinSpeedNTR3 = (TripDist/MaxTravTimeNTR3)*60 ;
  var MaxSpeedNTR3 = (TripDist/MinTravTimeNTR3)*60 ;
  if (MaxSpeedNTR3 > 75)
  {

```

```

        var MaxSpeedNTR3 = 75 ;
        var MinTravTimeNTR3 = (TripDist/MaxSpeedNTR3)*60;
    }
break;

case 5:
    var SpeedTR3 = 60;
    var SpeedNTR3 = 55;
    var TravTimeTR3 = Math.round((TripDist * 60) /
        (SpeedTR3 / PeakFactorTR));
    if (TravTimeTR3 > 60)
    {
        var TravTimeTR3 = 60;
    }
    var TravTimeNTR3 = Math.round((TripDist * 60) /
        (SpeedNTR3 / PeakFactorNTR));
    if (TravTimeNTR3 > 60)
    {
        var TravTimeNTR3 = 60;
    }
    var TollRate3 = 10 ;
    var TotToll3 = (Math.round((TollRate3 *
        TripDist)/5)/20).toFixed(2) ;
    var VarFactorTR3 = 5/100 ;
    var VarFactorNTR3 = 10/100 ;
    var TravTimeVarTR3 =
        Math.round((VarFactorTR3*PeakFactorTR*TravTimeTR3
        )/2) ;
    var TravTimeVarNTR3 =
        Math.round((VarFactorNTR3*PeakFactorNTR*TravTimeN
        TR3)/2) ;
    var MinTravTimeTR3 = TravTimeTR3 - TravTimeVarTR3 ;
    var MaxTravTimeTR3 = TravTimeTR3 + TravTimeVarTR3 ;
    var MinTravTimeNTR3 = TravTimeNTR3 -
        TravTimeVarNTR3 ;
    var MaxTravTimeNTR3 = TravTimeNTR3 +
        TravTimeVarNTR3 ;
    var MinSpeedTR3 = (TripDist/MaxTravTimeTR3)*60 ;
    var MaxSpeedTR3 = (TripDist/MinTravTimeTR3)*60 ;
    if (MaxSpeedTR3 > 85)
    {
        var MaxSpeedTR3 = 85 ;
        var MinTravTimeTR3 = (TripDist/MaxSpeedTR3)*60 ;
    }

```

```

var MinSpeedNTR3 = (TripDist/MaxTravTimeNTR3)*60 ;
var MaxSpeedNTR3 = (TripDist/MinTravTimeNTR3)*60 ;
if (MaxSpeedNTR3 > 75)
{
var MaxSpeedNTR3 = 75 ;
var MinTravTimeNTR3 = (TripDist/MaxSpeedNTR3)*60;
}
break;

case 6:
var SpeedTR3 = 65;
var SpeedNTR3 = 45;
var TravTimeTR3 = Math.round((TripDist * 60) /
(SpeedTR3 / PeakFactorTR));
if (TravTimeTR3 > 60)
{
var TravTimeTR3 = 60;
}
var TravTimeNTR3 = Math.round((TripDist * 60) /
(SpeedNTR3 / PeakFactorNTR));
if (TravTimeNTR3 > 60)
{
var TravTimeNTR3 = 60;
}
var TollRate3 = 5 ;
var TotToll3 = (Math.round((TollRate3 *
TripDist)/5)/20).toFixed(2) ;
var VarFactorTR3 = 10/100 ;
var VarFactorNTR3 = 10/100 ;
var TravTimeVarTR3 =
Math.round((VarFactorTR3*PeakFactorTR*TravTimeTR3
)/2) ;
var TravTimeVarNTR3 =
Math.round((VarFactorNTR3*PeakFactorNTR*TravTimeN
TR3)/2) ;
var MinTravTimeTR3 = TravTimeTR3 - TravTimeVarTR3 ;
var MaxTravTimeTR3 = TravTimeTR3 + TravTimeVarTR3 ;
var MinTravTimeNTR3 = TravTimeNTR3 -
TravTimeVarNTR3 ;
var MaxTravTimeNTR3 = TravTimeNTR3 +
TravTimeVarNTR3 ;
var MinSpeedTR3 = (TripDist/MaxTravTimeTR3)*60 ;
var MaxSpeedTR3 = (TripDist/MinTravTimeTR3)*60 ;
if (MaxSpeedTR3 > 85)

```



```

    {
    var MaxSpeedTR3 = 85 ;
    var MinTravTimeTR3 = (TripDist/MaxSpeedTR3)*60 ;
    }
var MinSpeedNTR3 = (TripDist/MaxTravTimeNTR3)*60 ;
var MaxSpeedNTR3 = (TripDist/MinTravTimeNTR3)*60 ;
if (MaxSpeedNTR3 > 75)
    {
    var MaxSpeedNTR3 = 75 ;
    var MinTravTimeNTR3 = (TripDist/MaxSpeedNTR3)*60;
    }
break;

case 7:
var SpeedTR3 = 60;
var SpeedNTR3 = 50;
var TravTimeTR3 = Math.round((TripDist * 60) /
    (SpeedTR3 / PeakFactorTR));
if (TravTimeTR3 > 60)
    {
    var TravTimeTR3 = 60;
    }
var TravTimeNTR3 = Math.round((TripDist * 60) /
    (SpeedNTR3 / PeakFactorNTR));
if (TravTimeNTR3 > 60)
    {
    var TravTimeNTR3 = 60;
    }
var TollRate3 = 15 ;
var TotToll3 = (Math.round((TollRate3 *
    TripDist)/5)/20).toFixed(2) ;
var VarFactorTR3 = 5/100 ;
var VarFactorNTR3 = 10/100 ;
var TravTimeVarTR3 =
    Math.round((VarFactorTR3*PeakFactorTR*TravTimeTR3
    )/2) ;
var TravTimeVarNTR3 =
    Math.round((VarFactorNTR3*PeakFactorNTR*TravTimeN
    TR3)/2) ;
var MinTravTimeTR3 = TravTimeTR3 - TravTimeVarTR3 ;
var MaxTravTimeTR3 = TravTimeTR3 + TravTimeVarTR3 ;
var MinTravTimeNTR3 = TravTimeNTR3 -
    TravTimeVarNTR3 ;

```

```

var MaxTravTimeNTR3 = TravTimeNTR3 +
    TravTimeVarNTR3 ;
var MinSpeedTR3 = (TripDist/MaxTravTimeTR3)*60 ;
var MaxSpeedTR3 = (TripDist/MinTravTimeTR3)*60 ;
if (MaxSpeedTR3 > 85)
    {
    var MaxSpeedTR3 = 85 ;
    var MinTravTimeTR3 = (TripDist/MaxSpeedTR3)*60 ;
    }
var MinSpeedNTR3 = (TripDist/MaxTravTimeNTR3)*60 ;
var MaxSpeedNTR3 = (TripDist/MinTravTimeNTR3)*60 ;
if (MaxSpeedNTR3 > 75)
    {
    var MaxSpeedNTR3 = 75 ;
    var MinTravTimeNTR3 = (TripDist/MaxSpeedNTR3)*60;
    }
break;

case 8:
    var SpeedTR3 = 65;
    var SpeedNTR3 = 50;
    var TravTimeTR3 = Math.round((TripDist * 60) /
        (SpeedTR3 / PeakFactorTR));
    if (TravTimeTR3 > 60)
        {
        var TravTimeTR3 = 60;
        }
    var TravTimeNTR3 = Math.round((TripDist * 60) /
        (SpeedNTR3 / PeakFactorNTR));
    if (TravTimeNTR3 > 60)
        {
        var TravTimeNTR3 = 60;
        }
    var TollRate3 = 10 ;
    var TotToll3 = (Math.round((TollRate3 *
        TripDist)/5)/20).toFixed(2) ;
    var VarFactorTR3 = 0/100 ;
    var VarFactorNTR3 = 10/100 ;
    var TravTimeVarTR3 =
        Math.round((VarFactorTR3*PeakFactorTR*TravTimeTR3
            )/2) ;
    var TravTimeVarNTR3 =
        Math.round((VarFactorNTR3*PeakFactorNTR*TravTimeN
            TR3)/2) ;

```

```

var MinTravTimeTR3 = TravTimeTR3 - TravTimeVarTR3 ;
var MaxTravTimeTR3 = TravTimeTR3 + TravTimeVarTR3 ;
var MinTravTimeNTR3 = TravTimeNTR3 -
    TravTimeVarNTR3 ;
var MaxTravTimeNTR3 = TravTimeNTR3 +
    TravTimeVarNTR3 ;
var MinSpeedTR3 = (TripDist/MaxTravTimeTR3)*60 ;
var MaxSpeedTR3 = (TripDist/MinTravTimeTR3)*60 ;
if (MaxSpeedTR3 > 85)
    {
    var MaxSpeedTR3 = 85 ;
    var MinTravTimeTR3 = (TripDist/MaxSpeedTR3)*60 ;
    }
var MinSpeedNTR3 = (TripDist/MaxTravTimeNTR3)*60 ;
var MaxSpeedNTR3 = (TripDist/MinTravTimeNTR3)*60 ;
if (MaxSpeedNTR3 > 75)
    {
    var MaxSpeedNTR3 = 75 ;
    var MinTravTimeNTR3 = (TripDist/MaxSpeedNTR3)*60;
    }
break;

default:
    alert ("Default");
}
}

else if ("{"INSERTANS:22858X38X102511}" == 2)
{
// smart adjusting
var SP2Ans = "{"INSERTANS:22858X75X1607}";
// Determine if toll option was selected in SPQ 2.
var SP2AnsA = SP2Ans.search("Toll:");
// If toll option was not selected, adjust toll rate
down by 35 to 70 percent.
if (SP2AnsA == -1 || SP2AnsA == "")
{
var randomNumberTfact =
    (35+Math.round(Math.random()*35))/100;
var TollRate3 = TollRate2*randomNumberTfact ;
document.getElementById('answer22858X76X160627').value
    = "downward" ;
}
}
else

```

```

{
// Toll road was selected, adjust toll rate up by 30
  to 90 percent.
var randomNumberTfact =
  (130+Math.round(Math.random()*60))/100;
var TollRate3 = TollRate2*randomNumberTfact ;
document.getElementById('answer22858X76X160627').value
  = "upward" ;
}
// Check to make sure toll rate is between 10 and 55
cents per mile after adjustment. Correct if not.
if (TollRate3 > 55)
{
  var TollRate3 = 55;
}
else if (TollRate3 < 10)
{
  var TollRate3 = 10;
}
// Randomly assign new speeds for toll/non-toll roads
and check for reasonableness of new trip speeds.
var SpeedTR3 = 60 + Math.floor(Math.random()*11);
var SpeedNTR3 = 45 + Math.floor(Math.random()*11);
var TravTimeTR3 = Math.round((TripDist * 60) / (SpeedTR3
  / PeakFactorTR));
if (TravTimeTR3 > 60)
{
  var TravTimeTR3 = 60;
}
var TravTimeNTR3 = Math.round((TripDist * 60) /
  (SpeedNTR3 / PeakFactorNTR));
if (TravTimeNTR3 > 60)
{
  var TravTimeNTR3 = 60;
}
var TotToll3 = (Math.round((TollRate3 *
  TripDist)/5)/20).toFixed(2) ;
var VarFactorTR3 = (Math.floor(Math.random()*11))/100 ;
var VarFactorNTR3 = (5 +
  Math.floor(Math.random()*11))/100 ;
var TravTimeVarTR3 =
  Math.round((VarFactorTR3*PeakFactorTR*TravTimeTR3)/2);

```

```

var TravTimeVarNTR3 =
    Math.round((VarFactorNTR3*PeakFactorNTR*TravTimeNTR3)/
    2);
var MinTravTimeTR3 = TravTimeTR3 - TravTimeVarTR3 ;
var MaxTravTimeTR3 = TravTimeTR3 + TravTimeVarTR3 ;
var MinTravTimeNTR3 = TravTimeNTR3 - TravTimeVarNTR3 ;
var MaxTravTimeNTR3 = TravTimeNTR3 + TravTimeVarNTR3 ;
var MinSpeedTR3 = (TripDist/MaxTravTimeTR3)*60 ;
var MaxSpeedTR3 = (TripDist/MinTravTimeTR3)*60 ;
if (MaxSpeedTR3 > 85)
    {
    var MaxSpeedTR3 = 85 ;
    var MinTravTimeTR3 = (TripDist/MaxSpeedTR3)*60 ;
    }
var MinSpeedNTR3 = (TripDist/MaxTravTimeNTR3)*60 ;
var MaxSpeedNTR3 = (TripDist/MinTravTimeNTR3)*60 ;
if (MaxSpeedNTR3 > 75)
    {
    var MaxSpeedNTR3 = 75 ;
    var MinTravTimeNTR3 = (TripDist/MaxSpeedNTR3)*60 ;
    }
}

// Determine which pictures will be displayed.
// For toll road:
if (SpeedTR3 > 65)
    { //Light traffic
    var picturerefTR3 = 1;
    }
else if (SpeedTR3 <= 65 && SpeedTR3 > 55 )
    { //Medium heavy traffic
    var picturerefTR3 = 2;
    }
else
    { //Heavy traffic
    var picturerefTR3 = 3;
    }

// For non-toll road:
if (SpeedNTR3 > 65)
    { //Light traffic
    var picturerefNTR3 = 1;
    }
else if (SpeedNTR3 <= 65 && SpeedNTR3 > 55 )

```

```

    { //Medium heavy traffic
    var picturerefNTR3 = 2;
    }
else
    { //Heavy traffic
    var picturerefNTR3 = 3;
    }

// Store SPQ 3 variables in LimeSurvey.
document.getElementById('answer22858X76X160613').value =
    SpeedTR3 ;
document.getElementById('answer22858X76X160614').value =
    SpeedNTR3 ;
document.getElementById('answer22858X76X160615').value =
    TravTimeTR3 ;
document.getElementById('answer22858X76X160616').value =
    TravTimeNTR3 ;
document.getElementById('answer22858X76X160617').value =
    TollRate3 ;
document.getElementById('answer22858X76X160618').value =
    TotToll3 ;
document.getElementById('answer22858X76X160619').value =
    VarFactorTR3 ;
document.getElementById('answer22858X76X160620').value =
    VarFactorNTR3 ;
document.getElementById('answer22858X76X160621').value =
    TravTimeVarTR3 ;
document.getElementById('answer22858X76X160622').value =
    TravTimeVarNTR3 ;
document.getElementById('answer22858X76X160623').value =
    MaxTravTimeTR3 ;
document.getElementById('answer22858X76X160624').value =
    MinTravTimeTR3 ;
document.getElementById('answer22858X76X160625').value =
    MaxTravTimeNTR3 ;
document.getElementById('answer22858X76X160626').value =
    MinTravTimeNTR3 ;
document.getElementById('answer22858X76X160628').value =
    picturerefTR3 ;
document.getElementById('answer22858X76X160629').value =
    picturerefNTR3 ;

```

APPENDIX C

NGENE CODE

```
Design
;alts=gpl,ml
;rows=24
;block=8
;eff=(rppanel,d)
;rep=1000
;rdraws=halton(400)
;model:
U(ml)=c[-2.11]+tt[n,-0.05,0.3]*ttlvl_m[12.85,13.85,15] + toll[n,-
0.12,0.1]*tlvl[0.75,1.5,2.25] + var[n,-0.06,0.5]*var_minute_ml[0,0.42,0.83]/
U(gpl)=tt*ttlvl_g[16.36,18,20]+var*var_minute_gl[0.9,1.8,2.7]
$
```

APPENDIX D

NLOGIT CODE

Data parsing code:

```
?*** create variables from data
? Only VEHTYPE=1 (passenger car) in this data

create;

? convert trippurp to commute/rec/work categories
if(trippurp=1)commpurp=1;
if(trippurp=2)recpurp=1;
if(trippurp=3)workpurp=1;

? convert weekday to wkday & wkend categories
if(weekday=1|weekday=7)wkend=1;
if(weekday>1&weekday<7)wkday=1;

? convert TRUSAGE to binary variables
if(trusage=1)use_nev=1;
(else)use_nev=0;

If(trusage>2)use_freq=1;
(else)use_freq=0;

? convert TIMEREF to time of day categories
if(timeref=1|timeref=2)tod_peak=1;

? convert GENDER to binary variables
if(gender=1)gendM=1;

? convert HHINCOME to binary variables
if(1<=hhincome&hhincome<8)LowInc=1;
if(8<=hhincome&hhincome<10)HighInc=1;
```


Alternative Specific Constant-Only MNL model for all survey types:

```
NLOGIT; Lhs=DECISION,NALTS,MODE;
        Choices = NTR,TR;
        Model:U(NTR)= 0/
        U(TR)= NTR_TR$
calc;list;LLc=LogL-kreg$
```

Base model for all survey types:

```
RPLOGIT; Lhs=DECISION,NALTS,MODE;
        Choices = NTR,TR;
        Halton;
        Maxit=50;pts=500;pds=PDS;
        Fcn= c_tt(t),
             NTR_TR(t);
        ecm= (NTR,TR);
        Model:
        U(NTR)=0+c_tt*travtime+n_ttv*ttvar+n_wkday*wkday/
        U(TR)=NTR_TR+c_time*travtime+t_toll*tottoll+t_tod*tod_
             peak+t_work*workpurp+t_gender*gendM+t_inc*highinc
        ;
        checkdata;
crosstab$
calc;list;r2adjC=1-((LOGL-kreg)/LLc);LLmnl=LogL;kmnl=kreg$
```

Builds best model for parsed data (survey types with [or without] pictures):

```
RPLOGIT; Lhs=DECISION,NALTS,MODE;
        Choices = NTR,TR;
        Halton;
        Maxit=50;pts=500;pds=PDS;
        Fcn= c_tt(t),
             NTR_TR(t);
        ecm= (NTR,TR);
        Model:
        U(NTR)=0+c_tt*travtime+n_ttv*ttvar/
        U(TR)=NTR_TR+c_time*travtime+t_toll*tottoll
             +t_work*workpurp+t_inc*highinc;
        checkdata;

crosstab$
calc;list;r2adjC=1-((LOGL-kreg)/LLc);LLmnl=LogL;kmnl=kreg$
```