

8-1-2012

## Statistical Analysis Of A Vehicle Miles Traveled Fee For Nevada

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STATISTICAL ANALYSIS OF A VEHICLE MILES TRAVELED  
FEE FOR NEVADA

by

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Bachelor of Science in Civil Engineering  
Purdue University  
2010

A thesis submitted in partial fulfillment  
of the requirements for the

**Master of Science in Engineering**

**Department of Civil and Environmental Engineering  
Howard R. Hughes College of Engineering  
The Graduate College**

**University of Nevada, Las Vegas  
August 2012**



THE GRADUATE COLLEGE

We recommend the thesis prepared under our supervision by

**Andrew Nordland**

entitled

**Statistical Analysis of a Vehicle Miles Traveled Fee for Nevada**

be accepted in partial fulfillment of the requirements for the degree of

**Master of Science in Engineering**

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**August 2012**

## ABSTRACT

### **Statistical Analysis of a Vehicle Miles Traveled**

#### **Fee for Nevada**

by

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Increases in the number of electric, hybrid-electric, and other alternative fuel vehicles, combined with increasing vehicle fuel efficiency present problems with the ability of the fuel tax to collect sufficient revenue. A Vehicle Miles Traveled (VMT) Fee is being considered as an option to replace the existing fuel tax for the collection of revenue for road maintenance, reconstruction and expansion. This study provides an analysis about costs, preference of a potential billing cycle, level of comfort with a mileage collection device, potential changes in transit use, and the effectiveness of a VMT Fee for Nevada. Multinomial logit models are developed using stated preference data gathered through a survey questionnaire to study some of the important aspects associated with users' preferences and attitudes towards the VMT Fee. A monthly bill is recommended as a method of reducing initial costs and to allow for gradual implementation of the fee. A linear regression model is used to estimate household miles traveled based on the 2009 National Household Travel Survey Data. Two 'revenue neutral' fees are compared to determine how well they collect revenue and how equitable they are to the users. A 3.3 cent/mile fee was determined to be most effective for collecting revenue and was found to be equitably distributed amongst roadway users.

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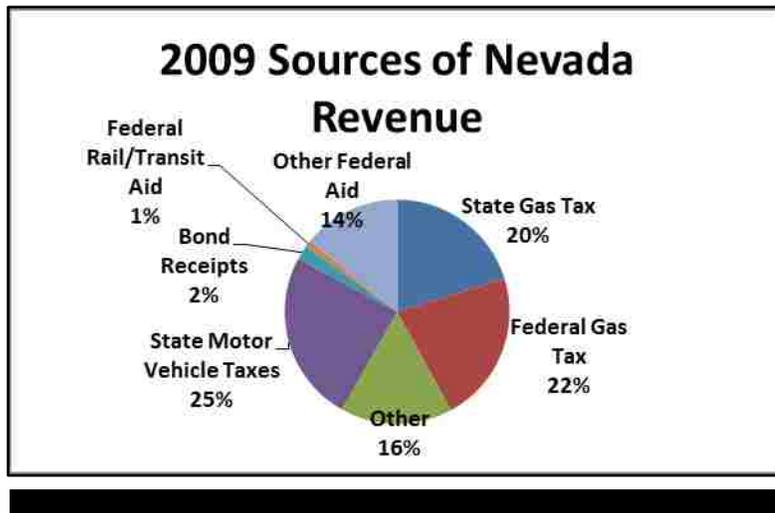
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## CHAPTER 1 PROBLEM STATEMENT

The main source of revenue for road maintenance and construction in Nevada is the state's fuel tax. Nevada introduced a tax of 2 cents/gallon in 1923; only four years after the first fuel tax of 1 cent/gallon was introduced in Oregon. Today, the total Nevada state fuel tax is about 55 cents/gallon with 18.4 cents/gallon representing the Federal fuel tax portion, 17.64 cents/gallon representing the state portion, and the remainder being represented by mandatory and optional county taxes. In 2009, \$937.4 million was allocated to the Nevada State Highway Fund. The distribution of revenue in Figure 1 shows 42% was allocated directly from the state and federal fuel taxes. Specifically, \$189.9 million came from the state fuel tax and another \$204.2 million from the federal fuel tax.



Although the current fuel tax is considerably higher than the initial tax, several factors have reduced the total collected value creating current and future revenue concerns. This reduction is a result of the tax not being indexed to inflation, increasing fuel efficiency, a growing revenue-need gap, increased usage on roadways, and the relatively low level of the tax compared

to other developed countries. As a consequence, the Federal Highway Trust Fund has outlays significantly larger than revenue projections, and will soon rely on borrowing to meet demand. Many states already rely on different types of tolls and other taxes to support their road and highway maintenance and construction such as sales taxes and highway tolls. Hence, it is necessary to explore alternative options to either help alleviate the problem or to completely replace the fuel tax to collect the required resources.

## 1.1 Background Information

The following sections describe the problem in more detail. Various potential alternatives are introduced. While some of the alternatives have been implemented elsewhere and have been proven effective, other alternatives represent a new course in transportation finance.

### 1.1.1 Inflation

Unlike other taxes, for example property taxes, fuel taxes are generally not indexed to inflation. Washoe County, Nevada is the exception with a county tax that is indexed to inflation. In 1956, the Federal Highway Act showed that the country was making an asserted commitment to a national highway system. At that time the average state fuel tax was 5.7 cents/gallon, not indexed to inflation. If the tax was linked to the Consumer Price Index (CPI), the average state fuel tax in 2005 would have needed to be 39.6 cents/gallon, when it actually was only 20.3 cents/gallon. Just to meet the inflated value the average tax would have to be nearly doubled.

### 1.1.2 Low Tax Value

Despite such a large difference between the actual value of the tax and what the tax would be if it were indexed to inflation, some argue that the inflated tax is still too low to satisfy the actual needs. Parry and Small (2002) developed a model to determine the optimal fuel taxes for the United States and the United Kingdom, countries with one of the lowest and highest tax rates, respectively. The model took into account parameters related to fuel efficiency, pollution

damages, congestion, and accident costs. The optimal fuel tax was determined to lie between the high value in the UK and the low value in the US, giving an optimal rate for the U.S of \$1.01 per gallon. This rate is nearly twice the national average even when including the 18.4 cents/gallon federal fuel tax.

#### 1.1.3 Increased Congestion

Between 1985 and 1999 VMT increased by 76 percent nationwide while total lane miles increased by only 3 percent (Wachs, 2006). The Federal Highway Administration expects VMT to increase, relative to 2000, by another 42 percent by 2020.

In Nevada, from 2010 to 2020 the population is expected to grow from 2.8 to 3.4 million. Although recently transit use and carpooling have increased in Las Vegas and Reno, highway travel in Nevada is expected to increase by 80 percent by 2020 (Peckman, 2006). The Nevada Department of Transportation has a required minimum Level of Service (LOS) D, providing little driver freedom at tolerable speeds and approaching unstable flow. In 2006, portions of I-15 and I-515 in Las Vegas were observed providing LOS F, forced flow with vehicles driving in lock step with one another, during peak hours. Without improvement, by 2015 more highway sections will reach LOS F. These same LOS concerns can be expected in Reno on I-80 and US 395. To alleviate these concerns, NDOT details a ten year budget from 2008-2015 of \$11 billion with \$6.2 billion earmarked for congestions relief. However, revenue over this period is only projected to be \$9.2 billion. Including total NDOT operating costs of \$2 billion over that period creates a budget shortfall of \$3.8 billion.

#### 1.1.4 Fuel Efficiency

Because fuel taxes are levied per gallon purchased, the collected revenue from the tax is being eroded by increasing fuel efficiencies. Corporate Average Fuel Economy (CAFÉ) standards, a federally mandated regulation to improve fuel economy, are expected to increase fuel efficiency from 27.5 MPG to 35 MPG between 2010 and 2016 (CBO, 2004). A 2005

Congressional Budget Office (CBO) report showed concern with increasing CAFÉ standards. In an analysis of the best method to reduce national fuel consumption by 10%, to lessen foreign oil dependence, only a 3.8 MPG increase in CAFÉ standards would reduce new vehicle fuel consumption by 10%. But, after 15 years, this change would decrease total fuel consumption by 10%. Without increasing the fuel tax, collected revenue would also be reduced by 10%.

#### 1.1.5 Revenue Gap

The effects of inflation along with increased fuel efficiency have caused a decrease in revenue. In contrast, the increased costs of construction and broader societal demands have increased the needed revenue. The Engineering Construction Cost Index tracks over time the average price of construction costs in 20 US cities. Between 1957 and 2005 the index rose nearly 850%. In Nevada, the construction costs rose 99.7% between 1992 and 2009. The last time the state levied portion of the fuel tax was raised was 1992. In Nevada, between 1992 and 2009 the per capita highway travel increased by 6.8% while the per capita fuel consumption decreased by 8.3% (Wachs, 2006). Transportation spending has also seen an increased burden due to the need for safe care of hazardous construction materials, collection and treatment of runoff water, and aesthetic and noise improvements for neighboring communities. Although all of these are in the public's interest, their increased burden raises costs.

#### 1.1.6 Revenue Diversion

In recent federal transportation funding legislation, revenue has been diverted away from the bills as earmarks for 'special projects' (Williams, 2007). The 1982 highway bill included just 10 of these earmarks. Since then, the number of earmarks has increased from 152 in 1987, to 538 in 1991, 1,849 in 1997, and 6,373 in the 2005 highway bill, worth a record of \$24.2 billion. Many of these earmarks were for legitimate transportation needs, yet many of them went to projects for removing graffiti, museum construction, and other non-transportation related projects.

## 1.2 Alternate Tax Methods

To properly support the transportation system more revenue is needed. There are various means to collect this revenue including new tax sources, increased current taxes, or completely new tax systems.

### 1.2.1 Local Sales Taxes

At the local level, sales taxes and other local taxes have proven to be very effective (Wachs, 2006). The biggest reason for their success is the requirement of approval from local voters. Increases to sales taxes such as vehicle registration fees must be approved by a majority vote on a local ballot. Despite increasing popularity in Europe, the US has only begun to use voter approval with 21 ballot measures in the 1990's and 43 measures in 2003. Other positive aspects include finite lifetimes of the tax increases, 15-20 years, and requiring voter approval to extend them. Money collected from the sale tax is used exclusively for specific projects outlined in the measure and politicians have very little discretion of how funds are allocated. Finally, tax increases, specifically the sales tax, applies a broader tax base from which to collect money from. Because local sales taxes rely on voter approval it highly possible the tax is not approved and no additional revenue would be collected.

### 1.2.2 State/Federal Fuel Tax

One alternative is to raise the taxes of the existing system; increasing the per gallon tax. Doing this would require solving many of its current problems. First, it must be indexed to inflation to prevent losing purchasing power. Secondly, after indexing the tax with current inflation rates, the tax would likely need to be raised again to ensure sufficient revenue collection for the present and future. However, increasing the fuel tax does not address problems relating to fuel efficiency including hybrid and electric vehicles.

### 1.2.3 Vehicle Miles Traveled Fee

A VMT Fee would charge drivers a small fee per mile traveled as opposed to the fuel tax per gallon of gasoline. Drivers would either have a device to collect their mileage installed in the vehicle or be subject to an audit by a government authority to record changes in mileage and provide a bill. A mileage collection device would preserve being able to pay-at-the pump, but might introduce privacy concerns for users, whereas an audit would preserve privacy, but would require paying the fee separately from purchasing fuel. The benefit of a VMT Fee is that drivers are taxed directly for road usage as opposed to fuel usage. A VMT Fee would be a completely new transportation funding system, eventually replacing the fuel tax.

Studies in Iowa (2010) and Oregon (2007) have shown the potential positive influence a VMT Fee could have.

### 1.2.4 High Occupancy Toll Lanes

A High Occupancy Toll (HOT) lane would be similar to High Occupancy Vehicle (HOV) lanes where vehicles would need a required minimum number of passengers to drive in the lane (DeCorla-Souza, 2003). In the case of a HOT Lane vehicles with less than the required number of passengers would be able to use the lane while paying a toll and vehicles with the required number of passengers would continue to use the lane free or pay a discounted toll, both using electronic toll collection. This system can also have variable pricing to make peak period traffic pay a higher toll than off peak traffic, or the variable toll can be raised and lowered based on the volume of the toll lane. A high toll at a high volume would discourage drivers from using the HOT. Thus, the HOT Lane helps reduce congestion and collects additional revenue from the tolls. Orange County, California, implemented this system in 1995 as express lanes on a 10 mile stretch of State Route 91; one of the most congested roads in America. Using a variable price toll

ranging from \$1.00 to as much as \$4.75, the express lanes carry 40% of the traffic volume during congested periods, despite having only one third of the capacity.

San Diego, California, introduced a HOT Lane on I-15 allowing single occupant vehicles to use the lane and pay the toll. The variable price system varies in 25 cent increments as often as every six minutes, varying from \$0.50 to \$4.00. During very high congestion, the toll can reach as high as \$8.00, helping the toll generate more than \$ 2 million annually.

### 1.3 Reason for VMT

The successful studies in Oregon and Iowa about using a VMT Fee to collect revenue have motivated further consideration of deploying the approach. The primary benefit of a VMT approach is a direct user pays relationship, very similar to the fuel tax, but based directly on road usage. Although the other options listed have proven to be successful, they provide small changes and alternatives for ‘additional’ revenue as opposed to an effective and efficient tax system. A VMT Fee system would provide a stable, sufficient source of revenue for road and highway maintenance and construction needs. In addition, a VMT Fee would help collect revenue lost from hybrid-electric, electric, and other alternative fuel vehicles.

### 1.4 Objective of Thesis

Human behavior towards a VMT Fee system will have a significant impact on the effectiveness of the system. The objective of this thesis is to analyze various aspects of a VMT Fee system for Nevada, including:

- i. Barriers of a VMT Fee System
- ii. Deployment alternatives
- iii. User’s perceptions to aspects of a VMT Fee System
- iv. Effectiveness of a VMT Fee System compared to the fuel tax
- v. Equity of a VMT Fee System for different socioeconomic groups

## 1.5 Organization of Thesis

This thesis is organized as follows. Chapter 2 analyzes some barriers associated with a VMT Fee and how other states have addressed them in different studies. Specific barriers are analyzed for Nevada using a survey questionnaire and the corresponding statistical analysis. A discrete choice modeling approach is chosen to analyze various deployment aspects. Different potential choice models are described. Then the final model estimates and model analysis is provided.

Chapter 3 develops a linear regression model to measure the effects of the VMT Fee. The model compares the current fuel tax to two VMT Fees. The analysis considers the effectiveness, the amount of revenue provided, and the associated equity.

Chapter 4 provides final conclusions and recommendations.

## CHAPTER 2 USERS' PERCEPTIONS AND ACCEPTANCE TOWARDS A VMT FEE SYSTEM IN NEVADA

### 2.1 Introduction

A VMT Fee is being researched by the Nevada Department of Transportation (NDOT) as an alternative to replace the existing fuel tax. Some states, including Iowa and Oregon have conducted field tests to study the development of a VMT Fee system. Both Iowa and Oregon recruited participants to test technology developed for collecting miles traveled. The goal of these studies was to determine the accuracy and reliability of the technology, viability of a VMT Fee in practice, and the level of comfort the participants have with the system.

This chapter focuses on studying users' perceptions and acceptance towards a VMT Fee system in Nevada. A survey questionnaire was developed to collect data. The models available for analyzing the survey data are described, including advantages and disadvantages. Models are developed and the corresponding specifications are provided. Then the models are analyzed to understand the information they provide and the relative importance and significance of the included variables and to check if the model is appropriate. Finally conclusions and recommendations are provided.

### 2.2 Barriers Associated with Implementing a VMT Fee System

Several barriers exist for implementing a VMT Fee. Users' perceptions and attitudes, applicable technology, and viability of the system are the primary barriers. Cost and time to fully implement a system also represent significant barriers.

#### 2.2.1 Public Perception

Public perception focuses on how the public sees the problems associated with the existing fuel tax and their concerns with the VMT Fee. Texas based focus groups (Baker, 2010)

revealed a lack of knowledge about the fuel tax. Participants noted that VMT Fees would adversely affect high mileage drivers compared to low mileage drivers. These participants were unable to grasp that with the existing fuel tax high mileage drivers are likely to pay more in taxes because they were likely purchasing more fuel than low mileage drivers.

A focus group in Minnesota found similar problems (Baker, 2010). Overall, participants felt they had been using roads for free and a VMT Fee would change that. Lack of trust in government was also common with this group. The mediators felt the participants did not believe the funding problems they were presenting. In general the participants believed the funding crisis was nonexistent. Previous public opinion studies in Minnesota showed a lack of knowledge about the current fuel tax (Buckeye, 2007). Few members of the study knew the actual value of the state's fuel tax, 38.4 cents/gallon, guessing anywhere between 9¢/gallon to \$1.00/gallon. The annual tax paid was estimated between \$50/vehicle to \$10,000/vehicle by the members of the study, while actual tax paid is around \$600 and \$700 per vehicle.

### 2.2.2 Public Acceptance

Public acceptance is necessary to make adequate changes to the mechanism currently being used to collect funds for highways. Five focus groups in Texas discussed different options for collecting VMT Fees (Baker, 2010). The options include an odometer reading based system with a fixed fee, a cellular/zone based system that applies a rate based on location, and a Global Positioning Satellite (GPS) based system to apply a rate based on location. Focus group members were asked to give their level of acceptance for each system. Privacy was a primary concern for the cellular-based and GPS-based systems. Many participants felt the use of either of these systems would allow the government to keep detailed travel information, regardless of the design of the system. Cost of both of these systems was also a major concern. Either system would require an in vehicle device and periodic uploads to a central database that would both require installation and incur high initial costs as well as operating and maintenance costs.

All three systems would be more involved with administering the fee than the current fuel tax is. To address this, different options were presented to the groups including installment plans, online payment, paying with vehicle registration, or allowing the payment to occur with fuel purchases. It was widely suggested a payment that would happen once annually would not be advised as households do not budget for a ‘lump’ tax for driving. Surprisingly, most participants stated they would be more accepting of the cellular or GPS-based systems if they allowed for paying at the pump.

The University of Iowa (Forkenbrock, 2002) determined a simple collection system would face less resistance from users. Complex systems involving road and location specific fees would allow for conducting travel demand analysis by uploading origin-destination information from the vehicles. Anticipated privacy concerns from road users prompted the need for a simpler system, one that would transmit only the total mileage fee, to attain the greatest level of public support.

### 2.2.3 Collecting Mileage and VMT Fee

The most contentious component is how the individual driver’s VMT will be calculated. Several options exist including both invasive and non-invasive technologies. Invasive technology includes using a device with GPS or similar system that tracks vehicle location to collect miles traveled. A GPS system would calculate mileage by tracking the position of the vehicle with latitude and longitude. Although potentially highly effective, many see this as a way for the government to track them.

In a 12 month VMT Field Study, the state of Oregon used GPS as part of its mileage collection system. An algorithm was developed to minimize privacy concerns (Whitty, 2007). This algorithm took data from the GPS, applied a pre-specified fee, and stored only the total fee. GPS location information was only received by the vehicle. No location information was sent from the vehicle back to the satellite, making it impossible to track the vehicle (Goodin, 2009).

A very similar system was used in the national study run by the University of Iowa (Hanley). This system used the vehicle's On-Board Diagnostic (OBD), existing in most vehicles from 2003 to the present, to determine the mileage and use GPS to determine the vehicle's location and apply the corresponding fee. GPS location information was only retained long enough to calculate the fee, and only the aggregated total mileage charge was transmitted to the operation center (Goodin, 2009).

A less invasive device from Davis Car Chip® used in Las Vegas in the summer of 2011 for a field test. This device collected miles traveled through the vehicle's OBD. Using this approach, mileage counts were accurate without creating privacy concerns. To calculate the VMT Fee, the device was connected to a wireless transmitter, which uploaded the mileage to a computer located at the gas station.

Other options include audits and receiving a bill for the fee owed over a certain period. Either of these options would require an initial physical reading of the odometer, a subsequent reading at the end of the cycle, and the driver would either be charged on site or would receive a bill in the mail (Forkenbrock, 2002). An alternative such as this is especially necessary for electric and other alternative fuel vehicles that are not compatible with a pay at the pump option because these vehicles will never use a gas station to refuel (Nevada VMT Study, 2010).

#### 2.2.5 Level of Comfort

Overall, support for the Oregon field study was high amongst the participants. At the end of the study 71% of the participants were comfortable with the ease and convenience of the in-vehicle device (Whitty, 2007). The accuracy of the device, within  $\pm 2\%$  of actual mileage (Kim, 2008), was acceptable to 70% of the participants. Finally, if the study were expanded to allow participants to refuel at every gas station in the state, 91% of the study participants said they would be willing to continue paying the VMT Fee.

The device used by the University of Iowa also received a high level of approval. Over 71% of the participants had positive views with only 17% feeling negatively towards it (Hanley, 2011). Application and payment of the fee was managed through a monthly bill. Over 60% of the participants favored the auditable bill, which provided the daily miles traveled, the location, and the corresponding VMT Fee.

#### 2.2.4 Cost of VMT Overhaul

Completely overhauling the fuel tax with a VMT Fee will, undoubtedly, require significant start-up costs. Installing the device used in Oregon into all of the state's vehicles would require over \$1 billion (Rufolo). This does not include costs associated with upgrading gas stations. Upgrading the fuel pumps and software for every station in Oregon would cost a total of \$28.6 million and \$2.7 million respectively. New computers would cost another \$1.7 million and operating costs would total \$2.4 million annually. To reduce these costs the intentions were for only new vehicles to require the device while existing vehicles would continue to pay the fuel tax. However, analysis performed using new vehicle purchase rates and vehicle scrap rates showed that it would take an estimated 20 years for 95% of vehicles on the road to have the VMT device installed (Forkenbrock, 2011).

Estimates for the state of New York with a 1 cent/mile fee indicate the system would incur annual operating costs of 17.87% of collected revenue after full implementation, assuming a six year deployment period. The capital costs to fully deploy the system in one year would require \$1.337 billion for the onboard units and \$104.5 million for gas station equipment.

#### 2.3 VMT for Nevada

In this study, four main aspects related to users' perceptions and acceptance of a VMT Fee system in Nevada were considered including implementation costs, comfort with the car chip device, preference of billing cycle length, and impacts on transit use. To gather information

about these aspects a survey questionnaire was developed. This survey collected socioeconomic information and opinions about the four emphasized aspects.

### 2.3.1 Survey development

The survey was developed to gather information about some of the main aspects of concern for implementing a VMT Fee. Previous analyses noted the high cost of fully implementing a pay-at-the pump VMT system. Because retaining a pay-at-the pump system is highly desirable, having information about the preferences of the users will help determine the initial steps to be taken. To gather the information survey responders were asked what their concern was of the implementation costs. The available responses were:

- i. Very Concerned
- ii. Somewhat Concerned
- iii. Neutral
- iv. Somewhat Unconcerned
- v. Very Unconcerned

With many options available to collect mileage information from drivers, and with a device already developed for the Las Vegas field test, public opinion about the device will help determine the best mileage collection system. Responders to the survey were asked about their level of comfort with the device for the field test. The available responses were:

- i. Very Uncomfortable
- ii. Somewhat Uncomfortable
- iii. Neutral
- iv. Somewhat Unconcerned
- v. Very Concerned

There are different options in terms of how to charge a VMT Fee. Survey responders were asked how frequently they would prefer to pay their fee. The available responses were:

- i. Monthly
- ii. Quarterly
- iii. Bi-Annually (Twice a year)
- iv. Annually
- v. None (Continue to pay at the pump during every refuel)

Although not an inherent trait of a VMT Fee system, change in transit use was decidedly important because of the potential effect a change in a major transportation tax structure might have on transit ridership. In a metropolitan area such as Las Vegas where transit is available, drivers may choose to substitute methods of transportation to keep their total VMT cost low. It is important to know if, and how often, users would change modes to ensure there is both sufficient transit availability and that revenue from the VMT fee is sufficient. Responders were asked if a VMT Fee would affect their transit use. The available responses were:

- i. Significantly Less Use
- ii. Somewhat Less Use
- iii. Neutral
- iv. Somewhat More Use
- v. Significantly More Use

Users' perceptions about the cost of implementing a VMT Fee system, comfort with the car chip, and billing cycle preference are very important because they are interrelated. Discomfort with the car chip or concern with the cost of implementing a VMT Fee system will greatly influence the need for a billing option. If there are high levels of concern with the initial costs or strong discomfort with having a mileage collection device installed, billing users for their road use will be the most practical way to implement a VMT Fee system. Understanding the preferences for different billing cycles will help decide if one fixed cycle is best or if different options are weighted equally and individuals should be able to choose from a set of cycles.

Conversely, preferring not to receive a bill will influence the need to maintain the current pay at the pump system.

To better understand and analyze the data collected about the different implementation options, socioeconomic information about the responder was also collected. This information can be used to draw connections between the responders and their choices about VMT characteristics. Some specific demographics include gender, age, level of education, and total household income.

A total of 173 survey responses were collected. Data was collected at public locations near the university. These locations included the student union at the university, local grocery stores, and local shopping centers. To attract people to take the survey, UNLV 'robot' pens were offered in response to the survey. The gender response rate was 55% male and 45% female. Nearly 70% of the responders were between the age of 18 and 34 with only 2% of the responders 65 or older. Implementing a VMT Fee system would take many years, therefore the heavy weight of young responders is not a problem as a VMT Fee would be more burdensome to younger people. No racial information was taken with the survey.

### 2.3.2 Discrete Choice Modeling

Discrete choice modeling is widely used in economic, transportation, and other fields to study a choice among a set of alternatives. These models statistically relate user's preferences and their socioeconomic characteristics to estimate the probability of a person choosing a particular alternative. Development of these models shows a significant advance in consumer choice behavior analysis. In transportation analysis, forecasting the demand for new products or innovation requires consumer preference information. However, *a priori* information about these new products or innovations is rarely available. This can be overcome through the use of stated reference experiments, which measure a consumer's preference about hypothetical changes.

## 2.4 Model Forms

Discrete choice modeling is used here to analyze users' perceptions and acceptance of a VMT system in Nevada. Various aspects of the system can be designed in different manners with many of them involving a discrete choice.

In this context, three important pieces of information for analysis are provided by the discrete choice models: (1) the probability of each outcome, (2) the explanatory variables that describe the probability, and (3) the relative importance of each variable.

Discrete choice models are typically based on the theory of utility maximization, where utility is formed by a systematic component and a random component. Different types of models can be obtained depending on the distributions used to represent the random component.

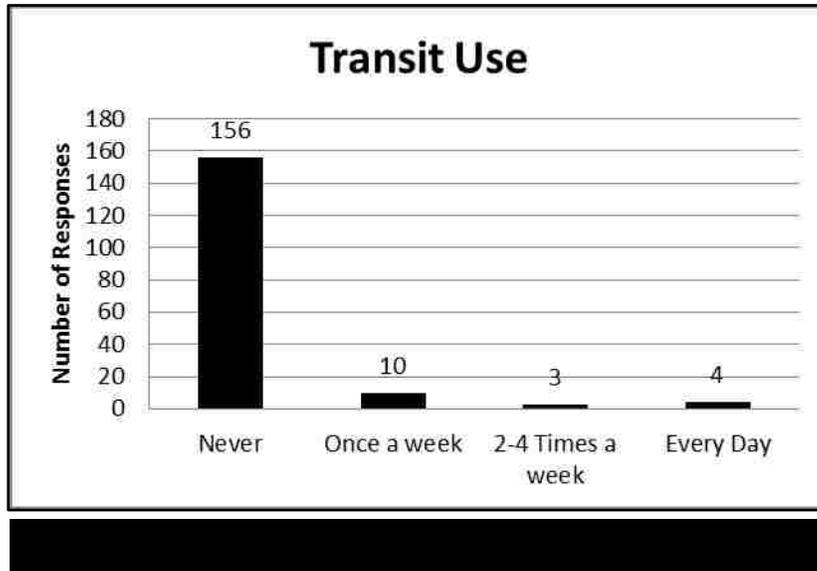
## 2.5 Modeled Points of Emphasis for VMT

Models for three of the four aspects of emphasis for a VMT Fee system were developed to analyze and understand their effects in Nevada. These models were developed to study the preference of a billing cycle, level of comfort with the Car Chip device, and the level of concern over the cost of implementing a VMT Fee system

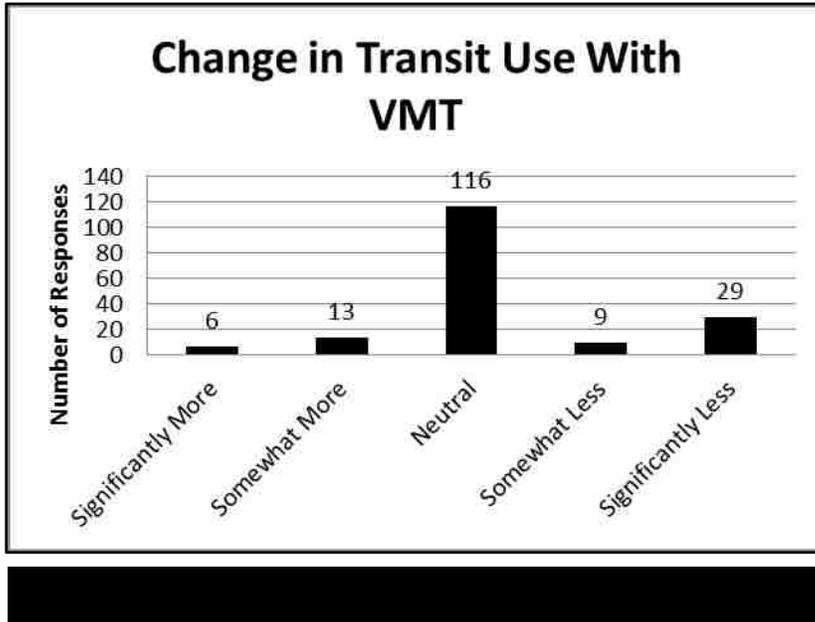
The VMT Fee Data collected from the survey consisted solely of socioeconomic information. Greene (1993) recommends Multinomial Logit (MNL) as economists with socioeconomic data most frequently use MNL models. Ordered probability models were also used in addition to the MNL models

### 2.5.1 Transit Use

Figure 2 shows the distribution of responses for current transit use in Las Vegas. Of the 173 responses only 17 people currently used transit, representing less than 10% of the total sample.



Similar results are seen in Figure 3 for the change in transit use after a VMT Fee is implemented. With a VMT Fee, only 19 people responded that they would use transit more and 38 responded they would use transit less. These low values before and after a hypothetical VMT Fee is implemented imply developing a model would be impractical and provide little insight.



### 2.5.2 Billing Cycle

The choices for the billing cycle (question #18 in the survey provided in Appendix 1) most closely follow a categorical distribution. That is, there are five possible outcomes and the probability of each outcome is separately specified. Categorically distributed dependent variables are associated with Multinomial Logit models. For developing the billing model, the response for ‘None’ was removed to analyze only the pertinent choices. These choices did have an ordered nature because each option represented a certain number of bills per year; 12 for Monthly, 4 for Quarterly, 2 for Bi-Annually and 1 for Annually. However, the order was not a range, but rather four discrete possibilities. Because of this it was decided against an ordered model and a MNL was used.

The best model for the Billing Cycle had a MNL specification and an adjusted  $\rho$ -squared value of 0.1205, calculated using the likelihood ratio:

$$Adjusted \rho^2 = 1 - \frac{LL\beta - N}{LL0} \quad (2.1)$$

Where  $LL\beta$  is the likelihood ratio of the estimated model,  $N$  is the number of estimated coefficients, and  $LL0$  is the likelihood ratio of a model with no constants or variables. This

adjusted  $\rho$ -squared is similar to the adjusted R-squared for linear regression showing the certainty of the estimated model. The set of equations for the billing model are shown here:

$$U(\textit{Monthly}) = 1.165 - 1.44 \times \textit{SMALL} - 0.945 \times \textit{LOWEDU} + 0.838 \times \textit{HM}$$

$$U(\textit{Quarterly}) = -0.95 \times \textit{SMALL} - 1.58 \times \textit{LOWEDU} + 0.506 \times \textit{LOWINC}$$

$$U(\textit{Bi - Annually}) = -1.15 - 0.95 \times \textit{SMALL} - 0.945 \times \textit{LOWEDU} + 1.08 \times \textit{LOWINC}$$

$$U(\textit{Annually}) = -0.853 + 1.08 \times \textit{LOWINC} \tag{2.2}$$

The alternative specific constants show the Monthly option is the most attractive, with the highest initial utility, meaning it has the highest initial preference of all the alternatives. With most bills being produced on a monthly basis, it is of no surprise that the Monthly option has the highest initial utility. Coefficients for the variables *SMALL* (household size with less than 3 people) and *LOWEDU* (less than a college graduate) both result in a decrease in utility. Households considered to be small see a decreased utility for all options except an annual bill. Small households likely have fewer expenses making it easier for them to pay once a year. The same can be said about households with low levels of education. Households driving more than 40 miles/day (*HM*) have an increased utility for a monthly bill. This utility is related to the increased cost from the high amount of driving, where a monthly bill makes it easier to budget. Low income households (*LOWINC*) would have an increased utility for all the alternatives except Monthly. Although difficult to budget for, it may be easier for low income households to save and pay fewer bills a year.

### 2.5.3 Cost Concern

The ranking of response opinions for the cost concern (question #17 in the survey in Appendix 1) warrants using an ordered model. Applying values of 1-5 to the responses allows for modeling without reducing the generality of the response. Ordered models are not always appropriate as they sometimes lack the flexibility necessary to control interior choice probabilities.

With the neutral response included the ordered models showed very little explanatory power. Both logit and probit models provided similar results. Each of these models had an adjusted  $\rho$ -squared value of 0.012. In addition neither model was able to predict results for the Somewhat Unconcerned and Very Unconcerned choices. In addition, each model estimated 113 neutral responses in contrast to only 53 actual responses.

To get a better model the Neutral responses were removed from the data set to estimate just those who either have concern or do not have concern for the cost. Again, both the probit and logit models were unable to estimate results for being unconcerned about the cost, and produced even lower adjusted  $r$ -squared values of 0.0038.

Poor results provided by ordered models motivated the use of multinomial models to estimate all of the possible outcomes. The Neutral response implies that responders either don't know about the potential costs of implementing a VMT Fee, or the costs are unimportant to them. Because of this, the Neutral responses were left out for the MNL model. The best model specification under MNL is shown below with an adjusted  $\rho$ -squared value of 0.171:

$$U(\textit{Very Concerned}) = 0.965 - 1.962 \times \textit{SMALL} - 0.773 \times \textit{YOUNG}$$

$$U(\textit{Somewhat Concerned})$$

$$= 1.033 - 1.625 \times \textit{SMALL} - 1.433 \times \textit{GENDER} + 0.866 \times \textit{LOWEDU}$$

$$U(\textit{Somewhat Unconcerned}) = -1.625 \times \textit{SMALL} - 0.999 \times \textit{KNOW}$$

$$U(\textit{Very Unconcerned}) = -2.605 \tag{2.3}$$

Considering only the constants, people are most likely to be Somewhat Concerned with the cost of VMT followed by being Very Concerned, Somewhat Unconcerned, and Very Unconcerned. Households with less than 3 people (*SMALL*), responders under the age of 35 (*YOUNG*), people with previous knowledge of a VMT Fee (*KNOW*), and Men (*GENDER*) all are factors causing a decrease in utility. Only people without a college degree (*LOWEDU*) show an increase in their utility for being Somewhat Concerned. Comparatively, people with a high level of education will have a higher probability for being very concerned. Previous knowledge

of a VMT Fee decreases the utility for being somewhat unconcerned. Although potentially contradictory, it shows people with knowledge of VMT are aware of the implementation costs, thus increasing the probability they are somewhat or very concerned with the cost.

#### 2.5.4 Car Chip

The same modeling process from the Cost Concern was used to analyze the level of comfort with the Car Chip. Ordered logit and Ordered probit models estimated similar models that produced the same aggregate results. Each of these models were only able to estimate Neutral and Somewhat Concerned choices, with 143 and 30 respective responses compared with 51 and 43 responses in the data set. These models also had statistically poor goodness-of-fits with adjusted  $\rho$ -squared values of 0.0046 for logit and 0.0041 for probit.

To improve the models, the Neutral responses were removed. Only marginally better models were estimated with this change. The respective adjusted  $\rho$ -squared values were 0.01085 for logit and 0.0078 for probit. Both of these models produced the same aggregate results: 36 Somewhat Comfortable, 66 Somewhat Concerned, and 20 Very Concerned.

As with the Cost Concern model, a model that estimates all of the possible choices is desired. A MNL model is developed to provide this information. Because of the weight of the Neutral response shown in the ordered models, it is not considered for the MNL model. The adjusted  $\rho$ -squared of 0.0298 for this model is slightly better than the ordered models, but still considerably low. The final estimated specification for the Car Chip model is shown here:

$$U(\textit{Very Comfortable}) = -1.481 + 1.022 \times \textit{LOWINC}$$

$$U(\textit{Somewhat Comfortable}) = 0$$

$$U(\textit{Somewhat Uncomfortable}) = -0.868 \times \textit{SMALL} + 0.861 \times \textit{PRIVACY} + 0.884 \times \textit{KNOW}$$

$$U(\textit{Very Uncomfortable}) = -0.392 - 0.868 \times \textit{SMALL} + 0.861 \times \textit{PRIVACY} + 0.884 \times \textit{KNOW} \tag{2.4}$$

Considering only the constant terms, being Somewhat Uncomfortable and Somewhat Comfortable imply people are fairly evenly split about the Car Chip. Having a high stated preference for privacy protection, and having previous knowledge of a VMT Fee increase the utility for being Somewhat Uncomfortable and Very Uncomfortable with the Car Chip. Previous knowledge of a VMT Fee might imply knowledge of previous studies with devices that used GPS to track mileage, giving increased utility to a level of being comfortable.

## 2.6 Analysis of Models

Each model was analyzed to determine if the IIA assumption for the MNL model was upheld, the elasticity of the variables, and the model's accuracy estimating choices compared to the stated choices. The IIA assumption can be tested by estimating a model for a subset of the alternatives and comparing the ratio of probabilities in subset to the ratio of probabilities for the same alternatives when all alternatives are available. Failure of the IIA assumption will occur when the ratio of the probabilities in both the subset and full set are different, or if the ordering of the probabilities is altered.

Elasticities are used in modeling to determine the relative effects of a variable. The elasticity of each variable will show its relative importance to the utility function. Direct-Elasticities will give misleading results for the models developed here due to the binary nature of the explanatory variables. Hence, direct pseudo-elasticity is calculated to determine the percent change in the utility of the alternative when the variable changes from 0 to 1. Direct pseudo-elasticity is calculated as:

$$E_{Xk} = \frac{P(Xk=1) - P(Xk=0)}{P(Xk=0)} \quad (2.5)$$

Where ' $Xk$ ' represents the variable ' $X$ ' for choice ' $k$ '.

The final point of emphasis is the accuracy of the estimation of the models compared to the stated results. All of the models use transformed, binary variables, giving a finite number of

potential variable inputs. For each set of inputs the specific number of responses was taken from the information in the data set. The number of outcomes for each choice is calculated as the product of the choice probability and the expected number of outcomes for a set, which is shown in Equation (2.6):

$$\text{Predicted Outcome for a Choice} = \frac{e^{U_k}}{\sum_{k=1}^K e^{U_k}} \times (\text{Total Outcomes for a Set}) \quad (2.6)$$

The accuracy of the model is the comparison of the predicted number of outcomes for each choice versus the stated total from the survey. Accuracy is calculated as:

$$\text{Accuracy} = \frac{\text{Total} - \sum (\text{Abs}(\text{Stated} - \text{Calculated}))}{\text{Total}} \times 100 \quad (2.7)$$

### 2.6.1 Billing Cycle

#### IIA Test

To test the IIA assumption, a model was developed with only the ‘Monthly’ and ‘Annually’ choice alternatives. The probability ratio of ‘Monthly’ to ‘Annually’ for this model was 2.02, and for the full model was 1.58. Under Luce’s choice axiom logit would not be an appropriate fit because of the change in the ratio (Luce, 1997). However, the ordering of the alternatives is not effected and therefore, under Gul’s choice axiom, a logit model is appropriate (Gul, 2010).

#### Pseudo-Elasticity

The pseudo-elasticities for the Billing model are shown in Table 1. Positive values indicate an increase in the choice probability for an alternative and negative values indicate a decrease in the choice probability. Small households have a very large increase in probability for Annual bills; more than double the probability of large households. This increase shows a preference for fewer bills, which is supported by the changes in Monthly, -35%, and Bi-Annually, -23.4%, but Quarterly sees an increase.

Low educated households see a decrease in every option except an annual bill, which sees an increase of 57%. This is likely due to the correlation between having a low level of education and having low income. Low income households see a decrease in Monthly bills and increases in all other choices. The progression of the increases shows an increased preference for fewer bills.

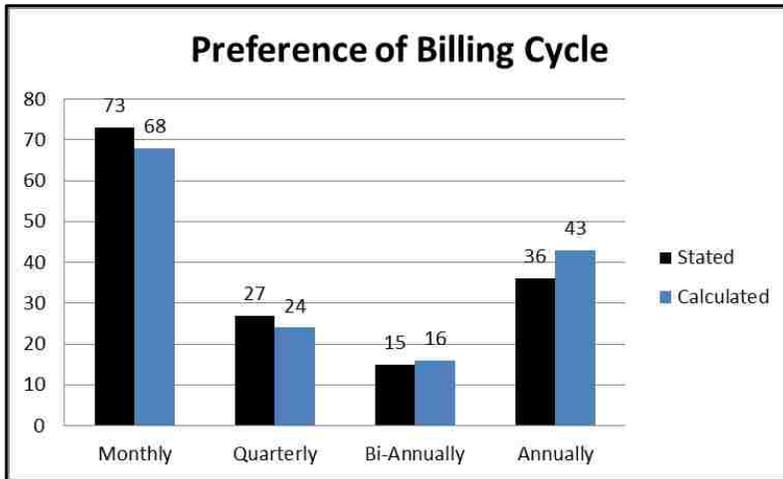
The high increase in Monthly bills for high mileage (HM) households shows the effect a VMT Fee would have. Intuitively higher mileage means more VMT Fee to be paid. Although a monthly bill would not change the total annual cost, a Monthly bill would be easier to budget and control.

**Table 1-Billing Cycle Elasticity**

Variable	Pseudo Elasticity for Billing Cycle			
	Monthly	Quarterly	Bi-Annually	Annually
<b>SMALL</b>	-35.0%	16.6%	-23.3%	104.4%
<b>LOWEDU</b>	-4.1%	-56.6%	-1.0%	57.4%
<b>HM</b>	46.4%	-37.3%	1.3%	-42.2%
<b>LOWINC</b>	-42.3%	8.7%	70.7%	100.6%

Accuracy

A comparison of the estimated model and the stated results is show in Figure 4. Quarterly and Bi-Annually, the choices with the fewest responses, are modeled most accurately. There is cross over between Annually and Monthly, with the model estimating more responses for Annually and fewer for Monthly. At the aggregate level the model for the Billing Cycle is almost 89% accurate.



The Annual choice is estimated at about 20% above than the stated value. All other alternatives are estimated within roughly  $\pm 10\%$  of the stated value. Overall, the model does not perfectly estimate the stated information. However, the overall percent difference is small enough for the model to be effective.

## 2.6.2 Cost Concern

### IIA Test

For the cost concern, a model was developed with Somewhat Concerned and Somewhat Unconcerned as the alternatives. The probability ratio in the model with just those two choices is 2.38, and the ratio in the full model is 2.55. These ratios are very similar; the difference is the effect of the full model estimating the alternatives slightly different than the partial model. Given the ratios are nearly equal and the ordering between the two did not change, a logit model is appropriate for this data.

### Pseudo-Elasticity

Table 2 shows the Pseudo-Elasticities for the variables in the Cost Concern model. Small households show an infinite increase in being Very Unconcerned resulting from zero responses for non-small households.

Young responders showed a propensity for approaching the middle of the range. In general the same can be concluded for responders with a low level of education. This shows uncertainty of the potential cost. More information and knowledge of the subject explaining the total impact might remove some of the uncertainty.

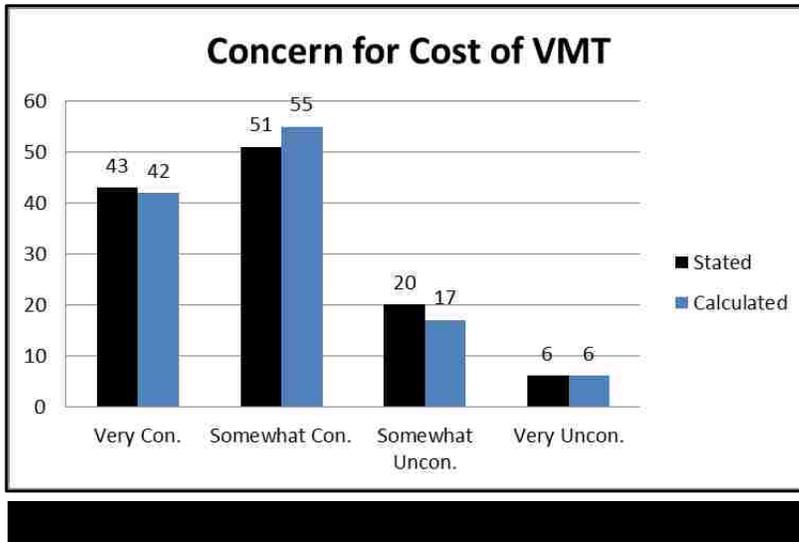
Prior knowledge of VMT generates a large increase in being Very Concerned about the cost. Increasing the flow of information about what the cost of VMT would entail, as stated for young and low educated households, would likely show further increases in concern about the cost.

**Table 2-Cost Concern Elasticity**

Variable	Pseudo-Elasticity for Cost Concern			
	Very Concerned	Somewhat Concerned	Somewhat Unconcerned	Very Unconcerned
<b>SMALL</b>	-17.1%	-7.9%	-1.7%	INF (P(0)=0)
<b>YOUNG</b>	-38.6%	23.3%	57.9%	10.5%
<b>GENDER</b>	63.6%	-49.5%	96.3%	309.7%
<b>LOWEDU</b>	-27.6%	12.2%	63.0%	-27.5%
<b>KNOW</b>	59.2%	-13.8%	-58.7%	-3.7%

#### Accuracy

Figure 5 shows the comparison between the stated and calculated values. The extremes are modeled very well with little or no difference. Overall the model has an accuracy of 93%.



### 2.6.3 Car Chip

#### IIA Test

The IIA test for the Car Chip was estimated using a model for ‘Somewhat Comfortable’ and ‘Somewhat Uncomfortable’. The probability ratio for the IIA model of ‘Somewhat Uncomfortable’ to ‘Somewhat Comfortable’ is 1.1, and the corresponding ratio for the full model the ratio is 1.2. Although the ratio for the full model is slightly higher than the IIA model, the ordering does not change making the logit specification appropriate.

#### Pseudo-Elasticity

The Pseudo-Elasticity values are shown in Table 3. Small households show a significant decrease in their level of comfort compared to large households. Smaller households are more likely to drive fewer miles, which could explain the increase in level of comfort.

The significant increase for being very comfortable for low income families is not surprising. Low income households have, on average, low fuel efficient vehicles that would benefit from a VMT Fee. This benefit is very likely a cause of the increased fuel efficiency.

Responders who indicated privacy was one of their top two important characteristics for a VMT Fee system show an increase in being uncomfortable with the Car Chip. Previous

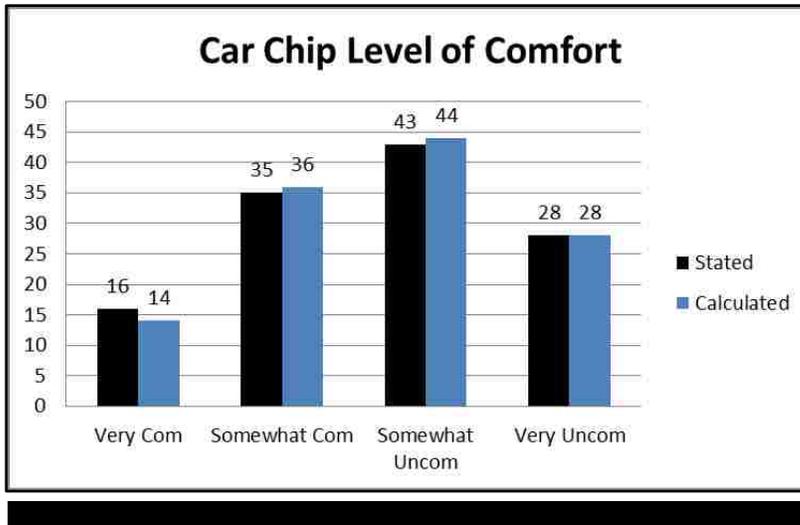
knowledge of a VMT Fee also leads to an increase in discomfort with the car chip. Additional information about the device or a demonstration showing what information the device records could help shift responses to being more comfortable.

**Table 3-Car Chip Elasticity**

<b>Variable</b>	<b>Pseudo-Elasticity for Car Chip Comfort</b>			
	Very Comfortable	Somewhat Comfortable	Somewhat Uncomfortable	Very Uncomfortable
<b>SMALL</b>	85.7%	48.6%	-25.7%	-25.7%
<b>LOWINC</b>	163.0%	-19.7%	-5.5%	-4.2%
<b>PRIVACY</b>	-4.2%	-28.2%	25.7%	11.0%
<b>KNOW</b>	-18.0%	-41.4%	29.1%	32.7%

#### Accuracy

Figure 6 shows the comparison of the stated and estimated values. Of the three models developed, the car chip is the most accurate at 96%. Only the Very Uncomfortable response is estimated with a difference greater than one. However, the marginal goodness of fit limits the model. It may represent the data set well, but it's possible it does not estimate well outside of the given data.



## 2.7 Conclusions and Recommendations

This chapter uses multinomial logit models to estimate and analyze consumer choice behavior relevant to a VMT Fee system. Although the logit model presents some strong assumptions, most notably the IIA assumption, tests were conducted to evaluate the impact of this assumption. The results indicated the IIA assumption is not a problem.

Analysis of the pseudo-elasticities shows drastic impacts for some of the variables in the models. Large percent changes for a particular alternative show the need to address the option further, as these large changes potentially represent isolated or uninformed groups. In the Billing Model, two of the variables show an over 100% increase in probability for choosing Annually, making it apparent that both a Monthly and Annual billing cycle are initially available. The cost concern model has a majority of its responses in the middle, being Somewhat Unconcerned and Somewhat Concerned about the cost. More information about the components, upgrades needed for gas stations, and operating costs will help people make a better informed decision. Finally for the Car Chip model, there are significant increase going to the extremes of being Very Comfortable and Very Uncomfortable. Demonstrations of how the Car Chip works and providing direct insight to the data collected will likely increase the overall level of comfort.

Only a Monthly bill is recommended initially. Although both Monthly and Annually are the most popular responses, one bill per year would be extremely difficult to budget for especially for low income and high mileage households. A monthly bill could be implemented to allow drivers to 'opt-in' to a VMT Fee system and stop paying the fuel tax. It would also decrease initial costs, eliminating the need to update fuel station technology and install in-vehicle technology. This will allow more time to develop an efficient, reliable collection system and help provide more information to the public to ease the overall level of comfort.

## CHAPTER 3 ECONOMIC IMPACTS OF A VMT FEE

### 3.1 Introduction

Currently, there is a consensus that the existing mechanism to collect funds for maintaining, operating, and expanding our highway transportation system needs to be modified to address emerging issues, such as its limitations with electric vehicles, declining revenue from increased fuel efficiency, and a relatively low tax value. As a replacement alternative for the existing Fuel Tax, several state and federal agencies have been considering a VMT Fee.

Increases in the number of electric, natural gas, and other alternative fuel vehicles present a problem for future road maintenance and construction. Under current conditions these vehicles do not pay for road usage because they are not paying the fuel tax. As the number of these vehicles increase, the revenue share lost from these vehicles will also increase. These vehicles occupy the same space on the road and cause relatively similar damage compared to regular fuel vehicles. Analysis by the National Academy of Sciences and the Energy Information Administration found that state and federal revenue could decline by as much as 5% in 2020 and 12.5% in 2030 as a result of increased hybrid sales (Wachs, 2010). Lawmakers in Oregon have proposed a 1.43 cent/mile fee on all plug-in and hybrid electric vehicles, in addition to the fuel tax, to compensate for the anticipated decline in collected revenue (Webber, 2011).

In 2007, the Oregon Department of Transportation (ODOT) completed a year-long field test studying the implementation of a VMT Fee-based system (Whitty, 2007). This test demonstrated the feasibility of using existing technology, including global positioning satellite and the vehicles' on-board diagnostic system, to measure VMT within an accuracy of  $\pm 2\%$  (Kim, 2008). It also showed the ability to develop a pay-at-the pump system without major changes to the current refueling process. It is expected that an alternative method to collect funds, such as a VMT Fee-based system, incurs additional costs. However, ODOT estimates an annual operating cost of \$1.6 million, which is less than 3% of the collected revenue.

The University of Iowa completed a national VMT Fee study in 2011 (Hanley, 2011). This study was completed with 2,650 participants in 12 different US locations. To collect the mileage this study used an on-board-unit temporarily installed in the vehicle of each participant. A GPS unit determined the vehicle's location and the vehicle's on-board computer uses a Geographic Information System (GIS) to determine the state, city, and municipality to apply the corresponding rate and store the information. Mileage was uploaded to a central database using commercial cellular data services. Over 23 million miles were collected during the survey and the device was able to successfully assign all but 0.6% to the correct jurisdiction.

The effective testing of VMT technology illustrated in previous studies shows the practicality of such a system. However, the success of the VMT Fee approach depends on its equity and effectiveness to collect the required resources.

Fricker and Kumapley (2002) developed a model to estimate VMT in Indiana using socio-economic data from the Nationwide Personal Transportation Survey. The model separated households into socioeconomic clusters based on income, household size, and vehicle ownership. Statewide annual VMT is calculated as the sum of the average effects from each of the clusters. VMT estimates from the model were 26% below recorded numbers for the estimated year. This difference is attributed to miles from vehicles not owned by households such as taxis, rental cars, and company vehicles. Hence, VMT is very difficult to estimate using household data only. However, the model was determined to be applicable for planning purposes.

Previous studies, including Weatherford (2010), Robitaille et al (2010), and Zhang and McMullen (2008), have developed regression models to evaluate several aspects associated with the deployment of a VMT Fee. Weatherford constructed a linear regression model using data from the 2001 National Household Travel Survey (NHTS) to analyze the impacts of implementing a national VMT Fee system. The model estimated the household's miles traveled as a function of:

- i. The average price per mile to drive

- ii. The number of vehicles
- iii. The annual household income
- iv. Other household characteristics
- v. Characteristics particular to the specific state/location

The VMT Fee rate was designed to be revenue neutral - implying the VMT Fee will generate the same amount of revenue as the current fuel taxes does - applying an approximated fee of 0.955 cents/mile. Weatherford found that around 59.8% of the households would experience an increased economic burden averaging an increase of approximately \$200 per year and 66.5% of households would experience a reduction in annual VMT with an average change of 2,125 fewer miles per year.

Robitaille (2010) also developed a linear model for estimating household miles traveled. The model was used to analyze a revenue neutral VMT Fee of 0.9 cents/mile to replace the federal fuel tax. This VMT Fee decreased total VMT by 0.4 percent. On average, changes in household consumer surplus, federal revenue, and social welfare were all less than one dollar per year, per household. As a percentage, all of these changes were negligible.

With a similar regression model for Oregon, Zhang and McMullen (2008) applied an expected revenue-neutral 1.2 cent/mile fee, and found that high income groups would see a net gain in their economic burden. However, the change in economic burden, positive or negative, across all income groups was less than 1/10 of a percent relative to each group's total income.

The Nevada Department of transportation has been conducting a series of VMT Studies. A total of seven VMT Fee alternatives were compared in the first study conducted by NDOT. The systems range from a flat fee to a pay-as-you-go option, as listed below:

- i. Single Fee System – Charge a uniform flat VMT Fee across the board on all vehicle types
- ii. Dual Fee System – Charge different fees for passenger cars and for light trucks

- iii. Triple Fee System – In addition to charging different fees for passenger cars and for light trucks, charge different fee for heavy trucks
- iv. Multiple-Fee Systems – Charge different fees by grouping different vehicles based on their makes, models, fuel efficiency, and year.
- v. Generalized Fee System – Charge different fee based on vehicle classification, roadway classification, and traffic conditions
- vi. Pay-as-you-go Fee System – Charge a fee based on the transportation needs by assessing the revenues versus needs annually
- vii. Full-Cost Fee System – Charge a fee based on the full cost of the transportation including direct construction, maintenance, operations, and indirect social costs

The second study conducted by NDOT consisted of a pilot field test performing a preliminary evaluation of a potential strategy to implement a VMT Fee system in Nevada. The field test completed in the summer of 2011 did not involve a vehicle tracking device. It was based on simple at-the-pump collection or periodic payments to minimize privacy concerns. As part of these tests, it was important to determine people's preferences and attitudes towards the VMT system. In addition, it was important to determine how the VMT Fee and other factors affect people's driving behavior and the corresponding amount of resources collected.

This study develops a linear regression model for Nevada using 2009 data from the National Household Travel Survey. Only data from Nevada and similar supporting data is used to create the model. Two pre-specified VMT Fees, 2.91 cents and 3.3 cents, are being used in this study. The fees were calculated based on average fuel efficiency of cars in Nevada and state fuel tax revenue.

The goal of this study is to assess the effectiveness of a VMT fee and determine the changes in equity at the household level. Results from a congestion pricing study in New York determined reducing congestion was a primary element for an effective congestion fee (Schaller, 2006). The fee would also have to be equitably distributed, not affecting the economic burden of

low income households greater than high income households. The effectiveness of the VMT Fees will be measured by the revenue collection capabilities and the resulting mileage reduction, and the equity of the VMT Fee will be determined by the effects on different socioeconomic groups.

## 3.2 Model Development

### 3.2.1 Model Base

Weatherford (2010) developed a linear model for the U.S., using 2001 NHTS data containing 58 variables. The model used location and household characteristics to calculate the annual household vehicle miles traveled. Some variables included in the model were price per mile to drive, household income, and number of household vehicles. The functional form of the model is given by Equation (3.1):

$$LN(\text{Annual VMT}) = f(\text{Price Per Mile}, \text{Household Characteristics}, \text{Location Characteristics}) \quad (3.1)$$

A linear relationship was desired because of its simplicity in estimation and ease of understanding. The Weatherford model, created with 2001 data, is used here as a reference point for the development of a Nevada-specific model using 2009 NHTS data (US DOT, 2009).

Although the data set includes many variables that could directly be used in a model, additional variables were created to improve the specification. An important variable used in previous studies has been the price per mile to drive. For this data set, this variable was derived from the available information in the 2009 NHTS data. The variability of fuel prices and its negative effects highlights the importance of this variable.

At the vehicle level, price per mile is calculated using Equation (3.2) as the ratio of the price per gallon and the vehicle's fuel efficiency:

$$Price/Mile = (Cost/Gallon)/(Miles/Gallon) \quad (3.2)$$

However, the model should use the average price per mile of the entire household. Average household price per mile is a weighted average, with each vehicle weighted by its mileage over the total miles traveled. Equation (3.3) shows the calculation for average household price per mile:

$$Avg Household Price/mile = \sum_{n=1}^N \frac{Mn}{M} \times \frac{\left(\frac{Cost}{Gallon}\right)_n}{\left(\frac{Miles}{Gallon}\right)_n} \quad (3.3)$$

Where ‘ $Mn$ ’ is the annual mileage of vehicle  $n$  and ‘ $M$ ’ is the total annual household miles traveled.

In the presence of a VMT fee, the fuel tax must be removed from the price per gallon. In this study, both the state and federal tax in Nevada are being considered. Equation (3.4) shows the calculation of the price per mile with the VMT fee added and the state and federal fuel taxes removed. This equation allows for easily changing the VMT fee to conduct sensitivity analysis.

Other variables were created to account for households owning various types of vehicles and vehicles with different fuel efficiencies. SUB1 is an indicator variable that takes the value ‘one’ if the household owns more than one type of vehicle, such as car, truck, van; otherwise, it takes on the value ‘zero’. Similarly, SUB2 is an indicator variable that takes the value ‘one’ if there is a vehicle in the household with 0.5 MPG additional efficiency relative to all the other vehicles in the household.

$$Avg Household VMT \frac{Price}{mile} = \left( \sum_{n=1}^N \frac{Mn}{M} \times \frac{\left(\left(\frac{Cost}{Gallon}\right) - State Tax - Federal Tax\right)_n}{\left(\frac{Miles}{Gallon}\right)_n} \right) + VMT \quad (3.4)$$

Other indicator variables in the model include: URBRUR, which takes the value ‘one’ for an urban household location, and ‘zero’ for rural; and HYBRID, which takes the value ‘one’ for households with hybrid vehicles, and ‘zero’ otherwise.

Other variables include: The logarithm of the household’s income, LOGINCA; The logarithm of the number of household vehicles, VEH; The logarithm of the calculated household

price/mile, LOGPMT; The number of household workers, WRKCOUNT; The total number of people in the household, HHSIZE; and the population per square mile for the household based on tract level housing, HTPPOPDN.

Interaction variables are created to show the interdependencies between an increase in price per mile and SUB1, SUB2, presence of hybrids, and household income. These interaction variables help explain household behavior relative to fluctuations in fuel price. Variable PSUB1 is the product of the LOGPMT and SUB1. Similarly, PSUB2 is the product of the LOGPMT and SUB2. HINC and PINC are the product of LOGPMT with HYBRID and LOGINCA, respectively.

Limitations exist with using a linear relationship to estimate household miles traveled. Traditionally, fuel usage with respect to fuel prices has been nearly inelastic. Hence, a change in fuel price will not necessarily result in a change in fuel usage. However, consumer behavior analysis (Li, 2011) determined increasing the fuel tax to be an effective method to reduce miles traveled. Variations in fuel prices are often seen as temporary, but the analysis showed consumers are more likely to see an increase in the fuel tax as permanent, which would lead consumers to reduce their mileage by decreasing their fuel usage. Because a VMT Fee represents a permanent change, a reduction in miles traveled could be a result of the change, making a linear relationship an appropriate choice. Another limitation represents the complete deterministic approach to developing the model. The presence of a stochastic element would help account for the probability of drivers reducing their mileage with the given changes. However this data was not available in the NHTS data set and therefore was not included in the development of the model.

### 3.2.2 Nevada Only Model

In the 2009 NHTS data, there are 249 responding households from Nevada. Missing information from some households, mostly price of fuel and household VMT, left only 235

complete observations. With this data, a linear regression model was estimated using Ordinary Least Squares. The best model specification, assuming a level of significance equal to 0.10, is denoted by Equation (3.5):

$$LN(\text{Annual VMT}) = f(LN(PMT), LN(VEH), WRKCOUNT, SUB1, PSUB1, HYBRID, HINC, HTPPOPDN) \quad (3.5)$$

This model does not include some variables that intuitively are expected to have an effect on annual household miles traveled. For example, the model does not include household income, urban or rural household location, and size of the household. In addition, the overall fit of the model seems weak, with the adjusted R-squared equal to 0.49. Missing expected variables coupled with a weak model fit suggest the need for further model development and additional data collection.

The sample size was increased by including additional households from U.S. Census Division 8. Each of the states in this census division (Nevada, Arizona, Utah, Colorado, Idaho, Montana, Wyoming, New Mexico) have population densities well below the national average. As a general rule, VMT increases with a decrease in population density, largely due to less walkability and reduced availability of transit. The metropolitan areas in these states all have similar population densities, suggesting that using data from these states is permissible. However, not all of the metropolitan areas from the added states have the same characteristics as the areas in Nevada. Any observation in an area with access to rail transit was removed because Nevada has no rail transit.

In addition, the U.S. Census Bureau's Metropolitan Statistical Area (MSA) was used to match the remaining metropolitan areas to those in Nevada. Considering the characteristics of the metropolitan areas in Nevada, the NHTS observations from other states used in this study have MSAs for populations between 1,000,000-2,999,999 without rail, between 250,000-499,999 without rail, and areas that do not fall into an MSA due to low population density and economic activity.

### 3.2.3 Full Model

With 1,106 additional households from the matching MSAs, the total number of observations increased to 1,341. A new regression model was estimated using all these data. The new model contains 12 explanatory variables. One variable present in the initial model but missing in the new model is SUB1. However, the new model includes new important variables, such as household income, urban/rural location, and household size. The new model has an adjusted R<sup>2</sup> value of 0.65 and a Durbin-Watson statistic of 2.01; this suggests that the model is not auto-correlated. Table 4 provides the coefficients, t-statistics and p-values for the best model specification.

**Table 4-Model Statistics**

Variable	Model Descriptive Statistics		
	Coefficient	t-statistic	P-Value
<b>Constant</b>	14.82	24.519	0.0000
<b>LOGPMT</b>	-2.29	-10.601	0.0000
<b>LOGINCA</b>	-0.50	-1.743	0.0814
<b>LOGVEH</b>	0.72	17.605	0.0000
<b>URBRUR</b>	-0.13	-3.983	0.0001
<b>WRKCOUNT</b>	0.11	6.170	0.0000
<b>SUB2</b>	-2.68	-6.854	0.0000
<b>PINC</b>	0.25	2.403	0.0163
<b>PSUB2</b>	1.05	7.466	0.0000
<b>HYBRID</b>	-1.04	-1.569	0.1166
<b>HINC</b>	0.42	1.697	0.0897
<b>HHSIZE</b>	0.07	6.493	0.0000
<b>HTPPOPDN</b>	-0.00003	-6.132	0.0000

The estimated coefficients have the expected signs, with the exception of LOGINCA. A negative sign for income implies that households drive less with increasing income. This can be a consequence of demanding schedules and the ability to work from home for some high-income households. In contrast, LOGPMT has an expected negative sign, since increasing price per mile

will result in less driving. Location variables URBRUR and HTPPOPDN have negative signs, suggesting that urban households and dense population areas drive less than their counterparts.

The indicator variables SUB2 and HYBRID have negative coefficients, implying that households with fuel-efficient vehicles drive less. However, this can be counterintuitive; people with money and the attitude that has them buy fuel-efficient vehicles also may be energy and environmentally conscious. They may try to drive less in order to save energy and produce fewer emissions.

PINC, the interaction between LOGPMT and LOGINCA, is positive indicating that increasing price to drive has less effect as household income increases. Similarly, the positive sign for LOGVEH, HHSIZE, and WRKCOUNT is expected as an increase in these variables is associated with an increase in driving.

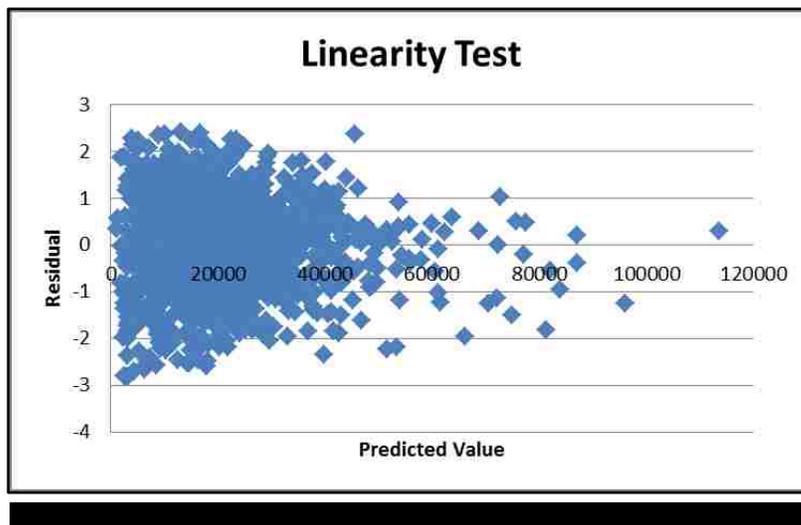
### 3.3 Testing the Model

There are several assumptions for linear regression models, which are often considered to be requirements for a linear model. To ensure that a linear model is appropriate the six assumptions to be checked are:

- i. Linear in parameters – linear relationship with variables
- ii. Zero mean of errors – independence of error terms across all observations ( $E[\varepsilon_i]=0$ )
- iii. Homoscedasticity of errors – error terms do not increase in value as the predicted value increases ( $VAR[\varepsilon_i] = \sigma^2$ )
- iv. Nonautocorrelation of errors – errors are independent across observations ( $COV[X_i, \varepsilon_j] = 0$  if  $i \neq j$ )
- v. Uncorrelated regressors and errors – exogeneity of regressors, implies values of regressors are influenced from ‘outside of the model’ - ( $COV [X_i, \varepsilon_j] = 0$  for all  $i$  and  $j$ )
- vi. Normality of errors – errors are normally distributed ( $\varepsilon_i \approx N(0, \sigma^2)$ )

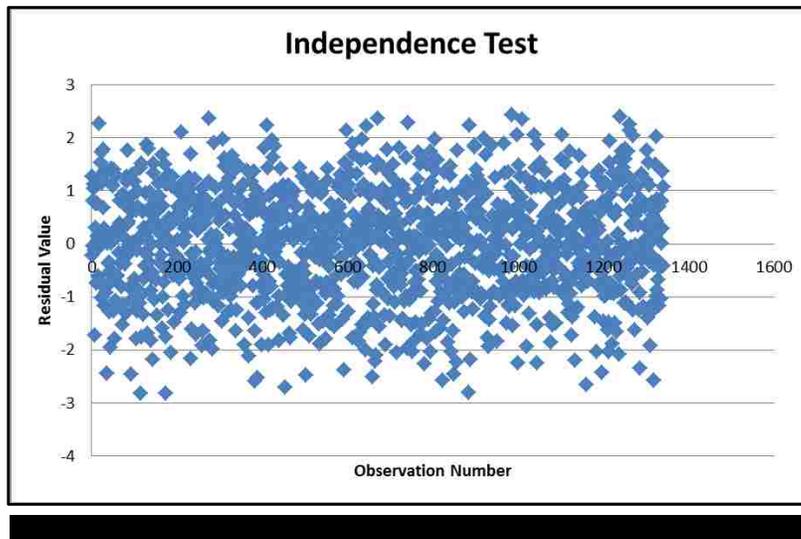
### 3.3.1 Linearity Assumption

Checking the linearity assumption often requires multiple plots. The primary method requires a plot of the fitted (predicted) values on the x-axis and the residuals (error terms) on the y-axis. If the assumption holds the plot will lack any gross nonlinear shape. Figure 7 shows the linearity plot for the Full model. For this model there is no obvious nonlinear shape and the residuals are generally evenly distributed around zero. In the case the assumption does not hold, each individual variable must be checked for linearity as well. A plot of each independent variable on the x-axis versus the residuals on the y-axis will help show which variable or variables may be incorrectly assumed linear. Because the predicted value test for linearity holds, testing each individual variable is not necessary. However, linearity plots for each independent variable can be found in the Linearity Appendix.



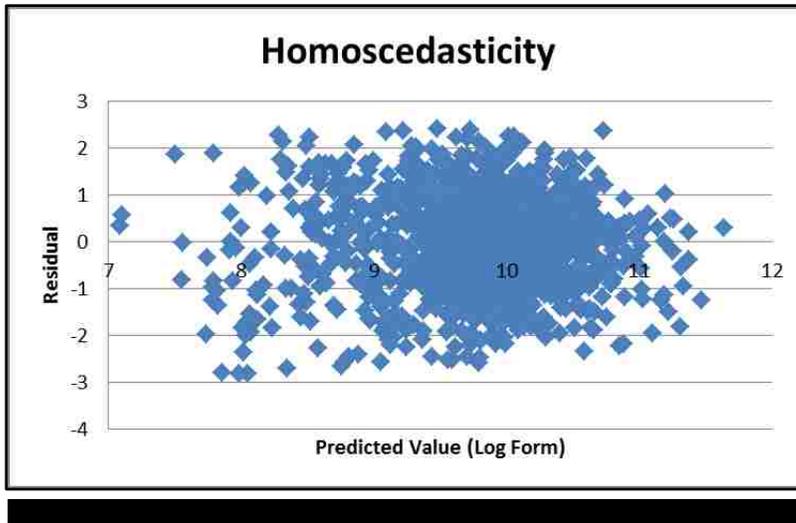
### 3.3.2 Independence Test

A check of the independence of the errors requires only a plot of the error term for each observation. Figure 8 shows the error terms are evenly distributed around zero and there is no gross nonlinear trend. Therefore the errors are independent and a linear model is appropriate.



### 3.3.3 Homoscedasticity

Checking for homoscedasticity requires the same plot as the initial check for linearity, plotting the predicted values versus the error terms. For homoscedasticity the check requires looking at the variance of the error terms as the predicted value increases. If the model is homoscedastic the variance of the error terms will not increase as the predicted values increase. Figure 9 shows the actual predicted value versus the error terms. The variance is evenly distributed around zero and consistent from lower to higher predicted values.



### 3.3.4 Nonautocorrelation of Regressors

Nonautocorrelation of regressors is tested with the Durbin-Watson statistic. This statistic detects the presence of autocorrelation, the relationship between values separated from each other by a given time lag, in the error terms of a regression analysis. The value is calculated from equation 3.6;

$$d = \sum_{t=2}^T \frac{(e_t - e_{t-1})^2}{\sum_{t=1}^T e_t^2} \quad (3.6)$$

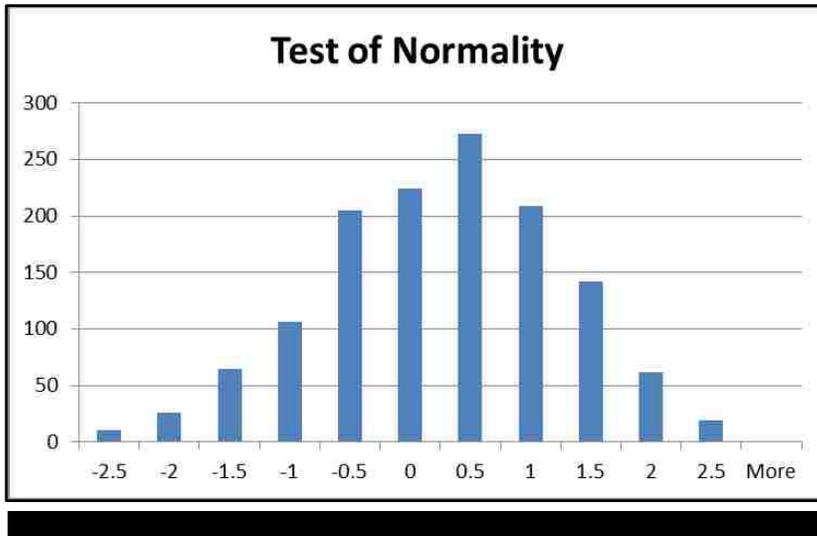
Where 'd' is the statistic, 'e<sub>t</sub>' is the error term for observation 't' and T is the total number of observations. The statistic can take value from 0 to 4, where a value of 2 suggests no autocorrelation. With a statistic equal to 2.01, the error terms in this model are not autocorrelated.

### 3.3.5 Uncorrelated Regressors and Errors

The uncorrelated regressors assumption is often referred to as the exogeneity assumption. Exogenous variables are those that vary independently of other variables in the model. Variables that are determined by factors outside the model are considered endogenous. A model with completely exogenous variables will follow the covariance of variables on the error of the model will be zero ( $COV [X_i, \epsilon_j] = 0$  for all  $i$  and  $j$ ). When the covariance between the variable and the error is zero there is no bias with the least squares estimate, but when the covariance is nonzero (endogenous) there is bias in the estimate. In the estimated model, all of the variables except for the variable HTPPOPDN (population density) variable have near zero covariance values. However, the variance for the variable HTPPOPDN dwarfs the magnitude of the covariance terms. In cases like this the bias resulting from the variable can be neglected.

### 3.3.6 Normality of Errors

Normality of errors, the final check, can be checked using one of four different ways: summary statistics including the first and third quartiles and maximum and minimum values, a histogram of the error terms, normal probability quantile-quantile plots of disturbances, and a chi-squared goodness-of-fit test. With many of the other variables requiring tests using the error terms, it was convenient to use them for the normality test as well. Figure 10 shows a histogram with an approximately normal distribution of the error terms. There is a slight right skew to the model; however it is not so severe that there is a problem with the distribution.



### 3.4 Model Analysis

Analysis of the model is conducted to estimate the VMT Fee in two ways; effectiveness and equity. Effectiveness represents how well the tax works in comparison to the fuel tax. This is mostly measured through the income collected relative to the initial conditions. Equity shows how fair the tax for the people it effects. This will be measured with the change in household miles traveled and the change in household annual cost to drive for different socioeconomic groups.

#### 3.4.1 Mileage Calculation

Annual mileage is calculated for each household for the existing fuel tax system and two ‘revenue neutral’ VMT fee scenarios: (i) a 3.3 cent/mile fee based on recent revenue collection, and (ii) a 2.91 cent/mile calculated from the fuel tax.

Household miles driven for the existing fuel tax system are calculated using the linear regression model with the household characteristics and the original price per mile value. The tax based revenue-neutral fee for passenger cars is calculated using Equation (3.7) as the ratio of the Nevada fuel tax (state maximum) of 55 cents/gallon and the average Nevada fuel efficiency of 18.9 MPG:

$$\text{Tax Based VMT Fee} = \frac{\frac{\text{Fuel Tax}}{\text{Gallon}}}{\frac{\text{Miles}}{\text{Gallon}}} = \frac{55}{18.9} = 2.91 \frac{\text{cents}}{\text{mile}} \quad (3.7)$$

The revenue based fee for passenger cars is calculated from the average revenue from taxable gallons of fuel and the average number of vehicle miles traveled by passenger cars from 2005-2009, shown by Equation (3.8):

$$\text{Revenue Based VMT Fee} = \frac{\text{Average Revenue}}{\text{Average VMT}} = \frac{63,070,615,800}{19,125,332,346} = 3.3 \frac{\text{cents}}{\text{mile}} \quad (3.8)$$

Using Equation (3.4), the price per mile is calculated for each household for both the 3.3 cent/mile fee and the 2.91 cent/mile fee. These price per mile values are used in the linear regression model to calculate the corresponding annual household miles traveled.

#### 3.4.2 Effectiveness

The annual miles estimated using the two VMT fees were compared with the miles corresponding to the fuel tax to determine the change in revenue and total miles traveled. Table 5 shows the calculated mileage and revenue for the fuel tax and the two VMT fees.

Annual miles traveled were calculated as the sum of the miles driven by the households in the data set. Revenue from the VMT fees was calculated using Equation (3.9) as the product of the total miles and the VMT fee.

$$\text{VMT Fee Revenue} = \text{Annual Miles Traveled} \times \text{VMT Fee} \quad (3.9)$$

Total gallons purchased were estimated using Equation (3.10) as the ratio of the total miles traveled by the households in the data set and the Nevada fuel efficiency average of 18.9 MPG.

$$\text{Gallons Purchased} = \frac{\text{Annual Miles Traveled}}{\text{Average Fuel Efficiency}} \quad (3.10)$$

Fuel tax revenue was calculated using Equation (3.11) as the product of the tax per gallon and the number of gallons purchased.

$$\text{Fuel Tax Revenue} = \text{Gallons Purchased} \times \text{Tax Per Gallon} \quad (3.11)$$

Table 5 shows the corresponding amount of miles traveled for the existing Fuel Tax and the two tested VMT fees. The results illustrate that the implementation of a VMT fee reduces the amount of miles traveled relative to the existing conditions (Fuel Tax). Even though the VMT fee of 3.3 cents/mile reduces total miles traveled the most, it is also the most revenue effective.

Both VMT fees show benefit compared to the existing Fuel Tax. A decrease in annual miles traveled could lead to a decrease in congestion, which can result in reduction in travel time and reduced damage to the road, which in turn will extend the life of the pavement. In addition, decreased miles traveled would lead to a decrease in emissions and fuel consumption.

**Table 5-Effectiveness of Tax Methods**

<b>Tax Method</b>	<b>Effectiveness of Tax Methods</b>			
	<b>Annual Miles Traveled</b>	<b>% Change in Miles</b>	<b>Revenue Collected</b>	<b>% Change in Revenue</b>
<b>Fuel Tax</b>	28,858,422	-	\$838,908	-
<b>VMT fee=2.91¢</b>	28,393,464	-1.61	\$826,250	-1.51
<b>VMT fee=3.3¢</b>	27,898,972	-3.32	\$920,666	9.75

### 3.4.3 Equity

Although the 3.3 cent/mile fee is shown to be very effective for the State of Nevada, there are some equity concerns for the citizens. The different socioeconomic aspects that will be used to calculate the equity include level of income, urban versus rural households, different racial groups, different family statuses, and households with fuel efficient vehicles.

Taking the same method used to estimate the 2.91 cent/mile fee and applying it to the 3.3 cent/mile fee generates a theoretical revenue-neutral state average fuel efficiency of 16.7 MPG. Thus, with the 3.3 cent/mile fee, owners of vehicles getting less than 16.7 MPG will see a slight decrease in their price per mile; owners of vehicles getting more than 16.7 MPG will see a slight

increase in their price per mile. This results in significantly more vehicles with an increased price per mile, resulting in an increase in the revenue collected and an average equity loss per household.

In contrast, because the 2.91 cent/mile fee is calculated using the Nevada average fuel efficiency, any negative effects are homogeneously distributed in the population. Because of a slight decrease in miles traveled and collected revenue, a 2.91 cent/mile fee actually provides, on average, a small equity benefit. The impact of the two VMT fees at the household-level (HH) are estimated in Table 6.

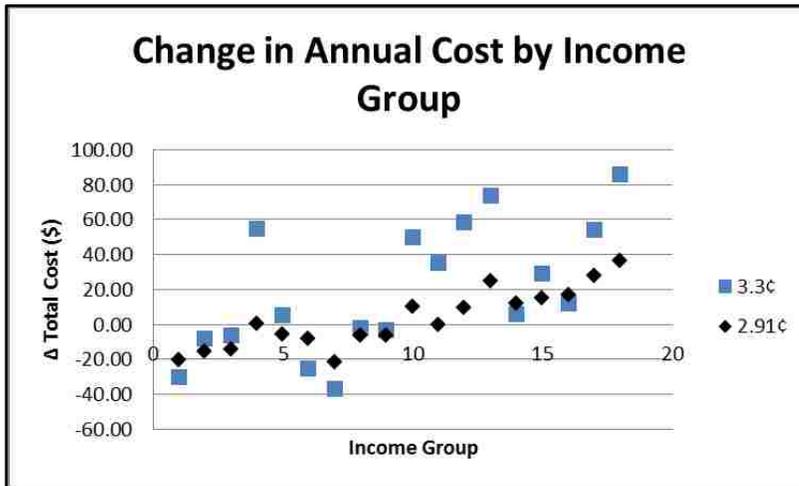
When analyzing the impact of the VMT fee at the household level, the 3.3 cent/mile fee results in a greater number of households with an increased tax burden. The 3.3 cent/mile fee results in 71.1% of the households having an increase in their tax burden; in contrast, the 2.91 cent/mile fee results in 59.1% of households with an increased tax burden. Both scenarios have households with a decrease or no change in their tax burden. The lesser benefit associated with the 3.3 cent/mile fee is a consequence of the increase in average annual household cost. In the case of the 2.91 cent/mile fee, although overall less revenue is collected, the average household still sees an increased cost. This illustrates the weight households with low average fuel efficiencies have in the sample.

**Table 6-Overall Equity Effects of the VMT Fees**

<b>Equity Effects of VMT Fee</b>				
<b>VMT Fee</b>	<b>Average Change in HH VMT (Miles)</b>	<b>Average Percent Change in HH VMT</b>	<b>Average Change in HH Annual Cost</b>	<b>Average Percent Change in HH Annual Cost</b>
<b>2.91¢</b>	-346.7	-1.47 %	\$ 9.04	0.18 %
<b>3.30¢</b>	-715.5	-3.53 %	\$ 31.97	0.37 %

## Income Groups

It is important that the VMT Fee not disproportionately affect lower income groups. Figure 11 shows the change in total household annual cost with the 2.91 cent fee and the 3.3 cent fee respectively. Both scenarios show an increasing trend, where higher income groups have a larger increase in annual cost than do lower income groups. The percent change relative to the median income level of each group is less than one tenth of one percent, plus or minus, with the exception of the three lowest income groups. However, for each fee all three of these groups have a decrease in their annual cost.



Despite the benefit for the three lowest income groups from the change in cost, the same is not true for annual miles traveled. The same three income groups have the largest percentage decrease in miles traveled of 4%-5% for the 2.91 cent fee compared to a decrease of 0.5%-3% for the other income groups and a 7%-8% decrease for the 3.3 cent fee compared to a decrease of 2%-6% for the other groups.

## Urban versus Rural Households

A common concern about a VMT Fee is the effect that it will have on rural households. In general, rural households drive more annually than do urban households making a VMT Fee problematic for rural households. However, rural households have, on average, lower fuel efficient vehicles. Table 7 shows the comparison between urban and rural households. Under both fees rural households see a much larger decrease in annual miles traveled and a slightly larger increase in annual cost.

**Table 7-Urban versus Rural Effects**

<b>Urban versus Rural Effects</b>				
	<b>2.91 Cent Fee</b>		<b>3.3 Cent Fee</b>	
	<b>Average Change in HH VMT (Miles)</b>	<b>Average Change in HH Annual Cost</b>	<b>Average Change in HH VMT (Miles)</b>	<b>Average Change in HH Annual Cost</b>
<b>Urban</b>	-31.03	\$3.04	-228.35	\$22.63
<b>Rural</b>	-375.85	\$7.87	-747.89	\$30.32

## Racial Groups

Analysis in the Weatherford model showed concern for the effects of a VMT Fee on different racial groups. Specifically, Asian households had the most adverse effects with a large increase in their annual cost to drive. Table 8 shows the effects for this model. The average effects for all racial groups are very similar. Each group drives fewer miles each year and has a higher annual cost. As with the Weatherford model, Asian households are affected the most. Although their annual change in miles is not greatly different than other groups, the change in annual cost to drive is more than 50% greater than the next closest group. These effects show Asian households have the highest average fuel efficiency of all the groups.

**Table 8-Racial Impacts**

<b>Racial Impacts of VMT Fee</b>				
<b>Race</b>	<b>2.91 Cent Fee</b>		<b>3.3 Cent Fee</b>	
	<b>Average Change in HH VMT (Miles)</b>	<b>Average Change in HH Annual Cost</b>	<b>Average Change in HH VMT (Miles)</b>	<b>Average Change in HH Annual Cost</b>
<b>White</b>	-346.30	\$8.69	-716.71	\$32.16
<b>African-American</b>	-264.80	\$25.40	-520.39	\$38.92
<b>Asian</b>	-681.47	\$41.01	-1136.33	\$77.34
<b>American Indian, Alaska Native</b>	-551.67	\$6.11	-988.36	\$21.50
<b>Multiracial</b>	-332.26	\$19.86	-730.85	\$51.92
<b>Hispanic/Mexican</b>	-356.43	\$10.12	-709.03	\$24.14
<b>Other</b>	-73.55	\$1.69	-352.83	\$9.75

Family Status

Family status represents the type of family in the household whether it be a single or multiple parent household, if they have children or not, and the age of their youngest child if they have children. It is important to determine the effects on the different kinds of families and determine if some family types are affected worse than others. The average effects are shown in Table 9.

**Table 9-Family Status Effects**

<b>Average Family Type Effects</b>				
<b>Family Type</b>	<b>2.91 Cent Fee</b>		<b>3.3 Cent Fee</b>	
	<b>Average Change in HH VMT (Miles)</b>	<b>Average Change in HH Annual Cost</b>	<b>Average Change in HH VMT (Miles)</b>	<b>Average Change in HH Annual Cost</b>
<b>1 Adult, No Children</b>	-674.35	-\$32.07	-1036.18	-\$37.95
<b>2+ Adults, No Children</b>	-375.46	\$21.07	-756.87	\$56.90
<b>1 Adult, Youngest Child 0-5</b>	-1483.17	-\$87.43	-2090.15	-\$129.97
<b>2+ Adults, Youngest Child 0-5</b>	-372.02	\$17.99	-776.34	\$47.35

<b>1 Adult, Youngest Child 6-15</b>	-692.06	\$6.42	-1076.57	\$6.88
<b>2+ Adults, Youngest Child 6-15</b>	-407.67	\$30.04	-872.10	\$74.13
<b>1 Adult, Youngest Child 15-21</b>	-805.41	\$7.82	-1227.70	\$17.27
<b>2+ Adults, Youngest Child 15-21</b>	-327.61	\$39.04	-831.65	\$86.96
<b>1 Adult, Retired, No Children</b>	-315.74	-\$12.31	-580.90	-\$23.30
<b>2+ Adults, Retired, No Children</b>	-170.17	-\$0.31	-479.35	\$16.48

The average effects show all family types driving less under the VMT Fees, with many of them paying more as well. Households with no children, specifically those with only one adult receive a large benefit by paying less to drive. Retired households have small changes in both miles traveled and annual cost, making them the least effected by either VMT Fee. Single parent households have the largest loss in mobility, especially compared to multiple parent households with their youngest child the same age. Comparatively, single parent households have a larger decrease in miles traveled but a smaller change in annual cost. This is likely a result of multiple parent households driving more than single parent households.

#### Fuel Efficient Vehicles

The tax based fee is calculated using the state fuel tax and average state fuel efficiency, creating a break even fuel efficiency level with a net gain for households with average fuel efficiency below the state average and a net loss for households with average fuel efficiency above the state average. In the model, households with at least two vehicles and one of which is at least 0.5 MPG more efficient than the other were considered to have a fuel efficient substitute vehicle.

**Table 10-Owning More Fuel Efficient Vehicle**

Presence of a More Fuel Efficient Vehicle	Effects of Owning a More Fuel Efficient Vehicle			
	2.91 Cent Fee		3.3 Cent Fee	
	Average Change in HH VMT (Miles)	Average Change in HH Annual Cost	Average Change in HH VMT (Miles)	Average Change in HH Annual Cost
No	-611.9	\$-29.15	-971.6	\$-52.86
Yes	-276.7	\$19.11	-647.9	\$54.36

Households with hybrid vehicles, in particular, would be affected by a VMT fee. The high-fuel-efficiency vehicles, requiring less purchased fuel, pay less fuel taxes. With the 2.91 cent/mile fee, households would not experience a significant difference because this fee is designed to be revenue-neutral. Hybrid owners with this fee would travel an average of 518 fewer miles a year and spend an average of 48 dollars more to drive per year. A 3.3 cent/mile fee would result in an average of 721 fewer miles driven and an increase of 127 dollars in travel expenditures per year.

Although these owners would pay more for driving less, the VMT fee system would provide more revenue for the state. The system would require hybrid owners to pay the same amount to drive as all other vehicles. As the primary reasons for purchasing hybrid vehicles are for their high average fuel efficiency and the resulting reduction in harmful emissions, a VMT Fee should not affect the incentive for purchasing these vehicles. At current fuel costs near \$4/gallon a 2012 Toyota Prius traveling 15,000 miles annually would pay about \$1200/year based on its combined fuel economy of 50 miles/gallon. Conversely, a Nevada vehicle with average fuel economy, 18.9 miles/gallon, would pay over \$3100/year in fuel costs, showing the sizeable benefit of driving a hybrid vehicle.

The 2009 NHTS data does not include data for households with electric vehicles. Hence, an analysis for this type of household is not provided.

### 3.5 Conclusion

The linear regression model developed in this study provides a mechanism to estimate changes on miles driven as consequence of different methods and rates to charge for the use of the highway system. Suggested transportation tax policy changes can be analyzed with the developed model, saving time and money while providing sound insights. The results in this study show a 3.3 cent/mile fee to be more effective than both the existing fuel tax and the 2.91 cent/mile fee, producing for the sample used in this study 9.71% additional revenue than the fuel tax system. It also shows the 3.3 cent/mile fee to be the least equitable, with 71.1% of households experiencing an increase in their tax burden. However, the 3.3 cent/mile fee results only in a 0.37% average annual cost increase per household. Overall, the analysis shows that the 3.3 cent/mile VMT Fee is sufficient to meet current and future revenue needs.

Also, the truck VMT in Nevada is around 2.1 billion in addition to the 19.15 billion passenger vehicles VMT. The impact of the truck VMT should be included in the analysis when determining a rate. Using the same method for developing the 3.3 cent VMT Fee semi-truck VMT Fee would be approximately 9 cents mile. A more complete analysis would include both passenger cars and semi-trucks, but a separate model would need to be estimated for semi-trucks.

The approach used in this study can be used as a framework for future studies in other states. Future analysis can consider impacts on congestion, travel times, and the potential savings from the decrease in emissions. Quantifying these impacts in financial terms will provide a comprehensive approach to evaluate the broad consequences of deploying a VMT fee system.

## CHAPTER 4 CONCLUSIONS AND RECOMMENDATIONS

Loss of revenue from the fuel tax is of growing concern. In-action to remedy this loss will create negative effects on roadways and highways that will inevitably fall into disrepair and become increasingly congested. Any policy intended to alleviate the issues with the existing fuel tax system must be properly vetted before an attempt to implement a solution. The analysis provided in this study represents a thorough vetting of a VMT Fee for Nevada.

This study determined the important characteristics of a VMT Fee based on users' perceptions and attitudes. A discrete choice modeling approach was used to evaluate various alternatives for deployment. The analysis determined users were not completely comfortable with the prospect of having a device installed in their vehicles to collect mileage, nor were they unconcerned with the potential cost required to fully implement a VMT Fee system, therefore a monthly bill is recommended to aid these problems. A monthly bill is recommended because it has the highest probability of all the alternatives and would provide the simplest option to budget for. This option would allow for a VMT Fee to be gradually introduced by allowing users to opt-in, while keeping initial costs low.

The economic analysis of two VMT Fees shows using a 3.3 cent/gallon fee to be the most effective, collecting more revenue and causing a decrease in annual miles traveled compared to the fuel tax. Although designed to be revenue neutral, this fee collects almost 10% more revenue than the fuel tax. This additional revenue will help alleviate budget shortfalls in current and future NDOT budgets helping provide resources for congestion relief and provide necessary revenue to account for the cost of implementing a pay-at-the pump system. Results about the equity analysis showed a wide range of effects; however, overall changes in annual cost represented a small change in the household's tax burden. The 3.3 cent/mile fee provides additional revenue without adversely affecting road users, establishing a VMT Fee as a legitimate alternative for collecting revenue for roads and highways.

The discrete choice modeling approach is data intensive; stronger models could be developed with more data. The same could be said for the linear regression model, as more households for Nevada would greatly improve the accuracy of the model. Further analysis of the linear regression model could include assessing the different VMT Fee options outlined including a dual fee system with different fees for different vehicle types and a multiple fee system with different fees based on vehicle fuel efficiency. Assessing those alternatives might show an equally effective option with lower equity concerns.

At current, a fully implemented VMT Fee system is not recommended. More public outreach and testing of mileage collection technology are needed to ease comfort concerns. Furthermore, the cost for full implementation is too high. Partial implementation with a mileage audit paid through a monthly bill could be implemented for alternative fuel vehicles and allow for regular fuel users to opt in if desired. Implementing a VMT Fee system in this manner will help capture revenue lost from alternative fuel vehicles and provide a small scale foundation for larger implementation in the future.

## **Appendix**

## Appendix 1: Vehicle Miles of Travel (VMT) Fee Survey

The Nevada Department of Transportation (NDOT) is currently researching a VMT Fee as a funding mechanism to replace the existing fuel tax and provide a viable funding source for our future transportation needs. The existing fuel tax system is affected by three important characteristics: electric and hybrid vehicles are not paying their fair share for road usage because they purchase significantly less or even no fuel thus paying little or no road usage tax, the current fuel tax has not been increased since 1993 and has lost purchasing power due to inflation, and the Corporate Average Fleet Economy, average combined fuel economy of all of an auto-makers production vehicles, is projected to increase up to 40% by 2016 causing further attrition of transportation revenue. A field test is to be conducted with a simple pay at-the-pump system. The system will read the mileage data at the pump and assess the mileage fee from an on-board-unit, which will only keep track of total miles traveled. In order to reduce collection and administration costs and privacy concerns, the study will explore the option of billing drivers for their VMT fee on an annual, bi-annual, or monthly basis, which could be very good for electric vehicles not going to the pump.

You are being asked to participate in this research study as a Nevada driver to provide your opinion of VMT and how you feel it would affect you. This study will help determine if a VMT Fee system is publically supported and what effects it would have. This survey is 19 questions long and should take 5-10 minutes to complete. You may skip any question you feel uncomfortable with. All information gathered in this study will be kept confidential and no reference will be made in written or oral materials that could link you to this study. By completing this survey you agree to participate in this research study and that you are 18 years of age.

If you have questions or concerns about the research study you may contact:

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If you have questions regarding the rights of research subjects, any complaints or comments regarding the manner in which the study is being conducted you may contact:

### **UNLV Office of Research Integrity – Human Subjects**

702-895-2794

877-895-2794 (Toll Free)

[IRB@unlv.edu](mailto:IRB@unlv.edu)

**Demographic Questions**

**1. Gender**

- a. Male                      b. Female

**2. Age**

- a. less than 18                      b. 18-24                      c. 25-34                      d. 35-44  
e. 45-54                      f. 55-64                      g. 65 and over

**3. Level of Education**

- a. High School or Less    b. Some College    c. College Graduate    d. Masters Degree    e. Ph.D.

**4. What is your total household income?**

- a. Less than \$30,000    b. \$30,000-\$59,999    c. \$60,000-\$99,999    d. \$100,000-\$149,999    e. \$150,000-\$249,999    f. \$250,000 or more

**5. What is the size of your household (number of people)? \_\_\_\_\_**

**6. On average, estimate how many miles you, yourself, drive a day?**

- a. 20 or less    b. 21-40    c. 41-60    d. 61-80    e. 81-100    f. More than 100

**7. What is the estimated average fuel economy, miles per gallon (mpg), of your vehicle?**

- a. Less than 10    b. 10-15    c. 16-20    d. 21-25    e. 26-30    f. 31-35    g. More than 35    h. N/A

**8. On average how many total peak period (7-9 AM, 4-6 PM) trips do you make a day?**

- a. 0 times a day    b. 1-2 times a day    c. 3-4 times a day    d. 5 or more times a day

**9. If you own a vehicle, what is the year and model of the vehicle?**

- a. Year \_\_\_\_\_    b. Model \_\_\_\_\_    c. Don't Own \_\_\_\_\_

**10. How often do you use transit (public transportation)?**

- a. Never \_\_\_\_\_    b. Once a week \_\_\_\_\_    c. 2-4 times a week \_\_\_\_\_    d. Every day \_\_\_\_\_

**11. On an average day, how often do you reveal personal information such as where you go and who you meet publicly accessible on social media such as Facebook and Twitter?**

- a. 0 times a day    b. 1-2 times a day    c. 3-4 times a day    d. 5 or more times a day

**12. Have you ever been involved in a traffic accident?**

No \_\_\_\_\_ Yes \_\_\_\_\_

- If yes, what type? a. injury only    b. property damage only    c. fatality

**13. Have been involved in a traffic accident in the last year?**

No \_\_\_\_\_ Yes \_\_\_\_\_

- If yes, what type? a. injury only    b. property damage only    c. fatality

**VMT Questions**

- 14. Prior to reading the introduction, what was your familiarity with a Vehicle Miles Travel (VMT) fee system?**  
a. Not Familiar                      b. Somewhat Familiar                      c. Very Familiar                      d. N/A
- 15. Rank the following VMT components based on personal importance from 1-5 (Five (5) being most important, one (1) being least important):**  
a. Ease of Use                      b. Reliability                      c. Transparency                      d. Convenience                      e. Privacy  
\_\_\_\_\_                      \_\_\_\_\_                      \_\_\_\_\_                      \_\_\_\_\_                      \_\_\_\_\_
- 16. The emphasis of the field test will be on a simple pay-at-the pump system. The system will read the change in odometer miles at each pump visit, and apply an established rate, without tracking vehicle location. What is your level of comfort with this system?**  
a. Very Comfortable                      b. Somewhat Comfortable                      c. Neutral                      d. Somewhat Uncomfortable                      e. Very Uncomfortable
- 17. What is your level of concern over the cost of implementing a replacement system of the fuel tax system?**  
a. Very Concerned                      b. Somewhat Concerned                      c. Neutral                      d. Somewhat Unconcerned                      e. Very Unconcerned
- 18. To minimize privacy concerns, cost of collection, cost of administration, and fraud and evasion of revenues, instead of paying at the pump would you be willing to pay the VMT fee (fuel tax) on any the following bases?**  
a. Annually                      b. Bi-Annually                      c. Quarterly                      d. Monthly                      e. N/A
- 19. How would a VMT fee affect your use of a transit system (bus, rail, etc.)?**  
a. Significantly More Use                      b. Somewhat More Use                      c. Neutral                      d. Somewhat Less Use                      e. Significantly Less Use

## Appendix 2: Logit Model Outputs

### A.2.1 Billing Cycle – Full Model

```

--> nlogit; lhs=LOGBILL; choices=monthly, quarter, b_annual, annual;
model:
u(monthly)= month*one + small1*SMALL + lowedu1*LOWEDU + hm*HM/
u(quarter) = 0*one + small3*SMALL + lowedu2*LOWEDU + lowinc1*LOWINC/
u(b_annual) = b_ann*one + small3*SMALL + lowedu1*LOWEDU + lowinc2*LOWINC...
u(annual) = annu*one + lowinc1*LOWINC$
normal exit from iterations. Exit status=0.

```

---

```

Discrete choice (multinomial logit) model
Maximum Likelihood Estimates
Model estimated: May 02, 2012 at 11:38:17AM.
Dependent variable           Choice
Weighting variable           None
Number of observations        151
Iterations completed          5
Log likelihood function       -174.1083
Log-L for Choice model =     -174.10833
R2=1-LogL/LogL*   Log-L fncn  R-sqrd  RsqAdj
No coefficients   -209.3304   .16826   .14949
Constants only   -185.7907   .06288   .04173
Chi-squared[ 7]   =   23.36472
Prob [ chi squared > value ] = .00147
Response data are given as ind. choice.
Number of obs.= 151, skipped 0 bad obs.

```

---

Variable	Coefficient	Standard Error	b/St. Er.	P[ Z >z]
MONTH	1.164683362	.39825208	2.924	.0035
SMALL1	-1.440358765	.47614030	-3.025	.0025
LOWEDU1	-.9447922658	.45726565	-2.066	.0388
HM	.8384479356	.45007836	1.863	.0625
SMALL3	-.9478289821	.51622888	-1.836	.0663
LOWEDU2	-1.575328456	.60724482	-2.594	.0095
LOWINC1	.5061129354	.36605564	1.383	.1668
B_ANN	-1.152459345	.56976354	-2.023	.0431
LOWINC2	1.080538709	.63267259	1.708	.0877
ANNU	-.8531034621	.51018315	-1.672	.0945

## A.2.2 Cost Concern – Full Model

```
--> nlogit; lhs=CODE; choices=CVN, CSN, CSY, CVY;
      model;
      u(CVN) = CVN*one+ small11*SMALL + young*YOUNG/
      u(CSN) = CSN*one+ small12*SMALL + gender1*GENDER + lowedu1*LOWEDU/
      u(CSY) = 0*one+ small2*SMALL + know*KNOW/
      u(CVY) = CVY*one$
Normal exit from iterations. Exit status=0.
```

```
-----+-----+
Discrete choice (multinomial logit) model
Maximum Likelihood Estimates
Model estimated: Apr 21, 2012 at 04:58:51PM.
Dependent variable           Choice
Weighting variable           None
Number of observations       120
Iterations completed         6
Log likelihood function      -128.8973
Log-L for choice model =    -128.89726
R2=1-LogL/LogL* Log-L fncn  R-sqrd  RsqAdj
No coefficients             -166.3553  .22517  .20530
Constants only              -141.5791  .08957  .06623
Chi-squared[ 6]            = 25.36368
Prob [ chi squared > value ] = .00029
Response data are given as ind. choice.
Number of obs.= 120, skipped 0 bad obs.
-----+-----+

```

Variable	Coefficient	Standard Error	b/St. Er.	P[ Z >z]
CVN	.9648522420	.44422056	2.172	.0299
SMALL1	-1.961742300	1.1427120	-1.717	.0860
YOUNG	-.7734320474	.42913598	-1.802	.0715
CSN	1.032706938	.38733118	2.666	.0077
SMALL2	-1.624975623	1.1273242	-1.441	.1495
GENDER1	-1.433533716	.41603632	-3.446	.0006
LOWEDU1	.8664519556	.42811289	2.024	.0430
KNOW	-.9994381536	.60609451	-1.649	.0992
CVY	-2.605491010	1.0436197	-2.497	.0125

### A.2.3 Car Chip – Full Model

```

--> nlogit; lhs=MCODE; choices=CCVY, CCSY, CCSN, CCVN;
model:
u(CCVY) = CCVY*one + lowinc*LOWINC /
u(CCSY) = 0*one/
u(CCSN) = 0*one+ small12*SMALL + p3*PRIVATE + know*KNOW/
u(CCVN) = CCVN*one + small12*SMALL + p3*PRIVATE + know*KNOW$
Normal exit from iterations. Exit status=0.

```

```

+-----+
| Discrete choice (multinomial logit) model |
| Maximum Likelihood Estimates              |
| Model estimated: May 02, 2012 at 02:06:04PM. |
| Dependent variable                       Choice |
| Weighting variable                       None   |
| Number of observations                    122   |
| Iterations completed                      6     |
| Log likelihood function                   -154.8700 |
| Log-L for choice model =                 -154.87000 |
| R2=1-LogL/LogL* Log-L fncn R-sqrd RsqAdj |
| No coefficients -169.1279 .08430 .06904 |
| Constants only -162.2586 .04554 .02963 |
| Response data are given as ind. choice. |
| Number of obs.= 122, skipped 0 bad obs. |
+-----+

```

Variable	Coefficient	Standard Error	b/St.Er.	P[ z >z]
CCVY	-1.480611185	.53283489	-2.779	.0055
LOWINC	1.021997320	.61585217	1.659	.0970
SMALL2	-.8681253703	.33343413	-2.604	.0092
P3	.8605936625	.37542287	2.292	.0219
KNOW	.8838758469	.39366639	2.245	.0248
CCVN	-.3919194255	.23672205	-1.656	.0978

## A.2.4 Billing Cycle – IIA Model

```

--> nlogit; lhs=LOGBILL; choices=M, A;
model;
u(M)= 0*one + small1*SMALL + lowedu1*LOWEDU + hm*HM/
u(A) = annu*one$
Normal exit from iterations. Exit status=0.

```

Discrete choice (multinomial logit) model				
Maximum Likelihood Estimates				
Model estimated: May 03, 2012 at 10:24:14AM.				
Dependent variable	Choice			
Weighting variable	None			
Number of observations	109			
Iterations completed	5			
Log likelihood function	-61.33053			
Log-L for choice model =	-61.33053			
R2=1-LogL/LogL*	Log-L fncn	R-sqrd	RsqAdj	
No coefficients	-75.5530	.18825	.15732	
Constants only	-69.1467	.11304	.07925	
Chi-squared[ 3]	= 15.63234			
Prob [ chi squared > value ] =	.00135			
Response data are given as ind. choice.				
Number of obs.= 109, skipped 0 bad obs.				

Variable	Coefficient	Standard Error	b/St.Er.	P[ Z >z]
SMALL1	-1.478535788	.48217964	-3.066	.0022
LOWEDU1	-1.064202913	.47906558	-2.221	.0263
HM	1.097257019	.62733250	1.749	.0803
ANNU	-1.761157634	.46317168	-3.802	.0001

### A.2.5 Cost Concern – IIA Model

```
--> nlogit; lhs=MCODE; choices= CSN, CSY;
model:
u(CSN) = CSN*one + gender1*GENDER + lowedu1*LOWEDU/
u(CSY) = 0*one + know*KNOW; PrintVC$
Normal exit from iterations. Exit status=0.
```

```
Discrete choice (multinomial logit) model
Maximum Likelihood Estimates
Model estimated: May 03, 2012 at 00:33:52PM.
Dependent variable          Choice
Weighting variable          None
Number of observations      71
Iterations completed        6
Log likelihood function     -33.44742
Log-L for Choice model =   -33.44742
R2=1-LogL/LogL* Log-L fncn  R-sqrd  RsqAdj
No coefficients             -49.2134  .32036  .27978
Constants only              -42.2125  .20764  .16034
Chi-squared[ 3]            = 17.53019
Prob [ chi squared > value ] = .00055
Response data are given as ind. choice.
Number of obs.= 71, skipped 0 bad obs.
```

Variable	Coefficient	Standard Error	b/St.Er.	P[ Z >z]
CSN	.9630605139	.48765104	1.975	.0483
GENDER1	-2.403368479	.76653186	-3.135	.0017
LOWEDU1	1.985696403	.75516894	2.629	.0086
KNOW	-1.764238401	.80197248	-2.200	.0278

## A.2.6 Car Chip – IIA Model

```

--> nlogit; lhs=MCODE; choices=CCSY, CCSN;
      model:
      u(CCSY) = 0*one/
      u(CCSN) = 0*one + s*SMALL + p*PRIVATE + k*KNOW$
Normal exit from iterations. Exit status=0.

```

```

+-----+
| Discrete choice (multinomial logit) model |
| Maximum Likelihood Estimates              |
| Model estimated: May 05, 2012 at 11:03:37AM. |
| Dependent variable                       | choice |
| weighting variable                       | None   |
| Number of observations                    | 78     |
| Iterations completed                      | 5      |
| Log likelihood function                   | -48.62554 |
| Log-L for Choice model =                 | -48.62554 |
| R2=1-LogL/LogL* Log-L fncn R-sqrd RsqAdj |
| No coefficients                          | -54.0655 | .10062 | .06464 |
| Constants only                           | -53.6545 | .09373 | .05748 |
| Response data are given as ind. choice.  |
| Number of obs.= 78, skipped 0 bad obs.  |
+-----+

```

Variable	Coefficient	Standard Error	b/St.Er.	P[ Z >z]
S	-.9084227884	.41722830	-2.177	.0295
P	.8204106565	.49672424	1.652	.0986
K	1.248293519	.49157100	2.539	.0111

Appendix 3: Utility Tables

A.3.1 Billing Cycle Matrix

<b>Billing Cycle Utility Matrix</b>									
<b>SMALL</b>	<b>LOWEDU</b>	0	1	0	0	1	1	0	1
	<b>HM</b>	0	0	1	0	1	0	1	1
	<b>LOWINC</b>	0	0	0	1	0	1	1	1
0	Monthly	1.165	0.22	2.003	1.165	1.058	0.22	2.003	1.058
	Quarterly	0	-1.58	0	0.506	-1.58	-1.074	0.506	-1.074
	Bi-Annually	-1.15	-2.095	-1.15	-0.07	-2.095	-1.015	-0.07	-1.015
	Annually	-0.853	-0.853	-0.853	0.227	-0.853	0.227	0.227	0.227
1	Monthly	-0.275	-1.22	0.563	-0.275	-0.382	-1.22	0.563	-0.382
	Quarterly	-0.945	-2.525	-0.945	-0.439	-2.525	-2.019	-0.439	-2.019
	Bi-Annually	-2.1	-3.045	-2.1	-1.02	-3.045	-1.965	-1.02	-1.965
	Annually	-0.853	-0.853	-0.853	0.227	-0.853	0.227	0.227	0.227



### A.3.2 Car Chip Utility Matrix

Car Chip Utility Matrix									
SMALL	LOWINC	0	1	0	0	1	1	0	1
	PRIVACY	0	0	1	0	1	0	1	1
	KNOW	0	0	0	1	0	1	1	1
0	CCVU	-1.481	-0.459	-1.481	-1.481	-0.459	-0.459	-1.481	-0.459
	CCSU	0	0	0	0	0	0	0	0
	CCSC	0	0	0.861	0.884	0.861	0.884	1.745	1.745
	CCVC	-0.392	-0.392	0.469	0.492	0.469	0.492	1.353	1.353
1	CCVU	-1.481	-0.459	-1.481	-1.481	-0.459	-0.459	-1.481	-0.459
	CCSU	0	0	0	0	0	0	0	0
	CCSC	-0.868	-0.868	-0.007	0.016	-0.007	0.016	0.877	0.877
	CCVC	-1.26	-1.26	-0.399	-0.376	-0.399	-0.376	0.485	0.485

Appendix 4: Probability Matrix

A.4.1 Billing Cycle Probability Matrix

<b>Billing Cycle Probability Matrix</b>									
<b>SMALL</b>	<b>LOWEDU</b>	0	1	0	0	1	1	0	1
	<b>HM</b>	0	0	1	0	1	0	1	1
	<b>LOWINC</b>	0	0	0	1	0	1	1	1
0	Monthly	0.648	0.623	0.810	0.455	0.792	0.389	0.658	0.595
	Quarterly	0.202	0.103	0.109	0.235	0.057	0.107	0.147	0.071
	Bi-Annually	0.064	0.061	0.035	0.132	0.034	0.113	0.083	0.075
	Annually	0.086	0.213	0.047	0.178	0.117	0.392	0.111	0.259
1	Monthly	0.448	0.348	0.652	0.252	0.552	0.162	0.437	0.309
	Quarterly	0.229	0.094	0.144	0.213	0.065	0.073	0.161	0.060
	Bi-Annually	0.072	0.056	0.045	0.119	0.038	0.077	0.090	0.063
	Annually	0.251	0.502	0.158	0.416	0.345	0.688	0.312	0.568

### A.4.2 Cost Concern Probability Matrix

Cost Concern Probability Matrix		Probability Matrix															
		0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SMALL	YOUNG	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	
	GENDER	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	
	LOWEDU	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	
	KNOW	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	
0	CVN	0.403	0.238	0.601	0.253	0.447	0.410	0.135	0.271	0.496	0.702	0.269	0.312	0.521	0.145	0.563	
	CSN	0.432	0.551	0.153	0.644	0.478	0.227	0.745	0.629	0.301	0.179	0.685	0.411	0.288	0.802	0.342	
	CSY	0.154	0.196	0.229	0.096	0.063	0.338	0.112	0.083	0.189	0.099	0.038	0.258	0.158	0.044	0.079	
	CVY	0.011	0.015	0.017	0.007	0.013	0.025	0.008	0.017	0.014	0.020	0.008	0.019	0.032	0.009	0.016	
1	CVN	0.309	0.171	0.478	0.189	0.345	0.297	0.097	0.196	0.387	0.570	0.202	0.226	0.380	0.104	0.445	
	CSN	0.464	0.556	0.171	0.673	0.518	0.230	0.749	0.636	0.329	0.204	0.719	0.416	0.294	0.806	0.378	
	CSY	0.165	0.198	0.255	0.101	0.068	0.344	0.112	0.083	0.206	0.112	0.040	0.261	0.162	0.044	0.087	
	CVY	0.062	0.074	0.096	0.038	0.069	0.129	0.042	0.085	0.077	0.114	0.040	0.098	0.165	0.045	0.089	

### A.4.3 Car Chip Probability Matrix

Car Chip Probability Matrix													
SMALL	LOWINC	0	1	0	0	1	1	0	1	1	1	0	1
	PRIVACY	0	0	1	0	1	0	1	1	0	1	1	1
	KNOW	0	0	0	1	0	0	1	0	1	1	1	1
0	CCVU	0.078333	0.191048	0.043806	0.043041	0.112926	0.111095	0.021013	0.111095	0.111095	0.021013	0.056286	0.056286
	CCSU	0.344458	0.302332	0.192629	0.189266	0.178704	0.175807	0.092402	0.175807	0.175807	0.092402	0.089072	0.089072
	CCSC	0.344458	0.302332	0.455668	0.458131	0.42273	0.425551	0.529082	0.425551	0.425551	0.529082	0.510019	0.510019
	CCVC	0.232351	0.204287	0.307897	0.309561	0.28564	0.287547	0.357503	0.28564	0.287547	0.357503	0.344622	0.344622
1	CCVU	0.11777	0.270586	0.07865	0.077611	0.191726	0.1895	0.043273	0.1895	0.1895	0.043273	0.11165	0.11165
	CCSU	0.517905	0.4282	0.34585	0.34128	0.303404	0.299882	0.190285	0.299882	0.299882	0.190285	0.176686	0.176686
	CCSC	0.217412	0.179754	0.343438	0.346785	0.301288	0.304719	0.457385	0.304719	0.304719	0.457385	0.424695	0.424695
	CCVC	0.146906	0.121461	0.252062	0.234324	0.203582	0.2059	0.309057	0.203582	0.2059	0.309057	0.286968	0.286968

Appendix 5: Economic Model Appendix

A.5.1 Nevada Only Model

```
--> Regress; LHS=LOGMI; RHS=one, LOGPMT, VEH, WRKCOUNT, SUB1,
PSUB1, HYBRID, HINC, HTPPOPDN;
plot; res=resid1; standard; plot$
```

---

Ordinary least squares regression weighting variable = none  
 Dep. var. = LOGMI Mean= 9.599252016 , S.D.= .9352007455  
 Model size: Observations = 235, Parameters = 9, Deg.Fr. = 226  
 Residuals: Sum of squares= 101.0982706 , Std.Dev.= .66883  
 Fit: R-squared= .506010, Adjusted R-squared = .48852  
 Model test: F[ 8, 226] = 28.94, Prob value = .00000  
 Diagnostic: Log-L = -234.3402, Restricted(b=0) Log-L = -317.2059  
 LogAmemiyaPrCrt.= -.767, Akaike Info. Crt.= 2.071  
 Autocorrel: Durbin-watson Statistic = 2.15977, Rho = -.07988

---

Variable	Coefficient	Standard Error	t-ratio	P[ T >t]	Mean of X
Constant	15.63100296	.86427235	18.086	.0000	
LOGPMT	-2.435662980	.30599733	-7.960	.0000	2.7995690
VEH	.7399830263	.14488613	5.107	.0000	.69072283
WRKCOUNT	.2054545565	.53299846E-01	3.855	.0002	1.0085106
SUB1	-4.555392833	1.1523116	-3.953	.0001	.66808511
PSUB1	1.739066766	.41403124	4.200	.0000	1.8918270
HYBRID	-4.396671717	1.5207295	-2.891	.0042	.51063830E-01
HINC	1.600225795	.58481241	2.736	.0067	.12905578
HTPPOPDN	-.3930634975E-04	.11011754E-04	-3.569	.0004	4068.0851

(Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

## A.5.2 Full Model

```

--> Regress; LHS=LOGMI; RHS=one, LOGPMT, LOGINCA, VEH, URBRUR, WRKCOUNT,
SUB2, PINC, PSUB2, HYBRID, HINC, HHSIZE, HTPPOPDN;
plot; res=resid1; standard; plot$

```

---

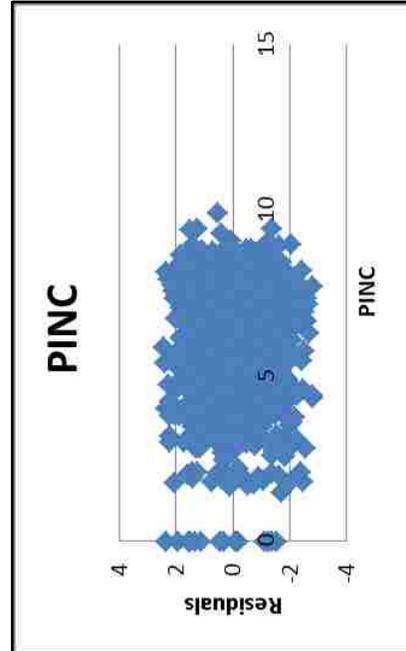
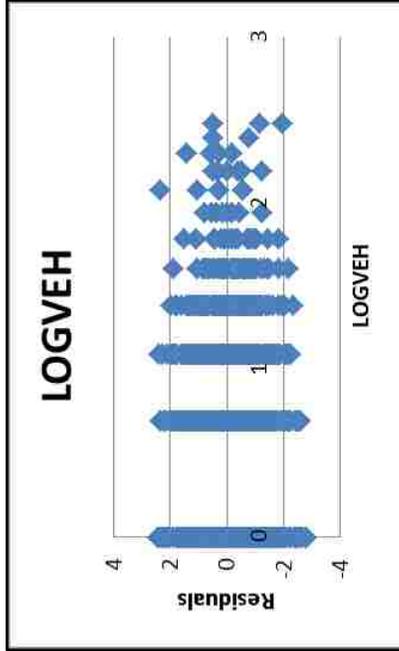
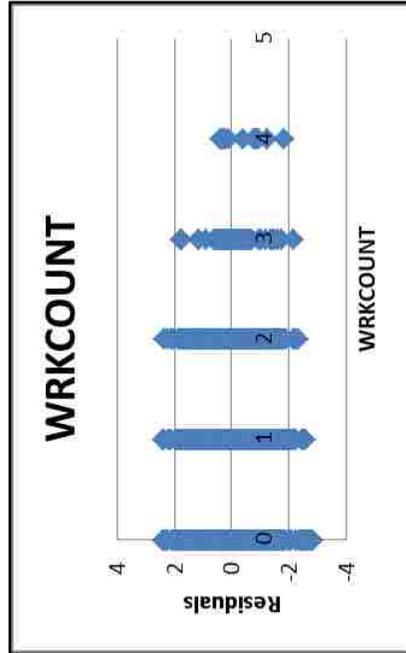
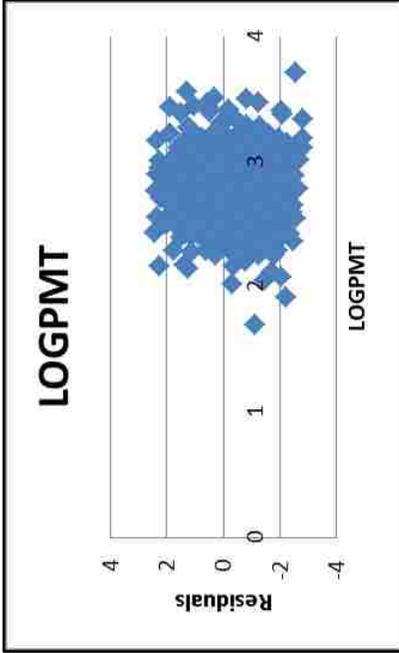
ordinary least squares regression weighting variable = none  
 Dep. var. = LOGMI Mean= 9.788715352 , S.D.= .8186747641  
 Model size: Observations = 1341, Parameters = 13, Deg.Fr.= 1328  
 Residuals: Sum of squares= 315.8551303 , Std.Dev.= .48769  
 Fit: R-squared= .648310, Adjusted R-squared = .64513  
 Model test: F[ 12, 1328] = 204.00, Prob value = .00000  
 Diagnostic: Log-L = -933.3292, Restricted(b=0) Log-L = -1634.0047  
 LogAmemiyaPrCrt.= -1.426, Akaike Info. Crt.= 1.411  
 Autocorrel: Durbin-watson Statistic = 2.00725, Rho = -.00363

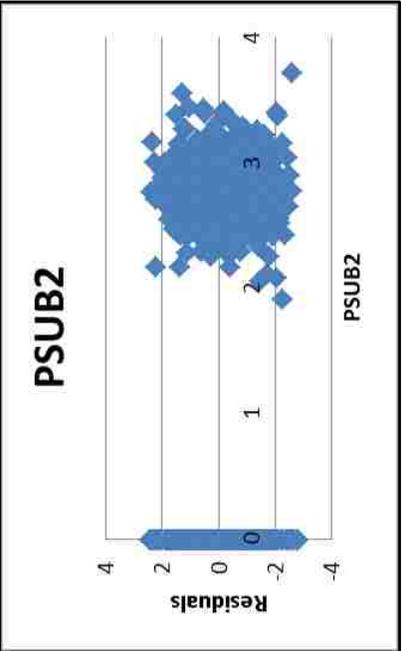
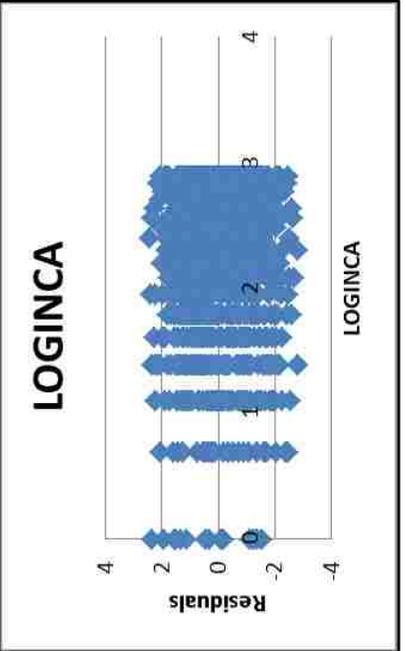
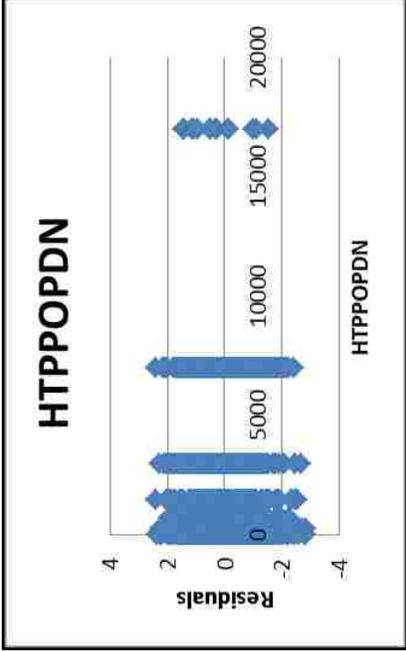
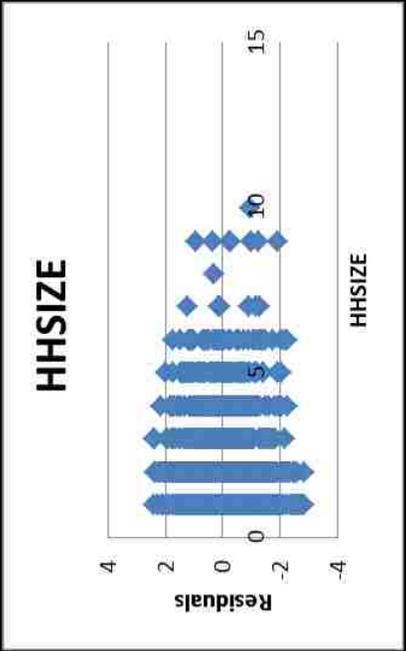
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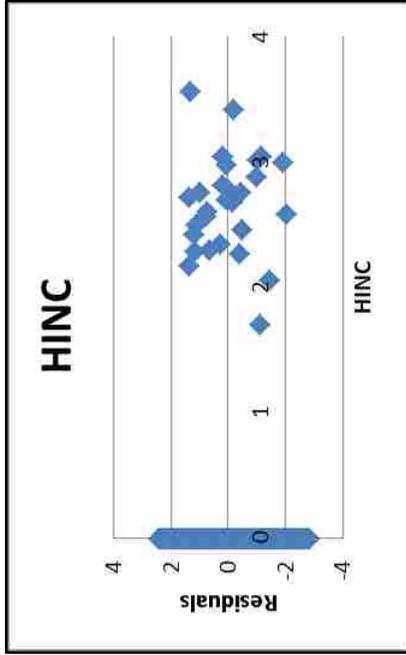
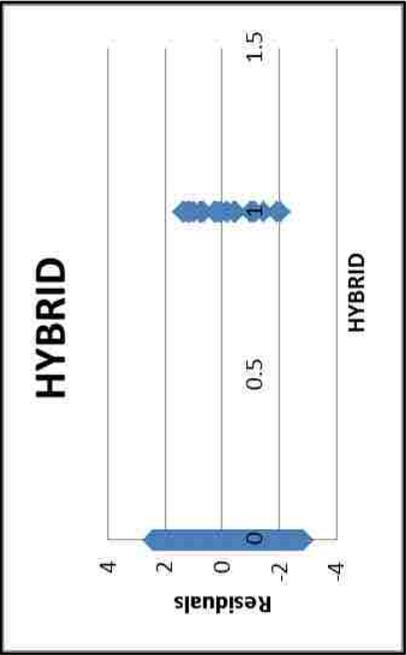
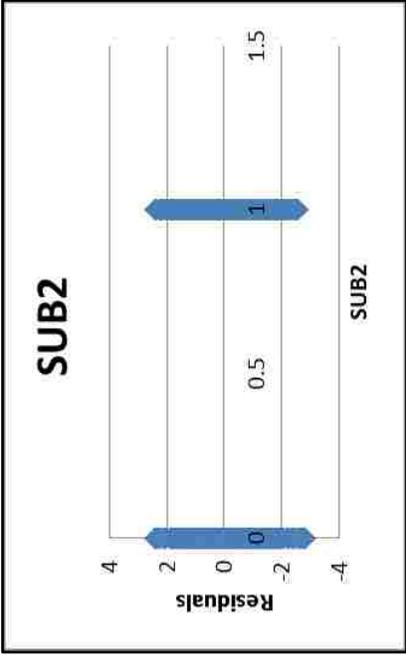
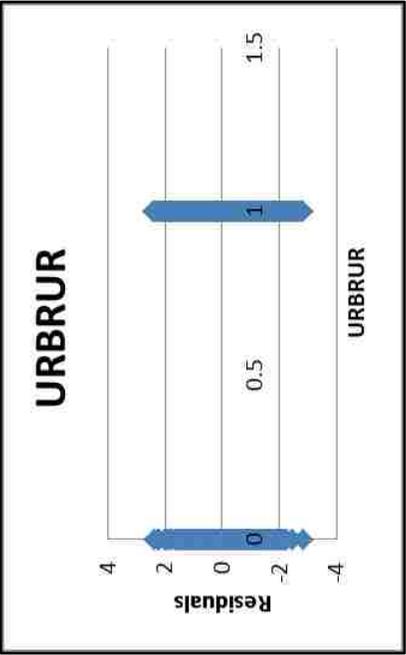
Variable	Coefficient	Standard Error	b/St.Er.	P[ z >z]	Mean of x
Constant	14.82456071	.60460742	24.519	.0000	
LOGPMT	-2.291123726	.21612160	-10.601	.0000	2.7800890
LOGINCA	-.4969894366	.28521246	-1.743	.0814	2.2506716
VEH	.7226693217	.41047971E-01	17.605	.0000	.80288157
URBRUR	-.1271841271	.31929610E-01	-3.983	.0001	.64951529
WRKCOUNT	.1088182155	.17637813E-01	6.170	.0000	1.0790455
SUB2	-2.678026812	.39075071	-6.854	.0000	.79120060
PINC	.2457336868	.10227161	2.403	.0163	6.2516798
PSUB2	1.047595162	.14030777	7.466	.0000	2.2041508
HYBRID	-1.042751268	.66441804	-1.569	.1166	.20879940E-01
HINC	.4180604236	.24637775	1.697	.0897	.55542426E-01
HHSIZE	.7042369793E-01	.10845681E-01	6.493	.0000	2.5421327
HTPPOPDN	-.3046354717E-04	.49677595E-05	-6.132	.0000	2288.3296

(Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

Appendix 6: Linearity Appendix







Appendix 7: Covariance Matrix

	LOGPMT	LOGINCA	VEH	URBRUR	WRKCOUNT	SUB2	PINC	PSUB2	HYBRID	HINC	HHSIZE	HIPPOPEN
LOGPMT	0.0472	-0.0054	0.0132	-0.0059	-0.0244	0.0045	0.0857	0.0451	-0.0025	-0.0034	-0.0179	-63.3074
LOGINCA	-0.0054	0.3891	0.1028	0.0101	0.2198	0.0775	1.0708	0.2114	0.0027	0.0068	0.2006	86.7222
VEH	0.0132	0.1028	0.2615	-0.0413	0.1798	0.1522	0.3180	0.4317	0.0030	0.0102	0.2167	-282.4480
URBRUR	-0.0059	0.0101	-0.0413	0.2278	0.0024	-0.0232	0.0153	-0.0695	-0.0024	-0.0082	0.0096	692.4370
WRKCOUNT	-0.0244	0.2198	0.1798	0.0024	0.8460	0.1091	0.5584	0.2819	0.0028	0.0074	0.5489	90.0650
SUB2	0.0045	0.0775	0.1522	-0.0232	0.1091	0.1653	0.2259	0.4606	0.0029	0.0081	0.1618	-171.4310
PINC	0.0857	1.0708	0.3180	0.0153	0.5584	0.2259	3.1808	0.6904	0.0012	0.0104	0.5203	98.4707
PSUB2	0.0451	0.2114	0.4317	-0.0695	0.2819	0.4606	0.6904	1.3156	0.0060	0.0195	0.4253	-527.5460
HYBRID	-0.0025	0.0027	0.0030	-0.0024	0.0028	0.0029	0.0012	0.0060	0.0205	0.0544	0.0036	-6.2114
HINC	-0.0034	0.0068	0.0102	-0.0082	0.0074	0.0081	0.0104	0.0195	0.0544	0.1480	0.0103	-21.1553
HHSIZE	-0.0179	0.2006	0.2167	0.0096	0.5489	0.1618	0.5203	0.4253	0.0036	0.0103	1.9395	31.4063
HIPPOPEN	-63.3074	86.7222	-282.4480	692.4370	90.0650	-171.4310	98.4707	-527.5460	-6.2114	-21.1553	31.4063	9498320

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