COMPREHENSIVE EQUITY ANALYSIS OF MILEAGE BASED USER FEES: TAXATION AND EXPENDITURES FOR ROADWAYS AND TRANSIT

A Thesis

by

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ABSTRACT

Lack of sustainable revenue generation for transportation infrastructure has created a need for alternative funding sources. The most prominent of which is the Mileage Based User Fee (MBUF), where drivers would be charged based on the number of miles they drive, thus holding them accountable for their use of the roadway. While numerous equity related issues have been addressed, the interrelation of transportation taxation and expenditures on all levels of government (State, County, and Local) is not well understood.

Using National Household Travel Survey data and information collected from over one hundred agencies, roadway taxation and expenditures were assigned to individual households in the Houston core based statistical area (CBSA). Using both Gini Coefficients and Theil Indices to analyze equity relationships, the research demonstrated that implementation of a MBUF would not have a pronounced effect on the current distribution of transportation taxation and expenditures, with the number of miles traveled and the total transit ridership remaining mostly unchanged. This also means that the equity of a MBUF is mostly equivalent to the current fuel tax. The relative winners of the current system are rural and high income urban households, while the relative losers are all other urban households.

Increasing the MBUF to meet the Texas 2030 Committee recommendations would decrease the average benefit to taxation ratio, causing households to receive less than they pay into the system. Additionally, it would decrease the total number of miles traveled by 22.8% and increase transit ridership by as much as 10.2%. Still, equity of this scenario changed little from the equity of the current transportation funding system. However, excluding public transit expenditures resulted in a statistically significant and undesirable

change in the Gini Coefficient, indicating that public transit has a positive impact on equity when considering the transportation system as a whole.

Due to relatively flat rate taxes (vehicle registration, property tax, sales tax, etc.), the higher the miles driven, the lower the effective tax is per mile. When miles traveled are decreased by 22.8%, the effective tax per mile increases, which is the reason why the average benefit to taxation ratio was reduced. If transportation related taxation were to shift towards user based methods, then the benefit to taxation ratio should tend towards a value of one, indicating that all users receive exactly the value they pay for. If revenues are increased while the methods of taxation remain the same, low income urban households will be negatively impacted to the greatest degree.

DEDICATION

To all those who form the light into my life, which illuminates all.

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NOMENCLATURE

AADT	Annual Average Daily Traffic
API	American Petroleum Institute
APTA	American Public Transportation Association
BESTMILE	NHTS Variable - Best estimate of annual miles
BLS	Bureau of Labor and Statistics
CBO	Congressional Budget Office
CBSA	Core Based Statistical Area
C_{Exp}	County transportation expenditure per county road DVM
$C_{Property}$	County property tax adjusted for transportation spending
C_{Sales}	County sales tax adjusted for transportation spending
$\%CR_{DVM}$	Percent of county road DVM on rural roads
$\%CU_{DVM}$	Percent of county road DVM on urban roads
DRVRCNT	NHTS Variable - Number of drivers in HH
DVM	Daily Vehicle Miles
EADMPG	NHTS Variable - EIA derived miles per gasoline-equivalent gallon estimate
FHWA	Federal Highway Administration
FLAG100	NHTS Variable - Flag indicating if 100% of the HH members completed the interview
FTA	Federal Transit Administration
Fuel Purchased	The total annual number of gallons purchased by each vehicle
FUELTYPE	NHTS Variable - Type of fuel

GAO	Government Accountability Office
GCOST	NHTS Variable - Fuel cost in nominal US dollars per gasoline equivalent gallon
GPS	Global Positioning System
HH	Household
HH Weight	Household survey weight
HHFAMINC	NHTS Variable - Derived total HH income
HHSIZE	NHTS Variable - Count of HH members
HHVEHCNT	NHTS Variable - Count of HH vehicles
HH_HISP	NHTS Variable - Hispanic status of HH respondent
HHRACE	NHTS Variable - Race of HH respondent
HOMEOWN	NHTS Variable - Housing unit owned or rented
HOUSEID	NHTS Variable - Household eight-digit ID number
HYBRID	NHTS Variable - Vehicle is Hybrid or uses alternate fuel
L_{Exp}	Local transportation expenditure per local road DVM
$L_{Property}$	Weighted average local property tax adjusted for transportation spending
L_{Sales}	Weighted average local sales tax adjusted for transportation spending
$\%LR_{DVM}$	Percent of local road DVM on rural roads
$\%LU_{DVM}$	Percent of local road DVM on urban roads
MATLAB	Software Package
MBUF	Mileage Based User Fee
METRO	Harris County Transit Authority
MCAR	Missing Completely at Random

MPG	Miles per gallon
M_{Sales}	Weighted average METRO sales tax
NCHRP	National Comparative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NHTS	National Household Travel Survey
NSTIF	National Surface Transportation Infrastructure Financing Commission
OHPI	Office of Highway Policy Information
PTUSED	NHTS Variable - How often respondent used public transit in past month
R_{Exp}	Average expenditure per DVM for rural roadway
R_{Split}	Percent of vehicles total VMT driven on rural roadways
RF	Radio Frequency
S_{Exp}	State transportation expenditure per state road DVM
S_{Sales}	State sales tax
$\%SR_{DVM}$	Percent of state road DVM on rural roads
$\%SU_{DVM}$	Percent of state road DVM on urban roads
T_{MBUF}	Difference in what transit pays for a MBUF compared to fuel tax
TF	Increase in transit fare revenue due to increase in total ridership
$TR_{Benefit}$	Total benefit transit receives due to roadway spending
TS	Total transit expenditures for all agencies (2008)
Tax	Respective state or federal fuel tax
TRB	Transportation Research Board
TxDOT	Texas Department of Transportation

U_{Exp}	Average expenditure per DVM for urban roadway
U_{Split}	Percent of vehicles total VMT driven on urban roadways
URBRUR	NHTS Variable - Household in urban/rural area
USDOT	Unites States Department of Transportation
VEHTYPE	NHTS Variable - Vehicle type
VEHYEAR	NHTS Variable - Vehicle Model year
VMT	Vehicle Miles Traveled
WRKCOUNT	NHTS Variable - Number of workers in HH

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1. INTRODUCTION

The fuel tax in the State of Texas, which consists of $0.20 applied to each gallon of gasoline purchased, has not increased since 1991. Both the Texas gasoline tax rate and the Texas diesel tax rate rank 40th in the country, with only 10 states having a lower tax rate (API 2013). While this may make Texas appealing to consumers, it also makes it challenging for Texas to fund transportation infrastructure needs. From 1991 to 2013 the State of Texas fuel tax has lost 40 percent of its purchasing power due to inflation (BLS 2013). According to the Texas Transportation Needs 2030 Committee, it will take a total investment of $270 billion dollars by 2035 in order to maintain current conditions and avoid a devastating 1.7 trillion dollar economic burden due to wasted fuel, time, and maintenance costs (Texas 2030 Committee 2011). While insufficient investment is a critical issue, it is not the only problem. The prices paid by users often do not reflect the true costs of that service nor do they reflect the true social costs in terms of delay and pollution. “This underpayment contributes to less efficient use of the system, increased pavement damage, capacity shortages, and congestion” (NSTIF 2009). An analysis of nine midwestern communities revealed that 80% of local funding was derived from mechanisms unrelated to road use (Forkenbrock 2004).

The Federal fuel tax, which consists of $0.184 applied to each gallon of gasoline purchased, has not increased since 1993. From 1980, the vehicle miles traveled in the Unites States increased by 95.5 percent, while the lane-miles have only increased by 8.8 percent (OHPI 2008). Even though mileage is increasing, experts estimate that average fuel consumption will drop by as much as 20 percent by 2025 due to increasing fuel efficiencies

(TRB 2006). This increase in fuel economy is expected to decrease federal fuel tax revenues by over 21 percent by 2040 (CBO 2011). The increase in hybrid and electric vehicles will further degrade the effectiveness of the fuel tax. The Obama administration recently finalized regulations to increase the fuel efficiency of cars and light duty trucks to 55.4 mpg by 2025, which will only exacerbate the situation (NHTSA 2012). However, the problem is immediate. According to the Congressional Budget Office, the National Highway Trust Fund will be insolvent by the year 2015 unless congress steps in (CBO 2013). This will be in addition to an $8 billion dollar infusion in 2008 and an additional $18.8 billion appropriation in 2012 which the fund required in order to meet its obligations (GAO 2011, GAO 2012). Due to these circumstances, the link between the taxes paid and benefits received by road users has been broken at the federal level (GAO 2012).

The issues presented demonstrate the primary weakness of the fuel tax as well as the issue with it going forward; it is not tied directly to roadway use. The lack of revenue sustainability has generated concern over the fuel tax's ability to meet infrastructure needs and the potential drastic consequences have prompted extensive research into funding alternatives for our transportation related infrastructure. One such option is the Mileage Based User Fee (MBUF), often called the Vehicle Miles Traveled (VMT) Fee. A mileage based user fee would charge road users according to the number of miles they drive, thus holding them accountable by directly tying the costs of road use to the benefits received. The essence of a MBUF system is that users pay their way, no more and no less. Over time it has become the consensus of transportation experts and economists that a MBUF system should be considered the leading alternative to the fuel tax (CBO 2011). Previous VMT initiatives demonstrate how such a system could work and show how it could lead to a more equitable and efficient use of the roadway (GAO 2012). Additionally, MBUFs may reduce congestion simply because the true cost of driving is more visible to drivers (NSTIF 2009). These are among the reasons why a MBUF is an attractive alternative. While lacking in political momentum, there have been several initiatives to move forward with a MBUF, including a bill recently introduced in Texas House of Representatives (House Bill 1309, 83rd Texas Legislature 2013). As the pubic begins to feel the repercussions of the current tax system and as agencies begin to run out of funding, the MBUF will become a possible reality.

1.1 RESEARCH PROBLEM

As with any method of taxation, equity becomes a primary concern. Transportation equity is defined as the actual and perceived "fairness" of how cost and benefit impacts are distributed (Litman 2002). While numerous studies have evaluated MBUF equity, none have addressed or included transportation spending, only revenue generation. Where and how the tax is collected is just as important as where and how it is spent. Additionally, there has been no research into the impact of a MBUF on public transit. Understanding the myriad of potential equity issues involved in both transportation taxation and spending is critical due to the widespread public mistrust of governmental agencies' ability to handle money (Cronin 2012; Grant Thornton 2010).

1.2 RESEARCH OBJECTIVES

The objective for this research was to evaluate equity in relation to transportation taxation and spending. The research was limited to the Houston Core Based Statistical Area (CBSA) for the purpose of simplicity, as this area contained all the elements needed for the analysis. The Houston CBSA is comprised of Austin, Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, San Jacinto, and Waller County. The taxation portion focused on replacing the fuel tax with a mileage based user fee and its relation to public transit. Comparing both taxation and spending will aid in providing a context for each, which current research lacks.

1.3 RESEARCH METHODOLOGY

First, the various household, income, geographic, and spending distribution assumptions under the current fuel tax were analyzed and evaluated. After properly weighting data from the 2009 National Household Travel Survey (NHTS), it was possible to compare income directly to auto ownership, fuel efficiency, and miles traveled. This was done for all households in the State of Texas, for households in all four core based statistical areas (CBSAs), and for urban and rural households. The reason these demographics were analyzed was to establish a thorough understanding for use in the equity analysis. Additionally, it ensured that the Houston CBSA was not substantially different from the rest of the state.

There were two primary steps in the second part of the analysis. The first step was to establish existing conditions under the fuel tax and the second was to analyze the changes when replacing it with a VMT tax.

The existing condition for the Houston Metropolitan area was comprised of the state fuel tax, the federal fuel tax, vehicle registration fees, transit fees, transit sales tax, Texas Department of Transportation (TxDOT) spending, grants received by the Harris County

Transit Authority (METRO), and the METRO sales tax. With these data, a comparison between the taxes paid and the benefits received could be undertaken.

After the existing conditions are established, the fuel tax was replaced by a mileage based user fee. For the purposes of this research, only a flat MBUF was considered, of which there were three scenarios: one that generated the same gross revenues as the current state fuel tax, one that accounted for implementation costs (same net revenue), and one that further increased revenue based on Texas 2030 Committee suggestions in order to meet future transportation needs (Texas 2030 Committee 2011). After establishing each of these cases, the equity of each was compared to the existing condition.

1.4 THESIS OUTLINE

The organization of this thesis is as follows: Section 1 provides the background and motivation for the potential adoption of a MBUF as well as some of its potential benefits. Section 2 reviews the available literature in order to provide a detailed understanding of MBUFs as well as how equity is defined and measured. Additionally, this section provides an overview of how transportation infrastructure is funded in the Houston area. Section 3 provides a summary of how the NHTS data was collected, filtered, and weighted. It also details the sources of taxation and expenditure information. Additionally, it covers miscellaneous data topics, such as the collection and estimation of daily vehicle miles and elasticity information. Section 4 details the methodology used for implementation costs, taxation assignment, MBUF calculation, and expenditure assignment. Section 5 includes all of the results obtained through the analysis as well as a discussion of their implications. Finally, Section 6 provides a summary of the important findings.

2. LITERATURE REVIEW

Background information pertinent to the research performed is presented in the following section. Topics included how a MBUF system might work, how a MBUF might be implemented, issues involved with MBUF implementation, equity definitions, common equity arguments, and objective measures of equity. While MBUF implementation is not the focus of this research, some understanding is necessary in order to facilitate a comprehensive equity analysis.

2.1 MILEAGE BASED USER FEES

MBUFs have become one of the most attractive alternatives to the fuel tax (CBO 2011; Larsen et al. 2012). Under a mileage based user fee system, road users would be charged according to the number of miles they drive, which would directly tie the costs of road use to the benefits received. Some of the benefits of MBUFs include increased cost recovery for new facilities, congestion management and traffic reduction, the ability to privately finance roadways, possible incentives for fuel efficient vehicles through lower rates, and a greater wealth of data for use in improving planning models (Forkenbrock and Hanley 2006).

There are several options for MBUF implementation and they vary in complexity. Several factors are key in MBUF implementation, though privacy is often the primary concern of the public. Many drivers are not comfortable with a governmental agency being able to track and log their location. Drivers in one study almost exclusively preferred the high privacy option (Hanley, 2011). The appropriate application of technology is a struggle between accountability, flexibility, and privacy.

For example, charges could be based on the annual miles driven via an odometer reading during vehicle registration every year. This method maximizes privacy and simplicity, but it does not take into account where those miles were driven and odometer tampering would be an issue (Kavalec and Setiawan 1997, NCHRP 2009). Additionally, any method that relies on collection during vehicle registration will discourage renewals and new registrations (Whittey 2007).

A simple and relatively cheap method would use cell phone technology to track vehicle movement. Under this system, cellular data would be uploaded to a central area, which would then determine the required fees and send the user a bill. Smart phone technology would also allow ease of payment. It was previously though that, while this method may work well for a small fleet, it invades privacy more than other options and is more expensive than the current system. Additionally, tampering may be pervasive (NCHRP 2009; Whittey 2007). A recent study by Battelle demonstrated the flexibility and suitability of using cell phone technology to track mileage (Battelle 2013). Additionally, privacy can be better protected by transmitting only a log of total mileage driven, while keeping location information stored locally. This allows a user to more easily dispute discrepancies and allows for auditing.

On Board Units (OBUs), which can include global positioning systems (GPS), radio frequency (RF), and other related technology, are another option. They come in two variations. The first is called a “thin” unit, where the location data is transmitted to a central databank which then calculates the vehicle's location and the associated fees. However, since all data is transmitted, there is little privacy, though tampering is reduced compared to the cellular method. The other option is called a “thick” unit. This system determines the position of the vehicle, the regulatory jurisdiction for its position, and the respective fee associated with travel internally. This unit will be more expensive, but better protects privacy, since only the identity of the vehicle and the associated fees will be transmitted (Hanley and Kuhl 2011; Puget Sound Regional Council 2008; Whittey 2007).

One of the most notable studies took place in Portland, Oregon. In the study, an on board GPS receiver calculated the fees and transmitted them via RF to the fuel pump, which then charged the drive the required fee (Whittey 2007). One of the primary benefits of this system is that it can be easily fit into existing infrastructure and would allow drivers to pay their fees with their preferred payment method. Additionally, there is little incentive for tampering, since users will be charged the regular gas tax if the on board device is not functional. This also allows for the system to be phased in slowly (Whittey 2007). New vehicles could come with an OBU installed, while older vehicles could be retrofitted if the owner wished too. However, electric vehicles in the fleet would need to be retrofitted regardless (Forkenbrock 2005).

Privacy concerns were minimized in the Oregon study by ensuring that no point data could be stored or transmitted during travel, since all communication could only be done at short range. The vehicle identification, the zone mileage totals, and fuel purchased were the only data centrally stored in order to identify possible device tampering (Whittey 2007). Even this amount of information, however, was not acceptable to some. Through the use of appropriate technology and encryption, the relative revenue share due to each agency could be transmitted anonymously. However, such a system will be difficult to audit and retrofitted vehicles would be easy to tamper with (Forkenbrock and Hanley 2006). A potential solution is for the OBU to keep track of the amount and location of fuel purchased, crediting the fuel tax towards the mileage fee (Forkenbrock 2005). Another disadvantage is that all vehicles need to keep up to date fee rates, which means that data must be transmitted to them in some fashion. This may reduce the flexibility of the system (CBO, 2012). Even given these issues, the technology has been proven to be mature and reliable (Puget Sound Regional Council 2008).

In the Oregon study, use of congestion pricing resulted in a 22% reduction of miles driven (Whittey 2007). In a study by the Pugit Sound Regional Council, congestion pricing resulted in a 12% reduction in miles traveled. The study demonstrated that variable tolling could reduce congestion and confirmed that optimum tolls would support expanding infrastructure when and where it's needed most (Puget Sound Regional Council 2008). Additionally, MBUFs may reduce congestion because they make the driver more aware of the true cost of road use (NSTIF 2009).

The general attitude towards a MBUF system improves dramatically after people become familiar with it. Favorability increased from 41% to 70% over the course of one study (Hanley and Kuhl 2011). In the Oregon study, 91% of the test participants expressed a preference for the MBUF system over the gas tax if it were available (Whittey 2007). The study also found that administrative costs would be relatively low (Whitty, 2007). If mass produced, OBUs could be as cheap as $50 (Forkenbrock and Hanley 2006). As the system develops, charges could be implanted for local communities as well, potentially reducing property and other local taxes (Forkenbrock 2005).

As the literature demonstrates, current technology is capable of handling a MBUF system, making it a very possible reality. Given that implementation is technically feasible, the potential impacts of such a fee will receive greater scrutiny. As with any tax, equity is a primary issue.

2.2 EQUITY

Equity concerning transportation usually refers to the actual and perceived "fairness" of how cost and benefit impacts are distributed. As would be expected, fairness is subjective and difficult to define. One must consider several types of equity, impacts, measures, and categories of people (Litman 2002).

There are two primary classifications of equity. Vertical equity concerns the distribution of impacts between individuals or groups with different needs and abilities. A policy is *progressive* if it favors disadvantaged groups since it makes up for existing inequities. A policy is *regressive* if it excessively burdens the disadvantaged (Litman 2002). Typically, when people talk about equity, they are referring to vertical equity. The income tax is considered vertically equitable since those with higher incomes are subject to a higher tax bracket. This type of equity with respect to income is based on the "ability to pay" principle, which states that "consumers of governmental goods and services should pay according their ability to pay, with lower income individuals paying less relative to those with higher income" (Baker et al. 2011). Generational equity, which concerns age cohorts instead of income, falls into this category. Services such as paratransit address this type of equity (NSTIF 2009).

Horizontal equity concerns the distribution of impacts between individuals or groups with equal ability and need. In other words, “equal individuals and groups should receive equal shares of resources, bear equal costs, and in other ways be treated the same” (Litman 2002). Therefore, no individuals or groups should be favored over others. The income tax is criticized in this area because there are various exemptions that allow households with the same income to pay different amounts. The “benefits” principle is the basis for this type of equity, which states that “those who pay a tax should be those that benefit from the public goods and/or services that are received” (Baker et al. 2011). Geographic equity falls into this category and “refers to the extent to which users and beneficiaries bear the cost burden for the portions of the system they use or benefit from, based on their geographic proximity to those portions” (NSTIF 2009).

Studies show the fuel tax to be regressive when compared to driver income (CBO 2011; Larsen et al. 2012; Weatherford 2012). Additionally, those studies suggest that an increase in either fuel tax or MBUFs would be less regressive. One study indicated that low-income drivers pay more through flat sales tax than they would through a MBUF (Schweitzer and Taylor 2008). While these studies address equity, there are much more detailed criticisms.

2.2.1 Equity Related MBUF Issues

Since one of the key aspects of a MBUF is that it would charge electric vehicles not currently paying the gas tax, there are many concerns regarding fuel efficiencies. These issues are usually a combination of both the benefits principle and the ability to pay principle. Concerned individuals claim that, since their hybrid and electric vehicles pollute less than other vehicles, they should pay less. The common assumption is that poor drivers will purchase cheap vehicles, which are older and less fuel efficient, causing the owners of more fuel efficient vehicles to shift the burden of transportation financing onto the poor drivers (NSTIF 2009; Whittey 2007). Since the lower quintile (a quintile is 1/5th of a population) of road users spend more on fuel as a percentage of their income, this means that low income rural drivers will spend more on fuel than their urban counterparts will since they have greater distances to travel. In addition to this, the price of goods reflects the fuel tax paid in order to transport them, which disadvantages the poor even more (CBO 2011, NSTIF 2009). It is taken as a fact that “residents of rural areas tend to have lower income levels than Metropolitan residents” (NSTIF 2009). A recent study comparing vehicle registrations to income area demographics supports the claim that lower income drivers have lower fuel efficiencies (Baker et al. 2011). However, the research did not directly compare income with fuel efficiency. A recent study by Larsen applied different MBUF rate structures for fuel efficiencies as well as for urban and rural driving (Larsen et al. 2012). Results demonstrated that vertical equity changes were minor. MBUF tax structures that take into account fuel efficiency, weight, and other measures may not be worth implementing simply because the differences work out to very small on per month basis for users (Whittey 2007). Another important finding is that increasing the revenue may make the tax more regressive (Larsen et al. 2012, NSTIF 2009). There is evidence to suggest that rural households would pay less under a mileage fee system (CBO 2011).

“Road tolling will be seen as unfair unless people understand that directly charging users addresses existing inequalities across users of the transportation system, and improves overall economic efficiency, leaving society with greater resources available to address remaining issues of fairness” (Puget Sound Regional Council 2008). One method suggested by the Pugit Sound Regional Council was to allocate funding for transit in order to provide for the disadvantaged. However, little is known about the equity relationship between transit and roadways in terms of tax collection or spending.

2.2.2 The Lorenz Curve and the Gini Coefficient

In order to analyze equity, one needs to apply objective measures that are directly comparable. The most commonly used measure, the Gini coefficient, is often considered to be the gold standard for vertical equity (De Maio 2007). The Gini coefficient is calculated based on the Lorenz curve, which is a plot of the cumulative proportion of benefits received versus the cumulative proportion of households, with absolute equality represented by a line bound by the points (0,0) and (1,1). An example Lorenz curve is shown in Figure 1.

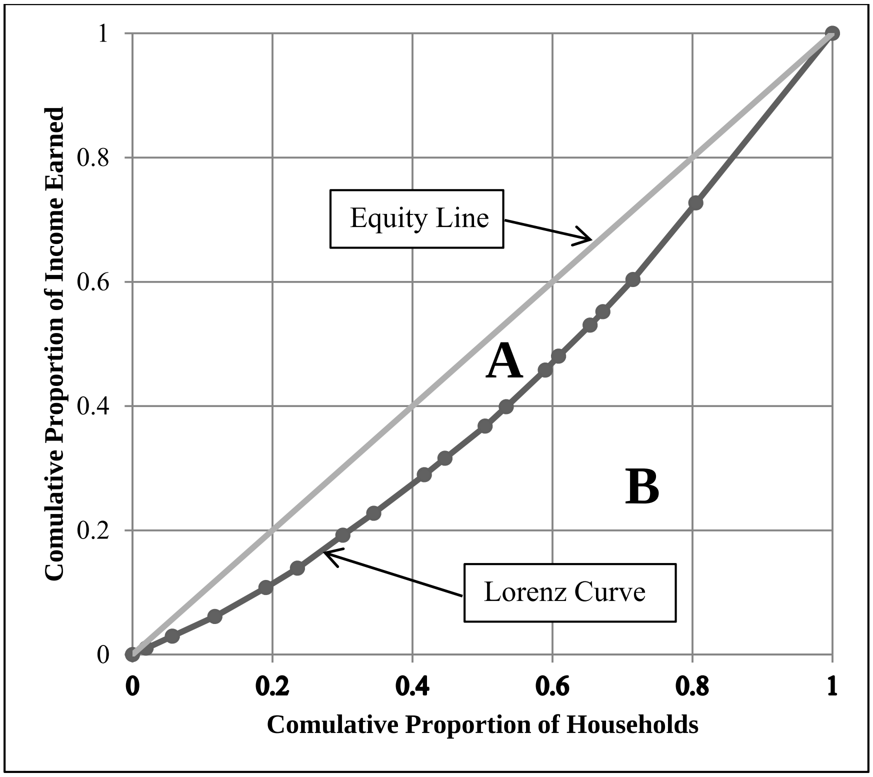

Figure 1. Example Lorenz Curve

The Gini coefficient, which ranges from zero to one, is a measure of inequity used to determine benefits distribution, shown mathematically in Equation (1). If each member of a society receives the same share of wealth, then the Gini coefficient will be equal to zero, indicating complete equality. If one individual holds all the wealth, then the coefficient would be equal to one, indicating complete inequality (Drezner et al. 2009).

$$G = \frac{A}{A+B} \ or \ 2 * A \tag{1}$$

The intuitive nature of the Gini coefficient as well as its simplicity has led to its widespread popularity since it allows for direct comparison between different units. However, it is not capable of differentiating between different kinds of inequalities. For example, two intersecting Lorenz curves, reflecting different income distributions, could yield the same Gini coefficient. Additionally, the coefficient is the most sensitive to the middle of the spectrum. Because of these drawbacks, Maio suggests that it should be one of many measures of inequality, as opposed to the standard (De Maio 2007).

2.2.3 The Theil Index

Another drawback of the Gini coefficient is that it is not decomposable, meaning that Gini coefficients for groups within the population do not combine to form a coefficient for the total population, which is an attribute the Theil Index possesses (De Maio 2007). The Theil index equation is as follows:

$$T = \sum_{p=1}^{n} \left(\frac{y_p}{Y}\right) * \ln\left(\frac{y_p}{Y} / \frac{1}{n}\right) \tag{2}$$

where y_p is the income for the p^{th} member of the population, Y is the population's total income, and n is the number of individuals in the population. This equation highlights "a possible intuitive interpretation of the Theil index as a direct measure of the discrepancy between the distribution of income and the distribution of individuals between mutually exclusive and completely exhaustive (MECE) groups" (Conceicao et al. 2001). If the population is divided into m generic MECE subgroups then Theil's T becomes:

$$T = T'_g + T_g^W \tag{3}$$

where $T'g$ is the between group component and Tg^W is the within group component. The simplicity of this decomposition becomes apparent when the between group component is considered.

$$T'_g = \sum_{i=1}^{m} \left(\frac{Y_i}{Y}\right) * \ln\left(\frac{Y_i}{Y} / \frac{n_i}{n}\right) \tag{4}$$

Now *i* represents population groups instead of individuals. Y_i is the group's share of income and n_i is the number of individuals in the group. Continuing, the within group component is simply that groups Theil T with a weight applied to it.

$$T_g^W = \sum_{i=1}^{m} \left(\frac{Y_i}{Y}\right) T^m \tag{5}$$

The Theil index for an individual group, T^m, is the same as Equation (2), except n is now the number of members in the group, y_p is now the income for the p^{th} member of the group, and *Y* is now the total income for the group.

The decomposability of Theil's T is clearly powerful, since it can determine sources of inequity within the population (Conceicao et al. 2001). The T statistic is less intuitive than the Gini coefficient since it is bound by [0, ln(n)]. However, this can be a desirable, since a larger would make more sense in an unequal society (Conceicao and Galbraith 2000). While the T statistic is always positive, the between group component can be negative, indicating that the group received less income than the average, which helps to determine inequality across the different groups (Conceicao et al. 2001). One of the criticisms of the Theil index is that it cannot compare different populations, which is one of the reasons the Gini coefficient is popular. However, if these different populations are considered to be subgroups, research has shown that the between group component in Equation (8) can be used to adequately compare them over time (Conceicao and Galbraith 2000).

The Theil index provides a useful addition to the Gini coefficient, allowing for a more comprehensive analysis than would have been possible otherwise. As the Gini coefficient is more widely used, it will allow for and easier comparison of this thesis to other research, while the Theil index will be used to isolate inequality in and between subgroups for a more thorough understanding of how a MBUF system might impact road users.

2.3 TRANSPORTATION SERVICES IN THE HOUSTON AREA

Transportation related infrastructure or service inside the Houston CBSA may be provided by one or more of several different entities, who often work cooperatively to provide and maintain transportation network. Entities responsible for providing these services, who also posses taxation ability, include the United States Government, the State of Texas, Austin County, Brazoria County, Chambers County, Fort Bend County, Galveston County, Harris County, Liberty County, Montgomery County, San Jacinto County, Waller County, the Metropolitan Transit Authority of Harris County (METRO), four other public transit agencies, and 127 municipalities.

As mentioned previously, both the US Government and the State of Texas impose a tax on motor fuel purchases. In addition to this, Texas collects a 6.25% sales and use tax on motor vehicles as well as a tax on motor oil (Texas Comptroller of Public Accounts 2013). The State also collects a motor vehicle registration fee. All of these are deposited into the State Highway Fund, 25% of which is then deposited into the school fund. The remaining amount is available for use by the Texas Department of Transportation (TxDOT). Drivers license fees, vehicle inspection fees, driver record request fees, motor carrier penalties, state traffic fines, and proceeds from the driver responsibility program are deposited into the Texas Mobility Fund, which TxDOT uses to finance mobility related projects (Legislative Budget Board 2006). TxDOT also distributes grants for small transit related entireties (TxDOT 2008).

The Texas Constitution allows for local entities to collect up to a combined 2% sales tax (Texas Comptroller of Public Accounts 2013). Austin, Brazoria, Liberty, and San Jacinto County collect a 0.5% sales tax while the municipalities collected an average sales tax of 1.43% (www.window.state.tx.us/taxinfo/local/city.html). In 1978, constituent area voters in the Houston area created METRO and approved a 1.0% sales tax in order to fund its operation (METRO 2013). By voter mandate, METRO must appropriate 25% of this sales tax to its constituents for roadway related improvements.

Texas also allows counties, who are often in charge of collections, to add an additional fee to their vehicle registrations. In 2008, Fort Bend, Harris, and San Jacinto Counties collect a registration fee of $11.50, while the other counties collect $10.00 only. Property taxes ($/$100 of assessed value) are set by the local entity and stack on top of each other. For example, one household may pay property taxes to the county, the city, a school district, utility districts, and a special development district. The average property tax collected in 2008 was $0.52096^{\$/\$100}$ for counties and $0.49540^{\$/\$100}$ for municipalities. Due to data availability and the focus of this thesis, revenue sources from heavy vehicles were not included. Detailed revenues and expenditures in the Houston CBSA are presented in Section 3.2.

3. DATA

Data extracted from the National Household Travel Survey serves as the foundation for the analysis, while transportation taxation and spending information (collected from numerous sources) builds upon it. The collection, organization, and use of the data is presented in the sections below.

3.1 NATIONAL HOUSEHOLD TRAVEL SURVEY

The 2009 National Household Travel Survey (NHTS) is a compilation of data collected from over 150,000 households across the United States and is available for download at their website (nhts.ornl.gov). The majority of surveys were paid for through the NHTS add-on program, which allowed agencies to request additional surveys. The Texas Department of Transportation (TxDOT) paid for 20,000 add-on surveys, bringing the total for the State of Texas to 22,255 households and over 45,000 vehicles. Included in the survey data are variables for household income, vehicle type, vehicle fuel efficiency, annual vehicle miles traveled, average price of fuel, and other important data that allows for easy computations without relying heavily on estimation (NHTS 2011). Additionally, the NHTS data includes weights so each household in the survey properly represents the total in the population. The survey contains three files relevant to the analysis, one for household information, one for vehicle related information, and one for person related information. The survey also contains a trip file, which includes trip information related to public transit. While each trip is related to a household, not all households are represented. Additionally, for the analysis, yearly totals will be required. The person file contains the PTUSED variable, which is the number of times the respondent used public transit in the previous month. This variable provides a better estimate for the analysis. Each household has a unique ID, which all vehicles and persons are linked to. The ability to tie vehicle data with household income is critical for the purposes of researching the impact of fee charges on vertical equity.

Missing values throughout the data set are perhaps the primary obstacle to its effective use. In order to perform an analysis, these missing values need to be addressed. There two primary categories of methods commonly used when dealing with missing survey data. The first, and simplest, is deletion. When using pairwise deletion, any entries with missing variables relevant to the analysis are removed. However, this assumes that the data is missing completely at random (MCAR). If this assumption is incorrect, bias may be introduced. Additionally, this technique is not very useful for small data sets, though that is not an issue with the NHTS data. The second primary method of dealing with missing data is replacement (or imputation). There are many different methods of imputation, such as mean, regression, hot deck, maximum likelihood, and multiple imputation (Tsikriktsis 2005). According to the NHTS weighting report, hot deck imputation was used in their weighting calculations (Rizzo et al. 2010). Additionally, Texas data was weighted to reflect the state as a whole, without any subareas. Since the analysis in this thesis concerns only the Houston CBSA, these existing weights may not properly reflect the demographics in the area. Additionally, for reasons discussed in the next section, the analysis requires that values for variables such as FLAG100 and VEHTYPE be deleted from the dataset, which means re-weighting will be needed regardless of the missing data method chosen.

Due to the reasons above and the large number of surveys available, pairwise deletion was used. According to Tsikriktsis, if the data is MCAR and each variable is missing less than 10% of its values, pairwise deletion is an acceptable method (Tsikriktsis 2005). An iterative raking process will be used to re-weight the data, which is similar to the process used by NHTS originally (Rizzo et al. 2010). Though the analysis will focus on Houston, the data was filtered and weighted for the entire state, with sub categories for each of the four primary metropolitan areas, in order to ensure that there were no irregularities. Table 1and Table 2 display the NHTS variables relevant to the weighing procedure and the analysis.

Table 1. NHTS Variables Relevant to the Weighting Procedure

NHTS Variable	Variable Definition
FLAG100	Flag indicating if 100% of the HH members completed the interview
HHFAMINC	Derived total HH income
HHSIZE	Count of HH members
HHVEHCNT	Count of HH vehicles
HH_HISP	Hispanic status of HH respondent
HH_RACE	Race of HH respondent
HOMEOWN	Housing unit owned or rented
HOUSEID	Household eight-digit ID number
URBRUR	Household in urban/rural area
WRKCOUNT	Number of workers in HH

Table 2. NHTS Variables Relevant to the Analysis

NHTS Variable	Variable Definition
BESTMILE	Best estimate of annual miles
DRVRCNT	Number of drivers in HH
EADMPG	EIA derived miles per gasoline-equivalent gallon estimate
FUELTYPE	Type of fuel
GCOST	Fuel cost in nominal US dollars per gasoline equivalent gallon
HYBRID	Vehicle is Hybrid or uses alternate fuel
PTUSED	How often respondent used public transit in past month
VEHTYPE	Vehicle type
VEHYEAR	Vehicle Model year

3.1.1 Filtering

The first step in the filtering procedure was to eliminate vehicle survey entries where the vehicle type variable was incomplete (VEHTYPE = -7, -8, -9, 8, 97). These entries were non-roadway vehicles such as golf carts, jet skis, etc., or were counted as such. This means that they were not included in the household vehicle count variable, which will be important for the weighting procedure. Consequently, this also means that households with zero vehicles were removed from the vehicle survey file, leaving 44,964 valid vehicle surveys.

It is important to determine the variables needed for the weighting procedure as well as for the analysis. Table 3 displays the selected variables, their filtering criteria, and the number of survey entries the filters affect in the Texas dataset. Several variables, such as HHSIZE, were not missing any values due to their having been hot deck imputed for the original NHTS weighting (Rizzo et al. 2010). The filtering assures that most variables have only valid entries, with two exceptions.

The FLAG100 variable ensures that the respective household survey was complete, meaning that all residents filled out the survey. This ensures that the survey will be an accurate representation of the population and will not bias the analysis with potentially unknown missing information. For this reason, the large percentage eliminated (>10% for pairwise deletion) is considered acceptable. All other variables are under this threshold.

The VEHTYPE variable eliminates the "Other Trucks" category, which could include any number of vehicle types. Since the survey focused on households, it was not practical to include large trucks because they are more often associated with commercial businesses. Additionally, large trucks pay very different fees compared to regular vehicles. For these reasons, the survey would not be representative of the population, thus large trucks were not included.

Table 3. Filtering Criteria and Effect

Filtering Criteria	Survey Households Meeting Criteria	Survey Households Not Meeting Criteria		Survey Vehicles Meeting Criteria	Survey Vehicles Not Meeting Criteria	
FLAG100 = 1	19,049	3,206	14.4%	37,530	7,434	16.5%
HHFAMINC ≠ -7, -8, -9	20,512	1,743	7.8%	41,923	3,041	6.7%
HH_RACE ≠ -7, -8, -9	22,098	157	0.7%	44,799	165	0.4%
HH_HISP ≠ -7, -8, -9	22,170	85	0.4%	44,668	296	0.7%
URBRUR ≠ -9	22,254	1	0.0%	44,963	1	0.0%
BESTMILE ≠ -9	21,367	888	4.0%	43,882	1,082	2.4%
VEHTYPE ≠ 5	22,114	141	0.6%	44,806	158	0.4%
EADMPG ≠ -9	21,150	1,105	5.0%	43,641	1,323	2.9%
HYBRID ≠ -7, -8, -9	22,098	157	0.7%	44,796	168	0.4%

Table 4 displays the surveys before and after filtering for each area. The percent of retained surveys suggests uniformity across the areas, indicating that no area is substantially different in terms of survey completion.

Table 4. Surveys Before and After Filtering by Area

Area	Survey Households Before Filtering	Survey Households After Filtering	Surveys Retained	Survey Vehicles Before Filtering	Survey Vehicles After Filtering	Survey Vehicles Retained
State of Texas	22,255	16,978	76.29%	44,964	33,287	74.03%
Austin CBSA	1,543	1,211	78.48%	3,073	2,340	76.15%
Dallas/Fort Worth CBSA	5,875	4,521	76.95%	11,971	8,962	74.86%
Houston CBSA	4,043	3,004	74.30%	8,054	5,828	72.36%
San Antonio CBSA	2,054	1,590	77.41%	4,099	3,107	75.80%

3.1.2 Weighting Procedure Setup

The filtered results (Table 4) then needed to be weighted so that they better represented vehicle owning households in Texas. Again, even though the analysis focused the Houston CBSA due to its public transit availability, the entire state was weighted so that the four Texas CBSAs could be compared. This was done in order to ensure that the weighting process did not create any unusual distributions or biases in the Houston CBSA. The average weights for each area are shown in Table 5. The State of Texas numbers include the four CBSAs as well as the rest of the state.

Table 5. Average Survey Weight by Area

Area	Households in Area	Survey Households After Filtering	Average Number of Households Each Survey Represents
State of Texas	8,527,938	16,978	502
Austin CBSA	637,229	1,211	526
Dallas/Fort Worth CBSA	2,201,105	4,521	487
Houston CBSA	2,004,427	3,004	667
San Antonio CBSA	738,162	1,590	464

County locations were obtained for each survey household through personal communication with NHTS. However, as the NHTS survey was not sampled at the county level, the data was not weighted based on county location. For this reason, the filtered data will only be weighted for the CBSAs.

The weighting procedure utilized control totals from the American Community Survey (ACS) obtained through the American Fact Finder website of the United States Census Bureau (factfinder2.census.gov). Control totals are simply the total number of households in a given strata. For example, in 2008 there were 695,170 households in the Houston CBSA with one vehicle. The majority of the NHTS data was collected during 2008, so control totals were selected to represent that year. Most were selected from the 2009 ACS 1-Year Estimate, as the data from 2008 appears in the 2009 release. However, totals for the Austin and San Antonio CBSAs were not available in this data set, though they were available in the 2010 ACS 3-Year Estimate. While the ACS discourages using the 3-year estimates as an average, it provided appropriate control totals for the purposes of the data weighting used here (U.S. Census Bureau 2008). Control totals were obtained for the variables listed in Table 6, with the exception of URBRUR. Control totals for URBRUR were determined via linear interpolation between the 2000 and 2010 United States Census, which was also obtained through the Fact Finder website.

Table 6. NHTS Variables For Which Control Totals Were Obtained

NHTS Control Total Variable
HHSIZE
HHFAMINC
HH_RACE
HH_HISP
HHVEHCNT
WRKCOUNT
URBRUR
HOMEOWN

Several adjustments were made to the NHTS data so that the categories would match the ACS control totals. The household size was capped to 7+ persons, the vehicle count was capped to 4+ vehicles, and the worker count was capped to 3+ workers. While the two surveys did not use the same income categories, they fit together neatly. Incomes groups 1-2, 11-12, 13-15, and 16-17 were collapsed together in order to match the ASC groups. The NHTS survey allowed the household respondent to indicate Hispanic as their race while the ACS survey did not, which leaves the question of what to do with these respondents. The assumption was that, if Hispanic were not an option for race in the ACS survey, the respondent would most likely indicate their race as “other”. The ACS percentages for the “other” race category and the NHTS percentages for the Hispanic (7) and “other” race (97) categories combined were similar, which supports the assumption. For this reason, Hispanic race NHTS respondents (7) were placed into the “other” race (97) category. Luckily, both surveys included a separate question for marking Hispanic status, which will help reduce any bias introduced by this assumption. A large number of respondents who marked their race as Hispanic also indicated that they were not Hispanic on the status variable. Regardless of the possible reasons for this, the distinction is important.

3.1.3 Weighting Procedure Methodology

An iterative raking method was used for the weighting procedure, often called proportional fitting, where weights are adjusted in an iterative process. The original NHTS weights for each household were used as the default starting values. For each iteration, the previous iteration's household weights (starting with the NHTS weights) were slowly adjusted closer to the control totals obtained in the precious section. After doing this for the State of Texas as a whole and each of the four CBSAs, the result was a set of household weights which make each survey representative of the general population.

For the first step in the iterative process, adjustment fractions are calculated. To do this, the total number of surveyed households were counted for each variable in Table 6, broken down into their respective values, i.e., the total surveyed households were counted by summing survey weights for HHSIZE 1, HHSIZE 2, etc. The control totals for the ACS data set were then divided by the new weighted totals in order to produce an adjustment fraction. An example may be viewed in Table 7. Weighted survey control totals were initially lower than the ACS control totals due to the households eliminated in the filtering process. For this reason, most of the first iteration adjustment fractions were above one, causing some of the new weighted totals to become greater than the ACS control totals.

Table 7. Example Iteration Adjustment for Household Size in the Houston CBSA

Household Size	Control Total (ACS)	Weighted Total (NHTS)	Adjustment Fraction
1	473,166	565,917	0.8361
2	594,681	585,185	1.0162
3	344,661	369,628	0.9324
4	312,956	284,648	1.0994
5	169,650	123,648	1.3720
6	65,446	44,819	1.4602
7	43,867	23,364	1.8775

Each household was then assigned a relevant adjustment fraction based on its individual characteristics. For example, based on Table 7, a household with 5 members would be assigned 1.3720 as their HHSIZE adjustment fraction. After fractions for all eight variables in Table 6 were assigned, they were averaged. This average was then multiplied by the current household weight, yielding new weights that sum closer to the ACS control total. This was done over multiple iterations before arriving at the final set of weights, as discussed below.

One option would be to develop a set of weights for each variable one at a time, then apply the adjustment fraction and move on to the next variable. However, this would not work. Take, for example, if just the fractions in Table 7 were used instead of the average for all eight categories, the resulting weighted number of households would perfectly sum to the control total number of households in the table and would be representative of the household size distribution. However, the results would not be accurate for any other variable. Simply using adjustment fractions for one variable at a time would lead to circular logic and would be continually biased towards the last variable used. For this reason, all eight were averaged. With each iteration, this technique gradually nudges the weighted number of households towards matching control total number of households without oscillating them between iterations. Calculating them in this way also helps maintain some of the sampling criteria inherently imbedded in the original NHTS weights.

If, for example, two control total variables are used instead of one, then the resulting weighted number of households would accurately reflect the distribution of control total households segmented by both of those variables. In the analysis, variables were used for which no ACS control totals were available. In order to ensure that the final weights reflect them accurately as possible, it is advisable to use more control variables. However, as more variables are used and the total number of surveys remains the same, an optimal solution may no longer exist. Additionally, certain weights may become dramatically large, which could lead to over sensitivity in the analysis (Battaglia et al. 2004). A maximum and minimum weight ensure that no one household could either dominate other households or end up becoming negligible. At the beginning of each iteration, the maximum weight was set to seven times the average state weight in Table 5, while the minimum was set at 1/50th that value (The original NHTS weights had a 50:1 maximum to minimum ratio). Lowering the maximum below this level quickly introduced very large errors due to an increased number of households failing to converge. The final value for the maximum and minimum were 3,500 and 70 respectively. 2.0% of the households were constrained by the maximum, while 5.6% were constrained by the minimum.

The adjustment calculations were run for the State of Texas as a whole and each of the four CBSAs independently. The population inside each CBSA was weighted to match the total for that CBSA, while the populations outside the CBSA were weighted so that they made up the difference between the state totals and the sum of the four CBSAs. For example, if a household was within the Houston CBSA, the previous iteration's weight would be counted towards the weighted total for the Houston CBSA. The adjustment fraction that household received would be based on the ACS control totals for the Houston CBSA only. The same was done for the other three CBSAs. All households were counted towards the weighted total for the state as a whole. However, only households outside of the four CBSAs were assigned an adjustment fraction based on the ACS control totals for the state as a whole. Effectively, the CBSA adjustment fractions trumped the state adjustment fractions where applicable. The reason this was done was to ensure that the final weights accurately reflect each CBSA, while still accurately representing the state as a whole. After multiple iterations, the final set of households weights were representative of each CBSA as well the state as a whole.

The entire process above was repeated 1000 times or until the average difference between the weights for each household fell below $1x10^{-8}$. The resulting weighted totals closely matched the ACS control totals. The difference between the control totals and final weighted totals for the household race variable are presented in Table 8. Out of all eight variables, HH_RACE had the greatest errors, the largest of which was 3.58% for Hawaiians in Texas (partially due to the control total being small). Dallas/Fort Worth, Houston, and San Antonio were within two households of their respective variable category control totals for all variables.

Table 8. Control Total Minus Final Weighted Total for Race (In Households)

HH_RACE	Texas	Austin CBSA	Dallas	Houston	San Antonio
White	109	-158	0	0	0
African	16	-15	0	0	0
Asian	13	-9	0	0	0
Native American	1	-1	0	0	0
Hawaiian	-169	0	0	0	0
Multiple	-27	200	0	0	0
Other	11	-17	0	-1	0

3.1.4 Replicate Weights

Standard deviations calculated with weighted data are usually inaccurate (below the actual standard deviation). Replicate weights are used to address this issue and yield more accurate standard error estimates than can be obtained by other methods. To create replicate weights, a certain percentage of the total data is randomly deleted. The resulting reduced data set is then put through the weighting procedure, yielding a new set of household weights. The number of replicate weight sets is typically determined by the percentage of the total data deleted. For example, if 1/100th of the data was deleted, then 100 sets of replicate weights would be required. However, each of the 100 replicate weight sets provided by NHTS did not have the same percentage of deleted data. As the method NHTS used to determine the percentages was unknown, instead of creating new weights, the original NHTS replicate weights were used in order to maintain the distribution of deleted data chosen by NHTS. Each of these 100 sets of NHTS replicate weights were put through the weighting procedure outlined in the previous section. The result was 100 different sets of household weights which make the surveys representative of the population. A given household weight is slightly different in each set due to the randomly deleted surveys.

Details for how to use the NHTS replicate weights are described in the NHTS User Guide (NHTS 2011). In order to obtain the standard error for an estimate, the estimate is first calculated 100 times based on each set of replicate weights. Then the results are inserted into Equation (6). Using a student t statistic value of 1.984 for 100 degrees of freedom, the 95% confidence interval for the estimate can be determined with Equation (7).

$$Standard\ Error = \sqrt{\frac{99}{100} * \sum_{i=1}^{100} [Rep(i) - x]^2} \quad (6)$$

$$95\%\ Confidence\ Interval = x \pm 1.984 * Standard\ Error \quad (7)$$

where *x* is the estimate (for example, BESTMILE) calculated using the final weights and *Rep(i)* is the estimate calculated based on replicate weight set *i*. The weighting process outlined in the previous section was repeated for each of the 100 replicate weight sets included in the original NHTS data.

3.2 DAILY VEHICLE MILES

In order to assign roadway benefits to individuals, the total use of the system needs to be determined. The daily vehicle miles (DVM) for a road segment is simply the annual average daily traffic (AADT) multiplied by the length of the segment, meaning it is an estimate of the total daily vehicle miles traveled (VMT). The DVM will contain all vehicles, including trucks, which are omitted from this analysis. However, when determining expenditures per mile driven, including them in the DVM allows for their share of roadway expenditures to be accounted for. Determining reasonable estimates for total DVM disaggregated by county and geographic location proved to be a challenge.

There are two sources of data for roadway infrastructure and use, the TxDOT Planning Department's roadway inventory database (www.txdot.gov/inside-txdot/division/transportation-planning.html) and OHPI Highway Statistics (www.fhwa.dot.gov/policyinformation/statistics/2008). Total centerline miles for the State of Texas are shown in Table 9. While the TxDOT's file includes some county and local roadways, it clearly is not comprehensive, though the totals for state owned roads closely match the OHPI information. Using the TxDOT file, daily vehicle miles can be accurately estimated for state roadways as each road segment includes an estimate for AADT.

Table 9. Texas Centerline Miles by Ownership

Owner	TxDOT File Centerline Miles			OPHI Highways Statistics Centerline Miles		
	Total	Urban	Rural	Total	Urban	Rural
State	80,395	14,005	66,389	81,043	13,786	67,257
County	8,237	2,355	5,885	145,632	12,671	132,961
Local	13,789	13,496	294	79,729	66,948	12,781

While the TxDOT file reported fewer county and local roads, urban roadways in Harris county appear to be an exception (98% of DVM for local areas was urban, see Table 10). The total mileage is still likely somewhat underestimated, but these numbers provided a reasonable starting point. Harris county had 9.0 local DVM per person based on locations with taxation (25,029,497 from Table 10divided by 2,780,551 from Table 11), which accounted for 93% of the population. Using this number, the urban DVM on local roads was estimated for the other counties. For example, multiplying 9.0 by the local population with taxation (17,997) in Chambers county yielded a total local DVM of 162,073. All cities and towns with taxation are not necessarily urban. For example, the local urban population with taxation in Chambers County was 88%, while the local rural population with taxation was 12%. The local urban and rural DVM is assumed to follow this ratio. For example, the local urban DVM for chambers county would be 88% of the total of 162,073. The results for Chambers County as well as the other counties are presented in Table 12.

Harris county had 3.9 county urban DVM per person based on urban population with taxation (10,870,578 from Table 10divided by 2,773,932 from Table 11), from which the urban DVM for other counties were estimated. For Chambers, the urban population with taxation was 15,787, yielding an estimate of urban county DVM of 61,867. The urban population with taxation was 55% of the total population of the county. Using this percentage as an estimate for the urban DVM, the total DVM for Chambers was 112,749.

Table 10. Harris County DVM from TxDOT File

Location	State Roads	County Roads	Local Roads
Urban DVM	54,844,385	10,870,578	25,029,497
Rural DVM	1,400,824	190,251	10,987

Table 11. Harris County Population Estimates

All Cities and Towns	All Cities and Towns With Taxation	Urban Cities With Taxation	Rural Towns With Taxation
2,994,964	2,780,551	2,773,932	6,619

The estimates created are presented in Table 12 and make intuitive sense. Counties with large urban populations like Brazoria, Fort Bend, and Montgomery have a large number of local miles driven, while rural counties such as San Jacinto have few. Chambers county highlights the reason why local estimates cannot be based on state roadway DVM. Interstate 10 passes through the entire length of the county, which accounts for the high number to state miles traveled. However, the county has a small population, so the local DVM should not be very substantial. The percentage DVM by group is shown in Table 12. Note that San Jacinto has no urban areas, therefore no urban DVM. To make calculations in the analysis simpler, the urban mileage breakdown for San Jacinto was replaced with the rural mileage. Table 13 displays the percentage of DVM driven on state, county, and local roads for both urban and rural areas.

Table 12. Estimated DVM by Road Ownership

Owner	**Austin**	**Brazoria**	**Chambers**	**Fort Bend**	**Galveston**
State	1,269,543	4,560,600	2,420,542	6,556,343	4,670,684
County	104,280	1,153,050	112,749	1,997,908	1,112,898
Local	113,326	1,931,851	162,073	2,239,243	2,241,053
Owner	**Harris**	**Liberty**	**Montgomery**	**San Jacinto**	**Waller**
State	56,245,209	1,892,604	8,552,671	705,745	1,745,771
County	15,423,961	295,613	1,617,060	43,103	140,815
Local	25,089,105	222,726	1,635,423	18,272	177,005

Table 13. Percent DVM by Geographic Location

County	Urban Area			Rural Area		
	State Roads	County Roads	Local Roads	State Roads	County Roads	Local Roads
Austin	72%	8%	19%	91%	6%	2%
Brazoria	52%	15%	33%	79%	16%	4%
Chambers	61%	12%	27%	97%	2%	1%
Fort Bend	63%	11%	26%	54%	44%	2%
Galveston	58%	13%	29%	54%	38%	8%
Harris	60%	12%	28%	23%	76%	1%
Liberty	65%	11%	25%	85%	13%	2%
Montgomery	70%	9%	21%	77%	21%	2%
San Jacinto	0%	0%	0%	92%	6%	2%
Waller	4%	29%	67%	95%	4%	1%

Based on the estimates above, the total yearly mileage for the Houston CBSA was 51.1 billion. The total mileage according to the NHTS data was 42.7 billion, or 85% of the estimated total, which leaves 15% of total mileage driven by trucks and other commercial vehicles. It should be noted that the NHTS data reflects all miles driven, not just miles on state, county, and local roads, such as distance driven on private property. However, this is expected to account for only a small percentage of the total miles driven for a household. Therefore, this total number of miles driven appears reasonable.

3.3 TRANSPORTATION TAXATION AND SPENDING

In order to provide a complete perspective for a MBUF, the entire system in which it operates needs to be understood. To achieve this aim, transportation related taxation and spending information was collected as follows:

- State level data was collected from the Texas Comptroller website (www.window.state.tx.us), TxDOT's District and County Statistics (www.txdot.gov/inside-txdot/division/finance/discos.html), and open records requests.
- County level data was collected from the Texas Comptroller website, the Texas Department of Motor Vehicles website (www.txdmv.gov), TxDOT District and County Statistics, county websites, county appraisal districts, and personal communication.
- City level data was collected from the United States Census (factfinder2.census.gov), the Texas Comptroller website, county appraisal districts, and city websites.
- Transit agency data was collected from National Transit Database (www.ntdprogram.gov/ntdprogram/), METROs website (www.ridemetro.org/Financials), and open records requests.

The state level taxes and fees examined here were specific to transportation, while local taxes were not. Fuel tax is reported directly to the state by individual businesses, thus there was no information for the total collected at the county level (David Reed pers. comm.). As the NHTS data allows the fuel tax paid to be directly calculated, total fuel revenues are not required. The state vehicle registration fees for 2008 are displayed in Table 14. These cane also easily be applied to each household using the NHTS data. Miscellaneous fees that could not be derived from NHTS needed to be estimated.

The average inspection fee per vehicle was $4.62, which was determined by dividing the total Texas revenue from inspections ($86,166,829) by the total registered vehicles in Texas (18,647,093). This is just the fee collected by the state; actual inspection prices reflect the respective businesses' charge for the service and are not included. The average fee for drivers licenses and driver record requests was $11.69, which was determined by dividing the total Texas revenue from fees ($179,667,613), by the total number of registered drivers in the state (15,374,063). As drivers licenses are not a regular annual expense, an average is appropriate. The total TxDOT expenditure per county is presented in Table 16 as well as the expenditure by annual DVM. The TxDOT expenditures collected from DISCOS do not include pass through grants or grants awarded by the state, which were accounted for in county and local expenditures.

Table 14. Vehicle Registration Fees for the State of Texas in 2008

Vehicle Model Year	Fee
2002 and Older	$40.80
2003, 2004, and 2005	$50.80
2006 and Newer	$58.80

Some counties and cities have a designated fund or department devoted to transportation, though this does not always include all of their transportation spending (overhead and grants are often not included). In order to obtain a reasonable estimate for county level transportation related taxation, the total county tax rates were multiplied by the percent of total revenue spent on transportation. This information is also presented in Table 16. For example, the property tax for Brazoria County, not including school or other districts, was .39000$^{\$/\$100}$ and the county spent 18.79% of its total revenue on transportation. Multiplying the two yields .07329$^{\$/\$100}$, which is an estimate of the average tax paid towards transportation expenditures. Additionally, the county sales tax was multiplied by 18.77% to get 0.094%, which is the average sales tax diverted to transportation.

For municipalities however, the method needed to be modified, as only county level resolution will be used from the NHTS survey. For the purpose of explanation, Table 15 contains local data collected for Chambers County. Local information for the other 9 counties may be viewed in Appendix A. Certain issues were encountered when collecting the required information from the local level. Each city has different accounting standards, given they would provide any financial documents at all. Some have separate departments for transportation, while smaller cities only have line items, which requires estimation for transportation spending. Where information was not available (Cove and Old River Winfree in Table 15), revenue was estimated based on linear regression versus population. To obtain this estimate, all municipalities with available revenue information were graphed versus their respective populations. The following linear equation was fitted to the data.

$$Revenue = y + x * Population \tag{8}$$

where *y* is the intercept and *x* is the estimate for the revenue per population. Unfortunately, the optimized function led to negative numbers for small populations. As small population municipalities were less likely to provide financial information, this was critical. For this reason, the intercept of the linear equation was constrained to zero. The population was based on the 2010 U.S. Census (several small towns only were only available in the 2000 census). The fitted equation yielded an estimated municipal revenue of $1675.7 per person. The amount spent on transportation as a percentage of total revenue was retained for each county (presented in Table 16). Revenues and expenditures were only calculated if the municipality had a sales or property tax on record; sales taxes are from the Texas Comptroller Website (www.window.state.tx.us/taxes) and property taxes are from their respective county appraisal district (www.austincad.net, www.brazoriacad.org, www.chamberscad.org, www.fbcad.org, www.galvestoncad.org, www.hcad.org, www.libertycad.com, www.mcad-tx.org, www.sjcad.org, and www.waller-cad.org).

After looking over the financial statements of cities who keep records over several years, total revenues tend not to change dramatically, though transportation spending may vary from year to year. This is especially true if the city receives any capital improvement grants. The earliest year of data available (closest to 2008) was used. As revenue does not change dramatically, the numbers are assumed to average to a reasonable estimate. Differences in accounting are also assumed to average out.

Table 15. Local Data for Chambers County

Municipality	Sales Tax	Property Tax	Population (Census)	Revenue	Transp. Expenditure	Estimated Revenue	Estimated Transp. Expenditure
Anahuac	1.00%	0.62425	2,210	$817,292	$71,110	$817,292	$71,110
Beach City	0.00%	0.00000	1,645	-	-	-	-
Cove	1.00%	0.00000	323	Unknown	Unknown	$541,251	$40,346
Double Bayou	0.00%	0.00000	400	-	-	-	-
Hankamer	0.00%	0.00000	525	-	-	-	-
Monroe City	0.00%	0.00000	90	-	-	-	-
Mont Belvieu	1.50%	0.39265	3,835	11,721,120	782155	$11,721,120	$782,155
Oak Island	0.00%	0.00000	363	-	-	-	-
Old River Winfree	1.50%	0.00000	1,364	Unknown	Unknown	$2,285,655	$170,379
Shoreacres	1.25%	0.00000	1,493	$2,091,590	$111,218	$2,091,590	$111,218
Seabrook	1.50%	0.62681	11,952	$17,505,000	$1,430,955	$17,505,000	$1,430,955
Smith Point	0.00%	0.00000	150	-	-	-	-
Weighted Average Tax	1.24%	0.42616	Total Rev./Exp.	$32,135,002	$2,395,438	$34,961,908	$2,606,164
Transportation Adjusted Tax	0.09%	0.03177	% Transp.		7.45%		7.45%

Weighted average sales and property taxes were calculated based on population, which included all cities and towns in the county (even small towns without any taxes). For Chambers, the result was 1.24% and .42616$^{\$/\$100}$ for sales and property tax respectively. The assumption made for sales tax was that the majority of spending occurs in one of these locations, with relatively little spending occurring in completely rural areas. A similar assumption was made for local property tax, except that it was only applied to urban households in the analysis. As completely rural areas and most rural towns do not have local property taxes (they still have county property taxes) and most large urban areas do, assigning local property taxes based on urban location was appropriate. Additionally, the tax rates for urban municipalities will outweigh the tax rates for rural municipalities due to the large difference in population. Therefore, issues with the application of the local property taxes should be minimal. Next, the weighted average was multiplied by the average transportation related local spending (7.5% from Table 15). For Chambers, the results were 0.09% and .03177$^{\$/\$100}$ for sales and property tax respectively. The same weighting method was used for the 1% METRO sales tax, as a few of its constituents were not wholly within Harris county.

Table 16. Taxation and Spending by County and Governmental Level

		Austin	Brazoria	Chambers	Fort Bend	Galveston
State	Daily Vehicle Miles	1,269,543	4,560,600	2,420,542	6,556,343	4,670,684
	TxDOT Spending	$10,200,209	$43,658,438	$59,083,813	$135,429,001	$109,429,821
	Spending / Annual DVM	$0.02201	$0.02623	$0.06687	$0.05659	$0.06419
County	Population	26,610	294,233	28,771	509,822	283,987
	Registered Vehicles	37,076	279,616	38,468	429,422	259,329
	Fuel Stations	22	136	25	181	129
	Total Revenue	$16,224,143	$141,294,435	$72,422,527	$273,440,458	$164,577,238
	Revenue per Person	$610	$480	$2,517	$536	$580
	Daily Vehicle Miles	104,280	1,153,050	112,749	1,997,908	1,112,898
	Transportation Spending	$5,218,685	$26,550,726	$8,166,697	$19,208,682	$12,206,563
	% Transportation Spending	32.17%	18.79%	11.28%	7.02%	7.42%
	Spending / Annual DVM	$0.13711	$0.06309	$0.19845	$0.02634	$0.03005
	Sales Tax	0.500%	0.500%	-	-	-
	Adjusted Based on Transportation Spending	0.161%	0.094%	-	-	-
	Property Tax ($/$100)	0.47960	0.39000	0.52214	0.55000	0.55860
	Adjusted Based on Transportation Spending	0.15427	0.07329	0.05888	0.03864	0.04143
	Vehicle Registration Fee	$10.00	$10.00	$10.00	$11.50	$10.00
Local	Municipal Urban Population with Taxation	10,116	204,510	15,787	243,421	245,364
	Municipal Rural Population with Taxation	2,468	10,007	2,210	5,230	3,488
	Town Population without Taxation	6,537	28,405	6,353	18,886	1,063
	Daily Vehicle Miles	113,326	1,931,851	162,073	2,239,243	2,241,053
	Total Transportation Spending	$882,075	$22,774,262	$2,606,164	$32,811,793	$37,134,394
	% Transportation Spending	5.59%	7.73%	7.45%	9.71%	9.63%
	Spending / Annual DVM	$0.02132	$0.03230	$0.04406	$0.04015	$0.04540
	Weighted Average Sales Tax Adjusted Based on Transportation Spending	0.056%	0.101%	0.092%	0.154%	0.173%
	Weighted Average Property Tax Adjusted Based on Transportation Spending	0.01169	0.04394	0.03177	0.04322	0.05034
	Metro Sales Tax	-	-	-	0.139%	-
	All Transit Revenue Miles	14,765	0	0	767,725	938,632

Table 16. Continued

		Harris	Liberty	Montgomery	San Jacinto	Waller
State	Daily Vehicle Miles	56,245,209	1,892,604	8,552,671	705,745	1,745,771
	TxDOT Spending	$698,574,728	$46,308,786	$228,228,197	$21,671,778	$8,613,283
	Spending / Annual DVM	$0.03403	$0.06704	$0.07311	$0.08413	$0.01352
County	Population	3,935,855	75,434	412,638	24,818	35,933
	Registered Vehicles	3,076,623	76,252	385,240	26,042	42,665
	Fuel Stations	1,529	34	151	7	26
	Total Revenue	$2,469,793,493	$42,291,838	$261,537,623	$16,628,937	$19,126,890
	Revenue per Person	$628	$561	$634	$670	$532
	Daily Vehicle Miles	15,423,961	295,613	1,617,060	43,103	140,815
	Transportation Spending	$373,484,374	$9,102,163	$76,212,732	$3,240,545	$3,937,295
	% Transportation Spending	15.12%	21.52%	29.14%	19.49%	20.59%
	Spending / Annual DVM	$0.09251	$0.08436	$0.12912	$0.20598	$0.07660
	Sales Tax	-	0.500%	-	0.500%	-
	Adjusted Based on Transportation Spending	-	0.108%	-	0.097%	-
	Property Tax ($/$100)	0.38923	0.56000	0.48880	0.62870	0.64253
	Adjusted Based on Transportation Spending	0.05886	0.12052	0.14244	0.12252	0.13227
	Vehicle Registration Fee	$11.50	$10.00	$10.00	$11.50	$10.00
Local	Municipal Urban Population with Taxation	2,773,932	21,347	170,581	0	17,329
	Municipal Rural Population with Taxation	6,619	3,385	11,020	2,029	2,327
	Town Population without Taxation	214,413	3,076	9,029	2,531	447
	Daily Vehicle Miles	25,089,105	222,726	1,635,423	18,272	177,005
	Total Transportation Spending	$390,198,463	$3,714,527	$23,024,474	$179,074	$2,652,955
	% Transportation Spending	8.66%	8.37%	11.72%	8.51%	10.16%
	Spending / Annual DVM	$0.04269	$0.04569	$0.03857	$0.02685	$0.04106
	Weighted Average Sales Tax Adjusted Based on Transportation Spending	0.081%	0.113%	0.088%	0.067%	0.178%
	Weighted Average Property Tax Adjusted Based on Transportation Spending	0.04939	0.04536	0.04213	0.01002	0.05330
	Metro Sales Tax	0.623%	-	-	-	0.098%
	All Transit Revenue Miles	63,110,626	0	1,390,034	83,603	19,938

3.3.1 Transit Agency Data

Information collected for transit agencies is presented in Table 17. Colorado Valley Transit and The District serve a few counties inside the Houston CBSA, though most of their service counties are not. Their numbers in the table below are a weighted average based on population for the counties they service within the Houston CBSA. By looking at the numbers presented, it is clear that METRO dominates the totals. For this reason, an error in estimation for the smaller agencies will not be substantial as most effort focused on obtaining accurate data for METRO. The average expenditure per unlinked trip was $5.39. Revenue miles per county are listed in Table 16.

Table 17. Transit Agency Data (Numbers are Restricted to Houston CBSA)

Agency	Total Fares Collected	Total Unlinked Trips	Total Expenditure	Total Revenue Miles
METRO	$56,701,736	125,080,144	$665,537,067	63,110,626
Galveston Island Transit	$208,726	499,920	$3,323,955	423,749
Fort Bend	$237,840	165,386	$3,086,912	767,725
Gulf Coast Center	$61,922	50,912	$2,357,046	514,883
Colorado Valley Transit	$40,000	30,500	$373,380	69,191
The District	$1,727,727	738,226	$6,879,468	1,593,112
Total	$58,977,951	126,565,088	681,557,828	66,479,286

For the purposes of this thesis, transit fares are considered a private cost, similar to how an individual's vehicle maintenance is be a privately incurred cost. As the analysis focuses on taxation, fares were not included. However, they were used to determine the increase in transit expenditures due to increased ridership. This was included in case the analysis demonstrated a dramatic increase in transit usage.

3.4 CONSUMER SPENDING

Information from the Bureau of Labor and Statistic's 2008 Consumer Spending survey is presented in Table 18 (www.bls.gov/cex). The BLS Consumer Survey contains expenditures by line item. To estimate sales taxable expenditures, exempt line items were removed based on Subchapter H of the Texas Tax Code (www.statutes.legis.state.tx.us/Docs/TX/htm/TX.151.htm). The average taxable auto purchases were included as well. This information represents vehicle purchases only, not other related vehicle spending. The consumer spending in Table 18 will be used to estimate the total paid in state, county, and local sales taxes. Consumer spending disaggregated by income was required, as an average would not accurately represent the difference between total sales taxation for high and low income households.

Table 18. Consumer Spending with Taxable Estimation

Household Income	Total Consumer Spending	Total Sales Taxable Consumer Spending	Total Taxable Auto Purchases
Less than $5,000	$23,036	$12,514	$430
$5,000 to $9,999	$19,125	$9,521	$810
$10,000 to $14,999	$21,120	$10,547	$606
$15,000 to 19,999	$25,536	$12,968	$1,346
$20,000 to $29,999	$30,367	$15,966	$1,770
$30,000 to $39,999	$35,778	$18,974	$2,069
$40,000 to $49,999	$40,527	$21,900	$2,098
$50,000 to $69,999	$50,465	$28,625	$3,093
$70,000 to $79,999	$58,742	$33,269	$3,114
$80,000 to $99,999	$67,180	$38,619	$3,916
$100,000 and more	$100,065	$59,140	$5,450

Source: Bureau of Labor and Statistic's 2008 Consumer Spending Survey

Unfortunately, the survey combined motor oil purchases with fuel purchases. For this reason, motor oil was not included in the analysis, as the bulk of this line item (fuel expenditures) are calculated elsewhere in this research. The total collected from its sale should very small compared to fuel tax revenue and it should not have much effect on distributions, especially considering that it at least partially tied to roadway use.

3.5 HOUSEHOLD PROPERTY VALUES

In order to apply the property taxes previously calculated, property values are required. Home values broken down by income were available for the American Community Survey (factfinder2.census.gov). The average value was a weighted calculation based on the average value for each category and the number of households in that category. The results are presented in Table 19.The average value for high income households may be slightly underrepresented due to the maximum value category being $500,000 or more. The average household value for this category was assumed to be $750,000, since households between $500 ,000 and $1 million accounted for 3.5% of total households, with households over $1 million accounting for 1.1% (this information was not available disaggregated by income). Additionally, the number of high income houses in the $500,000 or greater category accounted for 10.4% of the total for that category. Therefore, any issues with this assumption should be minimal.

Table 19. Average Home Values by Household Income

Household Income	Average Home Value
Less than $10,000	134,460
$10,000 to $19,999	112,570
$20,000 to $34,999	131,140
$35,000 to $49,999	137,830
$50,000 to $74,999	155,150
$75,000 to $99,999	184,760
$100,000 or More	282,040

The numbers above will provide reasonably accurate averages for homeowners, but renters require some additional discussion. Renters inevitably pay for the property tax on their dwelling, since the owner would not simply absorb the cost. For those renting a home, duplex, or townhouse, the value of the property, as well as the property tax, will be very similar to home owners. There was no information available for property taxes paid by apartment complexes or mobile homes, which account for 4.59% and 0.01% of all households in the Houston CBSA respectively. Due to the fact that they make up a small percent, the value of apartments or mobile homes, and thus the amount paid in property tax, was assumed to be roughly equivalent to what could be afforded by those who rent or own houses.

3.6 ELASTICITY

An elasticity is defined as the percent change in consumption resulting from a percent change in price (Litman 2013). Using elasticities, changes in travel behavior due to the change in the cost of travel can be reasonably estimated. For the purposes of this thesis, elasticities will refer to the percent change in either miles traveled or transit ridership based on the percent change in the cost of travel resulting from the implementation of a MBUF. For example, using an elasticity of -0.15, a 6% increase in the cost of travel would result in a 0.9% reduction in miles traveled. Wadud et. al. modeled disaggregated fuel price elasticities of travel demand for income quintiles via the Seemingly Unrelated Regression Feasible Generalized Least Squares Autoregressive (SUR-FGLS with AR (1)) model and for geographic distinction via Log-linear SUR-FGLS with AR (1) values (Wadud et al. 2009). Larsen combined these values into a cross classification table for urban and rural income quintiles , which are presented in Table 20 (Larsen et al. 2012).

Table 20. Fuel Price Elasticity of Travel Demand (VMT)

Household Income Quintile	Urban	Rural
Lowest	-0.447	-0.254
Lower Middle	-0.280	-0.159
Middle	-0.259	-0.147
Upper Middle	-0.335	-0.191
Highest	-0.373	-0.212
Total (Weighted Average)	-0.339	-0.192

Unfortunately, elasticities disaggregated by income and geographic location are not available for public transit ridership. Transit ridership elasticities based on fuel price have demonstrated accuracy in previous studies. Based on literature presented by the American Public Transportation Association, 0.185 was the average transit trip to fuel price elasticity (APTA 2011). As noted by APTA, this elasticity only represents areas where public transportation is available. The author of a recent thesis found a statistically significant elasticity of 0.096 specifically for the Houston CBSA (Lee 2012). While this may not be as reliable as other estimations, its shows that the Houston area may be less responsive compared to other areas. For this reason, the APTA elasticity will be considered to yield a high range number, while Lee's elasticity will be considered the lower range. Elasticity application will be further discussed in the methodology.

3.7 SUMMARY

In this section, the NHTS data was filtered and weighted. This data contained surveys for households, vehicles, persons, and trips and will be used to accurately tie various taxes and expenditures directly to household incomes, which is critical for an equity analysis. The result of the weighting and filtering process was a set of data with weights accurate to the State of Texas as a whole as well as for any of the four CBSA's. This was done in order to ensure that the Houston CBSA was not substantially different from the other areas. Additionally, replicate weights were included, which allow for more accurate estimations of standard error. The daily vehicle miles (DVM) for state, county, and local roads were estimated based on statistics from TxDOT's planning department. Estimates were also created for the distribution of total DVM between state, county, and local roads for urban and rural locations. Using these estimates will allow expenditures to be assigned to an individual's use of the roadway. These values along with taxation information were summarized in Table 16. Consumer spending habits obtained from the Bureau of Labor and Statistics contained expenditure line items disaggregated by household income. After eliminating line items exempt from sales tax, the average sales tax paid by income level can be estimated. Average home values obtained from the American Community survey will be used for property tax allocations. The elasticities used in the analysis were also discussed.

4. METHODOLOGY

For the analysis in this thesis, there were three different MBUF funding scenarios. The first was meant to be tax neutral, meaning that the MBUF would create the same gross revenue as the state fuel tax (it would ignore implementation costs). This scenario was meant to analyze any distributional impacts inherent in changing to a MBUF. The primary difference between the MBUF and the fuel tax when it comes to total taxes paid would be the fuel efficiency of each vehicle. This scenario would isolate that effect. The next scenario determines the increase in revenue required for implementation, including unit purchases, installation costs, operational costs, and individuals misreporting miles. This scenario provides a more realistic look at the MBUF and its equity, as all of the previous factors cannot simply be ignored. The final scenario increases the net revenue in order to meet Texas 2030 needs. This scenario will demonstrate any distributional changes with an increase in fees. Additionally, it will provide a relatable visualization of the true required cost of transportation moving into the future.

There were four steps in the analysis, (1) taxation calculation, (2) spending calculation, (3) MBUF calculation, and (4) equity calculation. The first three steps as well as the required implementation costs are detailed in the section below. MATLAB software was utilized in order to perform the analysis.

4.1 IMPLEMENTATION COST

A MBUF system is more likely to be implemented gradually (Forkenbrock 2005; Whittey 2007). However, there is no information available to predict who would voluntarily adopt a MBUF system and who would remain on the fuel tax system until forced to change.

Isolating these unknown trends would be difficult. For this reason, this thesis assumes that the system will be implemented at once. A similar assumption was made by Larsen et. al. (Larsen et al. 2012). An implementation similar to the Oregon study will be used, where gas stations read on board GPS units in order to ensure that the user is charged the appropriate fee. To implement this system, all vehicle would need to fitted with a GPS device and all service stations would need to be retrofitted in order to read the information provided from the GPS devices. The same process as described by Larsen will be used in this thesis with a few changes.

GPS unit prices have come down in recent years. According to Battelle, units may be purchased for under $100, though they may not have the accuracy and reliability needed for street level tracking (Battelle 2013). They list $150 for units better equipped for the task at hand, which provides a more conservative estimate for their cost. As noted by several authors, they may become cheaper if mass produced (Battelle 2013; Forkenbrock and Hanley 2006). With 3,547,500 vehicles in the Houston area, the total cost of outfitting all vehicles would be $532.1 million. According to the 2008 County Business Patterns (GBP) series of the United States Census Bureau (www.census.gov/econ/cbp), there were 10,420 gasoline stations in the State of Texas and 2,240 in the Houston CBSA. With a an installation price of $15,000 per station (Larsen et al. 2012), the total cost would to outfit all gas stations in the Houston CBSA would be $33.6 million. In order to be consistent with the revenue increase scenario (discussed below), 22 years will be the considered the total life span of the system, with the upfront cost paid for incrementally each year. With a 22 year yield of 4.5%, the total annual cost of installation would be $41 million.

According to the Texas 2030 Committee, $14.1 billion in additional revenue per year will be required for the State of Texas to maintain current traffic and roadway conditions. This figure includes pavement maintenance, bridge maintenance, urban mobility, rural mobility, and safety. Additionally, the figure was determined based on the period of time between 2008 and 2030 (22 years). The implantation costs were spread over this period of time so that the required revenue increase could be included with them. The required revenue increase for the Houston area ($3.29 billion) was determined based on its share of total NHTS miles driven. The additional revenue was assigned based on the breakdown of current state expenditures for each county. The assumption was that TxDOT will not dramatically alter their allocation process.

4.2 TAXATION ASSIGNMENT

Taxes were calculated using either household survey information or vehicle survey information, depending on which one was appropriate. Taxation assigned using the vehicle file is discussed first in the section below. After the all taxes were assigned for each vehicle, they were summed with the respective household taxes based on the HOUSEID variable. The results was a total for all transportation related taxes paid by each household.

The fuel tax collected for each vehicle was calculated using Equation (9). The equation was used to calculate both state and federal fuel taxes, where *Tax* is the applicable fee from Table 21 determined using the NHTS variable FUELTYPE. Originally, there were three survey vehicles that used propane. However, they were removed in the filtering process due to their surveys being incomplete. As their original NHTS weights were not very high, their effect should be negligible.

$$Fuel\,Tax\,Collected \;\; = Tax * Fuel\,Purchased\,(g) = \; Tax * \frac{BESTMILE}{EADMPG} \tag{9}$$

where BESTMIME is the NHTS vehicle file variable for miles driven and EADMPG is the NHTS vehicle file variable for fuel efficiency.

Table 21. Fuel Taxes

Fuel Type (FUELTYPE)	State	Federal
Gasoline	$0.2/gal	$0.184/gal
Diesel	$0.2/gal	$0.244/gal

A vehicle registration fee was assigned to each vehicle based on its age and the county of residence. The registration fee was $40.80, $50.80, and $58.80 for 2002 models or earlier, 2005 models or earlier, and new models, respectively (Table 14). The county registration fees were $10 per vehicle, with the exception of Fort Bend, Harris, and San Jacinto, where the registration fee was $11.50 (Table 16).

The remaining taxes were assigned based on household information (NHTS household file). The revenue generated from the sales tax was calculated using consumer spending information from Table 18 and the transportation spending adjusted rates presented in Table 22. The sales tax revenue from each household was determined using the following formulas:

$$County\,Sales\,Tax\,Revenue \;\; = \frac{Taxable\,Consumer\,Spending}{1 + S_{Sales} + C_{Sales} + L_{Sales} + M_{Sales}} * C_{Sales} \tag{10}$$

$$Local\ Sales\ Tax\ Revenue\ = \frac{Taxable\ Consumer\ Spending}{1 + S_{Sales} + C_{Sales} + L_{Sales} + M_{Sales}} * L_{Sales} \quad (11)$$

$$Metro\ Sales\ Tax\ Revenue\ = \frac{Taxable\ Consumer\ Spending}{1 + S_{Sales} + C_{Sales} + L_{Sales} + M_{Sales}} * M_{Sales}, \quad (12)$$

where S_{Sales} is the state sales tax, C_{Sales} is the applicable county sales tax based on the residence of the household, L_{Sales} is the applicable local sales tax based on the county of residence, and M_{Sales} is the applicable METRO sales tax based on the county of residence. As the consumer spending data were totals spent, they needed to be divided by the total combined sales tax rate in order to determine the amount spent excluding tax. Similarly, the revenue from state motor sales tax was calculated using the following formula:

$$State\ Auto\ Sales\ Revenue\ = \frac{Taxable\ Auto\ Spending}{1 + S_{Sales} + C_{Sales} + L_{Sales} + M_{Sales}} * S_{Sales} \quad (13)$$

County and local property taxes were assigned using the formula below. Local property taxes were only assigned if the household was in an urban location.

$$County\ Property\ Tax\ Revenue\ = \frac{Property\ Value}{100} * C_{Property} \quad (14)$$

$$Local\ Property\ Tax\ Revenue\ = \frac{Property\ Value}{100} * L_{Property}, \quad (15)$$

where *Property Value* is the applicable property value from Table 19, $C_{Property}$ is the county property tax rate ($/$100), and $L_{Property}$ was the county property tax rate ($/$100).

Table 22. Transportation Spending Adjusted County and Local Taxes

County	County Sales Tax	Local Sales Tax	METRO Sales Tax	County Property Tax	Local Property Tax
Austin	0.161%	0.056%	-	0.15427	0.20829
Brazoria	0.094%	0.101%	-	0.07329	0.04394
Chambers	-	0.092%	-	0.05888	0.03177
Fort Bend	-	0.154%	0.139%	0.03864	0.04322
Galveston	-	0.173%	-	0.04143	0.05034
Harris	-	0.081%	0.623%	0.05886	0.04939
Liberty	0.108%	0.113%	-	0.12052	0.04536
Montgomery	-	0.088%	-	0.14244	0.04213
San Jacinto	0.097%	0.067%	-	0.12252	0.01002
Waller	-	0.178%	0.098%	0.13227	0.05330

The average household revenue from state vehicle inspections was assigned using the following formula:

$$Inspection\ Revenue \ = \frac{\$4.62}{veh} * HHVEHCNT, \tag{16}$$

where *HHVEHCNT* is the NHTS variable for the number of vehicles per household. The average revenue from drivers license fees and driver record requests was calculated using the following formula:

$$Drivers\ Licence\ Revenue \ = \frac{\$11.69}{driver} * DRVRCNT, \tag{17}$$

where DRVRCNT is the NHTS variable for the number of drivers per household. The values in the two equations above were calculated based on total revenue for those categories divided by the total number of registered vehicles and drivers respectively (see section 3.3).

4.3 MBUF CALCULATION

The following section was repeated for each replicate weight in order to determine standard error estimates.

The revenue target for the MBUF was determined by summing the respective tax revenues that it would replace, with the total cost of implementation calculated based on the revenue scenario (same gross tax receipts, same net tax receipts, and revenue increase). Determining the required MBUF to meet this revenue target was an iterative process. First, the MBUF needed to meet the revenue target is calculated based on current VMT. If drivers were completely inelastic, this would be the end of the calculation. However, they will change their use of the roadway based on the change in price, which needs to be calculated. Afterwards, a new MBUF is calculated based on the new VMT and the process repeats. The details for the process are presented below.

First, the required MBUF fee to meet the target revenue is calculated with the following equation:

$$MBUF = \frac{Target\ Revenue}{\sum\ (VMT\ *\ HH\ Weight)}, \tag{18}$$

where *VMT* is the NHTS mileage driven by each vehicle and *HH Weight* is the household weight for each vehicle. The total annual amount paid by each vehicle due to the MBUF is then calculated with the following equation:

$$Total\ Annual\ MBUF\ Payment = VMT\ *\ MBUF \tag{19}$$

Next, the MBUF paid by each vehicle is combined with that vehicle's annual fuel expenditures (excluding fuel tax) to estimate the new "cost of fuel". As the elasticities are based on fuel price, in order to use them the MBUF needs to be included with the cost of fuel (as the fuel tax used to be). The annual fuel expenditure and the new combined "cost of fuel" are calculated with the following equations:

$$Annual\ Fuel\ Expenditure\ = Fuel\ Purchased\ (gal)\ *\ (GSCOST(\$) - Fuel\ Tax) \tag{20}$$

$$New\ Cost\ of\ Fuel\ = Fuel\ Expenditure + Total\ Annual\ MBUF\ Payment, \tag{21}$$

where *Fuel Purchased* is the same as calculated in Equation (9), *GSCOST* is the NHTS estimated average annual cost of fuel for the vehicle, *Fuel Tax* is the state fuel tax ($0.20), and *MBUF Payments* is the total mileage fee paid by each vehicle. Using this new cost of fuel, the percent change in price, VMT, and ridership are calculated for each vehicle.

$$\% \, Change \; in \; Price \;\; = \frac{New \; Cost \; of \; Fuel - Fuel \; Purchased \;\; * \;\; GSCOST}{Fuel \; Purchased \;\; * \;\; GSCOST} \tag{22}$$

$$\% \, Change \; in \; VMT \;\; = \% \, Change \; in \; Price \; * \; Fuel \; Elasticity \; of \; HH \tag{23}$$

$$\% \, Change \; in \; Ridership \;\; = \% \, Change \; in \; Price \; * \; Transit \; Elasticity \tag{24}$$

where the *Fuel Elasticity of HH* is the applicable household elasticity from Table 20. The Percent Change in Ridership for each household is calculated here because it is dependent on the change in each household's fuel price (which changes with each iteration). Next, the resulting change in vehicle miles traveled due to the MBUF is determined.

$$New \; VMT \;\; = BESTMILE \;\; * \;\; (1 + \% \, Change \; in \; VMT) \tag{25}$$

where *BESTMILE* is the NHTS variable for miles traveled. This *New VMT* is then substituted for the original *VMT* in Equation (18) and (19). The whole process is repeated until the total revenue from the MBUF is within $1 of the target revenue. After the VMT iterations have completed, the percent change in total VMT is calculated as follows:

$$\% VMT \;\; = \frac{\sum \; (New \; VMT \;\; * \;\; HH \; Weight) - \sum \; (BESTMILE \;\; * \;\; HH \; Weight)}{\sum \; (BESTMILE \;\; * \;\; HH \; Weight)} \tag{26}$$

Then the *% Change in Ridership* is used to calculate the new ridership for each household. The new total annual ridership is also calculated.

$$New\ Annual\ Ridership\ = PTUSED * 12\ *\ (1 + \%\ Change\ in\ Ridership) \qquad (27)$$

$$New\ Total\ Annual\ Ridership\ = \sum New\ Annual\ Ridership * HH\ Weight \qquad (28)$$

where PTUSED is the NHTS variable for the number of times transit was used in the past month. This variable was originally in the person file and was summed into the household file. The result was an estimate for the number of transit trips taken by each household over the past month. The total annualized PTUSED was 73.3 million, which is less than the 126.6 million recorded by all transit agencies in the area. However, the recorded number was for unlinked trips, while the PTUSED variable most likely includes linked trips. Therefore, the total from the NHTS survey should be less, as it is.

Applying the transit elasticity to each household in Equation (24) distributes the increase in total trips across households who used transit at least once in the previous month. In reality, some of these new trips would be from first time users. As it is impractical to determine which households would begin to use transit and what percentage of the increase they should receive, the method used above should provide a reasonable estimate. Additionally, with small increases in transit use any error will not be very substantial. For example, spreading a 5-10% increase in total transit trips over a large population will only be a few annual trips for the average household. Detailed numbers will be discussed later on.

4.4 EXPENDITURE ASSIGNMENT

As both the fuel tax and the MBUF tie taxation to road use, following the benefits principle, transportation spending should also reflect an individual's use of the roadway. Multiplying a household's VMT by the average expenditure per daily vehicle mile (DVM) for all levels of government provides a reasonable estimate of the benefit received. There are two ways the average expenditure could be assigned. The first is to assign an average based on all counties. Doing so would help account for out of county mileage, where a household travels to or through another county. However, local driving in a rural county is going to be dramatically different than local driving in and urban county like Harris. Calculating the average expenditure county by county can help take these differences into account. For this reason, the latter method was used.

The total spending in each county by each level of government was divided by its respective DVM, yielding and estimate for the expenditure per mile driven (and the benefit received for each mile driven by a user). As expenditures were not divided into urban and rural locations, the total DVM was used. Additionally, the NHTS survey does not provide an estimate for where household miles were driven. A mileage split for urban and rural locations was used by Larsen et. al. based on GPS tracking in the Waco area (Larsen et al. 2012). The number of miles driven by urban households on urban roadways was 78%, while the number of miles driven by rural households on urban roadways was 41%. For the purposes of this thesis, 80% and 40% were used for urban and rural household miles driven on urban roadways respectively. Unfortunately, the geographic distribution of miles traveled is not typically analyzed when using GPS tracking. The City of Waco may not be representative of the City of Houston, but should be representative of the other cities in the

Houston CBSA. The method for calculating the average expenditure per mile driven is as follows:

$$U_{Exp} = S_{Exp} * \%SU_{DVM} + C_{Exp} * \%CU_{DVM} + L_{Exp} * \%LU_{DVM} , \quad (29)$$

$$R_{Exp} = S_{Exp} * \%SR_{DVM} + C_{Exp} * \%CR_{DVM} + L_{Exp} * \%LR_{DVM} , \quad (30)$$

where *U* designates urban, *R* designates rural, *S* designates state, *C* designates county, *L* designates local. The values from Table 16 are presented in Table 23 for ease of reference.

Table 23. Expenditures per DVM

County	State	County	Local
Austin	$0.02201	$0.13711	$0.02132
Brazoria	$0.02623	$0.06309	$0.03230
Chambers	$0.06687	$0.19845	$0.04406
Fort Bend	$0.05659	$0.02634	$0.04015
Galveston	$0.06419	$0.03005	$0.04540
Harris	$0.03403	$0.09251	$0.04269
Liberty	$0.06704	$0.08436	$0.04569
Montgomery	$0.07311	$0.12912	$0.03857
San Jacinto	$0.08413	$0.20598	$0.02685
Waller	$0.01352	$0.07660	$0.04106

The total benefit received by each vehicle from all levels of governmental expenditure is calculated as follows:

$$User\ Benefit\ = VMT * \left[U_{Split} * \frac{U_{Exp}}{1 + \%VMT} + R_{Split} * \frac{R_{Exp}}{1 + \%VMT} \right], \qquad (31)$$

where U_{split} and R_{split} are the mileage splits mentioned above, U_{Exp} and R_{Exp} are the expenditures per mile calculated in Equations (29) and (30), *VMT* is the *New VMT* from the final iteration in the previous section, and *%VMT* is the percent change in total mileage from Equation (25). As the average expenditures are based on total DVM, which a mileage fee will reduce, they need to be adjusted. Since the miles traveled will likely decrease, *%M* will be a negative number and will thus increase the expenditure per DVM accordingly.

In order to determine how much households receive from public transit expenditures, the average expenditure per trip will be required. The total 2008 expenditures for all transit agencies ($681.6 million) as well as their total number of recorded unlinked trips (126.6 million) are available. However, there are several ways a MBUF would impact transit expenditures. First, transit agencies benefit from roadway expenditures, as bus service comprises the majority of total unlinked trips (84%). Next, transit agencies do not receive reimbursements for what they pay in fuel tax. As this is the case, they will not be exempted from the MBUF in this analysis. Finally, increase in transit usage will increase the total revenue from fares. As this analysis attempts to estimate the total user benefit received from all transportation taxation and expenditure, these factors need to be accounted for. The steps below describe how each of these factors will be addressed.

As public transit partially benefits from roadway expenditure, the miles driven by transit services needed to be taken into account. This is because transit users benefit from both transit expenditures and the roadways transit typically operates on. Based on METRO information, the majority of miles driven by busses are on local roads, while demand response is spread over all three levels. All HOV lanes are on state roads, though the miles driven on the rest of the trip are not. HOV miles are at least partially accounted for because they miles are included in the BESTMILE NHTS variable. Due to the lack of information and mixed variety of transit services, public transportation is assumed to benefit equally between state, county, and local roadway spending depending on the county in which the revenue miles were driven. For rural transit agencies, revenue miles per county were weighted estimates based on county population. The benefit received by public transit from roadway expenditure is calculated as follows, where the revenue miles are split evenly between state, county, and local roads:

$$TR_{Benefit} = \sum_{All\ Counties} [Revenue\ Miles * 0.3 * (S_{Exp} + C_{Exp} + L_{Exp})] \quad (32)$$

where S_{Exp}, C_{Exp}, and L_{Exp} are the average state, county, and local expenditures per state, county, and local roadway DVM respectively.

METRO does not receive any reimbursements for fuel taxes (Judith Bloss pers. comm.). Therefore, this analysis assumes they will be charged the MBUF along with all other vehicles. This may change, as exempting transit vehicles would not be difficult to do and would appear attractive to decision makers attempting to reduce the burden on low income households. As transit is primarily composed of buses and vans, which have low fuel efficiencies, it will likely benefit overall from a MBUF. Additionally, fuel tax expenditures by transit are included in their overall expenditures. In order to avoid double counting taxation, the difference between current fuel tax expenditures and MBUF expenditures by transit agencies will be used. For example, if transit agencies pay less under the MBUF, the result will be a positive number, while if they pay more the number will be negative. The difference in what transit pays is calculated as follows:

$$T_{MBUF} = Fuel\ Purchased\ (gal) * Fuel\ Tax - Total\ Revenue\ Miles * MBUF \qquad (33)$$

were T_{MBUF} is the difference in what transit pays under a MBUF as compared to the fuel tax, *Fuel Purchased* is the total number of gallons purchased for all transit agencies, *Fuel Tax* is the state fuel tax ($0.20), *Total Revenue Miles* is the revenue miles for all transit agencies ($66.5 million), and MBUF is the mileage fee calculated in the previous section. As only the revenue miles are available, this MBUF cost to transit will be slightly underestimated, though it will account for a very small portion of total transit expenditure. The fuel purchased by METRO was available in their financial statements, though no estimates were available for the other agencies. The average fuel efficiency based on revenue miles (not total miles) was 4.3 miles per gallon. The total fuel used by the other agencies was estimated with this number. Overall, transit agencies used 14.7 million gallons of diesel (96% of which was used by METRO). Additionally, METRO used 0.8 million gallons of gasoline, primarily for handicap accessible mini vans used for demand response transit.

Next, the total increase in revenues was calculated. Even though fares were not included as a fee, the total fare revenue ($59.0 million) was part of the total expenditure by public transit ($681.6 million). Therefore, the increase in fare revenue (TF) due to the increase in transit trips was included and is calculated as follows:

$$TF = Average\ Fare * [Original\ Total\ Ridership - New\ Total\ Ridership], \quad (34)$$

where the *Original Total Ridership* was 126.6 million and the *New Total Ridership* is from Equation (28). The average fare was $0.455 per trip and was based on total fare revenue ($59.0 million) divided by the total original ridership.

Now that these have been estimated, the transit expenditure per household may be determined. It is calculated as follows:

$$HH\ Transit\ Benefit = HH_R * \frac{TS + TR_{Benefit} + TF + T_{MBUF}}{New\ Total\ Ridership}, \quad (35)$$

where HH_R is the transit ridership for each respective household, *TS* is the total current expenditure by all transit agencies ($681.6 million), $TR_{Benefit}$ is the total received by transit agencies from roadway expenditures, *TF* is the average total increase in fare revenue due to the increase in transit trips, and T_{MBUF} is the difference paid under the MBUF system as compared to the fuel tax. The *New Total Ridership* is the sum of each HH_R.

If transit trips were to increase dramatically, total spending would likely increase due to additional grant eligibility. Since it is not possible to know what additional funding METRO would receive in the future, total current transit expenditure (TS) was not adjusted to take this into account. As the gross and net revenue scenarios will likely not increase trips by a dramatic amount, this assumption will be fine. The revenue increase scenario may cause the total benefit to transit users to be slightly underestimated.

5. RESULTS AND DISCUSSION

After properly filtering and weighting the NHTS data, household demographic relationships can be reasonably estimated. With the inclusion of transportation taxation and spending, the existing system can be analyzed and the effect of a MBUF determined. The equity of such a system in relation to other factors provides a complete perspective. This section presents the household demographic relationship finding, the MBUF analysis results, and the results of the equity analysis.

5.1 NHTS DEMOGRAPHICS

A thorough understanding of geographic and income relationships will aid in the interpretation of the equity analysis. Several assumptions are often made concerning these relationships. Specifically, it is assumed that lower income households have less fuel efficient vehicles, that rural households drive more miles, and that rural households have less income (Baker et al. 2011, NSTIF 2009; Whittey 2007). The analysis by Baker supports these assumptions, though in the research it was not possible to directly compare fuel efficiency to income (Baker et al. 2011). However, it is possible to do so with the NHTS data, from which the following conclusions were drawn. Income was broken down into even quintiles (five equal groups). As the number of households in each income category was not the same, these quintiles contain as close to the same number of households as possible. Demographic variations from the average are presented in Table 24. For additional information, figures in Appendix B include more detailed results.

Table 24. Variations from the Average for Select Demographics

	Low income	High Income	Urban	Rural
Fuel Efficiency	-4.3%	+1.8%	+0.7%	-3.1%
VMT by Vehicle	-11.7%	+5.6%	-2.4%	+10.5%
VMT by HH	-50.5%	+43.1%	-5.3%	+27.7%
% Hybrids	-1.1%	+1.0%	Not Significant	Not Significant

The average fuel efficiency for the State of Texas was 21.2 mpg. Lower income household vehicles were found to have lower fuel efficiencies, with the disparity between the upper quintile being 1.3 mpg. When comparing fuel efficiencies between urban and rural locations, the distinction is less clear. For the overall average, rural vehicles were less fuel efficient by 0.8 mpg. When broken down into by income the only income groups that had significantly different (95 percent confidence level) fuel efficiencies between urban and rural residents were the lower middle and upper middle quintiles. The average annual miles driven by households was 21,946. The upper quintile of households drove almost three times the number of miles compared the lower quintile. Additionally, rural households drove 7,323 more miles than urban households. The difference in urban rural mileage was due to the fact that rural households own 0.3 more vehicles than urban households. Based on mileage per vehicle, there was not statistical difference between low income urban and rural households (bottom two quintiles). Overall, however, rural vehicles drove 1,578 more miles than urban vehicles. High income vehicles drove 2,124 more miles than low income households. Given the higher mileage and lower elasticities of rural households, one would expect a MBUF to have a larger effect on them.

Hybrid ownership and mileage was found to be uniform between urban and rural areas, while higher incomes were found to own more hybrids. Additionally, lower income travelers drove their hybrids the same number of miles as for non-hybrids, while ownership of a hybrid for higher income households resulted in a greater number of total miles driven. This suggests that more lower income households purchase hybrids to save on their fuel purchases, while more higher income households either use those savings to drive more miles or are more likely to purchase a hybrid if they drive more than the average. The lack of statistical difference between urban and rural hybrid ownership and miles driven suggests that the impact of a MBUF would be uniform between them.

The percentage of total urban households made up by low incomes was 20.5%, while high incomes made up 18.9% (Table 25). On the other hand, low incomes made up 16.9% of the total number of rural households, while high incomes made up 19.3%. While the median income of rural households is lower than for urban (Gallardo 2012), the percentages indicate greater uniformity of income for rural areas. This suggests that there are more high income households than low income households in urban areas. However, when the effect of a MBUF system on low incomes is of concern, it should be kept in mind that 86% of low income households live in urban areas.

Table 25. Percentage of Households by Quintile

Income ($1000s)	**<20**	**20-40**	**40-65**	**65-100**	**100+**
Urban HH	20.5%	22.8%	19.4%	18.3%	18.9%
Rural HH	16.9%	20.4%	21.4%	22.0%	19.3%

One of the reasons for the analysis above was to ensure that the Houston CBSA variables were not substantially different from the other Texas CBSAs. The results for each CBSA are displayed in Table 26. Based on the findings, there was no statistical difference between the values for each variable in Table 27. For this reason, the results of the equity analysis are likely applicable to the other CBSAs in Texas with public transit services.

Table 26. Texas Core Based Statistical Area Demographics

CBSA	Austin	Dallas/Fort Worth	Houston	San Antonio
Vehicles per Household	1.8	1.8	1.8	1.8
VMT per Vehicle	12,627	12,156	12,311	12,126
VMT per Household	22,321	21,991	21,789	21,597
Weighted Average Fuel Efficiency	22.0	21.7	21.4	21.4
Percent Hybrids	2.80%	2.60%	2.50%	3.26%
Hybrid VMT per Non-Hybrid VMT	1.01	1.12	1.14	1.02

5.2 MBUF EFFECTS

The way a MBUF impacts how people use transportation is an important part of the equity of a MBUF. A situation where all individuals pay equally, but where those individuals only drive a small fraction of the miles they used to drive, may not be desirable. Information compiled in the tables below provides additional background when weighing alternatives. Using the replicate weights described in Section 3.1.4, confidence intervals can be determined for any estimate being considered, whether it is for the actual mileage fee or for an equity coefficient. These intervals help determine if any differences in the estimates are statistically significant, i.e. if they are different from another estimate. In their respective tables, *Lower* indicates the lower 95% confidence bound while *Upper* indicates the upper 95% confidence bound.

Displayed in Table 27 are the fees ($/mile) required to meet the target revenue. For the gross revenue neutral scenario, the fee was about 1 cent per mile, which replaces the Texas fuel tax and assumes that there were no implementation costs, operating costs, or people trying to cheat the system than compared to the gas tax. With reasonable costs for implementation, operation, maintenance, and leakage included, the fee would be 1.3 cents per mile, which shows that the overhead required for implementing a VMT scenario upfront is quite costly, especially considering that 1 cent per mile would pay for all state roadway infrastructure. This could likely be lowered if the system were implemented voluntarily over time, with users responsible for the purchase of the unit (smart phone owners may not need to purchase one at all), leaving only the cost for outfitting service stations up to the state. In order to meet the Texas 2030 Committee's goals, which would prevent worsening roadway and traffic conditions, the total fee required would be 13.9 cents per mile. The dramatic increase in fee for this scenario helps visualize how underfunded the current system is based on the 2030 Committee.

Table 27. Mileage Based User Fee by Scenario (Cents/Mile)

Scenario	MBUF	Lower 95%	Upper 95%
Gross Revenue	0.970	0.960	0.981
Net Revenue	1.342	1.328	1.356
Revenue Increase	13.922	13.506	14.337

The total vehicle miles traveled for each scenario, presented in Table 28, reveal a dramatic change. Based on the confidence intervals, the net revenue scenario will decrease total mileage by around 1%, while the revenue increase scenario will decrease the total miles driven by 22.8%. This reduction closely matches finding from the Oregon study, where congestion pricing (10 cents per mile) reduced miles traveled by 22% (Whittey 2007). Additionally, the visibility of the MBUF may further reduce the total miles driven. If the 2030 estimates do not include a large decrease in miles driven due to increased taxation, the total revenue required to maintain conditions may not be as high as stated.

Table 28. Vehicle Miles Traveled (Billions)

Scenario	VMT	Lower 95%	Upper 95%	%Change	Lower 95%	Upper 95%
Fuel Tax	43.67	42.54	44.81	-	-	-
Gross Revenue	43.61	42.48	44.75	-0.135%	-0.144%	-0.125%
Net Revenue	43.24	42.11	44.36	-0.996%	-1.011%	-0.981%
Revenue Increase	33.71	32.60	34.81	-22.814%	-23.397%	-22.231%

The percent decreases in vehicle miles traveled for each scenario disaggregated by quintile and geographic location are displayed in Table 29. As expected based on the elasticities, low income households reduced their total miles by the greatest amount, while high income household reduced their mile slightly more than medium income households. Again, as expected, urban households decreased their mileage to a greater degree than rural households. Considering that rural households already drive more miles than urban households, the MBUF may further increase the gap between the two. This should be kept in mind for the equity comparisons.

Table 29. Percent Change in VMT by Quintile and Geographic Location

Urban						
Income ($1000s)	**<20**	**20-40**	**40-65**	**65-100**	**100+**	**Average**
Gross Revenue	-0.20%	-0.17%	-0.13%	-0.11%	-0.13%	-0.14%
Net Revenue	-1.41%	-0.95%	-0.85%	-1.01%	-1.13%	-1.04%
Revenue Increase	-29.04%	-21.55%	-20.11%	-23.75%	-25.48%	-23.73%
Rural						
Income ($1000s)	**<20**	**20-40**	**40-65**	**65-100**	**100+**	**Average**
Gross Revenue	-0.08%	-0.01%	-0.09%	-0.12%	-0.01%	-0.08%
Net Revenue	-0.76%	-0.42%	-0.50%	-0.66%	-0.56%	-0.59%
Revenue Increase	-19.22%	-12.66%	-12.73%	-15.99%	-16.13%	-15.29%

The total NHTS transit ridership for high and low elasticities are displayed in Table 30 and Table 31 respectively. These two are considered to provide a low and high estimate for transit ridership. The increase in ridership for the net revenue scenario was between around 170,000 and 320,000 trips, while the revenue increase scenario was between 3.9 and 7.5 million trips. Such a large increase in the mileage based user fee for the revenue increase scenario may be high enough to encourage a very large increase in ridership, increasing the number of transit vehicles and making the mode more attractive to riders. For this reason, the low estimate is likely more accurate for the net revenue scenario, while the high estimate is may be more accurate for the revenue increases scenario. For the revenue increase scenario, the difference between the equity results in the next section when using the two different transit elasticities was not significant. This supports the assumption that the method of additional transit trip allocation would not lead to substantial errors.

Table 30. Transit Ridership (Millions) Based on Elasticity of 0.185

Scenario	Ridership	Lower 95%	Upper 95%	% Change	Lower 95%	Upper 95%
Fuel Tax	73.38	60.13	86.63	-	-	-
Gross Revenue	73.42	60.15	86.69	0.056%	0.000%	0.112%
Net Revenue	73.70	60.38	87.03	0.440%	0.342%	0.538%
Revenue Increase	80.90	66.03	95.77	10.248%	8.870%	11.625%

Table 31. Transit Ridership (Millions) Based on Elasticity of 0.096

Scenario	Ridership	Lower 95%	Upper 95%	% Change	Lower 95%	Upper 95%
Fuel Tax	73.38	60.13	86.63	-	-	-
Gross Revenue	73.40	60.14	86.66	0.029%	0.000%	0.058%
Net Revenue	73.55	60.26	86.84	0.228%	0.178%	0.279%
Revenue Increase	77.28	63.20	91.37	5.318%	4.603%	6.032%

An important finding was the average benefit (or expenditure) to taxation ratio for all households. The results are displayed in Table 32. Even though NHTS vehicle miles traveled accounted for roughly 85% of the total estimated DVM, users received more in value than they paid in taxes for all scenarios except the revenue increase scenario. This suggests that other groups such as businesses, most likely through property and sales tax, finance more than their share of the transportation network. While there was no statistical difference between the fuel tax and either the gross or net revenue scenarios, the revenue increase scenario will decrease the ratio. This means that increasing a MBUF while the other taxes and fees remain in place will cause households to receive less than the pay in taxes.

Table 32. Average Benefit/Taxation Ratio

Scenario	Average Ratio	Lower 95%	Upper 95%
Fuel Tax	1.1424	1.012	1.272
Gross Revenue	1.1407	1.011	1.271
Net Revenue	1.0568	0.936	1.177
Revenue Increase	0.8015	0.709	0.894

5.3 EQUITY

As discussed in Section 2, there are two types of equity: vertical and horizontal. Typically, reducing taxes and increasing benefits for lower income households would be considered more vertically equitable, while horizontal equity is achieved by ensuring all users receive the same benefit based on their use of the system. The MBUF is derived from the user pay principle, which the Gini Coefficient and Theil Index can estimate. When analyzing the results, both of these measures have two meanings. When considering incomes (benefits/expenditures), a lower Gini is desirable, indicating that each quintile receives the same amount of benefit. This interpretation reverses when considering taxation, where a larger burden on the higher income quintiles, and a correspondingly smaller burden on the lower quintiles, would be considered more vertically equitable.

Three different Gini Coefficients are presented for each revenue scenario in Table 33. The first is for taxation, the second for benefits received (expenditures), and the third for the ratio between the two. There was no statistical difference between any of the taxation or benefit coefficients. For the taxation with the revenue increase scenario, the lower number is less desirable, but expected since a user fee would inherently move the Lorenz curve closer to the equity line, i.e. all users would pay equally. However, due to the confidence intervals, the difference is negligible. The opposite is desired for the benefit coefficients. The larger number for the revenue increase scenario is less desirable. Again, however, the different is not statistically significant. The ratio coefficients are negative due to the lower two quintiles receiving a greater percentage of the distribution than higher quintiles (Lorenz curve plots may be viewed in Appendix C). Low incomes had slightly better ratios than high income households, with middle quintile ratios being almost exactly the average. When public transit benefits were excluded from the analysis (Equations (31) through (35) were ignored), the ratio Gini coefficient for the fuel tax was -0.033. Additionally, it was statistically different from the -.093 coefficient in the table below, indicating that public transit has a conclusive and desirable effect on equity. The lack of a statistical difference between ratio coefficients for the first two scenarios indicates that a MBUF would not have a dramatic effect on the comparative taxation and benefits received by the current system. Additionally, the lack of statistical difference between the fuel tax and the gross revenue scenario suggests that fuel efficiencies do not play a dramatic role in equity. However, the revenue increase scenario ratio was statistically different from the fuel tax, though narrowly so. This suggests that low income households would receive less than they do under the fuel tax.

Table 33. Gini Coefficients

Scenario	Taxation			Benefit			Ratio (Benefit/Tax)		
	Gini	Lower 95%	Upper 95%	Gini	Lower 95%	Upper 95%	Gini	Lower 95%	Upper 95%
Fuel Tax	0.179	0.170	0.188	0.137	0.113	0.160	-0.089	-0.109	-0.069
Gross Revenue	0.177	0.169	0.186	0.137	0.113	0.160	-0.088	-0.108	-0.068
Net Revenue	0.177	0.167	0.186	0.137	0.113	0.160	-0.089	-0.109	-0.069
Revenue Increase	0.170	0.155	0.185	0.162	0.142	0.182	-0.054	-0.070	-0.039

The Theil Index provides a useful addition to the Gini Coefficient due to its decomposability. The indices for the entire population are provided in Table 34. A higher number indicates a greater disparity between individuals within the population. As the indices are higher for the benefit received, it suggests that there is a greater disparity in who receives the benefits as compared to who pays the taxes. The lower indices for the ratio indicate that there is less disparity when use of the system is factored in to the taxes paid. The lack of a statistical difference between the scenarios indicates that whatever disparity exists will not be changed by a MBUF. Due to the Gini Coefficients, the source of benefit disparity is known. However, the decomposed Theil Indices reveal more than the Gini Coefficients.

Table 34. Theil Index

Scenario	Taxation			Benefit			Ratio (Benefit/Tax)		
	Theil	Lower 95%	Upper 95%	Theil	Lower 95%	Upper 95%	Theil	Lower 95%	Upper 95%
Fuel Tax	7.241	7.083	7.399	7.529	7.361	7.698	6.765	6.654	6.876
Gross Revenue	7.241	7.084	7.399	7.529	7.361	7.697	6.761	6.650	6.871
Net Revenue	7.250	7.092	7.408	7.530	7.361	7.698	6.761	6.650	6.872
Revenue Increase	7.356	7.196	7.515	7.479	7.305	7.652	6.730	6.618	6.842

The within group components of the Theil Index are presented in Table 35, Table 36, and Table 37. In other words, these are the Theil Indices for each sub group, which can reveal inequality between individuals within that sub group. Remember that only indices from the same population (same column) are comparable. As with the index for the entire population, the sub group indices don't show any difference between VMT alternatives. These numbers further support that a flat MBUF would not alter existing inequalities.

Table 35. Within Group Theil Index for Taxation

Location of HH	Urban					Rural				
Income ($1000s)	**<20**	**20-40**	**40-65**	**65-100**	**100+**	**<20**	**20-40**	**40-65**	**65-100**	**100+**
Fuel Tax	7.65	7.59	7.40	7.16	6.94	6.73	5.81	7.08	7.05	5.86
Gross Revenue	7.66	7.59	7.40	7.16	6.94	6.72	5.80	7.08	7.08	5.85
Net Revenue	7.68	7.60	7.41	7.17	6.94	6.76	5.81	7.09	7.11	5.87
Revenue Increase	7.96	7.78	7.53	7.24	6.96	7.09	5.91	7.15	7.28	5.97

Table 36. Within Group Theil Index for Benefits

Location of HH	Urban					Rural				
Income ($1000s)	**<20**	**20-40**	**40-65**	**65-100**	**100+**	**<20**	**20-40**	**40-65**	**65-100**	**100+**
Fuel Tax	8.25	8.09	7.68	7.35	7.12	7.11	5.98	7.20	7.33	6.03
Gross Revenue	8.25	8.09	7.68	7.35	7.12	7.11	5.98	7.20	7.33	6.03
Net Revenue	8.25	8.09	7.68	7.35	7.12	7.10	5.98	7.20	7.33	6.03
Revenue Increase	8.14	7.96	7.63	7.36	7.06	6.95	6.01	7.24	7.38	6.15

Table 37. Within Group Theil Index for Ratio

Location of HH	Urban					Rural				
Income ($1000s)	**<20**	**20-40**	**40-65**	**65-100**	**100+**	**<20**	**20-40**	**40-65**	**65-100**	**100+**
Fuel Tax	7.54	7.31	7.01	6.64	6.45	6.35	5.30	6.30	5.96	5.28
Gross Revenue	7.54	7.31	7.01	6.64	6.45	6.33	5.29	6.28	5.95	5.28
Net Revenue	7.56	7.31	7.01	6.64	6.45	6.33	5.28	6.27	5.95	5.27
Revenue Increase	7.60	7.22	6.93	6.58	6.41	6.12	5.26	6.27	5.96	5.29

The between group components of the Theil index are presented in Table 38, Table 39, and Table 40. Unlike the within group component above, all of these values are comparable, with numbers closer to zero being more desirable. Positive values indicate more income (or taxation) than households, while negative values represent more households than income (or taxation). This means that for taxation, positive values indicate the losers, while for transportation expenditures, positive values indicate the winners. To avoid confusion, the relative winners have been shaded in the tables below. If the source of inequality was not known, the indices below would reveal it, as they do. Again, there were no differences between revenue scenarios, supporting the assumption that the MBUF would not impact current distributions. Unlike the Gini Coefficient however, they show that, for the ratio, rural and high income urban households are the relative winners. Keep in mind that each household still receives far more in benefits than they pay into the system for (except for the revenue increase scenario). For this reason, all households can be considered winners, with some receiving a greater share than others. The indices below simply show who received the largest share. The greater number of miles driven by rural and higher income urban households may be the reason why they are the relative winners. Driving more miles decrease the effective average tax per mile due to flat rate costs such as vehicle registration and property taxes, which must be paid regardless of the number of miles driven. It should be noted that all of the numbers in the tables below are very close to zero, indicating that the relative winners and losers are determined by a narrow margin.

Table 38. Between Group Theil Component for Taxation

Location of HH	Urban					Rural				
Income ($1000s)	**<20**	**20-40**	**40-65**	**65-100**	**100+**	**<20**	**20-40**	**40-65**	**65-100**	**100+**
Fuel Tax	-0.053	-0.044	-0.009	0.018	0.127	-0.001	-0.001	-0.001	0.008	0.008
Gross Revenue	-0.053	-0.044	-0.009	0.017	0.126	-0.001	-0.001	-0.001	0.008	0.008
Net Revenue	-0.053	-0.044	-0.008	0.018	0.123	-0.001	-0.001	0.000	0.010	0.008
Revenue Increase	-0.057	-0.043	0.004	0.021	0.085	0.000	0.001	0.006	0.025	0.015

Table 39. Between Group Theil Component for Benefits

Location of HH	Urban					Rural				
Income ($1000s)	**<20**	**20-40**	**40-65**	**65-100**	**100+**	**<20**	**20-40**	**40-65**	**65-100**	**100+**
Fuel Tax	-0.048	-0.037	-0.008	0.011	0.071	0.000	0.001	0.006	0.026	0.015
Gross Revenue	-0.048	-0.037	-0.008	0.011	0.071	0.000	0.001	0.006	0.026	0.015
Net Revenue	-0.048	-0.037	-0.008	0.011	0.070	0.000	0.001	0.006	0.027	0.015
Revenue Increase	-0.058	-0.044	-0.003	0.015	0.059	0.000	0.006	0.020	0.048	0.029

Table 40. Between Group Theil Component for Ratio

Location of HH	Urban					Rural				
Income ($1000s)	**<20**	**20-40**	**40-65**	**65-100**	**100+**	**<20**	**20-40**	**40-65**	**65-100**	**100+**
Fuel Tax	-0.051	-0.052	-0.036	0.001	0.018	0.023	0.060	0.022	0.059	0.108
Gross Revenue	-0.051	-0.053	-0.036	0.001	0.018	0.023	0.061	0.021	0.061	0.110
Net Revenue	-0.050	-0.052	-0.036	0.000	0.019	0.023	0.060	0.020	0.058	0.108
Revenue Increase	-0.045	-0.052	-0.040	-0.009	0.019	0.022	0.072	0.024	0.056	0.110

6. SUMMARY AND CONCLUSIONS

The need for additional transportation infrastructure funding has created a need for alternative funding sources. The most prominent of those alternatives is the MBUF, where drivers would be charged based on the miles they drive, thus holding them accountable for their use of the roadway. Extensive research into the possible implementation and distributional impacts of MBUFs has taken place over recent years, though there are still many areas not well understood. One such area is how a MBUF would work in relation to other taxes and how much a road user would benefit from such a system. In fact, the big picture of how all transportation taxation and spending interrelates is not well understood. One key question in this area is how a MBUF might affect public transit ridership.

The research performed in this thesis, focusing on the Houston core based statistical area (CBSA), addresses these areas. Using the NHTS data, the cost of roadway use can be tied directly to a household and their respective income. Based on this data, several common equity related assumptions were supported. Rural households were found to have lower fuel efficiencies and to drive more miles than urban households. However, rural households drove the same number of miles per vehicle; the greater total mileage was due to their owning more vehicles. Additionally, high income households drove almost three times the number of miles than did low income households. Surprisingly, the distribution of rural households across income quintiles was more uniform than urban areas, with urban areas having a greater percentage of low income households (86% of all low income households were in urban areas) as compared to rural households.

Several different MBUF scenarios were analyzed. The MBUF required to cover implementation costs was 1.3 cents per mile, while the fee required to meet Texas 2030 needs was 13.9 cents per mile, highlighting the degree the current system could use additional funding. Implementation of a MBUF system would decrease total miles driven by only 1%, though a slightly larger reduction is likely due to the visibility of the MBUF. However, when rising the MBUF to 13.9 cents per mile to meet 2030 needs, total miles may be reduced by 22.8%. The resulting increase in transit ridership would be between 5.3% and 10.2% depending on which elasticity was used. For the net revenue scenario, ridership would increase by 0.2% to 0.4%, which would account for several hundred thousand annual trips.

Using both Gini Coefficients and Theil Indices to analyze equity relationships, there was little difference between MBUF scenarios and the fuel tax when it came to how much users pay versus how much they receive. The exception was the revenue increase scenario, which will cause households to receive, on average, less than they pay into the system. The relative winners of the current system are rural and high income urban households, while the relative losers are lower income urban households. However, this is purely for taxation and spending, which does not reflect the true total cost of using the transportation system (vehicle maintenance, transit fares, etc.). Excluding public transit expenditures resulted in a statistically significant and undesirable change in the Gini Coefficient, indicating that public transit has a positive impact on equity when considering the transportation system as a whole.

Overall, the research in this thesis demonstrates that implementation of a MBUF would not have a pronounced effect on current distributions, with the number of miles traveled and the total transit ridership remaining mostly unchanged. This also means that the equity of a MBUF is mostly equivalent to the current fuel tax, with winners and losers also remaining unchanged. However, increasing the MBUF to 13.9 cents per mile would decrease the average benefit to taxation ratio, causing households to receive less than they pay into the system. Additionally, it would decrease the total number of miles traveled by 22.8% and increase transit ridership by as much as 10.2%. Due to relatively flat rate taxes (vehicle registration, property tax, sales tax, etc.), the higher the miles driven, the lower the effective tax is per mile. When miles traveled are decreased by 22.8%, the effective tax per mile increases, which is the reason why the average benefit to taxation ratio was reduced. If transportation related taxation were to shift towards user based methods, then the benefit to taxation ratio should equalize towards a value of one, indicating that all users receive exactly the value they pay for. If revenues are increased while the methods of taxation remain the same, low income urban households will be impacted to the greatest degree.

6.1 RESEARCH LIMITATION

The research did not include trucks or commercial vehicles. However, based on NHTS data and the daily vehicle mile estimate, they only account for roughly 15% of total miles driven. Due to the lack of available information, several other estimates needed to be made. Most of these estimations yielded reasonable results. However, there was little confidence in the total daily vehicle miles driven on county roads. The state reported DVM was accurate and the local DVM could be reasonably estimated, but the county DVM estimation resulted in some deviation between the ten counties when it came to county expenditure per DVM. The maximum was 20 cents per mile, while the minimum was 2.6

cents per mile. However, it is possible that miles driven on county roads are simply not the same for different counties. For comparison, the maximum and minimum for state roadways was 8.4 and 1.3 cents per mile respectively while the maximum and minimum for local roadways was 4.6 and 2.1 cents per mile. When combining the numbers above into urban and rural expenditures, the county variations were no longer pronounced. For urban areas, the average maximum and minimum expenditure was 9.0 and 3.2 cents per mile while the average maximum and minimum for rural areas was 9.0 and 1.6 cents per mile.

6.2 RECOMMENDATIONS FOR FURTHER RESEARCH

Research into where and when miles are driven would prove beneficial for understanding transportation equity. For example, determining the number of miles driven on state, county, and local roads as well as the geographic location of those miles. In addition to this, better information is needed for the total DVM on county roadways. Given that this information is made available, or can be reasonably estimated, the next step would be to analyze the equity of VMT congestion pricing.

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APPENDIX A - DATA

Table 41. Local Data for Austin County

Municipality	Sales Tax	Property Tax	Population (Census)	Revenue	Transp. Expenditure	Estimated Revenue	Estimated Transp. Expenditure
Bellville	1.50%	0.27180	4,097	$2,322,532	$227,193	$2,322,532	$227,193
Bleiblerville	0.00%	0.00000	71				
Brazos Country	1.00%	0.11630	469	Unknown	Unknown	$785,903	$43,961
Buckhorn	0.00%	0.00000	20				
Burleigh	0.00%	0.00000	69				
Cat Spring	0.00%	0.00000	766				
Cochran	0.00%	0.00000	3,127				
Industry	1.50%	0.00000	304	Unknown	Unknown	$509,413	$28,495
Frydek	0.00%	0.00000	150				
Kenney	0.00%	0.00000	200				
Milheim	0.00%	0.00000	150				
Nelsonville	0.00%	0.00000	110				
New Ulm	0.00%	0.00000	650				
New Wehdem	0.00%	0.00000	100				
Peters	0.00%	0.00000	95				
Raccoon Bend	0.00%	0.00000	400				
San Felipe	1.50%	0.17680	747	Unknown	Unknown	$1,251,748	$70,020
Sealy	1.50%	0.30129	6,019	$8,801,359	$395,050	$8,801,359	$395,050
Shelby	0.00%	0.00000	175				
Wallis	1.50%	0.69410	1,252	Unknown	Unknown	$2,097,976	$117,356
Welcome	0.00%	0.00000	150				
Weighted Average Tax	0.99%	0.20829	Total Rev./Exp.	$11,123,891	$622,243	$15,768,931	$882,075
Transportation Adjusted Tax	0.06%	0.01165	% Transp.		5.59%		5.59%

Table 42. Local Data for Brazoria County

Municipality	Sales Tax	Property Tax	Population (Census)	Revenue	Transp. Expenditure	Estimated Revenue	Estimated Transp. Expenditure
Alvin	1.50%	0.80360	24,236	$26,748,274	$1,354,999	$26,748,274	$1,354,999
Amsterdam	0.00%	0.00000	193				
Angleton	1.50%	0.70600	18,862	$18,515,364	$1,102,609	$18,515,364	$1,102,609
Baileys Prairie	1.00%	0.00000	694	Unknown	Unknown	$1,162,936	$89,882
Bonney	0.00%	0.00000	384				
Brazoria	1.50%	0.72830	2,787	Unknown	Unknown	$4,670,176	$360,954
Brookside Village	1.00%	0.46000	1,960	Unknown	Unknown	$3,284,372	$253,846
Chocolate Bayou	0.00%	0.00000	60				
Clute	1.50%	0.69300	10,424	$13,229,301	$1,216,984	$13,229,301	$1,216,984
Damon	0.00%	0.00000	535				
Danbury	1.00%	0.76060	1,703	Unknown	Unknown	$2,853,717	$220,561
Danciger	0.00%	0.00000	357				
East Columbia	0.00%	0.00000	95				
Freeport	1.50%	0.70000	12,049	$15,662,529	$1,654,806	$15,662,529	$1,654,806
Hillcrest	0.00%	0.37451	722	$307,100	$16,000	$307,100	$16,000
Holiday Lakes	1.00%	0.92407	1,095	Unknown	Unknown	$1,834,892	$141,817
Iowa Colony	1.00%	0.00000	804	$530,564	$50,652	$530,564	$50,652
Jones Creek	1.00%	0.34000	2,130	Unknown	Unknown	$3,569,241	$275,863
Lake Jackson	1.50%	0.39000	26,849	$33,113,099	$1,697,868	$33,113,099	$1,697,868
Liverpool	1.00%	0.17580	404	$506,397	$66,062	$506,397	$66,062
Manvel	1.50%	0.58786	7,160	Unknown	Unknown	$11,998,012	$927,315
Old Brazoria	0.00%	0.00000	2,787				
Old Ocean	0.00%	0.00000	915				
Otey	0.00%	0.00000	318				
Oyster Creek	1.50%	0.39500	1,192	Unknown	Unknown	$1,997,434	$154,380
Pearland	1.50%	0.65260	91,252	$142,570,381	$11,913,119	$142,570,381	$11,913,119
Quintana	1.00%	0.02714	38	Unknown	Unknown	$63,677	$4,922
Richwood	1.25%	0.69366	3,012	$1,917,025	$217,632	$1,917,025	$217,632
Rosharon	0.00%	0.00000	21,233				
Sandy Point	0.00%	0.00000	30				
Surfside Beach	1.00%	0.35239	763	$1,366,411	$317,276	$1,366,411	$317,276
Sweeny	1.50%	0.76211	3,624	$1,632,373	$185,636	$1,632,373	$185,636
Weighted Average Tax	1.31%	0.56857	Total Rev./Exp.	$256,098,819	$19,793,642	$294,663,378	$22,774,262
Transportation Adjusted Tax	0.10%	0.04394	% Transp.		7.73%		7.73%

Table 43. Local Data for Fort Bend County

Municipality	Sales Tax	Property Tax	Population (Census)	Revenue	Transp. Expenditure	Estimated Revenue	Estimated Transp. Expenditure
Arcola	2.00%	0.95258	1,048			$1,756,134	$170,515
Beasley	2.00%	0.44828	590			$988,663	$95,996
Fulshear	2.00%	0.20592	2,000	$2,556,233	$95,558	$2,556,233	$95,558
Houston	1.00%	0.64375	38,000	$64,047,878	$5,592,319	$64,047,878	$5,592,319
Katy	1.00%	0.60540	3,526	$6,904,750	$568,000	$6,904,750	$568,000
Kendleton	1.00%	0.76632	466			$780,876	$75,821
Meadows Place	2.00%	0.79000	4,660	$3,249,330	$368,356	$3,249,330	$368,356
Missouri City	1.00%	0.51720	67,358	$43,637,000	$3,569,666	$43,637,000	$3,569,666
Needville	2.00%	0.39169	2,609	$1,158,214	$119,609	$1,158,214	$119,609
Orchard	2.00%	0.33123	408			$683,686	$66,384
Pleak	1.75%	0.00000	947	$128,945	$10,000	$128,945	$10,000
Richmond	2.00%	0.79000	11,081	$15,695,000	$2,003,832	$15,695,000	$2,003,832
Rosenberg	2.00%	0.52020	31,676	$45,509,000	$4,620,039	$45,509,000	$4,620,039
Simonton	2.00%	0.27000	718	$304,362	$66,655	$304,362	$66,655
Stafford	2.00%	0.00000	17,693	$18,342,051	$1,995,018	$18,342,051	$1,995,018
Sugar Land	2.00%	0.30000	84,511	$131,774,000	$13,354,000	$131,774,000	$13,354,000
Thompsons	1.00%	0.00000	246			$412,222	$40,025
Weighted Average Tax	1.59%	0.44511	Total Rev./Exp.	$333,306,763	$32,363,052	$337,928,344	$32,811,793
Transportation Adjusted Tax	0.15%	0.04322	% Transp.		9.71%		9.71%

Table 44. Local Data for Galveston County

Municipality	Sales Tax	Property Tax	Population (Census)	Revenue	Transp. Expenditure	Estimated Revenue	Estimated Transp. Expenditure
Bayou Vista	1.75%	0.35240	1,537	$856,078	$24,583	$856,078	$24,583
Clear Lake Shores	2.00%	0.00000	1,063	$6,754,706	$683,760	$6,754,706	$683,760
Dickinson	1.50%	0.40860	18,680	$11,462,052	$1,426,893	$11,462,052	$1,426,893
Friendswood	1.50%	0.57970	35,805	$33,692,793	$2,289,169	$33,692,793	$2,289,169
Galveston	2.00%	0.49400	47,743	$126,937,000	$9,479,789	$126,937,000	$9,479,789
Hitchcock	2.00%	0.47323	6,961			$11,664,548	$1,123,743
Jamaica Beach	1.00%	0.25110	983	$1,156,877	$85,900	$1,156,877	$85,900
Kemah	2.00%	0.26525	3,334			$5,586,784	$538,222
La Marque	2.00%	0.51430	14,509	$9,985,583	$1,071,263	$9,985,583	$1,071,263
League City	1.75%	0.63000	83,560	$119,765,331	$6,625,309	$119,765,331	$6,625,309
Santa Fe	2.00%	0.31140	12,222	$4,258,702	$918,634	$4,258,702	$918,634
Texas City	2.00%	0.42500	22,550	$51,715,486	$12,710,861	$51,715,486	$12,710,861
Tiki Island	1.00%	0.16631	968			$1,622,078	$156,268
Weighted Average Tax	1.80%	0.52256	Total Rev./Exp.	$366,584,608	$35,316,161	$385,458,017	$37,134,394
Transportation Adjusted Tax	0.17%	0.05034	% Transp.		9.63%		9.63%

Table 45. Local Data for Harris County

Municipality	Sales Tax	Property Tax	Population (Census)	Revenue	Transp. Expenditure	Estimated Revenue	Estimated Transp. Expenditure
Alief	0.00%	0.00000	144,688				
Atascocita	0.00%	0.00000	65,844				
Baytown	1.25%	0.78703	71,802	$124,888,886	$8,605,682	$124,888,886	$8,605,682
Bellaire	1.00%	0.39990	16,855	$28,723,576	$3,188,126	$28,723,576	$3,188,126
Bunker Hill Village	1.00%	0.27304	3,633	$7,676,391	$603,598	$7,676,391	$603,598
Clear Lake	0.00%	0.28000	141,980			$237,915,886	$20,606,013
Crosby	0.00%	0.00000	2,299				
Deer Park	1.00%	0.70500	32,010	$48,100,000	$1,272,160	$48,100,000	$1,272,160
El Lago	1.00%	0.47776	2,706			$4,534,444	$392,730
Friendswood	1.50%	0.58510	35,805	$33,692,793	$2,698,435	$33,692,793	$2,698,435
Galena Park	1.00%	1.03745	10,887	$8,542,108	$451,760	$8,542,108	$451,760
Hedwig Village	1.00%	0.22300	2,557			$4,284,765	$371,106
Hilshire Village	1.00%	0.63739	746	$1,260,095	$38,538	$1,260,095	$38,538
Hockley	0.00%	0.00000	300				
Houston	1.00%	0.63875	2,160,821	$3,642,000,000	$318,000,000	$3,642,000,000	$318,000,000
Howellville	0.00%	0.00000	36				
Hufsmith	0.00%	0.00000	250				
Humble	1.00%	0.20000	15,133	$35,278,992	$4,826,450	$35,278,992	$4,826,450
Hunters Creek Village	1.00%	0.18500	4,367	$4,975,082	$1,298,897	$4,975,082	$1,298,897
Jacinto City	1.00%	0.80153	10,553	$5,494,640	$601,140	$5,494,640	$601,140
Jersey Village	1.50%	0.74250	7,620	$8,944,476	$494,006	$8,944,476	$494,006
Katy	1.00%	0.59372	7,051	$13,809,500	$1,136,000	$13,809,500	$1,136,000
La Porte	1.75%	0.71000	33,800	$60,527,764	$3,397,908	$60,527,764	$3,397,908
Morgans Point	1.50%	0.64600	339	$2,337,400	$224,725	$2,337,400	$224,725
Nassau Bay	1.75%	0.69212	4,002	$7,205,413	$994,186	$7,205,413	$994,186
Pasadena	1.50%	0.59159	149,043	$82,598,382	$8,376,409	$82,598,382	$8,376,409
Piney Point Village	1.00%	0.21514	3,125			$5,236,563	$453,541
Rose Hill	0.00%	0.00000	480				
Shoreacres	1.25%	0.82467	1,493			$2,501,820	$216,684
South Houston	1.75%	0.67316	16,983			$28,458,413	$2,464,797
Southside Place	1.00%	0.34783	1,715			$2,873,826	$248,903
Spring Valley	1.00%	0.53976	3,715	$9,152,210	$1,645,239	$9,152,210	$1,645,239
Taylor Lake Village	1.00%	0.34860	3,544			$5,938,681	$514,352
Thompson	0.00%	0.00000	246				
Tomball	2.00%	0.25146	10,753	$28,016,242	$784,205	$28,016,242	$784,205
Waller	2.00%	0.49843	2,326	$3,363,821	$164,075	$3,363,821	$164,075

Webster	2.00%	0.25750	10,400	$24,174,651	$2,840,170	$24,174,651	$2,840,170
West University Place	1.00%	0.37411	14,787	$32,702,986	$3,288,626	$32,702,986	$3,288,626
Westfield	0.00%	0.00000	270				
Weighted Average Tax	0.94%	0.57026	Total Rev./Exp.	$4,213,465,408	$364,930,335	$4,505,209,805	$390,198,463
Transportation Adjusted Tax	0.08%	0.04939	% Transp.		8.66%		8.66%

Table 46. Local Data for Liberty County

Municipality	Sales Tax	Property Tax	Population (Census)	Revenue	Transp. Expenditure	Estimated Revenue	Estimated Transp. Expenditure
Ames	1.00%	0.32680	1,079			$1,808,080	$151,374
Cleveland	1.50%	0.69000	7,605	$10,979,847	$757,764	$10,979,847	$757,764
Daisetta	1.00%	0.56640	1,034			$1,732,674	$145,061
Dayton	1.50%	0.68520	5,709	$11,432,106	$1,366,171	$11,432,106	$1,366,171
Dayton Lakes	0.00%	0.38760	101			$169,246	$14,169
Devers	1.00%	0.12470	416			$697,091	$58,361
Hardin	1.00%	0.18110	755			$1,265,154	$105,920
Hull	0.00%	0.00000	669				
Kenefick	1.50%	0.00000	667			$1,117,692	$93,574
Liberty	1.50%	0.59000	8,033	$13,166,896	$854,764	$13,166,896	$854,764
Moss Bluff	0.00%	0.00000	65				
Moss Hill	0.00%	0.00000	49				
North Cleveland	1.00%	0.00000	263			$440,709	$36,897
Plum Grove	1.00%	0.00000	930			$1,558,401	$130,471
Rayburn	0.00%	0.00000	30				
Raywood	0.00%	0.00000	231				
Romayor	0.00%	0.00000	96				
Rye	0.00%	0.00000	76				
Weighted Average Tax	1.35%	0.54174	Total Rev./Exp.	$35,578,849	$2,978,699	$44,367,896	$3,714,527
Transportation Adjusted Tax	0.11%	0.04536	% Transp.		8.37%		8.37%

Table 47. Local Data for Montgomery County

Municipality	Sales Tax	Property Tax	Population (Census)	Revenue	Transp. Expenditure	Estimated Revenue	Estimated Transp. Expenditure
Conroe	2.00%	0.42000	56,207	$97,005,615	$15,487,829	$97,005,615	$15,487,829
Cut And Shoot	1.50%	0.00000	1,158			$1,940,461	$227,483
Four Corners	0.00%	0.00000	2,954				
Magnolia	2.00%	0.49140	1,111	$3,775,475	$104,569	$3,775,475	$104,569
Montgomery	2.00%	0.44500	489	$1,854,620	$315,132	$1,854,620	$315,132
New Caney	0.00%	0.00000	2,771				
Oak Ridge North	2.00%	0.63890	2,991	$4,258,748	$173,012	$4,258,748	$173,012
Panorama Village	1.25%	0.65170	1,965	$1,292,896	$3,827	$1,292,896	$3,827
Patton Village	1.00%	0.40910	1,391			$2,330,899	$273,255
Porter	0.00%	0.00000	2,146				
Roman Forest	0.00%	0.47060	1,279	$680,632	$76,650	$680,632	$76,650
Shenandoah	1.50%	0.32820	1,503	$11,320,662	$1,913,520	$11,320,662	$1,913,520
Splendora	1.00%	0.29780	1,275			$2,136,518	$250,467
Stagecoach	1.00%	0.54000	455	$301,570	$10,000	$301,570	$10,000
Willis	2.00%	0.58080	6,100	$2,329,903	$304,898	$2,329,903	$304,898
Woodlock	0.00%	0.54680	247			$413,898	$48,522
Woodbranch	0.00%	0.34480	1,305	$1,383,282	$47,100	$1,383,282	$47,100
The Woodlands Township	0.00%	0.32800	105,283	$65,376,545	$3,788,210	$65,376,545	$3,788,210
Weighted Average Tax	0.75%	0.35940	Total Rev./Exp.	$189,579,948	$22,224,747	$196,401,723	$23,024,474
Transportation Adjusted Tax	0.09%	0.04213	% Transp.		11.72%		11.72%

Table 48. Local Data for San Jacinto County

Municipality	Sales Tax	Property Tax	Population (Census)	Revenue	Transp. Expenditure	Estimated Revenue	Estimated Transp. Expenditure
Camilla	0.00%	0.00000	200				
Coldspring	0.00%	0.00000	691				
Evergreen	0.00%	0.00000	691				
Oakhurst	0.00%	0.00000	230				
Point Blank	1.00%	0.00000	559			$936,716	$79,687
Shepherd	1.50%	0.26460	2,029	$1,168,285	$99,387	$1,168,285	$99,387
Stephen Creek	0.00%	0.00000	135				
Urbana	0.00%	0.00000	25				
Weighted Average Tax	0.79%	0.11774	Total Rev./Exp.	$1,168,285	$99,387	$2,105,001	$179,074
Transportation Adjusted Tax	0.07%	0.01002	% Transp.		8.51%		8.51%

Table 49. Local Data for Waller County

Municipality	Sales Tax	Property Tax	Population (Census)	Revenue	Transp. Expenditure	Estimated Revenue	Estimated Transp. Expenditure
Brookshire	2.00%	0.62000	4,702	$2,248,683	$234,384	$2,248,683	$234,384
Hempstead	2.00%	0.32890	4,691			$7,860,709	$798,430
Katy	1.00%	0.59372	3,526	$4,506,803	$568,000	$4,506,803	$568,000
Pattison	1.00%	0.00000	447			$749,038	$76,081
Prairie View	1.75%	0.65779	4,410			$7,389,837	$750,603
Waller	2.00%	0.47150	2,326	$3,363,821	$225,457	$3,363,821	$225,457
Weighted Average Tax	1.75%	0.52478	Total Rev./Exp.	$10,119,307	$1,027,841	$26,118,891	$2,652,955
Transportation Adjusted Tax	0.18%	0.05330	% Transp.		10.16%		10.16%

APPENDIX B - NHTS DEMOGRAPHIC FIGURES

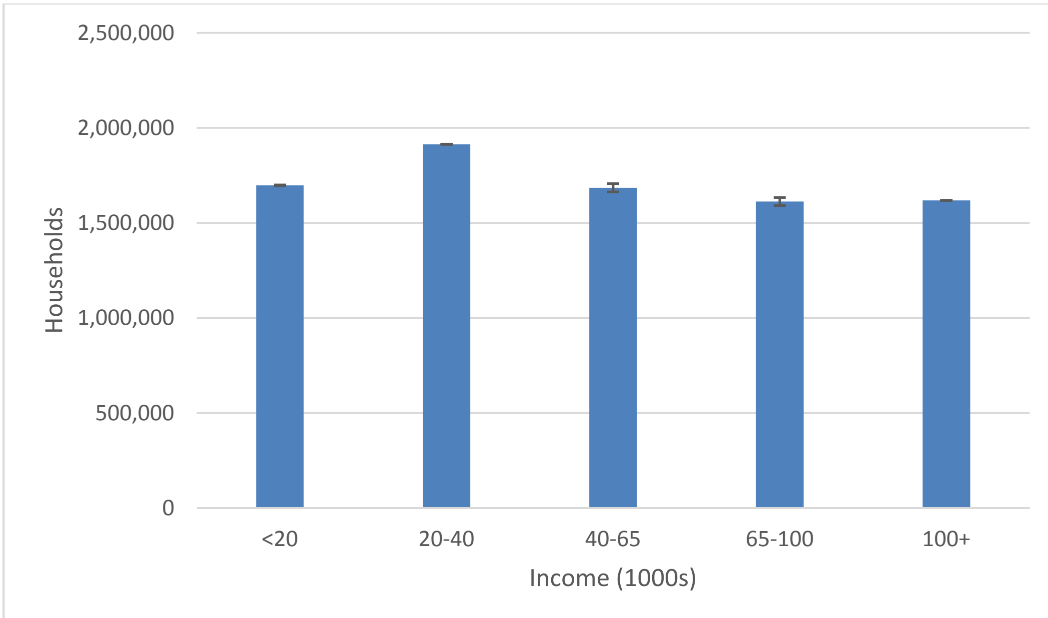

Figure 2. Texas Households by Income

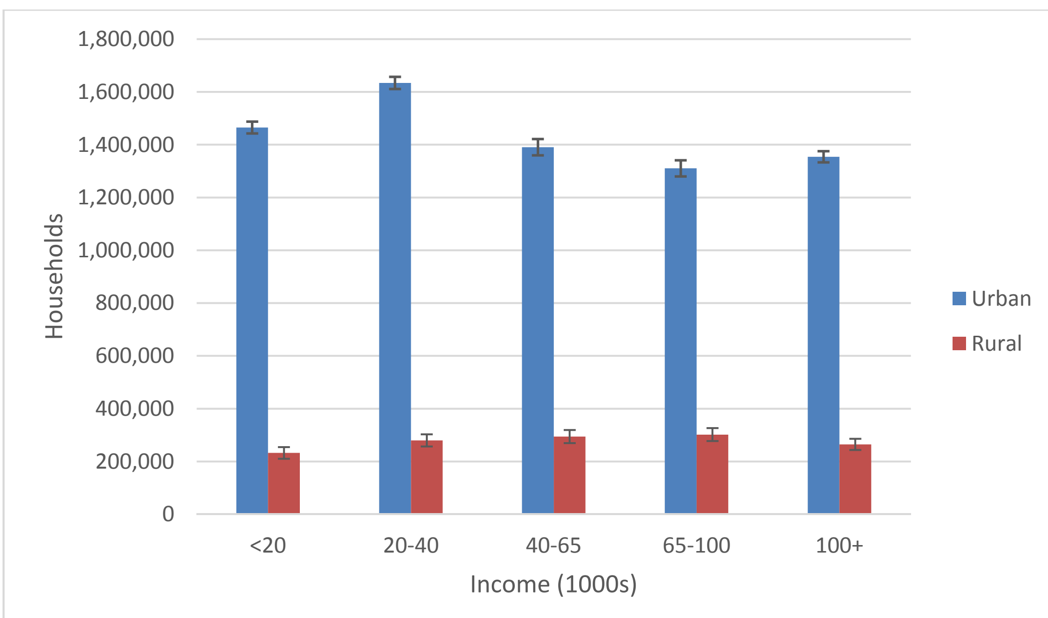

Figure 3. Urban and Rural Households by Income

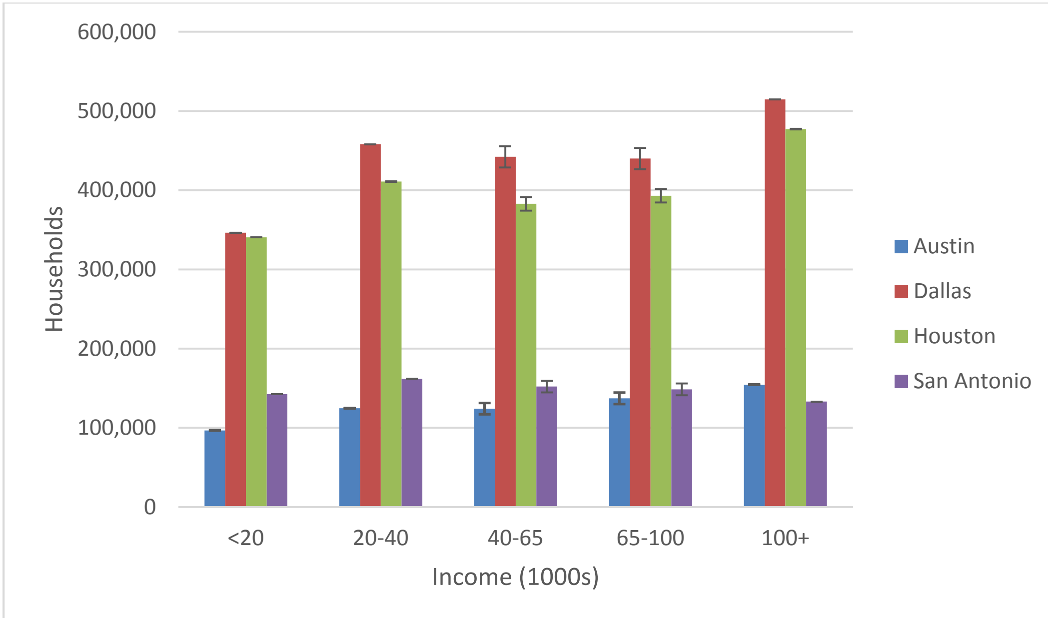

Figure 4. Core Based Statistical Area Households by Income

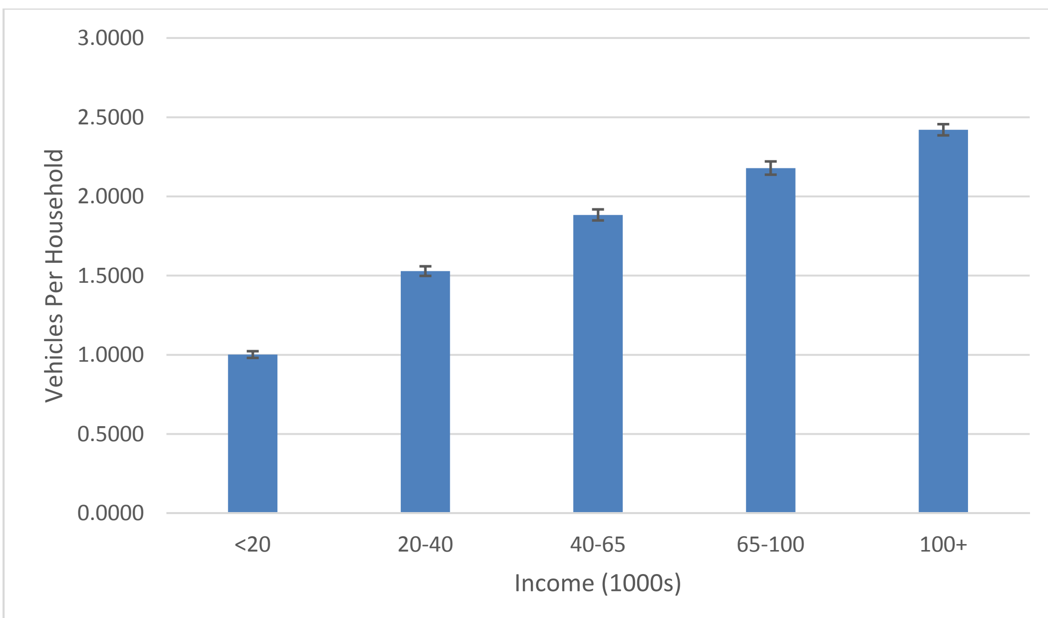

Figure 5. Texas Vehicles per Household

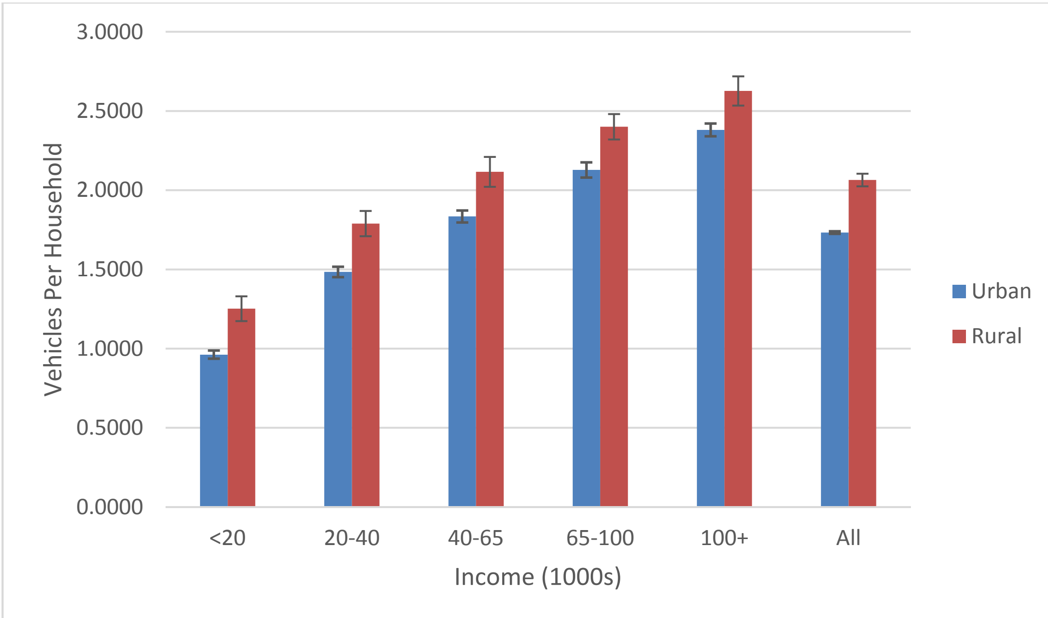

Figure 6. Urban and Rural Vehicles per Household

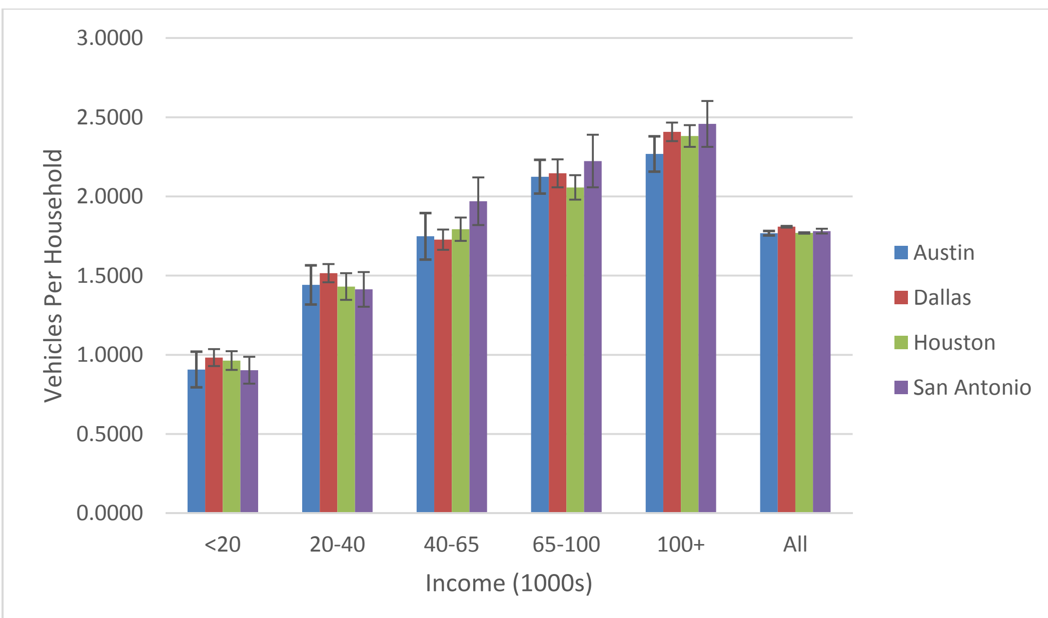

Figure 7. Core Based Statistical Area Vehicles per Household

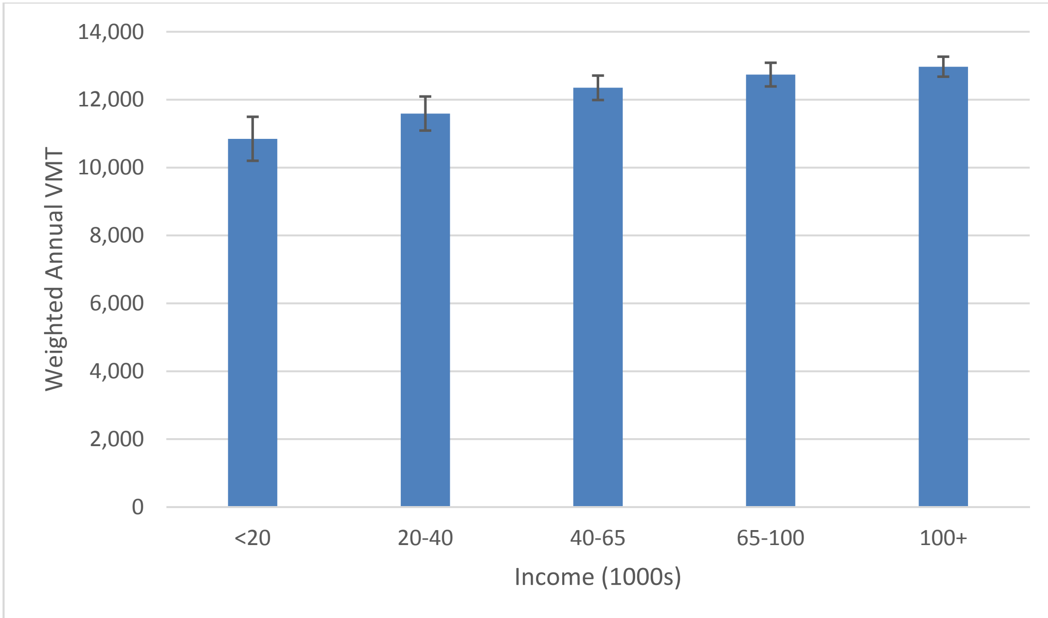

Figure 8. Texas Weighted Average VMT

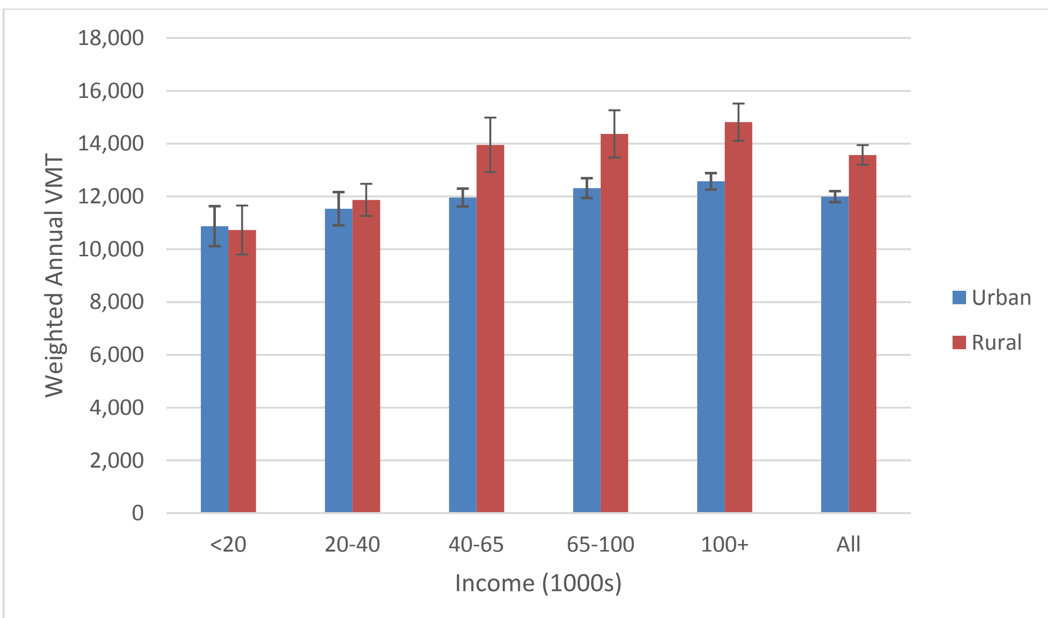

Figure 9. Urban and Rural Weighted Average VMT

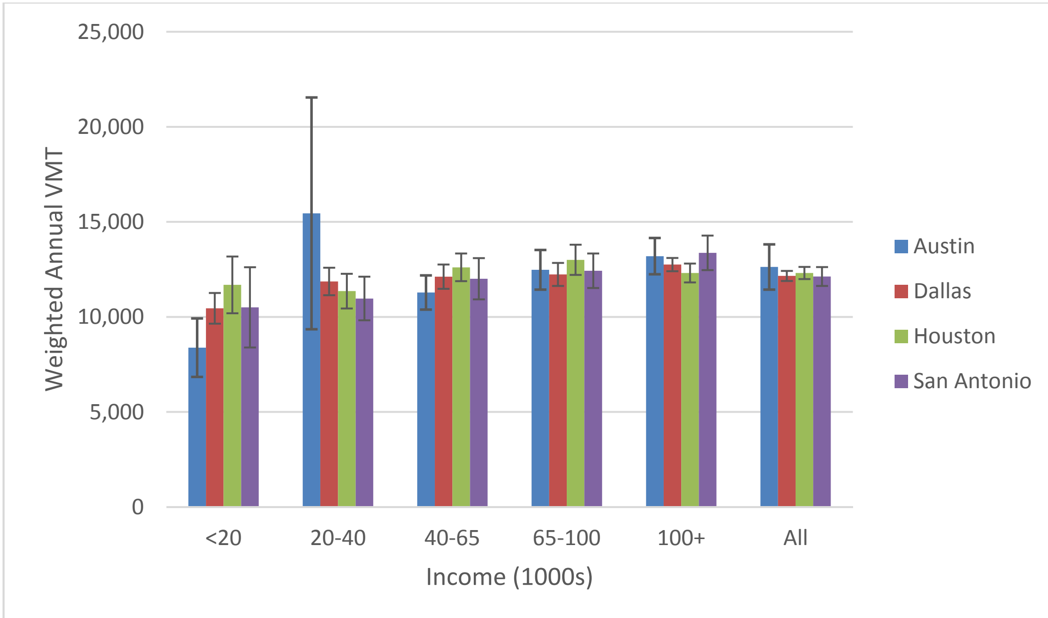

Figure 10. Core Based Statistical Area Weighted Average VMT

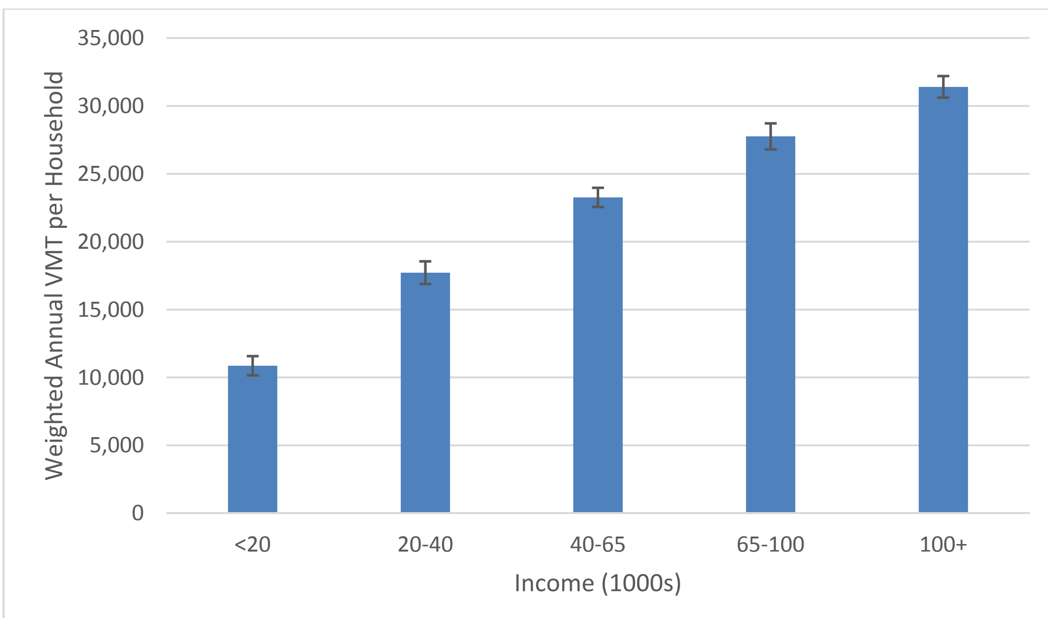

Figure 11. Texas Weighted Average VMT per Household

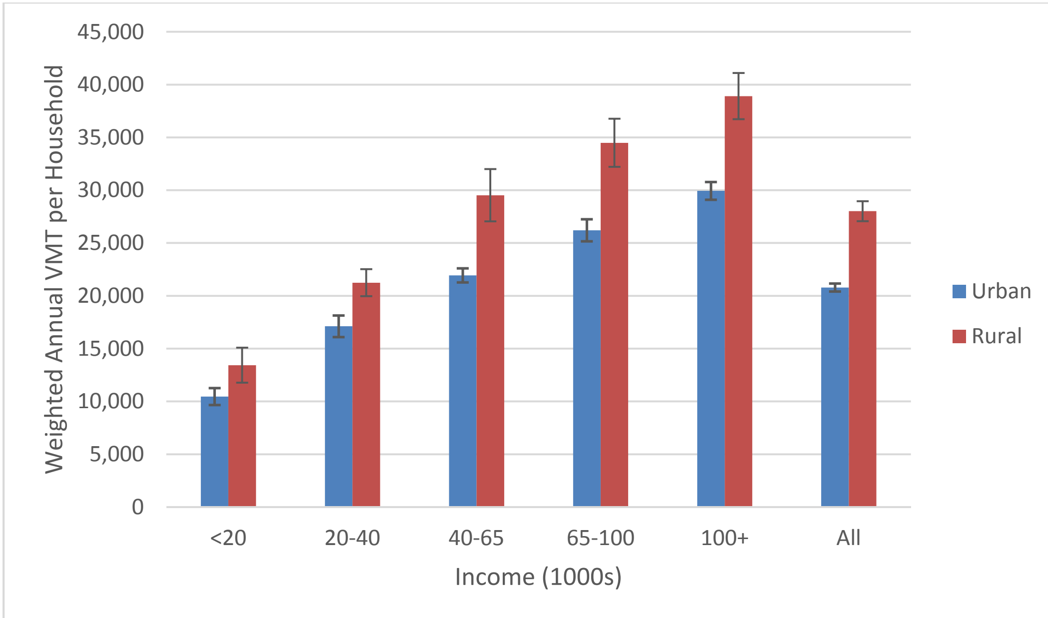

Figure 12. Urban and Rural Weighted Average VMT per Household

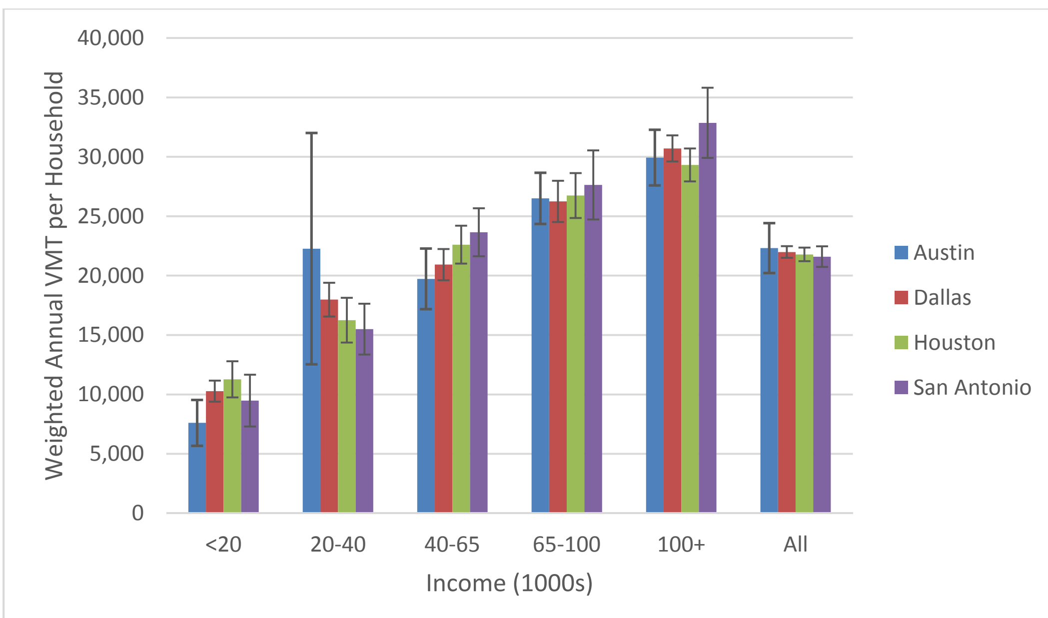

Figure 13. Core Based Statistical Area Weighted Average VMT per Household

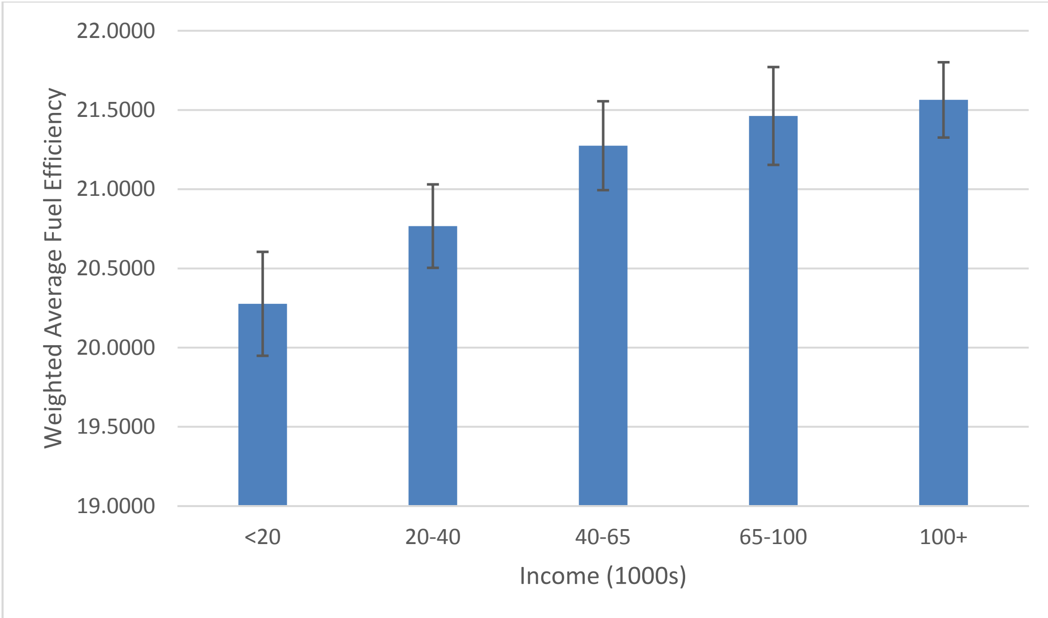

Figure 14. Texas Weighted Average Fuel Efficiency

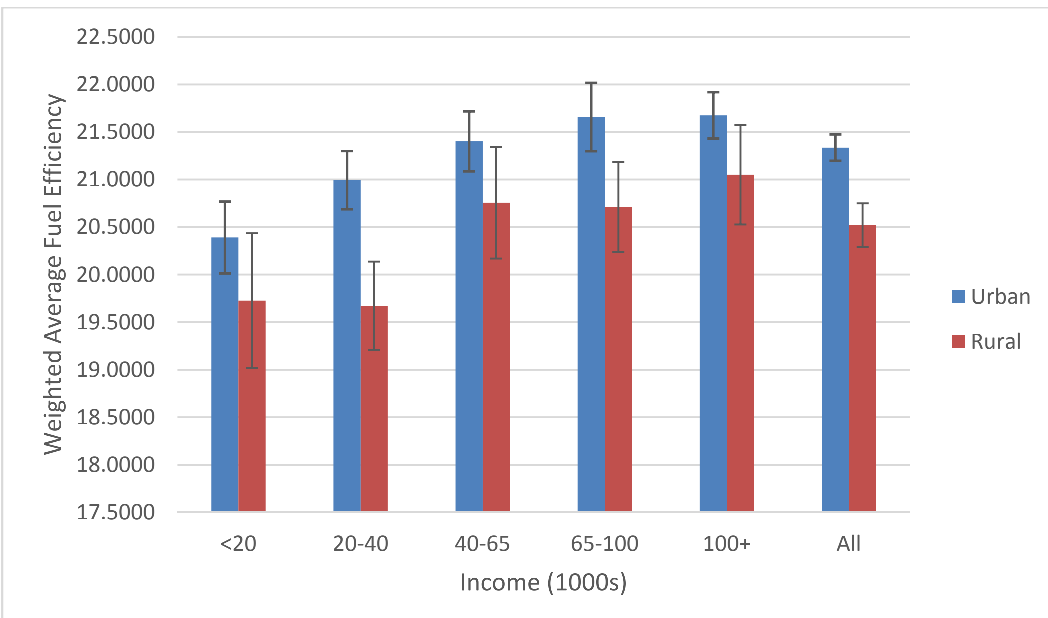

Figure 15. Urban and Rural Weighted Average Fuel Efficiency

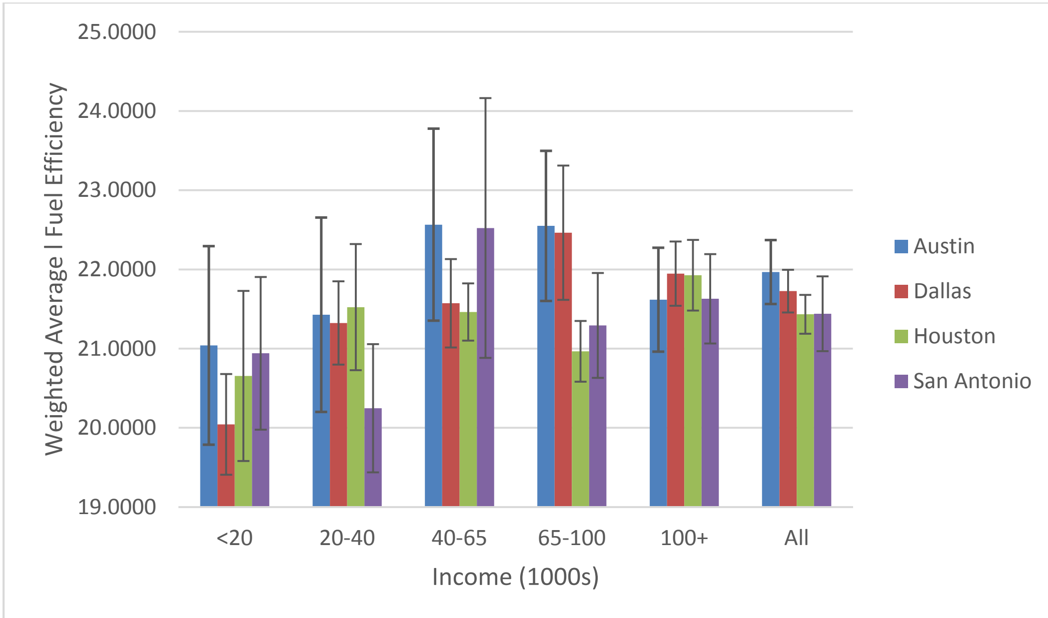

Figure 16. Core Based Statistical Area Weighted Average Fuel Efficiency

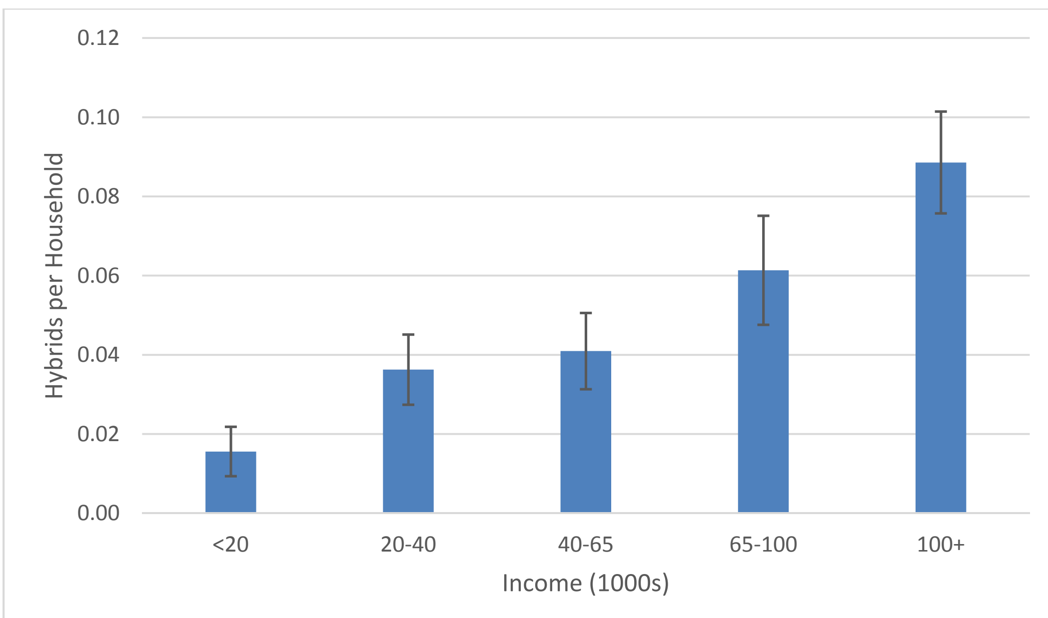

Figure 17. Texas Hybrids per Household

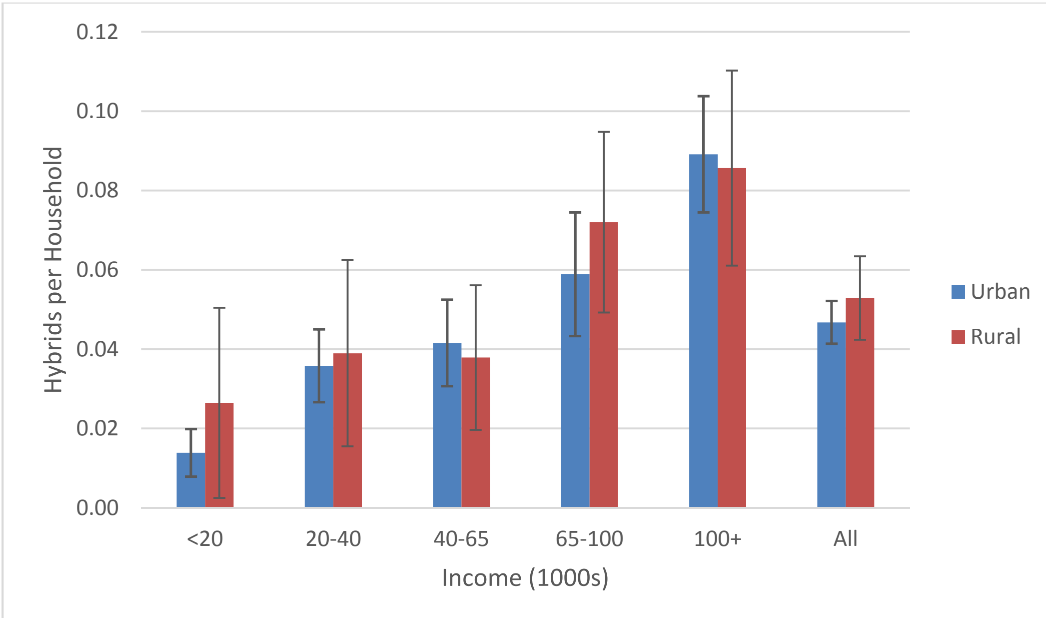

Figure 18. Urban and Rural Hybrids per Household

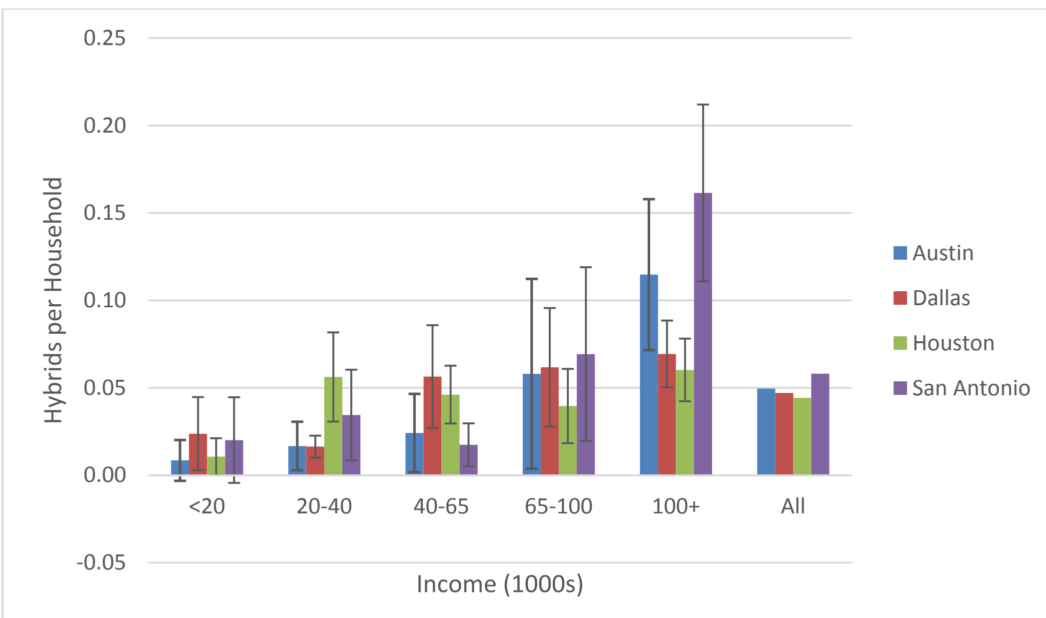

Figure 19. Core Based Statistical Area Hybrids per Household

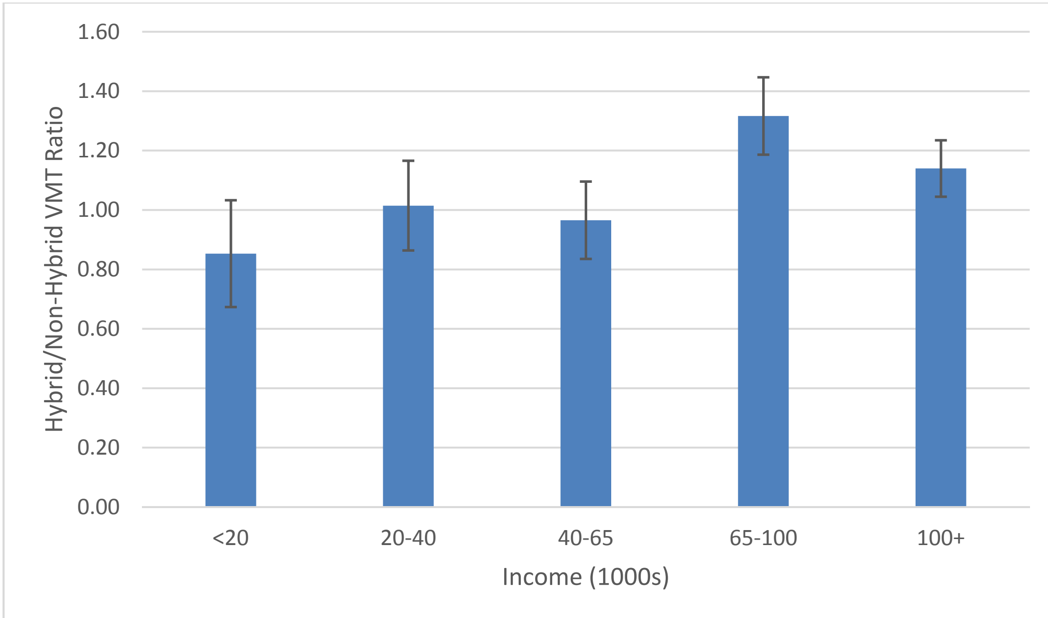

Figure 20. Texas Weighted Average VMT between Hybrids and Non-Hybrids

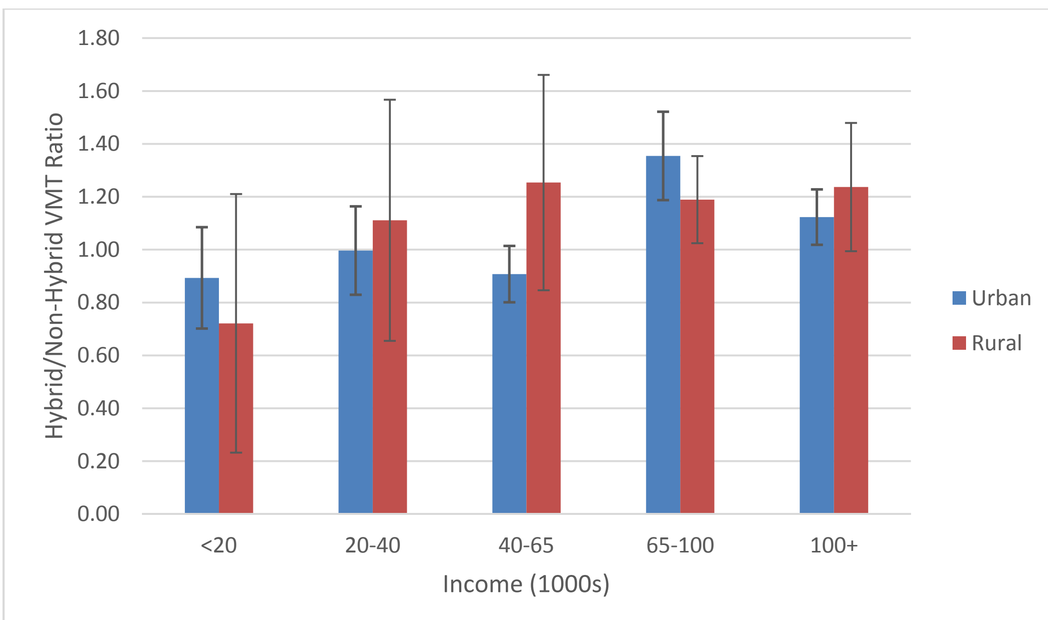

Figure 21. Urban and Rural Weighted Average VMT between Hybrids and Non-Hybrids

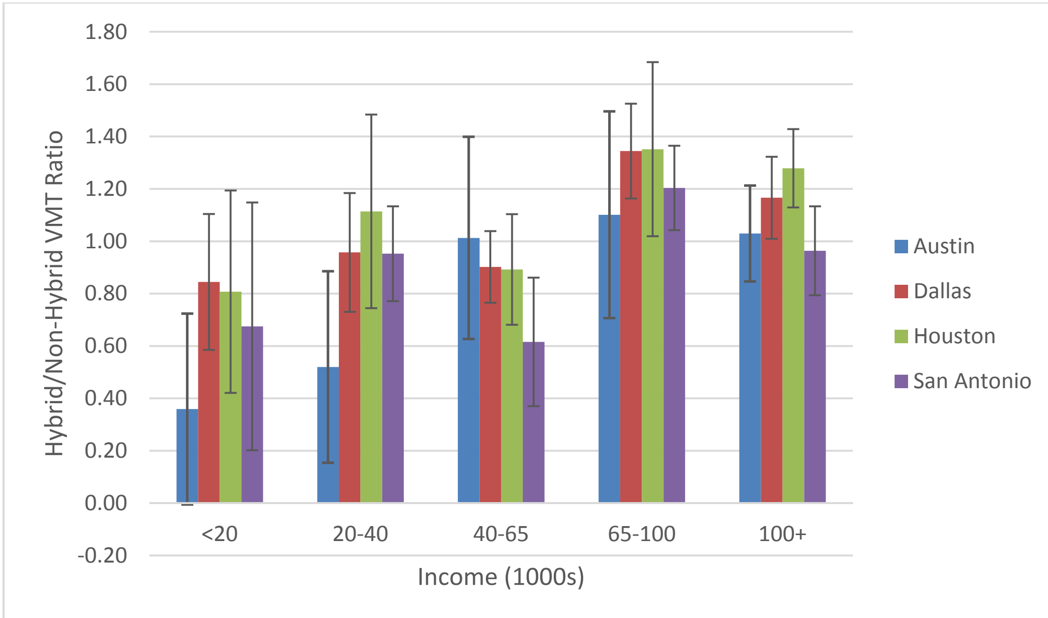

Figure 22. Core Based Statistical Area VMT between Hybrids and Non-Hybrids

APPENDIX C - LORENZ CURVE FIGURES

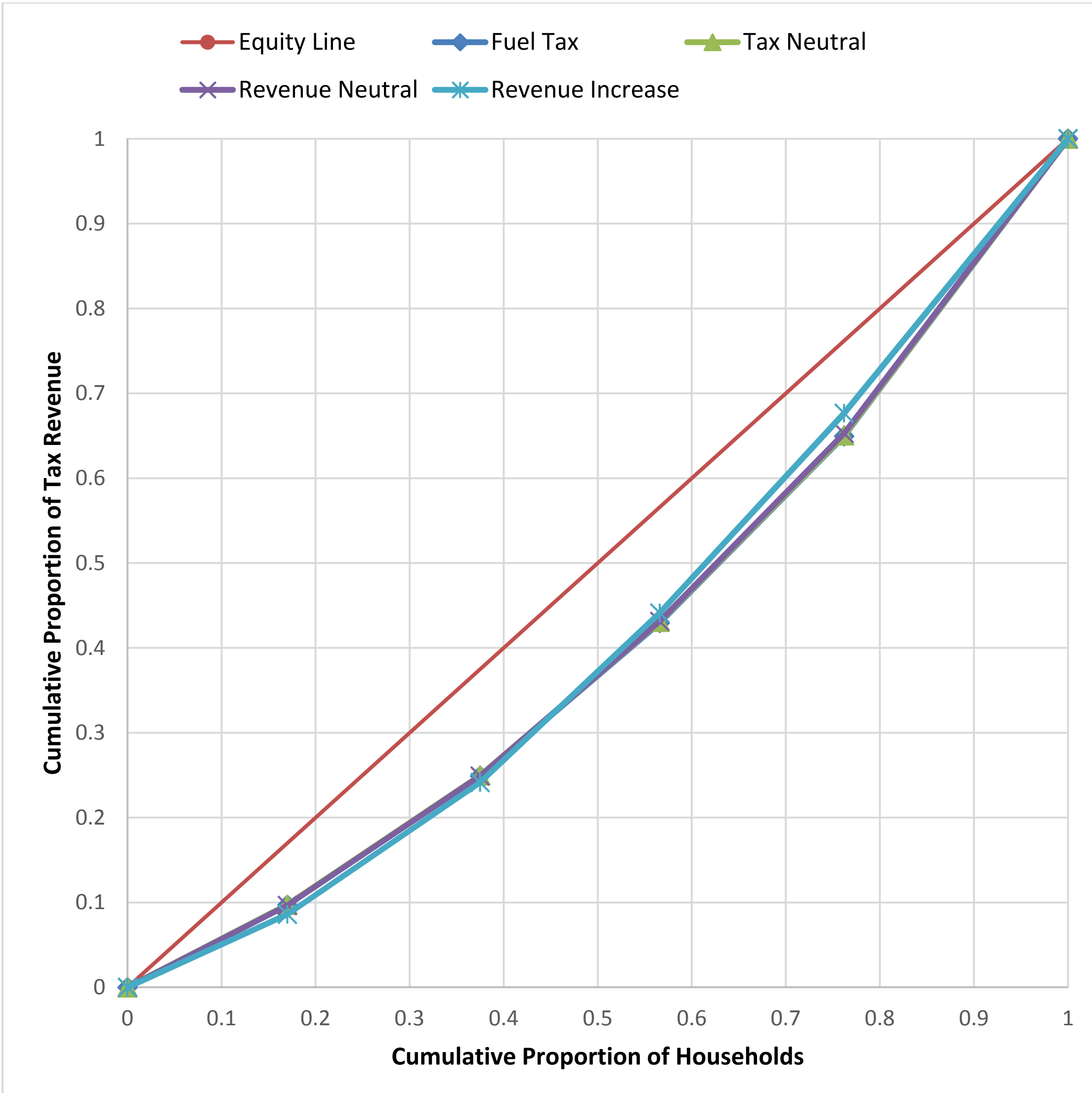

Figure 23. Taxation Lorenz Curves for Each Scenario

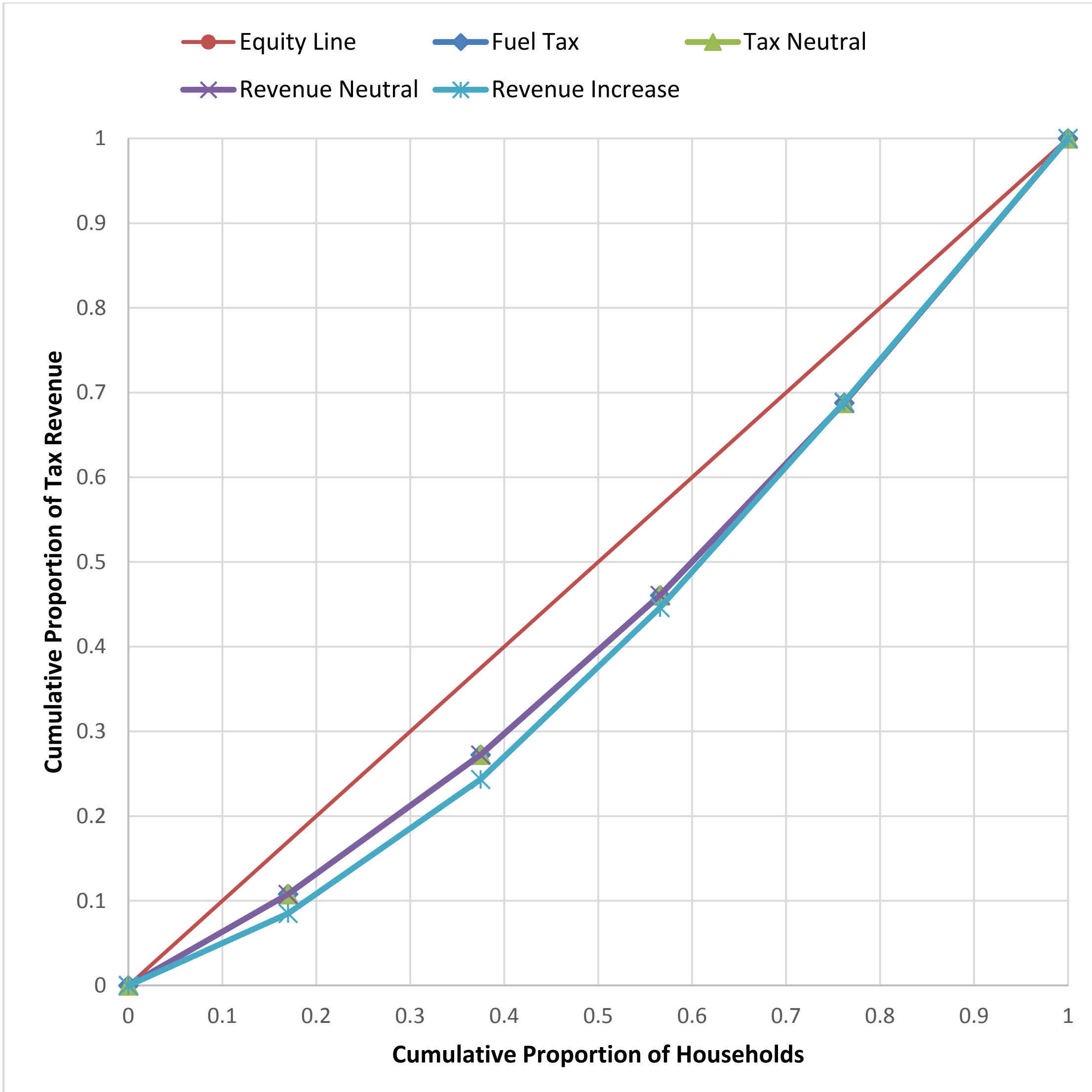

Figure 24. Benefit Lorenz Curves for Each Scenario

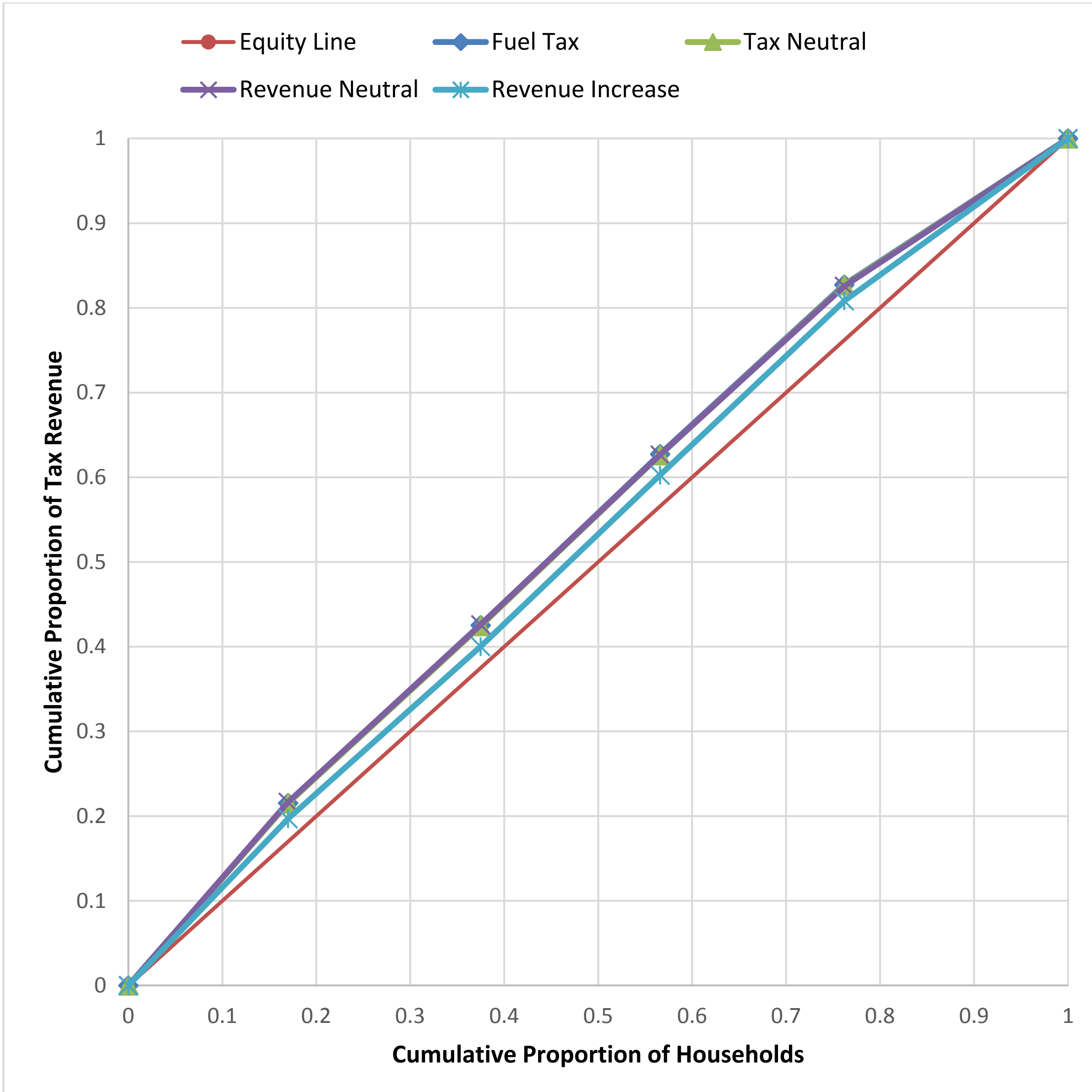

Figure 25. Ratio Lorenz Curves for Each Scenario

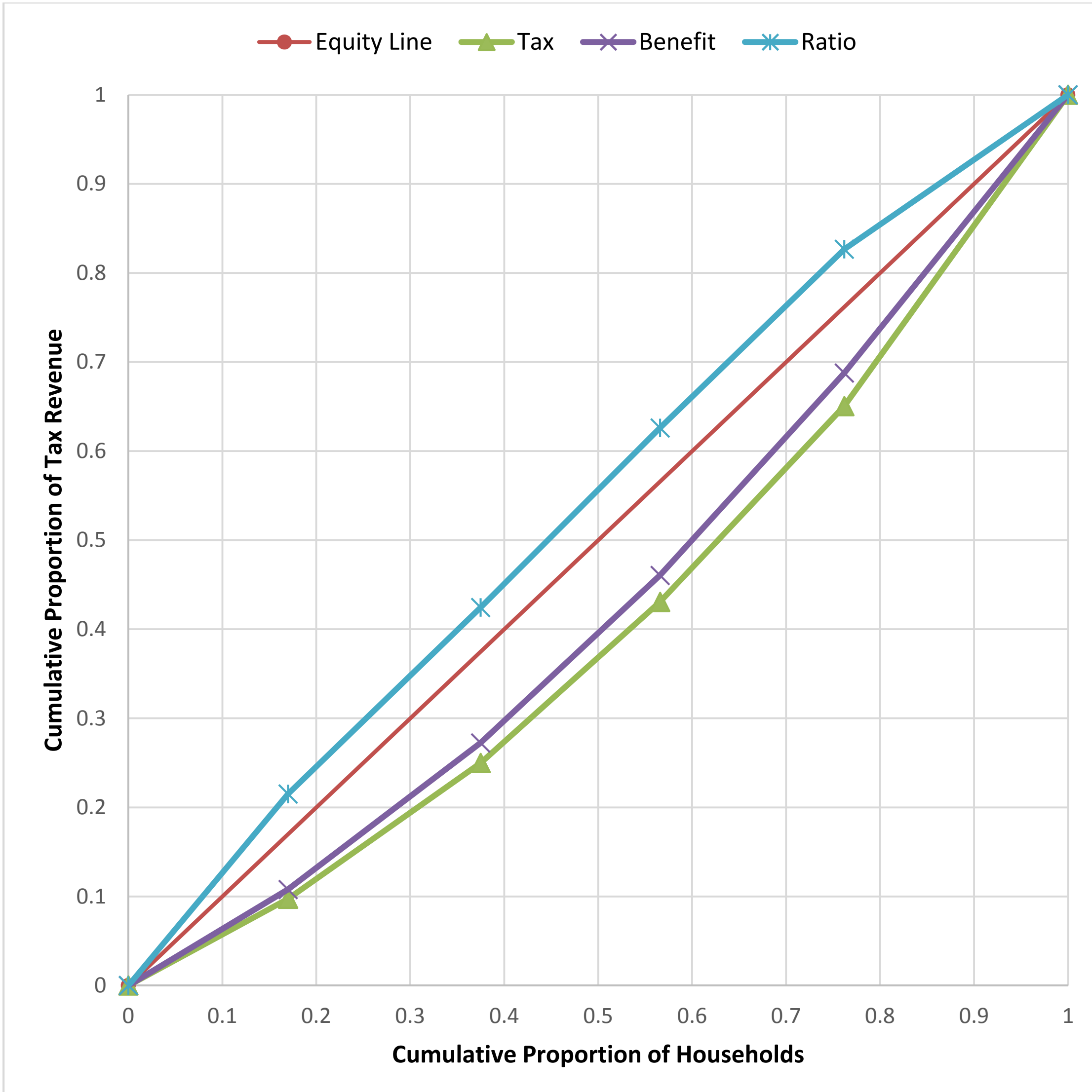

Figure 26. Fuel Tax Lorenz Curves

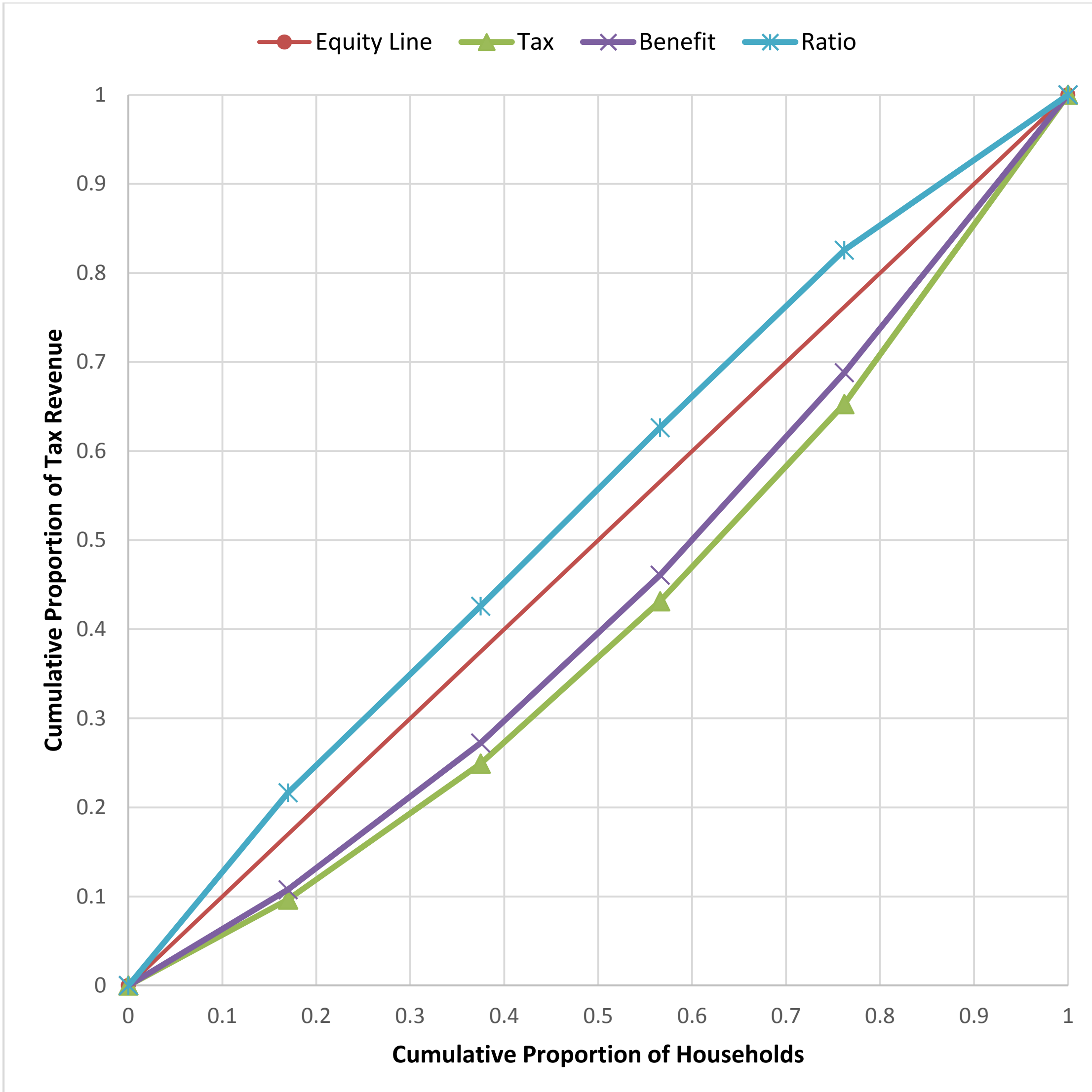

Figure 27. Tax Burden Neutral Lorenz Curves

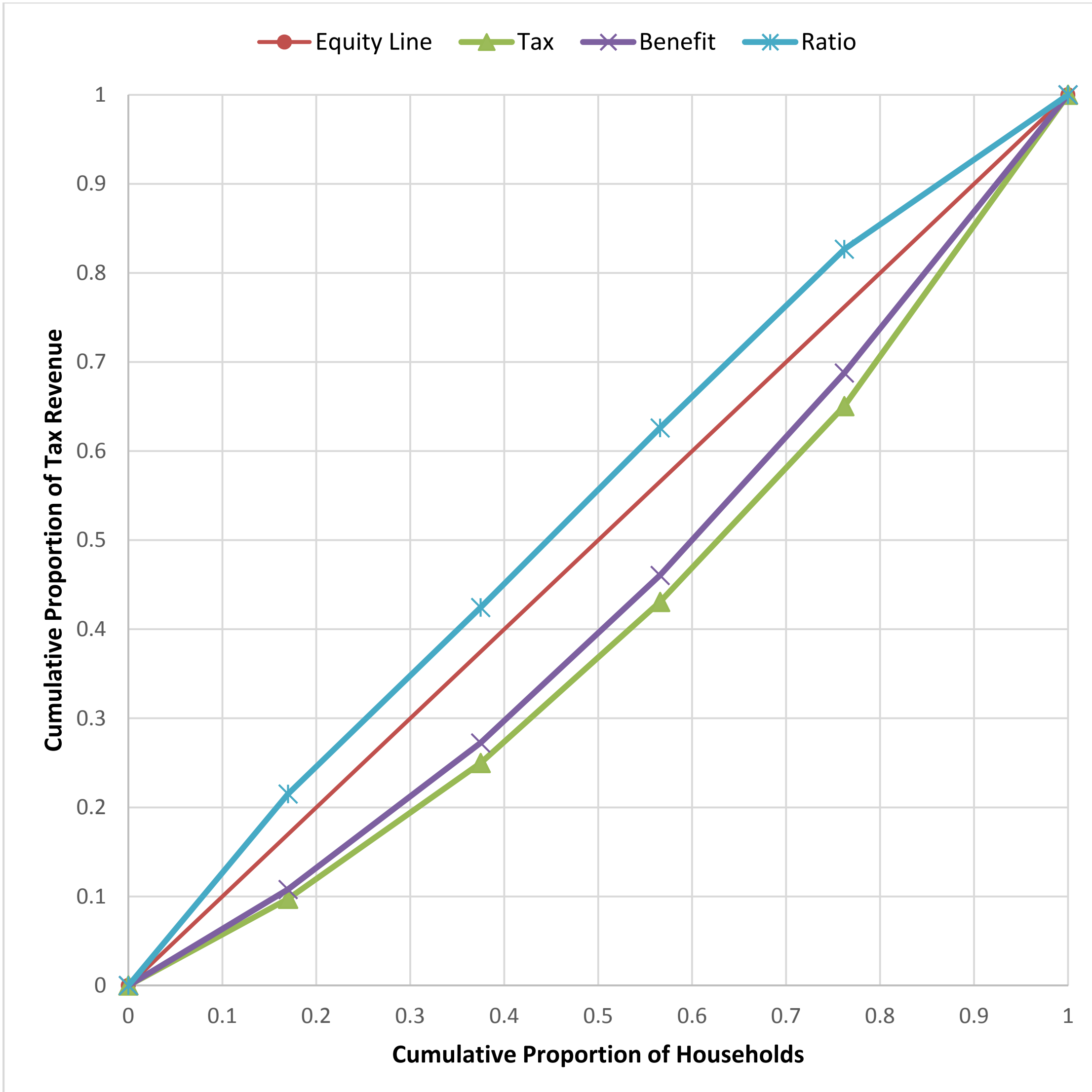

Figure 28. Revenue Neutral Lorenz Curves

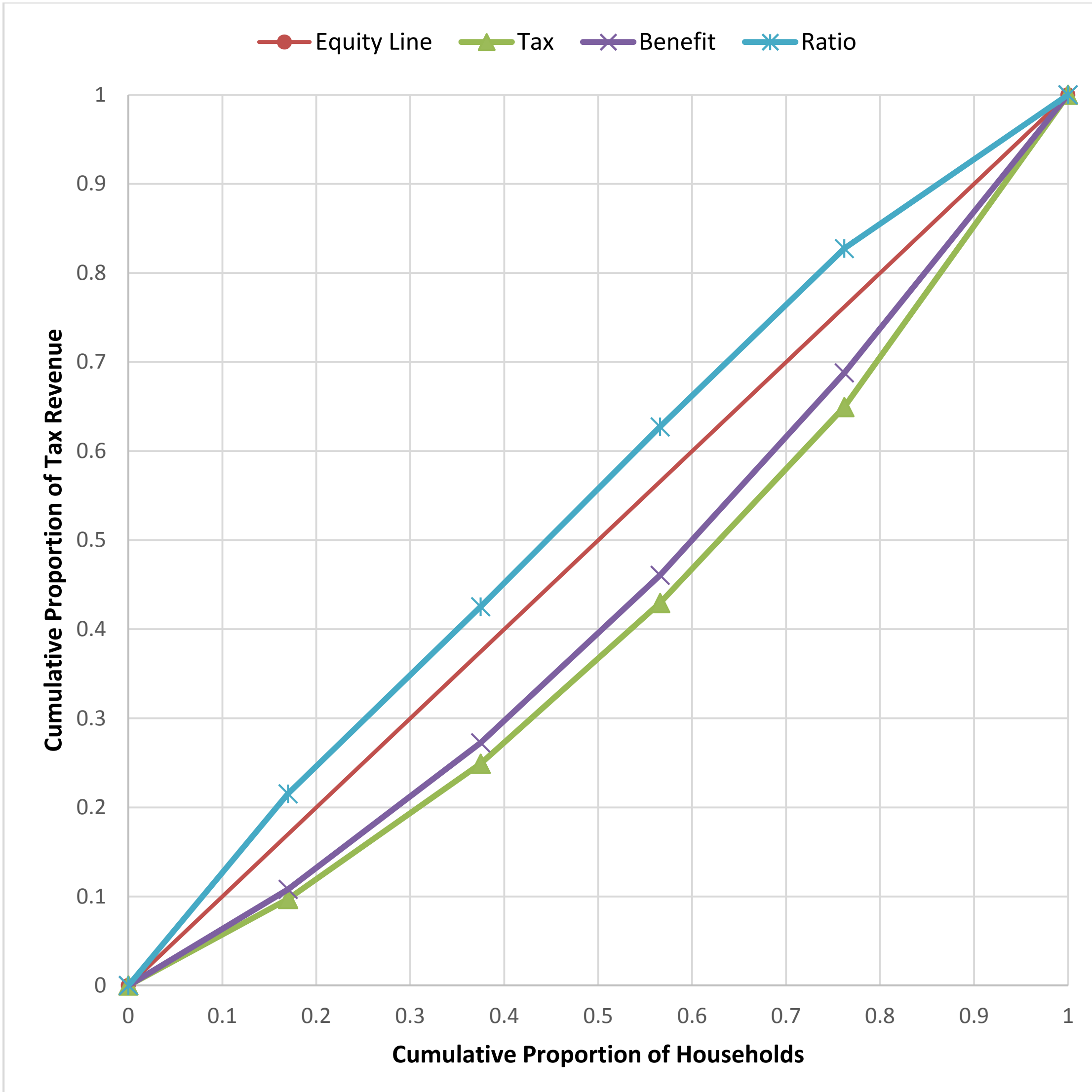

Figure 29. Revenue Increase Lorenz Curves

APPENDIX D - NHTS FILTERING CODE

Before running the MATLAB file below, the raw NHTS household, vehicle, person, and replicate weight files should be sorted for the state of Texas based on the state FIPS code, which is 48. The sorted household file should be renamed to "HHV2PUB TX Original.xlsx", the sorted vehicle file should be renamed to "VEHV2PUB TX Original.xlsx", the sorted person file should be renamed to "PERV2PUB TX Original.xlsx", and the sorted replicate weight file should be renamed to "TexasRepWeights Original.xlsx".

```
% File for filtering raw Texas NHTS data
% User input required on lines 46, 64, 111, and 116
% This file may take a little while to run

%--- Clear the command prompt and all variables from memory ---%
clc;
clear;

%--- Begin Counting Time ---%
tic

%--- Read Excel Files ---%
disp('Reading Excel Files...')
HH=xlsread('HHV2PUB TX Original.xlsx');
n=size(HH,1);
HH(:,44:46)=zeros(n,3);
VEH=xlsread('VEHV2PUB TX Original.xlsx');
m=size(VEH,1);
VEH(:,62:63)=zeros(m,2);
PER=xlsread('PERV2PUB TX Original.xlsx');
l=size(PER,1);
REP=xlsread('TexasRepWeights Original.xlsx');

%--- Tie column names to column numbers so later equations are
intuitive ---%
[~,HHHeading,~]=xlsread('HHV2PUB TX Original.xlsx','Sheet1','1:1');
for t=1:length(HHHeading)
    eval(['HF_' HHHeading{t} '= ' num2str(t) ';'])
end
HF_PTUSED=46;
[~,VEHHeading,~]=xlsread('VEHV2PUB TX Original.xlsx','Sheet1','1:1');
```

```
for t=1:length(VEHHeading)
    eval(['VF_' VEHHeading{t} '= ' num2str(t) ';'])
end
[~,PERHeading,~]=xlsread('PERV2PUB TX Original.xlsx','Sheet1','1:1');
for t=1:length(PERHeading)
    eval(['PF_' PERHeading{t} '= ' num2str(t) ';'])
end
[~,REPHeading,~]=xlsread('TexasRepWeights
Original.xlsx','TexasRepWeights','1:1');

%--- Display Elapsed Time ---%
toc

%--- Mark Invalid Surveys in Vehicle File ---%
disp('Marking Invalid Vehicle Surveys...')
for i=1:m
    % In the "if" line, add vehicle file only variables you want
    % to filter out and the filtering criteria.
    % Do not mark household file variables here.
    % The "||" is an "or" statement.
    % The "VF_" prefix on each variable is just a way to keep track
that it
    % is the column variable from the vehicle file.
    % If the line gets too long, use "..." to contintue it onto the
next line.
    if VEH(i,VF_HYBRID)<-1 || VEH(i,VF_BESTMILE)<0 ||
VEH(i,VF_EIADMPG)<0 || VEH(i,VF_VEHTYPE)==5
        VEH(i,62)=1;
    else
        VEH(i,62)=0;
    end
end

%--- Mark Invalid Surveys in Household File ---%
% HH Size, Owndership, and Worker Count Variables are Complete
disp('Marking Invalid Household Surveys...')
for i=1:n
    % In the "if" line, add your filtering criteria for household file
only
    % variables. The ones currently listed are mandatory for weighting.
    % The "HF_" prefix on each varialbe is just a way to keep track
that it
    % is the column variable from the household file.
    if HH(i,HF_HH_HISP)<0 || HH(i,HF_HH_RACE)<0 || HH(i,HF_HHFAMINC)<0
|| HH(i,HF_URBRUR)<0 || HH(i,HF_FLAG100)~=1
        HH(i,45)=1;
    else
        HH(i,45)=0;
    end
end

%--- Mark Households With Invalid Vehicles ---%
```

```
% Brings marker over from vehilce file into household file
disp('Marking Households For Elimination...')
for i=1:m

HH(HH==VEH(i,VF_HOUSEID),44)=HH(HH==VEH(i,VF_HOUSEID),44)+VEH(i,62);
end
% Add invalid makers
HH_Elim=HH(:,44)+HH(:,45);
% Set makers above 1 equal to 1
HH_Elim(HH_Elim(:,1)>1,1)=1;

%--- Mark Vehicles for Elimination ---%
% Brings final marker from household file into vehilce file
disp('Marking Vehicles for Elimination...')
for i=1:n
    VEH(VEH==HH(i,HF_HOUSEID),63)=HH_Elim(i,1);
end
VEH_Elim=VEH(:,63);

%--- Inlclude PTUSED from Person File ---%
disp('Including PTUSED...')
for i=1:l
    if PER(i,PF_PTUSED)>0

HH(HH==PER(i,PF_HOUSEID),46)=HH(HH==PER(i,PF_HOUSEID),46)+PER(i,PF_PTUS
ED);
    end
end

%--- Filter Out Invalid Surveys ---%
disp('Filter Out Invalid Surveys...')
HH_Filtered=HH(HH_Elim==0,:);
VEH_Filtered=VEH(VEH_Elim==0,:);
REP_Filtered=REP(HH_Elim==0,:);

%--- Construct Final Files For Weighting Procedure ---%
disp('Writing to File...')

% The household file variables already listed below are mandatory for
the weighting procedure.
% Enter any additional household variables you filtered by or will use.
% You can put them in any order you like.
HF_Header={'HF_HOUSEID' 'HF_HHSIZE' 'HF_HHFAMINC' 'HF_HH_RACE'
'HF_HH_HISP'...
    'HF_HHVEHCNT' 'HF_WRKCOUNT' 'HF_URBRUR' 'HF_HOMEOWN' 'HF_DRVRCNT'
'HF_PTUSED' 'HF_HH_CBSA' 'HF_WTHHFIN'};
% Enter any vehilce file variables you filtered by or will use.
VF_Header={'VF_HOUSEID' 'VF_HHSIZE' 'VF_HHFAMINC' 'VF_HH_RACE'
'VF_HH_HISP'...
    'VF_HHVEHCNT' 'VF_WRKCOUNT' 'VF_URBRUR' 'VF_HOMEOWN' 'VF_HH_CBSA'
'VF_VEHTYPE'...
    'VF_FUELTYPE' 'VF_VEHYEAR' 'VF_HYBRID' 'VF_EIADMPG' 'VF_GSCOST'
```

```
'VF_BESTMILE'};

% Converts the variables text you imputed above into column numbers and
% sorts out columns not used from the original file
HouseVars=zeros(1,length(HF_Header));
for t=1:length(HF_Header)
    eval(['HouseVars(t)' '=' HF_Header{t} ';'])
end
HHSURVEY=HH_Filtered(:,HouseVars);
VehicleVars=zeros(1,length(VF_Header));
for t=1:length(VF_Header)
    eval(['VehicleVars(t)' '=' VF_Header{t} ';'])
end
VEHSURVEY=VEH_Filtered(:,VehicleVars);

% Write the data to file
xlswrite('HHV2PUB TX.xlsx',HF_Header,'HHSURVEY','A1');
xlswrite('HHV2PUB TX.xlsx',HHSURVEY,'HHSURVEY','A2');
xlswrite('VEHV2PUB TX.xlsx',VF_Header,'VEHSURVEY','A1');
xlswrite('VEHV2PUB TX.xlsx',VEHSURVEY,'VEHSURVEY','A2');
xlswrite('TexasRepWeights.xlsx',REPHeading,'TexasRepWeights','A1');
xlswrite('TexasRepWeights.xlsx',REP_Filtered,'TexasRepWeights','A2');
%--- Display Elapsed Time ---%
toc
```

APPENDIX E - NHTS WEIGHTING CODE

The file below should only be run after running the filtering code. Copy the output files from the filtering code into a separate folder and then run this code.

```
% Household Weighting Function
% Note: This might take up to an hour depending on your computer
% Set k=101 on line 82 to ignore the replicate weights and run the
% calculations on just the normal weights
% You can improve the run time substantially by changing the required
error
% (e) on line 97. The default precision is not strictly necessary.

%--- Clear the command prompt and all variables from memory ---%
clc;
clear;

%--- Begin Counting Time ---%
tic

%--- Read Excel Files ---%
disp('Reading Excel Files...')

% Read Variables
HHFILE=xlsread('HHV2PUB TX.xlsx','HHSURVEY');
n=size(HHFILE,1);
HHFILE_Original=HHFILE;

% Read Replicate Weights
RepWeights=xlsread('TexasRepWeights.xlsx','TexasRepWeights');

% Read Control Totals
T_Size = xlsread('ControlTotals.xlsx','HHSIZE','A1:E100');
T_Inc = xlsread('ControlTotals.xlsx','HHFAMINC','A1:E100');
T_Race = xlsread('ControlTotals.xlsx','HH_RACE','A1:E100');
T_Hisp = xlsread('ControlTotals.xlsx','HH_HISP','A1:E100');
T_Veh = xlsread('ControlTotals.xlsx','HHVEHCNT','A1:E100');
T_Wrk = xlsread('ControlTotals.xlsx','WRKCOUNT','A1:E100');
T_Urb = xlsread('ControlTotals.xlsx','URBRUR','A1:E100');
T_Own = xlsread('ControlTotals.xlsx','HOMEOWN','A1:E100');
disp('Variable Read Complete')

%--- Tie column names to column numbers so later equations are
intuitive ---%
[~,HHHeading,~]=xlsread('HHV2PUB TX.xlsx','HHSURVEY','1:1');
```

```
for t=1:length(HHHeading)
    eval([HHHeading{t} '= ' num2str(t) ';'])
end

%--- Adjust Variable Groups to Match Control Total Groups ---%
disp('Adjusting Variables...')
for i=1:n
    % HH Size - Cap to match
    if HHFILE(i,HF_HHSIZE) > size(T_Size,1)
        HHFILE(i,HF_HHSIZE) = size(T_Size,1);
    end
    % HH Income - Need to manually adjust
    if HHFILE(i,HF_HHFAMINC) == 1
        HHFILE(i,HF_HHFAMINC) = 2;
    elseif HHFILE(i,HF_HHFAMINC) == 11
        HHFILE(i,HF_HHFAMINC) = 12;
    elseif HHFILE(i,HF_HHFAMINC) == 13 || HHFILE(i,3) == 15
        HHFILE(i,HF_HHFAMINC) = 14;
    elseif HHFILE(i,HF_HHFAMINC) == 17
        HHFILE(i,HF_HHFAMINC) = 16;
    end
    % HH Race - Set Hispanic to Other
    if HHFILE(i,HF_HH_RACE) == 7
        HHFILE(i,HF_HH_RACE) = 97;
    end
    % HH Vehicle Count - Cap to match
    if HHFILE(i,HF_HHVEHCNT) > size(T_Veh,1)-1
        HHFILE(i,HF_HHVEHCNT) = size(T_Veh,1)-1;
    end
    % HH Worker Count - Cap to match
    if HHFILE(i,HF_WRKCOUNT) > size(T_Wrk,1)-1
        HHFILE(i,HF_WRKCOUNT) = size(T_Wrk,1)-1;
    end
end
% Rank variables for easier computation in weighting
[~, ~, HHFILE(:,HF_HHFAMINC)]=unique(HHFILE(:,HF_HHFAMINC));
[~, ~, HHFILE(:,HF_HH_RACE)]=unique(HHFILE(:,HF_HH_RACE));
[~, ~, HHFILE(:,HF_HHVEHCNT)]=unique(HHFILE(:,HF_HHVEHCNT));
[~, ~, HHFILE(:,HF_WRKCOUNT)]=unique(HHFILE(:,HF_WRKCOUNT));


%--- The Weighting Procedure ---%
disp('Starting Weighting Procedure...')
% Repeat Process Below for Each Replicate Weight and Final Weight
for k=1:101

    % Set Up for the Weighting Procedure
    Final=RepWeights(:,(1+k));
    Final=repmat(Final,1,5);
    Final(HHFILE(:,HF_HH_CBSA)~=12420,2)=0;
    Final(HHFILE(:,HF_HH_CBSA)~=19100,3)=0;
    Final(HHFILE(:,HF_HH_CBSA)~=26420,4)=0;
```

```
    Final(HHFILE(:,HF_HH_CBSA)~=41700,5)=0;
    Adjust=ones(n,8,5);
    ave=sum(T_Size(:,1))/n;
    max=50*round(ave*7/50);
    min=max/50;
    x=0;
    e=1;
    while abs(e)>0.00000001 % Using a larger number will speed up run
time
        % Iteration
        x=x+1;
        % Apply Weight Limits
        Final(Final>max)=max;
        Final(Final<min & Final~=0)=min;

        % Calcluate Adjustment for Each Variable
        for i=1:5
            % Weight for Household Size
            W_Size(:,i) =
accumarray(HHFILE(:,HF_HHSIZE),Final(:,i),[],@sum);
            A_Size(:,i) = T_Size(:,i)./W_Size(:,i);
            % Weight for Household Income
            W_Inc(:,i) =
accumarray(HHFILE(:,HF_HHFAMINC),Final(:,i),[],@sum);
            A_Inc(:,i) = T_Inc(:,i)./W_Inc(:,i);
            % Weight for Household Race
            W_Race(:,i) =
accumarray(HHFILE(:,HF_HH_RACE),Final(:,i),[],@sum);
            A_Race(:,i) =T_Race(:,i)./W_Race(:,i);
            % Weight for Household Hispanic Status
            W_Hisp(:,i) =
accumarray(HHFILE(:,HF_HH_HISP),Final(:,i),[],@sum);
            A_Hisp(:,i) = T_Hisp(:,i)./W_Hisp(:,i);
            % Weight for Household Vehicle Count
            W_Veh(:,i) =
accumarray(HHFILE(:,HF_HHVEHCNT),Final(:,i),[],@sum);
            A_Veh(:,i) = T_Veh(:,i)./W_Veh(:,i);
            % Weight for Household Worker Count
            W_Wrk(:,i) =
accumarray(HHFILE(:,HF_WRKCOUNT),Final(:,i),[],@sum);
            A_Wrk(:,i) = T_Wrk(:,i)./W_Wrk(:,i);
            % Weight for Household Urban Status
            W_Urb(:,i) =
accumarray(HHFILE(:,HF_URBRUR),Final(:,i),[],@sum);
            A_Urb(:,i) = T_Urb(:,i)./W_Urb(:,i);
            % Weight for Household Owner Status
            W_Own(:,i) =
accumarray(HHFILE(:,HF_HOMEOWN),Final(:,i),[],@sum);
            A_Own(:,i) = T_Own(:,i)./W_Own(:,i);
        end

        % Assign Individual Ceofficients into Matrix
        for j=1:5
```

```
            for i=1:n
                Adjust(i,1,j)=A_Size(HHFILE(i,HF_HHSIZE),j);
                Adjust(i,2,j)=A_Inc(HHFILE(i,HF_HHFAMINC),j);
                Adjust(i,3,j)=A_Race(HHFILE(i,HF_HH_RACE),j);
                Adjust(i,4,j)=A_Hisp(HHFILE(i,HF_HH_HISP),j);
                Adjust(i,5,j)=A_Veh(HHFILE(i,HF_HHVEHCNT),j);
                Adjust(i,6,j)=A_Wrk(HHFILE(i,HF_WRKCOUNT),j);
                Adjust(i,7,j)=A_Urb(HHFILE(i,HF_URBRUR),j);
                Adjust(i,8,j)=A_Own(HHFILE(i,HF_HOMEOWN),j);
            end
        end

        % Calculate and Store Final Weight Adjustment Coeffieints for
Reference
        if k==101
            Coefficient(:,x)=mean(Adjust(:,:,4),2);
        end

        % Determine New Weights
        for i=1:5
            Final(:,i)=Final(:,i).*mean(Adjust(:,:,i),2);
        end
        % Substitute Texas Weights by CBSA Weights
        Final(HHFILE(:,HF_HH_CBSA)>1,1)=0;
        Final(:,1)=sum(Final,2);

        % Calculate Error and Set Minimum Number of Iterations
        if x>10
            e=mean(Final(:,1)-Final_prev(:,1));
        end
        Final_prev=Final;

        % Display Pass Number For Progress Tracking
        int=~mod(x/100,1);
        if  int==1
            disp(['Pass '  num2str(x) ' Complete'])
        end
        % Set Max Number of Iterations
        if x>999
            break
        end
    end
    % Store Weights for Each Pass
    Weight(:,k)=Final(:,1);
    disp(['Weight '  num2str(k) ' Complete'])
end

% Calculate Final Weighted Totals
for i=1:5
W_Size(:,i) = accumarray(HHFILE(:,HF_HHSIZE),Final(:,i),[],@sum);
W_Inc(:,i) = accumarray(HHFILE(:,HF_HHFAMINC),Final(:,i),[],@sum);
W_Race(:,i) = accumarray(HHFILE(:,HF_HH_RACE),Final(:,i),[],@sum);
```

```
W_Hisp(:,i) = accumarray(HHFILE(:,HF_HH_HISP),Final(:,i),[],@sum);
W_Veh(:,i) = accumarray(HHFILE(:,HF_HHVEHCNT),Final(:,i),[],@sum);
W_Wrk(:,i) = accumarray(HHFILE(:,HF_WRKCOUNT),Final(:,i),[],@sum);
W_Urb(:,i) = accumarray(HHFILE(:,HF_URBRUR),Final(:,i),[],@sum);
W_Own(:,i) = accumarray(HHFILE(:,HF_HOMEOWN),Final(:,i),[],@sum);
end

% Create Final Matrix with all Variables
HHFILEwWeight=[HHFILE_Original Weight];

% Generate Household File Heading
HF_REPHeading=cell(1,100);
for t=1:100
    HF_REPHeading{t} = ['HF_REP' num2str(t)];
end
HHHeadingwWeight=[HHHeading HF_REPHeading 'HF_Final_Weight'];

%--- Display Elapsed Time ---%
toc

%--- Write to Household File ---%
disp('Writing To Household File...')
xlswrite('HHV2PUB TX.xlsx',HHHeadingwWeight,'HHSURVEY','A1');
xlswrite('HHV2PUB TX.xlsx',HHFILEwWeight,'HHSURVEY','A2');
xlswrite('ControlTotals.xlsx',W_Size,'HHSIZE','J2');
xlswrite('ControlTotals.xlsx',W_Inc,'HHFAMINC','J2');
xlswrite('ControlTotals.xlsx',W_Race,'HH_RACE','J2');
xlswrite('ControlTotals.xlsx',W_Hisp,'HH_HISP','J2');
xlswrite('ControlTotals.xlsx',W_Veh,'HHVEHCNT','J2');
xlswrite('ControlTotals.xlsx',W_Wrk,'WRKCOUNT','J2');
xlswrite('ControlTotals.xlsx',W_Urb,'URBRUR','J2');
xlswrite('ControlTotals.xlsx',W_Own,'HOMEOWN','J2');

%--- Place Weights into Vehicle File ---%
disp('Writing to Vehicle File...')

% Read File
VEHFILE=xlsread('VEHV2PUB TX.xlsx','VEHSURVEY');
[~,VEHHeading,~]=xlsread('VEHV2PUB TX.xlsx','VEHSURVEY','1:1');
m=size(VEHFILE,1);

% Assign Weights to Each Vehicle and Add Them to File
for i=1:m
VehWeight(i,:)=Weight(HHFILE(:,1)==VEHFILE(i,1),:);
end
VEHFILE=[VEHFILE VehWeight];

% Generate Vehicle File Heading
VF_REPHeading=cell(1,100);
for t=1:100
    VF_REPHeading{t} = ['VF_REP' num2str(t)];
end
```

```
VEH_Heading=[VEHHeading VF_REPHeading 'VF_Final_Weight'];

% Write to file
xlswrite('VEHV2PUB TX.xlsx',VEH_Heading,'VEHSURVEY','A1');
xlswrite('VEHV2PUB TX.xlsx',VEHFILE,'VEHSURVEY','A2');
disp('Done')

%--- Display Elapsed Time ---%
toc
```

APPENDIX F - DEMOGRAPHIC CODE

The file below should only be run after running both the filtering and weighting files. It runs various calculations on the data and returns the point estimates as well as the standard error of each estimate.

```
% Statistical Variable Analysis

%--- Clear the command prompt and all variables from memory ---%
clc;
clear;

%--- Begin Counting Time ---%
tic

%--- Read Excel Files ---%
disp('Reading files...')

HHSURVEY=xlsread('HHV2PUB TX.xlsx','HHSURVEY');
m=size(HHSURVEY(:,1),1);

VEHSURVEY=xlsread('VEHV2PUB TX.xlsx','VEHSURVEY');
n=size(VEHSURVEY(:,1),1);

%--- Tie column names to column numbers so later equations are
intuitive ---%
[~,HHHeading,~]=xlsread('HHV2PUB TX.xlsx','HHSURVEY','1:1');
for t=1:length(HHHeading)
    eval([HHHeading{t} '= ' num2str(t) ';'])
end
[~,VEHHeading,~]=xlsread('VEHV2PUB TX.xlsx','VEHSURVEY','1:1');
for t=1:length(VEHHeading)
    eval([VEHHeading{t} '= ' num2str(t) ';'])
end

% Income Catagories
% 1-2   Less than $10,000
% 3     $10,000 to $14,999
% 4     $15,000 to $19,999
% 5     $20,000 to $24,999
% 6     $25,000 to $29,999
% 7     $30,000 to $34,999
% 8     $35,000 to $39,999
% 9     $40,000 to $44,999
```

```
% 10    $45,000 to $49,999
% 11-12 $50,000 to $59,999
% 13-15 $60,000 to $74,999
% 16-17 $75,000 to $99,999
% 18    $100,000 +

disp('Sorting...')

for j=1:101

    % Sort households by income and by Urban/Rural and CBSA distinction
    y=HF_REP1+j-1;
    TX_HH=zeros(5,7);
    for i=1:m;
        if HHSURVEY(i,HF_URBRUR)==1
            if HHSURVEY(i,HF_HHFAMINC)<=4
                TX_HH(1,2)=TX_HH(1,2)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=8
                TX_HH(2,2)=TX_HH(2,2)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=13
                TX_HH(3,2)=TX_HH(3,2)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=17
                TX_HH(4,2)=TX_HH(4,2)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=18
                TX_HH(5,2)=TX_HH(5,2)+HHSURVEY(i,y);
            end
        else
            if HHSURVEY(i,HF_HHFAMINC)<=4
                TX_HH(1,3)=TX_HH(1,3)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=8
                TX_HH(2,3)=TX_HH(2,3)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=13
                TX_HH(3,3)=TX_HH(3,3)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=17
                TX_HH(4,3)=TX_HH(4,3)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=18
                TX_HH(5,3)=TX_HH(5,3)+HHSURVEY(i,y);
            end
        end
        if HHSURVEY(i,HF_HH_CBSA)==12420
            if HHSURVEY(i,HF_HHFAMINC)<=4
                TX_HH(1,4)=TX_HH(1,4)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=8
                TX_HH(2,4)=TX_HH(2,4)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=13
                TX_HH(3,4)=TX_HH(3,4)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=17
                TX_HH(4,4)=TX_HH(4,4)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=18
                TX_HH(5,4)=TX_HH(5,4)+HHSURVEY(i,y);
            end
        elseif HHSURVEY(i,HF_HH_CBSA)==19100
            if HHSURVEY(i,HF_HHFAMINC)<=4
```

```
                TX_HH(1,5)=TX_HH(1,5)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=8
                TX_HH(2,5)=TX_HH(2,5)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=13
                TX_HH(3,5)=TX_HH(3,5)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=17
                TX_HH(4,5)=TX_HH(4,5)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=18
                TX_HH(5,5)=TX_HH(5,5)+HHSURVEY(i,y);
            end
        elseif HHSURVEY(i,HF_HH_CBSA)==26420
            if HHSURVEY(i,HF_HHFAMINC)<=4
                TX_HH(1,6)=TX_HH(1,6)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=8
                TX_HH(2,6)=TX_HH(2,6)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=13
                TX_HH(3,6)=TX_HH(3,6)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=17
                TX_HH(4,6)=TX_HH(4,6)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=18
                TX_HH(5,6)=TX_HH(5,6)+HHSURVEY(i,y);
            end
        elseif HHSURVEY(i,HF_HH_CBSA)==41700
            if HHSURVEY(i,HF_HHFAMINC)<=4
                TX_HH(1,7)=TX_HH(1,7)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=8
                TX_HH(2,7)=TX_HH(2,7)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=13
                TX_HH(3,7)=TX_HH(3,7)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=17
                TX_HH(4,7)=TX_HH(4,7)+HHSURVEY(i,y);
            elseif HHSURVEY(i,HF_HHFAMINC)<=18
                TX_HH(5,7)=TX_HH(5,7)+HHSURVEY(i,y);
            end
        end
    end
    TX_HH(:,1)=TX_HH(:,2)+TX_HH(:,3);

    % Sum Vehicles by Income and Calculate Average Fuel Economy and VMT
    x=VF_REP1+j-1;
    TX_VEH=zeros(5,7);
    TX_FUEL=zeros(5,7);
    TX_VMT=zeros(5,7);
    TX_HYBRID=zeros(5,7);
    TX_HYBRID_VMT=zeros(5,7);
    for i=1:n;
        if VEHSURVEY(i,VF_URBRUR)==1
            if VEHSURVEY(i,VF_HHFAMINC)<=4
                TX_VEH(1,2)=TX_VEH(1,2)+VEHSURVEY(i,x);

TX_VMT(1,2)=TX_VMT(1,2)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(1,2)=TX_FUEL(1,2)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
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                if VEHSURVEY(i,12)==1
                    TX_HYBRID(1,2)=TX_HYBRID(1,2)+VEHSURVEY(i,x);

TX_HYBRID_VMT(1,2)=TX_HYBRID_VMT(1,2)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=8
                TX_VEH(2,2)=TX_VEH(2,2)+VEHSURVEY(i,x);

TX_VMT(2,2)=TX_VMT(2,2)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(2,2)=TX_FUEL(2,2)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(2,2)=TX_HYBRID(2,2)+VEHSURVEY(i,x);

TX_HYBRID_VMT(2,2)=TX_HYBRID_VMT(2,2)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=13
                TX_VEH(3,2)=TX_VEH(3,2)+VEHSURVEY(i,x);

TX_VMT(3,2)=TX_VMT(3,2)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(3,2)=TX_FUEL(3,2)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(3,2)=TX_HYBRID(3,2)+VEHSURVEY(i,x);

TX_HYBRID_VMT(3,2)=TX_HYBRID_VMT(3,2)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=17
                TX_VEH(4,2)=TX_VEH(4,2)+VEHSURVEY(i,x);

TX_VMT(4,2)=TX_VMT(4,2)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(4,2)=TX_FUEL(4,2)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(4,2)=TX_HYBRID(4,2)+VEHSURVEY(i,x);

TX_HYBRID_VMT(4,2)=TX_HYBRID_VMT(4,2)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=18
                TX_VEH(5,2)=TX_VEH(5,2)+VEHSURVEY(i,x);

TX_VMT(5,2)=TX_VMT(5,2)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(5,2)=TX_FUEL(5,2)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(5,2)=TX_HYBRID(5,2)+VEHSURVEY(i,x);

TX_HYBRID_VMT(5,2)=TX_HYBRID_VMT(5,2)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
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                end
            end
        else
            if VEHSURVEY(i,VF_HHFAMINC)<=4
                TX_VEH(1,3)=TX_VEH(1,3)+VEHSURVEY(i,x);

TX_VMT(1,3)=TX_VMT(1,3)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(1,3)=TX_FUEL(1,3)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(1,3)=TX_HYBRID(1,3)+VEHSURVEY(i,x);

TX_HYBRID_VMT(1,3)=TX_HYBRID_VMT(1,3)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=8
                TX_VEH(2,3)=TX_VEH(2,3)+VEHSURVEY(i,x);

TX_VMT(2,3)=TX_VMT(2,3)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(2,3)=TX_FUEL(2,3)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(2,3)=TX_HYBRID(2,3)+VEHSURVEY(i,x);

TX_HYBRID_VMT(2,3)=TX_HYBRID_VMT(2,3)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=13
                TX_VEH(3,3)=TX_VEH(3,3)+VEHSURVEY(i,x);

TX_VMT(3,3)=TX_VMT(3,3)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(3,3)=TX_FUEL(3,3)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(3,3)=TX_HYBRID(3,3)+VEHSURVEY(i,x);

TX_HYBRID_VMT(3,3)=TX_HYBRID_VMT(3,3)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=17
                TX_VEH(4,3)=TX_VEH(4,3)+VEHSURVEY(i,x);

TX_VMT(4,3)=TX_VMT(4,3)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(4,3)=TX_FUEL(4,3)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(4,3)=TX_HYBRID(4,3)+VEHSURVEY(i,x);

TX_HYBRID_VMT(4,3)=TX_HYBRID_VMT(4,3)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=18
                TX_VEH(5,3)=TX_VEH(5,3)+VEHSURVEY(i,x);
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TX_VMT(5,3)=TX_VMT(5,3)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(5,3)=TX_FUEL(5,3)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(5,3)=TX_HYBRID(5,3)+VEHSURVEY(i,x);

TX_HYBRID_VMT(5,3)=TX_HYBRID_VMT(5,3)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            end
        end

        if VEHSURVEY(i,10)==12420
            if VEHSURVEY(i,VF_HHFAMINC)<=4
                TX_VEH(1,4)=TX_VEH(1,4)+VEHSURVEY(i,x);

TX_VMT(1,4)=TX_VMT(1,4)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(1,4)=TX_FUEL(1,4)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(1,4)=TX_HYBRID(1,4)+VEHSURVEY(i,x);

TX_HYBRID_VMT(1,4)=TX_HYBRID_VMT(1,4)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=8
                TX_VEH(2,4)=TX_VEH(2,4)+VEHSURVEY(i,x);

TX_VMT(2,4)=TX_VMT(2,4)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(2,4)=TX_FUEL(2,4)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(2,4)=TX_HYBRID(2,4)+VEHSURVEY(i,x);

TX_HYBRID_VMT(2,4)=TX_HYBRID_VMT(2,4)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=13
                TX_VEH(3,4)=TX_VEH(3,4)+VEHSURVEY(i,x);

TX_VMT(3,4)=TX_VMT(3,4)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(3,4)=TX_FUEL(3,4)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(3,4)=TX_HYBRID(3,4)+VEHSURVEY(i,x);

TX_HYBRID_VMT(3,4)=TX_HYBRID_VMT(3,4)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=17
                TX_VEH(4,4)=TX_VEH(4,4)+VEHSURVEY(i,x);
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TX_VMT(4,4)=TX_VMT(4,4)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(4,4)=TX_FUEL(4,4)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(4,4)=TX_HYBRID(4,4)+VEHSURVEY(i,x);

TX_HYBRID_VMT(4,4)=TX_HYBRID_VMT(4,4)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=18
                TX_VEH(5,4)=TX_VEH(5,4)+VEHSURVEY(i,x);

TX_VMT(5,4)=TX_VMT(5,4)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(5,4)=TX_FUEL(5,4)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(5,4)=TX_HYBRID(5,4)+VEHSURVEY(i,x);

TX_HYBRID_VMT(5,4)=TX_HYBRID_VMT(5,4)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            end
        elseif VEHSURVEY(i,10)==19100
            if VEHSURVEY(i,VF_HHFAMINC)<=4
                TX_VEH(1,5)=TX_VEH(1,5)+VEHSURVEY(i,x);

TX_VMT(1,5)=TX_VMT(1,5)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(1,5)=TX_FUEL(1,5)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(1,5)=TX_HYBRID(1,5)+VEHSURVEY(i,x);

TX_HYBRID_VMT(1,5)=TX_HYBRID_VMT(1,5)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=8
                TX_VEH(2,5)=TX_VEH(2,5)+VEHSURVEY(i,x);

TX_VMT(2,5)=TX_VMT(2,5)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(2,5)=TX_FUEL(2,5)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(2,5)=TX_HYBRID(2,5)+VEHSURVEY(i,x);

TX_HYBRID_VMT(2,5)=TX_HYBRID_VMT(2,5)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=13
                TX_VEH(3,5)=TX_VEH(3,5)+VEHSURVEY(i,x);

TX_VMT(3,5)=TX_VMT(3,5)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(3,5)=TX_FUEL(3,5)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
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                if VEHSURVEY(i,12)==1
                    TX_HYBRID(3,5)=TX_HYBRID(3,5)+VEHSURVEY(i,x);

TX_HYBRID_VMT(3,5)=TX_HYBRID_VMT(3,5)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=17
                TX_VEH(4,5)=TX_VEH(4,5)+VEHSURVEY(i,x);

TX_VMT(4,5)=TX_VMT(4,5)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(4,5)=TX_FUEL(4,5)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(4,5)=TX_HYBRID(4,5)+VEHSURVEY(i,x);

TX_HYBRID_VMT(4,5)=TX_HYBRID_VMT(4,5)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=18
                TX_VEH(5,5)=TX_VEH(5,5)+VEHSURVEY(i,x);

TX_VMT(5,5)=TX_VMT(5,5)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(5,5)=TX_FUEL(5,5)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(5,5)=TX_HYBRID(5,5)+VEHSURVEY(i,x);

TX_HYBRID_VMT(5,5)=TX_HYBRID_VMT(5,5)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            end
        elseif VEHSURVEY(i,10)==26420
            if VEHSURVEY(i,VF_HHFAMINC)<=4
                TX_VEH(1,6)=TX_VEH(1,6)+VEHSURVEY(i,x);

TX_VMT(1,6)=TX_VMT(1,6)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(1,6)=TX_FUEL(1,6)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(1,6)=TX_HYBRID(1,6)+VEHSURVEY(i,x);

TX_HYBRID_VMT(1,6)=TX_HYBRID_VMT(1,6)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=8
                TX_VEH(2,6)=TX_VEH(2,6)+VEHSURVEY(i,x);

TX_VMT(2,6)=TX_VMT(2,6)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(2,6)=TX_FUEL(2,6)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(2,6)=TX_HYBRID(2,6)+VEHSURVEY(i,x);
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TX_HYBRID_VMT(2,6)=TX_HYBRID_VMT(2,6)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=13
                TX_VEH(3,6)=TX_VEH(3,6)+VEHSURVEY(i,x);

TX_VMT(3,6)=TX_VMT(3,6)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(3,6)=TX_FUEL(3,6)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(3,6)=TX_HYBRID(3,6)+VEHSURVEY(i,x);

TX_HYBRID_VMT(3,6)=TX_HYBRID_VMT(3,6)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=17
                TX_VEH(4,6)=TX_VEH(4,6)+VEHSURVEY(i,x);

TX_VMT(4,6)=TX_VMT(4,6)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(4,6)=TX_FUEL(4,6)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(4,6)=TX_HYBRID(4,6)+VEHSURVEY(i,x);

TX_HYBRID_VMT(4,6)=TX_HYBRID_VMT(4,6)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=18
                TX_VEH(5,6)=TX_VEH(5,6)+VEHSURVEY(i,x);

TX_VMT(5,6)=TX_VMT(5,6)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(5,6)=TX_FUEL(5,6)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(5,6)=TX_HYBRID(5,6)+VEHSURVEY(i,x);

TX_HYBRID_VMT(5,6)=TX_HYBRID_VMT(5,6)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            end
        elseif VEHSURVEY(i,10)==41700
            if VEHSURVEY(i,VF_HHFAMINC)<=4
                TX_VEH(1,7)=TX_VEH(1,7)+VEHSURVEY(i,x);

TX_VMT(1,7)=TX_VMT(1,7)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(1,7)=TX_FUEL(1,7)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(1,7)=TX_HYBRID(1,7)+VEHSURVEY(i,x);

TX_HYBRID_VMT(1,7)=TX_HYBRID_VMT(1,7)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
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            elseif VEHSURVEY(i,VF_HHFAMINC)<=8
                TX_VEH(2,7)=TX_VEH(2,7)+VEHSURVEY(i,x);

TX_VMT(2,7)=TX_VMT(2,7)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(2,7)=TX_FUEL(2,7)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(2,7)=TX_HYBRID(2,7)+VEHSURVEY(i,x);

TX_HYBRID_VMT(2,7)=TX_HYBRID_VMT(2,7)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=13
                TX_VEH(3,7)=TX_VEH(3,7)+VEHSURVEY(i,x);

TX_VMT(3,7)=TX_VMT(3,7)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(3,7)=TX_FUEL(3,7)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(3,7)=TX_HYBRID(3,7)+VEHSURVEY(i,x);

TX_HYBRID_VMT(3,7)=TX_HYBRID_VMT(3,7)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=17
                TX_VEH(4,7)=TX_VEH(4,7)+VEHSURVEY(i,x);

TX_VMT(4,7)=TX_VMT(4,7)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(4,7)=TX_FUEL(4,7)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(4,7)=TX_HYBRID(4,7)+VEHSURVEY(i,x);

TX_HYBRID_VMT(4,7)=TX_HYBRID_VMT(4,7)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            elseif VEHSURVEY(i,VF_HHFAMINC)<=18
                TX_VEH(5,7)=TX_VEH(5,7)+VEHSURVEY(i,x);

TX_VMT(5,7)=TX_VMT(5,7)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BESTMILE);

TX_FUEL(5,7)=TX_FUEL(5,7)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_EIADMPG);
                if VEHSURVEY(i,12)==1
                    TX_HYBRID(5,7)=TX_HYBRID(5,7)+VEHSURVEY(i,x);

TX_HYBRID_VMT(5,7)=TX_HYBRID_VMT(5,7)+VEHSURVEY(i,x).*VEHSURVEY(i,VF_BE
STMILE);
                end
            end
        end
    end
    TX_VEH(:,1)=TX_VEH(:,2)+TX_VEH(:,3);
    TX_VMT(:,1)=TX_VMT(:,2)+TX_VMT(:,3);
```

```
    TX_FUEL(:,1)=TX_FUEL(:,2)+TX_FUEL(:,3);
    TX_HYBRID(:,1)=TX_HYBRID(:,2)+TX_HYBRID(:,3);
    TX_HYBRID_VMT(:,1)=TX_HYBRID_VMT(:,2)+TX_HYBRID_VMT(:,3);

    TX_HH(6,:)=sum(TX_HH,1);
    TX_VEH(6,:)=sum(TX_VEH,1);
    TX_VMT(6,:)=sum(TX_VMT,1);
    TX_FUEL(6,:)=sum(TX_FUEL,1);
    TX_HYBRID(6,:)=sum(TX_HYBRID,1);
    TX_HYBRID_VMT(6,:)=sum(TX_HYBRID_VMT,1);

    TX_AVE_VMT=TX_VMT./TX_VEH;
    Tx_AVE_HHMT=TX_VMT./TX_HH;
    TX_AVE_FUEL=TX_FUEL./TX_VEH;
    TX_AVE_VEHpHH=TX_VEH./TX_HH;
    TX_HYBRIDpVEH=TX_HYBRID./TX_VEH;
    TX_HYBRIDpHH=TX_HYBRID./TX_HH;
    TX_HY_AVE_VMT=TX_HYBRID_VMT./TX_HYBRID;
    TX_NONHY_AVE_VMT=(TX_VMT-TX_HYBRID_VMT)./(TX_VEH-TX_HYBRID);
    TX_HYVMTpNHYVMT=TX_HY_AVE_VMT./TX_NONHY_AVE_VMT;

    % Assing replicate values
    if j<101
        RepValues(:,:,j)=[TX_HH TX_VEH TX_AVE_VEHpHH TX_AVE_VMT
Tx_AVE_HHMT TX_AVE_FUEL TX_HYBRIDpVEH TX_HYBRIDpHH TX_HY_AVE_VMT
TX_NONHY_AVE_VMT TX_HYVMTpNHYVMT];
    end

    if j==101
        % Assign final values
        Values=[TX_HH TX_VEH TX_AVE_VEHpHH TX_AVE_VMT Tx_AVE_HHMT
TX_AVE_FUEL TX_HYBRIDpVEH TX_HYBRIDpHH TX_HY_AVE_VMT TX_NONHY_AVE_VMT
TX_HYVMTpNHYVMT];
        % Calculate standard error for each measurement
        for s=1:100
            RepValDiff(:,:,s)=RepValues(:,:,s)-Values;
        end
        RepValSQ=RepValDiff.^2;
        RepValVarTot=sum(RepValSQ(:,:,:),3);
        StdErr=sqrt(RepValVarTot.*99/100);
    end
    disp(['Weight '  num2str(j) ' Complete'])
end

Header={...
    'Income','Texas HH','Urban HH','Rural HH','Au HH','Da HH','Ho
HH','Sa HH',...
    'Texas VEH','Urban VEH','Rural VEH','Au VEH','Da VEH','Ho VEH','Sa
VEH',...
    'Texas VEH/HH','Urban VEH/HH','Rural VEH/HH','Au VEH/HH','Da
VEH/HH','Ho VEH/HH','Sa VEH/HH',...
    'Texas WAVMT','Urban WAVMT','Rural WAVMT','Au WAVMT','Da WAVMT','Ho
```

```
WAVMT','Sa WAVMT',...
    'Texas WAHHMT','Urban WAHHMT','Rural WAHHMT','Au WAHHMT','Da
WAHHMT','Ho WAHHMT','Sa WAHHMT',...
    'Texas WAFE','Urban WAFE','Rural WAFE','Au WAFE','Da WAFE','Ho
WAFE','Sa WAFE'...
    'Texas %HY','Urban %HY','Rural %HY','Au %HY','Da %HY','Ho %HY','Sa
%HY'...
    'Texas HY/HH','Urban HY/HH','Rural HY/HH','Au HY/HH','Da HY/HH','Ho
HY/HH','Sa HY/HH'...
    'Texas HY WAVMT','Urban HY WAVMT','Rural HY WAVMT','Au HY
WAVMT','Da HY WAVMT','Ho HY WAVMT','Sa HY WAVMT'...
    'Texas NONHY WAVMT','Urban NONHY WAVMT','Rural NONHY WAVMT','Au
NONHY WAVMT','Da NONHY WAVMT','Ho NONHY WAVMT','Sa NONHY WAVMT'...
    'Texas WAHYVMT/WANHYVMT','Urban WAHYVMT/WANHYVMT','Rural
WAHYVMT/WANHYVMT','Au WAHYVMT/WANHYVMT','Da WAHYVMT/WANHYVMT','Ho
WAHYVMT/WANHYVMT','Sa WAHYVMT/WANHYVMT'...
    };

disp('Writing to file...')

xlswrite('VariableAnalysis.xlsx',Header,'Totals','A1');
xlswrite('VariableAnalysis.xlsx',Values,'Totals','B2');
xlswrite('VariableAnalysis.xlsx',Header,'StdErr','A1');
xlswrite('VariableAnalysis.xlsx',StdErr,'StdErr','B2');

disp('Done')
toc
```

APPENDIX G - ANALYSIS CODE

The file below should only be run after running both the filtering and weighting code. This code requires the user to manually insert a separate column containing the county FIPS codes into the "HHVTPUB TX.xlsx" file. In order to obtain these codes, a confidentiality form must be completed and presented to the NHTS program manager.

```
%-------------------- Fuel Tax Analysis --------------------%
% clc; clear;
% Begin Counting Time
tic

%----------- Adjustable Inputs -----------%
disp('Reading Inputs...')

% Set to 0 to Ignore MBUF and Just Calculate Fuel Tax
% Set to 1 to Replace State Fuel Tax with MBUF
% Set to 2 to Replace All State Tax with MBUF
% Set to 3 to Replace State and Federal Fuel Tax with MBUF
% Set to 4 to Replace All Taxes with MBUF
VMTFlag=1;

% If Above Flag is Set, Select One of the Following
% Set to 1: MBUF Revenue Equal to Fuel Tax
% Set to 2: MBUF Revenue Accounting for Installation and Operating
Costs
% Set to 3: MBUF Increase
VMTRevFlag=1;
Increase=3290257228; % (in $)

% Transit Fuel Price Elasticity
% TransitElasticity=0.185;
 TransitElasticity=0.096;

% Average Fare Per Transit Trip (Total Fares Collected / Total Trips)
 AverageFare=58977951/126565088;

% Percent Cheaters
Cheat=0.10;
% Percent Operating Costs
Operate=0.10;
% Yield
Yield=0.0450;
```

```
% Life Span for System in Years
Years=22;
% Number of Gasoline Stations in Houston CBSA
NumStation=2240;
% Cost per Station ($)
CostPerStation=15000;
% Cost per Unit ($/unit) per Vehicle
CostUnit=150;

% Fuel Tax ($/gal)
TXGasTax=0.20;
TXDslTax=0.20;
USGasTax=0.184;
USDslTax=0.244;

% Vehicle Registration Fee ($/Reg)
TXRegFeeFlat=50.75;
CRegFeeFlat=20;
% Set flag to one in order to use above flat rate (default are 2008
rates)
RegFeeFlag=0;

% Average Driver License and Driver Records Fee ($/DL) (Total TX Fees
Collected/Total Licenced TX Drivers)
DLFeePerDriver=179667613/15374063;

% Average Inspection Fee ($/Veh) (Total TX Fees Collected/Total TX Veh)
VehInspFee=86166829/18647093;

% Sales Tax (County and Local Adjusted Based on Transportation
Spending)
TXSalesTax=0.0625;
CSalesTax=[0.00161;... %Austin
    0.00094;... %Brazoria
    0.00000;... %Chambers
    0.00000;... %Fort Bend
    0.00000;... %Galveston
    0.00000;... %Harris
    0.00108;... %Liberty
    0.00000;... %Montgomery
    0.00097;... %San Jacinto
    0.00000]; %Waller
LSalesTax=[0.00056;... %Austin
    0.00101;... %Brazoria
    0.00092;... %Chambers
    0.00154;... %Fort Bend
    0.00173;... %Galveston
    0.00081;... %Harris
    0.00113;... %Liberty
    0.00088;... %Montgomery
    0.00067;... %San Jacinto
    0.00178]; %Waller
```

```
MSalesTax=[0.00000;... %Austin
    0.00000;... %Brazoria
    0.00000;... %Chambers
    0.00139;... %Fort Bend
    0.00000;... %Galveston
    0.00623;... %Harris
    0.00000;... %Liberty
    0.00000;... %Montgomery
    0.00000;... %San Jacinto
    0.00098]; %Waller

% Property Tax Rates per $100 of Assessed Value (Adjusted Based on
Transportation Spending)
CPropTax=[0.15427;... %Austin
    0.07329;... %Brazoria
    0.05888;... %Chambers
    0.03864;... %Fort Bend
    0.04143;... %Galveston
    0.05886;... %Harris
    0.12052;... %Liberty
    0.14244;... %Montgomery
    0.12252;... %San Jacinto
    0.13227]; %Waller
LPropTax=[0.01165;... %Austin
    0.04394;... %Brazoria
    0.03177;... %Chambers
    0.04322;... %Fort Bend
    0.05034;... %Galveston
    0.04939;... %Harris
    0.04536;... %Liberty
    0.04213;... %Montgomery
    0.01002;... %San Jacinto
    0.05330]; %Waller

% Total Transit Ridership
TotalTransitRidership=126565088;

% Transit Fuel Used (Gallons)
TransitDslUsed=14681786;
TransitGasUsed=761028;

% TxDOT Spending (Does Not Include Grants)
TXSpending=[10200209;... %Austin
    43658438;... %Brazoria
    59083813;... %Chambers
    135429001;... %Fort Bend
    109429821;... %Galveston
    698574728;... %Harris
    46308786;... %Liberty
    228228197;... %Montgomery
    21671778;... %San Jacinto
    8613283]; %Waller
```

```
% County Spending (Includes Grants)
CSpending=[5218685;... %Austin
    26550726;... %Brazoria
    8166697;... %Chambers
    19208682;... %Fort Bend
    12206563;... %Galveston
    373484374;... %Harris
    9102163;... %Liberty
    76212732;... %Montgomery
    3240545;... %San Jacinto
    3937295]; %Waller

% Local Spending (Includes Grants)
LSpending=[882075;... %Austin
    22774262;... %Brazoria
    2606164;... %Chambers
    32811793;... %Fort Bend
    37134394;... %Galveston
    390198463;... %Harris
    3714527;... %Liberty
    23024474;... %Montgomery
    179074;... %San Jacinto
    2652955]; %Waller

% Total Transit Spending
TotalTransitSpending=681557828;

% Daily Vehicle Miles on Texas Roads
TXDVM=[1269543;... %Austin
    4560600;... %Brazoria
    2420542;... %Chambers
    6556343;... %Fort Bend
    4670684;... %Galveston
    56245209;... %Harris
    1892604;... %Liberty
    8552671;... %Montgomery
    705745;... %San Jacinto
    1745771]; %Waller

% Daily Vehicle Miles on County Roads
CDVM=[104280;... %Austin
    1153050;... %Brazoria
    112749;... %Chambers
    1997908;... %Fort Bend
    1112898;... %Galveston
    15423961;... %Harris
    295613;... %Liberty
    1617060;... %Montgomery
    43103;... %San Jacinto
    140815]; %Waller
```

```
% Daily Vehicle Miles on Local Roads
LDVM=[113326;... %Austin
    1931851;... %Brazoria
    162073;... %Chambers
    2239243;... %Fort Bend
    2241053;... %Galveston
    25089105;... %Harris
    222726;... %Liberty
    1635423;... %Montgomery
    18272;... %San Jacinto
    177005]; %Waller

% Tansit Revenue Miles
TransitRevMiles=[14765;... %Austin
    0;... %Brazoria
    0;... %Chambers
    767725;... %Fort Bend
    938632;... %Galveston
    63110626;... %Harris
    0;... %Liberty
    1390034;... %Montgomery
    83603;... %San Jacinto
    19938]; %Waller

% Percent of DVM by Owner and Location [US UC UL RS RC RL]
DVMP=[...
    0.72047 0.08476 0.19477 0.91479 0.06341 0.02180;... %Austin
    0.52046 0.14540 0.33413 0.79296 0.16480 0.04224;... %Brazoria
    0.60691 0.11919 0.27390 0.96747 0.02338 0.00914;... %Chambers
    0.62544 0.11357 0.26099 0.54427 0.43605 0.01967;... %Fort Bend
    0.58439 0.12602 0.28959 0.53665 0.38372 0.07963;... %Galveston
    0.60438 0.11979 0.27582 0.23293 0.75715 0.00991;... %Harris
    0.64611 0.10730 0.24659 0.85138 0.12993 0.01869;... %Liberty
    0.69901 0.09126 0.20973 0.76614 0.21171 0.02215;... %Montgomery
    0.91999 0.05619 0.02382 0.91999 0.05619 0.02382;... %San Jacinto
    0.03579 0.29236 0.67185 0.94875 0.03981 0.01144];   %Waller

% Sales Taxes NOT weighted for transportation spending
CSalesTaxRaw=[...
    0.00500;... %Austin
    0.00500;... %Brazoria
    0.00000;... %Chambers
    0.00000;... %Fort Bend
    0.00000;... %Galveston
    0.00000;... %Harris
    0.00500;... %Liberty
    0.00000;... %Montgomery
    0.00500;... %San Jacinto
    0.00000]; %Waller
LSalesTaxRaw=[...
    0.00999;... %Austin
    0.01307;... %Brazoria
    0.01237;... %Chambers
```

```
    0.01589;... %Fort Bend
    0.01798;... %Galveston
    0.00941;... %Harris
    0.01348;... %Liberty
    0.00752;... %Montgomery
    0.00790;... %San Jacinto
    0.01748]; %Waller

% County FIPS Codes
Austin=15;
Brazoria=39;
Chambers=71;
FortBend=157;
Galveston=167;
Harris=201;
Liberty=291;
Montgomery=339;
SanJacinto=407;
Waller=473;

%-------------------- Setup --------------------%

disp('Reading Files...')

% Read Variables
HHFILE=xlsread('HHV2PUB TX.xlsx','HHSURVEY');
VEHFILE=xlsread('VEHV2PUB TX.xlsx','VEHSURVEY');

% Sort for Houston CBSA
HuHH=HHFILE(HHFILE(:,12)==26420,:);
n=size(HuHH,1);
HuVEH=VEHFILE(VEHFILE(:,10)==26420,:);
m=size(HuVEH,1);

% Tie column names to column numbers so later equations are intuitive
[~,HHHeading,~]=xlsread('HHV2PUB TX.xlsx','HHSURVEY','1:1');
for t=1:length(HHHeading)
    eval([HHHeading{t} '= ' num2str(t) ';'])
end
[~,VEHHeading,~]=xlsread('VEHV2PUB TX.xlsx','VEHSURVEY','1:1');
for t=1:length(VEHHeading)
    eval([VEHHeading{t} '= ' num2str(t) ';'])
end

% Count Households in Quintiles
HHCount=zeros(5,3);
for i=1:n;
    if HuHH(i,HF_URBRUR)==1 %Urban
        if HuHH(i,HF_HHFAMINC)<=4
            HHCount(1,2)=HHCount(1,2)+HuHH(i,HF_Final_Weight);
        elseif HuHH(i,HF_HHFAMINC)<=8
            HHCount(2,2)=HHCount(2,2)+HuHH(i,HF_Final_Weight);
```

```
        elseif HuHH(i,HF_HHFAMINC)<=13
            HHCount(3,2)=HHCount(3,2)+HuHH(i,HF_Final_Weight);
        elseif HuHH(i,HF_HHFAMINC)<=17
            HHCount(4,2)=HHCount(4,2)+HuHH(i,HF_Final_Weight);
        else
            HHCount(5,2)=HHCount(5,2)+HuHH(i,HF_Final_Weight);
        end
    else %Rural
        if HuHH(i,HF_HHFAMINC)<=4
            HHCount(1,3)=HHCount(1,3)+HuHH(i,HF_Final_Weight);
        elseif HuHH(i,HF_HHFAMINC)<=8
            HHCount(2,3)=HHCount(2,3)+HuHH(i,HF_Final_Weight);
        elseif HuHH(i,HF_HHFAMINC)<=13
            HHCount(3,3)=HHCount(3,3)+HuHH(i,HF_Final_Weight);
        elseif HuHH(i,HF_HHFAMINC)<=17
            HHCount(4,3)=HHCount(4,3)+HuHH(i,HF_Final_Weight);
        else
            HHCount(5,3)=HHCount(5,3)+HuHH(i,HF_Final_Weight);
        end
    end
end
HHCount(:,1)=sum(HHCount,2);
HHCountP=HHCount(:,1)./sum(HHCount(:,1),1);

% Total Miles Driven By Category
MileCount=zeros(1,10);
for i=1:m;
    if HuVEH(i,VF_URBRUR)==1 %Urban
        if HuVEH(i,VF_HHFAMINC)<=4

MileCount(1,1)=MileCount(1,1)+HuVEH(i,VF_Final_Weight).*HuVEH(i,VF_BEST
MILE);
        elseif HuVEH(i,VF_HHFAMINC)<=8

MileCount(1,2)=MileCount(1,2)+HuVEH(i,VF_Final_Weight).*HuVEH(i,VF_BEST
MILE);
        elseif HuVEH(i,VF_HHFAMINC)<=13

MileCount(1,3)=MileCount(1,3)+HuVEH(i,VF_Final_Weight).*HuVEH(i,VF_BEST
MILE);
        elseif HuVEH(i,VF_HHFAMINC)<=17

MileCount(1,4)=MileCount(1,4)+HuVEH(i,VF_Final_Weight).*HuVEH(i,VF_BEST
MILE);
        else

MileCount(1,5)=MileCount(1,5)+HuVEH(i,VF_Final_Weight).*HuVEH(i,VF_BEST
MILE);
        end
    else %Rural
        if HuVEH(i,VF_HHFAMINC)<=4

MileCount(1,6)=MileCount(1,6)+HuVEH(i,VF_Final_Weight).*HuVEH(i,VF_BEST
```

```
MILE);
        elseif HuVEH(i,VF_HHFAMINC)<=8

MileCount(1,7)=MileCount(1,7)+HuVEH(i,VF_Final_Weight).*HuVEH(i,VF_BEST
MILE);
        elseif HuVEH(i,VF_HHFAMINC)<=13

MileCount(1,8)=MileCount(1,8)+HuVEH(i,VF_Final_Weight).*HuVEH(i,VF_BEST
MILE);
        elseif HuVEH(i,VF_HHFAMINC)<=17

MileCount(1,9)=MileCount(1,9)+HuVEH(i,VF_Final_Weight).*HuVEH(i,VF_BEST
MILE);
        else

MileCount(1,10)=MileCount(1,10)+HuVEH(i,VF_Final_Weight).*HuVEH(i,VF_BE
STMILE);
        end
    end
end

% Assign Elasticity to each Vehicle
Elasticity=zeros(m,1);
for i=1:m;
    if HuVEH(i,VF_URBRUR)==1 %Urban
        if HuVEH(i,VF_HHFAMINC)<=4
            Elasticity(i)=-0.447;
        elseif HuVEH(i,VF_HHFAMINC)<=8
            Elasticity(i)=-0.280;
        elseif HuVEH(i,VF_HHFAMINC)<=13
            Elasticity(i)=-0.259;
        elseif HuVEH(i,VF_HHFAMINC)<=17
            Elasticity(i)=-0.335;
        else
            Elasticity(i)=-0.373;
        end
    else %Rural
        if HuVEH(i,VF_HHFAMINC)<=4
            Elasticity(i)=-0.254;
        elseif HuVEH(i,VF_HHFAMINC)<=8
            Elasticity(i)=-0.159;
        elseif HuVEH(i,VF_HHFAMINC)<=13
            Elasticity(i)=-0.147;
        elseif HuVEH(i,VF_HHFAMINC)<=17
            Elasticity(i)=-0.191;
        else
            Elasticity(i)=-0.212;
        end
    end
end
```

```
%-------------------- Taxation Calculations --------------------%

%----------- Vehicle File -----------%
disp('Calculating Vehicle Taxes...')
TXRegFee=zeros(m,1);
CRegFee=zeros(m,1);
TXFuelTax=zeros(m,1);
USFuelTax=zeros(m,1);
for i=1:m
    % Assign State Vehicle Registration and Inspection Fee
    if RegFeeFlag==1
        TXRegFee(i,1)=TXRegFeeFlat+VehInspFee;
    else
        if HuVEH(i,VF_VEHYEAR)<=2002
            TXRegFee(i,1)=40.8+VehInspFee;
        elseif HuVEH(i,VF_VEHYEAR)<=2005
            TXRegFee(i,1)=50.8+VehInspFee;
        else
            TXRegFee(i,1)=58.8+VehInspFee;
        end
    end
    % Assign County Vehicle Registration Fee
    if RegFeeFlag==1
        CRegFee(i,1)=CRegFeeFlat;
    else
        if HuVEH(i,VF_CNTYFIPS)==FortBend ||
HuVEH(i,VF_CNTYFIPS)==Harris || HuVEH(i,VF_CNTYFIPS)==SanJacinto
            CRegFee(i,1)=11.5;
        else
            CRegFee(i,1)=10;
        end
    end
    % Assign Fuel Tax
    if HuVEH(i,VF_FUELTYPE)==1 %Diesel
        TXFuelTax(i,1)=TXDslTax;
        USFuelTax(i,1)=USDslTax;
    else
        TXFuelTax(i,1)=TXGasTax;
        USFuelTax(i,1)=USGasTax;
    end
end

% Fuel Tax Calculations and Revenue
CostofFuelNoTax=HuVEH(:,VF_GSCOST)-TXFuelTax-USFuelTax;
FuelPurchased=HuVEH(:,VF_BESTMILE)./HuVEH(:,VF_EIADMPG);
FuelExp=FuelPurchased.*HuVEH(:,VF_GSCOST);
FuelExpNoTax=FuelPurchased.*CostofFuelNoTax;
TXFuelRev=FuelPurchased.*TXFuelTax;
USFuelRev=FuelPurchased.*USFuelTax;
```

```matlab
% Assign Vehicle Taxes to Households
USFuelRevHH=zeros(n,1);
TXFuelRevHH=zeros(n,1);
TXRegFeeHH=zeros(n,1);
CRegFeeHH=zeros(n,1);
for i=1:m

USFuelRevHH(HuHH(:,HF_HOUSEID)==HuVEH(i,VF_HOUSEID),1)=USFuelRevHH(HuHH
(:,HF_HOUSEID)==HuVEH(i,VF_HOUSEID),1)+USFuelRev(i,1);

TXFuelRevHH(HuHH(:,HF_HOUSEID)==HuVEH(i,VF_HOUSEID),1)=TXFuelRevHH(HuHH
(:,HF_HOUSEID)==HuVEH(i,VF_HOUSEID),1)+TXFuelRev(i,1);

TXRegFeeHH(HuHH(:,HF_HOUSEID)==HuVEH(i,VF_HOUSEID),1)=TXRegFeeHH(HuHH(:
,HF_HOUSEID)==HuVEH(i,VF_HOUSEID),1)+TXRegFee(i,1);

CRegFeeHH(HuHH(:,HF_HOUSEID)==HuVEH(i,VF_HOUSEID),1)=CRegFeeHH(HuHH(:,H
F_HOUSEID)==HuVEH(i,VF_HOUSEID),1)+CRegFee(i,1);
end

% Fuel Taxes Paid By Transit
TXTransitFuelRev=TransitGasUsed*TXGasTax+TransitDslUsed*TXDslTax;
USTransitFuelRev=TransitGasUsed*USGasTax+TransitDslUsed*USDslTax;



%----------- Household File -----------%
disp('Calculating Household Taxes...')
Spending=zeros(n,1);
PropValue=zeros(n,1);
CPropTaxRev=zeros(n,1);
LPropTaxRev=zeros(n,1);
CSalesTaxRev=zeros(n,1);
LSalesTaxRev=zeros(n,1);
MSalesTaxRev=zeros(n,1);
for i=1:n
    %Assign Sales Taxable Spending, 1 for auto, 2 for total
    if HuHH(i,HF_HHFAMINC)==1
        Spending(i,1)=430; Spending(i,2)=12514;
    elseif HuHH(i,HF_HHFAMINC)==2
        Spending(i,1)=810; Spending(i,2)=9521;
    elseif HuHH(i,HF_HHFAMINC)==3
        Spending(i,1)=606; Spending(i,2)=10547;
    elseif HuHH(i,HF_HHFAMINC)==4
        Spending(i,1)=1346; Spending(i,2)=12968;
    elseif HuHH(i,HF_HHFAMINC)<=6
        Spending(i,1)=1770; Spending(i,2)=15966;
    elseif HuHH(i,HF_HHFAMINC)<=8
        Spending(i,1)=2069; Spending(i,2)=18974;
    elseif HuHH(i,HF_HHFAMINC)<=10
        Spending(i,1)=2098; Spending(i,2)=21900;
    elseif HuHH(i,HF_HHFAMINC)<=14
        Spending(i,1)=3093; Spending(i,2)=28625;
    elseif HuHH(i,HF_HHFAMINC)<=16
```

```
        Spending(i,1)=3114; Spending(i,2)=33269;
    elseif HuHH(i,HF_HHFAMINC)==17
        Spending(i,1)=3916; Spending(i,2)=38619;
    elseif HuHH(i,HF_HHFAMINC)==18
        Spending(i,1)=5450; Spending(i,2)=59140;
    end
    %Assign Property Value
    if HuHH(i,HF_HHFAMINC)<=2
        PropValue(i,1)=134460;
    elseif HuHH(i,HF_HHFAMINC)<=4
        PropValue(i,1)=112570;
    elseif HuHH(i,HF_HHFAMINC)<=7
        PropValue(i,1)=131140;
    elseif HuHH(i,HF_HHFAMINC)<=10
        PropValue(i,1)=137830;
    elseif HuHH(i,HF_HHFAMINC)<=15
        PropValue(i,1)=155150;
    elseif HuHH(i,HF_HHFAMINC)<=17
        PropValue(i,1)=184760;
    elseif HuHH(i,HF_HHFAMINC)==18
        PropValue(i,1)=282040;
    end
    %Assign Property Tax and Sales Tax Rates
    if HuHH(i,HF_CNTYFIPS)==Austin
        CPropTaxRev(i,1)=CPropTax(1,1)*PropValue(i,1)/100;
        if HuHH(i,HF_URBRUR)==1
            LPropTaxRev(i,1)=LPropTax(1,1)*PropValue(i,1)/100;
        end

CSalesTaxRev(i,1)=Spending(i,2).*CSalesTax(1,1)/(1+TXSalesTax+CSalesTax
Raw(1,1)+LSalesTaxRaw(1,1)+MSalesTax(1,1));

LSalesTaxRev(i,1)=Spending(i,2).*LSalesTax(1,1)/(1+TXSalesTax+CSalesTax
Raw(1,1)+LSalesTaxRaw(1,1)+MSalesTax(1,1));

MSalesTaxRev(i,1)=Spending(i,2).*MSalesTax(1,1)/(1+TXSalesTax+CSalesTax
Raw(1,1)+LSalesTaxRaw(1,1)+MSalesTax(1,1));

TXAutoSalesRev=Spending(i,1).*TXSalesTax/(1+TXSalesTax+CSalesTaxRaw(1,1
)+LSalesTaxRaw(1,1)+MSalesTax(1,1));
    elseif HuHH(i,HF_CNTYFIPS)==Brazoria
        CPropTaxRev(i,1)=CPropTax(2,1)*PropValue(i,1)/100;
        if HuHH(i,HF_URBRUR)==1
            LPropTaxRev(i,1)=LPropTax(2,1)*PropValue(i,1)/100;
        end

CSalesTaxRev(i,1)=Spending(i,2).*CSalesTax(2,1)/(1+TXSalesTax+CSalesTax
Raw(2,1)+LSalesTaxRaw(2,1)+MSalesTax(2,1));

LSalesTaxRev(i,1)=Spending(i,2).*LSalesTax(2,1)/(1+TXSalesTax+CSalesTax
Raw(2,1)+LSalesTaxRaw(2,1)+MSalesTax(2,1));

MSalesTaxRev(i,1)=Spending(i,2).*MSalesTax(2,1)/(1+TXSalesTax+CSalesTax
```

```
Raw(2,1)+LSalesTaxRaw(2,1)+MSalesTax(2,1));

TXAutoSalesRev=Spending(i,1).*TXSalesTax/(1+TXSalesTax+CSalesTaxRaw(2,1
)+LSalesTaxRaw(2,1)+MSalesTax(2,1));
    elseif HuHH(i,HF_CNTYFIPS)==Chambers
        CPropTaxRev(i,1)=CPropTax(3,1)*PropValue(i,1)/100;
        if HuHH(i,HF_URBRUR)==1
            LPropTaxRev(i,1)=LPropTax(3,1)*PropValue(i,1)/100;
        end

CSalesTaxRev(i,1)=Spending(i,2).*CSalesTax(3,1)/(1+TXSalesTax+CSalesTax
Raw(3,1)+LSalesTaxRaw(3,1)+MSalesTax(3,1));

LSalesTaxRev(i,1)=Spending(i,2).*LSalesTax(3,1)/(1+TXSalesTax+CSalesTax
Raw(3,1)+LSalesTaxRaw(3,1)+MSalesTax(3,1));

MSalesTaxRev(i,1)=Spending(i,2).*MSalesTax(3,1)/(1+TXSalesTax+CSalesTax
Raw(3,1)+LSalesTaxRaw(3,1)+MSalesTax(3,1));

TXAutoSalesRev=Spending(i,1).*TXSalesTax/(1+TXSalesTax+CSalesTaxRaw(3,1
)+LSalesTaxRaw(3,1)+MSalesTax(3,1));
    elseif HuHH(i,HF_CNTYFIPS)==FortBend
        CPropTaxRev(i,1)=CPropTax(4,1)*PropValue(i,1)/100;
        if HuHH(i,HF_URBRUR)==1
            LPropTaxRev(i,1)=LPropTax(4,1)*PropValue(i,1)/100;
        end

CSalesTaxRev(i,1)=Spending(i,2).*CSalesTax(4,1)/(1+TXSalesTax+CSalesTax
Raw(4,1)+LSalesTaxRaw(4,1)+MSalesTax(4,1));

LSalesTaxRev(i,1)=Spending(i,2).*LSalesTax(4,1)/(1+TXSalesTax+CSalesTax
Raw(4,1)+LSalesTaxRaw(4,1)+MSalesTax(4,1));

MSalesTaxRev(i,1)=Spending(i,2).*MSalesTax(4,1)/(1+TXSalesTax+CSalesTax
Raw(4,1)+LSalesTaxRaw(4,1)+MSalesTax(4,1));

TXAutoSalesRev=Spending(i,1).*TXSalesTax/(1+TXSalesTax+CSalesTaxRaw(4,1
)+LSalesTaxRaw(4,1)+MSalesTax(4,1));
    elseif HuHH(i,HF_CNTYFIPS)==Galveston
        CPropTaxRev(i,1)=CPropTax(5,1)*PropValue(i,1)/100;
        if HuHH(i,HF_URBRUR)==1
            LPropTaxRev(i,1)=LPropTax(5,1)*PropValue(i,1)/100;
        end

CSalesTaxRev(i,1)=Spending(i,2).*CSalesTax(5,1)/(1+TXSalesTax+CSalesTax
Raw(5,1)+LSalesTaxRaw(5,1)+MSalesTax(5,1));

LSalesTaxRev(i,1)=Spending(i,2).*LSalesTax(5,1)/(1+TXSalesTax+CSalesTax
Raw(5,1)+LSalesTaxRaw(5,1)+MSalesTax(5,1));

MSalesTaxRev(i,1)=Spending(i,2).*MSalesTax(5,1)/(1+TXSalesTax+CSalesTax
Raw(5,1)+LSalesTaxRaw(5,1)+MSalesTax(5,1));
```

```
TXAutoSalesRev=Spending(i,1).*TXSalesTax/(1+TXSalesTax+CSalesTaxRaw(5,1
)+LSalesTaxRaw(5,1)+MSalesTax(5,1));
    elseif HuHH(i,HF_CNTYFIPS)==Harris
        CPropTaxRev(i,1)=CPropTax(6,1)*PropValue(i,1)/100;
        if HuHH(i,HF_URBRUR)==1
            LPropTaxRev(i,1)=LPropTax(6,1)*PropValue(i,1)/100;
        end

CSalesTaxRev(i,1)=Spending(i,2).*CSalesTax(6,1)/(1+TXSalesTax+CSalesTax
Raw(6,1)+LSalesTaxRaw(6,1)+MSalesTax(6,1));

LSalesTaxRev(i,1)=Spending(i,2).*LSalesTax(6,1)/(1+TXSalesTax+CSalesTax
Raw(6,1)+LSalesTaxRaw(6,1)+MSalesTax(6,1));

MSalesTaxRev(i,1)=Spending(i,2).*MSalesTax(6,1)/(1+TXSalesTax+CSalesTax
Raw(6,1)+LSalesTaxRaw(6,1)+MSalesTax(6,1));

TXAutoSalesRev=Spending(i,1).*TXSalesTax/(1+TXSalesTax+CSalesTaxRaw(6,1
)+LSalesTaxRaw(6,1)+MSalesTax(6,1));
    elseif HuHH(i,HF_CNTYFIPS)==Liberty
        CPropTaxRev(i,1)=CPropTax(7,1)*PropValue(i,1)/100;
        if HuHH(i,HF_URBRUR)==1
            LPropTaxRev(i,1)=LPropTax(7,1)*PropValue(i,1)/100;
        end

CSalesTaxRev(i,1)=Spending(i,2).*CSalesTax(7,1)/(1+TXSalesTax+CSalesTax
Raw(7,1)+LSalesTaxRaw(7,1)+MSalesTax(7,1));

LSalesTaxRev(i,1)=Spending(i,2).*LSalesTax(7,1)/(1+TXSalesTax+CSalesTax
Raw(7,1)+LSalesTaxRaw(7,1)+MSalesTax(7,1));

MSalesTaxRev(i,1)=Spending(i,2).*MSalesTax(7,1)/(1+TXSalesTax+CSalesTax
Raw(7,1)+LSalesTaxRaw(7,1)+MSalesTax(7,1));

TXAutoSalesRev=Spending(i,1).*TXSalesTax/(1+TXSalesTax+CSalesTaxRaw(7,1
)+LSalesTaxRaw(7,1)+MSalesTax(7,1));
    elseif HuHH(i,HF_CNTYFIPS)==Montgomery
        CPropTaxRev(i,1)=CPropTax(8,1)*PropValue(i,1)/100;
        if HuHH(i,HF_URBRUR)==1
            LPropTaxRev(i,1)=LPropTax(8,1)*PropValue(i,1)/100;
        end

CSalesTaxRev(i,1)=Spending(i,2).*CSalesTax(8,1)/(1+TXSalesTax+CSalesTax
Raw(8,1)+LSalesTaxRaw(8,1)+MSalesTax(8,1));

LSalesTaxRev(i,1)=Spending(i,2).*LSalesTax(8,1)/(1+TXSalesTax+CSalesTax
Raw(8,1)+LSalesTaxRaw(8,1)+MSalesTax(8,1));

MSalesTaxRev(i,1)=Spending(i,2).*MSalesTax(8,1)/(1+TXSalesTax+CSalesTax
Raw(8,1)+LSalesTaxRaw(8,1)+MSalesTax(8,1));

TXAutoSalesRev=Spending(i,1).*TXSalesTax/(1+TXSalesTax+CSalesTaxRaw(8,1
)+LSalesTaxRaw(8,1)+MSalesTax(8,1));
```

```
    elseif HuHH(i,HF_CNTYFIPS)==SanJacinto
        CPropTaxRev(i,1)=CPropTax(9,1)*PropValue(i,1)/100;
        if HuHH(i,HF_URBRUR)==1
            LPropTaxRev(i,1)=LPropTax(9,1)*PropValue(i,1)/100;
        end

CSalesTaxRev(i,1)=Spending(i,2).*CSalesTax(9,1)/(1+TXSalesTax+CSalesTax
Raw(9,1)+LSalesTaxRaw(9,1)+MSalesTax(9,1));

LSalesTaxRev(i,1)=Spending(i,2).*LSalesTax(9,1)/(1+TXSalesTax+CSalesTax
Raw(9,1)+LSalesTaxRaw(9,1)+MSalesTax(9,1));

MSalesTaxRev(i,1)=Spending(i,2).*MSalesTax(9,1)/(1+TXSalesTax+CSalesTax
Raw(9,1)+LSalesTaxRaw(9,1)+MSalesTax(9,1));

TXAutoSalesRev=Spending(i,1).*TXSalesTax/(1+TXSalesTax+CSalesTaxRaw(9,1
)+LSalesTaxRaw(9,1)+MSalesTax(9,1));
    elseif HuHH(i,HF_CNTYFIPS)==Waller
        CPropTaxRev(i,1)=CPropTax(10,1)*PropValue(i,1)/100;
        if HuHH(i,HF_URBRUR)==1
            LPropTaxRev(i,1)=LPropTax(10,1)*PropValue(i,1)/100;
        end

CSalesTaxRev(i,1)=Spending(i,2).*CSalesTax(10,1)/(1+TXSalesTax+CSalesTa
xRaw(10,1)+LSalesTaxRaw(10,1)+MSalesTax(10,1));

LSalesTaxRev(i,1)=Spending(i,2).*LSalesTax(10,1)/(1+TXSalesTax+CSalesTa
xRaw(10,1)+LSalesTaxRaw(10,1)+MSalesTax(10,1));

MSalesTaxRev(i,1)=Spending(i,2).*MSalesTax(10,1)/(1+TXSalesTax+CSalesTa
xRaw(10,1)+LSalesTaxRaw(10,1)+MSalesTax(10,1));

TXAutoSalesRev=Spending(i,1).*TXSalesTax/(1+TXSalesTax+CSalesTaxRaw(10,
1)+LSalesTaxRaw(10,1)+MSalesTax(10,1));
    end
end
% Mobilty Fund Fee Average Revenue
TXDLRev=HuHH(:,HF_DRVRCNT).*DLFeePerDriver;
% Transit Fare Estimation
TransitRidership=HuHH(:,HF_PTUSED).*12;
OriginalTransitRidership=TransitRidership;



%---------- Spending Setup ----------%
if VMTRevFlag==3
    TXIncrease=(TXSpending./sum(TXSpending)).*Increase;
    TXBenefit=(TXSpending+TXIncrease)./(TXDVM.*365);
else
    TXBenefit=TXSpending./(TXDVM.*365);
end
CBenefit=CSpending./(CDVM.*365);
LBenefit=LSpending./(LDVM.*365);
TotalTransitBenefit=sum(TransitRevMiles.*(TXBenefit+CBenefit+LBenefit).
```

```
*0.3,1);
UBenefit=(DVMP(:,1).*TXBenefit+DVMP(:,2).*CBenefit+DVMP(:,3).*LBenefit)
;
RBenefit=(DVMP(:,4).*TXBenefit+DVMP(:,5).*CBenefit+DVMP(:,6).*LBenefit)
;
UrbanSplit=zeros(m,1);
for i=1:m
    if HuVEH(i,VF_URBRUR)==1 %Urban
        UrbanSplit(i)=0.8; % Urban HH Miles on Urban Road
    else
        UrbanSplit(i)=0.4; % Rural HH Miles on Urban Road
    end
end



disp('Calculating MBUF and Equity Measures...')
RepValues=zeros(25,3,100);
RepValDiff=zeros(25,3,100);
for k=1:101

    x=HF_REP1+k-1; % Household File Weight Column
    y=VF_REP1+k-1; % Vehicle File Weight Column

    %-------------------- VMT Calculations --------------------%
    if VMTFlag>0
        % Calculate Base Revenue for VMT System
        if VMTFlag==1
            BaseTargetVMTRev=sum(HuHH(:,x).*(TXFuelRevHH),1);
        elseif VMTFlag==2

BaseTargetVMTRev=sum(HuHH(:,x).*(TXFuelRevHH+TXRegFeeHH+TXDLRev+TXAutoS
alesRev),1);
        elseif VMTFlag==3

BaseTargetVMTRev=sum(HuHH(:,x).*(USFuelRevHH+TXFuelRevHH),1);
        elseif VMTFlag==4

BaseTargetVMTRev=sum(HuHH(:,x).*(USFuelRevHH+TXFuelRevHH+TXRegFeeHH+CRe
gFeeHH+TXDLRev+TXAutoSalesRev...

+CPropTaxRev+CSalesTaxRev+LPropTaxRev+LSalesTaxRev+MSalesTaxRev),1);
        end
        % Calculate Total Cost of Installation

TotalCostInstall=CostPerStation*NumStation+CostUnit*sum(HuVEH(:,y),1);
        % Coupon Rate
        CouponRate=Yield*TotalCostInstall;
        % Annual Value of Total Cost
        AnnTotCost=((TotalCostInstall)*(Yield))/(((1+Yield)^Years)-1);
        % Annual Cost of Installation Spread Out Over Investment Period
($);
```

```
        TotAnnInstallCost=CouponRate+AnnTotCost;
        % Calculate Total Revenue Required for VMT Fee
        if VMTRevFlag==1
            TargetVMTRev=BaseTargetVMTRev;
        elseif VMTRevFlag==2
            TargetVMTRev=(BaseTargetVMTRev+TotAnnInstallCost)/(1-
Operate-Cheat);
        elseif VMTRevFlag==3

TargetVMTRev=(BaseTargetVMTRev+TotAnnInstallCost+Increase)/(1-Operate-
Cheat);
        end



        % Calcualte Required VMT for Spcified Target Revenue
        count=0;
        e=100;
        NewVMT=HuVEH(:,VF_BESTMILE);
        VMTRev=zeros(m,1);
        PercentChangeinPrice=zeros(m,1);
        PercentChangeinVMT=zeros(m,1);
        PercentChangeinRidership=zeros(n,1);
        while e>1
            count=count+1;
            % New "Cost of Gas" for Elasticity Calcualtion
            NewCostofGas=VMTRev+FuelExpNoTax;
            if VMTFlag<=2
                NewCostofGas=NewCostofGas+USFuelRev;
            end
            % Calculate Percent Change in Price, VMT, and Ridership
            for i=1:m;
                if NewVMT(i)<=0
                    PercentChangeinPrice(i)=0;
                    PercentChangeinVMT(i)=0;
                else
                    PercentChangeinPrice(i)=(NewCostofGas(i)-
FuelExp(i))./FuelExp(i);

PercentChangeinVMT(i)=Elasticity(i).*PercentChangeinPrice(i);

PercentChangeinRidership(HuHH(:,HF_HOUSEID)==HuVEH(i,VF_HOUSEID),1)=Tra
nsitElasticity*PercentChangeinPrice(i);
                end;
            end
            % Calculate New VMT
            NewVMT=HuVEH(:,VF_BESTMILE).*(1+PercentChangeinVMT);
            VMTFee=TargetVMTRev/sum(NewVMT.*HuVEH(:,y),1);
            VMTRev=NewVMT.*VMTFee;

            % Calculate Error and Set Minimum Number of Iterations
            if count>4
                e=abs(TotalVMTRev-TargetVMTRev);
            end
```

```
            TotalVMTRev=sum(VMTRev.*HuVEH(:,y),1);
            % Display Pass Number For Progress Tracking (Every 10th
pass)
            int=~mod(count/10,1);
            if  int==1
                disp(['Pass '  num2str(count) ' Complete'])
            end
            % Set Max Number of Iterations
            if count>99
                break
            end
        end
        % New Transit Ridership and Fare
        TransitRidership=OriginalTransitRidership;

NewTransitRidership=TransitRidership.*(1+PercentChangeinRidership);
        % Assign VMT Revenue To Households
        VMTRevHH=zeros(n,1);
        for i=1:m

VMTRevHH(HuHH(:,HF_HOUSEID)==HuVEH(i,VF_HOUSEID),1)=VMTRevHH(HuHH(:,HF_
HOUSEID)==HuVEH(i,VF_HOUSEID),1)+VMTRev(i,1);
        end
    end

    % Reassign Variables
    if VMTFlag>0
        VMT=NewVMT;
        TransitRidership=NewTransitRidership;
        % Total Percent Change in VMT
        PCVMT=(sum(VMT.*HuVEH(:,y),1)-
sum(HuVEH(:,VF_BESTMILE).*HuVEH(:,y),1))/sum(HuVEH(:,VF_BESTMILE).*HuVE
H(:,y),1);
    else
        VMT=HuVEH(:,VF_BESTMILE);
        VMTFee=0;
        PCVMT=0;
    end

    %---------- Calculate Benefits Received ----------%
    VBenefit=zeros(m,1);

HBenefit=TransitRidership.*((TotalTransitBenefit+TotalTransitSpending+s
um((TransitRidership-
OriginalTransitRidership).*AverageFare.*HuHH(:,x),1)+(TXTransitFuelRev-
VMTFee*sum(TransitRevMiles,1)))/TotalTransitRidership);
    for i=1:m
        if HuVEH(i,VF_CNTYFIPS)==Austin
            VBenefit(i)=VMT(i)*(UrbanSplit(i)*UBenefit(1)/(1+PCVMT)+(1-
UrbanSplit(i))*RBenefit(1)/(1+PCVMT));
        elseif HuVEH(i,VF_CNTYFIPS)==Brazoria
            VBenefit(i)=VMT(i)*(UrbanSplit(i)*UBenefit(2)/(1+PCVMT)+(1-
UrbanSplit(i))*RBenefit(2)/(1+PCVMT));
```

```
        elseif HuVEH(i,VF_CNTYFIPS)==Chambers
            VBenefit(i)=VMT(i)*(UrbanSplit(i)*UBenefit(3)/(1+PCVMT)+(1-
UrbanSplit(i))*RBenefit(3)/(1+PCVMT));
        elseif HuVEH(i,VF_CNTYFIPS)==FortBend
            VBenefit(i)=VMT(i)*(UrbanSplit(i)*UBenefit(4)/(1+PCVMT)+(1-
UrbanSplit(i))*RBenefit(4)/(1+PCVMT));
        elseif HuVEH(i,VF_CNTYFIPS)==Galveston
            VBenefit(i)=VMT(i)*(UrbanSplit(i)*UBenefit(5)/(1+PCVMT)+(1-
UrbanSplit(i))*RBenefit(5)/(1+PCVMT));
        elseif HuVEH(i,VF_CNTYFIPS)==Harris
            VBenefit(i)=VMT(i)*(UrbanSplit(i)*UBenefit(6)/(1+PCVMT)+(1-
UrbanSplit(i))*RBenefit(6)/(1+PCVMT));
        elseif HuVEH(i,VF_CNTYFIPS)==Liberty
            VBenefit(i)=VMT(i)*(UrbanSplit(i)*UBenefit(7)/(1+PCVMT)+(1-
UrbanSplit(i))*RBenefit(7)/(1+PCVMT));
        elseif HuVEH(i,VF_CNTYFIPS)==Montgomery
            VBenefit(i)=VMT(i)*(UrbanSplit(i)*UBenefit(8)/(1+PCVMT)+(1-
UrbanSplit(i))*RBenefit(8)/(1+PCVMT));
        elseif HuVEH(i,VF_CNTYFIPS)==SanJacinto
            VBenefit(i)=VMT(i)*(UrbanSplit(i)*UBenefit(9)/(1+PCVMT)+(1-
UrbanSplit(i))*RBenefit(9)/(1+PCVMT));
        elseif HuVEH(i,VF_CNTYFIPS)==Waller

VBenefit(i)=VMT(i)*(UrbanSplit(i)*UBenefit(10)/(1+PCVMT)+(1-
UrbanSplit(i))*RBenefit(10)/(1+PCVMT));
        end
    end
    for i=1:m

HBenefit(HuHH(:,HF_HOUSEID)==HuVEH(i,VF_HOUSEID),1)=HBenefit(HuHH(:,HF_
HOUSEID)==HuVEH(i,VF_HOUSEID),1)+VBenefit(i,1);
    end
    Benefit=HBenefit.*HuHH(:,x);
    Benefit(Benefit==0)=1; % Ensures HH With No Benefit Does Not Cause
Errors In Calcualtions




    %-------------------- Equity Calculations --------------------%

    %---------- Setup ----------%
    % Calculate Total Tax Burden
    if VMTFlag==1

TaxBurden=HuHH(:,x).*(VMTRevHH+USFuelRevHH+TXRegFeeHH+CRegFeeHH+TXDLRev
+TXAutoSalesRev...

+CPropTaxRev+CSalesTaxRev+LPropTaxRev+LSalesTaxRev+MSalesTaxRev);
    elseif VMTFlag==2

TaxBurden=HuHH(:,x).*(VMTRevHH+USFuelRevHH+CRegFeeHH+CPropTaxRev+CSales
```

```
TaxRev...
            +LPropTaxRev+LSalesTaxRev+MSalesTaxRev);
    elseif VMTFlag==3

TaxBurden=HuHH(:,x).*(VMTRevHH+TXRegFeeHH+CRegFeeHH+TXDLRev+TXAutoSales
Rev+CPropTaxRev...
            +CSalesTaxRev+LPropTaxRev+LSalesTaxRev+MSalesTaxRev);
    elseif VMTFlag==4
        TaxBurden=HuHH(:,x).*(VMTRevHH);
    else % Non VMT Option

TaxBurden=HuHH(:,x).*(USFuelRevHH+TXFuelRevHH+TXRegFeeHH+CRegFeeHH+TXDL
Rev+TXAutoSalesRev...

+CPropTaxRev+CSalesTaxRev+LPropTaxRev+LSalesTaxRev+MSalesTaxRev);
    end
    TotalTaxBurden=sum(TaxBurden,1);
    TotalBenefit=sum(Benefit,1);
    RatioTaxBurden=TaxBurden; % Can't devide by zero...
    RatioTaxBurden(RatioTaxBurden==0)=1;
    Ratio=Benefit./RatioTaxBurden;
    Ratio(TaxBurden==0)=0;
    TotalRatio=sum(Ratio,1);

    % Sort Total Tax Paid by Quintile
    TaxGroup=zeros(5,3); % Tax Revenue for Quintile
    BenefitGroup=zeros(5,3); % Benefits for Quintile
    RatioGroup=zeros(5,3); % Ratio for Quintile
    for i=1:n;
        if HuHH(i,HF_URBRUR)==1 %Urban
            if HuHH(i,HF_HHFAMINC)<=4 %<20k
                TaxGroup(1,2)=TaxGroup(1,2)+TaxBurden(i,1);
                BenefitGroup(1,2)=BenefitGroup(1,2)+Benefit(i,1);
                RatioGroup(1,2)=RatioGroup(1,2)+Ratio(i,1);
            elseif HuHH(i,HF_HHFAMINC)<=8 %20-40k
                TaxGroup(2,2)=TaxGroup(2,2)+TaxBurden(i,1);
                BenefitGroup(2,2)=BenefitGroup(2,2)+Benefit(i,1);
                RatioGroup(2,2)=RatioGroup(2,2)+Ratio(i,1);
            elseif HuHH(i,HF_HHFAMINC)<=13 %40-65k
                TaxGroup(3,2)=TaxGroup(3,2)+TaxBurden(i,1);
                BenefitGroup(3,2)=BenefitGroup(3,2)+Benefit(i,1);
                RatioGroup(3,2)=RatioGroup(3,2)+Ratio(i,1);
            elseif HuHH(i,HF_HHFAMINC)<=17 %65-100k
                TaxGroup(4,2)=TaxGroup(4,2)+TaxBurden(i,1);
                BenefitGroup(4,2)=BenefitGroup(4,2)+Benefit(i,1);
                RatioGroup(4,2)=RatioGroup(4,2)+Ratio(i,1);
            else %100k+
                TaxGroup(5,2)=TaxGroup(5,2)+TaxBurden(i,1);
                BenefitGroup(5,2)=BenefitGroup(5,2)+Benefit(i,1);
                RatioGroup(5,2)=RatioGroup(5,2)+Ratio(i,1);
            end
        else %Rural
            if HuHH(i,HF_HHFAMINC)<=4 %<20k
```

```
                TaxGroup(1,3)=TaxGroup(1,3)+TaxBurden(i,1);
                BenefitGroup(1,3)=BenefitGroup(1,3)+Benefit(i,1);
                RatioGroup(1,3)=RatioGroup(1,3)+Ratio(i,1);
            elseif HuHH(i,HF_HHFAMINC)<=8 %20-40k
                TaxGroup(2,3)=TaxGroup(2,3)+TaxBurden(i,1);
                BenefitGroup(2,3)=BenefitGroup(2,3)+Benefit(i,1);
                RatioGroup(2,3)=RatioGroup(2,3)+Ratio(i,1);
            elseif HuHH(i,HF_HHFAMINC)<=13 %40-65k
                TaxGroup(3,3)=TaxGroup(3,3)+TaxBurden(i,1);
                BenefitGroup(3,3)=BenefitGroup(3,3)+Benefit(i,1);
                RatioGroup(3,3)=RatioGroup(3,3)+Ratio(i,1);
            elseif HuHH(i,HF_HHFAMINC)<=17 %65-100k
                TaxGroup(4,3)=TaxGroup(4,3)+TaxBurden(i,1);
                BenefitGroup(4,3)=BenefitGroup(4,3)+Benefit(i,1);
                RatioGroup(4,3)=RatioGroup(4,3)+Ratio(i,1);
            else %100k+
                TaxGroup(5,3)=TaxGroup(5,3)+TaxBurden(i,1);
                BenefitGroup(5,3)=BenefitGroup(5,3)+Benefit(i,1);
                RatioGroup(5,3)=RatioGroup(5,3)+Ratio(i,1);
            end
        end
    end
    TaxGroup(:,1)=sum(TaxGroup,2);
    TaxGroupP=TaxGroup(:,1)./sum(TaxGroup(:,1),1);
    BenefitGroup(:,1)=sum(BenefitGroup,2);
    BenefitP=BenefitGroup(:,1)./sum(BenefitGroup(:,1),1);
    RatioGroupGini=BenefitGroup./TaxGroup;
    RatioGroup(:,1)=sum(RatioGroup,2);
    RatioP=RatioGroupGini(:,1)./sum(RatioGroupGini(:,1),1);

    %---------- Tax Gini ----------%

    % Area A+B
    AreaAB=.5;
    % Tax Area B
    AreaB=.5*TaxGroupP(1,1)*HHCountP(1,1);
    for i=2:5
        AreaB=AreaB+.5*(sum(TaxGroupP(1:i,1),1)+sum(TaxGroupP(1:(i-
1),1),1))*HHCountP(i,1);
    end
    % Tax Gini Coefficient
    TaxGini=(AreaAB-AreaB)/AreaAB;

    % Benefit Area B
    AreaB=.5*BenefitP(1,1)*HHCountP(1,1);
    for i=2:5
        AreaB=AreaB+.5*(sum(BenefitP(1:i,1),1)+sum(BenefitP(1:(i-
1),1),1))*HHCountP(i,1);
    end
    % Benefit Gini Coefficient
    BenefitGini=(AreaAB-AreaB)/AreaAB;
```

```
    % Ratio Area B
    AreaB=.5*RatioP(1,1)*HHCountP(1,1);
    for i=2:5
        AreaB=AreaB+.5*(sum(RatioP(1:i,1),1)+sum(RatioP(1:(i-
1),1),1))*HHCountP(i,1);
    end
    % Ratio Gini Coefficient
    RatioGini=(AreaAB-AreaB)/AreaAB;



    %---------- Tax Theil ----------%

    TaxTheil=zeros(10,3);
    BenefitTheil=zeros(10,3);
    RatioTheil=zeros(10,3);
    FinalTaxTheil=0;
    FinalBenefitTheil=0;
    FinalRatioTheil=0;
    TotalHuHH=sum(HHCount(:,1),1);

    % Within Group Component and Final Theil for Error Checking
    for i=1:n
        if TaxBurden(i,1)>0
            if HuHH(i,HF_URBRUR)==1 %Urban
                if HuHH(i,HF_HHFAMINC)<=4 %<20k

TaxTheil(1,1)=TaxTheil(1,1)+(TaxBurden(i,1)/TaxGroup(1,2))*log(TaxBurde
n(i,1)*HHCount(1,2)/TaxGroup(1,2));

BenefitTheil(1,1)=BenefitTheil(1,1)+(Benefit(i,1)/BenefitGroup(1,2))*lo
g(Benefit(i,1)*HHCount(1,2)/BenefitGroup(1,2));

RatioTheil(1,1)=RatioTheil(1,1)+(Ratio(i,1)/RatioGroup(1,2))*log(Ratio(
i,1)*HHCount(1,2)/RatioGroup(1,2));
                elseif HuHH(i,HF_HHFAMINC)<=8 %20-40k

TaxTheil(2,1)=TaxTheil(2,1)+(TaxBurden(i,1)/TaxGroup(2,2))*log(TaxBurde
n(i,1)*HHCount(2,2)/TaxGroup(2,2));

BenefitTheil(2,1)=BenefitTheil(2,1)+(Benefit(i,1)/BenefitGroup(2,2))*lo
g(Benefit(i,1)*HHCount(2,2)/BenefitGroup(2,2));

RatioTheil(2,1)=RatioTheil(2,1)+(Ratio(i,1)/RatioGroup(2,2))*log(Ratio(
i,1)*HHCount(2,2)/RatioGroup(2,2));
                elseif HuHH(i,HF_HHFAMINC)<=13 %40-65k

TaxTheil(3,1)=TaxTheil(3,1)+(TaxBurden(i,1)/TaxGroup(3,2))*log(TaxBurde
n(i,1)*HHCount(3,2)/TaxGroup(3,2));

BenefitTheil(3,1)=BenefitTheil(3,1)+(Benefit(i,1)/BenefitGroup(3,2))*lo
g(Benefit(i,1)*HHCount(3,2)/BenefitGroup(3,2));
```

```
RatioTheil(3,1)=RatioTheil(3,1)+(Ratio(i,1)/RatioGroup(3,2))*log(Ratio(
i,1)*HHCount(3,2)/RatioGroup(3,2));
                elseif HuHH(i,HF_HHFAMINC)<=17 %65-100k

TaxTheil(4,1)=TaxTheil(4,1)+(TaxBurden(i,1)/TaxGroup(4,2))*log(TaxBurde
n(i,1)*HHCount(4,2)/TaxGroup(4,2));

BenefitTheil(4,1)=BenefitTheil(4,1)+(Benefit(i,1)/BenefitGroup(4,2))*lo
g(Benefit(i,1)*HHCount(4,2)/BenefitGroup(4,2));

RatioTheil(4,1)=RatioTheil(4,1)+(Ratio(i,1)/RatioGroup(4,2))*log(Ratio(
i,1)*HHCount(4,2)/RatioGroup(4,2));
                else %100k+

TaxTheil(5,1)=TaxTheil(5,1)+(TaxBurden(i,1)/TaxGroup(5,2))*log(TaxBurde
n(i,1)*HHCount(5,2)/TaxGroup(5,2));

BenefitTheil(5,1)=BenefitTheil(5,1)+(Benefit(i,1)/BenefitGroup(5,2))*lo
g(Benefit(i,1)*HHCount(5,2)/BenefitGroup(5,2));

RatioTheil(5,1)=RatioTheil(5,1)+(Ratio(i,1)/RatioGroup(5,2))*log(Ratio(
i,1)*HHCount(5,2)/RatioGroup(5,2));
                end
            else %Rural
                if HuHH(i,HF_HHFAMINC)<=4 %<20k

TaxTheil(6,1)=TaxTheil(6,1)+(TaxBurden(i,1)/TaxGroup(1,3))*log(TaxBurde
n(i,1)*HHCount(1,3)/TaxGroup(1,3));

BenefitTheil(6,1)=BenefitTheil(6,1)+(Benefit(i,1)/BenefitGroup(1,3))*lo
g(Benefit(i,1)*HHCount(1,3)/BenefitGroup(1,3));

RatioTheil(6,1)=RatioTheil(6,1)+(Ratio(i,1)/RatioGroup(1,3))*log(Ratio(
i,1)*HHCount(1,3)/RatioGroup(1,3));
                elseif HuHH(i,HF_HHFAMINC)<=8 %20-40k

TaxTheil(7,1)=TaxTheil(7,1)+(TaxBurden(i,1)/TaxGroup(2,3))*log(TaxBurde
n(i,1)*HHCount(2,3)/TaxGroup(2,3));

BenefitTheil(7,1)=BenefitTheil(7,1)+(Benefit(i,1)/BenefitGroup(2,3))*lo
g(Benefit(i,1)*HHCount(2,3)/BenefitGroup(2,3));

RatioTheil(7,1)=RatioTheil(7,1)+(Ratio(i,1)/RatioGroup(2,3))*log(Ratio(
i,1)*HHCount(2,3)/RatioGroup(2,3));
                elseif HuHH(i,HF_HHFAMINC)<=13 %40-65k

TaxTheil(8,1)=TaxTheil(8,1)+(TaxBurden(i,1)/TaxGroup(3,3))*log(TaxBurde
n(i,1)*HHCount(3,3)/TaxGroup(3,3));

BenefitTheil(8,1)=BenefitTheil(8,1)+(Benefit(i,1)/BenefitGroup(3,3))*lo
g(Benefit(i,1)*HHCount(3,3)/BenefitGroup(3,3));

RatioTheil(8,1)=RatioTheil(8,1)+(Ratio(i,1)/RatioGroup(3,3))*log(Ratio(
```

```
i,1)*HHCount(3,3)/RatioGroup(3,3));
                elseif HuHH(i,HF_HHFAMINC)<=17 %65-100k

TaxTheil(9,1)=TaxTheil(9,1)+(TaxBurden(i,1)/TaxGroup(4,3))*log(TaxBurde
n(i,1)*HHCount(4,3)/TaxGroup(4,3));

BenefitTheil(9,1)=BenefitTheil(9,1)+(Benefit(i,1)/BenefitGroup(4,3))*lo
g(Benefit(i,1)*HHCount(4,3)/BenefitGroup(4,3));

RatioTheil(9,1)=RatioTheil(9,1)+(Ratio(i,1)/RatioGroup(4,3))*log(Ratio(
i,1)*HHCount(4,3)/RatioGroup(4,3));
                else %100k+

TaxTheil(10,1)=TaxTheil(10,1)+(TaxBurden(i,1)/TaxGroup(5,3))*log(TaxBur
den(i,1)*HHCount(5,3)/TaxGroup(5,3));

BenefitTheil(10,1)=BenefitTheil(10,1)+(Benefit(i,1)/BenefitGroup(5,3))*
log(Benefit(i,1)*HHCount(5,3)/BenefitGroup(5,3));

RatioTheil(10,1)=RatioTheil(10,1)+(Ratio(i,1)/RatioGroup(5,3))*log(Rati
o(i,1)*HHCount(5,3)/RatioGroup(5,3));
                end
            end

FinalTaxTheil=FinalTaxTheil+(TaxBurden(i,1)/TotalTaxBurden)*log(TaxBurd
en(i,1)*TotalHuHH/TotalTaxBurden);

FinalBenefitTheil=FinalBenefitTheil+(Benefit(i,1)/TotalBenefit)*log(Ben
efit(i,1)*TotalHuHH/TotalBenefit);

FinalRatioTheil=FinalRatioTheil+(Ratio(i,1)/TotalRatio)*log(Ratio(i,1)*
TotalHuHH/TotalRatio);
        else
        end
    end
    % Between Group Component
    for i=1:5

TaxTheil(i,2)=(TaxGroup(i,2)/TotalTaxBurden)*log((TaxGroup(i,2)/TotalTa
xBurden)/(HHCount(i,2)/TotalHuHH));

BenefitTheil(i,2)=(BenefitGroup(i,2)/TotalBenefit)*log((BenefitGroup(i,
2)/TotalBenefit)/(HHCount(i,2)/TotalHuHH));

RatioTheil(i,2)=(RatioGroup(i,2)/TotalRatio)*log((RatioGroup(i,2)/Total
Ratio)/(HHCount(i,2)/TotalHuHH));

TaxTheil((i+5),2)=(TaxGroup(i,3)/TotalTaxBurden)*log((TaxGroup(i,3)/Tot
alTaxBurden)/(HHCount(i,3)/TotalHuHH));

BenefitTheil((i+5),2)=(BenefitGroup(i,3)/TotalBenefit)*log((BenefitGrou
p(i,3)/TotalBenefit)/(HHCount(i,3)/TotalHuHH));
```

```
RatioTheil((i+5),2)=(RatioGroup(i,3)/TotalRatio)*log((RatioGroup(i,3)/T
otalRatio)/(HHCount(i,3)/TotalHuHH));
    end
    TaxTheil(:,3)=[TaxGroup(:,2)./TotalTaxBurden;
TaxGroup(:,3)./TotalTaxBurden];
    BenefitTheil(:,3)=[BenefitGroup(:,2)./TotalBenefit;
BenefitGroup(:,3)./TotalBenefit];
    RatioTheil(:,3)=[RatioGroup(:,2)./TotalRatio;
RatioGroup(:,3)./TotalRatio];

FinalTaxTheilCheck=sum(TaxTheil(:,2)+TaxTheil(:,1).*TaxTheil(:,3),1);

FinalBenefitTheilCheck=sum(BenefitTheil(:,2)+BenefitTheil(:,1).*Benefit
Theil(:,3),1);

FinalRatioTheilCheck=sum(RatioTheil(:,2)+RatioTheil(:,1).*RatioTheil(:,
3),1);

    % Calculate Standard Error for Weights
    if k<101
        RepValues(:,:,k)=[TaxGini BenefitGini RatioGini;...
            FinalTaxTheil FinalBenefitTheil FinalRatioTheil;...
            TaxTheil(:,1) BenefitTheil(:,1) RatioTheil(:,1);... %
Within Group Theil
            TaxTheil(:,2) BenefitTheil(:,2) RatioTheil(:,2);... %
Between Group Theil
            sum(HuVEH(:,VF_BESTMILE).*HuVEH(:,y),1)/1e9
sum(VMT.*HuVEH(:,y),1)/1e9 PCVMT;... % Total Original VMT, Total New
VMT, and Percent Change in VMT
            sum(OriginalTransitRidership.*HuHH(:,x),1)/1e6
sum(TransitRidership.*HuHH(:,x),1)/1e6
(sum(TransitRidership.*HuHH(:,x),1)-
sum(OriginalTransitRidership.*HuHH(:,x),1))/sum(OriginalTransitRidershi
p.*HuHH(:,x),1);... % Total Original Ridership, Total New Ridership,
Percent Change in Ridership
            VMTFee TotalRatio/n 0]; % VMT Fee and Average Ratio
    end
    if k==101
        Values=[TaxGini BenefitGini RatioGini;...
            FinalTaxTheil FinalBenefitTheil FinalRatioTheil;...
            TaxTheil(:,1) BenefitTheil(:,1) RatioTheil(:,1);... %
Within Group Theil
            TaxTheil(:,2) BenefitTheil(:,2) RatioTheil(:,2);... %
Between Group Theil
            sum(HuVEH(:,VF_BESTMILE).*HuVEH(:,y),1)/1e9
sum(VMT.*HuVEH(:,y),1)/1e9 PCVMT;... % Total Original VMT, Total New
VMT, and Percent Change in VMT
            sum(OriginalTransitRidership.*HuHH(:,x),1)/1e6
sum(TransitRidership.*HuHH(:,x),1)/1e6
(sum(TransitRidership.*HuHH(:,x),1)-
sum(OriginalTransitRidership.*HuHH(:,x),1))/sum(OriginalTransitRidershi
p.*HuHH(:,x),1);... % Total Original Ridership, Total New Ridership,
Percent Change in Ridership
```

```
            VMTFee TotalRatio/n 0]; % VMT Fee and Average Ratio
        for s=1:100
            RepValDiff(:,:,s)=RepValues(:,:,s)-Values;
        end
        RepValSQ=RepValDiff.^2;
        RepValVarTot=sum(RepValSQ(:,:,:),3);
        StdErr=sqrt(RepValVarTot.*99/100);
    end
    disp(['Weight '  num2str(k) ' Complete'])
end


if VMTFlag>0
    NewMileCount=zeros(1,10);
    for i=1:m;
        if HuVEH(i,VF_URBRUR)==1 %Urban
            if HuVEH(i,VF_HHFAMINC)<=4

NewMileCount(1,1)=NewMileCount(1,1)+NewVMT(i,1).*HuVEH(i,VF_Final_Weigh
t);
            elseif HuVEH(i,VF_HHFAMINC)<=8

NewMileCount(1,2)=NewMileCount(1,2)+NewVMT(i,1).*HuVEH(i,VF_Final_Weigh
t);
            elseif HuVEH(i,VF_HHFAMINC)<=13

NewMileCount(1,3)=NewMileCount(1,3)+NewVMT(i,1).*HuVEH(i,VF_Final_Weigh
t);
            elseif HuVEH(i,VF_HHFAMINC)<=17

NewMileCount(1,4)=NewMileCount(1,4)+NewVMT(i,1).*HuVEH(i,VF_Final_Weigh
t);
            else

NewMileCount(1,5)=NewMileCount(1,5)+NewVMT(i,1).*HuVEH(i,VF_Final_Weigh
t);
            end
        else %Rural
            if HuVEH(i,VF_HHFAMINC)<=4

NewMileCount(1,6)=NewMileCount(1,6)+NewVMT(i,1).*HuVEH(i,VF_Final_Weigh
t);
            elseif HuVEH(i,VF_HHFAMINC)<=8

NewMileCount(1,7)=NewMileCount(1,7)+NewVMT(i,1).*HuVEH(i,VF_Final_Weigh
t);
            elseif HuVEH(i,VF_HHFAMINC)<=13

NewMileCount(1,8)=NewMileCount(1,8)+NewVMT(i,1).*HuVEH(i,VF_Final_Weigh
t);
            elseif HuVEH(i,VF_HHFAMINC)<=17

NewMileCount(1,9)=NewMileCount(1,9)+NewVMT(i,1).*HuVEH(i,VF_Final_Weigh
```

```
t);
            else

NewMileCount(1,10)=NewMileCount(1,10)+NewVMT(i,1).*HuVEH(i,VF_Final_Wei
ght);
            end
        end
    end
    PercentChangeMile=(NewMileCount-MileCount)./MileCount;
end
Percentage=[TaxGroupP BenefitP RatioP];

% You will need to change this to suit your needs
disp('Writing to File...')
if VMTFlag==0
    xlswrite('Results.xlsx',Values,'TXFuel','A2');
    xlswrite('Results.xlsx',StdErr,'TXFuel','D2');
    xlswrite('Results.xlsx',MileCount,'TXFuel','C60');
    xlswrite('Results.xlsx',HHCountP,'TX Gini','A2');
    xlswrite('Results.xlsx',Percentage,'TX Gini','B2');
else
    if TransitElasticity>.125
        if VMTRevFlag==1
            xlswrite('Results.xlsx',Values,'TXFuel','H2');
            xlswrite('Results.xlsx',StdErr,'TXFuel','K2');
            xlswrite('Results.xlsx',NewMileCount,'TXFuel','C61');
            xlswrite('Results.xlsx',Percentage,'TX Gini','F2');
        elseif VMTRevFlag==2
            xlswrite('Results.xlsx',Values,'TXFuel','O2');
            xlswrite('Results.xlsx',StdErr,'TXFuel','R2');
            xlswrite('Results.xlsx',NewMileCount,'TXFuel','C62');
            xlswrite('Results.xlsx',Percentage,'TX Gini','J2');
        elseif VMTRevFlag==3
            xlswrite('Results.xlsx',Values,'TXFuel','V2');
            xlswrite('Results.xlsx',StdErr,'TXFuel','Y2');
            xlswrite('Results.xlsx',NewMileCount,'TXFuel','C63');
            xlswrite('Results.xlsx',Percentage,'TX Gini','N2');
        end
    else
        if VMTRevFlag==1
            xlswrite('Results.xlsx',Values,'TXFuel','H31');
            xlswrite('Results.xlsx',StdErr,'TXFuel','K31');
            xlswrite('Results.xlsx',Percentage,'TX Gini','F8');
        elseif VMTRevFlag==2
            xlswrite('Results.xlsx',Values,'TXFuel','O31');
            xlswrite('Results.xlsx',StdErr,'TXFuel','R31');
            xlswrite('Results.xlsx',Percentage,'TX Gini','J8');
        elseif VMTRevFlag==3
            xlswrite('Results.xlsx',Values,'TXFuel','V31');
            xlswrite('Results.xlsx',StdErr,'TXFuel','Y31');
            xlswrite('Results.xlsx',Percentage,'TX Gini','N8');
        end
    end
```

```
end
disp('Done')
toc
```