Impact of Vehicle Registration Fee on Travel Behavior

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THESIS
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SU

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACS	American Community Survey
CBD	Central Business District
DMV	Department of Motor Vehicles
EV	Electric Vehicles
GDP	Gross Domestic Product
HTF	Highway Trust Fund
LBS	Pound-Mass
MNL	Multinomial Logit Regression
MPG	Miles-per-gallon
NHTS	National Household Travel Survey
NCSL	National Conference of State Legislatures
OLM	Ordered Logit Model
OLS	Ordinary Least Square
ORNL	Oak Ridge National Laboratory
PPP	Public Private Partnership
TOD	Transit Oriented Development
US	United States
VIF	Variance Inflation Factor
VMT	Vehicle Miles Traveled

EXECUTIVE SUMMARY

This study examines impacts of vehicle registration fee on vehicle ownership and vehicle miles driven (VMT) using data from Texas. With the declining condition of transportation infrastructure and challenging fiscal environment in the country, states are trying to improve the infrastructure. To fill the gaps in funding, vehicle registration fee is being increased in several states. However, there is a dearth of knowledge about how the increase in fee may impact auto ownership and travel behavior, which is the gap in literature that this study strives to address.

The study is conducted for the state of Texas, both at the county and disaggregate level. The impact is measured specifically for two aspects, vehicle ownership and Vehicle Miles Traveled (VMT) using Multinomial Logit (MNL) and linear regression techniques, respectively. The data for the vehicle registration fee is obtained from Texas Department of Transportation and for vehicle ownership and VMT from the 2009, National Household Travel Survey (NHTS). The data for control variables is obtained from the 2009 NHTS and the American Community Survey (ACS).

The results from the analysis show that vehicle registration fee does have surprisingly significant impact on the vehicle ownership but does not have significant impact on the VMT. Hence, increase in registration fee may lead to decline in vehicle ownership, which may impact funds generated from vehicle registration fee and may also impact the automobile industry.

1. INTRODUCTION

1.1 Need for Study

The state of transportation infrastructure is declining in the United States (US) due to aging infrastructure, inefficient maintenance, and insufficient funding. The US road system is financially dependent, mainly on the federally administered Highway Trust Fund (HTF) for the maintenance and development of infrastructure. The main source of revenue for the HTF is the motor fuel tax, which has been declining for the past few years and has severely restricted the spending capacity of transportation agencies. With the escalating need to maintain roads and bridges and decline in transportation funding, both federal and state governments are looking for alternative funding sources. One of the funding mechanism readily adopted by many states is increasing the vehicle registration fee. The fee is a fixed consumer cost associated with vehicle ownership, hence a more reliable source of revenue, as compared to use-based taxes.

However, an increase in the vehicle registration fee may also impact the travel behavior of people, leading to the decline of vehicle ownership in households. Also, with the change in vehicle ownership status, VMT may decline (per capita, per household, or per vehicle). This can further lead to change in the mode. The decreased vehicle ownership may also impact the expected amount of fund generated from increase in the fee, contrary to the expectation of increasing the funds. Thus, it would decrease the reliability of vehicle registration fee as a funding resource. It may also affect the automobile industry, which is

important to the US economy. Hence, from the policy perspective, it is important to understand impacts of the increase in vehicle registration fee on auto ownership and travel behavior, to analyze its role as a funding source and its implications on the transportation industry and the economy. To this end, the main research question investigated in this thesis is "how does the vehicle registration fees affect vehicle ownership and VMT?"

1.2. Objectives of Study

The main objectives of the study are –

1. To analyze the impacts of vehicle registration fee on vehicle ownership.
2. To analyze the impacts of vehicle registration fee on VMT per vehicle.
3. To understand the implications of vehicle registration fee, increase on the economy and as a funding resource.

1.3 Overview of the Study Framework

Figure 1 depicts the steps undertaken for the study. The research began with investigating the current trends of increases in vehicle registration fees and their reasons in several states across the country. The cases of different states were analyzed to find out the widespread nature of increase in the fee. The main reason identified for states to increase vehicle registration fee is the gap in transportation funds. Further investigation was conducted on the gap in funds and its impact on the economy to establish the need for study. This also helped in formulating the objectives for the study.

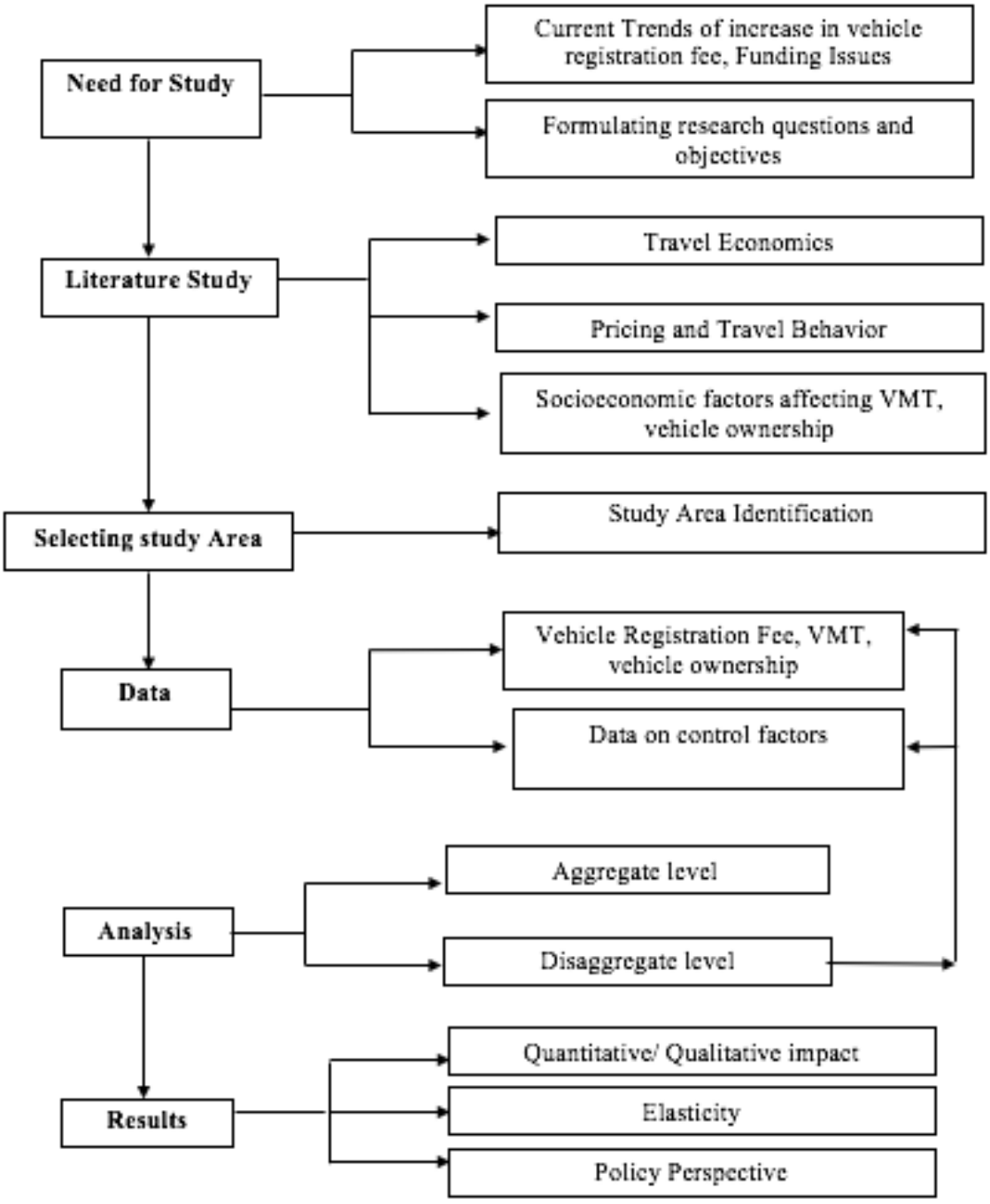

Figure 1: Flowchart of Methodology for Study

After the need for the study was established and the research objectives were determined, literature review was carried out to understand the concepts of transportation economics, travel behavior and the impact on travel behavior by fixed costs and variable costs of transportation, specifically vehicle ownership and VMT. Both, the theories and empirical studies were reviewed to understand the qualitative and quantitative impacts, as well as to learn how the impacts can be measured.

Next, ways in which the vehicle registration fee is assessed across the 50 states were studied. The state of Texas was chosen as the study area because of its importance at the national level as well as based on the availability of data. Next, data was collected for vehicle registration fee, vehicle ownership and VMT. Since in Texas, the vehicle registration fee is assessed at the county level, data was first collected at the county level. Then, I could obtain the zip code level information for the records from the 2009 NHTS which helped in identifying geographic location of each record at the place level and led to performing disaggregate analysis. Also, literature review was done to identify the other key factors that impact vehicle ownership and VMT. Data about these identified control factors was gathered from the NHTS and the ACS. Regression analysis, with vehicle ownership and VMT as the dependent variables, were performed at both the aggregate and disaggregate levels. The results from regression analysis were used to understand the possible effects that change in vehicle registration fee may have on travel behavior and its impact on the economy and reliability of the fee as a funding resource.

1.4 Structure of the Document

The thesis is divided into eight chapters. Following this introductory chapter, the second chapter describes in detail about the need for study. It discusses the gap in transportation funds, alternative funding resources and cites examples of the states in which vehicle registration fees have been raised or is proposed. The third chapter describes existing literature on the relevant topics of transportation economics, pricing and travel behavior and the socio-economic factors that impact vehicle ownership and VMT. The fourth chapter describes the rationale behind the selection of study area and information about it. The fifth chapter states the formulated hypothesis for study based on literature review and describes the data used for analysis. The sixth chapter gives the results of regression analysis, which are used to analyze the impact of vehicle registration fee on vehicle ownership and VMT. It also examines elasticity of travel behavior with respect to vehicle registration fee. As the results from aggregate level analysis were not satisfactory, they are put in Appendix B. The seventh chapter gives conclusions from analysis and possible implications of the results. It is followed by the concluding chapter, giving the aspects for future research and limitations to the study. The appendices are given in the last.

2. NEED FOR STUDY: DECLINING TRANSPORTATION FUNDING AND NEED FOR NEW FUNDING MECHANISMS

Transportation sector has a strong impact on the economy. However, decline in the quality of transportation infrastructure can cost the economy significantly. Hence, the infrastructure must be maintained for which funds are needed. The chapter discusses how vehicle registration fee is being considered as a possible funding source and the possible impacts, increase in fee can have on the travel behavior of people and its reliability as a funding source.

2.1. US Transportation Sector and impact of Crumbling Infrastructure

Transportation sector is one of the major contributors to the economy of the United States (US). As per the Bureau of Transportation Statistics, the share of transportation sector to the US Gross Domestic Product (GDP) in the year 2015 was 9 %, approximately valued at $1.6 trillion. As per a report by Business Roundtable (2015), "Transportation infrastructure is the backbone of a modern, competitive and productive economy. Interrelated and mutually reinforcing transportation infrastructure systems facilitate the efficient movement of goods and services, promote trade and commerce, connect supply chains, and reduce operating costs across a diverse set of industries." (pg. 1). As transportation industry and economy share a complex relationship, it is imperative for transportation infrastructure to be in a good shape. Also, there is a need to modernize the existing transportation infrastructure system along with its maintenance (Business

Roundtable, 2015). However, the vast US transportation infrastructure is facing a crunch because of the aging system and neglect. As per the report by Business Roundtable (2015), the overall infrastructure quality of the US ranks 16th in the world. The dilapidated infrastructure results in congestion, which adversely impacts the economy (Weisbrod, Vary and Treyz, 2001). In 2011, urban highway congestion cost to the US economy was more than $120 billion (Business Roundtable, 2015). In addition, the deferred maintenance is going to make infrastructure condition worse in future. As per the American Society of Civil Engineers, negligence towards infrastructure will cost the economy $4 trillion in GDP and 2.5 million jobs by 2025 (Denham, 2017).

2.2 Reasons for decline in Transportation Funding

A loss to the economy by the outdated infrastructure mandates substantial investment in infrastructure. The US is primarily an automobile dependent country, with almost 85 % of people using cars for commuting to work (US Census Bureau, 2015b). Also, the average vehicle ownership per household in the country is slightly higher than the average drivers per household (US Census Bureau, 2015c).

At present, the Interstate Highway System stands at 47,662 miles of the road network (Bureau of Transportation Statistics, a). The Highway Trust Fund (HTF) was established in 1956 to construct the Interstate Highway System. It has served as the main funding source for many surface transportation projects in the country and supports the transit funding needs by the Mass Transit Account (Hall J. and Hall L., 2006). The main

source of revenue for the combined HTF is the tax levied on fuel (Moore and Poole, 2010). The tax levied on the fuel can be represented by the following equation:

FT = FedT * fuel/gallon + ST * fuel/gallon + 0.1 * fuel/gallon + MT/CT * fuel/gallon

where, FT = Fuel Tax on per gallon of gasoline

FedT = Federal fuel tax, which is 18.3 cents for gasoline and 24.3 on diesel, per gallon (Lowry, 2015)

ST = State tax which varies by state

FT/CT = tax levied at municipal or county level on fuel

Although, the combined HTF, state and local funds get its revenue from other sources as well, fuel tax remains as the major funding source, which has not been raised at the Federal level since 1993 (Lowry, 2015). Fuel tax accounts for almost 90% of the HTF revenues (Lowry, 2015). Therefore, due to the decline in the fuel tax rate (inflation-adjusted), the HTF, state and local funds have experienced a decline in the past few years. In 2015, the combined annual deficit of the HTF and the Mass Transit Account was approximately $13 billion and is expected to grow to $22 billion by 2025 as predicted by the Congressional Budget Office (CBO) if the current trend continues (Sargent, 2015).

The other major reason for decline in the revenue generated from the fuel-based tax is the improved fuel efficiency of vehicles, which has reduced total fuel consumption, thereby decreasing the fuel tax. The fuel efficiency of an average non-commercial road vehicle on road has increased from 20.1 miles per gallon (mpg) in 2002 to 21.6 mpg in 2012, which is 7.5% increase, thereby decreasing total gas sales (The PEW Charitable

Trusts, 2014). In addition, decrease in the VMT due to change in travel behavior, especially in the urban areas has further reduced the fuel-based tax (Chiachiere, 2013), although the decline in VMT has stopped in the past two years. Hence, the US is experiencing a financial crisis of transportation funds at all the levels of government.

2.3. Alternate Funding and Finance Sources

The federal, state and local government across the country are considering and implementing several options to address the declining transportation funds. One of the main options that has been under consideration for a long time is raising the gas tax rate. However, this is not a long-term solution because of the decrease in fuel consumption. Another funding source which is being considered is the mileage-based tax or VMT tax. However, it has associated security and privacy concerns of travelers as they can be tracked by Global Positioning System (GPS) technology on which mileage-based tax rely. Other concerns are related to inequity in tax assessment, as the same tax rate is applied to all vehicles irrespective of their varying efficiency. Another potential source is the toll collected on road facilities. Public-Private Partnerships (PPP) is also a potential source, which is being used widely for financing major transportation projects in the US. The PPP model is used not only for transportation projects but also for other physical and social infrastructure projects (Deye, 2015).

A more common approach being used in present time by many states and municipal governments to deal with the gap in transportation funds is increasing the vehicle

registration fee. It is deemed more reliable in comparison to increasing the variable costs in which there is some uncertainty associated with the revenue received by the increase in cost. (Benning, 2016; Scanlon; 2017, Johnson; 2017; Bierschbach, 2016).

2.4. Vehicle Registration Fee as a Funding Source

Vehicle registration fee is an annual charge that vehicle owners pay to the state in the US for maintaining their vehicle registration. The amount of fee charged is assessed by each state's Department of Motor Vehicles (DMV) and collected either at the county or at the municipal level. The collected fee is distributed between the state and local governments. The fee is charged in addition to the vehicle license fees, weight fees, special plate fees, county/district fees and owner responsibility fees. A detailed list of the vehicle registration fee assessment mechanism used in different states is provided in Appendix A (National Conference of State Legislatures, 2017).

The list of factors that help in determining the registration fee, which vary from state to state, are given below: (Sparks, 2012)

- Vehicle Usage Type: Most of the states assess the fee based on the type of use of the vehicle in combination with the weight of the vehicle and the age of vehicle.

- Vehicle price: Some of the states also assess the fee in proportion to the price of vehicle set by the manufacturer. The fee depreciates as the price of vehicle decreases with time and becomes constant after a few years.
- Trade-in value – For the people who trade in used cars for new cars, the vehicle fee is based on the trade-in value of the car.
- Registration Period – The total cost of vehicle registration is affected by the period of registration that might vary from a single year to several years.
- Fuel type – A few states also consider the fuel type of vehicle to assess vehicle registration fee. However, with electric and hybrid vehicles in the market, the vehicle registration fee for such vehicles is high relative to gasoline fuel based vehicles in some states like Michigan, Georgia, Washington etc. (Richard M.G., 2015)
- Some states also consider city or county of residence, lien information and vehicle specifications such as the number of cylinders to assess vehicle registration fee.

Vehicle registration fee has increased in several states and local governments in the recent years and other states are considering to increase it as well. As the US has high vehicle ownership, with approximately 91% of household's owning at least a vehicle and 57% of households owning two or more vehicles (US Census Bureau, 2015a), the funds generated from increasing vehicle registration fee would be significant. Following are some of the examples from the recent history of vehicle registration fee increase in the US.

The state of Texas has increased its vehicle registration handling fee in 2017 to fill in the budget gap and to make the state DMV self-funded (Benning, 2016). The state had previously increased the vehicle registration fee in 2011 by simplifying the assessment of fees for light vehicles (6000 pounds or less) from a complicated structure to a flat rate value of $50.75 per year. In addition, the state mandated all counties to charge a separate fee for vehicle registration (Dickson, 2011).

The state of Minnesota is considering to increase the vehicle registration fee to pay for road and bridge improvements. As per the proposed plan, one of the recommendations is to increase the gas tax by 5-cent per gallon along with increasing the license tab fees from $10 to $20. Also, the state charges an additional fee equal to the percentage value of the vehicle cost, which has been increased from 1.25% to 1.63%. The second option does not include gas tax increase; hence the base registration fee would be $20; $35 being the minimum fee and 1.63% increase in the rate of the value of vehicle cost (Bierschbach, 2016).

The state of Hawaii is also considering to increase the vehicle registration fee from $45 to $50 and annual motor vehicle weight tax by 0.25 cent per-pound. The funds generated from the fee increase will be used to repair and maintain the state highways which are in bad shape (Johnson, 2017).

In the state of California, the governor has proposed a hike in the vehicle registration fee from $43 to $53 as part of the state budget deal to fund the DMV and

California Highway Patrol. The fee will continue to rise incrementally based on the California Consumer Price Index. (Adler, 2016).

In the state of Arizona, the Senate panel has approved an increase in the vehicle registration fee in lieu of the unsuccessful attempts to increase the statewide gas tax. The legislation is expected to increase the rate on the value of vehicle rate by 1.5%, which is the measure for assessing the registration fee. The increase in fee rate is supposed to raise the funds by $120 million a year and support road improvement projects (Fischer H., 2017).

The state of Michigan has raised the vehicle registration fee by 20% for both passenger cars and commercial trucks starting in 2017. The increase in vehicle registration fee is a part of the transportation funding plan, which will raise an additional $200 million annually for transportation improvements in the state. (Ockerman, 2016).

The House of Representatives in the state of Indiana has recently approved a bill that will raise the vehicle registration fee in the state by $15. This step is one of the several initiatives taken to raise funds for improvement of roads and bridges which are going to increase the funds by $1.2 billion annually (Cook T. and Lange K.L., 2017).

The map in Figure 2 shows the initiatives taken towards raising vehicle registration fee and other fees in the previous years by the states in the country. All the cases mentioned above reflect the potential of vehicle registration fee to act as a revenue source as the fee is a fixed consumer cost in contrast to other options that are variable in nature. Also, as the fee is already being charged, it will be convenient and cost effective to collect the fee without any new administrative efforts and statewide implementation will be easier.

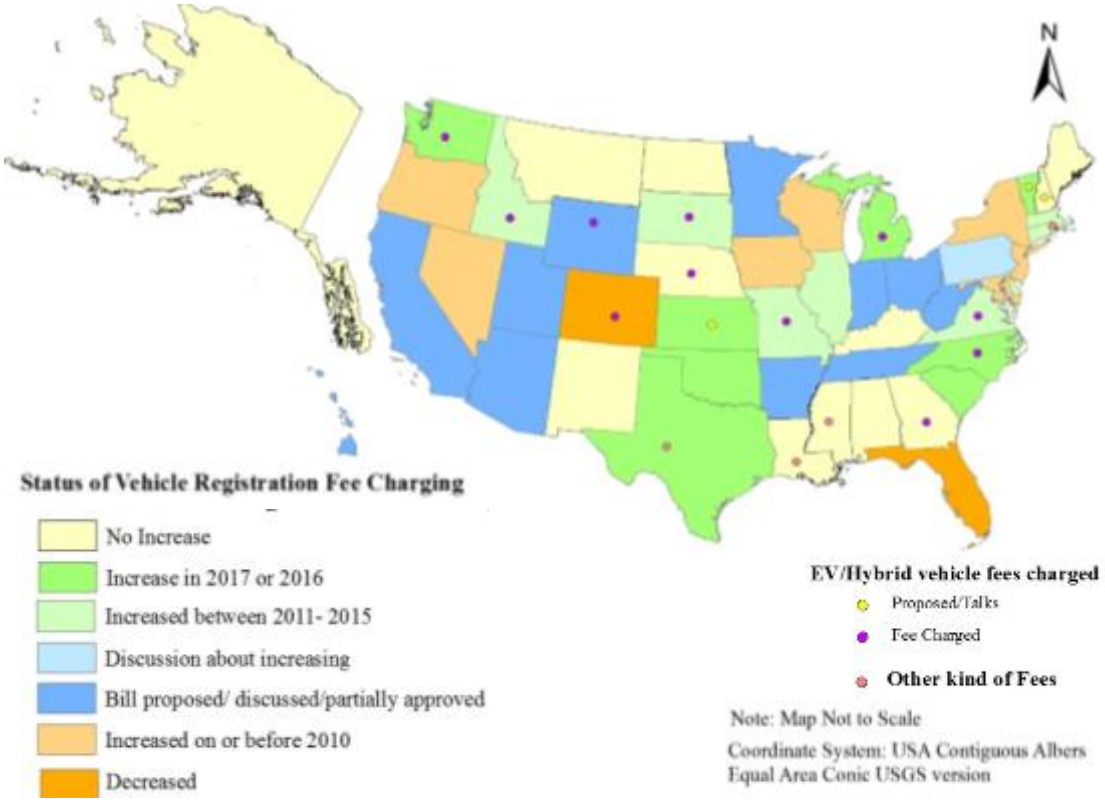

Figure 2: Map showing increase in vehicle registration fee, Electric/Hybrid vehicle fee and other surcharges by state. Source: Author

2.5. Vehicle Registration Fee and Travel Behavior

Vehicle registration fee, in spite of being looked upon as a reliable source for supporting the transportation funding needs, will also increase the transportation costs on the consumer end, which is bound to have many impacts. The increase in vehicle registration fee may alter the vehicle ownership, miles traveled and could lead to change in travel mode of the people. An increase in the vehicle registration fee can make people

get rid of unused extra vehicle they own, especially impacting the lower income drivers, who may not be able to afford the increase in their transportation costs. Change in the vehicle ownership may decline the overall VMT, which can further impact other funding sources being considered that are dependent on VMT. Further, it may also lead to change in the mode share and increase usage of public transportation. On the contrary, as the fee is charged annually or biennial, it is likely that the hike in fee to support transportation funding is going to be marginalized or it must be substantial in amount, to impact the travel behavior of drivers. Hence, it is necessary to understand the impact of vehicle registration fee on travel behavior, specifically on vehicle ownership.

Also, from the policy perspective any negative impact on the vehicle ownership due to increase in the fee is going to impact the funds generated. Hence, increase in vehicle registration may not produce expected amount of additional revenue. On a macroscopic level, change in vehicle ownership would severely impact the vast automobile industry, that has high contribution to the GDP, valuing to $16 million in 2015 (Bureau of Economic Analysis, 2015). A slight decline in vehicle ownership due to increase in the fee could lead to decline of demand in the auto industry and impact the GDP contribution. Further, it would also lead to the decline of employment opportunities in the automobile industry.

Hence, it is important to understand the utility of vehicle registration fee tool in the wake of such tumultuous times when transportation funds are declining, the transportation infrastructure has aged and needs repair and the political scenario of the country is turbulent.

3. LITERATURE REVIEW

This chapter discusses the key concepts of transportation demand and supply, followed by the elasticity of travel demand, specifically for vehicle ownership and VMT. It also discusses the socio-economic factors that impact vehicle ownership and VMT.

3.1. Transportation: Demand and Supply

Transportation is a vital service for people in their day-to-day life. It differs from other regular consumer goods as it is a 'derived demand', which is created in response to the need of reaching a destination for participating in an activity and has utility to the person. Travel on its own generates disutility in most cases unless it is a leisure activity. The cost, incurred during travel, directly influences usage of other goods and services as the travel cost is an indirect cost included in the price of the good (Kawamura, 2016). Therefore, the decision associated with travel is made to minimize the cost of travel, thereby decreasing the price of good or service by a change in mode, destination, good or service.

The cost of travel plays an integral role when a decision is made about performing a trip as it indicates if the trip would be economically beneficial to the person. There are several internal costs associated with travel depending on the mode. These costs can be fixed costs related to ownership such as registration cost, vehicle insurance cost or variable costs based on the use such as fuel cost, road tolls, parking fee, public transport usage fee.

Apart from the monetary costs, there are other non-monetary internal costs such as the opportunity cost of travel that impact travel behavior (Kawamura, 2016).

Different costs associated with travel have varied impact on its behavior and patterns. A change in the fixed costs of transportation associated with vehicle ownership may lead to a change in the ownership status of people. Also, the change in costs can make people change the type of vehicle they own (Litman, 2017b; Notteboom and Rodrique, n.d.; Jong et al., 2009). Change in the variable costs can lead to change in the type of vehicle owned and may also change the mode of travel to minimize the cost of travel. In addition, the cost can make people change their destination if there is an alternative place, close by. The people can also get rid of the leisure trips to save money on the fuel cost (Litman, 2017b; Notteboom and Rodrique, n.d.; Jong et al., 2009).

Another major cost is the parking cost, especially in the Central Business District (CBD). A change in the parking cost directly impacts vehicle ownership (Guo, 2013). However, the cost also depends on the availability of alternative modes of travel. Thus, mode shift is also a result of parking cost (Christiansen, Engebretsen, Fearnley and Hannssen, 2017). Also, both fixed and variable tolls can make people change their destination traveled and impact the number of trips performed (Litman, 2017b; Liu, Triantis and Sarangi, 2010).

Apart from the monetary costs, internal non-monetary costs such as travel time also impact travel behavior. Travel time cost is viewed as the opportunity cost associated with travel, which is defined as the value of what a person gives up while making choice for a

trip or the value of next best opportunity (Mankiw, 2001). Increase in travel time due to congestion or long distance can make people switch to transit. On the flip side, the increased out of vehicle travel time for transit can make people prefer cars. However, the value associated with travel time varies from person to person and depends on the reason for the trip. Hence, the impact of travel time on travel behavior is classified based on the reason for the trip (Litman, 2017b; Iseki, Taylor and Miller, 2006).

3.2. Travel Elasticity

The magnitude of impact that any transportation cost has on the travel behavior can be measured using elasticity. It is a microeconomic aggregate that gives the demand of a transportation service at a point in time around a price range (Lee, 2000). A negative elasticity indicates that effect on travel is opposite to its cause whereas a positive elasticity indicates that the effect on travel is positively associated with its cause.

The variation of transport costs has a different impact for each mode on the travel behavior, but the overall demand remains inelastic. Commuting is relatively inelastic in terms of the monetary costs for private vehicles, because of the low fuel cost in the US, and other fixed costs associated with the vehicle being marginalized over the use of the vehicle in the entire year (Morris, 2014, Circella and Handy, 2014). In addition to the independent sensitivity to price change, availability of different travel modes also influences each other by acting as alternative modes of travel. More number of options available for travel makes a travel mode more sensitive to price change (Litman, 2017b).

Price elasticity of travel is also impacted by the type of trip and traveler. Work trips are relatively less elastic to monetary price change and more elastic to change in travel time. Personal trips, such as those for recreation and shopping, are sensitive to changes in the monetary cost of travel. However, it also varies with the income level. High-income travelers are usually less sensitive to price change as compared to low-income travelers (Federal Highway Administration, 2012a).

Transportation elasticity values are also impacted by the time-period over which it is measured. Change in cost of transportation takes a long time to show its full effects often impacting long-term decisions of housing location etc. for an individual. As per Dargar and Gately (1997), short-term elasticity values (less than 2 years) are usually one-third of long-term elasticity values (more than 10 years) (as cited in Litman, 2017). A typical example is the impact of low fuel price in the US on the urban morphology, which resulted in dispersed suburban living culture and on high vehicle ownership per person in the country.

Also, the price elasticity is significantly influenced by the transport price assessment mechanism, which may vary across different administrative boundaries. This results in varying transportation cost incurred for owning the same vehicle and travel patterns in different administrative boundaries (Litman, 2017b; Ottosson, Lin and Chen, 2012). An example of this is vehicle registration fee which varies from state to state in the US and within the state, by municipalities if they charge an additional fee.

As the price elasticity is dependent on several factors that impact demand, it is restrictive in terms of transferability. It is specific to a time point and to a group of users

and difficult to generalize to a large group of users. Also, days and seasonal variation limits transferability of elasticity measured in one context to another one (Lee, 2000).

3.3. Price Elasticity of Vehicle Ownership

Vehicle ownership is closely related to the household income. With an increase in the household income from the lower level, vehicle ownership increases but at a declining rate (Blumenberg and Pierce, 2012 as cited in Litman, 2017b). As per Kopits and Cropper (2003, as cited in Litman, 2017b) the vehicle ownership rates level off at USD 16000 (2003-dollar rate) per capita annual income. According to the results from the National Household Travel Survey (NHTS, 2009), about 24 % of households in poverty did not own a vehicle and more than 98 % of households with the income level of $100,000 or more owned at least one vehicle (FHWA, 2014).

According to a study by Jong et al. (2009), change in the fixed costs impact vehicle ownership and variable costs impact vehicle use. A summary list of elasticity values of vehicle ownership with respect to fixed cost from different studies is given in Table I.

Source:	**Fixed Cost Elasticity Value**
Blok & Klooster (1989) -NL	-0.1
De Jong (1990) - NL	-1.1
De Jong (1997) – Norway	-0.8
De Jong et. al (2009)	-0.4

TABLE I: ELASTICITY VALUES OF VEHICLE OWNERSHIP WITH RESPECT TO FIXED COST, SOURCE: JONG ET. AL. (2009)

Also, household vehicle ownership is more sensitive to fixed costs because they can be avoided by getting rid of the car as compared to variable costs that impact the amount of travel. The short-run and long-run vehicle ownership elasticities with respect to income are 0.32 and 0.81, respectively (Goodwin et al., 2004 as cited in Federal Highway Administration (FHWA), 2012a).

3.4. Price Elasticity of Vehicle Miles Traveled

There are several factors which affect the VMT of a person, primarily being the costs associated with driving a vehicle. The fixed costs affect VMT indirectly by reducing the chances to drive because of its impact on vehicle ownership. It is the variable costs that have a much more direct impact on VMT.

The impact of fuel cost on VMT has been one of the most researched topics in the field of travel behavior. The short-run elasticity value mostly fall in the range of -0.02 to -0.22 with an average of -0.15. and the long-run mostly range between -0.06 to -0.6 with an average around -0.3 (FHWA, 2012a). The main reason for the mild impact of fuel prices on VMT is the low fuel prices. The average fuel price per gallon across the nation has gone down to $2 per gallon which is the lowest since 2009 and is expected to fall even further (AAA, 2017 as cited in CNN). On the other hand, household income levels have increased, which directly affects expenditure on transportation. The real (inflation adjusted to 2010 dollars) median per capita income rose by 88 % from USD 14,999 to USD 28,293 between 1967 to 2000. The fuel efficiency for all vehicles also increased by almost 38% between

1960 and 2000 from 12.4 mpg to 17 mpg (Litman, 2012), leading to an increase in VMT for same expenditure on fuel. In addition, the lack of viable alternative options to driving in most areas in the US makes the changes in fuel price even less sensitive to VMT (Hoekstra, 2015). A study by Hymel (2014) on the factors influencing VMT in the state of California suggest that vehicle registration fee is not correlated to decline in VMT.

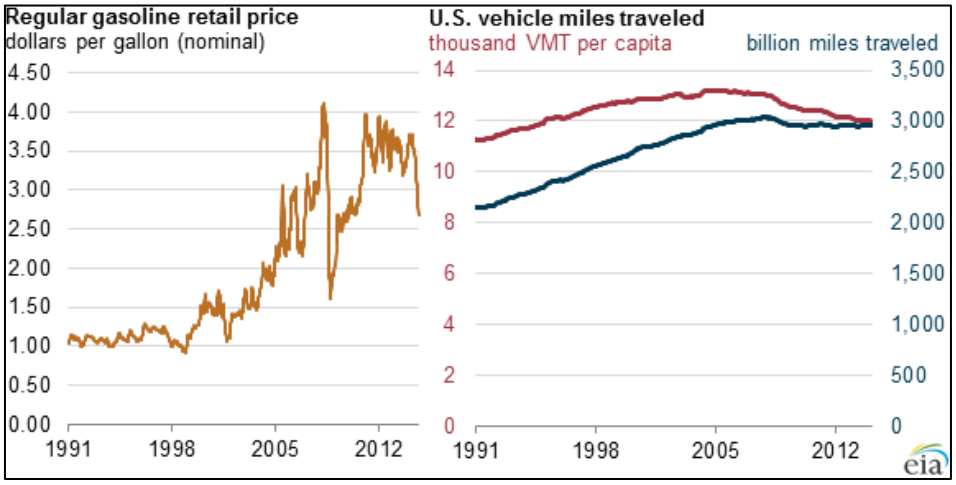

Figure 3: Change in VMT and Gasoline Price. Source: U.S. Energy Information Administration, based on Federal Reserve Bank of St. Louis

3.5. Socioeconomic Factors Impacting Vehicle Ownership

Automobile is a common asset owned by the people across all different socio-economic groups because of the benefits associated with it. However, vehicle ownership is impacted by changes in surroundings, household characteristics, socio-economic changes etc. To isolate the effect of registration fees on vehicle ownership in the analysis, it is important to control for the socioeconomic factors.

According to a study by Prevedouros and Schofer (1992), the number of drivers in household has the largest impact on automobile ownership. With an increase in the drivers in household, household vehicle ownership increases. However, after a point, increasing number of drivers in household stops corresponding with vehicle ownership thereby decreasing the vehicle ownership per capita. The number of workers in household directly impacts the number of vehicles owned (Eakins, 2013; Whelan, 2005). Also, the number of school going children in household influences the automobile ownership (Ewing et al., 2004). In addition, the number of dependents in household, i.e. people below 16 or above 65, impact vehicle ownership (Pyddoke and Creutzer, 2014; Prevedouros and Schofer, 1992).

Household income is another important determinant of vehicle ownership (Dargay and Hanly, 2000 as cited in Pyddoke and Creutzer, 2014; Prevedouros and Schofer, 1992; Creemers et.al., 2011). Further, as per Prevedouros and Schofer (1992), the type of vehicle and number of vehicles owned is directly influenced by income levels, as lower-income households are not able to spend money on automobiles as compared to higher-income group households.

Apart from the intrinsic individual and household factors, land use patterns also impact vehicle ownership. According to Dargay and Hanly (2007), vehicle ownership decreases with population density (Pyddoke and Creutzer, 2014). Land use diversity also impacts vehicle ownership. Single-use developments lead to increased vehicle ownership, because of the increase in distance to the frequently visited places such as grocery shops.

On the other side, mixed-use developments increase walk trips and use of public transportation, thereby reducing vehicle ownership levels. Hence, transit availability also influences vehicle ownership (Lynch, 1986 as cited in Sotani and Somenhalli, 2005; Potoglou and Kanaroglou 2008 as cited in Eakins, 2013).

In addition, a study by Sotani and Somenhalli (2005) also showed that variables related to urban structure, such as the job to housing balance ratio, residential density also influence vehicle ownership. High residential density is negatively related to vehicle ownership, as denser areas generally have better access to public transport and parking area limitations (Small and Verhoef, 2007; Holtzclaw et al., 2002; Ritter and Vance, 2013).

Apart from these, neighborhood factors, such as pedestrian connectivity and street width, also influence vehicle ownership (Hess and Ong, 2002). Improved accessibility to public transportation by Transit Oriented Development (TOD), decreases vehicle ownership levels (Lynch, 1986 as cited in Sotani and Somenhalli, 2005). Location of the workplace in the suburbs or rural areas is correlated to high vehicle ownership because of the lack of other modes of transportation (Prevedouros and Schofer, 1992; Pyddoke and Creutzer, 2014). Vehicle ownership is also influenced by factors such as travel time and cost. Out-of-vehicle travel time for transit, negatively impacts mode share of transit, and bolsters travel by car, thus increasing car ownership (Iseki, Taylor, and Miller, 2006). Apart from the indirect costs, vehicle ownership is influenced by the fixed costs of owning a vehicle such as the vehicle registration fee, insurance, license costs (Federal Highway Administration, 2012a; Litman, 2017b).

3.6. Socioeconomic Factors Impacting Vehicle Miles Traveled

VMT is affected by several factors such as the built environment, socio-economic factors, demographic factors, transportation availability etc. The demand for driving which directly impacts VMT is conducive to the supply of road infrastructure (Hansen and Huang, 1996).

Demographic factors together with employment status also affect VMT. People in the age group of 16 to 64 who work tend to have higher VMT as compared to older population or people who do not work (Hilde, Rixey, Womeldorff and Walters, 2014; William and Chigoy, 2016). The intergenerational changes also impact VMT, as the travel behavior differs across different generations. It is impacted significantly by changes in the economy (Hilde, Rixey, Womeldorff and Walters, 2014; William and Chigoy, 2016; Circella, Tiedman, Handy and Mokhtarian, 2015).

The household structure also impacts VMT. Households with children or older people have a higher VMT as compared to households with no children or older age group people (Mokhtarian, 2015). Further, the household size, the number of licensed drivers in household, the number of workers in household are positively related to household VMT (William and Chigoy, 2016; Circella, Tiedman, Handy and Mokhtarian, 2015; Zhang et al., 2012; Nasri and Zhang, 2014). Also, increase in income and higher vehicle ownership lead to increase in VMT. However, several studies suggest that with an increase in income, VMT rises quickly but gradually becomes constant as income rises to high-income levels, thereby indicating that the relationship is nonlinear (Holtzclaw et al., 2002; Salon, 2014).

In addition to income, the costs associated with driving a vehicle, such as fuel cost may also impact VMT (William and Chigoy, 2016; Litman, 2012). However, the impact varies by time period. In the short run, impacts are, change in driving style, reduction in VMT or change in the mode of travel. In the long run, impacts can be switching to a fuel-efficient car or change in living patterns, which leads to decrease in miles driven (Circella, Handy and Boarnet, 2014). However, in the US, due to low gas prices, the fuel cost is relatively inelastic and does not impact VMT.

Apart from the above-mentioned factors, VMT is significantly impacted by built environment factors. The 3D's, namely density, diversity and design impact VMT. Compact cities and neighborhoods lead to decline in miles driven. In addition, they have better accessibility to transit and less parking space, which deters driving (Cervero and Kockelman, 1997). Diversity in land use also reduces driving as places such as grocery stores and jobs are located at a close distance or nearby a transit facility. In addition, design factors such as good sidewalks, dedicated bike lanes also promote usage of non-motorized modes for travel, thereby reducing VMT. Transit Oriented Development (TOD) is the perfect example of how a compact, mixed-use development, bolsters decline in VMT and has environmental benefits too (Haas, Miknaitis, Cooper, Young and Benedict, 2010). Further, work related factors such as job availability, jobs to labor force ratio have a positive impact on VMT, as more jobs increase travel. Also, the distance of job locations to residential areas shares a negative relationship with VMT (Nasri and Zhang, 2014).

4. STUDY AREA: TEXAS

This chapter discusses the state of Texas, which is the study area for this research. It also describes the way in which vehicle registration fee is assessed across the state and how it has increased over time.

4.1. Texas: Growing Economy and Transportation

Texas is one of the fastest growing states in the country. It is the second largest state in the country by area and the largest amongst the 48 contiguous states with an area of 268,596 sq. miles (US Census Bureau, 2010). It also has the second highest population amongst the states and had 27,862,596 residents in the year 2016 (US Census Bureau, 2016c). The state is divided into 254 counties. It is leading both in terms of increase in population as well as economic growth. The state saw a growth of 3.8% in GDP in 2015, ranking second amongst all states in terms of the GDP growth for the year. The state also experienced a population increase of 1.58 % between the years 2015 and 2016, which is the highest numeric growth for any state in the country (US Census Bureau, 2016b). It also has five of the top 15 cities in terms of population growth in the country. (US Census Bureau, 2016a).

The state of Texas, in addition to being the largest state in the mainland area of the country, also has the highest public road length, 313,596 miles in 2014 (USDOT, FHWA as cited in Institute of Policy and Social Research, 2016), which corresponds with driving

as the dominant mode of travel. Around 91 % of the people drove to work in 2015 (US Census Bureau, 2015c). Also, the increase in suburban population together with expanding urban areas has bolstered driving as the predominant mode of travel in the state as in many parts of the US. Apart from that, the lack of good transit options, especially in the rural areas has led to increased driving in the state. The state experienced an increase of 47 % in VMT from 162.2 billion to 237.8 billion between the years 1990 and 2010 and is expected to further grow another 35 % by the year 2030. The GDP at the same time increased by 107 % adjusted for inflation (State of Texas, Legislative Budget Board Staff, 2015).

4.2. Growing Transportation Needs of Texas State

With the growing economy of the state, funds are required to construct and maintain adequate infrastructure for supporting development. As of 2015, the Texas Department of Transportation had $23.2 billion in all funds to administer the state transportation system and required additional $5 billion in revenue per fiscal year to maintain road and bridge conditions at the levels of traffic in the year 2010. The major source of revenue for transportation funds in the state apart from federal funds is the fuel tax which has declined due to the stagnant fuel tax rates (State of Texas, Legislative Budget Board Staff, 2015).

Thus, there has been a funding gap in the state. As per a report by the Legislative Budget Board Staff (State of Texas, 2015), in 2013, there was an annual deficit of $4 billion between the amount of federal and state revenues projected to be available and the funding needed to maintain levels of congestion in the year 2010 and maintenance of highways.

Several methods are being considered by the state to support its funding needs. One of the explored options is the increase in vehicle registration fee. If the state vehicle registration fee would have been increased by $5 in 2016, the gain in revenue would have been $249 million in the year 2016-2017 (State of Texas, Legislative Budget Board Staff, 2015).

4.3. Vehicle Registration Fee in Texas

Annual Vehicle registration fee in the state prior to 2011 for automobiles was based on the age and weight (in pounds) of the vehicle. Table II shows the fee schedule. In addition to the state fees, most of the counties also charged an additional fee that ranged between $0 to $20 with an average of $10. Also, the state charged mailing fee of $1 and reflectorization fee of $0.3.

As noted earlier the basis of vehicle registration fee was changed in 2011, to simplify the complex procedure of vehicle registration fee assessment. The annual vehicle registration fee for all automobiles/trucks weighing equal to or less than 6000 pounds was increased by $10 to $50.75. The counties continued to charge an additional fee, with some counties increasing the county fee. Automation fee and department of public safety fee, $1 each, was also charged, which replaced the reflectorization fee (Dickson, 2011; Texas DMV, 2012). The average annual fee charged across all the counties in the state is $62.65 with a standard deviation of $2.78. Figure 4 shows a map of vehicle registration fee by county across the state.

Model year or weight in pounds	**Fee**
2004 and older models (below 6,000 lbs.)	$40.80
2005, 2006 and 2007 models (below 6,000 lbs.)	$50.80
2008 and newer models (below 6,000 lbs.)	$58.80
6,001 lbs. And over (regardless of model year)	$25.00 plus 60¢ cwt plus

TABLE II: SCHEDULE OF VEHICLE REGISTRATION FEE IN TEXAS BEFORE 2011, SOURCE: TEXAS DMV, 2010

In the year 2017, the state has again increased the processing and handling fee for vehicle registration renewals by $0.75 for in-person payment of fees and by $3.75 for payment by mail or through grocery store transactions. The fees paid through online transactions is going to cost less by $0.25. The change in handling fee of vehicle registration renewals is a step towards making the DMV in Texas self-funded and not rely on the State Highway Fund (Begley, 2016; Mekelburg, 2016).

Hence, with the increase in vehicle registration fee in one of the largest and the fastest growing states in the country, it is important to understand its impact on the people and their travel behavior. Any significant negative impact on travel behavior by the increase in vehicle registration fee can have an adverse effect on the funding utility of the fee, economy of the state and make it less desirable for the people to live.

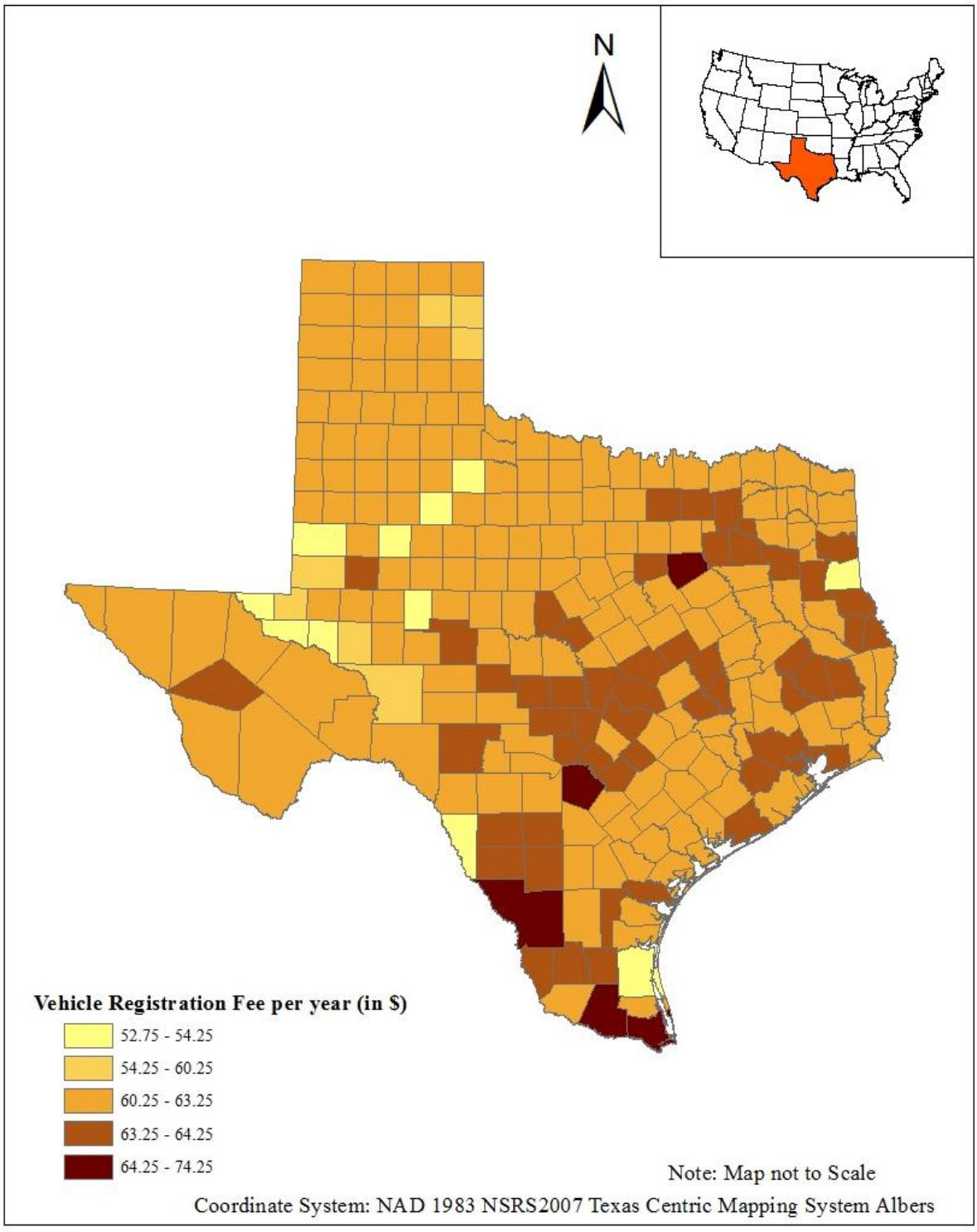

Figure 4: Map showing Vehicle Registration Fee by county in Texas for automobile weighing less than 6,000 lbs. in 2009., Data Source: TX DMV, Map created by Author

5. ANALYSIS FRAMEWORK

This chapter discusses the research hypothesis and describes in detail the data used for analysis, including the source and some basic descriptive statistics.

5.1. Research Hypothesis

Based on the literature review, the following hypotheses about the study can be formulated:

- Vehicle Ownership is negatively impacted by vehicle registration fee increase when controlled for other factors. However, the magnitude of impact may be modest as driving is the dominant mode of travel and other fixed costs are greater as compared to the amount of annual vehicle registration fee.
- Vehicle registration fee increases VMT per vehicle, when other factors are controlled as the car owners, will try to reduce the average cost of driving by utilizing each vehicle more intensely. However, this is based on the consumer behavior theory, and due to the modest amount of the registration fees in relation to the cost of purchasing a vehicle or even insurance, it is conceivable that the effect does not exist or too small to detect.

5.2. Data

The analysis is conducted at both the aggregate (i.e. county) and the disaggregate (i.e. household) levels. However, the results from aggregate level analysis were not deemed reliable possibly due to aggregation error. Descriptive statistics about the aggregate level

data are in Appendix B and disaggregate level data are given below. The hypothesis is tested using MNL Regression for vehicle ownership and Ordinary Least Square (OLS) regression for VMT. The independent variable is vehicle registration fee and the dependent variables are vehicle ownership and VMT, that are tested in separate models. Several factors that are known to impact vehicle ownership and VMT, identified in Chapter 3, are used in the respective models as control variables.

The study uses data from the 2009 NHTS database, which is the most recently available source of data on vehicle ownership and VMT at the individual and household level. The 2009 NHTS database is usually available only at the state level and the add-on data (geographic information for data beneath state level) is available only for some of the states including Texas. I was able to obtain the disaggregate level information for the records of Texas from the 2009 NHTS. Therefore, selection of study area as the state of Texas is driven by the availability of reliable data which is the biggest state and fastest growing economy for which add-on data is available. Data about the independent variable of vehicle registration fee and control variables are also driven by the fact that the dependent variables data is obtained for the year 2009 from the 2009 NHTS database.

5.2.1 Vehicle Registration Fee

The vehicle registration fee data is estimated for each county based on the vehicle registration fee assessment scheme that was in place prior to 2011(including 2009). The vehicle is assumed to be a passenger car of weight less than 6,000 lbs. and purchased

between the years 2008 and 2009. The state fee was $58.8 per year in 2009 along with the varying amounts of county fees, the $1 of mailing fee and $0.3 of reflectorization fee (Texas DMV, 2010). The vehicle registration fee was determined for each record of household or vehicle in the 2009 NHTS data set based on the county in which the household is located. The average fee for the vehicle type mentioned above across all counties in Texas in 2009 was $70.4 with a standard deviation of $2.56. The fee in most of the counties has the variable county level fee around $10, with the highest fee being $20 and the lowest being $0. Most of the counties having low vehicle registration fee are rural counties located in the western part of the state. In contrast, the counties with the higher vehicle registration fee are mostly located in the eastern or central-eastern part of the state (as seen in Figure 4). Cameron and Hidalgo counties have the highest vehicle registration fee of $80.1 and are located at the southern tip of the state on the border of Mexico.

5.2.2 Vehicle Ownership

Household vehicle ownership was obtained directly from the 2009 NHTS database for the analysis, using each record of household data as a record for the analysis. The zip code of each household record is used to identify the Census place in which it is located. Some of the control variables such as job availability, residential density etc. are estimated based on the census place in which they are located. The zip code areas cannot be used as geographical unit for analysis since not all the socioeconomic variables are available in American Community Survey (ACS) at the zip code level for the year 2009. The household

records located in unincorporated areas are removed, as there is no data available for them about the place level variables in ACS. Further, the outliers are eliminated from the data.

In the final data set, the average household vehicle ownership in the state is 1.95 and standard deviation is 0.93, which shows that the number of vehicles owned do not vary much across the state. The maximum household vehicle ownership across the state is 8.

5.2.3 Vehicle Miles Traveled

The rational way to measure the impact of vehicle registration fee on miles traveled is by analyzing it for each vehicle, as the fee is charged for each vehicle. Therefore, VMT per vehicle is used as the dependent variable.

The data of annual VMT per household vehicle is taken from the 2009 NHTS database, which gives self-reported annual miles (called Annual Miles in the dataset) and a single odometer reading of the vehicle taken at the time of survey, that is used to estimate annual mileage for each vehicle record. However, the self-reported annual miles may not be accurate because they are approximations by respondents and not all vehicle records have a reported odometer reading. Hence, Oak Ridge National Laboratory (ORNL) estimated the number of miles driven for each vehicle which is known as BESTMILE in the NHTS data. However, the BESTMILE estimates have been synthesized to fill in the missing responses and correct for suspected errors in the self-reported mileages.

The analysis is conducted for both the self-reported Annual Miles and BESTMILE. The variables are estimated based on the census place in which primary driver of each

vehicle is located, identified from the zip code of primary driver. The data for the control variables is taken from the ACS. The records having Annual VMT values of 200,000 miles (outliers) are eliminated from the data set as it seems unrealistic. Further, almost 20 % of the records have a missing value for at least one control variable from the 2009 NHTS database. Hence, those records also were excluded. Finally, the vehicle records located in unincorporated areas are removed, because there is no data available for some of the control variables such as job availability, job to labor force ratio, residential density, job to housing balance ratio etc.

In the final data set, the average self-reported annual miles per vehicle across the state was 11,151 miles with a standard deviation of 10,215 miles. The high standard deviation may be because of the approximation of data by respondents. The maximum self-reported annual miles per vehicle was 192,000 miles. The average BESTMILE per vehicle was 12,025 miles with a standard deviation of 9,813 miles.

5.2.4 Control Variables

Based on the literature review (Chapter 3), several variables that are known to affect vehicle ownership and VMT were identified and included in the regression analysis. The data were obtained from the ACS and the NHTS for the year 2009. Basic statistics for the disaggregate level data of the control factors are given below:

Household Size

The data for household size is obtained from the ACS. The average household size in the state was around 2.65 in 20089. The standard deviation is 1.26. The maximum household size in the state based on data was 12.

Household Factors – Number of Drivers, Adults, Workers in Household

The data for the number of drivers, adults, and workers are obtained from the 2009 NHTS database. The data is directly obtained from the household records. Table III contains average value and standard deviation for all the household variables.

Variable	Average Value	Standard Deviation
Number of drivers in household	1.83	0.73
Number of adults in household	1.91	0.66
Number of workers in household	0.95	0.86

TABLE III: DESCRIPTIVE STATISTICS FOR NUMBER OF DRIVERS, ADULTS AND WORKERS IN HOUSEHOLD

Household Income

The data is obtained directly from the NHTS 2009 household database. The data, which is reported as income groups, is ordinal in nature. The best estimate of the average annual household income group range, based on the income group, is between $50,000 to $55,000. The standard deviation is high at around $25,000.

Household having people above the age of 65/below the age of 16

The data for households having people above the age of 65 or below the age of 16 is determined from the "lifecycle" variable in the 2009 NHTS database. The lifecycle variable gives information on the household structure which is used to construct a dummy variable to show the presence or absence of people above 65 years of age or 16 years of age in the household into separate variables. Around 38% of the households in the state based on the data had people above 65 years of age and around 56% of the households in the state had people below 16 years of age in 2009.

Travel time to work

Travel time to work data is available in the 2009 NHTS database, but the information is missing in almost 60 -70 % of records. Hence, mean commute time to work data is used from the ACS 2005-2009 estimates (ACS Table: S0801) based on the census place where the household is located. The average travel time to work was around 23.3 minutes with a standard deviation of approximately 6.3 minutes and the maximum commute time was around 57 minutes in 2009.

Fuel Price

The data for the price of fuel was obtained directly from the 2009 NHTS database. The data in the 2009 NHTS is based on the household location and average pump price for the week of the interview (NHTS, 2009). The average value of fuel price was 279 cents per gallon in 2009 with a standard deviation of 95 cents. The maximum fuel price across the state based on the data was 397 cents per gallon in 2009.

Toll Paid on Interstate

The 2009 NHTS database also provides information about whether the person paid a toll on the day of travel or not, which is used by creating a dummy variable for all the vehicle records, indicating if the primary driver of vehicle paid a toll on the Interstate Highway on the travel day or not. Although it is an approximation, as the data is based only on a single day and several records had missing values, only 4.6% out of the total records paid toll on an Interstate Highway on the travel day.

Residential Density

The gross residential density is calculated for each Census place based on the ACS data (Table: B25001) of the number of housing units and the land area of each place. The average gross residential density in the state based on the data, across all the NHTS records located in Census places, was around 800 housing units per square mile with a standard deviation around 493 housing units per square mile.

Job Availability

Job availability, which is the number of jobs per person for the 16-64 age group people is calculated for each Census place where the 2009 NHTS records are located. The number of jobs for each Census place was calculated based on spatial analysis using the data from ‘On the Maps’ (2009) website and the number of people with the 16-64 age group that is taken from the ACS. The average job availability in the state based on the data, across all the NHTS records located in Census places, was around 0.014 jobs per 16-64 age group person with a standard deviation of 0.007.

Jobs to Housing Balance Ratio

The job to housing balance ratio is calculated for each Census place in which the household is located is calculated from the ACS (Table: CB 900A1) and the number of housing units' data also from the ACS (Table: B25001). The average value of job to housing balance ratio based on the data was 0.026 with a standard deviation of 0.011.

Usage of Public Transit

The data about public transit usage in a month was directly obtained from the 2009 NHTS database which gives information about the frequency of public transit use in the month prior to the survey. However, due to the high rate of missing responses, it is converted into a dummy variable. Almost, 6% of the people used transit.

Education Level

The data for educational attainment is directly obtained from the 2009 NHTS database file and attached to the vehicle records based on the primary driver of the vehicle. It is present as an ordinal variable. The average educational attainment of a person in the dataset, was an associate or vocational degree.

Apart from the control factors discussed above, several other control factors were considered. However, either they were not significant in the model results or the data had too many missing responses to be considered reliable. Thus, they are not included in the model. The list of control factors that were tested for producing the best fit model is given in Table IV.

Variables	**Source**
Population Density	ACS
Household Size	NHTS
number of workers in household	NHTS
number of adults in household	NHTS
number of drivers in household	NHTS
Median Household Income	ACS
Household Income	NHTS
Labor Force	ACS
Number of people employed	ACS
Avg. no. Number of Jobs across Place	https://onthemap.ces.census.gov/
Job to Labor Force Ratio	ACS
Job Availability	ACS
Residential Density	ACS
Job to Housing Balance Ratio	ACS
Percentage of Households having below 16 age population	NHTS
Percentage of Households having above 65 age population	NHTS
Percentage of people working outside county	ACS
Percentage of people working outside state	ACS
Percentage of people using transit to work	ACS
Avg. number of times transit is used in the month prior to survey	NHTS
Education Attainment	NHTS
Distance to Work	NHTS
Travel time to work (in minutes)	ACS
Gas Price (in cents)	NHTS
Annual Fuel Cost (nominal UD dollars)	NHTS
Payment of toll on Interstate	NHTS
Transit Service Miles	Texas DOT
Percentage of people who feel access to transit is an issue	NHTS
Percentage of people who feel fuel cost is an issue	NHTS
Percentage of people who feel congestion is an issue	NHTS

TABLE IV: LIST OF CONTROL FACTORS

6. ANALYSIS

This chapter discusses the analysis. Although the analysis was carried out at two different levels: aggregate (county) and disaggregate (household), the results from the aggregate level analysis were deemed not reliable possibly due to aggregation errors, hence they are included in Appendix B of the manuscript. Also, according to Train (1986), vehicle ownership is better understood when analyzed at disaggregate level, as it can capture heterogeneity between households or persons while aggregate analysis often introduces aggregation bias. Disaggregate data typically contains greater variation in each modeled factor than in aggregate data, producing a more precise estimation of the underlying parameters possible (as cited in Ritter and Vance, 2013). The chapter begins with the presentation and interpretation of the results from the analysis. The chapter concludes with the estimation of the elasticity of vehicle ownership and VMT per vehicle with respect to the registration fee.

6.1.1 Vehicle Ownership

As described in Section 5.2.2, the household vehicle ownership data for the disaggregate analysis is obtained from the 2009 NHTS household file. The independent variable is vehicle registration fee and the dependent variable is vehicle ownership. As vehicle ownership is a categorical variable, vehicle ownership models are best analyzed in the form of a discrete choice model (Jong et al., 2009). While there are advantages and

disadvantages associated with MNL and Ordered logit (OLM) models, the MNL is attractive in this case as it provides separate parameter estimates for each level of vehicle ownership, while the OLM would result in a single set of parameters for all levels. Bhat and Pulugurta (1998) argued that this property of MNL allows for the true utility maximization as vehicle ownership decisions cannot be determined by a single continuous propensity function and are not always successive in nature. Hence, MNL technique is used.

Again, several control variables were used to isolate, to the extent possible, the impact of vehicle registration fee on vehicle ownership. Several combinations of control variables were tried to construct the best fit model that also satisfy the required conditions. MNL was run by classifying data in 5 categories based on the number of vehicles in household. The categories were 0, 1, 2, 3 and 4 or more vehicles per household. The category of 1 vehicle per household was used as the base category in all model estimations. The results of the final MNL regression model are given below in Table V.

Household Vehicle Ownership	**0**	**2**	**3**	**4**
Coefficients				
(Intercept)	-0.784	-1.707	-1.66	-2.951
Registration Fee	0.041	-0.055	-0.118	-0.153
Number of Workers in Household	-0.067	0.411	0.605	0.69
Residential Density	0.0002	-0.0002	-0.0006	-0.001
Family Income	-0.223	0.124	0.162	0.198
Job Availability	-10.081	8.958	11.671	18.982

Household Vehicle Ownership	**0**	**2**	**3**	**4**
Number of Drivers in Household	-2.596	2.483	3.988	4.847
Household having below 16 age people	-0.654	0.669	0.142	0.191
Household Having above 65 age people	-0.824	0.970	0.515	0.839
Standard error				
(Intercept)	0	0.002	0.001	0.0008
Registration Fee	0.001	0.001	0.002	0.003
Number of Workers in Household	0.046	0.046	0.055	0.067
Residential Density	0	0	0	0
Family Income	0.019	0.004	0.006	0.009
Job Availability	0.000	0.000	0.000	0.000
Number of Drivers in Household	0.107	0.050	0.073	0.086
Household having below 16 age people	0.050	0.077	0.068	0.080
Household Having above 65 age people	0.049	0.078	0.076	0.098
P-Value				
(Intercept)	0.00	0.00	0.00	0.00
Registration Fee	0.00	0.00	0.00	0.00
Number of Workers in Household	0.00	0.00	0.00	0.00
Residential Density	0.00	0.00	0.00	0.00
Family Income	0.00	0.00	0.00	0.00
Job Availability	0.00	0.00	0.00	0.00
Number of Drivers in Household	0.00	0.00	0.00	0.00
Household having below 16 age people	0.00	0.00	0.00	0.00
Household Having above 65 age people	0.00	0.00	0.00	0.00
Residual Deviance: 29868.62	Pseudo R Square			
AIC: 29940.62	log lik': 0.3187723 (df=36)			

TABLE V: RESULTS FROM MNL REGRESSON OF HOUSEHOLD VEHICLE OWNERSHIP

The calculated pseudo R-square of the model is 0.31, which is considered good or even excellent for MNL. The results from Wald Statistics test show that all the variables in the model are statistically significant with the p-values being virtually equal to zero.

The estimated parameters for the vehicle registration fee indicate that the fee has a statistically significant negative impact on vehicle ownership. As vehicle registration fee increases, people are probably going to get rid of the extra vehicle (or forgoing the purchase of extra vehicle), thereby decreasing the number of vehicles owned. This is reflected in the decrease in the values of the coefficients for the registration fee as vehicle ownership increases (with the value for the 4 + category being the greatest). Whereas with the decrease in the vehicle registration fee, people are going to increase the number of vehicles owned.

The number of drivers in household has a positive relationship with vehicle ownership. This is not surprising and agree with past research. It is logical that with increase in the number of people who can drive in household, which include most adults, vehicle ownership increases. Also, the number of workers in household has a positive relationship with vehicle ownership as more people need to travel per household and do not have a lot of other options for commuting to work. In Texas, transit connectivity is low in most places, apart from the major urban areas, same as other states in the country. Also, most of the drivers in the state prefer to drive alone (around 79% of the people drove alone to work in 2009 (ACS)), hence increase in the number of workers in household increases vehicle ownership.

On the other hand, looking at the household structure, household vehicle ownership has a positive relationship with the households having people 16 years or below age, which is reasonable as more the number of people below permissible driving age in the household, there is more requirement for them to be driven to places, that increases vehicle ownership.

The presence of person over 65 years of age in household or above has a positive relationship with vehicle ownership as they would need personal vehicles for all trips because of its convenience. It has a higher impact in rural areas as compared to urban areas (as shown in Tables VI and VII) and where other modes of travel are available and places visited on a day to day basis such as neighborhood markets are often at a walking distance.

The regional factor of job availability has a positive relationship with vehicle ownership. Job availability is the ratio of available jobs to labor force. The natural interpretation of this result is that when there are more chances for people to be employed and drive to work, they tend to own more vehicle. Residential density has an inverse relationship with vehicle ownership as with denser places, markets are at proximity, thereby reducing need to own vehicle. Also, denser places which mostly represent urban areas, parking costs are high, thereby reducing vehicle ownership. Alternatively, residential density may be capturing the level of transit availability or simply the level of urbanization of Census places. Job Housing Balance is a significant factor but is highly correlated with job availability. Hence, it is not included in the model.

To understand the effects of the vehicle registration fee in detail, the data was split into urban and rural areas using the urban-rural classification variable present in the 2009 NHTS database and regression was conducted for each dataset. Around 74% of the records in the data belong to urban areas and 26% records belong to rural areas. The results of the regression are shown in Tables VI and VII. The impact of vehicle registration fee on vehicle ownership is significant in both urban and rural areas. The magnitude of coefficient is

greater in rural areas which indicates that rural area households are impacted more by the increase in vehicle registration fee. This may be explained by the fact that the income levels are relatively low in the rural areas as compared to urban areas. According to the ACS data, the average annual median household income in the urban census place areas of Texas was around $50,000 whereas in rural areas the income was around $45,000 in 2009. However, for the households having 3 vehicles or 4 or more vehicles, the magnitude of impact is slightly higher for urban areas. This could presumably be because in urban areas it is costlier to retain extra vehicles due to increase in fixed cost and especially parking, and alternative modes of transportation are likely to be available.

Household Vehicle Ownership	**0**	**2**	**3**	**4**
Coefficients:				
(Intercept)	-1.896	-1.837	-2.309	-4.584
Registration Fee	0.051	-0.054	-0.109	-0.147
Number of Workers in Household	-0.073	0.430	0.571	0.676
Residential Density	0.0004	-0.0003	-0.001	-0.001
Family Income	-0.262	0.130	0.169	0.216
Job Availability	-2.335	8.880	2.079	28.208
Number of Drivers in Household	-2.582	2.535	4.090	5.056
Household having below 16 age people	-0.342	0.457	-0.085	-0.007
Household Having above 65 age people	-0.509	0.749	0.153	0.552
Standard Errors:				
(Intercept)	0.000	0.002	0.001	0.000

Household Vehicle Ownership	**0**	**2**	**3**	**4**
Registration Fee	0.002	0.002	0.003	0.004
Number of Workers in Household	0.059	0.052	0.063	0.078
Residential Density	0.0001	0.0001	0.0001	0.0001
Family Income	0.022	0.006	0.008	0.012
Job Availability	0.0000	0.0001	0.0001	0.0001
Number of Drivers in Household	0.116	0.057	0.083	0.098
Household having below 16 age people	0.056	0.057	0.070	0.087
Household Having above 65 age people	0.054	0.068	0.086	0.053
P-value				
(Intercept)	0	0	0	0
Registration Fee	0	0	0	0
Number of Workers in Household	0	0	0	0
Residential Density	0	0	0	0
Family Income	0	0	0	0
Job Availability	0	0	0	0
Number of Drivers in Household	0	0	0	0
Household having below 16 age people	0	0	0	0
Household Having above 65 age people	0	0	0	0
Residual Deviance: 21424.86	Pseudo R Square			
AIC: 21496.86	log lik': 0.3413638 (df=36)			

TABLE VI: RESULTS OF MNL REGRESSION MODEL OF IMPACT ON HOUSEHOLD VEHICLE OWNERSHIP IN URBAN AREAS

Household Vehicle Ownership	**0**	**2**	**3**	**4**
Coefficients:				
(Intercept)	11.366	-2.542	-1.604	-3.785
Registration Fee	-0.123	-0.046	-0.120	-0.125
Number of Workers in Household	0.038	0.363	0.687	0.712
Residential Density	-0.00008	-0.00002	-0.0002	-0.001
Family Income	-0.052	0.110	0.145	0.165
Job Availability	-2.096	2.512	7.168	7.213
Number of Drivers in Household	-2.721	2.319	3.724	4.429
Household having below 16 age people	-2.373	1.405	0.904	0.859
Household Having above 65 age people	-2.279	1.709	1.556	1.585
Standard Errors:				
(Intercept)	0.000	0.007	0.004	0.002
Registration Fee	0.004	0.003	0.005	0.006
Number of Workers in Household	0.105	0.100	0.113	0.128
Residential Density	0.0003	0.0001	0.0001	0.0002
Family Income	0.039	0.010	0.013	0.017
Job Availability	0.0001	0.0003	0.0006	0.0006
Number of Drivers in Household	0.277	0.103	0.146	0.163
Household having below 16 age people	0.131	0.161	0.137	0.150
Household Having above 65 age people	0.125	0.163	0.148	0.178
P-value				
(Intercept)	0.00	0.00	0.00	0.00
Registration Fee	0.00	0.00	0.00	0.00
Number of Workers in Household	0.00	0.00	0.00	0.00
Residential Density	0.74	0.73	0.13	0.00
Family Income	0.00	0.00	0.00	0.00
Job Availability	0.00	0.00	0.00	0.00
Number of Drivers in Household	0.00	0.00	0.00	0.00
Household having below 16 age people	0.00	0.00	0.00	0.00
Household Having above 65 age people	0.00	0.00	0.00	0.00
Residual Deviance: 8249.771	Pseudo R Square			
AIC: 8321.771	log lik' : 0.2541023(df=36)			

TABLE VII: RESULTS OF MNL REGRESSION MODEL OF IMPACT ON HOUSEHOLD VEHICLE OWNERSHIP IN RURAL AREAS

In the next set of regression models, the households were split into three groups by income: lower-income group ($0 - $39,999), middle-income group ($40,001-$99,999), and high-income group ($100,000 and above) (Cashwell, 2008). Around 71% of the records in the data belongs to medium income group, 27% belongs to lower income group and around 2% belongs to higher income group. The summary of results of the coefficient value of vehicle registration fee from the models for different income groups is given in Table VIII and detail results are given in Tables XV, XVI and XVII, Appendix C.

Household Vehicle Ownership	**0**	**2**	**3**	**4**
Coefficient for Registration fee (Lower income)	0.021	-0.045	-0.086	-0.052
SE (P-value)	0.002 (0.00)	0.002 (0.00)	0.004 (0.00)	0.006 (0.00)
Coefficient for Registration fee (Medium income)	0.218	-0.069	-0.144	-0.228
SE (P-value)	0.002(0.00)	0.002(0.00)	0.004(0.00)	0.006 (0.00)
Coefficient for Registration fee (High income)	0.137	-0.058	-0.125	-0.158
SE (P-value)	0.010 (0.00)	0.018 (0.00)	0.017(0.00)	0.021 (0.00)

TABLE VIII: SUMMARY RESULTS FOR IMPACT OF VEHICLE REGISTRATION FEE ON VEHICLE OWNERSHIP FOR DIFFERENT INCOME GROUPS

For all income groups, vehicle registration fee has a statistically significant negative effect on vehicle ownership for all categories. However, the magnitude of the coefficients for the middle and high-income groups are considerably greater than that for the lower

income group. Possibly, for meiddle and higher income group households, owning additional vehicles is a discretionary choice, while for lower income families that own fewer vehicles, all the cars are needed to satisfy their travel needs. Thus, increase in the vehicle registration fee, may encourage relatively wealthy people to get rid of extra cars.

6.1.2. Elasticity of Vehicle Ownership

Based on the coefficient values of the model from Table V, the weighted average elasticity with respect to the vehicle registration fee is calculated. The formula used for calculating weighted average elasticity is:

$$E^{P}_{1} = \Sigma P_i (1- P_i)\beta_1 x_1 / \Sigma P_i$$

Where, E^{P}_{1} is the average elasticity of the probability to be in a category of vehicle ownership with respect to registration fee

P_i is the probability of being in a vehicle ownership category for a household

β_1 is the coefficient value of the vehicle registration fee variable for the category

x_1 is the vehicle registration fee for the household

The elasticity values for the four vehicle ownership categories are given in Table IX. The elasticity values show that with a 1% increase in the vehicle registration fee, the probability to not own any vehicles will increase by 1.2%. On the other hand, the probability of owning 2, 3, and 4 and more vehicles will decrease by 1.02%, 6.07% and 8.33%, respectively. Although the signs are intuitive, the magnitude of percentage change is relatively high, especially for the probability of owning 3 and 4 or more vehicles.

Fee Increase		0	2	3	4
$ 5 increase	Percentage Change	2.47	0.43	-0.07	-0.205
	Numeric Change	1481.47	3539.667	-192.167	-203.97
10% increase	Percentage Change	2.73	0.44	-0.13	-0.29
	Numeric Change	1635.97	3652.37	-370.63	-292.7

TABLE IX: ELASTICITY VALUE FOR VEHICLE OWNERSHIP

Since these are elasticities of probabilities for the households to own certain number of vehicles, Monte-Carlo simulations were run to estimate the possible range of probability values and its impact on the decline in household vehicle ownership. The simulation results give numeric change in the total number of households by vehicle ownership category and is run for two scenarios, when vehicle registration fee is increased by $5 and the fee is increased by 10%. The results of numeric and percentage change in the number of households in respective ownership categories are given in Table X.

Category	Elasticity Value
Elasticity value for household vehicle ownership of 0	1.20
Elasticity value for household vehicle ownership of 2	-1.02
Elasticity value for household vehicle ownership of 3	-6.07
Elasticity value for household vehicle ownership of 4	-8.33

TABLE X: RESULTS FROM MONTE-CARLO SIMULATION FOR VEHICLE OWNERSHIP ELASITICTY

The results from Monte-Carlo simulation show that despite high elasticities, the decreases in the number of households with 3 or 4 or more vehicles are modest as compared to increase in the number of households with 2 vehicles or no vehicles. It should be noted however that this simulation is conducted for the households in the 2009 NHTS dataset, which represents a miniscule share (0.2 %) of the total households in Texas. As such, even though the percentage changes are small, the real-life impact for all the households in Texas can be significant in terms of total number of vehicles owned.

6.2. Vehicle Miles Traveled

As described in detail in Section 5.2.3, VMT data is obtained from the 2009 NHTS database. The regression analysis is conducted for both the self-reported Annual Miles and the BESTMILE using OLS technique. The dependent variable is VMT per vehicle, the independent variable is vehicle registration fee and the control variables that impact VMT (as discussed in Chapter 3). Various Combinations of control factors were tried to derive the final model. The model is estimated for both linear fit and log transformed fit. The adjusted R-square value is higher for linear model (0.078) as compared to the log transformed model (0.056). Also, the F-statistic value is higher for linear model (212.9) with a p-value virtually equal to 0 as compared to log transformed model (147.9). Hence, the linear model seems to represent impact of vehicle registration fee on VMT per vehicle in a better manner. The detail of the linear model is given in Table XI and the log transformed model is given in Appendix C: Table XVIII.

VMT per vehicle using Annual Miles data						
Variables	**Coefficient Estimate**	**Standard Error**	**t value**	**Pr(>|t|)**	**Signif-icance**	**VIF**
(Intercept)	12069.966	2473.548	4.88	0	***	
Registration Fee	-73.970	34.573	-2.139	0.032	*	1.0232
Number of drivers in the household	-301.300	121.708	-2.476	0.013	*	2.335
Job Availability	46255.157	8780.928	5.268	0	***	1.191
Household Size	601.266	60.968	9.862	0	***	1.853
Residential Density	-1.7119	0.131	-13.004	0	***	1.200
People who payed toll on Interstate on Travel Day	2268.047	275.430	8.235	0	***	1.037
Number of workers in household	975.136	91.803	10.622	0	***	2.146
Travel Time to work	69.399	11.439	6.067	0	***	1.055
Household Income	274.993	13.278	20.71	0	***	1.504
Number of vehicles in household	-622.105	56.923	-10.929	0	***	1.296
Household having above 65 age people	-1900.700	159.677	-11.903	0	***	1.758
Education level	-124.028	55.804	-2.223	0.0263	*	1.261
Residual standard error: 9808 on 29877 degrees of freedom						
Multiple R-squared: 0.0785			Adjusted R-squared: 0.0781			
F-statistic: 212.9 on 12 and 29877 DF, p-value: < 2.2e-16						

TABLE XI: RESULTS FROM LINEAR REGRESSION MODEL OF VEHICLE MILES TRAVELED PER VEHICLE BASED ON ANNUAL MILES DATA

The reason for the poor fit of the model can be attributed to the non-monotonic distribution of the control variables. Most of the variables plotted against VMT per vehicle, show positive slope near the lower values, which turns negative as the value passes mode value

of the variable. The VIF values show multicollinearity is not present in the model, results of which are shown in Table XI. However, the residual plot of the linear model shows heteroscedasticity is present (Figure 5, Appendix C) and even log-transformation of the model does not address the issue in a satisfactory manner (residual plot in Figure 6, Appendix C). It is confirmed again by the Breusch-Pagan (bp) test.

The model shows that vehicle registration fee does impact VMT per vehicle at the household level, however, the p-value is relatively high. When the model is tested for urban area records and rural area records separately, vehicle registration fee is insignificant. Therefore, the impact of registration fee on VMT per household vehicle seem to be modest at best.

The other factors that impact VMT per household vehicle are household size, the number of workers in household, both with positive associations. These are intuitive results. However, the number of drivers in household has a negative relationship with VMT per household vehicle. This is because the VMT per household vehicle value initially rises with an increase in the number of drivers in household, but after the number of drivers in household reaches around 4, it starts to decline. The number of vehicles in household has a negative relationship with VMT per household vehicle. Presumably, this is because the intensity of use for each vehicle declines with each additional car in the household. Household income also has a positive relationship with VMT per household vehicle, which is also intuitive. Further, a household with older people (above 65 years of age) tends to have lower VMT per vehicle. This is also intuitive since older people tend to drive less.

The model also shows that people who pay a toll on the Interstate Highway System tend to have a higher VMT per vehicle as they tend to drive to farther locations. The education level of the primary driver negatively influences VMT per household vehicle. Further analysis done using different education levels as separate dummy variables in the model shows that people with some degree (vocational) or an associate degree, tend to have the highest VMT on average. In contrast, the people with high education level, i.e. master's degree or above tend to drive less. Bachelor's degree was not statistically significant.

Residential density has a negative relationship with VMT per vehicle because presumably, households in compact areas need to drive less especially for non-work trips. In contrast, job availability has a positive impact on VMT per vehicle. The reason is not clear, but people living in job-rich areas seem to use their vehicles more intensely. Since in the state of Texas transit usage to work is low, 1.5 % (ACS, 2015); most people drive to work which may also increase VMT per vehicle with an increase in job availability. Also, the positive effect of travel time to work is intuitive, since longer commuting distance put mileages on cars. Gas price did not turn out to be significant in the model, hence it was not included.

The arc elasticity value for VMT per vehicle associated with an increase in the vehicle registration fee from the lowest ($60.1) to the highest ($80.1) in the state of Texas is -0.4. The results using BESTMILE as dependent variable from 2009 NHTS in the linear model, are given in Appendix C, Table XIX as they were not satisfactory.

7. SYNTHESIS AND CONCLUSIONS

Results from the previous chapter suggest that vehicle registration fee does impact vehicle ownership. The results align with the economic theory about fixed costs, that they impact vehicle ownership, which in this case is the vehicle registration fee. Although other fixed costs of buying and owning a car, e.g. insurance is much more, increase in the vehicle registration fee is likely going to make people get rid of their extra vehicles to avoid paying an annual fee for a less used vehicle which may not be used sufficiently to marginalize the cost. On the other hand, a decrease in the vehicle registration fee is not going to significantly increase vehicle ownership as the travel needs of a household would not increase proportionately to significantly increase the vehicle ownership. Further, the level of impact that vehicle registration fee is going to have on vehicle ownership varies across different geographic locations. The impact is more in rural areas as compared to urban areas, probably because of their lower income levels. Also, it may be affected by the presence of transit and depends on socio-economic variables, such as household income. Thus, the magnitude of impact can vary based on local conditions of surroundings as well as factors pertaining to an individual.

In several states, vehicle registration fee is a major transportation funding source. Hence, any negative impact on vehicle ownership because of increase in the vehicle registration fee will reduce the funds generated from the annual vehicle registration fee contrary to expectations. Instead of boosting the transportation funds, increase in vehicle

registration fee may aggravate the issue of gap in the transportation funds in a state. This would further limit the expending capacity of states on transportation infrastructure. In such a scenario, the states might shift to harnessing the variable costs for supporting transportation funding requirements. However, with the concerns surrounding the variable costs over privacy, equity; the implementation could be difficult.

In contrast to vehicle ownership, the impact on VMT per vehicle by vehicle registration fee is less significant. Since VMT per vehicle is a measure of vehicle use, it is impacted more by use based costs. However, it is interesting that the analysis found that VMT per household vehicle is not statistically associated with gas price.

A decrease in automobile ownership can severely affect the massive automobile industry in the country, which has already hit its peak and is expected to decline in the coming years (Associated Press, 2017). The decline in vehicle ownership is going to impact GDP contribution of the industry and employment in the industry. On the contrary, reduction in the vehicle registration fee is not going to boost the automobile industry much, as the vehicle ownership status is not going to increase considerably due to the decrease in vehicle registration fee.

From the policy perspective, an increase of vehicle registration fee can lead to a decline in vehicle ownership, if the fee is increased consecutively to support the funding gaps (like in California) and if it is not implemented selectively by considering the socio-economic and location-specific factors. The vehicle registration fee is an annual fee, whose cost gets marginalized over usage of the car, hence it does not impact VMT. However, if

the fee is increased significantly, it is likely to negatively impact both ownership and VMT, especially for lower income group people, who may not be able to afford even a single vehicle.

Hence, the effect on vehicle ownership and VMT should be considered when the hike in vehicle registration fee is considered as a source to fund transportation needs by state and local governments, because of its far-ranging impact on the economy, environment, and travel patterns.

8. LIMITATIONS AND FUTURE WORK

This study is an exploratory work to understand how increase in the vehicle registration fee is going to affect travel behavior and utility of vehicle registration fee as a funding source. Hence, there are certain limitations to the study. Also, the research work is a stepping stone towards understanding the impact of an increase in the fixed cost consumer fee on travel behavior and their utility as a funding source. This chapter concludes the thesis by discussing the limitations of this study and proposes some of the potential scopes for future research.

8.1 Limitations

- One of the main limitations of the study was the availability of data, which restricted the selection of study area to the state of Texas. In addition, several control variables were not available for the year or at the geographic scale of analysis, such as the local built environment factors that are known to impact VMT.
- The mode share in the state of Texas restricts the generalization of results to some extent. The state of Texas is predominantly an automobile dependent state and is significantly different from some other states in the country like New York, Illinois, Massachusetts where a significant percentage of people use transit for work (US Census Bureau (2009).
- The study also has statistical limitations due to constraints of time. In particular, the fit for the regression model for the VMT is less than ideal.

8.2 Future Work

The study can be expanded further by increasing the scope of work. Some of the possible directions for future research work are:

- The impact of vehicle registration fee can be analyzed on mode share as well. As the results of the study indicate, change in vehicle registration fee impacts vehicle ownership. Hence, this impact may result in the change of mode share.
- Pair longitudinal study can be done to analyze impact of the change in vehicle registration over time.
- The study can also be done across different states by including data for big states such as New York, Illinois, and Massachusetts.
- The study can also be done for analyzing the impact of vehicle registration fee increase on freight vehicles and its effect on the freight industry.
- As the study concludes, that vehicle registration does impact vehicle ownership. Hence, change in vehicle ownership may also impact mode share, which may lead to change in the environmental impacts by automobiles.
- As many states are also charging an extra registration fee for hybrid vehicles and EV, hence impact of the fee charged for these vehicles can be analyzed on the usage of hybrid/electric vehicles. Further, its ramifications on the policies related to making transportation more sustainable can be studied.

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APPENDIX A: Vehicle Registration Fee in different States of the US

Source: National Conference of State Legislatures (NCSL)

State name	Number of years' fee is assessed	Fee calculation Basis / average fee for passenger cars
Alabama	2	$23(standard) based on vehicle type, weight
Alaska	1	$100 (standard)based on weight of vehicle
Arizona	1 or 2	$8 ($8.25 in metro Tucson and phoenix) and air quality research fee ($1.5) and $1 (3-day permit fee) and vehicle license tax assessed for each $100 of vehicle value ($2.8 new vehicle, $2.89 used, $4 alternative fuel) what is assessed as 60% of the MSRP and reduced by 16.25% each year)
Arkansas	2 or 3	$17 cars 3,000 lbs. Or less, $25 cars 3,00 lbs. - 4,500 lbs., $30 cars over 4,500 lbs.+$2.50 validation decal for all automobiles
California	1	$46 plus additional fees based on the type of vehicle, license plate type, and the owner's county of residence and driving record
Colorado	1	Based upon the year, weight, taxable value and month of registration. Varies by county
Connecticut	2	$80
Delaware	1	$40
District of Columbia	1	3,499 lbs. And under: $72, 3,500 to 4,999 lbs.: $115, 5,000 lbs. Or more: $155, historic vehicles: $25
Florida	1	$225 - initial registration + $14.50- vehicle under 2,500 lbs., $22.50 - vehicle between 2,500 lbs. -3,499 lbs., $32.50 - vehicle over 3,500 lbs.
Georgia	1	$20
Hawaii	1	All vehicles - $45 + for every vehicle up to 4,000 pounds net weight - $0.0075 per pound, for every vehicle between 4,000 and 7,000 pounds - $0.01 per pound, for every vehicle between 7,000 and 10,000 pounds, $0.0125 per pound, for every vehicle over 10,000 pounds - $ 150 flat fee county fee - Honolulu city and county -$0.04 per pound,

State name	Number of years' fee is assessed	Fee calculation mechanism / average fee for passenger cars
		Maui county - $0.0125 per pound, Hawaii county - $0.0075 per pound, Kauai county - $0.0125 times vehicle weight plus $0.0075
Idaho	1	$69 for vehicles one or two years old - $57 for vehicles three to six years old - $45 for vehicles seven or more years old.
Illinois	1	$101
Indiana	1	$21.35
Iowa	1	Weight <= 10,000 lbs.- 40 cents per hundred pounds of vehicle weight + vehicles up to 7 years old - 1.00% of list price, vehicles 8-9 years old -75% of list price, vehicles up to 10-11 years old - 50% of list price, for vehicles 12 years old and older registration fee is $50.
Kansas	1	less than 4500 lbs. $35.00, over 4500 lbs. $45.00
Kentucky	1	$21
Louisiana	2	$20.00 minimum for 2 years (based upon .1% percent of selling price)
Maine	1	$35
Maryland	2	$135 - 3,700 lbs. Or less, $187 - over 3,700 lbs.
Massachusetts	2	$60
Michigan	1	Model prior to 1983 - fee based on weight of the vehicle; after 1983, fee based on price of the vehicle; fees vary from $30 to $148, decline in fees by 10% each year until fifth renewal.
Minnesota	1	Based on value of vehicle, minimum of vehicles 10 year or older - $35
Mississippi	1	$14
Missouri	1 or 2	Less than 12 horsepower (hp) - $18.25, 12 hp - 23 hp: $21.25, 24 hp - 35 hp: $24.25, 36 hp - 47 hp: $33.25, 48 hp - 59 hp: $39.25, 60 hp - 71 hp: $45.25, 72 hp and greater: $51.25 +$3.50 - yearly

State name	Number of Years fee is assessed	Fee calculation mechanism / average fee for passenger cars
Montana	1 or 2	Under 4 yrs. Old $217.00, 5 – 10 yrs. Old $87.00, 11+ yrs. Old $28.00
Nebraska	1	$15
Nevada	1	$33
New Hampshire	1	0-3000 lbs. $31.20 ($2.60 per month), 3001-5000 lbs. $43.20 ($3.60 per month), 5001-8000 lbs. $55.20 ($4.60 per month), 8001-73,280 lbs. $ .96 per hundred lbs. Gross weight
New Jersey	1	Fees range from $35.50 to $84, based on age and weight
New Mexico	1 or 2	$27 to $62 for one year and $54 to $124 for two years
New York	1 or 2	$26 to $34 - less than 2,150 lbs., $35.50 to $43.50 for 2,151 lbs. - 2,750 lbs., $45.50 to $53.50 for 2,751 lbs. - 3,350lbs., $55 to $66.50 for 3,351 lbs. - 3,950 lbs., $69 to $81 for 3,951 lbs. - 4,550 lbs., $83.50 to $95.50 for 4,551 lbs. - 5,150lbs., $98 to $110 for 5,151 lbs. - 5,750 lbs., $112.50 to $139 for 5,751 lbs. - 6,950 lbs., $140 for 6,951 lbs. And up + additional fees varying by county
North Carolina	1	$36
North Dakota	1	Fees range from $49 to $274, depending on weight of vehicle and first year registered, purchase price, year model
Oklahoma	1	$96 - 1st - 4th years of registration, $86 - 5th -8th years of registration, $66- 9th -12th years of registration, $46 - 13th - 16th years of registration, $216- 17th + years of registration+ additional $5 in other fees
Oregon	2 or 4	$86 - 2, $172 - 4 years, county fee for Multnomah - $19
Pennsylvania	1 or 2	Based on vehicle type and weight - $65 for 1 year, $130 - 2 year
Rhode Island	2	$4000 (less than 4000lbs, passenger) based on vehicle weight + $1.50 technology fee
South Carolina	1	$24 (passenger car), based on age and gross weight
South Dakota	1	Based on unladed vehicle weight and age of vehicle ($31.5 - $180), 4 % excise tax, lower fees for vehicles 9 year or older

State name	Number of years' fee is assessed	Fee calculation mechanism / average fee for passenger cars
Tennessee	1	$21 (standard plate fee) + county and city fee apply separately + wheel tax
Texas	1	$50.75 + county fee +automation fee + public safety fee
Utah	1	Depending on vehicle type, registered weight, county, and other factors.
Vermont	1	76 - gas or diesel, $132 - other fuel
Virginia	1, 2 or 3	$40.75 - less than 4,000 lbs.$45.75 - more than 4,000 lbs. - yearly
Washington	1	$30 (all-terrain vehicles), also depends on several unique factors such as vehicle type and weight, where you live, plate type and more.
West Virginia	1	$30, based on vehicle type, weight and plate type
Wisconsin	1	$75
Wyoming		$15 + county registration that is calculated by a percentage of factory price and age of the vehicle

APPENDIX B: Aggregate Model: Results

R code:

```
Data = read.table ("/Users/shubhayanukil/Desktop/Thesis_latest_agg.csv" , header = TRUE, fill  = TRUE, sep = ",")
summary(Data)
Data[!complete.cases(Data),]
options(scipen = 999)
NewData_Urb = subset(Data , CN_DSTRCT=='Urban')

NewData_Rur = subset(Data , CN_DSTRCT=='Rural')


#plot VMT and REG_FEE data
plot(Data$VMT,Data$REG_FEE)

# trial - VMT regression 1
reg1 = lm ( VMT_NEW ~ REG_FEE + MED_HH_INC + TR_USE_ORIG + EMP +JOB_HOUS_BAL + HH_VEH, data = Data)
summary(reg1)

# trial - VMT -regression 2
reg2 = lm (WT_VMT ~ REG_FEE + WT_HH_WORK + TT_WORK + TR_USE_NEW_ORIG , data = Data)
summary(reg2)


reg2_log = lm (log(WT_VMT) ~ log(REG_FEE) +log(WT_HH_WORK) + log(TT_WORK)  + log(TR_USE_NEW) , data = Data)
summary(reg2_log)

vif(reg2)
vif(reg2_log)

# Heteroscedasticity
par(mfrow=c(2,2)) # init 4 charts in 1 panel
plot(reg2_log)
VMT.stdres = rstandard(reg2)
VMT.stdres2 = rstandard(reg2_log)
qqnorm(VMT.stdres2, ylab="Sample Quantiles", xlab="Theoretical Quantiles", main="VMT")
qqline(VMT.stdres2)
```

```
lmtest::bptest( reg2 )
lmtest::bptest( reg2_log )


# trial - Household Ownership - regression 3
reg3_log = lm ( log(WT_HH_VEH) ~ log(REG_FEE) + log(RES_DENS) + log
(MED_HH_INC) + log(WT_HH_DR) + log(TR_WORK) , data = Data)
summary(reg3_log)

reg3 = lm ( WT_HH_VEH ~ REG_FEE + RES_DENS + MED_HH_INC +
WT_HH_DR + TR_WORK_ORIG , data = Data)
summary(reg3)

#multicollinearity
install.pacages('car')
require(car)
?vif
vif(reg3)
vif(reg3_log)

# Heteroscedasticity test
residplot3 = resid(reg3)
VMT.stdres = rstandard(reg3)

qqnorm(VMT.stdres, ylab="Standardized Residuals", xlab="Normal Scores",
main="VMT")
qqline(VMT.stdres)

par(mfrow=c(2,2)) # init 4 charts in 1 panel
plot(reg3)

lmtest::bptest( reg3 )
lmtest::bptest( reg3_log )
```

Data

The aggregate level analysis is done at the county level, where data for the dependent variables of vehicle ownership, VMT; independent variables of vehicle registration fee and

control variables are assessed at the county level. The dependent variables value for each county in the state is calculated by taking average of the variable value for each household record belonging to the county. However, the minimum sample size considered for calculating statistically significant value of the variable for each county is 20. Only 128 counties have 20 or more records for both the dependent variables. Consequently, only 128 out of 254 counties are used for analysis. Basic descriptive statistics for the dependent, independent and control variables in the year 2009 are given below in Table VIII.

Variables	**Mean Value**	**Standard Deviation**
Vehicle Registration Fee (in $)	70.4	2.56
Vehicle Ownership	1.9	0.24
Vehicle Miles Traveled (Annual Miles)	14,465	2,746
Household Size	2.65	0.23
number of workers in household	1.07	0.19
number of adults in household	1.87	0.16
number of drivers in household	1.75	0.16
Household Income (in $)	44,444	10,440
Job Availability	0.62	0.26
Gross Residential Density (housing units per square mile)	75.24	154.21
Job to Housing Balance Ratio	0.63	0.26
Percentage of people working outside county	20%	
Percentage of people working outside state	1.30%	
Travel time to work (in minutes)	24	5.2
Avg. number of times transit is used in the month prior to survey	1.5 times in a month	
Percentage of people using transit to work	0.60%	

TABLE XII: DESCRIPTIVE STATISTICS OF VARIABLES FOR AGGREGATE LEVEL ANALYSIS

The results of the best fit model at aggregate level for vehicle ownership and VMT are given below.

Household Vehicle Ownership						
Variables	**Coefficient Estimate**	**Standard Error**	**t value**	**Pr(>|t|)**	**Significance**	**VIF**
(Intercept)	1.717	0.713	2.406	0.017	*	
Registration Fee	-0.020	0.01	-1.959	0.052	.	1.078
Residential Density	-0.0002	0	-1.82	0.071	.	2.087
Median Household Income	0.0000038	0	1.923	0.056	.	1.260
weighted number of drivers in household	0.860	0.107	8	0	***	1.207
Percentage of people using transit to work	-3.447	3.321	-1.038	0.301		1.968
Significance codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1						
Residual Standard Error: 0.1826 on 122 degrees of freedom						
Multiple R-squared : 0.457	Adjusted R-squared: 0.4348					
F-Statistic: 20.54 on 5 and 122 DF, p-value: 000000000000007791						

TABLE XIII: RESULTS OF LOGARITHMIC REGRESSION MODEL OF IMPACT ON VEHICLE OWNERSHIP PER HOUSEHOLD (AGGREGATE LEVEL)

Vehicle Miles Traveled Per Vehicle						
Variables	**Coefficient Estimate**	**Standard Error**	**t value**	**Pr(>|t|)**	**Signific - ance**	**VIF**
(Intercept)	8.941	2.887	3.097	0.002	**	
log(Registration Fee)	-0.176	0.672	-0.262	0.793		1.046
log(Weighted number of workers in household)	0.347	0.084	4.119	0	***	1.066
log(Travel time to work)	0.352	0.070	5.038	0	***	1.037
log(Number of times transit is used to work in last month)	-0.011	0.005	-2.304	0.022	*	1.068
Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1						
Residual Standard Error: 0.1707 on 123 degrees of freedom						
Multiple R-squared: 0.2973		Adjusted R-squared: 0.2745				
F-Statistic: 8.0245 on 4 and 123 DF, p-value < 000000007257						

TABLE XIV: RESULTS OF LOGARITHMIC REGRESSION MODEL OF IMPACT ON VEHICLE MILES TRAVELED PER VEHICLE (AGGREGATE LEVEL)

The Adjusted R-square value shows that the models are significant and vehicle registration fee impact vehicle ownership but not VMT. This is in accordance with the literature study about impact of fixed costs on vehicle ownership and VMT. But both the models are missing some of the key variables known to impact vehicle ownership and VMT.

Hence, they are not the best results to analyze the impact of vehicle registration fee on vehicle ownership and VMT.

APPENDIX C: Disaggregate Analysis

Vehicle Ownership

R Code :

```
options("scipen" = 10)
options()$scipen

Data = read.table("/Users/shubhayanukil/Desktop/Thesis/Disaggregate_HH_R.csv" ,
header = TRUE, fill  = TRUE, sep = ",")
summary(Data)

require(foreign)
require(ggplot2)
require(MASS)
require(Hmisc)
require(reshape2)

Data_urb = subset(Data , URB_RUR == "1")
Data_rur = subset(Data , URB_RUR == "2")
Data_low = subset(Data , FAMINC_GROUP == "1")
Data_med = subset(Data , FAMINC_GROUP == "2")
Data_high = subset(Data , FAMINC_GROUP == "3" )


#Ownership regression  - MNL
levels(Data$HH_VEH_4)

Data$HH_VEH_4
Data$HH_VEH_4 <- factor( Data$HH_VEH_4)


Data$HH_VEH_42 <- relevel ( Data$HH_VEH_4, ref = 2)
Data$HH_VEH_42

library(nnet)
reg_own_no = multinom( HH_VEH_42 ~  REG_FEE   +  HH_WORK_ORIG +
RES_DENS   + FAMINC + JOB_DENS_ORIG +  HH_DR_ORIG + BELOW_16_ORIG
+  ABOVE65_ORIG   ,  data = Data)
sum_reg <- summary(reg_own_no, Wald = T)
sum_reg
```

```
#Wald Statistics
sum_reg$Wald.ratios
pchisq(sum_reg$Wald.ratios^2,1, low = F)

#p-value
z <- summary(reg_own_no)$coefficients/summary(reg_own_no)$standard.errors
z
p <- (1 - pnorm(abs(z), 0, 1))*2
p

#pseudo R square
reg_own_no_null = multinom(HH_VEH_42~  1  ,  data = Data_high)
summary(reg_own_no_null)

pseudo_R2 <- 1 - (logLik(reg_own_no)/logLik(reg_own_no_null))
pseudo_R2
```

Income Group

Lower Income Group – MNL Regression for Household Vehicle Ownership

Household Vehicle Ownership	**0**	**2**	**3**	**4**
Coefficients:				
(Intercept)	1.059	-1.793	-2.415	-7.717
Registration Fee	0.021	-0.045	-0.086	-0.052
Number of Workers in Household	-0.174	0.330	0.605	0.606
Residential Density	0.000	0.000	-0.001	-0.001
Family Income	-0.372	0.153	0.235	0.227
Job Availability	-7.189	11.214	5.459	13.652
Number of Drivers in Household	-2.699	2.079	3.051	3.703
Household having below 16 age people	-0.543	0.336	0.008	0.317
Household Having above 65 age people	-0.709	0.688	0.501	0.825
Standard Errors:				
(Intercept)	0.0003	0.006	0.003	0.001

Household Vehicle Ownership	**0**	**2**	**3**	**4**
Registration Fee	0.002	0.003	0.004	0.006
Number of Workers in Household	0.141	0.064	0.087	0.123
Residential Density	0.0001	0.0001	0.0001	0.0002
Family Income	0.033	0.016	0.027	0.045
Job Availability	0.0000	0.0002	0.0001	0.0001
Number of Drivers in Household	0.128	0.064	0.103	0.141
Household having below 16 age people	0.067	0.119	0.100	0.116
Household Having above 65 age people	0.063	0.121	0.105	0.099
P-value				
(Intercept)	0	0	0	0
Registration Fee	0.00	0.00	0.00	0.00
Number of Workers in Household	0.00	0.00	0.00	0.00
Residential Density	0.00	0.00	0.00	0.00
Family Income	0.00	0.00	0.00	0.00
Job Availability	0.00	0.00	0.00	0.00
Number of Drivers in Household	0.00	0.00	0.00	0.00
Household having below 16 age people	0.00	0.00	0.00	0.00
Household Having above 65 age people	0.00	0.00	0.00	0.00
Residual Deviance: 11641.44	Pseudo R Square			
AIC: 11713.44	log lik' : 0.2820205 ((df=36))			

TABLE XV: RESULTS OF MNL REGRESSION MODEL OF IMPACT ON VEHICLE OWNERSHIP FOR LOWER INCOME GROUP (DIS-AGGREGATE LEVEL)

Middle Income Group – MNL Regression for Household Vehicle Ownership

Household Vehicle Ownership	**0**	**2**	**3**	**4**
Coefficients:				
(Intercept)	-15.409	-1.338	-0.944	1.066
Registration Fee	0.218	-0.069	-0.144	-0.228

Household Vehicle Ownership	**0**	**2**	**3**	**4**
Number of Workers in Household	1.084	0.373	0.540	0.770
Residential Density	0.000	-0.001	-0.001	-0.001
Family Income	0.000	0.111	0.150	0.170
Job Availability	-24.503	4.187	12.702	18.915
Number of Drivers in Household	-2.474	2.962	4.645	5.472
Household having below 16 age people	-1.841	0.914	0.423	0.599
Household Having above 65 age people	-0.537	1.051	0.571	1.263
Standard Errors:				
(Intercept)	0.000	0.004	0.002	0.001
Registration Fee	0.013	0.004	0.005	0.007
Number of Workers in Household	0.005	0.082	0.094	0.112
Residential Density	0.0004	0.0001	0.0001	0.0002
Family Income	0.073	0.015	0.019	0.026
Job Availability	0.0000	0.0002	0.0002	0.0002
Number of Drivers in Household	0.003	0.088	0.125	0.143
Household having below 16 age people	0.004	0.123	0.108	0.127
Household Having above 65 age people	0.004	0.125	0.118	0.154
P-value				
(Intercept)	0	0	0	0
Registration Fee	0.00	0.00	0.00	0.00
Number of Workers in Household	0.00	0.00	0.00	0.00
Residential Density	0.00	0.00	0.00	0.00
Family Income	0.00	0.00	0.00	0.00
Job Availability	0.00	0.00	0.00	0.00
Number of Drivers in Household	0.00	0.00	0.00	0.00
Household having below 16 age people	0.00	0.00	0.00	0.00
Household Having above 65 age people	0.00	0.00	0.00	0.00
Residual Deviance: 11402.7	Pseudo R Square			
AIC: 11474.7	log lik': 0.2648692 (df=36)			

TABLE XVI: RESULTS OF MNL REGRESSION MODEL OF IMPACT ON VEHICLE OWNERSHIP FOR MIDDLE INCOME GROUP (DIS-AGGREGATE LEVEL)

High Income Group – MNL Regression for Household Vehicle Ownership

Household Vehicle Ownership	**0**	**2**	**3**	**4**
Coefficients:				
(Intercept)	1.964	-10.060	-11.158	-12.170
Registration Fee	0.137	-0.058	-0.125	-0.158
Number of Workers in Household	1.308	0.410	0.578	0.583
Residential Density	0.000	0.000	0.000	-0.001
Family Income	-1.078	0.483	0.538	0.545
Job Availability	-10.903	16.885	20.826	32.719
Number of Drivers in Household	2.283	3.448	5.518	6.482
Household having below 16 age people	-1.113	1.048	0.582	0.502
Household Having above 65 age people	-0.117	0.901	0.445	0.469
Standard Errors:				
(Intercept)	0.000	0.002	0.002	0.002
Registration Fee	0.010	0.018	0.018	0.022
Number of Workers in Household	0.017	0.091	0.092	0.100
Residential Density	0.0008	0.0001	0.0002	0.0002
Family Income	0.004	0.071	0.067	0.082
Job Availability	0.0000	0.0002	0.0002	0.0001
Number of Drivers in Household	0.006	0.097	0.071	0.072
Household having below 16 age people	0.008	0.115	0.115	0.135
Household Having above 65 age people	0.008	0.160	0.133	0.146
P-value				
(Intercept)	0.00	0.00	0.00	0.00
Registration Fee	0.00	0.00	0.00	0.00
Number of Workers in Household	0.00	0.00	0.00	0.00
Residential Density	0.9891	0.7176	0.0357	0.0004
Family Income	0.00	0.00	0.00	0.00
Job Availability	0.00	0.00	0.00	0.00
Number of Drivers in Household	0.00	0.00	0.00	0.00
Household having below 16 age people	0.00	0.00	0.00	0.00
Household Having above 65 age people	0.00	0.00	0.00	0.00
Residual Deviance: 6416.119	Pseudo R Square			
AIC: 6488.119	log lik': 0.2259217 (df=36)			

TABLE XVII: RESULTS OF MNL REGRESSION MODEL OF IMPACT ON VEHICLE OWNERSHIP FOR HIGH INCOME GROUP (DIS-AGGREGATE LEVEL)

Vehicle Miles Traveled

R Code:

```
#Data
Data_Ann = read.table("/Users/shubhayanukil/Desktop/Annualmiles_R.csv" , header = TRUE, fill = TRUE, sep = ",")
summary(Data_Ann)

Data_urb = subset(Data_Ann , URBRUR == "1")
Data_rur = subset(Data_Ann , URBRUR == "2")

#VMT regression - Annual Miles
reg_VMT_lin = lm( ANNMILES_ORIG ~ REG_FEE + HH_ADL + JOB_DENS_ORIG + HHSIZE + RES_DENS + PAYTOLL_ORIG + HH_WORK_ORIG + TT_WORK + HHFAMINC + HH_VEH_ORIG + ABOVE_65_ORIG + EDUC, data = Data_Ann )
summary(reg_VMT_lin)


reg_VMT = lm( log(ANNMILES) ~ log(REG_FEE) + log (HH_DR) + log(JOB_DENS) + log (HHSIZE) + log(RES_DENS) + log (PAYTOLL) + + log(HH_WORK) + log(TT_WORK) + log(HHFAMINC)+ log(HH_VEH) + log (ABOVE_65) +log(EDUC), data = Data_Ann )
summary(reg_VMT)

#VMT regression - Bestmile
reg_Bestmile_lin = lm( BESTMILE_ORIG ~ REG_FEE + HH_DR + JOB_DENS_ORIG + HHSIZE + RES_DENS + PAYTOLL_ORIG + HH_WORK_ORIG + TT_WORK + HHFAMINC + HH_VEH_ORIG + ABOVE_65_ORIG + EDUC, data = Data_Ann )
summary(reg_Bestmile_lin)


reg_Bestmile = lm( log(BESTMILE) ~ log(REG_FEE) + log(JOB_DENS) + log (HHSIZE) + log(RES_DENS) + log (PAYTOLL) + + log(HH_WORK) + log(TT_WORK) + log(HHFAMINC)+ log(HH_VEH) + log (ABOVE_65) +log(EDUC), data = Data_Ann )
summary(reg_Bestmile)

#Multicollinearity
install.pacages('car')
require(car)
?vif
```

```
vif(reg_Bestmile)
vif(reg_Bestmile_lin)
vif(reg_VMT)
vif(reg_VMT_lin)

# Heteroscedasticity test
par(mfrow=c(2,2)) # init 4 charts in 1 panel
plot(reg_VMT_lin)

plot(reg_VMT)

# bp test
lmtest::bptest( reg_Bestmile )

lmtest::bptest( reg_VMT )
lmtest::bptest( reg_VMT_lin
```

Logarithmic Model of impact on VMT per vehicle using Annual Miles data

Variables	**Coefficient Estimate**	**Standard Error**	**t value**	**Pr(>|t|)**	**Signif-icance**	**VIF**
(Intercept)	6.637	1.711	3.878	0	***	
log(Registration Fee)	0.262	0.404	0.649	0.516		1.027
log(Number of Drivers in Household)	0.014	0.039	0.364	0.715		2.334
log(Job Availability)	0.058	0.021	2.685	0.007	**	1.190
log(Household Size)	0.200	0.029	6.714	0	***	2.354
log(Residential Density)	-0.065	0.013	-4.849	0	***	1.188
log(People who payed toll on Interstate on Travel Day)	0.033	0.006	5.161	0	***	1.033

Variables	Coefficient Estimate	Standard Error	t value	Pr(>|t|)	Signif-icance	VIF
log(Number of workers in household)	0.029	0.003	7.581	0	***	1.876
log(Travel time to work)	0.240	0.040	5.86	0	***	1.070
log(Household Income)	0.314	0.018	16.7	0	***	1.487
log(Number of vehicles in household)	-0.016	0.003	-4.235	0	***	1.013
log(Household has above 65 people)	-0.030	0.003	-8.095	0	***	1.762
log(Education level)	0.145	0.024	5.897	0	***	1.2590
Significance codes: 0 '***' 0.001 '**' 0.01 '*'. 0.05 '.' 0.1 ' ' 1						
Residual standard error: 1.576 on 29877 degrees of freedom						
Multiple R-squared: 0.056			Adjusted R-squared: 0.055			
F-statistic: 147.9 on 12 and 29877 DF, p-value: < 2.2e-16						

TABLE XVIII: RESULTS OF LOGARITHMIC REGRESSION MODEL OF IMPACT ON VEHICLE MILES TRAVELED BASED ON ANNUAL MILES DATA (DIS-AGGREGATE LEVEL)

Linear Model of impact on VMT per vehicle using Best Miles Data

VMT per vehicle using BESTMILE data						
Variables	**Coefficient Estimate**	**Standard Error**	**t value**	**Pr(>|t|)**	**Signific-ance**	**VIF**
(Intercept)	10499.881	2405.701	4.365	0	***	
Registration Fee	-31.005	33.625	-0.922	0.356		1.023
Number of drivers in the household	-69.68	118.37	-0.589	0.556		2.335
Job Availability	45219.385	8540.075	5.295	0	***	1.191
Household Size	638.04	59.296	10.76	0	***	1.853

Variables	Coefficient Estimate	Standard Error	t value	Pr(>|t|)	Significance	VIF
Residential Density	-1.214	0.128	-9.484	0	***	1.200
People who payed toll on Interstate on Travel Day	1115.798	267.875	4.165	0	***	1.037
Number of workers on household	752.787	89.286	8.431	0	***	2.146
Travel Time to work	39.646	11.126	3.563	0	***	1.055
Household Income	177.189	12.914	13.721	0	***	1.504
Number of vehicles in household	-489.762	55.362	-8.847	0	***	1.296
Household having above 65 age people	-1763.418	155.297	-11.355	0	***	1.758
Education level	-7.466	54.274	-0.138	0.890		1.261
Significance codes: 0 '***' 0.001 '**' 0.01 '*'. 0.05 '.' 0.1 ' ' 1						
Residual standard error: 9539 on 29877 degrees of freedom						
Multiple R-squared: 0.0563		Adjusted R-squared: 0.0559				
F-statistic: 148.6 on 12 and 29877 DF, p-value: < 2.2e-16						

TABLE XIX: RESULTS OF LINEAR REGRESSION MODEL OF IMPACT ON VEHICLE MILES TRAVELED BASED ON BESTMILES DATA (DIS-AGGREGATE LEVEL)

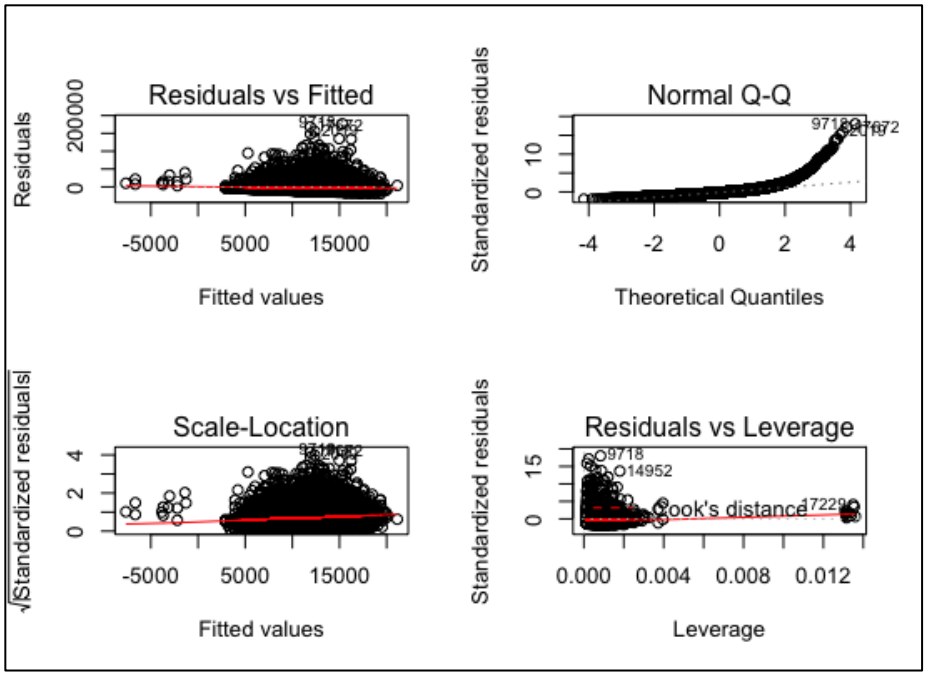

Figure 5: Residual Plot for Linear VMT per vehicle model using Annual Miles data, Source: R

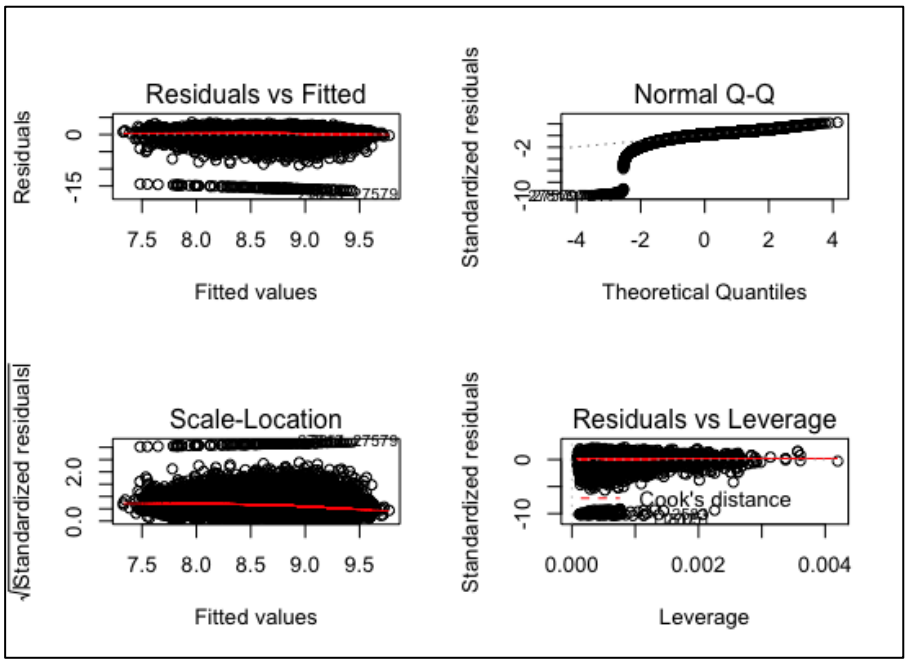

Figure 6: Residual Plot for Log Transformed VMT per vehicle model using Annual Miles data, Source: R

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